Government of South Australia

SA Water

Public Health Aspects of Recycled Water

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OVERVIEW

- Introduction - RR
- Guidelines for Water Recycling - RR
- Recycled water hazards - RR
- Quantifying and managing pathogen risk - BvdA
- Bolivar & VPS scheme - BvdA
- Questions - BvdA

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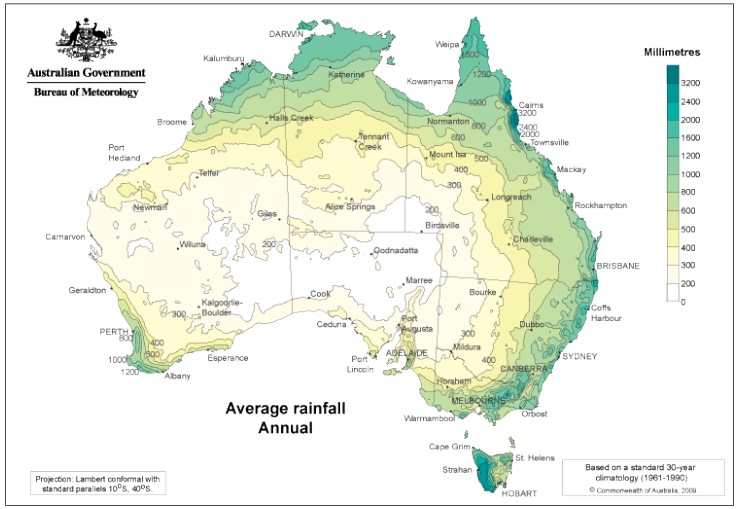
INTRODUCTION

Introduction – drivers & sources

Drivers for recycling

- Drought
- Depletion of traditional water sources
- Potable water substitution
- New supply: agriculture/ horticulture
- Environmental: minimising N, SS, BOD discharge
- Liveability – green spaces/ reducing heat load
- Growing population



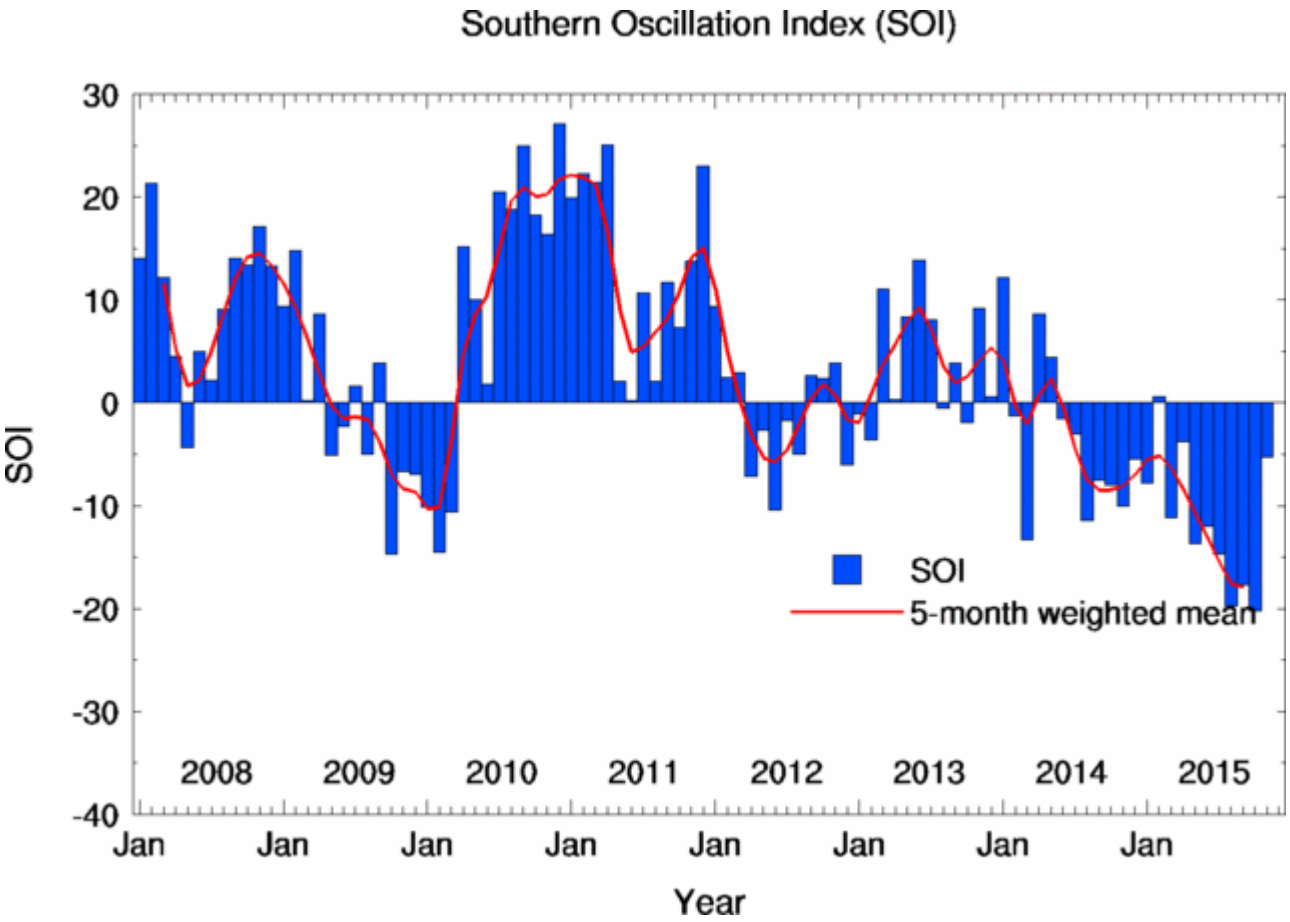
Sources

- Treated wastewater
- Treated stormwater
- Grey water
- Blends of the above

Recycled water

- Water generated from sewage, greywater or stormwater systems and treated to a standard that is *fit for purpose*.

Introduction – SOI an indication of drought



Introduction - recycled water uses

- Household dual reticulation (toilet flushing, laundry)
- Car washing
- Road making & dust control
- Street cleaning, fire fighting,
- Non-interactive water features (2^{o} contact fountains)
- Commercial food crops
- Non food crops (pasture, fodder)
- Municipal irrigation (golf courses, school ovals, parks)
- Indirect potable reuse
  - Groundwater recharge (e.g. City of Perth)
  - Stream replenishment (Hawkesbury-Nepean River, NSW)

Introduction - SA Water recycled water schemes

Wastewater as a source

- 24 wastewater treatment plants - 16 recycled water schemes
- All metropolitan plants have significant reuse
- Bolivar is the largest scheme, Glenelg, Christies are significant

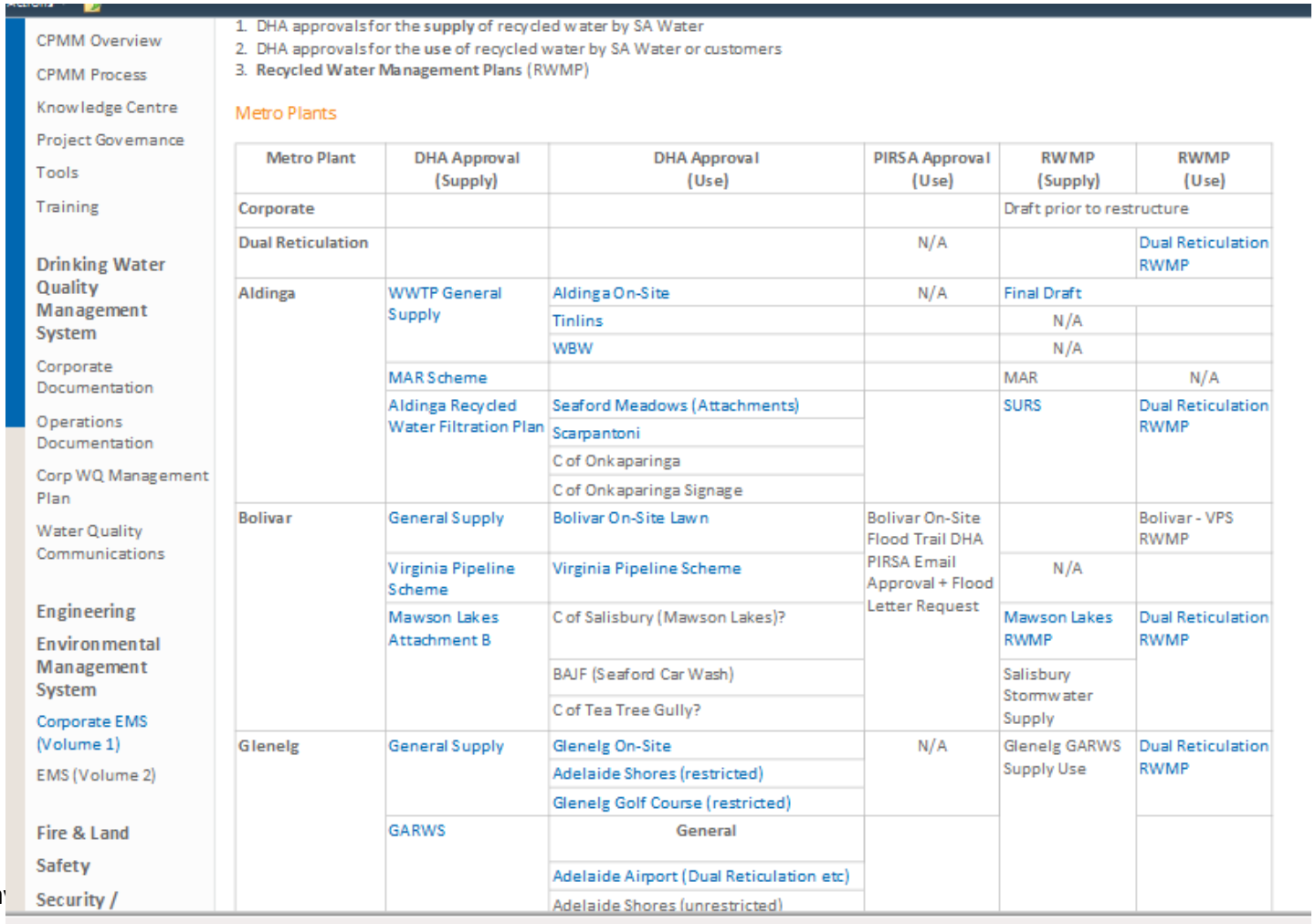
Stormwater as a source

- X3 stormwater schemes (AA, BI, LP)

Managed aquifer recharge (ASR method)

- X4 operational schemes involving MAR (AA, BI, LP, Aldinga)
- Research at Bolivar ASR, Salisbury ASTR

Introduction - SA Water metropolitan schemes



CPMM Overview
CPMM Process
Knowledge Centre
Project Governance
Tools
Training

Drinking Water Quality Management System

Corporate Documentation
Operations Documentation
Corp WQ Management Plan
Water Quality Communications

Engineering

Environmental Management System

Corporate EMS (Volume 1)
EMS (Volume 2)

Fire & Land Safety Security /

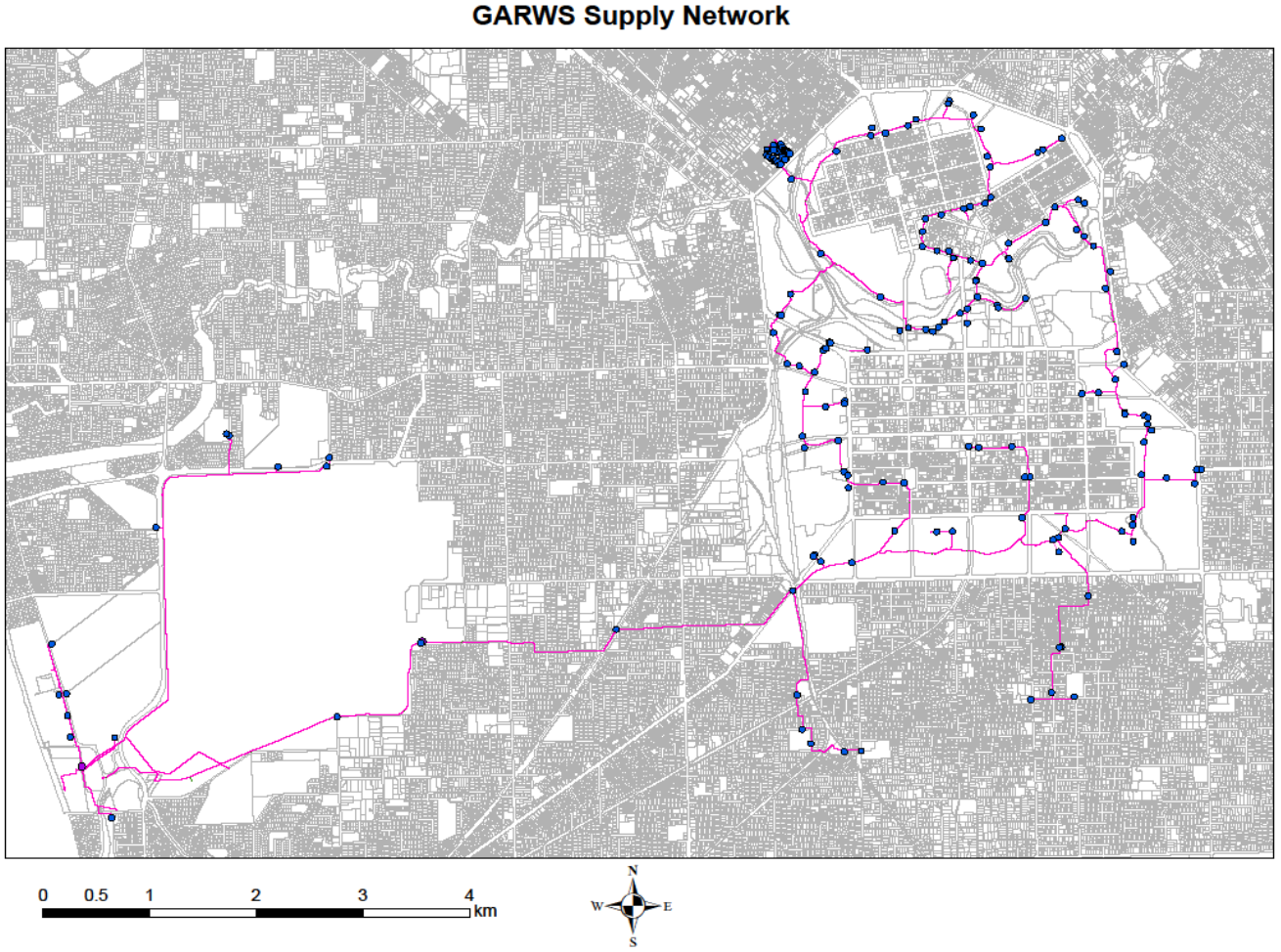
1. DHA approvals for the **supply** of recycled water by SA Water
2. DHA approvals for the **use** of recycled water by SA Water or customers
3. **Recycled Water Management Plans** (RWMP)

Metro Plants

Metro Plant	DHA Approval (Supply)	DHA Approval (Use)	PIRSA Approval (Use)	RWMP (Supply)	RWMP (Use)
Corporate				Draft prior to restructure	
Dual Reticulation			N/A		Dual Reticulation RWMP
Aldinga	WWTP General Supply	Aldinga On-Site	N/A	Final Draft	
		Tinlins		N/A	
		WBW		N/A	
	MAR Scheme			MAR	N/A
	Aldinga Recycled Water Filtration Plan	Seaford Meadows (Attachments)		SURS	Dual Reticulation RWMP
		Scarpantoni			
		C of Onkaparinga			
		C of Onkaparinga Signage			
Bolivar	General Supply	Bolivar On-Site Lawn	Bolivar On-Site Flood Trail DHA PIRSA Email Approval + Flood Letter Request		Bolivar - VPS RWMP
	Virginia Pipeline Scheme	Virginia Pipeline Scheme		N/A	
	Mawson Lakes Attachment B	C of Salisbury (Mawson Lakes)?		Mawson Lakes RWMP	Dual Reticulation RWMP
		BAJF (Seaford Car Wash)		Salisbury Stormwater Supply	
		C of Tea Tree Gully?			
Glenelg	General Supply	Glenelg On-Site	N/A	Glenelg GARWS Supply Use	Dual Reticulation RWMP
		Adelaide Shores (restricted)			
		Glenelg Golf Course (restricted)			
	GARWS	General			
		Adelaide Airport (Dual Reticulation etc)			
		Adelaide Shores (unrestricted)			

E.g. Glenelg-Adelaide Recycled Water Scheme

E.g. Glenelg-Adelaide Recycled Water Scheme

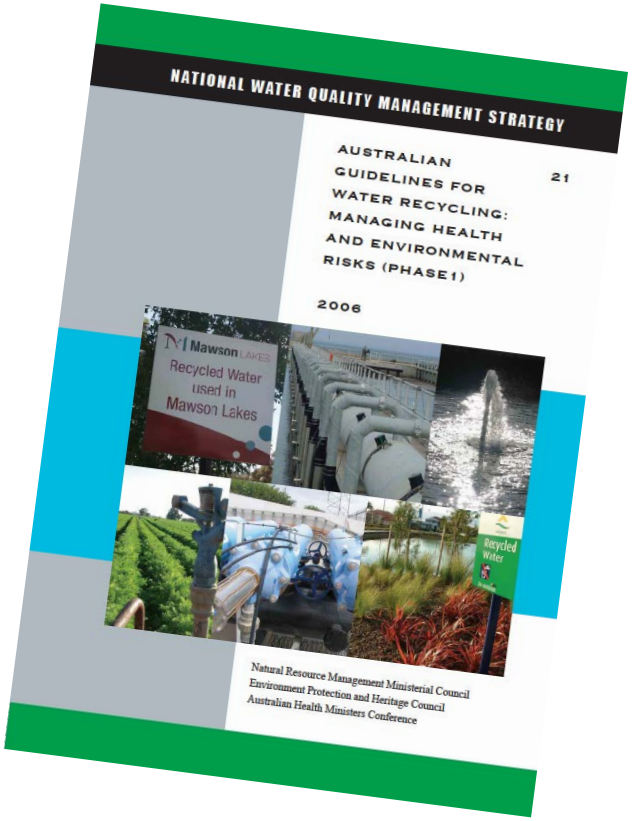


Introduction - SA Water regional schemes

Regional Plants

Regional Plant	DHA (Supply)	DHA Approval (Use)	PIRSA Approval (Use)	RWMP (Supply)	RWMP (Use)
Angaston	General Supply	Burgemeister Vineyards			Burgemeister
Bird In Hand	General Supply	On-Site Use		Bird In Hand	
		Watkins?			
		AF Parker & Sons			
		Petaluma			
Finger Point	N/A	N/A		N/A	N/A
Gumeracha	General Supply	PIRSA (forestry)			
Hahndorf	General Supply	Cedars			
Heathfield	N/A	N/A		N/A	N/A
Mannum	General Supply	Mannum Golf Club			
		Emergency Irrigation Area			
Millicent	General Supply	Croser			
Mount Burr	N/A	N/A		N/A	N/A
Murray Bridge	General Supply	Commonwealth of Australia			
		Keppa Road Pastoral			
Nangwarry	N/A	N/A		N/A	N/A
Naracoorte	N/A	N/A		N/A	N/A
Pt Augusta East	N/A	City of Port Augusta			
Pt Augusta West	General Supply	Port Augusta West Golf Club			
Port Lincoln	General Supply	Port Lincoln Council		Pt Lincoln	
	(Tuna Plant Mixing)	St Josephs College		Appendix	
Port Pirie	N/A	N/A		N/A	N/A

GUIDELINES FOR WATER RECYCLING



SA Guidelines (2012-2017)

- Reflect AGWR (2006) Phase 1
  (risk based management approach)
- Provide guidance for development of schemes
- Not a code, but assist compliance with SA Public Health Act (2015)
- Require **supply** and **use** approvals
- Approvals require an assessment of health based targets & a risk / recycled water management plan – RWMP (more on this later)

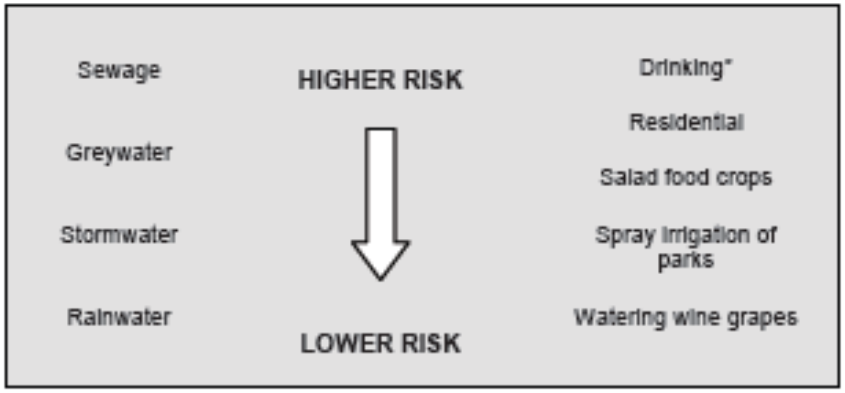


Figure 1: Relative risk associated with recycled water use

Australian Guidelines for Water Recycling

-guidelines to manage risk

- Public Health
  - Australian Guidelines for Water Recycling:

    Managing health and environmental risks (2006)

    Stormwater harvesting and reuse (2008)

    Managed aquifer recharge (2009)

    Augmentation of drinking water supplies (2008)
  - *Australian Drinking Water Guidelines outline chemical thresholds*
  - *Australian Drinking Water Health Based Targets Manual (2015)*

National Water Quality Management Strategy & Guidelines

a NRMMC–EPHC–NHMRC (2008)
b Current document
c NRMMC–EPHC–NHMRC (2009)
d NRMMC–EPHC–AHMC (2006)
e NHMRC–NRMMC (2004)
f ANZECC–ARMCANZ (2000a)
g ARMCANZ–ANZECC (1995)
h ANZECC–ARMCANZ (2000b)
i ARMCANZ–ANZECC (1994).

Figure 1.1 National Water Quality Management Strategy guidelines and documents

Australian Guidelines for Water Recycling

Principles of sustainable use

Box 1.1 Principles of sustainable use of recycled water

Sustainable use of recycled water is based on three main principles:

- protection of public and environmental health is of paramount importance and should never be compromised
- protection of public and environmental health depends on implementing a preventive risk management approach
- application of preventive measures and requirements for water quality should be commensurate with the source of recycled water and the intended uses.

Adherence to these principles requires:

- an awareness and understanding of how recycled water quality management can affect public health and the environment
- maintenance of recycled water schemes and reinforcement of the importance of ongoing management (by senior managers, to employees, stakeholders and end users)
- an organisational philosophy that supports continuous improvement and cultivates employee responsibility and motivation
- ongoing communication between regulators, owners, operators, plumbers and other stakeholders as well as end users, supported by audit and inspections.

Australian Guidelines for Water Recycling

Box 1.4 Risk management approach to water quality and use

A risk management approach involves identifying and managing risks in a proactive way, rather than simply reacting when problems arise. In applying this approach to water recycling, the first step

Guidelines outline a consistent risk management framework - 12 Elements – *same applies to the ADWG*

Element 1: Commitment to responsible use and management of recycled water - *Regulatory and formal requirements*

Element 2: Assessment of the recycled water system - *intended uses and water quality*

Element 3: Preventive measures for recycled water management - *CCP*

Element 4: Operational procedures and process control - *Detection of process failures*

Element 5: Verification of recycled water quality and environmental performance – *Water quality monitoring*

Element 6: Management of incidents and emergencies – *Hazardous events and communication*

Element 7: Operator, contractor and end user awareness and training

Element 8: Community involvement and awareness

Element 9: Validation, research and development

Element 10: Documentation and reporting

Element 11: Evaluation and audit

Element 12: Review and continual improvement

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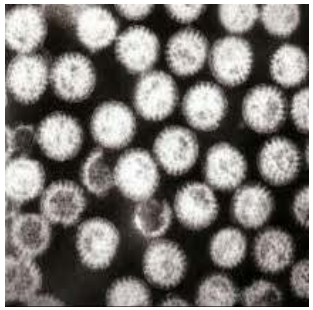
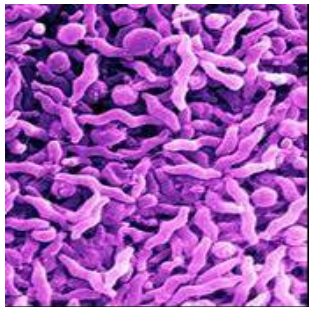
RECYCLED WATER HAZARDS





Recycled water hazards (i.e. water quality)

Todays focus

Hazard	Example
1. Pathogens / microbiology	Viruses (V), Protozoa (P), Bacteria (B), cyanobacteria
2. Inorganic chemicals	Metals - Lead, Copper, Arsenic
3. Salinity & sodicity	Salinity
4. Nutrients	Nitrogen, Phosphorous
5. Organic chemicals	Pesticides, herbicides
6. Turbidity & particulates	Suspended solids, algae

Jan 2016

Storage – Hazards

Hazard	Example
Lagoons	
Microbiology	Algae, cyanobacteria, zooplankton
Salinity	Salinity
Turbidity & particulates	Suspended solids
Managed aquifer recharge (MAR) - aquifer	
7. Radionuclides	Alpha radiation
8. Pressure, flow rates, volumes & levels	Waterlogging
9. Contaminant migration in fractured rock & karstic	High hydraulic conductivity
10. Aquifer dissolution & aquitard & well stability	Excess sand recovery
11. Impacts on groundwater dependent ecosystems	Levels outside historical range
12. Greenhouse gases	Excessive energy use

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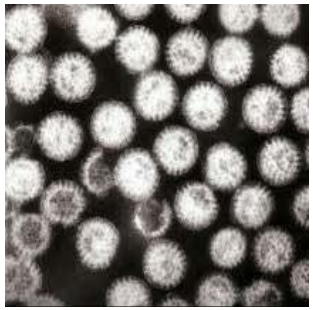
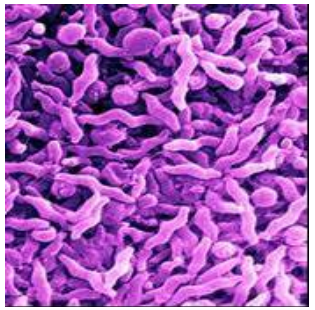
HAZARDS - PATHOGENS





Hazards of public health concern

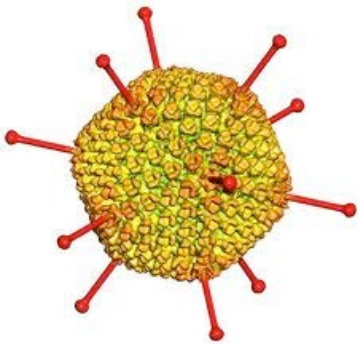
Pathogens

- Human & animal faeces are the major sources
- Abundant in sewage (and storm water?)
- Disease can result from ***acute*** exposure to ***low*** doses
- Enteric illnesses (gastroenteritis), respiratory diseases, fever, wound & eye infection, meningitis, etc
- Disease severity (burden) can vary
  - Incorporated into risk management

Table 3.1 Microorganisms of concern in raw sewage

Pathogen type	Examples	Illness
Bacteria	*Salmonella*	Gastroenteritis, reactive arthritis
	Campylobacter	Gastroenteritis, Guillain–Barré syndrome
	Pathogenic *Escherichia coli*	Gastroenteritis, haemolytic uraemic syndrome
	Shigella	Dysentery
	Yersinia	Gastroenteritis, septicaemia
	Vibrio cholerae	Cholera
	Atypical *Mycobacteria*	Respiratory illness (hypersensitivity pneumonitis)
	Legionella spp	Respiratory illness (pneumonia, Pontiac fever)
	Staphylococcus aureus	Skin, eye, ear infections, septicaemia
	Pseudomonas aeruginosa	Skin, eye, ear infections
	Helicobacter pylori (?)	Peptic ulcers
Viruses	Enterovirus	Gastroenteritis, respiratory illness, nervous disorders, myocarditis
	Adenovirus	Gastroenteritis, respiratory illness, eye infections
	Rotavirus	Gastroenteritis
	Norovirus	Gastroenteritis
	Hepatitis A	Infectious hepatitis
	Calicivirus	Gastroenteritis
	Astrovirus	Gastroenteritis
	Coronavirus	Gastroenteritis
Protozoa	*Cryptosporidium*	Gastroenteritis
	Giardia	Gastroenteritis
	Naegleria fowleri	Amoebic meningitis
	Entamoeba histolytica	Amoebic dysentery
Helminths	*Taenia (T. saginata)*	Tapeworm (beef measles)
	Ascaris	Roundworm
	Trichuris	Whipworm

Source: Adapted from Feacham et al (1983), Geldreich (1990), NRC (1996), Bitton (1999)



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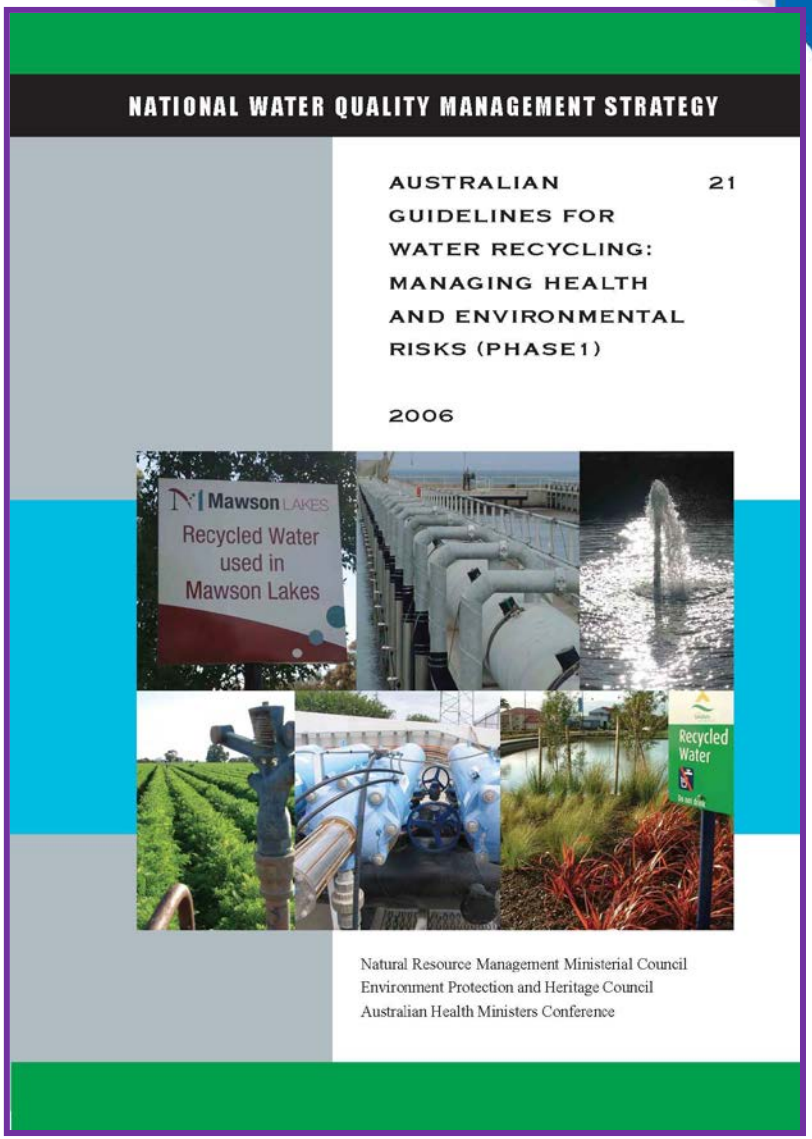
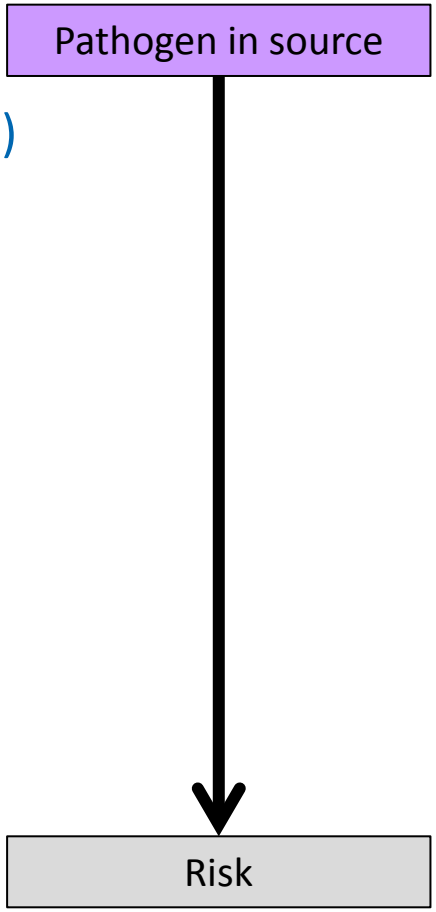
PATHOGENS – HEALTH BASED TARGETS

- Latest national guidelines
  - Consistent approach for risk management of reuse schemes
  - Move away from ‘too little, too late’ endpoint monitoring
  - Promotes **QMRA**
  - System analysis to identify hazards, barriers, exposure & vulnerabilities
  - Integration of **best available science** into water quality management



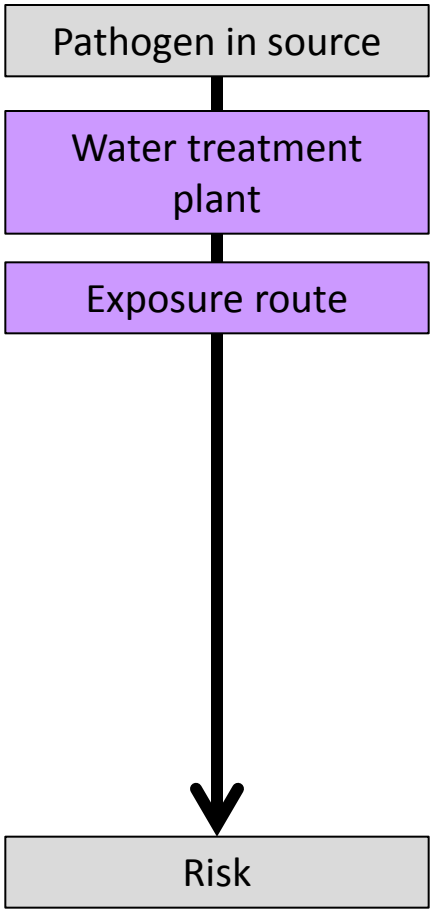
QMRA considers

- Hazard Identification
  - Identification of source water (stormwater or sewage)
  - Identify major hazards
  - Pathogen source(s) and concentrations



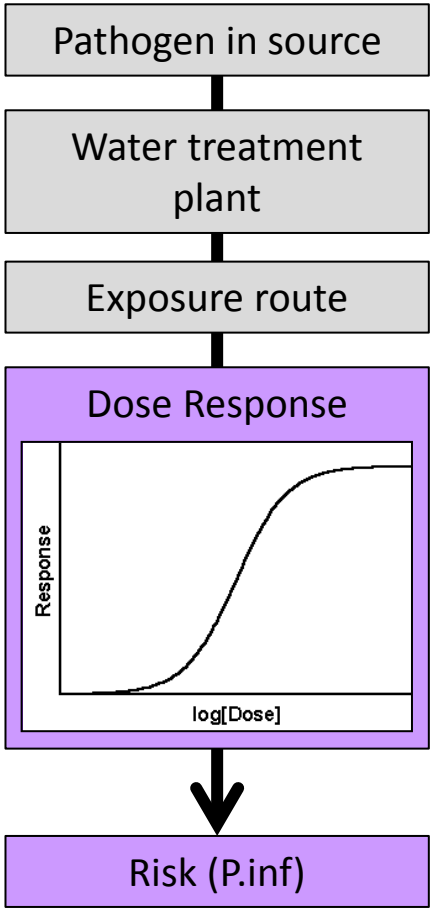
Exposure assessment

- Identify barriers (CCP) that minimise exposure
- Quantify pathogen fate/removal
- Quantify exposure routes
  - Volume & frequency
  - Depends on end-use
  - Typically ingestion (consumer foods, irrigators, homes supplied with due-reticulation)
- Estimate pathogen dose



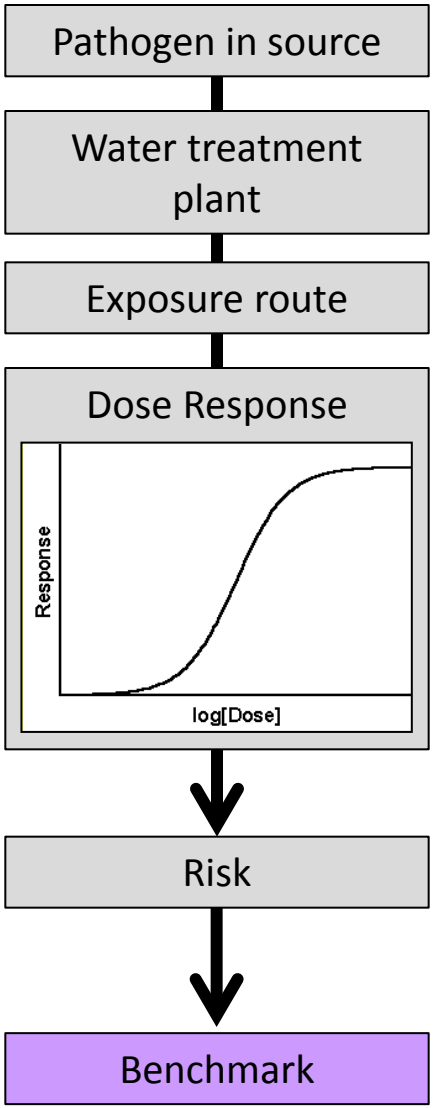
Dose-response

- Relationship between pathogen dose & likelihood of illness
- Identify the dose associated with infection
- Obtained from investigations of outbreaks or from experimental human-feeding studies
  - Provided in the guidelines

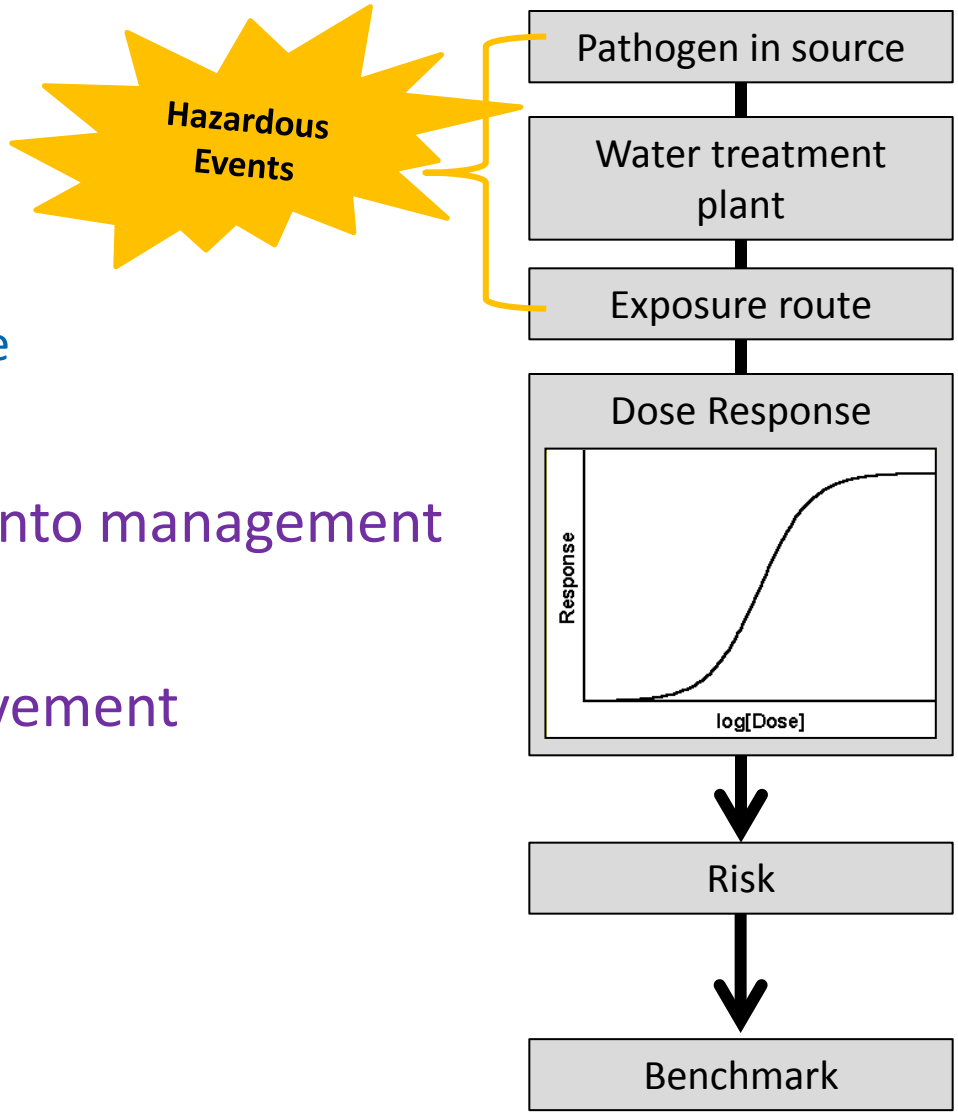


Risk characterisation

- Benchmark defines tolerable level risk
- Traditionally P_{inf} <10^{-4} (US EPA/NL)
- However disease severity (burden) can differ between pathogens
- Disability Adjusted Life Years (DALY) incorporates severity of disease (morbidity + mortality)
- Reuse benchmark = 10^{-6} DALYs per person per year (WHO/AUS)

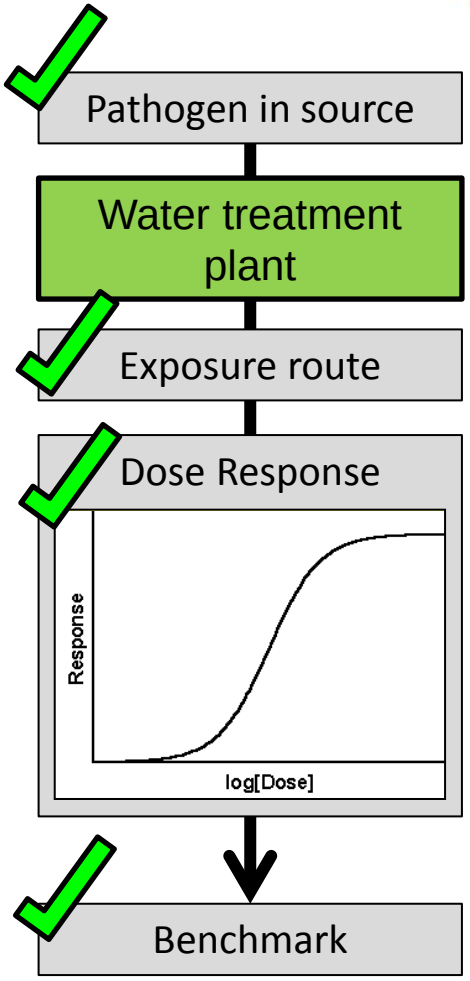


- Scenario analysis
  - Consider hazardous events
  - Identify vulnerabilities
  - Type, Frequency, Consequence
- Bring best available science into management
- Review and continual improvement



Health Based Targets

- Once we know the scenario we define level of treatment that is required
- Called “Health Based Targets”
- Performance ‘Goals’ that must be met to ensure that risk is not exceeded
- Level of pathogen removal log removal value (LRV)
- Depends on:
  - Source concentration
  - Exposure (↑exposure = ↑dose = ↑HBT)
  - Pathogen (burden)
- Described in the guidelines

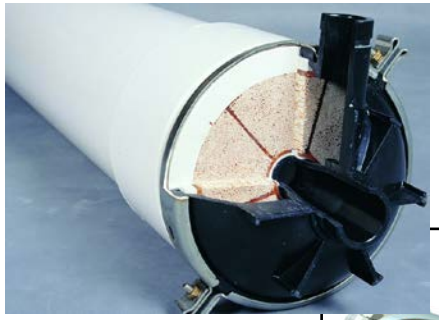


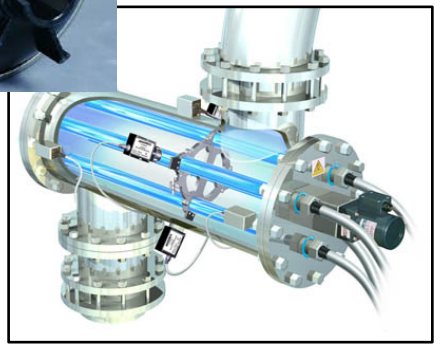
- **Examples of HBT**
- Determined by:
  - A) End-use. i.e. opportunity for exposure
  - B) Pathogen type (P,V,B)
- Reuse scheme needs to meet these targets to ensure risk of disease is tolerable

Activity	Route of exposure	Log reduction		
		Crypto-sporidium	Rotavirus	*Campylo-bacter*
Commercial food crops	Ingestion – Lettuce – Other produce			
	Total	**4.8**	**6.1**	**5.0**
Dual reticulation				
Garden irrigation	Ingestion of sprays Ingestion – Low – High			
	Total	**4.4**	**5.8**	**4.6**
Garden food crops	Ingestion – Lettuce – Other produce			
	Total	**4.0**	**5.3**	**4.2**
Internal uses				
Toilet flushing	Ingestion of sprays	3.1	4.5	3.3
Washing machine	Ingestion of sprays	2.1	3.5	2.3
Cross-connections	Ingestion	4.7	6.1	4.8
Total internal use (no garden use)		4.7	6.1	4.8
Total residential use (garden + internal)		4.9	6.3	5.1
Municipal irrigation	Ingestion of sprays	3.7	5.2	4.0
Dual reticulation plus municipal irrigation	Ingestion water and sprays	5.0	6.4	5.1
Fire fighting	Ingestion water and sprays	5.1	6.5	5.3

Identify preventative measures

- Selection of barriers (CCP) needed to meet HBT
- Achieved by
  - **Treatment controls** using technology and/or
  - **Reduce exposure** either by using preventive measures at the site of use (drip irrigation vs. spray) or by restricting uses (irrigation of cereal crops vs. raw vegetables)
- Multiple barriers





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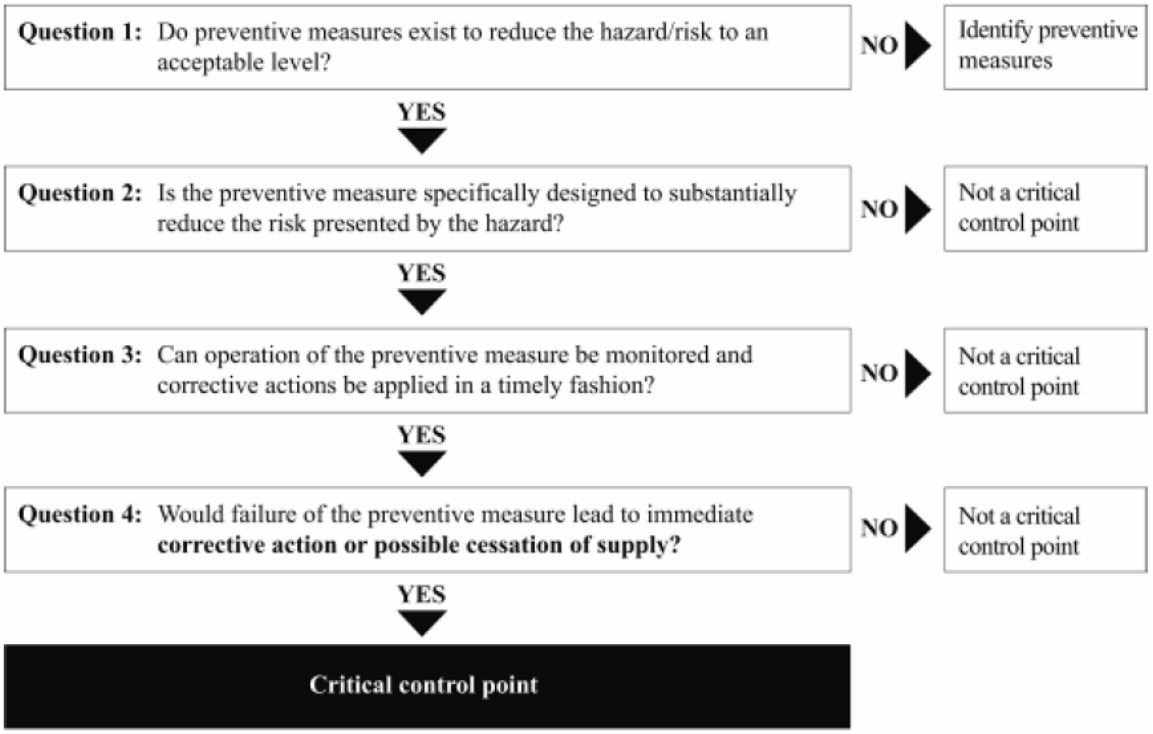
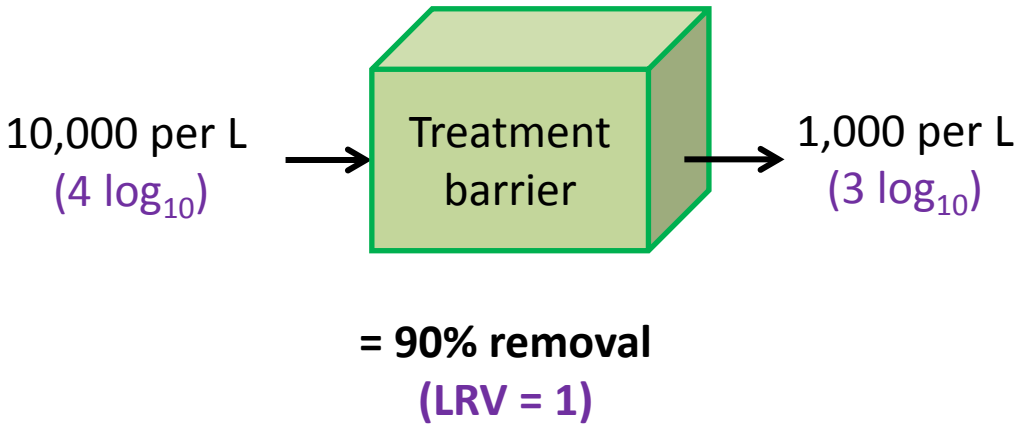
Questions to be asked for each hazard identified in Element 2 as representing a moderate to very high risk and requiring removal or reduced exposure to assure supply of safe recycled water.

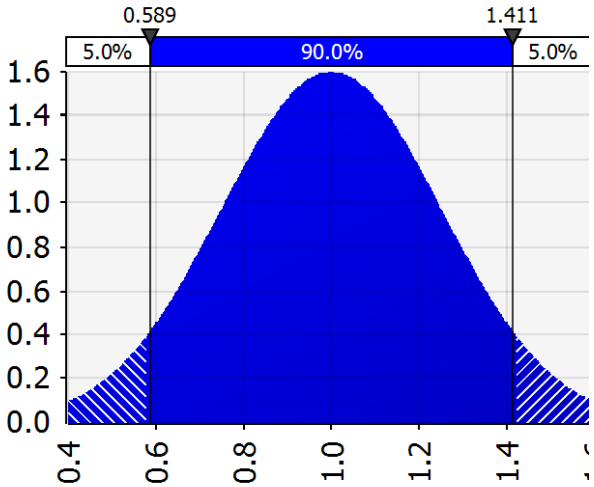


- Link operational parameters with LRV performance
- Understand hazardous events
- Barriers are covered in DHA supply and use approvals

Validation – will it work?

- Validation of treatment barriers to ensure HBT can be achieved
  - Measure LRV of each barrier
  - Multiple measurements (performance variability)
  - Credit based on 5th percentile value (conservative)
  - In consultation with DHA





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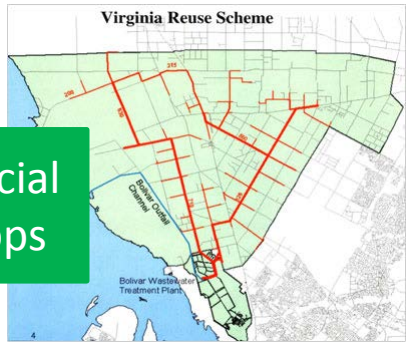
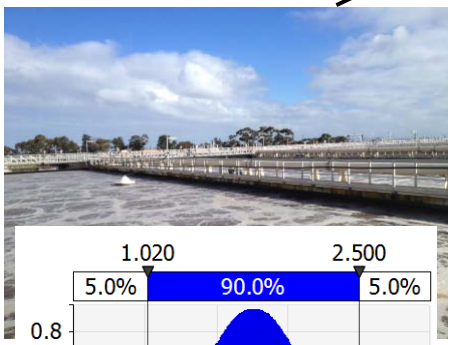
PATHOGENS – BOLIVAR & VPS

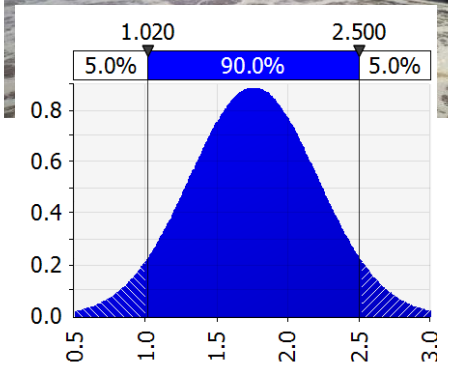
Example: HBT for Protozoa at Bolivar WWTP

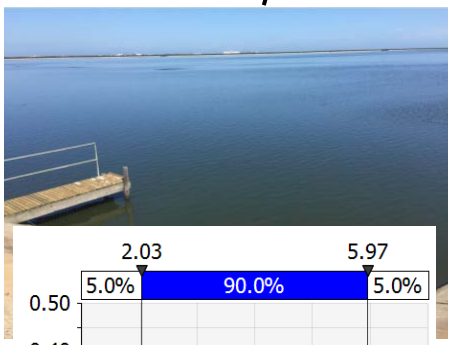


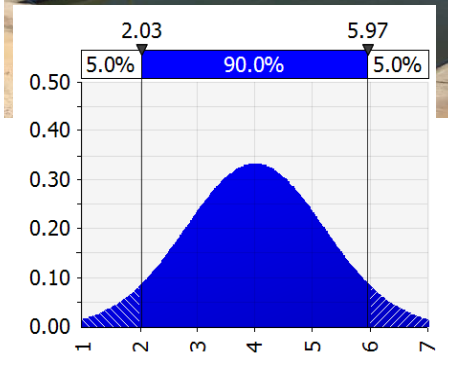
Source → HBT for Protozoa = LRV of 5.0 → Commercial food crops

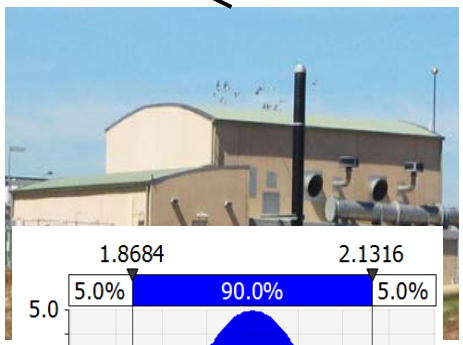
1.0 | 2.0 | 2.0 | 0.0

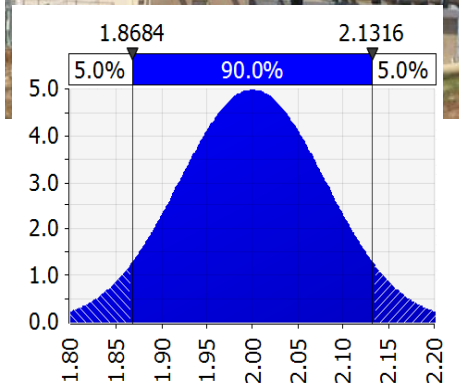






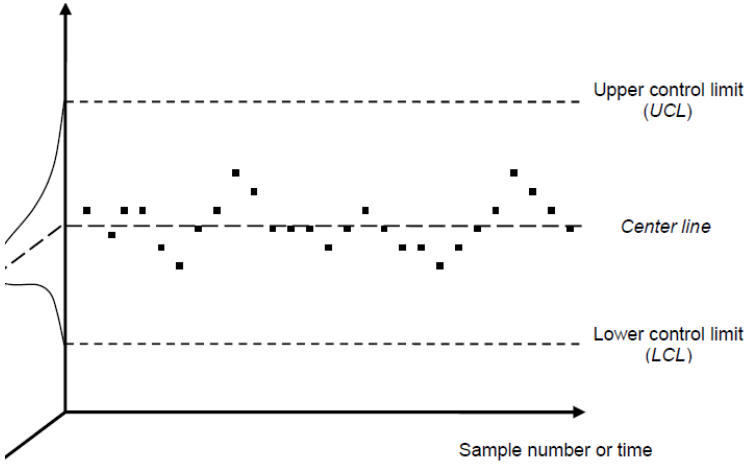






Bolivar & VPS

- DHA supply approval & Risk Management Plan (RWMP)
  - Details barriers and acceptable operating limits
  - Incident criteria
  - **Target criteria –** performance goals to provide early warning that the critical limit is being approached
  - **Critical limits –** distinguishes acceptable from unacceptable performance (HE)
  - Barriers: 1) Trade waste management, 2) primary & secondary treatment, 3) lagoons, 4) DAFF coagulation/filtration, 5) chlorine disinfection, 6) user controls



Summary

- We need to manage risk of reclaimed water given hazards and opportunity for exposure
- Move from compliance monitoring to system analysis based on risk assessment
- Emphasis of "knowing your system" so risks can be better managed
  - Identify hazards and hazardous event
  - Exposure assessment
  - Define HBT required to deliver safe reclaimed water
  - Identify CCP needed to achieve HBT (treatment or onsite control)
  - Validate CCP to show they can achieve LRV (HBT)
  - For CCP, identify key monitoring parameters that distinguishes acceptable from unacceptable performance
- Use above info to guide risk management plans
  - Based on 12 Elements

Question slides

Health-based targets continued...

- Different **health-base targets** for different pathogens
  - Some are more infectious than others and severity of illness (disease burden) will differ
- Impractical to set human health-based targets for all pathogens
  - Information such as concentration, dose response, disease burden not available for all pathogens in sewage
- Therefore the guidelines use Reference or Index pathogens
  - *Campylobacter* for bacteria
  - rotavirus and adenovirus for viruses
  - *Cryptosporidium* for protozoa
- Why?
  - Represent 3 key pathogen groups (bacteria, virus and protozoa)
  - All associated with faecal contamination
  - Good Dose Response data available
  - Reasonably infective

Box 3.1 Disability adjusted life years (DALYs)

The various hazards that can be found in sources of recycled water can have very different health outcomes. Some outcomes are mild (eg diarrhoea) while others can be severe (eg haemolytic uraemic syndrome associated with *Escherichia coli* O157:H7 or cancer). Assessment of these outcomes and allocation of resources based on severity of impact requires a mechanism for quantifying impacts. Disability adjusted life years (DALYs) provide this mechanism for both microbial and chemical parameters. Standard risk assessments determine the likelihood of infection or illness. DALYs convert these likelihoods into burdens of disease.

The basic principle of the DALY is to weight each health impact in terms of severity within the range of zero for good health to one for death. The weighting is then multiplied by duration of the effect and the number of people affected by the effect. In the case of death, duration is regarded as the years lost in relation to normal life expectancy.

Hence, DALYs = YLL (years of life lost) + YLD (years lived with a disability or illness).

In this context, disability refers to conditions that detract from good health. In these guidelines it generally relates to illness, but in other arenas it can relate to physical or mental impairment.

Using this approach, a mild diarrhoea with a severity weighting of 0.1 and lasting for 7 days results in a DALY of 0.002, whereas death of a 1-year old resulting in a loss of 80 years of life equates to a DALY of 80.

Using an Australian example, infection with rotavirus causes:

- mild diarrhoea (severity rating of 0.1) lasting 3 days in 97.5% of cases
- severe diarrhoea (severity rating of 0.23) lasting 7 days in 2.5% of cases
- rare deaths of very young children in 0.015% of cases

The DALY per case = (0.1 x 3/365 x 0.975) + (0.23 x 7/365 x 0.025) + (1 x 80 x 0.00015)
= 0.0008 + 0.0001 + 0.012
= 0.013

Infection with *Cryptosporidium* can cause watery diarrhoea (severity weighting of 0.067) lasting for 7 days with extremely rare deaths in 0.0001% of cases. This equates to a DALY per case of 0.0015.

Campylobacter can cause diarrhoea of varying severity, Guillain–Barré syndrome of varying severity, reactive arthritis and occasional deaths. The calculated DALY per case is 0.0046.

Based on DALYs per case, the impacts of the three pathogens is rotavirus > *Campylobacter* > *Cryptosporidium*.

DALYs per case is based on Havelaar and Melse (2003), with a modification using Australian data for rotavirus, as described in WSAA (2004).

Health based targets

- Benchmark to ensure risk to humans is acceptable or tolerable risk
- Microbial risk
  - DALY
- Chemical risk, *Australian Drinking Water Guidelines* (NHMRC–NRMMC 2004)
  - Threshold highest dose that causes no adverse effects (NOEL)

Table 4.1 Constituents potentially found in recycled water, which could pose a risk to the environment

General		
• Biochemical oxygen demand (BOD)	• Odour	• Total dissolved salts (TDS)
• Dissolved oxygen	• pH	• Total organic carbon (TOC)
• Hardness ($CaCO_3$)	• Suspended solids	• Turbidity
• Hydraulic load	• Temperature	
Nutrients		
• Boron	• Magnesium	• Sodium
• Calcium	• Nitrogen	• Sulfur
• Chloride	• Phosphorus	
• Iron	• Potassium	
Metals/metalloids/halides		
• Aluminium	• Copper	• Mercury
• Arsenic	• Cyanide	• Molybdenum
• Barium	• Fluoride	• Nickel
• Beryllium	• Iodine/iodide	• Selenium
• Bromate	• Iron	• Silver
• Cadmium	• Lead	• Tin
• Chromium	• Manganese	• Zinc
Surfactants		
• Alkane ethoxy sulfonates (AES)	• Linear alkylbenzene sulfonates (LAS)	• Secondary alkane sulfonates (SAS)
Organic compounds		
• Acrylamide	• Dichlorobenzenes	• Polyaromatic hydrocarbons
• Alkyl phenols	• Ethylenediaminetetraacetic acid (EDTA)	• Polychlorinated biphenyls
• Alkyltins compounds		• Styrene
• Bisphenol A	• Epichlorohydrin	• Trichlorobenzenes
• Chlorinated dioxins	• Hexachloro-butadiene	• Vinyl chloride monomer
• Chlorobenzene	• Nitrilotriacetic acid	
	• Phthalates	
Volatile organics		
• Benzene	• Ethylbenzene	• Trichloroethene
• Carbon tetrachloride	• Tetrachloroethene	• Xylenes
• Dichloroethanes	• Toluene	
• Dichloromethane	• 111-trichloroethane	
Pesticides or their metabolites (some examples)		
• 2,4-D	• Chlorpyrifos	• Heptachlor and epoxide
• Aldicarb	• Diazinon	• Lindane
• Aldrin/dieldrin	• Dichloro-diphenyl-trichloroethane (DDT)	• Organic mercurials
• Atrazine		• Pyrethroids
• Chlordane	• Diuron	• Other insecticides, fungicides and herbicides
	• Endosulfan	
Algal toxins		
• Cylindrospermopsin	• Nodularin	• Saxitoxins
• Microcystins		

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