Australian Water Recycling
Centre of Excellence

Demonstration of robust water recycling: Interim Recycled Water Quality Management Plan

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Australian Water Recycling Centre of Excellence

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About the Australian Water Recycling Centre of Excellence

The mission of the Australian Water Recycling Centre of Excellence is to enhance management and use of water recycling through industry partnerships, build capacity and capability within the recycled water industry, and promote water recycling as a socially, environmentally and economically sustainable option for future water security.

The Australian Government has provided $20 million to the Centre through its National Urban Water and Desalination Plan to support applied research and development projects which meet water recycling challenges for Australia's irrigation, urban development, food processing, heavy industry and water utility sectors. This funding has levered an additional $40 million investment from more than 80 private and public organisations, in Australia and overseas.

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1 Introduction

1.1 Purpose of the RWQMP

The Davis Station Recycled Water Quality Management Plan (**RWQMP**) has been prepared for the Australian Antarctic Division (**AAD**) Davis Advanced Water Treatment Plant (**AWTP**). The purpose of the RWQMP is to ensure the AWTP plant produces water that is fit for purpose. That purpose is to meet the environmental requirements for the outfall for Davis Station wastewater treatment process and to potentially provide options for alternative potable water sources. As a consequence, the AWTP will protect public health and the environment. The structure and content of the RWQMP has been prepared in accordance with national recycled water guidelines, phases 1 and 2.

This is an Interim RWQMP for Davis Station. It is not a completed RWQMP as there are sections remaining that require data from operation of the AWTP at Davis Station, and this has not yet occurred. Additionally, there are also management arrangements that the AAD need to confirm before the plan can be finalised. Hence, the report provides a framework for AAD to complete a RWQMP for Davis Station and identifies where review of data is required and makes suggestions for management and governance of the recycled water system. These suggestions and identification of data for review are written in red within the report.

1.2 Water Recycling Scheme Background

Davis is the AAD's most southerly station and is located on the Ingrid Christensen Coast of Princess Elizabeth Land, Antarctica. Davis Station is a scientific research base that is manned by a variety of scientific and operational personnel all year round. Through the various station activities that occur a considerable quantity of wastewater is generated each year. At present, the raw wastewater is collected and mechanically macerated before being directly discharged to the ocean via an outfall pipeline. An Environmental Impact Assessment (EIA) conducted in 2009/2010 by the AAD identified that the wastewater outfall was having an impact upon local marine environment (Environmental Impact Assessment of the Davis Station Wastewater Outfall, version 7, 14 September, 2011, AAD). As an initiative to reduce the environmental impact and to improve Australia's ability to meet its obligations under the *Antarctic Treaty (Environmental Protocol) Act 1980*, the AAD instigated a project to replace the current treatment process, and include water recycling at Davis Station.

The project was split into two separate stages. The first stage was handled by AAD and required the installation of a suitable secondary treatment plant. The second stage of the project required the installation of an advanced water treatment plant capable of producing a treated water of a potable quality for reuse at the station. To assist with this second stage of the project, a Project Team was assembled, consisting of a number of academic and industry partners, to provide expert advice regarding the design, construction, commissioning, validation and verification of an advanced water treatment plant for Davis Station. The Australian Water Recycling Centre of Excellence (**AWRCoE**) "Robust Recycling Project" provided a grant to fund this second stage of the project.

Water recycling at Davis Station will consist of the raw wastewater being treated via a membrane bio-reactor (MBR) to produce a secondary treated effluent quality of an acceptable standard to allow further treatment via a multi-barrier advanced water treatment plant. The Davis AWTP consists of seven process units and has the capacity to generate 22kL/day of treated water to a potable quality for reuse at the station. The AWTP was commissioned and its performance validated and verified at the Self's Point Wastewater Treatment Plant (SPWWTP), Newtown, Hobart. Following the completion of the performance validation and verification the AWTP will be shipped to Davis Station. It is expected that the Davis Station Water Recycling Scheme will be operational by 2017.

1.3 Management Commitment

The Australian Antarctic Division is committed to the provision of sustainable water supply and sewerage services at all its Antarctic bases. In recognition of this, the Senior Management of AAD has provided direction relating to the management of recycled water and the environment. The direction provided by the Senior Management sets the framework for the management of recycled water at AAD's Antarctic bases. The Senior Management of AAD is committed to providing recycled water delivery systems which manage environmental and health risks.

AAD ensures that adequate resources are allocated for recycled water programs, including adherence to the RWQMP and HACCP plan, and that our operators are educated about the risks and correct use of recycled water. AAD ensures that these programs are adhered to by conducting audits of recycled water management systems and by investigating health and environment incidents. AAD's commitment to the cycle of continuous improvement will be used to improve recycled water management systems where deficiencies are found.

1.4 Scope of the RWQMP

The scope of the RWQMP applies to the operation of the AWTP at Davis Station to provide treated water of a potable quality as an optional / supplementary drinking water supply. Note the treatment of tarn water for drinking water supply via the existing reverse osmosis plant at Davis Station does not form part of this RWQMP.

In summary, the structure of the RWQMP consists of the following sections:

- Section 2 – Description of the water recycling system both at Self's Point and Davis Station;
- Section 3 – Risk assessment method and outcomes;
- Section 4 – Control points, monitoring parameters and limits;
- Section 5 – Validation Results;
- Section 6 – Improvement Plan;
- Section 7 – DAWTP Monitoring;
- Section 8 – Non-conformances;
- Section 9 – Record Keeping; and
- Section 10 – Support Programs.

1.5 Regulatory and formal framework

Antarctica is an Australian Territory and as such falls under the legal jurisdiction the Australian Capital Territory (ACT). However, the AAD is a Commonwealth Agency and does not fall under the legal jurisdiction of the ACT, but rather is under federal jurisdiction. To provide a regulatory and formal framework to accommodate both legal jurisdictions the following national guidelines have been used to prepare the RWQMP:

- Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1) (2006) (**AGWR Phase 1**); and
- Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2) (2008) (**AGWR Phase 2**).

The RWQMP was reviewed by a panel of drinking water regulatory experts convened by the AWRCoE.

AAD should have the document approved by a 3rd party once the document is finalised. Currently the review by AWRCoE has only been on the interim RWQMP.

It must be noted that should the operation of the AWTP be outsourced to an external third party (i.e. a private water business) the legal jurisdiction would be that of the ACT. In this case the *Australia Capital Territory Public Health Act (1997) and Drinking Water Code of Practice (2007)* would be applicable.

1.6 Intended Use Statement and Exposure Route

The intended use of the water produced by the Davis Recycled Water Scheme is to:

- Initially provide a safe environmental discharge of tertiary treated effluent from Davis Station.
- With the possibility, subject to future requirements and community acceptance, to provide an optional/supplementary potable water supply for the purposes described below:
  - **General Use** – potable water quality for station usage e.g. kitchen, personal hygiene (washing, showering, laundry), laboratory work, medical purposes, workshop (operations and maintenance) and hydroponics.
  - **Consumption** – potable water quality for consumption by the station population and for the preparation of food.

- The **routes of exposure** associated with the Davis Recycled Water Scheme are from ingestion, inhalation and dermal contact. The highest exposure is direct consumption. It is this document that outlines the management plan to meet the environmental requirements for the outfall for Davis station wastewater treatment process and to potentially provide options for alternative potable water sources. As a consequence the AWTP will protect public health and the environment.

2 Roles and responsibilities

The following section details the Davis Water Recycling Scheme roles and responsibilities.

2.1 Recycled Water Supplier and Scheme Manager

The AAD is the Davis Water Recycling Scheme Supplier and Manager. The AAD is responsible for implementing and maintaining the RWQMP. The Scheme Manager has a duty of care to provide safe recycled water for the intended uses as specified in this RWQMP.

The Duty of Care holder for the Davis Station Recycled Water Scheme is:

Name:	Australian Antarctic Division
Address:	203 Channel Highway, Kingston Tasmania 7050
Primary Person Responsible:	Rob Wooding
Position:	General Manager Support Centre
Contact Details:	t: (03) 6232 3483 m: 0447 604 742 e: Rob.Wooding@aad.gov.au

2.1.1 List of Contact Details

The table below lists the name, roles and responsibilities for other key AAD personnel involved in the provision of safe recycled water at Davis Station.

Table 2.1 Key AAD personnel roles and responsibilities.

Name	Role	Responsibilities
David Waterhouse	Infrastructure Engineer	Owner of the DAWTP equipment and overall responsibility for maintenance and operation.
Tony Fleming	Director	Responsible for the AAD
Tim Price	Mechanical Services Officer	Responsible for the operation and maintenance of the DAWTP
(changes from year to year)	Davis Station Leader	Responsible for the day to day operation of the Station including Emergency Management and Incident reporting.

2.2 End Users

The end users of the water supplied by the Davis Recycled Water Scheme are the station personnel and any visitors to the station. It is the responsibility of the Scheme Manager to ensure that the end users are informed, educated and trained in the “conditions of use” of the water supplied by the Davis Recycled Water Scheme. Management strategies, initiatives and programs undertaken are provided in Appendix G and H of this RWQMP. Please consult with AAD for further information.

3 Davis Station recycled water scheme description

The purpose of this section is to provide a description of the Davis Station Water Recycling Scheme with an overview of the location and operating conditions, the source water characteristics, treated water production, quality and supply, intended uses and infrastructure.

3.1 System Overview

The Davis Water Recycling Scheme will provide the station with up to 22kL per day of treated water suitable for direct potable reuse as an optional or supplementary drinking water supply. The scheme consists of the collection of wastewater generated through station activities that is secondary treated via a membrane bio-reactor (MBR) process, followed by advanced treatment via a multi-barrier treatment process incorporating ozone, ceramic microfiltration, biological activated carbon (BAC) filtration, reverse osmosis (RO), ultraviolet disinfection (UV), calcite contactor and chlorine disinfection. The final treated water is stored in a clear water storage tank prior to being supplied to end users via the station distribution system. The distribution system consists of a piped network that is heat traced to prevent freezing.

3.1.1 Location and Site Description

Davis is the most southerly Australian Antarctic station and is situated 2250 nautical miles south-south-west of Perth, on the Ingrid Christensen Coast of Princess Elizabeth Land. The station is located in the Vestfold Hills, an ice-free area of about 400 square kilometres the largest coastal ice-free area in Antarctica. The climate is moderated by the rocks of the Vestfold Hills with a summer temperature maximum of +13^{O}C and a winter minimum of -40 ^{O}C with an average yearly wind speed of around 20km/h (www.antarctic.gov.au).

The site location for the MBR and AWTP process units is in close proximity to other station facilities in an area that can accommodate the operational requirements. The harsh environmental conditions at Davis present wastewater and water treatment challenges. To account for this a purpose built building has been constructed to house the process units and ancillary systems such as service and process air, backwash and chemical clean in place (CIP) systems. The building is designed to maintain a room temperature of 19^{O}C. Figure 3.1 is a photograph of the building that will house the treatment facilities and figure 3.2 illustrates the location of the building in relation to other station facilities.

Figure 3.1 The Davis Station building that is to house the treatment plant facilities.

Figure 3.2 Aerial view of Davis Station indicating location of the building that is to house the treatment facilities.

3.1.2 Source Water Inputs

The AAD has identified source water inputs from the following locations at Davis Station:

The Living Quarters (LQ) - consisting of the kitchen and dining areas with potential source water inputs from kitchen waste (microorganisms, fat and grease, nutrients and organic loading from food waste, a source of surfactants / detergents).

The Sleeping and Medical Quarters (SMQ) - consisting toilets / bathrooms and medical facilities with potential source water inputs from human waste (microorganisms, nutrients, organic loading and hormones), personal hygiene products (surfactants, pharmaceuticals) and medical waste (pharmaceuticals, CoCs).

Science (SCI) - consisting of the laboratory facilities with potential source water inputs from seawater discharged during experimental work, general laboratory discharge containing CoCs, formaldehyde, heavy metals, radioactive material, dye products.

Operations (OPS) - consisting of workshops / outbuildings, storage areas and machinery operations with potential source water inputs from operational maintenance waste / spillage (source of oil and petroleum products, other volatile organic compounds, spillage in storage areas (source of CoCs), performing operational duties (source of CoCs).

All buildings are soaked in brominated fire retardants (polybrominated diphenyl ethers (PBDE)) a fire prevention measure that presents a contamination risk should leaching in to the wastewater stream occur.

3.2 Secondary Treatment Process Description

The coagulation and MBR process provides secondary level wastewater treatment at Davis Station. The treated effluent is either discharged to a detention equalisation tank as feedwater supply for the AWTP or discharged directly to the ocean via a valve in place prior to the tank. The effluent is monitored online prior to discharge to the detention equalisation tank for the following parameters to comply with environmental discharge requirements:

- Phosphate;
- Ammonia;
- Nitrate;
- Turbidity; and
- Temperature.

3.3 Davis Advanced Water Treatment Plant

3.3.1 AWTP Overview

The purpose built building will provide a constant temperature of 19^{O}C for optimal process performance and will protect the infrastructure from deterioration. The volume of wastewater generated varies from season to season as the station population fluctuates from an estimated 120 people present during summer and down to 18 over winter. The expected operating conditions of the AWTP are:

- The AWTP has been designed to operate up to 24 hour hours a day during the summer months to meet full recycled water treatment capacity for the station. During winter the plant is expected to operate with significantly shorter run times, or once every 2-3 days.
- The AWTP has been designed for minimal maintenance during the winter months (April-September), when technical expertise and equipment may not be available. Any major maintenance is intended to be conducted during the summer season (Oct-March).
- The AWTP will treat up to 70% of waste water collected onsite to potable water quality as specified by the AGWR Phase 2. If the water is used to supplement the drinking water supply at Davis in the future, at least 30% of station supply must continue to be taken from the station tarn, to be treated in the existing drinking water treatment plant.

The point of supply defines the location where the AWTP final treated water is monitored against water quality criteria prior to supply to end users. The point of supply for the Davis Recycled Water Scheme is located post chlorine contact tank prior to the bulk clear water storage.

3.3.2 Site Layout

The AWTP plant will be located in the new Services Building extension (see Figure 3.3 below). The footprint of the AWTP plant is approximately 8m x 7m. Refer to Appendix C for detailed drawings of the process. The influent will be sourced directly from the newly installed and commissioned waste treatment plant, comprising pre-screening, BNR and MBR processes. The product water from the AWTP will be able to be directed either to environmental discharge or feed into one of the water tanks that are used to supply Davis station. Figure 3.4 presents a simplified plan for the layout of the services building.

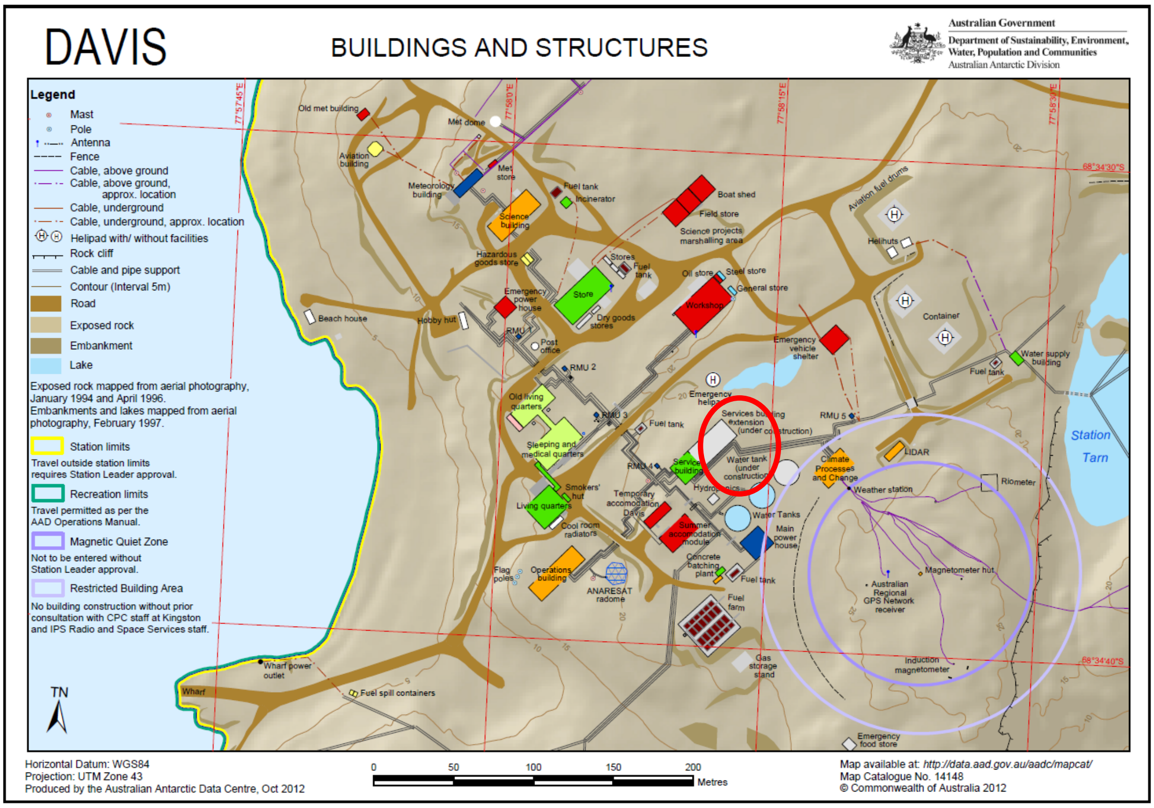


Figure 3.3 Buildings and services layout at Davis Station. New extension to service building circled in red.

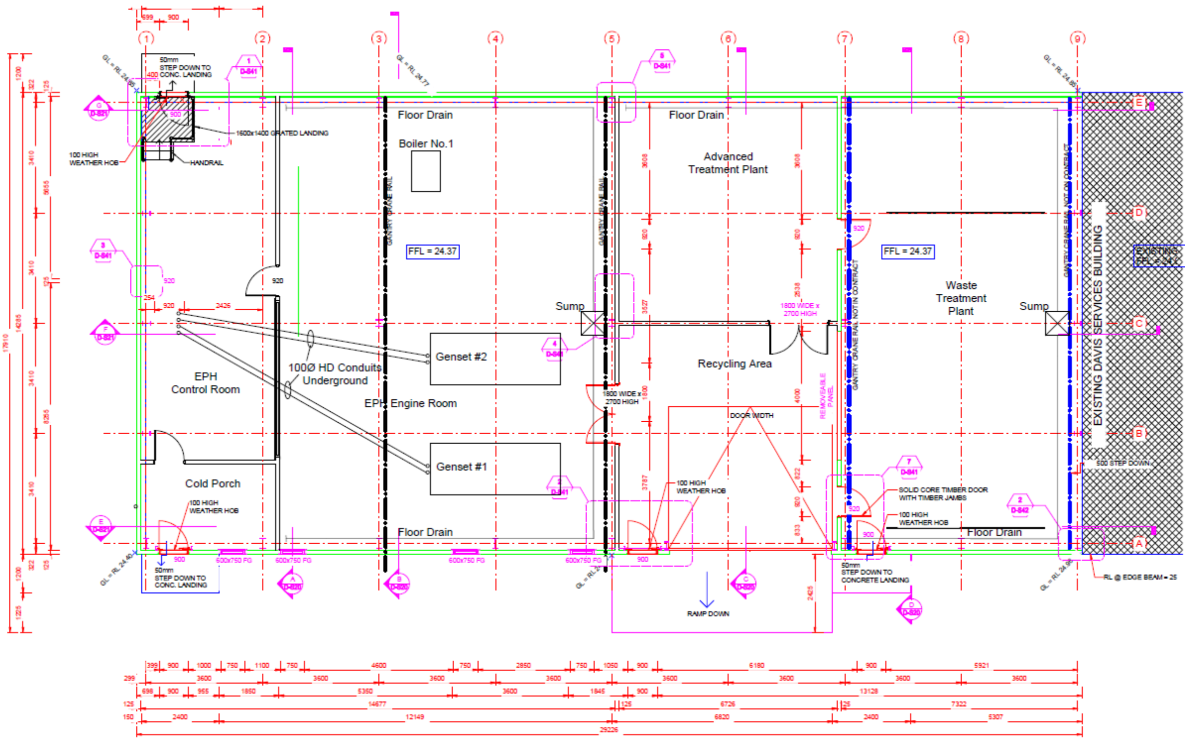


Figure 3.4 Location of waste treatment plant and advanced treatment plant in new services building extension.

3.3.3 Influent Characteristics

The AWTP feedwater is the MBR treated effluent supplied from a detention tank. Table 3.1 below presents the minimum standard MBR effluent quality requirements. The parameters marked * are expected values and the parameters marked # are the AWTP design feedwater quality specifications, and therefore, the MBR effluent must meet this criteria. Values obtained from the Davis Advanced Water Treatment Plant Function Description version 1.4 dated 27 June 2014 (AAD, 2014).

Parameter	Value
Biochemical Oxygen Demand (BOD5)*	<20mg/L
Suspended Solids (SS)*	<10mg/L
Total Nitrogen (TN)*	<10mg/L
Turbidity*	Max: 1NTU
pH*	Min: 6 Max: 8
Ammonia#	<5mg/L
Phosphorous#	<5mg/L
Bromide#	<0.69 mg/L
True colour#	<10HU
TOC / DOC#	<10mg/L

Table 3.1 AWTP Feedwater Quality (minimum standard MBR effluent requirements)

3.3.4 Design Basis

The AWTP is designed to produce up to 20kL/day (20,160 L/day) of treated water to potable quality standard. This is achieved via a multi-barrier process incorporating ozone, ceramic microfiltration (MF), biologically activated carbon (BAC) filters, reverse osmosis (RO), ultraviolet (UV) disinfection, chlorine disinfection and a calcite filter process unit for final pH correction.

3.3.5 Process Flow Diagram

The Davis Station Water Recycling Scheme process flow diagram is provided as figure 3.5 below.

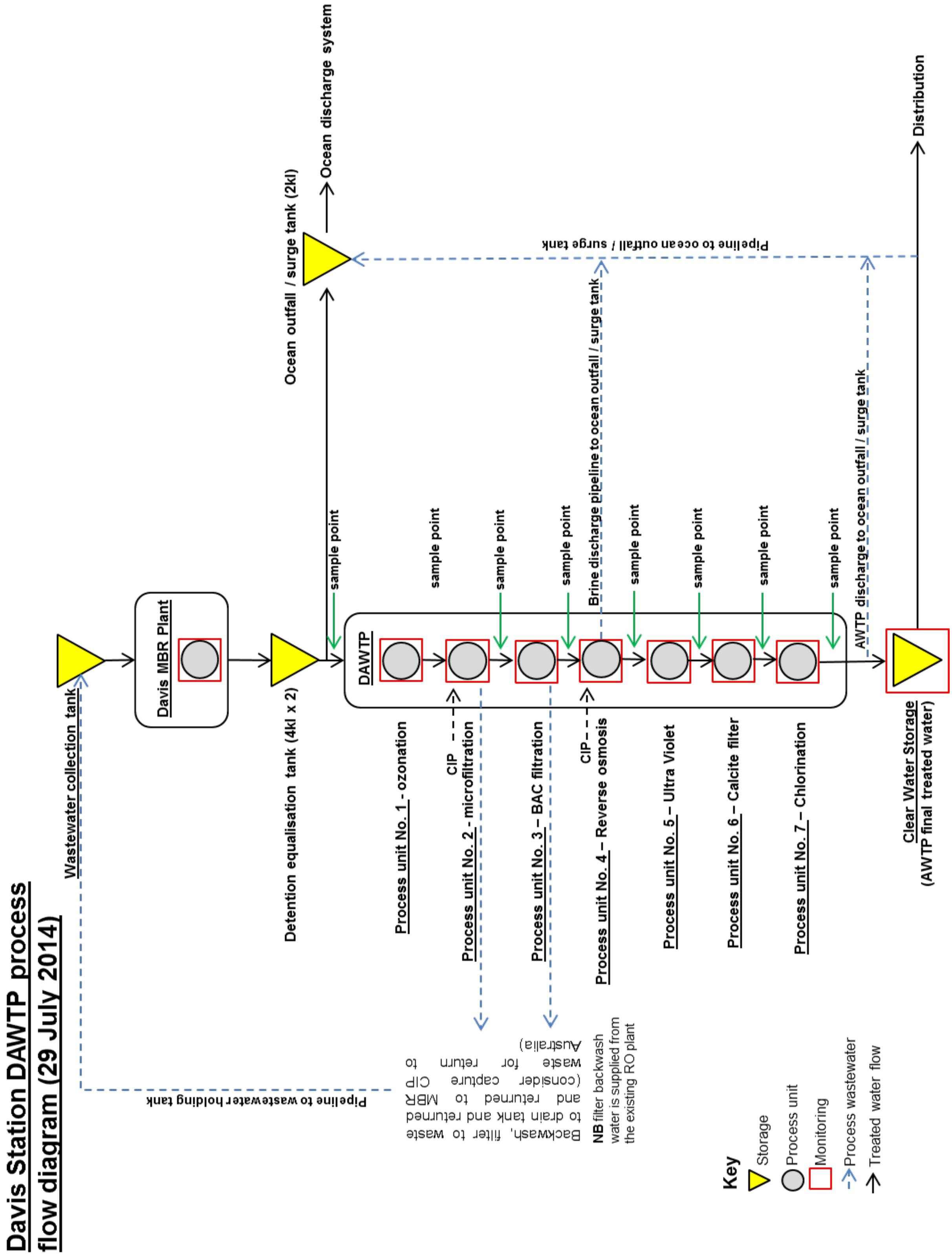


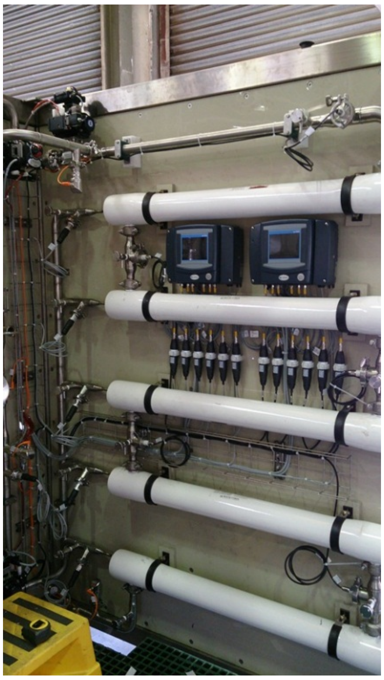
Figure 3.5 Davis Station Recycled Water Scheme Process Flow Diagram.

3.3.6 Treatment Process Components

Table 3.2 AWTP Process Unit Description.

Process Barrier & Name	Description
No. 1 MBR	The AWTP feedwater is the MBR treated effluent supplied from a detention tank. The MBR acts as a barrier for pathogens (virus, bacteria and protozoa). Credible LRV for MBR are 4 for protozoa and bacteria and 3 for virus. Monitoring Systems • Continuous online turbidity analysis (<0.2 NTU), post MBR to detect membrane failure. • Post MBR measurement of pH (6-8), ammonia (<2 mg/L), nitrate, phosphorus and temperature (>13ºC), • MBR operating parameters: flux < 32 $L.m^{-2}.h^{-1}$, transmembrane pressure ≤85 kPa
No.2 Ozonation 	This is the first AWTP process and consists of one ozone generator and contactor. It is applied in the treatment process as a strong oxidant for oxidising taste and odour compounds, trace organic compounds (TrOCs) and to increase the biodegradability of natural organic matter. As a disinfectant it is effective for virus and bacteria and less so for protozoa. Credible LRV achieved for ozone systems document in the functional description are protozoa 0 – 0.5, bacteria 4 and viruses 4. The ozone design flow is 21.5g/hr and capacity flow is 30g/hr. Monitoring Systems • Ozone residual meter after contact tank is used to adjust the ozone generator dosing flow. • Water temperature is measured to calculate the contact time (*ct*) for disinfection to achieve the required LRV.
No.3 Microfiltration 	This is the second AWTP process and consists of two ceramic microfiltration cells (MF). The MF process provides a physical barrier to the passage of suspended solids and high molecular weight dissolved solids in water. It is effective at removal of bacteria and protozoa. The design LRV for microfiltration in the function description - protozoa 4, bacteria 1 and viruses 1. Monitoring Systems • Transmembrane pressure (TMP); • Turbidity meter post MF (<0.2 NTU triggers PDT); and • Pressure Decay Test (PDT).

<table>
<tr><th>Process Barrier & Name</th><th>Description</th></tr>
<tr><td>No.4 Biologically Activated Carbon (BAC) Filter
</td><td>This is the third AWTP process and consists of one BAC filter bed. The BAC filter provides enhanced removal of TrOCs, metals and Dissolved Organic Carbon (DOC) when used in conjunction with ozonation. The purpose of the ozone / BAC filter process combination is to reduce chemicals of concern (CoCs). The BAC filter operates in two modes of treatment adsorption and biological. In adsorption mode the carbon surface physically absorbs a range of dissolved solids. In biological mode, the bacteria that live in the pores of the carbon assimilate organic matter from the water to use as a food source.

Monitoring Systems
Flow rate to determine Empty Bed Contact Time (EBCT);
Turbidity post filter (<0.2 NTU used as an indicator of solids breakthrough and sloughing of biological material from the filter); and
Differential pressure measured across filter i.e. filter headloss to initiate a filter backwash.</td></tr>
<tr><td>No.5 Reverse Osmosis
</td><td>This is the fourth process and consists of five reverse osmosis housings in series with a design recovery rate of 70%. The RO process is important for the reduction of Total Dissolved Solids (TDS) and further removal of CoCs post ozone / BAC treatment and further pathogen reduction. A mixing tank is located prior to the RO process to ensure a consistent feedwater salinity to prevent sudden changes in osmotic pressure and/or flow across the membranes to allow greater water recovery to occur. Design LRV for RO as documented in the function description – protozoa 2, bacteria 1.5 and viruses 1.5.

Monitoring Systems
Normalised spec. flux;
Normalised permeate conductivity;
Normalised salt rejection;
Normalised DP;
Feedwater and permeate flow (design cover is 70%);
Membrane differential pressure (feed fouling index);
Online conductivity meter – used to monitor membrane integrity; and
Pressure decay test (PDT) to demonstrate credible LRV of 2 for protozoa and bacteria.</td></tr>
</table>

Process Barrier & Name	Description
No.6 Ultraviolet Disinfection 	This is the fifth AWTP process and consists of two UV reactors in series. The UV process is a non-chemical process whereby pathogens contained in the water are exposed to a dose of ultraviolet radiation near the peak of germicidal effectiveness 250 – 270 nanometers (nm). This exposure results in the deactivation of the DNA or RNA of the pathogen rendering it unable to reproduce. The design LRV for the UV system as documented in the functional description - protozoa 4, bacteria 4, viruses 4. A UV dose of 186mJ/cm^2 is must be achieved to meet the required LRV. Monitoring Systems • Flow through UV system used to determine residence time; • UV intensity (transmitted UV (mJ/cm^2)); and • UV dose (UV intensity multiplied by residence time). • UVT > 95%/cm.
No.7 Calcite Contactor 	This is the sixth AWTP process unit and is not a barrier for reduction or control of a water quality hazard. It consists of one calcite contactor to provide effective alkalinity and pH adjustment to drinking water standards as the RO permeate is low in ion content and alkalinity. Adjustment is to pH 7 – 8.5 and alkalinity >40 mg$CaCO_3$/L. Monitoring Systems • Top up duration (total volume of water processed triggers preventative maintenance (PM) task); and • Online treated water pH measured post contactor.
No.8 Chlorination Disinfection 	This is the seventh AWTP process unit. It consists of a sodium hypochlorite dosing facility. Chlorine is very effective for the deactivation of pathogen microorganisms providing adequate contact time and chlorine residual is achieved for the system. Chlorine is dosed prior to a contact tank where the water is held for the required contact time. Two chlorine contact tanks allow continuous plant operation. Design LRV for the chlorination system as documented in the functional description – protozoa 0, bacteria 4, viruses 4 . The design *ct* is 22mg.min/L. Monitoring Systems • Chlorine residual after the required contact time; • Chlorine residual directly after the static mixer will be measured online; • Online pH prior to the static mixer; and • Water temperature.

4 DAWTP Treated Water Quality Objectives

The treated water quality objectives values presented in the tables below were obtained from the Davis Advanced Water Treatment Plant Function Description version 1.4 dated 27th June, 2014 (AAD, 2014).

4.1 Water Quality Requirements

Table 4.1 below presents the AWTP final physical and chemical treated water quality specifications.

Parameter	Minimum Value	Maximum Value	Units
Turbidity	-	0.05	NTU
pH	6	8	Units
Chlorine residual (free)	0.05	-	mg/L
Alkalinity	40	-	mg/L$CaCO_3$
Total Dissolved Solids (TDS)		500	mg/L
Iron	-	0.05	mg/L
Manganese	-	0.02	mg/L
Aluminium	-	0.1	mg/L
Ammonia	-	0.1	mg/L
Bromate	-	0.02	mg/L
Colour	-	5	HU
Taste and Odour	-	Acceptable	N/A
Total coliforms	-	0	orgs/100mL
E.coli	-	0	org/100mL
THMs	-	0.2	mg/L
NDMA	-	100	ng/L

Table 4.1: AWTP final physical and chemical treated water quality specification

4.2 Pathogen Removal Capability

Table 4.2 below presents the minimum pathogen specific LRVs required for the AWTP final treated water.

Pathogen	LRV	**Comment**
Viruses	12.1	Required LRV 12.1 for norovirus from study by Barker *et al* 2013
Bacteria	12.3	Required LRV 12.3 for campylobacter study by Barker *et al* 2013
Protozoa	10.4	Required LRV 10.4 for giardia from study by Barker *et al* 2013

Table 4.2: AWTP minimum pathogen LRV specification.

4.2.1 Treatment process target pathogen LRVs

Table 4.3 presents the minimum pathogen specific LRVs for each process barrier for the AWTP.

Process	LRV					
	Virus		Bacteria		Protozoa	
	Claimed	Credible	Claimed	Credible	Claimed	Credible
MBR	2	3	2	4	2	4
Ozone	2	4	2	4	0	0
Ceramic MF	1	4	1	4	4	4
Biologically Activated Carbon (BAC)	0		0		0	
Reverse Osmosis	1.5	4	1.5	4	2	4
Ultra violet disinfection	4	4	4	4	4	4
Calcite Filter	0		0		0	
Chlorination	4	4	4	4	0	0
Total	**14.5**	**23**	**14.5**	**24**	**12**	**16**
Required for Davis Station (Barker et al, 2013)	**12.1**		**12.3**		**10.4**	

Table 4.3: Claimed and Achievable LRVs for Unit Processes.

4.3 Management of health risks posed by chemicals

In addition to risk from pathogens, health risks posed by the presence of various chemicals in the wastewater stream will also need to be managed. This section of the RWQMP details the processes that will be used to manage this risk.

The environment in which this direct potable reuse arrangement would operate is unique, as there is a high degree of control of the chemicals that are allowed into Davis Station, and once those chemicals are on the Station, there is the ability to control how and when they are used, in addition to the risk mitigation provided by the AWTP.

Therefore, a hierarchy of control approach will be used to manage health risks posed by chemicals. The components of this hierarchy are:

- The assessment of chemicals prior to them arriving at the Station. If the chemical is rated as posing a very high risk to human health, a less toxic alternate chemical will be sought.
- If a less toxic alternative cannot be found, then consideration will be given to storing individual chemicals in the least practical volumes possible, so as to minimise the risk should a spill accidentally occur.
- AAD maintains a chemical management system called GoldFFX (by ChemWatch) which holds a list of all chemicals used at all AAD sites. The list can be used as the basis for conducting ongoing risk assessments in relation to the chemicals that may end up in the wastewater system at Davis Station.
- Strict controls will be put in place to ensure that chemicals are not washed down sinks, or into the wastewater system. This is particularly important for chemicals used in the onsite laboratory and workshop. Refer to Antarctic Science Program and Operations Program project plans, which are required to specify all chemicals used.
- Spill controls are in place to minimise spill risk, but also to alert operators of the AWTP of the occurrence of a spill, so that appropriate action can be taken. Refer to the AAD Spill Response procedure.
- Despite the previously-listed controls, various chemicals will make their way into, or be present in, the wastewater system. Therefore, the last control mechanism will be the various treatment processes present at the AWTP. The table below provides an overview of the types of chemicals the various treatment processes at the AWTP are capable of managing.

More detailed information on the evidence that underpins Table 4.4 can be found in the report "Risk Assessment of the Removal of Chemicals of Concern in the Davis Station Advanced Water Treatment Plant."

Table 4.4: Management of chemical risks by the treatment processes at the DAWTP.

Process	Removes these classes/groups of chemicals	Removal is based upon
MBR	Hydrophobic chemicals with a Log (D)>3.2 @pH 8 where D is the partition coefficient of the chemical between water and Octanol Ammonia, nitrite and nitrate Inorganic phosphates Organic N and P Particulate radio-nucleotides	The membrane acts as a physical barrier to the passage of particulate/suspended solids. The pore size of the membrane is nominally 35 nm, which is far greater in size than the majority of suspended particulates. The membrane also acts as a barrier to dissolved organic and inorganic species through adsorption and entrapment in the fouling layer. This then allows predation by the biomass. Total nitrogen, including ammonia, nitrates and nitrite is removed through a biological nitrogen removal process and total phosphate is reduced through the dosing of ferric salts.
Ozone	Aromatic molecules with electron withdrawing groups including hydroxyl, amino, acylamino, alkoxy or alkyl Deprotonated amines Nonaromatic alkenes	Chemicals are oxidised in contact with ozone and by OH radicals generated in the presence of ozone. The main target is organic compounds with double or multiple bonds and aromatic molecules. Ozone is very effective with electron donors such as C=C double bonds or aromatic rings with certain functional groups. Compounds with electron-withdrawing groups (EWG's) are poorly active to ozone, meanwhile, the OH radical is shown to be indiscriminate in oxidization reactions.
Ceramic MF	No specific classes of molecules removed.	Removal of CoC's by Ceramic MF is by adsorption onto the fouling layer and onto solid particulates that will then be removed by size exclusion. Fragmented organic residues may coagulate and form particulates that are then removed by size exclusion.
Biologically Activated Carbon (BAC)	No specific classes of molecules removed.	Removal of CoC's by BAC is by adsorption onto the carbon and bacterial assimilation. Hydrophobic molecules and molecular fragments are favoured for adsorption on the BAC.
Reverse Osmosis	Charged molecules and ions Ammonia, nitrite and nitrate Inorganic phosphates Particulate radio-nucleotides Chemicals adsorbed to particulates Reduced removal of neutral organic molecules below 200 MW	Removal of CoC's is through size exclusion (MW cut-off) and ionic rejection from the polymer network of the RO membrane. An extra mechanism of removal is entrapment in the filtration fouling layer.
Ultra violet disinfection	No specific classes of molecules removed.	No expected effect in terms of CoC removal
Calcite Filter	No specific classes of molecules removed.	Alkalinity of water is increased through dissolution of $CaCO_3$. No removal of CoC's expected
Chlorination	No specific classes of molecules removed.	No expected effect in terms of CoOC removal

The same alert and critical limits that are applied at the designated CCPs can be used to monitor the presence of elevated chemical risk.

The only class major class of chemicals of concern that falls outside the above hierarchy of control are pharmaceuticals. Because of the nature of the restricted access to Davis Station there a number of privacy concerns associated with disclosing what pharmaceuticals may be in use on the station at any one time.

Whilst not being able to directly control what pharmaceuticals may be on the station at any one time, as detailed in Table 4.4 above, and in report “Risk Assessment of the Removal of Chemicals of Concern in the Davis Station Advanced Water Treatment Plant,” the AWTP should be able to effectively remove any pharmaceuticals that may be present. Therefore, it is considered that any risks posed by pharmaceuticals can be adequately managed.

5 Validation of treatment processes

5.1 Demonstration plant validation

5.1.1 Plant flow

The Davis AWTP will produce up to 22kL per day of treated water suitable for direct potable reuse. This will be achieved via a multi-barrier treatment process incorporating MBR, ozone, ceramic microfiltration (MF), biological activated carbon (BAC) filtration, RO, UV disinfection, calcite contactor and chlorine disinfection.
Due to the seasonal nature of the stations the plant must be designed to deal with large variations in volume of water to be treated. Therefore the design values for the plant treatment volumes are as follows:

Maximum volume treated: 20.16 kl/day
Minimum volume treated: 2.55 kl/day

The instantaneous flowrate has been determined to be that which can achieve the maximum daily volume in 24 hours of continuous operation. This has been calculated as 20 L/min. Hence the MBR, ozone-ceramic membrane- BAC- RO systems have been designed for 20 L/min flow. Downstream systems (UV, chlorine) have been designed for proportionally less (14 L/min) based on a RO recovery of 70%.

The table below (Table 5.1) describes the methods that have been used to validate the claimed log reduction values for the treatment processes listed in Table 4.3. More details on these methods can be found in Appendix B.

Table 5.1: Validation methods for each treatment barrier.

Process	Validation method^^
MBR	Review of available literature on MBR removal characteristics. Conservative value chosen, based on known performance characteristics of MBRs
Ozone	USEPA Guidance material on ozone CT values, as well as on-site challenge at Selfs Point testing using *E. coli* and somatic coliphage
Ceramic MF	Certification of the membrane that is being used by the Department of Health Services, State of California, USA.
Reverse Osmosis	Conductivity measurement as a conservative parameter for bacteria and virus USEPA Guidance material on Pressure Decay Tests for membrane filters for protozoa
Ultra violet disinfection	Measured UV dose based on USEPA Guidance
Chlorination	The Department of Health, Victoria, *Guidelines for Validating Treatment Processes for Pathogen Reduction*

^^ Please refer to Appendix B – Log Reduction Value Table, for more information on the validation methods that were used to validate each treatment barrier

6 Operational and monitoring process control

6.1 Monitoring and Corrective Actions

6.1.1 HACCP

A water quality risk assessment is required as part of the AGWR Phase 1 and Phase 2. The risk assessment provides the basis for ensuring that the AWTP process and preventative measures implemented by the AAD within its operational responsibility are capable of removing and/or inactivating (the identified significant water quality hazards) or reducing to a level that meets the product specifications (water quality criteria) when approved. The aim of the risk assessment is to identify and assess any potential human health risk that may result from the use of the AWTP final treated water supplied as an optional / supplementary potable water supply. The risk assessment process was conducted over three day period.

6.1.1.1 Assembling the Team

The risk assessment team members involved in the risk assessment process was a selection of AAD employees, academic and industry partners with a broad range of relevant scientific, technical and operational knowledge, experience and expertise. Further details regarding the team members attending the workshops is provided below in Table 6.1 Risk Assessment Team.

Workshop Attendee	Attendance Day(s)	Organisation	Position	Experience
Tony Foy	Day 1	AAD	Engineering Manager	40+ years of industrial experience spanning many industries as an engineer and manager. 7 years' experience with the AAD as Engineering Manager.
David Waterhouse	Day 1 & 2	AAD	Project Engineer	10+ years' experience as an electrical engineer in various industries. 7 years with the AAD, 2 of which were spent in Antarctica.
Joe Brennan	Day 1 & 2	AAD	Project Officer	20+ years of experience working in Antarctica both at station and as a project supervisor from Australia. Plumbing background and wide range of experience in a variety of other industries.
Tim Price	Day 1 & 2	AAD	Mechanical Services Officer	30+ years of experience working in Antarctica both at station and as a supervisor from Australia. Plumbing and mechanical services background.
Michael Packer	Day 1, 2 and 3	AAD	Project Manager	15 years as a design and installation engineer specialising in control system and instrumentation in a wide range of industries including pharmaceutical manufacturing, food and beverage and fresh and waste water processing. Participated in many HAZOP and HACCP workshops.

Peter Scales	Day 1 & 2	University of Melbourne	Director, Australia-China Water Centre, Deputy Dean, School of Engineering Theme leader water, Carlton Connect Initiative	>20 years of experience in separations technologies and the treatment of waste water. Water and waste water treatment expertise.
Kathryn Mumford	Day 1 & 2	University of Melbourne	Lecturer, Department of Chemical and Biomolecular Engineering	>5 years experience in Antarctica and other cold climates and remote communities on waste clean-up and remediation. Application of bioremediation strategies.
Stephen Gray	Day 1, 2 & 3	University of Victoria	Director, Institute for Sustainability and Innovation	>22 years water research experience at CSIRO and Victoria University. Water quality and water treatment expertise
Jianhua Zhang	Day 1, 2 & 3	University of Victoria	Post-doctoral fellow, Institute for Sustainability and Innovation	Chemical Engineering, > 7 years operational experience in a textile factory, PhD on desalination process, expertise in water treatment process
Kathy Northcott	Day 2 & 3	Veolia	Senior Process Engineer, Victorian Region	18 years operational and process engineering experience in the gas, power and water industries. Technical expert in water and wastewater treatment operations, particularly in the areas of ozone, BAC and microfiltration.
Adrian Knight	Day 3	University of Melbourne	Research Assistant, Department of Chemical and Biomolecular Engineering	>5 years expertise in laboratory processes, waste process measurements and safety systems implementation.
Nicholas Milne	Day 3	University of Victoria	Post-doctoral fellow, Institute for Sustainability and Innovation	Expert in industrial water recycling, water quality and water quality analysis. 7+ years water treatment research, 1 year spectroscopist at Chevron in a QA/QC environment
Colin Ellett	Day 3 (second half)	Veolia	Projects Supervisor, Victorian Region	25+ years operational experience in water and wastewater operations. Significant experience in operation of multi-barrier treatment plants, as well as delivery of a number of major capital projects.

Table 6.1 Risk Assessment Team

6.1.1.2 Risk Assessment Method

The HACCP and risk assessment method was based upon the AGWR Framework Chapter 2 (assessment of the drinking water supply system) and element three (preventative measures for drinking water quality management). Reference was made to the AGRW Phase 2 for specific descriptors for health qualitative measures of likelihood, consequence and impact.

The approach taken during the HACCP workshop was unconventional due to the limited amount of water quality data available for the Davis Station system. A conventional HACCP process is usually supported by a vast array of water quality data generated over a period of time, in some cases decades, for various locations within a water supply system. This was not the case for the Davis Station system. The water quality data that existed was from a few Davis Station sampling events that provided a snapshot of the chemical contaminants that were present in the wastewater at that point in time and a quantitative microbial risk assessment (QMRA) conducted by the University of Melbourne (Barker *et al* 2013).

In contrast to a conventional water quality system assessment, the physical isolation of the Davis Station system was unique and because of this the source water inputs were well known to AAD personnel. The AAD is the only source of the contaminants likely to be in the wastewater, as all products that are present at the station are shipped there by the AAD and used by AAD personnel. No other source water inputs exist controlled or uncontrolled. For this reason it was important that the HACCP team assembled consisted of AAD personnel with firsthand operational knowledge regarding the products that are shipped to Davis Station, the application of the products and the potential that these products have to enter the wastewater stream. This enabled a desktop HACCP process to be conducted that did not rely on data from a comprehensive water quality assessment. The team was able to construct a source water input and wastewater stream profile to identify the potential water quality hazards likely to exist in the AWTP feedwater, assess the risks posed by each of these hazards and capability of the AWTP to manage/control these risks.

6.1.1.3 Hazard Identification

The identification of the hazards likely to exist for the source water and to occur or be present at each of the system process steps was based upon the use of the following information:

- The quantitative microbial risk assessment (QMRA) that was undertaken to determine the pathogen reduction requirements for direct potable reuse at Davis Station (Barker *et al* 2012);
- The water quality data from samples collected at Davis Station;
- The firsthand working station knowledge provided by the AAD personnel attending the workshop; and
- The expert opinion and knowledge provided by the scientific and technical workshop attendees experienced in the fields of water treatment and water quality.

6.1.1.4 Risk Assessment Process

For each of the water quality hazards identified the team used a qualitative risk assessment process determine the maximum risk or inherent risk to end users i.e. the risk posed without removal via the AWTP barriers. The team then considered each of the AWTP treatment steps and their effectiveness at removing, inactivating or reducing each water quality hazard assuming during normal operational conditions the treatment step was working effectively. When a treatment step was identified as essential for hazard removal, the removal effectiveness was validated. The risk assessment process considered the hazardous events that could occur at each treatment step which may reduce the effectiveness of the treatment step or the event of treatment failure i.e. abnormal operating conditions and any water quality hazard that may be introduced at each treatment step e.g. by-product formation. After considering all of the preventative / control measures in place to mitigate and manage risk (this ranged from the physical treatment process steps to management and administrative practice used by the AAD at Davis Station) the residual risk for each water quality hazard was then determined i.e. the risk posed with the risk mitigation measures in place.

A qualitative risk assessment process was used based upon the guidance given by the ADWG and AGWR Phase 1. For each water quality hazard a risk score for likelihood (A – E) and consequence (1 – 5) was agreed upon by the team using the information given in Table 6.2 and 6.3 below. This risk score for likelihood and consequence was used to classify the level of risk posed (insignificant – catastrophic) using the ADWG qualitative risk analysis matrix presented in Table 6.4. This process was used to determine both inherent and residual risk.

The team considered any water quality hazard with a risk rating of moderate and above to be significant.

Table 6.2: Qualitative measures of likelihood (ADWG, 2011).

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

Parenthesis contains information from the AGWR (2008) for qualitative measures of likelihood.

Table 6.3: Qualitative measures of consequence or impact (ADWG, 2011).

Level	Descriptor	Example description
1	Insignificant	Insignificant impact, little disruption to normal operation, low increase in normal operational costs *(Insignificant impact or not detectable)*
2	Minor	Minor impact for small population, some manageable operation disruption, some increase in operational costs *(Health – minor impact for small population)*
3	Moderate	Minor impact for large population, significant modification to normal operation but manageable, operation costs increased, increased monitoring *(Health – minor impact for large population)*
4	Major	Major impact for small population, systems significantly compromised and abnormal operation if at all, high level of monitoring required *(Health – major impact for small population)*
5	Catastrophic	Major impact for large population, complete failure or systems *(Health – major impact for large population)*

Parenthesis contains information from the AGWR (2008) for qualitative measures of consequence or impact.

Table 6.4: Qualitative risk analysis matrix: level of risk classification (ADWG, 2011).

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

6.1.1.5 Determining CCPs and QCPs

The ADWG details the criteria that a preventative measure must meet for selection as a CCP. A CCP has several operational requirements, including:

- Operational parameters that can be measured and for which critical limits can be set to define the operational effectiveness of the activity (e.g. chlorine residuals for disinfection)
- Operational parameters that can be monitored frequently enough to reveal any failures in a timely manner (online and continuous monitoring is preferable)

- Procedures for corrective action that can be implemented in response to deviation from critical limits.

The ADWG provides a critical control point decision tree, and this was used to determine the potential CPPs applicable to the operation of the Davis Station AWTP.

Where preventative (control) measures do not meet the criteria for CCP, however, and they were still considered important operational/process steps to ensuring the quality of the final product, these were termed Quality Control Points (QCPs).

6.1.1.6 Risk Assessment Outcomes

There were a total of one hundred and twenty four water quality hazards identified for the Davis Station system that were likely to exist in the AWTP feedwater, to be present at or to occur at each treatment step. These are discussed further in each of the sections below.

6.1.1.7 Overall findings

During normal routine station operations the highest ranking source water risks to pass through the MBR process into the AWTP feedwater is from pathogenic microorganisms - bacteria, viruses, and protozoa. Identification of specific target pathogens was not part of the HACCP workshop, and this occurred during the validation and verification phase.

Other **high** ranking water quality risks likely to pass through the MBR process and be present in the AWTP feedwater during normal routine station operations are from:
Brominated flame retardant compounds;

TOC/DOC;

Colour;

Pharmaceutical products and their metabolites;

Chemicals of Concern (CoCs) the team considered CoCs broadly as carcinogens, endocrine disruptors and hormones;

Antiseptics;

Volatile Organic Carbon (VOCs) water dispersible; and

Cleaning products from disposal of field waste.

Source water risks to pass through the MBR process and pose a **moderate** risk in the AWTP feedwater during normal station operations are from:
Residual cleaning chemicals – ammonia based (all buildings);

Nutrients (nitrogen and phosphorous) human waste from station, field trip waste disposal and kitchen activities);

Turbidity;

Personal hygiene products - surfactants;

Colour (kitchen activities);

Antibiotics – including penicillin as an allergen;

Bacteria from yeast cultures;

Formaldehyde;

Dye residual and chemical products; and

Bromine – release of spa water to wastewater stream.

6.1.1.8 Hazardous Events Identified

The hazardous events (or abnormal operating conditions) identified contributing to elevated source water or process water risks are:
A gastrointestinal disease outbreak at the station resulting in the wastewater stream having an elevated pathogenic microorganism loading

A station spill event that is not adequately contained or is washed into a drain resulting in the following water quality hazards (contaminants) to enter the wastewater stream:

- Glycol;
- Hydrocarbons from a fuel or oil spill;
- Cleaning products (all products);
- Radioactive material and heavy metals from the science building; and
- Iron and manganese from a treatment chemical spill.

Bulk disposal via the wastewater stream of unusable food products i.e. out of date or rotten resulting in a slug dose to the system elevating the risk posed by the following water quality hazards:

- Nutrients (nitrogen and phosphorous);
- TOC/DOC;
- Turbidity;
- Colour; and
- TDS.

Failure of existing RO system providing potable water to the station resulting in an elevated risk from the following water quality hazards:

- Microorganisms;
- Bromide;
- Silica; and
- Chloride.

Equipment or process failure or suboptimal operating performance resulting in chemical under/over dose situation or inadequate/reduced treatment capability e.g. MBR, membrane or disinfection failure.

6.1.1.9 Treatment Capability

The outcome of the risk assessment indicated that the AWTP treatment barriers will adequately control the health risk derived from the microorganism risks present under normal station operations and during a gastrointestinal disease outbreak at the station affecting a third of the population. The table below is a revised LRV listing for the AWTP current as of 6 May 2014.

Table 6.5: Required minimum pathogen LRV for AWTP final treated water.

Pathogen	Minimum pathogen LRV
Viruses	12.1
Bacteria	12.3
Protozoa	10.4

The risk assessment outcome (Bartlett *et al*., 2015)indicated that the AWTP treatment barriers should adequately control the health risk derived from physical, chemical and radiological source water hazards that pass through the MBR process to the AWTP feedwater or that may occur at a treatment step. However, it must be noted that the team made assumptions regarding some of the risk determinations documented and that further research will be required to fill the knowledge gaps and reduce the risk assessment uncertainty (refer to section 6.1.1.10 below).

The following water quality hazards were identified as occurring during the treatment process.
The formation of bromate during the ozonation process from bromide in DAWTP feedwater posing a very high risk; and

The formation of formaldehyde from aldehyde in the DAWTP feedwater posing a moderate risk.

6.1.1.10 Risk Uncertainty

While the source water input and wastewater stream profile was based on firsthand working station knowledge, there remains a degree of uncertainty concerning the dispatch of chemical products, the use of certain products and the disposal or return to Australia policy.

Hence it is imperative to the implementation of the Davis Station Recycled Water Scheme that a Recycled Water Policy is maintained by the AAD and is supported by management and operational procedures that are aligned with certain risk determinations. For example:

- managing source water inputs through a controlled approved Davis Station chemical/products inventory,
- chemical management procedure, such as, onsite storage, handling and use, spill response/containment,
- waste management procedures, and
- products for return to Australia procedures.

The establishment of the above and the communication of this information to the AWTP demonstration operations validation and verification team will assist with reducing the uncertainty associated with certain risk determinations.

The AAD chemical inventory forms the basis of a quantitative chemical risk assessment “QCRA”, by:

- Preparation of a chemical risk decision tree (or matrix) that can identify chemicals likely to pass through key process barriers, based on typical characteristics (ie molecular weight, charge, solubility etc.)
- Calculation of maximum concentrations, based on chemical volumes purchased by the AAD.
- Review of COC’s, disinfection by-products and other relevant trace organic chemicals against the Self’s Point operational data and bioassay results and preparation of chemical removal validation report.

The above information will be used for:

- Determination of maximum allowable container volumes and storage volumes at Davis station.
- Implementation into the selection and approvals process for all new chemicals brought to site.

6.1.1.11 Outcomes for Option / Supplementary Drinking Water Supply

The resulting risk profile produced a low residual risk rating for each water quality hazard identified. Based upon this the AWTP treatment processes are capable of reducing significant water quality hazards to a level that meet water quality criteria suitable for an optional / supplementary drinking water supply

6.2 Critical Control Points

Preparation of a hazard risk register to identify hazardous events and corrective actions have been identified for the AWTP, that aim to avoid harm to human health. Summarised in Table 6.6 are the CCPs and QCPs (Quality Control Points) for each of the treatment process units relevant to the demonstration plant. Refer to Appendix K for a full list of the HACCP risk register.

6.2.1 Critical Control Points and Limits

Table 6.6: CCPs and QCPs of the DAWTP.

Critical Control Plan - Davis Advanced Water Treatment Plant					
AWTP-CCP-1-2		**Davis Station MBR Effluent Quality**			
Potential Hazard(s):		**Sub-performance of Nutrient Removal system** may result in potential: ▪ Reduced treatment capability and effectiveness of the Advanced Water Treatment Plant process units. CCP for pathogen removal			
Key Control Measure(s):		**Nutrient Removal Plant Final treated effluent (post detention tank)**			
		Ammonia (mg/L) Targets based expected MBR water quality	**Turbidity (NTU)** Target based on expected MBR water quality	**pH (units)** Target based on AAD plant FD	**Temperature (^{O}C)** Target based on AAD FD (target)
Target Criteria:		<1 mg/L	<0.2NTU	6.5 – 7.5	19^{O}C
Alert Limit:		> 1 mg/L 1 instrument reading	>0.2 for 1 instrument reading	pH<6.5 or >7.8 for 1 instrument reading	<16 or >28 for 1 instrument reading
Critical Limit:		>2 mg/L for 2 instrument readings	>0.2 NTU for 2 instrument readings	<6 or >8 for 2 instrument readings	<13 or >30 for 2 instrument readings
Monitoring:	**What:**	Ammonia (mg/L)	Turbidity (NTU)	pH (units)	Temperature (^{O}C)
	How:	Ammonia analyser (on-line) with grab sample & onsite testing weekly for verification	Turbidity analyser (online) with grab sample & onsite testing weekly for verification	pH analyser (online) with grab sample & onsite testing weekly for verification	Feedwater temperature (online) with grab sample & onsite testing weekly for verification
	When:	Continuous SCADA, Weekly verification with handheld instruments	Continuous SCADA Weekly verification with handheld instruments	Continuous SCADA Weekly verification with handheld instruments	Continuous SCADA
	Where:	Feed to MBR effluent storage tank	Feed to MBR effluent storage tank	Feed to MBR effluent storage tank	Feed to MBR effluent storage tank
	Who:	Automatic, AWTP field operator & AWTP control operator			
	Records:	SCADA trends, alarm pages, operator daily inspection logs			

Corrective Action:	What action is required?	When to action?	Who is responsible?	Records
	Analyser checks and calibration – check analysers (probes and flow to instrumentation), perform measurement verification check and perform calibration if required.	Alert limit	AWTP Field Operator	SCADA
	Notification of Supervisor	Alert limit	AWTP Field Operator	Plant Diary
	Automatic shutdown (turbidity, temperature, pH)	Critical	Automatic	SCADA
	Manual plant shutdown (Ammonia)	Critical	AWTP Control Operator	SCADA
	Divert flow to ocean outfall/surge tank for discharge	Critical	Automatic	SCADA; plant diary
	Operator checks – review SCADA trends, influent quality, visual plant and process inspection etc.	Alert & Critical	AWTP Operators (field and control)	Plant diary;
	Analyser checks and calibration – check analysers (probes and flow to instrumentation), perform measurement verification check and perform calibration if required. For TasWater analysers – check online readings against sample & test.	Critical	AWTP Field Operator	Plant diary; instrument records. Lab testing record.
	Notification of supervisor	Critical	AWTP Field Operator	Plant diary; incident report
	Generate an incident report	Critical	AWTP Control Operator	Incident report form and register

Critical Control Plan - Davis Station Advanced Water Treatment Plant

AWTP-CCP-2		**Oxidation Control**	
Potential Hazard(s):		**Sub-performance of ozonation system** may result in potential: ▪ partial oxidation of compounds reducing the contaminant removal efficiency of the BAC filter process e.g. CoCs, TOC/DOC and pharmaceuticals; ▪ formation of by-products e.g. formaldehyde, bromate, THMs; and; ▪ reduced effectiveness of the microfiltration process. ▪ Reduced LRV for pathogen removal	
Key Control Measure(s):		**Ozone System**	
		Ozone residual (mg/L) Target based on USEPA CT values for virus and bacteria	**Ozone dose (mg/L)** Target based on: -CoC removal capability at specific ozone dose as demonstrated at Self's Point. -Claimed LRV of 2 for virus and bacteria as demonstrated at Self's Point (Zhang *et al*, 2015)
Target Criteria:		0.25 mg/L Based on USEPA CT values for 0.5 LRV for protozoa	14 mg/L
Alert Limit:		<0.1 mg/L for > 10 mins	<12 mg/L for > 10 mins
Critical Limit:		< 0.05mg/L Based on ozone Ct calculation LRV tables for AWTP	< 11.7 mg/L
Monitoring:	**What:**	Ozone residual (mg/L)	)
	How:	Online analyser (L3045)	on ozone –in-gas analyser and feedwater flowmeter
	When:	Continuously (specify SCADA polling intervals)	Continuously (Specify SCADA polling intervals)
	Where:	Post ozone contactor tank	Ozone dosing point
	Who:	Automatic, AWTP Field Operator & AWTP Control Operator	Automatic, AWTP Field Operator & AWTP Control Operator
	Records:	SCADA trends, alarm pages; operator daily inspection log	SCADA trends, alarm pages; operator daily inspection log

These target values will need to be reviewed and amended once better feedwater quality data is developed at Davis station. It's highly likely that a significantly lower dose will be required post-MBR.

Corrective Action:	What action is required?	When to action?	Who is responsible?	Records
	Automatic plant shutdown	Alert limit	Automatic	SCADA
	Manual plant shutdown	Anytime	WTP Field Operator	SCADA
	Operator checks – review SCADA trends (dosing rate, ozone residual, flow rates), DAWTP feedwater quality, visual plant inspection and ozone system etc.	Alert & critical	WTP Control Operator	SCADA; plant diary
	Analyser checks and calibration – check analyser (probe and flow to instrument), perform measurement verification check, re-calibrate if required.	Alert & critical	WTP Field Operator	Plant diary; instrument records
	Notification of supervisor	Alert & Critical	WTP Field Operator	Plant diary; incident report
	Generate an incident report	Alert & critical	WTP Control Operator	Incident report form and register
	Automatic plant shutdown	Alert limit	Automatic	SCADA

Critical Control Plan - Davis Station Advanced Water Treatment Plant

AWTP-CCP-3	**Filtration Control**	
Potential Hazard(s):	**Sub-performance of microfiltration system** may result in potential: ▪ Bacteria, protozoa passage through to treated water; and; ▪ Reduced effectiveness of subsequent treatment processes due to passage of solids/organic matter (e.g. reverse osmosis, UV disinfection and chlorination).	
Key Control Measure(s):	**Microfiltration system**	
	Pressure Decay Test (PDT) – log reduction value	**Turbidity (NTU)** Need to mask the turbidity for the first 10 minutes following backwash due to bubbles
Target Criteria:	>4.2 log removal (protozoa)	< 0.2 NTU
Alert Limit:	<4.2 log removal from PDT	>0.2 NTU for > 10mins
Critical Limit:	< 4 log removal from PDT Target based on LRV table for AWTP	> 0.2 NTU for 2 instrument readings Target based on MF system at Bendigo WTP

Monitoring:			
	What:	Calculated log reduction value	Turbidity (NTU)
	How:	Pressure decay test	Online turbidity analyser (L3088)
	When:	At least once per plant run	Continuously (insert SCADA polling intervals)
	Where:	Each membrane	Filtrate turbidity analyser
	Who:	Automatic, AWTP Field Operator & Control Operator	Automatic, AWTP Field Operator & Control Operator
	Records:	SCADA	SCADA

Corrective Action:	**What action is required?**	**When to action?**	**Who is responsible?**	**Records**
	Automatic plant shutdown	Critical limit	Automatic	SCADA
	Manual plant shutdown	Anytime	WTP Field Operator	SCADA
	Direct integrity test after turbidity >0.4 NTU	Alert limit	Automatic	SCADA
	Operator checks	Alert & critical	WTP Field Operator	Plant diary; SCADA
	Analyser checks and calibration	Alert & critical	WTP Field Operator	Plant diary; instrument records
	Visual inspection	Alert & critical	WTP Field Operator	Plant diary
	Notification of supervisor	Alert & Critical	WTP Field Operator	Plant diary; incident report
	Generate an incident report	Alert & critical	WTP Control Operator	Incident report form and register

Critical Control Plan - Davis Station Advanced Water Treatment Plant

AWTP-CCP-4 Reverse Osmosis Control

Potential Hazard(s):

Sub-performance of reverse osmosis systems may result in potential:

- Total Dissolved Solids (TDS) passage through to treated water;
- Organic matter (TOC/DOC) passage through to treated water reducing the effectiveness of subsequent treatment processes (e.g. chlorination) and contributing to the formation of by-products (e.g. THMs);
- Contaminant e.g. Chemicals of Concern (CoCs) passage through to treated water; and;
- Pathogenic microorganism passage through to treated water (protozoa).

		Reverse Osmosis system		
Key Control Measure(s):		**Pressure Decay Test - LRV**	**Conductivity (uS/cm)**	**Chemical sampling & analysis**
Target Criteria:		2.5 log reduction	1.7 LRV	> 90% removal of CoCs Based on annual chemical sampling and analysis across RO system, compared against verification report from Self's Point
Alert Limit:		2.1 log reduction	<1.6 LRV for > 1 instrument reading	
Critical Limit:		<2 log reduction Target based on protozoa.	<1.5 LRV for 2 instrument readings	
Monitoring:	**What:**	Calculated log reduction value	Calculated log reduction value	Percentage removal of CoCs across RO
	How:	Pressure decay test	Online analyser (L3121-feed, L3154-permeate)	Sampling and chemical analysis, verified against Self's Point operating data.
	When:	Every XX hours as scheduled in SCADA	Continuously (insert SCADA polling intervals)	Annually
	Where:	Single stage of 5 elements	Single stage of 5 elements	Single stage of 5 elements
	Who:	AWTP Field Operator & Control Operator		AWTP Field Operator, approved analytical laboratory
	Records:	SCADA		External lab testing records

Corrective Action:	**What action is required?**	**When to action?**	**Who is responsible?**	**Records**
	Automatic plant shutdown	Critical limit	Automatic	SCADA
	Manual plant shutdown	Anytime	AWTP Field Operator	SCADA
	Operator checks	Alert & critical	AWTP Field Operator	Plant diary; SCADA
	Analyser checks and calibration	Alert & critical	AWTP Field Operator	Plant diary; instrument records

	Visual inspection	Alert & critical	AWTP Field Operator	Plant diary
	Notification of supervisor	Alert & Critical	AWTP Field Operator	Plant diary; incident report
	Generate an incident report	Alert & critical	AWTP Control Operator	Incident report form and register

Critical Control Plan - Davis Station Advanced Water Treatment Plant

AWTP-CCP-5		**Disinfection Control**			
Potential Hazard(s):		**Sub-performance of ultraviolet systems** may result in potential: ▪ Bacteria, protozoa, virus passage through to treated water; and; ▪ Ineffective deactivation/kill of pathogenic bacteria with possible regrowth occurring post treatment in storage and/or the distribution.			
Key Control Measure(s):		**Ultraviolet System** **UV Dose (mJ/cm^2)** to achieve 4 Log Reduction Value virus, bacteria, protozoa			
Target Criteria:		>300 mJ/cm^2			
Alert Limit:		<300mJ/cm2 (for 2 consecutive instrument readings – based on the lower limit of aged lamps and less than this does represents lamps are close to their end life)			
Critical Limit:		<186 mJ/cm^2 Based on AAD plant FD			
Monitoring:	**What:**	Calculated dose			
	How:	UV intensity and plant flow = contact time (*ct* - mJ/cm^2) (L3167, L3171, L3176, Flow-L3153)			
	When:	Continuously (during plant run time)			
	Where:	UV lamp			
	Who:	Automatic, AWTP Field Operator & Control Operator			
	Records:	SCADA trends, alarm pages; operator daily inspection log			
Corrective Action:		**What action is required?**	**When to action?**	**Who is responsible?**	**Records**
		Automatic plant shutdown	Critical limit	Automatic	SCADA
		Manual plant shutdown	Anytime	WTP Field Operator	SCADA
		Operator checks	Alert & critical	WTP Field Operator	Plant diary; SCADA
		Analyser checks and calibration	Alert & critical	WTP Field Operator	Plant diary; instrument records
		Visual inspection	Alert & critical	WTP Field Operator	Plant diary
		Notification of supervisor	Alert & Critical	WTP Field Operator	Plant diary; incident report
		Generate an incident report	Alert & critical	WTP Control Operator	Incident report form and register

Critical Control Plan - Davis Station Advanced Water Treatment Plant

AWTP-CCP-6		Final pH Correction Control			
Potential Hazard(s):		**Sub-performance of calcite filter system** may result in potential: ▪ Imbalance of ion and alkalinity content in the treated water; and; ▪ pH range that may reduce the effectiveness of the chlorination treatment process.			
Key Control Measure(s):		**Calcite Filter System**			
		pH (units)			
Target Criteria:		7.0			
Alert Limit:		pH <7.0 and >7.9 for 1 instrument reading			
Critical Limit:		pH <6.5 and >8.0 Targets based on Selfs Point operating data			
Monitoring:	**What:**	pH (units)			
	How:	Online pH analyser (L3188)			
	When:	Continuously (during plant run time)			
	Where:	Post static mixer			
	Who:	AWTP Field Operator & Control Operator			
	Records:	SCADA trends, alarm pages; operator daily inspection log			
Corrective Action:		**What action is required?**	**When to action?**	**Who is responsible?**	**Records**
		Automatic plant shutdown	Critical limit	Automatic	SCADA
		Manual plant shutdown	Anytime	WTP Field Operator	SCADA
		Operator checks – review SCADA trends (calcite level, flow rates), DAWTP feedwater quality, visual plant inspection etc.	Alert & critical	WTP Field Operator & Control Operator	SCADA; plant diary
		Analyser checks and calibration – check analyser (probe and flow to instrument), perform measurement verification check, re-calibrate if required.	Alert & critical	WTP Field Operator	Plant diary; instrument records
		Notification of supervisor	Alert & Critical	WTP Field Operator	Plant diary; incident report
		Generate an incident report	Alert & critical	WTP Control Operator	Incident report form and register
		Automatic plant shutdown	Critical limit	Automatic	SCADA

Critical Control Plan - Davis Station Advanced Water Treatment Plant

AWTP-CCP-7 Disinfection Control

Potential Hazard(s):		**Sub-performance of chlorination systems** may result in potential: ▪ Bacteria, protozoa, virus passage through to treated water; and; ▪ Ineffective deactivation/kill of pathogenic bacteria with possible regrowth occurring post treatment in storage and/or the distribution.			
Key Control Measure(s):		**Chlorination System** **ct (mg.min/L)** to achieve 4 Log Reduction Value virus and bacteria			
Target Criteria:		>24 mg.min/L			
Alert Limit:		<24 mg.min/L for 1 instrument reading			
Critical Limit:		<22 mg.min/L for 2 instrument readings Based on pH 8.5			
Monitoring:	**What:**	Calculated ct value			
	How:	Chlorine residual, flow meter and temperature (Cl-L3198, Cl-L3205, TT-L3181, Flow-L3153) *ct* mg.min/L			
	When:	Continuously (during plant run time)			
	Where:	At contact tanks (recirculating flow)			
	Who:	Automatic, AWTP Filed Operator & Control Operator			
	Records:	SCADA trends, alarm pages; operator daily inspection log			
Corrective Action:		**What action is required?**	**When to action?**	**Who is responsible?**	**Records**
		Divert product water to MBR storage tank	Critical limit	Automatic	SCADA
		Manual plant shutdown	Anytime	WTP Field Operator	SCADA
		Operator checks	Alert & critical	WTP Field Operator	Plant diary; SCADA
		Analyser checks and calibration - sensors and feed hypochlorite concentration	Alert & critical	WTP Field Operator	Plant diary; instrument records
		Visual inspection	Alert & critical	WTP Field Operator	Plant diary
		Notification of supervisor	Alert & Critical	WTP Field Operator	Plant diary; incident report
		Generate an incident report	Alert & critical	WTP Control Operator	Incident report form and register

Critical Control Plan - Davis Advanced Water Treatment Plant

AWTP-QCP-1		**Source Water Input Management**				
Potential Hazard(s):		<u>Inadequate</u> **source water input management** practices may result in potential: • Entry of unknown contaminants into the wastewater stream and passage through to treated water or the formation by-products; and; • Excessive contaminant loading in the wastewater stream compromising the treatment capability of the SWWTP and AWTP.				
Key Control Measure(s):		**Chemical / Substance Management and Waste Management**				
		Approved Chemical and Substances Register	**Davis Station Chemical and Substances Inventory**	**Waste Management Plans & Return to Australia Policy**	**Incident & Emergency Management Procedures**	**Training Programs and Awareness Tools**
Target Criteria:		-Purchase of ONLY approved chemicals and substances.	-Inventory of chemicals and substances at the Station (purpose; quantities; storage location etc.)	-Waste Management Plans in place for kitchen, workshop, medical clinic, and laboratory. -Include return to Australia waste products and management of these.	- Spill management contingency plans. - Clear incident notification and reporting procedures	- Correct use and disposal of chemicals and substances training. - Spill management training; - Awareness tools (i.e. labelling, posters or policies displayed at the station.
Monitoring:	**What:**	Check of purchases against approved list and Davis Station inventory.	What is present, is it approved, use, quantities, and storage location and is storage appropriate (risk of spill / leak and entry into wastewater stream).	Waste management plans	-Spill management contingency plans accessible to station personnel; -Spill kits stocked and located in appropriate position.	-Adherence to chemical/substance use, management and waste disposal practices; -Clear display at station of what to be aware of (signage)
	How:	Audit	Inspection	Approved prior to departure	Inspection	Observation
	When:	Needs to be checked	Summer	Prior to expedition departure	Summer	Ongoing
	Where:	Australia	All station buildings	Australia	All station buildings	Australia
	Who:	Internal AAD auditor	AAD stores personnel	AAD Environmental department	Operators	All station personnel
	Records:	Audit report	Chemical inventory and inspection checklist	Copy of plans and record of approval	Inspection checklist	Training records, awareness initiatives

Corrective Action:	What action is required?	When to action?	Who is responsible?	Records
	Actions from audit reports	As applicable	As assigned	Reports, forms
	Action from incident	As applicable	As assigned	Reports, forms
	Training initiatives	As required	As assigned	Reports, forms

Critical Control Plan - Davis Advanced Water Treatment Plant

AWTP-QCP-2		Davis Station MBR Effluent Quality			
Potential Hazard(s):		**Sub-performance of Nutrient Removal system** may result in potential: ▪ Reduced treatment capability for removal of Chemicals of Concern (CoCs)			
Key Control Measure(s):		**Nutrient Removal Plant** **Final treated effluent (post detention tank)**			
		Ammonia (mg/L) Targets based expected MBR water quality	**Turbidity (NTU)** Target based on expected MBR water quality	**pH (units)** Target based on AAD plant FD	**Temperature (^{O}C)** Target based on AAD FD (target)
Target Criteria:		<1 mg/L	<0.2 NTU	6.5 – 7.5	$19^{O}C$
Alert Limit:		> 1 mg/L 1 instrument reading	>0.2 for 1 instrument reading	pH<6.5 or >7.8 for 1 instrument reading	<16 or >28 for 1 instrument reading
Critical Limit:		>2 mg/L for 2 instrument readings	>0.2 NTU for 2 instrument readings	<6 or >8 for 2 instrument readings	<15 or >30 for 2 instrument readings
Monitoring:	**What:**	Ammonia (mg/L)	Turbidity (NTU)	pH (units)	Temperature (^{O}C)
	How:	Ammonia analyser (on-line) with grab sample & onsite testing weekly for verification	Turbidity analyser (online) with grab sample & onsite testing weekly for verification	pH analyser (online) with grab sample & onsite testing weekly for verification	Feedwater temperature (online) with grab sample & onsite testing weekly for verification
	When:	Continuous SCADA, Weekly verification with handheld instruments	Continuous SCADA Weekly verification with handheld instruments	Continuous SCADA Weekly verification with handheld instruments	Continuous SCADA
	Where:	Feed to MBR effluent storage tank	Feed to MBR effluent storage tank	Feed to MBR effluent storage tank	Feed to MBR effluent storage tank
	Who:	Automatic, AWTP field operator & AWTP control operator			
	Records:	SCADA trends, alarm pages, operator daily inspection logs			

Corrective Action:	**What action is required?**	**When to action?**	**Who is responsible?**	**Records**
	Analyser checks and calibration – check analysers (probes and flow to instrumentation), perform measurement verification check and perform calibration if required.	Alert limit	AWTP Field Operator	SCADA
	Notification of Supervisor	Alert limit	AWTP Field Operator	Plant Diary
	Automatic shutdown (turbidity, temperature, pH)	Critical	Automatic	SCADA
	Manual plant shutdown (Ammonia)	Critical	AWTP Control Operator	SCADA

	Divert flow to ocean outfall/surge tank for discharge	Critical	Automatic	SCADA; plant diary
	Operator checks – review SCADA trends, influent quality, visual plant and process inspection etc.	Alert & Critical	AWTP Operators (field and control)	Plant diary;
	Analyser checks and calibration – check analysers (probes and flow to instrumentation), perform measurement verification check and perform calibration if required. For TasWater analysers – check online readings against sample & test.	Critical	AWTP Field Operator	Plant diary; instrument records. Lab testing record.
	Notification of supervisor	Critical	AWTP Field Operator	Plant diary; incident report
	Generate an incident report	Critical	AWTP Control Operator	Incident report form and register

6.3 Safe Work Instructions

The Operation and Maintenance (O&M) Manual(s) for the AWTP is an overarching document which includes specific details on safe work instructions (SWIs) that is required for optimum functionality of the plant.

A draft O&M manual has been prepared by the AAD, with assistance from Victoria University and the University of Melbourne (see Appendix L for an attached copy) and is currently under review by the Robust Recycling project team in order to ensure that each CCP has been detailed. Below is a brief list of the contents documented in the AWTP O&M Manual(s).

Table 6.7: Outline of the Operations and Maintenance Manuals.

Operations Manual	Maintenance Manual
Plant Operation modes	Schedules
Plant Control	Equipment
Equipment Operation	Instruments
Alarms Monitoring and Reporting	Valves
	Electrical
	Preventative Maintenance

In addition to the O&M Manual(s), additional procedures have been created for the entire scheme during the development of the HACCP Risk Register, in order to ensure health and environmental compliance. The following list provides a summary of the SWIs for the AWTP.

Table 6.8: Summary of SWIs.

Activity	SWI
Sampling	Routine Sampling Section 1 sampling Section 2 sampling Section 3 sampling Section 4 sampling
Inspections	Routine inspection
Calibrations	Online chlorine Online pH Online Turbidity Online ozone residual Online conductivity
Chemical cleaning	SMBS makeup Acid CIP for MF Acid CIP for RO Bulk chemical loading Manual chemical addition Hypo concentration
Maintenance	RO feed filter replacement

7 Monitoring of system performance

Process performance has been confirmed by testing at the commencement of operation (i.e. after all instruments are calibrated and alarm checks were undertaken). This was carried out at the design instantaneous flowrate of 20L/min.

Provided all these tests pass, the AWTP will be commissioned and verified.

To ensure that the AWTP continues to perform to the required standard, and produces water that is fit for its intended purpose, a comprehensive monitoring program has been put in place. The following sections provide details of this monitoring program.

7.1 On-site Verification of critical instruments

Post commissioning of the AWTP, third-party witness testing will been undertaken to test each of the CCP alert levels and alarms to demonstrate that the system is operating appropriately. This includes:

- two point calibration checks on all critical instruments (i.e. instruments that assessing the performance of critical control points);
- checks of alarm functions for each critical limit, including confirmation of alarm set points, and continuity of alarm statuses from the field to SCADA and pager systems;
- recording of alarm statuses on the SCADA system for audit purposes and manual inspections; and
- measurements and sampling that confirm all other process limits are not exceeded and that the process being monitored is stable at high and moderate flow rates.

Refer to Appendix J for the verification testing plan.

7.2 Online Water Quality Monitoring

Continuous, online water quality monitoring will be undertaken and CCPs and QCPs in accordance with the monitoring requirements set out in Section 6, Table 6.6. Any measurements falling outside critical limits detailed in Table 6.6 will be investigated to identify the cause, and the AWTP will not be restarted until the fault is fixed.

In addition to the online process monitoring that will occur at all CCPs and QCPs the following parameters will be measured online in the final water produced by the AWTP:

- pH
- turbidity
- free chlorine residual
- conductivity

These parameters are inclusive of a number of process control instruments that will be used to monitor that the ozone, ceramic membrane filtration, BAC, reverse osmosis, UV disinfection and chlorine disinfection processes are working as designed.

All online instruments will be calibrated in accordance with AAD's Schedule for Instrument Calibration. Calibration procedures are documented for all process equipment, and the frequency and method of calibrations is put into AAD's maintenance program. Any instruments which fail calibration will be taken out of service and replaced with a suitably-calibrated instrument.

If any onsite, handheld instruments (such as chlorine residual monitors and pH meters) they will be regularly calibrated and recalibrated if the deviation is greater than the required maximum error.

7.3 Ongoing plant monitoring program

Over and above the online water quality monitoring that is part of the AWTP, a long-term monitoring program has been prepared as part of this RWQMP. This program is required to be undertaken by AAD for ongoing compliance purposes. AAD will undertake the sampling program, either based on grab samples or, if endorsed by a relevant regulator, through the use of passive samplers. Records of all monitoring results and analyses are to be kept for at least 10 years in order to analyse trends and demonstrate ongoing compliance with the objectives of any relevant guidelines. It is important that the monitoring program is reviewed every few years to assess any possible changes in guidelines or the emergence of any other issues that need to be addressed by the program.

The objectives of the long-term monitoring program are to:

- monitor the concentrations of a number of parameters that are used to indicate pathogens and chemicals of potential concern to human health and the natural environment, and that address any risks associated with the uses of the recycled water produced by the AWTP;
- provide baseline data and trends for these indicator parameters to allow early detection of potential problems.

The ranges of pathogens and chemicals included in the long-term monitoring program are:

- bacteria
- protozoan (oo)cysts
- viruses
- nitrogen and phosphorus
- metals and metalloids non-metallic
- inorganics
- synthetic organic chemicals
- endocrine disrupting chemicals
- pharmaceuticals.

Table 7.1 presents the long term Sampling Schedule for Ongoing Monitoring. The proposed long term monitoring program is scheduled annually. This low frequency of monitoring has been adopted due to the remoteness of the location and the lack of access to commercial NATA laboratory facilities, coupled with an intensive program of verification at Self's Point. Also included in Table 7.1, where relevant and/or available, are the water quality guideline values for primary contact recreational (i.e. swimming) and aesthetic purposes. These guideline values are the ones currently specified in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (1992), published by the Australian and New Zealand Environment and Conservation Council (ANZECC).

Table 7.1: Sample schedule for ongoing monitoring.

Parameter	MBR	AWTP	ANZECC
***Escherichia coli* (*E. coli*)**	**AAD need to provide their proposed sampling schedule for when the system is at the base**		**Not exceed 150 faecal coliform organisms/100mL, or 35 enterococci organisms/100mL**
Total Coliforms			
Giardia and *Cryptosporidium*			
Coliphage			
Adenovirus			
pH			5.0-9.0
Turbidity			
BOD5 and Suspended Solids			
Total N, Ammonia-N, TKN, NO3-N, NO2-N			Nitrate-N 10000 Nitrite-N 1000 Ammonia (as N) 10
Total Phosphorous			
Metals and Metalloids			
TDS, EC			
Disinfection by-products, including NDMA			
PAH, BTEX, VOCs, Aliphatic HCs, SVOC, PCBs, pesticides			
Representative pharmaceutical compounds			
Representative EDCs			

8 Prerequisite Programs

ADD has the following prerequisite programs in place to support the effectiveness of this RWQMP.

- Quality Management System;
- Environmental Management System; and
- OH&S Management System.

These systems are described in detail below.

8.1 Quality Management System

AAD should consider certifying their Quality Management System for managing the Recycled Water Scheme

AAD is committed to continuous improvement in all our processes to ensure that water and wastewater services are delivered efficiently and effectively, with consistent outcomes and acceptable risk.

All quality documentation is available to staff, and this includes this RWQMP, the Operating and Maintenance Manuals relating to the operation of the **AWTP**, and the Work Procedures detailing how the **AWTP** is managed.

All these documents are available online through AAD's computer network or can be accessed at remotely, if needed. Controlled hard copy of the manuals and procedures are also available at Davis Station.

8.1.1 Quality Assurance for Installation

Design and construction of the **AWTP** was undertaken under a Quality Assurance system to ensure that the facility was fit for purpose.

8.1.2 Operation and Maintenance Manuals and Procedures

Operation and Maintenance Manuals for the **AWTP** contain information relating to the installation, operation, maintenance of the system and each component of the system.

Operation and Maintenance Procedures are documented in the Quality Management System.

A full list of the Operation and Maintenance procedures relating to the **AWTP** is given in Appendix L.

8.1.3 Calibration of Monitoring Equipment

Calibration of all monitoring equipment is carried out in accordance with the Operation and Maintenance Manual for the **DAWTP**.

8.1.4 Chemical Quality Assurance

The following chemicals are required for the process:

- Hydrochloric Acid (HCL) - Reverse Osmosis Membrane Cleaning
- Sodium Hydroxide (NaOH) – Reverse Osmosis Membrane Cleaning
- Sulphuric acid (H_2SO_4) – Ceramic Microfiltration
- Sodium Hypochlorite – Recycled Water Disinfection, Ceramic Microfiltration Chemically Enhanced Backwash
- Sodium Metabisulphite - Reverse osmosis membrane preservation.

Standard Operating Procedures have been developed for the ordering, delivery, storage, handling and spill clean-up of chemicals for water treatment. These documents can be found at Davis Station.

8.2 Environmental Management System

AAD maintains an Environmental Management System (EMS) certified to AS/NZS ISO14001:2004. This includes the Environmental Policy containing commitments to legislative compliance and continual improvement

The key function of the EMS is to identify and record the environmental aspects, impacts and control measures associated with our business activities. This enables the business to minimise its impacts to the environment and maintain legislative compliance.

8.3 OH&S Management System

AAD is committed to ensuring that all staff and contractors employed by AAD undertake all work in a safe manner. To be able to do this, all hazards and risks related to Occupational Health & Safety (OH&S) need to be reduced as far as is reasonably practicable.

AAD manages Occupational Health and Safety related risks as part of the Integrated Quality System. The Safety Management section of the Integrated Quality System is externally certified to Australian Standard AS/NZS 4801:2001 – Occupational Health and Safety Management Systems.

9 Emergency and incident management

This section addresses the appropriate and immediate responses to incidents or emergencies to protect public and environmental health. These immediate and appropriate responses will maintain users‟ confidence in recycling water and AAD's reputation.

Continuous performance and compliance with targets should always be the goal, but it is unrealistic and potentially dangerous to expect that faults and incidents will not occur. In most cases, considered, controlled and timely responses will prevent such events from posing a risk to public health or requiring public notification. Hazard events that may lead to emergency situations are summarised in Table 9.1.

Table 9.1: Incidents and their appropriate response and required notification.

Incidents	Responses	Possible further investigation/qualification	
Non-conformance with critical limits, guideline values and other requirements	System maintenance, tank and sump cleaning or scouring. Shutdown supply of recycled water. Alternative selection of water sources.	Work to isolate recycled water.	AAD
Accidents that increase levels of contaminants or cause failure of treatment systems (e.g. spills and incorrect dosing of chemicals)	Secondary WWTP Spill Kits. Chemical risk decision tree analysis and maximum allowable volumes to be stored onsite. Operator training. Plant and system documentation on operations and maintenance.	Diversion and retreatment capacity of the process of out of spec water.	AAD
Equipment breakdown and mechanical failure	Preference towards simplicity of process control. Automatic shutdown or flow diversion.	Online turbidity, pH, conductivity and disinfection residuals for product water.	AAD
Prolonged power outages	Automatic shutdown or flow diversion.	End use not critical and therefore if power out AAD will not supply to station.	AAD
Unauthorised use of recycled water	Regular inspection of reuse applications and distribution pipework		AAD
Human actions	Staff training and awareness. Closed community with staff carefully selected and vetted by the AAD.		AAD
Misuse of product water	Staff training and awareness. Signage around site. Boundaries defined to ensure integrity of scheme with respect to works and maintenance.		AAD
Accidental or deliberate contamination of sewage	On-line instrumentation at various points of the process (pH, turbidity, nutrients, conductivity etc.) will monitor significant changes in source water quality or damage to membranes. Instruments can initiate a plant shutdown, alarms or other appropriate response.	Additional water quality testing to investigate cause of contamination.	AAD

9.1 Incidents and Emergency Response Protocol

Measures that are recommended so that incidents and emergencies for the recycled water scheme are appropriately managed are:

- Train employees and regularly test emergency response plans; and
- Investigate any incidents or emergencies and revise protocols as necessary

9.1.1 Emergency incident notification

In the event of an emergency incident, as the supplier and scheme manager AAD must notify the appropriate person/s within the Department of Sustainability, Environment, Water, Population & Communities, and any other relevant regulatory body and affected parties as soon as possible.

The designated regulator should be notified of the following: a system failure that may potentially impact on the users of the water supply; 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 be prompt and include details of corrective and future preventative action being taken. The same event classifications and processes exist for recycled water as are implemented for potable water.

Following any incident or emergency situation, an investigation should be undertaken and all involved staff should be debriefed, to discuss performance and address any issues or concerns. The investigation should consider factors such as:

- What was the initial cause of the problem?
- How was the problem first identified or recognised?
- What were the most critical actions required?
- What communication problems arose and how were they addressed?
- What were the immediate and longer term consequences?
- How well did the protocol function?

9.1.2 Define communication protocols

Effective communication is vital in managing incidents and emergencies. Clearly defined protocols for both internal and external communications should be established, with the involvement of relevant agencies, including health departments and other regulatory agencies. The protocols will define time requirements and mechanisms for reporting. Potentially serious incidents will be reported immediately verbally, and also be provided in written form to ensure that they are received.

Protocols will include a contact list of key people, agencies and businesses, detailed notification forms, procedures for internal notification; and definitions of responsibilities and authorities. Contact lists should be updated regularly (six month) to ensure they are accurate.

The aim of the protocol is to ensure effective communication between Government agencies in the event of incidents associated with recycled water. The protocol includes notification of users of recycled water and other relevant bodies.

The nominated media point-of-contact is the AAD.

9.2 Review and Documentation

This RWQMP and any relevant associated documentation (e.g. water quality risk register) will be reviewed by AAD's Potable Water Management Committee in accordance with any change in legislative requirements, regulatory body/advisory panel recommendation, in response to national recycled water and drinking water guideline changes and in response to any system change e.g. introduction of a new chemical / pharmaceutical or at frequency of no less than every two years.

10 Employee awareness and training

The knowledge, skills, motivation and commitment of employees and contractors ultimately determine AAD's (the scheme manager) ability to usefully operate a recycled water system. It is vital that awareness, understanding and commitment to performance optimisation and continuous improvement are developed and maintained within the organisation.

10.1 General Employee Awareness

Employees and contractors must be appropriately skilled and trained in the management and operation of water supply systems, as their actions can have a major impact on recycled water quality and public health and the receiving environment.

Employees should have a sound knowledge base from which to make effective operational decisions. This requires training in the methods and skills required to perform their tasks efficiently and competently, as well as knowledge and understanding of the impact their activities can have on water quality.

Training needs should be identified, and adequate resources made available to support appropriate programs for AAD employees. AAD has a learning and development team who coordinates training identification and delivery, where relevant this includes training associated with reclaimed water.

The following areas are required to be addressed in order for the operation of a successful recycled water scheme:

- General recycled water quality
- Water microbiology and water chemistry
- Recycled water treatment, including primary, secondary and tertiary treatment
- Source control
- Hydraulic, nutrient and contaminant balances at sites of use or discharge
- Distribution management
- Sampling, monitoring and analysis of recycled water
- Interpretation and recording of results
- Maintenance of equipment.

Operators, contractors and end users need to be aware of the potential consequences of system failure, and of how decisions can affect public and environmental health.

10.2 Specialist Employees Training

Operators and contractors involved with the AWTP are required to undertake the appropriate training specific to the conditions of the demonstration plant and associated components.

10.2.1 Operators and contractors

In the case of recycled water treatment and reticulation, an understanding of recycled water quality management is essential for empowering and motivating operators and associated contractors to make effective decisions. They should be aware of:

- AAD's recycled water quality policy;
- the principles of risk management;
- characteristics of the recycled water system and preventative strategies in place through the system;
- regulatory and legislative requirements roles and responsibilities of employees and departments; and
- how their actions can affect water quality, and public and environmental health.

Employees should also be trained in other aspects of recycled water quality management, including incident and emergency response, documentation, record keeping, reporting, and research and development.

Training programs should encourage employees to communicate and think critically about the operational aspects of their work.

Methods to increase employee awareness can include employee education and induction programs, newsletters, guidelines, manuals, notice boards, seminars, briefings and meetings.

11 Documentation and reporting

This section has been adapted from Coliban Water's RWRMP. AAD will need to verify that what is written matches there current practice, or the text needs to be modified to reflect current practice

11.1 Documentation

The records for all monitoring results reside in a centralised database contained on AAD's network. Data can then be extracted from the database and reported. Field online instrument data resides in the SCADA system and is extracted, trended and alarmed using appropriate software.

Critical control points are detailed in the HACCP plan, along with supporting programs for maintenance and operation. The HACCP plan contains the detailed monitoring and verification plans, along with the storage location for the data including:

- Breaches of critical limits and corrective actions taken;
- Inspection and maintenance records;
- Details of emergencies and corrective actions taken;
- SCADA records;
- Flow meter records;
- Plant setting records;
- Process diaries;
- Alarm logs; and
- Notification logs.

Most CCPs have on-line instrument monitoring of critical parameters and the system logs all alarms. Alarms are indicated on the SCADA alarm page.

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

11.2 AAD Water Reporting

In the event of an incident (such as the supply of off-specification water) AAD will inform relevant agencies and stakeholders. AAD will assess whether staff on the base need to be informed, and carry out liaison as necessary.

The relevant agencies 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 the base);
- An emergency of incident that potentially places public health at risk; or
- Any changes to the RWQMP or operation of the treatment process that may potentially impact on achieving the required microbiological criteria.

These protocols are reviewed annually by the Potable Water Management Committee, along with all other documentation.

11.3 Notification of Non-compliance

Email notification of exceedance results will be provided to relevant agencies and stakeholders. Follow-up testing and analysis, the reporting of the results of these test, and details of the mitigation measures that are to be put in place, will also be provided to relevant agencies and stakeholders when these events take place.

11.4 Department of Environment Reporting

An annual report will be prepared by AAD and submitted to the Department of Environment, which will include a summary of the performance of the AWTP, a summary of all instances of non-compliance and an analysis of monitoring data.

11.5 Auditing

Periodic auditing of the RWQMP will be undertaken to ensure that AAD is meeting its obligations.

Auditing will comprise of internal audits conducted by trained staff, and external audits undertaken by an appropriately-qualified auditor.

The frequency of audits will be determined by the Potable Water Management Committee in consultation with relevant agencies and stakeholders and will depend on the outcomes of the internal audits. It is anticipated that external audits will occur at least every three years.

11.6 Auditing, Review and Improvement Program

AAD is committed to the ongoing review and improvement of the RWQMP.

This RWQMP will be reviewed every 2 years by the Potable Water Management Committee. The review will take into consideration changes to:

- Water quality;
- Treatment processes;
- Relevant guidelines;
- Regulatory requirements;
- Supporting AAD policies; and
- Supporting programs.

12 Commissioning the RWQMP

Commissioning will be a robust process involving the testing of parameters related to the pathogen removal processes and measurements of critical limits.

The relevant documents are provided in Appendix M.

13 References

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AAD to add detail for the Appendices

Appendix A Secondary Treatment Performance Monitoring Provisions

Appendix B Log Reduction Value Table

Appendix C Chemicals of concern log reduction report

Appendix D Robustness Report

Appendix E Verification Testing Plan

Appendix F HACCP Risk Register & HACCP Report

Appendix G Operation and Maintenance (O&M) Manual

Appendix H Commissioning Documentation