# Epsom Spring Gully Recycled Water Project

## Recycled Water Quality Management Plan

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Prepared for:

Coliban Water

By:

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June 2008

# Revision History

| Revision Number | Prepared By | Description | Date |
|---|---|---|---|
| 0 | Kirsty Johns /Grant Haylock / Dahlia Goldberg | Final Issue to EPA | 25 July 2007 |
| 1 | Kirsty Johns | | |
| 2 | Johanna Schortinghuis | Update Milestone 2 | 2 June 2008 |

# Document Acceptance

| Action | Name | Signed | Date |
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| Reviewed by | Andrew Watson | | |
| Approved by | David Papps | | |
| On behalf of | **Beca Pty Ltd** | | |

# Annual Review and Revision Record

| Revision Number | Prepared By | Description/ Sections Revised | Date | Approved By | Date |
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# Glossary

| | |
|---|---|
| ANZECC | Australian and New Zealand Environment and Conservation Council |
| BNR | Biological Nutrient Removal |
| CAMS | Campaspe Asset Management Services |
| DHS | Department of Human Services |
| DSE | Department of Sustainability and Environment |
| EIP | Environment Improvement Plan |
| EOLL | End of Lamp Life |
| EPA | Environment Protection Authority |
| ESGRWP | Epsom Spring Gully Recycled Water Project |
| HACCP | Hazard Analysis Critical Control Point |
| HAV | Hepatitis A Virus |
| HEMP | Health and Environmental Management Plan |
| HLPS | High Lift Pump Station |
| LLPS | Low Lift Pump Station |
| LPHO | Low Pressure High Output |
| MS2 | Male Specific Number 2 Bacteriophage (virus) |
| NTU | Nephelometric Turbidity Units |
| NWRI | National Water Research Institute |
| P&ID | Process and Instrumentation Diagram |
| RED | Reduction Equivalent (UV) Dose |
| REIP | Regional Environment Improvement Plan |
| RO | Reverse Osmosis |
| RWF | Recycled Water Factory |
| RWQMP | Recycled Water Quality Management Plan |
| SCADA | Supervisory Control And Data Acquisition |
| SWTR | Surface Water Treatment Rule |
| UF | Ultra Filtration |
| UV | Ultra Violet |
| WRP | Water Reclamation Plant |

# 1 Introduction

## 1.1 Management Commitment

The management of Coliban Water is committed to providing recycled water delivery systems which manage both environmental and health risks. Coliban Water will make best endeavours to provide that adequate resources for recycled water programs, including adherence to the REIP, RWQMP, HACCP plans and the HEMPs; and that the public is educated about the risks and correct use of recycled water. Coliban Water will check that these programs are adhered to, by conducting audits of recycled water management systems and by investigating health and environment incidents. Coliban Water's commitment to the cycle of continuous improvement will be used to improve recycled water management systems, where deficiencies are found.

## 1.2 Purpose of the Recycled Water Quality Management Plan

The Recycled Water Quality Management Plan (RWQMP) for the Epsom Spring Gully Recycled Water Project (ESGRWP) includes a detailed assessment of the water treatment process and identifies the monitoring and control that is necessary to produce water of an appropriate quality for the proposed end uses.
This Recycled Water Quality Management Plan supersedes all previous versions.

## 1.3 Description of the Scheme

### 1.3.1 Background

Waterplan 2055 outlines Coliban Water's approach to securing sufficient water for the region for the next 50 years. Four key areas have been identified, as shown in Figure 1, and the Epsom Spring Gully Recycled Water Project is part of the supply side management actions to arise from this.

Low water levels in Coliban Water's storages have given the implementation of the project urgency, with Milestone 1 completed and the completion of Milestone 2 due for mid 2008. Milestone 1 provides treatment to Class A standard, pumping and a transfer pipeline for the Class A water. Milestone 2 is the addition of membrane treatment to further improve the quality of the water and reduce salinity.

The existing Bendigo WRP has an average inflow of approximately 5,500 ML/year and produces, on average, approximately 15 ML/d of treated effluent (Class B[1] recycled water). The first priority is to provide this Class B water to Perseverance Mining, secondly to feed the ESGWRP and thirdly to supply some on-site and off-site irrigators. The remainder is discharged to Bendigo Creek under an EPA licence. Treatment at the Bendigo WRP consists of biological nutrient removal, filtration and ultraviolet (UV) disinfection.

1 Classified as Class B effluent under the Victorian EPA Guidelines for Environmental Management – Use of Reclaimed Water, Publication 464.2, June 2003.

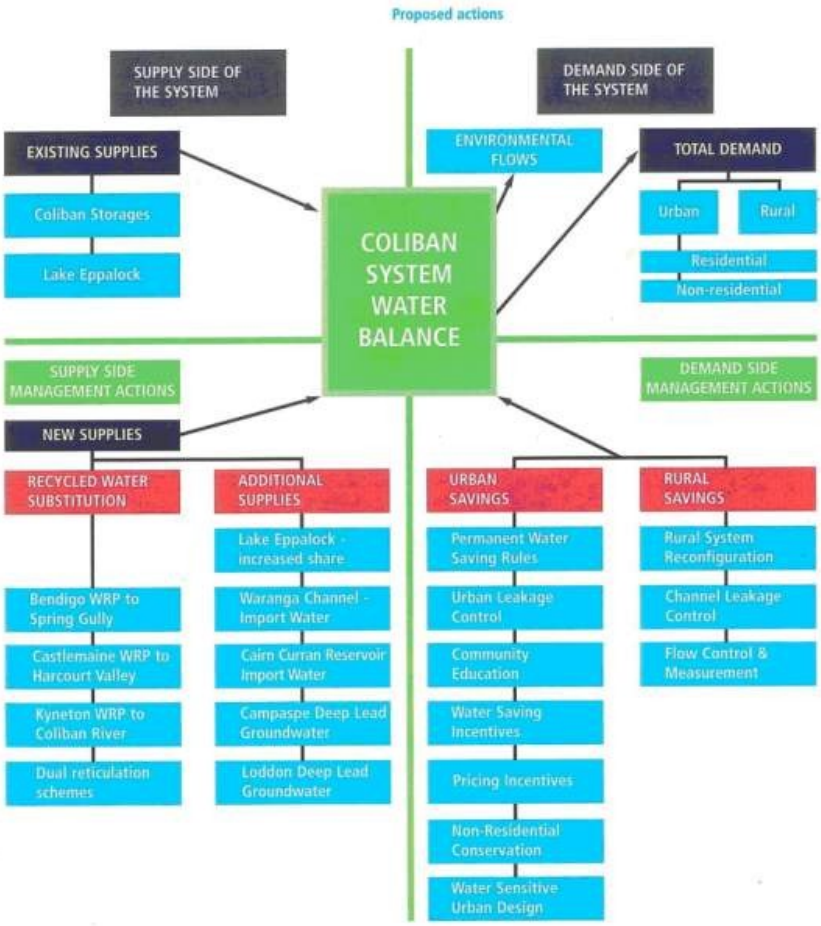


Figure 1 – Coliban Water Balance Diagram

### 1.3.2 Overview

The project takes water from the Bendigo WRP. Water is further disinfected using increased UV capacity and chlorination (installed during Milestone 1). Milestone 2 involves a parallel train to Milestone 1 consisting of membrane treatment of a portion of the flow (output flow of 3ML/d membrane treated water), by ultra filtration (UF) and reverse osmosis (RO), to reduce salinity and nutrients. Electro-Dialysis Reversal (EDR) will reduce the waste stream flow (RO concentrate). Brine lagoons will be used for treatment of the RO concentrate by evaporation. Treated water is pumped along a 14 km pipeline to Spring Gully Reservoir that was installed as part of Milestone 1. With the completion of the Milestone 2 works, the treated water will have a lowered salinity. An overview diagram is shown below, with detailed diagrams attached in Appendix A.

Figure 2, project schematic giving an overview of the project, is on the next page.

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Previous page - Figure 2 – Overview of the Project

### 1.3.2 Customers

Coliban Water can supply the recycled water to four classes of consumers. Examples of the uses to which each consumer will put the recycled water are summarised in Table 1. A risk assessment was undertaken to assess the specific risks to the end users. This is included in the REIP appendices. Additional details about each customer will be given in the plans to be provided by each customer. Coliban Water will maintain records of users, complying with the requirements of the privacy legislation.

Coliban Water will supply customers who cannot accept recycled water from a separate source. The Chief Veterinary Officer has provided provisional approval of the treatment process for helminth removal. This approval is subject to 6 months testing following commissioning, in order to demonstrate that the log removal of helminths is 4 log or greater. The results of this test will be available in late 2008 and then provided to the EPA, DHS and DPI for review. The HACCP sets out restrictions on use from the CVO in relation to calves of up to 12 months old.

**Table 1**

**Uses of Recycled Water**

| Category of Use | Consumers | Use |
|---|---|---|
| Rural customers | ■ Individual customers<br>■ Public open space areas (as per category below) | ■ Garden watering<br>■ Toilet flushing<br>■ Stock drinking*<br>■ Irrigation of pasture and crops*<br>■ Washing machine<br>■ General outdoor |
| Public open spaces (e.g. public parks, botanic gardens, recreation reserves, sports ovals, schools, racecourse, golf course) | ■ City of Greater Bendigo<br>■ Schools<br>■ Community-managed facilities<br>■ Privately-managed facilities | ■ Irrigation of parks, gardens and sports fields.<br>■ Toilet flushing<br>■ General outdoor<br>■ Filling water features and ponds |
| Standpipe | ■ Commercial/Industrial users<br>■ City of Greater Bendigo | ■ Dust suppression<br>■ Road construction<br>■ Watering of parks and gardens |
| Commercial/Industrial | ■ Hospital laundry<br>■ Others (future) | ■ Washing machine use<br>■ Dust suppression<br>■ Wash-down of vehicles<br>■ Appropriate commercial uses |

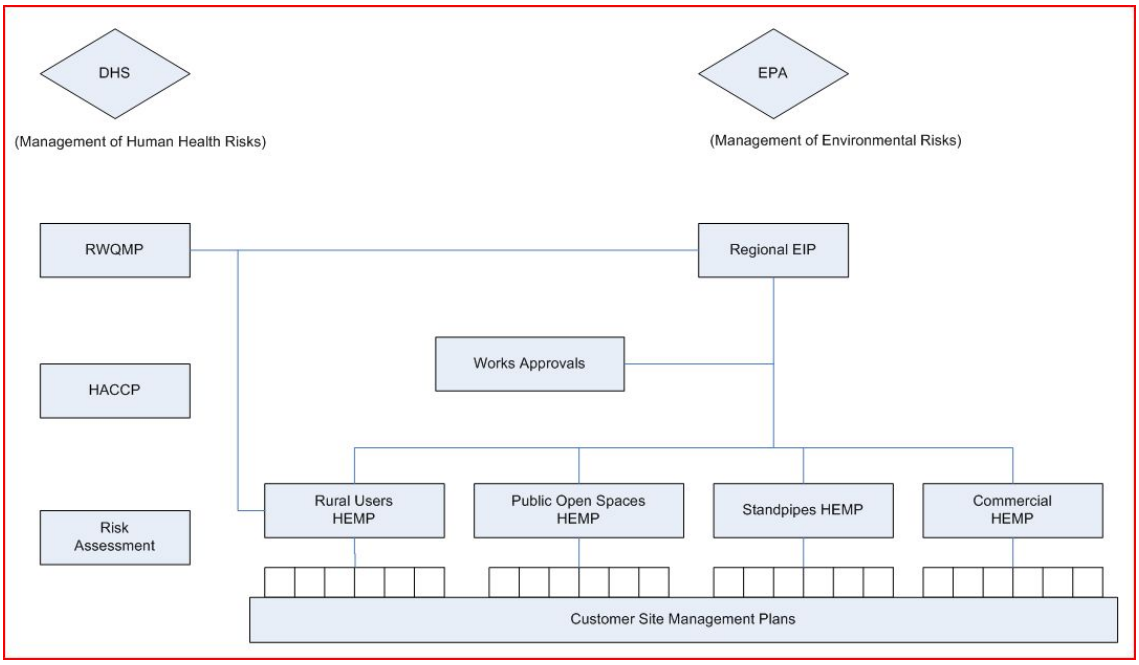
* Pigs must be excluded from contact with recycled water.

## 1.4 Scope of the RWQMP

The RWQMP addresses the method of assurance that water of Class A quality is being produced by the Recycled Water Factory (RWF). The RWQMP forms part of the Regional Environment Improvement Plan (REIP), which is submitted to the Environment Protection Authority (EPA).

Figure 3, below, shows the relationship between the RWQMP, REIP and end-user scheme management plans.

Figure 3 – RWQMP Relationships




The RWQMP has been developed with a HACCP plan. Coliban Water maintains a quality management system, and the HACC

P and RWQMP are being integrated into this system, as discussed in the HACCP plan.

## 1.5 Approval of the RWQMP

This document will be submitted to the Department of Human Services (DHS) for review, as part of the DHS endorsement of Class A recycled water production at the RWF.

The RWQMP, as are all documents included for approvals, is a controlled document. Following review, updated versions will be issued in accordance with Coliban Water's standard procedure.

# 2 Roles and Responsibilities

Roles and responsibilities are summarised in Table 2 below and discussed in further detail in the REIP.

**Table 2**
**Summary of Responsibilities**

| Item | Responsible |
|---|---|
| Provision of recycled water to the quality standards set out in the RWQMP and HEMPs | Coliban Water |
| Annual review of Regional EIP | Coliban Water |
| Annual review of HEMPs | Coliban Water |
| Annual review of Customer Site Management Plans | Coliban Water |
| Annual review of RWQMP and HACCP | Coliban Water |
| Annual report to EPA, including all monitoring results as required by RWQMP, HACCP and HEMPs | Coliban Water |
| Maintenance and update of operational management programmes | Coliban Water |
| Monitoring of water quality at plant and at Spring Gully Reservoir | Coliban Water |
| Provision of alternative supply where necessary | Coliban Water |
| Maintain record of recycled water users | Coliban Water |
| Provide EPA with annual list of recycled water users | Coliban Water |
| Communication with customers during an incident | Coliban Water |
| Notification of EPA of an incident or exception within 14 days | Coliban Water |
| Notification of EPA of an emergency immediately | Coliban Water |
| Compliance with customer site management plan and HEMP | Customer |
| Assessment and review of customer compliance | Coliban Water |
| Statutory audit, in compliance with AS/NZS 19011:2003 *Guidelines for Quality and/or Environmental Management Systems Auditing* | External party, arranged by Coliban Water |
| Action against users who do not comply with HEMP and site management plan | Coliban Water |

# 3 Description of the Plant

## 3.1 System Inputs

The Bendigo WRP accepts wastewater from the City of Greater Bendigo, comprising of domestic and trade waste inputs and septic tanker waste (septic waste accepted on-site). Further details of trade waste inputs can be found in the introductory sections of the HACCP plan.

## 3.2 Existing Treatment Plant

The existing treatment plant is a biological nutrient removal plant, with maturation lagoons, tertiary filtration and UV disinfection. Further details of the plant can be found in the HACCP plan.

## 3.3 Recycled Water Factory

Table 3, below, shows the proposed flows through the new works. Works were carried out in two areas. Minor upgrading work has been undertaken at the existing tertiary plant, and the Class A treatment plant has been constructed. This work has been carried out in two milestones. The overall new recycked water treatment plant will be referred to as the Recycled Water Factory (RWF).

**Table 3**
**Flow Through RWF**

| Description | Min Flow (ML/D) | Design Flow (ML/D) |
|---|---|---|
| Class A Train (Milestone 1) | 1.2 | 9.9 |
| Membrane treated water (Milestone 2) | 1.5 | 3.0 |
| Final water tank to high lift pumping station | 1.2 | 12.9 |
| High lift pumping station to pipeline | 3 | 12.9 |

### 3.3.1 Tertiary Plant Upgrading

Bendigo WRP receives inflows from sewage sourced from domestic and trade waste activities and septic tank waste, which is received by tanker. The control of these inflows is discussed in the HACCP. Following a storm, inflows to the plant exceed the capacity of the WRP. Excess flow was diverted directly into Lagoon 1, effectively meaning no pathogen removal through the activated sludge and Biological Nutrient Removal (BNR) could be claimed for this diverted flow. Accordingly, the storm flows are diverted to WRP Lagoon 4, which is not connected to the treatment process. From here the storm flow will evaporate or be used for onsite irrigation.

A gate is manually set at the inlet works to throttle the flow to the BNR plant. The setting of this depends on the number of secondary clarifiers in service. The flow rates were adjusted so as to pass the BNR plant validated flow through four secondary clarifiers

1 secondary clarifier in service 7.0 ML/d
2 secondary clarifiers in service 14.0 ML/d
3 secondary clarifiers in service 21.0 ML/d
4 secondary clarifiers in service 28.0 ML/d

The validated flow will be extended in steps of a maximum of 15% above the critical limit, by microbiological monitoring during wet weather flows. The design capacity of the Bendigo WRP BNR and secondary clarifiers is about 81 ML/day (Peak Wet Weather Flow).

Improvements have been made to the turbidity monitoring to allow more accurate monitoring of

the existing works, and therefore ongoing security of the water quality of the tertiary filter effluent supplied to the RWF. Improvements may also be made in future to the secondary coagulant/coagulant aid dosing upstream of the filters if these are found necessary to give increased security of the water quality supplied to the Class A works.

### 3.3.2 Milestone 1

In order to supply water from the WRP, a wet well was installed at the break-in to the existing effluent pipe. This allows water to pass to the low lift pump station (LLPS) for pumping to the RWF. The LLPS will pump the water to the new treatment facility.

The water is first chlorinated using sodium hypochlorite (chosen to avoid the installation of a gas chlorination facility with its associated OH&S risks). This is dosed prior to the contact tank, to provide at least the minimum required chlorine contact time for 4 log removal of viruses. The chlorinated water then passes through a second train of UV disinfection. This will further increase the pathogen removal through the treatment process. For further details refer to Table 7. This facilitates the final reduction in pathogens to classify the water as Class A. In order to reduce the chlorine residual leaving the plant to < 0.1 mg/L, the water is dechlorinated using a solution of sodium metabisulphite.

The addition of chemical treatment has some risks to the environment and to operational health and safety. These are discussed in section 6.2 of the REIP.

Following treatment the water passes to the final water tank, which is a concrete structure external to the building. It acts as a wet well to the high lift pump station (HLPS), buffering any irregularity of flow through the treatment. The HLPS will pump Class A water along the Epsom Spring Gully Pipeline to the Spring Gully Reservoir and any users along the pipeline.

Electrical and control facilities needed to operate the Class A works are installed within the building. An upgrade to the site power has been carried out. For further details of the control system see the Control Philosophy and P&IDs in Appendices A and B.

### 3.3.3 Milestone 2

a. Ultrafiltration

Ultrafiltration is required as pre-treatment to reverse osmosis in order to minimise excess fouling of the RO membranes. These membranes will reject suspended solids, colloidal particles, bacteria, and viruses.

The system incorporates automatic backwashing, effectively removing solids and microorganisms that collect on the membrane surface during the filtration process. This includes chemical dosing in some cases to enhance backwash effectiveness. Backwash water will be returned to the inlet works of the Bendigo WRP.

b. Reverse Osmosis

A two stage RO plant is to follow the UF membranes. The RO plant includes a complete anti-scalant system including chemical tanks, bunding, dosing pumps and pipework.

RO technology was the preferred technology for salt reduction, and it will also achieve enhanced nutrient reduction.

The modular nature of the reverse osmosis plant gives it flexibility to cope with changes to influent quality, particularly in relation to TDS and Nutrients. Additional membrane modules can be installed in the future, or as an alternative, the water quality can be adjusted by decreasing the flow through the non-RO train, thereby increasing the proportion of flow through the RO train.

An automatic clean-in-place type membrane cleaning system is provided, with waste from this being evaporated in the brine lagoons.

c. Waste and Discharges

The UF and RO processes generate two separate waste streams. The backwash from the UF contains suspended solids, colloidal particles, bacteria and viruses, and will be returned to the head of the WRP for treatment. The operation of the RO plant produces a continuous waste stream in the form of a concentrated brine solution. This will be further concentrated by the electrodialysis reversal (EDR) process and then disposed of to onsite lagoons for evaporation, as discussed below.

## 3.4 Brine Lagoons

A series of four lagoons plus a deep store, bitterns and crystalliser is to be constructed. The deep store has already been constructed.

At Epsom, evaporation does not significantly exceed rainfall in wet years, reducing the efficiency of evaporation of the EDR concentrate stream. To reduce the effect of rainfall, brine will be pumped back to the deep store during winter. Any rainfall in the dry remaining lagoons will be piped to WRP lagoons 4 and 5 during this period, and will not return to the treatment process. The rainwater in the brine lagoons will be tested for salinity prior to transfer to the wastewater lagoons. If the transfer cannot be made then the saline rainwater will be retained in the brine lagoons and evaporated with the RO/EDR waste.

The cross sectional design of the lagoons, included in Appendix C, includes an HDPE liner for the deep store. The gross lagoon areas are shown in Table 4,

**Table 4**
**Gross Lagoon Areas**

| Pond Type | Area (Ha) |
|---|---|
| Deep Store | 4.8 |
| Evaporation Pond 1 | 5.9 |
| Evaporation Pond 2 | 1.5 |
| Crystallisation Pond | 0.8 |
| Bitterns Pond | 0.2 |
| **TOTAL** | **13.2** |

There are limited opportunities for reuse of the dried salt, both because it has been produced from wastewater and because of the limited quantities produced. Commercial sales of the bitterns may be possible. Disposal of some of the dried product to landfill will be required. Although the waste will not require disposal for approximately 20 years, it is noted that locally, currently only the Tullamarine landfill site is licensed to accept this waste.

Groundwater monitoring wells have been installed on site around the lagoons.

**Transfer Pipeline**

A brine waste discharge pipe, which runs parallel to Eaglehawk Creek will transfer brine waste from the RWF to the brine lagoons. This existing pipe has been extended to carry the brine solution from the RWF to the deep store.

As the transfer pipe will run adjacent to Eaglehawk Creek, a monitoring system is installed to detect leaks in the pipe. An electromagnetic flowmeter is installed at both ends of the transfer pipe to enable leak detection in the pipe during operation.

## 3.5 Pipeline and Distribution

A diagram of the final recycled water pipeline route is provided in Appendix C.

The pipe route starts at the Recycled Water Pumping and Treatment Facility site within the existing Bendigo WRP, near the intersection of Howard Street and Bowles Road, and runs south through Bendigo, along creeks, cycle paths and roads, until it reaches Spring Gully Road.

It runs along Spring Gully Rd and turns west up Shakespeare St to the Spring Gully Reservoir.

Off-takes at various points along the pipeline will be provided for public open spaces, standpipes and commercial use.

For further details of the control system see the Control Philosophy in Appendix B.

# 4 Water Quality Objectives

## 4.1 Legislation and Guidelines

EPA Discharge Licence governs water quality at Bendigo WRP. This existing licence will continue to apply to discharges to Bendigo Creek.

The EPA Use of Reclaimed Water[2] and Dual Pipe Water Recycling Schemes Guidelines[3] set the level of treatment and water quality objectives needed to address the environmental, public health and quality issues associated with Class A recycled water systems.

The Australian and New Zealand Environment and Conservation Council (ANZECC) Guidelines for Fresh and Marine Water Quality[4] discuss water quality in the context of irrigation for agricultural use. In particular they cover salinity, chloride and heavy metals. These have been considered in developing the water quality envelope applied to the project.

The Australian Guidelines for Water Recycling[5] provide further guidance on assessment of potential impacts from key recycled water quality parameters.

## 4.2 Water Quality Requirements

The recycled water from the ESGRWP meets Class A requirements as defined by the EPA guidelines. In order to demonstrate that treatment is operating effectively and continues to meet Class A standard, the recycled water must meet the following key parameters:

Pathogens:

- <10 *E coli*/100mL (as indicator of bacterial pathogens);
- helminth removal by filtration, or by appropriate lagoon detention, approved by the Chief Veterinary Officer;
- 6 log reduction of protozoan parasites, from raw sewage to recycled water; and
- 7 log reduction of viruses, from raw sewage to recycled water.

Water quality objectives that will be used to provide further confirmation of the effectiveness of treatment, in cases where treatment processes deem necessary, are:

- Turbidity < 2 NTU (24 hour median, pre-disinfection), maximum 5 NTU;
- $BOD_5$ median < 10 mg/L;
- Suspended Solids median < 5 mg/L;
- pH 6 – 9 maximum

## 4.3 Current Water Quality

Physical and chemical water quality data for the Bendigo WRP tertiary effluent (and therefore Milestone 1), as well as the combined stream from the RWF (i.e. Milestones 1 and 2), are

[2] Guidelines for Environmental Management: Use of Reclaimed Water; EPA Victoria (Publication 464.2), June 2003.

[3] Guidelines for Environmental Management: Dual Pipe water Recycling Schemes – Health and Environmental Risk Management; EPA Victoria (Publication 1015), October 2005.

[4] Australian New Zealand Guidelines for Fresh and Marine Water; Volume 4, ANZECC, ARMCANZ; October 2000.

[5] National Water Quality Management Strategy (Publication 21), Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1), Environment Protection and Heritage Council, November 2006.

summarised in Table 5 below. An ongoing maintenance and monitoring programme is in place at the Bendigo WRP and water quality is expected to improve with this programme. The combined stream column in Table 5 shows the water quality at the design flows (9.9 ML/day for Milestone 1 and 3.0 ML/day for Milestone 2).

This table is presented in further detail the REIP appendices.

**Table 5**
**Water Quality Parameters**

| Parameter | Treated effluent quality from BWRP/ Milestone 1 – Expected Limit (95%ile)* | Expected Combined Stream from RWF | Suitable for the purposes end uses listed in this document (as taken from HEMP) |
|---|---|---|---|
| $BOD_5$ | 11.7 mg/L | < 3 mg/L | Yes |
| Suspended Solids | 3.5 mg/L | < 1 mg/L | Yes |
| Turbidity | 1.33 NTU | < 2 NTU | Yes |
| Salinity | 850 mg/L TDS | < 350 mg/L TDS[6] | Yes |
| Sodium | 212 mg/L*[7] | < 200 mg/L | Yes |
| Calcium | 41 mg/L* | < 40 mg/L | Yes |
| Magnesium | 33 mg/L* | < 30 mg/L | Yes |
| Chloride | 314 mg/L* | < 250 mg/L | Yes |
| Boron | 0.080 mg/L* | < 0.1 mg/L | Yes |
| Alkalinity (CaCO3) | 260 mg/L* | < 170 mg/L | Yes |
| Cyanide | Not measured, but expected to be < 0.001 mg/L | < 0.002 mg/L | Yes |
| Total Nitrogen | 8 mg/L | < 5 mg/L | Yes |
| Phosphorus | 0.5 mg/L | < 0.5 mg/L | Yes |
| pH | 6-9 | 6-9 | Yes |
| Heavy Metals | Refer Appendix J | Within irrigation water standards and stock drinking water standards | Yes |
| Arsenic | 0.0069 mg/L* | < 0.013 mg/L | Yes |
| Microbiological quality | Class A | < 10 E.coli/100mL | Yes |
| Chlorine disinfection residual | < 0.1mg/L | < 0.01 mg/L at point of use | Yes |

Note that the major ions reported in the effluent quality column have been based on data from 2003 to 2007, during which time both Eppalock and Malmsbury source waters were used for Bendigo's water supply. Since September 2007, when primarily water from Colbinabbin (ex

[6] Based on normal average water conditions. Excludes high salinity periods in Lake Eppalock during drought.

[7] Results for asterisked parameters are from 4 samples taken 27 July, 1 & 8 August, and 28 September 2006. When estimating combined stream, major ions have been adjusted to allow for extreme TDS of 900 mg/L, compared with median TDS of 480 mg/L when samples were taken.

Waranga Channel) has been used, TDS values have dropped to less than 550 mg/L. It is expected therefore, that major ions would have dropped accordingly during this period.

A chemical risk assessment has been carried out. See HEMPs for details.

## 4.4 Water Quality Requirements for Irrigation

Risk assessments have been carried out for salinity, nutrients and contaminants related to the water quality requirements for irrigation. These can be found in the REIP appendices, and are summarised in this section.

### 4.4.1 Salinity

The water quality requirements for recycled water as set out in the various EPA Victoria guideline documents, as well as the draft National Guidelines for Water Recycling[8] were reviewed, and the key issue established was the salinity of the recycled water used for irrigation.

The potential impacts of using recycled water for irrigation, and the associated level of risk, are summarised in Table 6 below. For a more detailed explanation of each particular impact, refer to the Regional EIP.

**Table 6**
**Salinity - Summary and Conclusion**

| Potential Salinity Impact | Associated Risk | Management Required |
|---|---|---|
| *On-site (plant and stock health)* | | |
| Increasing Soil Salinity (Osmotic Effect) | Low (with exception of limited areas of impermeable soils) | Improve impermeable soils, or avoid irrigating salt sensitive plants on impermeable soils. |
| Foliar Injury | Low (except for some sensitive plants) | Avoid sprinkler irrigation direct to plant leaves in the heat of the day. |
| Sodicity | Low | No specific practices. |
| Cadmium Uptake | Low | No specific practices. |
| Stock Drinking | Low | No specific practices. |
| *Off-site environment* | | |
| Surface Waters | Low | Restrict irrigation runoff. |
| Groundwater | Low | No specific practices. |

Generally the risks related to the salinity of the recycled water are low and recommended management practices are detailed in the HEMPs.

### 4.4.2 Nutrients

Nutrients are required for healthy plant growth and are therefore beneficial to the customer. However an excess build up of nutrients in the soil can result in migration to surface waters and groundwater causing algal blooms and associated water quality problems. The nutrients applied in the recycled water are well below plant uptake rates, so the risk of excess build up in the soil is very low.

[8] *National Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1)*, 2006, Environment Protection and Heritage Council, and National Resource Management Ministerial Council

Customers will be advised through the HEMPs and site management plans about the nutrient levels in the recycled water. This enables them to adjust their fertiliser use. Further details can be found in the REIP.

### 4.4.3 Contaminants and Heavy Metals

Chemicals entering the sewerage system are managed through trade waste control, substantially diluted with other waste and generally removed or degraded by the treatment processes. The concentrations of contaminants that are of health concern are within the levels permitted by the various guidelines covering recycled water, referred to above. This is further discussed in the REIP.

# 5 Preventative Risk Management System

## 5.1 Pathogen Removal Capability

The capability of the existing Bendigo WRP process and the Milestone 1 works to remove the DHS target pathogens are summarised in Table 7. This performance is based on monitoring data gathered from July 2006 up to 19 March 2007.

**Table 7**
**Log Removal of Pathogens**

| Pathogen | | Bendigo Water Reclamation Plant & Milestone 1 | | | | | |
|---|---|---|---|---|---|---|---|
| | Class A Target Log Removal[a] | Activated sludge (BNR) [d] | Dual media filtration[d] | UV dis-infection (Trojan)[f] | Chlorina-tion | UV dis-infection (wedeco) | TOTALS |
| **Enteric viruses**[e] | | | | | | | |
| Median | 7 | 3.4 | 0.0 | 0.3 | 4 | 0.7 | 8.4 |
| Critical limit | 6[b] | 2.2 | -0.2 | (0.3) | (4) | (0.7) | 7.0 |
| **Cryptosporidium** | | | | | | | |
| Median | 6 | 1.7 | 1.4 | 3 | 0 | 3 | 9.1 |
| Critical limit | 5[b] | 0.8 | 0.6 | (0.3) | | (0.3) | 7.3 |
| **Giardia cysts** | | | | | | | |
| Median | 6 | 2.5 | 1.2 | 3 | 0 | 3 | 9.7 |
| Critical limit | 5[b] | 1.8 | 0.7 | (0.3) | | (0.3) | 7.7 |
| **Helminth ova** | | | | | | | |
| Critical limit | See note c | 2 | 2 | 2 | 0 | 0 | 4 |
| **Bacteria** | | | | | | | |
| Median | < 10 E.coli/100 mL | 2.9 | 1.0 | > 0 | 3.5 | 0 | << 10 /100 mL |

Notes:

a. Microbial criteria for Class A recycled water as defined in Table 5.1 of the Guidelines for Environmental Management: Dual Pipe Water Recycling Schemes – health and environmental risk management (EPA Victoria Publication 1015, October 2005).

b. This value is the critical limit for log removal (i.e. the point below which recycled water produced is not considered acceptable for use as a Class A product).

c. EPA Guidelines for Environmental Management: Use of Reclaimed Water specifies treatment measures to reduce helminth numbers, and further guidance is provided by the Deputy Chief Veterinary Officer (to Jeff Cummins EPA, 1 May 2007). Required performance is 4 log removal of taeneid eggs. DCVO requested 6 monthly sampling for taeneid ova in the class A water and stated the required detection limit is 1 ova/20L.

d. At worst case, indicated by 5th percentile performance.

e. The log removal values for enteric viruses are based on fRNA bacteriophages.

The following table presents a summary of the pathogen removal capacity of the stream that passes through the Milestone 2 train comprising: Ultrafiltration (UF), Reverse Osmosis (RO) and Electro Dialysis Reversal (EDR) processes.

**Table 8**
**Log Removal of Pathogens – UF/RO/EDR Process**

| Pathogen | | Bendigo Water Reclamation Plant & Milestone 2 | | | | | |
|---|---|---|---|---|---|---|---|
| | Class A Target Log Removal[a] | Activated sludge (BNR) [d] | Dual media filtration[d] | UV dis-infection (Trojan)[f] | Ultra-filtration[g] | Reverse Osmosis[g] | TOTALS |
| **Enteric viruses[e]** | | | | | | | |
| Median | 7 | 3.4 | 0.0 | 0.3 | 3.0 | 1.7 | 8.4 |
| Critical limit | 6[b] | 2.2 | 0.0 | 0.3 | 3.0 | 1.7 | 7.2 |
| **Cryptosporidium** | | | | | | | |
| Median | 6 | 1.7 | 0.0 | 3.0 | 3.8 | 1.7 | 10.2 |
| Critical limit | 5[b] | 0.8 | 0.0 | 3.0 | 3.8 | 1.7 | 9.3 |
| **Giardia cysts** | | | | | | | |
| Median | 6 | 2.5 | 0.0 | 3.0 | 3.8 | 1.7 | 11.0 |
| Critical limit | 5[b] | 1.8 | 0.0 | 3.0 | 3.8 | 1.7 | 10.3 |
| **Helminth ova** | | | | | | | |
| Critical limit | See note c | Provisional agreement from CVO, subject to testing currently underway. | | | 3.8[h] | 1.7[h] | >5.5 |
| **Bacteria** | | | | | | | |
| Median | < 10 E.coli/100 mL | 2.9 | 0.0 | > 0 | 3.0 | 1.7 | << 10 /100 mL |

Notes:

a. Microbial criteria for Class A recycled water as defined in Table 5.1 of the *Guidelines for Environmental Management: Dual Pipe Water Recycling Schemes – Health and Environmental Risk Management* (EPA Victoria Publication 1015, October 2005).

b. This value is the critical limit for log removal (i.e. the point below which recycled water produced is not considered acceptable for use as a Class A product).

c. EPA *Guidelines for Environmental Management: Use of Reclaimed Water* specifies treatment measures to reduce helminth numbers and further guidance is provided in Section 3.6 of the National guidelines NWQMS National Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1) (NRMMC 2006).

d. At worst case, indicated by 5$^{th}$ percentile performance.

e. The log removal values for enteric viruses are based on fRNA bacteriophages.

f. Only approved by DHS up to 14.5 ML/day.

g. The flowsheet for the UF/RO/EDR process shows a recycle stream from the EDR process back to just upstream of the UF process. In this case nearly all microorganisms rejected by the RO process are recycled back to the UF. This is because the EDR membranes move mainly salts through the membranes by means of an electrical potential difference. Viruses and small neutrally charged particles cannot pass through the membrane and remain in the product stream. However an overall virus (or other pathogen balance) shows that even with the 100 % EDR pathogen recycle stream, the

UF and RO process log reductions can be added to determine the pathogen log removal value through the Milestone 2 process.

h. Helminth ova similar in size to *Cryptosporidium* and *Giardia*, and therefore 3.8-log removal assumed.

Validation data for the claimed log removals is presented in Section 6.

## 5.2 HACCP

The complete treatment process has been analysed in terms of the Hazard Analysis Critical Control Point (HACCP) preventive risk management system but adapted for recycled water, the framework which is set out in Appendix C of EPA Publication 1015, *Dual Pipe Water Recycling Schemes* [9].

The purpose of the HACCP is to identify all hazards in the treatment process that could cause the final product to be out of specification, such that it could cause illness or injury. In conducting the hazard analysis, consideration should be made of:

- the likely occurrence of the hazard;
- the impact and severity that the hazard causes.

Only significant hazards are considered further. These are hazards that are categorised as medium or high on the residual risk categorisation matrix.

A workshop was held to establish the risks and consider initial mitigation measures and control points for Milestone 1. Coliban Water, CAMS, Beca, EPA and DHS attended this workshop. In the case of the Milestone 2 works, a desktop-HACCP was conducted to determine whether there were any Critical or Quality Control Points, for the UF/RO/EDR process. In doing this, a check was made backwards through the process to ensure there were no new or altered critical limits for the BNR, lagoons, tertiary filters and primary UV disinfection system. There were no new requirements for the existing plant, related to the HACCP performance of the UF/RO/EDR system. The quality of the existing BNR/Tert Filter/UV effluent is also sufficient to meet the physico-chemical water quality parameters specified for Victorian Class A effluent. This is provided the chemical dosing, located upstream of the UF process, is operated to meet the requirement for Total Phosphorus.

All Critical control points (CCP) are given further consideration. Monitoring variables are developed for each CCP, and critical limits are determined for each variable. These are limits that prevent, eliminate, or reduce to an acceptable level, the occurrence of the safety hazard. The setting of these limits must be based upon scientific data.

There may be more than one CCP applied to eliminate one hazard.

A monitoring regime of scheduled measurements is then developed, to measure compliance with the critical limits, with real time monitoring favoured. Corrective actions should these measurements cause alarm are assigned, and consist of:

- adjusting the process to bring the measured parameters back within the critical limits; and
- quarantining off-specification product, until it can be made safe or otherwise disposed.

Full details of the HACCP methodology are contained in the HACCP report, attached separately.

[9] EPA Victoria, "Guidelines for Environmental Management, Dual Pipe Recycling Schemes- Health and Environmental Risk Management", Publication 1015, October 2005, pp 5 – 21.

The CCPs and Quality Control Points (QCPs) determined by the HACCP are summarised in Table 9.

**Table 9**
**Critical and Quality Control Points**

| CCP/QCP No. | CCP/QCP Name |
|---|---|
| QCP 1 | Sewer Catchment – Total Dissolved Solids |
| CCP 1 | Sewer Catchment – Chemical Incidents |
| CCP2 | BNR Plant |
| CCP 3 | Secondary Clarifiers (OST) |
| CCP 4 | Lagoon Storage |
| CCP 5 | Filtration Through Tertiary Filters |
| CCP 6 | Primary UV Disinfection (Trojan UV3000Plus) at Tertiary Filters |
| QCP 2 | Low Lift Pump Station |
| CCP 7 | Free Chlorination |
| CCP 8 | Secondary UV Disinfection (Wedeco TAK55 HP) at Chlorine Contact Tank |
| QCP 3 | Dechlorination |
| CCP9 | BML Effluent Acceptance* |
| CCP 10 | Final Water Tank |
| QCP 4 | High Lift Pump Station |
| CCP11 No. 1<br>CCP11 No. 2 | Epsom Spring Gully Main |
| CCP 12 No. 1<br>CCP 12 No. 2<br>CCP 12 No. 3 | Spring Gully Reservoir |
| CCP 13 | Rural Channels for Stock, Domestic and Agricultural Irrigation |
| CCP 14 | Standpipes |
| CCP 15 | Recycled Water Reticulation (including public open space irrigation) |
| CCP16 | Industrial And Commercial Use |
| CCP17 | Ultrafiltration Membranes |
| CCP18 | Reverse Osmosis Membranes |

* BML flow has now been discontinued.

The supporting programmes applying to the recycled water system are detailed in the HACCP Plan.

## 5.3 Process

Process and Instrumentation Diagrams (P&ID) and the Control Philosophy are included in Appendices A and B.

# 6 Validation

## 6.1 Existing Bendigo WRP

The existing treatment plant is a Modified University of Capetown type biological nutrient removal plant. The plant is flexible enough to be operated in other configurations. The plant is rated to treat 27 ML/day domestic wastewater and trade waste. The plant processes include:

- Screening and grit removal;
- BNR process;
- Primary alum dosing;
- Lagoons;
- Secondary alum dosing and deep bed dual media filters; and
- UV Disinfection.

### 6.1.1 Existing BNR Plant

Sampling and analysis has been undertaken over the past six months to determine the capability of the treatment process to remove pathogens. This testing was based around use of indigenous microorganisms. The analysis focussed on the following indigenous pathogens:

- Bacteria (*E.coli*);
- Virus (F specific RNA phages);
- *Cryptosporidium*; and
- *Giardia.*

The following table summarises the measured removals of these pathogens:

**Table 10**
**Summary of Existing Plant Pathogen Log Removals**

| Plant Process and Pathogen | Median $Log_{10}$ Removal | 5th Percentile $Log_{10}$ Removal | Number of Samples Tested |
|---|---|---|---|
| Across BNR Plant | | | |
| E.coli | 2.9 | 1.2 | 24 |
| fRNA Phage | 3.4 | 2.2 | 24 |
| Crypto | 1.7 | 0.8 | 15 |
| Giardia | 2.5 | 1.8 | 14 |
| | | | |
| Across Lagoons | | | |
| E.coli | 2.3 | 0.8 | 23 |
| fRNA Phage | 2.6 | 2.0 | 23 |
| Crypto | 0.91 | -0.7 | 14 |
| Giardia | 1.14 | - 0.2 | 15 |
| | | | |
| Across Tertiary Filters | | | |
| E.coli | 1.0 | - 0.6 | 23 |
| fRNA Phage | 0.0 | - 0.7 | 22 |
| Crypto | 1.4 | 0.6 | 14 |
| Giardia | 1.2 | 0.7 | 16 |
| | | | |

| Plant Process and Pathogen | Median $Log_{10}$ Removal | 5th Percentile $Log_{10}$ Removal | Number of Samples Tested |
|---|---|---|---|
| Across BNR to Outlet Tertiary Filters | | | |
| E.coli | 5.9 | 4.6 | 24 |
| fRNA Phage | 6.3 | 4.7 | 23 |
| Crypto | 3.7 | 2.8 | 16 |
| Giardia | 4.6 | 3.9 | 16 |
| | | | |
| BNR plus Tertiary Filters | | | |
| E.coli | 3.9 | 0.6 | - |
| fRNA Phage | 3.4 | 2.0 | - |
| Crypto | 3.1 | 1.4 | - |
| Giardia | 3.7 | 2.5 | - |
| | | | |

The sum of the median removals across the BNR treatment plant and the tertiary filters is adopted as the microbiological removal performance of the existing treatment plant. The mean is shown here because the Dual Pipe Recycling Guidelines[10] specify that the log removals shall be median values of the sample set. The 5th and 95th percentile values are specified as the critical limits for removal, beyond which the recycled water is not considered to meet the Class A standard.

Table 11 summarises the physical and chemical operational parameters during the validation period. Further information is found in the Bendigo WRP Validation Report in Appendix F.

**Table 11**
**Operational Parameters During Sampling Period**

| Site and Parameter | 5th Percentile | Median | 95th Percentile | Standard Deviation | Number of Test Results |
|---|---|---|---|---|---|
| **Influent** | | | | | |
| Raw sewage flow [ML/day] | 12.4 | 13.64 | 16.2 | 1.8 | 168 |
| pH [units] | 7.0 | 7.5 | 8.6 | 0.52 | 163 |
| Temperature [°C] | 18 | 21.0 | 25 | 2.8 | 168 |
| **BNR Process** | | | | | |
| SRT [days] | 23 | 27 | 60 | 16 | 170 |
| ML pH [units] | 7.2 | 7.6 | 8.0 | 0.30 | 163 |
| Temperature [°C] | 17 | 22 | 26 | 3.6 | 168 |
| **Secondary Clarifier** | | | | | |
| Sludge Blanket Levels [m] | 0.08 | 0.98 | 3.98 | 1.23 | 586 |
| pH [units] | 7.1 | 7.5 | 8.1 | 0.35 | 162 |
| Turbidity [NTU] | 1.2 | 3.0 | 9.6 | 4.0 | 152 |
| Suspended solids [mg/L] | 2.0 | 6.0 | 27 | 12 | 159 |
| DSVI [mL/L] 4x dilution | 150 | 185 | 280 | 50 | 34 |
| Scum cover [% area] | 0 | 5 | 10 | | |

[10] Victorian EPA, "Guidelines for Environmental Management, Dual Pipe Recycling Schemes – Health and Environmental Risk Management", Pub No. 1015, October 2005, p 16.

| Site and Parameter | 5th Percentile | Median | 95th Percentile | Standard Deviation | Number of Test Results |
|---|---|---|---|---|---|
| Primary alum dose [L/hr] | 0 | 0 | 90 | 34 | 169 |
| **Lagoon Outlet to Tertiary Filters** | | | | | |
| Secondary alum dose [L/hr] | 16.8 | 37.5 | 51 | 13 | 168 |
| **Tertiary Filter Outlet** | | | | | |
| pH [units] | 6.8 | 7.3 | 8.0 | 0.37 | 162 |
| Temperature [°C] | 13 | 20 | 26 | 4 | 167 |
| UV transmittance [%] | 55 | 63 | 68 | 4.4 | 19 |
| Turbidity [NTU] | 0.35 | 0.48 | 1.1 | 0.48 | 165 |
| Apparent Colour [C units] | 25 | 30 | 40 | 4. | 20 |

Sludge Blanket Level is the sludge depth in the cone at a point midway radially from the centre to the clarifier wall. 5.18 m minus blanket depth equals actual depth to solids layer from the walkway, radially midway along the walkway.

Abbreviations: SRT – solids retention time
ML – mixed liquor
MLSS – mixed liquor suspended solids
DSVI – diluted sludge volume index

The removal of helminths has been estimated by desktop study. Further detail can be found in Appendix F, the existing treatment plant microbiological reductions validation.

### 6.1.2 Existing Ultraviolet Disinfection Unit

The existing UV disinfection unit is a Trojan UV300Plus unit, consisting of 112 low pressure high output (LPHO) lamps, in two banks. The validation of the existing UV unit is based upon the draft USEPA Ultraviolet Disinfection Guidance Manual[11] protocol. The sizing of the unit was approved by the Victorian Department of Human Services (DHS)[12]. Please refer to Appendix G, for further details of UV disinfection validation.

The required reduction equivalent dose (RED) was determined under the USEPA Tier 1 criteria, extrapolated to a 0.3 log reduction. The capacity of the unit has been reassessed, by altering the statistical calculation basis of original test doses delivered in the validation test, in accordance with USEPA UV disinfection rating protocol. A self-assessment of compliance with the requirements of USEPA UVDGM was carried out. There were a small number of non-compliances. The unit provides 0.3 log adenovirus inactivation under the following conditions:

- Maximum flowrate of 168 L/s (14.5 ML/d);
- Minimum UV transmittance of 56 %;
- End of lamp life factor (EOLL) of 98% at 9,000 hrs;
- Fouling factor of 95%; and
- Full power.

It is important to note that the sizing is based upon the use of Trojan supplied Heraeus lamps. These lamps have a 12% higher output to the conventional (LSI) lamps. The lamps shall be changed at 9,000 hours operation.

[11] USEPA, "Ultraviolet Disinfection Guidance Manual – Draft", EPA 815-D-03-007, June 2003.

[12] Correspondence Jan Bowman, Victorian DHS to Andrew Watson, Beca, dated 6 October, Ref ADD/06/28917

The unit provides a UV RED of 40.5 mJ/cm$^2$. The data were fitted to an equation of the form:
RED (mJ/cm$^2$.bank) = A x UVT (%) ^ b / Flow (L/s.lamp) ^c x Power x $F_{fouling}$ x $F_{EOLL}$
The constants for the equation are confidential and have been provided to Beca from the distributor under a confidentiality agreement.

The RED applied provides a 3.0 $\log_{10}$ reduction of *Cryptosporidium* and *Giardia*.
The unit is flow paced to turn on banks and modulate lamp UV power output in response to changes to flow increases and UV transmittance decreases, and fouling of the lamps. This logic is scaled on a conventional correlation of the UV dose, rescaled to fit the RED requirement.

## 6.2 Milestone 1 Works

### 6.2.1 Approach

Because Milestone 1 of the project had to be delivered within a fast-track program, the approach of relying on recognised industry guidelines and manufacturer's validations, in preference to on-site challenge testing was taken. Not only were there concerns over the associated time involved in challenge testing, but also the testing costs and the risks if equipment had been purchased and did not perform as expected.

### 6.2.2 Chlorination

Somewhat unexpectedly, there are no satisfactory industry guidelines on suitable C.t values for achieving 4 log inactivation of viruses. The guidance available was either very conservative for a fully nitrified tertiary effluent (e.g. California DHS Title 22 of 450 mg.min/L), or seemingly inadequate for a tertiary effluent (USEPA Surface Water Treatment Rule (SWTR) requirement for drinking water of 6 mg.min/L). Recognising the variability in chemical composition and particle size in different wastewaters, it was decided to undertake testing specific to the Bendigo WRP tertiary effluent, with a series of bench-scale tests to determine C.t values for the male specific number 2 bacteriophage (MS2) virus, adapt the results for the hepatitis A virus (HAV) (the target virus). The test methodology is found attached as Appendix E. In summary it was found:

- Chlorine doses of 8 to 10 mg/L achieved a free chlorine residual of 4-6 mg/L at the time of dosing and a free chlorine residual of 2.0 – 3.5 mg/L after 30 minutes.
- A worst case C.t of 10 mg.min/L was observed to provide a 4 $\log_{10}$ reduction of MS2 at pH 8 and temperature 20 °C.
- Hepatitis A and MS2 's response to chlorine are pH specific. Further details can be found in Appendix E.
- A maximum pH of 9.0 has been set for the effluent, after chlorination. The required worst-case Ct for a four log reduction of HAV is 9.2 × 133% = 12.3 mg.min/L. This value has also been adopted because Norwalk virus and like viruses are more resistant than Hepatitis A.
- Apply a 50% safety factor to the Ct, to allow for effects of particle attachment and virus aggregation between MS2 and Hepatitis A, shortfall of data at very low Ct values, excursions in effluent quality, short circuiting, swings in chlorine residual control, errors in free residual chlorine measurement, etc. The required Ct is thus 18.4 mg.min/L for water temperatures down to 10°C. At higher pHs the HAV is relatively more sensitive to free chlorine than MS2. Hepatitis is one of the more chlorine resistant viruses. Other viruses would be inactivated to a greater extent.
- The chlorine contact tank has volume of 485 kL. Apply a 0.67 factor (superior baffled tank) to the contact volume to cater for non-plug flow to give a contact volume of 325 kL. At maximum flow rates of 412 kL/hr, the detention time is 47 minutes ($t_{10}$). Thus the minimum required outlet free chlorine concentration is 0.39 mg/L based on a Ct, of $t_{10}$×outlet free chlorine residual, of 18.4 mg.min/L. The critical limit is set at 0.42 mg/L for water temperatures down to 10°C.
- The free chlorine residual starts at 3.7 mg/L and decays to 0.0.39 mg/L. Integration of the residual with respect to time from 0 to 47 minutes gives a C.t of 78.9 mg.min/L, which

exceeds the required 18.4 mg.min/L.

- For water temperatures between 7°C and 10°C a outlet free chlorine residual critical limit of 0.51 mg/L is set.

On commissioning of the treatment plant, the plug flow efficiency factor for the chlorine contact tank was tested and confirmed by tracer testing,

### 6.2.3 Secondary Ultraviolet Disinfection Unit

The UV disinfection unit is a Wedeco TAK55-HP unit, consisting of 144 Spektrotherm LPHO lamps, in three banks. As for the existing UV unit, the validation of the Secondary UV unit is based upon the draft USEPA Ultraviolet Disinfection Guidance Manual[13] protocol and the sizing of the unit was approved by the Victorian Department of Human Services (DHS)[14]. The validation was based upon testing carried out by Carollo Engineers, on tertiary treated wastewater. The unit was validated according the NWRI protocol, however the experimental dose raw data was converted statistically to the requirements of the USEPA protocol. The required RED was determined under the Tier 1 criteria, extrapolated to a 0.7 log reduction. Please refer to Appendix G, for complete details of the validation. A self-assessment of compliance with the requirements of USEPA UVDGM was carried out. There were a small number of non-compliances. The unit is designed to provide 0.70 log adenovirus reduction at worst-case conditions:

- Maximum flowrate of 114.6 L/s;
- Minimum UV transmittance of 56 %;
- End of lamp life factor (EOLL) of 87 % at 12,000 hrs;
- Fouling factor of 80%;

The unit provides a UV RED of 63.4 mJ/cm$^2$. The data were fitted to an equation of the form:
RED (mJ/cm$^2$.bank) = A x UVT (%) ^ b / Flow (L/s.lamp) ^c x Power x $F_{fouling}$ x $F_{EOLL}$
The constants for the equation are confidential and have been provided from the distributor under a confidentiality agreement.

The RED applied provides a 3.0 $\log_{10}$ reduction of *Cryptosporidium* and *Giardia*.

The unit is flow paced to turn on banks and modulate lamp UV power output in response to changes to flow increases and UV transmittance decreases, and fouling of the lamps. This logic is based on a correlation of the validated RED, based on the above formula.

It has been found from the chlorination trials that there is an improvement in UV transmittance due to bleaching of colour. It is expected that minimum transmittance will be approximately 60%.

## 6.3 Milestone 2 Works

### 6.3.1 Ultrafiltration

a. System Details

The ultrafiltration system is a Norit SXL 225 UFC model, on two skids, with an inside-out (dead end from both ends) flow mode, using a PES/PVP blend membrane material with a pore size of 0.035 μm absolute (0.03 μm nominal).

[13] USEPA, "Ultraviolet Disinfection Guidance Manual – Draft", EPA 815-D-03-007, June 2003.

[14] Correspondence Noel Cleaves, Victorian DHS to Andrew Watson, Beca, dated 20 October, Ref ADD/06/30082

b. Claimed Removal

A 3.0 $\log_{10}$ virus and 3.8 $\log_{10}$ protozoan parasite removal is claimed for the UF membranes, at the end of their useful life. The following sections summarise the evaluation undertaken to support these claims.

c. Manufacturer's Performance Testing

The initial virus removal performance of these UF membranes has been tested by challenge testing with MS2 bacteriophage, by the membrane manufacturer, Norit Membrane Technologies B.V. Greater than 5 $\log_{10}$ removal was observed for the new membranes.

A comparison of the challenge testing and ESGRWP conditions was carried out. Overall it is considered that the exceptions above do not significantly impact negatively on the microbiological removal performance of the UF membranes, in the full-scale facility compared with the pilot test conditions.

The California Department of Health has approved these UF membranes as suitable under the Surface Water Treatment Rule[15]. The conditions of approval are detailed in Table 12, below.

**Table 11**
**California DHS Approval Conditions**

| Manufacturer | Model | Maximum Log Removal Value (LRV) | | | Max Flux Loading [$L.m^{-2}.hr^{-1}$] | TMP [psi (bar)] |
|---|---|---|---|---|---|---|
| | | Virus | Giardia | Crypto-sporidium | | |
| Norit/X-Flow | SXL-225 UF | 4 | 4 | 4 | 127 | 31 (2.14) |

We note that the Epsom system will be operating at significantly lower flux rates and trans-membrane pressures than the California DHS endorsement. While the California DHS approves these membranes, as being able to achieve 4-log virus, *Cryptosporidium* and *Giardia* removal, the following discussion considers the membrane system in the context of the USEPA *Membrane Filtration Guidance Manual* and other advice, and proposes lesser removals.

d. Direct Integrity Testing

The resolution of the Air Integrity Test (AIT), which will be a pressure decay test, was checked using the *MFGM* and for the Norit system is able to detect an effective opening size of less than 3.0 µm subject to being carried out at pressure of 100 kPa, subject to the test being carried out at a water temperature of 8°C or greater.

The sensitivity of the direct integrity test in relation to one fibre cut at the potting in one skid is 3.8 log.

The Upper Control Limit (UCL) when operating at a TMP of 0.85 bar is 1.9 kPa/min, and at 0.20 bar is 5.4 kPa/min. The critical limit is set at the UCL, plus a conservative allowance for pressure decay due to diffusion. Each time the AIT is undertaken the actual TMP value that is representative of the previous operating period is fed into the equation to determine the UCL that applies to that test.

e. Virus Removal

While documentation provided by Norit membrane demonstrates that the system should be able to achieve a minimum of 3.9 log removal of viruses subject to passing of the AIT, to allow for

[15] R.H. Sakaji, "Response to November 30, 2005 Letter Re: Norit X-Flow SXL-225 Membrane(Commercial Designation UFC M5LE)", California Department of Health Services, 14 March 2006.

some loss of integrity during the life of the membranes, virus removal will be 3.0 $\log_{10}$ at the end of membrane life as loss of integrity for viruses may occur through wear of the membrane fibre wall rather than through breakage and such sub-micron paths will not be able to be detected by the AIT.

Particle counting of particles in the range 2-5 micron is used at Epsom as a continuous method of detecting membrane defects. The Pressure Decay Test will be used daily at Epsom. This testing will be backed up by MS2 bacteriophage challenge testing, which will be carried out every second year, commencing two years from commissioning, following a full Chemically Enhanced Backwash (CEB3).

f. Critical Limits

The following critical limits apply to the proposed monitoring regime:

- Particle counting > 10 particles /mL in the size range of 2-5 micron. Exceedance of this limit for up to 3 minutes three CIP cycles would shutdown the UF train system and trigger the SOP responses.
- Turbidity Prior to commissioning the particle counter, and for those periods when the particle counter is off-line for calibration or servicing, > 0.10 NTU. Exceedance of this limit for up to 15 min would immediately shutdown of the particular UF treatment train.

Post installation of particle counting > 0.15 NTU. Exceedance for up to 15 minutes would trigger an immediate shutdown of the particular UF treatment train.

Following shutdown the SOP responses will be followed.

- Air Integrity Testing (pressure decay method) > (UCL + diffusive air flow), which is equivalent to a log removal value of 3.8 $\log_{10}$ of particles down to 3 microns (100 kPa test pressure).
  Breach of Critical Limit means that the train will be isolated and the SOP followed.
- MS2 Challenge > 3.0 $\log_{10}$ minimum removal, when projected two years hence. Exceedance would trigger shutdown and repair or replacement of the faulty membrane module(s) after CEBW. Alternatively, derating of the $\log_{10}$ removal performance could occur until replacement can be undertaken.
- TMP Trans-membrane pressure (TMP) of 0.85 bar.
- Flux The feed flow to each skid will be continuously monitored and will have a limit of 85 $m^3$/hr per skid, equivalent to a flux limit of 66.4 $L.m^{-2}.hr^{-1}$.
- Minimum temperature 8°C

It is proposed to correlate one parameter against another, to refine critical limits with time. The challenge testing LRV results will be trend plotted, to identify any trend in, and predict, deterioration of the membranes.

### 6.3.2 Reverse Osmosis

a. System Details

The reverse osmosis membrane units are in a two skid configuration, each in a 2-stage 10:5 vessel array, using GE AG8040F400 Brackish Water Desalination membranes of a thin film polyamide material.

b. Claimed Removal

A 1.7 $\log_{10}$ virus and 1.7 $\log_{10}$ protozoan parasite removal is claimed for the RO membranes at the end of their useful life. The following sections summarise the evaluation undertaken to support these claims.

c. Pathogen Removal

Rhodamine WT, dye removal testing, every two years (commencing on commissioning) will be used. The ASTM Method[16] (D 6908-03) states that the removal of Rhodamine WT can be directly correlated with virus removal. The Rhodamine WT test will provide a conservative log removal performance for virus and protozoan parasites, and will be used to confirm that EC removal performance is a conservative surrogate for the claimed LRVs.

At the recovery and rejection rates at which the RO is expected to operate, the likely change in EC across the RO membrane will be 1.7 $\log_{10}$. On the basis of the work reported in Kitis et al.[17] the critical limit of 1.7 log has been set as being the practical limitation on the amount of EC removal that can be measured. The work reported in the paper by Kitis et al. showed that intact RO membranes achieved MS2 LRVs of between 5.5 and 7, and even tests with compromised elements or O-rings were able to achieve MS2 LRVs of 2.5 or greater. The paper shows that in all cases the LRV for MS2 was always greater that the LRV for EC. Hence the use of the LRV for EC as a conservative on-line surrogate for virus removal.

d. Critical Control Limits

- For electrical conductivity the proposed Critical Limit is an LRV of 1.7 log. Exceedance of the EC Critical Limit for up to 15 minutes will trigger shutdown and identification and rectification of the affected RO pressure vessel, or a Rhodamine WT dye challenge test. Normalised salt rejection will be checked manually each day to confirm that TDS removal does not drop below a LRV of 1.7. Each fortnight the EC of the permeate from each pressure vessel will be checked.
- In the case of the Rhodamine WT dye test the ASTM method (D 6908-03) indicates that the dye log removal can be directly translated to virus log removal without any correction factor (as discussed this will provide a conservative estimate of LRV). The Critical Limit is thus a minimum of 1.7 $\log_{10}$ removal of Rhodamine WT dye from the inlet to outlet of the skid.
- ORP will be used as a surrogate for possible free chlorine contact with the RO membrane. The Critical Limit will be +250 mV.
- Differential pressure Critical Limit is 300 kPa
- Permeate recovery Critical Limit is 85%.

The RO also operates under a number of quality limits.

### 6.3.3 Electrodialysis Reversal Process

The purpose of the Electrodialysis Reversal (EDR) process is to concentrate the RO concentrate stream so as to reduce the quantity of brine requiring evaporation. The dilute (product) water contains any suspended solids including any protozoa and viruses. This stream is returned to the head of the UF process. A mass balance has shown that despite this virus recycle, the net virus (and protozoan parasite) removal is the sum of the UF and RO log removal values.

[16] ASTM International, " D 6908-03 Standard Practice for Integrity Testing of Water Filtration Membrane Systems", USA, Practice C – Soluble Dye Test, pp 9 – 11.

[17] Kitis M., Lozier J.C., Kim J-H., Mi B., Marinas B.J. "Microbial Removal and Integrity Monitoring of RO and NF Membranes", J AWWA, 95 (12), 2003, pp. 105-119.

## 6.4 Commissioning Validation

The commissioning process will be carried out robustly with respect to parameters related to the pathogen removal processes and measurement of critical limits. This will include:

- maintenance and testing of parameters related to the existing plant, in accordance with the existing plant critical limits; and
- testing of new instruments and critical limits.

This will include:

- two point calibration checks for all critical instruments;
- checks of alarm functions for each critical limit, including confirmation of alarm setpoints, continuity of alarm statuses through from field to SCADA and pager;
- recording of alarm statuses on the SCADA system, for audit purposes; and
- manual inspections, measurements and sampling that confirm all other critical limits are not exceeded and that the process is stable at high and moderate flow rates.

The results of validation can be found in the Commissioning Report, which are appended, as Appendix I.

## 6.5 Post Commissioning Validation

Section 3 of the HACCP sets out the validation required for each CCP.
Instruments not subject to confirmation monitoring will be regularly calibrated. Calibration of all instruments will be carried out in accordance with CAMS Schedule for Instrument Calibration. Calibration procedures are documented for all process equipment and frequency and method of calibration as per the manufacturers instruction. Programming of these calibrations is put into the CAMS maintenance programming software (Mainpac) which automatically produces a schedule for compliance with the QMS. Instruments subject to confirmation monitoring are listed in the ESGRWP – Grab Sampling Schedule for Ongoing Monitoring. These include; chlorine residual monitors and pH meters. These instruments will be recalibrated if the deviation is greater than the required maximum error.

# 7 Verification

## 7.1 Verification Process

Full details of HACCP reviews can be found in Section 3 of the HACCP Plan, in the Verification section for each CCP and QCP.

## 7.2 Water Quality Monitoring

As detailed above, the Class A streams will be sampled and analysed for the parameters in the "Grab Sample Schedule for Ongoing Monitoring" (refer Appendix D). This program includes analysis of many possible hazardous, pharmaceutical and chlorinated organic substances.

# 8 Emergency and Incident Management

## 8.1 Incidents and Impacts

Incidents may affect the environment, or animal or human health through surface or groundwater pollution or soil contamination. These incidents may include:

- Deviation from specification of water quality;
- Toxic algal bloom in recycled water storages;
- Recycled water – potable water reticulation cross connection;
- Unauthorised use of recycled water;
- Failure of brine transfer pipe; and
- Spill of hazardous material.

Coliban Water will include in their operating procedures, emergency responses to out of specification water, and other incidents. These have been defined through the HACCP. Following the establishment of critical control points in the HACCP a corrective action plan has been developed, based on Coliban Water's potable water Risk Management Plan template. The objective for the corrective action plan is to:

- Bring the process back under control as soon as possible;
- Where possible dispose of any unsafe water before it can reach the customer; and
- Generate improvement plans to avoid recurrence of exceedance of critical limits.

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Actions upon deviation from critical limits are outlined below. Coliban Water are putting in place a number of emergency procedures relating to recycled water. These will include actions to be carried out where it has not been possible to dispose of below specification water prior to it reaching the consumer. These are covered in the HACCP plan. This table is written in standard process control language.

**Table 13**
**Water Quality Deviation Actions**

| Location | Action Upon Deviation from Critical Limits |
|---|---|
| Hazardous chemical discharged to Bendigo WRP sewage catchment | Bypass at Inlet Works to Lagoon 4 in the event of possible significant toxicants, until the event subsides. Prevent effluent going to RWF if possible. |
| High salinity in Bendigo WRP influent | Increase desalination capacity or reduce flow through Class A train to maintain a lower TDS in the final water. Consider change over to Malmsbury water source. Consult users, if not prepared to accept, shut down RWF. |
| Bendigo WRP Low Influent Load due to Power Failure exceeding 12 hours | Influent flow will overflow to Lagoon No.4. Swap power supplies if supply available. If both supplies unavailable contact the power authority and consider a generator, if outage is likely to be extended. |
| Bendigo WRP Influent Flow High High | Automatically diverts excess to Lagoon No. 4, for subsequent irrigation on the site woodlot, until the event subsides. |

| Location | Action Upon Deviation from Critical Limits |
|---|---|
| BNR process breaches critical limits | Shutdown RWF until problem is rectified. Allow flow to overflow to Bendigo Creek, provided compliant with EPA Licence, or allow to accumulate in Lagoons 1 to 3, or bypass to Lagoon 4. Consider whether to perform tests on BNR process and/or Lagoons before restarting RWF. |
| Storage and maturation Lagoons Blue-Green Algae bloom leading to algal toxins | Bypass affected lagoon(s) if possible, otherwise shutdown RWF and allow effluent to flow to Bendigo Creek, if EPA compliant. Response as per Coliban Water BGA Management & Response Plan 2007 |
| Tertiary filtration High High Turbidity or effluent Phosphorus | Stop RWF, and bypass tertiary effluent to Bendigo Creek if compliant with licence. Shut down Tertiary TP flow if necessary to rectify problem, – allow WRP flow to accumulate in Lagoons Nos. 1 to 3 until rectified. |
| Primary UV Disinfection (Trojan UV3000Plus) Level 1 Alarm | Shut down Tertiary TP flow– Allow WRP flow to accumulate in Lagoons Nos. 1 to 3 until rectified. On restarting consider the need to perform tests before restarting. |
| Chlorination System Level 1 Alarm (residual analysers) | Shut down RWF – Tertiary TP flow overflows to Bendigo Creek until rectified.<br><br>Rectify all baffle wall sealing faults when identified (6 monthly inspection). |
| Secondary UV Disinfection (Wedeco TAK55HP) Level 1 Alarm | Shut down RWF flow – Tertiary TP flow overflows to Bendigo Creek until rectified. Consider the need to perform tests before re-starting system. |
| Dechlorination System Alarm (residual analyser) LAHH | Shut down RWF flow – Tertiary TP flow overflows to Bendigo Creek until rectified. |
| Final Water Tank high E.coli | Shut down RWF, investigate the cause upstream. Maintain bird and vermin screens on tank openings |
| Epsom Spring Gully Main contamination arising during a break or its repair | As per CW/CAMS QMS. Audits of repair/maintenance data. |
| Contamination of Recycled Water Supply due to Backflow | Inspect and remedy faults |
| Spring Gully Reservoir adverse water quality (H2S, low DO, manganese, microbiological contamination) | Undertake investigations to identify the source of the problem and rectify. |
| Spring Gully Reservoir Blue-Green algae bloom | Coliban Water BGA Management & Response Plan |
| Standpipes – recycled water used for potable | Licensing of Water Carters |

| Location | Action Upon Deviation from Critical Limits |
|---|---|
| Recycled water reticulation (including public open space) cross connections to potable supply | Investigate all possible sources microbial or chemical contamination. |
| Industrial and Commercial Use contamination of Recycled Water by backflow and cross connection | Rectify improper use or inadequate agreements or HEMPs. |
| Ultrafiltration membrane integrity compromised | In the event of critical limit being breached, the defective skid will be isolated and integrity testing techniques will be used to identify the cause of failure. The skid will not be brought back on line until the problem is remedied. |
| Reverse osmosis membrane integrity compromised | In the event of critical limit being breached, the defective skid will be isolated and integrity testing techniques will be used to identify the cause of failure. The skid will not be brought back on line until the problem is remedied. |

Coliban Water maintains an Emergency Management and Response Plan, which covers the actions, roles and responsibilities of Coliban Water Staff and others in the case of a real or potential incident which could threaten the health and safety of persons, damage to property or the environment and service to customers. This plan is for use in conjunction with other plans, including:

- Dam Safety Emergency Plans;
- Coliban Water/Campaspe Asset Management Services (CAMS) Quality Management System Part 3 Emergency Response Standard Operation Procedures - Management Manual;
- Coliban Water/CAMS Quality Management System Parts 9 – 14 Operations Standard Operation Procedures - Operational Manual;
- Safe Drinking Water Act – Drinking Water Quality Management Manual;
- Blue Green Algae Management & Response Plan; and
- Spill response plan as part of Coliban Water/CAMS QMS 9.3 Chemical Storage & Handeling.

The Blue Green Algae response plan currently has three alert levels, with actions ranging from an increase in monitoring to treatment at source or the use of an alternative supply. This plan is being updated to include information on recycled water, and information will be forwarded as available.

The HEMPs will outline procedures for incidents relevant to end use of the recycled water. Copies of Coliban Water Blue Green Algae Management and Response Plan and Emergency Management and Response Plan can be found in the Regional Environmental Improvement Plan, as Appendices E and F respectively.

## 8.2 Review of Protocols

Coliban Water's emergency protocols are reviewed regularly and form part of their controlled document system. The methodology for this is in compliance with the quality management system.

Alterations to the HACCP plan must be endorsed by the Department of Human Services.

# 9 Documentation and Reporting

## 9.1 Monitoring

A long-term monitoring program has been prepared as part of the project. This includes monitoring of bacteria, protozoan (oo)cysts, viruses, nitrogen and phosphorus, metals and metalloids, non-metallic inorganics, synthetic organic chemicals and pesticides. There will also be online monitoring of pH, turbidity and electrical conductivity of the final water from the plant. In addition there will be monitoring of the chlorine residual at the outlet of the chlorine contact tank and the intensity of the lamps in the UV treatment. Details of the long-term monitoring program, including frequency of monitoring, can be found in Appendix D of the report.

The records for all monitoring results reside in the Coliban owned Data warehouse. This is populated automatically from CAM's Laboratory service provider Ecowise through their LIMS system. From the Data Warehouse data can then be extracted and reported. Field online instrument data resides in the SCADA system and is extracted, trended and alarmed using Citect software.

Critical control points are detailed in the HACCP plan, along with supporting programmes for maintenance and operation. Locations of monitoring data are listed against the relevant critical control point, in Section 3 of the HACCP plan. Records of all monitoring programs are kept. An annual report will be submitted to the EPA including analysis of monitoring data.

Most CCPs have on-line instrument monitoring of critical parameters and the Bendigo WRP Citect system logs all alarms. Two systems send alarm messages to the duty operator(s). Alarms are indicated, on the SCADA alarm page, on the duty pagers/mobile phones and by flashing light in the main control room.

All procedures for sampling, calibration, quality checks and procedural review are documented and are reviewed through the CAMS QMS every two years.

## 9.2 Incident Reporting

In the event of an incident (such as the supply of off-specification water to customers) Coliban Water will inform the EPA, DHS and other relevant agencies and stakeholders. Coliban will assess whether customers need to be informed, and carry out liaison as necessary.

Incidents that occur on customer's property will be reported to Coliban Water and included in the annual standard reporting process. Included in each customer's plan will be a reporting methodology for incidents which impact on others.

In accordance with the requirements of section 12.2 of the "GEM: Dual pipe water recycling schemes"[18], DHS must be notified in the event of any of the following:

- a system failure that may potentially impact on the end users of the recycled water (e.g. supply of off-specification water to customers);
- an emergency of incident that potentially places public health at risk (e.g. identified cross connection between recycled water and the drinking water supply); or
- any changes to the RWQMP or operation of the treatment process that may potentially impact on achieving the required microbiological criteria.

[18] EPA Victoria, "Guidelines for Environmental Management: Dual pipe water recycling schemes – Health and Environmental Risk Management", Pub 1015, October 2005, pp 45-46.

Customers must also report annually to Coliban Water a description of the area irrigated and any other information required by the agreement between Coliban and the customer.

These protocols will be reviewed annually with all other documentation.

# 10 Employee Awareness and Training

## 10.1 Operations Staff

### 10.1.1 Plant

Operators are specifically trained in all aspects of wastewater treatment and have completed Certificate 3 in Water Industry Operations, a nationally accredited course. In-house training and competency tests are conducted frequently.

A course of instruction for operational staff involved in operating and maintaining the RWF will be run. This course will demonstrate the operation of all systems and make the staff competent in operating and maintaining those systems. All necessary documentation and equipment to carry out the training will be provided.

The Operations and Maintenance manuals will be handed over before the instruction.
The instruction will include:

HACCP Introduction and Responsibilities
HACCP Response to exceedance of Critical Limits

Process overview and requirements

Pumps
Compressors
UV system
UF system
RO System (including EDR)
Chemical dosing system
Sampling systems and analysers
Control system and SCADA
Maintenance requirements for all the above

This training will be documented in CAMS QMS procedures, particularly the 13.1.19 series (Bendigo WRP and Water Factory). These procedures will be issued prior to operation of the plant commencing, and all staff will be briefed on their contents.

### 10.1.2 Pipeline

Operational staff involved in operating and maintaining the pipeline will be instructed in the new procedures that are being put in place. These include disinfection procedures for tools, and general operational requirements.

Contractors working on the pipeline (including burst repair, plumbers etc) will receive instruction prior to starting work.

### 10.1.3 Reservoir

Operational staff involved in operating and maintaining Spring Gully Reservoir will be instructed in the new procedures that are being put in place. These include the new monitoring programme, and corrective actions from the CCPs.

## 10.2 Office Based Staff

Instruction and documentation will be provided to office based staff detailing the appropriate uses, and prohibited use, of recycled water. Procedures for notifying customers and authorities of any incident or emergency will be issued prior to the Class A water being pumped, and staff will be briefed on these as appropriate.

Training of all staff will be ongoing as part of the review of the environmental and health approval documentation.

Customer centre staff will be the first point of call for users, and it is necessary that they can answer emergency queries, and they will be particularly trained in this. Coliban Water is employing a Recycled Water Officer, who will be responsible for managing the HEMPs, CSMPs and other environmental documentation. This person will be given full training required for their position.

# 11 Audit, Review and Improvement

The RWQMP will be reviewed annually, as described in section 8.3 of the REIP. The review will take into consideration changes to:

- Customer base;
- Water quality;
- Treatment processes;
- DHS guidelines;
- Regulatory requirements;
- Coliban Water policies;
- Supporting programmes; and
- EPA Guidelines

Any changes that potentially impact on human health protection measures should be endorsed by the DHS.

The RWQMP is subject to EPA statutory audit within 12 months of implementation. Ongoing audits will be discussed with the EPA. Internal audit and check requirements are detailed in the HACCP plan.

The Bendigo WRP recycled water process shall be subject to HACCP audit within 12 months of implementation.

HEMPs and operating agreements shall be subject to rotating random audits each winter.

Appendix A

# Process Flow Diagram and P&IDs

Appendix B

# Control Philosophy

Appendix C

# Pipeline Route Diagram

Appendix D

# Ongoing Monitoring Programme

Appendix E

# Spring Gully Reservoir Monitoring Programme

Appendix F

# Chlorination Testing and Validation Report

Appendix G

# Bendigo WRP Validation Report

Appendix H

# UV Validation Report

Appendix I

# Commissioning Report

Appendix J

# Heavy Metals

Appendix K

# Membrane validation report