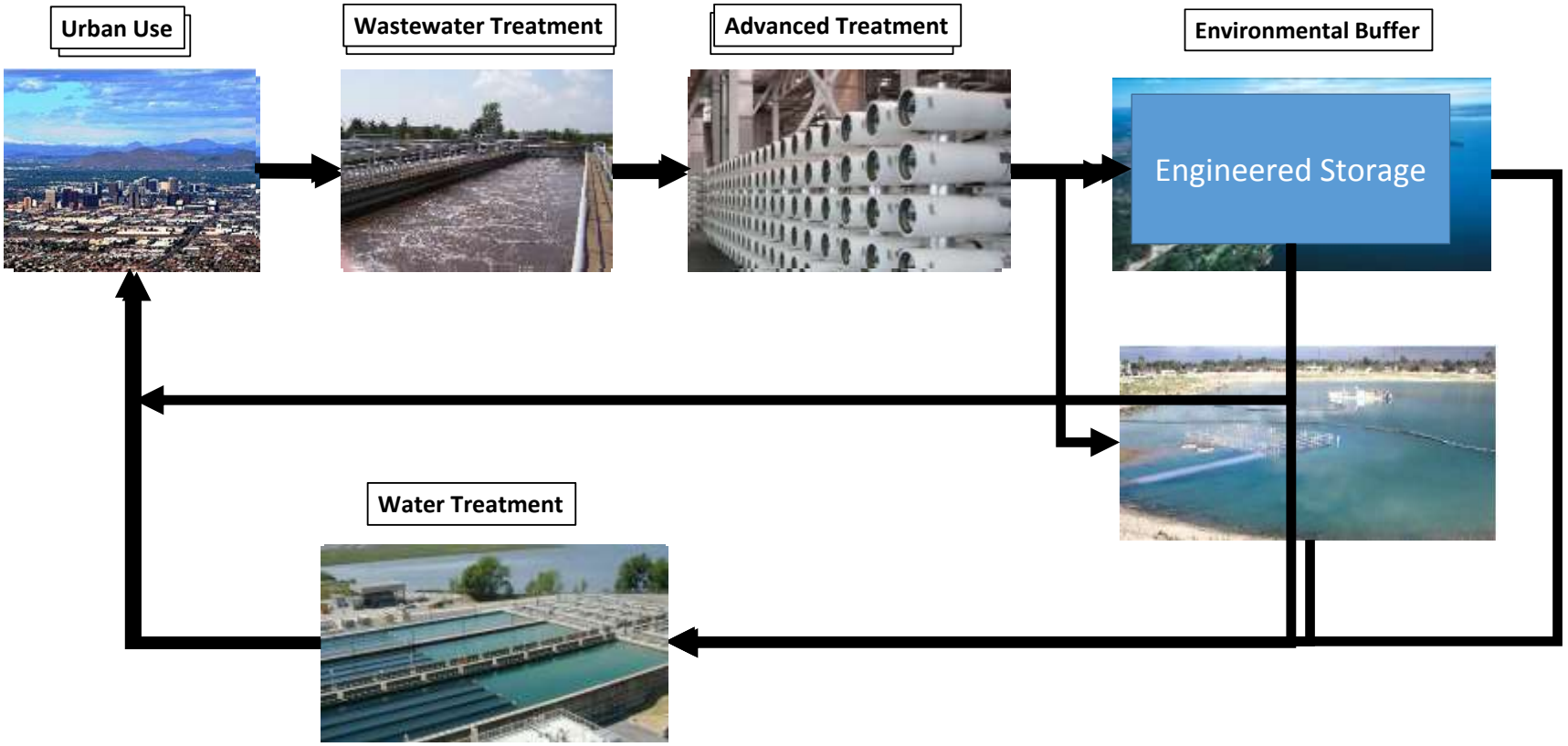
Critical Control Points

Assessment to Quantify Robustness and Reliability of Multiple Treatment Barriers for a DPR Scheme

WATEREUSE RESEARCH

HAZEN AND SAWYER
Environmental Engineers & Scientists

Direct Potable Reuse - The Definition



Direct Potable Reuse

DPR- Raising the Stakes

Convincing a skeptical public

Convincing regulators

Can We Trust the Technology?

Can We Trust Operations?

Trust but Verify

WRRF 13-03

Critical Control Point Assessment to Quantify Robustness and Reliability of Multiple Treatment Barriers of a DPR Scheme

WRRF 13-13

Development of Operation and Maintenance Plan and Training and Certification Framework for Direct Potable Reuse (DPR) Systems

Can We Trust the Technology?

WRRF-13-03:

Critical Control Point Assessment to Quantify Robustness and Reliability of Multiple Treatment Barriers of a DPR Scheme

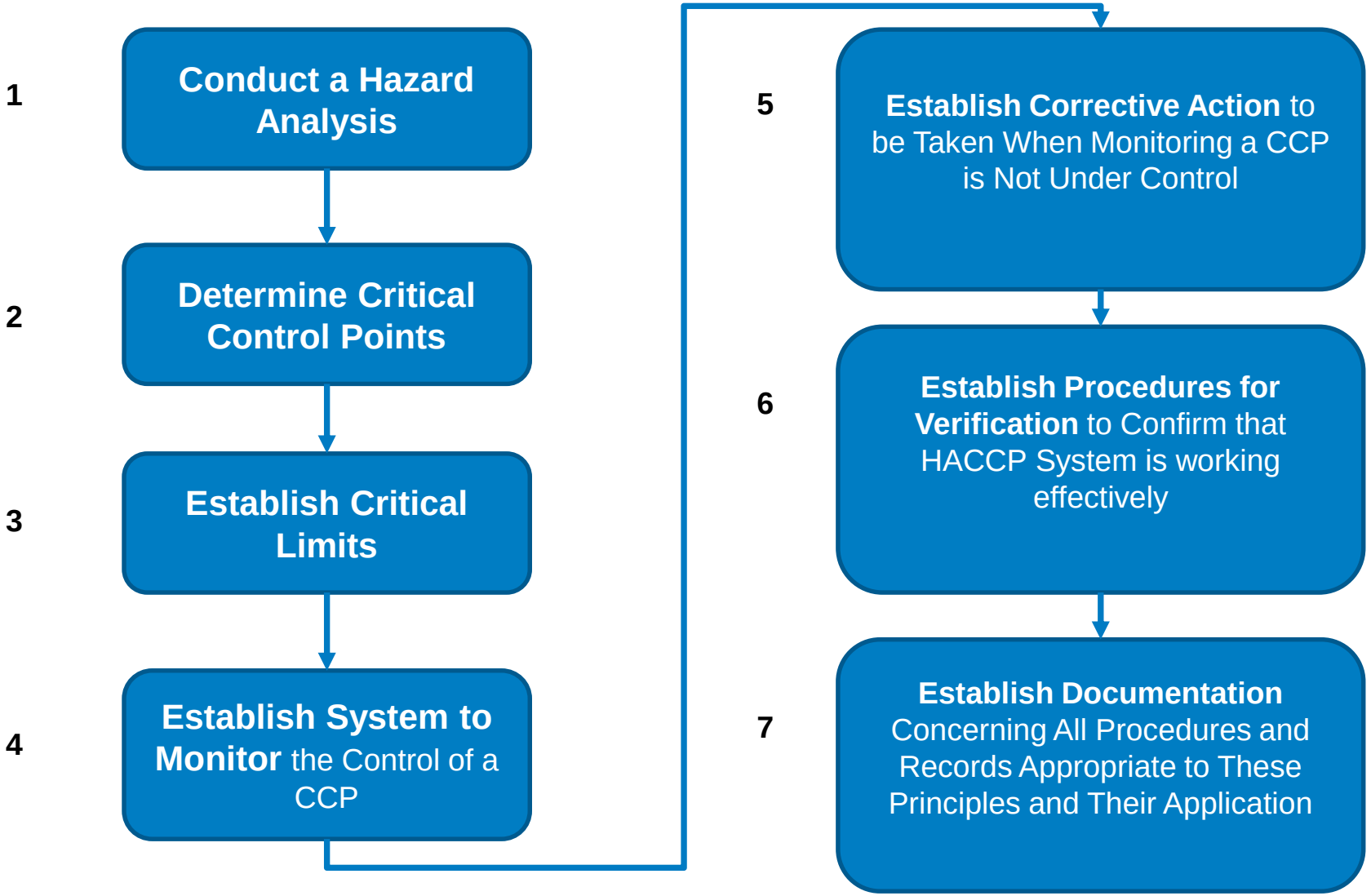
Hazard Analysis and Critical Control Points (HACCP)

- Systematic preventative approach to Food Safety.
- Common with TQM – focuses on process barriers rather than end of pipe quality.
- FDA/USDA mandatory for juice and meat.
- Applied to drinking water treatment.
- A number of examples for IPR and other recycled water production

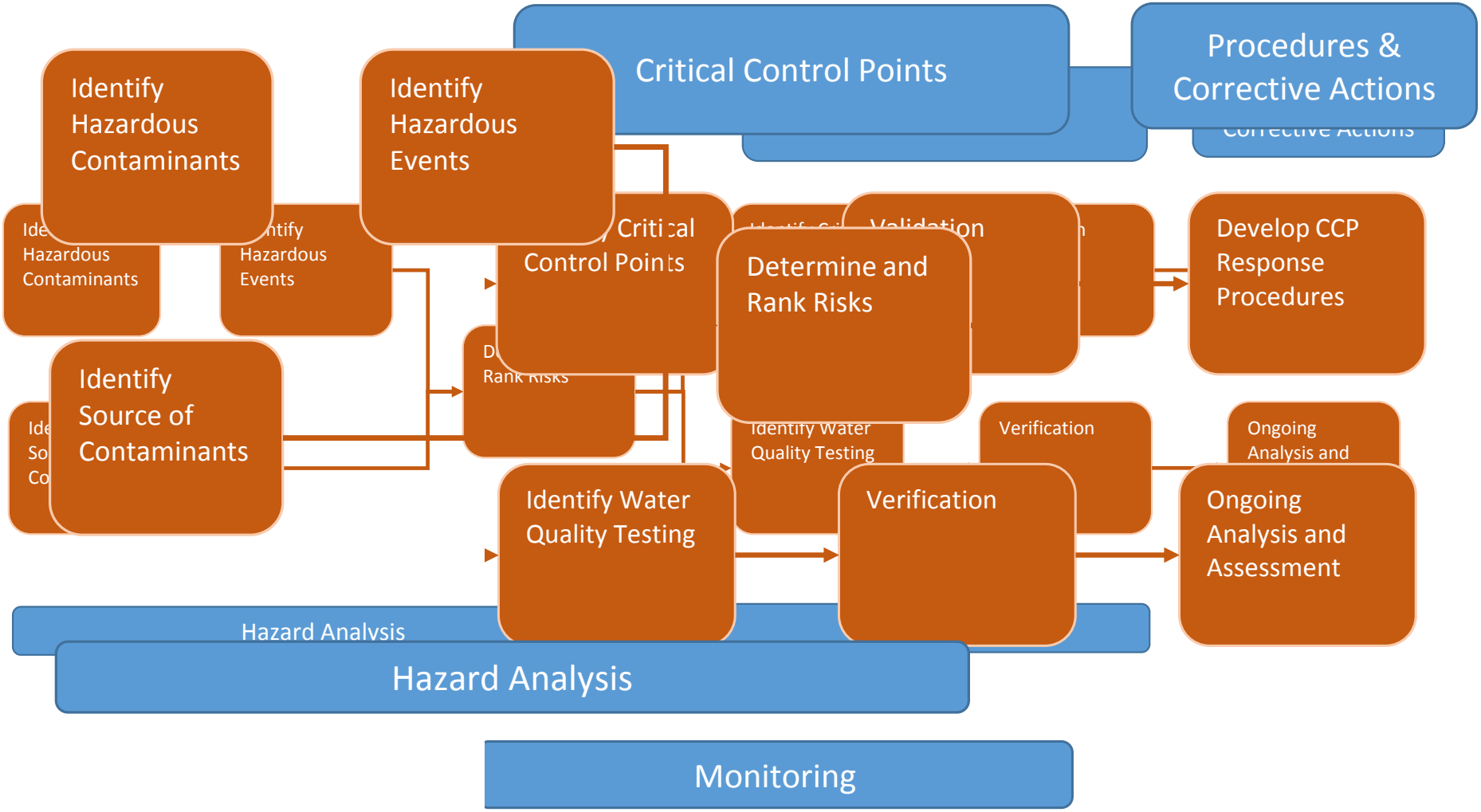
Conceived in 1960s by Pillsbury for NASA

Defined in ISO 22000 – Food Safety

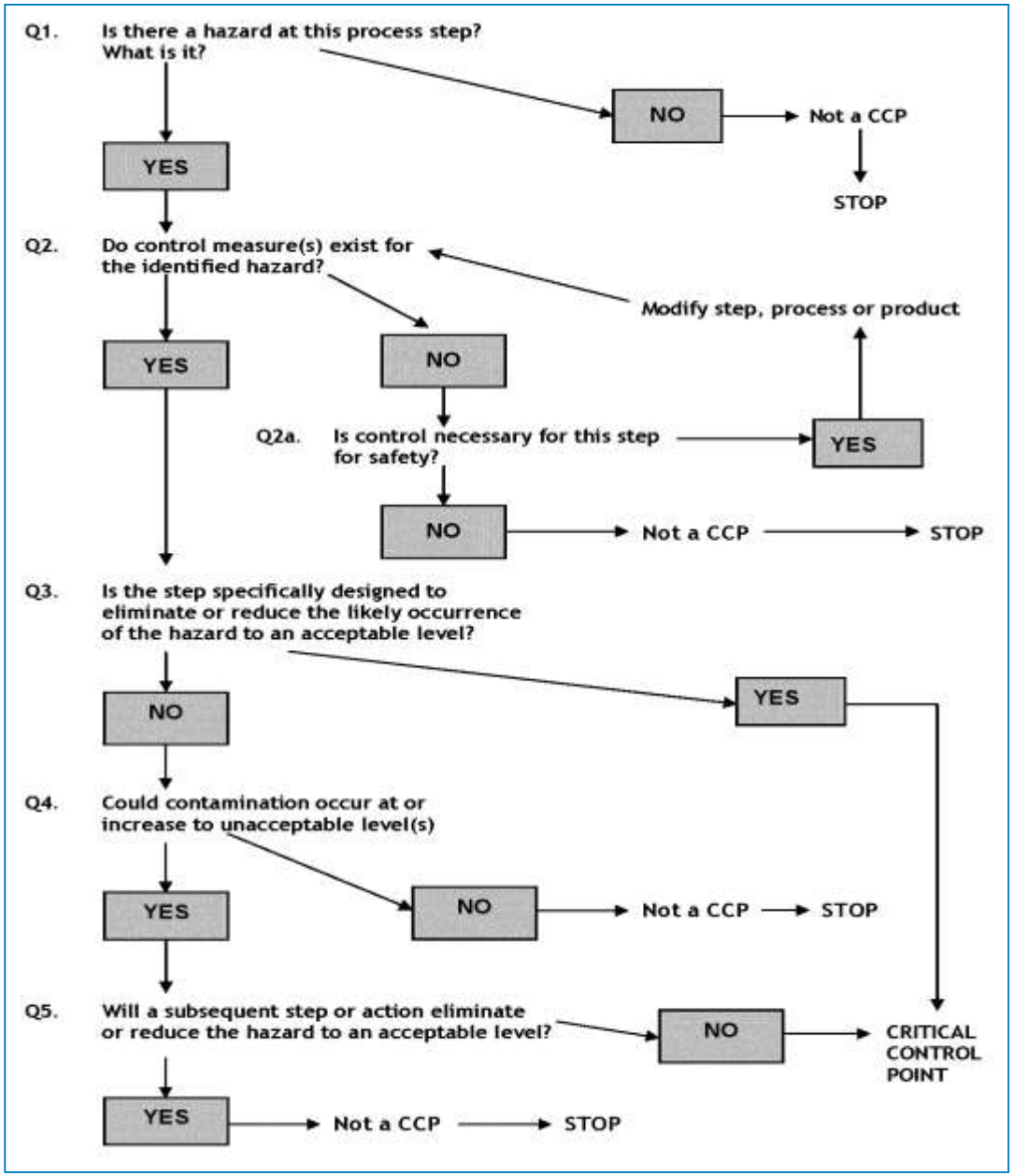
The 7 HACCP Principles



HACCP Approach Applied to Recycling



Select Critical Control Points – Control Hazards



Clear methodology for Critical Control Point Selection

Halliwell et al WRRF 09-03

Example – Western Corridor Recycled W

CCP 1

Activated Sludge Process
(On Line Ammonia)

CCP 2

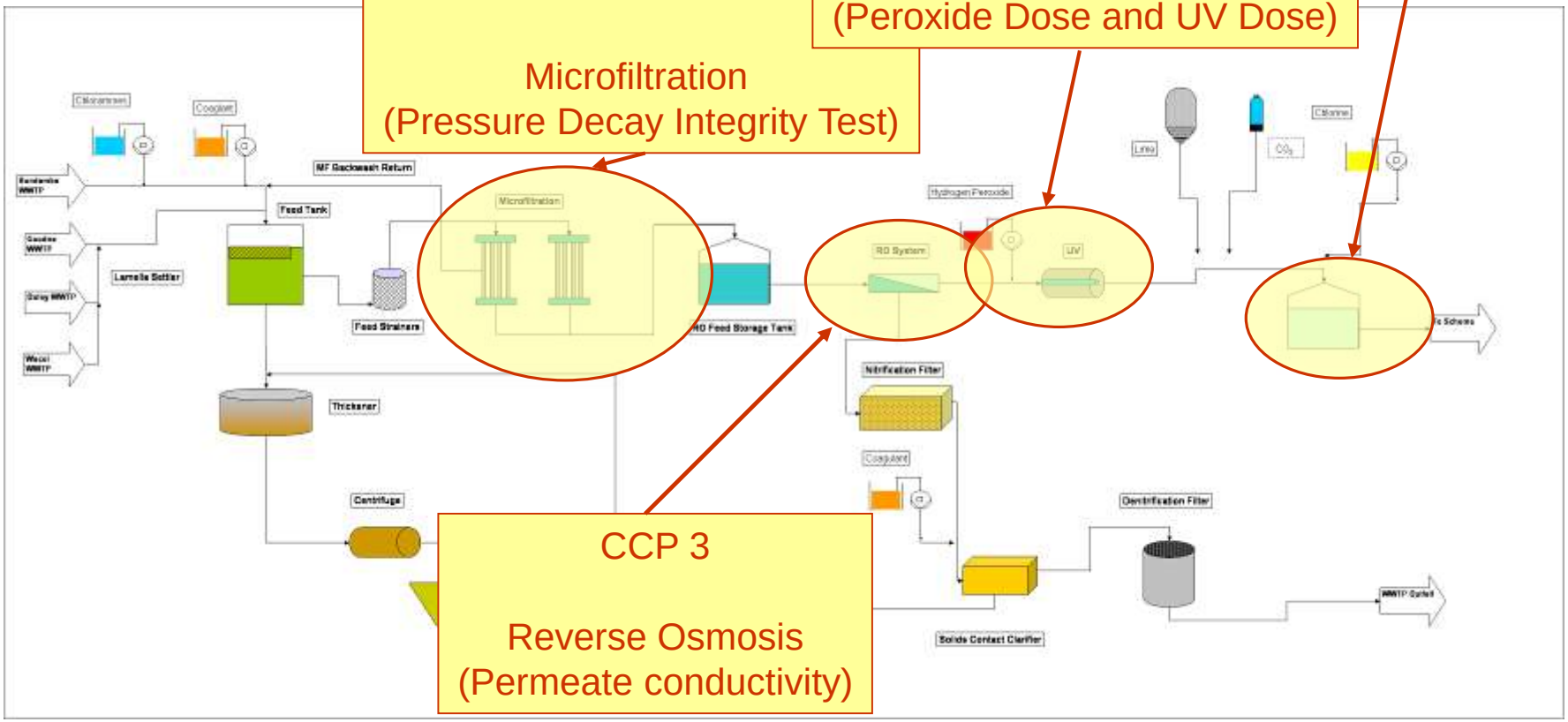
Microfiltration
(Pressure Decay Integrity Test)

CCP 4

Advanced Oxidation
(Peroxide Dose and UV Dose)

CCP 5

Chlorine Dose
(CT)



CCP 3

Reverse Osmosis
(Permeate conductivity)

Establish Critical Limits

- The HACCP team establishes critical limits to assess whether a particular control measure is effective.
- If this critical limit is exceeded or not met, it triggers the need for a corrective action.
- The critical limit can be either a numerical limit (e.g., chlorine residual concentration, system pressure) or a yes/no type response on whether a particular control measure was completed .

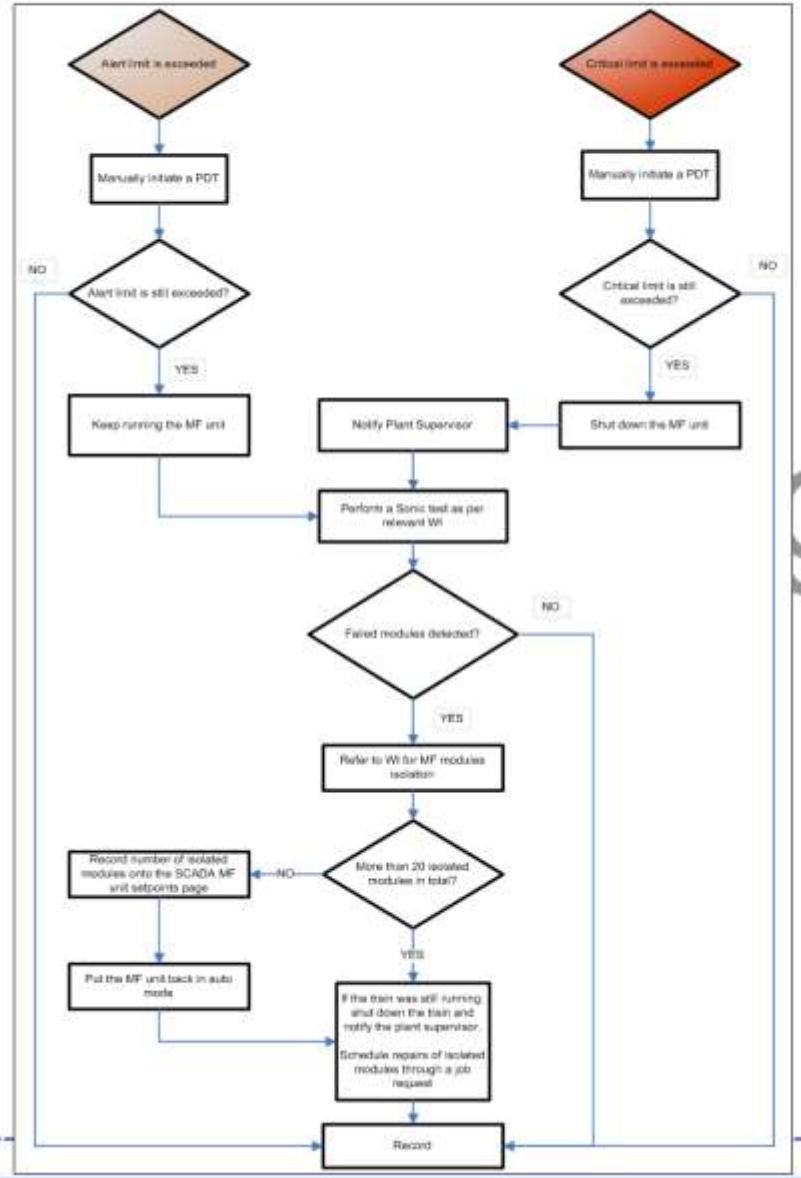
Parameter	SCADA TAG	Alert limit exceeded if	Critical limit exceeded if
Train-specific combined RO permeate	220x-05	Conductivity > 100 uS/cm	Conductivity > 150 uS/cm

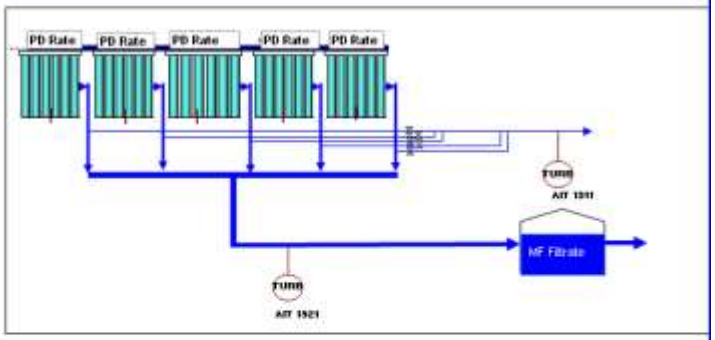
Example limit – Western Corridor Qld Australia

Operational Response

ALERT/CRITICAL LIMITS

Parameter	SCADA ANALYSERS TAG NUMBER	Alert limit exceeded if	
Daily Integrity Test (Pressure Decay Test)	NA	> 2.0 kPa / minute for 2 consecutive tests	> 3.0 kPa / minute





RELATED WORK INSTRUCTIONS

Title	Ref #
Pressure Decay Test (PDT)	
Module inspection for integrity : sonic test	
MF modules isolation and pin repairs	

NOTIFY INSTANTLY

Who	What	To Whom ?
Any Persons onsite noticing alarm	Alert/Critical Limit exceeded	Operations Staff
Operations Staff	Critical Limit Exceeded, analyser checked	Plant Supervisor
Operations Staff	Incident	Incident Response Team

RECORD

Who	What	Where
Operations Staff	Any Breach in Alert Limits	WTP log
Operations Staff	Any Breach in Critical Limits	Incident report
SCADA	Turbidity, daily integrity test	SCADA System
Operations Staff	Actions	WTP Log

EMERGENCY/SAFETY ISSUES

What	Who	Where

Where has HACCP been Used in Recycling

- Western Corridor Recycled Water Project, Brisbane Australia (ISO 22000 Certified).
- PUB, Singapore SS 444:998 (Singapore Standard)
- Melbourne Water
- SA Water (South Australia)
- Elements in the US, but current concern is additional requirements.

Our Project - Team 13-03

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Utility and Other Partners

wingoc
every drop counts

CITY OF SCOTTSDALE

Water Campus

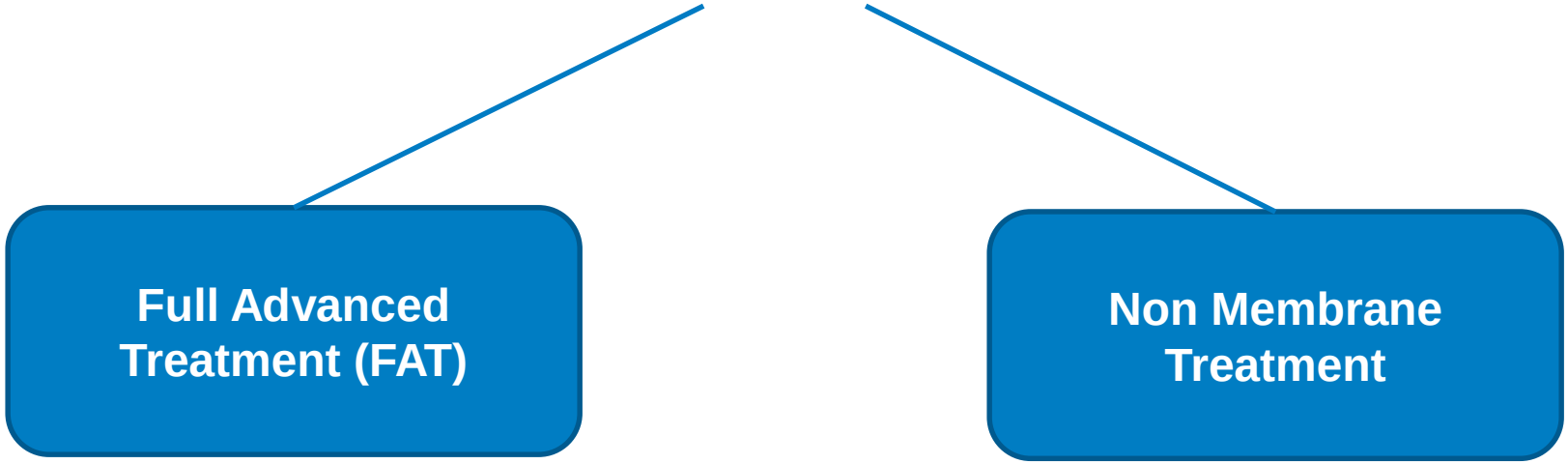
Australian Water Recycling
Centre of Excellence

WEST BASIN MUNICIPAL WATER DISTRICT

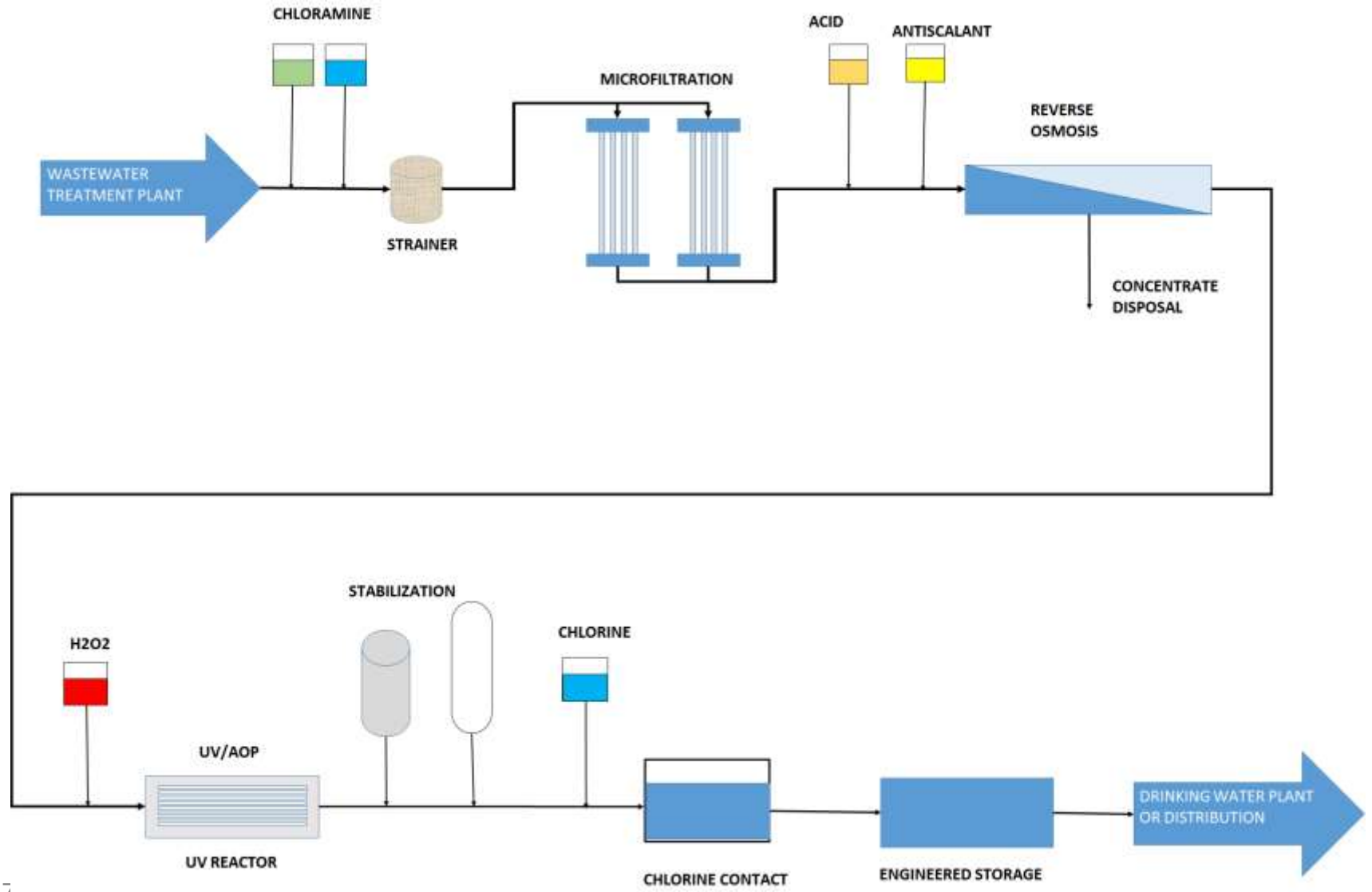
VEOLIA
WATER

Goals for 13-03

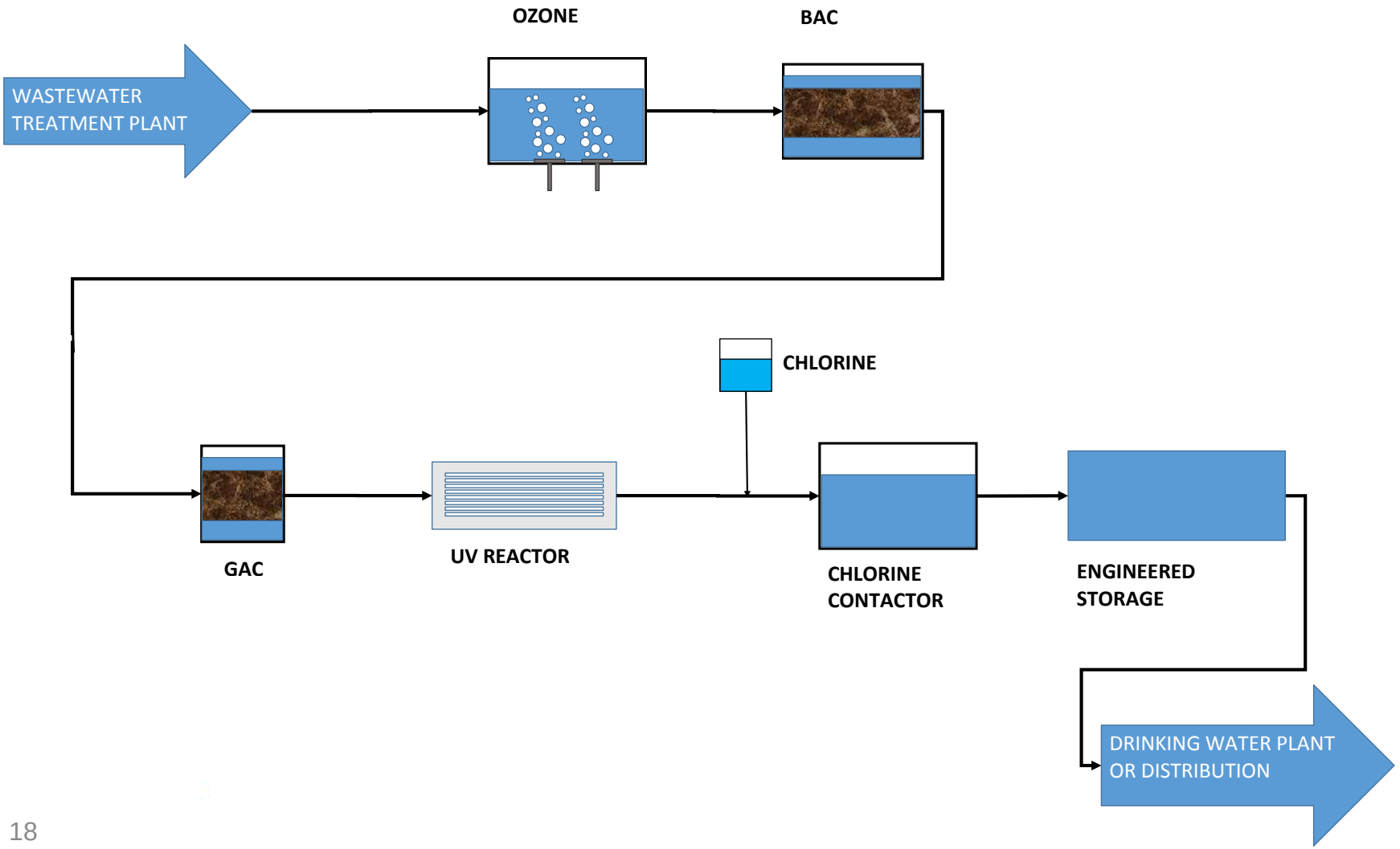
Conduct a hazard assessment to identify health risks, identify water quality objectives and identify critical control points for 2 treatment trains.



FAT - MF/UF – RO – UV/H_2O_2 – Cl_2 – Engineered Storage



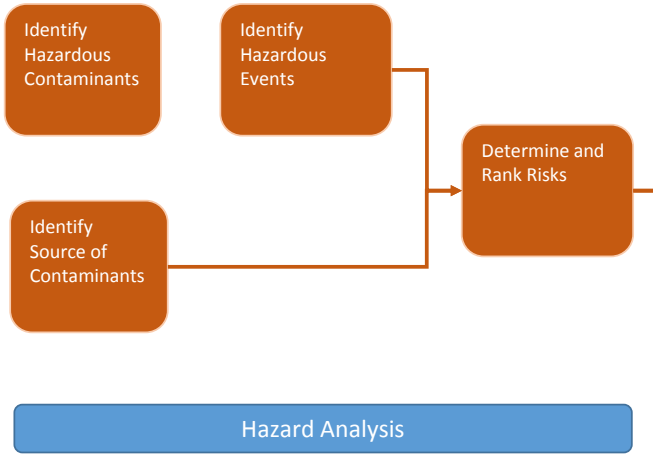
Non FAT - O_3 – BAC – GAC – UV – Cl_2 – Engineered Storage



Conduct a Hazard Analysis

- Identify hazards and hazardous events.
- Assess and quantify those risks.
- Describe how hazards and hazardous events are to be managed and which control measures need to be implemented.

Source Water Analysis



Likelihood	Consequence				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	Low (E1)	Moderate (E2)	High(E3)	Very High (E4)	Very High (E5)
Likely	Low (D1)	Moderate (D2)	High (D3)	Very High (D4)	Very High (D5)
Possible	Low (C1)	Moderate (C2)	High (C3)	Very High (C4)	Very High (C5)
Unlikely	Low (B1)	Low (B2)	Moderate (B3)	High (B4)	Very High (B5)
Rare	Low (A1)	Low (A2)	Low (A3)	High (A4)	High (A5)

Identify Source Water Hazards

Began with a literature review

- Source concentrations in literature.
- Reviewing data from participating utilities.

		Concentration		
		Primary Effluent	Secondary Effluent	Tertiary Effluent
Microorganisms	**UNITS**			
Cryptosporidium	oocysts/L	67-333 [1]	0-9 [1] 0-10 [13]	0-0.4 [1]
Giardia lamblia	cysts/L	533-2,033 [1]	0-32 [1] 50-16,500 [13]	0-2.1 [1]
Heterotrophic plate count (HPC)				
Legionella			340 [33]	2.5-6 [33]
Total Coliforms (incl. fecal coliform and E. Coli)	CFU/mL	29,000-48,000 [1] ~10,000 [2]	41-78 [1] ~100 [2]	1.1-4.8 [1] ~1 [2]
Viruses (enteric) - Salmonella, Shingella, etc	PFU/mL		0.6-13,000 [13] 21 [24]	
Inorganics and metals				
Aluminum (Al)	mg/L	0.55-0.799 [38]	48 [4] 0.01 [27a] 0.060-0.280 [38]	0.03 [27b]
Antimony (Sb)	ug/L	90 [30]	ND [39]	0.327-5.420 [5a]
Arsenic (As)	ug/L	1 [30] 442000 [32]	1850 [32] 0.8-1 [38] 50 [39]	0.919-2.866 [5a] 0.832-3.569 [5b]
Asbestos	MFL			<0.2 [48]
Barium (Ba)	ug/L		0.001 [27a]	0-5.800 [5a] 0-4.610 [5b]
Beryllium (Be)	ug/L	5 [30]		0-0.041 [5a] 0-0.086 [5b]
			8.4 [3]	

Determined our Treated Water Quality Objectives

Target water quality -EPA primary drinking water regulations and included California Drinking Water Regulations.

Used lower of the two values where applicable

Focus on action levels and notification levels.

The team agreed not to include secondary standards unless an argument can be made for specific individual constituents.

Identify Hazardous Events

Disease outbreak – high pathogen load

Accidental contamination of the catchment

Formation of DBPs in the process train

Failure of biological processes

High rainfall event – bypassed treatment

Catastrophic membrane integrity breach

Overdosing, underdosing or contamination of chemicals

Semi Quantitative Risk Assessment

We established a model source water based on CA facilities

Contaminant

Risk before treatment

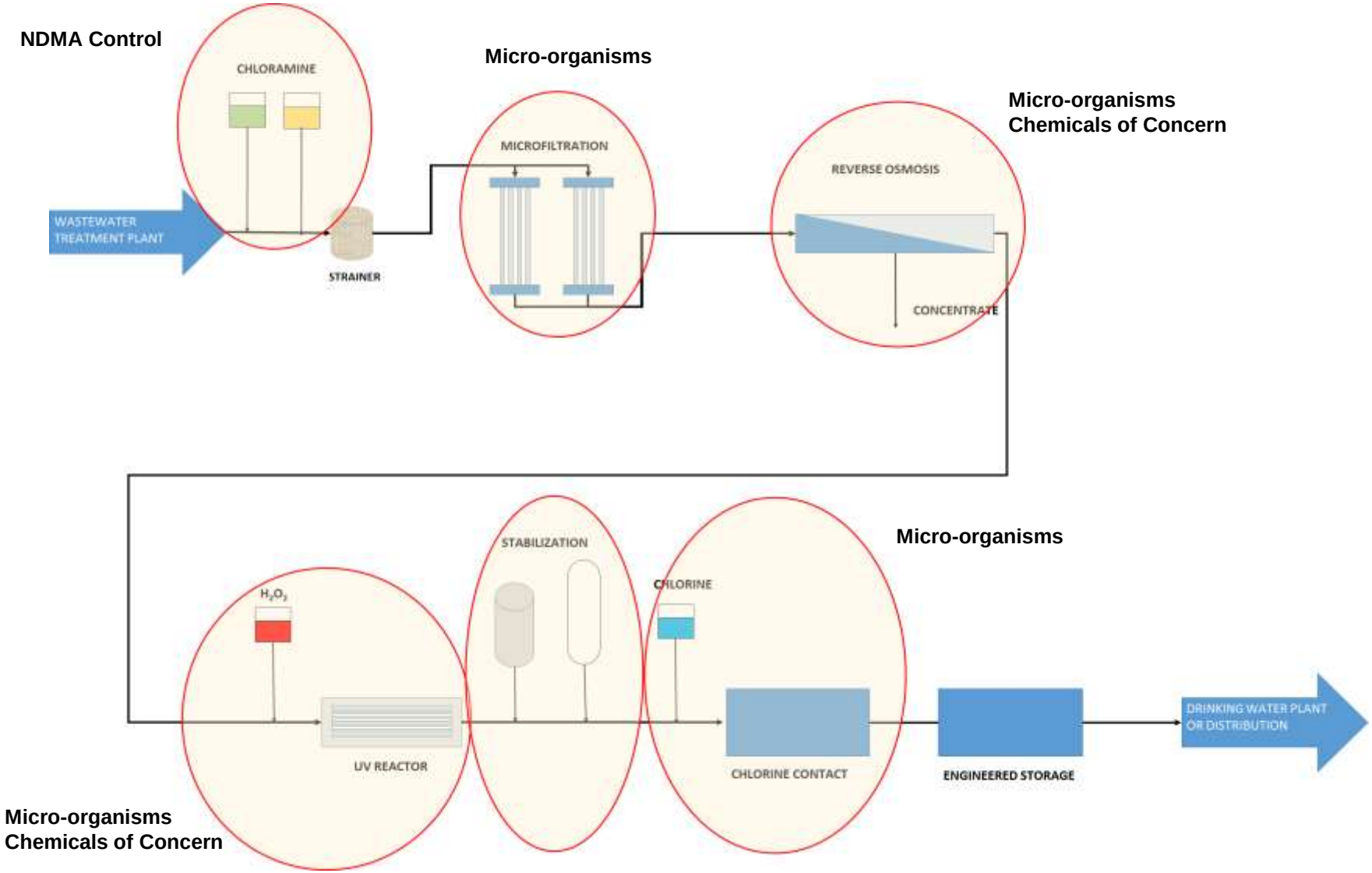
Risk post treatment

Inherent Risk and Assessment of Treatment Barriers

These assessments determine the hazards in the source at an unacceptable level and whether the treatment process is adequate to treat them.

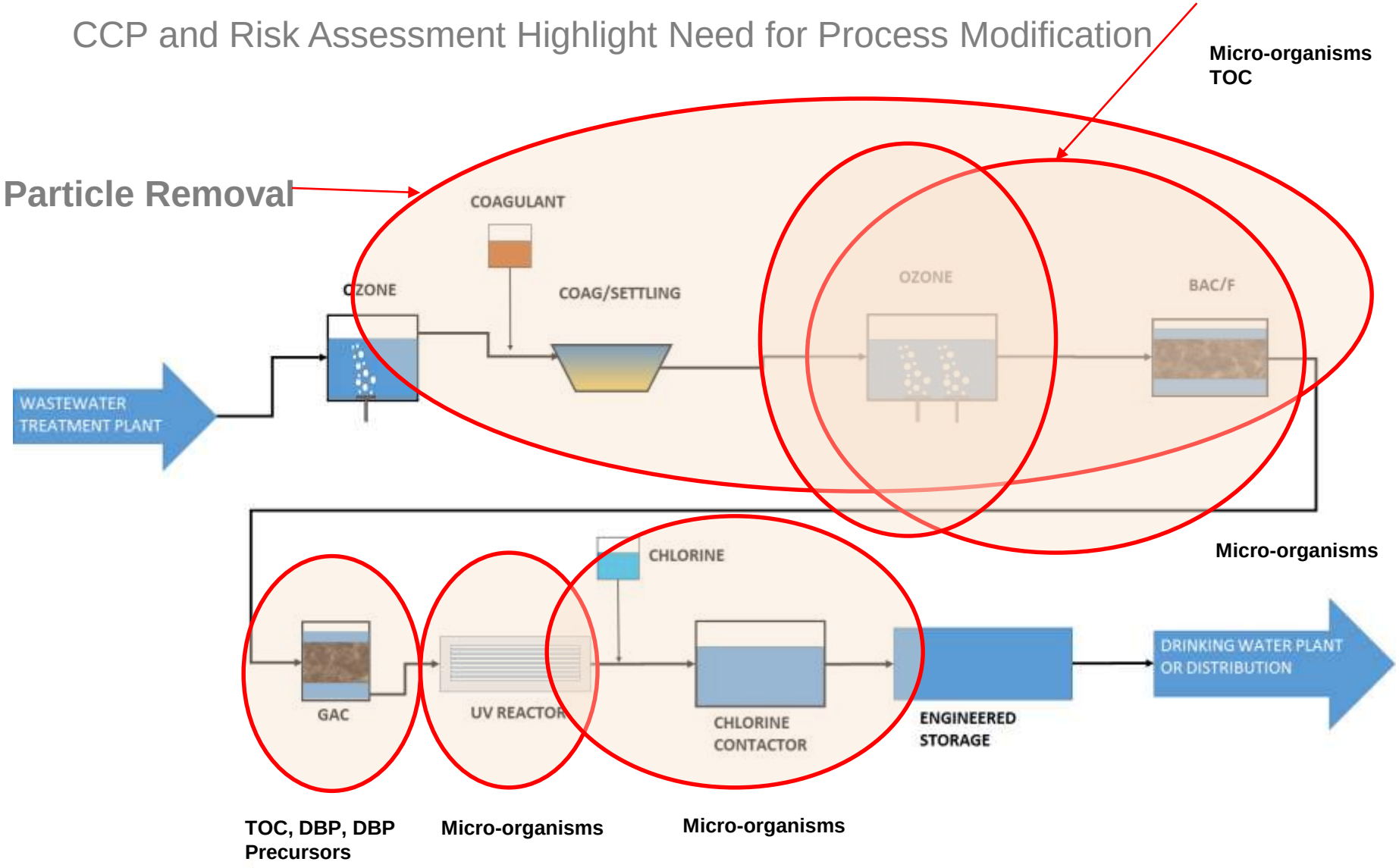
								Inherent Risk (based on drinking feedwater directly at 2L per day)						Barrier Assessment (based on drinking the product water assuming all barriers worked as designed)		
Hazard	Target (lesser of EPA & CDPH)	Max concentration in source	Unit	Ratio Max/Target	Impact	Source	Notes	Consequence	Likelihood	Risk	Uncertainty	Required treatment efficiency	Treatment Barriers	Consequence	Likelihood	Risk
Biological																
Cryptosporidium	0				Acute Health	Domestic waste - human and animal faecal matter Contamination of storage reservoirs		Catastrophic	Almost Certain	Very High (E1)	Certain	10 log	UF, RO, UV, Chlorine	Insignificant	Rare	Low (A1)
Giardia lamblia	0				Acute Health	Domestic waste - human and animal faecal matter Contamination of storage reservoirs		Catastrophic	Almost Certain	Very High (E1)	Certain	10 log	UF, RO, UV, Chlorine	Insignificant	Rare	Low (A1)
Heterotrophic plate count (HPC)					N/A	?	Only an indicator									
Legionella	0				Acute Health	Cooling tower bleed?	Not really expected but TBC	Catastrophic	Unlikely	Very High (D1)	Uncertain	10 log	UF, RO, UV, Chlorine	Insignificant	Rare	Low (A1)

CCPs – FAT Train



CCPs – Non FAT Train

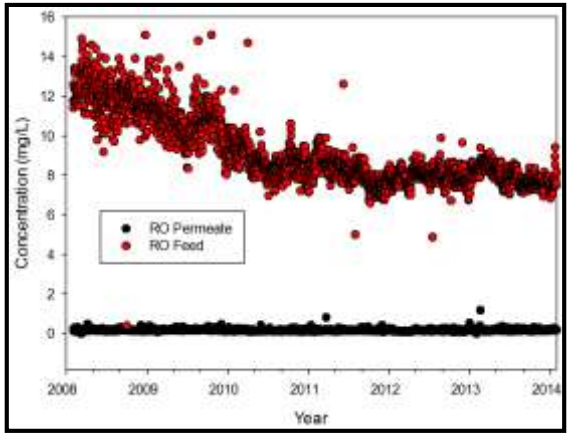
CCP and Risk Assessment Highlight Need for Process Modification

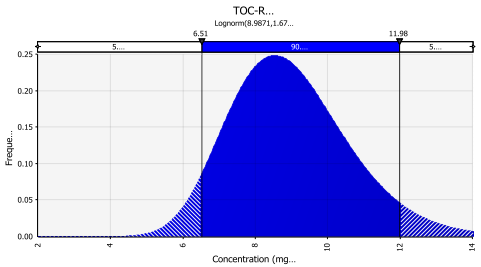


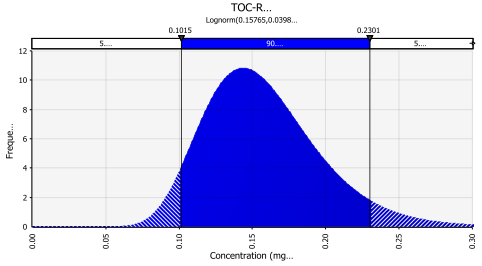
How Reliable are these CCPs?

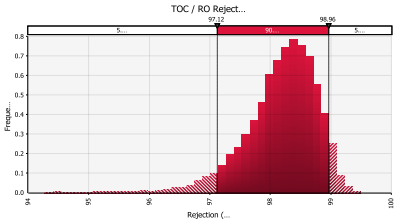
Quantify Reliability with Statistical Analysis

Monte Carlo Simulation from Full Scale Operating Data

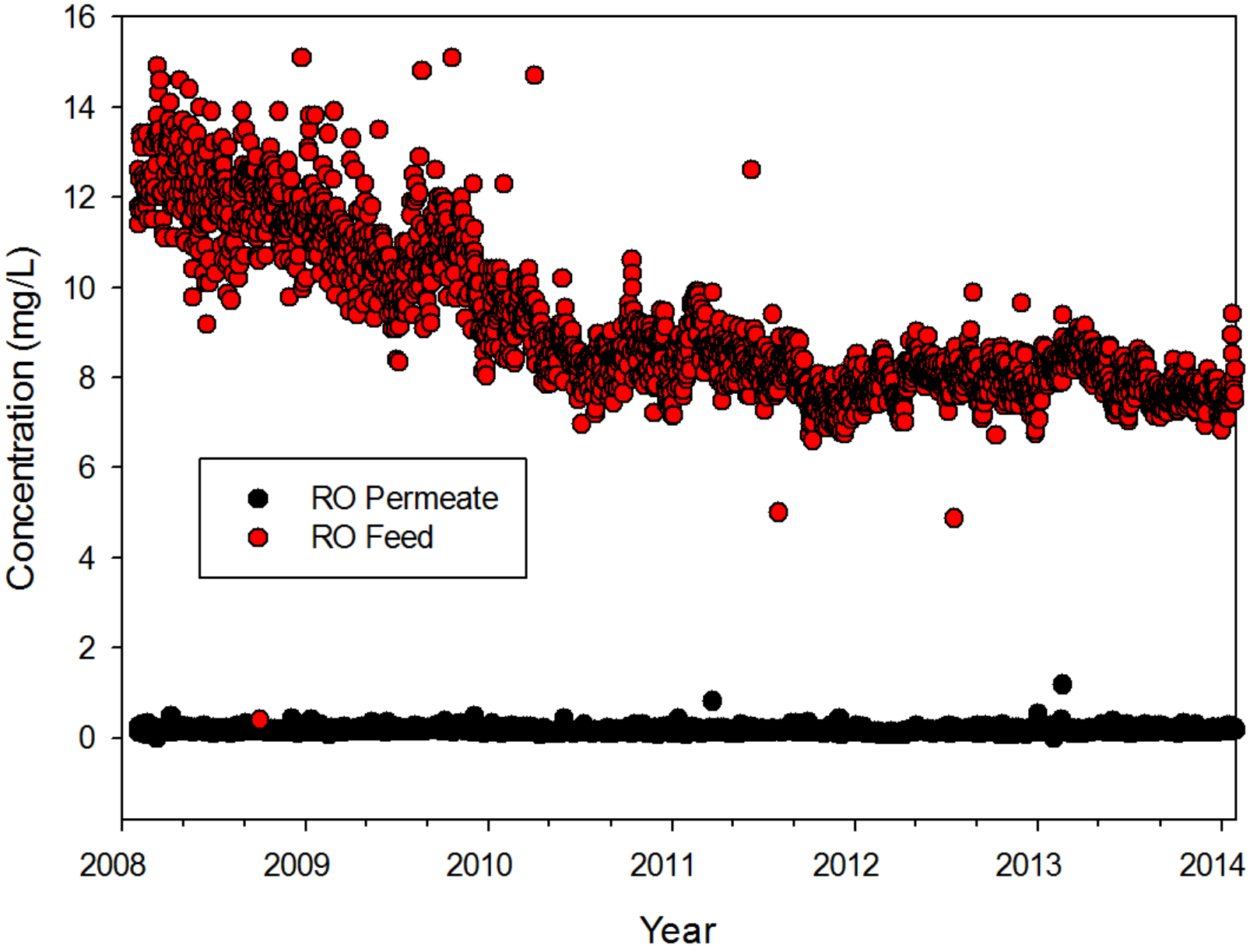




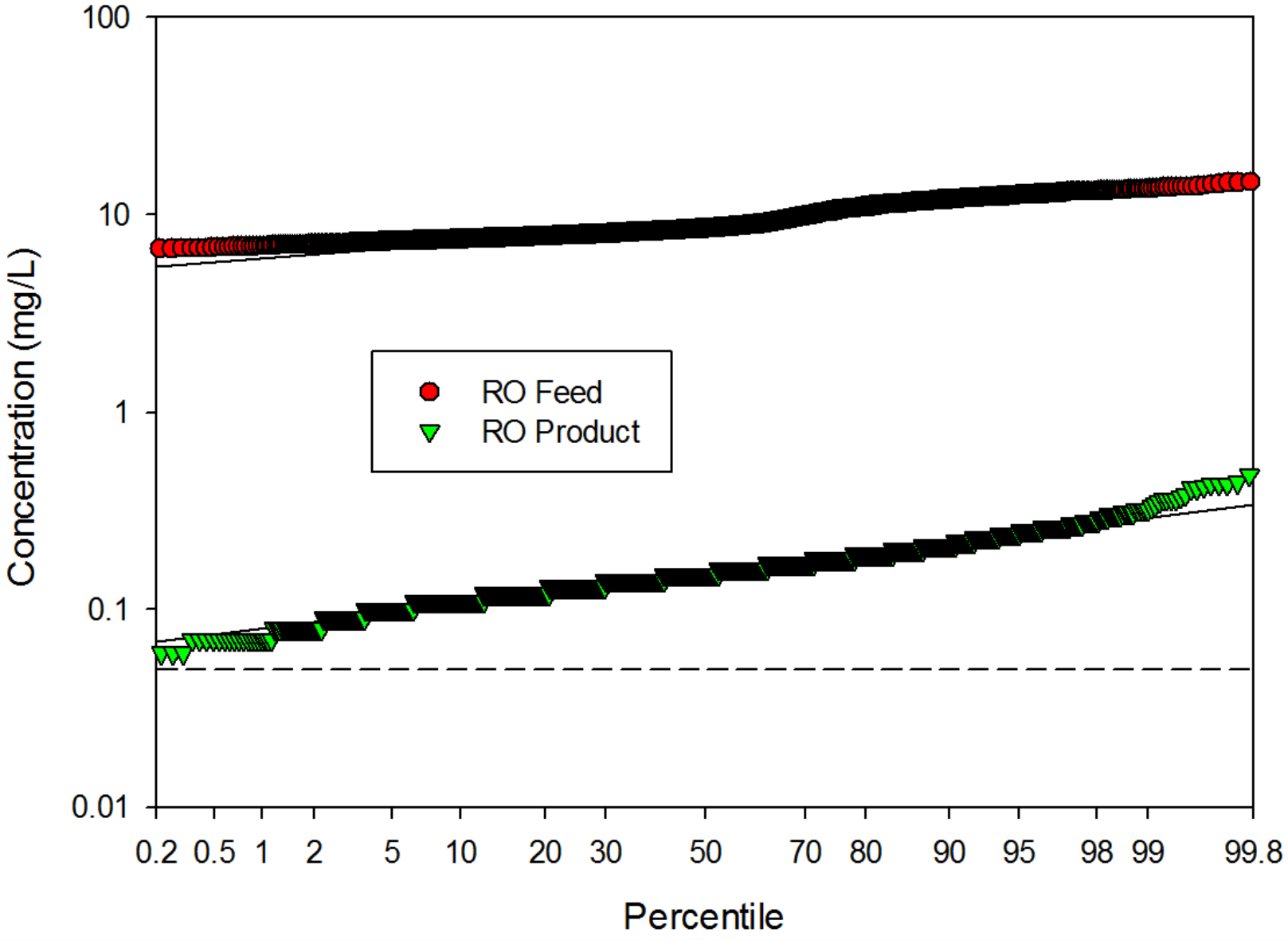




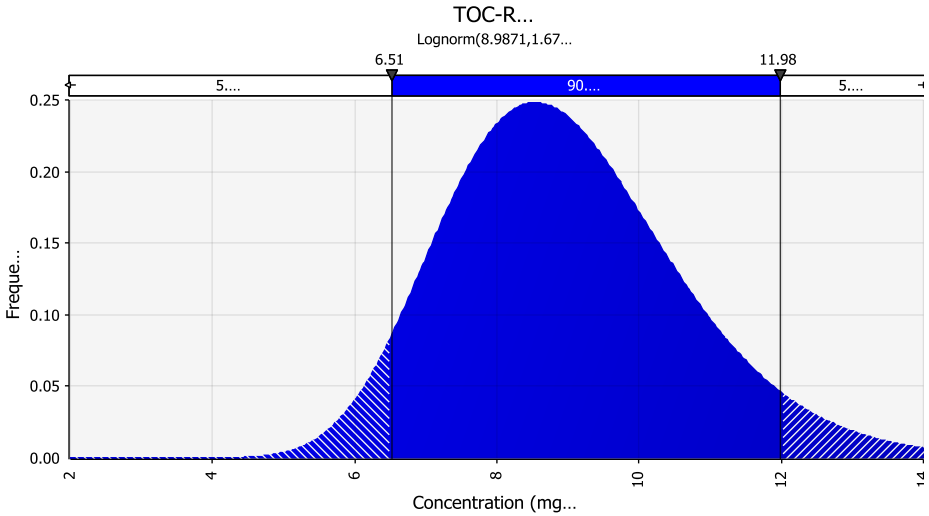
TOC time series

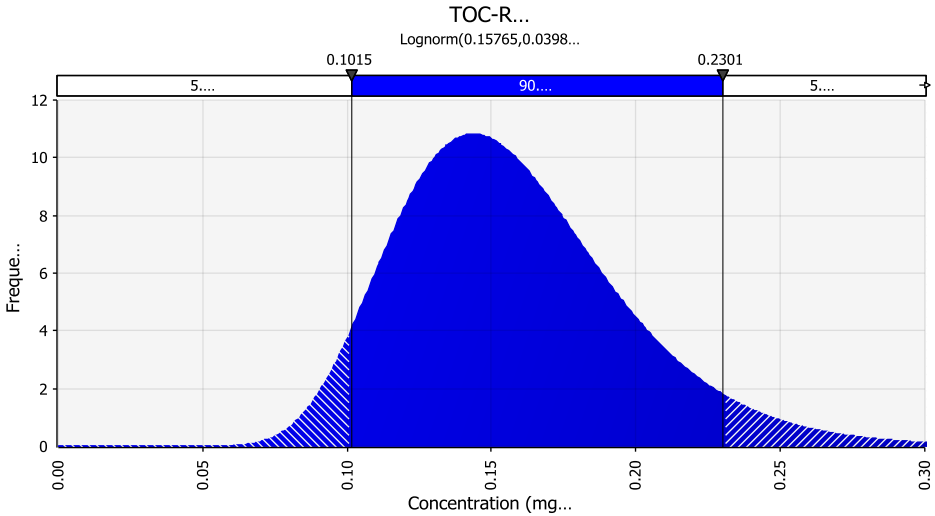


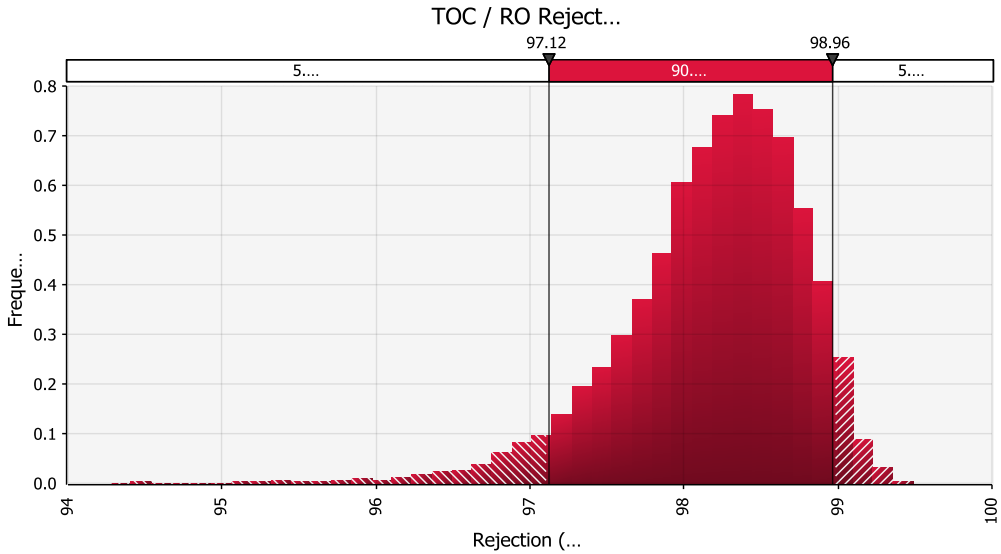
TOC lognormal probability plot



TOC Rejection (%) by RO

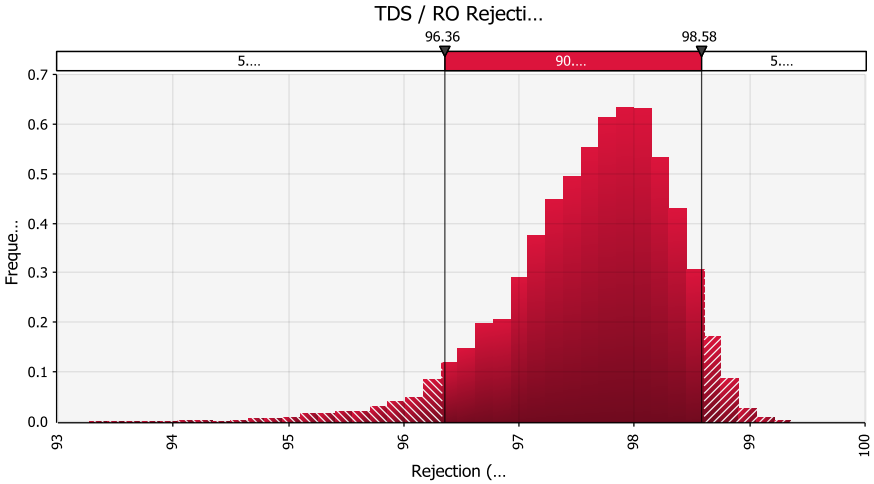


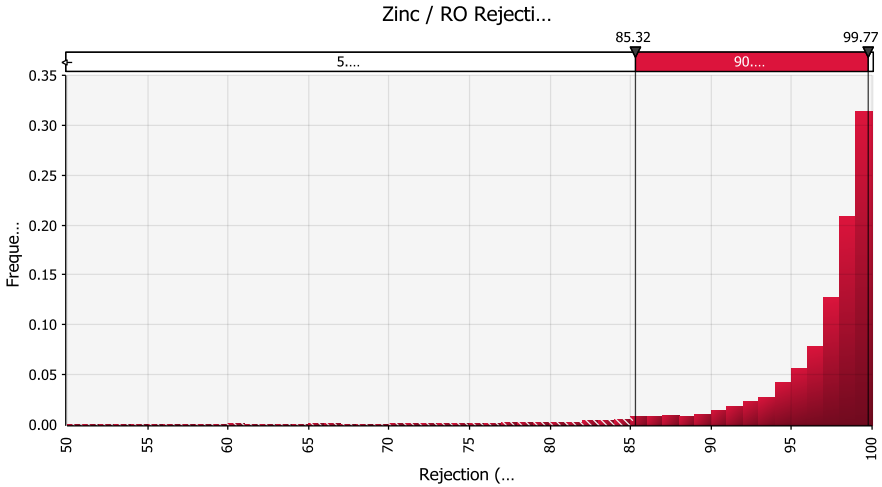


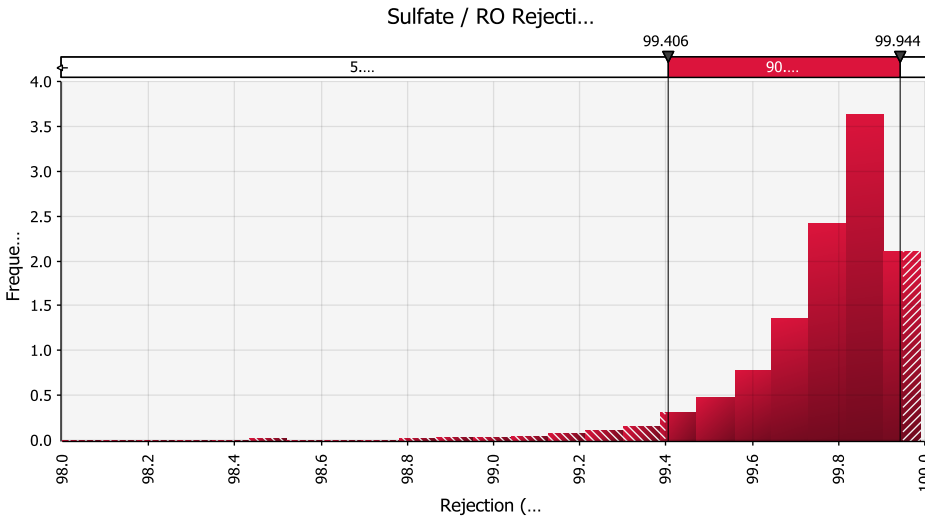


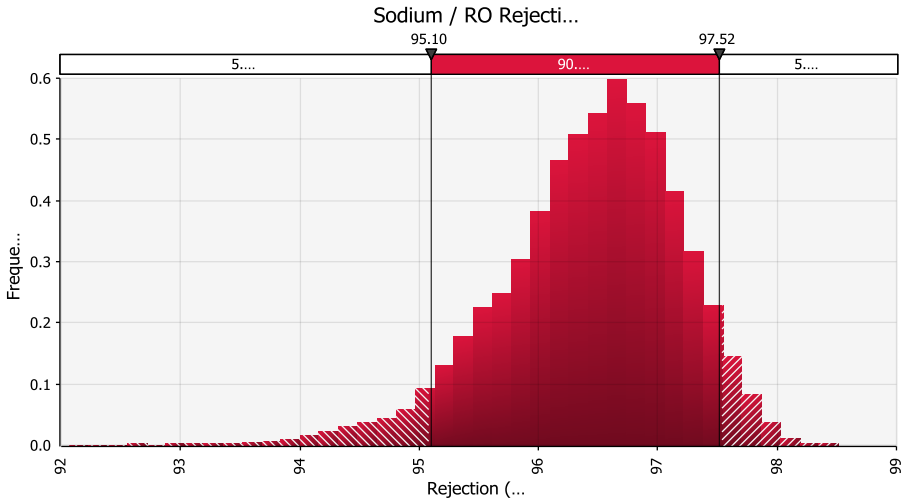
$$\boldsymbol{R(\%) = \frac{C_{f-}C_{p}}{C_{f}} \times 100}$$

RO rejection (%) by Monte Carlo simulation







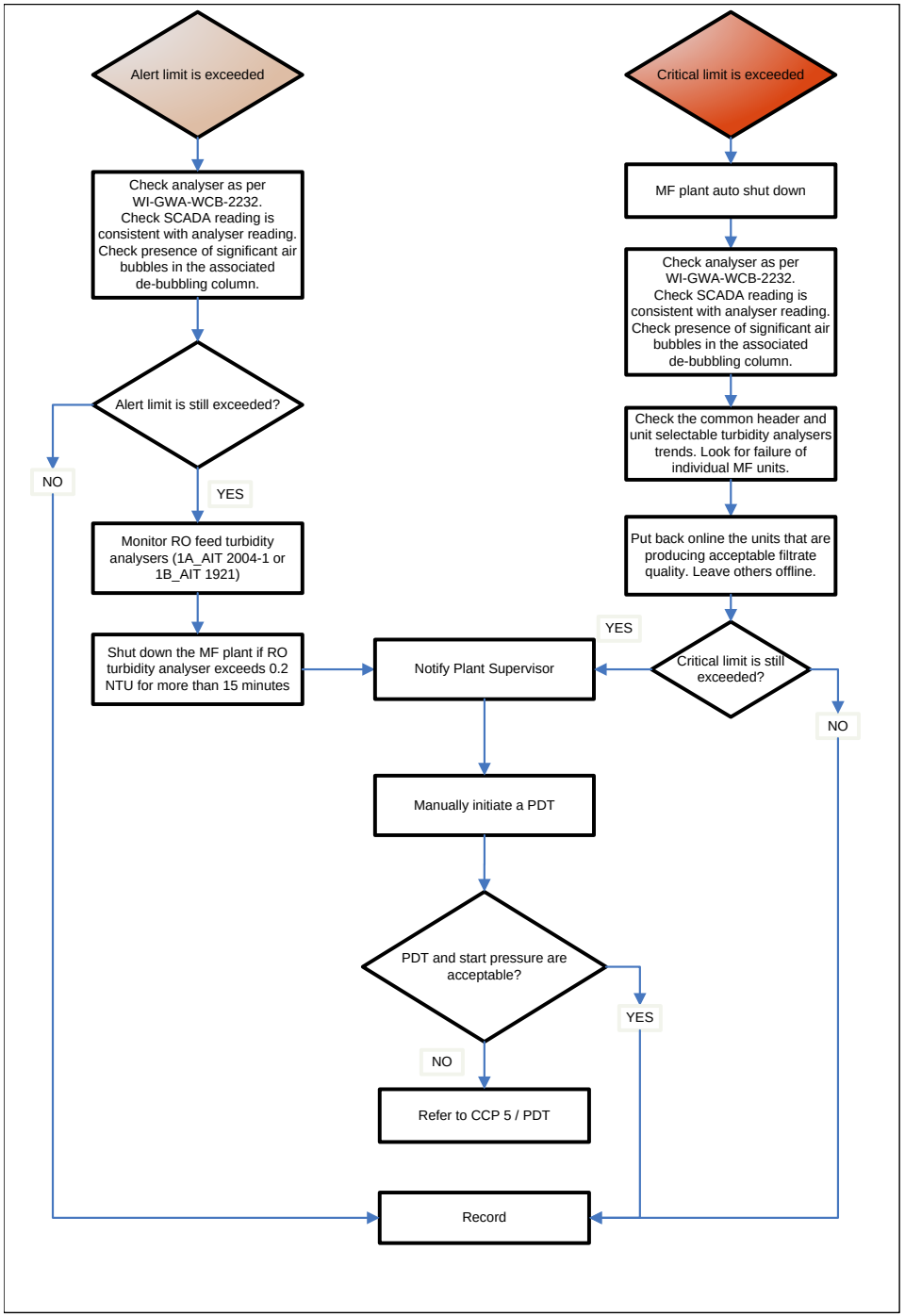


Where to From Here..

Conduct Bench/Pilot Level Challenge Test Studies

- Identify gaps following review of full scale plants.
- Planned full scale plant tests (Scottsdale Water Campus)
- Additional bench scale for gaps if required.

Develop Standard Design Approaches and Response Strategies



Can We Trust Operations?

WRRF-13-13:

Development of Operation and Maintenance Plan and Training and Certification Framework for Direct Potable Reuse (DPR) Systems

Successful Operations

- Designed correctly.
- **Operation must be realistic and practical.**
- **Assets and Infrastructure Maintained and Highly Reliable**.

The Human Element

Robust and reliable operational plans and systems to understand and manage operational risks.

Our Team

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Debbie Burris
DDB Engineering
Co PI

John Caughlin
Operator Star

Jim Vickers
Separation Processes Inc

Ben Stanford PhD
Hazen and Sawyer
Co PI

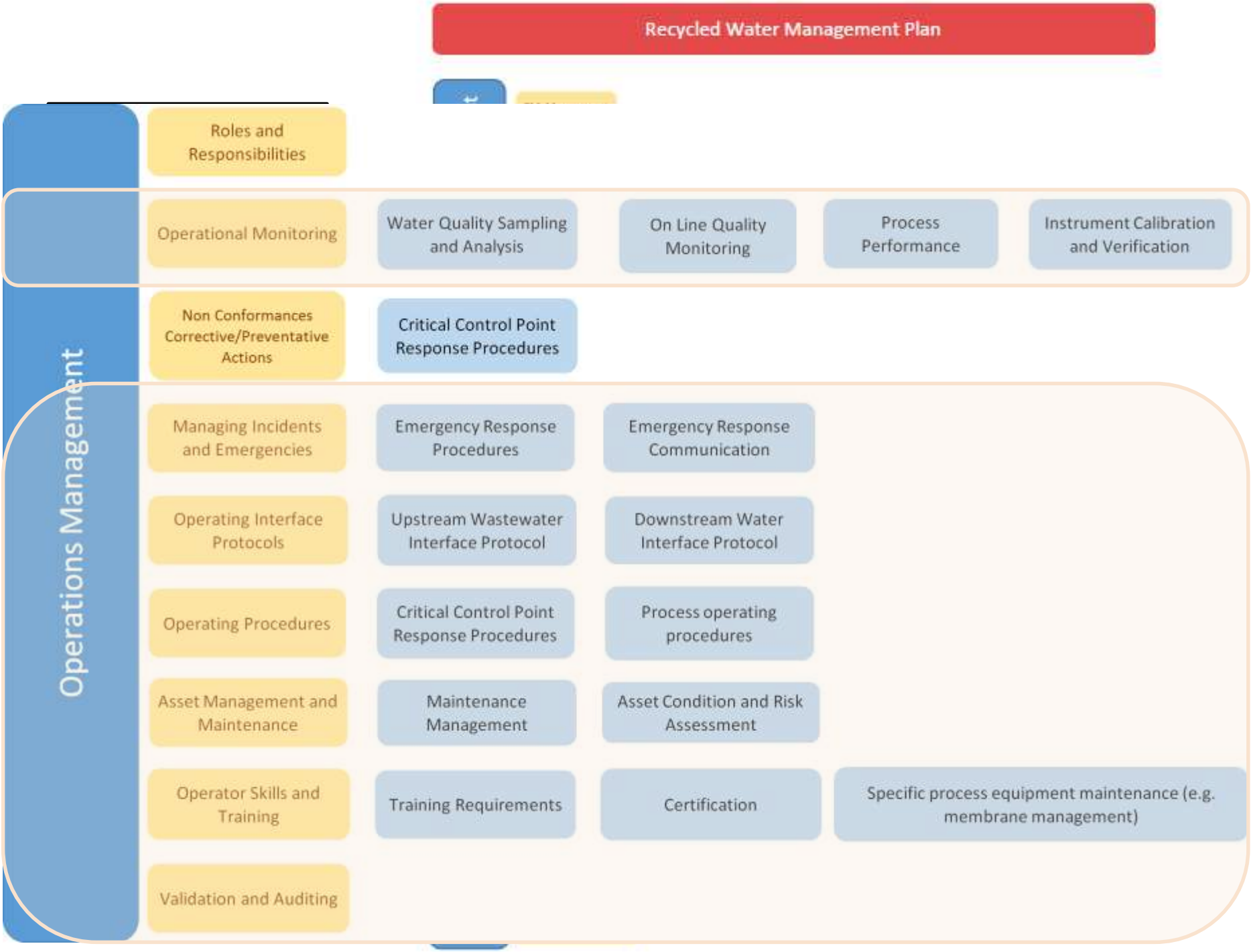
Utility and Other Partners

Phase 1: Develop a Standard Operations and Maintenance Plan for DPR Schemes

Operating Protocols/ Framework

Regulatory Framework

Operator Certification Program


Recycled Water Management Plan
Operations Management
Roles and Responsibilities
Operational Monitoring
Water Quality Sampling and Analysis
On Line Quality Monitoring
Process Performance
Instrument Calibration and Verification
Non Conformances Corrective/Preventative Actions
Critical Control Point Response Procedures
Managing Incidents and Emergencies
Emergency Response Procedures
Emergency Response Communication
Operating Interface Protocols
Upstream Wastewater Interface Protocol
Downstream Water Interface Protocol
Operating Procedures
Critical Control Point Response Procedures
Process operating procedures
Asset Management and Maintenance
Maintenance Management
Asset Condition and Risk Assessment
Operator Skills and Training
Training Requirements
Certification
Specific process equipment maintenance (e.g. membrane management)
Validation and Auditing

CA Regulations and DPR?

CCR Title 17, Division 1, Chapter 5, Group 4

Cross Connection/Backflow Connection

CCR Title 22, Division 4, Chapter 3

Water Recycling Criteria (IPR Orange County GWRS)

Groundwater Recharge

Surface Water (pending)

DPR ?

Evaluation of the California Code of Regulations and Recommendations

Gap analysis of existing regulations and recommendations

Gap Analysis is Under way

	RECYCLED WATER REQUIREMENTS					DRINKING WATER REQUIREMENTS		
	Water Recycling Criteria/Requirements Pertaining to Operation, Certifications, and Training	Title 22, California Code of Regulations (CCR) PR - GWR (DPH-14-003E, effective 6/18/14 Surface Applications	ubsurface Application	Title 22, CCR Division 4, Chapter 3 ater Recycling Criteri	Title 23, CCR Division 7, Chapter 9 Water Code	Title 17, CCR Division 1, Chapter 5 hitation (Environment	Drinking Water Criteria/Requirements Pertaining to Operation, Certifications, and Training	Policy Memo 97-005 DDW (CDPH, CDHS) Extremely Impaired Sources	Title 22, CCR Division 4 Drinking Water
1	Obta						Obtain a permit. A permit issued by DDW for use of an	Section C. 8 *"Submittal of a permit application"* and Section C. 12 *"Issuance*	Chapter 14, Article 1, Section 64001
2	Prior of a p a tre							Section C. 6 *"Alternative sources evaluation"*	Chapter 15, Article 2, Section 64414
3	Lab a DDW Chen seco Optir							Section C. 4 *"Effective Monitoring and Treatment"*	Chapter 15, Article 2, Section 64415
4	Recycled water used for Cat 4 shall be from a waste water agency that administers an industrial pretreatment program that assesses the fate of and monitors for DDW/RWQCB-specified contaminants through the treatment systems, includes an outreach program to minimize discharges of contaminants at the source, and maintains an inventory of chemicals and contaminants at the sources.	Section 60320.106	Section 60320.206				that levels of contaminants will not increase beyond the proposed treatment system's capability. Prepare and submit an extremely impaired source water quality surveillance plan that includes monitoring between the origin of contamination and the extremely impair source that is proposed for drinking water. Sanitary surveys shall be conducted initially and	Section C. 3 *"Source Protection"* and Section C. 4 *"Effective Monitoring and Treatment"*	Chapter 15, Article 3, Section 64427 and Section 64330
5	Include in ODP: on-going monitoring to verify performance of treatment processes to achieve their credited log reduction of pathogens	Section 60320.108 (d)	Section 60320.208 (d)				Submit a sampling plan for monitoring water quality to DDW.		Chapter 15, Article 2, Section 64416
6	Demonstrate underground retention time using an added								

28

Title 22, Article 5, Section 60314

The methods of operation of a dual plumbed recycled water system shall be described to assure avoidance of cross-connections between the recycled water and potable water piping systems.

Who should the permitting authority be?

Phase 2: Develop a DPR Training and Certification Curriculum Framework for DPR System Operators

Recommend DPR System Staffing

Benchmark Staffing from IPR Utilities

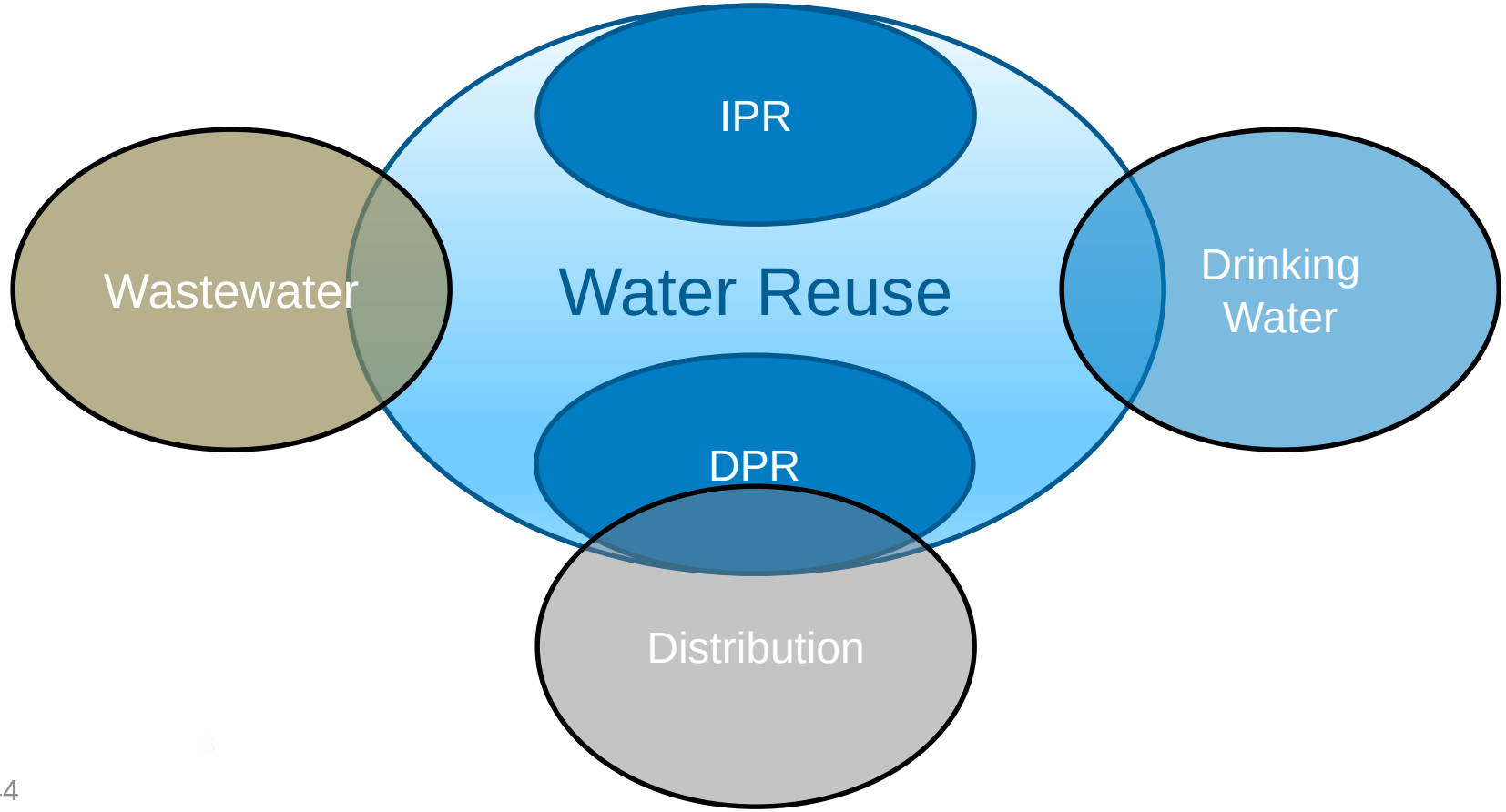
Include anticipated regulatory requirements

Incorporate HACCP Requirements

How Does Operator Certification Fit?

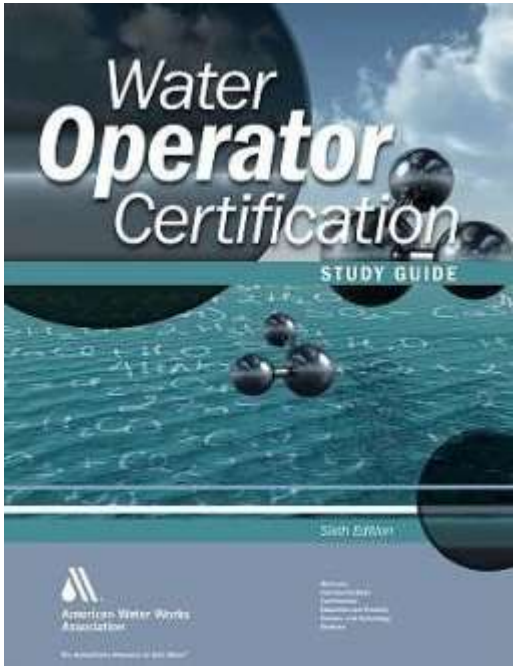
Certification for drinking water, wastewater and distribution.

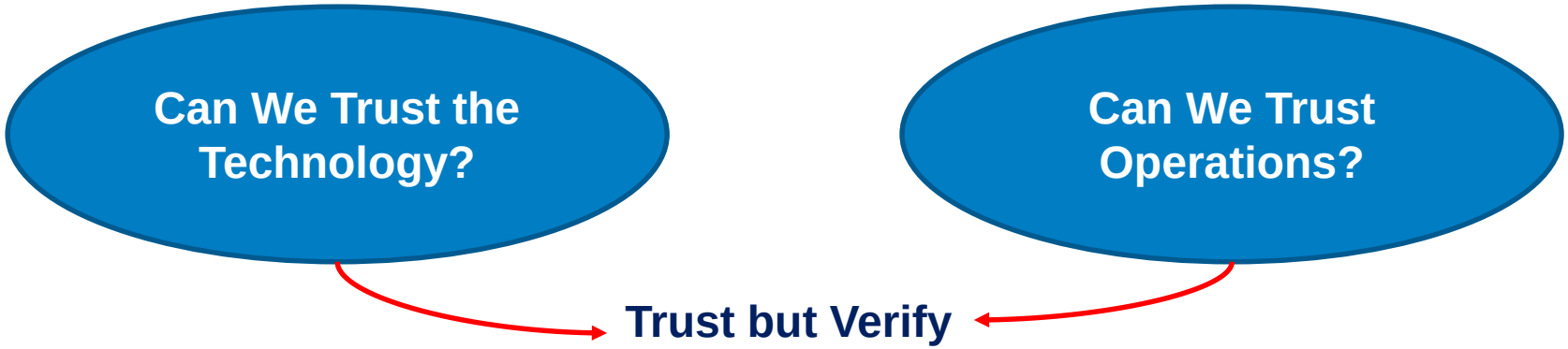
Where should DPR fit?



Develop Recommended Operator Staff Training and Certification Framework

- Based on gap analysis previously conducted.
- Technology and important operational systems/processes.
- Training co-ordination experience .





YES

13-03
Technical Validation

YES

13-13
Operational Validation

Thank You

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Bull Pen – Log Removals

FAT	Virus	Giardia	Crypto
Chloramine	0	0	0
MF	0	4	4
RO	2	2	2
UV/AOP	4	4	4
Stab	0	0	0
Cl2	4	2	0
	10	12	10
Non FAT	Virus	Giardia	Crypto
Coag/BAF	2	3	3
(ozone)	3	2	2
GAC	0	0	0
UV	2	4	4
Cl2	4	2	0
	11	11	9

Bull Pen – Risk Assessment Methodology

Risk Assessment Methodology

This is the risk assessment methodology used, which has been adopted from the AGWR.

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

Level	Consequence	Description	Detailed Example
5	Catastrophic	Major impact for a large population	Widespread acute health impact expected,
4	Major	Major impact for a small population	Potential acute health impact affecting a
3	Moderate	Minor impact for a large population	Repeated breach of a chronic health
2	Minor	Minor impact for small population	Elevated levels of a chronic health parameter
1	Insignificant	Insignificant impact or not detectable	No expected health impacts or an isolated

Bull Pen – Risk Assessment Methodology

Likelihood	Consequence				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	Low (E1)	Moderate (E2)	High(E3)	Very High (E4)	Very High (E5)
Likely	Low (D1)	Moderate (D2)	High (D3)	Very High (D4)	Very High (D5)
Possible	Low (C1)	Moderate (C2)	High (C3)	Very High (C4)	Very High (C5)
Unlikely	Low (B1)	Low (B2)	Moderate (B3)	High (B4)	Very High (B5)
Rare	Low (A1)	Low (A2)	Low (A3)	High (A4)	High (A5)

Uncertainty	Description
Certain	There is 5 years of continuous monitoring data, which has been trended and assessed, with at
Confident	There is 5 years of continuous monitoring data, which has been collated and assessed, with at
Reliable	There is at least a year of continuous monitoring data available, which has been assessed; or
Estimate	There is limited monitoring data available; or
Uncertain	There is limited or no monitoring data available; or