Kooragang Water Pty Ltd

ACN 609 789 808

KWPL-IMS-DOC-003
KIWS Recycled Water Quality Management Plan

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Acronyms and Abbreviations

AGWR	Australian Guidelines for Water Recycling (2006)
AWTP	Advanced Water Treatment Plant
BOD	Biological Oxygen Demand
CCD	Customer Commercial Development
CCP	Critical Control Point
CCT	Chlorine Contact Tank
CFU	Colony forming units
CIP	Clean in Place
CMMS	Computerised Maintenance Management System
Ct	Concentration x contact time (dose of disinfectant)
DALY	Disability-adjusted life year
DECC	Department of Environment Climate Change
DoH	NSW Department of Health
DWE	Department of Water and Energy
EC	Electrical Conductivity
EPA	Environmental Protection Authority
EPL	Environment Protection Licence
EPHC	Environment Protection and Heritage Council
HACCP	Hazard Analysis and Critical Control Point
HWA	Hunter Water Australia
HWC	Hunter Water Corporation
IOP	Infrastructure Operating Plan
IPART	Independent Pricing and Regulatory Tribunal
KIWS	Kooragang Industrial Water Scheme
KWPL	Kooragang Water Pty Ltd
LP	Low Pressure

LRV	Log10 reduction value
MF	Membrane Filtration
MLD	Megalitres per day
MoU	Memorandum of Understanding
MSDS	Material Safety Data Sheet
NATA	National Association of Testing Authorities
NCIG	Newcastle Coal Infrastructure Group
NRMMC	Natural Resource Management Ministerial Council
NSW	New South Wales
NTU	Nephelometric Turbidity Units
NWQMS	National Water Quality Management Strategy
OH&S	Occupational Health and Safety
O&M	Operations and Maintenance
PDT	Pressure Decay Test
PFU	Plaque forming units
PLC	Programmable Logical Controller
POEO	Protection of the Environment Operations
QCP	Quality Control Point
RO	Reverse Osmosis
RWMP	Recycled Water Management Plan
RWQMP	Recycled Water Quality Management Plan
SCADA	Supervisory Control And Data Acquisition
SIP	Standard Incident Procedure
SOP	Standard Operating Procedure
TDS	Total Dissolved Solids
TN	Total Nitrogen
TP	Total Phosphorus
TRIM	Tower Records Information Management
TSS	Total Suspended Solids

UV	Ultraviolet
WICA	Water Industry Competition Act (NSW)
WQP	Water Quality Plan (non-potable water)
WSAA	Water Services Association of Australia
WWTW	Wastewater Treatment Works

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Introduction

The Kooragang Industrial Water Scheme (KIWS) advanced water treatment plant (AWTP) is a 10.5 megalitre per day (10.5 MLD) membrane filtration (MF) and reverse osmosis (RO) recycling plant commissioned in December 2014. The scheme is currently owned by WUA-Midco, via its 100% owned subsidiary Kooragang Water Pty Ltd ('**KWPL**'), and was purchased from Hunter Water Corporation ('**Hunter Water**') in November 2017. The scheme is operated by SUEZ Water Pty Ltd ('**SUEZ**') under a 15-year operations and maintenance (O&M) contract with KWPL.

Hunter Water Corporation ('**HWC**') operates the Shortland Wastewater Treatment Works (WWTW) and KWPL has operational responsibility for the Kooragang Industrial Water Scheme (KIWS) and distribution to the end users of the water. Treated effluent is supplied by HWC to KWPL under a supply agreement which includes contractual water quality obligations and minimum volume requirements from Shortland WWTP which enable the KIWS scheme to continue to meet its recycled water supply obligation

A summary of the contractual structure of the KIWS is outlined in Figure 1.

The AWTP processes treated secondary effluent from Hunter Water's Shortland Wastewater Treatment Works (WWTW) that would otherwise be directed for marine discharge, therefore reducing the volume of treated effluent discharged into the natural environment and reducing the demand on the potable water system for industrial water uses. The scheme was established initially to supply recycled water to Orica and is currently being expanded to supply water to a new industrial customer, Newcastle Coal Infrastructure Group ('**NCIG**').

The initial scheme operation was governed by Hunter Water's Recycled Water Management Plan and upon transition of ownership of the scheme to KWPL, the Network Operator and Retail Supply Licenses were held by SUEZ. Under this licensing regime the scheme operation has been governed by a SUEZ Recycled Water Management Plan.

The KIWS Scheme has been audited annually in-line with IPART requirements while under the governance of both Hunter Water and SUEZ and no major issues have been identified with this scheme.

The Network Operator and Retail Supply Licenses are in the process of being transitioned to KWPL and this Recycled Water Quality Management Plan has been prepared to govern the scheme operation under this licensing regime.

Management support to the KIWS Scheme is provided by Water Utilities Australia Pty Ltd ('**WUA**') which is also a 100% owned subsidiary of WUA Mid Co. Pty Ltd. These resources are provided under a Resources Deed between KWPL and WUA.

KWPL is the retail supplier of both recycled water and potable water to Orica. The supply of recycled water occurs via the scheme as outlined above with the supply of potable water occurring via a wholesale potable water supply agreement between Hunter Water and KWPL whereby potable water continues to be supplied to the Orica site by Hunter Water via their existing potable water network.

KWPL supplies recycled water only to NCIG with the supply of potable water to NCIG continuing to occur via a standard retail supply arrangement between Hunter Water and NCIG.

This Recycled Water Quality Management Plan (RWQMP) for the KIWS forms a part of KWPL's overall management plan framework for the operation of its sustainable water network providing recycled water to industrial customers in the Mayfield/Kooragang Island areas (the "Services"). The RWQMP is intended to provide an overview of the KIWS recycled water treatment scheme as well as to set out how KWPL and it contracted operational agent SUEZ operates the AWTP in line with its obligations under the Water Industry Competition Act (NSW) (WICA). The document represents a consolidated RWQMP that integrates the following WICA Licence Plans:

- Water Quality Plan (non-potable water).

- Infrastructure Operating Plan.
- Retail Supply Management Plan (non-potable and potable water).

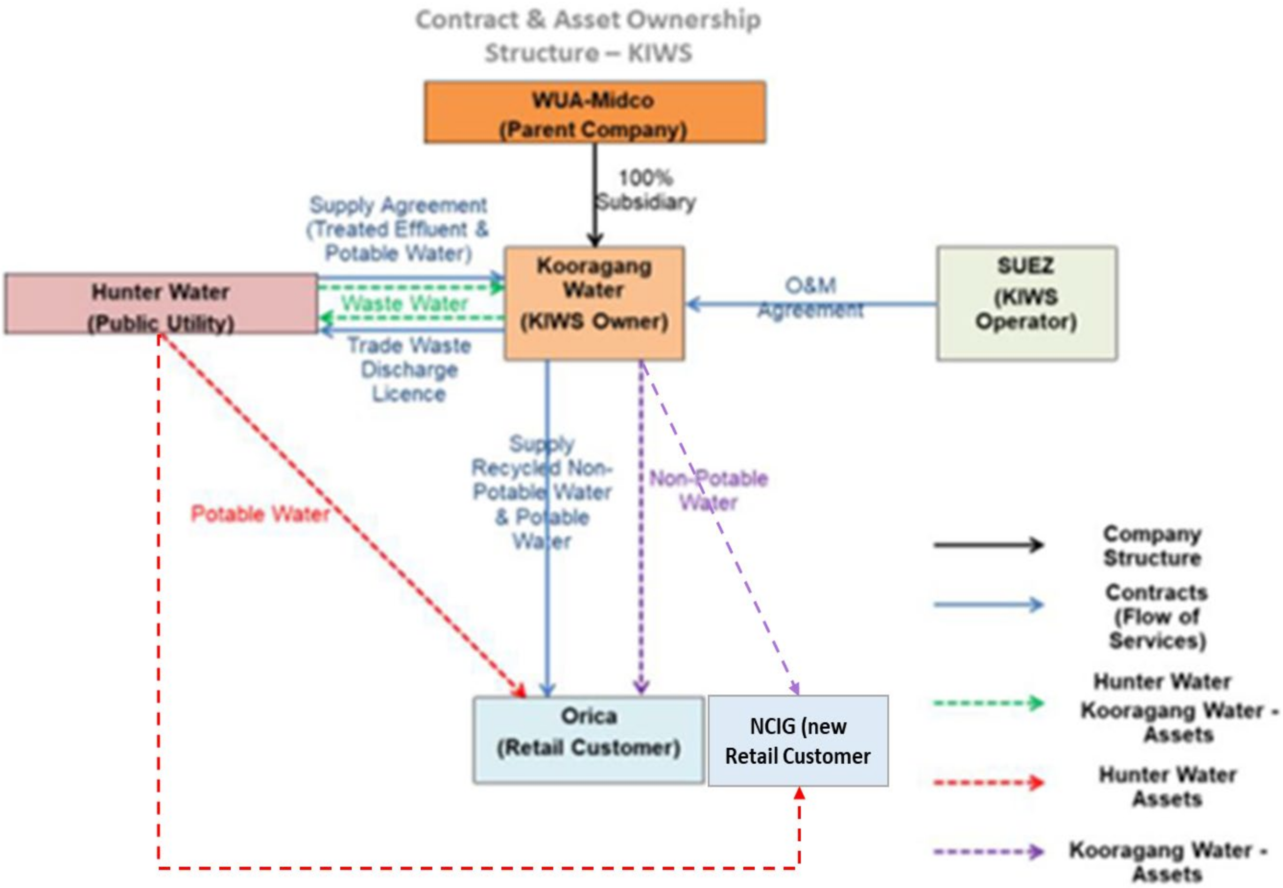

Figure 0-1: Corporate Structure and Interaction

1. ELEMENT 1: Commitment to Responsible Use of the Management of Recycled Water

1.1 Responsible Use of Recycled Water

WUA is the management entity responsible for the management of the KIWS Scheme and holds all staff, resources, policies and procedures relevant to the KIWS Scheme (outside of those provided by SUEZ under the Operations and Maintenance Agreement).

WUA currently holds licenses for water utility businesses in South Australia (via ESCOSA) and NSW (via IPART) and provides in-house operations for its South Australian businesses with outsourced operations for its NSW businesses.

WUA operates a consolidated Quality, Health, Safety and Environmental Management (QHSE) System that is certified to:

- ISO9001 Quality Management,
- ISO45001 Health & Safety,
- ISO14001 Environmental Management.

WUA's core philosophy is to operate in an environmentally and socially responsible manner, to deliver water services for municipal, agricultural, industry and residential sectors which are compliant with water standards, other applicable laws and regulations, while meeting all customer service expectations.

WUA's management of the scheme licensing, contracts, policies and procedures is the responsibility of the Chief Operating Officer in conjunction with the Risk and Compliance Officer.

WUA's commitment to the responsible use of recycled water is reflected in the document **WUA-IMS-DOC-001 Quality, Health, Safety and Environment Policy**.

SUEZ is a global specialist in large-scale water and wastewater operations and has a firm commitment to the responsible supply and use of recycled water. SUEZ brings to the table a wide range of expertise in the development, operation and control of recycled water systems.

Areas of expertise include:

- Operation and maintenance of water, wastewater and treatment systems and infrastructure.
- Planning and design of water and wastewater treatment systems as well as associated infrastructure.
- Risk assessment, including comprehensive evaluation of health and environmental hazards.
- Customer relations and commercial agreement management.
- Contract and project management.
- Detailed understanding of plumbing systems and requirements.

SUEZ' scheme-specific requirements are managed by the Contract Manager (Nadeem Akram) who ensures awareness and currency of regulatory and formal requirements, and the Operations Manager who is responsible for implementation of the processes on-site

In situations where SUEZ do not have personnel with sufficient expertise, or do not have the resources to undertake work, suitably qualified contractors and consultants are engaged to execute tasks on behalf of SUEZ.

WUA and SUEZ have respective internal risk and audit teams that manage the governance and financial management of KIWS. SUEZ provide monthly performance reports to WUA on all aspects of scheme performance and bi-monthly Project Control Group meetings are held between the parties to ensure the effective on-going co-ordination of the scheme. These reports and meetings include the following key topics:

- Injuries and Incidents,
- Water quality performance,
- Recycled and potable water delivery volumes,
- Chemical, electricity etc. consumption,
- Maintenance and capital works
- Customer feedback
- Risks and risk management,
- Audits and corrective actions.

1.2 Regulatory and Formal Requirements

KWPL is regulated by IPART via the Water Industry Competition Act (WICA) and holds the Network Operator's License and retail suppliers Licenses for the KIWS Scheme. Compliance with this RWQMP is a requirement of these licenses and will be audited annually by an IPART approved auditor to ensure compliance with the associated obligations.

This RWQMP has been developed in accordance with the Australian Guidelines for Water Recycling: Managing Health and Environmental risks (Phase 1) ('**AGWR**'; EPHC, NRMMC & NHMRC; 2006, as amended from time to time) as well as any additional requirements set by NSW Health, SafeWork NSW, the Environmental Protection Authority (EPA) and overseen by the Independent Pricing and Regulatory Tribunal (IPART).

In addition, numerous regulatory and formal requirements relate to recycled water schemes. Regulatory and formal requirements are periodically reviewed as part of the periodic review of this document and in response to advice from regulators and stakeholders.

1.3 Partnerships and Engagement of Stakeholders

Details of the key stakeholders' relevant roles and responsibilities are listed in

Table 1-1.. The identified external end users of recycled water (Orica and NCIG) have entered into separate supply agreements with Kooragang Water Pty Ltd (KWPL) which specify the respective roles and responsibilities of the customers and KWPL.

Any future changes to the way in which the water will be utilised by the end users, or if additional end users are supplied by KIWS, will result in the revision of existing agreements and/or the development of new agreements between end users and KWPL. Ongoing consultation between Orica and NCIG as the end users of the recycled water from KIWS occurs to maintain end user involvement in the scheme.

Both Orica and NCIG have developed Recycled Water Management Plans to ensure they have appropriate knowledge and management of the recycled water in their respective site operations.

Table 1-1 Recycled Water Scheme Stakeholders.

Stakeholder	Roles and Responsibilities
NSW Health	Public heath advice
Environmental Protection Authority (EPA)	Regulatory oversight and advice - environment
Independent Pricing and Regulatory Tribunal (IPART)	Regulatory oversight and advice – pricing and reporting. Network Operator and Retail Supplier Licence
SafeWork NSW	Occupational health and safety regulation and advice
Kooragang Water Pty Ltd	KIWS Owner Licenced Recycled Water provider RWQMP Owner – through and in partnership with SUEZ, monitor the supply of recycle water which complies with AGWR and this RWQMP Supplier of retail potable water to Orica
SUEZ	KIWS operator and maintainer, acting as KWPL agent Monitor the supply of recycle water which complies with AGWR and this RWQMP To inform NSW health about any breach or potential breach of AGWR or any relevant guidelines specified by NSW Health as soon as practically possible.
Orica	Usage of recycled water Management of on-site delivery infrastructure Ensuring recycled water is used as per agreement with KWPL
NCIG	Usage of recycled water Management of on-site delivery infrastructure Ensuring recycled water is used as per agreement with KWPL
Hunter Water Corporation	Raw water supplier of partially treated sewage effluent to the KIWS AWTP Supplier of wholesale potable water to KWPL for retail supply to Orica.
Hunter H2O	Designer of the original scheme (as part of the Hunter Treatment Alliance) and technical adviser to WUA/KWPL on the on-going operation of the scheme.

1.4 Design & Construction

The KIWS was originally designed and constructed by the Hunter Water Alliance (‘**HWA**’), a subsidiary entity of Hunter Water. HWA ensured the original plant design and construction was in-line with Hunter Water standards and commissioning and subsequent operation of the plant has demonstrated the effectiveness of the original design.

In 2019, WUA engaged Hunter H2O to undertake a concept report to consider options to upgrade the KIWS treatment plant to service new customer demands. Following on from the outcomes of this concept study, SUEZ has been engaged to complete the design and upgrade of the treatment plant in-line with the design developed in the concept report. As the current O&M contractor for the KIWS plant, and with an international capability in process design, SUEZ are well placed to deliver the upgrade works expanding on the current plant design and specifications. Hunter H2O have been engaged by WUA to provide technical advice and design review through the project delivery phase.

2. ELEMENT 2 – Assessment of the Recycled Water System

An overview of the KIWS is provided in Figure 2-1.

2.1 Source of Recycled Water, Intended Uses, Receiving Environments and Routes of Exposure

2.1.1 Source water

Recycled water is sourced from the Shortland WWTW that is owned by Hunter Water and operated and maintained by Veolia. Treated effluent is supplied to the KIWS from the Shortland WWTP under the Agreement for the Supply of Treated Effluent and Potable Water between HWC and WUA ('**Treated Effluent Supply Agreement**'). This agreement includes specific obligations covering the quality of treated effluent to be supplied under the Treated Effluent Supply Agreement which are summarised below.

Table 2-1 Treated Effluent Supply Upper Limiting Values

Shortland Effluent	Unit	Specification
Parameter		**90th%ile (less than or equal to)** **Over a rolling 4 week period**
Aluminium	mg/L	0.2
Alkalinity	mg/LCaCO3	140
Arsenic	mg/L	0.005
BOD_5	mg/L	30
Calcium	mg/L	40
Cl	mg/L	206
Cr(VI)	mg/L	0.01
Cu	mg/L	0.03
Total Iron	mg/L	0.80
F	mg/L	1
K	mg/L	30
Magnesium	mg/L	15
Sodium	mg/L	200
NFR (TSS)	mg/L	40
NH3-N	mg/L	3
pH		6 to 8
Reactive Silica	mg/L	15
Sulphate	mg/L	140
TDS	mg/L	750
TKN	mg/L	6
TOC	mg/L	15
TON	mg/L as N	10
Total Hardness	mg/CaCO3	150
TP	mg/L	6
Zn	mg/L	0.1
Grease	mg/L	5

Table 2-2 Treated Effluent Supply On-line Trigger Values

Shortland Effluent Parameter	Unit	Maximum Allowable Limit	Sample Method	Frequency[2]	Monitor Location
Turbidity	NTU	25	Online	10% over rolling 48 hr period	Downstream of Shortland Facility Effluent Transfer Pump
Conductivity	µS/cm	1700	Online	10% over rolling 24hr period	Downstream of Shortland Facility Effluent Transfer Pump
Total Chlorine	mg/L	7	Online	10% over rolling 24hr period	Downstream of Shortland Facility Effluent Transfer Pump

1. Instruments will be polled on a 1 minute interval while effluent pumps are operating at the Shortland Facility.

Shortland Effluent Parameter	**KIWS Cut-off** Values below only recorded whilst the Shortland Facility effluent pump is operating	**HWC (Shortland Effluent) Cut-in** Values below only recorded whilst the Shortland Facility effluent pump is operating
Turbidity	No more than 10% of values can be above the Maximum Allowable Limit over a rolling 48 hour period. These are the values included in the calculation of the rolling 48hr period	Once 90% or more of values are below the Maximum Allowable Limit over a rolling 24 hour period These are the values included in the calculation of the rolling 24hr period
Conductivity	No more than 10% of values can be above the Maximum Allowable Limit over a rolling 24 hour period. These are the values included in the calculation of the rolling 24hr period	Once 90% or more of values are below the Maximum Allowable Limit over a rolling 24 hour period These are the values included in the calculation of the rolling 24hr period
Total Chlorine	No more than 10% of values can be above the Maximum Allowable Limit over a rolling 24 hour period. These are the values included in the calculation of the rolling 24hr period	Once 90% or more of values are below the Maximum Allowable Limit over a rolling 24 hour period These are the values included in the calculation of the rolling 24hr period

The upper limiting values outlined in Table 2-1 are the maximum values for the respective water quality criteria that meet the original design requirements of the KIWS. If the treated effluent exceeds this quality, then KWPL is not obliged to treated the effluent as it may result in damage or limited capacity of the KIWS treatment plant. In such an event KWPL would supply potable water to its customers.

The on-line trigger values outlined in Table 2-2 provide on-line control to automatically divert treated effluent away from the treatment plant when the water quality has exceeded specific agreed values. Hunter Water have the responsibility to review the risks, operations and management of the sewage catchment and operations at Shortland WWTW to ensure that the contractual effluent quality targets for the effluent supplied to KIWS meet requirements.

Communication between Veolia and Hunter Water, and SUEZ and WUA in relation to the KIWS is governed by the Hunter Water and KIWSP Operations Protocol ('**Operations Protocol**'). This Operations Protocol outlines the responsibility for communication between Veolia and Hunter Water for events that result in or may result in a treated effluent quality event. This Operations Protocol includes both on-line and incident specific communication requirements and has been designed to manage the quality and quantity of treated effluent in-line with the obligation to supply recycled water in-line with this RWQMP.

2.1.2 Intended Uses

Recycled water from KIWS is supplied to Orica and NCIG. The customer end uses for the recycled water are summarised in Table 2-3.

Table 2-3 Uses of Recycled Water

Category of Use	Customer	End Use
Industrial Use (Unrestricted)	Orica	Process water
Industrial Use (Unrestricted) Fire Fighting	NCIG	Process water On-site Fire Fighting Systems
AWTP on site reuse	Self (SUEZ, operator of KWPL)	On site plant uses, e.g. hose down, chemical dosing

2.1.3 Routes of exposure

Potential routes of exposure for each of the intended end-uses are listed in Table 2-4.

Table 2-4 Routes of Exposure

Intended End Use		Route of Exposure
Industrial Use (Unrestricted)	Orica NCIG	Ingestion of water from sprays Inhalation of water from sprays during operation/maintenance of processes Contact with water from sprays during operation/maintenance of processes
Fire Fighting	NCIG	During firefighting activities, exposure to fire fighters through: Ingestion of water from sprays Inhalation of water from sprays during
AWTP on site reuse	KIWS	Ingestion of water from sprays Inhalation of water from sprays during operation/maintenance of processes Contact with water from sprays during operation/maintenance of processes

2.1.4 Receiving environments

The intended uses of KIWS product water do not include discharge to the environment. Discharge to the Hunter River will only occur as overflows when the raw water tank and the product water tank are full, or RO permeate has not met the disinfection specifications and can't be supplied to the end user. These flows are of the same or better quality than the existing discharge of secondary effluent to the Hunter River from Shortland WWTW. The normal discharges from Shortland WWTW are managed under the EPA POEO licence for the Shortland WWTW (Licence Number 1680). In addition, of relevance to WICA, a KIWS AWTP EPA POEO licence is in place to permit accidental or emergency discharges from the KIWS AWTP of up to 100 ML per year (Licence Number 20757).

The end use and application of recycled water is under the control of the customers (Orica and NCIG respectively). Additionally, the receiving environments and potential hazards were taken into consideration during the risk assessment process, as described in Section 2.4

2.1.5 Inadvertent or unauthorised use

KIWS supplies recycled water to specific industrial customers and the management of the recycled water and inadvertent use of the recycled water is the responsibility of each customer. This is managed through the respective customers RWQMP's.

2.2 Recycled Water System Analysis

2.2.1 Flow through KIWS

The design flows and loads adopted for the KIWS are summarised in Table 2-5.

Table 2-5 Design flows through KIWS

Parameter	Unit	Capacity (MLD)
Influent flows	MLD	12.6
Production Capacity	MLD	10.5
Losses (incl. backwashing of auto strainers, MF and RO systems)	MLD	2.1

The Treated Effluent Supply Agreement includes contractual obligation on Hunter Water for the volume of treated effluent to be supplied to the KIWS. This ensures Hunter Water are obliged to supply the required influent flows of 12.8MLD

2.2.2 Treatment Process

The treatment processes performed at KIWS are described in detail in the following sections.

Chloramine Dosing

Chlorine is dosed at Shortland WWTW. However, chlorine can be hazardous to RO membranes. Therefore, chloramine dosing occurs upfront of the auto strainers. Carrier water is added to each separate chemical (i.e. sodium hypochlorite and aqueous ammonia). These two streams are combined in a static mixer, located within the Aqueous Ammonia chemical bund, to form chloramines. The intention is to always maintain a free ammonia residual through the plant to ensure that there is no free chlorine in the raw water, which would oxidise the RO membranes.

Purpose: To prevent microbiological growth through the plant and ensure that there is no free chlorine in the system that may damage RO membranes.

Auto Strainers

The auto strainers are Amiad EBS model type with 300 µm weave wire screens, which backwashes periodically based on a differential headloss across the screens or on time. Once initiated the auto strainer operates continuously to screen incoming flows. The backwash process occurs twice per day and produces approximately 420 L per backwash but is dependent on operating pressures and solids content of the incoming effluent.

Purpose: To provide physical protection for the MF system.

Microfiltration

The MF plant is a Pall Microza MF system with a nominal pore size of 0.1 µm. It consists of three trains each with a maximum continuous feed flow of 16.3 L/s (total 49 L/s), which will be increased to 21.6 L/s (total 65 L/s) with the addition of membrane modules to achieve ultimate capacity in Stage 2.

Periodically the MF system carries out a backwash cycle to remove the captured suspended solids from the membrane surface and diverts them to the backwash handling system for disposal off site. The MF backwash process uses MF filtrate which is stored in the MF backwash tank with a storage capacity of 10 kL.

Purpose: Removal of pathogens and suspended solids

Reverse Osmosis

The primary RO process (‘**PRO**’) consists of four (4) trains (single pass, two stages) that are fed from the RO feed water tank via cartridge filters. Antiscalant and sulphuric acid are dosed downstream of the Low Pressure (LP) feed pumps to protect the RO membranes from scale-forming compounds and improve performance.

Brine from the PRO process above is further treated through a Brine Recovery Unit (‘**BRU**’) to produce additional permeate that is recirculated back to the head of the PRO for re-treatment. This enables the plant capacity to be increased from the original design capacity of 9ML/d to 10.5ML/d. There is no change to the recycled water quality output of the plant. The BRU system consist of a two-stage single pass system.

Citric acid and hydrochloric acid, caustic soda and a RO proprietary cleaning agent are used for chemical cleaning of the PRO and BRU membranes, also referred to as a Clean in Place (CIP) and maintenance cleans.

Purpose: Removal of dissolved salts, pathogens and all other particulates.

Degas Tower

RO permeate enters the Degas Tower at a high level and is distributed across the footprint area of the tower by way of a trough distribution system before dropping through the tower under gravity. Air introduced into the tower at low level, passes up through the RO permeate. Internal packing media within the tower assists in maximising the exposure of permeate with air to ensure CO2 is brought out of solution and released as a gas.

Purpose: To remove CO2 from the RO permeate.

Chlorination

Sodium hypochlorite is dosed into the feed main upstream of the chlorine contact tank (CCT). The main chlorination step occurs within the CCT. The contactor is a 700 kL tank, providing a hydraulic retention time (HRT) of 112 minutes at Stage 1 maximum design flow and 84 minutes at Stage 2 maximum design flow.

The aim of the CCT is to achieve 4 Log virus reduction by chlorine inactivation. The required dose or Ct (disinfectant concentration x contact time) for chlorine inactivation of coxsackie B5 virus is 11 mg.min/L at a pH of less than 7.5 with a water temperature of greater than 10°C (Keegan et al., 2012). This increases to 27 mg.min/L for a pH of up to 9.0 with the control system adjusting the target based on the pH measured.

Purpose: Inactivation of pathogens (viruses and bacteria) and prevention of algal and biological growth in storage and distribution system.

2.2.3 On-site Storage

Product Water Tank

The product water tank provides 4.2 ML storage equating to approximately 12 hours hydraulic retention time at Stage 1, and 9 hours at Stage 2, under average flow conditions of 139 L/s. A magnetic flow meter is located on the outlet to the product water tank to accurately record flows to the end user.

2.2.4 Distribution

On-site Service Water

A service water system is provided using product water stored in the product water tank. Two vertical multistage centrifugal pumps operate on variable speed drives in a duty/standby configuration. The service water system provides water for the following applications:

- Carrier water for the sulphuric acid dosing
- Carrier water for the chloramine dosing using aqueous ammonia
- Carrier water for the chloramine dosing using sodium hypochlorite
- Hose reels for wash down

Product Water Pumps

The product water pumps transfer water from the product water tank to the end users, Orica and NCIG, and are located outside adjacent to the Product Water tank. The product water pumps have on-line redundancy with a duty/ stand-by arrangement and are fitted with variable speed drives to enable a level set point to be maintained within the Orica/NCIG tank. The product water pumps have a nominal capacity of 15MLD.

Transfer Pipeline

Recycled water is transferred from the product water tank to Orica via an 8 km pipeline of a nominal diameter of 400mm DN HDPE PN12. The product water pipeline has a nominal capacity of 15MLD to match the capacity of the product water pumps.

Recycled water is transferred from product water tank to NCIG via a 70m x DN200 branch connection to the 8 km pipeline of a nominal diameter of 400 mm. This Branch connection is located approximately 5.2km from the KIWS Plant

Recycled water is delivered to the individual customers on-site receival tanks which provide some balancing storage to manage short term outages at the KIWS. The transfer system is designed to fill the customers receival tanks in-line with their respective contractual obligations. The customers maximum daily supply obligations collectively align with the total production capacity of the treatment plant (10.5MLD).

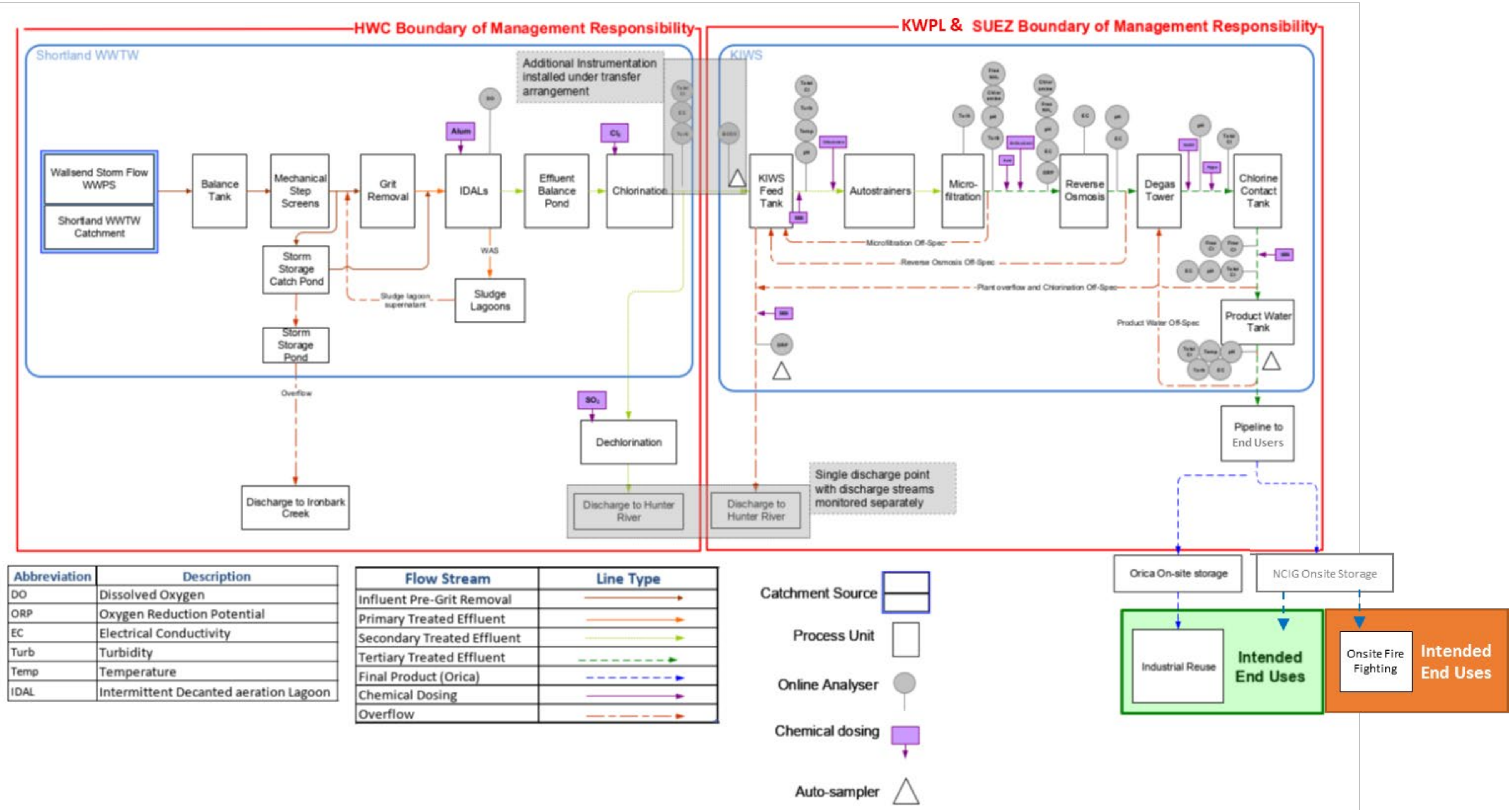

Figure 2-1 Recycled water system diagram showing KIWS (the subject of this RWQMP), Shortland WWTW and End Users.

2.2.5 Water Quality Objectives

Legislation and Guidelines

EPA Environment Protection Licence (EPL) Nos. 1680 and 20757 govern overflows and discharges from KIWS. The AGWR set the level of treatment needed to address the public health and quality issues associated with providing recycled water fit for the end uses as described in Table 2-3. The Australian and New Zealand Environment and Conservation Council (ANZECC) Guidelines for Fresh and Marine Water Quality (2000) and the DECC (now EPA) Use of Effluent by Irrigation Environmental Guidelines (2004) discuss water quality in the context of irrigation for agricultural use. These guidelines have been considered in developing the water quality objectives applied to the KIWS recycled water scheme.

Original KIWS Target and Claimed Log Reduction Values

The original log reduction targets for the scheme were calculated at an Exposure Workshop held in May 2008 between representatives from Hunter Water Corporation, the end user at the time (Orica) along with water treatment and recycled water professionals.

At the 2008 workshop the expected exposure of employees to recycled water whilst undertaking specific tasks was identified and quantified. Risks were estimated in disability-adjusted life years (DALYs) given those exposures. Pathogen log_{10} reduction value (LRV) targets were set for viruses, protozoa and bacteria such that the risk to worker health would not exceed the one in one million health-based target given in the AGWR. From the results of the workshop it was determined that the most exposed group at Orica would be the Nitrate Plant operators and using this highest calculated exposure, the minimum pathogen LRV from raw effluent required to provide a 'fit for purpose' final product for this group were calculated (Table 2-6). Based on validation of process treatment units at KIWS the log reduction values being claimed for the respective process units are summarised in Table 2-7. Refer to Section 8.1 for the information pertaining to the validation of the processes for the achievement of the stated LRVs.

Table 2-6 Target pathogen LRVs for KIWS (Industrial End Use)

Pathogen	Target LRV
Virus	5.1
Protozoa	3.6
Bacteria	3.8

Table 2-7 Summary of the Claimed and Target Log Reduction Values (Original Claim)

Pathogen	Virus	Protozoa	Bacteria
Target LRV	**5.1**	**3.6**	**3.8**
Microfiltration	0.5	4	4
Reverse Osmosis	1	1	1
Chlorination	4	0	4
Total Claimed LRV	**5.5**	**5.0**	**9.0**
Differential	**+0.4**	**+1.4**	**+5.2**

Water Quality Requirements

To demonstrate that treatment is operating effectively and continues to meet quality standards, the recycled water must meet the key parameters as described in the following sections. Additional treated water targets for the KIWS as agreed with Orica and NCIG, are summarised in Table 2-8.

Table 2-8 Water Quality Target Summary Values for KIWS

			Orica			NCIG	
ID #	**Assessable Parameter**	**Units**	**50%ile**	**90%ile**	**Max**	**Target Limit*****	**Critical Limit*****
1	TDS	mg/L		<50		50	150
2	Chloride	mg/L		<15		15	45
3	Calcium	mg/L		<5		5	20
4	pH	mg/L		5.5 - 7.5		5.5 – 7.5	
5	Total Hardness	mg/L CaCO3		<10	30	10	50
6	Alkalinity	mg/L CaCO3		<20		20	40
7	Total Silica (SiO2)	mg/L		<2		2	4
8	Iron	mg/L		<0.015		0.015	0.05
9	Copper	mg/L		<0.05	0.1	0.05	0.1
10	Total N	mg/L N	<1.8	<2.5		2.5	4
11	Ammonia (free)	mg/L N		<0.5		0.5	1
12*	Thermotolerant coliforms or *E. coli*	MPN or CFU/100 mL		Not Detectable		0	0
13	Somatic coliphage	PFU/100 mL		Not Detectable		0	0
14**	*Clostridium perfringens*	CFU/100 mL		Not Detectable		0	0
15	TOC	mg/L C		<1		1	2
16	Total Phosphorus	mg/L P		<0.05		0.05	
17	TSS	mg/L		<2		2	5
18	Chloramine	mg/L		<0.5	1	0.5	1
19	Aluminium	mg/L		<0.1		0.1	0.2
20	Temperature	°C		<27	27	27	30
21	Potassium	mg/L		<3		3	5
22	Zinc	mg/L		<0.2		0.1	0.5
23	Fluoride	mg/L		<0.1		0.1	0.5
24	Sulphate	mg/L		<5		5	10
25	Carbon dioxide	mg/L		<5		5	10
26	Sodium	mg/L		<15		15	30
27	Hexavalent Chromium	mg/L		<0.002		0.002	0.01
28	Arsenic	mg/L		<0.002		0.002	0.01

*Note that the original treated water quality targets originally agreed with Orica in 2008 included mention of 'Faecal coliforms'. That term is now outdated and no longer used except for historical reasons. Since that time the use of thermotolerant coliforms or E. coli is accepted, with the latter being preferred, as mentioned numerous times throughout the AGWR.

**Note that the original treated water quality targets originally agreed with Orica in 2008 included mention of Cryptosporidium among the parameters to be monitored with a target of no detected oocysts/50 L. Since that time, the monitoring program has evolved to move to the use of the microbial indicator Clostridium perfringens to provide a more reliable and cost-effective means of demonstrating the effectiveness of the barriers to chlorine-resistant microorganisms. Just as E. coli is used as an indicator of bacterial pathogens, and coliphage is used as an indicator of viral pathogens, C. perfringens is a credible indicator for protozoan pathogens in this context. Therefore, whilst the specified targets relating to Cryptosporidium have not been changed, the routine monitoring program has been updated to reflect modern practice in relation to microbial verification monitoring, as described in Table 5.5 of the AGWR, that utilises the microbial indicator Clostridium perfringens for routine verification. The verification target in this case is no detection of C. perfringens CFU/100 mL sample, as summarised in the KIWS Recycled Water Quality Monitoring Plan.

***When a Target Limit is exceeded notification is required to NCIG, supply to NCIG must cease when a Critical Limit is exceeded.

Both Orica and NCIG incorporate the recycled water into their operational processes differently hence have slightly different water quality requirements. The water quality targets for Orica have been in place for a number of years and have proven to be effective in operating their on-site process water system. In the case of NCIG, they are required to remineralise the recycled water to prevent damage to their infrastructure and have specific EPA License criteria that have been considered by NCIG in agreeing their water quality targets.

2022 Additional End User Requirements

A new end user for the Recycled Water from KIWS was obtained in 2022, Newcastle Coal Infrastructure Group (NCIG). NCIG uses potable water and onsite captured stormwater within its raw water supply system for its operational water. NCIG's existing raw water system has been setup to preferentially use captured stormwater over potable water supply where conditions permit. When demand exceeds availability of captured stormwater, potable water is drawn to supplement supplies

NCIG's raw water system is used for the following activities on site

- Dust suppression supply water (stockpile yard sprays, dump station unloading sprays, conveyor dust and belt washing sprays, stacker/reclaimer and shiploader wetting and dust suppression sprays).
- Process water supply hoses throughout inbound (Trains), stockyard area (coal stockpiling) and outbound (Shiploading) areas. Raw water is also used for wash downs of hardstand areas, vehicles and other coal handling equipment.
- Water supply for onsite veneering activities. Veneering activities involve the mixing of raw water with veneering product before it is sprayed onto coal stockpiles to assist with minimizing dust generation.
- Water supply for onsite firefighting system. The raw water system on site is used as the primary feed for NCIG site firefighting ring main which can be accessed in the case of a fire on site.

Recycled Water will be used by NCIG to supplement the sites raw water system to be used in preference to potable water reducing the volume of potable water that is required on site for NCIG's industrial processes.

NCIG's review of their existing raw water system and the existing quality of the recycled water from KIWS satisfied their WH&S review of the use of recycled water. However as indicated the existing raw water supply also supplies the onsite firefighting systems, including a firefighting ring main on the site.

The log credits required for firefighting in the AGWR are compared with the original plant LRV's in Table 2-9 below. This identifies a deficit in LRV's attributed to KIWS in the original RWMP. To address the additional LRV requirements KWPL a review of current processes, water quality results and technology was undertaken. This is review was undertaken as part of an update to the *Kooragang Industrial Water Scheme Validation Report* (provided as Appendix A).

This review determined that the additional LRV could be claimed for two existing processes, as summarised in Table 2-. Full details on the limits and monitoring can be found in Table 4-1.

Table 2-9 Fire Fighting Target and Claimed Log Reduction Values

Pathogen	Virus	Protozoa	Bacteria
Current Target LRV	5.1	3.6	3.8
Current Claimed Process	5.5	5	9
FireFighting Target (AGWR)	6.5	5.1	5.3
Current Differential (vs Fire Fighting)	**-1**	**-0.1**	**+3.7**

Table 2-10: Additional LRV claims

	Process Point	Description	Monitoring & Control
1	Inlet feed to KIWS (on the MF feedline)	An additional CCP quality monitoring point of Turbidity (>10 NTU for >60min) from the KWIS Microfiltration feed tank. In addition, KWIS has an online UV BOD at Shortland WWTW discharge (dechlorination building). The Shortland WWTW effluent (KWIS feed) quality is seen to reflective of effective secondary treatment of Shortland WWTW, and as a result an additional 0.5 log credit (V, P, B) from Shortland WWTW.	KWPL will control the process supply and if the new CCP Target/limits are not met supply to NCIG will cease, however Recycled Water production will continue for Orica. As a result, KIWS has full control over the new CCP points/targets and there is no impact to the current Hunter Water arrangement. This point and control of the process will be with KIWS. Further the online UV BOD analysers is a KIWS owned asset but located at the HW site at the Shortland WWTW dechlorination building as a result UV BOD is used as a QCP point. KWIS operators will review the alarm to determine if supply to NCIG will continue or to contact HW to discuss if there have been treatment issues at Shortland WWTW. The alarm code will be housed in the KIWS PLC and based on UV BOD signal from Shortland.
2	KIWS RO	The current KIWS RO CCP will have additional calcium monitoring across the RO system of 1.5 $\log_{10}$ removal [~96.8%], to gain additional 0.5	Change in [Ca], to calculate the log reduction of [Ca] over the RO process of 1.5 $\log_{10}$ removal [~96.8%], is the newly added critical limit for the existing process and this is readily achieved

		log credit (V,P,B)	based on historical performance. The current EC removal target will continue, and if this is exceeded onsite calcium monitoring undertaken to confirm [Ca] removal. Weekly testing using the onsite laboratory to compare the Calcium ion [Ca] of the combined permeate to the feed. The onsite testing will be for hardness as $CaCO_3$ and a calcium equivalent will be calculated. Offsite testing will continue as calcium. If the [Ca] reduction target is confirmed to be exceeded recycled water to NCIG will cease, however production to Orica will continue.

In applying the additional critical control points outlined in Table 2-10, the adjusted LRV against the firefighting (NCIG) would be sufficient as shown in Table 2-11

Table 2-11 Updated Claimed Log Reduction Values for the KIWS

Pathogen	Virus	Protozoa	Bacteria
Fire Fighting (NCIG) Target LRV	**6.5**	**5.1**	**5.3**
Process			
Treated Effluent (new)	*0.5*	*0.5*	*0.5*
Microfiltration	0.5	4	4
Reverse Osmosis *(updated increase)*	~~1~~ 1.5	~~1~~ 1.5	~~1~~ 1.5
Chlorination	4	0	4
Total Claimed LRV	**6.5**	**6.0**	**10**
Differential	**0**	**+0.9**	**+4.7**

It should be noted that the current treatment process (without additional LRV claim) meets Orica's LRV requirements, as a result the additional LRV claim would only apply to recycled water being supplied to NCIG. If the additional critical control point requirements are not being achieved, supply to NCIG can be stopped via an actuated valve at the NCIG connection point controlled by the KIWS plant and recycled water could continue to be supplied to Orica.

If new CCP critical limits are exceeded and NCIG supply ceases, while Orica supply continues, recommencement of supply to NCIG will only be able to offtake recycled water once the NCIG off-specification water has been passed through the network (using Orica use as a 'flush') and NCIG in-specification recycled water has been passed through the network past the NCIG offtake point.

NSW Fire Consultation

As firefighting was identified as an intended end use, NCIG has undertaken consultation with NSW Fire. A summary of consultation is included below:

- 9th February 2022 – NCIG provided email correspondence to Commander Dirk Spec (Commander Spec; Metro North - Acting Zone Commander Fire and Rescue NSW) briefly outlining the recycled water project at NCIG. NCIG provided an overview of the interactions with NCIG's raw water system (which included fire water). NCIG Offered to meet and present project details in person. Commander Spec responded by phone call advising that NSW Fire and Rescue wouldn't be opposed to the project and that they were quite used to sites having recycled water in use.
    - Commander Spec explained that from Fire and Rescue NSW's perspective, it was important that adequate signage was in place at NCIG to warn fire fighters that respond, in the case of an emergency, of the presence of recycled water.
    - Commander Spec did recommend that NCIG consult with Mayfield West Fire Brigade as they are NCIG closest responding station.

- 15th February 2022 – NCIG undertook a site inspection with representatives from Mayfield West Fire Brigade. This was onsite at NCIG and was intended to provide information on the Recycled Water Project. The Presentation was received well with no concerns raised about the project.

Future Reviews

Should KIWS need to significantly modify the treatment process, or the customers wish to change their intended recycled water end uses, a review of the recycled water system will be undertaken.

2.3 Assessment of Recycled Water Quality Data

To inform the previous recycled water quality risk assessments (from 2012 to 2018), data from the Shortland WWTW was reviewed. During operation, water quality data is collected within the SCADA system (Shortland WWTW and KIWS). This data is reviewed over time and after specific events (e.g. wet weather) to assess the reliability of the plant and to determine whether improvements and/or process optimisation is required.

By assessing data, the trends of each parameter over an extended period of time can be shown. This allows for trend analysis to occur and the effects of rainfall and seasonal effects can be seen. From trend analysis, management practices can be altered so that peak conditions can be allowed for, such that there is minimal impact on end-users or the environment.

Data generated from ongoing verification and operational monitoring can be reviewed periodically, as required, to assess the following factors in relation to the recycled water scheme:

- To account for changes in the end uses or treatment process.

- To analyse trends that may indicate cumulative changes in influent and effluent water qualities and/or preventative measure treatment efficacy.

- To investigate potential seasonal variations or cumulative effects on water quality to optimise the treatment process throughout the year.

Within the 2021/2022 review the effluent and recycled water quality data associated with the new proposed CCP and additional RO claim was reviewed to confirm that these were appropriate and reliable monitoring points and limits, this review was undertaken as part of the update to the *Kooragang Industrial Water Scheme Validation Report* (provided as Appendix A).

2.4 Hazard Identification and Risk Assessment

Effective risk management involves the identification and analysis of all potential hazards and hazardous events. A HACCP Plan was originally drafted following a risk assessment workshop held on 10 August 2012. The workshop at the time was aimed at determining the potential hazards and preventative measures in place for the KIWS – when the scheme was owned and operated by Hunter Water. From the workshop the original HACCP Plan and Report was produced.

The HACCP Plan was updated by SUEZ during June 2016 during which a risk assessment was undertaken to assess the specific risks to the end users as summarised in the Hazard Analysis and Critical Control Point (HACCP) Plan. The results of this assessment are given as Appendix B to this RWQMP which contains the following information relevant to this element:

- The approach used to hazard identification and risk assessment.
- The identification and documentation of hazards and hazardous events for each component of the scheme including inadvertent and unauthorised use or discharge.
- Estimation of the level of risk of each identified hazard to determine significant risks. Documentation of risk management priorities.
- Evaluation of the main sources of uncertainty.
- Review requirements.

The HACCP Plan was independently reviewed and updated during both July and October 2016 and July 2018 (summaries of those review meetings are also given as Appendix B). During those reviews the workshops considered the potential hazards and preventative measures in place for the KIWS based on the same methodology used during the original HACCP assessment. One of the outcomes of those meetings was that it was considered that there would be the opportunity to remove the overflow CCP (CCP 5) from the RWQMP in due course and to reassign it as a QCP (QCP3). That change took place following the July 2018 review.

Within the 2022 update a risk assessment review was undertake as part of the transfer of the RWQMP from a SUEZ document to a KWPL document. This included a review the of risk definitions (consequence and likelihood, and matrix) based on KWPL corporate risk framework, as provided in Appendix C. The risk assessment also considered the additional control points and monitoring based on the additional LRV claim for NCIG onsite firefighting intended use. This risk assessment was held on 7 December 2021 and attended by representatives from WUA, SUEZ, NCIG, NSW Health, Hunter H2O and independent expert observer. The updated risk assessment sheets with attendance details are provided in Appendix C.

Note that Appendices B and C need to be taken together to represent the background and most current HACCP Report. With Appendix B covering the original HACCP Plan and Appendix C providing records of how that plan has evolved and the most recent risk review.

The hazard identification and risk assessment review process entails forming a risk assessment team and systematically reviewing the hazards, risks and their assessment, along with evaluating uncertainties. The team participants, methodologies adopted and results of these assessments and reviews are summarised in the appended workshop summary documents. Future reviews and revisions of these assessments are anticipated to take place either following major changes in infrastructure, following directives from regulators or following major incidents.

Reviews may also take place at periodic intervals of up to several years apart if not otherwise triggered. Those future reviews are anticipated to adopt essentially the same process adopted in undertaking the previous reviews, albeit possibly modified in response to changing guidelines or regulator requests.

3. ELEMENT 3 – Preventative Measures for Recycled Water Management

3.1 Preventative Measures and Multiple Barriers

Based upon the system specific hazard identification performed at the risk assessment and HACCP workshop, control measures were identified to ensure that the level of protection to control identified hazards would be proportional to the associated risk. Based upon the implementation of the preventative measures residual risk was estimated.

The most recent HACCP Report is located in Appendix C summarises the process utilised to identify control measures and estimate residual risk. It also documents the outcomes of the workshop, including each hazard/risk and its associated control measures. Appendix B covers the previous HACCP Plan

3.2 Critical Control Points

A critical control point (CCP) is defined as an activity or process where control can be applied and is essential for preventing hazards that represent high risks or can reduce them to acceptable levels. As per the AGWR, CCPs require the following:

- Operational parameters that can be monitored and for which critical limits can be set to define effectiveness.
- Operational parameters that can be monitored frequently to reveal any failures in a timely manner.
- Procedures for corrective action that can be implemented in response to deviation from critical limits.

A Quality Control Point (QCP) is a point, step or procedure that is not classified as a Critical Control Point because it is a management process step rather than an operational control or an operational process step, which has a limited capacity to be monitored and/or corrective action taken in a timely manner.

The identification of CCPs and QCPs for KIWS was performed during the risk assessment and HACCP workshop. There are four CCPs in operation at KWIS:

1. CCP1- Effluent Inflow (representing Shortland WWTW),
2. CCP2 - Microfiltration,
3. CCP3 - Reverse Osmosis and
4. CCP4 - Chlorination processes

Further details on the CCPs and QCPs are provided below:

- CCP1 – Effluent Infow - originally at the scheme's creation Shortland WWTW was considered to CCP1 – Shortland WWTW.
  - However, during the transition of the scheme from Hunter Water to WUA/SUEZ and as the additional LRV was not required for the Orica end use it was removed as a CCP, but the nomenclature for consistency remained (leaving it as archived as non-active 'CCP1').
  - In the 2022 review CCP1 was reinstated for an additional 0.5 LRV claim for the NCIG end use of onsite firefighting. The CCP1 is based on the inflow effluent turbidity to KIWS. This is a change as although this CCP represents effective secondary treatment at Shortland WWTW, the CCP point is not at the WWTW but at the MF feed line. If the

quality turbidity objective is not achieved control will be with KIWS to manage the response.

- QCP 1 – Shortland WWTW (Secondary Treatment). New QCP as part of the 2022 update, using online UV BOD monitoring at the Shortland WWTW Dechlorination/Discharge location. This analyser is a KWIS instrument on Hunter Water site. This QCP1 monitoring is to further support CCP1 as an additional monitoring to demonstrate effective secondary treatment at Shortland WWTW. The UV BOD value is transmitted from the Shortland site to the KIWS site and monitored by the KIWS PLC. If the QCP1 value is exceeded, the KIWS PLC raises an alert on the KIWS SCADA.

- CCP2 – Microfiltration (a CCP to yield low enough turbidity over the whole process).

- QCP2 – Microfiltration (a QCP to yield turbidity low enough over individual trains).

- CCP3 – Reverse Osmosis (a CCP to yield low enough Electrical Conductivity (EC) over the whole process).

    - In the 2022 review CCP3 was updated to include monitoring for Calcium ion removal over the RO process to allow for a higher LRV claim

- QCP3 – Reverse Osmosis (a QCP to yield low enough Electrical Conductivity (EC) over individual trains).

- CCP4 – Chlorination (a CCP to provide adequate chlorine dose)

- QCP4 – Dechlorination (an environmental control point related to overflow to the Hunter River and formally identified as CCP5 but downgraded to a QCP following the July 2018 workshop since overflow is not a necessary condition).

3.2.1 Mechanisms for Operation Control

As part of the process to identify CCPs and to reliably achieve the required water quality operational limits were set for each CCP. The two types of limits set are categorised as critical limits and target criteria. Critical limits and target criteria are defined as follows:

- Critical limits – a prescribed tolerance that distinguishes acceptable from unacceptable performance; deviation from a critical limit represents a loss of control of a process and indicates there may be an unacceptable environmental or health risk.

- Alert criteria – aim to prove an early warning that a critical limit is being approached; are more stringent that critical limits so that corrective action can be instituted before an unacceptable health or environmental risk occurs.

Critical limits and target criteria for each identified CCP are documented in the HACCP Plan and Report located in Appendix B and Appendix C and summarised in Table 4-1.

4. ELEMENT 4 – Operational Procedures and Process Control

4.1 Operational Procedures

4.1.1 Identify procedures for processes and activities

During the transfer of the asset to KWPL, Hunter Water provided the original KIWS Operations Manual for the AWTP along with the associated Computer- aided Design (CAD) drawings, electrical drawings, Piping and Instrumentation Diagrams (P&IDs), Standard Operating Procedures (SOPs) and Safe Work Methods Statements (SWMS) for the site. KWPL was provided with these documents including the relevant Functional Description, P&IDs, SOPs and SWMS.

4.1.2 Document procedures and compile an operation manual

As the contracted operator, SUEZ has converted the Hunter Water documents into its own format or archived them unchanged, as appropriate. As part of that process KWPL and SUEZ operators have inspected the AWTP and checked the CAD drawings, electrical drawings, P&IDs, SOPs and SWMS to flag any required updates. If and when updated these documents will be issued as SUEZ drawings but will otherwise be left as they are. Particular attention has been given to checking and verifying details of the CCPs during those reviews.

The upgrade of the plant to incorporate the BRU has resulted in a change to the plant design. This project has been undertaken as a D&C Contract with SUEZ as the principal contractor and SUEZ are responsible for the provision of updated documentation arising from the project. By engaging SUEZ to perform these works, KWPL ensures continuity of operation through the plant upgrade and consistency of design with the current plant documentation and operating knowledge.

Hard copies of drawings and P&IDs are located in the Control Room and electrical drawings are located in the Switch Room. In addition, all documents are stored and managed within the SUEZ Integrum document and records management system (see Element 10).

4.2 Operational Monitoring

The AGWR defines operational monitoring as routine monitoring of control parameters identified within the treatment systems and recycled water usage steps, to confirm that processes are under control. Operational monitoring is designed to provide advance warning that systems may be deviating from a point where control may be lost.

Operational monitoring occurs at intervals more frequent than the time that it takes to carry out appropriate corrective responses. Operational monitoring systems include online monitoring devices in order to allow for alarmed interlocks with process equipment and alarm monitoring for rapid response through the plant PLC. Regular observations are used for monitoring the status of equipment and systems at the site that do not have PLC monitoring.

Operational monitoring incorporates notification of SCADA alarms and faults, which are reported on the local SCADA and via 24 hour monitoring. SUEZ software monitors plant performance more generally. Alarms generated through SCADA have priorities assigned to each fault based on the requirement to maintain effluent quality and plant operation. The most crucial representative operating parameters are logged in the KIWS plant spreadsheet, this assists operations staff to interpret data and trends in effluent quality and equipment operation and highlight gradual deviations from normal operation.

Table 4-1 provides a summary of SUEZ's operational monitoring activities for the KIWS relevant to the CCPs and QCPs outlined above.

Table 4-1 Summary of Critical Control Point Operational Monitoring Activities for KIWS.

Process or Step to be monitored	Parameter to be monitored	Monitoring location	Frequency	Unit	Control Limits		Corrective Action(s) – to be applied when Critical Limits are exceeded.
					Alert Limit	Critical Limit	
Effluent Inflow Quality (CCP1 and QCP1) Relevant to NCIG Supply ONLY	uV BOD (QCP1)	Shortland WWTW discharge (diversion) dechlorination building	Continuous Online	mg/L	No more than 10% above 30 mg/L over rolling 24 hour period	NA	• If the alert limit is exceeded, the KIWS PLC will generate an alert on the KIWS SCADA. • At next opportunity, KIWS operations to contact Hunter Water/Veolia to discuss situation. • If the situation at Shortland is likely to worsen, NCIG to be notified at earliest opportunity of potential cessation of supply • No automatic diversion occurs •
	Turbidity (related to CCP1)	Located at MF feed line after the MF feed tank	Continuous Online	NTU	> 8 NTU for > 60 mins	> 10 NTU for > 60 mins	• SCADA to cease supply to NCIG • Verify turbidity meter result (bench scale tests) and calibrate meter if required • Investigate feed water conditions. • Await until feedwater conditions meet CCP Limits before recommencement of NCIG Supply. • KWIS operators to contact Hunter Water as required
Membrane filtration (CCP2 and QCP2)	Turbidity (related to CCP2)	Combined permeate	Continuous Online	NTU	> 0.10 NTU for > 15 min	> 0.15 NTU for > 40 min	• Verify combined turbidity meter result and calibrate meter if required • Shut down entire MF system and investigate output from individual trains • Undertake a PDT on each MF train and view the process to identify any module faults. • Isolate and repair any leaking valves • Isolate and repair any identified membrane faults (broken fibres, o-rings)

Process or Step to be monitored	**Parameter to be monitored**	**Monitoring location**	**Frequency**	**Unit**	**Control Limits**		**Corrective Action(s) – to be applied when Critical Limits are exceeded.**
					Alert Limit	**Critical Limit**	
Membrane filtration (CCP2 and QCP2)	Turbidity (related to QCP2)	Individual trains	Continuous Online	NTU	> 0.20 NTU for > 10 min	> 0.3 NTU for > 20 min	• Verify individual turbidity meter result and calibrate meter if required • Investigate and isolate individual train/s if they are exceeding the turbidity limit using online turbidity meter on individual trains • Undertake a PDT on each MF train and view the process to identify any module faults. • Isolate and repair any leaking valves • Isolate and repair any identified membrane faults (broken fibres, o-rings)
	Pressure Decay Rate (related to CCP2)	Membrane skid	Daily online	kPa/5 min	PDT > 7 kPa	PDT > 7 kPa for three consecutive tests OR PDT > 10 kPa for an individual test	• Shut down MF system following a critical failure Isolate train that is exceeding PDT value • Repeat PDT and view the process to identify any module faults. • Isolate and repair any identified membrane faults (broken fibres, o-rings) • Isolate and repair any valve leaks
Reverse Osmosis (CCP3 and QCP3)	Relevant to NCIG Supply ONLY Calcium ion [Ca]	Combined permeate (related to CCP3)	Weekly (onsite calcium testing unit)	Log10; %removal	EC online monitoring and alert levels	The drop in [Ca] must exceed 1.5 log10 ~ 96.8%	• If EC Alert Limit level breached (40 µS/cm for >30 min), take samples and verify the feed and permeate Calcium, to calculate removal differential (percent and log). OR if routine [Ca] samples show < 96.8% • If [Ca] results show removal< 96.8%, NCIG supply ceases • Recommence supply when calcium test results show required performance target > 96.8%
	Electrical Conductivity	Combined permeate (related to CCP3)	Continuous Online	µS/cm	> 40 µS/cm for > 30 min	> 70 µS/cm for > 60 min	• Investigate the EC of the individual trains • Investigate whether there has been a chemical clean or module replacement

Process or Step to be monitored	Parameter to be monitored	Monitoring location	Frequency	Unit	Control Limits		Corrective Action(s) – to be applied when Critical Limits are exceeded.
					Alert Limit	Critical Limit	
Reverse Osmosis (CCP3 and QCP3)		EC of the combined permeate compared to the EC of the feed to calculate the Log reduction of EC over RO process (related to CCP3)	Continuous Online	%	< 94% reduction in EC for > 30 min (94% is equivalent to an LRV of 1.22)	< 90% reduction in EC for > 60 min (90% equivalent to an LRV of 1.0)	• Take samples and verify the feed and permeate EC meters, calibrate/replace if required • Verify the feed and permeate Calcium, to calculate removal differential (percent and log). • Shutdown train/s that have high permeate EC and investigate cause • Check delivered maintenance equals planned maintenance • Check dosing of acid and antiscalant • Check the performance of each train, are the trains highly fouled and in need of chemical cleaning?
Chlorination System (CCP4)	Ct	CCT outlet (related to CCP4)	Continuous Online	mg•min/L	< 13 mg.min/L (pH < 7.5) for > 20 min < 30 mg.min/L (pH > 7.5 and < 9.0) for > 20 min	< 11 mg.min/L (pH < 7.5) for > 20 min < 27 mg.min/L (7.5 < pH < 9) for > 20 min	• Divert off-spec water, continue to operate to bring plant back into control • Investigate and verify the chlorine meter readings and calibrate/replace if required • Investigate and verify the pH meter readings and calibrate/replace if required • Investigate the chlorine dosing system operation and control • Investigate set-points and upstream operations than could influence pH and chloramine dosing levels.
	pH	CCT outlet (related to CCP4)	Continuous Online	pH units	> 7.5 for > 30 min	> 9 for > 10 min	
	Temperature	CCT outlet (related to CCP4)	Continuous Online	°C		< 10 for > 10 min	

4.3 Operational Corrections

4.3.1 Procedures for Corrective Action

Table 4-1 provides a summary of the operational corrections, should the monitored parameters indicate that final effluent quality is not suitable for use; contact will be made with the recycled water customers and supply of recycled water ceased until recycled water quality has returned to acceptable limits.

Procedures for corrective action have been developed in conjunction with the development of critical and target limits for the CCPs.

4.3.2 Establish rapid communication systems to deal with unexpected events

The plant operators/technicians monitor plant operations and alarms via mobile IT platforms such as SCADA alarms and remote operating programs and devices (laptops/iPads). In that way operational staff can monitor and respond to the SCADA alarms in response to critical or unexpected events.

If recycled water is potentially unsuitable for use, the recycled water customer will be informed and recycled water supply will be ceased. The customer will be notified once recycled water is again suitable for use.

If the quality of recycled water delivered to the customer reaches a level that may present a risk to public or environmental health, an incident will be declared and the customer, as well as IPART, NSW Health, EPA, SafeWork NSW and/or Hunter Water, (as applicable), will be notified immediately, as discussed in Element 6. These notification procedures are outlined in the following documents:

- SUEZ's Communication Protocols with Orica Kooragang Industrial Water Scheme Document 110-SE-OM-000-MP-001,
- Hunter Water and KIWS Operations Protocol, and
- NCIG and KIWS Communication Protocol.

4.4 Equipment Capability and Maintenance

Operational procedures and SCADA ensure that equipment performance is continuously monitored and failures can be detected promptly. The control logic for the KIWS is designed to provide sufficient functionality in order to reduce the risk of sending recycled water of an inappropriate quality to the reuse scheme and equipment has sufficient flexibility and process control.

There are also a number of points where redundancy has been built into the system to provide reliability during unforeseen breakdowns or hazardous events. For example, the following have been implemented:

- Duty/standby arrangements for pump facilities and auto strainers.
- Enough capacity in the MF system and RO systems for continuous operation when one skid is offline.
- The option to provide potable water to the customer if the AWTP cannot provide sufficient fit-for-purpose water (noting that such a backup supply of water is considered a routine matter that does not constitute a non-compliance or trigger for notification of regulators such as IPART).

The site is fed by two transformers although there is no redundancy and the KIWS would only be able to operate critical parts of the plant in the event that one transformer were lost. There is a program in place for load shedding and the option of operating in batch mode if required. There is only very limited space for overflow storage on site. However, the AWTP can stop receiving treated effluent from the WWTW by placing the raw water tank offline. Alternatively, the AWTP can overflow to the river under the SUEZ EPA Environment Protection Licence (EPL) for KIWS (No. 20757) dated 6 September 2016 relating to accidental discharges from the KIWS AWTP. However, given that wastewater receival can be stopped, such an event would be highly unlikely to occur in practice.

4.4.1 Asset Management Plan

SUEZ has developed the KIWS Asset Management Plan (AMP). The AMP is subjected to annual review and within that process the condition of assets is assessed and the plans for the management and maintenance of those assets is refined. General information on asset condition is provided from periodic asset condition assessments that are scheduled under the computerised maintenance management system (CMMS) “INfOREAM”.

The AMP has been informed by the KIWS Asset Criticality Review 110-SE-OM-000-RP-001 that involved an assessment of risk related to asset failure and identification of asset criticality. The Review considered the estimated frequency and severity of asset failure. Severity considered the impact of asset failure on safety, process (quality and quantity) and environment as well as cost. The Review considered the mitigation of those risks through preventive maintenance processes at defined frequencies and/or the maintenance of an inventory of potentially necessary critical spare parts. The document considers the system redundancy built into the infrastructure.

At the more detailed level, asset maintenance and management is supported by the INfOREAM system that lists specific assets, their general descriptions and properties (such as material, size, age, capacity) and preventive maintenance arrangements and schedules. The CMMS generates reminders and alerts to undertake tasks, produces work orders and supports tracking and recording of works completed and resources allocated against the work order. The maintenance procedures are linked to asset life cycle optimisation, safe and reliable performance of the infrastructure, service criticality and business risk. Actions scheduled in INfOREAM include reactive, preventive and predictive maintenance.

Over the longer term, the KIWS Renewals Plan 110-SE-OM-000-WS-001 has been developed to cover the infrastructure over the 15 year life of the contract. The Plan considered major asset maintenance and replacement to ensure good long-term plant condition and performance over time. The Plan considered estimated lifespan of critical assets, condition assessment and works management as well as renewal of the infrastructure or run-to-fail options. A schedule of capital works for asset renewal, replacement and development has been included. Costings have been forecast over the future 15-year life-cycle covering capital (replacement), operations, maintenance and management and administration expenditure.

SUEZ assesses its performance internally with respect to KPIs for completion rate of tasks. The asset maintenance and management schedules are reviewed periodically to respond to experience with the system through a continuous improvement process.

Interface points between KIWS and Hunter Water Corporation or Orica infrastructure and NCIG are set out in the contracts. This includes:

- Schedule 4 Recycled Water Meter Location of the Recycled Water Agreement (22 September 2021) between Kooragang Water Pty Ltd and NCIG.
- Schedule D Proposed Delivery Point of the Non Potable Water Supply Agreement (1 August 2011) between Kooragang Water Pty Ltd and Orica Australia Pty Ltd.
- Schedule 6 Orica Potable Water Delivery Point and Schedule 7 Treated Effluent Delivery Point of the Supply Agreement (Agreement for the Supply of Treated Effluent and Potable Water) (Version 1 – currently being updated, 17 December 2015) between Hunter Water Corporation and Kooragang Water Pty Ltd.

SUEZ prepares an annual budget including proposed capital works for submission to KWPL as part of finalisation of KWPL’s annual budgeting processes. This budget is considered and reviewed through the

Project Control Group ('**PCG**') that monitors the performance of the O&M contact between SUEZ and KWPL. Once agreed the budget is finalised and capital works are delivered by SUEZ in accordance with the approved budget,.

4.4.2 Infrastructure documentation

In relation to the records of the design and construction drawings and particulars, Hunter Water has provided the KIWS CAD drawings, electrical drawings, P&IDs and Functional Description. Downer has provided the Electrical Manual. These documents were checked and updated by SUEZ as the operational contractor of the KIWS and converted to SUEZ format where appropriate, or archived in their existing format. These documents include the locations of secondary infrastructure as well as alternative sources of water and alternative infrastructure, where relevant.

The upgrade of the plant to incorporate the BRU has resulted in a change to the plant design. This project has been undertaken as a D&C Contract with SUEZ as the principal contractor and SUEZ are responsible for the provision of updated documentation arising from the project. By engaging SUEZ to perform these works, KWPL ensures continuity of operation through the plant upgrade and consistency of design with the current plant documentation and operating knowledge.

4.4.3 Equipment Inspection and Maintenance Schedule

SUEZ has scheduled electrical and mechanical maintenance for KIWS equipment. These schedules are stored within the maintenance module of SUEZ's INfOREAM CMMS. Maintenance schedules are completed by field staff and recorded within the CMMS. Equipment is monitored operationally 24/7 via SCADA, and a priority alarm system is in place to inform required parties of the criticality of system failure.

Onsite equipment is monitored by KIWS operators as a part of daily operating procedures as outlined for each piece of equipment detailed in the asset register and within the CMMS maintenance schedule. Instruments are calibrated regularly based on manufacturer's instructions and the CMMS maintenance schedule.

4.5 Materials and Chemicals

Chemicals used at KIWS are obtained through a purchasing contract from quality assured suppliers. This ensures that plants have a reliable supply of quality chemicals and are matched to batch numbers. These contracts are managed by a specialised contracts and procurement group within SUEZ.

Chemical levels are monitored by operators and are ordered through the purchasing contract on an as needs basis.

SUEZ maintains a detailed dangerous goods register that contains the quantities of chemicals stored at each site, detailed risk assessments for the storage facility including the required actions of operators and personnel.

SUEZ has a full procurement management process that includes PRO-005 Evaluation of Suppliers and F&A- 005 Purchasing Specifications. The latter covers requirements for chemicals received to be supplied with an appropriate materials safety data sheet (MSDS), to be inspected upon receipt and to be managed on site with reference to site-specific procedures.

SUEZ has developed a site-specific procedure for chemical receipt.

5. ELEMENT 5 – Verification of Recycled Water Quality and Environmental Performance

Verification is the application of methods, procedures, tests and other evaluations, in addition to laboratory and online analytical monitoring to determine whether a recycled water management system is performing as intended and meeting associated quality targets. Verification monitoring assesses the overall performance of the recycled water treatment process at KIWS and the quality of recycled water against the targets and criteria established in this document.

The following activities are undertaken to assess the effectiveness of documented processes in demonstrating compliance with the water quality objectives:

- Recycled water quality monitoring
- Short-term evaluation of results
- Documentation and reliability
- Monitor customer satisfaction
- Implement corrective actions when required.

Verification monitoring provides an opportunity for a detailed review of data collected over time and the effectiveness of relevant management procedures. The outcomes of the verification monitoring process may include the identification of treatment stages that may not be performing to the required standard, re-defining critical or control limits and revising or improving management processes.

5.1 Recycled Water Quality Monitoring

5.1.1 Recycled Water Quality Monitoring Plan

Verification monitoring of recycled water quality confirms that the product delivered by KIWS meets water quality objectives. Verification monitoring includes monitoring of microbial indicators as well as selected chemical parameters.

The monitoring program has been drawn from the Hunter Water Recycled Water Quality Monitoring Plan for KIWS to develop the KIWS Recycled Water Quality Monitoring Plan Kooragang Industrial Water Scheme. The Monitoring Plan includes a table of what is tested and how often and sets out the concentration limits for parameters monitored.

5.1.2 Laboratory accreditation

A laboratory accredited for the specified tests by the National Association of Testing Authorities (NATA), which at the time of writing is the local ALS laboratory, carries out analyses undertaken as part of water quality verification monitoring.

5.2 Satisfaction of Users of Recycled Water

KWPL recognises that customer satisfaction is essential for the success of recycled water schemes, and customer complaints and enquiries need to be resolved in a timely and appropriate manner. SUEZ as KW operational agent reviews satisfaction levels as part of SUEZ's monthly reports and 6-monthly reports and visits the recycled water customer every 6 months. Complaints received by SUEZ will be utilised constructively to continuously improve their service provision and to identify any problems that need to be addressed with regards to the provision of recycled water from KIWS.

KWPL has bi-annual meetings with each customer to obtain direct feedback on performance of the scheme and to understand current and future water supply and quality requirements. These meetings ensure longer term planning for any changes in water needs of the customers can be appropriately considered by KWPL. Operational issues arising from these meetings are addressed with SUEZ (where appropriate) via the bi-monthly PCG meetings.

5.3 Short Term Evaluation of Results

The objective evaluation is to verify that the quality of water supplied to the end users conforms to the water quality specification and meets user expectations.

The concentration limits for the monitored parameters is based on Schedule E Non Potable Water Specifications of the Non Potable Water Supply Agreement between KWPL and Orica, and Schedule 3 of the Recycled Water Agreement (22 September 2021) between Kooragang Water Pty Ltd and NCIG, and are provided in Table 2-8. If a case of non- conformance is identified as a result of the evaluation, the KIWS operator SUEZ will implement immediate corrective actions or incident responses.

A plant datasheet has been developed into which operators input external laboratory results and other plant- specific information which then provide the critical plant operational data contained in monthly and exceedance reports. SUEZ's technical support teams, both within Australia and overseas, are able to login to the system in real-time and assist the operators to troubleshoot issues and advise on process improvements.

5.4 Reporting Mechanisms

Verification monitoring results are summarised in the monthly and annual reports produced by SUEZ and submitted to KWPL. These reports are reviewed by SUEZ and KWPL through the PCG where the overall performance of the KIWS is assessed and contractual KPI's are monitored.

In addition, the Annual Compliance Report to IPART summaries the verification monitoring results.

5.5 Corrective Responses

Corrective responses to non-conformance are undertaken by the SUEZ the KIWS AWTP Operators. The actual response varies depending on the level and type of event. As a minimum, treatment processes are monitored and inspected to ensure normal operation and, if required, further sampling is carried out. There may be a review of control measure performance and associated operational monitoring systems should it be deemed necessary.

5.5.1 Response to water quality verification monitoring exceedances

Where verification monitoring results exceed the concentration limits for monitored parameters, as specified within the Contract between KWPL and Orica, KWPL and NCIG respectively, corrective responses are required. These concentration limits are given in Schedule E Non Potable Water Specifications of the Non Potable Water Supply Agreement (1 August 2011). The following roles and responsibilities apply:

- The laboratory services provider (ALS) under its contract with SUEZ only has an obligation to notify SUEZ KIWS AWTP operators of all results and are not responsible for notifying third parties.

- Responsibility for reviewing results provided by the laboratory services provider and for identifying exceedances of the data submitted by the laboratory rests in the SUEZ KIWS AWTP Operators.

- Notifications to the customers (Orica & NCIG), supplier (Hunter Water) and other potentially relevant stakeholders (e.g. EPA, SafeWork NSW or NSW Health) are the responsibility of the SUEZ KIWS AWTP Operators.

- Notifications to the regulator (IPART) are the responsibility of WUA as the current license holder, However where appropriate SUEZ as the acting agent of WUA may notify IPART if this is deemed appropriate and in the event of an emergency.

- It is necessary to respond immediately to significant system failures that pose a risk to public or the environmental or adversely affect recycled water quality for an extended period of time.

- Significant operational issues are escalated by SUEZ to KWPL as required under the Operations and Maintenance Contract which allows KWPL to manage its broader contractual and regulatory responsibilities over and above the day-to-day operational responsibility of SUEZ.

5.5.2 Response customer notifications

Corrective responses are implemented where necessary following reports from Orica or NCIG to the SUEZ KIWS AWTP Operators. The SUEZ KIWS AWTP Operators are responsible for those responses from a day-to-day operational perspective.

As noted above, Significant operational issues are escalated by SUEZ to KWPL/WUA as required under the O&M Contract which allows KWPL/WUA to manage its broader contractual and regulatory responsibilities over and above the day-to-day operational responsibility of SUEZ.

ELEMENT 6 – Management of Incidents and Emergencies

5.6 Communication

5.6.1 Define communication protocols with the involvement of relevant agencies

Internal Notifications

Treatment plant operators and team leaders are responsible for providing notifications to key SUEZ staff in the case of potential incidents, such as:

- Treatment systems exceeding critical limits
- Recycled water quality failure to meet specifications from verification monitoring
- Major equipment breakdown or mechanical failure

External Notifications

Hunter Water, Orica, NCIG, NSW Health, SafeWork NSW and/or EPA (as appropriate) are notified if an incident occurs that has the potential to impact the customer, the environment and/or public health as summarised in Table 5-1.

Table 5-1 Incident notification protocols for the KIWS

NSW Health, IPART, Orica, NCIG and Hunter Water Notifications	
Event/Water Quality Parameter	**Circumstances**
Any Major or Crisis Recycled Water Incident	Reported incidents of recycled water cross-connection or excessive consumption Reported illness potentially associated with recycled water exposure or consumption
CCP process failure resulting in supplied recycled water not meeting specification	Upon notification that recycled water had been supplied from treatment operations without the critical limits being met
Verification monitoring exceeding health-related requirements for the recycled water	*E. coli* in the final product water (1 org/100 mL or greater)
Office of Environment and Heritage, IPART, Orica, NCIG and Hunter Water Notifications	
Event/Water Quality Parameter	**Circumstances**
Confirmed environmental impact associated with recycled water	This could include events such as: • Confirmed ground water contamination • Long term soil contamination • Fish kills or damage to aquatic systems • Destruction of vegetation

Notification procedures to Orica are outlined in KWPL's Communication Protocols with Orica Kooragang Industrial Water Scheme Document 110-SE-OM-000-MP-001 as well as the Hunter Water and KIWSP Operations Protocol.

Notification procedures to NCIG are outlined in KWPL's NCIG and KIWS Communication Protocol.

5.6.2 Develop a public and media communications strategy

It is critical to maintain community confidence and trust during and after an emergency situation, as such communication with the public and media is essential to ensure that correct information is passed to the community and to alleviate any fears. SUEZ as the operational agent for KWPL, has a dedicated communications group that handles external and internal responses (Media and Government Relations member of the Crisis Management Team).

5.7 Incident and Emergency Response Protocols

5.7.1 Define potential incidents and emergencies, and document procedures and response plans

Incidents are defined as occurrences that may affect the environment or human health through surface or groundwater pollution or soil contamination.

Emergencies are occurrences where there is immediate real or potential to:

- Threaten the health and safety of persons
- Damage property
- Damage the environment
- Threaten the service of customers.

5.7.2 Investigate incidents and emergencies, and revise protocols

In the event of an incident or emergency SUEZ is committed to carrying out an immediate investigation covering factors such as:

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

The investigation process will conclude with a debriefing session of all involved staff to discuss performance and address any issues or concerns. Appropriate documentation and reporting of the incident or emergency to relevant stakeholder agencies and the regulator will be undertaken in a report. If deemed necessary appropriate changes to existing protocols will then be made. These can sit in either the broad corporate procedure or the site-specific plan.

SUEZ adopts a standard reporting procedure for incidents (Incident Reporting and Investigation Procedure OHS-005). In addition, SUEZ will notify Orica and NCIG, IPART, NSW Health, SafeWork NSW and EPA, as required. A series of Incident Management protocols has been developed to guide a number of foreseeable incidents and there is a draft SUEZ KIWS HSE Management Plan Kooragang Industrial Water Scheme (KIWS) Health, Safety & Environment for the site.

6. ELEMENT 7 – Operator, Contractor and End User Awareness and Training

6.1 Operator, Contractor and End User Awareness and Involvement

It is critical to the successful operation of the KIWS that operators and contractors have sufficient awareness and training regarding the potential consequences of system failures as well as how decisions can affect public and environmental health. It is imperative that operators are also involved in decision-making processes and development of management strategies.

SUEZ is committed to ensuring that operators have a thorough understanding of recycled water quality management. End users are made aware of restrictions on recycled water use, management requirements as well as safe practices through recycled water customer agreements (Recycled water customer agreements between Orica and NCIG with Kooragang Water Pty Ltd

6.2 Operator, Contractor and End User Training

SUEZ is committed to ensuring that all staff members are adequately trained and suitably able to carry out their roles. All sections within SUEZ are required to ensure that new employees undertake an induction program that covers (at a minimum) standard safety procedures relevant to their section. This induction includes emergency response/evacuation and where necessary an asset specific induction.

6.2.1 Identification of Training Needs and Resources

With respect to human resources capacity, the plant is operated by two dedicated operators. In addition, if required, SUEZ can provide operational staff from other plants globally to support short periods of increased demand or to backfill roles during periods of leave or absence.

Training and personnel development needs are identified by SUEZ. If training gaps are identified, comments will be passed through to SUEZ's Human Resources (HR) group so that the appropriate training course can be organised.

All SUEZ water operations staff are required to have (or be working towards) a relevant Certificate III (or above) in Water Operations. In addition, there are plant-specific training needs identified in the KIWS Training Matrix worksheet that summarises the specific expectations for the KIWS AWTP that covers training, competency and certifications related to safety, electrical, quality, water industry training, etc.

For new SUEZ staff, there is a standard corporate induction for new employees that includes an induction day as well as on line intranet-based training and face-to-face meetings. Similarly, there is an induction for the KIWS plant for staff that are new to that site. That site-specific induction is provided by the Contract Manager and/or the Site team. Personnel are trained in the operation and maintenance policies and procedures. On an ongoing basis, SUEZ has a technical training calendar run from SUEZ's Head Office in Paris and offers internal training on a variety of topics.

6.2.2 Training Documentation

The document HR-005 Training & Development procedure formalises the system and provides the training matrix for operators that operate the KIWS AWTP. The operational groups from within SUEZ identify their training needs and supply information on training completed to HR. Then, HR in turn centrally consolidates and records completed training into a spreadsheet. All SUEZ training attendance that is notified to HR is recorded and stored within SUEZ's HR system on that spreadsheet. All training courses are accompanied by a training evaluation form that allows for appraisal of training effectiveness. HR ensures that training and competencies are kept current, where appropriate.

7. ELEMENT 8 – Community Involvement and Awareness

7.1 Consultation with users of recycled water and the community

Both Orica and NCIG were actively involved in risk assessments leading up to their respective connection to the scheme, and as a result have developed their own RWQMP's to govern their management of the recycled water on their sites. Under their respective Supply Agreements Orica and NCIG are required to undertake education of their site employees as is required under their work place compliance obligations.

7.2 Communication and Education

The KIWS treatment plant building is equipped with an Education Facility that provides an overview of the KIWS Scheme as well as broader education of recycling of treated wastewater. As part of the agreement between KWPL and HWC, SUEZ undertakes tours of the KIWS treatment plant for HWC for local schools and community groups and may undertake its own tours.

As the supply of water occurs within the industrial sites of the end users, no broader community education is required.

7.2.1 Information on the Impact of Unauthorised Use

Under the Supply Agreements between KWPL and Orica, and KWPL and NCIG, both Orica and NCIG are required to undertake education of their site employees as is required under their work place compliance obligations. Both Orica and NCIG have also developed their own RWQMP's.

As NCIG's recycled water supply is used within the onsite fire fighting system, NCIG has undertaken engagement and consultation with NSW Fire and local fire station to inform them on the introduction of recycled water onsite. Information sessions have been held with NSW Fire representatives as outlined in Section 2.2.5.

7.2.2 Information on Benefits of Recycled Water

As outlined in Section 7.2 KWPL undertakes tours of the KIWS for local schools and community groups on behalf of Hunter Water. This provides broader community education on the benefits of recycled water.

WUA, as the owner of KWPL, owns and operates a number of other recycled water schemes across Australian and as such is an active promoter of recycled water.

8. ELEMENT 9 – Validation, Research, and Development

Validation is the process used to confirm that specific treatment processes operating at KIWS are capable of achieving the claimed LRV (refer Table 2-6).

8.1 Validation of Processes

The design of the KIWS has been validated at a desktop level to ensure that the target recycled water quality criteria will be met.

In addition, since the completion of the validation report a number of updates have been made to the relevant evidence and the associated alert and critical limits. In addition, as part of the 2022 update, review of the treatment process and recycled water quality was undertaken to support the additional LRV claim and additional QCP, CCP monitoring and limits. This was captured within an update to the aforementioned validation report (provided as Appendix A).

8.1.1 Revalidation Requirements

KWPL is committed to the re-validation of its processes and procedures in the event that conditions within the recycled water system change. This may include the following scenarios:

- Significant changes to influent quality (may be caused by increase in industrial wastewater generators in the catchment).
- Changes to the treatment process.
- Changes to the end product target quality, resulting in a change in process unit performance requirements.
- Changes in legislation, regulations or guidelines governing the reuse of municipal wastewater.

Revalidation will also initiate the requirement for review of this RWQMP document and possibly re-auditing under WICA if the change is significant.

8.1.2 Design of Equipment

If future upgrades require the inclusion of new technologies, KWPL and SUEZ will undertake validation of the new equipment and infrastructure to ensure continuing reliability. KWPL and SUEZ's validation program will allow for the development of design specifications that will ensure future equipment and upgrades will be capable of meeting intended treatment requirements as well as providing necessary process flexibility and control.

8.1.3 Investigation

SUEZ has a global role in the water sector and undertakes its own research and investigations as well as taking part in joint partnerships and collaborations.

WUA operates a number of recycled water schemes across Australia and as such remains abreast of the latest information relating to recycled water schemes. WUA also engages with technical forums and has a site of technical advisors (ie. Hunter H2O, ARUP, SMEC, etc.) that are actively involved in the recycled water sector.

9. ELEMENT 10 – Documentation and Reporting

9.1 Management of Documentation and Records

9.1.1 Storage and Management

Documentation pertinent to the management of recycled water quality is stored within SUEZ's main database (server) and is referenced and accessed via the Integrated Management System (IMS). SUEZ uses the Integrum document and records management system for control of its documents and records. Integrum houses and provides links to documents and records and explicitly captures information such as version history, approval, responsibility and update. Relevant documents, such as policies, management plans and procedures, are available at all SUEZ facilities via Integrum. An overview of how SUEZ manages its documents and records is given under the procedures Documents and Data Control (F&A-001) and Record and Archives (F&A-002).

SUEZ has developed a KIWS HSE Management Plan Kooragang Industrial Water Scheme (KIWS) Health, Safety & Environment document that provides the overarching summary of how the quality system, documents and records relating to health, safety and environment are managed for the site.

SUEZ has an Integrated Management System (IMS) that is accredited to ISO9001, ISO14001, ISO18001 and AS4801. KIWS is covered within those systems.

Older versions of documents are retained for the records, such as older MS Word format HACCP plans and previous Recycled Water Quality Management Plan drafts.

WUA has an Integrated Management System (IMS) that is accredited to ISO9001, ISO45001, and ISO14001. KWPL/KIWS is covered within those systems

9.1.2 Review

Documents referenced within the Integrum system can be scheduled for periodic review. The next review date is captured within Integrum, which in turn issues email notifications as reminders to the party responsible for the document and its review. The frequencies of review are scheduled in accordance with risk.

For KIWS, documentation relating to recycled water systems, including asset management systems, will be regularly reviewed and revised to ensure that they reflect changing circumstances.

9.2 Reporting

9.2.1 Internal Reporting

SUEZ prepares monthly internal reports for KWPL covering compliance with the WICA Network Operator's Licence, customer agreements, performance evaluation and any operational anomalies or issues that occur during that period.

More detailed quarterly reports are prepared by SUEZ which are reviewed by the PCG established between KWPL and SUEZ to manage the on-going operations of the scheme.

Additional reports are produced by SUEZ covering the following aspects:

- Asset Management plans (annually with a 5-year rolling forecast),
- RO and MF membrane performance reports,
- Annual budgets and KPI performance reports,

9.2.2 External Reporting

SUEZ as the agent of WUA/KWPL reports to IPART on an annual basis as required under the IPART Reporting Manual. This reporting will transition to KWPL upon transfer of the license to KWPL.

10. ELEMENT 11: Evaluation and Audit

10.1 Long-Term evaluation of results

In accordance with the IPART Reporting Manual, the Annual Compliance Report covering the previous financial year (i.e., ending 30 June each year) will be submitted to IPART before 31 August each year. The Report provides a summary of the results achieved during the previous year. This helps to illustrate.

- Performance against numerical guideline values for verification monitoring results, regulatory requirements or agreed levels of service.
- Emerging issues and trends.
- Priorities for improving process performance and recycled water quality management.

10.2 Audit of Recycled Water Quality Management

Internal and external audits take place as part of SUEZ's internal audit program in accordance with procedure Auditing SYS-005. This auditing is essential for ensuring that SUEZ and recycled water users meet their obligations.

The audits cover compliance with the ISO 9001, ISO 4801, ISO 14001 and ISO 18001 management systems that cover quality, environment and safety. Annual external audits of SUEZ take place although any one site, such as KIWS, might not be picked every year, depending on the schedule. The first external certification audit of the KIWS site is anticipated before end 2018.

The periodic auditing schedule includes internal auditing against this document. In addition, this Licence Plan document is subject to external audits by IPART WICA auditors.

ISO system and Licence Plan IPART audit reports are issued to the CEO of the SUEZ Water and Treatment Solutions business. Results of the ISO audits are displayed at SUEZ offices via its audit certificates.

KWPL also undertakes audits of its management of the scheme in accordance with the requirements of KWPL's certification to ISO9001, ISO45001, and ISO14001, Upon transfer of the IPART License to KWPL auditing of the scheme will be managed by KWPL and both internal and regulatory audit results are reported internally by KWPL via their Risk and Compliance Committee which is a committee of the WUA Board. Audit results are subsequently presented to the WUA Board and corrective actions are tracked to ensure actions are implemented in accordance with management recommendations.

The results of IPART's Licence Plan audits are available on their website (www.ipart.nsw.gov.au).

11. ELEMENT 12: Review and Continuous Improvement

11.1 Review by Senior Managers

Continuous improvement and review are currently facilitated through review of performance and audit reports as well as routine meetings between KWPL, SUEZ, Hunter Water and Orica and NCIG to discuss the scheme operation.

Senior management review is provided by the Operations Support Manager for SUEZ Water Australia & New Zealand who attends the meetings with Orica, NCIG and Hunter Water and reviews and ensures delivery of performance and audit reports.

SUEZ and KWPL meet quarterly via a Project Control Group to review the performance of the scheme. Audit actions and opportunities for improvement are reported and tracked to ensure actions are completed in accordance with the recommendations.

KWPL reports on the performance of all business units bi-monthly at the WUA Board Meetings which includes the performance of the KIWS Scheme. Internal and regulatory audit reports are reviewed by the WUA Risk and Compliance Committee which is a committee of the WUA Board. Audit results are subsequently presented to the WUA Board and corrective actions are tracked to ensure actions are implemented in accordance with management recommendations.

11.2 Recycled Water Quality Management Improvement Plan

The RWQMP is subject to periodic improvement and update. It is intended that the RWQMP will be updated in response to findings from periodic reviews of performance and in response to changes in circumstances that require improvements to the scheme.

The most recent source of improvement recommendations was the 2022 HACCP Workshop which was held 7 December 2021 and which is attached as part of Appendix C. A number of recommended improvement actions were identified from that review.

Beyond that, continuous improvement and review in relation to water quality and infrastructure operation is currently facilitated through review of performance and audit reports as well as annual meetings between KWPL, SUEZ, Hunter Water and Orica and NCIG to discuss the scheme operation.

12. References

Keegan, A., Wati, S., Robinson, B. (2012) Chloramine disinfection of human pathogenic viruses in recycled water (#62M-2114). Prepared by the Australian Water Quality Centre for the Smart Water Fund, Victoria.

APPENDIX A: Kooragang Industrial Water Scheme Validation Report (Updated 2022)

Kooragang Industrial Water Scheme
Validation Report

Title: Kooragang Industrial Water Scheme - Validation Report

Authors: (A/0/1) S. Williamson; Hunter Treatment Alliance (HTA)

Authors: (2/3) Matthew Bloomfield; Hunter H2O

Current Revision: 3

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DOCUMENT REVISION HISTORY

Rev.	Description	Author/ Company	Reviewed By	Date of Review	Approved By	Date of Approval
A	Draft	S. Williamson (Hunter Treatment Alliance)	Z. Matheson	5/12/12		
0	Draft for Review by NSW Health	S. Williamson (Hunter Treatment Alliance)	Z. Matheson, D. Bartley, M. Bloomfield, K. Moore	29/01/2013		
1	Updated to reflect new disinfection Ct values.	S. Williamson (Hunter Treatment Alliance)	Z. Matheson	22/1/14	Z. Matheson	29/01/14
2	Updated to reflect additional Log Credits	M. Bloomfield (Hunter H2O)	C. Laydon	06/12/2021		
3	Incorporating feedback from NSW Health	M. Bloomfield (Hunter H2O)	C. Laydon	04/04/2022		

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Executive Summary

The validation report has been updated (Revision 3) to reflect the addition to the scheme of an end use that has a greater exposure to the Recycled Water (fire fighting) than the original scheme. This use has been determined to require pathogen reduction in excess of the level nominated in the original scheme desktop validation.

The previous version (Version 1) was authored under the Hunter Treatment Alliance (HTA). This revision (Version 3) has been updated by Hunter H2O (See Document Revision History Table. The updated Sections are in the majority Sections 1, 3, 5.2.1, 5.4.1 and 7.

The Kooragang Industrial Water Scheme (KIWS) takes secondary treated effluent from Shortland WWTW and applpies additional treatment barriers to produce a treated water that is safe to use as industrial water.

The *Australian Guidelines for Water Recycling (AGWR): Managing Health and Environmental Risks* (EPHC, NRMMC & NHMRC; 2006) outline a risk management approach for the use of recycled water in Australia. The guidelines incorporate a generic framework that can be applied to any system that is recycling water. The framework contains 12 elements that all need to be considered for the risk management approach to be successful. These guidelines have been employed to define the required microbiological quality of the product water through an exposure assessment. Element 5 of the guidelines, 'Validation', is the process whereby the pathogen reduction capability of the process units that function together to provide pathogen removal is confirmed.

This validation report confirms that the design of the KIWS has been ***validated*** at a desktop level to ensure that the target recycled water quality criteria will be met. The technologies proposed have been extensively employed and tested on many Australian and International recycled water applications.

As stated in the AGWR, in determining that the scheme "will perform" published scientific evidence has been applied to demonstrate that technologies selected, and their control, for the recycled water treatment process will achieve the adopted pathogen log reduction targets.

The validated Log Reduction Value and the Log Reduction Value (LRV) required for the water to be 'fit for purpose' are summarised in Table 1.

Table 1: Log Reduction Claim Summary

Process Unit	Claimed LRV		
	Bacteria	Protozoa	Virus
Conventional Primary and Secondary effluent treatment	0.5	0.5	0.5
Microfiltration	4	4	0.5
Reverse Osmosis	1.5	1.5	1.5
Chlorination	4	0	4
Total	**10**	**6**	**6.5**
KIWS Target	**5.3**	**5.1**	**6.5**

Following commissioning of the treatment process an assessment of the overall performance of the treatment system and the quality of the recycled water being supplied to the end user, ***verification***, was undertaken. Initial verification monitoring demonstrated that the plant "was performing" as intended and ongoing verification monitoring (reference RWQMP) has continued to demonstrate the ability of the plant to produce water that is fit for purpose.

For complete clarity it is recommended that this report is read in conjunction with the KIWS HACCP Plan and the KIWS Verification Plan.

1.0 INTRODUCTION

1.1 BACKGROUND

Recycled water has the potential to contain significant concentrations of pathogenic microorganisms. For this reason, it is essential that recycled water is treated to minimise the microbial hazards to safe levels determined through the process of a risk assessment based upon the end use of the recycled water. The *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks* (EPHC, NRMMC & NHMRC; 2006) outlines a risk management approach for the use of recycled water in Australia. The guidelines incorporate a generic framework that can be applied to any system that is recycling water. The framework contains 12 elements that all need to be considered for the risk management approach to be successful. Element 9, validation, is the process whereby the pathogen reduction capability of the process units that function to provide pathogen removal is confirmed, in this case, using a desktop study. This document contains the desktop validation of the Kooragang Industrial Water Scheme (KIWS).

1.2 SCOPE OF THIS DOCUMENT

The purpose of this document is to summarise the process validation of KIWS. The focus of this document is on health risks as the water is not intended for any specific land application to trigger the assessment of environmental risks from short or long term land application.

The design of the KIWS has been **validated** at a desktop level to ensure that the target recycled water quality criteria will be met. The technologies proposed have been extensively employed and tested on many Australian and International recycled water applications.

As per the AGWR, to determine whether the scheme “will perform”, published scientific evidence has been applied to demonstrate that technologies selected for the recycled water treatment process will be able to achieve the adopted pathogen log reduction targets.

1.3 DESCRIPTION OF THE SCHEME

KIWS treats secondary effluent from Shortland Wastewater Treatment Works (WWTW), which comprises the following treatment processes:

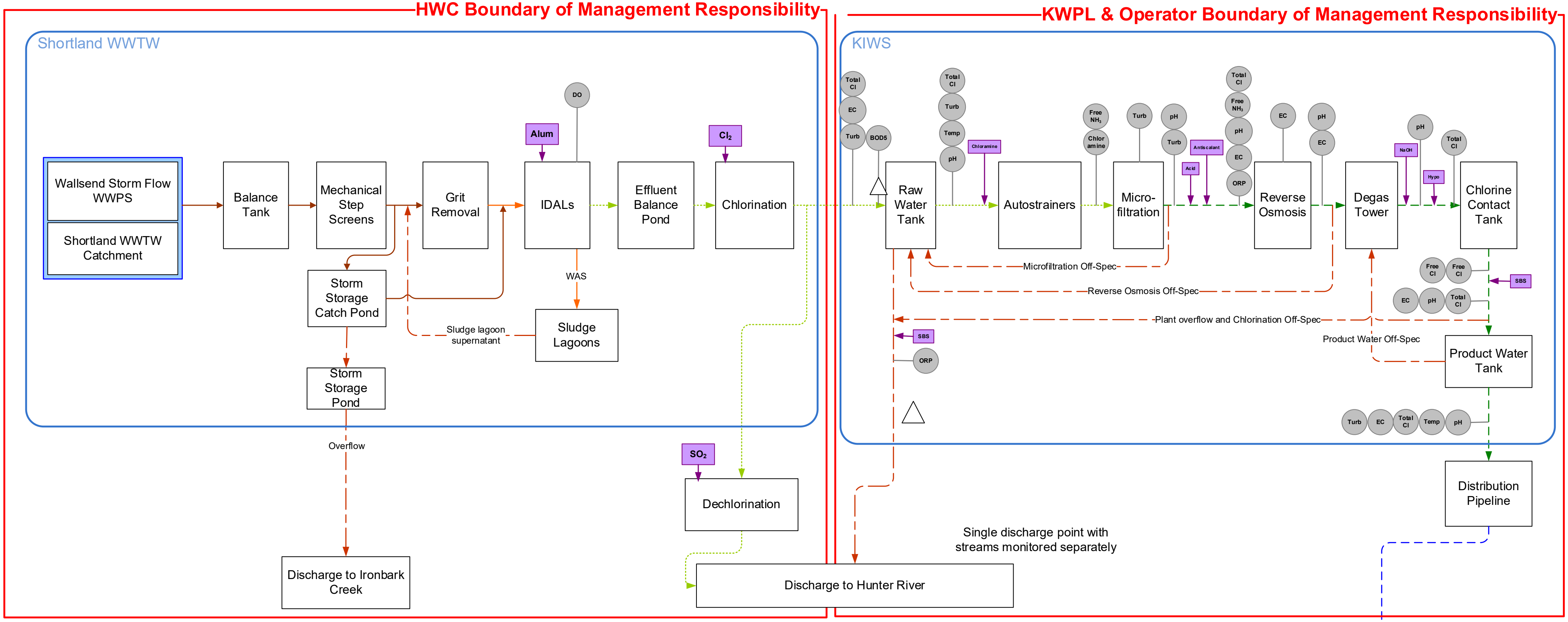
- Screens and grit removal
- Activated sludge process (IDAL)
- Chlorination

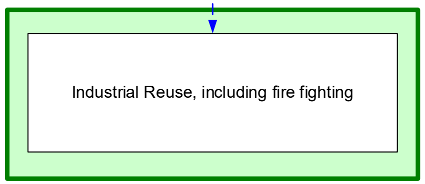
The KIWS plant consists of the following:

- Chloramination
- Strainers,
- Microfiltration (MF),
- Reverse osmosis (RO),
    - 4 x two stage, single pass primary RO units
    - 1 x single stage brine recovery unit returning water to the primary RO feed tank creating a partial ‘2 pass’ system.
- Degas tower
- Chlorination
- Dechlorination.

The flow is collected in a product water tank before it is pumped into a ~8km distribution system with multiple end users.

A simple process Flow Diagram of the Advanced Water Treatment Plant (AWTP) that forms the scheme is included as Figure 1.





Intended End Uses

Abbreviation	Description
DO	Dissolved Oxygen
ORP	Oxygen Reduction Potential
EC	Electrical Conductivity
Turb	Turbidity
Temp	Temperature
IDAL	Intermittent Decanted aeration Lagoon

Flow Stream	Line Type
Influent Pre-Grit Removal	
Primary Treated Effluent	
Secondary Treated Effluent	
Tertiary Treated Effluent	
Final Product (Orica)	
Chemical Dosing	
Overflow	

Catchment Source	
Process Unit	
Online Analyser	
Chemical Dosing	
Auto Sampler	

Figure 1 KIWS Process Flow Diagram

1.4 WATER QUALITY TARGETS

The original log reduction targets for the scheme were calculated at an Exposure Workshop held in May 2008 between representatives from Hunter Water Corporation, the end user (ORICA) and water treatment and recycled water professionals.

At the workshop the expected exposure of employees to recycled water whilst undertaking specific tasks was identified and quantified. Using a base impact to an individual of no more than 1 in 1,000,000 Disability affected Life Years (DALY's[1]) a risk based log reduction target for virus, protozoa and bacteria and guidance from *Australian Guidelines for Water Recycling, Managing Health and Environmental Risks* (EPHC, NRMMC & NHMRC; 2006). These exposure pathways were adopted for the maximum challenge of the scheme.

From the results of the workshop was determined that the most exposed group at Orica would be the Nitrate Plant operators and using this highest calculated exposure, the minimum pathogen log reductions from raw effluent, to a 'fit for purpose' final product for this group were calculated (refer Table 2).

Table 2 Target Log Reduction Values for KIWS specific to ORICA end use

Pathogen	Target LRV
Virus	5.1
Protozoa	3.6
Bacteria	3.8

To allow for additional end uses the exposure risk for firefighting has been added to the exposure pathways. Table 3.7 of the AGWR (EPHC, NRMMC & NHMRC; 2006) provides guidance on the Log reductions for priority uses of recycled water, including fire fighting, which is provided in Table 3.

Table 3 Target Log Reduction Values for fire fighting as an end use (AGWR)

Pathogen	Target LRV
Virus	6.5
Protozoa	5.1
Bacteria	5.3

With respect to non-microbial water quality, treated water targets for the scheme are driven by those for Orica, and are summarised in Table 4. These targets have been used as a basis to identify process risks with the proposed scheme. The target water quality is to be achieved at the outlet of the product water pumps.

Table 4: Summary of the Water Quality Targets

ID #	Assessable Parameter	Units	50%ile	90%ile	Max
1	TDS	mg/L		<50	
2	Chloride	mg/L		<15	
3	Calcium	mg/L		<5	
4	pH	mg/L		5.5 - 7.5	

[1] For more information on the calculation of target LRV's based on DALY's and specific exposure to recycled water refer to the AGWR – 2006. Section 3, Box 3.1 and table 3.7.

ID #	Assessable Parameter	Units	50%ile	90%ile	Max
5	Total Hardness	mg/L $CaCO_3$		<10	30
6	Alkalinity	mg/L $CaCO_3$		<20	
7	Total Silica (SiO2)	mg/L		<2	
8	Iron	mg/L		<0.015	
9	Copper	mg/L		<0.05	0.1
10	Total N	mg/L N	<1.8	<2.5	
11	Ammonia (free)	mg/L N		<0.5	
12	Faecal Coliforms	cfu/100mL		Not Detectable	
13	Somatic Coliphage	-		Not Detectable	
14	Cryptosporidium	oocysts/50 L		Not Detectable	
15	TOC	mg/L C		<1	
16	Total Phosphorus	mg/L P		<0.05	
17	TSS	mg/L		<2	
18	Chloramine	mg/L		<0.5	1
19	Aluminium	mg/L		<0.1	
20	Temperature	°C		<27	27
21	Potassium	mg/L		<3	
22	Zinc	mg/L		<0.2	
23	Fluoride	mg/L		<0.1	
24	Sulphate	mg/L		<5	
25	Carbon dioxide	mg/L		<5	
26	Sodium	mg/L		<15	
27	Hexavalent Chromium	mg/L		<0.002	
28	Arsenic	mg/L		<0.002	

2.0 METHODOLOGY

To demonstrate pathogen removal of a treatment process or combination of processes, the actual removal efficiency is calculated by measuring the influent and effluent concentrations of a particular assessable pollutant. However, with recycled water the numbers of indigenous pathogens present in the raw source water (i.e. in this case chlorinated secondary treated effluent otherwise destined for the environment) are too low to be able to demonstrate the high level of pathogen removals adopted for this project. Therefore, for this project, the best approach is to provide validation using a desktop review combined with verification sampling during the initial stages of the scheme.

There are several other reasons why a desktop validation is adequate for the KIWS including the following:

- A multi-barrier process train, utilising proven technology has been adopted for the KIWS
- The microfiltration system has been pre-validated and has been conditionally accepted by the California Department of Health Services (under Title 22) as an alternative filtration technology for the treatment of surface water
- The selected processes are commonly used for industrial reuse applications in Australia
- There is significant published data to support the individual process units and overall performance of the treatment train.

This desktop validation leverages the extensive testing that has already been undertaken on membrane and disinfection systems by suppliers and other water utilities. The US, in particular California, has been at the forefront of formal validation of water recycling processes for the past decade.

Desktop validation has been performed only for those treatment process units that were identified as critical control points (CCPs) for pathogens, bacteria and virus as part of the hazard analysis and critical control point (HACCP) planning process including the following:

- Microfiltration
- Reverse osmosis
- Chlorination.

The following components of each treatment process have been considered during this desktop validation:

- Design information
- Log removals claimed
- Relevant, recognised guidelines and standards
- Monitoring methods
- Control, critical limits and actions
- On-going verification monitoring

3.0 SHORTLAND WWTW

3.1 INTRODUCTION AND PROCESS OVERVIEW

Shortland WWTW is an Intermittently Decanted Extended Aeration Lagoon (IDAL) activated sludge plant which was commissioned in 1998. The existing plant comprises:

- An inlet works with mechanical screening and grit removal facilities
- Facilities for aluminium sulphate dosing
- Two intermittently decanted extended aeration (IDEA) reactors
- An effluent balance pond
- A wet weather bypass flow storage and return system
- A chlorination system
- An effluent pumping system to transfer flows to the Hunter River
- A de-chlorination system
- Aerobic digestion system comprising:
    - Aerobic digestion lagoon 1 (ADL1)
    - Aerobic digestion lagoon 2 (ADL2)
    - Floating surface aerators
    - Digested waste activated sludge (DWAS) pumping station
- Sludge thickening and dewatering system comprising:
    - Two gravity drainage decks (GDD)
    - Two belt filter presses (BFP)
    - One polymer dosing system
    - Foul water pumping station
    - Sludge off-loading system

The effluent pumping station transfers chlorinated effluent via an approximately 11 kilometres long pipeline to the Hunter River. The effluent is supplied to the KIWS or de-chlorinated by sulphur-di-oxide dosing prior to discharging to the river.

3.2 DESKTOP VALIDATION ASSESSMENT

The Shortland WWTW is an activated sludge process which is a standard well-established treatment process. The *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks* (EPHC, NRMMC & NHMRC; 2006) provides indicative log removals of enteric pathogens and indicator organisms for numerous processes, including Primary and Secondary treatment, which Shortland WWTW has.

In considering Table 3.4 of the AGWR (Figure 2) the Shortland WWTW has the following range of log reductions, which are the starting point for the Desktop Validation.

Table 5 Shortland WWTW Indicative Log Reductions

Pathogen	AGWR Indicative LRV
Virus (including adenoviruses, rotaviruses and enteroviruses)	0.5 – 2.0
Protozoa (*Giardia and cryptosporidium*)	0.5 – 1.5
Bacteria (*Escherichia coli* and Bacterial Pathogens)	1.0 – 3.0

Table 3.4 Indicative log removals of enteric pathogens and indicator organisms

Treatment	Indicative log reductions[a]							
	Escherichia coli	Bacterial pathogens (including *Campylobacter*)	Viruses (including adenoviruses, rotaviruses and enteroviruses)	Phage	*Giardia*	*Cryptosporidium*	*Clostridium perfringens*	Helminths
Primary treatment	0–0.5	0–0.5	0–0.1	N/A	0.5–1.0	0–0.5	0–0.5	0–2.0
Secondary treatment	1.0–3.0	1.0–3.0	0.5–2.0	0.5–2.5	0.5–1.5	0.5–1.0	0.5–1.0	0–2.0
Dual media filtration with coagulation	0–1.0	0–1.0	0.5–3.0	1.0–4.0	1.0–3.0	1.5–2.5	0–1.0	2.0–3.0
Membrane filtration	3.5–>6.0	3.5–>6.0	2.5–>6.0	3–>6.0	>6.0	>6.0	>6.0	>6.0
Reverse osmosis	>6.0	>6.0	>6.0	>6.0	>6.0	>6.0	>6.0	>6.0
Lagoon storage	1.0–5.0	1.0–5.0	1.0–4.0	1.0–4.0	3.0–4.0	1.0–3.5	N/A	1.5–>3.0
Chlorination	2.0–6.0	2.0–6.0	1.0–3.0	0–2.5	0.5–1.5	0–0.5	1.0–2.0	0–1.0
Ozonation	2.0–6.0	2.0–6.0	3.0–6.0	2.0–6.0	N/A	N/A	0–0.5	N/A
UV light	2.0–>4.0	2.0–>4.0	>1.0 adenovirus >3.0 enterovirus, hepatitis A	3.0–6.0	>3.0	>3.0	N/A	N/A
Wetlands — surface flow	1.5–2.5	1.0	N/A	1.5–2.0	0.5–1.5	0.5–1.0	1.5	0–2.0
Wetlands — subsurface flow	0.5–3.0	1.0–3.0	N/A	1.5–2.0	1.5–2.0	0.5–1.0	1.0–3.0	N/A

N/A = not available; UV = ultraviolet

a Reductions depend on specific features of the process, including detention times, pore size, filter depths, disinfectant

Sources: WHO (1989), Rose et al (1996, 2001), NRC (1998), Bitton (1999), USEPA (1999, 2003, 2004), Mara and Horan (2003).

Figure 2. Table 3.4 of the AGWR

Water Quality Research Australia (WQRA) produced a report in 2012 titled "Quantification of pathogen removal in Australian Activated sludge plants (Phase 1 and 2)". (Water Quality Research Australia, March 2012).

The project undertook a data review including 12 Australian wastewater treatment plants and reported that there was not a lot of data available and the standard deviations were high for some data sets. From the data the report concludes that the indicators and pathogens gave LRVs of 2.8 $\log_{10}$ for bacteria, 1 to 1.5 $\log_{10}$ for protozoa and 1.5 to 2.9 $\log_{10}$ for viruses.

Key findings of the report included (direct extracts from the report)

- *Dramatic changes in operation, such as loss of aeration (leading to anaerobic conditions), significant reductions in MLSS concentrations (i.e. < 1000 mg/L) or significant reductions in hydraulic retention times would be needed to meaningfully impact pathogen reduction performance"*
- *Solids removal (with adsorbed pathogens) is the key pathogen reduction step for activated sludge treatment.*
- *The literature overwhelmingly suggests that activated sludge plants (ASPs) readily achieve 1- 2 $\log_{10}$ removal of bacteria and viruses.*
- *Cryptosporidium may have lower rates of removal of around 0.5 to 1.0 log10; however, it is not possible to provide a definitive ratio between the two parasites. The Cryptosporidium removals*

range was similar to the Giardia removals, although approximately 50% lower. The data suggests that activated sludge treatment should be able to achieve 0.5 to 1.5 log_{10} removal of Cryptosporidium.

The literature review undertaken as part of the report was presented in Table 2-1 of the report and is reproduced below as Figure 3 to support the AGWR indicative values.

Table 2-1. Summary of log_{10} reduction values for bacterial, viral, parasitic and indicator pathogens collated from the literature

	Log_{10} reduction (converted from % removal)				Log_{10} reduction			
Pathogen /Indicator	**No. of papers**	**Mean**	**Median**	**SD**	**No. of papers**	**Mean**	**Median**	**SD**
Coliphage	Rose, 2001 Omura, 1989	1.77	1.77	0.01	Rose, 1996 Rose, 2004	1.2	1.2	0.7
Enterovirus	Rose, 2001	1.66	-	-	Rose, 1996 Rose, 2004 Ottoson, 2006	2.5	1.9	1.3
F-RNA phage	-	-	-	-	Zhang, 2007 Ottoson, 2006 Lucena, 2004 Rose, 2004	2.3	2.1	0.7
Somatic coliphage	-	-	-	-	Rose, 2004 Zhang, 2007 Ottoson, 2006 Lucena, 2004	1.9	1.6	0.8
Total enteric virus	Yanko, 1993 Aulicino, 1996 Rolland, 1983	1.00	0.94	0.03	Sedmak, 2005	2.4	2.4	0.5
E. coli		-	-	-	Ottoson, 2006	2.44	-	-
Faecal coliforms	Rose, 2001 Omura, 1989 Aulicino, 1996 Rolland, 1983	1.35	1.46	0.01	Rose, 1996 Rose, 2001 Zhang, 2007 Lucena, 2004	1.9	2	0.2
Entercocci	Omura, 1989	1.52	-	-	Rose, 2004 Ottoson, 2006 Lucena, 2004	2.2	2.2	0.7
C. perfringens	-	-	-	-	Rose, 2004 Ottoson, 2006 Lucena, 2004	1.7	1.7	0.6
Giardia	Rose, 1996, Robertson, 2000 Casson, 1990 Chauret, 1995 Neto, 2006 Caccio, 2003 Reinoso, 2008	0.87	1.05	0.06	Rose, 2001 Rose, 2004 Chauret, 1999 Mayer, 1996 Ottoson, 2006	2	2	0.8
Cryptosporidium	Rose, 1996 Robertson, 2000, Chauret, 1995 Neto, 2006 Reinoso, 2008	0.73	1.59	0.14	Rose, 2001 Rose, 2004 Chauret, 1999 Mayer, 1996 Ottoson, 2006 Montemayor,2005	1.7	1.5	0.6

Figure 3. Table 2-1 of Quantification of pathogen removal in Australian Activated sludge plants (Phase 1 and 2)

The report, *Pathogen Reduction and Survival in Complete Treatment Works*[2] reviewed numerous studies and included reference to *Concentration of norovirus during wastewater treatment and its impact on*

[2] Oakley, S. and Mihelcic, J.R. (2019). Pathogen Reduction and Survival in Complete Treatment Works. In: J.B. Rose and B. Jiménez-Cisneros (eds), Water and Sanitation for the 21st Century: Health and Microbiological Aspects of Excreta and Wastewater

oyster contamination (Flannery, 2012) and *Quantitative detection of human adenoviruses in wastewater and combined sewer overflows influencing a Michigan river* (Fong, 2010) that looked at complete treatment works, without a disinfection step. The following excerpts are taken from the report.

"Fong et al. (2010) monitored adenovirus reduction for one year in an activated sludge plant discharging to a Michigan (U.S.) river and sampled secondary effluent before disinfection with chlorine."

"An excellent example of an activated sludge plant discharging to the ocean without disinfection and the consequent effects of pathogens is presented by Flannery et al. (2012). The treatment plant served a population equivalent of 91,600, with a daily flow rate of 45,000 m3 /d, and discharged to the ocean through a 400-m outfall at a depth of 10 m."

Using average data the Bacteria Log_{10} reduction was 1.49 and the Virus Log_{10} reduction of 0.8 to 1.77 for these studies.

Another relevant study referenced is that of Rose et al. (2004) which reported on a detailed study of six activated sludge treatment plants in the U.S. by monitoring reduction of indicator bacteria and viruses, enteric viruses, and two protozoan pathogens, Cryptosporidium and Giardia, in individual unit processes. For secondary effluents the Log_{10} reductions found by Rose et al were

- Faecal coliforms log_{10} reduction of 1.62 to 3.11
- Enterovirus log_{10} reduction of 1.85 to 2.44
- Giardia log_{10} reduction of 1.23 to 2.67
- Cryptosporidium log_{10} reduction of 1.11 to 1.92

3.3 LOG REDUCTION CLAIM

From the papers reviewed, the range of log_{10} pathogen reduction values indicated in the AGWR for "secondary treatment" are well supported. In fact, there appears to be a reasonable body of evidence to support a claimed log reduction for Shortland WWTW of at least 1.0 for all pathogens, with virus possibly being consistently higher at 1.5 log_{10}, or more.

However, to maintain a high degree of conservatism the maximum pathogen LRV that is to be attributed to the Shortland WWTW process has been selected as the lowest end of the indicative values published in the AGWR Table 3.4 (Figure 2). This is considered conservative as

1. The chlorine disinfection step at Shortland WWTW has not been included in the assessment and would have a positive impact on the reduction of Bacteria and Virus.
2. Published data presented supports an increased claim for all pathogens, with virus reduction being consistently reported above 1 log_{10}.

Table 13 summarises the claimed log reduction for the Shortland WWTW for bacteria, protozoa and viruses.

Table 6 Shortland WWTW Log Reduction Claim

Bacteria	Protozoa	Virus
Log_{10} Removal Claim		
0.5	0.5	0.5

Management (Global Water Pathogen Project). (J.R. Mihelcic and M.E. Verbyla (eds), Part 4: Management Of Risk from Excreta and Wastewater - Section: Sanitation System Technologies, Pathogen Reduction in Sewered System Technologies), Michigan State University, E. Lansing, MI UNESCO. https://doi.org/10.14321/waterpathogens.49 Acknowledgements: K.R.L. Young, Project Design editor; Website Design: Agroknow (http://www.agroknow.com) Last published: August 1, 2019

3.4 CRITICAL AND TARGET LIMITS

For the purpose of ensuring that the claimed log reductions are achieved and the Shortland WWTW is operating effectively as a primary and secondary treatment process, turbidity of the effluent will be utilised as a pathogen surrogate.

The target limit represents the value, which if exceeded, indicates the process should be monitored to ensure the turbidity does not increase further. If the critical limit is exceeded corrective action, as per the HACCP plan, will be initiated to bring the system back under control.

Whilst the key findings of "Quantification of pathogen removal in Australian Activated sludge plants (Phase 1 and 2)". (Water Quality Research Australia, March 2012) state that

- *Dramatic changes in operation, such as loss of aeration (leading to anaerobic conditions), significant reductions in MLSS concentrations (i.e. < 1000 mg/L) or significant reductions in hydraulic retention times would be needed to meaningfully impact pathogen reduction performance"*

As no specific correlation between effluent turbidity and pathogen removal performance is able to be found in literature a conservative approach has been taken to set a Target and Critical limit. The value is based on the effluent turbidity typically produced from the Shortland WWTW operation. That is the turbidity of effluent when Shortland WWTW is operating within its design.

Further, to maintain control over the process at the KIWS site, to improve the reliability of the control point, it is recommended to measure the turbidity on the feed to the microfiltration units, on the outlet of the 'raw water' balance tank (MF feed tank). As such, some level of buffering and settlement, which will improve the Shortland effluent turbidity, was considered in setting the Critical limit provided in Table 7.

Table 7: Critical and Target Limits

Parameter	Unit	Target Limit	Critical Limit
KIWS Feed (Continuous online turbidity)	NTU	< 15	> 10 for more than 60 consecutive minutes

4.0 MICROFILTRAION

4.1 INTRODUCTION

The process of microfiltration (MF) is characterised by its ability to remove suspended or colloidal particles via a sieving mechanism based on the size of the membrane pores relative to that of the particulate matter. MF is also often utilised for the removal of the larger types of pathogens: protozoa, most species of bacteria and some viruses.

4.2 PROCESS OVERVIEW

The MF plant is a Pall Microza MF system with a nominal pore size in the range of 0.1 µm. It will consist of three trains that will be fed from the raw water tank with larger solids removed by autostrainers (refer Figure 3). Water pumped from the raw water tank by the MF Feed pumps is analysed by the following instruments:

- Temperature (TIT 2043)
- pH (AIT 2042)
- Turbidity (AIT 2045)
- Total Chlorine (AIT 2047)

Sodium hypochlorite (hypo) and ammonia are diluted with process water and combined in the appropriate ratio to form monochloramine. The concentrated monochloramine solution is then dosed upstream of the strainers to assist in preventing biological fouling of the strainers and membranes. The level of monochloramines (AIT 2053) and free ammonia (AIT 2055) are measured downstream of the strainers to confirm their presence. In particular the presence of free ammonia confirms that there is no free chlorine present as the two species cannot exist for any practical time together in solution.

The filtered water, or permeate is monitored continuously for turbidity is measured on all three MF trains (AIT 2202, AIT 2302, AIT 2402). The permeate from all three trains is combined in a common permeate line and the turbidity of this combined stream is measured (AIT 2115). The combined permeate pH is also measured (AIT 2113) prior to the flow entering the RO feed tank to check for gross contamination following membrane chemical cleaning.

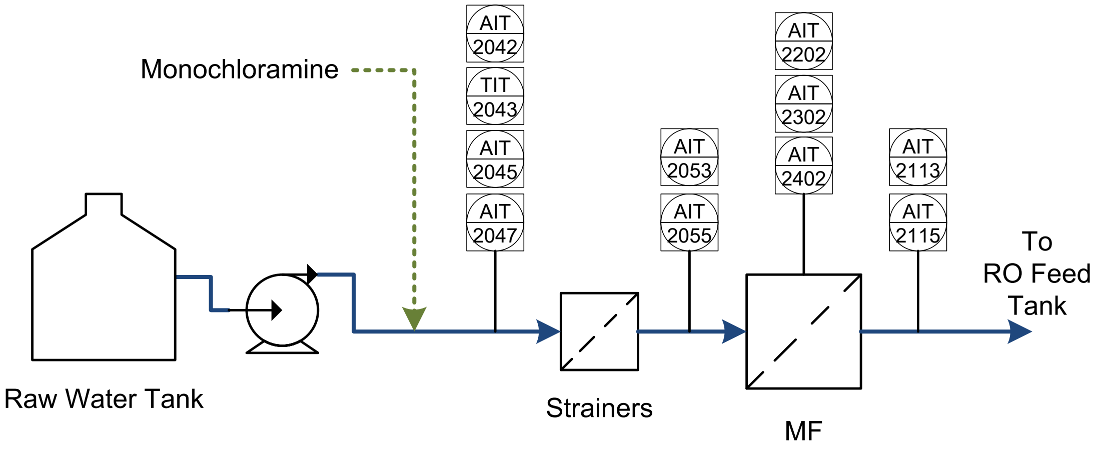


Figure 4 MF Process Flow Diagram

Table 8: MF Design Data

Parameter	Unit	Value	
		Stage 1	Stage 2
Manufacturer	-	Pall	
Element Type	-	Microza UNA-620A	
Element Material	-	PVDF	
Flow Configuration	-	Hollow Fibre (Outside – In)	
Nominal Pore Size	µm	0.1	
Nominal Design Feed Flow	ML/day	13	17
Maximum Feed Flow	L/s	205	273
Minimum Continuous Feed Flow	L/s	49	65
Design Net Filtrate production	ML/day	12	16
MF Recovery	%	95	95
Number of Skids	#	3	3
Number of Modules/skid	#	85	115
Membrane filtration area / module	m^2	50	50
Membrane filtration area / system	m^2	12,750	17,250
Net Filtrate Production per Train	ML/day	4	5
Average Filtrate Flow per Train	L/s	47	62
Peak Instantaneous Filtrate Flow per Train	L/s	81	108
Flux (Net)	L/m^2-hr	45	45
Flux (Instantaneous includes CIP, MIT, Backflush)	L/m^2-hr	68	67
Flux (Max Instantaneous)	L/m^2-hr	75	75
Maximum Transmembrane Pressure (TMP)	kPa	250	250

4.3 DESKTOP VALIDATION ASSESSMENT

The US EPA *Membrane Filtration Guidance Manual* (MFGM) was developed in conjunction with the *Long Term 2 Enhanced Surface Water Treatment Rule* (LT2ESWTR) to elaborate on the rule requirements associated with membrane filtration and to assist utilities with the application of membrane filtration systems for compliance with the rule. In Australia the only existing document providing guidance on validation, the *Guidelines for Validating Treatment Processes for Pathogen Reduction* (Department of Health Victoria, 2010), which states that validation of membrane filtration systems in Victoria are required to be validated using the methodology contained within the MFGM. Based on this, KIWS has utilised the MFGM as background to best practice for the validation of the MF system.

The key statements within the MFGM are that "removal efficiency of a membrane filtration process must be established through a **product-specific challenge test** and **direct integrity testing**" and that during ongoing operation of the facility as part of an integrity verification program "**continuous indirect integrity monitoring**" is required to compliment the direct integrity testing.

To comply with these statements, the validation performed by Pall (Pall, 2008) has been reviewed to ensure that its methodology complies with the MFGM.

4.3.1 CHALLENGE TEST

As part of the product validation performed by Pall, challenge testing was performed (Dwyer, 2004) using 3rd party facilities operated by the University of New Hampshire (UNH). The equation used to calculate LRV is shown below.

$$LRV_{C-test} = \log(C_f) - \log(C_p)$$

Where: $LRV_{C\text{-test}}$ = log removal value demonstrated during challenge testing

C_f = feed concentration measured during challenge testing

C_p = filtrate concentration measured during challenge testing

Based on the challenge results the Pall Microza MF membranes were approved (Sakaji, 2005) as a pre-validated system by the California Department of Health Services (CDHS). The validation certificate issued by the CDHS is provided in Appendix 1. The approved *Cryptosporidium* LRV's are listed in Table 9.

Table 9 Approved *Cryptosporidium* Log Reduction Values

Membrane Type	UNH $LRV_{C\text{-test}}$	CDHS $LRV_{C\text{-test}}$
Pall Microza UNA-620A	5.3	4.0

Note that the operating conditions of flux and TMP, for KIWS are both less than the maximums listed in the CDHS approval.

4.3.2 DIRECT INTEGRITY TESTING

Direct integrity testing (DIT) refers to the ability to apply a test directly to the membrane without the use of surrogates or extrapolation. The test that is used by PALL is referred to as a pressure-decay membrane integrity test (MIT or PDT).

An MIT involves removing the water and pressurising the inside (lumen) of every membrane fibre with air, isolating the lumen side of the membranes, opening the shell side and monitoring the rate of pressure decay of the entire train over a set time period. Due to the structure of the membrane air, at the pressure used, will not pass through an integral fibre and so any loss in air pressure on the lumen side is a result of a leak that may indicate a direct connection between feed and filtered water. A small amount of pressure decay will also be seen from diffusion of the air into the water in the membrane pores. The source of the leak can be from broken or damaged membrane fibres or o-rings, or valves not sealing correctly.

A diffusive airflow test provides a direct measure of the airflow through an integrity breach. According to the MFGM DITs must follow three criteria:

1. Resolution (3 μm hole detection)

2. Sensitivity (LRV verification)
3. Frequency (once/day).

The value recorded in kPa/minute is referred to as the Pressure Decay Rate and can be used with other system characteristics to calculate a theoretical membrane log removal value (LRV) of particles of a given size. The validation conducted by PALL to show the Microza MF system meets these criteria are summarised in the following sections.

4.3.2.1 Resolution

The LT2ESWTR requires that the DIT resolution is a 3 µm breach (consistent with the removal of *Cryptosporidium* particles. For pressure-based integrity testing a 3 µm breach is equivalent to applying a testing pressure higher than the bubble point pressure of that hole, which is defined in the MFGM as follows:

$$P_{test} = \left(0.193 \cdot \kappa \cdot \sigma \cdot \cos\theta\right) + BP_{\max}$$

Where: P_{test} = integrity test pressure (psi)

K = pore shape factor (dimensionless)

σ = air-liquid surface tension (dynes/cm)

θ = liquid-membrane contact angle (°)

BP_{max} = maximum back pressure (psi)

For calculating P_{test}, Pall utilised conservative values of K (1), θ (0°, ie. hydrophilic) and σ (74.9 dynes/cm [0.0749 N/m], 5°C). Giving a result of: P_{test} = 14.5 + BP_{max}. Based on the fact that the Microza module is 2m high with a hydrostatic head of 20.7 kPa (3 psi), the P_{test} for direct integrity testing must be at least 120.7 kPa (17.5 psi).

4.3.2.2 Sensitivity

Sensitivity is defined as the maximum LRV that can be verified by direct integrity testing (LRV_{DIT}). This value is equivalent to the claimable LRV when the $LRV_{C\text{-}test}$ is greater than LRV_{DIT}. Pall calculated the sensitivity of the Microza membranes using the equations relating LRV to pressure decay rate (PDR) contained the MGFM as follows:

$$LRV_{DIT} = \log\left\{\frac{\left(Q \cdot ALCR \cdot P_{atm}\right)}{\left(PDR_{MIN} \cdot V_H \cdot VCF\right)}\right\}$$

Where: Q = plant flow (gpm) – system specific

ALCR = air-liquid conversion ratio

V_H = hold up volume (ft^2) – system specific

VCF = volume concentration factor (dimensionless) – 1.08 based on experimental data (Sethi *et al.*, 2004)

$$ALCR = 170 \cdot Y \cdot \left\{\frac{\left(p_1 - p_2\right)\cdot\left(p_1 + P_{atm}\right)}{\left(T \cdot TMP\right)}\right\}^{0.5}$$

Where: T = design temperature (°K)

p_1 = pressure at inlet of broken fibre (41.7 psi)

p_2 = pressure at outlet of broken fibre (17.8 psi)

TMP = maximum pressure differential during filtration cycle (psi) – system specific

K= flow resistance coefficient = *f*•D/L

Y = net expansion factor = $1-(aK^{-b} \cdot (p_1-p_2)/p_1)$ – see table below

L = length of fibre lumen for bypass (0.06 m)

D = diameter of fibre lumen (0.6 mm)

f = friction factor (0.025)

K	a	b
1.2 – 10	0.7588	0.2905
15 - 100	0.4486	0.0801

To validate the calculated sensitivity, Pall compared the calculated results with a microbial challenge test at a production-scale plant in San Patricio, TX (Sethi *et al.,* 2004). In the test hollow fibres in a single module were cut prior to microbial challenge and integrity testing (pressure hold test) occurring. The calculated and measured LRV_{DIT} comparison is shown in Figure 4. The figure shows that the Microza membranes at the San Patricio plant have a very similar LRV_{DIT} as calculated.

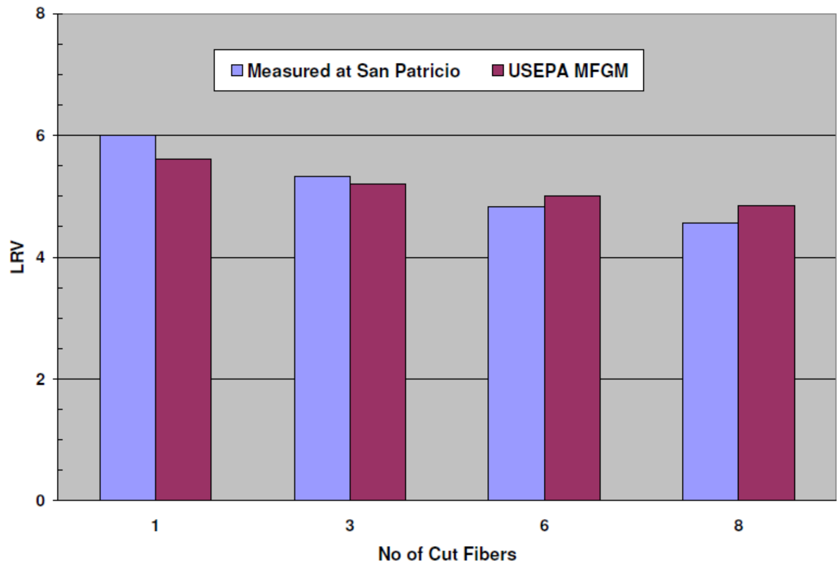


Figure 5 Measured and Calculated LRV_{DIT} for different numbers of cut fibres

The DIT upper control limit (UCL) is a response, that when exceeded, signifies an integrity problem and triggers a set of diagnostic responses. That is, when exceeded, the membrane skid has a lower theoretical LRV than the claimed LRV and must be taken offline for diagnostics.

Pall has defined the UCL for their membranes as being the PDR (psi/min) for a given critical LRV. Figure 5 shows the PDR as measured at the San Patricio plant. Based on these results, Pall recommends a PDR of 1.03 kPa/min (0.15 psi/min,) corresponding to a LRV of 4.

It should be noted that the value of the UCL is dependent on the membrane system flow (Q) and the membrane TMP as follows;

- Q – as the flow increases the UCL value increases. That is, for a given size integrity breach/hole the greater the system flowrate the better the LRV will be.
- TMP – as the TMP increases the UCL value decreases. That is, more water will travel through an integrity breach at a higher TMP, in proportion to the volume of water filtered, and hence the LRV will be worse at a higher TMP.

Therefore utilising the worst case scenario for calculating the UCL would be to use the maximum TMP and the minimum instantaneous flow rate. However there is considered to be sufficient conservatism in the LRV calculations, test conditions and use of 95^{th} percentiles in the establishment of the pathogen load onto the membranes that for verification monitoring purposes a single PDR based on typical flow and TMP parameters can be utilised over the entire range of flows and TMP's for the UCL.

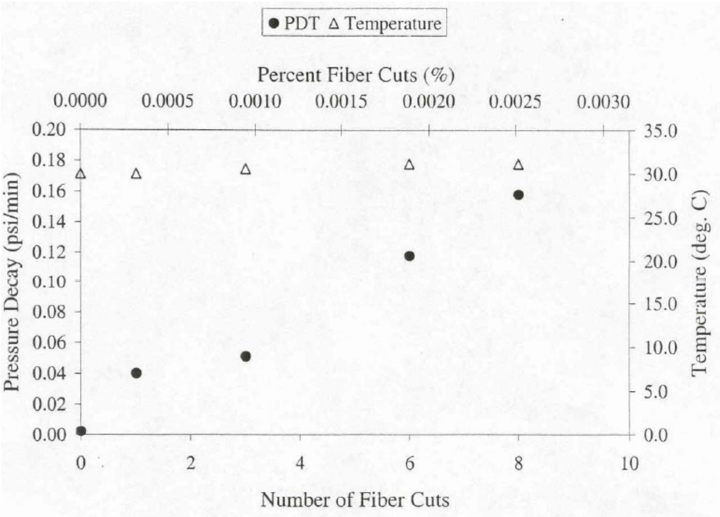


Figure 6 PDR for different numbers of cut fibres measured at San Patricio (Sethi *et al.,* 2004)

4.3.2.3 Frequency

A PDT will be performed at least once per day on each train.

4.3.3 CONTINUOUS INDIRECT INTEGRITY MONITORING

During plant operation continuous indirect integrity monitoring will be used in addition to direct integrity monitoring as verification of membrane performance as a method of detecting gross membrane system failure between PDT's on each of the membrane units. Gross failure is referenced because the failure would need to be large as it has been demonstrated that there is not a direct correlation between turbidity and fibre breaks until a significant number of fibres have been damaged/broken.

4.3.4 VIRUS REMOVAL

The LT2ESWTR does not address the removal of viruses by membrane filtration. In the US state regulating agencies are responsible for developing their own policies based on challenge results.

MS2 phage challenge testing was performed on the Pall Microza MF membranes by UNH and also by the US engineering firm, HDR Engineering. The results from these tests were submitted to the CDHS, which approved a virus log reduction credit in untreated water and direct-coagulated (15 mg/L ferric chloride). The approved virus LRVs are shown in Table 10.

Table 10 Approved Virus Log Reduction Values

Membrane Type	Untreated Water $LRV_{C\text{-}test}$	Coagulated Water $LRV_{C\text{-}test}$
Pall Microza UNA-620A	0.5	2.5

4.3.5 BACTERIA REMOVAL

E. coli challenge testing was also performed by UHN. The resulting LRV for bacteria is shown in Table 11. A LRV of 4 was approved by the CDHS for the system (refer Appendix 1).

Table 11 Approved Bacteria Log Reduction Values

Membrane Type	Filtrate (cfu/100 mL)	$LRV_{C\text{-}test}$
Pall Microza UNA-620A	Below method detection limit	6.94

4.3.6 COMPARISON OF PALL VALIDATION WITH KIWS

As part of validation of the KIWS system the validation performed by Pall has been compared with the KIWS design. Table 12 summarises the differences between the Pall validation and the KIWS MF design to show that the KIWS MF system will operate within the envelope previously validated by Pall and thus will achieve the claimed LRVs.

Table 12 Pall MF validation versus the KIWS MF system

Parameter	Unit	Pall Validation Limits	KIWS MF System
Minimum MIT Pressure	psi	17.5	26.1
	kPa	120.7	180
Maximum Pressure Decay Rate	psi/min	0.15	0.145
	kPa/min	1.03	1.00
Maximum Instantaneous Flux	gfd	120	44
	lmh	204	75
Maximum TMP	psi	43.5	36.3
	kPa	300	250

4.4 LOG REDUCTION CLAIM

The maximum pathogen LRV that is attributed to the membrane filtration process at the KIWS is calculated as the lowest of the paired log_{10} reductions. That is, the most conservative LRV attributed under the tested operating envelope was adopted. Table 13 summarises the claimed log reduction over the membrane process for bacteria, protozoa and viruses based on the validation sampling program.

Table 13 Membrane Log Reduction Claim

Bacteria	Protozoa	Virus
Log_{10} Removal Claim		
4	4	0.5

4.5 CRITICAL AND TARGET LIMITS

For the purpose of ensuring that the claimed log reductions are achieved and the MF barrier is in-tact, with the information currently available the following critical and target limits have been set. Below the critical limit (refer If the critical limit is exceeded corrective action, as per the HACCP plan, will be initiated to bring the system back under control.

Table 14) the claimed log reductions will be achieved. The target limit represents the value, if exceeded, indicates the process should be monitored to ensure the turbidity does not increase further. If the critical limit is exceeded corrective action, as per the HACCP plan, will be initiated to bring the system back under control.

Table 14: Critical and Target Limits

Parameter	Unit	Target Limit	Critical Limit
Maximum Pressure Decay Rate (Test start pressure >120kPa)	kPa/min	< 0.6	> 0.8 for 3 consecutive tests ***OR*** > 1 for an individual test
Combined Permeate Turbidity to trigger a Membrane Integrity Test	NTU	< 0.1	> 0.15 for greater than 15 minutes

5.0 REVERSE OSMOSIS

5.1 INTRODUCTION

Reverse osmosis (RO) membranes have been shown to be able to achieve removal of all types of pathogens from wastewater. However, as quantities of indigenous pathogens in the RO feed water are below detection limit it is not feasible to directly calculate pathogen log removal through sampling of the operating RO system. Given that RO is a developed technology the following sections demonstrate, through scientific evidence, that the KIWS RO system will perform as intended as a barrier to protozoa, bacteria, virus and salt.

In the original desktop validation, validation requirements set out in the Draft Guidelines for Validating Treatment Processes for Pathogen Reduction (Department of Health Victoria, 2010) the following parameters have been used to demonstrate that the KIWS RO system will operate within an envelope in which similar systems have achieved the required pathogen log reduction:

- Feedwater composition: pH, temperature, EC
- Operational conditions: pressure, flux, recovery, flow
- Membrane properties: pore size, manufacturer, surface charge

Since the original desktop validation there have been numerous investigations targeted at identifying a surrogate for pathogens that could be used to increase the log reduction claim for reverse osmosis (RO). Of these, the most commonly adopted is the online monitoring of total organic carbon as this can be used to consistently demonstrate a 2 log10 reduction in organics and this can be corelated to a 2 log10 reduction in pathogens (Australian WaterSecure Innovations Ltd, 2017).

However, with increasing confidence in the reliability of reverse osmosis, and improvements in measuring low levels of metals there has been a move to utilise sulfate (Australian WaterSecure Innovations Ltd, 2017) and calcium as surrogates (R. Shane Trussell, 2017) as a more cost effective solution.

5.2 PROCESS OVERVIEW

The Primary RO process consists of four (4) trains (single pass, two stages) that will be fed from the RO feed water tank via cartridge filters. As shown in Figure 9, antiscalant and sulphuric acid are dosed downstream of the Low Pressure (LP) feed pumps to protect the RO membranes from scale-forming compounds and improve performance. Citric acid and hydrochloric acid, caustic soda and a RO proprietary cleaning agent are used for chemical cleaning of the membranes, also referred to as a Clean in Place (CIP) and maintenance cleans.

Free ammonia (AIT 3090) is measured to confirm the there is no free chlorine present. The water downstream of the cartridge filters is monitored with the following online instruments:

- Conductivity (AIT 3094)
- pH (AIT 3092)
- ORP (AIT 3096)

Each of the four (4) RO trains consist of two membrane stages. For process control and monitoring conductivity is measured on the permeate lines from each of the stages, and the brine lines from each stage with the following instruments:

- Conductivity (AIT 3X14) – Stage 1 Permeate
- Conductivity (AIT 3X57) – Stage 2 Permeate
- Conductivity (AIT 3X18) – Stage 1 Brine
- Conductivity (AIT 3X81) – Stage 2 Brine
- Temperature (TIT 3X78) – Combined Permeate

Where X is either 2, 3 4 or 5 for trains 1, 2, 3, and 4.

The combined permeate of the four (4) RO trains is monitored prior to degassing using the following instruments:

- Conductivity (AIT 3902) – Combined Permeate
- pH (AIT 3901)

The permeate conductivity of the BRU is monitored by AIT 9008.

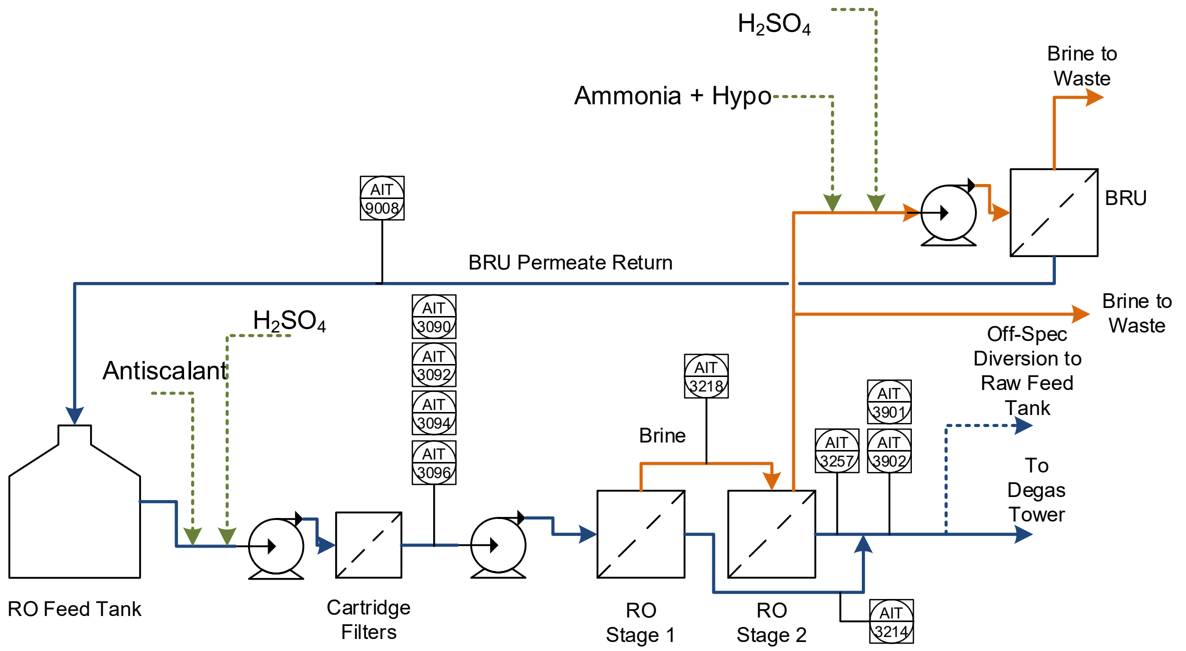


Figure 7 RO Membrane Process Flow Diagram, including BRU

The original design flows for the system are summarised in Table 15.

Table 15: Primary RO Design Data, including BRU

Parameter	Unit	Value
Manufacturer	-	Hydranautics
Element Type	-	ESPA2-LD
Element Material	-	Composite Polyamide
Element Configuration	-	Low Fouling Spiral Wound
Element Diameter	mm	200
Element Length	mm	1016
Active Membrane Filtration Area per Element	m^2	37.1
Nominal Pore Size	µm	0.001
Number of RO trains	#	4
Stages	#	2
Pressure Vessel Array, each Skid or Sub-train	-	14:8
Elements per Train	#	154
Total Number of Elements	#	616
Design Permeate Capacity (per train)	ML/day	2.625
Design Permeate Capacity (all trains)	ML/day	10.5
Max Permeate Flow (all trains)	L/s	121.5
Min Permeate Flow (one train online)	L/s	26
Elements per Pressure Vessel	#	7
Design Average Membrane Flux	l/m^2-hr	18

Parameter	Unit	Value
Expected pH Range	-	6.5 – 7.0
Target Recovery	%	77.8%
Minimum Salt Rejection	%	99.5
Typical operating Temperature	ºC	22
Maximum operating Temperature	ºC	30

5.2.1 BRINE RECOVERY UNIT

To maximise the feedwater production with a limited feed water a Brine Recovery Unit (BRU) is being installed to process the primary RO unit concentrate and return it to the RO feed tank for re-processing. Once completed the addition of the BRU will allow for an increased production of industrial water from an original 9 ML/d to 10.5 ML/d increasing the plant recovery from ~ 75% to ~ 87.5%.

The permeate from the BRU returns to the RO feed tank and will have the effect of slightly reducing the TDS level of the feed to the Primary RO.

Table 16: BRU Design

Parameter	Unit	Value
Element Material	-	Composite Polyamide
Element Configuration	-	Low Fouling Spiral Wound
Element Diameter	mm	200
Element Length	mm	1016
Active Membrane Filtration Area per Element	m^2	37.1
Number of RO trains	#	1
Stages	#	1
Pressure Vessel Array, each Skid or Sub-train	-	18
Elements per Train	#	108
Total Number of Elements	#	108
Design Permeate Capacity	ML/day	1.5
Expected pH Range	-	6.5 – 7.0
Target Recovery	%	50%
Minimum Salt Rejection	%	99.5
Typical operating Temperature	ºC	22
Maximum operating Temperature	ºC	30

5.3 DESKTOP VALIDATION ASSESSMENT

The following sections contain a desktop assessment of the KIWS RO process. This study was performed to provide evidence that the RO process will be capable of achieving the required pathogen LRVs. The methodology that has been employed is a comparison with other RO systems using equivalent thin film composite membranes with similar flow rates, flux, and feed water quality.

5.3.1 METHODOLOGY

The US EPA MFGM was developed in conjunction with the LT2ESWTR to elaborate on the rule requirements associated with membrane filtration and to assist utilities with the application membrane filtration systems for compliance with the rule. However, the MFGM does not regulate the use of membranes for the removal of viruses. In Australia the *Guidelines for Validating Treatment Processes for*

Pathogen Reduction (Department of Health Victoria, 2010) has recognised that electrical conductivity (EC) is a valid integrity indicator and surrogate for virus LRV calculation.

EC measurements detect the level of salt/solute in water. Using the logic that virus particles (the smallest in particle size of the pathogen group) are smaller than salt molecules, it can be assumed that given a constant feed EC, if the level of salt increases in the permeate the EC level can provide a conservative indication passage of virus particles from the feed to the permeate side.

EC measuring instruments are reliable and sensitive being able to detect changes that are of the order required to use as a surrogate. However, there are limitations to the application of the permeate EC as a stand-alone surrogate and these are why the difference in feed and permeate EC is utilised and not just permeate EC. Primarily the issue is derived from RO being a diffusion process and hence there will always be a level of salt in the permeate of a 100% integral system so high levels of removal cannot be measured by EC as a surrogate regardless of the ability of the system. This does however mean that the measurement is conservative and hence appropriate.

The following operational impacts also stem from the RO system being based on diffusion:

- *Feed water EC and temperature* – As the feed water EC and temperature goes up the permeate EC will go up hence a single EC value should not be utilised as a CCP, but the actual log removal of EC from the feed to the permeate.
- *System recovery* – As system recovery is increased the permeate EC will increase (i.e. rejection with decrease) due to the higher concentration of salt at the membrane interface and associated higher salt diffusion indicating a lower LRV even of an integral system. In relation to EC as a surrogate this impact renders the surrogate more conservative.
- *Flux* – As flux is increased there is a greater dilution effect and the EC of the permeate will decrease (i.e. rejection will increase), indicating a greater LRV. This is the same effect as for MF and whilst there will be a change to the permeate EC given a constant feed EC it has no effect on using EC as a surrogate.
- *Fouling* – Fouling of an integral membrane can have an effect on the salt passage, both up or down, and therefor EC of the permeate. Whilst there will be a change to the permeate EC from fouling over time, given a constant feed EC, the fouling effect does not adversely impact its use as a surrogate.

When these impacts are considered there is a typical maximum removal of 99% (feed EC of 1,000 µS/cm and permeate EC of 10 µS/cm), which is equivalent to an LRV of 2. In practice the lower the EC of the feed water the more difficult it becomes to practically and consistently measure an EC removal of 99% and the LRV, even of an otherwise integral system, will trend towards an LRV of 1.

Based on this, EC rejection will be utlised comparing similar RO systems to KIWS for the validation of the RO system.

The specific steps included the following:

- Literature review to compile data from other RO systems utilising Hydranautics ESPA membranes
- Comparison of feed quality, permeate quality and operational parameters between other plants utilising the same membranes that have undergone challenge
- Confirmation of operational envelope in which the KIWS RO system will reliably achieve the claimed pathogen log reduction

5.3.2 LITERATURE REVIEW

There have been many studies related to the development of integrity testing and the removal of constituents in wastewater. There are various documents that give broad ranges of log removal for pathogens including the following:

- 2.7 – 6.6 log_{10} virus removal – Smeets et al (2006)
- > 6.0 log_{10} virus removal – Australian Guidelines for Water Recycling (2006)
- 2.7 – 6.5_{10} virus removal – Adham et al (1998)
- 4.0 – 5.0_{10} virus removal – Lozier et al (1994)

Table 17 summarises the operational parameters, feed and permeate water quality, and log removal data that is available publically and/or for plants operated/designed by CH2M HILL for a range of RO installations, both pilot and full scale.

The key points that Table 17 demonstrate include the following:

- Flux ranges from 17.6 lmh to 40 lmh
- Recovery rates for the referenced systems that are not simply individual modules are in the range of 70% to 85%.
- The Orange County Water District Groundwater Replenishment System, although much larger, uses the same membranes and operates at a similar feed pressure, flux and minimum % rejection to KIWS and consistently achieves greater than 1.5 $\log_{10}$ removal of EC based on the averages of three years of operational data
- EC log removal ranges from 1.16 to 2.
- Using membranes from Hydranautics (ESPA1), Adham et al. (1998) obtained a minimum MS2 phage log removal of 4.2 and a *Cryptosporidium* log removal of > 5.7

Table 17: Published and operational data obtained for existing RO systems

	Reference	KIWS	Adham et al (1998)	Mi et al (2004)	Franks et al (2011) - Hydranautics	Bellona et al (2012)	Bartels et al (2010) - Hydranautics	Singh et al (2012)	OCWD (2009)	OCWD (2010)	OCWD (2011)	CH2M HILL Data (2012)	Yabbie Pond (2010)	CH2M HILL Data (2008)	CH2M HILL Data (2011)	Zornes et al (2011)
Scale			Lab	Lab	Pilot	Pilot	Pilot (Bedok)	Pilot (Beenyup)	Full (Orange County Water District Groundwater Replenishment System)			Oxnard Advanced Water Purification Facility	Bendigo RWF	Bundamba	Luggage Point	Gippsland Water Factory
Membrane	Type	**EPA2-LD**	ESPA1-4040	ESPA1-2540	ESPA2-LD	ESPA2-4040	ESPA2	ESPA2	ESPA2			ESPA2	AG8040F400	TFC-HR MegaMagnum	Toray TML 20-400	Toray TML 20-400
	Dimensions (mm)	**200x1016**	102x1030	64.5x1016	200x1016	102x1030	200x1016	200x1016	200x1016			200x1016	201x1016	457x1549	201x1016	201x1016
	Number of Trains	**4**	1	1	1	1	1	1	15			2	2	3	4	2
Operating Conditions	Number of elements per train	**1078**	1	1	1	21	12		1050				15	65	1470	273
	Flow (MLD)	**9**		0.02			1.92	0.10	18.90			24.00	3.84	8.8	66.0	8.0
	Flow (L/s)	**110**		0.21			22.2	1.1	218.75			277.78		102	764	93
	Surface area per element (m^2)	**37.1**	7.9	2.6	37.1	7.9		37.1	37.1			37.1	37.2	260	37	37
	Flux (lmh)	**16.4**				25.5	40.0		20.4			16.2		17.7	18	17.6
	Permeate recovery (%)	**75**		10	55	85	75	80	85			80-85	70-80	85	85	75-85
	Minimum rejection (%)	**99.5**		98	99.6	99.6			99.6				99			
	Applied Pressure (Mpa)	**0.105**		1.5 (max)					0.1 - 0.16			0.19	0.13			
Feed Quality	Conductivity (µS/cm)	**1250**				1023.2	1074	~1000-2000	1769	1684	1608	3382.86	1310	1162	3490	
	TOC (mg/L)	**12.51**		6.5	7.1			4.8-11.0	10.13	8.54	8.17					
	TDS (mg/L)	**658.2**		1100	1500		698		1013	1027	964			697		
	Turbidity (NTU)								0.03	0.144	0.118	0.12		<0.1	0.16	
	Temperature (ºC)	**25**		25	25		30						17	27		
	pH	**6.5**		5.6-6.2	7		7.1		6.65	6.69	6.7	6.40	7.0	6.8	7.2	
	Chloride (mg/L)	**168**			225	123.1			230.7	227.3	215.8			177		
	Phosphate (mg/L)	**6**				0.4										
	Silica (mg/L)	**143.1**			26.7	10.7			22.73	21.16	<1			7		
	NO_3 (mg/L as N)	**8.03**			9.5	2.7			2.48	9.38	9.28			2.0	2.1	
	SO_4	**114.4**			247				285.9	264.7	238.1			188		
	Alk (mg/L as $CaCO_3$)	**79.5**			135	216			299.2	300.6	305.7					
Permeate Quality	TDS (mg/L)	**<50[Note 1]**					48.4		20.22	20.5	21.96			23		
	NO3 (mg/L as N)				0.11	0.27	2.4		0.28	0.89	0.95			0.2		
	SO_4				0.092		0.1		<0.5	0.64	0.27			<0.1		
	Alk (mg/L as CaCO3)				4.2		9.0		<1	<1	<1					
	Conductivity (µS/cm)	**<95[Note 2]**					74	14-80	42.44	36.13	37.03	60.87	24	35	99	
	Turbidity (NTU)								0.184	0.03	0.03			<0.1		
	TOC (mg/L)				<0.5	0.3		0.7-2.5	0.1	0.06	0.15					
	Chloride (mg/L)				1.01	2.4	15.9		4	4.31	4.56			4.3		
	Silica (mg/L)				0.075	0.2			<1	<1	<1			0.2		
Log Removal	Conductivity	**>1.1[Note 3]**	2				1.16	~1.99 (min)	1.62	1.67	1.64	1.74	1.74	1.52	1.55	1.79
	Rhodamine WT												2.53			2.58
	MS2 Phage		4.2 (min)	5.4 (min)												
	Giardia		> 5.7													
	Cryptosporidium		>5.7													
	TOC					1.98		~1.88 (min)	2.01	2.15	1.74					

Note 1. Contractual requirement, above 50mg/L the solute requirement is not met; Note 2. Calculated from the ratio of feed water TDS and conductivity; and Note 3. Based on feed of 1,250 µS/cm

5.4 OPERATIONAL AND VALIDATION DATA ANANLYSIS

Operational and validation data has been obtained from several plants with RO systems that utilise EC as a method of indirect integrity testing. Data from these facilities is presented in Table 18.The table shows that the minimum log removal of EC at each of the five plants is consistently greater than 1 $\log_{10}$ (even in compromised membranes – refer GWF data). Based on the fact that the majority of membrane elements show similar salt rejections and operating conditions to those expected at KIWS (refer Table 17) it can be expected that the EC rejection measured at the five plants will occur at KIWS, indicating that a minimum of 1 $\log_{10}$ removal of viruses will occur.

It should be noted that only Gippsland Water Factory (GWF) supplies recycled water for industrial purposes; the other four plants utilise water for water with greater potential for human contact, with three plants (Bundamba, Luggage Point and Oxnard) are all designed to supply recycled water for indirect potable reuse. It terms of proven removal of viruses, GWF and the Bendigo Recycled Water Facility (RWF) were validated using rhodamine WT dye challenge testing. The results of the challenge testing showed that the RO membranes at each plant were able to achieve greater than 2.5 $\log_{10}$ removal of viruses (Gippsland Water, 2011; Yabbie Pond, 2010). Both plants have been approved to supply recycled water in Victoria and have the following approved virus LRVs:

- GWF – 2 $\log_{10}$ (using TOC (primary) and EC (secondary) to indirectly measure integrity)
- Bendigo RWF – 1.7 $\log_{10}$ (using EC to indirectly measure integrity)

Table 18 Operational Data Summary of Six RO Systems

		EC Feed (µS/cm)	EC Permeate (µS/cm)				EC Log removal				Temp	Feed Pressure (kPa)		
Oxnard CH2M HILL Data (2012)			Stage 1	Stage 2	Stage 3	Combined	Stage 1	Stage 2	Stage 3	Combined				
	Max	4102	42	119	338	74	2.00	1.61	1.18	1.79	24	1328		
	Avg	3401	36	96	258	61	1.98	1.55	1.12	1.75	23	1202		
	Median	3425	36	93	244	61	1.98	1.55	1.12	1.75	23	1197		
	Min	2795	29	75	202	47	1.95	1.51	1.07	1.72	23	1097		
	Count	27	27	27	27	27	27	27	27	27	27	27		
Bundamba CH2M HILL Data (2007)			Train 1	Train 2	Train 3		Train 1	Train 2	Train 3			Train 1	Train 2	Train 3
	Max	1280	36	43	38		1.60	1.52	1.66		27	1067	1099	1099
	Avg	1230	34	39	33		1.56	1.50	1.57		27	990	1030	1009
	Median	1226	35	39	33		1.57	1.51	1.57		27	957	1056	988
	Min	1194	31	37	27		1.53	1.45	1.52		26	928	896	895
	Count	13	11	8	12		11	8	12		13	11	8	12
Luggage Point CH2M HILL Data (2011)			Train 1	Train 2	Train 3	Train 4	Train 1	Train 2	Train 3	Train 4				
	Max	5000	162	143	131	161	1.49	1.54	1.58	1.49				
	Avg	3490	99	97	97	103	1.55	1.55	1.56	1.53				
	Median	3800	120	98	101	109	1.50	1.59	1.58	1.54				
	Min	1300	28	43	31	39	1.66	1.48	1.62	1.52				
	Count	31	12	15	14	18	12	15	14	18				
Bendigo RWT Yabbie Pond (2010)							Skid 1	Skid 2				Skid 1	Skid 2	
	Max						2.89	2.89						
	Avg						2.66	2.67			11	124	280	
	Median						2.54	2.55						
	Min						2.54	2.55						
	Count						15	15						

		EC Feed (µS/cm)	EC Permeate (µS/cm)	EC Log removal			Temp	Feed Pressure (kPa)
				Train 1	Train 2	Train 1 with leak		
Gippsland Water Factory Zornes et al (2011)	Max			1.77	1.79	1.73		
	Avg							
	Median							
	Min			1.71	1.79	1.72		
	Count							

5.4.1 LOG REMOVAL SURROGATES

Given the capacity of reverse osmosis to effectively reduce pathogens by more than the originally claimed 1.0 log_{10} (Table 17), operational data has been reviewed to consider the opportunity to increase the log credit claimed for the reverse osmosis process through existing or additional monitoring.

Figure 7 provides a graphical representation of three key parameters, EC, calcium and sulphate used as surrogates for pathogen reduction across a reverse osmosis unit. The Total Organic Carbon was also considered using weekly grab samples. On consideration, experience at other sites has indicated that online TOC is required to achieve the sensitivity required with the sample easily contaminated at the very low levels (<0.2 mg/L TOC) required to demonstrate > 1.5 LRV.

From an assessment of the data, whilst the EC and sulphate consistently demonstrate > 1 log_{10}, calcium is the only surrogate considered able to consistently demonstrate that the reverse osmosis process is in-tact and achieving a reduction of more than 1.5 log_{10}. In real terms the calcium is consistently 25 to 35 mg/L in the raw water and in the order of 0.05 mg/L in the RO permeate.

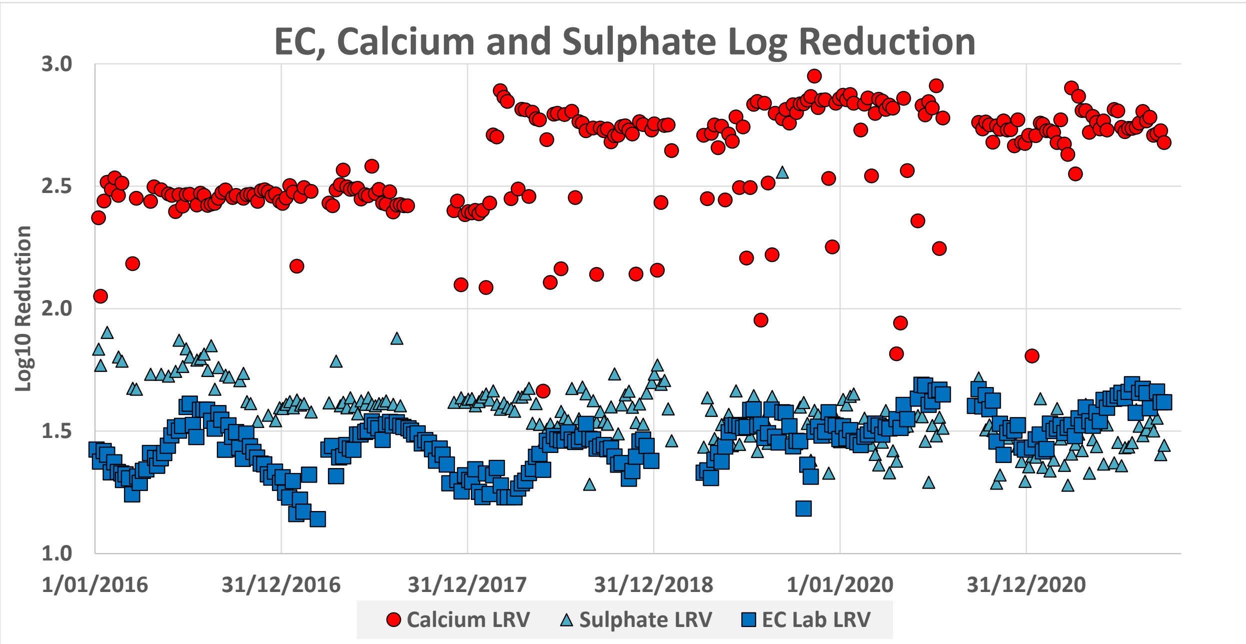


Figure 8. EC, Calcium and Sulphate Log Reduction across the Primary RO

Given the opportunity to utilise calcium a literature review was undertaken.

A report produced by the U.S Department of the Interior Bureau of Reclamation (R. Shane Trussell, 2017) identified calcium as an ion of interest to demonstrate RO log rejection measuring ≥ 1.9 LRV, noting that this was constrained as calcium was not detected in the permeate and so the LRV could only be that allowed by the feed concentration. The report goes on to identify strontium as another candidate as it has a very low detection limit and they were able to demonstrate a 3.3 log_{10} reduction. Strontium is not routinely measured at KIWS and hence is not applicable at this time.

The Australian produced *Reverse osmosis and nanofiltration Validation protocol* (Australian WaterSecure Innovations Ltd, 2017) does not reference calcium, but does reference sulfate as an indicator (daily grab samples and spiking as an option) noting that the selection needs to consider the feedwater concentreation and analytical method being applied.

The *National Validation Guidelines for Water Recycling: Reverse Osmosis Membranes* project report (Australian Water Recycling Centre of Excellence, 2015) suggest that "In theory continuous measurement of polyvalent ion rejection such as sulfate, calcium or magnesium monitoring would also be an applicable technique providing a sensitivity increase compared to conductivity monitoring; however, there are currently no available economic instruments for online measurement". The focus of this report being to find a measurement that was continuous as best practice.

Whilst not referencing calcium as a surrogate the Journal article, *Direct Potable Reuse Microbial Risk Assessment Methodology: Sensitivity Analysis and Application to State Log Credit Allocations* (Jeffrey A. Soller, 2018) considered reverse osmosis log credits and log reduction from a literature review to produce the following figure that demonstrates that a credit of 2 log_{10} (utilized with RO applications in California for direct potable reuse) was below the reported rejection of various pathogens.

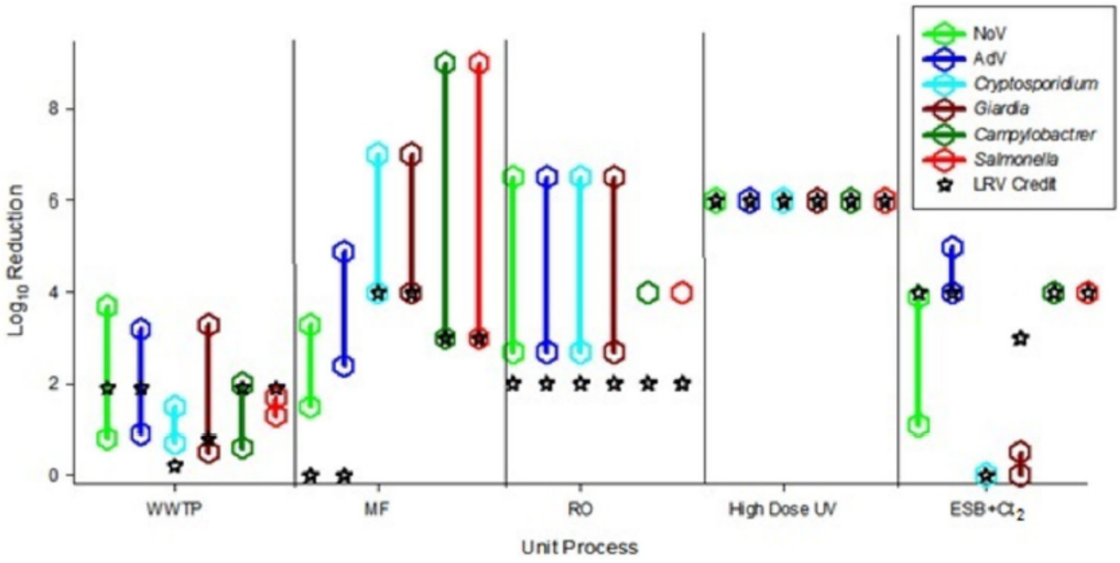


Figure 3.
Comparison of log reduction values from literature review and unit process credits values. Symbols represent minimum and maximum values from literature review. See legend in Figure 1 for abbreviations.

Figure 9 Comparison of LRV Credit and Literature (Jeffrey A. Soller, 2018)

5.5 LOG REDUCTION CLAIM

Literature and recent plant validation data has shown that a minimum virus log removal that can be achieved by RO membranes is 2.5 log_{10} and specifically a maximum of 4.2 log_{10} for ESPA membranes (Adham et al., 1998). Literature and operational data, from other sites, has also shown that using EC as an online continuous measurement of indirect integrity can demonstrate more than 1.5 log_{10}. However, data from the KIWS (Figure 7) demonstrates that EC is not sufficient to consistently demonstrate more than 1.5 log_{10}.

With a goal to claim 1.5 log_{10}, additional surrogates were considered. From a review of operational data and a review of literature there was found to be an opportunity to utilise a monovalent ion, in this case calcium, to demonstrate the integrity of the membranes up to 2.5 log_{10}. The key discussion point is the frequency of testing and ability to react in a reasonable time such that the measurement can be an appropriate tool at the reverse osmosis control point.

To this end frequency of measurement needs to reflect the risk, which is related to the use of the water for fire fighting. Hence, the criticality of the measurement is reduced in comparison to an application such as direct potable reuse, where information is required as soon as possible to protect public health.

With a multibarrier process and online continuous monitoring of the permeate EC, there is a surrogate to identify a major membrane failure/leak that would reduce the effectiveness of the RO as a barrier to pathogens. In the same way as filtered water turbidity is used to identify major failures of a micro/ultra filtration system in real time, and a direct integrity test is used daily to identify much smaller integrity issues.

What remains is a consideration of risk associated with a minor membrane issue that is not able to be detected by a change in the EC but may be detected by monitoring the calcium rejection after a period of days. In this case, given the end use which is being targeted is an emergency scenario, the long term consistent operation of reverse osmosis, which is a mature technology and conservatism in the additional barriers (in particular the Shortland WWTW) it is considered reasonable to claim 1.5 log_{10} based on weekly calcium testing.

Additional operational measures, including the EC of individual streams on the RO trains will be employed as quality control points.

Minimum LRVs for bacteria and protozoa have been set conservatively at a minimum of 1.5 log_{10} as, based on cell size, these are larger than virus and hence will have at least an equivalent removal.

Table 19 summarises the claimed LRVs over the RO membrane process for bacteria, protozoa and viruses.

Table 19 RO Membrane Log Reduction Claim

Bacteria	Protozoa	Virus
Log_{10} Removal Claim		
1.5	1.5	1.5

5.6 CRITICAL AND TARGET LIMITS

For the purpose of ensuring that the claimed log reductions and TDS limit for contractual requirements are continually achieved in the recycled water being utilised by the end users, the following critical and target limits are recommended.

The electrical conductivity is measured continuously at a number of locations with the combined permeate meter being the instrument used for the CCP.

Calcium will be measured through taking a grab sample of the RO feed and combined RO permeate.

Table 20: Critical and Target Limits

Parameter	Unit	Critical Limit	Target
EC (Continuous online)	µS/cm	70 µS/cm for > 60 minutes	< 30 µS/cm
		< 1 LRV for a period of 60 minute	>1.5 LRV
Calcium (Grab Sample)	mg/L	< 1.5 LRV (Typically, <0.7 mg/L with a 5th percentile of 23.6 mg/L in the feed)	> 2.0 LRV (Typically, ≤0.2 mg/L with a 5th percentile 23.6 mg/L in the feed)

6.0 CHLORINATION VALIDATION

6.1 INTRODUCTION

There is a substantial volume of scientific evidence available identifying the capability of chlorination to remove virus and bacteria, with inactivation of virus being the limiting factor. The validation of log reduction of viruses is based upon the Ct value, which is defined as;

C = concentration of disinfectant (mg/L)

t = contact time (mins)

The Ct disinfection concept uses a combination of free chlorine residual concentration (in mg/L) and the effective disinfectant contact time (in minutes), to quantify the capability of a chemical disinfection system to provide effective pathogen inactivation. The use of this concept involves determining the Ct values required at actual operating conditions (flow, temperature, and pH) and ensuring that the employed disinfection process achieves these values at all times.

This design of the chlorine disinfection system at the KIWS is based upon Black *et al.,*(2009), which developed Ct values based on inactivation of Coxsackie B5 virus rather than Hepatitis A virus, and is the prescribed Ct reference within the *Guidelines for Validating Treatment Processes for Pathogen Reduction* (Department of Health Victoria, 2010). The data within Black et al (2009) is considered to supersede the US EPA (1991) Ct values that have previously been in widespread use.

6.1.1 CT VALUES

Table 21 summarises the Ct values that are required to be achieved to provide inactivation of viruses by free chlorine. KIWS has been designed to achieve a 4-log inactivation of viruses and bacteria, therefore under the corresponding pH and temperature conditions the Ct values needed to achieve 4-log inactivation must be achieved for the recycled water to be of the target quality.

Table 21: CT Values (mg•min/L) for Inactivation of Viruses by Free Chlorine (Source: Keegan et al., 2012)

pH	Log_{10} Reduction Credit		
	2	3	4
≤ 7.5	≥ 7	≥ 9	≥ 11
≤ 9	≥ 16	≥ 21	≥ 27

Note: The log_{10} reduction credits assigned to bacteria have been set at the log_{10} reduction credits assigned for viruses based upon a greater resistance of virus to free chlorine than bacteria.

6.2 PROCESS OVERVIEW

The chlorine contact tank (CCT) is a lined steel panel tank without internal baffles. It is 9.74 m in diameter and 10.02 m in (wall) height giving a total active volume of 700 kL. Chlorine is dosed in the form of sodium hypochlorite upstream of the CCT and prior to an inline static mixer. The chlorinated solution then enters the bottom of the CCT via a sparge pipe, to promote plug flow, and limit mixing and short circuiting.

Based on the definition of baffling factors contained within the EPA Guidance Manual LT1ESWTR Disinfection Profiling and Benchmarking (US EPA, 2003) a conservative assumption of a baffle factor of 0.3 has been made giving an effective disinfection volume of 210 kL.Chlorine residual is measured at the outlet of the chlorine contact tank.

The following instruments are employed to monitor and control the process:

- Temperature (TIT 4049)
- pH (AIT 4048)
- Total Chlorine (AIT 4543)

At the outlet of the CCT free chlorine is measured to confirm that the free chlorine residual meets the concentration to achieve the required Ct values for 4-log inactivation of viruses using the following duty/duty instruments:

- Free chlorine (AIT 4520)
- Free chlorine (AIT 4521)

To complete the process in relation to the quality of water required by the end user the disinfected water is dosed with sodium bisulphite to reduce the total chlorine level. The following instruments are employed:

- Conductivity (AIT 4539)
- pH (AIT 4538)
- Total chlorine (AIT 4537)

Product water quality is also monitored just before entering being transferred to Orica using the following instruments:

- Temperature (TIT 4822)
- Conductivity (AIT 4824)
- pH (AIT 4822)
- Turbidity (AIT 4830)
- Total chlorine (AIT 4826)

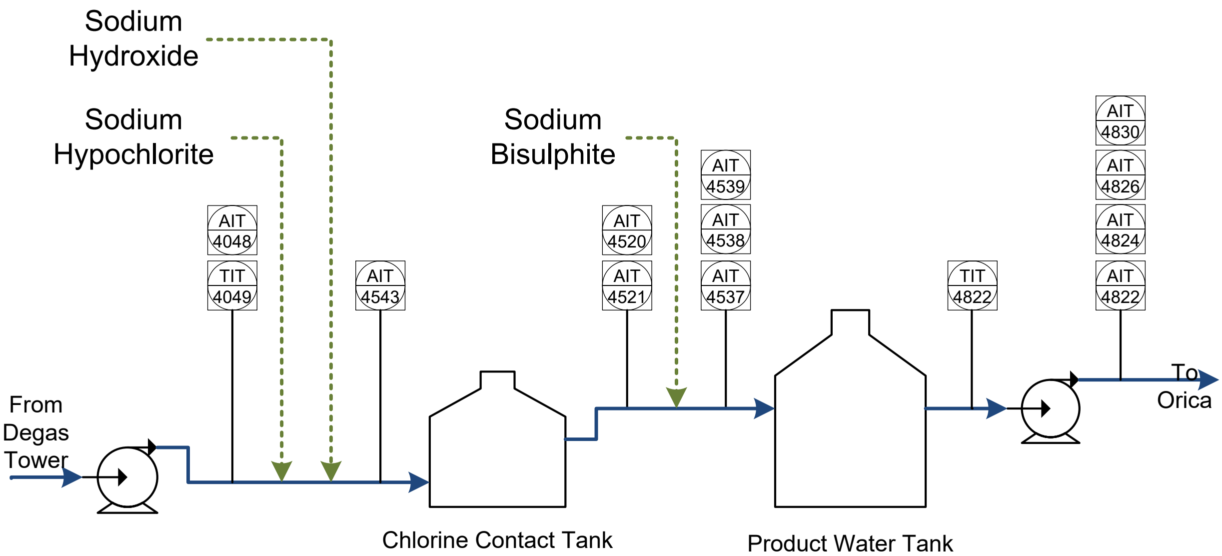


Figure 10 Product Water System to Orica

6.3 DESKTOP DISINFECTION ASSESSMENT

A desktop application of standard Ct values has been applied to the disinfection process at the KIWS. This study was performed to provide evidence that the chlorination process is capable of achieving the required pathogen LRVs.

6.3.1 CONTACT TIME CALCULATION

The theoretical disinfection contact time is determined by multiplying the baffle factor (T_{10}/T) by the theoretical detention time, which will give an estimate of the actual disinfection value. Theoretical detention time is calculated based on the volume of the chlorine contact tank and the transfer rate to the CCT.

6.3.2 CT CALCULATION

Chlorination Ct values are calculated by multiplying the effluent free chlorine level (in mg/L) by the contact time (in minutes):

Ct (mg•min/L) = Concentration (mg/L) x Time (minutes)

e.g a free chlorine value of 1 mg/L with a contact time of 5 minutes gives a Ct = 5 mg•min/L

6.3.3 RESULTS

Table 22 summarises the CCT parameters and the achievable flowrates from plant start up to ultimate plant capacity. The maximum flowrate has been used as this is considered a worst case scenario. It also shows the results of the calculations to determine the theoretical minimum detention time and theoretical minimum disinfection contact time.

Table 22: Theoretical Detention Time and Disinfection Contact Time

Parameter	Unit	Value	Theoretical Minimum Detention Time (mins)	Theoretical Minimum Disinfection Contact Time (mins)
Chlorine Contact Tank (CCT) Active Volume	L	700,000		
Baffle Factor (T_{10}/T)	-	0.3		
Effective Disinfection volume	L	210,000		
Maximum Flowrate	L/s	110	106.0	31.8

Using the calculated theoretical disinfection contact time the achievable Ct value at maximum flow and for a free chlorine concentration of 0.4mg/L is calculated based upon an expected minimum free chlorine residual of 0.4 mg/L (refer Table 23).

Table 23: Ct calculations

Parameter	Theoretical Minimum Disinfection Contact Time (mins)	Expected Minimum Free Chlorine Residual (mg/L)	Ct (mg•min/L)	Minimum required Ct*
Maximum Flowrate	31.8	0.4	12.7	11

** To achieve 4 log_{10} inactivation of viruses by free chlorine at pH ≤ 7.5 whilst the water temperature is ≥ 5°C.*

6.3.4 BOUNDARY ANALYSIS

An analysis has been performed to define the boundaries within which disinfection at the KIWS will meet the requirements to achieve the claimed LRV. The analysis shows the impact on the critical free chlorine concentration for a minimum 4-log_{10} virus and bacteria inactivation to ensure that the value utilised is conservative.

The following scenarios have been considered:

- Lowest water temperature
- Maximum instantaneous flow rate through the contact tank (minimum contact time)
- Most adverse pH
- Turbidity

6.3.4.1 Lowest Water Temperature

Analysis of the historical feed water temperature range was performed on the feed water (ie. the effluent from Shortland WWTW). The results indicate the minimum water temperature of KIWS feed water is 13 ºC. For the purpose of calculating Ct the minimum temperature is for the validation to hold true is 5 ºC, which is less than the minimum water temperature that will enter the CCT. Increased temperature has no effect.

A free chlorine concentration of ***0.4 mg/L is valid for all predicted temperature scenarios***.

6.3.4.2 Maximum Instantaneous Flow

Calculations above have been performed using the maximum flow rate possible from the transfer pumps and hence the minimum contact time, t. As such any lower flow rate lower than this will give a greater contact time and, for a given free chlorine concentration, give a larger Ct.

A free chlorine concentration of ***0.4 mg/L is valid for all predicted flow scenarios***.

6.3.4.3 Most adverse pH

The water quality modelling undertaken on the RO system and degas tower indicates that the pH will be around 6.1, which will result in a water that is less than a pH of 7.5 at the CCT outlet hence the adoption of the target of a Ct of 11 mg•min/L.

However should the modelling prove to be incorrect and the pH increase above 7.5 at the outlet of the CCT the Ct required for 4-log_{10} virus inactivation will increase from 11 mg•min/L to 27 mg•min/L and this will be managed automatically by the PLC and in the Control plan for CCP 4. As the flow rate is a function of plant production the free chlorine concentration target must be altered in the event of a pH above 7.5 at the exit of the CCT.

Figure 10 is a graphical representation of the free chlorine concentration required at the two different pH ranges, at variable flows, and shows the critical limits for the two following pH scenarios:

- At temperatures greater than 10°C and at pH less than 7.5, the minimum chlorine residual concentration required to achieve a 4-log inactivation of viruses at maximum instantaneous flow is 0.35 mg/L. ***A value of 0.4 mg/L is to be used***.
- At temperatures greater than 10°C and at pH less than 9, the minimum chlorine residual concentration required to achieve a 4-log inactivation of viruses at maximum instantaneous flow is 0.85 mg/L. ***A value of 0.9 mg/L is to be used as required to manage this pH scenario.***

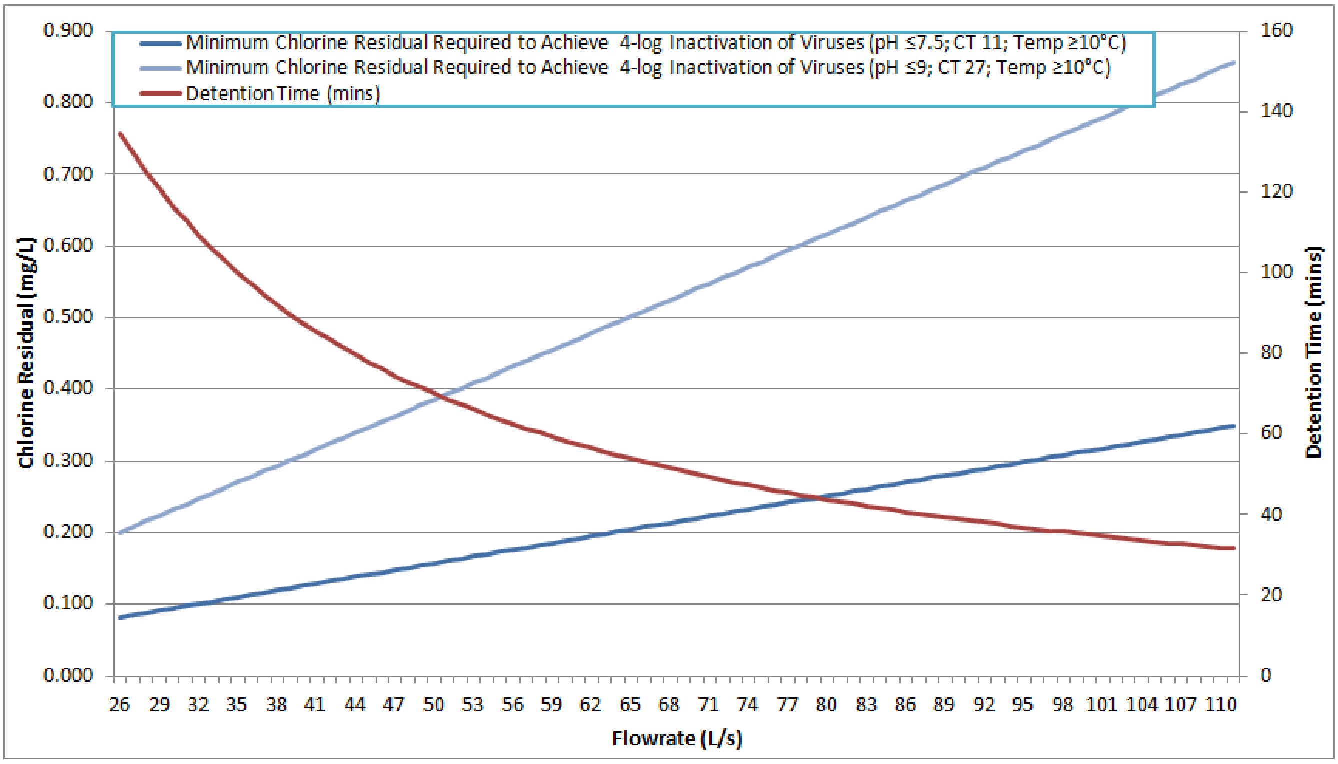


Figure 11 Minimum free chlorine residual required to achieve 4-log virus inactivation at various flowrates.

The most adverse pH value expected at KIWS is less than a pH value of 9, at which point disinfection cannot be guaranteed.

6.3.4.4 Turbidity

The Ct values used apply to water of turbidity less than or equal to 2 NTU. Following dual membrane treatment steps of MF and RO the turbidity of the water in the CCT will always be < 1 NTU so turbidity will have no impact on the free chlorine concentration target at the outlet of the CCT.

6.4 LOG REDUCTION CLAIM

This desktop validation has demonstrated that the required Ct values for 4-log_{10} inactivation of viruses and bacteria will be reliably achieved with the designed chlorination system. Table 24 summarises the claimed log reduction over the chlorination process for bacteria, protozoa and viruses.

Table 24 Chlorination Log Reduction Claim

Bacteria	Protozoa	Virus
Log_{10} Removal Claim		
4	0	4

6.5 CRITICAL AND TARGET LIMITS

For the purpose of ensuring that the claimed log reductions are continually achieved in the recycled water being utilised by the end users, the following operational envelope has been set. Within this envelope (refer Table 25) the claimed log reductions will be achieved.

Table 25: Operational Envelope

Parameter	Unit	Minimum	Maximum
Turbidity	NTU	-	0.5
pH (online)	-	-	9.0
Temperature	°C	5	-
Maximum Flow	L/s	-	110
Minimum Free Chlorine Residual	mg/L	0.4	-

It should be noted that the claimed LRVs can be achieved outside this operating envelope, if the critical limits outlined in Table 26 are not exceeded. As chlorination functions as a CCP within the system critical and target limits have been set for it. If critical limits are exceeded water must be diverted to the raw water feed tank.

Table 26: Critical and Target Limits

Parameter	Unit	Critical Limit	Target Limit
pH	-	< 9	7
Temperature	°C	> 10	>10
Ct	mg•min/L	> 11 (pH <7.5) > 27 (pH <9)	15 (pH <7.5) 31 (pH <9)
Free Chlorine Note 1.	mg/L	> 0.35 mg/L (pH <7.5) > 0.85 mg/L (pH <9)	> 0.5 mg/L (pH <7.5) > 1.0 mg/L (pH <9)

Note 1. Whilst a given Ct is required, for operational simplicity, the free chlorine concentration at the exit of the CCT will be used based on a worst case maximum flow even though the Ct at lower flow rates will be higher than that required.

7.0 SUMMARY

The desktop validation performed has demonstrated that the process units selected for KIWS will be able to achieve the LRVs summarised in Table 27.

Table 27: Log Reduction Claim Summary

Process Unit	Claimed LRV		
	Bacteria	Protozoa	Virus
Shortland WWTW	0.5	0.5	0.5
Microfiltration	4	4	0.5
Reverse Osmosis	1.5	1.5	1.5
Chlorination	4	0	4
Total	**10.0**	**6.0**	**6.5**
Orica Target	**3.8**	**3.6**	**5.1**
Fire Fighting Target	**5.3**	**5.1**	**6.5**

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Appendix 1 – MF Validation Certificate

APPENDIX B: Hazard Analysis and Critical Control Point (HACCP) Plan (SUEZ July 2018)

KOORAGANG INDUSTRIAL WATER SCHEME

HAZARD ANALYSIS & CRITICAL CONTROL POINTS (HACCP) PLAN REVIEW 2018

Document Control

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Matthew Hutton	Dan Deere	Peter Segura

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Acronyms and Abbreviations

AGWR	Australian Guidelines for Water Recycling
AWTP	Advanced Water Treatment Plant
CCP	Critical Control Point
HACCP	Hazard Analysis and Critical Control Points
HWC	Hunter Water Corporation
KIWS	Kooragang Industrial Water Scheme
QCP	Quality Control Point
RWQMP	Recycled Water Quality Management Plan
WUA-Midco	Water Utilities Australia - Midco
WWTP	Wastewater Treatment Plant

1. Introduction

1.1 Background

The Kooragang Industrial Water Scheme (KIWS) has been operating since November 2014 supplying recycled water to Orica. Initially, this was managed via Hunter Water Corporations' (HWC) Recycled Water Quality Management Plan (RWQMP). Ownership of part of the scheme was transferred to Water Utilities Australia (WUA) Midco in 2017, who then engaged SUEZ for operation of the scheme. A Hazard Analysis and Critical Control Point (HACCP) Plan and associated risk assessment worksheet is an integral part of the SUEZ RWQMP for the scheme.

1.2 Boundaries of Management Responsibility

The boundary of management responsibility was split between Hunter Water Corporation (HWC) and WUA-Midco. HWC retain responsibility for the operation of Shortland Wastewater Treatment Plant (WWTP) and SUEZ now has operational responsibility for the Kooragang Industrial Water Scheme (KIWS) and distribution to the end user of the water (Orica). The boundaries are shown in Figure 1.

1.3 HACCP Plan

A risk assessment worksheet and HACCP plan was developed during the design and delivery stages of the scheme by the Hunter Treatment Alliance. The worksheet and plan identified hazards, defined the Critical Control Points (CCP) for operation and established the limits, monitoring systems, corrective action and verification procedures associated with these CCPs. The risk assessment worksheet and associated HACCP plan documents have been updated several times by the previous owners and operators of the scheme. This current document details the 2018 review and update of the risk assessment worksheet and the HACCP plan to reflect the scheme as it is now operated by SUEZ.

Note that the structure and layout of the historical HACCP Plan and risk assessment worksheet documentation has been largely retained for the purposes of traceability of change between the original, various updates and the most recent version of the document and risk assessment. It is acknowledged that this creates quite a complex document structure, particularly for the risk assessment worksheet. However, the importance of traceability was considered to be sufficient that the documents weren't simplified by deleting historical information. In due course an updated version of the risk assessment might be created to remove historical information that is no longer relevant.

2. Hazard and CCP Review Workshop

As a starting point in developing this 2018 version, the previous 2016 version of the risk assessment worksheet and HACCP Plan was reviewed to confirm all hazards had been identified and confirm the selection of CCPs, operating limits, monitoring systems, corrective actions and verification procedures.

2.1 Hazard Review and Critical Control Points Identification

2.1.1 Participants

The risk assessment worksheet and HACCP plan review workshop was carried out on 30 July 2018 at the Mayfield West Advanced Water Treatment Plant (referred to in this report as KIWS).

Participants in the workshop are listed in Table 1.

The process flow diagram together with boundaries of responsibility is shown in Figure 1. Since its previous iteration, the diagram has been updated with additional on-line analysers having been installed at the discharge from Shortland WWTP / Inlet to KIWS (Total Chlorine, Conductivity, Turbidity and BOD_5).

2.1.2 Identification of Hazards and Control Measures

Previous workshops, documented in the previous risk assessment worksheets and HACCP Plans, identified hazards associated with elements of the reuse scheme from catchment to customer. These included hazards that were microbiological, chemical, environmental and physical. In this review workshop, each identified hazard was reviewed in the context of the amended boundaries of management responsibility, with a view to identifying any changes impacting the hazard, consequence or likelihood. Where changes and new hazards were identified, the risks were re-evaluated by the participants.

Associated control measures were also evaluated by the attendees to determine or confirm criticality.

The full list of identified hazards, including hazards identified at previous workshops, is located in the risk assessment worksheet which is nominated as Appendix 1. As noted above, the worksheet includes the document history back to 2009, prior to the construction of the KIWS and prior to SUEZ being involved with the project.

2.1.3 Risk Assessment Review

The risk assessment review followed the same procedures adopted for the original risk assessment. These are documented in the previous HACCP plans and reproduced below for ease of reference.

As per the Australian Guidelines for Water Recycling, (AGWR), risk was assessed at two levels:

- **Maximum (uncontrolled) risk** – risk in the absence of control measures, which is useful for identifying high priority risks, determining where attention should be focused and preparing for emergencies;
- **Residual (controlled) risk** – risk after consideration of control measures, which provides an indication of the safety and sustainability of the recycled water scheme or the need for control measures.

The level of risk associated with each hazard was determined based on how likely the event is to occur (likelihood) and its potential impact on health or the environment (consequence). For consistency with previous risk assessments measures of likelihood and consequence were taken from the *Hunter Water Corporation Procedure Manual – Enterprise Risk Management* (2007) and are listed in Table 2 and Table 3.

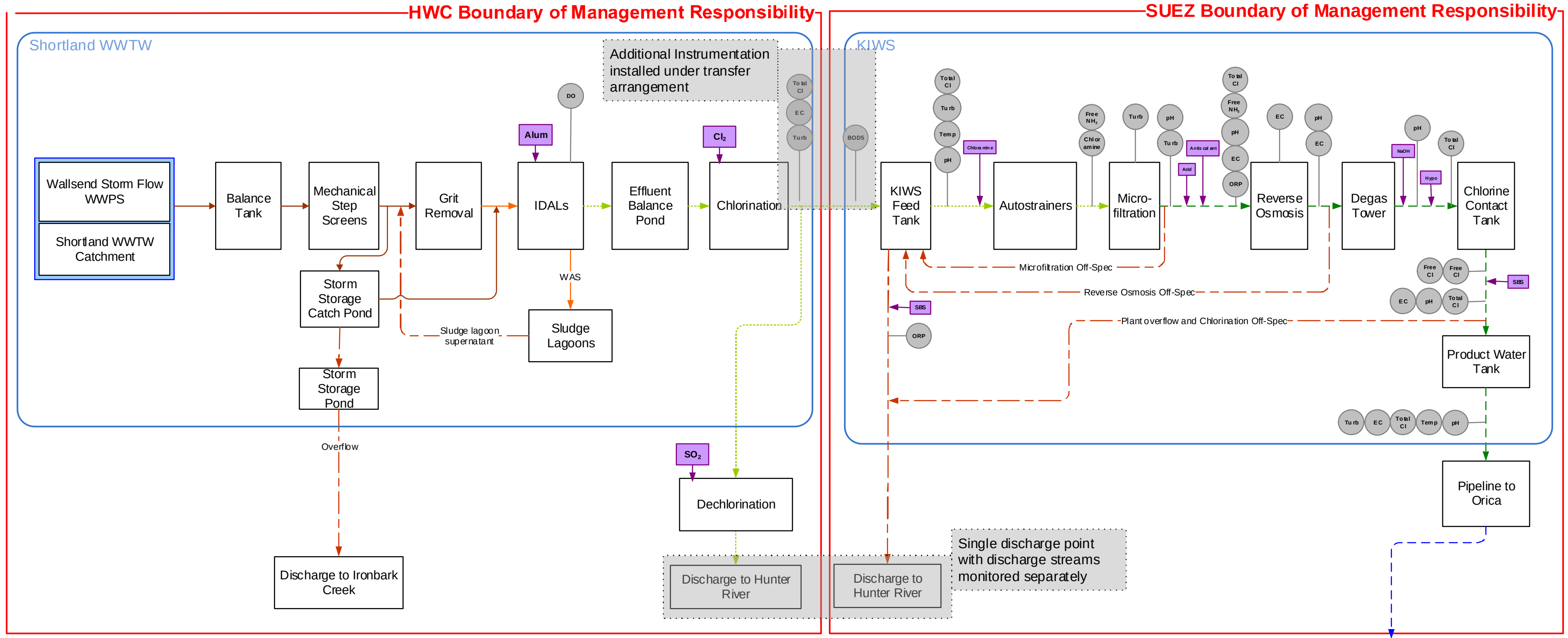
The AGWR do not require any particular method or set of risk assessment rating criteria to be utilised and, therefore, the HWC criteria were considered acceptable and adequate for the purpose of the review of the risk assessment worksheet and HACCP Plan. The benefit of utilising the same criteria to assess risk as those used previously was considered to outweigh the possibly benefit of using modified alternative risk rating criteria.

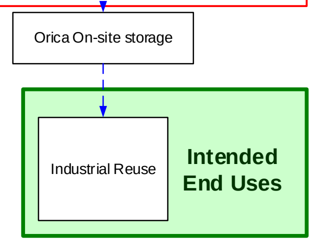
In relation to uncertainty, the AGWR recommend that as part of the risk assessment, the risk assessment team "Evaluate the main sources of uncertainty for each hazard and hazardous event". The AGWR do not specify any particular method or approach for evaluating uncertainties. The methodology adopted by Suez in evaluating uncertainties was to assess, for each risk whether there were any significant uncertainties and, if so, note what those uncertainties were, along with any comments on those uncertainties and actions to reduce them. This uncertainty evaluation was conducted by the risk assessment team as part of the risk assessment workshop. The results of the uncertainty evaluation were recorded in the risk assessment worksheet.

Table 1: Risk Assessment and CCP Review Workshop Participants

Name	Role	Organisation
Veronique Bonnelye	Technical Support Manager	SUEZ
Dave Colley	Industrial Plant Coordinator	SUEZ
Dan Deere (Facilitator)	Water Futures	Water Futures
Matt Hutton	Process and Operations Expert	SUEZ
Richard John	KIWS Technician	SUEZ
Patrick Kang	Proposals Engineer – Membrane Expert	SUEZ
Peter Segura	Operations Support Manager	SUEZ

2.1.4 Process Flow Diagram of the recycled water scheme





Abbreviation	Description
DO	Dissolved Oxygen
ORP	Oxygen Reduction Potential
EC	Electrical Conductivity
Turb	Turbidity
Temp	Temperature
IDAL	Intermittent Decanted aeration Lagoon

Flow Stream	Line Type
Influent Pre-Grit Removal	
Primary Treated Effluent	
Secondary Treated Effluent	
Tertiary Treated Effluent	
Final Product (Orica)	
Chemical Dosing	
Overflow	

Catchment Source	
Process Unit	
Online Analyser	
Chemical Dosing	

Figure 1: Boundaries of Management Responsibility

Table 2: Qualitative Measures of Hazard Likelihood

Level	Indicative Frequency	Description
5	Multiple times in a year	Known or expected to happen often
4	1 in a year or so	Known to reoccur approximately annually
3	1 in 5 years or multiple times over 10 years	-
2	1 in 10 years or multiple times in 20 years	Could occur 3 or 4 times over my working life
1	1 in 50 years or less frequent	Remotely possible, but unlikely to occur in my lifetime

Table 3: Qualitative Measures of Hazard Consequence

Level		Public Health/Water Quality	Environmental Sustainability
5	Extreme	Major health impact for large population (e.g. 2000 people); Permanent damage to people's health; Suspension or cessation of activity / shutdown ordered.	Off-site toxic release with major detrimental effect; Alteration to biological or biochemical systems.
4	High	Health outbreak on a small scale (e.g. single suburb); No long-term health effects; Formal warning from investigator, external investigation initiated.	Off-site toxic release with long term impacts
3	Medium	No health impacts; Aesthetic impact affecting a large population; Minor regulation breach (non-technical).	Off-site release with short term impact
2	Low	No health impacts; Aesthetic impact contained to a localised area; Minor regulation breach of a technical nature (no action or fines likely).	Onsite release; Possible outside assistance required
1	Insignificant	Isolated, transient incident; No health impacts and minimal aesthetic impact on a limited area; Minor breach that is reported via an annual return (no action or fines likely).	Contained onsite release, limited or no environmental impact, minimal rate of contamination.

The level of risk of each identified hazard was determined based upon the scores generated. Table 4 shows the risk level matrix that was utilised to rank the risks as low, moderate high and very high.

Table 4: Qualitative Risk Level Matrix

Likelihood	Consequences				
	1 - Insignificant	2 – Low	3 - Medium	4 - High	5 - Extreme
1	Low	Low	Low	High	High
2	Low	Low	Moderate	High	Very High
3	Low	Moderate	High	Very High	Very High
4	Low	Moderate	High	Very High	Very High
5	Low	Moderate	High	Very High	Very High

2.1.5 Hazard / Risk Assessment Review Results

Previous assessments identified hazards with maximum (uncontrolled) risk levels in the high and very high categories which were deemed unacceptable along with the control measures required to reduce residual (controlled) risks to low or moderate levels. This review assessment focussed on identifying changes in context or circumstance that add potential to impact hazards or controls in place.

Table 5, below, lists hazards where changes were identified, together with new hazards and the implications on the previous assessment. The table summarises hazards where circumstances have changed, or where new information was required for workshop participants to make a decision that was influenced by important uncertainties. In the latter case, actions were identified to clarify the potential hazard and consequent risk to reduce the uncertainties. The invited HWC and Orica representatives did not express concerns about the scheme and had taken part in multiple previous risk assessments for the scheme. As such, whilst invited, no HWC or Orica representatives were represented in the workshop. Therefore, where relevant, some of the identified upstream sewerage and Shortland WWTW risks, and the downstream end-user risks, will be referred to HWC and Orica, respectively, for their awareness and assessment and comment if they see fit.

It was noted that many risks hadn't previously been assessed but were merely included to enable them to be considered alongside their controls. Where this historical decision not to score some risks had been made, in most cases, SUEZ did not add new scores to those risks. Many of the unscored risks related to either HWC or Orica risks and controls and, therefore, those risks were retained more as a checklist of risks for noting by HWC and Orica and for those parties to consider in their risk assessments. However, newly added risks were scored. In addition, where it was considered warranted, some of the previously unscored risks were scored. In future there may be value in fully reviewing and revising the risk assessment and potentially removing or rescoring the remaining unscored risks. As part of beginning this process, during the 2018 review, a number of risks identified in previous risk assessments were removed (albeit retained in strikethrough font for traceability), due to them being no longer applicable and/or their coverage in other risks.

The full risk assessment, which includes details of the control measures and identification of CCPs is provided in Appendix 1.

Table 5: Re-assessed and New Potential Hazards and Risks Identified during the July 2018 HACCP Review

Risk Number	Workshop at which risk first identified	Process	Potential Hazard	Un-controlled Risk	Description of Change, Comment or Action
5	Risk Assessment 2009	Whole of Sewer Catchment	Whole of Sewer Catchment	Not scored	The inherent risk is scored as item number 1. HWC control this risk under existing programs. The assessment team mentioned the operations protocol with HWC and added the uncertainty in that protocol. A follow up action was recommended as follows: When next meeting with HWC ask them to acknowledge their role in controlling the sewer catchment and seek feedback on how risks from illegal inputs to the wastewater system are controlled. Document that feedback to help close out the identified uncertainty.
10	HACCP Oct 2011	General plant	Failure to implement the controls - risk rises towards inherent risk. Reconsidered to be high risk.	High	This risk has been previously rated with respect to the inherent risk. During the workshop the controlled risk was updated and scored as low.

Risk Number	Workshop at which risk first identified	Process	Potential Hazard	Un-controlled Risk	Description of Change, Comment or Action
11	HACCP Sept 2012	General plant	Analyser Failure/misreading	High	The inherent risk was reduced from 4-4 to 3-3 to align with item number 10. The controlled risk was reduced to 1-3 given the new controls in place and so the risk was considered acceptably low.
12	HACCP Sept 2012	General plant	Plant shutdown	Low	Updated the information on contingencies and rated the risk as inherently low due to the potable backup system being available to the customer.
21	Risk Assessment 2009	General plant	Failure to implement the controls - risk rises towards inherent risk	Not scored	This risk has been previously unrated with respect to the inherent risk. During the workshop the controlled risk was scored as low.
27	HACCP Sept 2012	Shortland WWTW	Alum dosing failure resulting in high TP Total Phosphorous	High	No longer a CCP for Suez and hence CCP1 is no longer part of the scheme. The Shortland WWTW and KIWS are split. HWC control the Shortland WWTW risks.
28	HACCP Sept 2012	Shortland WWTW	Aeration failure resulting in high TN	High	No longer a CCP for Suez and hence CCP1 is no longer part of the scheme. The Shortland WWTW and KIWS are split. HWC control the Shortland WWTW risks.
29	HACCP Sept 2012	Shortland WWTW	Alum dosing failure resulting in poor settleability - high TSS	Moderate	No longer a CCP for Suez and hence CCP1 is no longer part of the scheme. The Shortland WWTW and KIWS are split. HWC control the Shortland WWTW risks.
35	HACCP Sept 2012	Shortland WWTW	DO probe failure	Moderate	No longer a CCP for Suez and hence CCP1 is no longer part of the scheme. The Shortland WWTW and KIWS are split. HWC control the Shortland WWTW risks.
37	Risk Assessment 2009	Shortland WWTW	Poor total N removal due to WWTP operational problems leading to environmental impacts	Not scored	Although the scheme is compliant, there are challenges arising due to fluctuating ammonia concentrations in the influent. When next meeting with HWC ask them to consider how this fluctuation can be better controlled. Document that feedback to help keep a record of how this risk is being managed.
38	Risk Assessment 2009	Shortland WWTW	Excessive solids carryover or short circuit from decant leading to final recycled water contamination	Not scored	Added the new upstream turbidity meter to the list of monitoring and control processes documented.
79	HACCP Review 2016	KIWS plant influent	High salinity reaching the plant via Shortland WWTW	High	Added the new upstream EC meter to the list of monitoring and control processes documented.
80	HACCP Review 2016	KIWS plant influent	High salinity discharge from raw water tank to the environment	High	The risk struck through as it was either no longer relevant or covered in other risks.
81	HACCP Review 2016	KIWS plant influent	High chlorine levels that exceeds capacity of plant	Moderate	Added the new upstream chlorine analyser to the list of monitoring and control processes documented.

Risk Number	Workshop at which risk first identified	Process	Potential Hazard	Un-controlled Risk	Description of Change, Comment or Action
82	HACCP Review 2016	KIWS plant influent	High chlorine discharge from raw water tank to the environment	Moderate	Added the new upstream chlorine analyser to the list of monitoring and control processes documented. Noted that this is not a CCP but is a QCP for environmental risk.
84	HACCP Review 2016	KIWS plant influent	Process upset at Shortland WWTW pushing high Ammonia to KIWS, potentially causing a requirement to increase chlorine injection and discharge of product water outside of contractual limits for discharge of nitrogen or chloramines	High	Not a CCP for Suez and hence CCP1 is no longer part of the scheme. The Shortland WWTW and KIWS are split. HWC control the Shortland WWTW risks.
85	HACCP Review 2016	KIWS plant influent	Process upset at Shortland WWTW pushing high BOD on to KIWS, potentially causing fouling of membranes and an increase in the required frequency of backwash cycles and potentially a plant shutdown	Moderate	Not a CCP for Suez and hence CCP1 is no longer part of the scheme. The Shortland WWTW and KIWS are split. HWC control the Shortland WWTW risks. In addition, BOD_5 Analyser installed upstream of the plant to detect upstream process failure at the KIWS plant.
86	HACCP Review 2016	KIWS plant influent	Process upset at Shortland WWTW pushing high BOD on to KIWS, potentially high BOD discharge from raw water tank to environment	Low	Not a CCP for Suez and hence CCP1 is no longer part of the scheme. The Shortland WWTW and KIWS are split. HWC control the Shortland WWTW risks. In addition, BOD_5 Analyser installed upstream of the plant to detect upstream process failure at the KIWS plant.
87	HACCP Review 2016	KIWS plant influent	Process upset at Shortland WWTW pushing high Phosphorous to KIWS, potentially causing scaling and increased CIP, and discharge of product water outside of contractual limits	Moderate	Not a CCP for Suez and hence CCP1 is no longer part of the scheme. The Shortland WWTW and KIWS are split. HWC control the Shortland WWTW risks.
41	HACCP Oct 2011	KIWS Feed Tank	Online monitoring at the KIWS plant and if out of spec the valve will be closed and out of spec water diverted back to the River.	High	The risk was previously unscored and has now been scored after the instruments that have been commissioned were considered in rating the risk.
42	HACCP Oct 2011	KIWS Feed Tank	If out of spec water there is storage and Orica will be notified if this tank goes to Low level such that they can take potable water rather than recycled water.	Low	The risk was previously unscored and has now been scored.
43	HACCP Oct 2011	KIWS Feed Tank	Turbidity to monitor “Health” of Shortland WWTW	Not Scored	The risk struck through as it was either no longer relevant or covered in other risks.
45	HACCP Oct 2011	MF Backwash Return to Shortland WWTW	Concentration of pathogens from KIWS returned back to Shortland WWTW. 4 log of pathogens removed at KIWS are then become more concentrated before returning to KIWS.	Not Scored	Noted the Hunter Water trade waste agreements address this risk.
46	HACCP Sept 2012	Microfiltration	Pathogen breakthrough	High	Updated the list of controls.

Risk Number	Workshop at which risk first identified	Process	Potential Hazard	Un-controlled Risk	Description of Change, Comment or Action
47	HACCP Sept 2012	Microfiltration	Membrane Integrity Test (MIT) failure - false negative	High	Updated the list of controls.
48	HACCP Sept 2012	MF Backwash tank	None identified	Not Scored	The risk struck through as it was either no longer relevant or covered in other risks.
88	HACCP Review 2016	MF Backwash tank	Trade waste agreement (new contractual boundary)	Not Scored	The risk struck through as it was either no longer relevant or covered in other risks.
49	Risk Assessment 2009	Microfiltration	Membrane integrity failures such as broken fibres, leaky O rings etc, leading to sub-optimal removal of pathogens that results in final water being hazardous to health	Not Scored	The risk struck through as it was either no longer relevant or covered in other risks.
50	Risk Assessment 2009	Microfiltration	Backwash water backflow into the product water line	Not Scored	The risk struck through as it was either no longer relevant or covered in other risks.
51	Risk Assessment 2009	Microfiltration	Cleaning chemicals contaminating the product water causing health or environmental impacts	Not Scored	The risk struck through as it was either no longer relevant or covered in other risks.
52	HACCP Oct 2011	Reverse Osmosis	Cleaning chemicals contaminating the product water causing health or environmental impacts. Reconsidered to be low risk.	Not Scored	The risk struck through as it was either no longer relevant or covered in other risks.
53	HACCP Sept 2012	Reverse Osmosis	Pathogen breakthrough	High	Updated the list of controls.
54	HACCP Sept 2012	Reverse Osmosis	Free chlorine breakthrough upstream of RO	High	Updated the list of control instrumentation.
55	Risk Assessment 2009	Reverse Osmosis	Membrane integrity failures such as tears, leaky O rings etc, leading to suboptimal removal of pathogens that results in final water being hazardous to health	Not Scored	The risk struck through as it was either no longer relevant or covered in other risks.
56	Risk Assessment 2009	Reverse Osmosis	Concentrate bleed water flowing into the product water line	Not Scored	The risk struck through as it was either no longer relevant or covered in other risks.
57	Risk Assessment 2009	Reverse Osmosis	Cleaning chemicals contaminating the product water causing health or environmental impacts	Not Scored	The risk struck through as it was either no longer relevant or covered in other risks.
89	HACCP review 2016	Microfiltration & Reverse Osmosis	Instrument failure or lost signal	High	Critical Spares review process completed and noted in the controls.
58	HACCP Sept 2012	Chlorination	Instrument failure or lost signal	High	The risk struck through as it was either no longer relevant or covered in other risks.
59	HACCP Sept 2012	Chlorination	Pathogen breakthrough	High	Updated instrumentation used for control
60	HACCP Sept 2012	Chlorination	Total chlorine breakthrough.	Moderate	Contract compliance only
61	HACCP Sept 2012	Chlorination	Free chlorine analyser failure	Moderate	Updated control details

Risk Number	Workshop at which risk first identified	Process	Potential Hazard	Un-controlled Risk	Description of Change, Comment or Action
63	HACCP Oct 2011	Chemical Dosing	Over dosing of chemicals has potential to discharge chlorinated permeate to Hunter River.	Low	Risk scored
66	HACCP Sept 2012	Chloramine Dosing	High chloramine concentration leading to environmental (and membrane) impacts. Reconsidered based on design changes.	High	The risk struck through as it was either no longer relevant or covered in other risks.
67	HACCP Sept 2012	Dechlorination	Chlorinated flows being sent to Hunter River resulting in Suez not meeting license conditions.	High	The risk struck through as it was either no longer relevant or covered in other risks.
90	HACCP review 2016	Product water tank	Pathogen regrowth in tank when supply to Orica is not required	High	Updated controls.
68	Risk Assessment 2009	Distribution System	Cross-connections becoming excessive leading to too many people consuming the water as though it were drinking water and suffering health effects	Not Scored	The risk struck through as it was either no longer relevant or covered in other risks.
69	Risk Assessment 2009	Distribution System	Use of recycled water for planned flushing leading to environmental impacts	Not Scored	The risk struck through as it was either no longer relevant or covered in other risks.
92	HACCP Review 2018	Distribution System	Ingress of ground water into distribution pipe	Low	New risk added
70	Risk Assessment 2009	Distribution System	Discharge of recycled water via bursts, breaks (civil works) and leaks leading to environmental impacts	Low	Controls updated
71	Risk Assessment 2009	End uses	Orica staff not conforming to the end user controls - taking bottles of water home for demineralised water and then being consumed and causing health effects	Not Scored	Refer these hazard items to Orica for comment and confirmation that no changes have taken place which will affect the risk assessment.
72	Risk Assessment 2009	End uses	Orica staff not conforming to the end user controls - taking undue risks and becoming excessively exposed and causing health effects	Not Scored	Refer these hazard items to Orica for comment and confirmation that no changes have taken place which will affect the risk assessment.
73	Risk Assessment 2009	End uses	Off-site uses of recycled water such as tankers taking recycled water away for pressure vessel testing, but being used as drinking water and causing health effects	Not Scored	Refer these hazard items to Orica for comment and confirmation that no changes have taken place which will affect the risk assessment.
74	Risk Assessment 2009	End uses - cooling towers	Concentration of hazards in the water due to cycling leading to health or environmental impacts	Not Scored	Refer these hazard items to Orica for comment and confirmation that no changes have taken place which will affect the risk assessment.
75	Risk Assessment 2009	End uses - cooling towers	Excessive Legionella growth and health effects due to loss of control in response to the change in water quality, both moving to recycled water and changing between potable top up and recycled water in future	Not Scored	Refer these hazard items to Orica for comment and confirmation that no changes have taken place which will affect the risk assessment.

Risk Number	Workshop at which risk first identified	Process	Potential Hazard	Un-controlled Risk	Description of Change, Comment or Action
76	Risk Assessment 2009	End uses. Multiple Barriers	Multiple barrier process failure leading to pathogens breaking through and causing health effects. Orica staff not conforming to the end user controls - taking bottles of water home for demineralised water and then being consumed and causing health effects.	Not Scored	Risk no longer applicable so this row was marked in strikethrough.
77	Risk Assessment 2009	Storage (2 ML)	Pathogens and slimes growing in reservoir potentially more readily than in drinking water due to higher nutrients	Not Scored	Refer these hazard items to Orica for comment and confirmation that no changes have taken place which will affect the risk assessment.
78	Risk Assessment 2009	Storage (2 ML)	Ingress of pathogens into reservoir through bird and animal faeces leading to detectable E. coli counts health issues	Not Scored	Refer these hazard items to Orica for comment and confirmation that no changes have taken place which will affect the risk assessment.

2.1.6 Critical Control Points

Where additional hazards or changes to previously identified hazards impacted critical control points, these were re-assessed using the same methodology as adopted for the previous assessment, re-stated below for ease of reference:

A critical control point (CCP) is defined as: "a point, step or procedure at which control can be applied and a water quality hazard can be prevented, eliminated or reduced to acceptable levels" (Codex Alimentarius, 2010).

During the workshop the control measures identified to mitigate the identified risks were assessed in terms of their ability to prevent, eliminate hazards or reduce water quality risk.

The decision tree methodology shown in Figure 2 was followed to assess the hazards, risks and preventative measures with the aim of determining what qualifies as CCPs within the KIWS. Some professional judgement was applied in relation to nominated preventive measures as CCPs in cases where the decision tree was somewhat ambiguous, as is often the case in CCP identification processes.

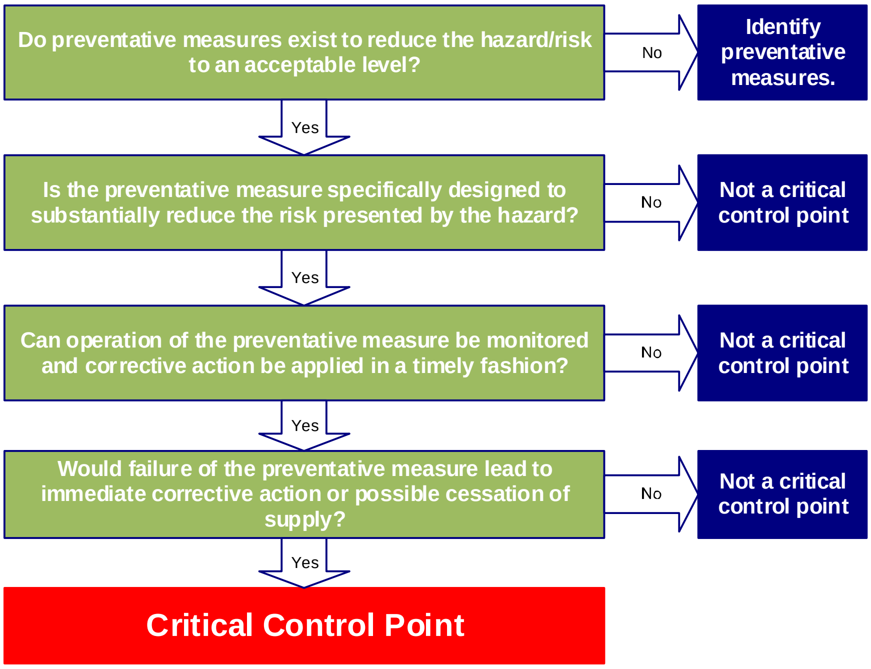


Figure 2: CCP Decision Tree (AGWR, 2006)

The workshop outcomes are located in the table in Appendix 1. No new CCPs were identified in the workshop, however additional instrumentation is now available which assists with monitoring parameters previously identified as CCPs (as noted on the flow diagram in Figure 1). In other cases CCPs were revised to reflect changes in scheme ownership, as follows:

The Shortland WWTW (formally CCP1) – **Aeration cycle dissolved oxygen level and alum dosing rate**

- This was previously considered a CCP but was removed from the scope of this HACCP Plan as it falls outside KIWS boundary and is managed by HWC at Shortland WWTP. Going forward, the identity and term CCP1 will not be used at KIWS, but is noted to have been historically referring to the upstream processes managed by HWC. This retention of the historical numbering system will ensure all current and historical documentation pertaining to CCP2, CCP3, and CCP4 does not change. However, CCP1 is no longer considered part of this RWMP.

QCP3 (formally CCP5) – **Dechlorination before discharge to Hunter River – ORP**

- This fifth CCP was reviewed and changed to a QCP, numbered QCP3, since it related to environmental rather than health concerns. That does not take away from its importance, but merely reflects that CCPs are typically focused on significant health risks. No change to the operation of former CCP5, now QCP3, results from this change of classification.

2.1.7 Action Plan

Actions identified for follow-up are summarised in Table 6, and relate to Orica and HWC follow up to ensure stakeholder and supplier/customer relationships are clear and understood.

Table 6: Follow up actions Identified during July 2018 HACCP Review

Hazard Reference	Action	Responsibility
5	When next meeting with HWC ask them to acknowledge their role in controlling the sewer catchment and seek feedback on how risks from illegal inputs to the wastewater system are controlled. Document that feedback to help close out the identified uncertainty.	SUEZ and HWC
37	Although the scheme is compliant, there are challenges arising due to fluctuating ammonia concentrations in the influent. When next meeting with HWC ask them to consider how this fluctuation can be better controlled. Document that feedback to help keep a record of how this risk is being managed.	SUEZ and HWC
71 to 75 and 77 to 78	Refer these hazard items to Orica for their awareness and seek comment and confirmation that no changes have taken place which will affect the risk assessment.	SUEZ and Orica

APPENDIX 1: KIWS HACCP Risk Assessment - July 2018

Number	Workshop at which this risk was first added	Process Step Name	Potential Hazardous Event Description	Further Comments/Description: C=chemical; P=physical; M=microbial; E=environmental; H=Health	Uncontrolled Risk: Consequence	Uncontrolled Risk: Likelihood	Uncontrolled Risk: Risk Level	Do control measures exist for this Hazard? (yes/no)	Control Measures to be Considered	Controlled Risk: Consequence	Controlled Risk: Likelihood	Controlled Risk: Risk Level	CCP Question 1	CCP Question 2	CCP Question 3	CCP Question 4	CCP?	Uncertainty 30 July 2018: Significant uncertainty identified?	Uncertainty 30 July 2018: Description of uncertainty/comment/action	Risk Assessment Review 31 May 2016: Changes identified?	Risk Assessment Review 31 May 2016: Description of change/comment/action
1	HACCP Oct 2011	Whole of Sewer Catchment	Reconsidered and remains a valid risk - Illegal dumping occurs yearly from tanker delivery. Continuity of discharge is the consequence on the biological plant.	E/H - Caused by phenolics, aromatic hydrocarbons or toxic heavy metals, leading to pathogens and nutrients and carbonaceous material getting through	3	4	High	Yes	HWC control this risk. Trade Waste Agreements are in place to control this risk. Education of the general public via training, website etc such that they know what shouldn't be put to sewer.	Not Scored		Not Scored	Y	Y	N	N	No	No		No	
2	Risk Assessment 2009	Whole of Sewer Catchment	Planning permits allow new development into the sewer catchment which mean the plant cannot treat the sewage	M/H/C/P - Excessive loads	Not Scored		Not Scored	Yes	Flow is monitored Section 50 approval required under HWC Act for new developments Plant has EP design well above current inputs	1	1	Low	Y	Y	N	N	No	No		No	
3	Risk Assessment 2009	Whole of Sewer Catchment	Illegal dumping into the sewer that may influence membrane (fouling, damage) resulting in a health/environmental impact	E/H - Petrochemicals, diesel	Not Scored		Not Scored	Yes	Dilution is an inherent control for small, household scale dumping events Operator observation and response for plant, when plant manned, and pump stations Public reporting of odour leading to response On line detection and response to low DO events On line detection and response at downstream controls on membranes	1	2	Low	Y	Y	N	N	No	No		No	
4	Risk Assessment 2009	Whole of Sewer Catchment	Illegal dumping that may influence biological treatment leading to poor N and C removal or poor pathogen or hazardous chemical removal for a few weeks or more	E/H - Caused by phenolics, aromatic hydrocarbons or toxic heavy metals, leading to pathogens and nutrients and carbonaceous material getting through	Not Scored		Not Scored	Yes	Dilution is an inherent control for small, household scale dumping events Operator observation and response for plant, when plant manned, and pump stations Public reporting of odour leading to response for some substances On line detection and response to low DO events On line detection and response at downstream controls on membranes	1	3	Low	Y	Y	N	N	No	No		No	
5	Risk Assessment 2009	Whole of Sewer Catchment	Illegal Dumping that damages end use causing health or environmental impacts	E - Toxic and radiological chemicals, Heavy metals, including Cd and strontium	Not Scored		Not Scored	Yes	Dilution is an inherent control Trade waste controls for known hazardous discharges Sludge would typically concentrate the hazardous chemicals out of the water phase and they are monitored for metals RO would largely reject the hazardous chemicals Operations protocol requires HW to notify Suez in the event of a non compliance	1	1	Low	Y	Y	N	N	No	Yes	Effective management is Hunter Water responsibility. Notify Hunter Water via risk assessment report.	No	
6	Risk Assessment 2009	Whole of Sewer Catchment	Pathogen loading from outbreaks in the catchment leading to levels of pathogens too great to be handled by treatment leading to health impacts for recycled water users	H - Pathogens	Not Scored		Not Scored	Yes	Public health notification and surveillance system would detect the outbreak and lead to review of risks Treatment barriers typically perform better than their worst-case performance so the log credits are typically much greater than the required levels	2	2	Low	Y	Y	N	N	No	No		No	
7	Risk Assessment 2009	Whole of Sewer Catchment	Endocrine disrupting chemicals getting through the process causing health and environmental effects	EDCs	Not Scored		Not Scored	Yes	Secondary sewage treatment RO treatment End use is not drinking water	1	1	Low	Y	Y	N	N	No	No		No	
8	Risk Assessment 2009	Whole of Sewer Catchment	Excess household disinfectants and pool chemicals use impacting downstream use	E/H - Bleach	Not Scored		Not Scored	Yes	Dilution is an inherent control for small, household scale dumping events. Operator observation and response for plant, when plant manned, and pump stations. Public reporting of odour leading to response for some substances. On line detection and response to low DO events. On line detection and response at downstream controls on membranes	1	3	Low	Y	Y	N	N	No	No		No	
9	Risk Assessment 2009	Whole of Sewer Catchment	Tree root control agents having a downstream impact on use	E - Root foam	Not Scored		Not Scored	Yes	End use does not include irrigation Dilution is an inherent control HWC operators oversee the application and control the dose Activity is localised	1	1	Low	Y	N	N	N	No	No		No	
10	HACCP Oct 2011	General Plant	Failure to implement the controls - risk rises towards inherent risk. Reconsidered to be high risk.	E/H - All	3	3	High	Yes	Implementation of RWQMP	3	1	Low	Y	N	N	N	No	No		No	
11	HACCP Sept 2012	General Plant	Analyser Failure/misreading	C, M	3	3	High	Yes	All analysers were serviced upon handover. Laboratory equipment was replaced. The laboratory manual was added. The analyser service os now managed by the maintenance system. Daily check by operator. Rotational calibration/maintenance by operators or technicians - maintenance schedule. Chloramine analyser on service agreement. Ability to put plant shut down hold on during calibration.	1	3	Low	Y	Y	Y	N	No	No		No	
12	HACCP Sept 2012	General Plant	Plant shutdown	P, M, C	1	1	Low	No	Customer has alternative water (potable supply). Diesel flush pump available to flush and protect RO membranes.	1	1	Low	N	N	Y	N	No	No		No	
13	HACCP Sept 2012	General Plant	Lock out under power failure	P	2	1	Low	No		2	1	Low	N	N	Y	N	No	No		No	
14	Risk Assessment 2009	General Plant	Instrument failure	-	Not Scored		Not Scored	Yes	Covered under supporting programs - O&M and HAZOP			Not Scored	Y	Y	N	N	No	No		No	
15	Risk Assessment 2009	General Plant	Instrument calibration out of spec	-	Not Scored		Not Scored	Yes	Covered under supporting programs - Calibration program			Not Scored	Y	Y	N	N	No	No		No	
16	Risk Assessment 2009	General Plant	Global power failure	-	Not Scored		Not Scored	Yes	Covered under supporting programs - O&M and HAZOP			Not Scored	Y	Y	N	N	No	No		No	
17	Risk Assessment 2009	General Plant	Local power failure to process leading to acute load of excessive contamination reaching WRP	-	Not Scored		Not Scored	Yes	Covered under supporting programs - O&M and HAZOP			Not Scored	Y	Y	N	N	No	No		No	

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18	Risk Assessment 2009	General Plant	Training	-	Not Scored		Not Scored	Yes	Covered under supporting programs - Training			Not Scored	Y	Y	N	N	No	No		No	
19	Risk Assessment 2009	General Plant	Materials and chemicals	-	Not Scored		Not Scored	Yes	Covered under supporting programs - Materials and chemicals			Not Scored	Y	Y	N	N	No	No		No	
20	Risk Assessment 2009	General Plant	Chemical quality	-	Not Scored		Not Scored	Yes	Covered under supporting programs - Materials and chemicals			Not Scored	Y	Y	N	N	No	No		No	
21	Risk Assessment 2009	General Plant	Failure to implement the controls - risk rises towards inherent risk	E/H - All	Not Scored		Not Scored	No	RWQMP PLC & SCADA controls	3	1	Low	Y	Y	N	N	No	No		No	
22	HACCP Oct 2011	Shortland WWTW	Chlorination not sufficient		Not Scored	1	Not Scored	Yes	Monitored daily by the operator. Have Free chlorine analyser at KIWS and topping up pre MF so not an issue really.	Not Scored		Not Scored	Y	N	N	N	No	No		No	
23	HACCP Oct 2011	Shortland WWTW	Phosphorous levels		Not Scored	1	Not Scored	No	Look at on line "Phosphate" monitor to pre MF	Not Scored		Not Scored		Y	N	N	No	No		No	
24	HACCP Oct 2011	Shortland WWTW	Poor total N removal due to WWTP operational problems leading to environmental impacts. Reconsidered to be low risk.	E - Nitrogen	Not Scored	1	Not Scored	No		Not Scored		Not Scored	N	N	N	N	No	No		No	
25	HACCP Oct 2011	Shortland WWTW IDAL	Continuity issue with regards capacity. If 1 IDAL was off line for a few hours 12 MLD could be treated by the other IDAL for a few hours only if an equipment failure occurred.		Not Scored	1	Not Scored	Yes	Redundancy in the equipment, aerators.	Not Scored		Not Scored	Y	Y	N	N	No	No		No	
26	HACCP Oct 2011	Shortland WWTW Inlet Works	Increased use of the wet weather ponds		Not Scored	1	Not Scored	No	Limitation of the flows due to pump capacity and PLC code. Risk of algae transfer through the plant. Short term loss of capacity of the plant.	Not Scored	2	Not Scored	Y	N	N	N	No	No		No	
27	HACCP Sept 2012	Shortland WWTW	Alum dosing failure resulting in high TP Total Phosphorous	C	3	3	High	Yes	Alarm on alum dosing pumps - signal from pumps. Another measure to ensure dosing flow is present - operator daily check.	1	3	Low	Y	Y	N	N	No	No		No	
28	HACCP Sept 2012	Shortland WWTW	Aeration failure resulting in high TN	C	3	3	High	Yes	Operator monitoring. Online alarms.	1	3	Low	Y	Y	N	N	No	No		No	
29	HACCP Sept 2012	Shortland WWTW	Alum dosing failure resulting in poor settleability - high TSS	P	2	3	Moderate	Yes	Alarm on alum dosing pumps - signal from pumps. Another measure to ensure dosing flow is present - operator daily check. Weekly settleability manual sampling/analysis (frequency to be reviewed during commissioning)	1	3	Low	Y	Y	N	N	No	No		No	
30	HACCP Sept 2012	Shortland WWTW	Wet weather event causing quality change. TSS will change quickly.	P	3	3	High	Yes	Consider alarm at Shortland WWTW indicating that it is operating in wet weather mode to potentially increase frequency sampling.	1	3	Low	Y	Y	N	N	No	No		No	
31	HACCP Sept 2012	Shortland WWTW	Decant failure.	P	2	3	Moderate	Yes	Alarms.	1	3	Low	Y	Y	N	N	No	No		No	
32	HACCP Sept 2012	Shortland WWTW	High DO	C	2	3	Moderate	Yes	Online monitoring. Alarms	1	3	Low	Y	Y	Y	N	No	No		No	
33	HACCP Sept 2012	Shortland WWTW	Trade waste	C	3	2	Moderate	Yes	DO monitoring. Dilution. Tankers no longer delivering waste to site	1	2	Low	Y	Y	N	N	No	No		No	
34	HACCP Sept 2012	Shortland WWTW	Sludge bulking - slow	C,P	2	3	Moderate	Yes	Weekly SVI testing.	1	3	Low	Y	Y	N	N	No	No		No	
35	HACCP Sept 2012	Shortland WWTW	DO probe failure	C,P	2	3	Moderate	Yes	Two in each tank with discrepancy alarm.	1	3	Low	Y	Y	N	N	No	No		No	
36	HACCP Sept 2012	Shortland WWTW	High ammonia resulting in high chlorine demand.	C	2	3	Moderate	Yes	Manual data collection - auto-notification.	1	3	Low	Y	Y	Y	N	No	No		No	
37	Risk Assessment 2009	Shortland WWTW	Poor total N removal due to WWTP operational problems leading to environmental impacts	E - Nitrogen	Not Scored		Not Scored	Yes	Regulatory controls on HWC and Orica discharges Customer contract controls between HWC and Orica Plant currently operated to remove nitrogen and monitored against that (both process and receiving water monitoring) Some further reduction through RO (~60%)	2	5	Moderate	Y	Y	N	N	No	No		No	
38	Risk Assessment 2009	Shortland WWTW	Excessive solids carryover or short circuit from decant leading to final recycled water contamination	E/H - Pathogens, solids, metals, etc	Not Scored		Not Scored	Yes	Catch pond to catch over flow On line turbidity at inlet to recycled water plant linked to response in the event of high turbidity Operator observations Membrane processes downstream Head loss and back wash cycle rates. Turbidimeter installed at Dechlorination building (before KIWS raw water tank)	1	1	Low	Y	Y	N	N	No	No		No	
39	Risk Assessment 2009	Shortland WWTW	PLC fails and doesn't alarm at the same time as a failure	E/H - Pathogens, nutrients	Not Scored		Not Scored	Yes	PLC failure is detected and leads to an alarm in its own right - failsafe design Valve shuts to protect the environment if the PLC or power fails and diverts sewage to the storage ponds	1	1	Low	Y	Y	Y	N	No	No		No	
40	Risk Assessment 2009	Shortland WWTW and UV system	Bypass of the WWTW so that raw sewage reaches the water recycling plant due to operator error or sabotage leading to health impacts or environmental impacts	E/H - Pathogens, Carbon	Not Scored		Not Scored	Yes	Valves and alarms in place to ensure that only treated secondary effluent is pumped to KIWS.	1	2	Low	Y	Y	N	N	No	No		No	
79	HACCP Review 2016	KIWS plant influent	High salinity reaching the plant via Shortland WWTW	C	3	4	High	Yes	New instrumentation and alarms and automatic diversion (by Hunter Water) away from KIWS. Conductivity meter installed at Dechlorination building (before KIWS raw water tank)	3	1	Low	Y	Y	Y	N	No	No		Yes	New instrument will be available for monitoring
80	~~HACCP Review 2016~~	~~KIWS plant influent~~	~~High salinity discharge from raw water tank to the environment~~	~~E~~	~~3~~	4	High	~~Yes~~	~~New instrumentation and alarms and automatic diversion (by Hunter Water) away from KIWS~~	~~3~~	~~1~~	~~Low~~	~~Y~~	~~Y~~	~~Y~~	~~N~~	No	No		~~Yes~~	~~New instrument will be available for monitoring. Consequence rating assumes that there is an environmental license limitation on salinity discharge to river - to be checked to confirm that this is a CCP~~
81	HACCP Review 2016	KIWS plant influent	High chlorine levels that exceeds capacity of plant	C	3	2	Moderate	Yes	New instrumentation and alarms and automatic diversion (by Hunter Water) away from KIWS. Chlorine meter installed at Dechlorination building (before KIWS raw water tank)	3	1	Low	Y	Y	Y	N	No	No		Yes	New instrument will be available for monitoring

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82	HACCP Review 2016	KIWS plant influent	High chlorine discharge from raw water tank to the environment	E	3	2	Moderate	Yes	New chlorine instrumentation and alarms and automatic diversion away from KIWS. Suez has a licence with conditions.	3	1	Low	Y	Y	Y	N	No	No		Yes	New instrument will be available for monitoring. Assessment assumes the level of chlorine coming on to plant may exceed capacity of SBS system to neutralise free chlorine
83	HACCP Review 2016	KIWS plant influent	Process upset at Shortland WWTW pushing high TSS on to KIWS, potentially causing blinding of strainers and MF fouling	C, P	3	4	High	Yes	New instrumentation (turbidity) and alarms and automatic diversion (by Hunter Water) away from KIWS	3	1	Low	Y	Y	Y	N	No	No		Yes	New instrument will be available for monitoring
84	HACCP Review 2016	KIWS plant influent	Process upset at Shortland WWTW pushing high Ammonia to KIWS, potentially causing a requirement to increase chlorine injection and discharge of product water outside of contractual limits for discharge of nitrogen or chloramines	C, P	3	4	High	Yes	Refer Shortland WWTW HACCP	2	5	Moderate	Y	Y	N	N	No	No		Yes	Assumes timely communication
85	HACCP Review 2016	KIWS plant influent	Process upset at Shortland WWTW pushing high BOD on to KIWS, potentially causing fouling of membranes and an increase in the required frequency of backwash cycles and potentially a plant shutdown	M, C	3	2	Moderate	Yes	Refer Shortland WWTW HACCP for CCP on aeration, and New instrumentation (BOD) and alarms and automatic diversion (by Hunter Water) away from KIWS	3	1	Low	Y	Y	N	N	No	No		Yes	BOD trend can be used to review cause
86	HACCP Review 2016	KIWS plant influent	Process upset at Shortland WWTW pushing high BOD on to KIWS, potentially high BOD discharge from raw water tank to environment	E	3	1	Low	Yes	Refer Shortland WWTW HACCP for CCP on aeration, and New instrumentation (BOD) and alarms and automatic diversion (by Hunter Water) away from KIWS Level monitoring in raw water tank and automatic diversion (by Hunter Water) away from KIWS	3	1	Low	Y	Y	N	N	No	No		Yes	BOD trend can be used to review cause
87	HACCP Review 2016	KIWS plant influent	Process upset at Shortland WWTW pushing high Phosphorous to KIWS, potentially causing scaling and increased CIP, and discharge of product water outside of contractual limits	C	2	4	Moderate	Yes	Refer Shortland WWTW HACCP for CCP on alum dosing, and Lab monitoring	2	3	Moderate	Y	Y	N	N	No	No		Yes	Assumes timely communication
41	HACCP Oct 2011	KIWS Feed Tank	Online monitoring at the KIWS plant and if out of spec the valve will be closed and out of spec water diverted back to the River.		3	3	High	Yes	Control measures have been implemented with analysers upstream (at dechlorination building) of the plant bypass Refer to abovementioned risk for influent water	3	1	Low	Y	Y	N	N	No	No		Yes	New instruments will be available for monitoring, these to be considered in HACCP review for Shortland WWTW.
42	HACCP Oct 2011	KIWS Feed Tank	If out of spec water there is storage and Orica will be notified if this tank goes to Low level such that they can take potable water rather than recycled water.		1	4	Low	Yes	Communication with Orica Potable water backup supply	1	4	Low	Y	Y	N	N	No	No		No	
43	~~HACCP Oct 2011~~	~~KIWS Feed Tank~~	~~Turbidity to monitor "Health" of Shortland WWTW~~		~~Not Scored~~		~~Not Scored~~	~~Yes~~	~~Turbidity as CCP. Need to assess maintenance requirements and timing of turn around to fix analyser. Review need for spares. Review operational parameters for alarms such that turbidity spikes do not issue an alarm to operators.~~	~~Not Scored~~		~~Not Scored~~	~~N~~	~~N~~	~~N~~	~~N~~	~~No~~	~~No~~		~~Yes~~	~~Instrument availability has been assessed and confirmed as part of SUEZ FMECA.~~
44	HACCP Sept 2012	Autostrainers	Issues with biological build-up in strainers	P	2	4	Moderate	Yes	Chloramine dosing upstream to minimise fouling. New turbidity instrumentation at the dechlorination building	1	2	Low	Y	N	N	N	No	No		Yes	Additional instrumentation now available for monitoring
45	HACCP Oct 2011	MF Backwash Return to Shortland WWTW	Concentration of pathogens from KIWS returned back to Shortland WWTW. 4 log of pathogens removed at KIWS are then concentrated up and then returned back to Shortland WWTW.				Not Scored	Yes	Backwash returned from KIWS is of better quality than the raw sewage currently received and Hunter Water trade waste agreements address this risk. It can be assumed that Shortland WWTW will continue to reduce pathogens through the biological process. As long as operation remains within design parameters this risk is covered by the existing CCPs and additional instrumentation allows direct monitoring for turbidity, nitrogen and chlorination.	Not Scored		Not Scored	Y	N	N	N	No	No		Yes	Additional instrumentation is now available for monitoring. Further data should be gathered to confirm treatment efficacy to allow this question to be addressed quanitiatively should it be raised in subsequent reviews. See also item 88.
46	HACCP Sept 2012	Microfiltration	Pathogen breakthrough	M	3	3	High	Yes	Plant shut down. Manual closing of valve so that RO feed tank overflows. MIT, turbidity monitoring . Maintenance management plan implemented	1	3	Low	Y	Y	Y	Y	Yes	No		No	
47	HACCP Sept 2012	Microfiltration	Membrane Integrity Test (MIT) failure - false negative	P	3	3	High	Yes	Alarms. Skid shutdown interlock.	1	3	Low	Y	Y	Y	Y	Yes	No		No	
48	~~HACCP Sept 2012~~	~~MF Backwash tank~~	~~None identified~~				~~Not Scored~~	~~No~~		~~Not Scored~~	~~1~~	~~Not Scored~~						~~No~~		~~No~~	
88	~~HACCP Review 2016~~	~~MF Backwash tank~~	~~Trade waste agreement (new contractual boundary)~~				~~Not Scored~~	~~No~~	~~Auto sampler~~	~~Not Scored~~		~~Not Scored~~						~~No~~		~~Yes~~	~~Refer discussion against item 45.~~
49	~~Risk Assessment 2009~~	~~Microfiltration~~	~~Membrane integrity failures such as broken fibres, leaky O rings etc, leading to sub-optimal removal of pathogens that results in final water being hazardous to health~~	~~H - Pathogens~~	~~Not Scored~~		~~Not Scored~~	~~Yes~~	~~Upstream and downstream controls.~~ ~~Parallel systems, more than one membrane skid.~~ ~~Procurement of appropriate parts and fittings.~~ ~~Pressure decay integrity testing to detect these types of failures at regular intervals linked to response, alarm to operator.~~ ~~Filtrate turbidity on line and alarmed leading to response, probably automated shut off.~~ ~~Downstream storage which has dilution and supply continuity/response time benefits~~	~~1~~	~~2~~	~~Low~~	~~Y~~	~~Y~~	~~Y~~	~~Y~~	~~Yes~~	~~No~~		~~No~~	
50	~~Risk Assessment 2009~~	~~Microfiltration~~	~~Backwash water backflow into the product water line~~	~~H - Pathogens~~	~~Not Scored~~		~~Not Scored~~	~~Yes~~	~~Designed out in this system~~	~~Not Scored~~		~~Not Scored~~						~~No~~		~~No~~	~~Check historical data on MF integrity to validate claim.~~
51	~~Risk Assessment 2009~~	~~Microfiltration~~	~~Cleaning chemicals contaminating the product water causing health or environmental impacts~~	~~E/H - Possibly hypo, caustic, sulphuric acid, hydrochloric acid, citric acid etc~~	~~Not Scored~~		~~Not Scored~~	~~Yes~~	~~Reverse osmosis membranes downstream. CIP is automated EFP and recovery cleans would be automated. Training in relation to chemical controls. pH monitoring downstream with follow-up of alarm limits~~	~~1~~	~~1~~	~~Low~~	~~Y~~	~~Y~~	~~Y~~	~~N~~	~~No~~	~~No~~		~~No~~	~~Turbidity and ORP instruments also provide means of monitoring.~~
52	~~HACCP Oct 2011~~	~~Reverse Osmosis~~	~~Cleaning chemicals contaminating the product water causing health or environmental impacts. Reconsidered to be low risk.~~	~~E/H - Possible caustic, antiscalants, etc~~			~~Not Scored~~	~~No~~	~~Designed out in this system~~	~~Not Scored~~		~~Not Scored~~						~~No~~		~~No~~	
53	HACCP Sept 2012	Reverse Osmosis	Pathogen breakthrough	M	3	3	High	Yes	Conductivity on each stage on SCADA. Conductivity and LRV on combined flow. Shut down of stage.	1	3	Low	Y	Y	Y	Y	Yes	No		No	

					Uncontrolled Risk					Controlled Risk			CCP Question					Uncertainty 30 July 2018		Risk Assessment Review 31 May 2016	
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54	HACCP Sept 2012	Reverse Osmosis	Free chlorine breakthrough upstream of RO	C, P	3	3	High	Yes	ORP meter - online Free Ammonia meter - online Chloramine meter - online Shutdown interlock in control system	1	3	Low	Y	Y	Y	N	No	No		Yes	SUEZ to check the available documentation is current. If so, prepare RFI to HWC to query why this was not considered / included as part of CCP3 which does not mention SBS dosing, Ammonia dosing or ORP monitoring. Refer section 4.4.2 of supplementary design report
~~55~~	~~Risk Assessment 2009~~	~~Reverse Osmosis~~	~~Membrane integrity failures such as tears, leaky O rings etc, leading to suboptimal removal of pathogens that results in final water being hazardous to health~~	~~H - Pathogens~~	~~Not Scored~~		~~Not Scored~~	~~Yes~~	~~Upstream WWTW, UV, MF and Chloramine and exposure controls. Parallel systems, more than one membrane skid. Procurement of appropriate parts and fittings. Permeate EC on line and alarmed leading to response, probably automated shut off. Downstream storage which has dilution and supply continuity/response time benefits~~	~~2~~	~~2~~	~~Low~~	~~Y~~	~~Y~~	~~Y~~	~~N~~	~~No~~	No		~~No~~	~~From early risk assessment. Details covered in other parts of this risk assessment (multiple barrier approach)~~
~~56~~	~~Risk Assessment 2009~~	~~Reverse Osmosis~~	~~Concentrate bleed water flowing into the product water line~~	~~H - Pathogens~~	~~Not Scored~~		~~Not Scored~~	~~Yes~~	~~Designed out in this system~~	~~Not Scored~~		~~Not Scored~~						~~No~~		~~No~~	
~~57~~	~~Risk Assessment 2009~~	~~Reverse Osmosis~~	~~Cleaning chemicals contaminating the product water causing health or environmental impacts~~	~~E/H - Possible caustic, antiscalants, etc~~	~~Not Scored~~		~~Not Scored~~	~~Yes~~	~~Designed out in this system~~	~~Not Scored~~		~~Not Scored~~						~~No~~		~~No~~	
89	HACCP review 2016	Microfiltration & Reverse Osmosis	Instrument failure or lost signal	P, C, M	3	3	High	Yes	Plant shut-down. Criticality review completed. Appropriate spares now carried.	2	1	Low	Y	Y	N	N	No	No		No	This supports identification of the individual trains as QCPs
~~58~~	~~HACCP Sept 2012~~	~~Chlorination~~	~~Instrument failure or lost signal~~	~~P, C, M~~	~~3~~	~~3~~	~~High~~	~~Yes~~	~~Plant shut-down. Consider multiple instruments/critical spares for critical instrumentation. Sum readings where multiple trains are involved.~~	~~2~~	~~1~~	~~Low~~	~~Y~~	~~Y~~	~~Y~~	~~Y~~	~~Yes~~	~~No~~		~~Yes~~	~~The original wording of this suggests that the risk is identified for MF and RO, and not chlorination – hence this has been included in item 89 above.~~
59	HACCP Sept 2012	Chlorination	Pathogen breakthrough	M	3	3	High	Yes	Free chlorine analyser upstream and downstream of CCT. Flow meter upstream of CCT. Temperature and pH included to set the CT target. CT target set to ensure adequate pathogen removal.	2	1	Low	Y	Y	Y	Y	Yes	No		No	
60	HACCP Sept 2012	Chlorination	Total chlorine breakthrough in product water tank	C	2	3	Moderate	Yes	Total chlorine analyser downstream of CCT Shutdown interlocks in place.	2	1	Low	Y	Y	Y	N	No	No		No	Not mentioned in CCP5 for dechlorination, probably as this is related only to contractual limits? Prepare RFI to HWC.
61	HACCP Sept 2012	Chlorination	Free chlorine analyser failure	M	2	3	Moderate	Yes	Duty/duty analysers. Program discrepancy alarm between two analysers - plant shut down if discrepancy is detected. Operator maintenance of analyser.	2	1	Low	Y	Y	N	N	No	No		No	CCP4
62	HACCP Sept 2012	Chlorination	High Ct value - increase in TDS due to increase in chlorine dose	C, P	3	3	High	Yes	TDS increase in final product will be minimal. Flow control enabled to reduce chance of requiring increase in hypochlorite dose to meet Ct.	1	3	Low	Y	Y	Y	N	No	No		No	
63	HACCP Oct 2011	Chemical Dosing	Over dosing of chemicals has potential to discharge chlorinated permeate to Hunter River.	C, E	3	1	Low	Yes	Dechlorination on line to Hunter River	3	1	Low	Y	N	N	N	No	No		No	
64	HACCP Sept 2012	Dechlorination	SBS doing affects pH.	C, E	1	2	Low	Yes		1	2	Low	Y	Y	Y	N	No	No		No	
65	HACCP Sept 2012	Chemical Dosing	Sulphuric acid malfunction causing high pH	C	2	1	Low	Yes	pH monitoring downstream of MF.	2	1	Low	Y	Y	N	N	No	No		No	
66	~~HACCP Sept 2012~~	~~Chloramine Dosing~~	~~High chloramine concentration leading to environmental (and membrane) impacts. Reconsidered based on design changes.~~	~~E - Chlorine or chloramine~~	~~3~~	~~3~~	~~High~~	~~Yes~~	~~Ammonia meter - online to ensure no free chlorine passes through RO membranes. Final disinfection with hypochlorite downstream of RO membranes. Dechlorination available.~~	~~1~~	~~3~~	~~Low~~	~~Y~~	~~Y~~	~~N~~	~~N~~	~~No~~	~~No~~		~~No~~	
~~67~~	~~HACCP Sept 2012~~	~~Dechlorination~~	~~Chlorinated flows being sent to Hunter River resulting in Suez not meeting license conditions.~~	~~C, E~~	~~3~~	~~3~~	~~High~~	~~Yes~~	~~Dosing and instrumentation provided to dechlorinate off spec water. Free chlorine and total chlorine analysers.~~	~~1~~	~~3~~	~~Low~~	~~Y~~	~~Y~~	~~Y~~	~~N~~	~~No~~	~~No~~		~~No~~	~~CCP5.~~
90	HACCP review 2016	Product water tank	Pathogen regrowth in tank when supply to Orica is not required	M	3	3	High	Yes	SOP - rechlorinate / recycle water in tank. Chlorine analysers. Tank inspections. Meeting requirements of customer.	3	1	Low	N	N	N	N	No	No			Research configuration to confirm available controls
~~68~~	~~Risk Assessment 2009~~	~~Distribution System~~	~~Cross-connections becoming excessive leading to too many people consuming the water as though it were drinking water and suffering health effects~~	~~H - Pathogens, Chemicals~~	~~Not Scored~~		~~Not Scored~~	~~Yes~~	~~Backflow prevention within the site (HWC)~~ ~~Backflow prevention on site (Orica)~~ ~~There is a break tank air gap top up for the existing fire fighting storage would provide the backup water (Orica)~~ ~~Pressure lower in recycled water lines, not pressurised on site until within tower basis which are fed by air break tanks (Orica)~~ ~~Plumbing modification and control procedure for plumbing works (Orica)~~	~~E~~	~~2~~	~~Moderate~~	~~Y~~	~~Y~~	~~N~~	~~N~~	~~No~~	~~No~~		~~yes~~	~~Use of 'E' during earlier risk assessment prevented automatic risk calculation. Consequence unknown~~ ~~No longer applicable~~
~~69~~	~~Risk Assessment 2009~~	~~Distribution System~~	~~Use of recycled water for planned flushing leading to environmental impacts~~	~~E - Chloramine~~	~~Not Scored~~		~~Not Scored~~	~~Yes~~	~~Notify DECC in the event of planned activities.~~ ~~Discharge to less sensitive receiving environments where possible.~~	~~3~~	~~1~~	~~Low~~	~~Y~~	~~Y~~	~~N~~	~~N~~	~~No~~	~~No~~		~~yes~~	~~Not applicable~~

Number	Workshop at which this risk was first added	Process Step Name	Potential Hazardous Event Description	Further Comments/Description: C=chemical; P=physical; M=microbial; E=environmental; H=Health	Uncontrolled Risk: Consequence	Uncontrolled Risk: Likelihood	Uncontrolled Risk: Risk Level	Do control measures exist for this Hazard? (yes/no)	Control Measures to be Considered	Controlled Risk: Consequence	Controlled Risk: Likelihood	Controlled Risk: Risk Level	CCP Question 1	CCP Question 2	CCP Question 3	CCP Question 4	CCP?	Uncertainty 30 July 2018: Significant uncertainty identified?	Uncertainty 30 July 2018: Description of uncertainty/comment/action	Risk Assessment Review 31 May 2016: Changes identified?	Risk Assessment Review 31 May 2016: Description of change/comment/action
92	HACCP Review 2018	Distribution System	Ingress of ground water into distribution pipe	C, M, P	2	1	Low	Yes	Pressurised pipe. Flow meters with discrepancy monitoring will alert to sudden flow events due to bursts/breaks. Fusion welded polypipe.	2	1	Low	N	N	N	N	No	No			
70	Risk Assessment 2009	Distribution System	Discharge of recycled water via bursts, breaks (civil works) and leaks leading to environmental impacts	E - Chloramine	2	2	Low	Yes	Minimise discharge of water to the environment where possible through response. Flow meters with discrepancy monitoring will alert to sudden flow events due to bursts/breaks. Dial-before-you-dig linked to pipe location maps/GIS Standard operating procedure/response to minimise discharge through isolation valves and repair of fault. Fusion welded polypipe.	2	1	Low	Y	Y	N	N	No	No		No	Pipeline maintenance to be captured in environmental and asset management plans
91	HACCP Review 2016	Brine Disposal	Breakage of pressurised underground pipework to manhole E9583	E	3	2	Moderate	Yes	Dial-before-you-dig linked to pipe location maps/GIS Standard operating procedure/response to minimise discharge	3	1	Low	n	n	n	n	No	No		Yes	New risk identified, capture inspection and maintenance requirements in asset management plan
71	Risk Assessment 2009	End uses	Orica staff not conforming to the end user controls - taking bottles of water home for demin water and then being consumed and causing health effects	H - Pathogens and perception of pathogens	Not Scored		Not Scored	Yes	Control by Orica	1	1	Low	Y	Y	N	N	No	Yes	Orica to advise their controls	Unknown	Refer to Orica for comment
72	Risk Assessment 2009	End uses	Orica staff not conforming to the end user controls - taking undue risks and becoming excessively exposed and causing health effects	H - Pathogens and perception of pathogens	Not Scored		Not Scored	Yes	Control by Orica	1	1	Low	Y	Y	N	N	No	Yes	Orica to advise their controls	Unknown	Refer to Orica for comment
73	Risk Assessment 2009	End uses	Off-site uses of recycled water such as tankers taking recycled water away for pressure vessel testing, but being used as drinking water and causing health effects	H - Pathogens and perception of pathogens	Not Scored		Not Scored	Yes	Control by Orica	1	1	Low	Y	Y	N	N	No	Yes	Orica to advise their controls	Unknown	Refer to Orica for comment
74	Risk Assessment 2009	End uses - cooling towers	Concentration of hazards in the water due to cycling leading to health or environmental impacts	E/H - Chemicals	Not Scored		Not Scored	Yes	Control by Orica	2	2	Low	Y	Y	N	N	No	Yes	Orica to advise their controls	Unknown	Refer to Orica for comment
75	Risk Assessment 2009	End uses - cooling towers	Excessive *Legionella* growth and health effects due to loss of control in response to the change in water quality, both moving to recycled water and changing between potable top up and recycled water in future	H - *Legionella*	Not Scored		Not Scored	Yes	Control by Orica	2	2	Low	Y	Y	N	N	No	Yes	Orica to advise their controls	Unknown	Refer to Orica for comment
~~76~~	~~Risk Assessment 2009~~	~~Multiple Barriers~~	~~Multiple barrier process failure leading to pathogens breaking through and causing health effects. Orica staff not conforming to the end user controls - taking bottles of water home for demineralised water and then being consumed and causing health effects.~~	~~H - Pathogens~~	~~Not Scored~~		~~Not Scored~~	~~Yes~~	~~Multiple barriers. Downstream barriers often stop operating inherently if upstream barriers fail. Exposure controls. Oversight by regulator and audits. Two separate plants (WWTW, WRP) PLC controls with UPS. Automated monitoring. Manual checks and attendance at plants. Supporting programs (maintenance, training etc.). Verification testing of recycled water quality weekly. HAZOP process to failsafe design where practicable, e.g. loss of power = loss of pumps, interlocks etc. Best practice approach. Proven technologies. Worst case assumptions used in guidelines and process design and operation. Critical limit monitoring at control points with shut down. Independent monitoring at each control point.~~	~~1~~	~~2~~	~~Low~~	~~Y~~	~~Y~~	~~N~~	~~N~~	~~No~~	~~No~~		~~No~~	~~Superseded by subsequent risk assessments~~
77	Risk Assessment 2009	Orica storage and network	Pathogens and slimes growing in reservoir potentially more readily than in drinking water due to higher nutrients	H - Pathogens	Not Scored		Not Scored	Yes	Control by Orica	Not Scored		Not Scored	Y	N	N	N	No	Yes	Orica to advise their controls	Unknown	Refer to Orica for comment
78	Risk Assessment 2009	Orica storage and network	Ingress of pathogens into reservoir through bird and animal faeces leading to detectable E. coli counts health issues	H - Pathogens	Not Scored		Not Scored	Yes	Control by Orica	Not Scored		Not Scored	Y	N	N	N	No	Yes	Orica to advise their controls	Unknown	Refer to Orica for comment

APPENDIX 2: KIWS HACCP Risk Assessment Background Information Report 2018

APPENDIX C: Hazard Analysis and Critical Control Point (HACCP) Hunter H2O Report 2022.

hunterh2o

Kooragang Industrial Water Scheme

HACCP Report

Water Utilities Australia

APRIL 2022

ABN 16 602 201 552

Report Details

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Contents

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Appendices

1 Introduction

The purpose of this Hazard Analysis and Critical Control Point (HACCP) report is to develop and consolidate the key risks and management approaches for the Kooragang Industrial Water Scheme (KIWS) in which produced water is utilised by third party commercial end users, Orica and new proposed end user NCIG.

The KIWS follows the *Australian Guidelines for Water Recycling 2006: Managing Health and Environmental Risks (Phase 1)*. This scheme uses treated effluent from the Shortland WWTW managed by Hunter Water and is then treated at the advanced treatment plant at Mayfield West which is owned by Kooragang Pty Ltd (KPL) and is operated by SUEZ.

It should be noted that this HACCP report follows on from several previous HACCP assessments and respective reports, which is summarised in Section 1.1 and Section 2. It is recommended that the previous HACCP report (Kooragang Industrial Water Scheme Hazard Analysis & Critical Control Points (HACCP) Plan Review 2018, SUEZ) provided as Appendix A, is read to provide full background to this this assessment.

The scope of this HACCP workshop was to provide a review of the previous HACCP which was undertaken under by SUEZ and to review the SUEX risk definitions so as to transfer risks to KWPL/WUA (revise the SUEZ risk definitions to align with KWPL/WUA risk definitions). The risk workshop also reviewed risks of the proposed new end user of the scheme NCIG.

1.1 Summary of HACCP Workshops

Table 1-1: HACCP Workshop and Activities Timeline

Timeline	Summary of HACCP Activities	HACCP Owner
2012	A HACCP Plan was originally drafted following a risk assessment workshop held on 10 August 2012. The workshop at the time was aimed at determining the potential hazards and preventative measures in place for the KIWS – when the scheme was owned and operated by Hunter Water. From the workshop the original HACCP Plan and Report was produced.	HW
2016	The HACCP Plan was updated by SUEZ during June 2016 during which a risk assessment was undertaken to assess the specific risks to the end users as summarised in the Hazard Analysis and Critical Control Point (HACCP) Plan. The HACCP Plan was independently reviewed and updated during both July and October 2016	SUEZ
2018	The HACCP Plan was independently reviewed and updated in 2018. One of the major outcomes in 2018 was to remove the overflow CCP (CCP 5) from the RWMP and reassign it as a QCP (QCP3). That change took place following the July 2018 review.	SUEZ
2022 (this update	To review the SUEZ risk assessment and transfer to KWPL/WUA risk profile. To review the risks associated with the new proposed end user (NCIG)	KWPL/ WUA

1.2 Report Structure

This report provides background to the KIWS, including a description of the treatment process and its pathogen log reduction capability and a comparison of the log reduction capability of the treatment process against the end use requirements. This provides context to the discussions that were held at the HACCP workshops. Following the background information on the schemes, the methodology and findings of the HACCP workshop.

2 Background

The Kooragang Industrial Water Scheme (KIWS) has been operating since November 2014 supplying Recycled Water to Orica. Initially, the scheme was then owned and managed by Hunter Water.

Ownership of part of the scheme was transferred to Water Utilities Australia (WUA) in 2017, via its subsidiary Kooragang Water Pty Ltd (KWPL) who then engaged SUEZ for operation of the scheme. Under this licensing regime the scheme operation has been governed by a SUEZ Recycled Water Management Plan. The end user of the scheme Orica, continued to be the primary end user of the KIWS and Orica's potable water supply (including for top up/backup supply for industrial use) while produced by Hunter Water, is sold through KIWS under a retail licence.

The contract and asset Ownership Structure of the scheme is summarised below in Figure 2-1

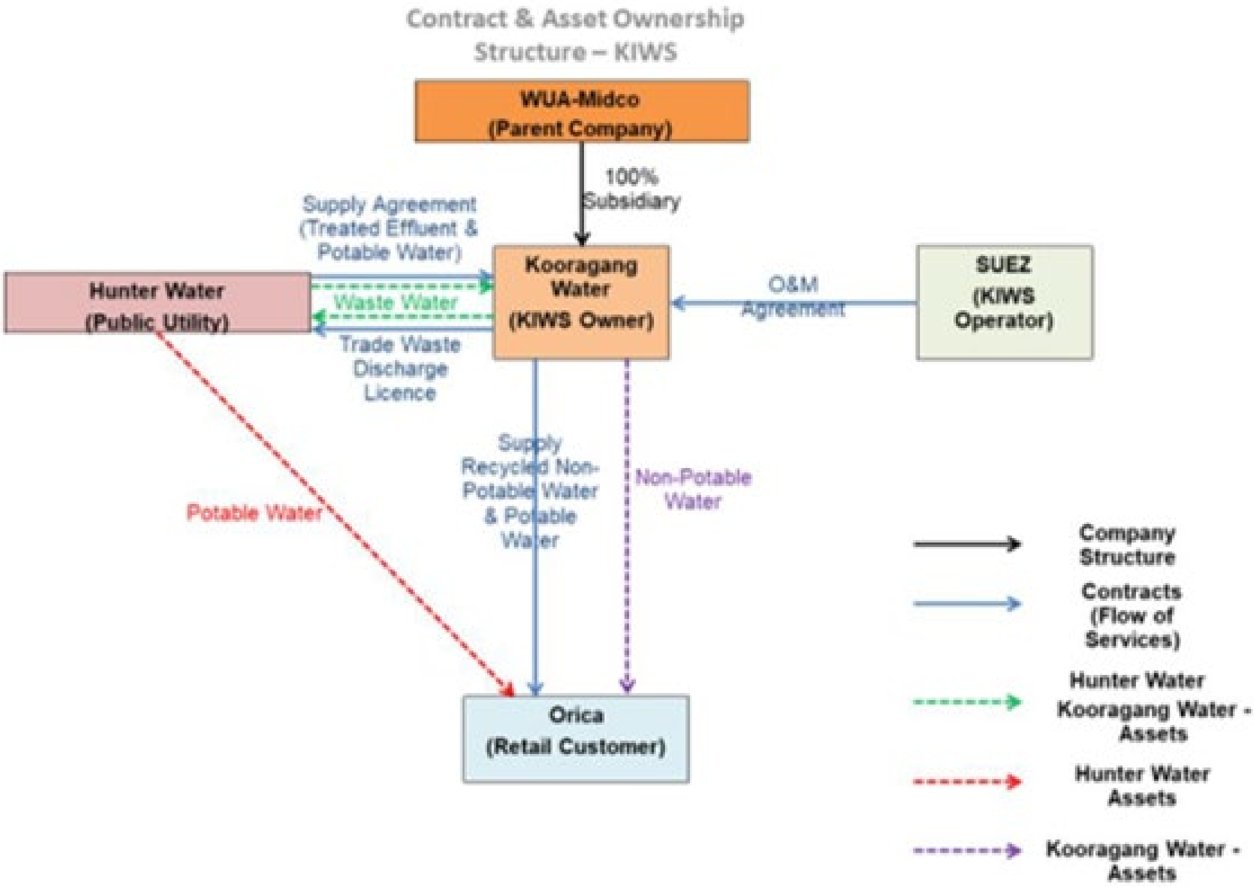


Figure 2-1: Corporate Structure and Interaction

During the transition of ownership to KWPL, the boundary of management responsibility was split between Hunter Water Corporation (HW) and KWPL. HW retains responsibility for the operation of Shortland Wastewater Treatment Works (WWTW) and KWPL now has operational responsibility for the Kooragang Industrial Water Scheme (KIWS) and distribution to the end user of the water (Orica).

The day-to-day operation of KIWS is managed by SUEZ under a long term Operations and Maintenance Agreement with KWPL.

The scheme was established initially to supply Recycled Water to Orica and is currently being expanded to supply Recycled Water to a new industrial customer, Newcastle Coal Infrastructure Group ('NCIG').

3 Treatment and Log Reduction Targets

3.1 Shortland WWTW

The AWTP processes uses treated effluent from Hunter Water's Shortland Wastewater Treatment Works (WWTW) that would otherwise be directed for marine discharge at the Hunter River.

The Shortland WWTW is a secondary treatment wastewater treatment plant which has the following major treatment steps

- **Primary Treatment**
  - Provides screening and grit removal
- **Secondary Biological Treatment**
  - Through treatment within an Intermediately Aerated Decant Lagoons (IDAL)
- **Disinfection**
  - Using chlorination

Following disinfection if the required quality which meets the supply contract requirements it is then provided to KIWS. If the effluent does not meet quality requirements the effluent is then diverted away from KIWS where the effluent is then dechlorinated and discharged to the environment (South Channel Hunter River).

As outlined the operations and management of Shortland WWTW is within Hunter Water's area of responsibility and the supply interface is managed through a contractual supply agreement between Hunter Water and KWPL. The agreement includes key effluent quality parameters and limits which are monitored via online instrumentation at the supply/diversion point. These online analysers and contractual limits are automated within the Hunter Water SCADA system to divert the effluent from KIWS to the Hunter River if quality is not achieved.

A summary of the contractual effluent quality parameters and limits are provided in Table 3-1

Table 3-1: Shortland WWTW Effluent Quality Requirements

Shortland Parameter	Unit	Maximum Allowable Limit	Sample Method	Frequency	Monitor Location	KIWS Cut-off Values below only recorded whilst the Shortland Facility effluent pump is operating	HWC (Shortland effluent) Cut-in Values below only recorded whilst the Shortland Facility effluent pump is operating
Turbidity	NTU	25	Online	10% over rolling 48 hr period	Downstream of Shortland Facility Effluent Transfer Pump	No more than 10% of values can be above the Maximum Allowable Limit over a rolling 48-hour period. These are the values included in the calculation of the rolling 48hr period.	Once 90% or more of values are below the Maximum Allowable Limit over a rolling 24-hour period. These are the values included in the calculation of the rolling 24hr period.
Conductivity	µS/cm	1700	Online	10% over rolling 24 hr period	Downstream of Shortland Facility Effluent Transfer Pump	No more than 10% of values can be above the Maximum Allowable Limit over a rolling 24-hour period. These are the values included in the calculation of the rolling 24hr-period.	Once 90% or more of values are below the Maximum Allowable Limit over a rolling 24-hour period. These are the values included in the calculation of the rolling 24hr period.
Total Chlorine	mg/L	7	Online	10% over rolling 24 hr period	Downstream of Shortland Facility Effluent Transfer Pump	No more than 10% of values can be above the Maximum Allowable Limit over a rolling 24-hour period. These are the values included in the calculation of the rolling 24hr period.	Once 90% or more of values are below the Maximum Allowable Limit over a rolling 24-hour period. These are the values included in the calculation of the rolling 24hr period.

3.2 KIWS

The KIWS AWTP has the following major process steps, which are also illustrated on the following pages as Figure 3-1:

- ***Chloramine Dosing***
  - Chlorine is dosed at Shortland WWTW. However, chlorine can be hazardous to RO membranes. Therefore, chloramine dosing occurs upfront of the auto strainers. This is to prevent microbiological growth through the plant and ensure that there is no free chlorine in the system that may damage RO membranes.
- ***Auto Strainers***
  - To provide physical protection for the MF system.
- ***Microfiltration***
  - The MF system has a nominal pore size of 0.1 µm. It consists of three trains each with a maximum continuous feed flow of 16.3 L/s (total 49 L/s). The membranes removal some of pathogens and suspended solids, and also protects the RO membranes
- ***Reverse Osmosis***
  - The primary purpose of the RO process is the removal of dissolved salts, pathogens and all other particulates. The Ro processes consists of four (4) trains (single pass, two stages) that are fed from the RO feed water tank via cartridge filters.
- ***Degas Tower***
  - RO permeate enters the Degas Tower, air introduced into the tower passes up through the RO permeate. Internal packing media within the tower assists in maximising the exposure of permeate with air to ensure CO2 in the final water is brought out of solution and released as a gas.
- ***Disinfection***
  - Sodium hypochlorite is dosed into the feed main upstream of the chlorine contact tank (CCT). The aim of the CCT is to achieve 4 Log virus reduction by chlorine inactivation. The required dose or Ct is 11 mg.min/L. Chlorination also assist in the prevention of algal and biological growth in storage and distribution system.
- ***Product Water Tank***
  - The product water tank provides 4.2 ML storage equating to approximately 12 hours hydraulic retention time. A magnetic flow meter is located on the outlet to the product water tank to accurately record flows to the end user.
- ***On-site Service Water***
  - A service water system is provided using product water stored in the product water tank.. The service water system provides water for the following applications:
    - Carrier water for the sulphuric acid dosing
    - Carrier water for the chloramine dosing using aqueous ammonia
    - Carrier water for the chloramine dosing using sodium hypochlorite
    - Hose reels for wash down
- ***Product Water Pumps***
  - The product water pumps transfer water from the product water tank to the end users and are located outside adjacent to the Product Water tank.

3.3 Transfer Pipelines

3.3.1 Orica

Recycled Water is transferred from the product water tank to Orica via a DN400 x 8 km pipeline.

3.3.2 NCIG

Recycled Water is to be transferred from product water tank to NCIG via a 70m x DN200 branch connection to the main DN400 x 8 km pipeline. This Branch connection is to be located approx. 5.2km from the KIWS Plant

3.4 End Users

Recycled Water from KIWS is supplied to Orica and to be supplied to NCIG. The customer end uses for the Recycled Water are summarised in Table 3-2.

Table 3-2 Uses of Recycled Water

Category of Use	Customer	End Use
Industrial Use (Unrestricted)	Orica	Process water
Industrial Use (Unrestricted) Fire Fighting	NCIG	Process water Onsite Fire Fighting Systems
AWTP on site reuse	Self (SUEZ, operator of KWPL)	On site plant uses, e.g. hose down, chemical dosing

Potential routes of exposure for each of the intended end-uses are listed in Table 3-3.

Table 3-3 Routes of Exposure

Intended End Use		Route of Exposure
Industrial Use (Unrestricted)	Orica NCIG	Ingestion of water from sprays Inhalation of water from sprays during operation/maintenance of processes Contact with water from sprays during operation/maintenance of processes
Fire Fighting	NCIG	During firefighting activities, exposure to fire fighters through: Ingestion of water from sprays Inhalation of water from sprays during dust suppression and fires
AWTP on site reuse	KIWS	Ingestion of water from sprays Inhalation of water from sprays during operation/maintenance of processes Contact with water from sprays during operation/maintenance of processes

3.4.1 Orica

Orica Kooragang is an industrial manufacturing plant for ammonia, carbon dioxide, ammonium nitrate and nitric acid. The facility includes an ammonia plant, three nitric acid plants, two ammonium nitrate plants and a product dispatch facility.

- Ammonia Plant
- Nitric Acid Plants
- Ammonium Nitrate Plants

Recycled Water is used extensively onsite for industrial applications, in cooling towers and demineralisation processes. Due to these end uses the water from AWTP at KI has a lower mineral content to prevent scaling.

When the scheme was established, Orica undertook an internal exposure and WH&S assessment to determine end uses, potential worker exposure and required WH&S measures to manage the employee risks associated with the use of Recycled Water on their site.

3.4.2 NCIG

KWPL has been in discussions with Newcastle Coal Infrastructure Group (NCIG) to supply NCIG with Recycled Water for their onsite industrial uses. The current demand for potable water at NCIG is currently in the order of approximately 400 – 500ML/yr. KWPL are looking to upgrade the current treatment process to accommodate for the additional volume demand for NCIG. This upgrade will *not* require any additional supply from Shortland WWTW to supply NCIG.

NCIG currently uses potable water and onsite captured stormwater within its raw water supply system for its operation. Recycled Water will be used by NCIG to supplement the sites raw water system. The introduction of Recycled Water will reduce the volume of potable water that is required on site for NCIG's industrial processes. NCIG's raw water system also supplies its firefighting ring main across the site.

NCIG's existing raw water system has been setup to preferentially use captured stormwater over potable water supply where conditions permit. When demand exceeds availability of captured stormwater, potable water is drawn to supplement supplies. It is anticipated that Recycled Water, once connected, will be drawn to supplement the sites raw water system preferentially over potable water where conditions permit.

NCIG's raw water system is used for the following activities on site

- Dust suppression supply water (stockpile yard sprays, dump station unloading sprays, conveyor dust and belt washing sprays, stacker/reclaimer and ship loader wetting and dust suppression sprays).
- Process water supply hoses throughout inbound (Trains), stockyard area (coal stockpiling) and outbound (Ship loading) areas. Raw water is also used for wash downs of hardstand areas, vehicles and other coal handling equipment.
- Water supply for onsite veneering activities. Veneering activities involve the mixing of raw water with veneering product before it is sprayed onto coal stockpiles to assist with minimising dust generation.

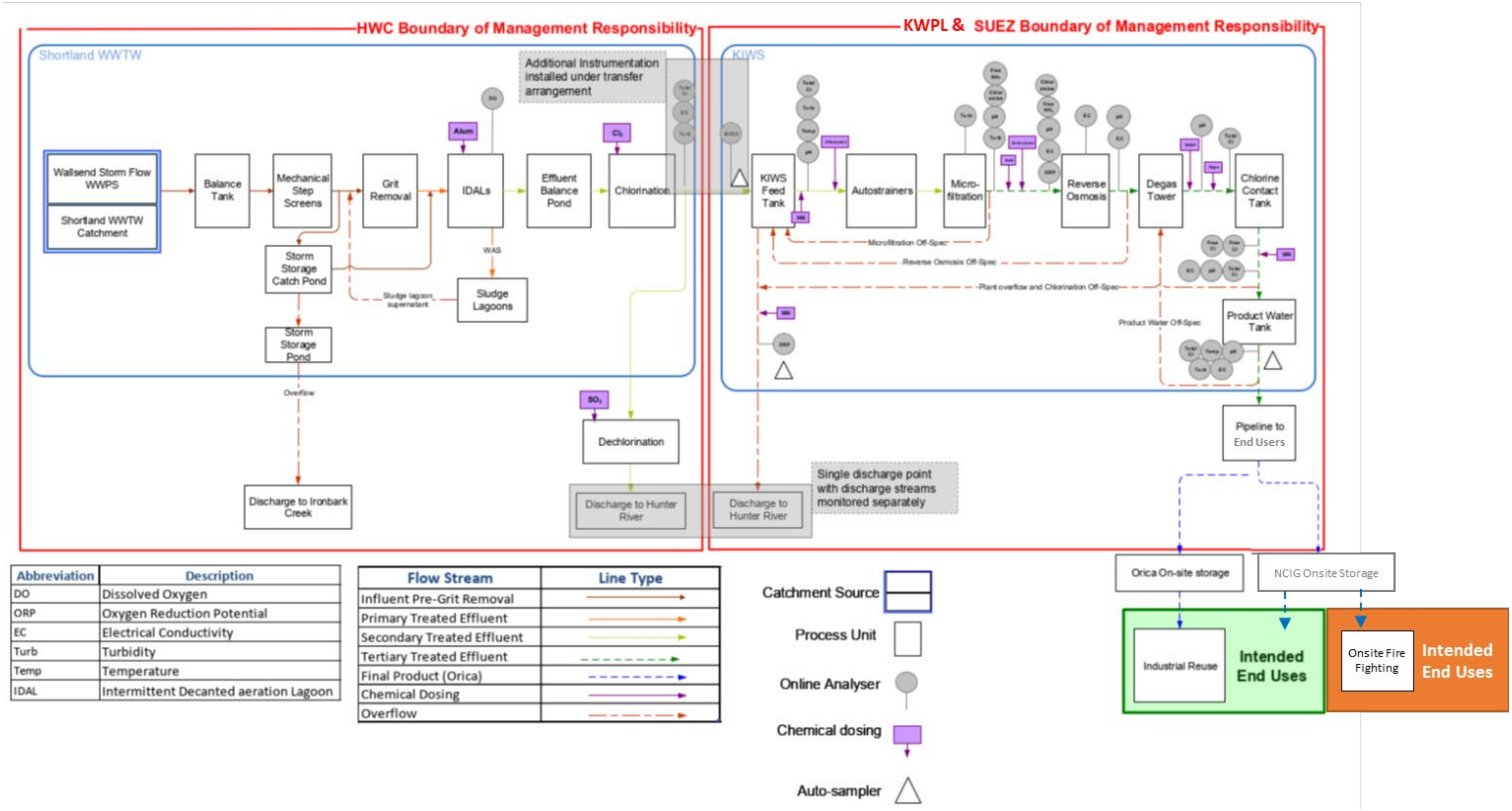
NCIG has backflow prevention on its incoming potable water supply to site which is tested annually. Potable water supply to site buildings and staff/contractor amenities will remain unchanged as they are not connected to the site raw water system.

NCIG have reviewed their own site supply systems and will be responsible for the management of Recycled Water at their premises beyond the metering/connection point (point of delivery). NCIG will be provided with a contractual Recycled Water quality at the point of delivery by WUA. The management of Recycled Water beyond this point will be responsibility of NCIG.

NCIG have undertaken an extensive review of the use of Recycled Water onsite in consultation with their respective operational teams and has undertaken a site-based risk assessment to address the proposed introduction of Recycled Water at its operation.

NCIG is currently in the process of developing a Recycled Water Management Plan which will document and provide guidance on how Recycled Water will be safely reused on its site for its intended end uses. Based on discussions with NCIG, the Recycled Water will be used as a supplementary water source for its raw water supply system.

NCIG is directly engaging with NSW Fire to discuss the proposed use of Recycled Water within its raw water system which supplies its firefighting infrastructure.



Abbreviation	Description
DO	Dissolved Oxygen
ORP	Oxygen Reduction Potential
EC	Electrical Conductivity
Turb	Turbidity
Temp	Temperature
IDAL	Intermittent Decanted aeration Lagoon

Flow Stream	Line Type
Influent Pre-Grit Removal	
Primary Treated Effluent	
Secondary Treated Effluent	
Tertiary Treated Effluent	
Final Product (Orica)	
Chemical Dosing	
Overflow	

Figure 3-1: Summary of the Shortland WWTW and KIWS Scheme

4 Log Reduction Targets

4.1 Current Scheme Log Reduction Values

The current scheme, with Orica as the end user, uses the Recycled Water for onsite industrial purposes and has a Log Reduction Value (LRV) target of [Virus, Protozoa, Bacteria (V;P;B) of 5.1; 3.6; 3.8. With the current treatment process claiming [Virus, Protozoa, Bacteria (V;P;B) of 5.5; 5; 9. As shown in Table 4-1

Table 4-1: Summary of the Claimed and Target Log Reduction Values

Pathogen	Virus	Protozoa	Bacteria
Target LRV	**5.1**	**3.6**	**3.8**
Claimed Process			
Microfiltration	0.5	4	4
Reverse Osmosis	1	1	1
Chlorination	4	0	4
Total KIWS Process Claimed LRV	**5.5**	**5.0**	**9.0**

4.2 Current CCPs

To ensure that Recycled Water meets the quality and LRV requirements the current scheme has the following CCPs, adjustment and critical limits, as shown on the following page.

Table 4-2: Current CCPs and Limits

Process or Step to be monitored	Parameter to be monitored	Monitoring location	Frequency	Unit	Control Limits		Corrective Action(s) – to be applied when Critical Limits are exceeded.
					Alert Limit	Critical Limit	
Membrane filtration (CCP2 and QCP1)	Turbidity (related to CCP2)	Combined permeate	Continuous Online	NTU	> 0.10 NTU for > 15 min	> 0.15 NTU for > 40 min	• Verify combined turbidity meter result and calibrate meter if required • Shut down entire MF system and investigate output from individual trains • Undertake a PDT on each MF train and view the process to identify any module faults. • Isolate and repair any leaking valves • Isolate and repair any identified membrane faults (broken fibres, o-rings)
	Turbidity (related to QCP1)	Individual trains	Continuous Online	NTU	> 0.20 NTU for > 10 min	> 0.3 NTU for > 20 min	• Verify individual turbidity meter result and calibrate meter if required • Investigate and isolate individual train/s if they are exceeding the turbidity limit using online turbidity meter on individual trains • Undertake a PDT on each MF train and view the process to identify any module faults. • Isolate and repair any leaking valves • Isolate and repair any identified membrane faults (broken fibres, o-rings)
	Pressure Decay Rate (related to CCP2)	Membrane skid	Daily online	kPa/5 min	PDT > 7 kPa	PDT > 7 kPa for three consecutive tests OR PDT > 10 kPa for an individual test	• Shut down MF system following a critical failure Isolate train that is exceeding PDT value • Repeat PDT and view the process to identify any module faults. • Isolate and repair any identified membrane faults (broken fibres, o-rings) • Isolate and repair any valve leaks
	Electrical	Combined permeate	Continuous	µS/cm	> 40 µS/cm	> 70 µS/cm	

Process or Step to be monitored	Parameter to be monitored	Monitoring location	Frequency	Unit	Control Limits		Corrective Action(s) – to be applied when Critical Limits are exceeded.
					Alert Limit	Critical Limit	
Reverse Osmosis (CCP3 and QCP2)	Conductivity	(related to CCP3)	Online		for > 30 min	for > 60 min	• Investigate the EC of the individual trains • Investigate whether there has been a chemical clean or module replacement • Take samples and verify the feed and permeate EC meters, calibrate/replace if required • Shutdown train/s that have high permeate EC and investigate cause • Check delivered maintenance equals planned maintenance • Check dosing of acid and antiscalant • Check the performance of each train, are the trains highly fouled and in need of chemical cleaning?
		EC of the combined permeate compared to the EC of the feed to calculate the Log reduction of EC over RO process (related to CCP3)	Continuous Online	%	< 94% reduction in EC for > 30 min (94% is equivalent to an LRV of 1.22)	< 90% reduction in EC for > 60 min (90% equivalent to an LRV of 1.0)	
Chlorination System (CCP4)	Ct	CCT outlet (related to CCP4)	Continuous Online	mg•min/L	< 13 mg.min/L (pH < 7.5) for > 20 min < 30 mg.min/L (pH > 7.5 and < 9.0) for > 20 min	< 11 mg.min/L (pH < 7.5) for > 20 min < 27 mg.min/L (7.5 < pH < 9) for > 20 min	• Divert off-spec water, continue to operate to bring plant back into control • Investigate and verify the chlorine meter readings and calibrate/replace if required • Investigate and verify the pH meter readings and calibrate/replace if required • Investigate the chlorine dosing system operation and control • Investigate set-points and upstream operations than could influence pH and chloramine dosing levels.
	pH	CCT outlet (related to CCP4)	Continuous Online	pH units	> 7.5 for > 30 min	> 9 for > 10 min	
	Temperature	CCT outlet (related to CCP4)	Continuous Online	°C		< 10 for > 10 min	

4.2.1 Proposed Additional LRV Credits

As previously outlined the Recycled Water is also intended to be used onsite and potentially for use in firefighting systems at NCIG. In review of the current Scheme LRV and fire fighting LRV targets, as shown in Table 4-3, the current scheme has a deficit to meet these fire fighting requirements.

Table 4-3: Fire Fighting Target and Claimed Log Reduction Values

Pathogen	Virus	Protozoa	Bacteria
Current Target LRV	**5.1**	**3.6**	**3.8**
Current Claimed Process	5.5	5	9
Fire Fighting Target	**6.5**	**5.1**	**5.3**
Current Differential	**-1**	**-0.1**	**+3.7**

To address the additional LRV requirements KWPL proposed approach is to gain additional log credits is through two additional monitoring points/parameters, as outlined in Table 4-4.

Table 4-4: Proposed additional monitoring points/parameters

	Process Point	Description	Monitoring & Control
1	Effluent transfer point to KIWS (from Shortland WWTW)	The quality monitoring point of Turbidity becomes a new Critical Control Point to gain an additional 0.5 log credit (V, P, B) from Shortland WWTW.	KWPL will control the process supply and if the new CCP Target/limits are not met supply to NCIG will cease, however Recycled Water production will continue for Orica. As a result, KIWS has full control over the new CCP points/targets and there is no impact to the current Hunter Water arrangement. This point and control of the process will be with KIWS. If the Turbidity quality is exceeded Recycled Water to NCIG will cease, however production to Orica will continue.
2	KIWS RO	The KIWS process will have additional calcium monitoring across the RO system to gain additional 0.5 log credit (V,P,B)	Change in [Ca], to calculate the log reduction of [Ca] over the RO process, is the newly added critical limit for the existing process and this is readily achieved based on historical performance. Weekly testing using the onsite laboratory to compare the Calcium ion [Ca] of the combined permeate to the feed. EC provides a more frequent online monitoring parameter as an ongoing surrogate, as per the current (The drop in EC must exceed 90%). If the EC quality is exceeded Recycled Water to NCIG will cease, however production to Orica will continue.

In applying the additional monitoring points and parameter the adjusted LRV against the firefighting (NCIG) would be sufficient as shown in Table 4-5.

Table 4-5: Proposed Additional LRVs

Pathogen	Virus	Protozoa	Bacteria
Fire Fighting (NCIG) Target LRV	**6.5**	**5.1**	**5.3**
Proposed Claim of Process			
Shortland WWTW (new)	*0.5*	*0.5*	*0.5*
Microfiltration	0.5	4	4
Reverse Osmosis *(LRV increased)*	~~1~~ *1.5*	~~1~~ *1.5*	~~1~~ *1.5*
Chlorination	4	0	4
Total KIWS Process Claimed LRV	**4.0**	**0.0**	**4.0**
Differential	**0**	**+ 0.9**	**+4.7**

4.3 Proposed CCPs and Monitoring

As outlined in Table 4-4 2 additional monitoring had been proposed to support the additional LRV claim. Before the workshop and with initial correspondence with NSW Health a new CCP1 and additional parameters and limits associated with CCP2 were proposed to ensure Recycled Water quality was meeting the LRV treatment levels, this is shown in Table 4-6 with additional information and changes italicised.

It should be noted that the current treatment process (without additional LRV claim) meets Orica's LRV requirements, as a result the additional LRV would only apply to the stream being supplied to NCIG. If the additional quality requirement for turbidity, can't be achieved at any time Recycled Water would continue to Orica. This is illustrated in Figure 4-1, on the page following Table 4-6.

Table 4-6: Proposed CCP changes

Process or Step to be monitored	Parameter to be monitored	Monitoring location	Frequency	Unit	Control Limits		Corrective Action(s) – to be applied when Critical Limits are exceeded.
					Alert Limit	**Critical Limit**	
Effluent Inflow Quality (CCP1)	*Turbidity (related to CCP1)*	*Located at MF feed line after the MF feed tank*	*Continuous Online*	*NTU*	*> 20 NTU for > 10 min*	*> 25 NTU for > 60 mins*	• *SCADA to cease supply to NCIG* • *Verify turbidity meter result (bench scale tests) and calibrate meter if required* • *Investigate feed water conditions.* • *Await until feedwater conditions meet CCP Limits before recommencement of NCIG Supply.*
Reverse Osmosis (CCP3 and QCP2)	*Relevant to NCIG Supply ONLY* *Calcium ion [Ca]*		*Weekly (investigate onsite calcium testing unit (such as selective ion probe unit)*	*Log10; %removal*	***EC online** as per below*	*The drop in [Ca] must exceed 1.5 log10 ~ 96.8%*	• *If EC Trigger level <94% breached, take samples and verify the feed and permeate Calcium, to calculate removal differential (percent and log). OR if routine [Ca] samples show < 96.8%* • *If [Ca] results show removal< 96.8%, NCIG supply ceases* • *Recommence supply when calcium test results show required performance target > 96.8%*
	Electrical Conductivity	Combined permeate (related to CCP3)	Continuous Online	µS/cm	> 40 µS/cm for > 30 min	> 70 µS/cm for > 60 min	• Investigate the EC of the individual trains • Investigate whether there has been a chemical clean or module replacement • Take samples and verify the feed and permeate EC meters, calibrate/replace if required • Shutdown train/s that have high permeate EC and investigate cause • Check delivered maintenance equals planned maintenance • Check dosing of acid and antiscalant • Check the performance of each train, are the trains highly fouled and in need of chemical cleaning?

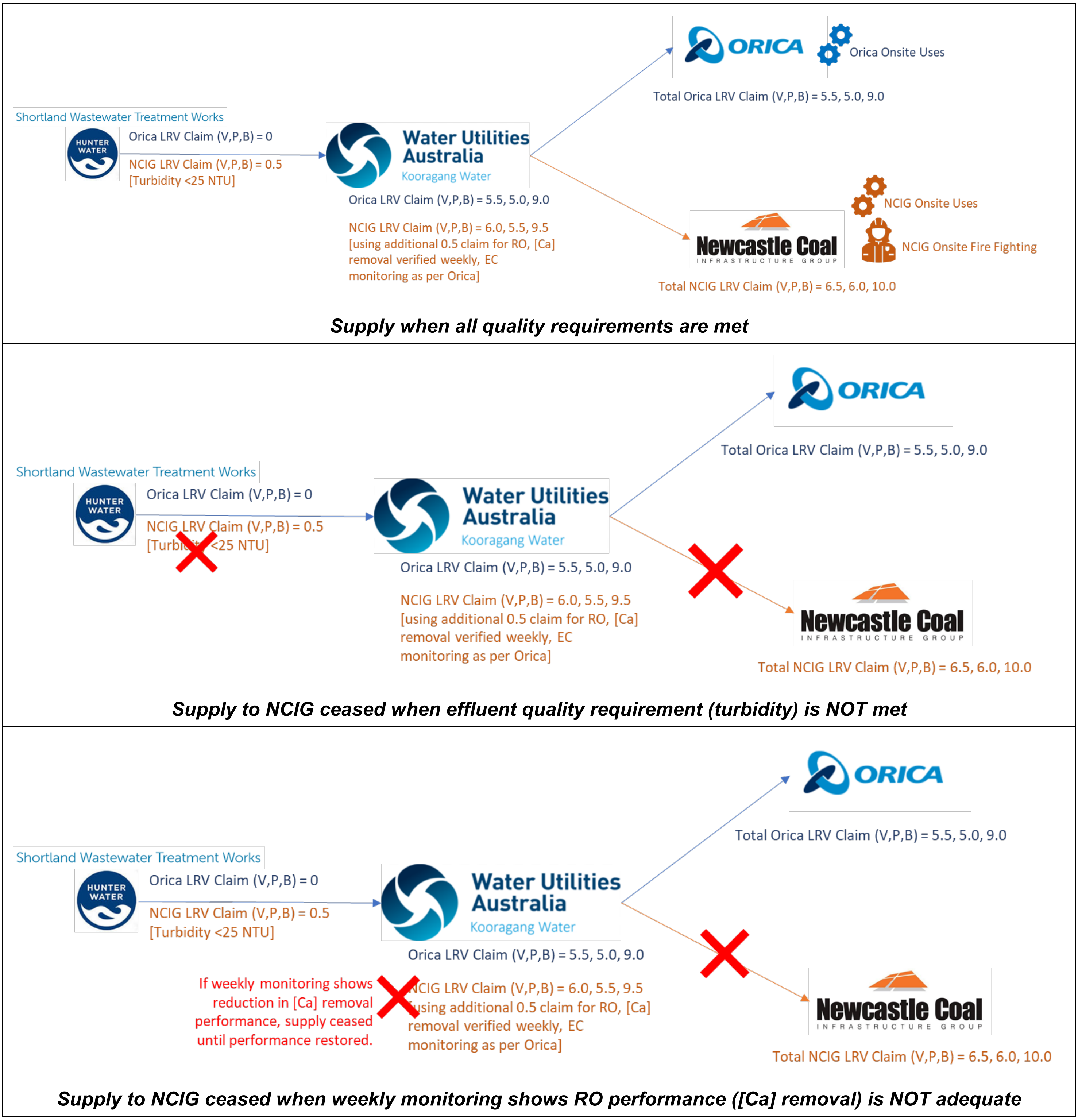


Figure 4-1: Proposed Supply Arrangement

5 Review of Risk Definitions

Within the previous SUEZ workshops, SUEZ used their corporate risk assessment definitions. As part of the transfer of this assessment from SUEZ to a KWPL/WUA document, the likelihood and consequence definitions were compared as shown in Table 5-1 and Table 5-2 on the following page, along with differences in the risk matrices as shown in Table 5-3 and Table 5-4.

It was found that there was not a direct equivalence and as a result each risk line in the previous SEUZ risk assessment was rescored using the KWPL/WUA risk framework. This occurred prior to the HACCP workshop.

The majority of the risk items maintained the same risk levels, however there were a small number of risk lines which did have a slight shift. This was captured within the risk assessment sheets for each risk item which is provided in Appendix B.

Table 5-1: Consequence Definition Comparison

Consequence Definitions		SUEZ (HAZARD ANALYSIS & CRITICAL CONTROL POINTS (HACCP) PLAN REVIEW 2018, SUEZ)		WUA (Used in 2021/22 Risk Assessment)	
		Public Health/Water Quality	**Environment**	**People**	**Environment**
5	**Extreme**	Major health impact for large population (e.g. 2000 people); Permanent damage to people's health; Suspension or cessation of activity / shutdown ordered.	Off-site toxic release with major detrimental effect; Alteration to biological or biochemical systems	Death or multiple life threatening injuries	High level serious environmental harm (serious environmental harm that affects the wider community)
4	**High**	Health outbreak on a small scale (e.g. single suburb) No long-term health effects; Formal warning from investigator, external investigation initiated.	Off-site toxic release with long term impacts	Life threatening injury or multiple serious injuries causing hospitalisation	Serious environmental harm (actual or potential serious environmental harm that is of a high impact or on a wide scale)
3	**Medium**	No health impacts; Aesthetic impact affecting a large population; Minor regulation breach (non-technical).	Off-site release with short term impact	Serious injuries causing hospitalisation or multiple medical treatment cases	Material environmental harm (actual or potential serious environmental harm that is not trivial)
2	**Low**	No health impacts; Aesthetic impact contained to a localised area; Minor regulation breach of a technical nature (no action or fines likely).	Onsite release; Possible outside assistance required	Minor injury or 1st Aid Treatment Case	Environmental nuisance (unsightly or offensive condition caused by pollution)
1	**Insignificant**	Isolated, transient incident; No health impacts and minimal aesthetic impact on a limited area; Minor breach that is reported via an annual return (no action or fines likely).	Contained onsite release, limited or no environmental impact, minimal rate of contamination.	Injuries or aliments not requiring medical treatment	Minor environmental consequence (minor spill)

Table 5-2: Likelihood Definition Comparison

Likelihood Definitions	**SUEZ** (HAZARD ANALYSIS & CRITICAL CONTROL POINTS (HACCP) PLAN REVIEW 2018, SUEZ)		**WUA** (Used in 2021 Risk Assessment)	
5	Multiple times in a year	Known or expected to happen often	>1 in 10 days	Is expected to occur in most circumstances
4	1 in a year or so	Known to reoccur approximately annually	1 in 10 - 100 days (Up to 3 times a year)	Will probably occur
3	1 in 5 years or multiple times over 10 years	.-.	1 in 100 - 1,000 days (up to once in 3 years)	Might occur at some time in the future
2	1 in 10 years or multiple times in 20 years	Could occur 3 or 4 times over my working life	1 in 1,000 - 10,000 days (Up to once in ~ 30 years)	Could occur but doubtful
1	1 in 50 years or less frequent	Remotely possible, but unlikely to occur in my lifetime	1 in 10,000 - 1,000,000 days (> than once in 30 years)	May occur in exceptional circumstances

Table 5-3: SUEZ Risk Matrix

SUEZ (HAZARD ANALYSIS & CRITICAL CONTROL POINTS (HACCP) PLAN REVIEW 2018, SUEZ)					
	Consequence				
Likelihood	1	2	3	4	5
1	Low	Low	Low	High	High
2	Low	Low	Moderate	High	Very High
3	Low	Moderate	High	Very High	Very High
4	Low	Moderate	High	Very High	Very High
5	Low	Moderate	High	Very High	Very High

Table 5-4: WUA Risk Matrix

2021/2022 Risk Matrix (Numerical), Based on WUA					
	Consequence				
Likelihood	1	2	3	4	5
1	1	2	3	4	5
2	2	4	6	8	10
3	3	6	9	12	15
4	4	8	12	16	20
5	5	10	15	20	25

Risk Level	Low	Moderate	High	Very High
Value	1 to 3	4 to 9	10 to 16	20 to 25

6 HACCP

6.1 Recycled Water Quality Assessment

Within the 2021/2022 review the effluent and Recycled Water quality data associated with the new proposed CCP and additional RO claim was reviewed to confirm that these were appropriate and reliable monitoring points and limits, this review was undertaken as part of the update to the Kooragang Industrial Water Scheme Validation Report (provided as Appendix C):

6.2 HACCP Workshop

The details and attendance of the previous workshops are provided in previous HACCP reports in Appendix B.

The 2021 Workshop was held on the 7th December 2021, the attendance included representatives from WUA, SUEZ, NCIG, NSW Health, Hunter H2O and an independent expert observer. The actual attendance list is provided as part of the HACCP risk assessment sheets as Appendix B

The workshop on the 7th December 2021 focused on the public health risks associated with the new end user and the proposed additional LRV claim and supporting CCP changes.

Following the 7th December workshop a number of smaller sessions were held to review all the previous risk lines, the attendance of these sessions is also provided in Appendix B. The full revised risk assessment sheets were sent to all attendees for feedback for finalisation within this report.

6.3 HACCP Workshop Outcomes Summary

The full risk assessment sheets are provided in Appendix B, along with a summary table of outcomes provided as a separate risk assessment sheet in Appendix B and is also provided as Table 6-1.

Table 6-1: Action Items from 2021/22 HACCP workshop

Risk Line Item	Risk Owner	Process/Location	Potential Hazardous Event Description	Revised risk level	Action
93	WUA/ SUEZ	KIWS plant influent	Process upset at Shortland WWTW pushing high Turbidity on to KIWS, out of specification influent for NCIG supply	**8**	There are alarms and controls on the inlet turbidity to the MF, these are to be interlocked on the NCIG supply (to be installed). When determining when to reinstate supply after quality is complaint, there needs to be consideration of the hydraulic detention time within KIWS system, tanks and pipelines, include NCIG offtake point/line, to ensure there is adequate delay to allow in-specification RW to reach NCIG (using Orica's typical usage as 'flush' volume). NSW Health is to review and confirm on CCP and proposed monitoring which is the basis of the proposed control for this risk assessment. Risk has been revised based on that the CCP and LRV claim will meet satisfaction by NSW Health, this to be confirmed by further discussion following workshop. NCIG to have undergoing consultation with NSW Fire & Rural Fire (NCIG to review Pre-Incident Plan (PIP) regarding fire event)
94	WUA/ SUEZ	Reverse Osmosis	Calcium breakthrough indicating that there could be potential for Pathogen breakthrough and out of spec Recycled Water for NCIG supply.	**8**	When determining when to reinstate supply after quality is complaint, there needs to be consideration of the hydraulic detention time within KIWS system, tanks and pipelines, include NCIG offtake point/line, to ensure there is adequate delay to allow in-specification RW to reach NCIG (using Orica's typical usage as 'flush' volume). NSW Health is to review and confirm on CCP and proposed monitoring (calcium and EC online and Ca bench monitoring program) which is the basis of the proposed control for this risk assessment. Risk has been revised based on that the CCP and LRV claim will meet satisfaction by NSW Health, this to be confirmed by further discussion following workshop. NCIG to have undergoing consultation with NSW Fire & Rural Fire (NCIG to review Pre-Incident Plan (PIP) regarding fire event).
NCIG 1.01	NCIG	End uses - dust suppression	Off-site spray drift exposing public to Recycled Water. Key area of focus is public roads and shared areas. Neighbours to the East. Inhalation risk to public receptors. Spray drift has been known to occur during high wind conditions, North- West direction. Risk has been assessed with RW in specification to NCIG requirements, as result health impact is considered to be lower (compared to risk line NCIG 1.02) . General note that the water used within the raw water supply is also shandy of stormwater and potable water. Risk assessment scope is limit to RW supply, and risk assessment considers all RW is being used as raw water.	**6**	ALL ACTIONS RAISED IN THIS RISK ASSESSMENT to be included in NCIG RWQMP. NCIG to follow up on the history of spray drift impacts, current controls (IDS), and complaints management system. NCIG to provide Buffer distances to public roads. NCIG to provide relevant public health risk information from internal RW risk assessment (GHD report)

NCIG 1.02	NCIG	End uses - dust suppression	Off-site spray drift exposing public to Recycled Water. Key area of focus is Public roads and shared areas. Inhalation risk to public receptors, during high wind conditions, North- West direction. Neighbours to the East. RW out specification to NCIG requirements, health impact is considered to be higher . Noting that the water used within the raw water supply is also shandy of stormwater and potable water. Risk assessment scope is limit to RW supply impacts considering all RW is being used as raw water.	**4**	As per risk line NCIG 1.01
NCIG 1.03	NCIG	End uses - fire fighting	RW doesn't meet quality requirements, fire fighters exposed to higher pathogen loading. Depending on the level of out of Spec quality could impact on consequence, precautionary approach to take Level 4 consequence	**8**	This risk is based on current operations of the KIWS and current fire fighting system. Fire protocols are to be reviewed considering the addition of RW, there is potential for NCIG to switch off RW supply to the raw tanks (fill tanks with potable water) in an event of a fire (this is yet to be reviewed/confirmed). NCIG to consider Recycled Water signage on the fire hydrants. Communication is ongoing between NCIG and Fire (NSWFire and Rural). Review actions associated with WUA Risk Assessment line item 94
NCIG 1.04	NCIG	Back flow to potable water supply	Backflow of RW supply from NCIG, contaminating potable water main (Hunter Water Main), causing wider illness/infection in the community. RW inspec	**4**	WUA to have further engagement with HW to discuss the RW supply and highlight the current backflow arrangement with plumbing team (group that manage the backflow devices) and the proposed RW supply.
NCIG 1.05	NCIG	NCIG internal site cross connection/back flow contaminating potable water onsite	Internal cross connection, (e.g. inappropriate plumbing connection) of potable water lines within NCIG which could lead to visitors (public) being exposed to RW. In spec RW.	**8**	NCIG to review piping labelling of existing raw water and signage for Recycled Water. NCIG to update site induction & training. NCIG to consider an annual cross connection check, (turn off the water main and check potable water taps), taking into consideration NCIG current plumbing checks/procedures.
NCIG 1.06	NCIG	NCIG storage and network	Storage tanks integrity breach leads to contamination of the supply creating out of spec conditions which escalate health risk which has been rated in previous items	**8**	NCIG tank inspections and integrity (including checking that vermin proofing is in place and intact) to be confirmed
NCIG 1.07	NCIG	NCIG storage and network	storage overflow/break in RW supply line from metering point (onsite at NCIG) - Recycled Water continues to be supplied creating an overflow	**4**	RW supply pipeline (on NCIG site) will have differential flow monitoring to detect water loss on NCIG site, to be integrated into NCIG control system (currently in place). Storage buffer tank to be installed with level sensors and emergency overflow. Update PIRMP to include Recycled Water risks. Note on risk ranking - Consequence was reduced in the mitigated risk, as the controls will control/reduce the amount of RW potentially discharged which reduces the overall impact (consequence) on the environment.
NCIG 1.08	NCIG	NCIG storage and network	Slimes/algae growing in ponds & tanks potentially more readily than in storm water due to higher nutrients from RW. Onsite issue only, not external environmental impact. External environment impact is a multiple failure scenario and is considered only a remote eventual. This is the incremental risk above the current situation without RW.	**4**	NCIG operational water management plan currently in place, to be updated to include RW.

6.4 Revised CCPs/QCPs

In review of the risk assessment, feedback from stakeholders and further review of operational data, the original proposed CCPs where further refined to further strengthen the additional LRV claim.

With the changes/additional CCP and respective monitoring italicised as shown in Table 6-2.

Table 6-2: Revised CCPs, Parameters and Limits

Process or Step to be monitored	Parameter to be monitored	Monitoring location	Frequency	Unit	Control Limits		Corrective Action(s) – to be applied when Critical Limits are exceeded.
					Alert Limit	Critical Limit	
Effluent Inflow Quality (CCP1 and QCP1) Relevant to NCIG Supply ONLY	uV BOD (QCP1)	Shortland WWTW discharge (diversion) dechlorination building	Continuous Online	mg/L	No more than 10% above 30 mg/L over rolling 24 hour period	NA	• Hunter Water SCADA provides alarms • Hunter Water SCADA automatically diverts effluent to Hunter Rivers, prevents feed to KIWS • KIWS operators to contact Hunter Water as required
	Turbidity (related to CCP1)	Located at MF feed line after the MF feed tank	Continuous Online	NTU	> 15 NTU for > 30 min	> 10 NTU for > 60 mins	• SCADA to cease supply to NCIG • Verify turbidity meter result (bench scale tests) and calibrate meter if required • Investigate feed water conditions. • Await until feedwater conditions meet CCP Limits before recommencement of NCIG Supply. • KIWS operators to contact Hunter Water as required
Membrane filtration (CCP2 and QCP2)	Turbidity (related to CCP2)	Combined permeate	Continuous Online	NTU	> 0.10 NTU for > 15 min	> 0.15 NTU for > 40 min	• Verify combined turbidity meter result and calibrate meter if required • Shut down entire MF system and investigate output from individual trains • Undertake a PDT on each MF train and view the process to identify any module faults. • Isolate and repair any leaking valves • Isolate and repair any identified membrane faults (broken fibres, o-rings)

Process or Step to be monitored	Parameter to be monitored	Monitoring location	Frequency	Unit	Control Limits		Corrective Action(s) – to be applied when Critical Limits are exceeded.
					Alert Limit	Critical Limit	
Membrane filtration (CCP2 and QCP2)	Turbidity (related to QCP2)	Individual trains	Continuous Online	NTU	> 0.20 NTU for > 10 min	> 0.3 NTU for > 20 min	• Verify individual turbidity meter result and calibrate meter if required • Investigate and isolate individual train/s if they are exceeding the turbidity limit using online turbidity meter on individual trains • Undertake a PDT on each MF train and view the process to identify any module faults. • Isolate and repair any leaking valves • Isolate and repair any identified membrane faults (broken fibres, o-rings)
	Pressure Decay Rate (related to CCP2)	Membrane skid	Daily online	kPa/5 min	PDT > 7 kPa	PDT > 7 kPa for three consecutive tests OR PDT > 10 kPa for an individual test	• Shut down MF system following a critical failure Isolate train that is exceeding PDT value • Repeat PDT and view the process to identify any module faults. • Isolate and repair any identified membrane faults (broken fibres, o-rings) • Isolate and repair any valve leaks
Reverse Osmosis (CCP3 and QCP3)	*Relevant to NCIG Supply ONLY* *Calcium ion [Ca]*	*Combined permeate (related to CCP3)*	*Weekly (investigate onsite calcium testing unit)*	*Log10; %removal*	***EC monitoring and alert levels***	*The drop in [Ca] must exceed 1.5 log10 ~ 96.8%*	• *If EC Alert Limit level breached (40 µS/cm for >30 min), take samples and verify the feed and permeate Calcium, to calculate removal differential (percent and log). OR if routine [Ca] samples show < 96.8%* • *If [Ca] results show removal< 96.8%, NCIG supply ceases* • *Recommence supply when calcium test results show required performance target > 96.8%*
Reverse Osmosis (CCP3 and	Electrical Conductivity	Combined permeate (related to CCP3)	Continuous Online	µS/cm	> 40 µS/cm for > 30 min	> 70 µS/cm for > 60 min	• Investigate the EC of the individual trains • Investigate whether there has been a chemical clean or module replacement

Process or Step to be monitored	Parameter to be monitored	Monitoring location	Frequency	Unit	Control Limits		Corrective Action(s) – to be applied when Critical Limits are exceeded.
					Alert Limit	Critical Limit	
QCP3)		EC of the combined permeate compared to the EC of the feed to calculate the Log reduction of EC over RO process (related to CCP3)	Continuous Online	%	< 94% reduction in EC for > 30 min (94% is equivalent to an LRV of 1.22)	< 90% reduction in EC for > 60 min (90% equivalent to an LRV of 1.0)	• Take samples and verify the feed and permeate EC meters, calibrate/replace if required • Verify the feed and permeate Calcium, to calculate removal differential (percent and log). • Shutdown train/s that have high permeate EC and investigate cause • Check delivered maintenance equals planned maintenance • Check dosing of acid and antiscalant • Check the performance of each train, are the trains highly fouled and in need of chemical cleaning?
Chlorination System (CCP4)	Ct	CCT outlet (related to CCP4)	Continuous Online	mg•min/L	< 13 mg.min/L (pH < 7.5) for > 20 min < 30 mg.min/L (pH > 7.5 and < 9.0) for > 20 min	< 11 mg.min/L (pH < 7.5) for > 20 min < 27 mg.min/L (7.5 < pH < 9) for > 20 min	• Divert off-spec water, continue to operate to bring plant back into control • Investigate and verify the chlorine meter readings and calibrate/replace if required • Investigate and verify the pH meter readings and calibrate/replace if required • Investigate the chlorine dosing system operation and control • Investigate set-points and upstream operations than could influence pH and chloramine dosing levels.
	pH	CCT outlet (related to CCP4)	Continuous Online	pH units	> 7.5 for > 30 min	> 9 for > 10 min	
	Temperature	CCT outlet (related to CCP4)	Continuous Online	°C		< 10 for > 10 min	

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Appendix A Kooragang Industrial Water Scheme Hazard Analysis & Critical Control Points (HACCP) Plan Review 2018, SUEZ

Appendix B HACCP Workshop Sheets (incl. summary of actions, and attendance details)

Appendix C Kooragang Industrial Water Scheme Validation Report, 2022 Update

APPENDIX D: Additional KIWS Locality Information