DEVELOPING A NATIONWIDE WATER REUSE RESEARCH ROADMAP

HOSTED BY THE WATER RESEARCH FOUNDATION

MARCH 6, 2022

2022 WateReuse SYMPOSIUM

SHAPING OUR PAST &

CHARTING OUR FUTURE

WRF Team Introductions

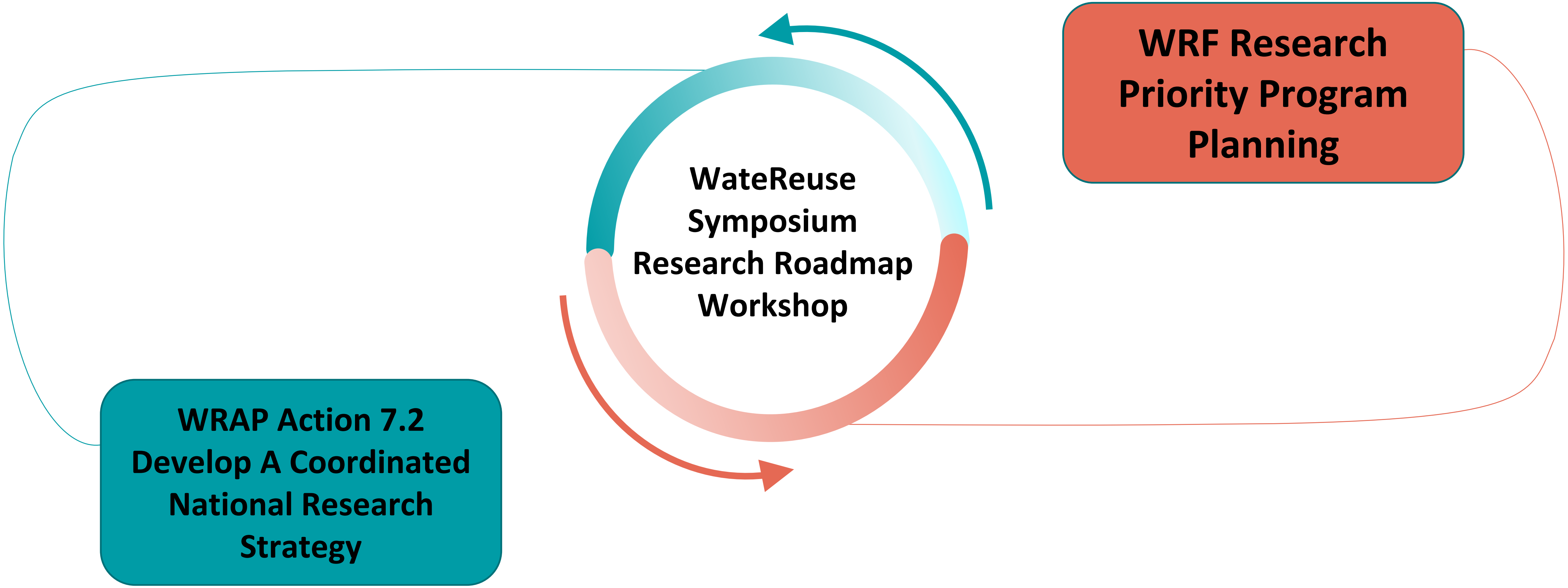
Julie Minton
Research Unit Lead

Erin Partlan
Innovation Program Manager

Katie Spahr
Research Program Manager

Lyndsey Bloxom
Research Program Manager

Today’s Workshop Is Dual-purpose



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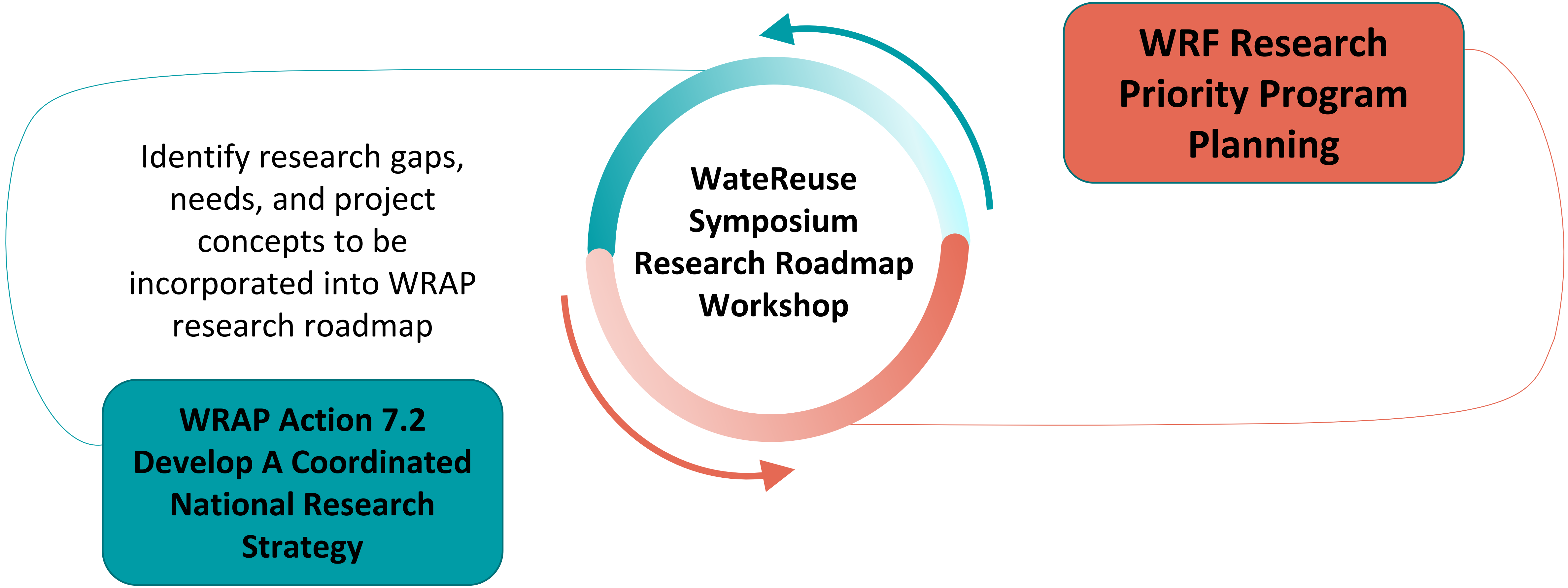
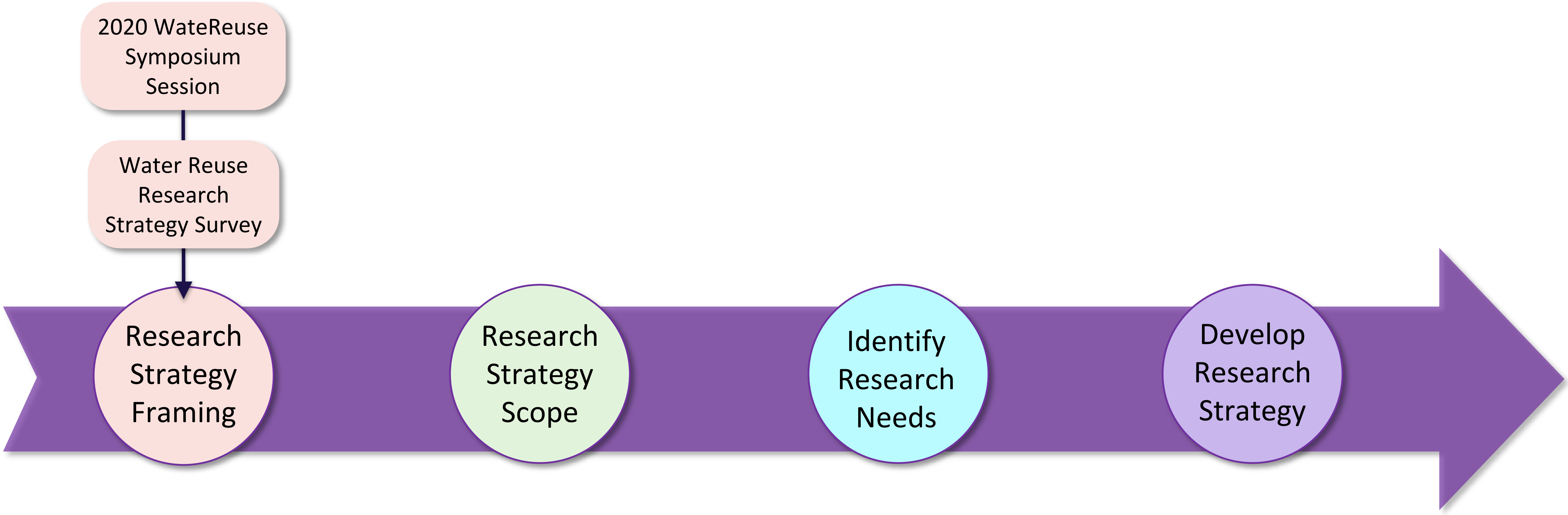


WRAP Action 7.2 Description

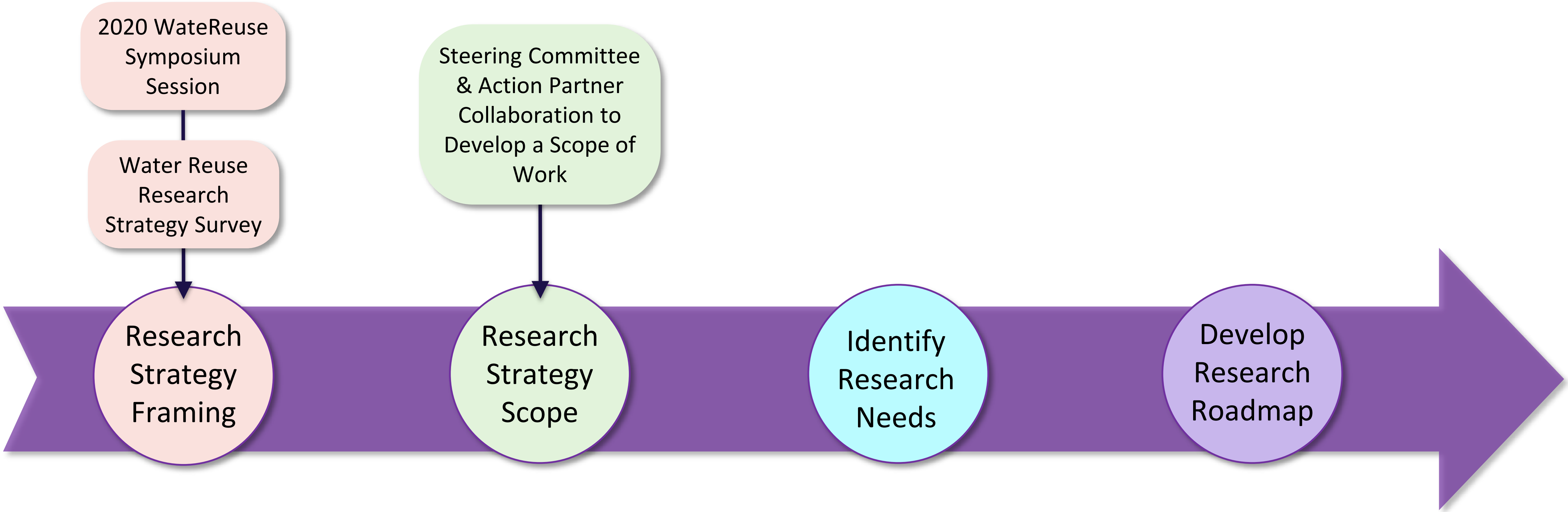
Develop a Coordinated National Research Strategy

"The strategy should include a **prioritized list of research needs across various water reuse applications and sources of water** for potential reuse, including those specific through public input."

WRAP Action 7.2 Implementation Milestones



WRAP Action 7.2 Implementation Milestones



Steering Committee & Action Partners

Steering Committee

Pinar Balci
NYDEP

Chris Impelliteri
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Action Partners

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WateReuse Association

Claudio Ternieden
Water Environment Federation

WRAP Action 7.2 Scope Of Work

Approach Organized by Source Water / End Use

- Stormwater
- Municipal Water for Drinking (Potable Reuse)
- Nonpotable reuse (urban, commercial)
- Environmental reuse
- Industrial, Ag Reuse

Task 1: Identify Challenges / Gaps

Task 2: Rank Needs & Develop Research Projects

Task 3: Develop Research Strategy

WRAP Action 7.2 Scope Of Work

Approach Organized by Source Water / End Use

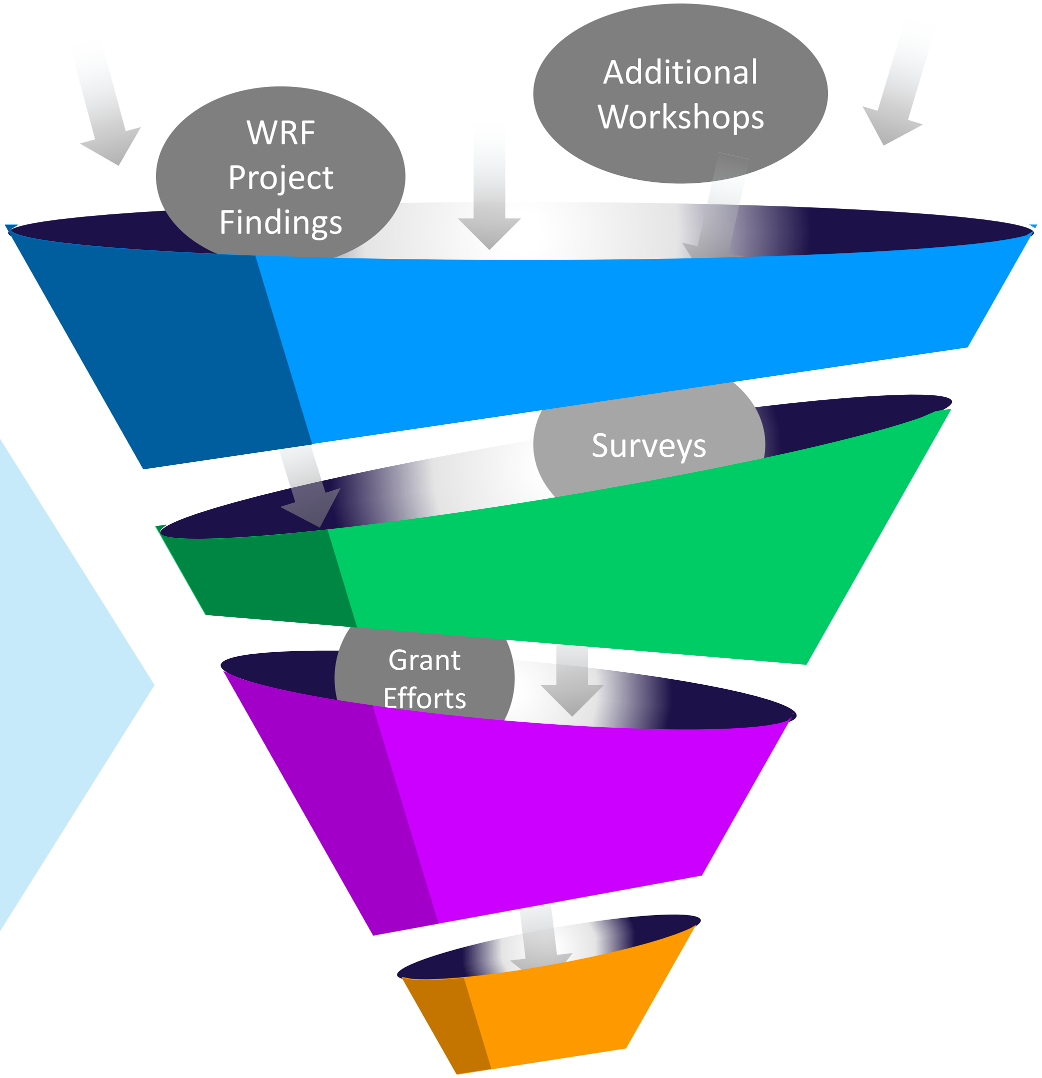
- Stormwater
- **Municipal Water for Drinking (Potable Reuse)**
- Nonpotable reuse (urban, commercial)
- Environmental reuse
- Industrial, Ag Reuse

Project concepts developed today will support the Potable Reuse Topic

WRAP Action 7.2 Scope Of Work

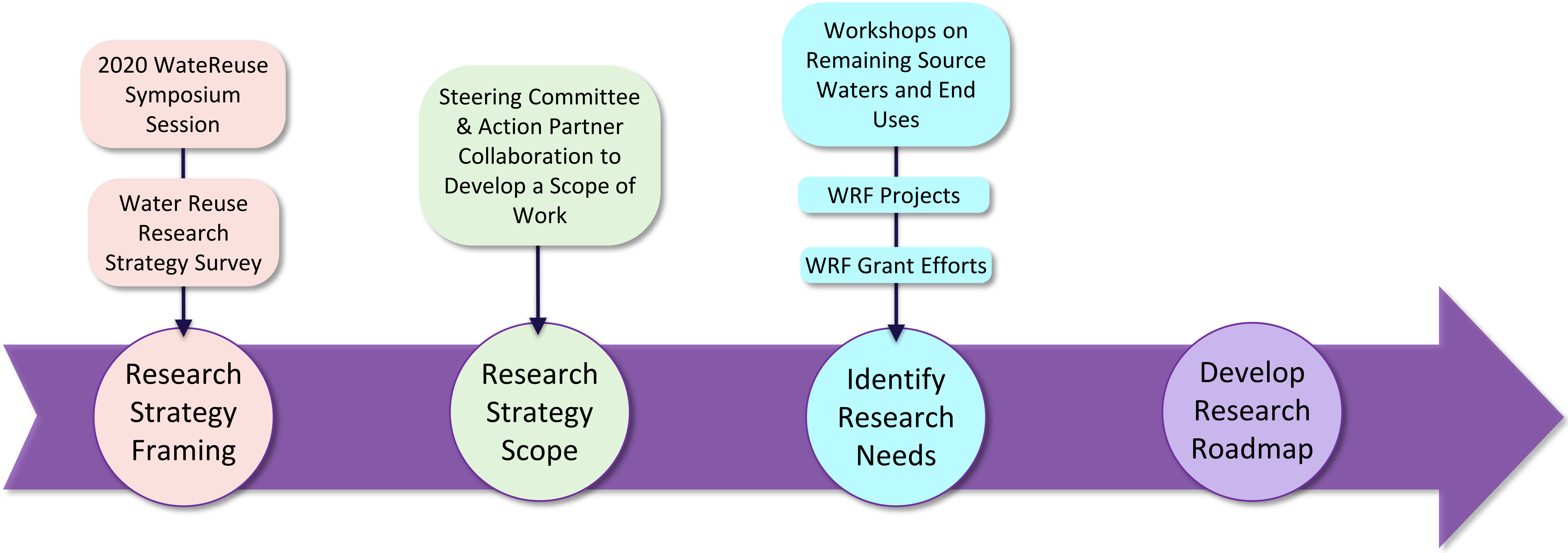
Approach Organized by Source Water / End Use

- Stormwater
- Municipal Water for Drinking (Potable Reuse)
- Nonpotable reuse (urban, commercial)
- Environmental reuse
- Industrial, Ag Reuse

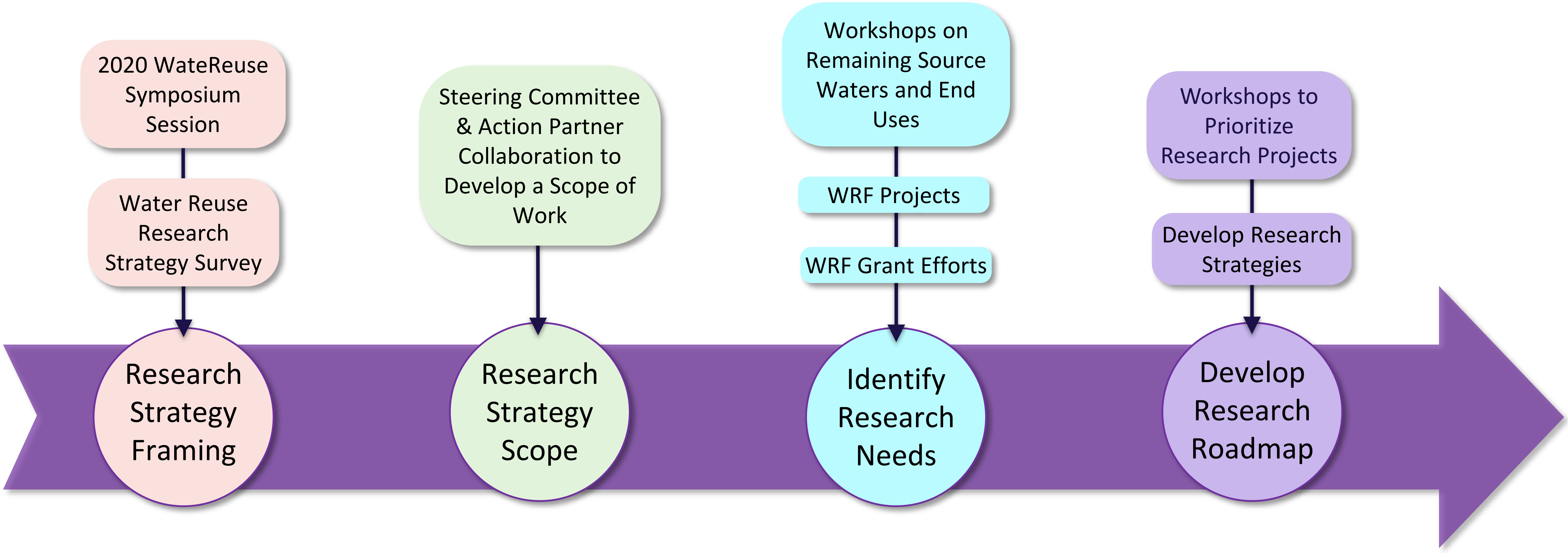


Multiple Inputs to address remaining source waters & end uses

WRAP Action 7.2 Implementation Milestones



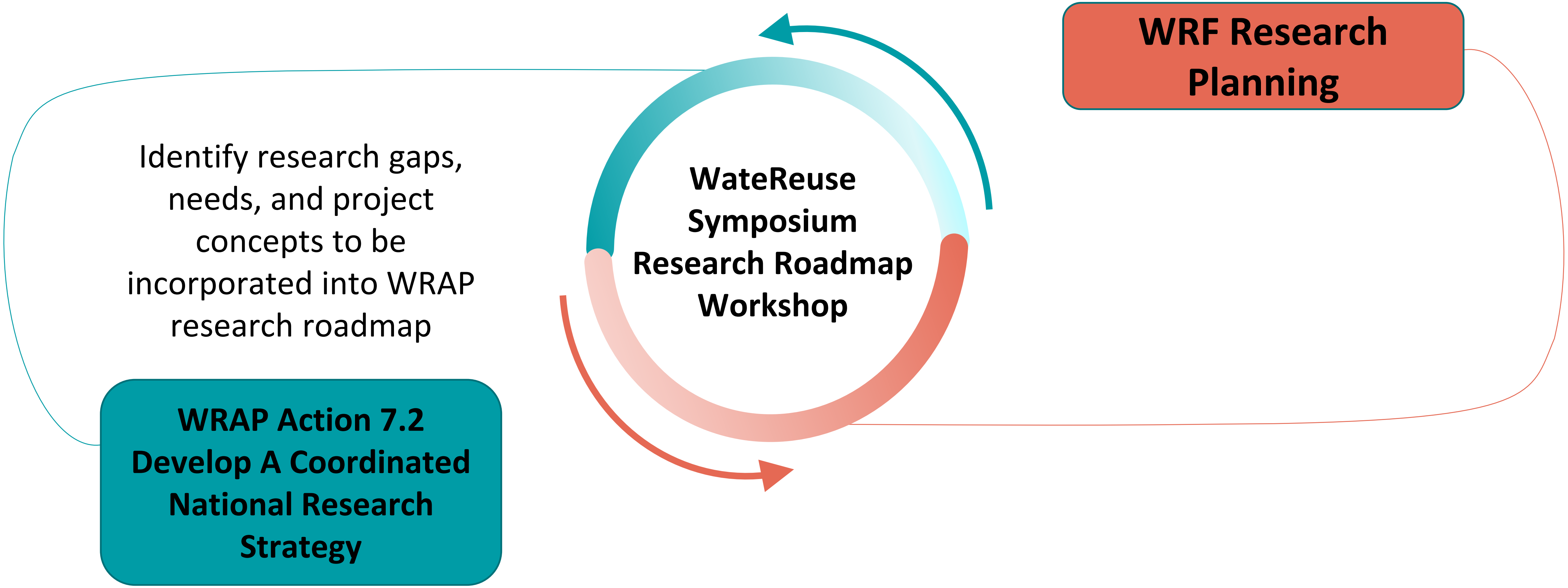
WRAP Action 7.2 Implementation Milestones



The Water Reuse Action Plan (WRAP)
EPA Overview

Justin Mattingly
Environmental Protection Specialist – Office of Water

Today’s Workshop Is Dual-purpose



Today's Workshop Is Dual-purpose

WRAP Action 7.2 Develop A Coordinated National Research Strategy

Identify research gaps, needs, and project concepts to be incorporated into WRAP research roadmap

WateReuse Symposium Research Roadmap Workshop

WRF Research Planning

Identify research project concepts to be considered for funding within WRF's 2022 Research Priority Program

WRF 2022 Research Priority Program

Research Themes

Resource Efficiency & Recovery
Advancing the sector toward a circular economy

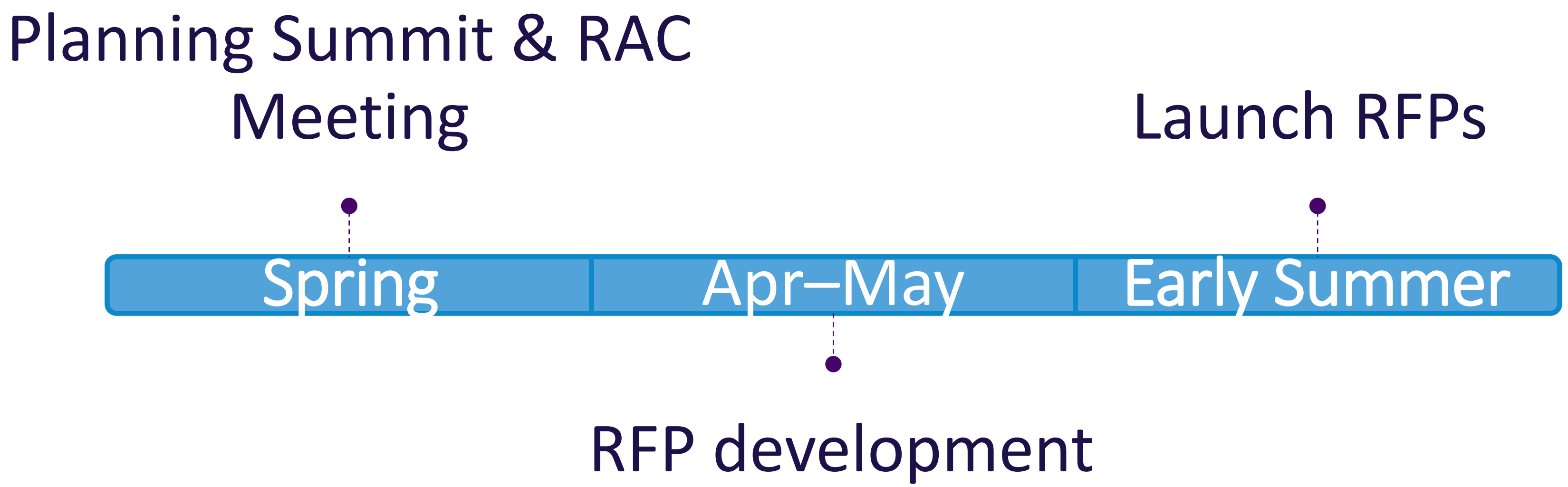
Treatment Optimization
Maximizing performance of treatment processes and technologies to produce clean and safe water

Resilient Infrastructure
Improving the water sector's resilience by overcoming infrastructure and water quality challenges

Utility Operations and Management
Supporting financially sustainable, optimized, and forward-thinking utilities

Healthy Communities and Environment
Improving watershed resilience, enhancing community benefits, and protecting public health and the environment

WRF 2022 Research Priority Program



Project concepts developed today will feed into the Planning Summit

Today's Workshop Format

Part 1

Presentations

Topic 1: Source Water	Topic 2: Treatment

Facilitated Breakouts on Topics 1 & 2

5 tables topic 1	5 tables topic 2

Goal of breakouts: develop project concepts

3-5 project concepts per table	Title, objectives, budget

Part 2

Presentations

Topic 3: Monitoring	Topic 4: Implementation

Facilitated Breakouts on Topics 3 & 4

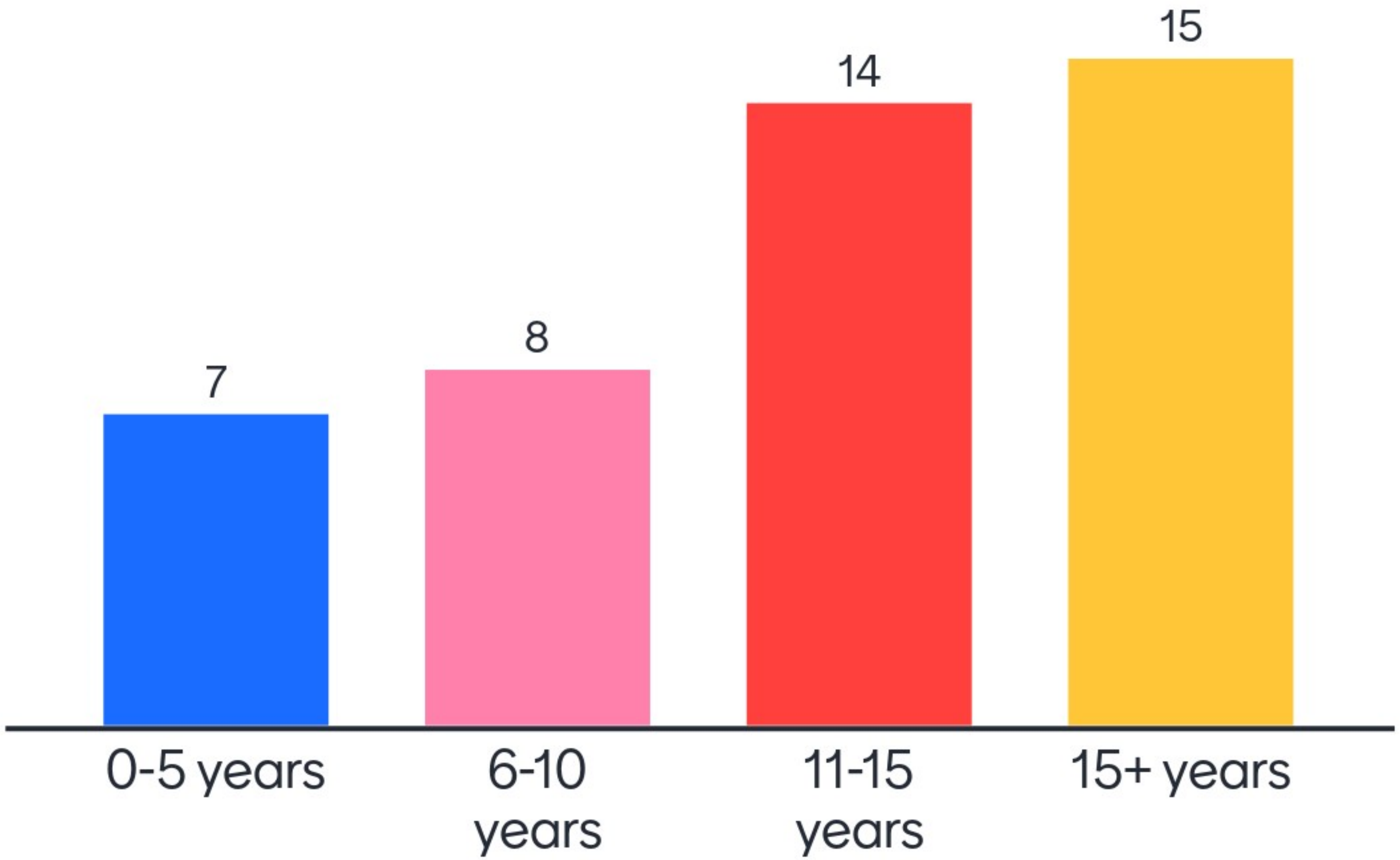
5 tables topic 3	5 tables topic 4

Goal of breakouts: develop project concepts

3-5 project concepts per table	Title, objectives, budget

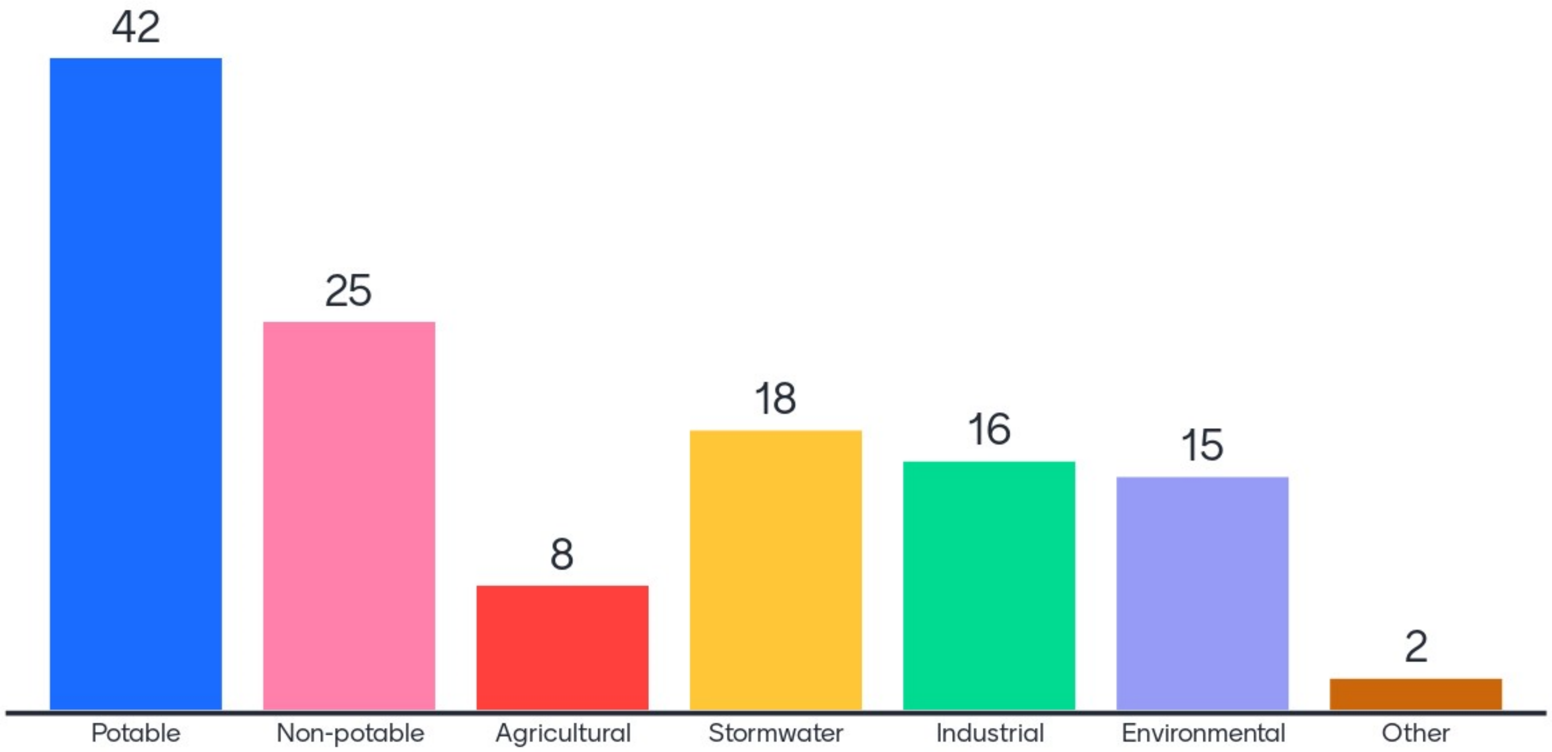
Poll Question Warm-up: How long have you been interested in water reuse?

Mentimeter



44

What type of reuse are you/your agency most interested in?



48

PART 1: Source Water & Treatment Speakers

Shane Trussell
Trussell Technologies

Vijay Sundaram
AECOM

Erin Mackey
Brown & Caldwell

DEVELOPING A NATIONWIDE WATER REUSE RESEARCH ROADMAP

SOURCE WATER CONSIDERATIONS

SHANE TRUSSELL
TRUSSELL TECHNOLOGIES, INC.

MARCH 6, 2022

2022 WateReuse SYMPOSIUM

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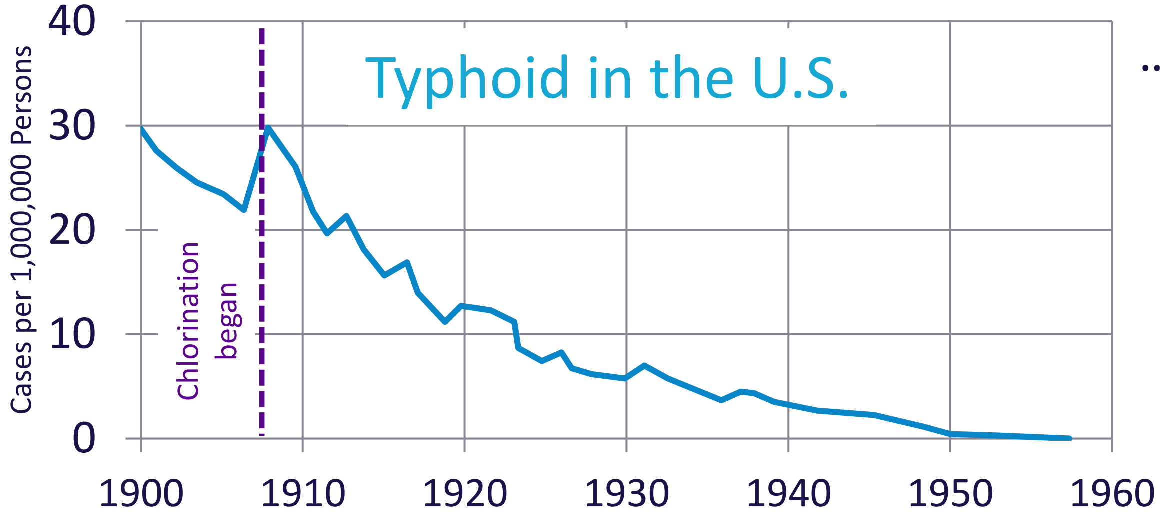
Source Waters for Potable Uses

History has taught us to keep these streams separated…



Adapted from CDC, 1997

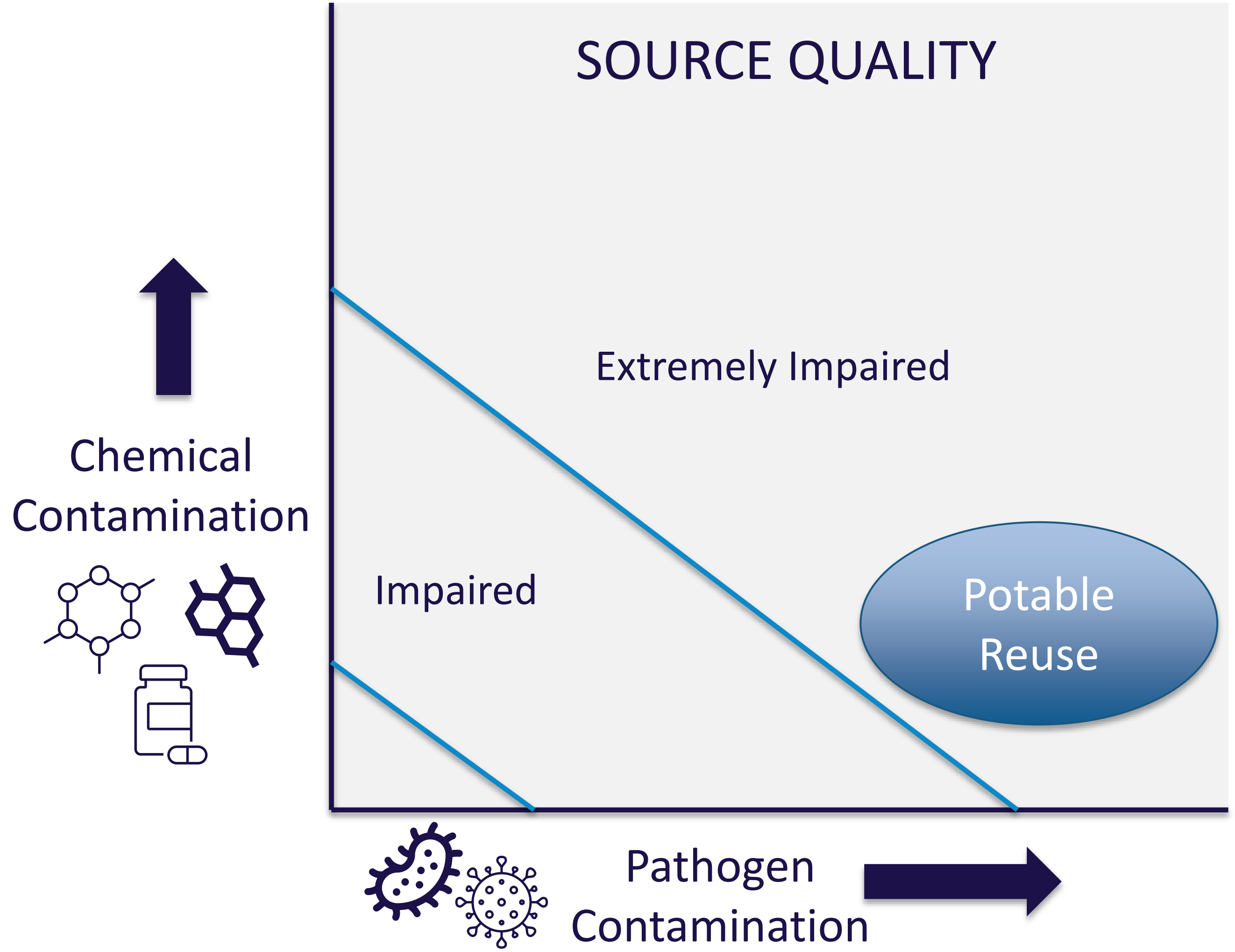
…because of the threat of waterborne diseases.

Broad Street Well determined to be the source of a cholera outbreak in 1854 by John Snow

Must Cross the Streams to Address Today's Water Issues

Increasing pressure on our limited water supplies….

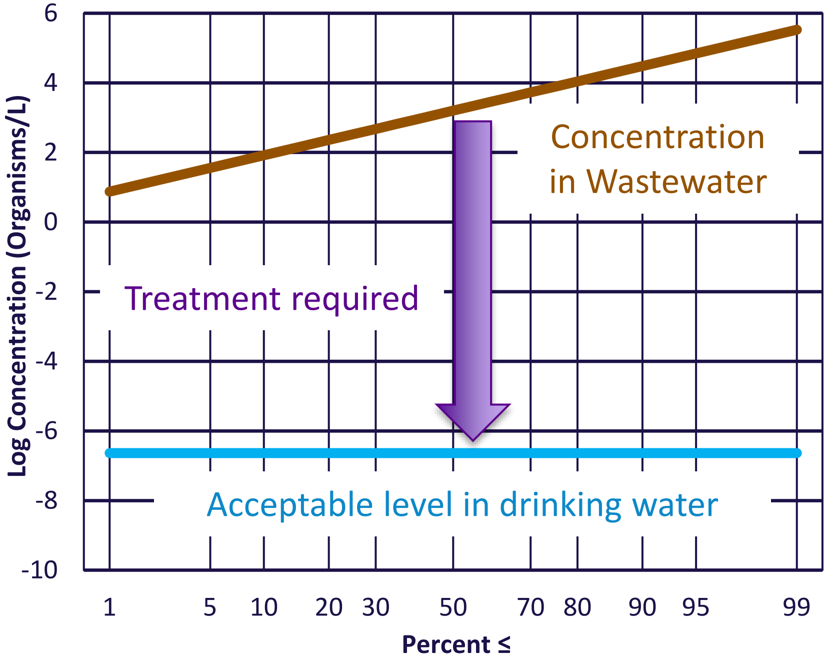
What are today's threats?



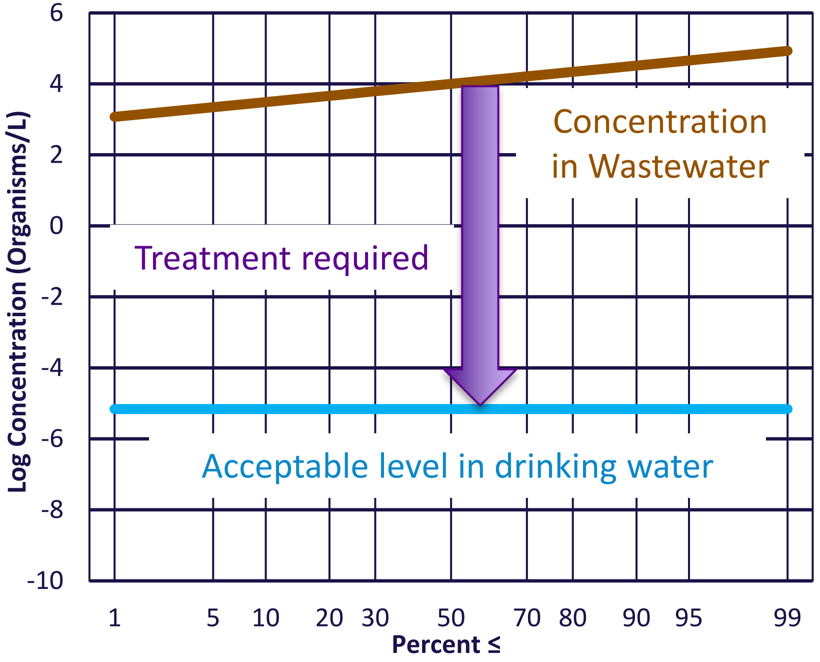
Even though pathogens remain the larger threat…
…there is a large focus on chemicals.

Pathogens in Wastewater

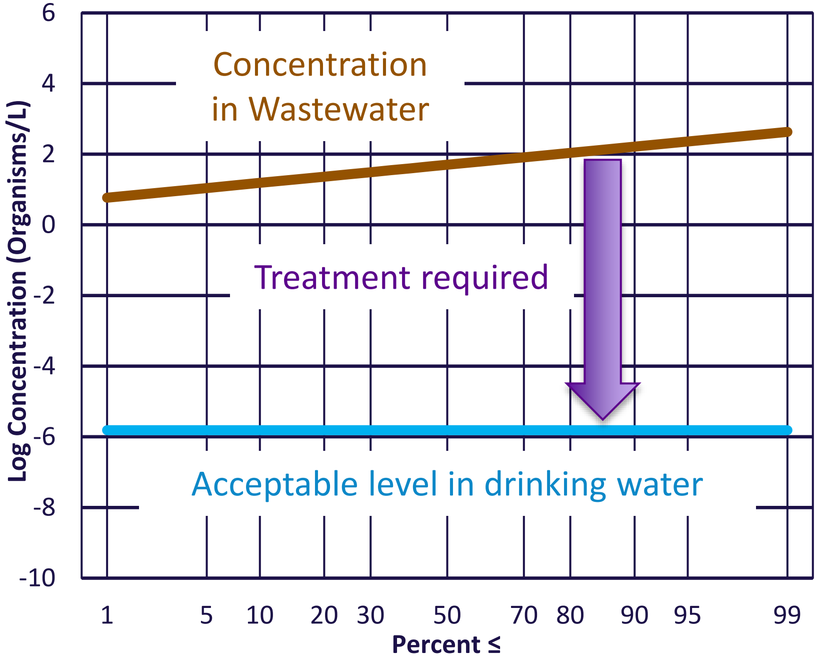
Enteric Virus



Giardia



Cryptosporidium



Pathogens are <u>always</u> present at high concentrations in wastewater. We need a high degree of treatment to reduce concentrations to acceptable levels.

WRF 4989 – Pathogen Monitoring in Untreated Wastewater

WRF 4951 – Tools to Evaluate Quantitative Microbial Risk and Plant Performance/Reliability

WRF 5047 – Demonstration of Pathogen Removal Credits in Wastewater Reuse: 21st Century Guidance Materials for Study Plans and Reporting

Chemicals in Wastewater – Ready to Drink?

Table 3.3. Median TOrC Concentrations in ng/L for Secondary Effluents at Reference Treatment Facilities

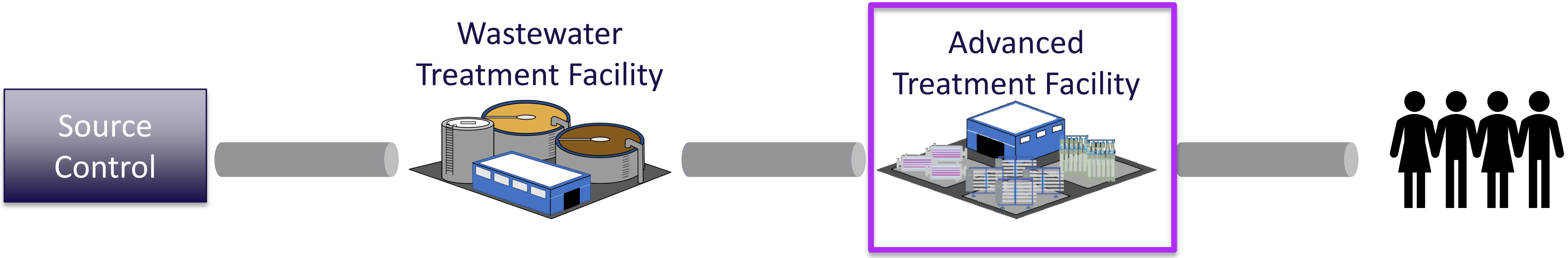
Compound	NWRI IAP Criteria	LACSD SJCWRP n = 4	EPWUFred Hervey WRP n = 4	UOSA Millard H. Robbins Jr. WRP n = 4	SD AWPF n = 12	OCWD GWRS[1] n = 1	WBMWD ECLWRF[1] n = 1
Atenolol	4000	63	110	130	130	555	980
Carbamazepine	10,000	192	328	185	190	263	240
DEET	200,000	53	33	51	130	528	690
Estrone	320	NDL[2]	<36[4]	<46[4]	<4	41	NM[5]
Meprobamate	200,000	351	174	115	125	401	<320
PFOA	400	11	11.5	24	NM	NM	23
PFOS	200	<14	NDL[3]	<13	NM	NM	NM[5]
Primidone	10,000	166	120.5	148	91	100	270
Sucralose	150,000,000	25,450	35,500	34,950	41,000	NM	80,000
TCEP	5000	NDL[3]	406	335	375	338	980
Triclosan	2,100,000	89	NDL[3]	27	64	324	460

Notes: [1]Only one set of secondary effluent data was available for OCWD GWRS and WBMWD ECLWRF.
[2]NDL = near detection limit (2 measurements taken, one <DL, one >DL).
[3]NDL = near detection limit (4 measurements taken: two <DL, two >DL).
[4]One measurement
[5]Not measured
Public health criteria from the NWRI IAP are presented for comparison.

Source: WERF 11-02

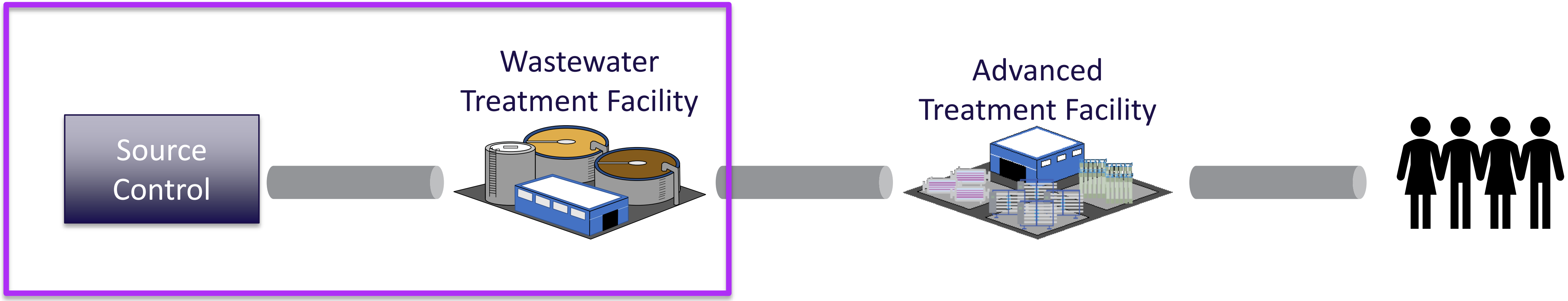
- Secondary effluents generally meet most drinking water standards
- Common exceptions are:
  - Nitrogen
  - NDMA
  - PFOA, PFOS
  - TDS
- Yet we all still know we need more treatment!

Controlling Pathogens and Chemicals



We often focus on advanced treatment for controlling pathogens and chemicals

Controlling Pathogens and Chemicals

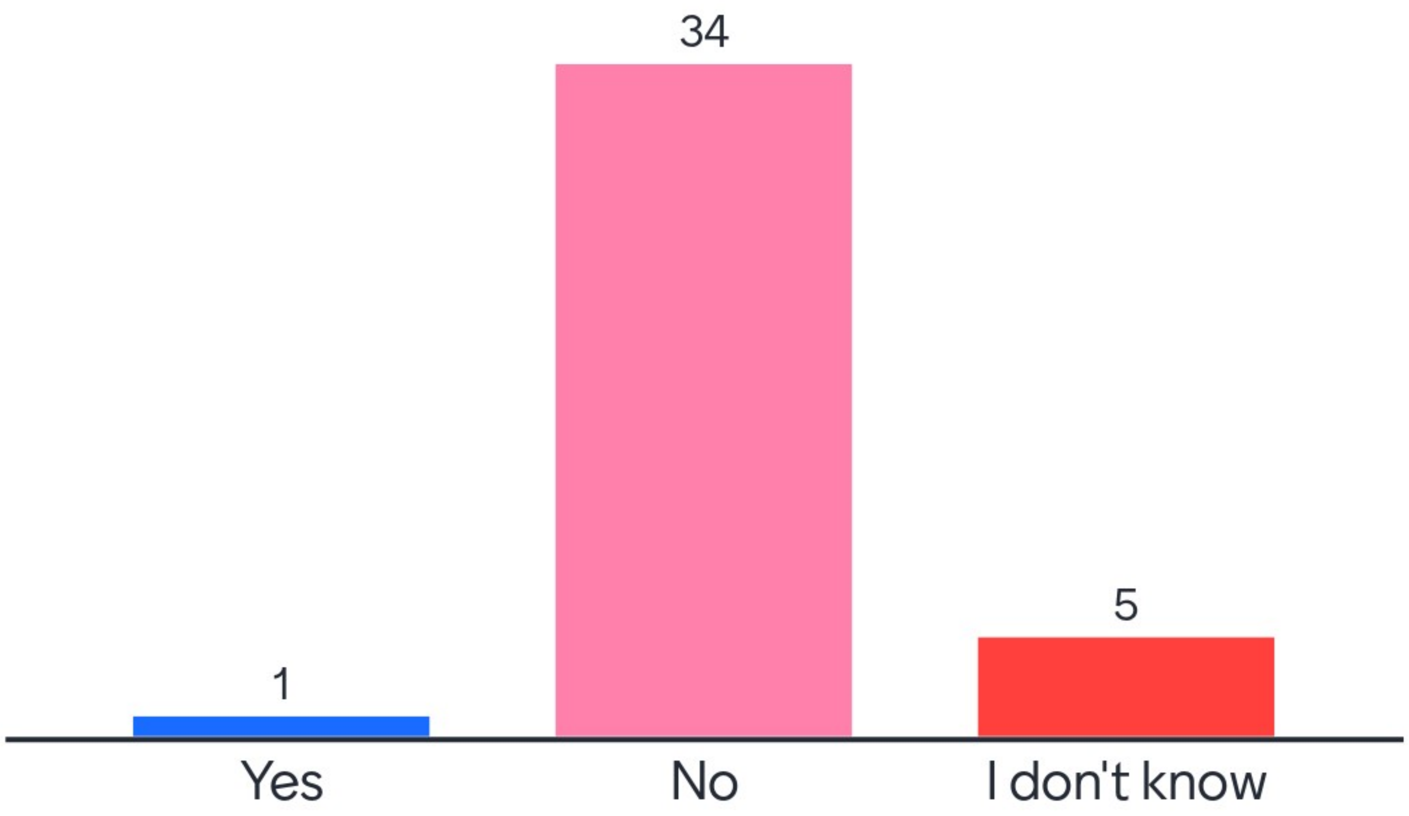


But we should also consider the important role of these upstream processes in providing reliable protection against these contaminants

Secondary Treatment Needs to be Reliable for Potable Reuse

- Biology can greatly enhance source water quality
  - Lower turbidity
  - Lower TOC
  - Lower CECs
  - Nutrient removal

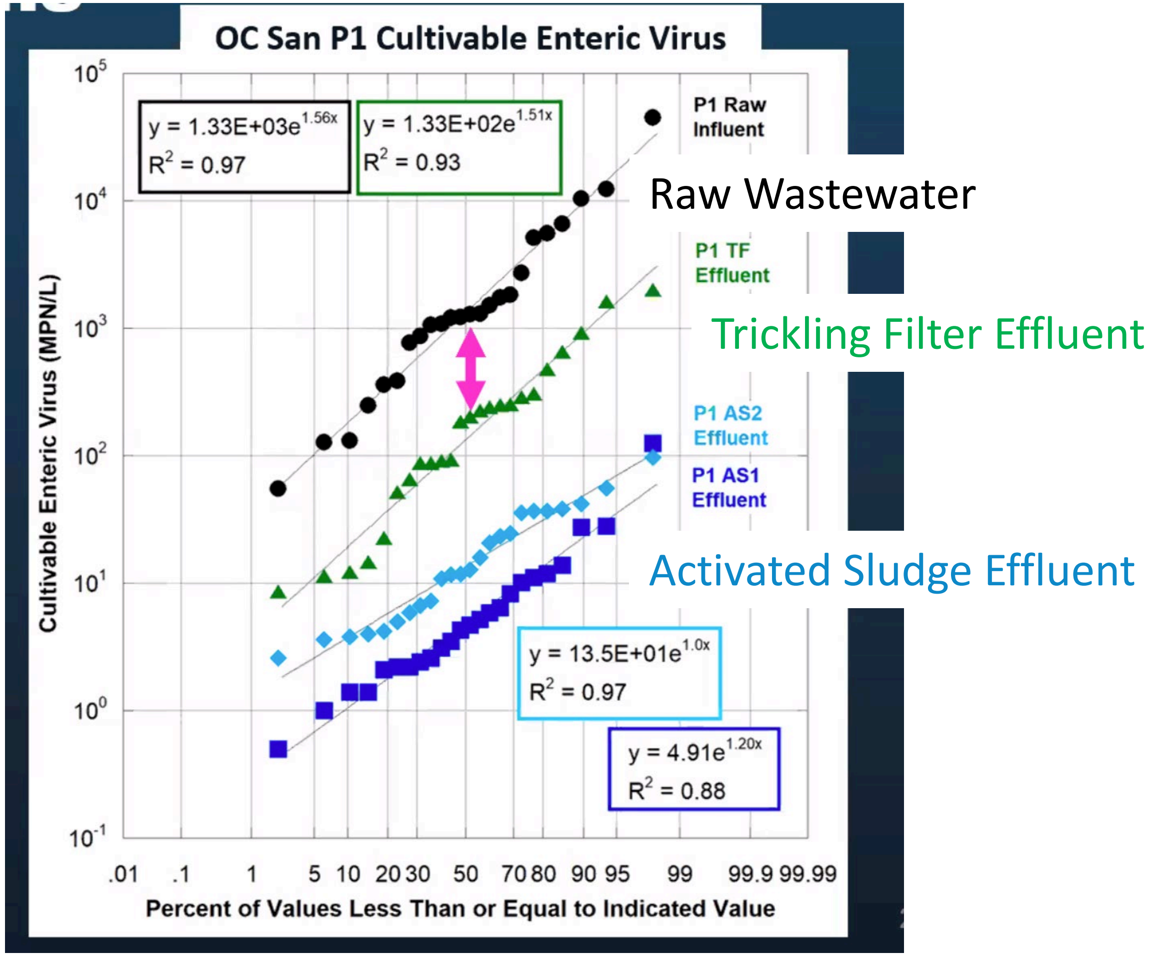
Do all nitrification processes provide the same pretreatment?



40

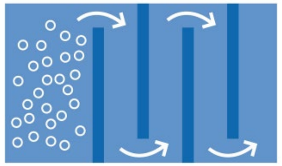
Fixed-film is less effective

Parameter	Fixed Film	Suspended Growth
Turbidity	~10 NTU	~2-5 NTU
TOC	~20 mg/L	~6-10 mg/L

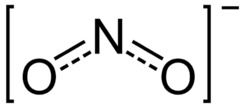


Wastewater Treatment – Benefits of Reliable Nitrification

OZONE

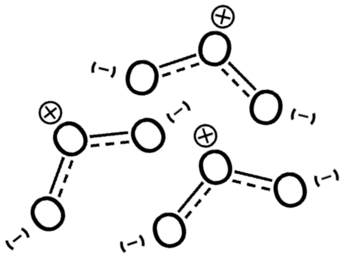


1 mg/L NO_2-N



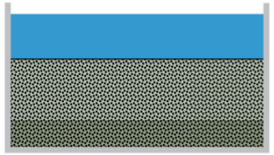
consumes

~3.5 mg/L O_3

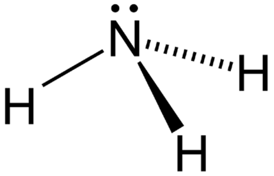


Excess nitrite results in increase ozone demand

BAC

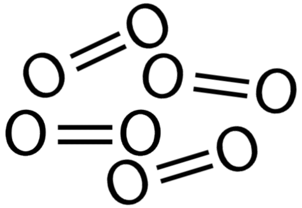


1 mg/L NH_3-N



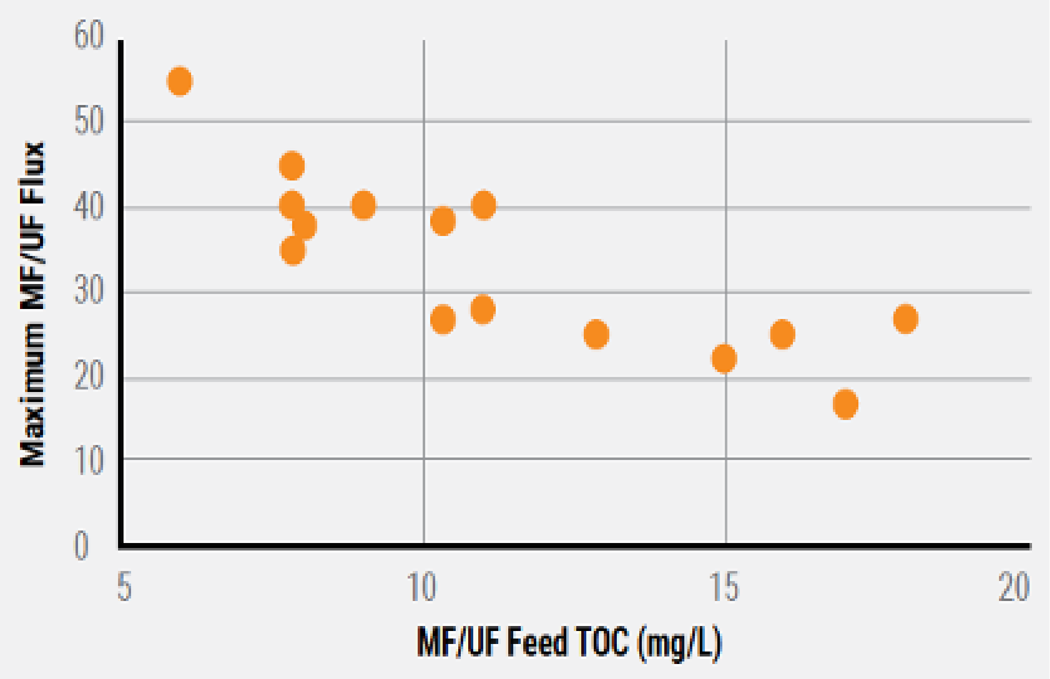
consumes

~4.6 mg/L O_2



Excess ammonia creates anerobic conditions

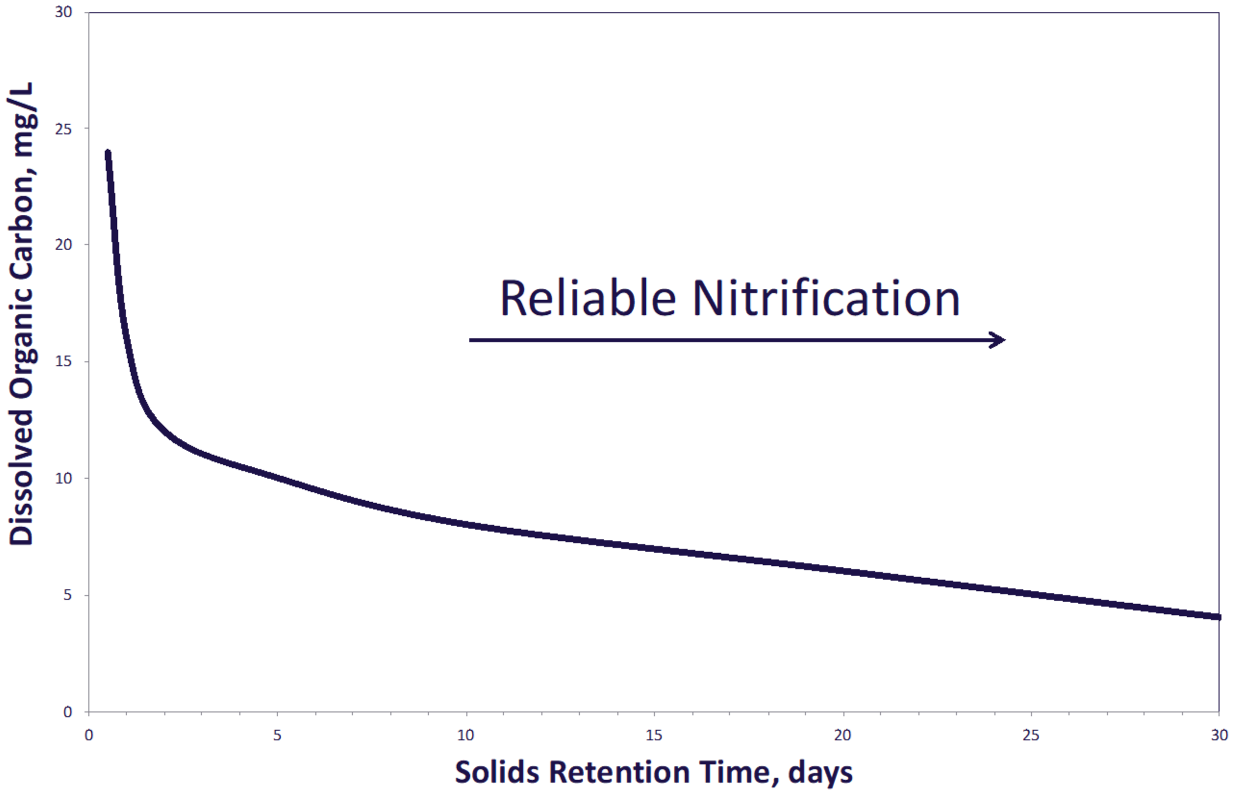
Wastewater Treatment – Benefits of Reliable Nitrification

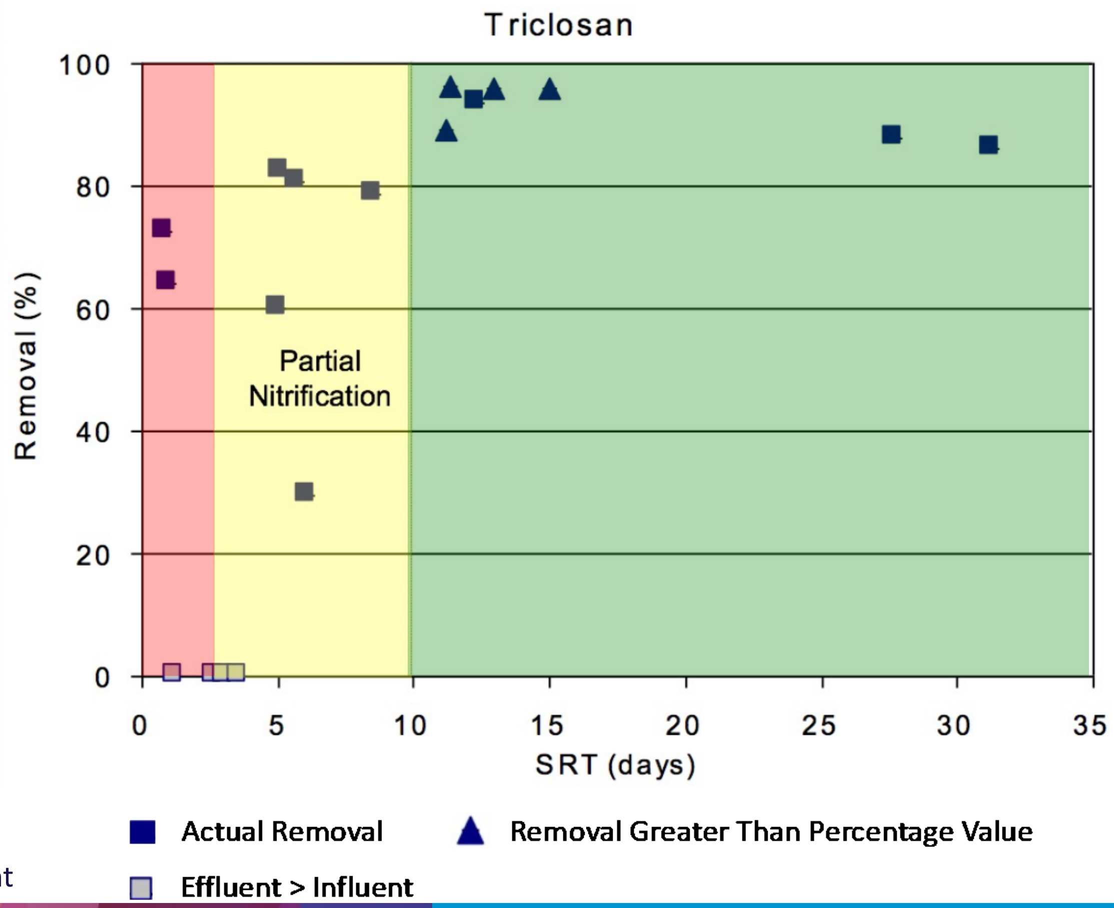


- Reliable nitrification means lower organics
- Lower organics results in increased fluxes, decreased operating pressures, and reduced number of chemical cleans

Wastewater Treatment – Benefits of Reliable Nitrification

- Reliable nitrification also directly impacts contaminant removal, reduces loads on AWT



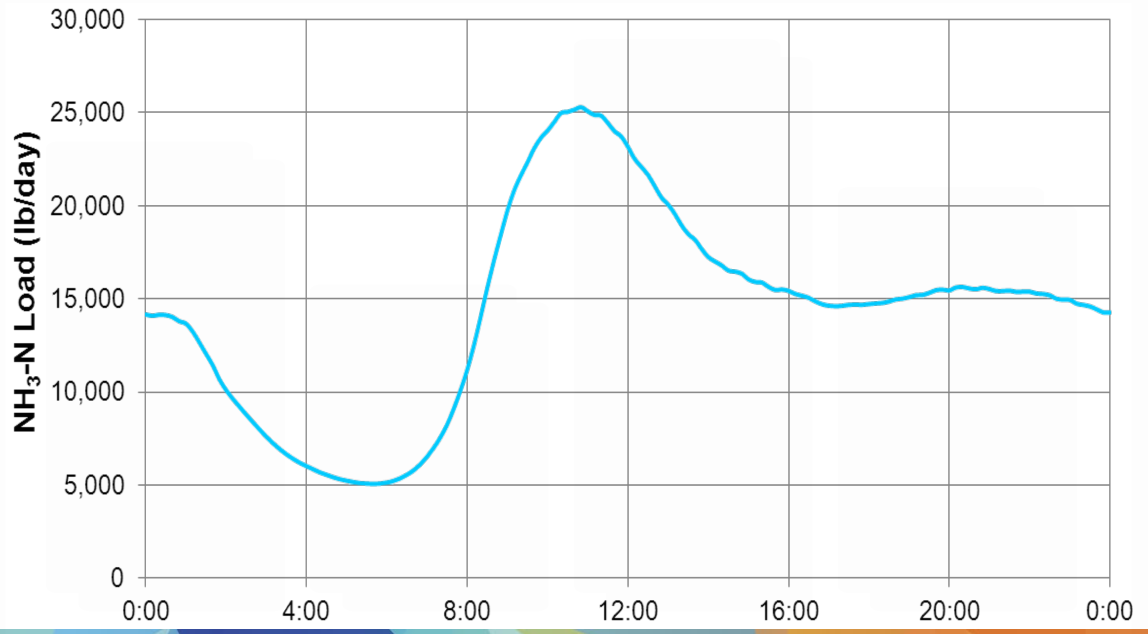


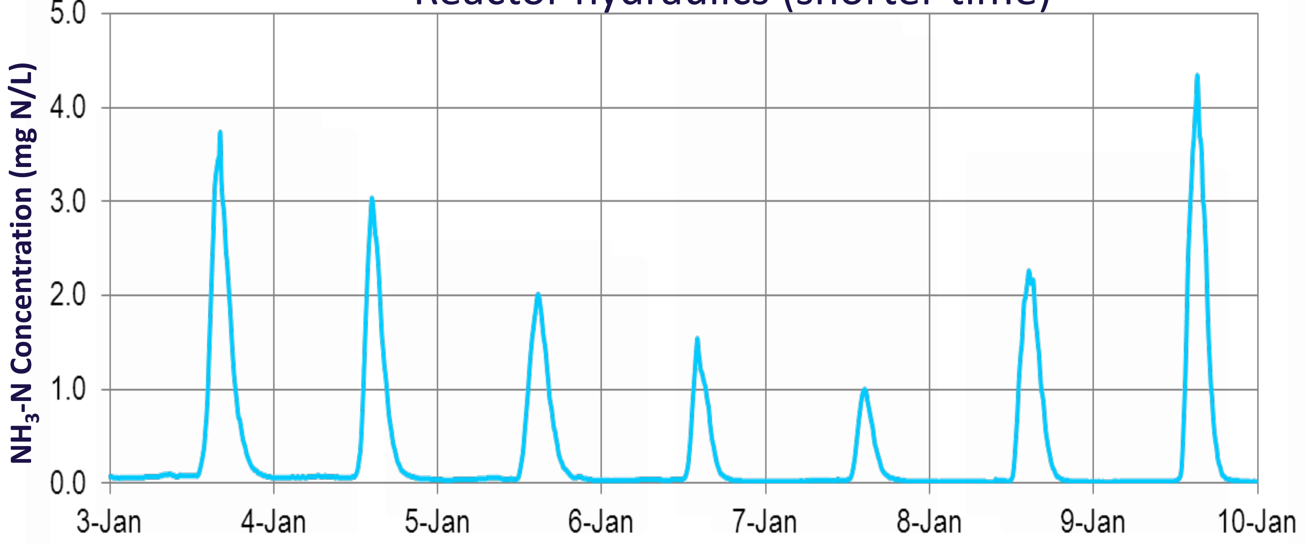
WRF 1347 – Trace Organic Compound Indicator Removal during Conventional Wastewater Treatment

Benefits of Flow Equalization

Lack of flow EQ impacts:

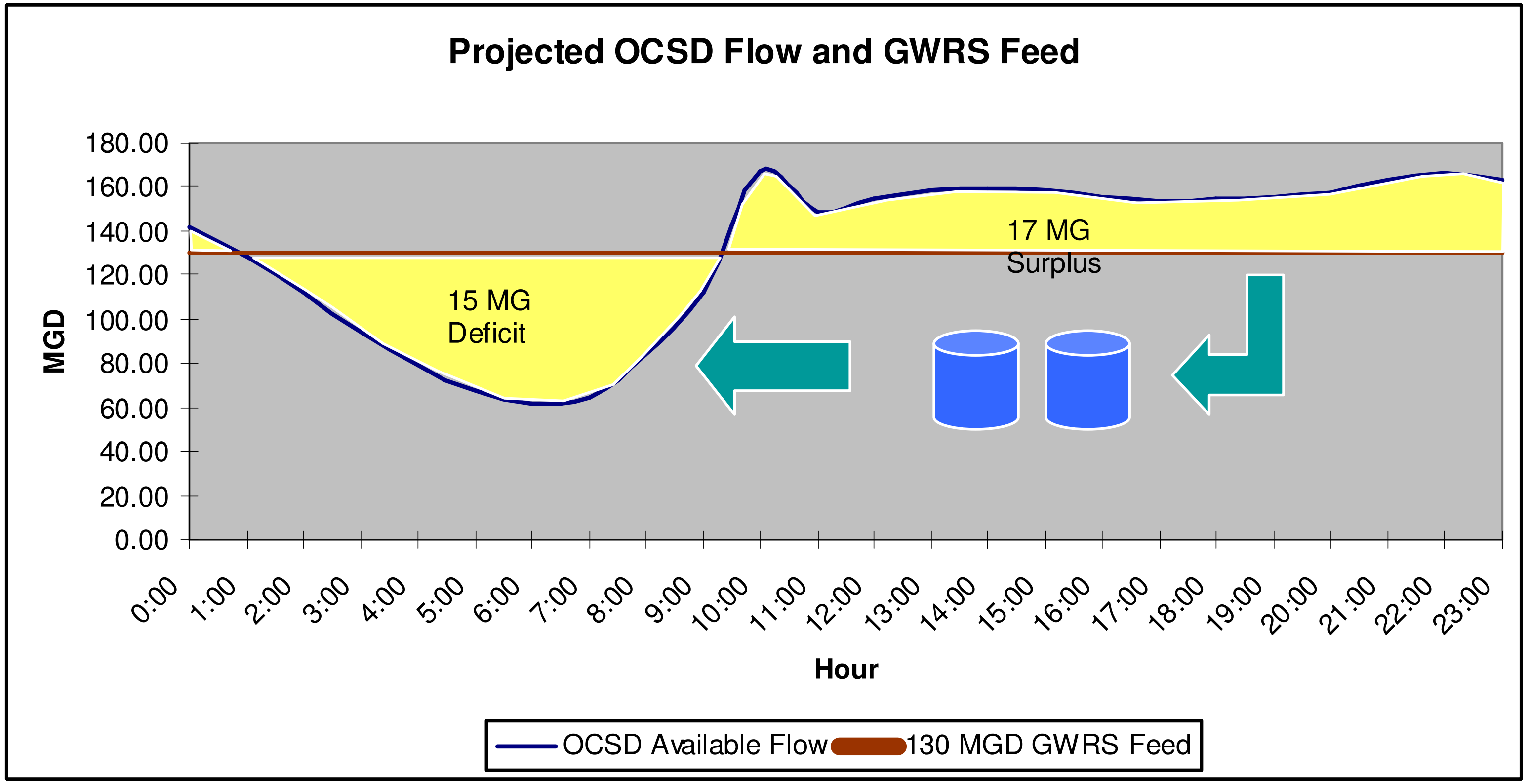
- Reactor conditions (increased load)
- Reactor hydraulics (shorter time)



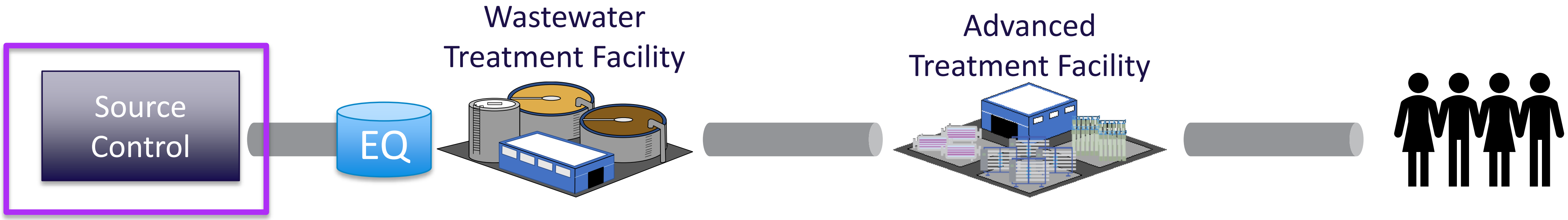


Flow Equalization – It Just Makes Sense

- Potable reuse treatment trains are complex and expensive
- Flow EQ reduces the capacity required
- Ensures full utilization of that investment
- Allows operations to focus on a more consistent routine



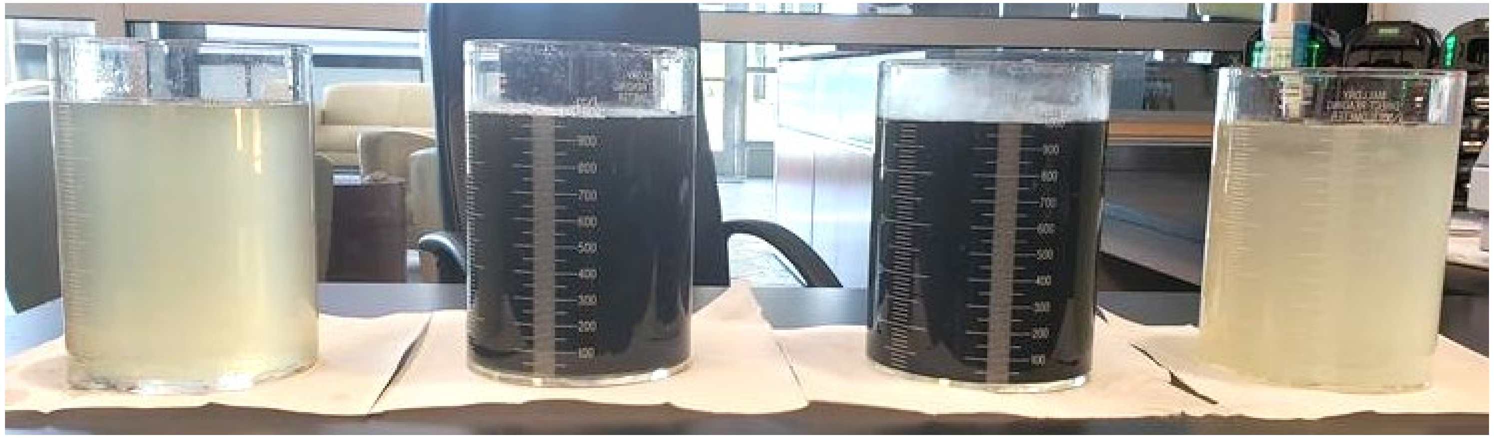
Source Control



- Source control strategies include:
  - Inventories of chemicals in sewershed
  - Local limits developed for public health compounds
  - Online sewershed monitoring

WRF 4960 – An Enhanced Source Control Framework for Industrial Contaminants in Potable Reuse
WRF 5048 – Integrating Real-Time Collection System Monitoring Approaches into Enhanced Source Control Programs for Potable Reuse
WRF 1706 – Guidelines for Source Water Control Options and the Impact of Selected Strategies on Direct Potable Reuse
NWRI Panel – Enhanced Source Control Recommendations for Direct Potable Reuse in California

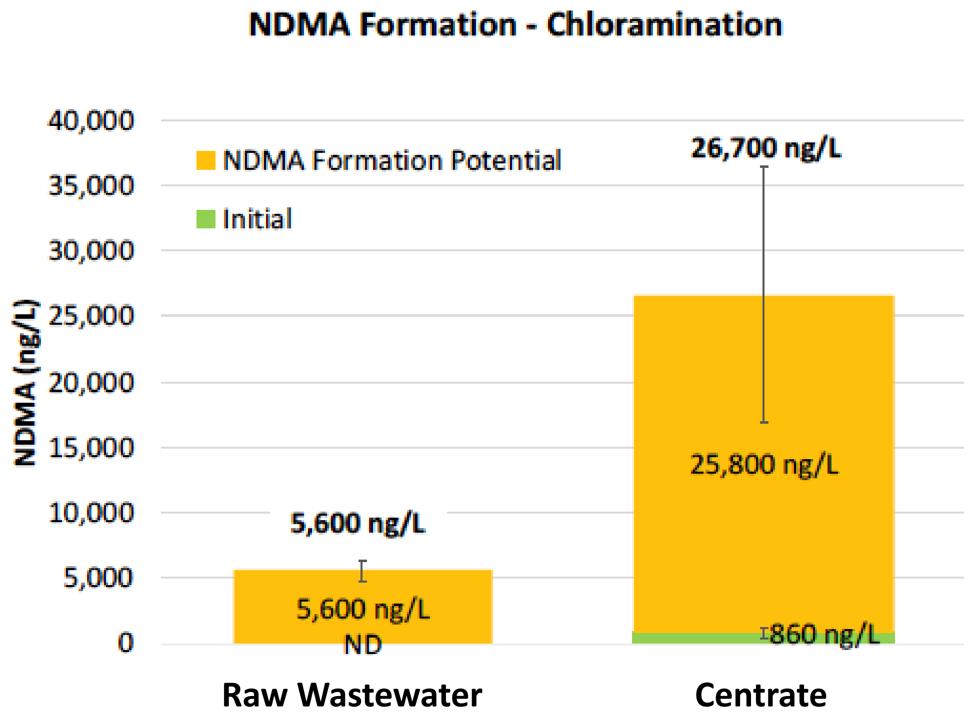
Managing Sidestreams

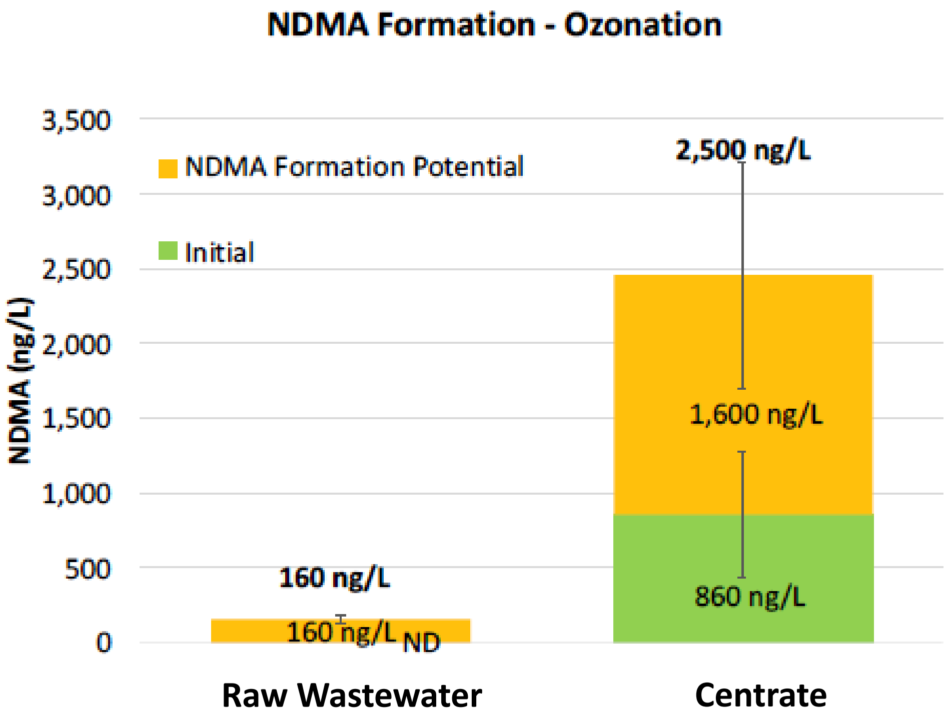


	Primary Effluent	Centrate	Wet scrubber	DAFT underflow
TSS (mg/L)	100	1,314	1,727	111
COD (mg/L)	400	1,693	1,432	191
NH3 (mg/L-N)	45	726	329	41.6
Ortho P (mg/L-P)	6	190	74	3.4

Managing Sidestreams

- Centrates have much greater NDMA formation potential





Research Needs

Source Control

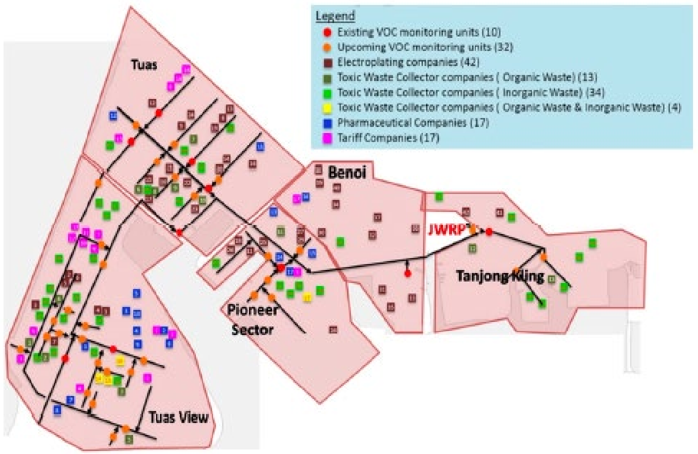
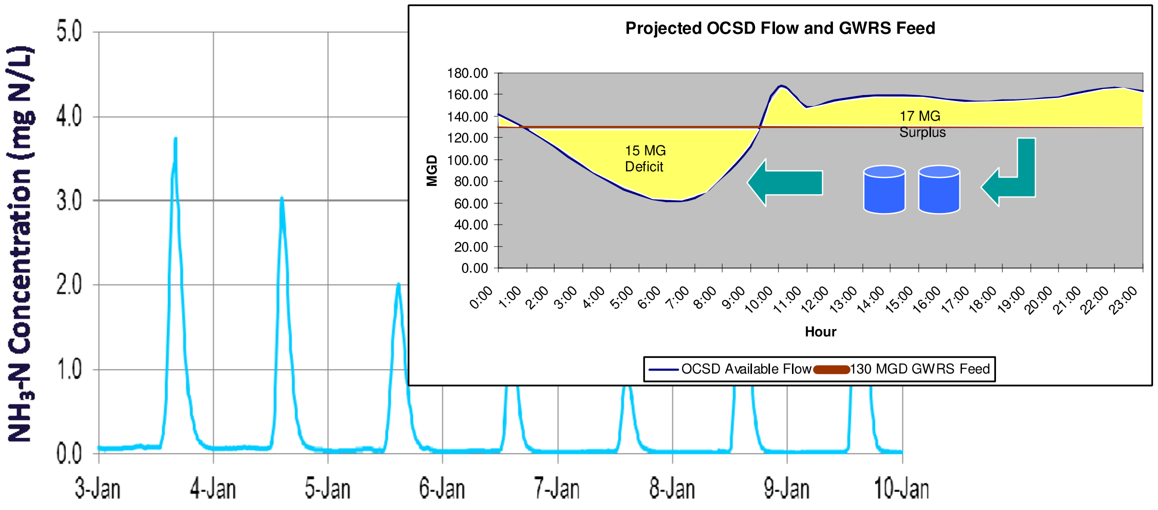


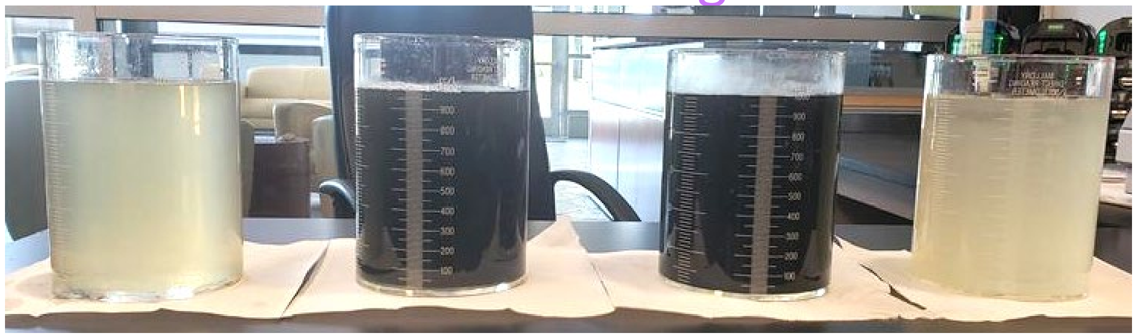
Figure 4-11. Distribution of Industrial Dischargers in the JWRP Catchment Area and Location of VOC Monitoring Units.
Source: Courtesy of PUB.

Flow EQ

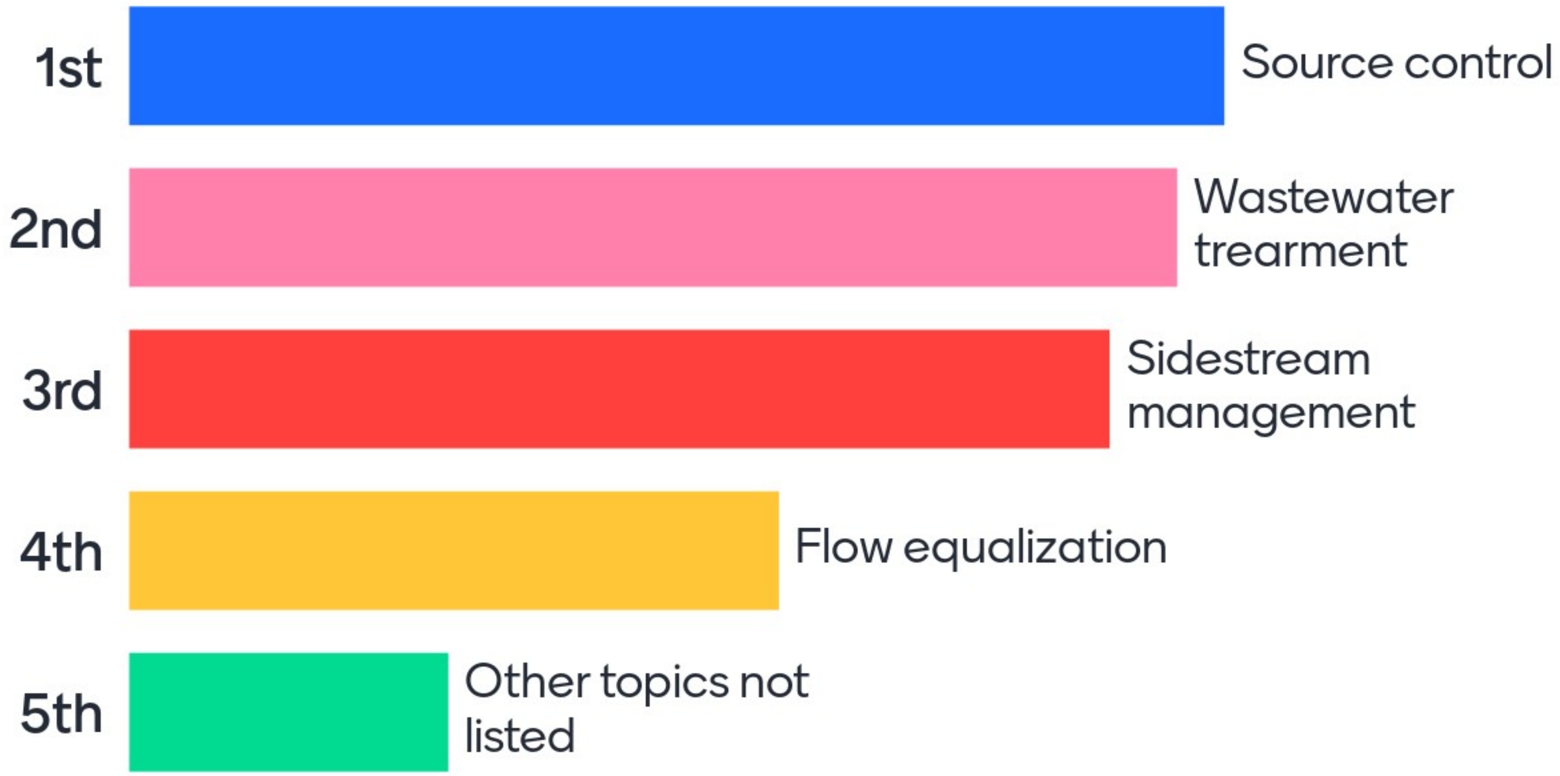


Wastewater Treatment

Sidestream Management



Which source water topic do you think we need more research on? Rank them in order.



48

Potential Research Project #1

- Impacts of Sidestreams as a Component of Source Water for Potable Reuse ($350k – 2 years)
  - Evaluate different ratios of primary effluent to centrate/filtrate flow for treatment in a secondary process
  - Evaluate impacts on biological performance, membrane fouling, and chemicals of concern
  - Optional: evaluate sidestream treatment to mitigate negative impacts on potable reuse facility
  - 1 year bench-scale testing at minimum, but pilot preferred

Potential Research Project #2

- Public health and process benefits of nitrification as pretreatment to an AWPF ($200k – 1 year)
  - Quantify the benefits of improved water quality on the membrane performance (MF & RO) and membrane life from full-scale facilities
  - Survey water quality (TSS, Turbidity, BOD, COD) chemicals of concern (TOC, CECs, NDMA, other) from non-nitrifying and nitrifying facilities
  - Evaluate the impacts on Ozone/BAC for a non-nitrified and nitrified water
  - Evaluate the impacts on UV/HOCl for a non-nitrified and nitrified water
  - Quantify differences in anticipated AWPF effluent quality for a non-nitrified and nitrified water
  - Survey facilities with and without tertiary filters to quantify the benefits of filtered water quality on disinfection and downstream AWPF

Potential Research Project #3

- Flow Equalization for Potable Reuse ($200k – 1 year)
    - Quantify the benefits of primary flow equalization (EQ) on the secondary process (loading and effluent quality) and consider diurnal conditions
    - Survey water quality (TSS, Turbidity, BOD, COD) chemicals of concern (TOC, CECs, NDMA, other) from facilities with and without primary flow EQ
    - Quantify differences in anticipated AWPF feedwater quality for a diurnal pattern with and without primary flow EQ
        - Discuss impacts on O3/BAC and other advanced treatment processes
    - Evaluate the impacts of sidestreams with and without primary flow EQ on the secondary process

TREATMENT

RESEARCH NEEDS WORKSHOP

ERIN MACKEY, PH.D., P.E.
BROWN AND CALDWELL

VIJAY SUNDARAM, PH.D., P.E.
AECOM

MARCH 6, 2022

2022 WateReuse SYMPOSIUM

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Focus of this research area

- Treatment technologies
  - Optimization
  - Use
  - New
  - Impacts
- Achievement of necessary LRVs
- Operations
- Redundancy

Background – Treatment-Related Questions We Typically Need to Answer

- What's the source water quality?
- What LRVs & MCLs do we need to meet?
  - Microbes
  - Contaminants
- How do we demonstrate treatment?
- What simultaneous goals do I have to meet?
- What processes do I want to use?
- What order do I want to use them in?
  - Efficiencies
  - Synergies
- How do I need to control (operate) it?
- Do I have control challenges?

State of the Science – What Have We Already Looked at?

Project #	MBR; Pre-chlor; GAC; O3; BAF
4997	Membrane Bioreactor Validation Protocols for Water Reuse
4959	Evaluation of Tier 3 Validation Protocol for Membrane Bioreactors to Achieve Higher Pathogen Credit for Potable Reuse
4916	Impact of Pre-Chlorination and GAC Treatment on DBP Formation and Overall Toxicity in DW
5092	Understanding & Improving Reuse Biofilter Performance during Transformation from GAC to BAC
5035	Impact of Bromate Control on Ozone Oxidation/Disinfection and Downstream Treatment Processes in Potable Reuse
4776	Optimization of Ozone-BAC Treatment Processes for Potable Reuse Applications
4872	Characterization of Organic Carbon and Microbial Communities for the Optimization of BAC Filtration for Potable Reuse
4777	Demonstration of High Quality Drinking Water Production Using Multi-Stage Ozone Biological Filtration: A Comparison of DPR with Existing IPR
4832	Evaluation of CEC Removal by Ozone/BAF Treatment in Potable Reuse Applications

State of the Science – What Have We Already Looked at?

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4997	Membrane Bioreactor Validation Protocols for Water Reuse
4959	Evaluation of Tier 3 Validation Protocol for Membrane Bioreactors to Achieve Higher Pathogen Credit for Potable Reuse
4916	Impact of Pre-Chlorination and GAC Treatment on DBP Formation and Overall Toxicity in DW
5092	Understanding & Improving Reuse Biofilter Performance during Transformation from GAC to BAC
5035	Impact of Bromate Control on Ozone Oxidation/Disinfection and Downstream Treatment Processes in Potable Reuse
4776	Optimization of Ozone-BAC Treatment Processes for Potable Reuse Applications
4872	Characterization of Organic Carbon and Microbial Communities for the Optimization of BAC Filtration for Potable Reuse
4777	Demonstration of High Quality Drinking Water Production Using Multi-Stage Ozone Biological Filtration: A Comparison of DPR with Existing IPR
4832	Evaluation of CEC Removal by Ozone/BAF Treatment in Potable Reuse Applications

Themes:

- MBR - earning LRVs
- Ozone/GAC
  - Efficacy
  - Process optimization
  - Equivalency to FAT
  - DBP formation and control
- Pre-chlorination toxicity

State of the Science – What Have We Already Looked at?

Project #	UV; UV-AOP; Post-treatment; WTP impacts
4764	UV Disinfection Knowledge Base for Reuse Applications
5050	UV/Chlorine AOP: Assessment of Applicability, Operational Issues, and Potential By-Products
4699	Kinetic Modeling and Experimental Investigation of Chloramine Photolysis in Ultraviolet-Driven Advanced Water Treatment
4780	Evaluating Post Treatment Challenges for Potable Reuse Applications
4600	Soil Aquifer Treatment Characterization with Soil Columns for Groundwater Recharge in the San Fernando Valley
5049	Public Health Benefits and Challenges for Blending of Advanced Treated Water with Raw Water Upstream of a SWTP in DPR

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4600	Soil Aquifer Treatment Characterization with Soil Columns for Groundwater Recharge in the San Fernando Valley
5049	Public Health Benefits and Challenges for Blending of Advanced Treated Water with Raw Water Upstream of a SWTP in DPR

Themes:

- Earning LRVs
  - UV
  - SAT
- Improving design and ops
  - UV & UV/Cl
  - Post-treatment
  - DPR ⟶ WTP
- DBP formation w/UV-AOP

State of the Science – What Have We Already Looked at?

Project #	WQ: organic matter, NDMA; NPR; decentralized reuse
4783	Fate of Sulfonamide Antibiotics through Biological Treatment in WRRFs Designed to Maximize Reuse Applications
4771	Characterizing and Controlling Organics in Direct Potable Reuse Projects
5005	Securing the Future of Direct and Indirect Potable Reuse: NDMA Formation Pathways and Precursors
4779	NDMA Precursor Control Strategies for Direct Potable Reuse
4756	Management of *Legionella* in Water Reclamation Systems
4991	Defining Potential Chemical Peaks and Management Options

State of the Science – What Have We Already Looked at?

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4991	Defining Potential Chemical Peaks and Management Options

Themes:

- Contaminant occurrence & control
  - CECs
    - WWT
    - AWTF
  - *Legionella*

State of the Science – What Have We Already Looked at?

Project #	Misc. PR process performance
4766	From Collection System to Tap: Resiliency of Treatment Processes to Direct Potable Reuse
1697	Guidelines for Engineered Storage for Direct Potable Reuse
1695	Equivalency of Advanced Treatment Trains for Potable Reuse
4957	Compiling Evidence of Pathogen Reduction through Managed Aquifer Recharge and Recovery
4958	New Techniques, Tools, and Validation Protocols for Achieving Log Removal Credit across NF and RO Membranes
4833	Impact of Wastewater Treatment Performance on AWT Processes and Finished Water Quality
5047	Guidelines for the Demonstration of Pathogen Log Removal Credits in Wastewater Treatment

State of the Science – What Have We Already Looked at?

Project #	Misc. PR process performance
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4833	Impact of Wastewater Treatment Performance on AWT Processes and Finished Water Quality
5047	Guidelines for the Demonstration of Pathogen Log Removal Credits in Wastewater Treatment

Themes:

- Documenting PR efficacy & reliability
  - Treatment train combos
  - DPR
- Understanding upstream effects on AWT
- Demonstrating LRVs
  - Membranes
    - WWT

State of the Science – What Have We Already Looked at?

Project #	NPR
4831	Hybrid NF/RO Sodium Removal Process: Phase 2 Pilot Study
1709	Framework for the Successful Implementation of On-site Industrial Water Reuse
5040	Successful Implementation of Decentralized Reuse and Treatment Systems
4691	PureWaterSF: Building-Scale Potable Water Reuse Demonstration Project
4778	Treating Municipal Reclaimed Water for Multipurpose Industrial Reuse Applications at an Electric Utility and for Wetlands Rehydration in Florida

State of the Science – What Have We Already Looked at?

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Themes:
- Guidelines for treatment
  - Industrial
  - Decentralized
  - Improving WQ

Example Projects

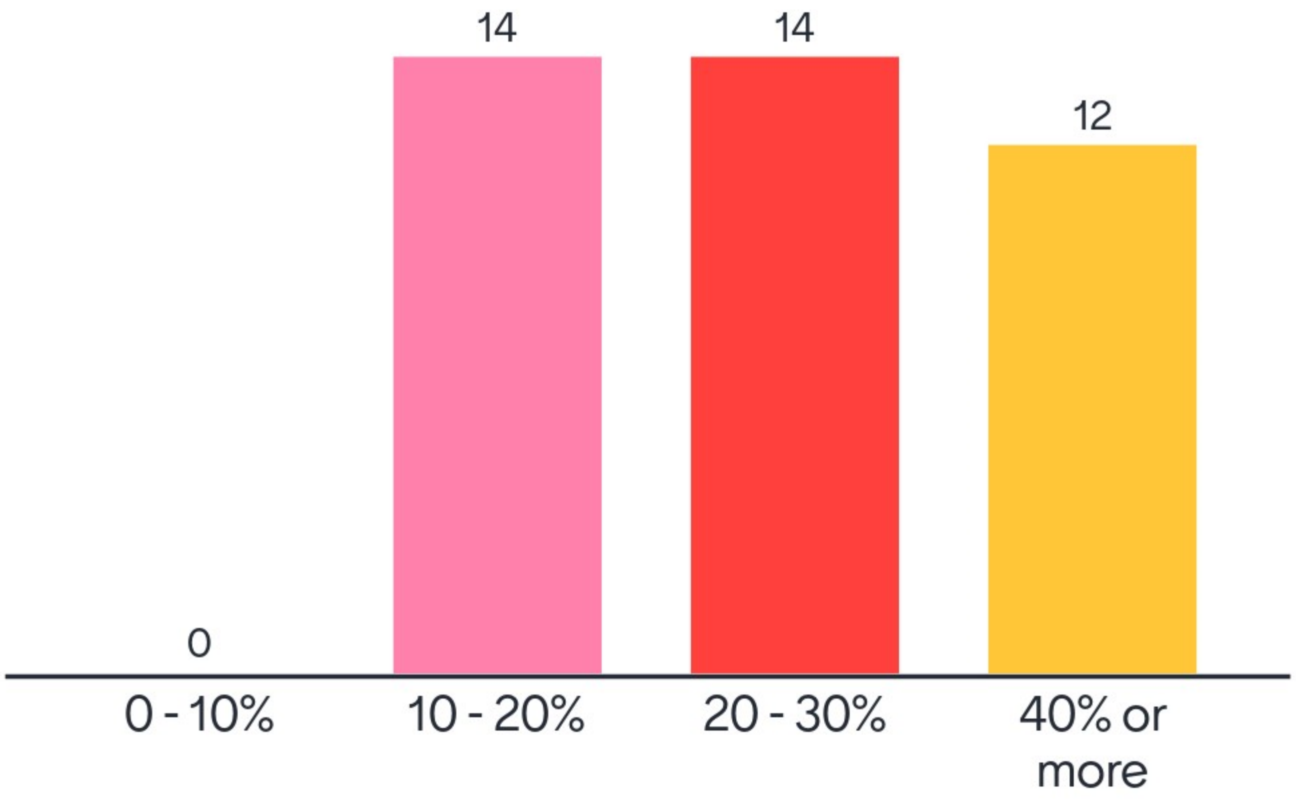
5050: UV/Cl

- Objectives
  - UV/Cl implementation guidance
  - DBP formation study
- Team
  - Ron Hoffman, U of Toronto
  - Erin Mackey, BC
- Findings
  - Design guidance manual
  - DBP formation and toxicity methods for evaluation
- Budget: $150,000

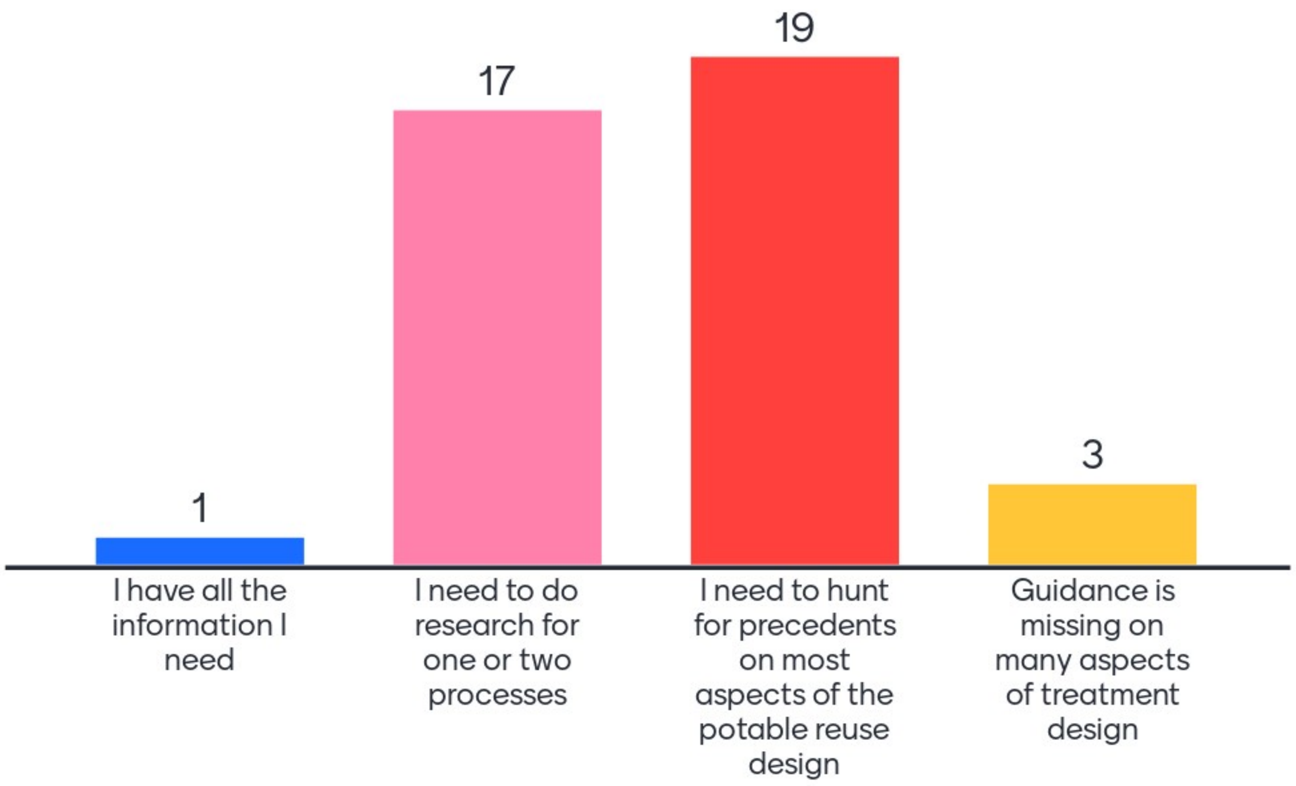
Ozone/BAC (4776 & OneWater Nevada)

- Objectives
  - CEC removal across Ozone/BAC
  - Ozone and BAC design optimization
- Team
  - Krishna Pagilla, UNR
  - Lydia Teel, TMWA
  - Zia Bukhari, American Water
  - Ruth Marfil-Vega, Shimadzu
  - Vijay Sundaram, AECOM
- Findings
  - Ozone and BAC design guidance
  - NDMA removal across BAC requires acclimation time
- WRF 4776 Budget: $553,500

In your opinion, how much reduction in potable reuse energy demand can be achieved with further research and optimization?



How readily available is the process design and performance data you need to design a system to meet treatment requirements?



Mentimeter

40

Knowledge Gaps

- **Energy footprint associated with potable reuse implementation**
  - Potable reuse treatment solutions add on higher energy demand beyond the aeration and pumping demands (i.e., baseline). Therefore, minimization of overall energy demand from raw wastewater to treated water distribution is required
- **Treatment guidelines specific to potable reuse compliance**
  - Developing treatment guidelines specific to potable reuse applications will provide a more sustainable framework in the longer run (e.g., ozone disinfection LRV guidelines developed specifically for potable reuse applications vs. utilizing drinking water ozone LRV tables)
- **Balancing innovation vs. safety/reliability within potable reuse treatment**
  - Developing more knowledge on treatment strategies performance (e.g., leveraging MBRs for various goals; 1,4 dioxane removal from BAC) creates a culture of continuous advancement within the industry

Example Project Concepts

- Energy Minimization + Innovation vs. Safety/Reliability:
  - Question: Given the projected demand for potable reuse, how can we reduce overall energy footprint moving forward?
  - Objective: Develop "big picture" strategies to reduce energy footprint from facility siting, planning, secondary treatment, advanced treatment, blending, WTP, and distribution
  - Budget: $350,000
  - Volunteers: TBD
  - Partners: WEF, AWWA

Example Project Concepts

- Potable Reuse Specific Treatment Guidelines:
  - Question: How do we know how much ozone treatment we need to achieve disinfection goals?
  - Objective: Develop a protocol for establishing LRVs for ozone (with and without peroxide) when the dissolved ozone residual is either very low or zero
  - Budget: $350,000
  - Volunteers: Vijay Sundaram, Germano Salazar-Benites, Lydia Teel, and others
  - Partners: AWWA, EPA

PART 1: Source Water & Treatment Facilitators

Source Water

Greta Zornes, CDM

Samir Mathur, CDM

Jean Debroux, Kennedy Jenks

Jeff Mosher, SAWPA

Treatment

Steve Katz, Suez

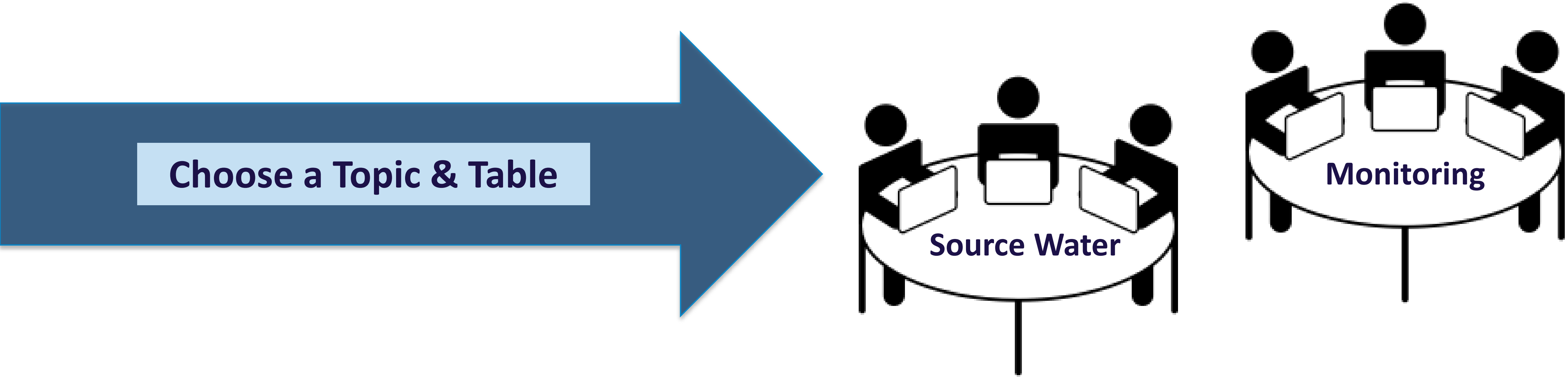
Chris Hill, AECOM

Brian Pecson, Trussell

Denise Funk, Brown & Caldwell

Breakout Group Structure

- 40 minutes total for small group brainstorming
- Tables are separated by topic
- Facilitators will guide group discussion
  - 1 min intros
  - Group project concept development using giant Sticky Notes



Developing Successful Project Concepts

GOAL per table: 2-4 project concepts

Components of a Project Concept:

- Research Project Title
  - Short and understandable
- Problem Statement
  - What is the issue or challenge that needs to be addressed and why?
- Research Objective(s)
  - Given the problem, what is this research project trying to achieve?
- Budget
- Volunteers to help finalize project concept

BREAK

Please return for Part 2 of the Workshop by 3:30 PM

PART 2: Monitoring & Implementation Speakers

Troy Walker
Hazen and Sawyer

Eva Steinle-Darling
Carollo

Any Salveson
Carollo

Trent Stober
HDR

DEVELOPING A NATIONAL WATER REUSE RESEARCH ROADMAP

PERFORMANCE MONITORING

TROY WALKER (HAZEN AND SAWYER)
ANDREW SALVESON (CAROLLO)

MARCH 6, 2022

2022 WateReuse SYMPOSIUM

SHAPING OUR PAST & CHARTING OUR FUTURE

Intros

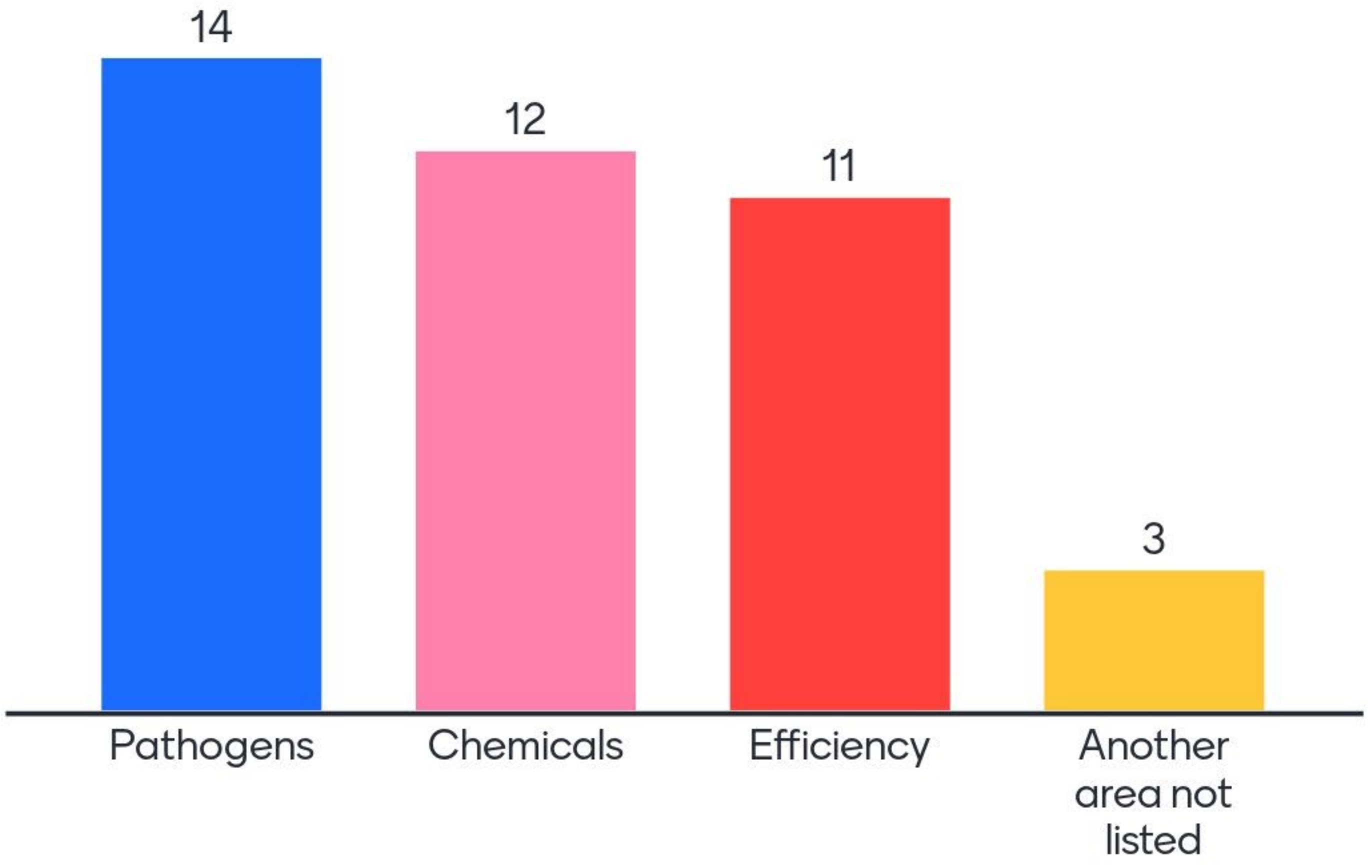
- Hazen
- Water Reuse Practice Lead
- Working in reuse since 1994
- PI or co-PI on a several monitoring focused projects for the Water Research Foundation

- Carollo Engineers
- Water Reuse Chief Technologist
- Implementing Potable Reuse Projects Since 1998
- PI or co-PI on a range of treatment and monitoring projects for the Water Research Foundation

Background

- Monitor What Matters, Where It Matters
  - Pathogens
  - Chemicals
  - Efficiency
- Too often, data is collected, not used, and process performance degrades
- "Smart" systems provide a better future for more efficient and more confident operation

Where is research most needed for system monitoring?



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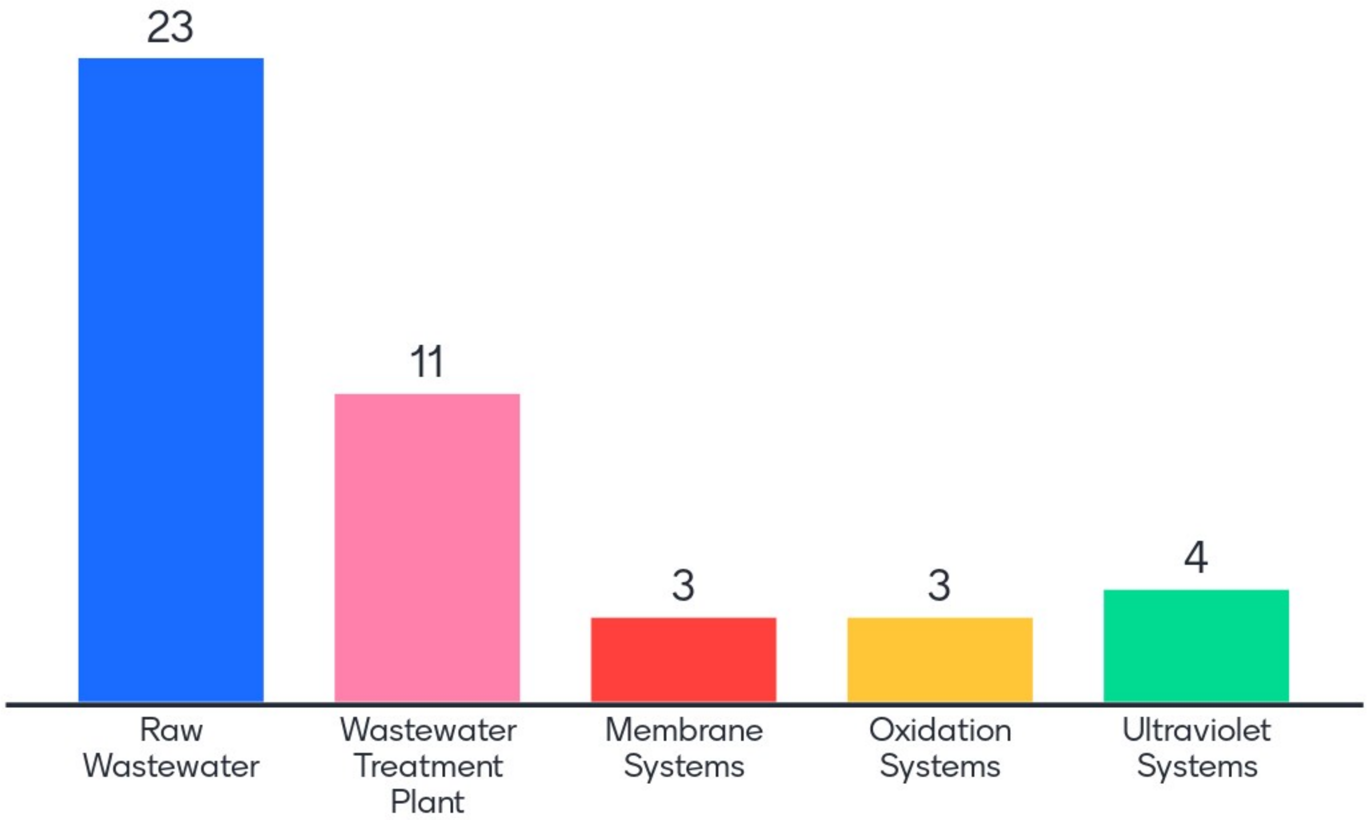
What part of the treatment process poses the greatest risk?



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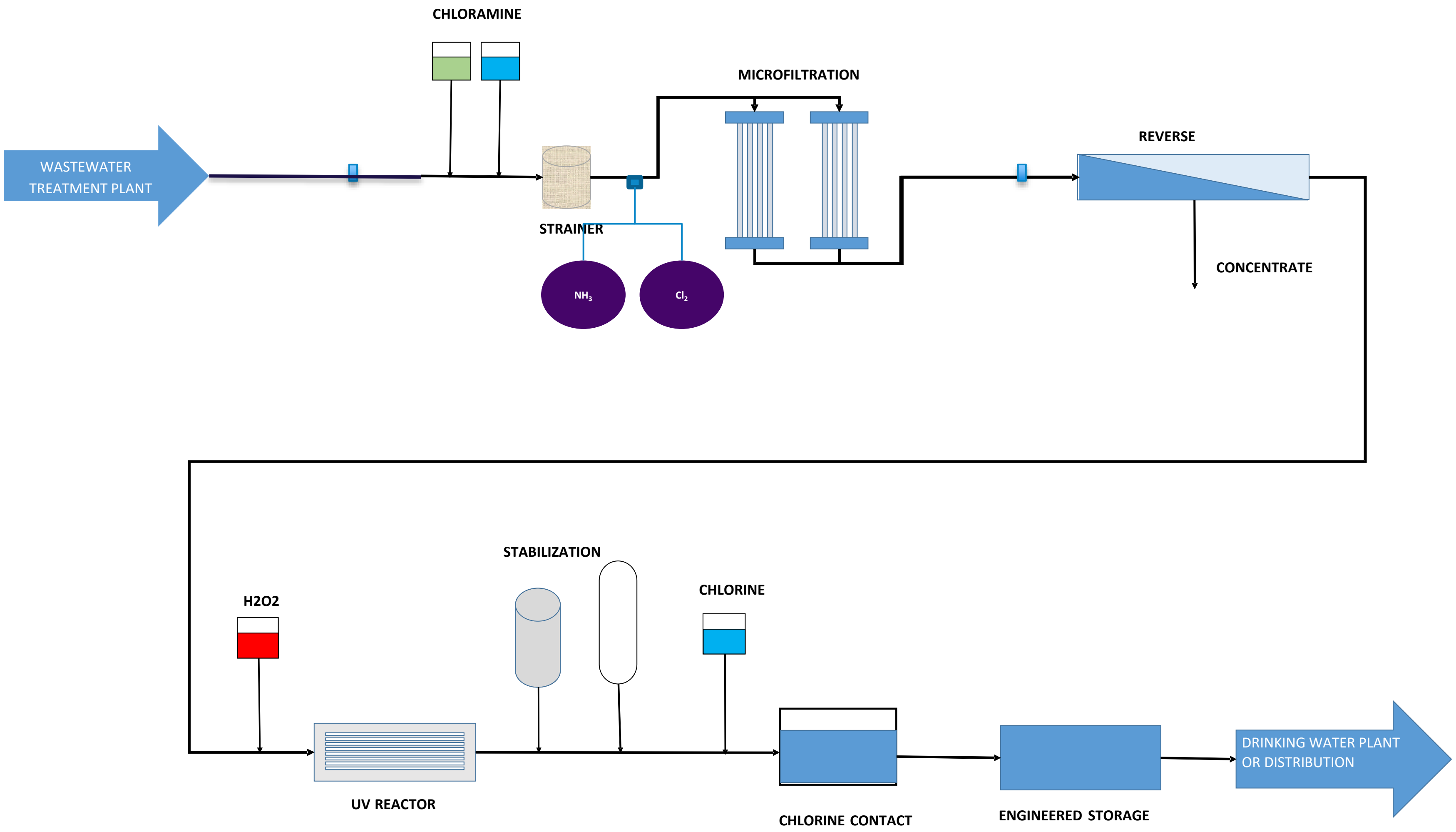
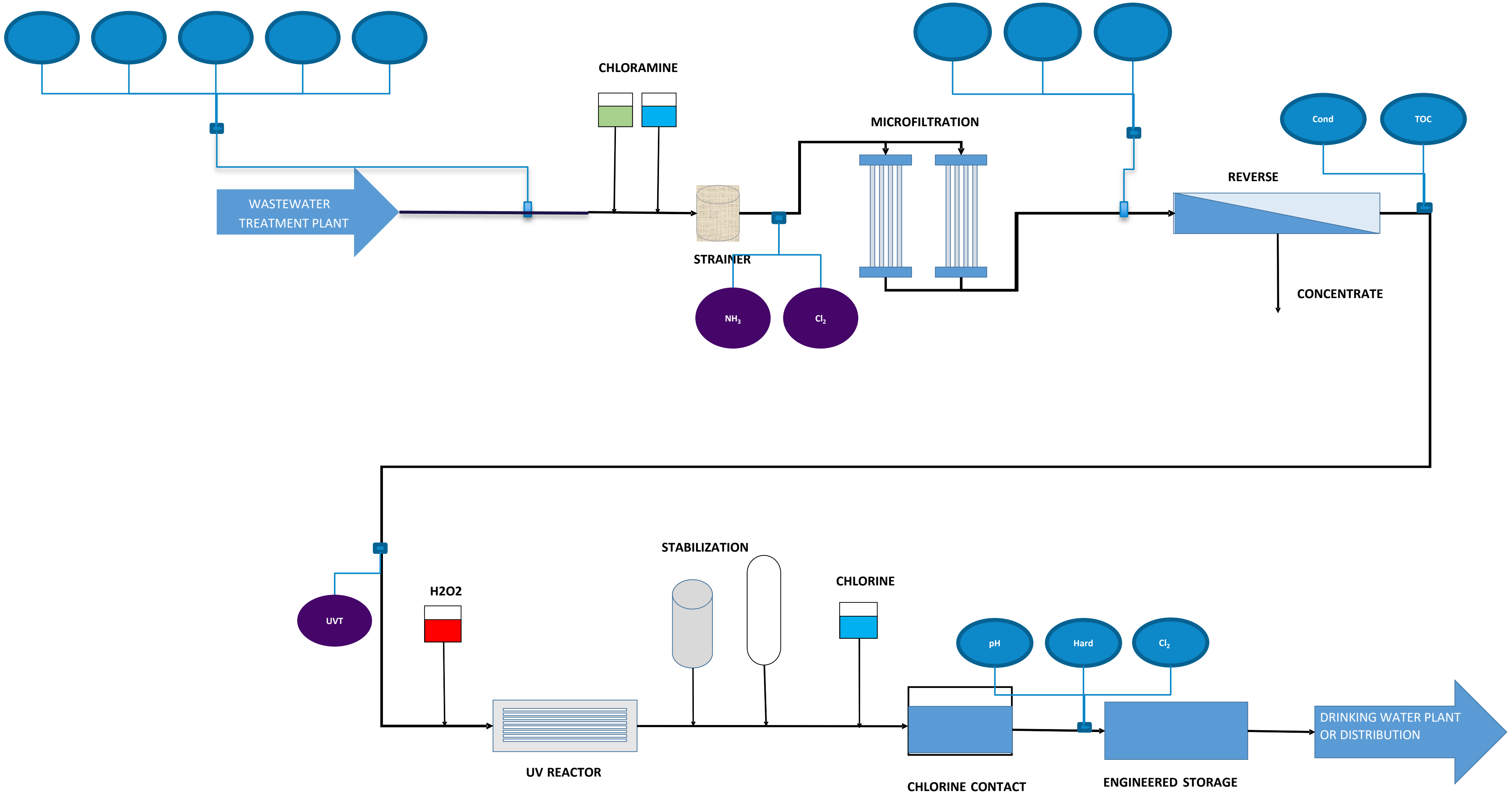
Potable Reuse Requires Extensive Monitoring



Potable Reuse Requires Extensive Monitoring



Critical Control Points Provide Protection

Hazard Analysis and Critical Control Point Methodology (HACCP)

What Does the CCP Approach Provide?

Review and Manage Risks to Protect Public Health

Holistic Review / Robust Methodology – source water to distribution

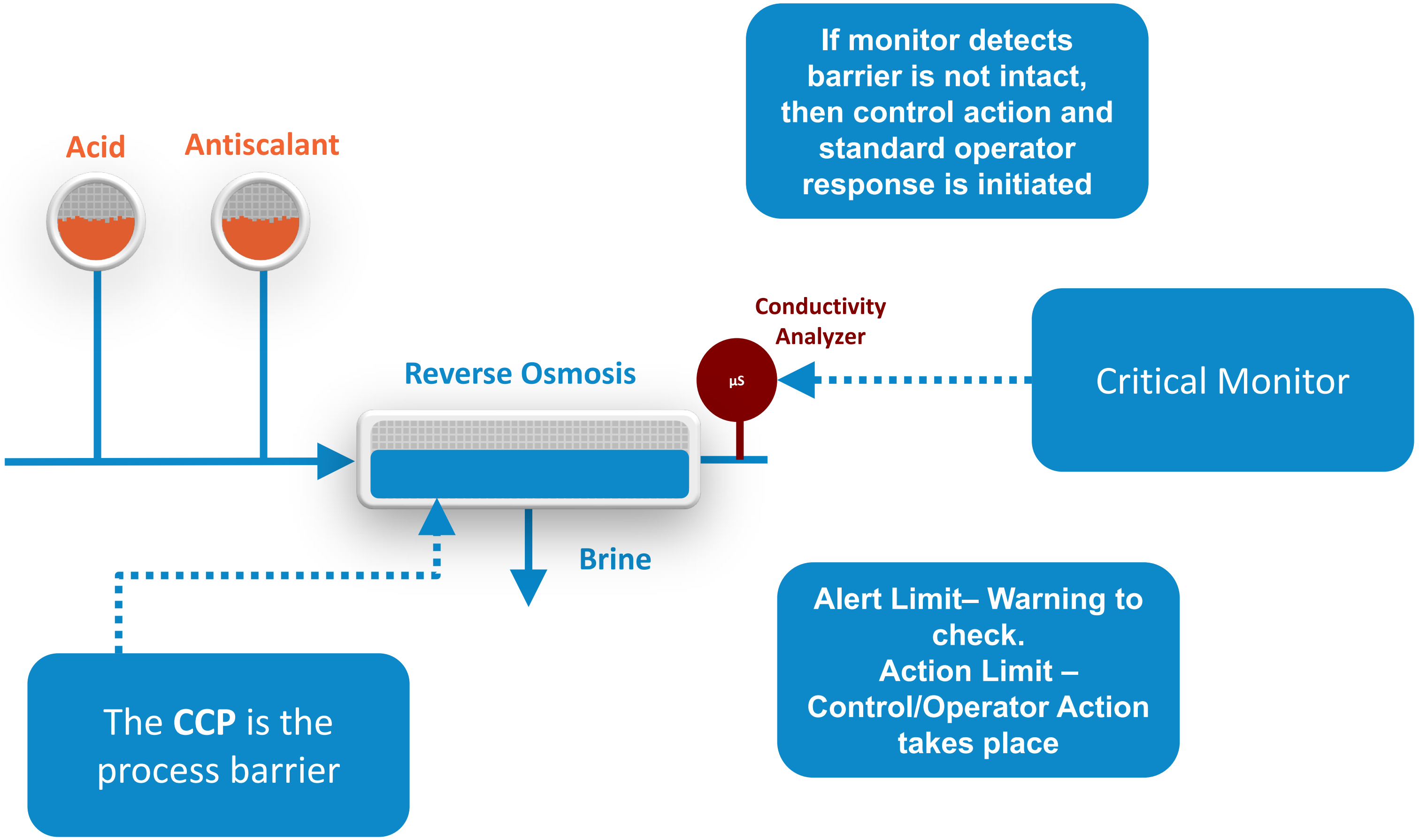
What are the risks?	What are the right technologies?	How are we sure they are working?	How do we respond if a barrier fails?
Contaminants/ Hazardous Events	Treatment Barriers	Monitoring	Operating Response

Focus is on health relevant contaminants.

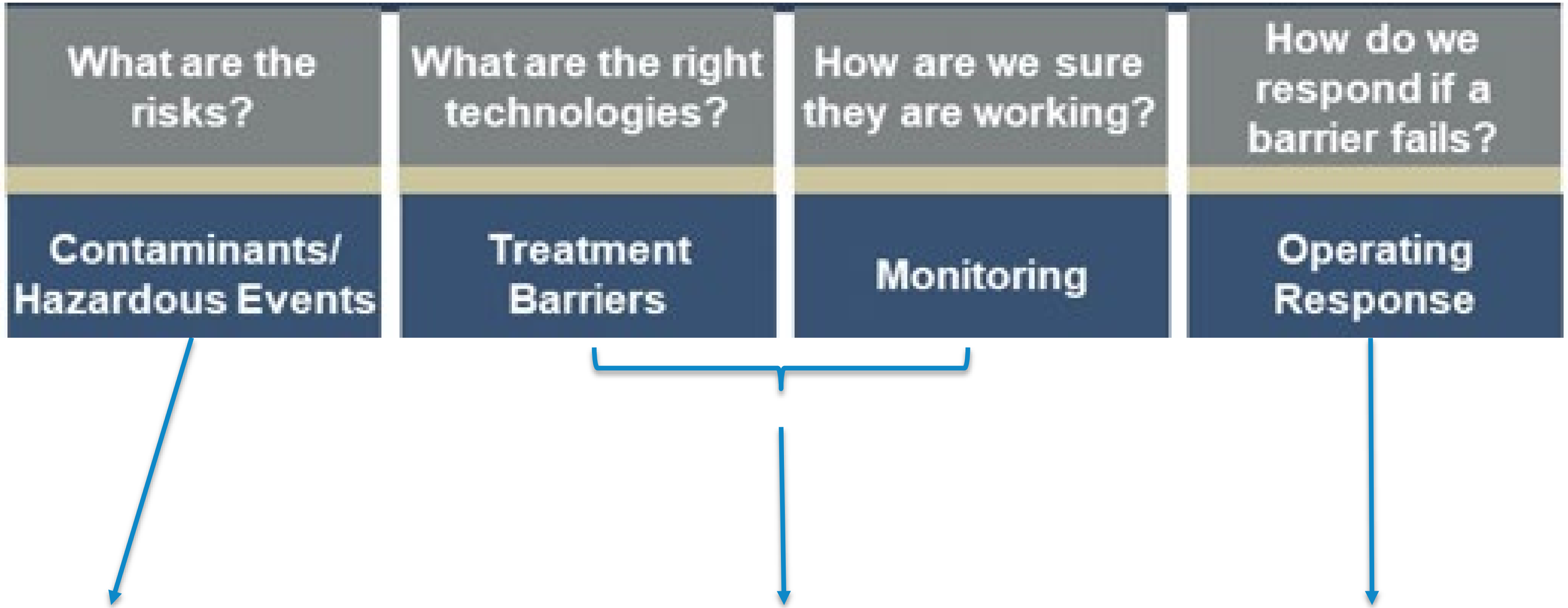
WRF 13-03

What Is a Critical Control Point (CCP)?

CCPs are points in the treatment process that are specifically designed to reduce, prevent, or eliminate a human health hazard and ***for which controls exist*** *to ensure the proper performance of that process.*



Improved Monitoring is the Key



WRF 13-13

Improved source monitoring

More sensitive monitoring.
Better Log removal.

Rapid response.
Reliable instrumentation

State of the Science

State of the Science

Project #	Project Name	Status
5104	Use of DNA Nanostructure as Viral Surrogates in Potable Reuse Applications	Ongoing
5079	Assessing Water Quality Monitoring Needs, Tools, Gaps, and Opportunities for Potable Water Reuse	Ongoing
5052	Standardizing Methods with QA/QC Standards for Investigating the Occurrence and Removal of ARB/ARGs in Wastewater and Advanced Treated Water	Ongoing
5048	Integrating Real-Time Collection System Monitoring Approaches into Enhanced Source Control Programs for Potable Reuse	Ongoing
5041	Enteric Virus Log Removal in Wastewater Treatment for Potable Reuse	Ongoing
4992	Evaluating Analytical Methods for Detecting Unknown Chemicals in Recycled Water (DPR-5)	Ongoing
4961	The Use of Next Generation Sequencing (NGS) Technologies and Metagenomics Approaches to Evaluate Water and Wastewater Quality Monitoring and Treatment Technologies	Ongoing
4959	Evaluation of Tier 3 Validation Protocol for Membrane Bioreactors to Achieve Higher Pathogen Credit for Potable Reuse	Ongoing
4958	New Techniques, Tools, and Validation Protocols for Achieving Log Removal Credit across NF and RO Membranes	Ongoing
4957	Compiling Evidence of Pathogen Reduction through Managed Aquifer Recharge and Recovery	Ongoing
4955	Indicator Viruses for Advanced Physical Treatment Process Performance Confirmation	Ongoing
4954	Integration of High-Frequency Performance Data for Microbial and Chemical Compounds Control in Potable Reuse Treatment Systems	Ongoing
4951	Tools to Evaluate Quantitative Microbial Risk and Plant Performance/Reliability (DPR-1)	2021
4937	Contaminants of Emerging Concern in Decentralized Water Reuse Systems by Non-Targeted Analysis	Ongoing
4774	Molecular Methods for Measuring Pathogen Viability/Infectivity	2021
4908	Demonstrating Real-Time Collection System Monitoring for Potable Reuse	2020
4759	Integrated Management of Sensor Data for Real Time Decision Making	2019
4508	Assessment of Techniques to Evaluate Water Quality from Direct and Indirect Potable Reuse Facilities	2019

State of the Science

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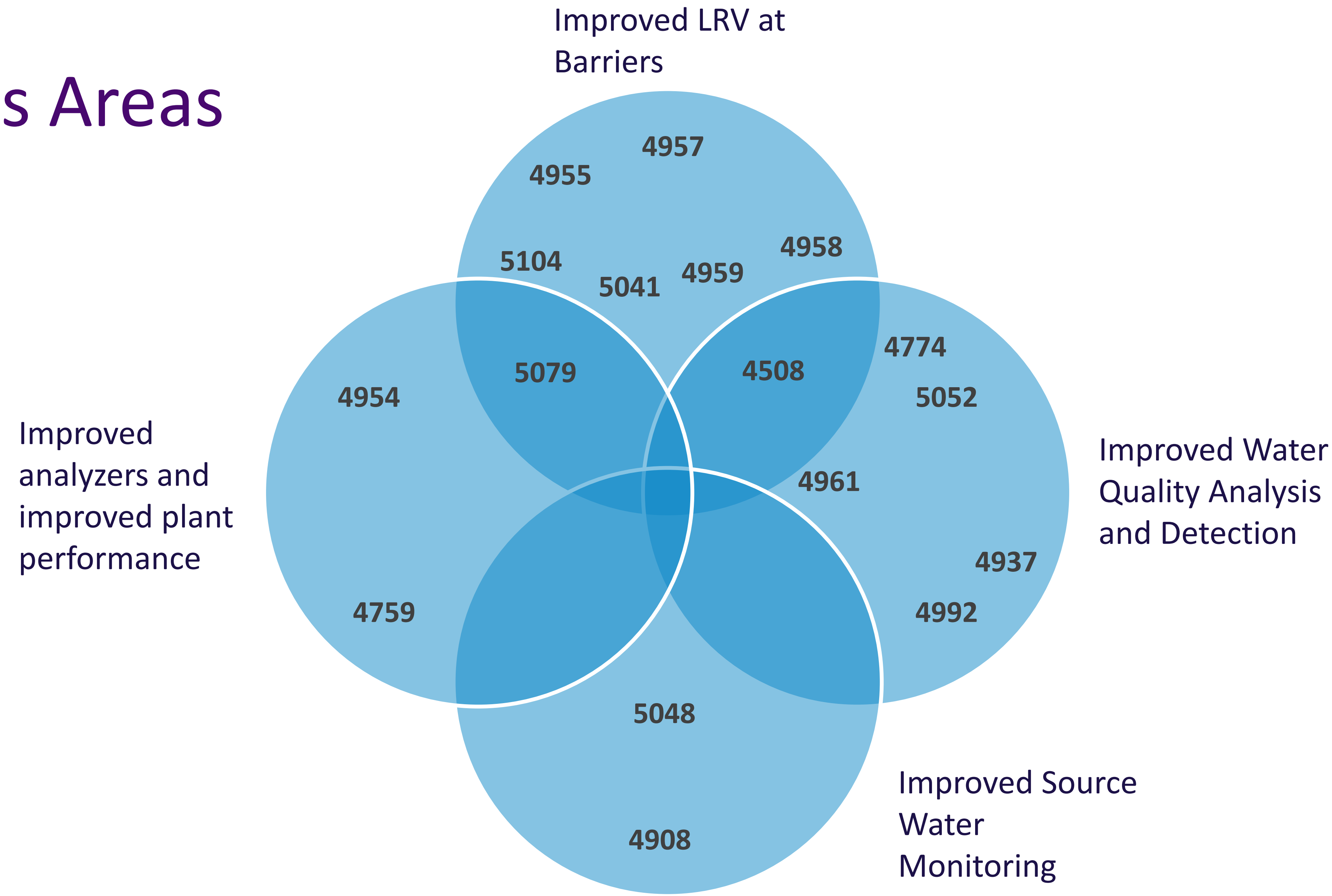
4759	Integrated Management of Sensor Data for Real Time Decision Making	
4508	Assessment of Techniques to Evaluate Water Quality from Direct and Indirect Potable Reuse Facilities	

Yikes! How Do We Sort Through All of This?

Focus Areas


Improved LRV at Barriers
4957
4955
5104
5041
4959
4958
5079
4508
4774
5052
4954
Improved analyzers and improved plant performance
4961
Improved Water Quality Analysis and Detection
4937
4759
4992
5048
4908
Improved Source Water Monitoring

Raw Wastewater Monitoring

California Division of Drinking Water Requires Real-Time Sewershed Monitoring for DPR…and WRF 4908 and 5048 Finds Solutions

Addendum version 3-22-2021

(b) A DiPRRA shall work with the wastewater management agency to utilize local limits and other discharge control methods such that the DPR treatment is not adversely affected. Local limits must be designed to protect the public health and water quality for potable reuse.

(c) The source control program must be audited by an independent party at least every five years. The audit shall use the "Control Authority Pretreatment Audit Checklist and Instructions", EPA, 833-B-10-001, February 2010.

(d) A DiPRRA shall implement a sewershed surveillance program to receive early warning of a potential occurrence that could adversely affect the DPR treatment and that contains the following:

(1) On-line monitoring instrumentation at critical locations that measure surrogate(s) that may indicate a chemical peak;

(2) Notification by the pretreatment program of any failure that results in the release of contaminants above allowable limits;

California Water Boards


Expectations
PEAK OF INFLATED EXPECTATIONS
WRF
5048
2022
2019
SLOPE OF ENLIGHTENMENT
PLATEAU OF
PRODUCTIVITY
TROUGH OF DISILLUSIONMENT
INNOVATION
TRIGGER
Source: https://www.gartner.com/en/research/
methodologies/garner-hype-cycle.
Time

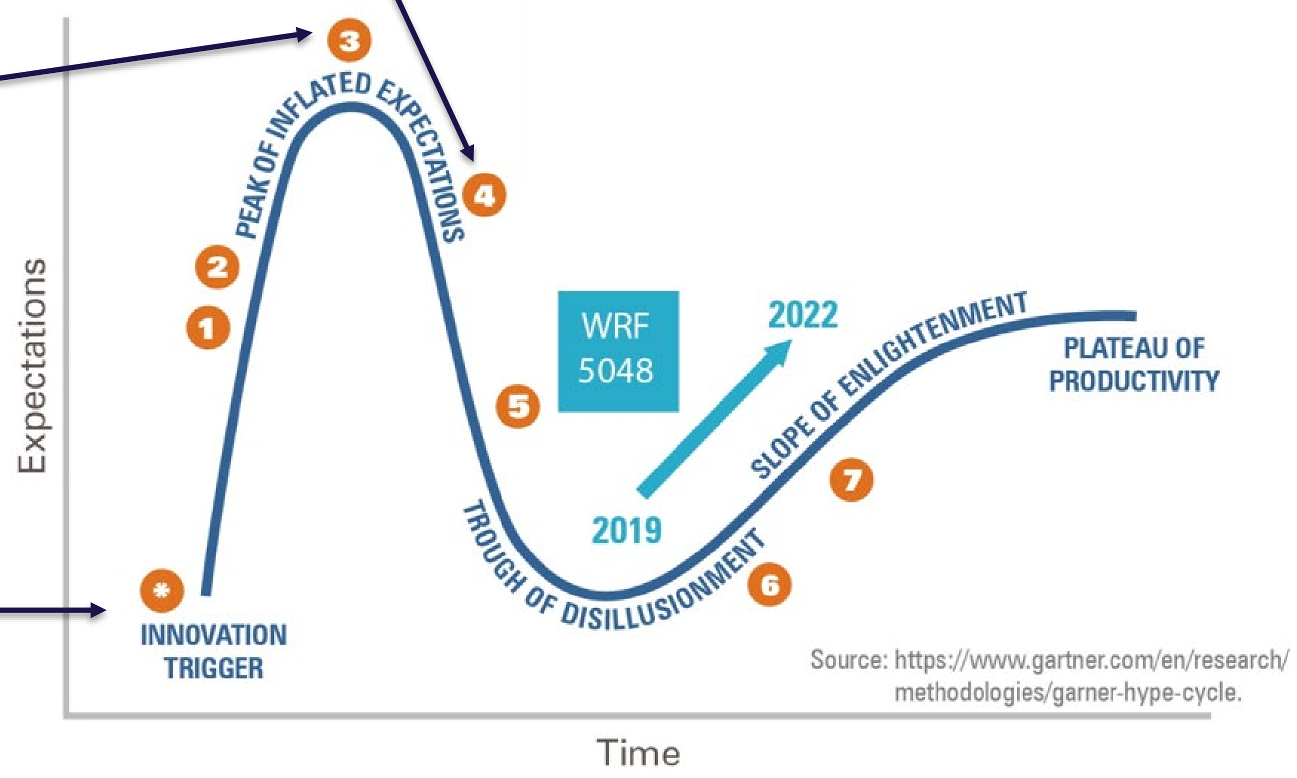
Idea conceived to use real-time sewershed monitoring for potable reuse

Sensors for broader variety of water quality parameters become available
(optical, specific metals, automated GC/MS)

Idea conceived to use real-time sewershed monitoring for potable reuse

WRF 4908
Reality strikes back:
Maintenance, ragging, etc.

Sensors for broader variety of water quality parameters become available (optical, specific metals, automated GC/MS)

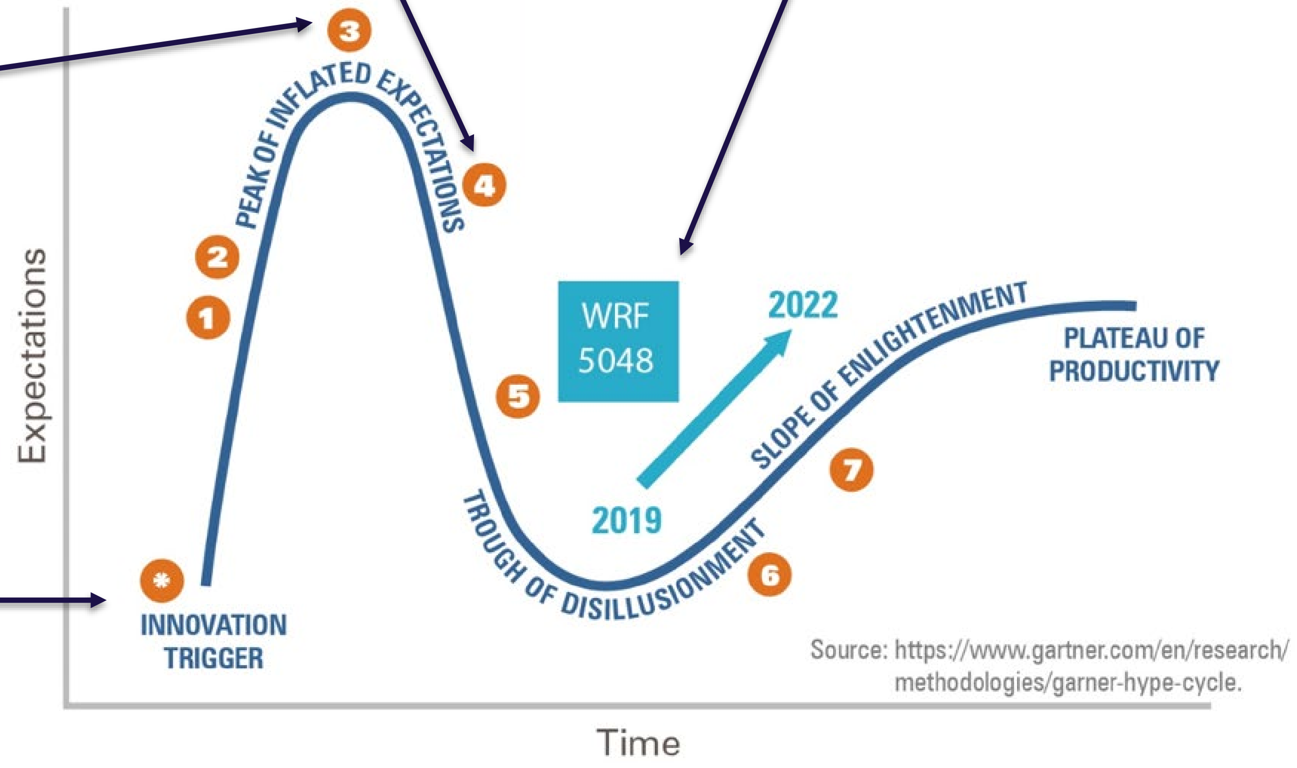


Idea conceived to use real-time sewershed monitoring for potable reuse

WRF 4908
Reality strikes back:
Maintenance, ragging, etc.

This project:
balance, realism, practical guidance

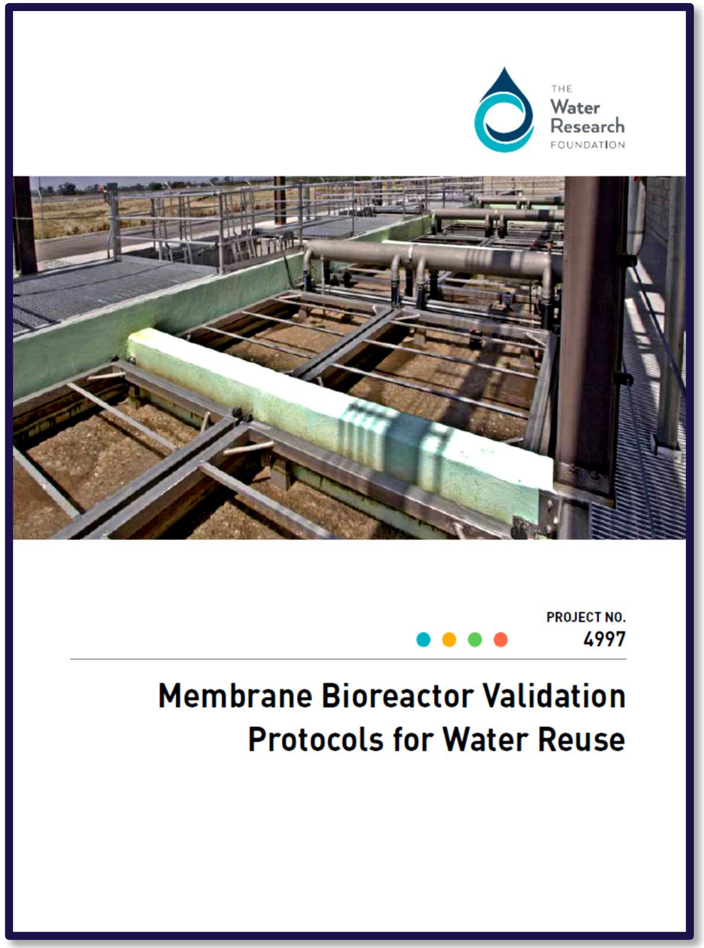
Sensors for broader variety of water quality parameters become available
(optical, specific metals, automated GC/MS)

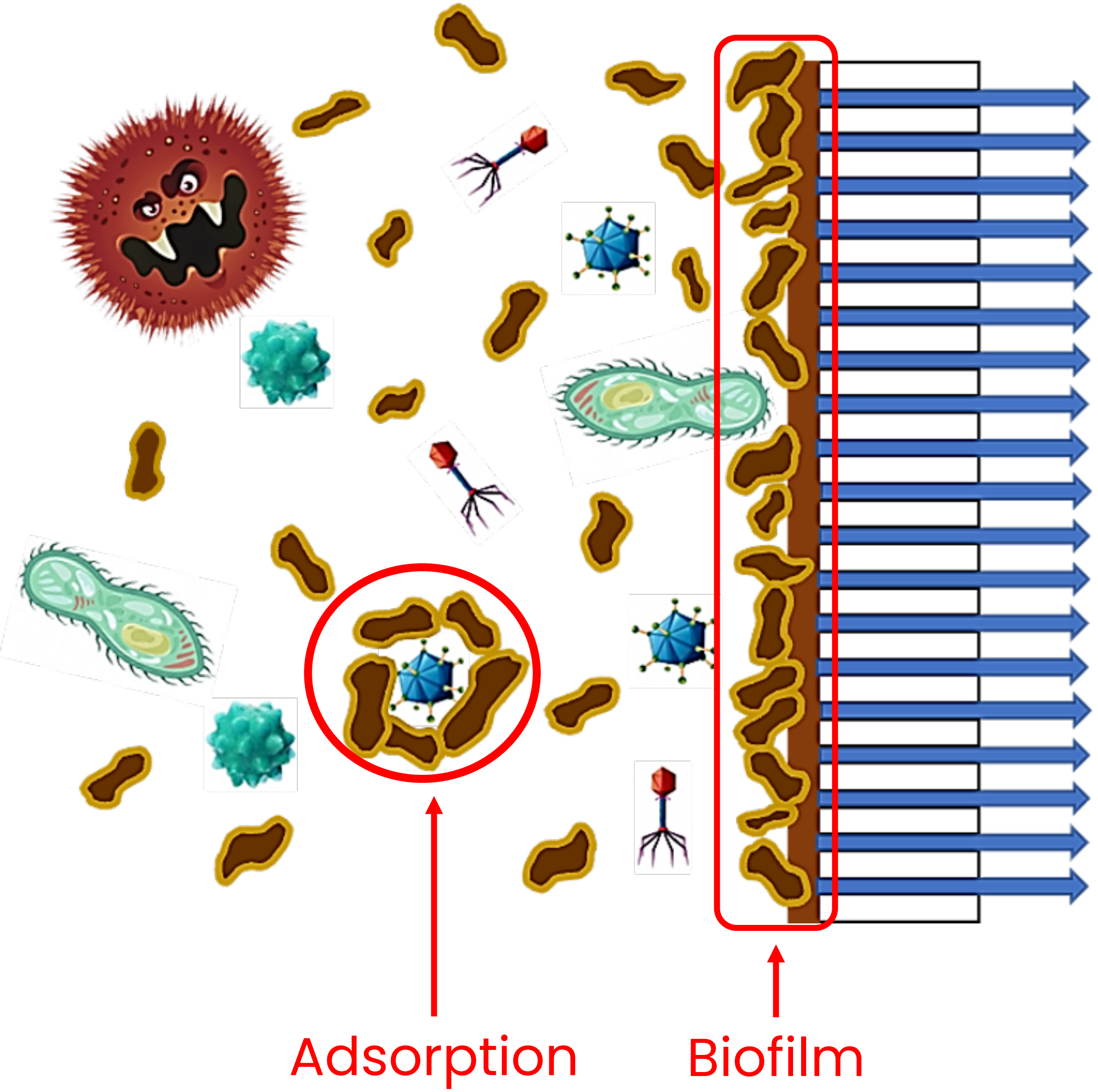


Idea conceived to use real-time sewershed monitoring for potable reuse

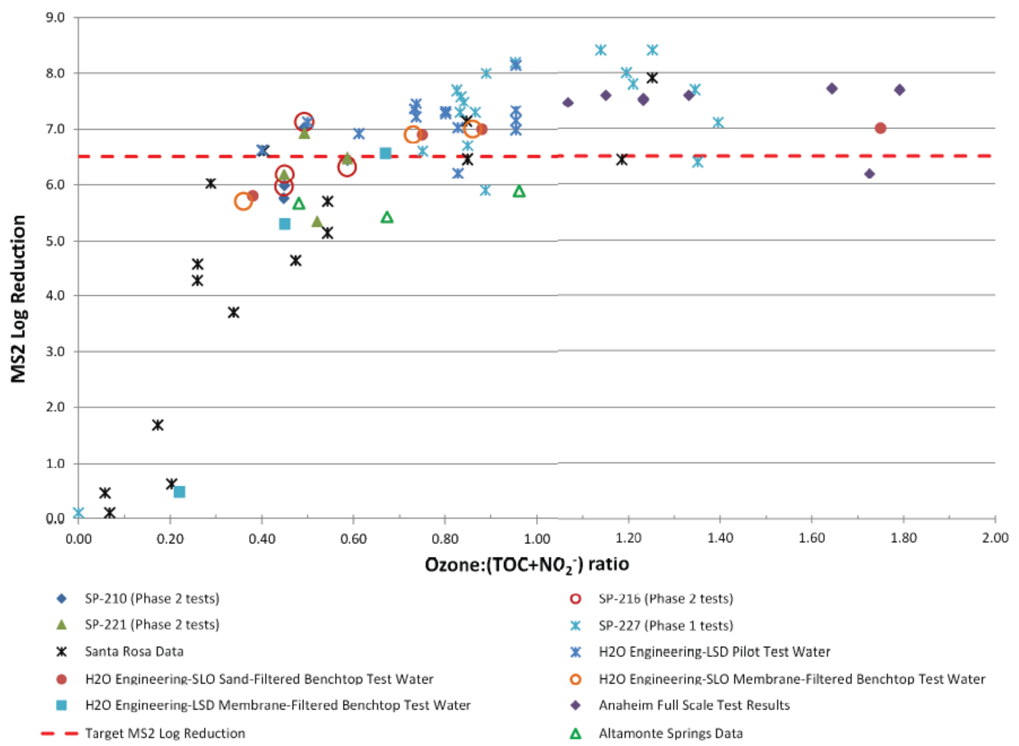
Pathogen Removal Performance and Surrogates

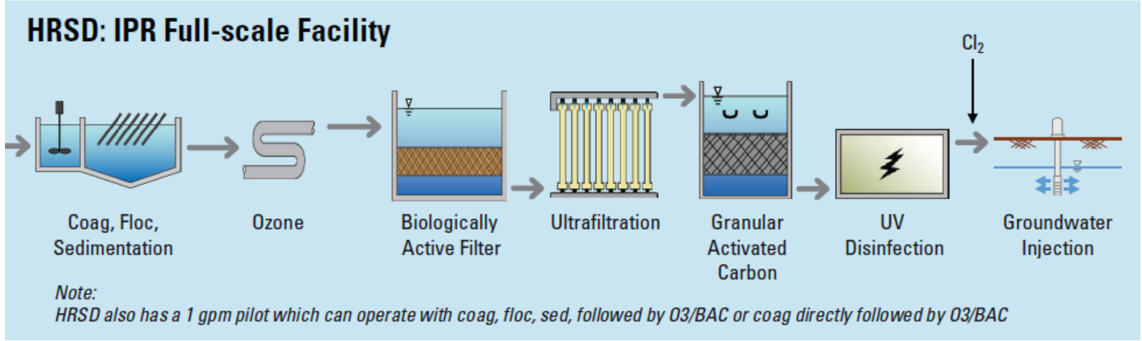
MBRs Remove Pathogens, but WRF 4997 & 4959 Defined How They Do It



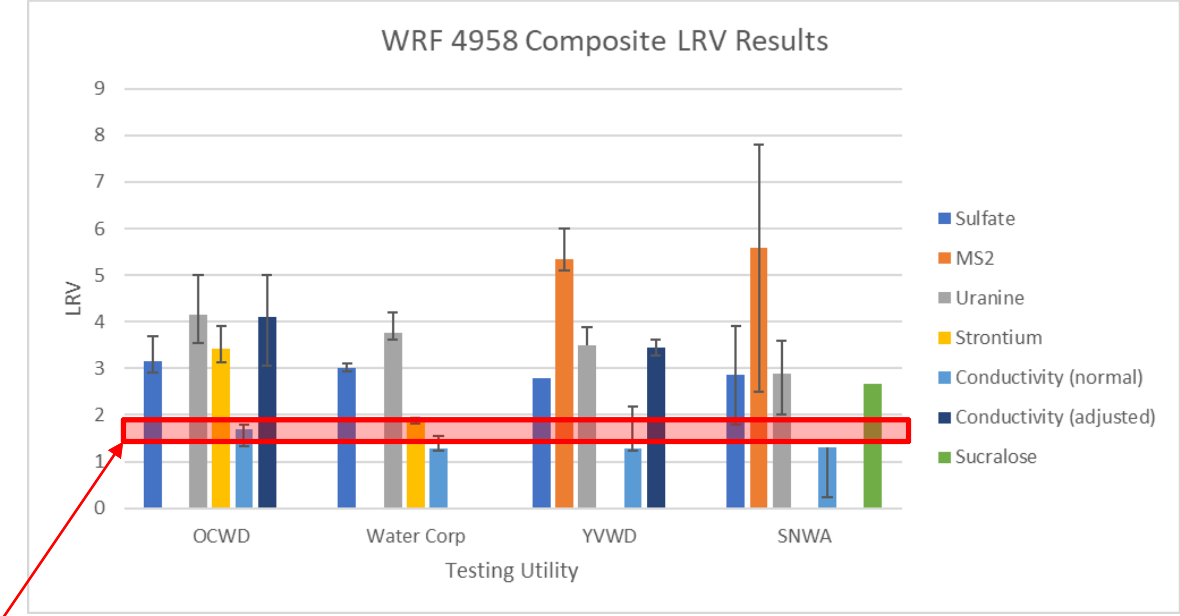


Ozone is a Fabulous Virus and Bacteria Disinfectant, and Biofiltration Can Provide a Pathogen Barrier…WRF 5129 Will Define Performance and Monitoring



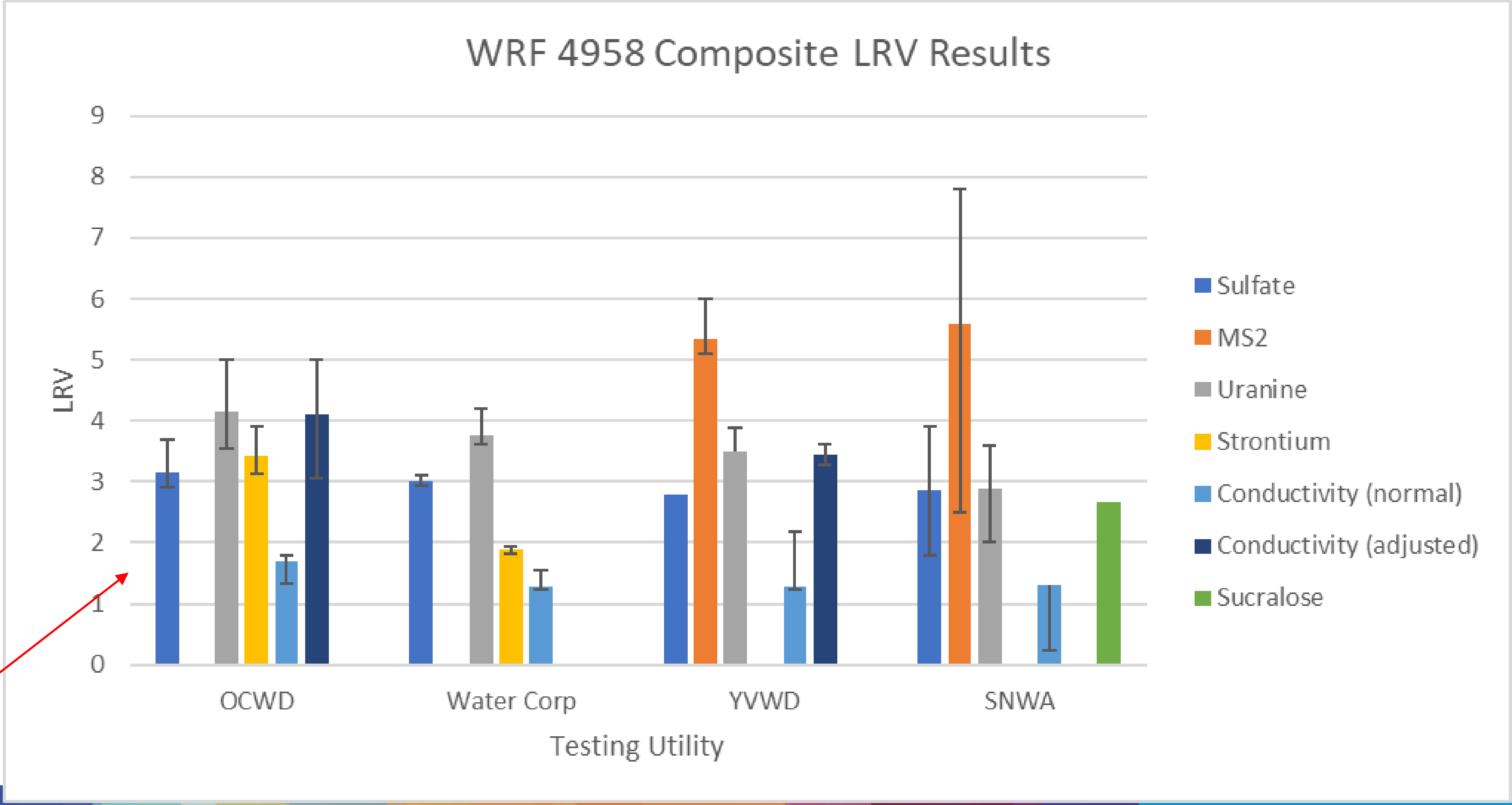


RO Removes Salt, TOC, and All Pathogens to a Significant Level…But WRF 4958 is Detailing the Proper Surrogates to Correlate with LRV



Current 1.5-2.0 LRV

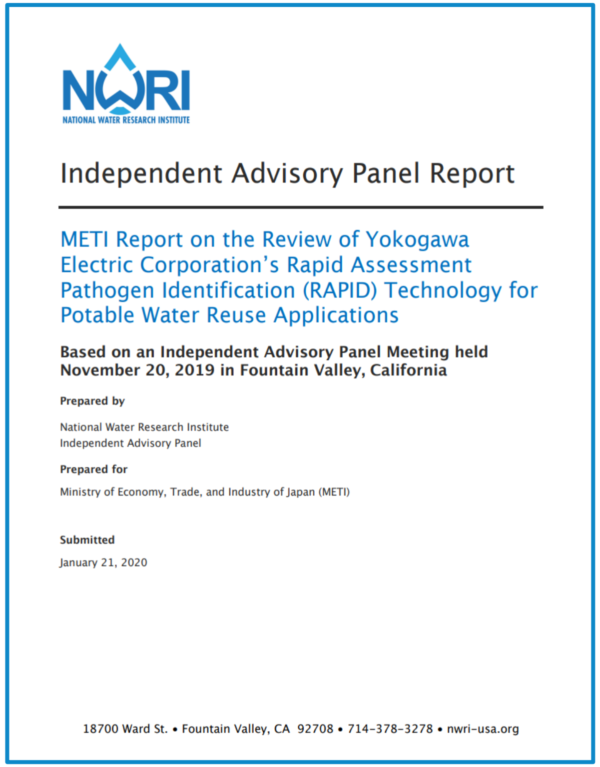
WRF 4958 Composite Results



Current 1.5-2.0 LRV

The Holy Grail for Pathogen Monitoring May Be Just Around the Corner…and WRF Needs to Think About Funding It!

The Holy Grail for Pathogen Monitoring May Be Just Around the Corner…and WRF Needs to Think About Funding It!



NWRI
NATIONAL WATER RESEARCH INSTITUTE

Independent Advisory Panel Report

METI Report on the Review of Yokogawa Electric Corporation's Rapid Assessment Pathogen Identification (RAPID) Technology for Potable Water Reuse Applications

Based on an Independent Advisory Panel Meeting held November 20, 2019 in Fountain Valley, California

Prepared by

National Water Research Institute
Independent Advisory Panel

Prepared for

Ministry of Economy, Trade, and Industry of Japan (METI)

Submitted

January 21, 2020

18700 Ward St. • Fountain Valley, CA 92708 • 714-378-3278 • nwri-usa.org

Water Research 206 (2021) 117735

Contents lists available at ScienceDirect

Water Research

journal homepage: www.elsevier.com/locate/watres

ELSEVIER

Applicability of pepper mild mottle virus and cucumber green mottle mosaic virus as process indicators of enteric virus removal by membrane processes at a potable reuse facility

Midori Yasui [a], Hikaru Iso [a], Shotaro Torii [a], Yasuhiro Matsui [b], Hiroyuki Katayama [a,*]

[a] Department of Urban Engineering, School of Engineering, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, Japan
[b] Yokogawa Electric Corporation Japan

ARTICLE INFO

Keywords:
Process indicator
Human enteric virus
Water reuse
Microfiltration
Ultrafiltration
Reverse osmosis
Abbreviation: MF, microfiltration
UF, ultrafiltration
RO, reverse osmosis
UV/AOP, ultraviolet light and advanced oxidation process
AIV, aichi virus
PMMOV, pepper mild mottle virus
CGMMV, cucumber green mottle mosaic virus
Crassphage, cross-assembly phage
LRV, log reduction value
EF, effluent
MNV, Murine Norovirus
PCE, primary concentration efficiency
MPC, molecular process control
ORSV, Odontoglossum Ringspot Virus
MME, molecular method efficiencies
NV GI, norovirus GI
NV GII, norovirus GII
AdV, adenovirus

ABSTRACT

Treatment of wastewater for potable reuse is increasingly becoming a suitable alternativ
the growing urban water needs worldwide. Potable reuse requires reduction of enteric vi
they do not pose a risk to human health. Advanced water treatment trains (e.g., microf
tration (UF), reverse osmosis (RO), and ultraviolet light and advanced oxidation proce
significant protection and reduce virus loads in highly treated final product waters. Eve
principal concern, the performance of virus removal by membrane processes is not e
objective of this study was to evaluate the applicability of Aichi virus (AiV), pepper mild
cucumber green mottle mosaic virus (CGMMV), and cross-assembly phage (crAssphag
process indicators for MF, UF, and RO. Virus log reduction values (LRVs) based on gene
molecular methods were determined for MF and UF. The median LRVs of all viruses obt
were 2.9 and 3.1, respectively. The LRVs of the proposed indicators were lower than t
viruses. The morphological and physicochemical difference among indicators was not
Therefore, all proposed indicator viruses were determined to be suitable candidates as pr
and UF. Regarding RO, most of the viruses measured in this study were undetectable in p
and CGMMV were detected showing median LRVs of 2.8 and 2.5, respectively. PMMoV
ommended as good process indicators of physical virus removal for the overall water tre

1. Introduction

Globally, fresh water shortages are expanding due to climate change, urbanization, population growth, and increased water demands (Leverenz et al., 2011). Water reuse offers a viable strategy to maintain a stable water supply and has recently been adopted in many regions of the world. One way to accomplish this situation is introducing advanced water treatment trains (e.g., Microfiltration (MF), ultrafiltration (UF),

reverse osmosis (RO), and ultraviolet light and
process (UV/AOP)), which treat wastewater to p
pathogen-free water. Virus removal is a key factor
the planned potable reuse facilities because waste
virus concentrations (CCR, 2015, 2021; TWDB, 20

For potable reuse, viruses in wastewater must
that do not impact human health (Sano et al., 20
number of fecal viruses in stools has been as hi

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https://doi.org/10.1016/j.watres.2021.117735
Received 15 June 2021; Received in revised form 25 September 2021; Accepted 29 September 2021
Available online 3 October 2021

Trace Chemical Monitoring

For DPR, Regulations Reflect Fear of Unknown Chemical Pollutants. More Research is Needed to Address This Concern

- O_3:BAC Requirements
- 10:1 Dilution Requirements
- 1 LRV NDMA, formaldehyde, and acetone requirements

A Proposed Framework of Regulating Direct Potable Reuse in California Addendum
version 8-17-2021

DPR Framework 2nd edition Addendum – Early Draft of Anticipated Criteria for Direct Potable Reuse

Table of Contents

Note 2
§ 64669.00 Application 2
§ 64669.05 Definitions 3
§ 64669.10 General Requirements 5
§ 64669.15 Permit 6
§ 64669.20 Public Meeting 8
§ 64669.25 Joint Plan 9
§ 64669.30 Technical, Managerial, Financial Capacity 10
§ 64669.35 Operator Certification 12
§ 64669.40 Wastewater Source Control 13
§ 64669.45 Pathogen Control 15
§ 64669.50 Chemical Control 19
§ 64669.55 Water Safety Plan 25
§ 64669.60 Regulated Contaminants & Physical Characteristic Control 25
§ 64669.65 Additional Monitoring 28
§ 64669.70 Laboratory Analysis 32
§ 64669.75 Engineering Report 33
§ 64669.80 Operations Plan 34
§ 64669.85 Pathogen and Chemical Control Point Monitoring and Response Plan 36
§ 64669.90 Monitoring Plan 39
§ 64669.95 Compliance Reporting 40
§ 64669.100 Annual Report 42
§ 64669.105 Cross-Connection Control 43
§ 64669.110 Corrosion Control and Stabilization 43

Artificial Intelligence and Machine Learning to Best Utilize **BIG DATA**

Smart Systems that Learn, Adapt, and Improve Both Water Quality and Efficiency is the Next Frontier for System Monitoring

- Nutrients and Performance →
- Airflow ↓
- Power ↓

YOKOGAWA

PURE WATER PROJECT
LAS VIRGENES-TRIUNFO
Bringing Our Water Full Circle

THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

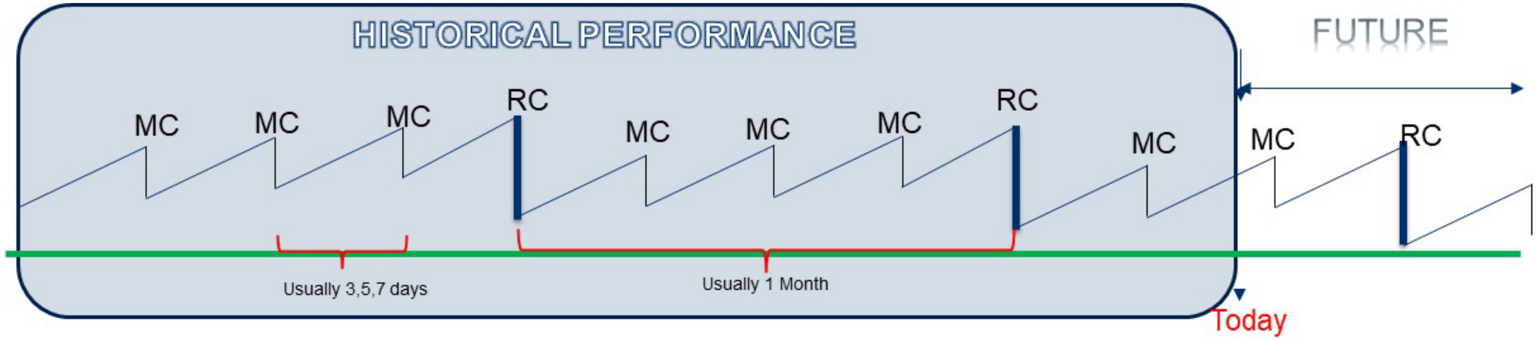
Activated Sludge is Well Proven, but AI/ML for Potable Reuse is Just Beginning

YOKOGAWA

PURE WATER PROJECT
LAS VIRGENES-TRIUNFO
Bringing Our Water Full Circle

NWRI
NATIONAL WATER RESEARCH INSTITUTE

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION



Knowledge Gaps

- Direct Correlation Studies Between Raw Wastewater Quality and Potable Reuse Risk
- Real Time Pathogen Monitoring
- Trace Chemical Monitoring and Risk Minimization
- Extended AI/ML Studies for Potable Reuse Water Quality, Efficiency, and Risk Minimization

Example Project Concepts

- **Finding Correlations Between Raw Wastewater Quality and Potable Reuse Risk**
  - ✓ Builds Upon WRF 5048 and 4960
  - ✓ Identifies Chemical Pollutants that Pose Risk to Purification Trains
  - ✓ Determines Correlations Between Target Chemical and Surrogates
  - ✓ $250,000

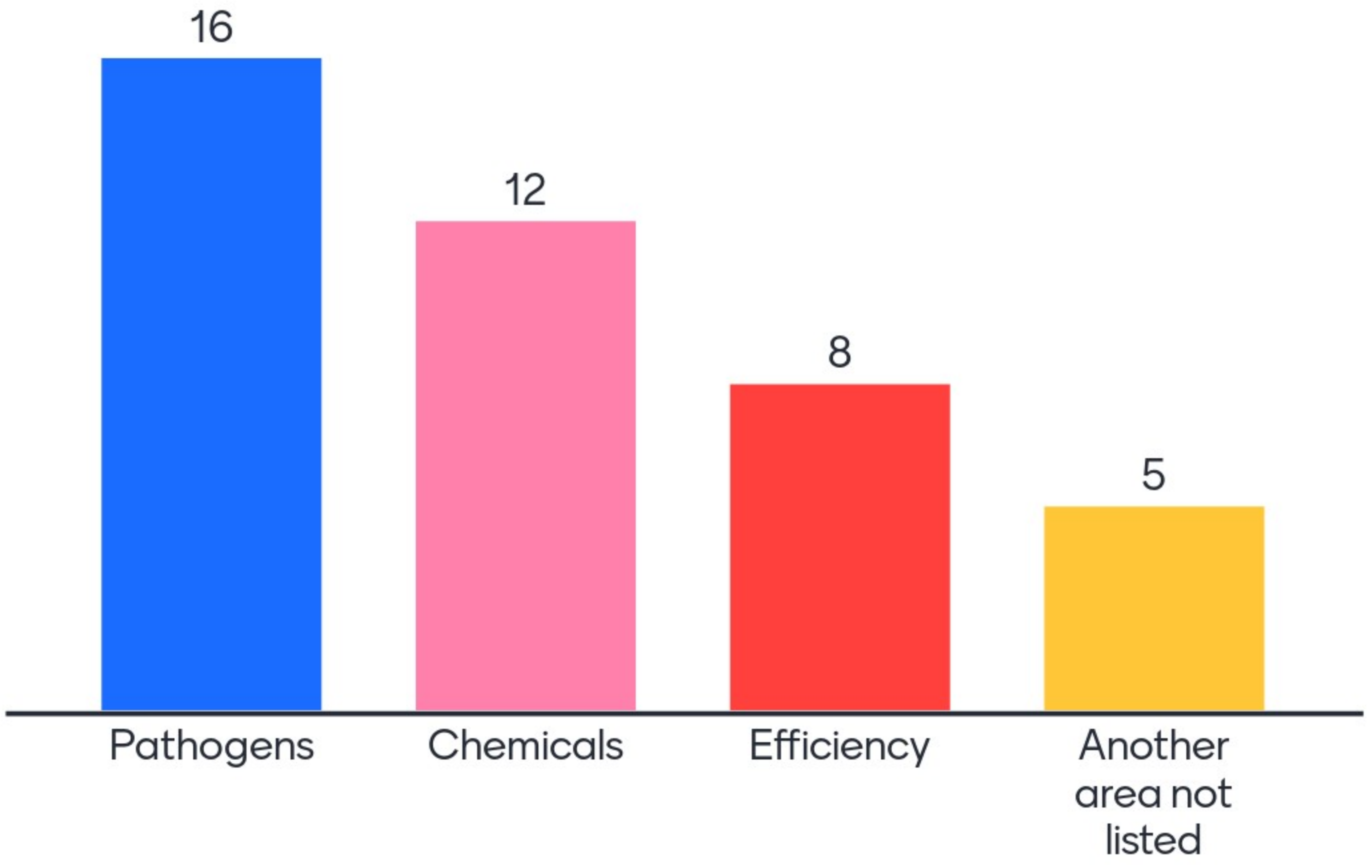
- **Real Time Pathogen Monitoring Demonstration Testing**
  - ✓ Builds Upon NWRI Efforts
  - ✓ Identifies Analytical Methods for (near) Real Time Monitoring of Different Pathogens and Surrogates
  - ✓ Includes Online Demonstration
  - ✓ $350,000

Example Project Concepts

- **Evaluation of Chemical Spikes in RO Permeate and Post RO Ozone/BAC Evaluation**
  - ✓ Detect Chemical Pollutants That Pass Through RO
  - ✓ Determine Risk and Treatability Through Ozone/BAC
  - ✓ $350,000

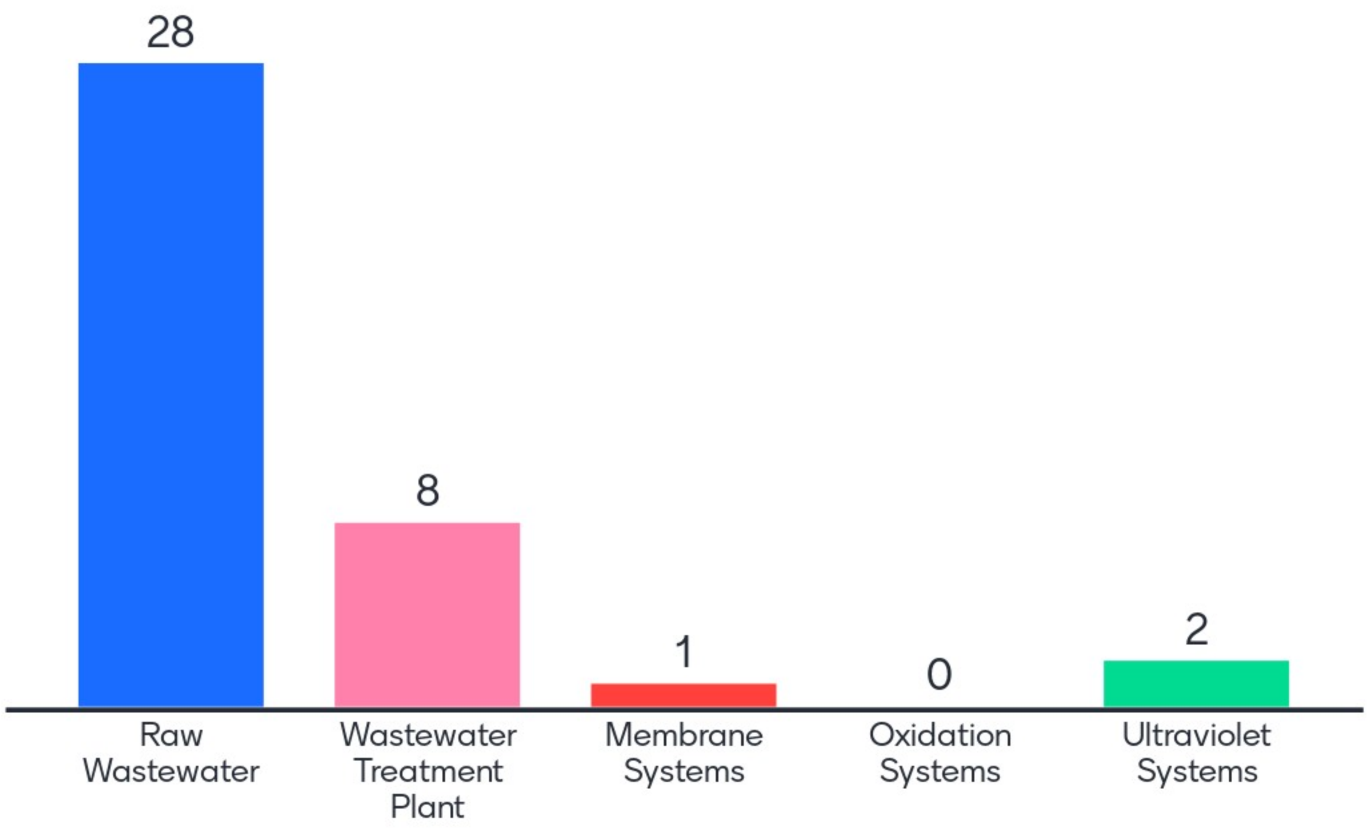
- **Use of AI/ML for Potable Reuse Water Quality, Efficiency, and Risk Minimization**
  - ✓ Builds Upon MWD, USBR, NAWI grants
  - ✓ Identifies Approaches to Improve Efficiency and Protect Water Quality
  - ✓ Includes Operations Engagement
  - ✓ $250,000

Where is research most needed for system monitoring?



41

What part of the treatment process poses the greatest risk?



37

MAJOR FACTORS INFLUENCING REUSE IMPLEMENTATION SUCCESS

EVA STEINLE-DARLING
CAROLLO

TRENT STOBER
HDR

MARCH 6, 2022

2022 WateReuse SYMPOSIUM

SHAPING OUR PAST & CHARTING OUR FUTURE

Speaker Introductions

Eva Steinle-Darling
Carollo Water Reuse Practice Director
Decision Support for Reuse Implementation Success

Trent Stober
HDR Utility Management Services Director
Partnerships for Reuse Implementation Success

What is the most important success factor for reuse implementation?

Mentimeter

42

Part I:
Decision Support for Reuse Implementation Success

WRF Provides LOTS of Decision Support

In 3 Major Categories

1. Applied engineering & science
2. Synthesis report(s) on reuse R&D
3. Decision support guidance & tools

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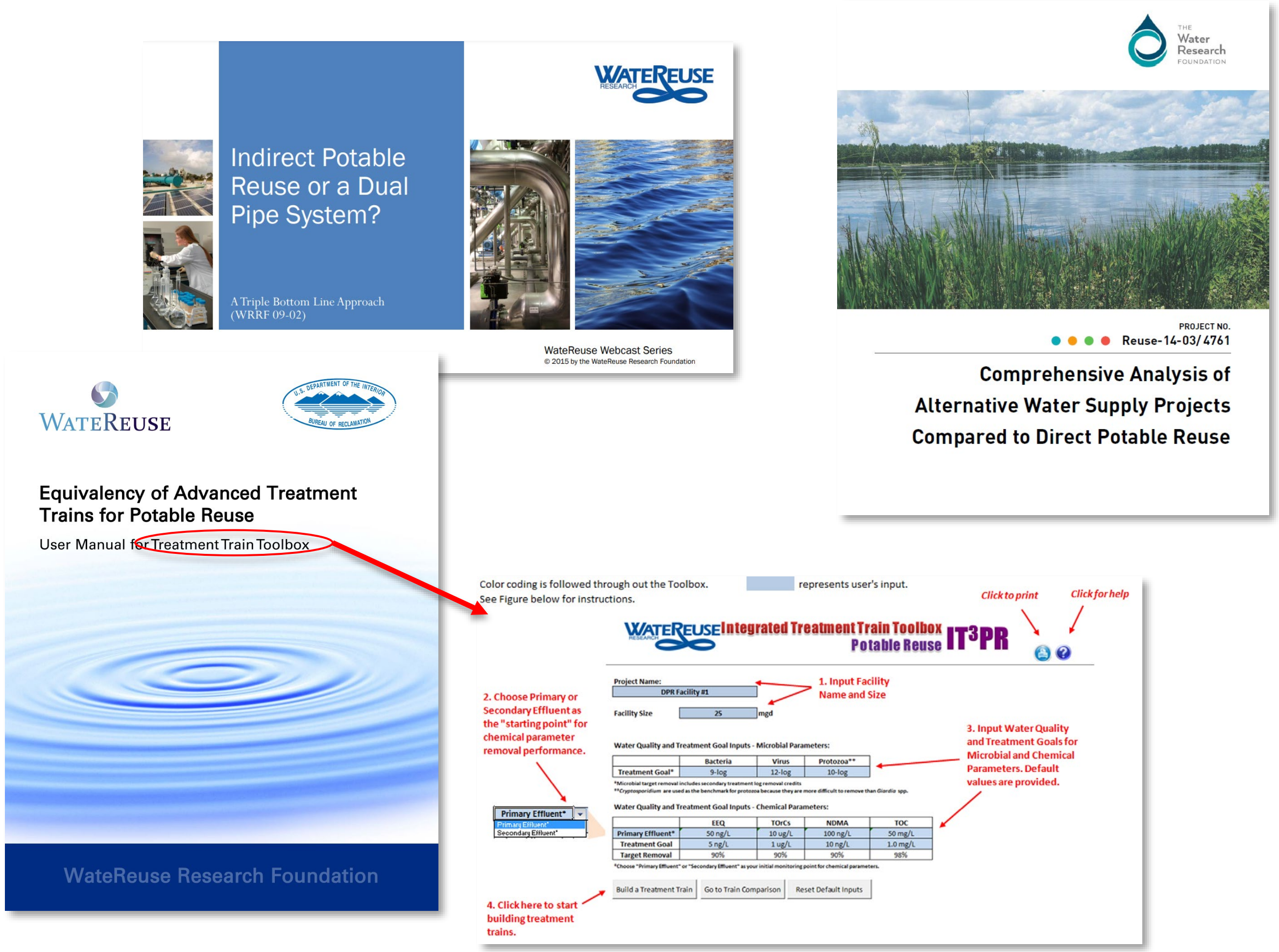


WRF Provides LOTS of Decision Support

In 3 Major Categories

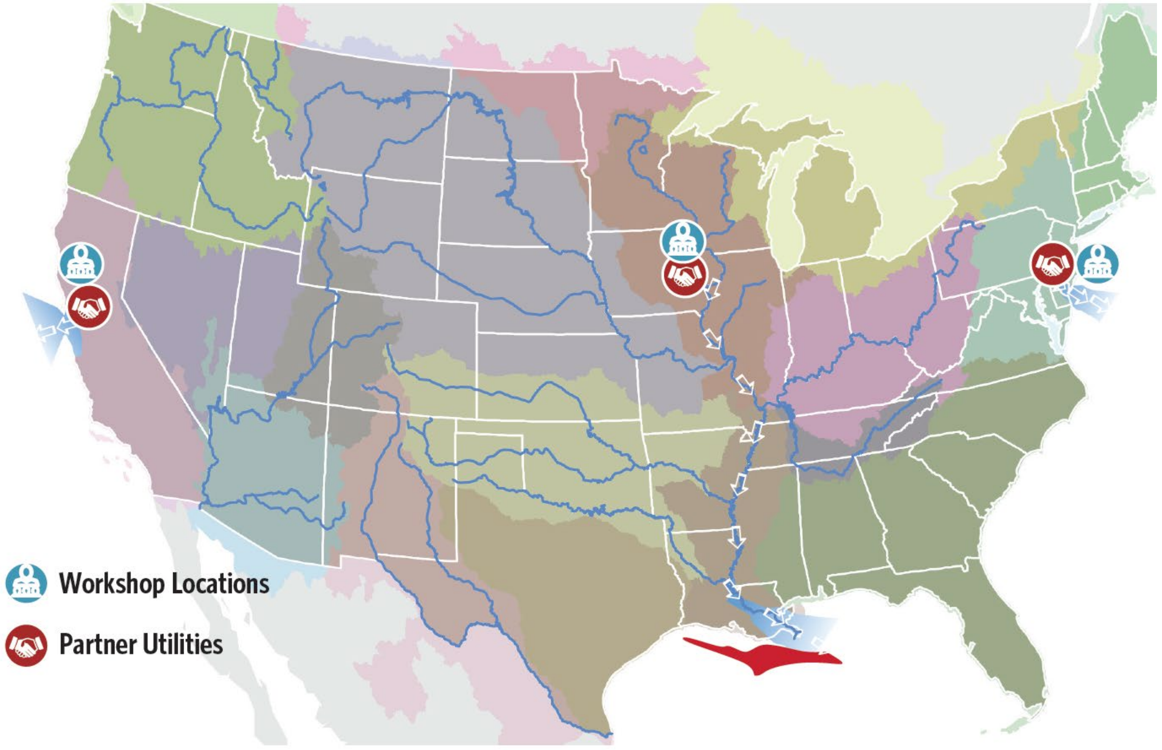
1. Basic engineering research
2. Synthesis report(s) on reuse R&D
3. Decision support **guidance & tools**

But decision support tools struggle with the human side…

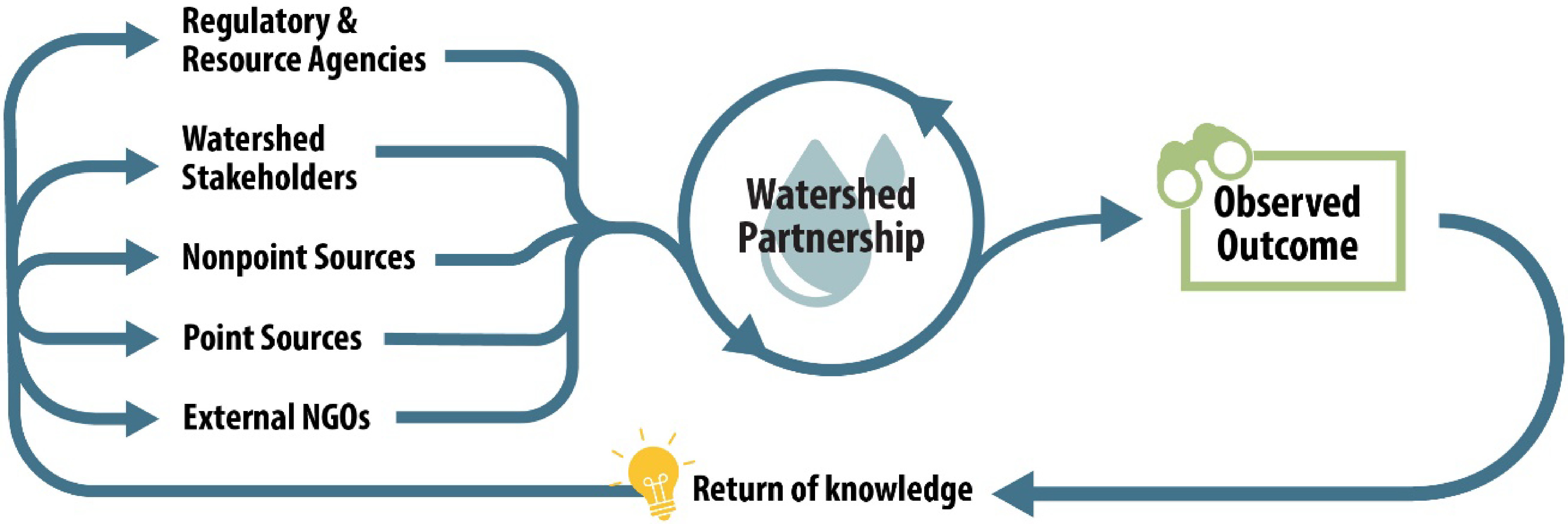
Part II: Partnerships for Reuse Implementation Success

Holistic Approach to Improved Nutrient Management: Phase 1 (WRF RFP#4974)

Figure 1. US Watersheds and Strategic Locations of Partner Utilities and Workshop Locations

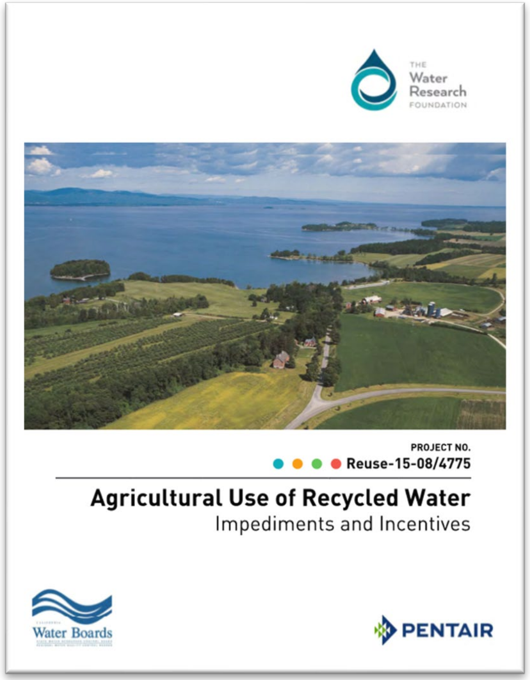


Optimal Watershed Partnership to Yield Water Quality Improvements through Adaptive Management



Agricultural Use of Recycled Water Impediments and Incentives (WRF #4775, #4956)

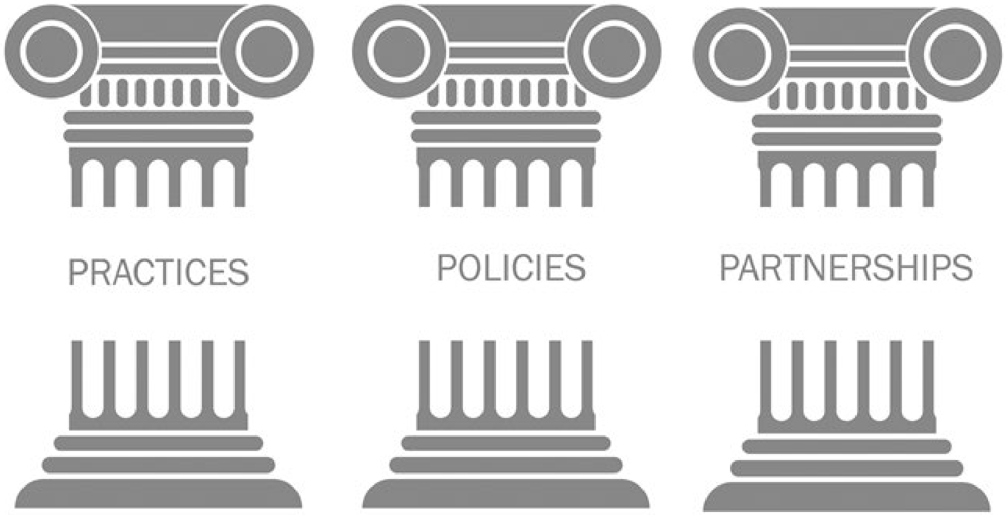
- Water Quality
- Water Quantity
- Technology
- Regulatory & Institutional
- Economic & Financial
- Outreach & Coordination
- Supply/Demand Imbalance
- Perceived Risks
- Food System Supply Chain Complexities



Addressing Impediments and Incentives for Agricultural Reuse | The Water Research Foundation (waterrf.org)

WRF 4974 Phase 1 Findings from Tasks 1 and 2
Development of Task 3 Research Roadmap Phase 2

Key Factors Influencing Holistic Nutrient Management

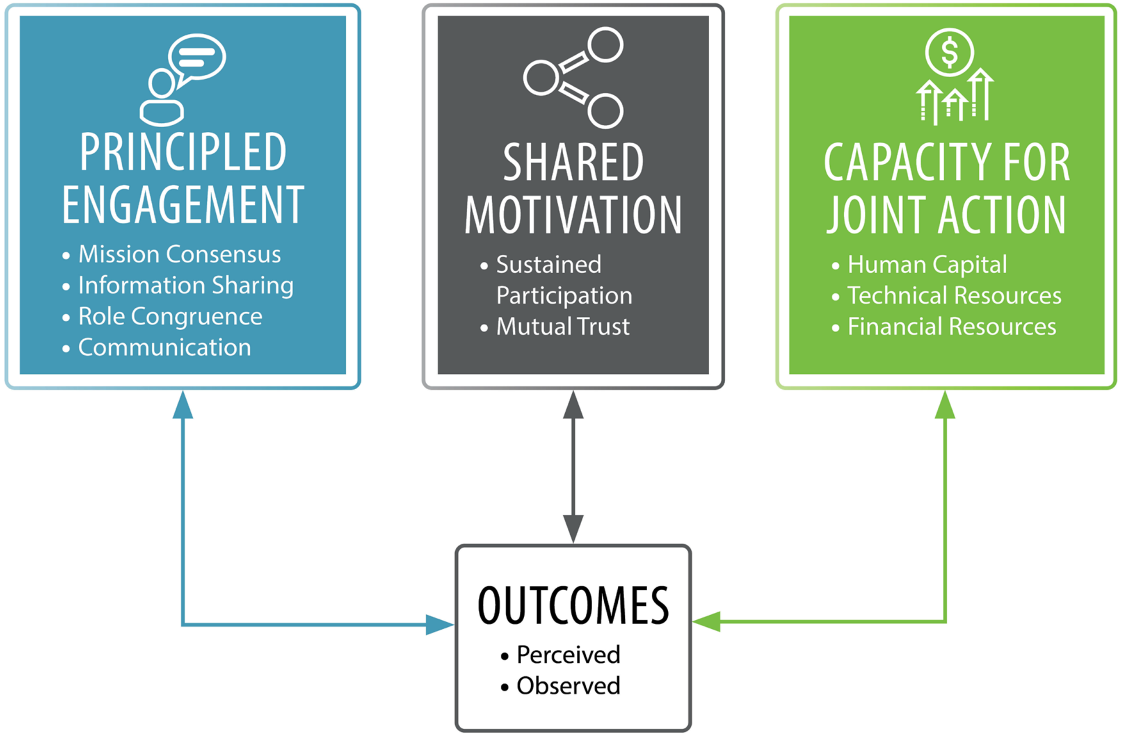


- Practices
  - Nutrient Removal Treatment
  - Best Management Practices
- Policies
  - Regulatory Frameworks
  - Watershed Governance
- Partnerships
  - Collaboration
  - Leadership

Improving the Effectiveness of Collaborative Governance Regimes: Lessons from Watershed Partnerships

Biddle, 2017

- Tests the collaboration components of the *Integrated Collaborative Governance Regime* framework coupled with empirical assessments of environmental performance.
- Using a bivariate correlation analysis, the research provided evidence on the importance of the collaborative elements and how they correlate with one another.
- Surveyed participants from the 26 watershed partnerships within the National Nonpoint Source Monitoring Program.
- Research with environmental progress is typically limited due to the inability to control confounding factors.



Improving the Effectiveness of Collaborative Governance Regimes: Lessons from Watershed Partnerships

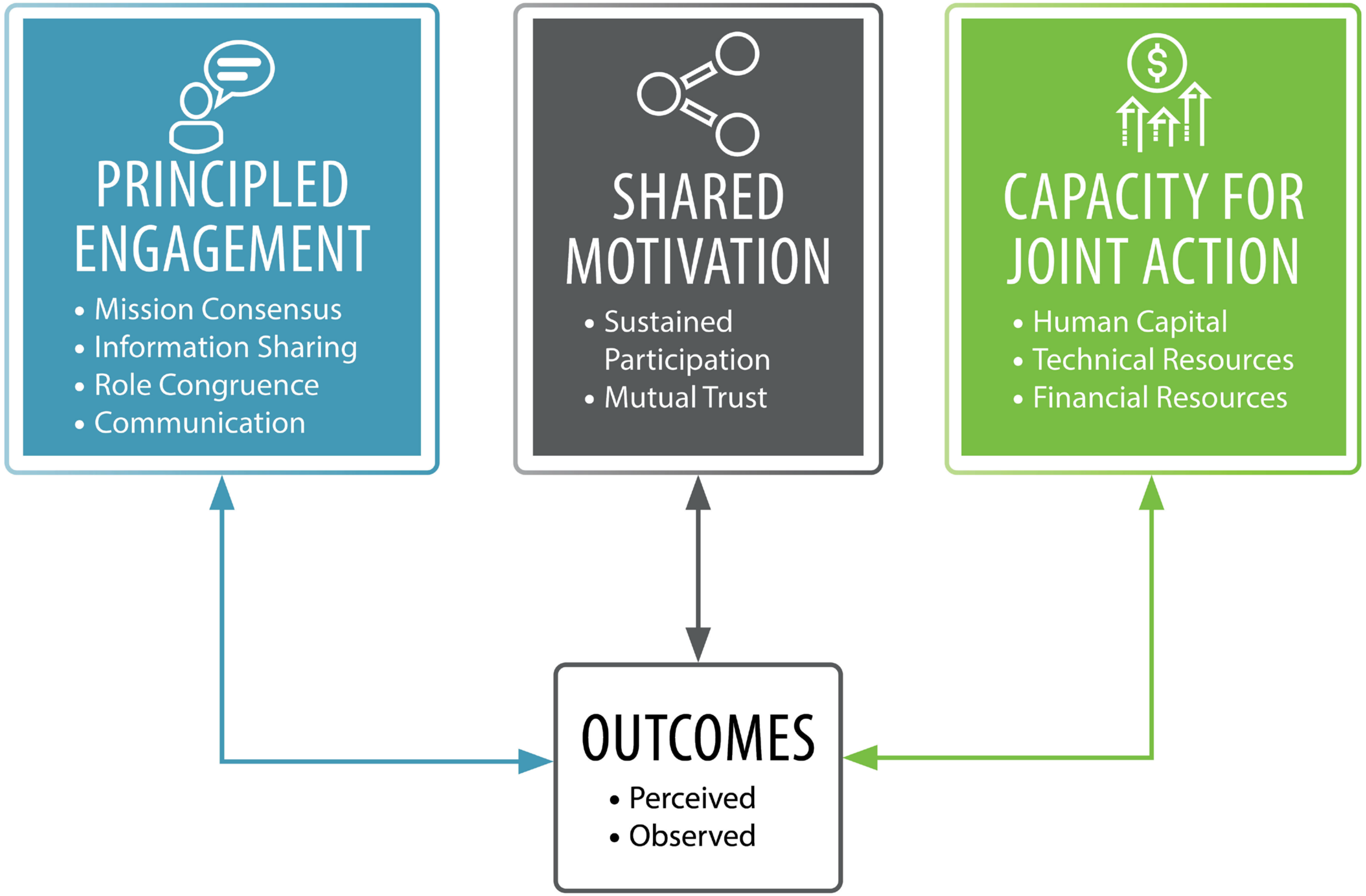
Biddle, 2017

Table 5. Correlation Analysis—Interrelationships among Collaboration Dynamic Components

Collaboration dynamic components	Collaboration dynamic components: Mission consensus	Role congruence	Info-sharing	In-person communication	Frequent communication	Sustained participation	Mutual trust	Expertise	Knowledge	Technical resources	Sustain funding
Mission consensus	—	—	—	—	—	—	—	—	—	—	—
Role congruence	0.21	—	—	—	—	—	—	—	—	—	—
Info-sharing	0.24[a]	0.53[b]	—	—	—	—	—	—	—	—	—
In-person communication	0.37[c]	0.2	0.53[b]	—	—	—	—	—	—	—	—
Frequent communication	0.46[b]	0.45[b]	0.43[b]	0.34[c]	—	—	—	—	—	—	—
Sustained participation	0.43[b]	0.47[b]	0.21	0.28	0.45[b]	—	—	—	—	—	—
Mutual trust	0.37[c]	0.42[b]	0.54[b]	0.49[b]	0.43[b]	0.25	—	—	—	—	—
Expertise	0.03	0.24	0.38[c]	0.39[c]	0.43[b]	0.08	0	—	—	—	—
Knowledge	0.01	−0.13	0.22	0.1	0.34[c]	−0.15	0.39[b]	0.27[a]	—	—	—
Technical resources	0.34[c]	0.31[c]	0.04	0.1	0.37[b]	0.46[b]	0.2	−0.04	−0.14	—	—
Sustain funding	0.34[c]	0.41[b]	0.14	0.31[c]	0.39[b]	0.54[b]	0.35[c]	−0.08	−0.15	0.55[b]	—

[a] $p < 0.10$.
[b] $p < 0.01$.
[c] $p < 0.05$.

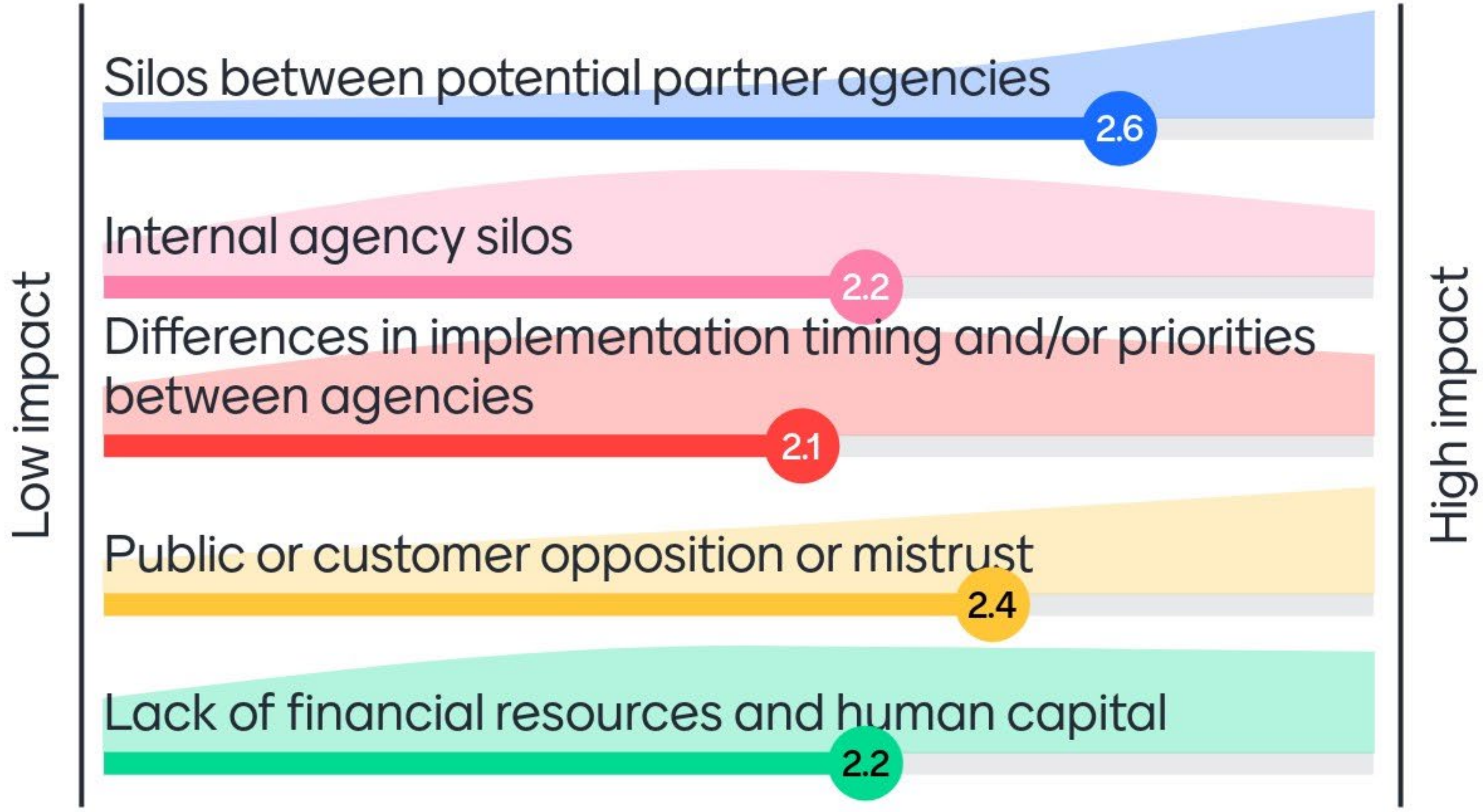
Integrative Collaborative Governance (ICG) Model: A Tested Structure for Improved Partnerships



		Definitions
Principled Engagement	Mission Consensus	Clear definition of the common purpose and objectives. The mission needs to be well articulated and incorporate goals that facilitate alignment.
	Information Sharing	Equitable communication of scientific and technical information to groups within the partnership. This practice facilitates innovation.
	Role Congruence	Ensuring the right people have the right tasks AND are able to carryout those tasks. Reduces the likelihood of free riding.
	Communication	Frequent face-to-face communication is best. Face-to-face communication builds trust. Frequent communication keeps people engaged.
Shared Motivation	Sustained Participation	Continued and engaged involvement through the course of the project. It is important to have to same people at the table to reduce transaction costs.
	Mutual Trust	Increases interaction and enhances communication. Building trust will break down silos within partnerships.
Capacity for Joint Action	Human Capital	Technical expertise, local knowledge and understanding, and skills are essential assets to watershed partnerships.
	Technical Resources	The equipment and software necessary to carryout sampling programs.
	Financial Resources	Adequate budget is critical to reaching goals and experiencing environmental improvements. The ability to leverage funding across multiple sources enhances the sustainability of the project.

From your experience, how strongly do these partnership issues impact effective reuse implementation?

Mentimeter



44

R&D Needs to Support Reuse Implementation Success?

R&D Needs to Support Reuse Implementation Success?

We *DON'T* need more (software) tools:

- Costs and technologies change too rapidly
- Project specifics often dominate outcomes
- Who is going to maintain the software?

R&D Needs to Support Reuse Implementation Success?

We **DO** need **Guidance** that provides:

- Periodic compilations on a topic (e.g. #1717 for IPR/DPR or #4917 for Biofiltration)
- Training materials (e.g. #Reuse 13-13 and #Reuse 15-05 for DPR)
- “Easier access” to more challenging technical material (e.g. #5082 on PFAS…?)
- Case study compilations that provide real-world success stories?
- Temporal evaluation of multiple effective reuse programs to identify key success factors
- Reuse program chartering toolkit
- Strategic communication toolkit (e.g. #Reuse 12-02 for desalination)

PART 2: Monitoring & Implementation

Monitoring

Zeynep Erdal, Black &Veatch

Greg Wetterau, CDM Smith

Dave Smith, Water Innovation Services

Rob McCandless, Brown & Caldwell

Implementation

Erin Messner, AWWA

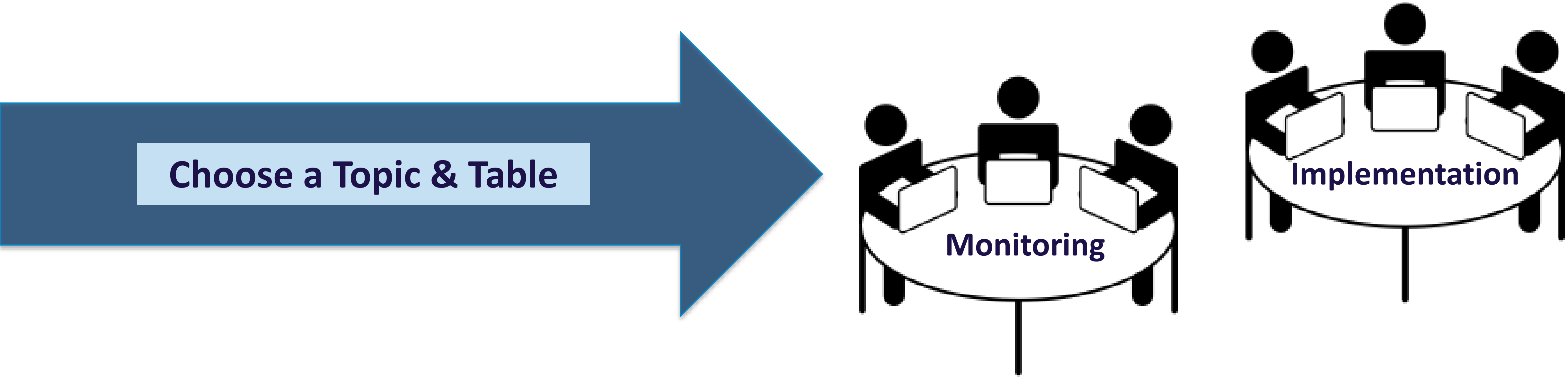
Pinar Balci, NYDEP

Aliza Furneaux, WateReuse

Haley Falconer, City of Boise

Breakout Group Structure

- 40 minutes total for small group brainstorming
- Tables are separated by topic
- Facilitators will guide group discussion
  - 1 min intros
  - Group project concept development using giant Sticky Notes



Developing Successful Project Concepts

GOAL per table: 2-4 project concepts

Components of a Project Concept:

- Research Project Title
  - Short and understandable
- Problem Statement
  - What is the issue or challenge that needs to be addressed and why?
- Research Objective(s)
  - Given the problem, what is this research project trying to achieve?
- Budget
- Volunteers to help finalize project concept

Next Steps: Follow-up Prioritization Survey

We Want Your Input!

WATER REUSE RESEARCH PROJECT PRIORITIZATION SURVEY

REVIEW AND PRIORITIZE project ideas developed during Sunday's workshop: Developing and Nationwide Water Reuse Research Roadmap