Developing a Nationwide Water Reuse Research Roadmap Workshop

Hosted by the Water Research Foundation

At the 37th Annual National WateReuse Symposium

March 7, 2022

WORKSHOP PURPOSE

A water reuse research roadmap workshop was held at the 37th Annual WateReuse Symposium in San Antonio, TX on March 5th, 2022, to leverage the vast breadth of knowledge and variety of experience of the Symposium attendees on the topic of municipal potable water reuse. The workshop was structured to be highly interactive, providing participants with an overview of the current state of research in water reuse and an opportunity to discuss their specific research needs and collaborate on the development of potential research project concepts. The workshop was organized by The Water Research Foundation (WRF) in collaboration with the WateReuse Association and was supported by numerous industry experts from public and private organizations (see Workshop Participants section below).

The primary purpose of the workshop was to address Phase 2 of the Scope of Work for completion of the Water Reuse Action Plan (WRAP) Action Item 7.2 – *Develop a National Research Strategy for Water Reuse*. Action 7.2 aims to identify research needs and key stakeholders that can provide the necessary scientific underpinning to support operations and policy decisions by regulatory agencies and utilities. The Scope of Work outlines a phased approach that addresses the complexity of this action by tackling the various water reuse source water and end use alternatives independently. These source water and end use alternatives and their associated phase within the scope of work are as follows:

Phase 1: Stormwater Capture and Use

Phase 2: Municipal Reuse for Drinking Water (Potable Use)

Phase 3: Agricultural Reuse

Phase 4: Non-potable Reuse

Phase 5: Environmental Reuse

Phase 6: Industrial Reuse

WRF and our partners focused this workshop on obtaining inputs for Phase 2 - Municipal Reuse for Drinking Water (Potable Reuse). Inputs for the remaining phases of the Scope of Work will be derived from various ongoing and future research projects and workshops. These details, as developed, can be found by selecting Action No. 7.2 on the *EPA's National Water Reuse Action Plan: Online Platform* available at https://www.epa.gov/waterreuse/national-water-reuse-action-plan-online-platform.

The secondary purpose of the workshop was to identify potable reuse research gaps and potential project concepts that could be utilized in WRF's Research Priority Program planning process for the 2022 funding year. The Research Priority Program (RPP) is WRF's largest program, receiving an allocation of 60% of the annual research budget. The RPP is governed by a Board-appointed Research Advisory Council (RAC) that meets to approve the program direction and funded projects. In 2022, the RAC approved a program structure that included five overarching research themes, each centered around a problem statement:

Efficient Resource Use and Recovery: Advancing the water sector toward a circular economy.

Treatment Optimization and Intensification: Maximizing performance of treatment processes and new technologies to produce clean and safe water.

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

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

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

The research themes were used to develop project concepts to be funded under the 2022 RPP during a WRF-led planning summit that was held throughout the month of April 2022. The summit was comprised of representatives from utilities, consultants, academics, regulators, partner organizations, and water sector partners. The water reuse research concepts developed during the workshop were provided to the summit participants as potential concepts for further development during the summit.

The dual-purpose of the workshop, as described above, was highlighted during the workshop's opening session using the graphic shown in Figure 1 below.

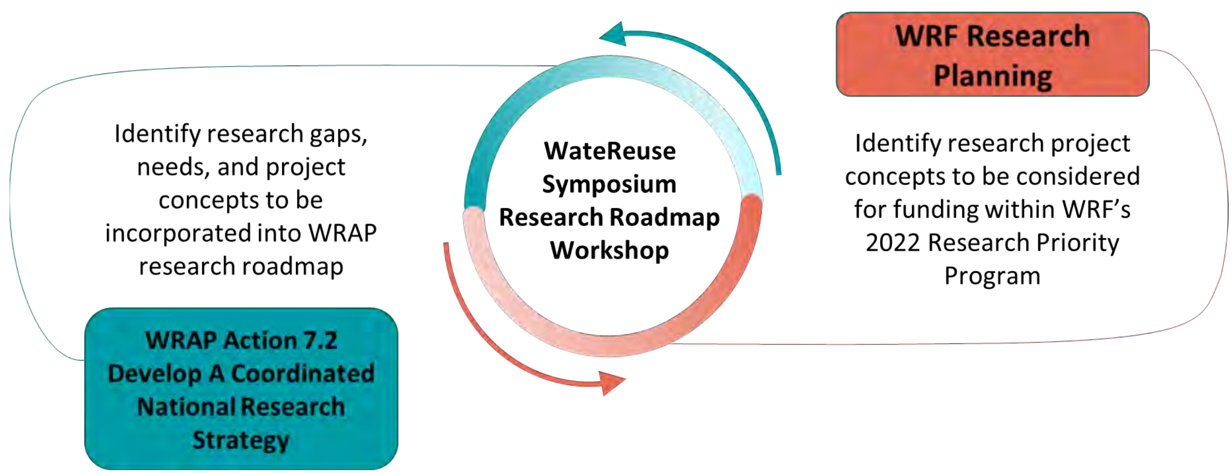


Figure 1. The workshop was designed to be dual-purpose, providing inputs for the WRAP Action 7.2 research strategy and WRF's research planning process.

WORKSHOP PARTICIPANTS

WRF worked collaboratively with the WateReuse Association to plan and execute the workshop during day one of the 37th Annual WateReuse Symposium. Hosting the event in collaboration with the WateReuse Symposium ensured the event would reach a broad audience of water reuse stakeholders and to reduce participant travel requirements and/or the need for an entirely virtual workshop to obtain a large group of attendees. In total, over 75 industry experts from the public and private sectors participated in the workshop, as either invited speakers or facilitators, or as audience members engaged in facilitated collaboration.

The Symposium was marketed extensively to water reuse leaders and experts in the United States and beyond. The event was marketed regularly over the course of six months to the WateReuse Association's list of over 20,000 contacts, including multiple mentions of the workshop and a special spotlight on the workshop in February 2022. The Symposium and workshop were also marketed specifically towards water reuse thought leaders via specific outreach to WateReuse state and regional sections and topical committees. The workshop was further publicized through marketing partnerships with associations and trade media including American Water Works Association, International

Ultraviolet Association, Water Environment Foundation, Water and Wastes Digest, and more. Workshop-specific advertisements highlighted the dual-purpose of the event to convey the importance of attendance for stakeholders actively engaged in or planning water reuse projects.

Invited speakers were identified by WRF staff based on their leadership on previous or ongoing water reuse research projects funded by the Foundation and their known experience and knowledge base in each of their respective presentation topics. Collaboration facilitators were identified jointly by WRF and the WateReuse Association, based on their experience working on water reuse projects and their active engagement with WateReuse through committees or events. The invited speakers and facilitators are listed below in Figure 2, and their role in the workshop is described in detail in the *Workshop Structure* section.

Speakers	**Collaboration Facilitators**
Julie Minton, WRF Katie Spahr, WRF Erin Partlan, WRF Lyndsey Bloxom, WRF Justin Mattingly, EPA <u>Source Water</u> Shane Trussell, Trussell Technologies <u>Treatment</u> Vijay Sundaram, AECOM Erin Mackey, Brown & Caldwell <u>Monitoring</u> Troy Walker, Hazen & Sawyer Andy Salveson, Carollo <u>Implementation</u> Eva Steinle-Darling, Carollo Trent Stober, HDR	Aliza Furneaux, WateReuse Association Brian Pecson, Trussell Technologies Chris Hill, AECOM Dave Smith, EPA ret. Denis Funk, Brown & Caldwell Erin Messner, AWWA Greg Wetterau, CDM Smith Greta Zornes, CDM Smith Haley Falconer, City of Boise Jean Debroux, Kennedy Jenks Jeff Mosher, SAWPA Justin Mattingly, EPA Pinar Balci, NYCDEP Robert McCandless, Brown & Caldwell Samir Mathur, CDM Smith Steve Katz, Suez Zeynep Erdal, Black & Veatch

Figure 2. Invited speakers and workshop breakout collaboration facilitators and their respective public or private organizations.

WORKSHOP STRUCTURE

WRF opened the workshop with an introductory slide presentation covering the dual-purpose of the workshop, including details of the major milestones for completion of WRAP Action 7.2 and the research themes and planning timelines for WRF's 2022 RPP. Justin Mattingly, from the EPA's Office of Water, also gave an introductory presentation on the broader progress and goals of the WRAP.

Following the opening session and introductory presentations, the workshop proceeded in a two-part structure with a 30-min refreshment break between Parts 1 & 2 (see Table 1 below). In each part, presentations were given on two water reuse topic areas, followed by facilitated collaboration in breakout groups on those two topics. This structure was developed to ensure audience members and facilitators would have the information fresh in their minds during the collaborative breakouts and to allow attendees the flexibility to attend only one part of the workshop. The water reuse topic areas included source water, treatment, monitoring, and implementation. Included in Appendix A is the full slide presentation deck for the workshop, including the opening session and all topic area presentations.

	Time	TABLE 1. WORKSHOP STRUCTURE
Part 1	1:00-1:20	**Opening Session** Water Research Foundation Reuse Research Planning – WRF Staff Overview of EPA WRAP: Develop a National Research Strategy – Justin Mattingly, EPA
	1:20-1:40	**Source Water** Speaker(s): Shane Trussell, Trussell Tech Identification of variation in source waters, sources and concentrations of contaminants, key contaminants of concern (both established and emerging) and the associated public health risks.
	1:40-2:00	**Treatment** Speaker(s): Vijay Sundaram, AECOM and Erin Mackey, Brown & Caldwell Established treatment technologies, achievement of necessary log reductions, operational considerations, and treatment redundancy.
	2:00-2:45	**Facilitated Collaborative Reuse Research Concept Development** Breakout Table Discussion led by Facilitators Attendees work in break-out small groups to brainstorm reuse research project concepts that support source water and treatment advancement
	2:45-3:00	Small Groups Report Out
		3:00-3:30 Break
Part 2	3:30-3:50	**Monitoring** Speaker(s): Troy Walker, Hazen and Sawyer and Andy Salveson, Carollo Identification of surrogates and log reduction credits for pathogens, rapid and online monitoring, and the use of critical control points.
	3:50-4:10	**Implementation** Speaker(s): Eva Steinle-Darling, Carollo and Trent Stober, HDR Potable reuse resilience, adapting to climate change, demonstration of reliability, outreach programs and building public trust.
	4:10-4:50	**Facilitated Collaborative Reuse Research Concept Development** Breakout Table Discussion led by Facilitators Attendees work in break-out small groups to brainstorm reuse research project concepts that support source water and treatment advancement.
	4:50-5:00	Small Groups Report Out

Table 1. The workshop structure and schedule, divided into two parts, each part comprised of expert presentations and collaboration small groups.

Presentations: State of the Research

The presentations portion of the workshop included a comprehensive review of completed and in-progress water reuse research covering the topics of source water, treatment, monitoring, and implementation individually. Invited speakers were selected for each topic and asked to prepare a 20-minute presentation covering key recent research findings to set the stage for collaborative discussions on potential research gaps. Additionally, audience engagement during the presentations was solicited through live survey questions that were spread throughout each presentation. The speakers for each topic and highlights of their presentations are outlined below. Their slide presentations, including poll questions and results, can be found in Appendix A.

Source Water

The topic of source water was covered by Shane Trussell (Trussell Technologies). The presentation highlighted the change in the water sector, driven by reuse, from the historical separation of wastewater and drinking water streams to the need to now “cross streams” to address today’s water issues. The source water quality threats identified for water reuse included chemical and pathogen contamination. Pathogens such as enteric virus, Giardia, and Cryptosporidium were named and described as being “always present at high concentrations in wastewater” and, although it was recognized that secondary effluents generally meet most drinking water standards, it was noted that there are chemicals of exception that still require additional treatment (Nitrogen, NDMA, PFAS chemicals). Shane highlighted the important role that upstream processes, including nitrification, flow equalization, source control, and sidestream management, can provide in protection against contaminates – in addition to the more common focus on advanced treatment for removal. The key takeaways regarding the considerations for and benefits of each of these upstream processes, relevant WRF research projects, and potential new research projects were presented. Presentation details can be found in Appendix A.

Treatment

The topic of treatment was covered by Erin Mackey (Brown and Caldwell) and Vijay Sundaram (AECOM). Areas of focus within the topic of treatment that were outlined included treatment technologies, achievement of the necessary Log Removal Values (LRVs), redundancy, and operations. The speakers described the treatment-related questions that water managers involved in planning for reuse treatment typically need to answer, beginning with source water quality, moving through treatment objectives and goals, identifying processes and the order in which to use them, and assessing the need for control and any control challenges that might exist. The speakers highlighted the extensive suite of existing research in treatment, covering numerous themes including earning LRVs, process efficiency, improving design & operations, contaminant occurrence and control, and improving guidelines for treatment. The relevant WRF research projects, knowledge gaps within the topic of treatment, and potential new research projects were presented. Presentation details can be found in Appendix A.

Monitoring

The topic of monitoring was covered by Troy Walker (Hazen and Sawyer) and Andrew Salveson (Carollo Engineers). The speakers highlighted the need for extensive monitoring in potable reuse for pathogens, chemicals, and treatment efficacy. However, they also observed that, although data is very often collected, it is not consistently used which can lead to degradation of process performance. The use of Critical Control Points (CCP) and improved monitoring during all phases of the CCP approach was identified as the key to ensuring the reduction, prevention, or elimination of human health hazards. This improved monitoring included source monitoring, more sensitive monitoring and better log removal in treatment, and reliable instrumentation with rapid response during operations. The speakers highlighted the extensive suite of existing research within the topic of monitoring, summarized into four overlapping focus areas: improved analyzers and improved plant performance; improved Log Removal Values at barriers; improved water quality analysis and detection; and improved source water monitoring. The relevant WRF research projects, identified knowledge gaps, and potential new research projects were presented, organized by the key monitoring considerations of raw wastewater monitoring, pathogen removal performance and surrogates, trace chemical monitoring, and artificial intelligence and machine learning. Presentation details can be found in Appendix A.

Implementation

The topic of Implementation was covered by Eva Steinle-Darling (Carollo Engineering) and Trent Stober (HDR). The speakers broke the topic of implementation into two parts, each leading to reuse success: decision support and partnerships. The presentation highlighted the existing decision support resources provided by WRF research and the need for guidance that provides new resources such as training materials, case study compilations, and strategic communications tools. One key knowledge gap identified within the topic of implementation was on partnership building. The presentation described recent work completed on holistic approaches to watershed management including collaborative governance and discussed the potential for application of similar approaches in water reuse. The relevant WRF research projects, knowledge gaps, and potential new research topics were presented. Presentation details can be found in Appendix A.

Facilitated Breakouts: Collaborative Research Project Concept Development

Facilitated breakout groups were held after the presentations in Part 1 and Part 2 of the workshop (see Table 1). Each session was structured to allow attendees to choose their own topic of interest using roundtables with topic labels. Each roundtable had at least one pre-assigned facilitator to guide the discussion and take notes on the research needs discussed and project concepts developed, using giant sticky notes (expert facilitators can be found in Figure 2). Each facilitated breakout ended with a “report-out” by the table facilitator, presenting a high-level overview of the project concepts developed by the group to the entire workshop audience. Following each table’s report-out, the giant sticky notes were stuck on the wall of the workshop space and displayed throughout the remainder of the workshop for reference. A collage of photos from the breakouts is shown below in Figure 3.

Figure 3. Facilitated collaboration during the breakout sessions. Each table discussed one topic and an expert facilitator took notes on research needs identified and project concepts developed.

WORKSHOP OUTCOMES

Project Concepts Developed

In total, 59 project concepts were developed under the four reuse topic areas. The simplified titles of each concept are listed in Table 2 below. The details of the projects, including a problem statement, objectives, and a budget estimate, are provided in Appendix B, if developed. Some breakout groups focused on developing more concepts with less detail and vice versa. It should be noted that some project concepts were very similar in nature and therefore combined by WRF staff to create the final project concept list below.

TABLE 2. PROJECT CONCEPTS DEVELOPED DURING FACILITATED BREAKOUTS
Source Water Research Projects
Pretreatment for Industrial Programs to Improve Reuse
Impact and Management of Wastewater Sidestreams for Reuse
Impacts of Organics Management and Treatment Processes on IPR/DPR
Evaluate the Impacts of New/Innovative Wastewater Treatment Processes on Source Water Quality
Source Water Characterization of Industrial Discharges and Impacts on Municipal Wastewater

Building National Consensus on (and Database of) the Presence, Variability, and Concentrations of Constituents in Source Waters
Public Health and Process Benefits of Nitrification as a Pretreatment to an AWPF
Economic, Water Quality, Operations, and Energy Impacts on Advanced Water Treatment Facilities of Full Nitrifying vs. non-Nitrifying source water
Onsite Potable Reuse Needs (Smaller Sewershed Challenges)
Impact of Stormwater's Water Quality on Municipal Wastewater Reuse
Impacts of Enhanced Source Control on Local Industries
Flow Equalization for Potable Reuse
Assessment of Membrane Fouling / Foulants to Inform Source Control, Pretreatment, and/or Wastewater treatment
Managing Reuse Based on Impacts of Combined Sewer Overflows
Assess Competing Needs for Wastewater Facilities
Implications of Occasional Secondary Wastewater Source Waters on Potable Reuse
Treatability of Co-produced Water for Reuse
Treatment Research Projects
Alternative Treatment Processes: Reimagining Advanced Water Treatment Trains
Developing a Standard Protocol for Wastewater Treatment Effluent Characterization
Optimizing Process and Energy Efficiency in Potable Reuse
Viral Surrogates for Ozone Log Removal Values (LRV) for Potable Reuse
Pass-through Chemicals' Occurrence and Related Public Health Risk
Balancing the Competing Objectives of Energy Minimization and Innovation with Safety and Reliability
Quantifying Energy Demand Associated with Alternative Water Supplies
Alternative Approaches to Improve Energy Conservation for Energy Reduction
Best Practices of Monitoring Pathogens in Potable Reuse*
Impacts of Process Design on Pathogen LRVs in Membrane Bioreactors*
Development of Surrogate Monitoring for Pathogens in Membrane Bioreactors*
Understanding the Nature and Impact of Biofiltration Biology*
Treatment Options for Tough-to-Treat Wastewater Streams and the Impact on Effluent Quality and Downstream Unit Operations*
Treatment Trains Working Together - Understanding the Impacts of Upstream Treatment on Downstream Unit Operations*
Monitoring Research Projects
Finding Correlations Between Raw Wastewater Quality and Potable Reuse Risk
Use of AI / Machine Learning for Potable Reuse Water Quality, Efficiency, and Risk Minimization
Adapting PCR Methods for Real Time / Near Real Time Monitoring
Wastewater Effluent Early Warning System - Assessing Low Probability / High Threat Events
Guidance Document for Advanced Treatment Monitoring and Implementation / Keeping Up with the Instruments and Monitoring Effectiveness
Monitoring Strategy to Incorporate Stormwater as a Reuse Source
Accessible Monitoring for Small Systems (relevant tech, cost/benefit)
Better Understanding CECs for Potable Reuse: Non-Targeted Analysis (NTA) Method Robustness Study
Evaluation of Chemical Spikes in RO Permeate and Post RO Ozone/BAC

Demonstration Testing (building on NWRI Efforts) for Real Time / Near Real Time Monitoring
VOC Monitoring for Control and Detection of Low Molecular Weight Organic Spikes
Monitoring of Compounds that Affect Operations but are Not Harmful (e.g. food grade glue)
Implementation Research Projects
Regional Approaches to Brine Management
Building Public Trust in Reuse Programs (Specific to Constituents of Concern; Exposure Pathways; Blind Sampling/Comparison to Other Utilities)
Interagency Collaboration for Reuse: Understanding Successes, Failures, And Guidance
Identifying Changing Workforce Development Needs for Reuse & Innovation
Defining An Acceptable Level of Risk for reuse Projects (Environmental Health, Public Health, Economic)
How To Create Business Case for Reuse Programs (Establishing and Quantifying Costs and Benefits, and Document and Quantify Risks)
Framework To Bring Together Local, State Regulators / State Programs, And Federal Agencies to Promote Responsible Reuse Implementation
Risk Assessment of Potable Use of Recycled Water to Support Public Review and Acceptance (includes outreach toolkit)
Outreach Approaches for Including Disadvantaged Communities / Underserved Communities in Project Planning
Developing Consumer Confidence Reports / Project Water Quality Reports for Recycled Water Projects
FAQ To Expect When You're Implementing a Water Reuse Project
Impacts Of Water Rights in Pursuing Reuse Projects
Impacts Of Regionalization of Wastewater Treatment Facilities on Recycled Water Project Implementation
Case Studies/Examples of Reuse Marketing Programs
How Do We Challenge the Concept / Mindset That Potable Reuse Is Too Expensive?
Guidance for Construction of Interagency Agreement for Potable Reuse Projects

Table 2. The project concepts developed under each reuse topic area during the facilitated breakout sessions.

** Project concepts were mistakenly omitted from the online survey tool*

<u>Prioritization Survey</u>

Following the workshop, all project concepts developed were placed into an online survey for follow-up prioritization by the workshop attendees and other key water reuse stakeholders who were not able to join the event (Appendix C). In a rush to get the survey live, 6 project concepts were not included in the final survey; they have been flagged in Table 2. The survey also provided fill-in-the-blank spaces for additional project concept suggestions beyond those developed during the workshop. The survey link was shared during a plenary session on the final day of the Symposium and distributed via email through the WateReuse listserv. In total, 68 total survey responses were received over the period approximately one week.

<u>Rankings</u>

The survey allowed for respondents to select their top 4 projects within each topic area. The combined scores of all respondent selections provided a relative ranking across the projects, with those being selected the most ranking the highest. The survey results are presented in Appendix D.

Write-In Projects

The project suggestions received through write-in responses in the survey are included below in Table 3.

TABLE 3. PROJECT CONCEPTS SUGGESTED BY SURVEY RESPONDENTS AS WRITE-INS
Suggested Research Projects Related to Potable Reuse
Consortium to bring synergies and lessons learned state by state potable reuse experiences
Source control for PFAS and other CECs through outreach to industries.
BAC acclimation: strategies for improving acclimation timing and performance
Compare costs/benefits of implementing potable reuse projects with costs/benefits of offsetting demand for potable water through implementation of non-potable reuse projects.
Engineered and Nature Based Biological Treatment Processes/Systems/Systems of Systems that Support Potable Reuse - critical knowledge for the regulators and the utilities to better understand the capabilities of their existing systems and for avoiding the prescriptive treatment trains incorporated into regulations.
The psychology and sociology of water recycling. Understanding how individuals and communities process information.
High levels of reduction of molecular targets (including ARGs and viruses)
Suggested Research Projects Related to Non-potable Reuse
Protecting groundwater quality when irrigating above agronomy rates with reuse water.
Parallel to the evaluation of multi-agency collaboration challenges/strategies in WRAP Action 2.16 focusing on wastewater reuse, evaluate multi-agency collaboration challenges and strategies focusing on stormwater capture and use (which could consider both potable and non-potable uses of captured stormwater)
Development of multi-benefit projects in the age of climate change and circular economy - putting together the tailored building blocks for our communities to achieve sustainable and resilient resources -- water reuse (Potable and Non-Potable) is a critical enabler at the center of this framework.
Accumulation and release of microbes by BAC

WORKSHOP FOLLOW-UP

Following the close of the prioritization survey, WRF staff used the project rankings to identify the priority projects that fit within WRF's Research Themes and could be used as suggested research project concepts for experts participating in the WRF research planning summit. Several projects moved forward through the summit process including concepts on brine solutions, stormwater integration, decentralized/onsite reuse, engagement with disadvantaged/small communities, and interagency collaboration.

All project concepts developed during this workshop and included in this summary report will be included in the deliverables for the WRAP Action 7.2. This summary document will be posted on the online WRAP platform for use and reference by other WRAP action leads and the greater water reuse community. To further advance the WRAP Action 7.2, additional workshops, similar in structure and nature to the subject workshop, will be conducted on the water reuse topics outlined in the action scope of work phases that are not being addressed through other ongoing research efforts. As completed, additional summary reports will be produced and posted on the online platform.

APPENDICES

Appendix A: Workshop Presentation Slides Including All Speakers/Topics & Audience Poll Results

Appendix B: Project Concepts Developed During Facilitated Breakout Sessions

Appendix C: Follow-Up Prioritization Survey

Appendix D: Follow-Up Prioritization Survey Results

Appendix A

Workshop Presentation Slides Including All Speakers/Topics & Audience Poll Results

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

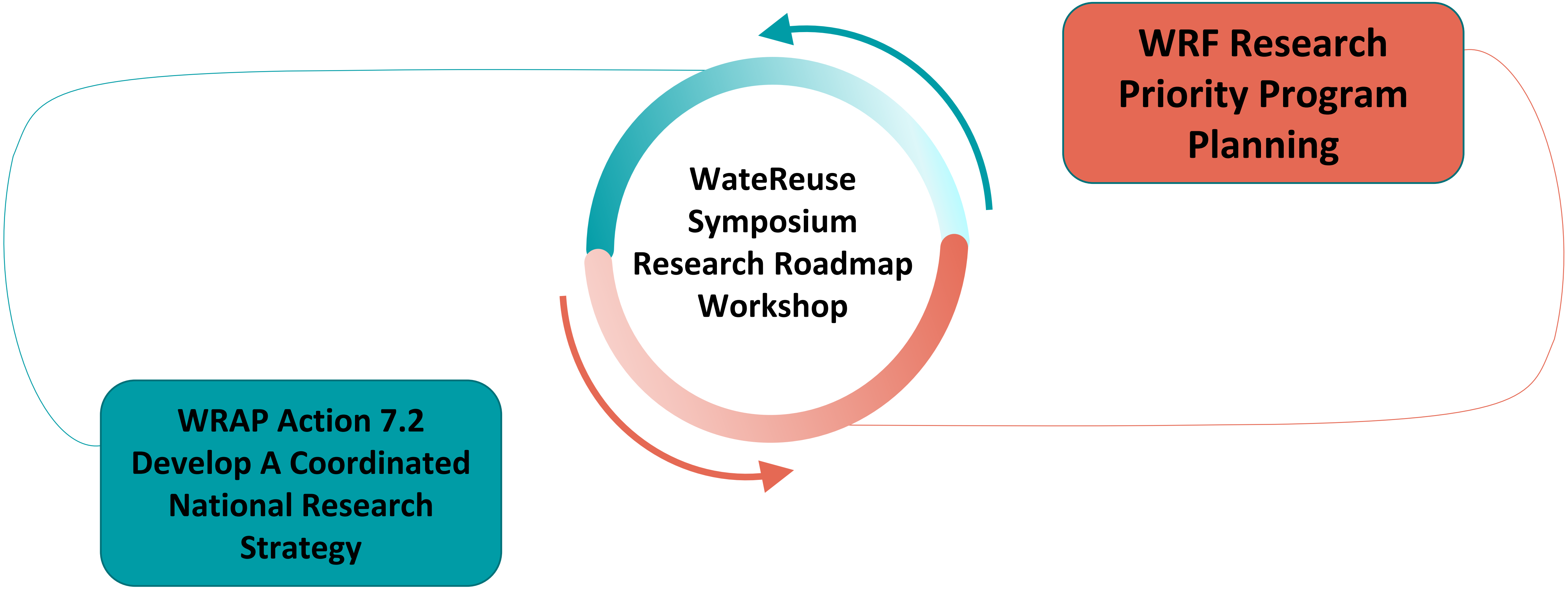
Julie Minton
Research Unit Lead

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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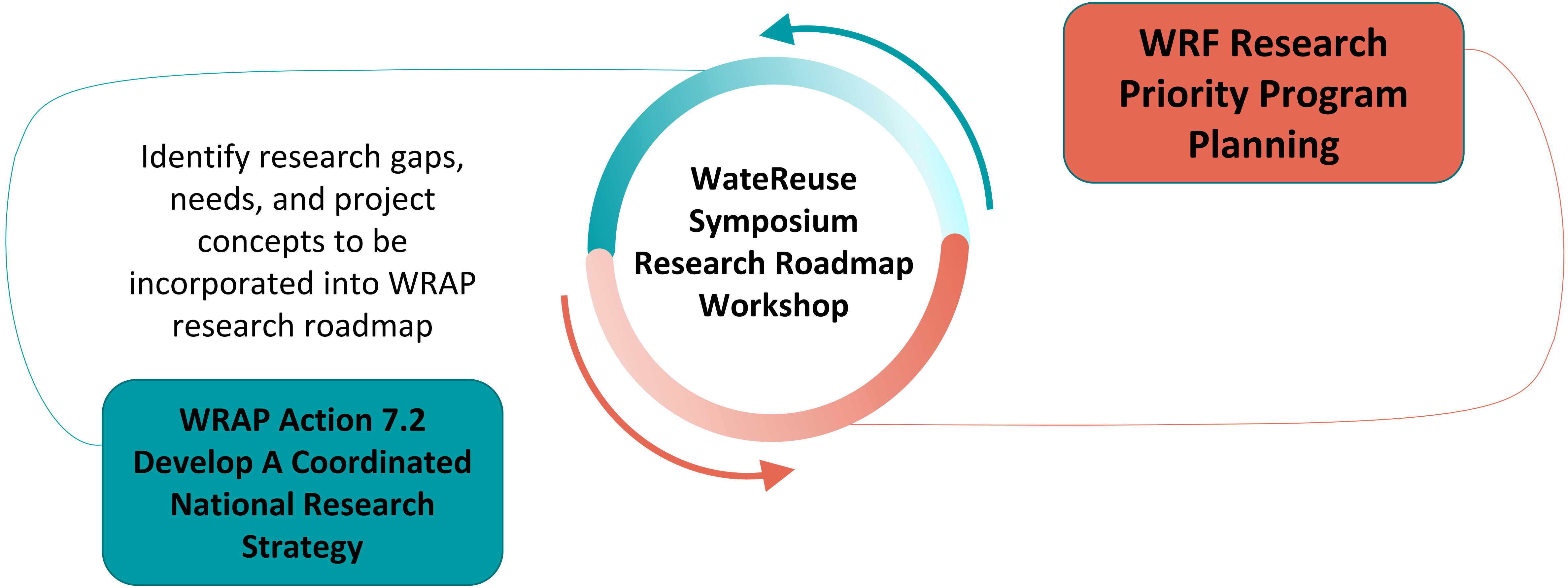
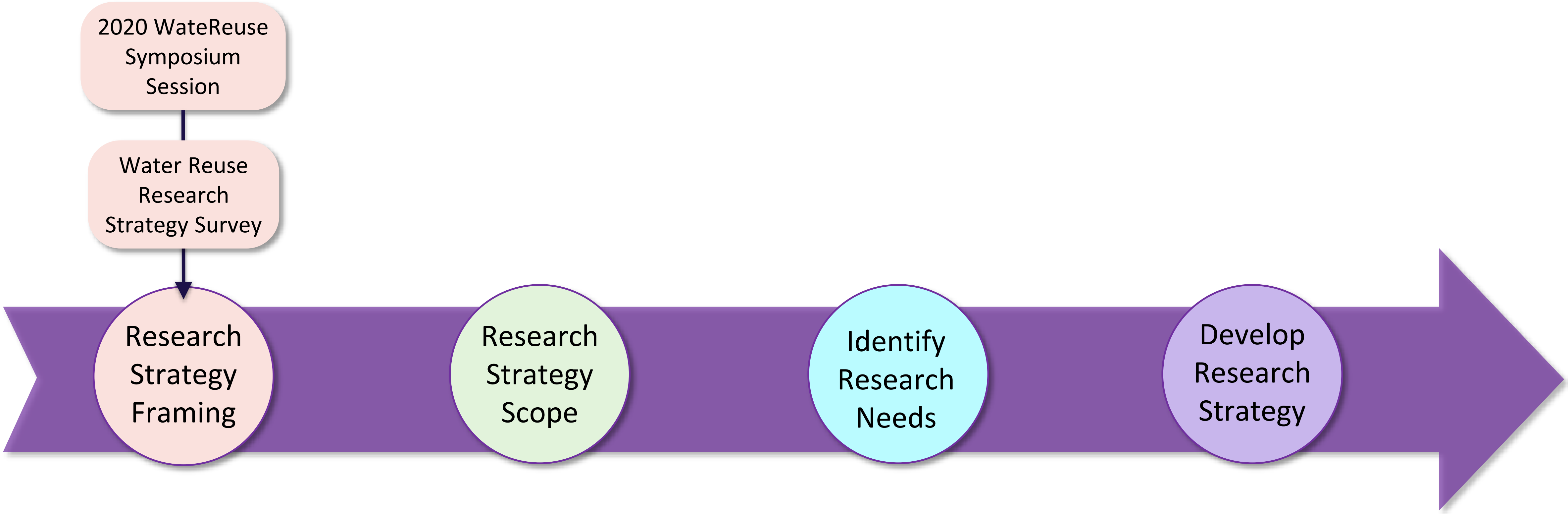


WRAP Action 7.2 Description

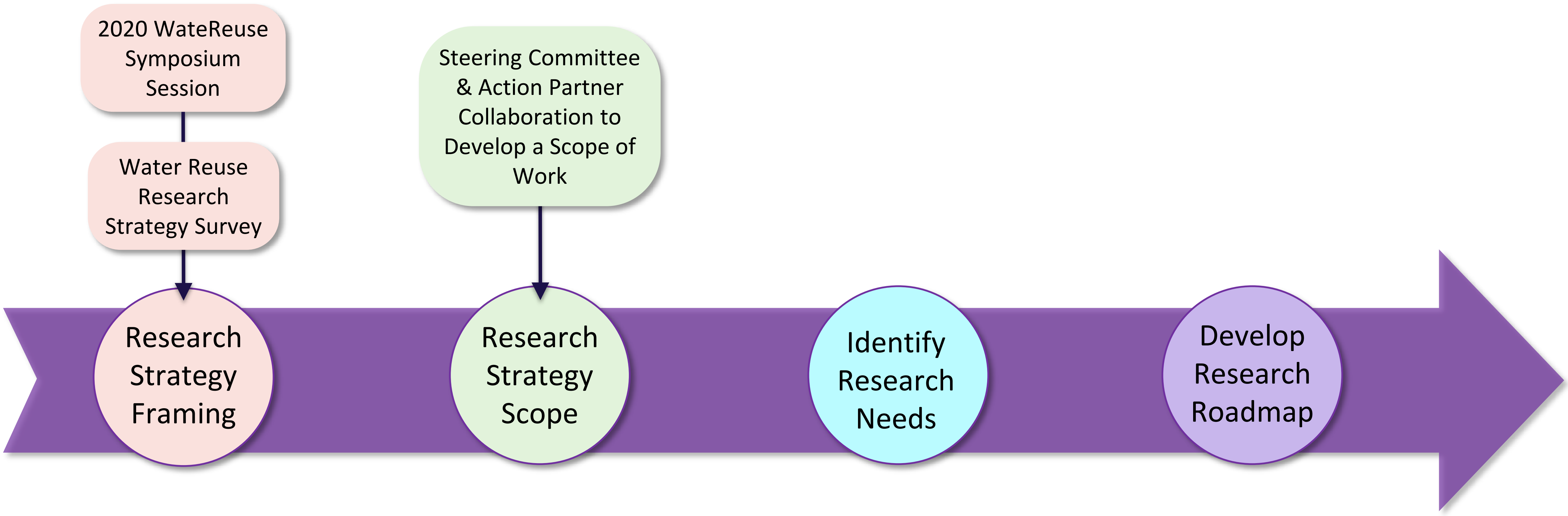
Develop a Coordinated National Research Strategy

“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
EPA

Greta Zornes
CDM Smith

Jeff Mosher
SAWPA

Claire Waggoner
CASWB

Action Partners

Sharon Nappier
EPA

Greg Fogel
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

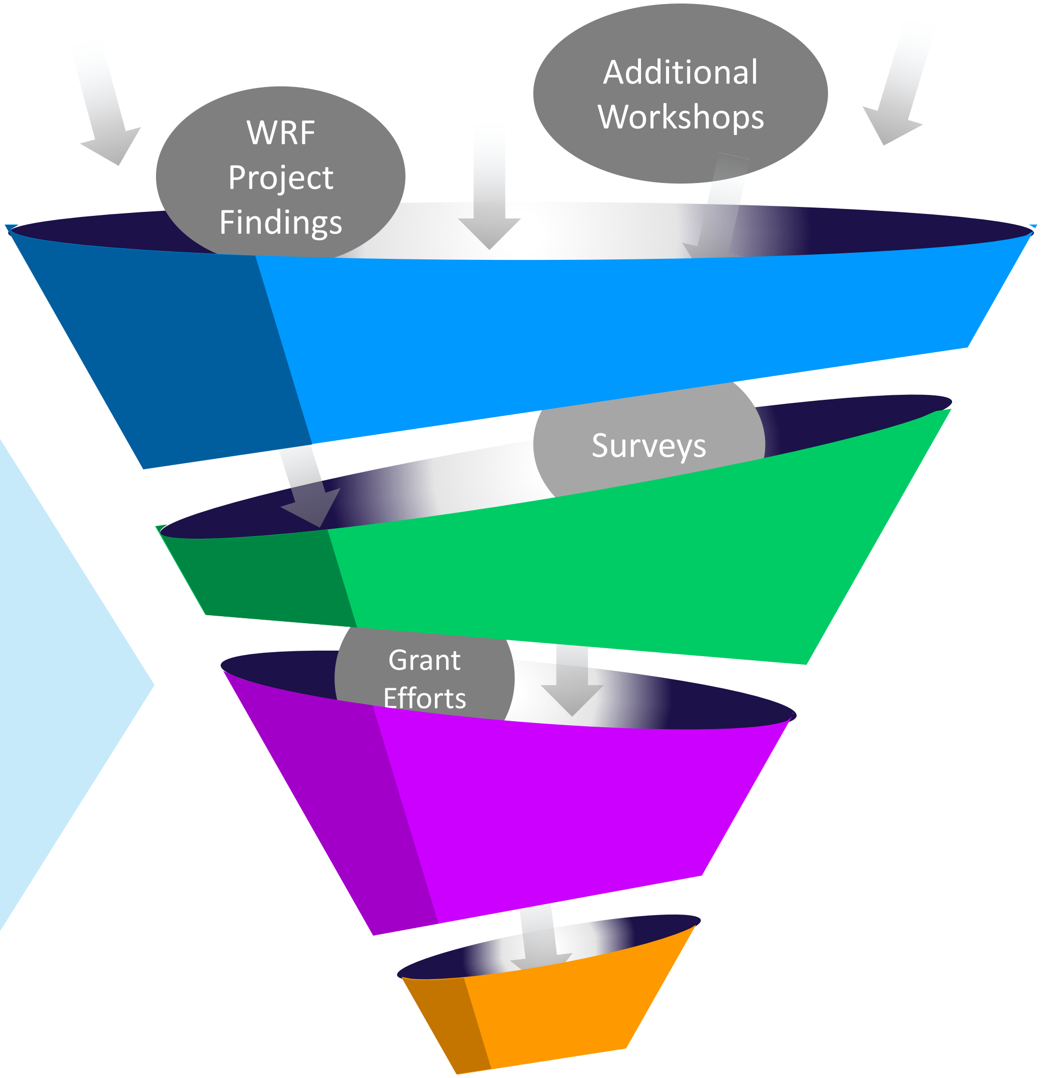
- Stormwater
- **Municipal Water for Drinking (Potable Reuse)**
- Nonpotable reuse (urban, commercial)
- Environmental reuse
- Industrial, Ag Reuse

Project concepts developed today will support the Potable Reuse Topic

WRAP Action 7.2 Scope Of Work

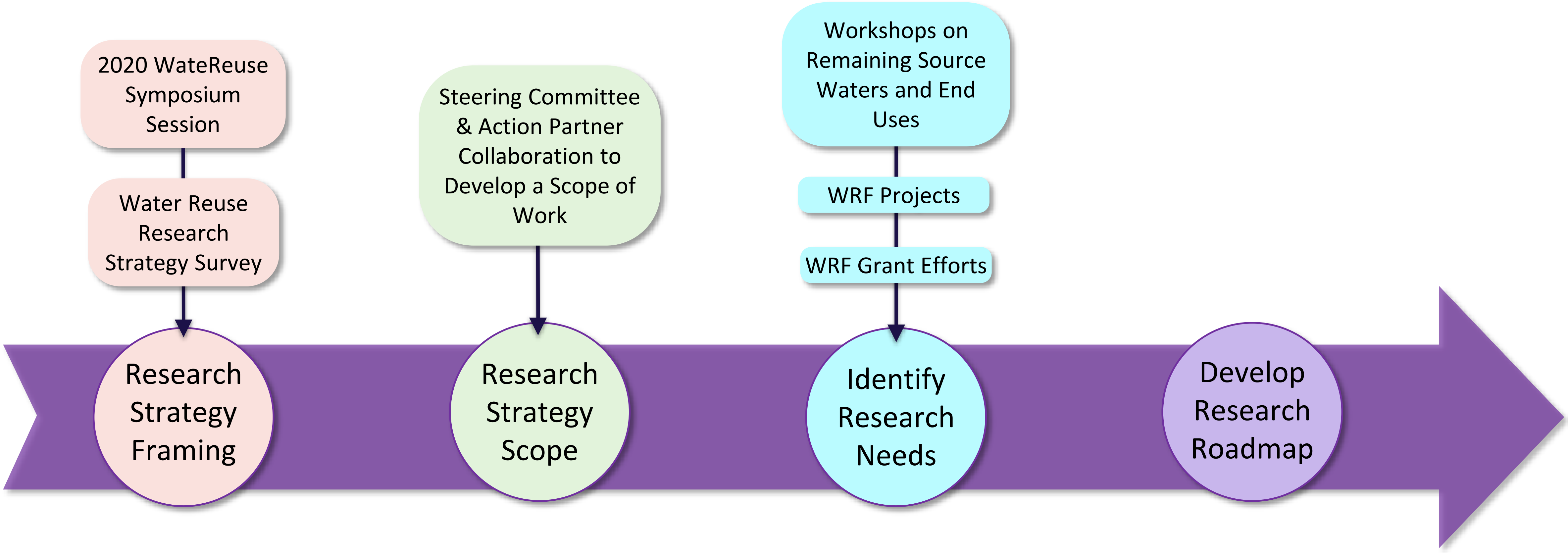
Approach Organized by Source Water / End Use

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

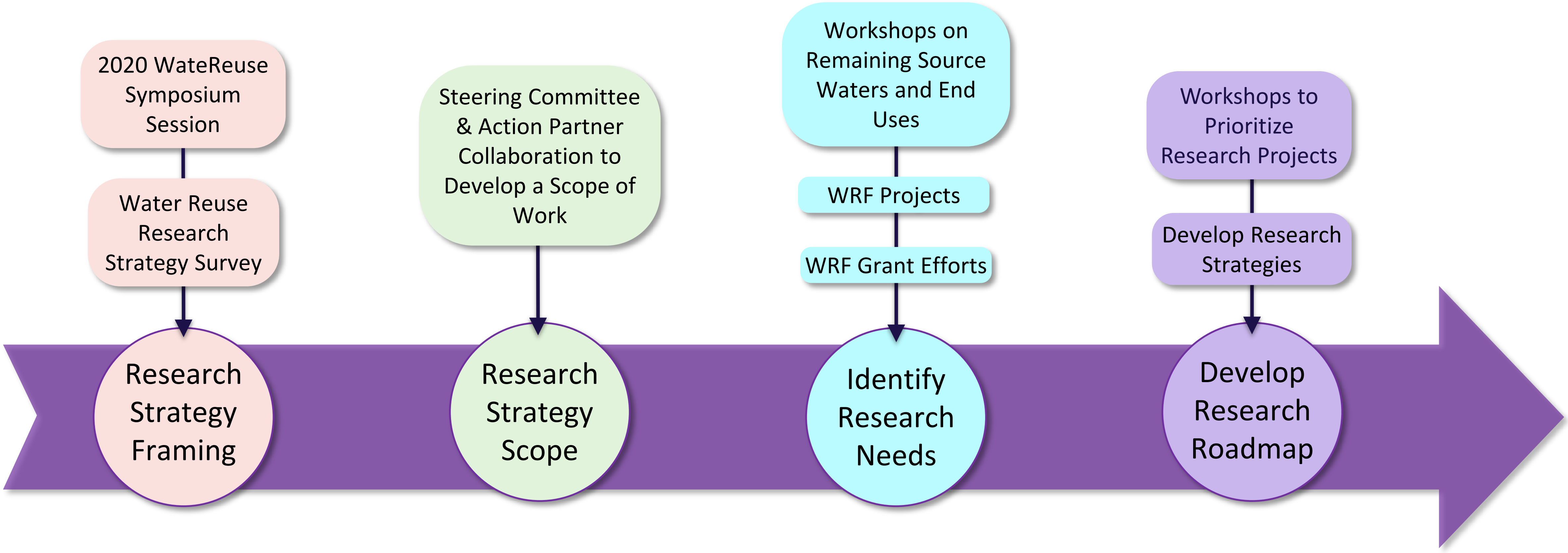


Multiple Inputs to address remaining source waters & end uses

WRAP Action 7.2 Implementation Milestones



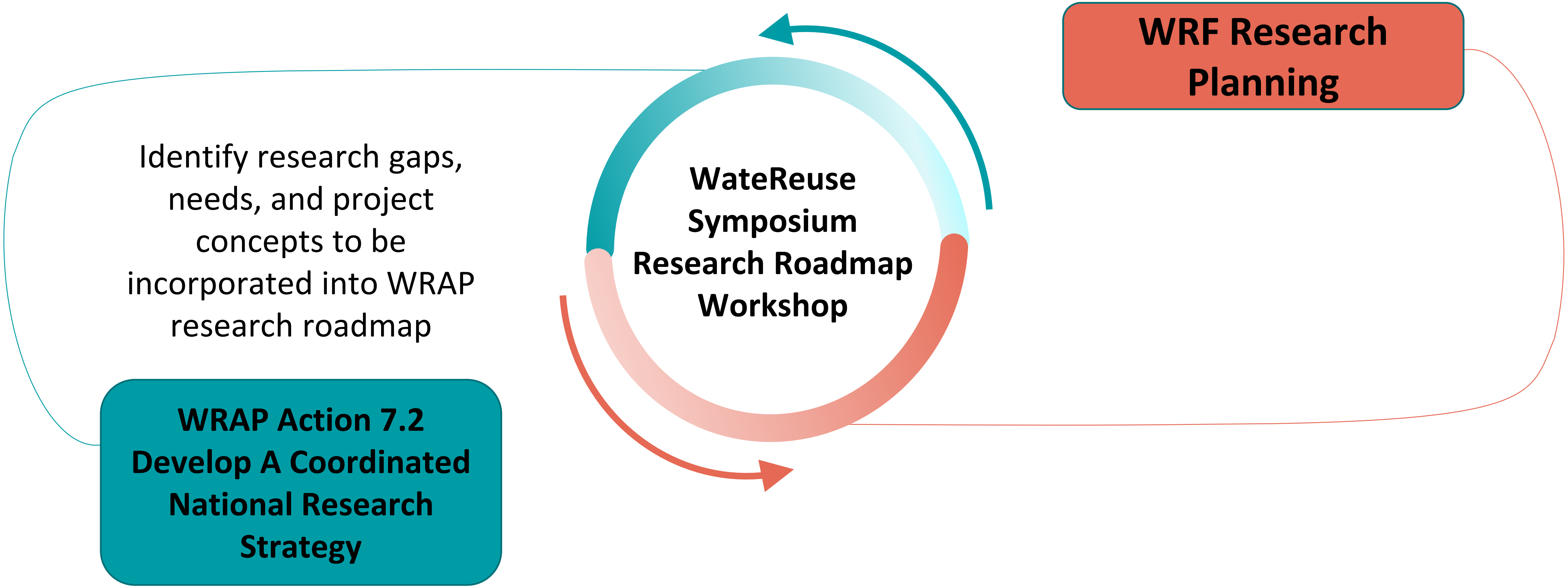
WRAP Action 7.2 Implementation Milestones



The Water Reuse Action Plan (WRAP)
EPA Overview

Justin Mattingly
Environmental Protection Specialist – Office of Water

Today's Workshop Is Dual-purpose



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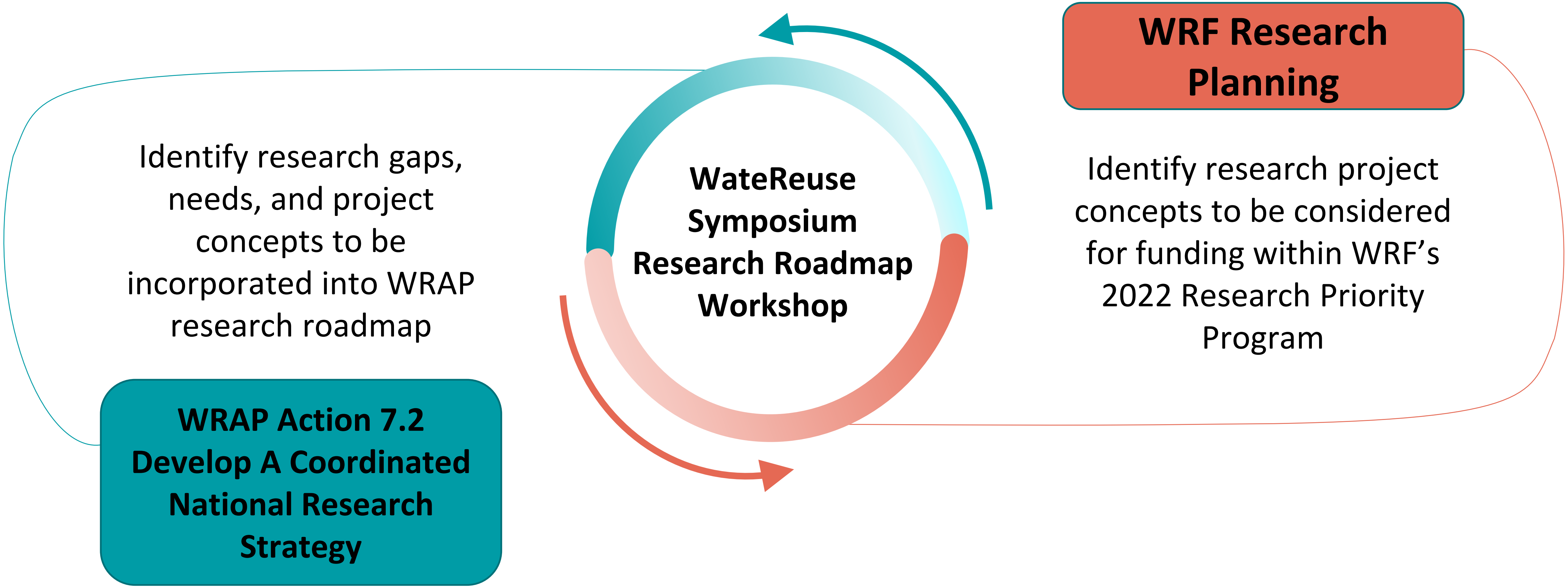


WRF 2022 Research Priority Program

Research Themes

Resource Efficiency & Recovery
Advancing the sector toward a circular economy

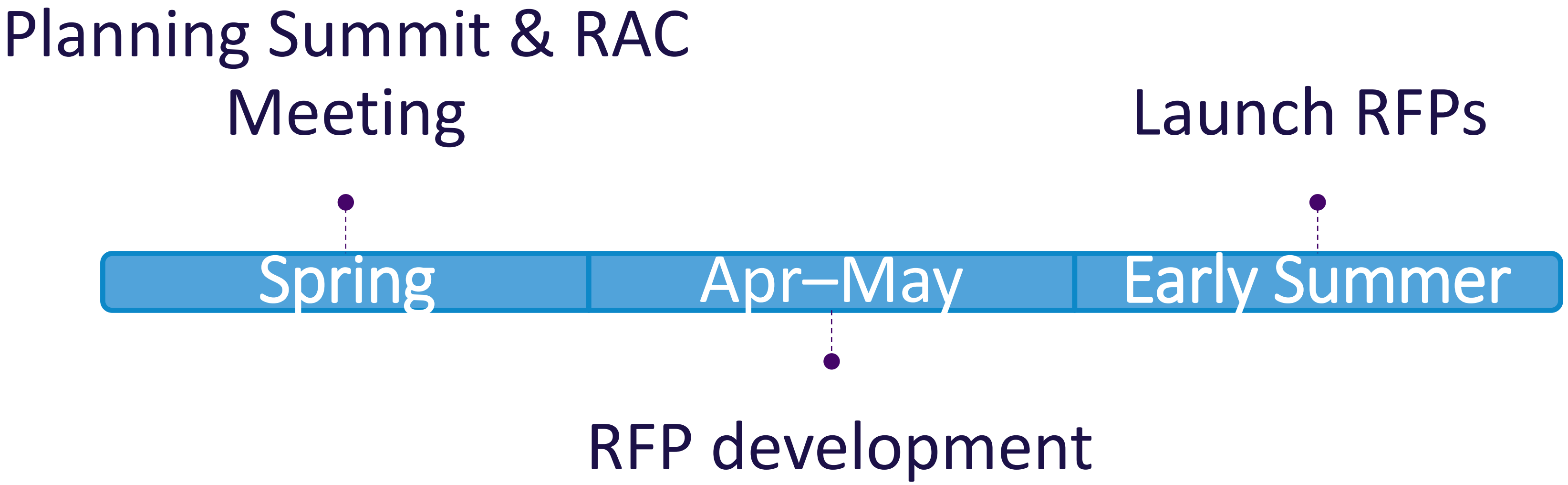
Treatment Optimization
Maximizing performance of treatment processes and technologies to produce clean and safe water

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

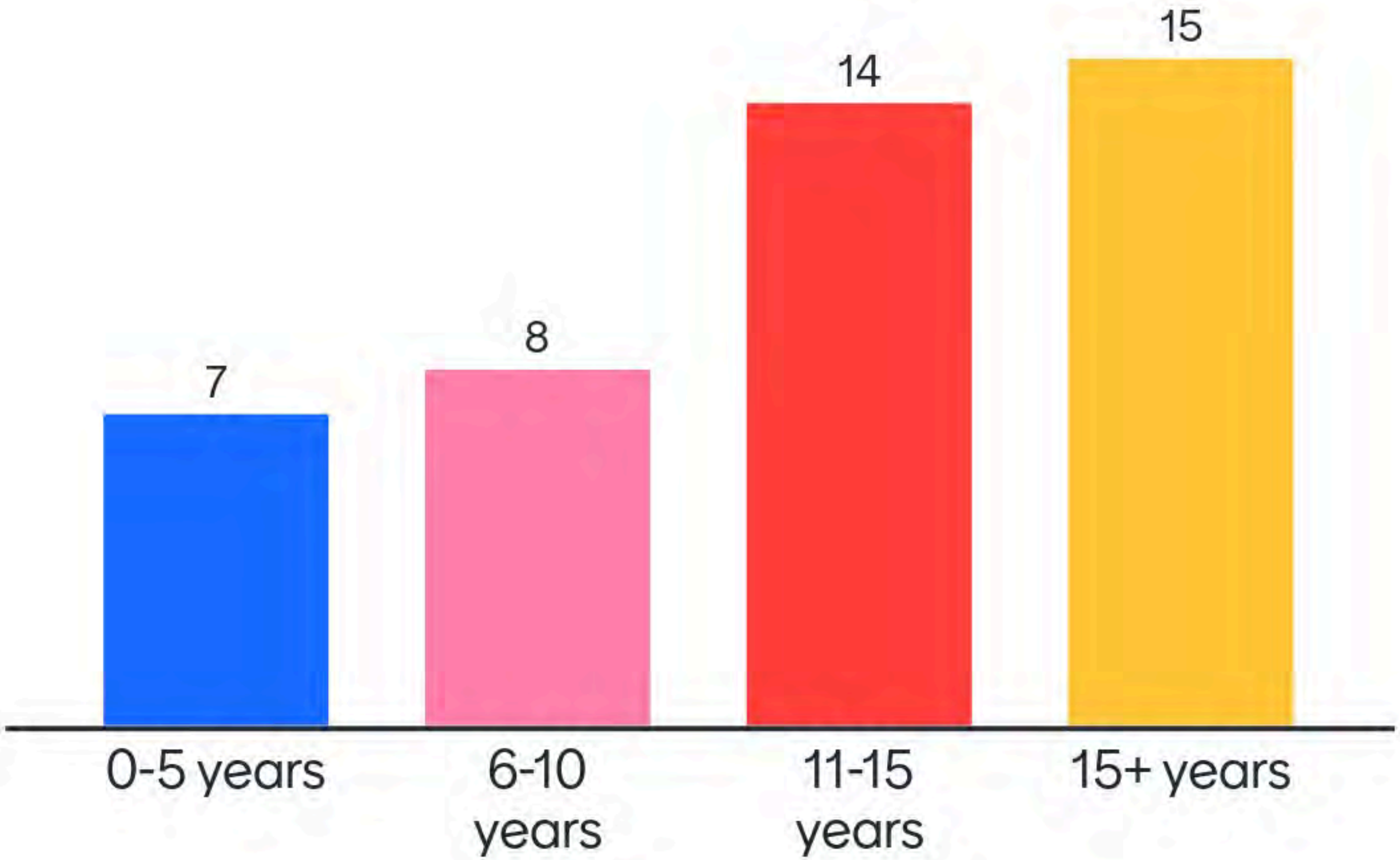
↓

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



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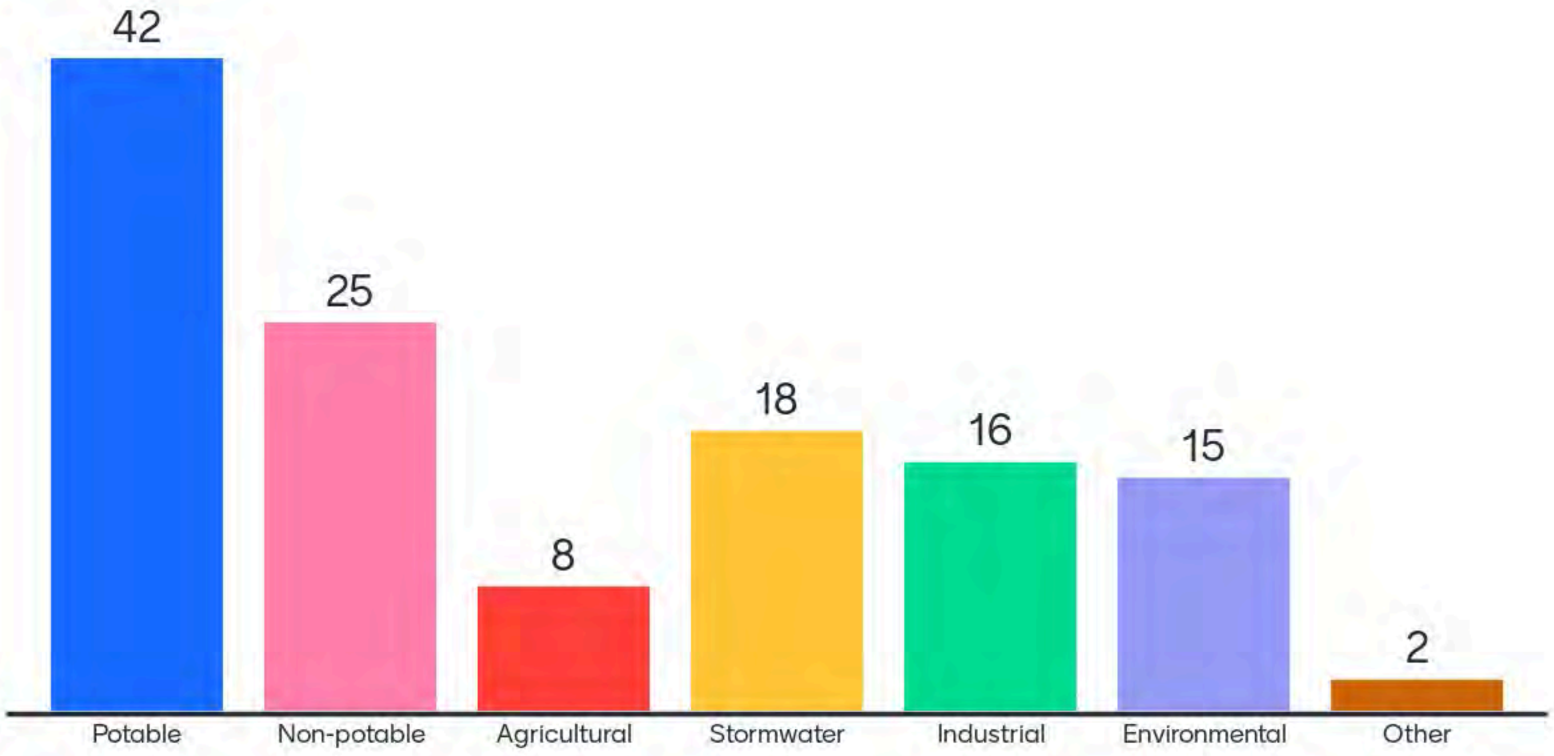
What type of reuse are you/your agency most interested in?

Mentimeter



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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

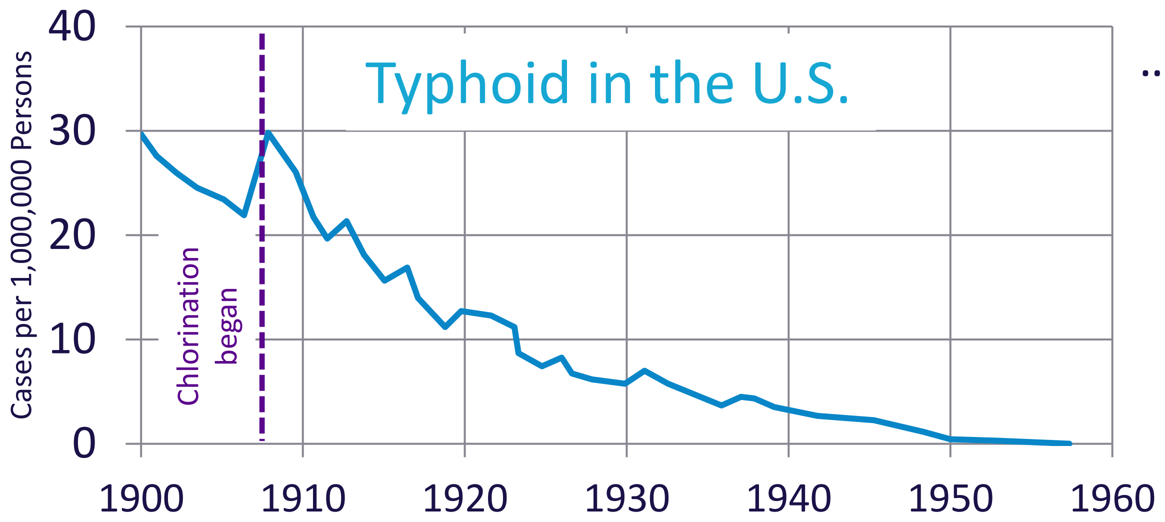
SHANE TRUSSELL
TRUSSELL TECHNOLOGIES, INC.

MARCH 6, 2022

2022 WateReuse SYMPOSIUM

SHAPING OUR PAST &
CHARTING OUR FUTURE

Source Waters for Potable Uses



Adapted from CDC, 1997

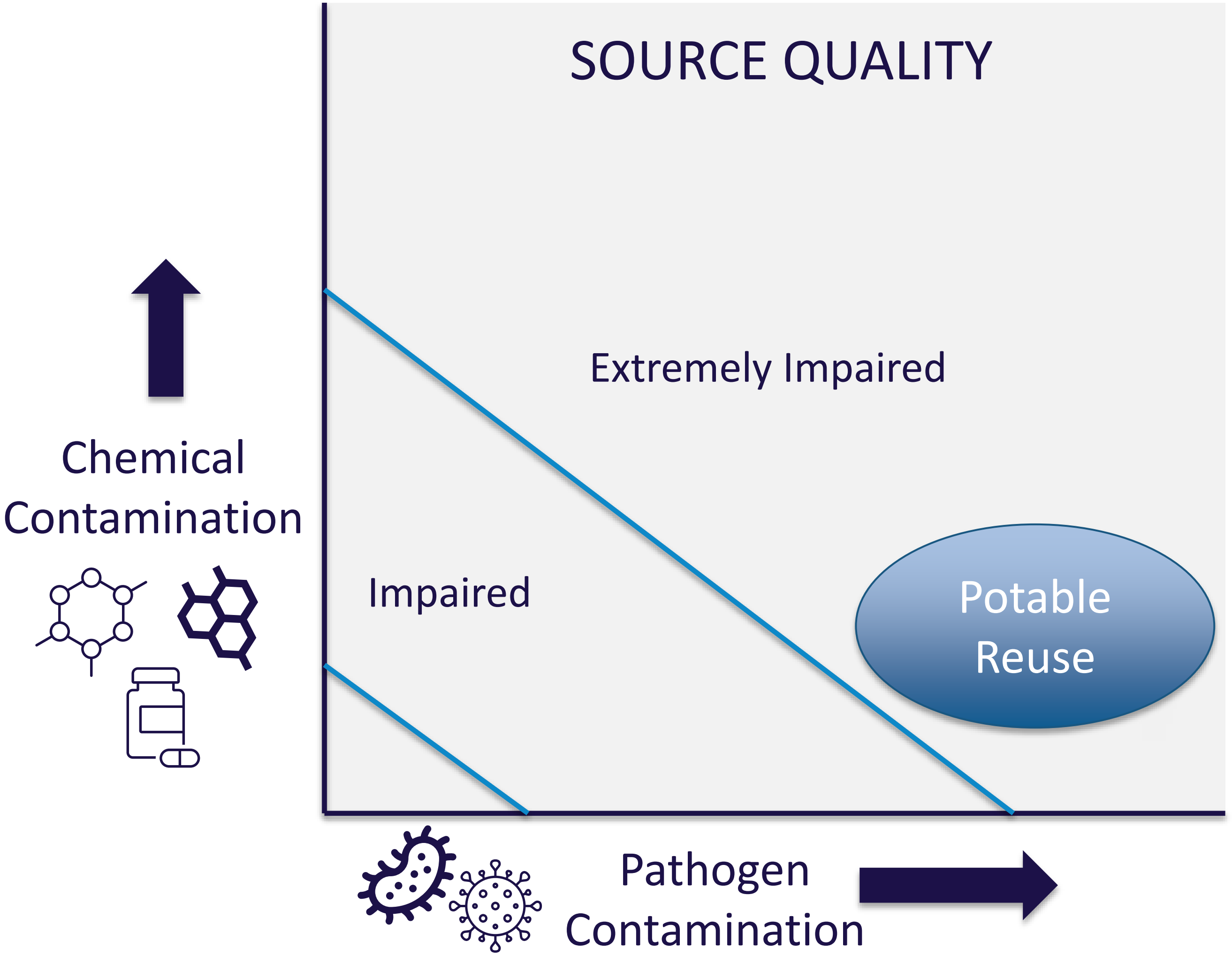
…because of the threat of waterborne diseases.

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

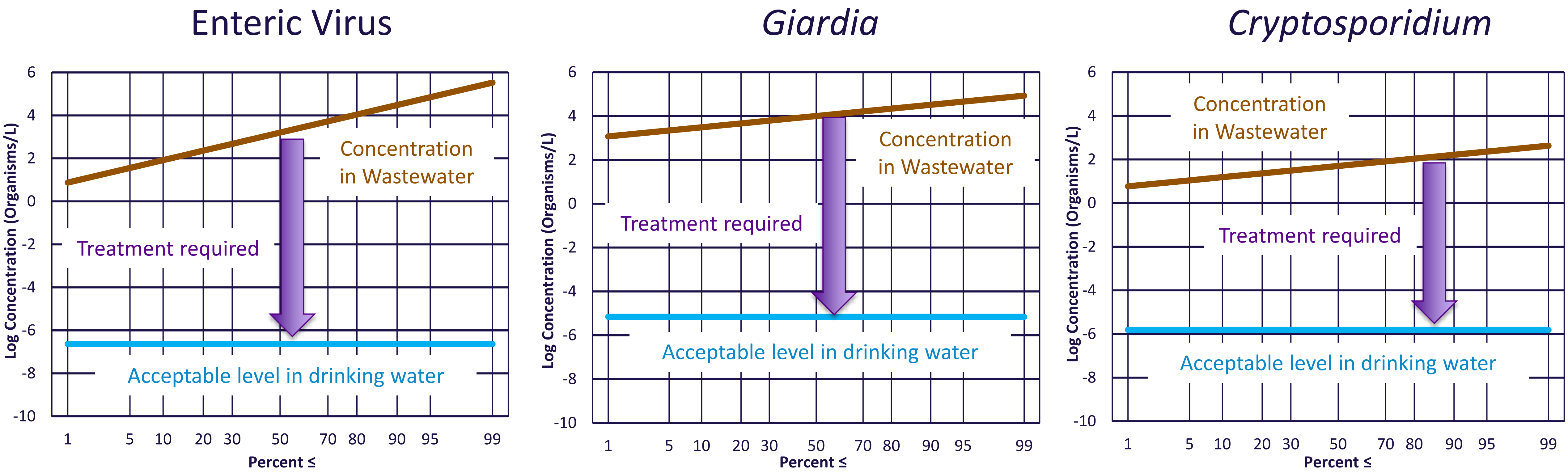
Increasing pressure on our limited water supplies….

What are today's threats?



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

Pathogens in Wastewater



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

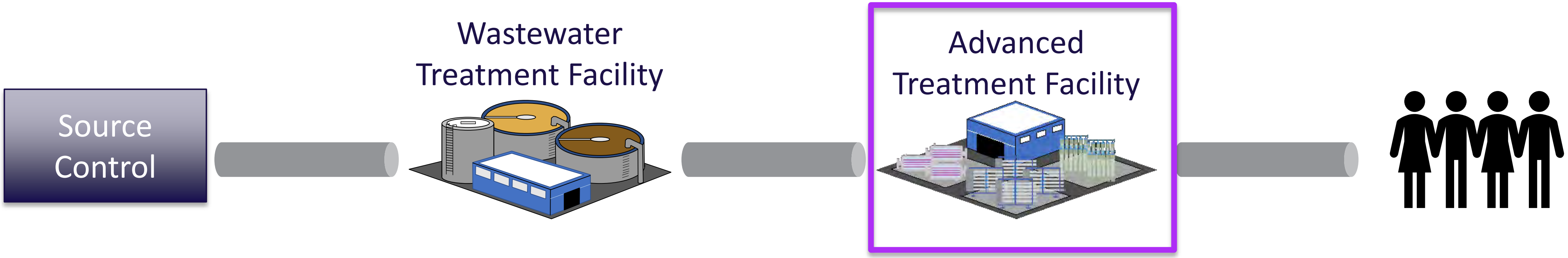
Compound	NWRI IAP Criteria	LACSD SJCWRP n = 4	EPWUFred Hervey WRP n = 4	UOSA Millard H. Robbins Jr. WRP n = 4	SD AWPF n = 12	OCWD GWRS[1] n = 1	WBMWD ECLWRF[1] n = 1
Atenolol	4000	63	110	130	130	555	980
Carbamazepine	10,000	192	328	185	190	263	240
DEET	200,000	53	33	51	130	528	690
Estrone	320	NDL[2]	<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

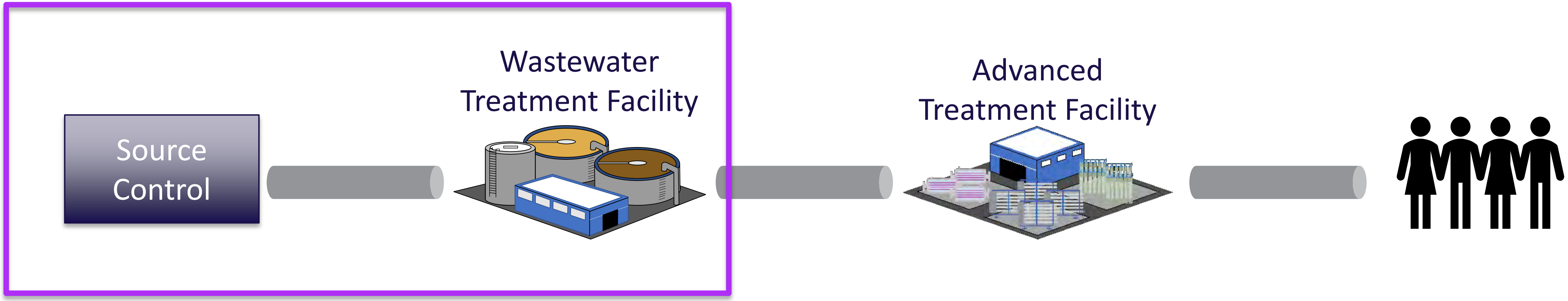
- Secondary effluents generally meet most drinking water standards
- Common exceptions are:
  - Nitrogen
  - NDMA
  - PFOA, PFOS
  - TDS
- Yet we all still know we need more treatment!

Controlling Pathogens and Chemicals



We often focus on advanced treatment for controlling pathogens and chemicals

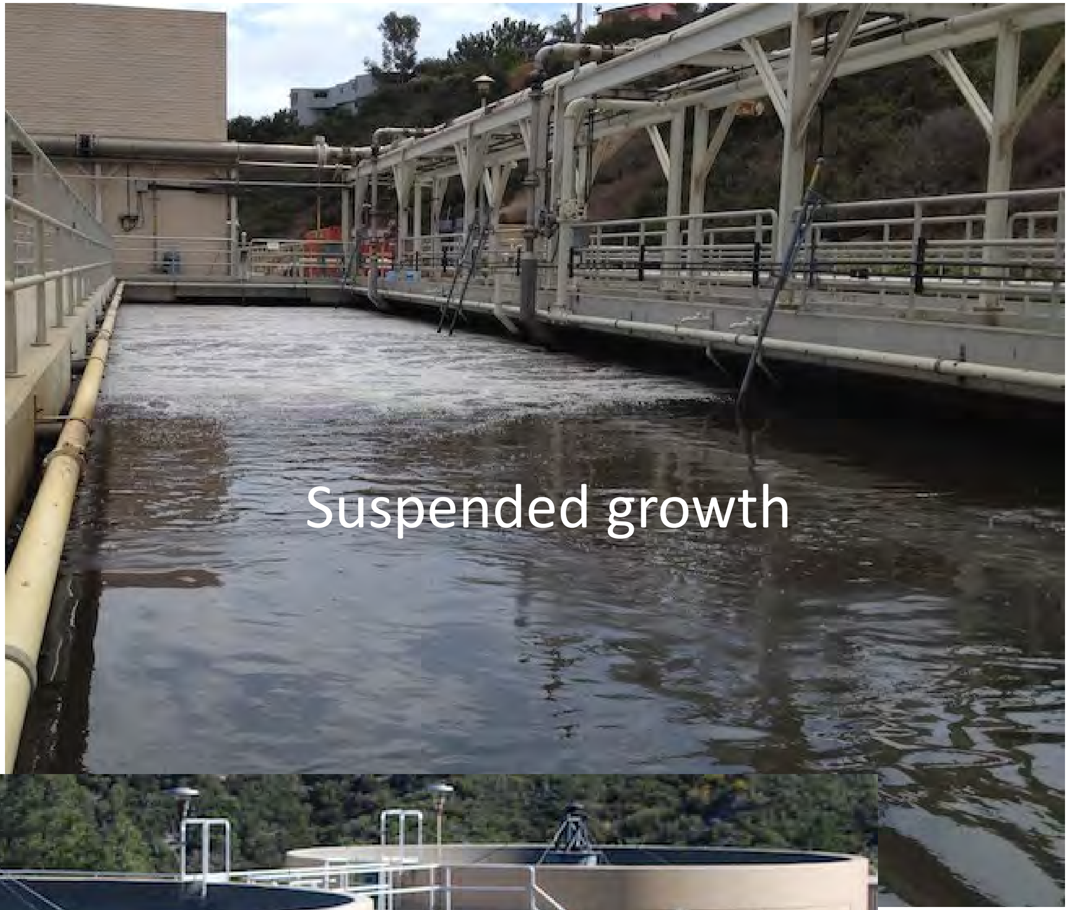
Controlling Pathogens and Chemicals



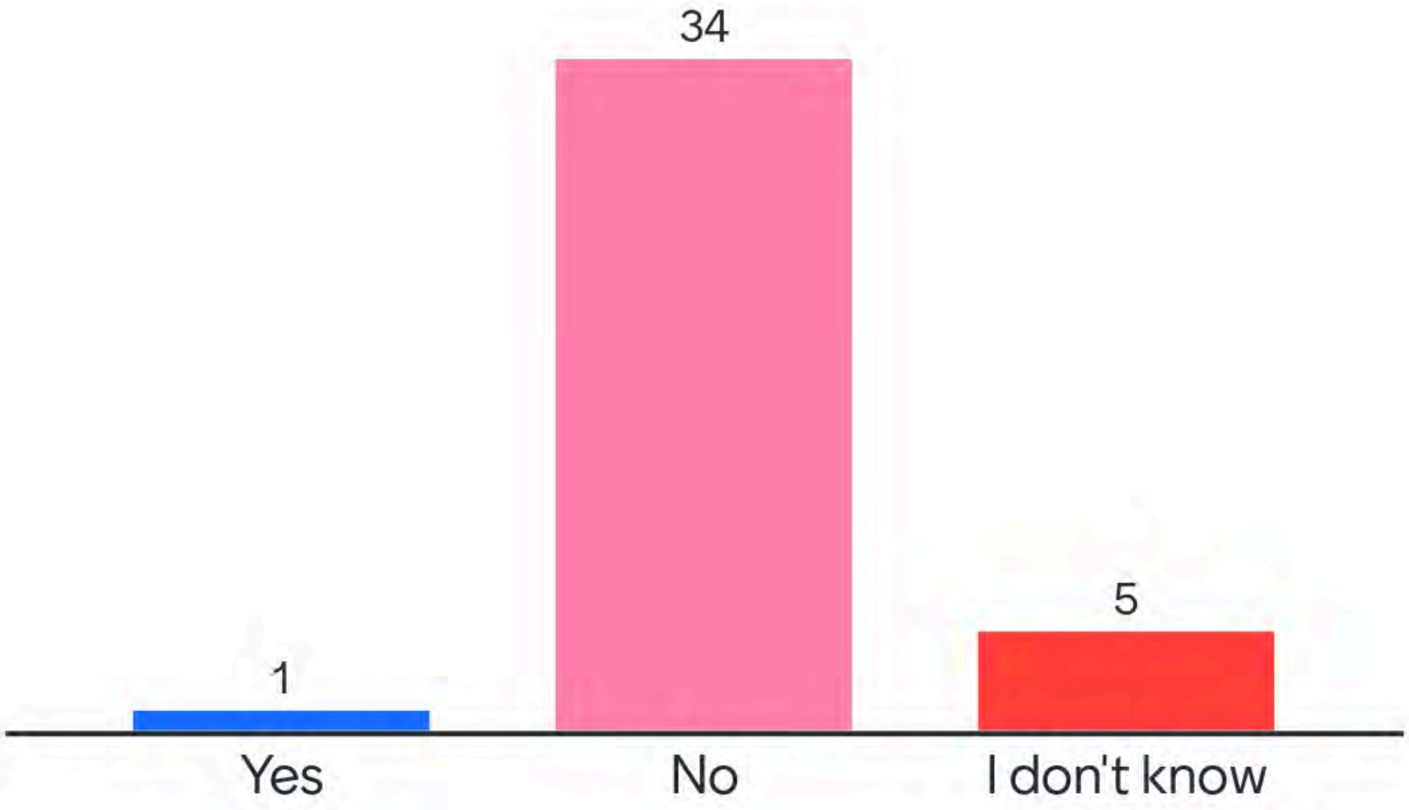
But we should also consider the important role of these upstream processes in providing reliable protection against these contaminants

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?



Mentimeter

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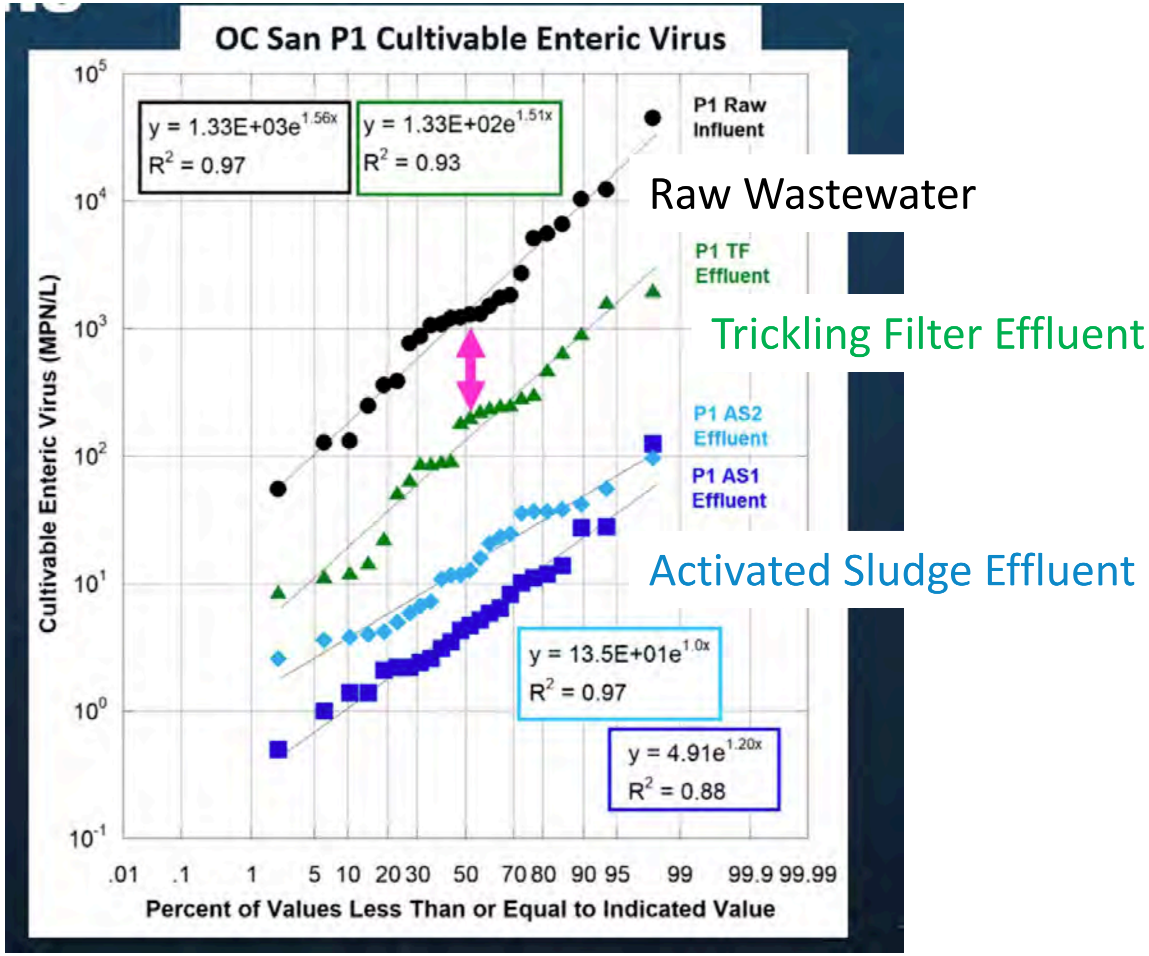
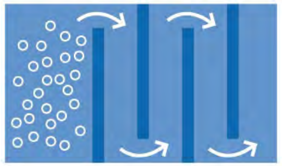
Fixed-film is less effective

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

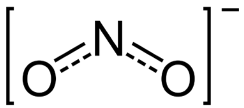


Wastewater Treatment – Benefits of Reliable Nitrification

OZONE

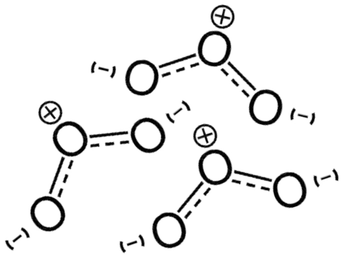


1 mg/L NO_2-N



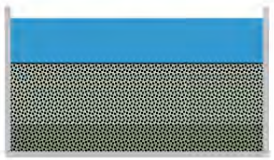
consumes

~3.5 mg/L O_3

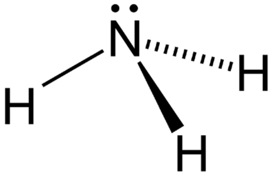


Excess nitrite results in increase ozone demand

BAC

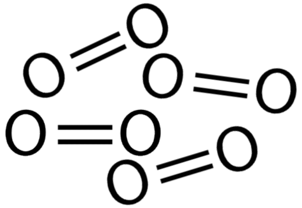


1 mg/L NH_3-N



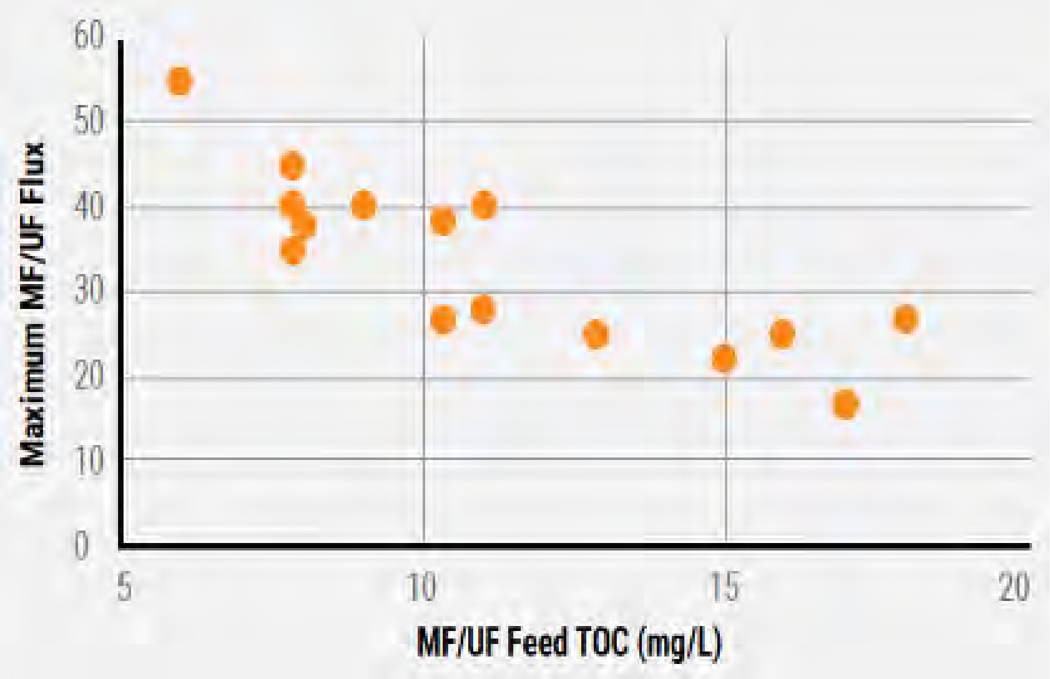
consumes

~4.6 mg/L O_2



Excess ammonia creates anerobic conditions

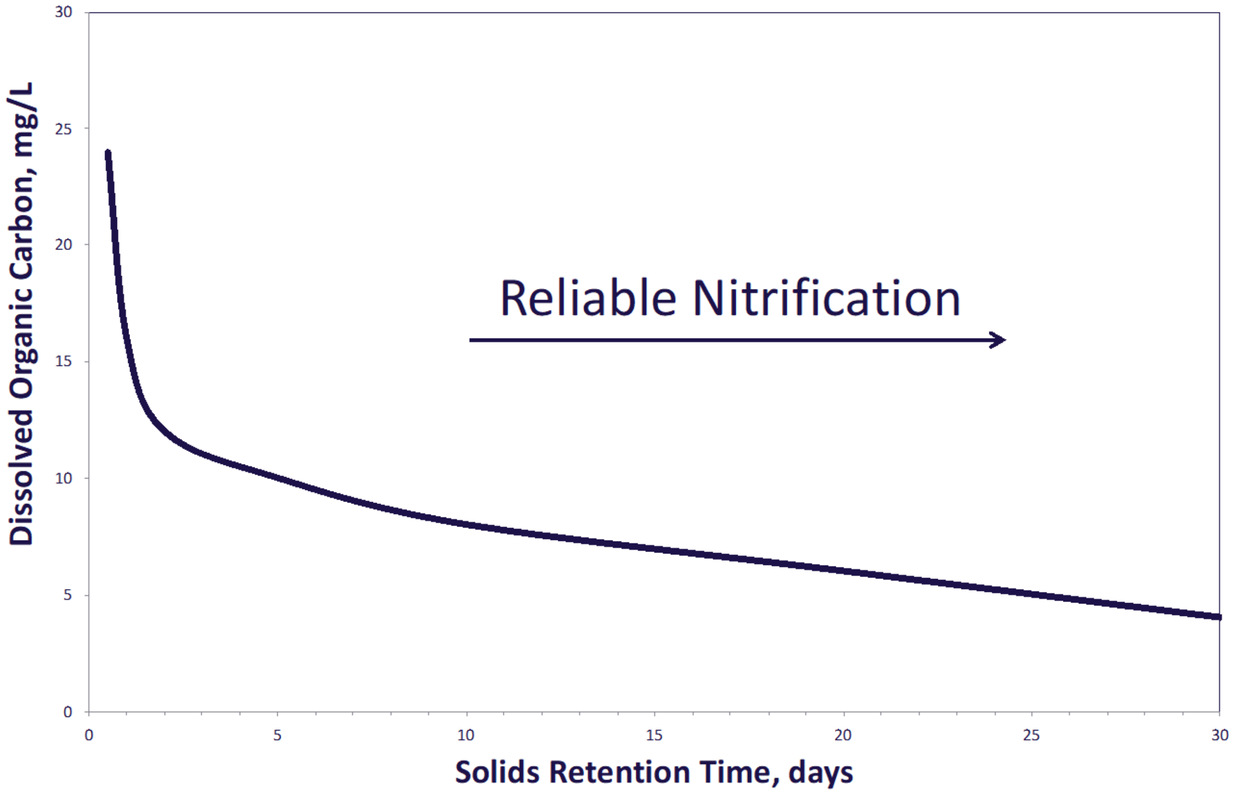
Wastewater Treatment – Benefits of Reliable Nitrification

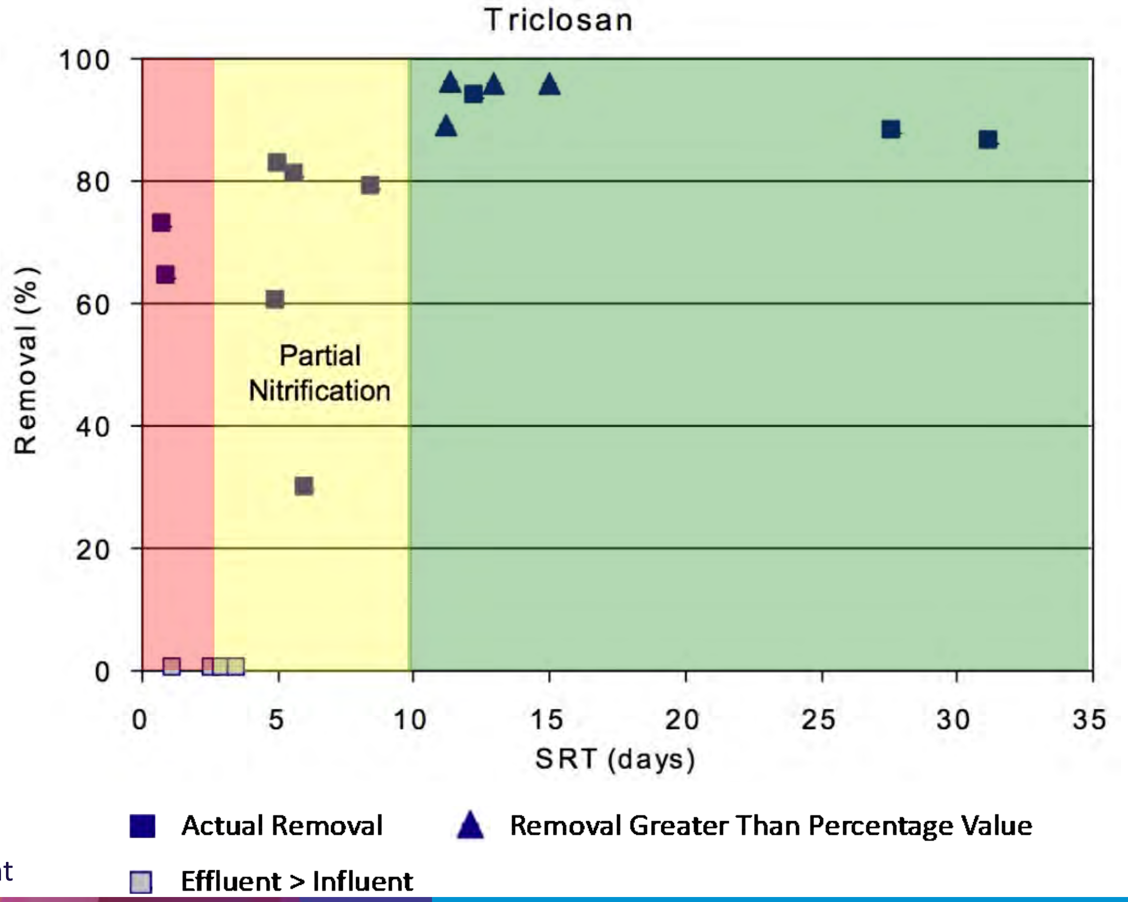


- Reliable nitrification means lower organics
- Lower organics results in increased fluxes, decreased operating pressures, and reduced number of chemical cleans

Wastewater Treatment – Benefits of Reliable Nitrification

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



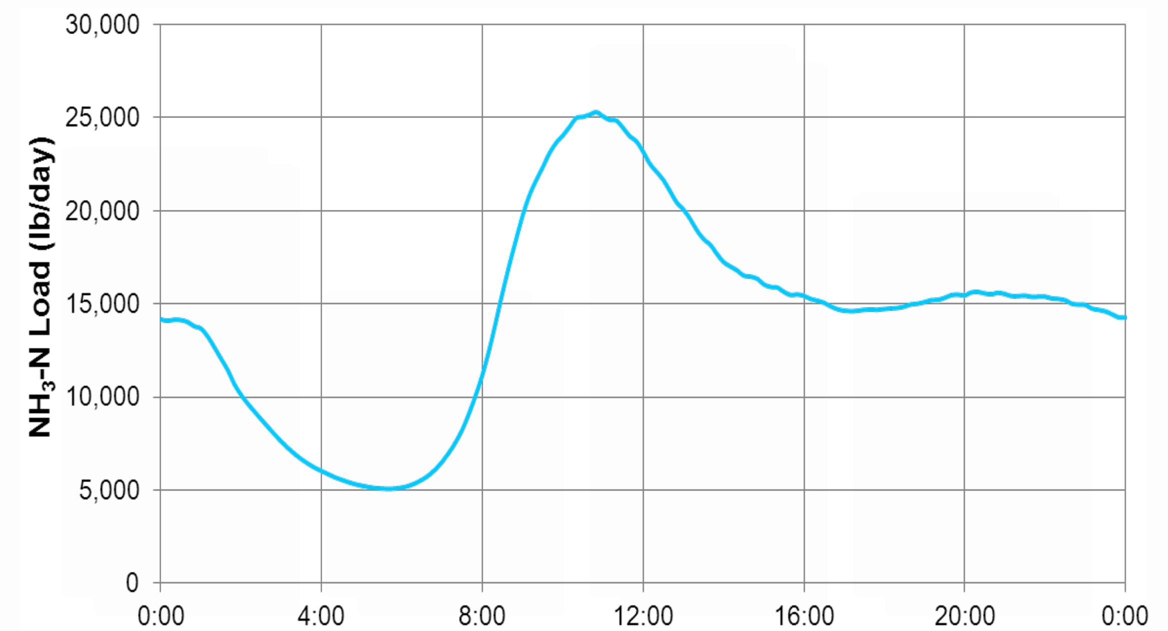


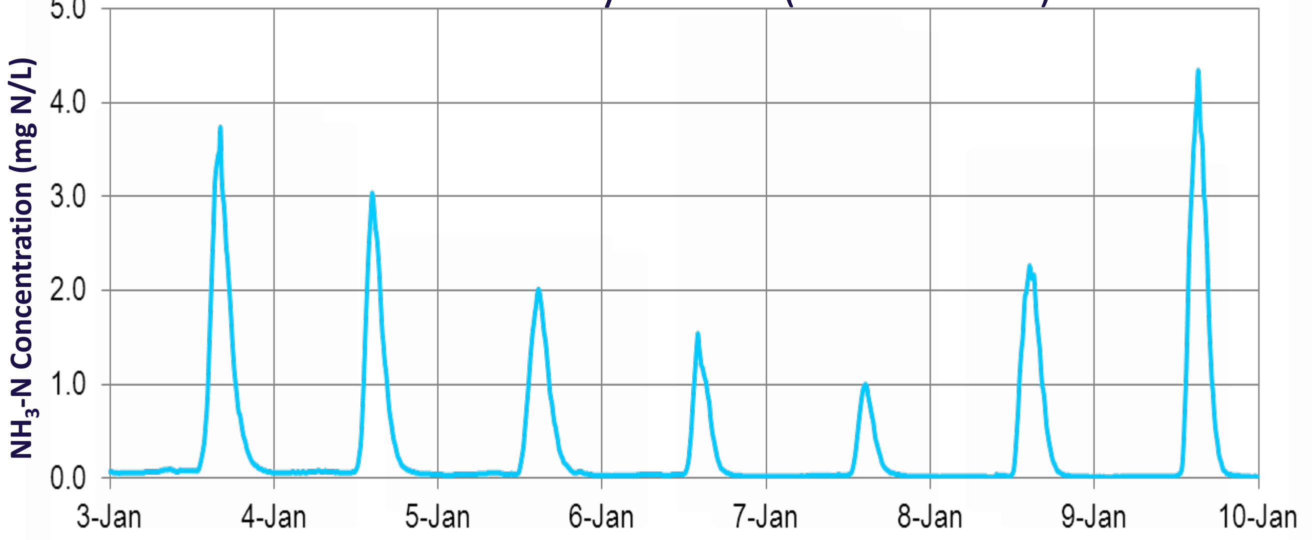
WRF 1347 – Trace Organic Compound Indicator Removal during Conventional Wastewater Treatment

Benefits of Flow Equalization

Lack of flow EQ impacts:

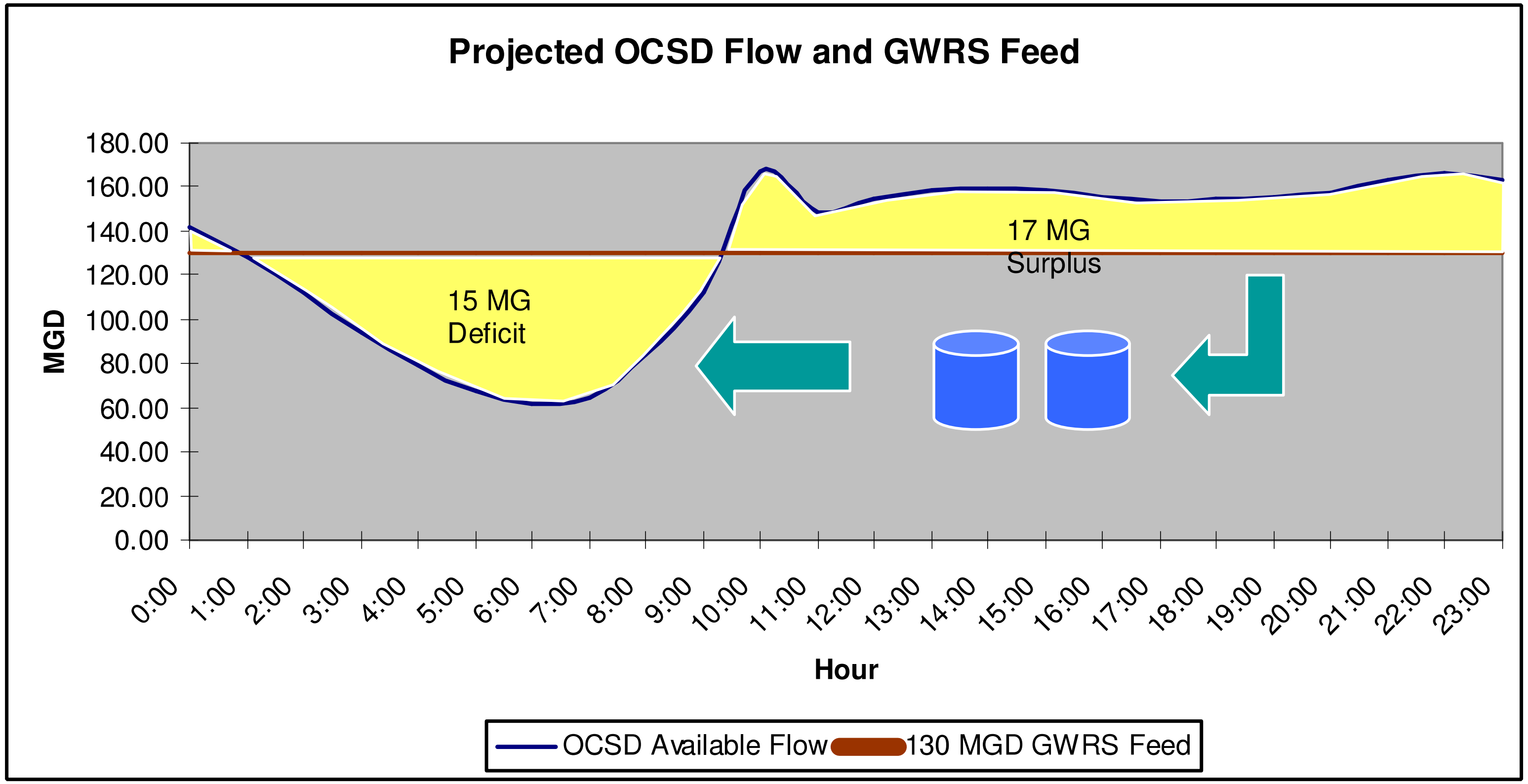
- Reactor conditions (increased load)
- Reactor hydraulics (shorter time)



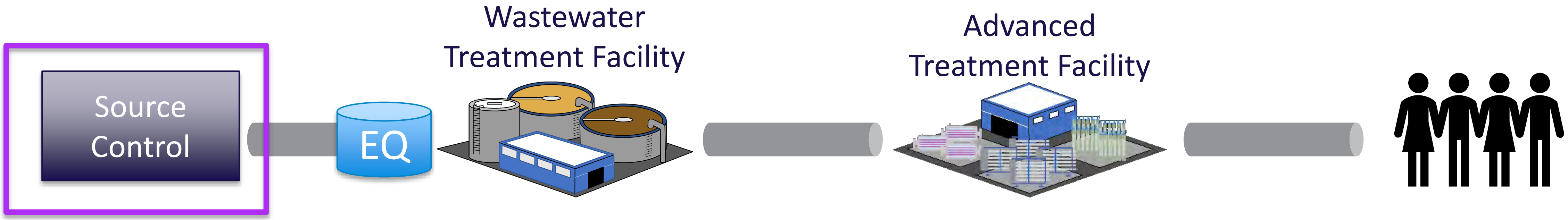


Flow Equalization – It Just Makes Sense

- 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



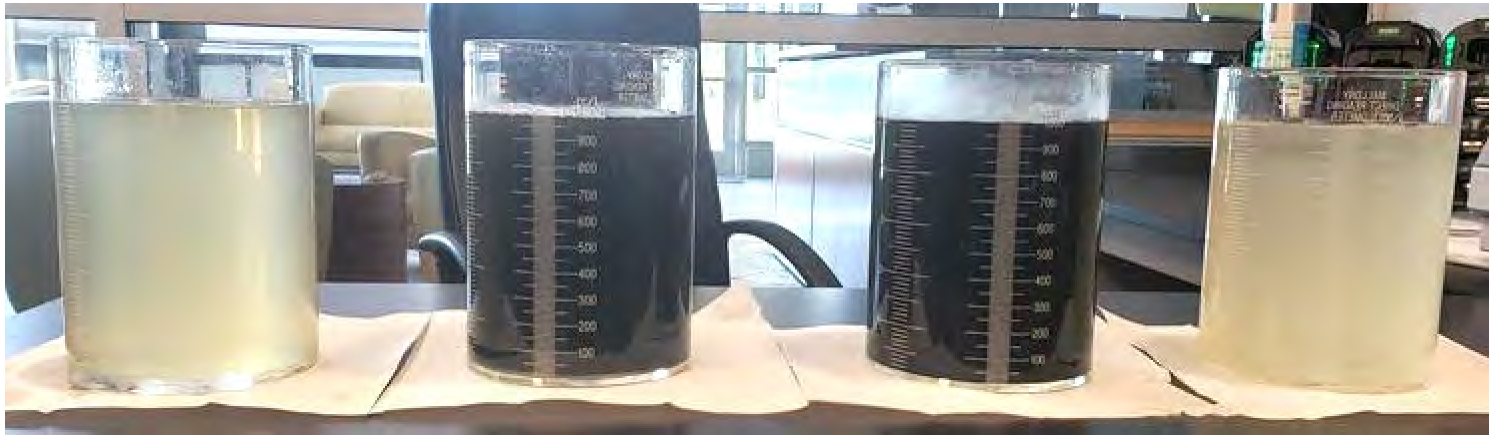
Source Control



- 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

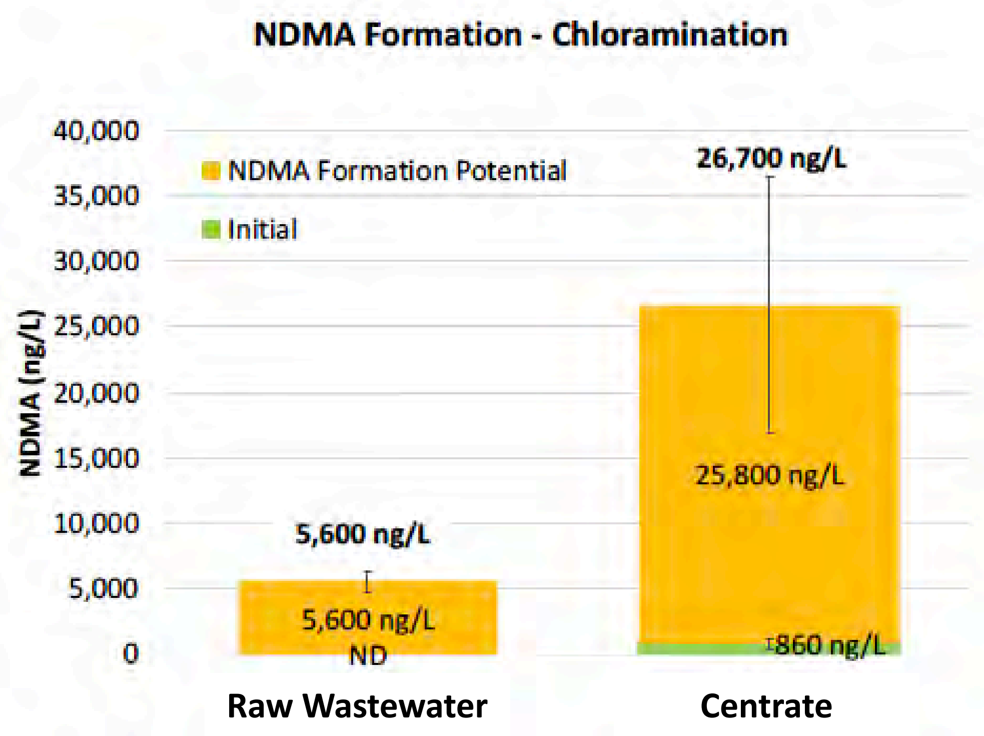
Managing Sidestreams

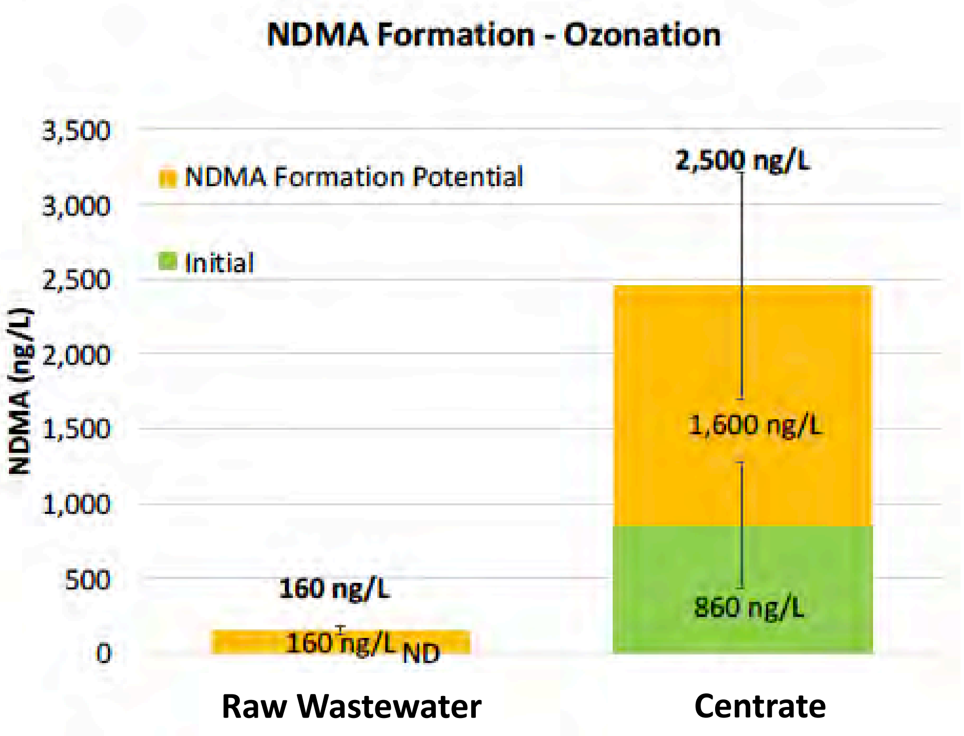


	Primary Effluent	Centrate	Wet scrubber	DAFT underflow
TSS (mg/L)	100	1,314	1,727	111
COD (mg/L)	400	1,693	1,432	191
NH3 (mg/L-N)	45	726	329	41.6
Ortho P (mg/L-P)	6	190	74	3.4

Managing Sidestreams

- Centrates have much greater NDMA formation potential





Research Needs

Source Control

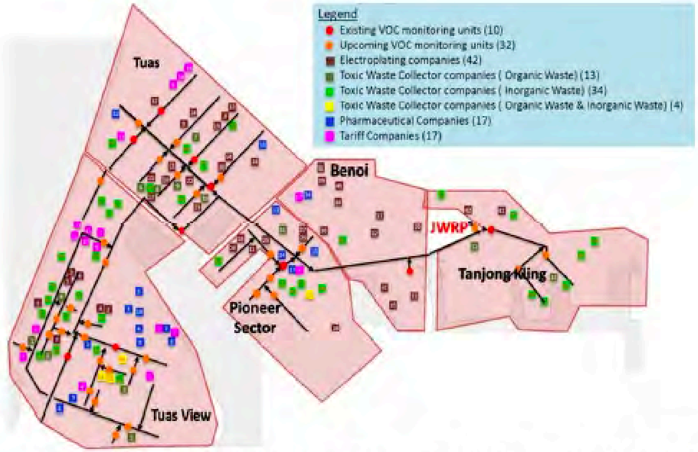
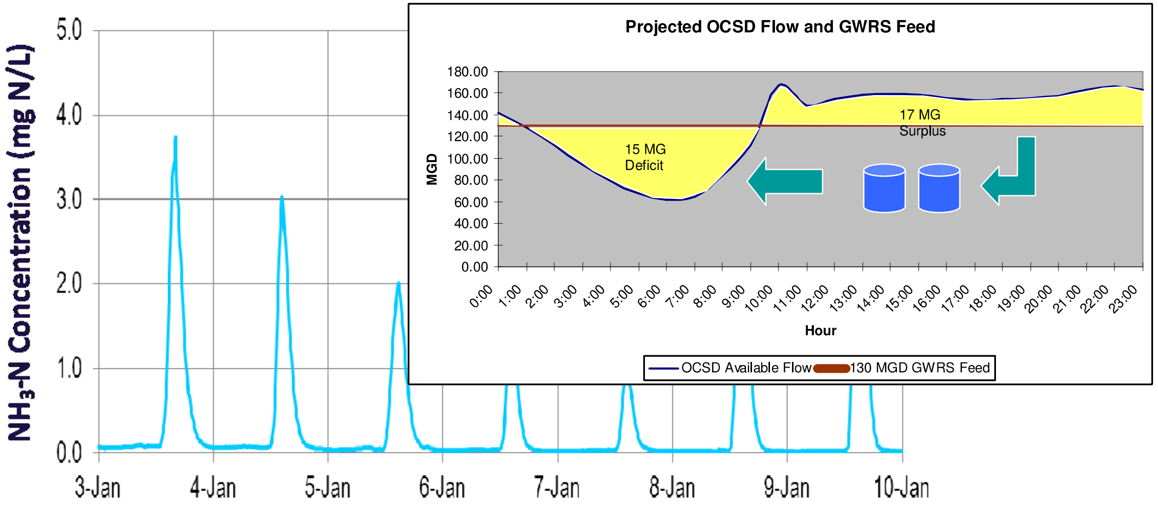


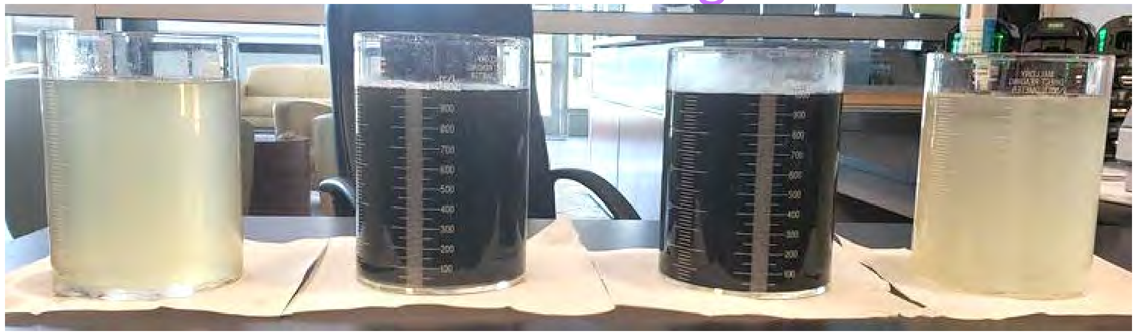
Figure 4-11. Distribution of Industrial Dischargers in the JWRP Catchment Area and Location of VOC Monitoring Units.
Source: Courtesy of PUB.

Flow EQ

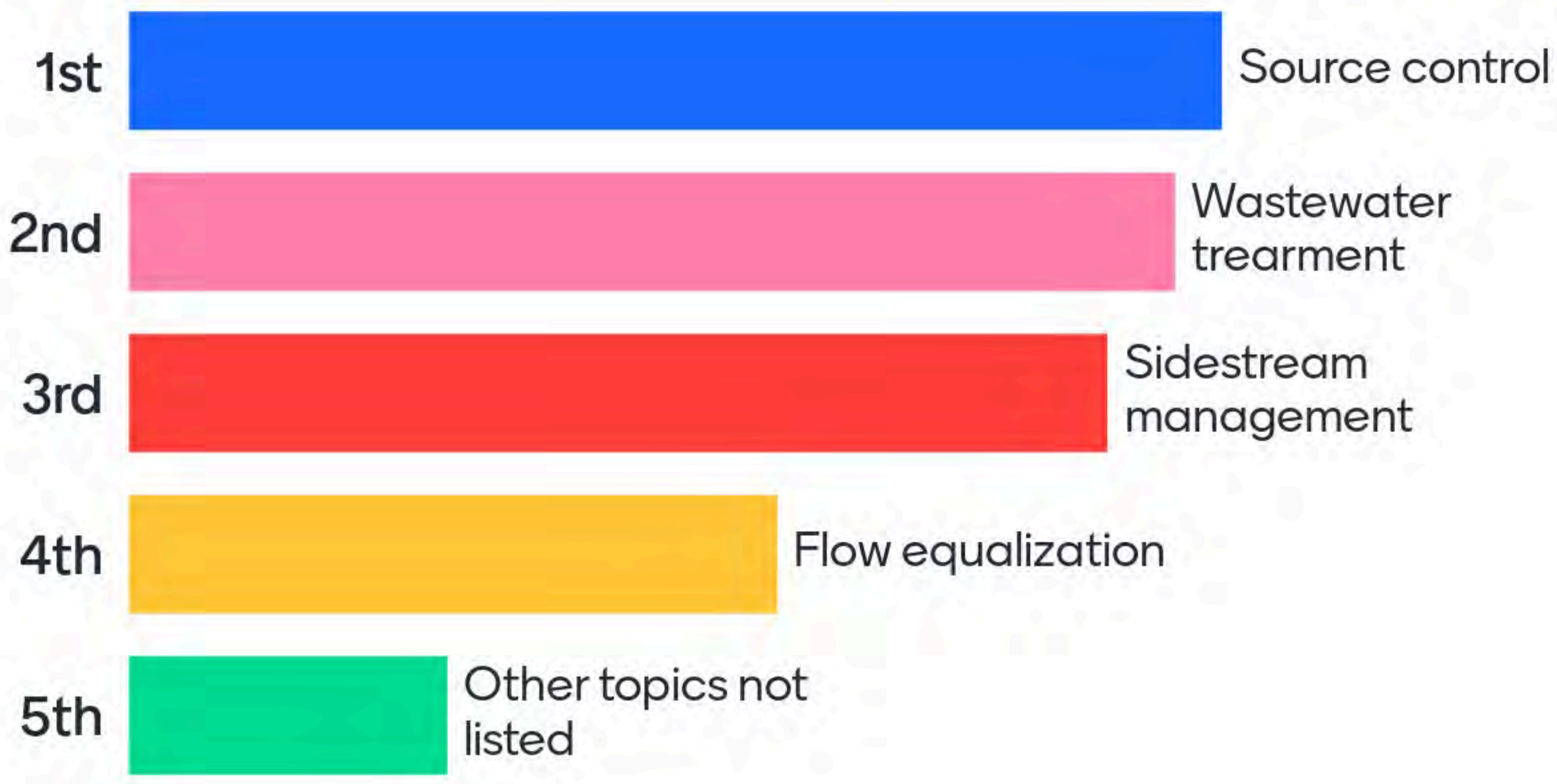


Wastewater Treatment

Sidestream Management



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



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

SHAPING OUR PAST & CHARTING OUR FUTURE

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

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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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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?

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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?

Project #	NPR
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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

Themes:

- Guidelines for treatment
  - Industrial
  - Decentralized
  - Improving WQ

Example Projects

5050: UV/Cl

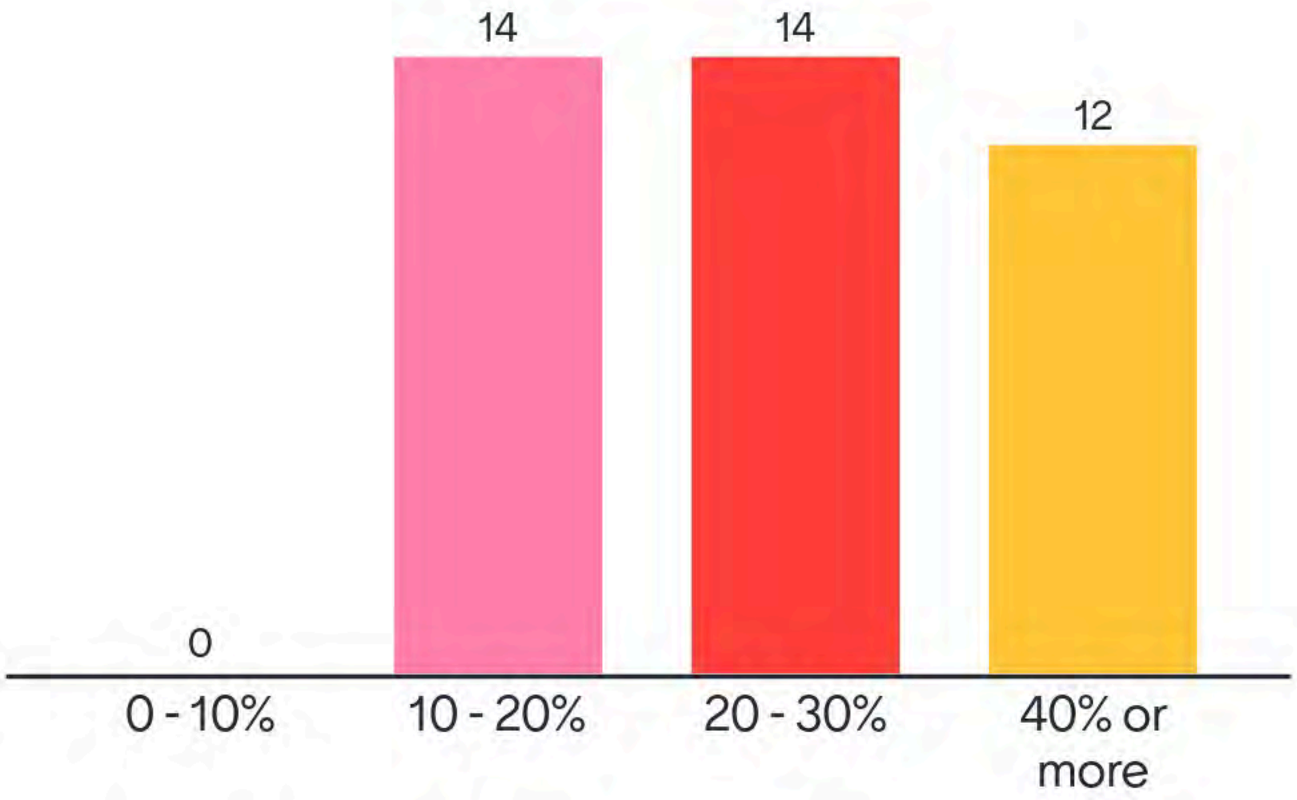
- Objectives
  - UV/Cl implementation guidance
  - DBP formation study
- Team
  - Ron Hoffman, U of Toronto
  - Erin Mackey, BC
- Findings
  - Design guidance manual
  - DBP formation and toxicity methods for evaluation
- Budget: $150,000

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?

Mentimeter



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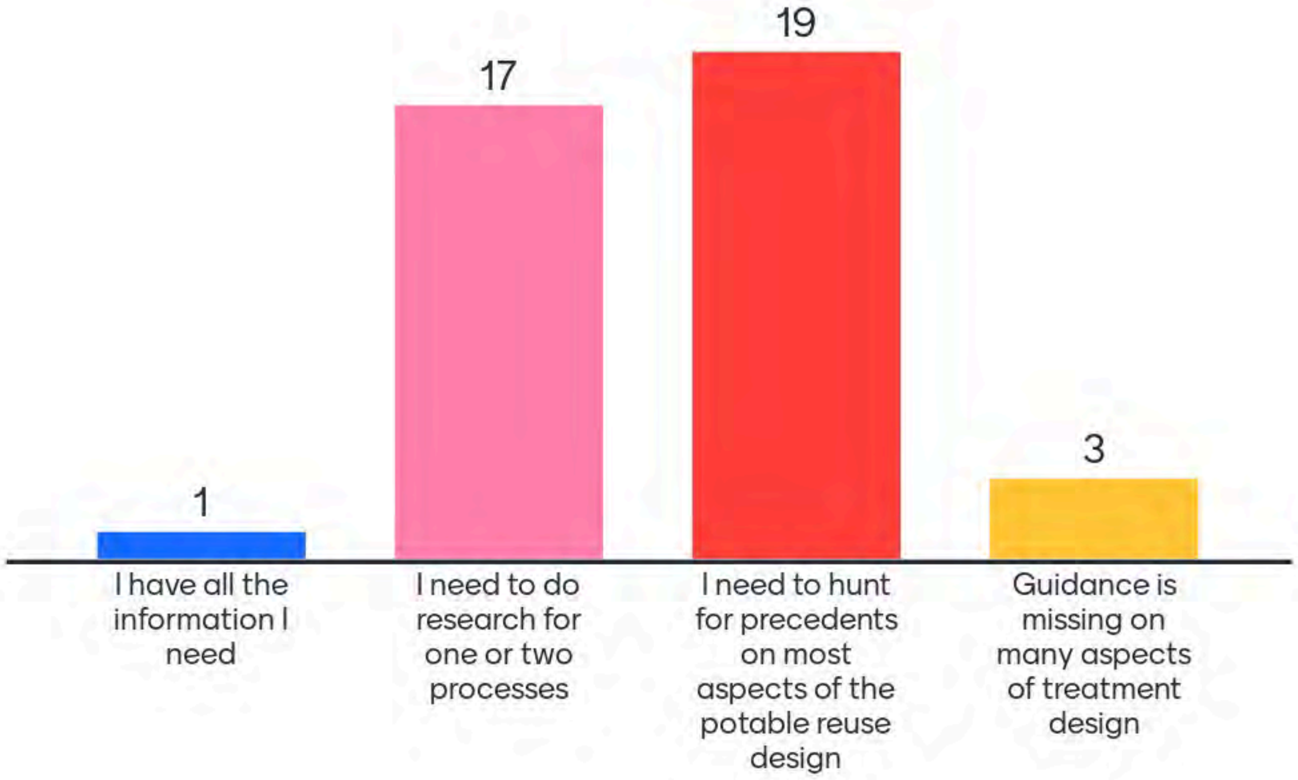
How readily available is the process design and performance data you need to design a system to meet treatment requirements?

Mentimeter



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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

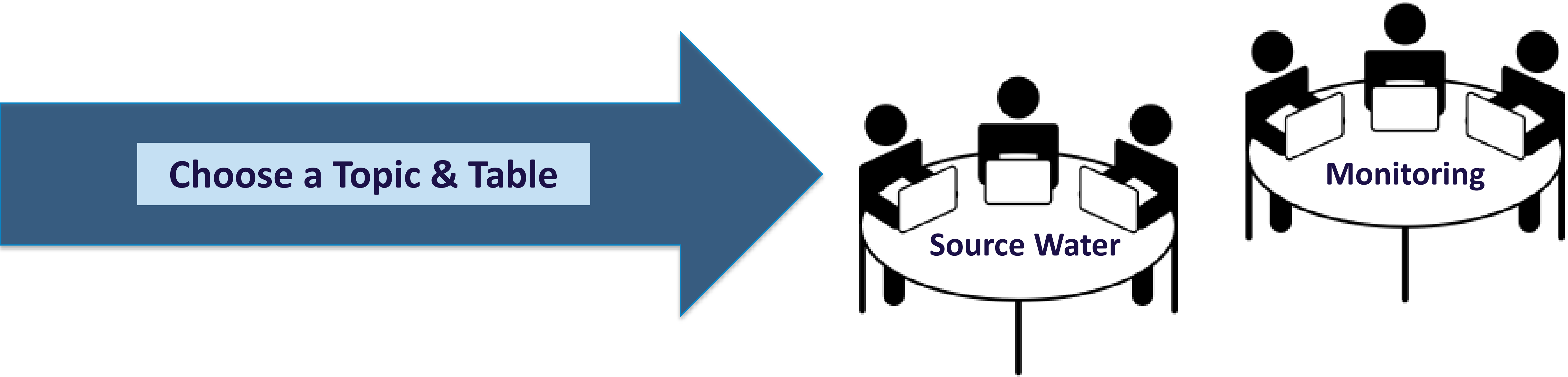
- Potable Reuse Specific Treatment Guidelines:
  - Question: How do we know how much ozone treatment we need to achieve disinfection goals?
  - Objective: Develop a protocol for establishing LRVs for ozone (with and without peroxide) when the dissolved ozone residual is either very low or zero
  - Budget: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

PART 1: Source Water & Treatment Facilitators

Source Water	Treatment
Greta Zornes, CDM	Steve Katz, Suez
Samir Mathur, CDM	Chris Hill, AECOM
Jean Debroux, Kennedy Jenks	Brian Pecson, Trussell
Jeff Mosher, SAWPA	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

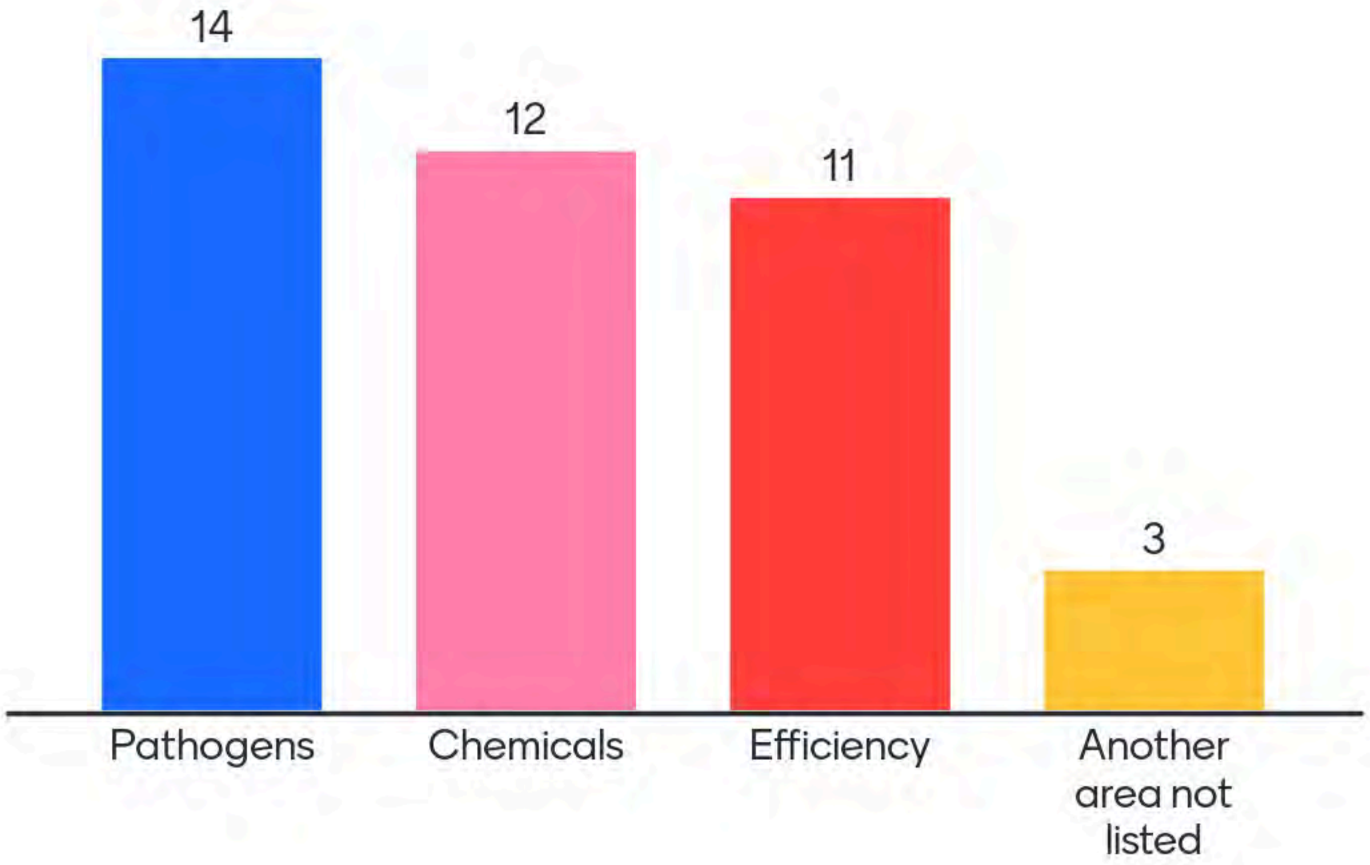
- Carollo Engineers
- Water Reuse Chief Technologist
- Implementing Potable Reuse Projects Since 1998
- PI or co-PI on a range of treatment and monitoring projects for the Water Research Foundation

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?

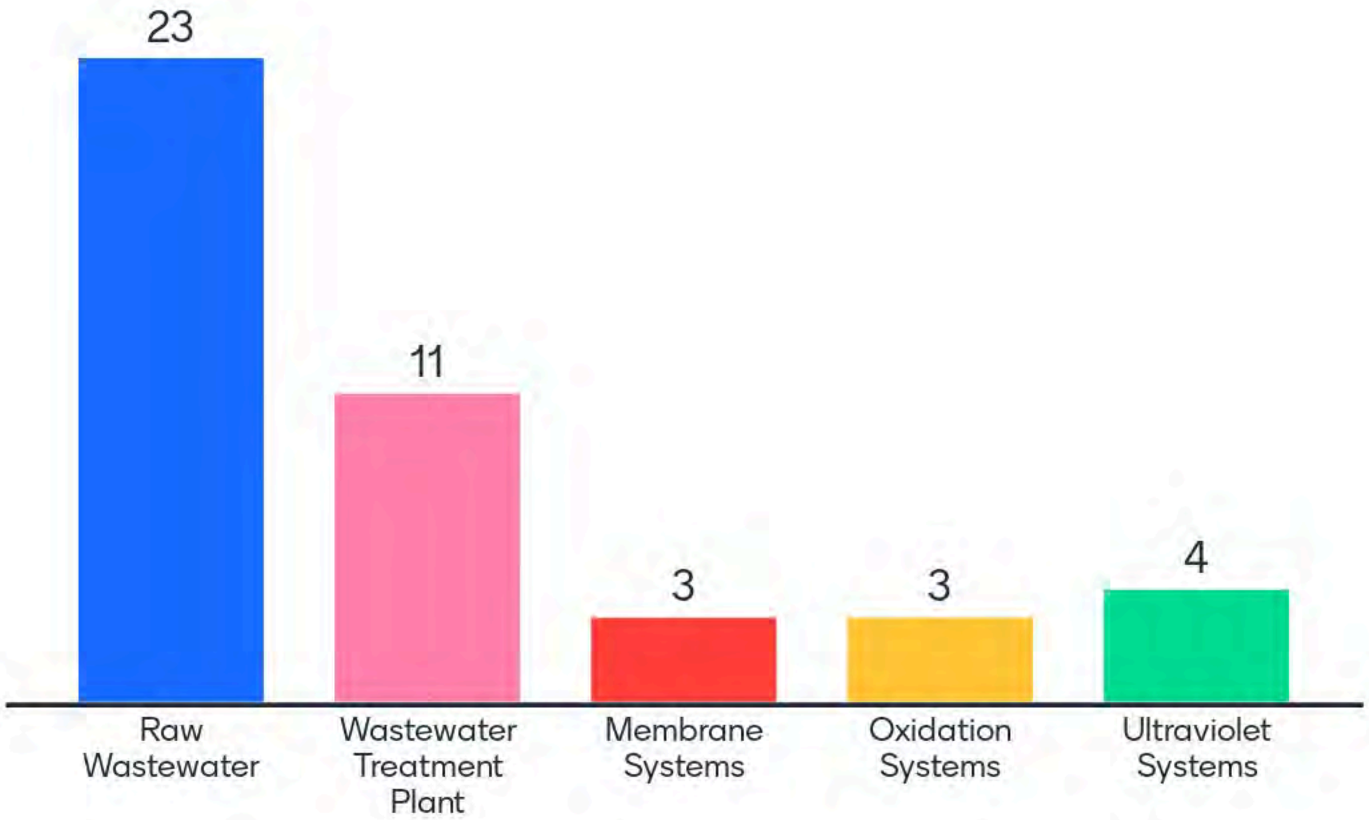
Mentimeter



40

What part of the treatment process poses the greatest risk?

Mentimeter



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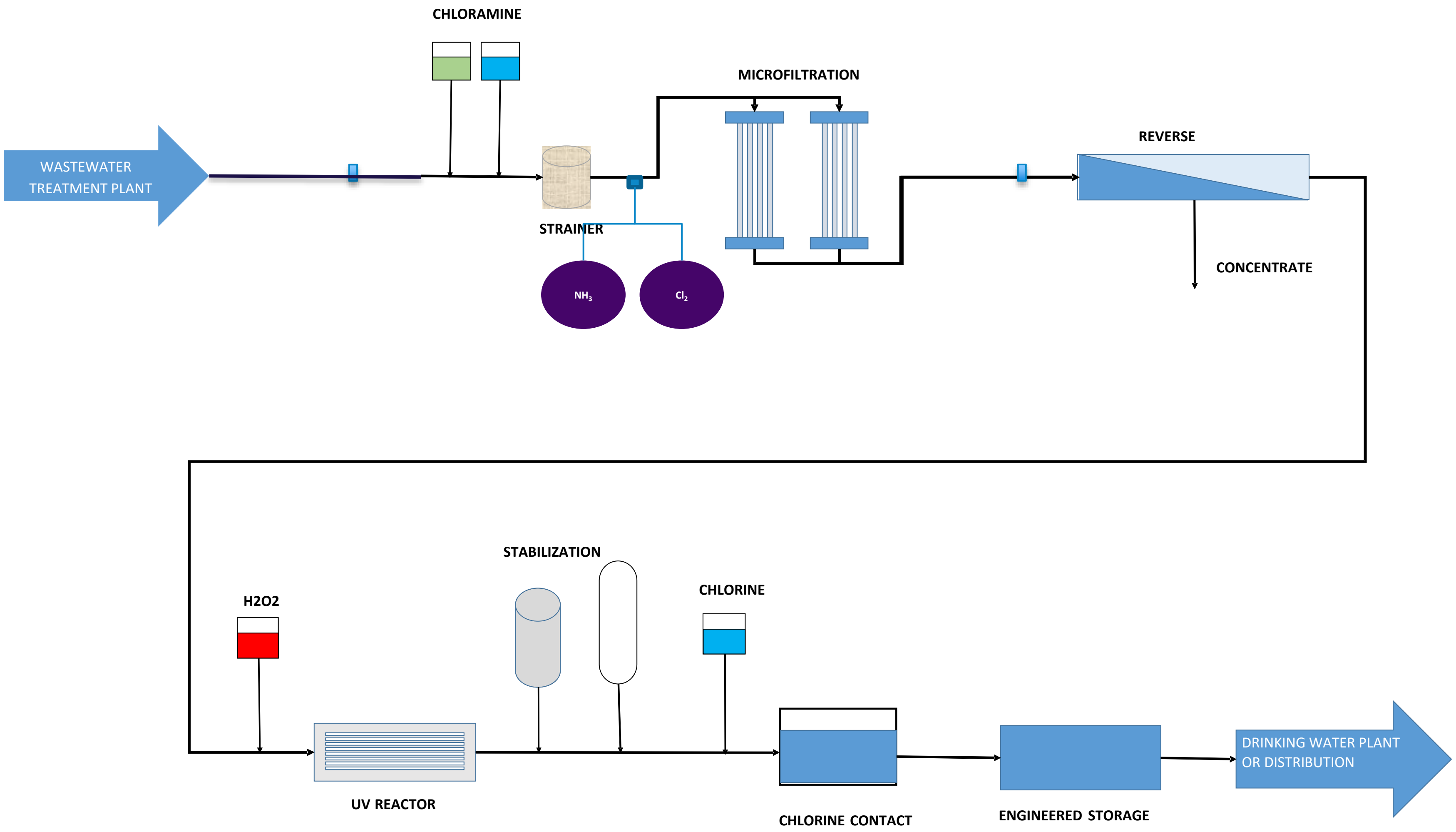
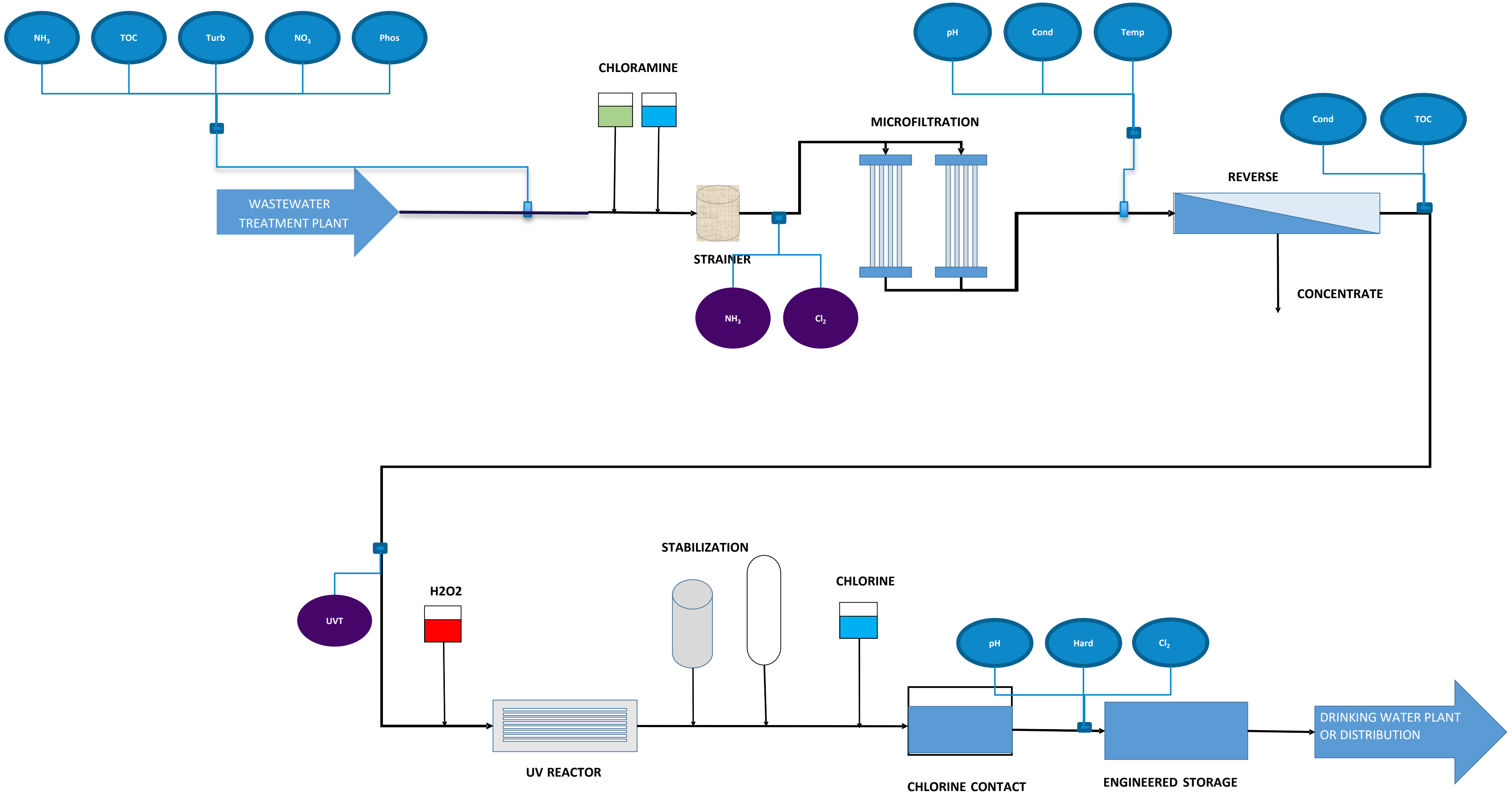
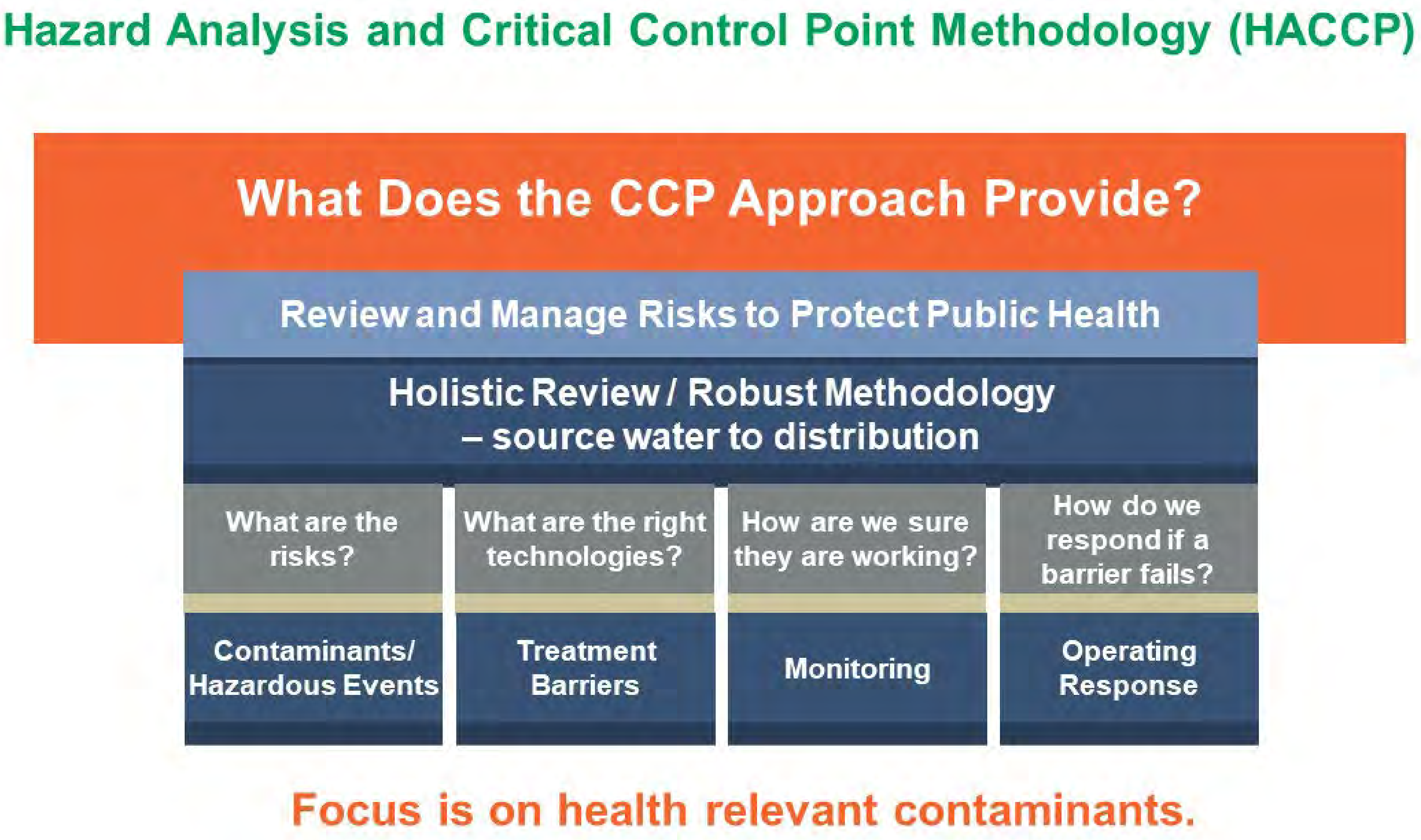
Potable Reuse Requires Extensive Monitoring



Potable Reuse Requires Extensive Monitoring



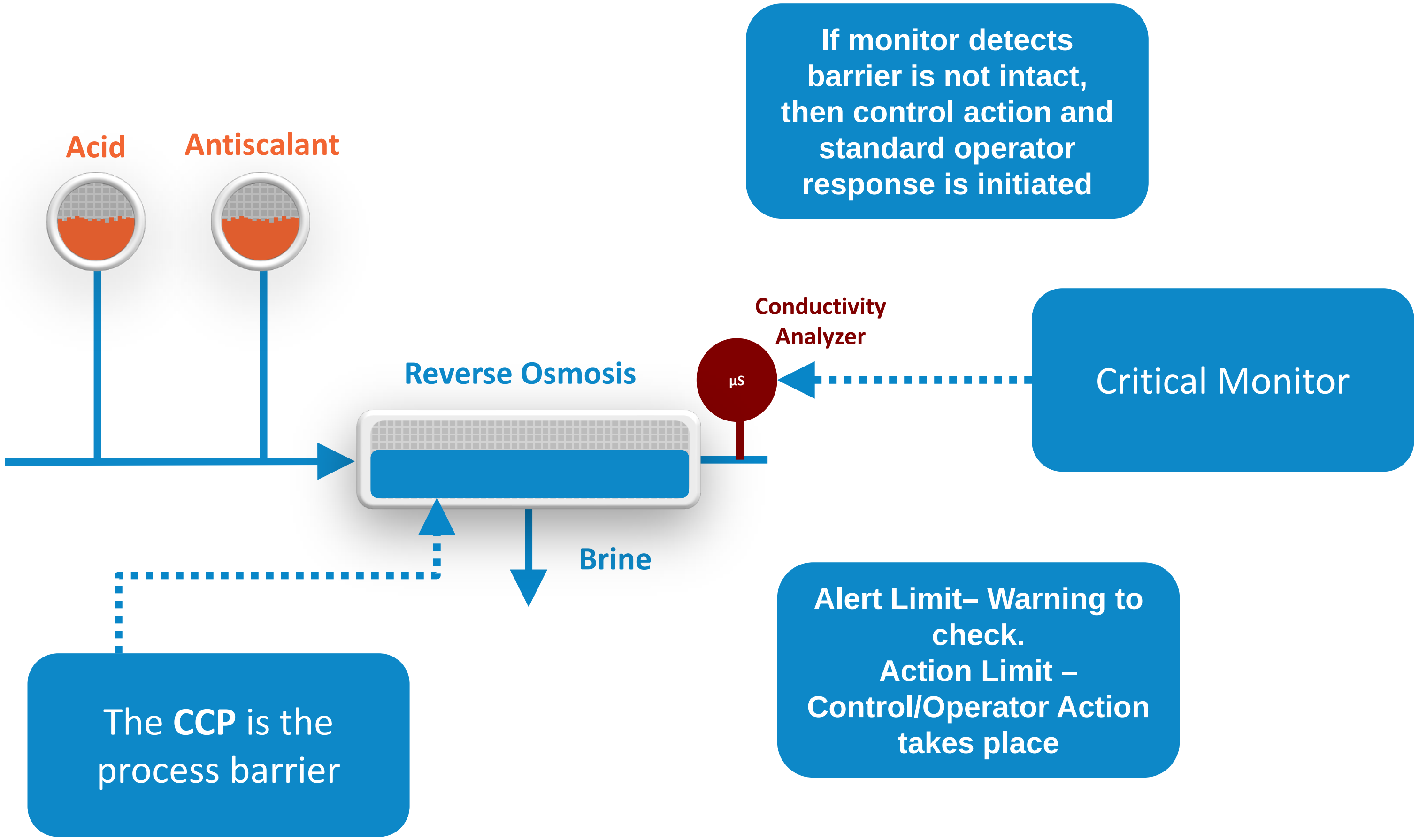
Critical Control Points Provide Protection



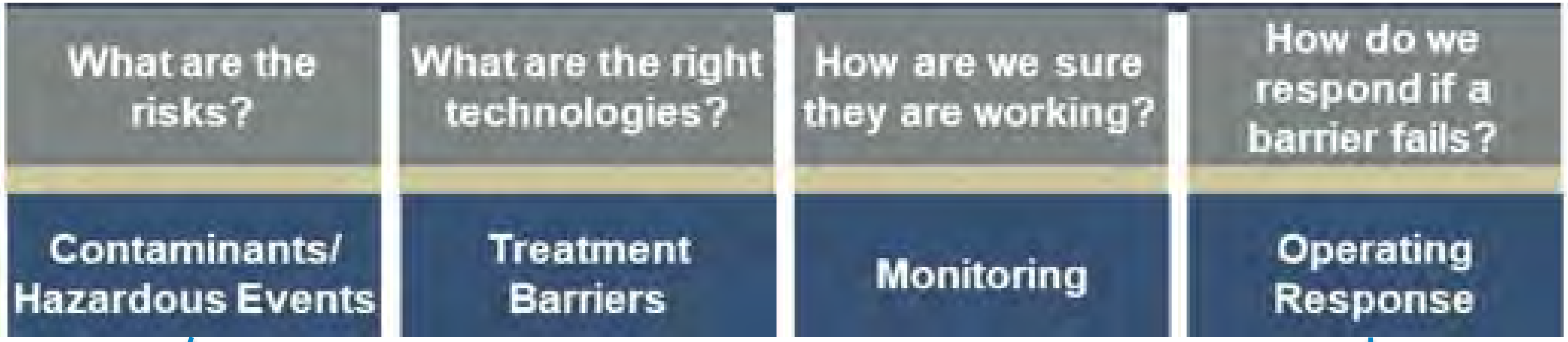
WRF 13-03

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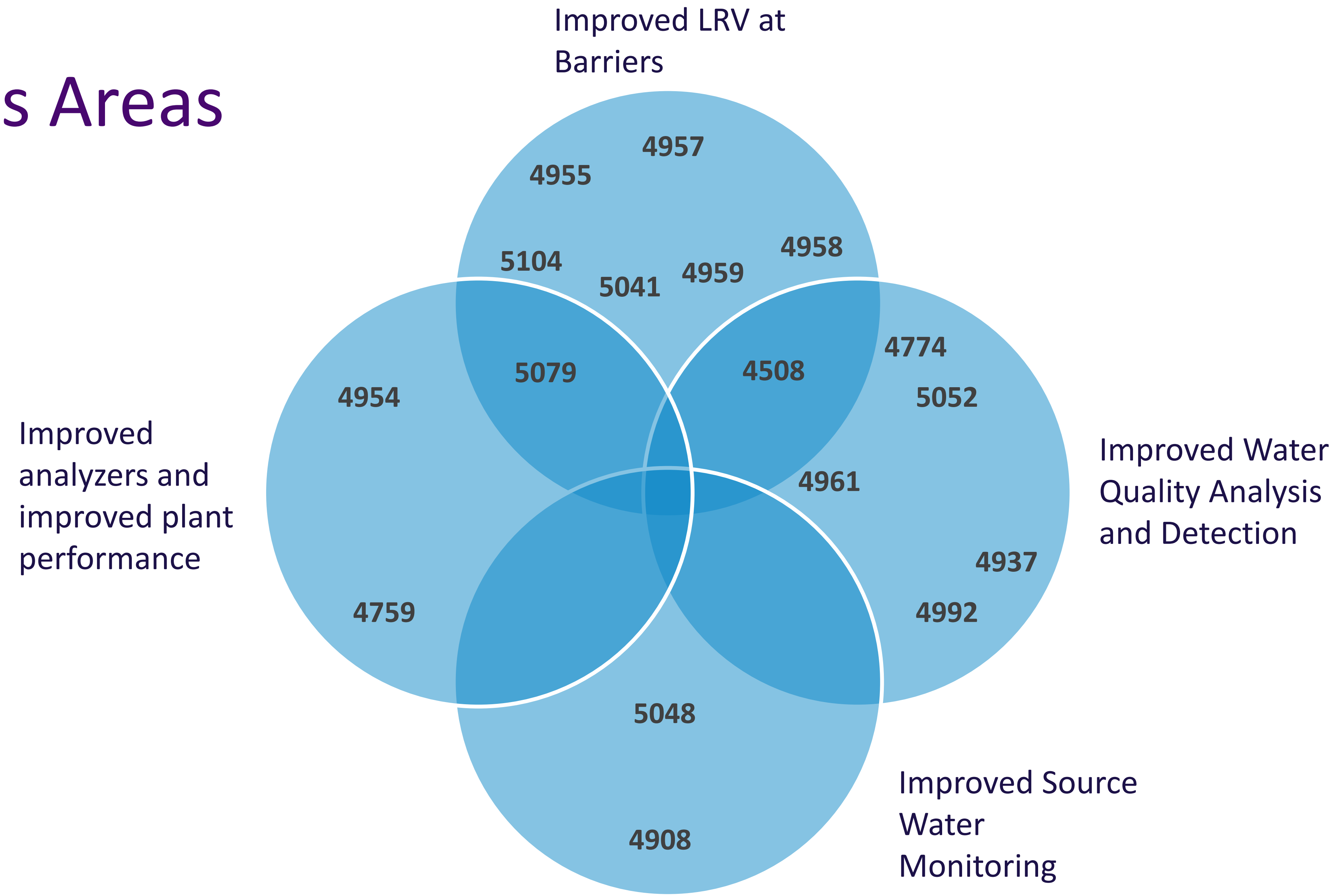
4759	Integrated Management of Sensor Data for Real Time Decision Making	
4508	Assessment of Techniques to Evaluate Water Quality from Direct and Indirect Potable Reuse Facilities	

Yikes! How Do We Sort Through All of This?

Focus Areas


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

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.

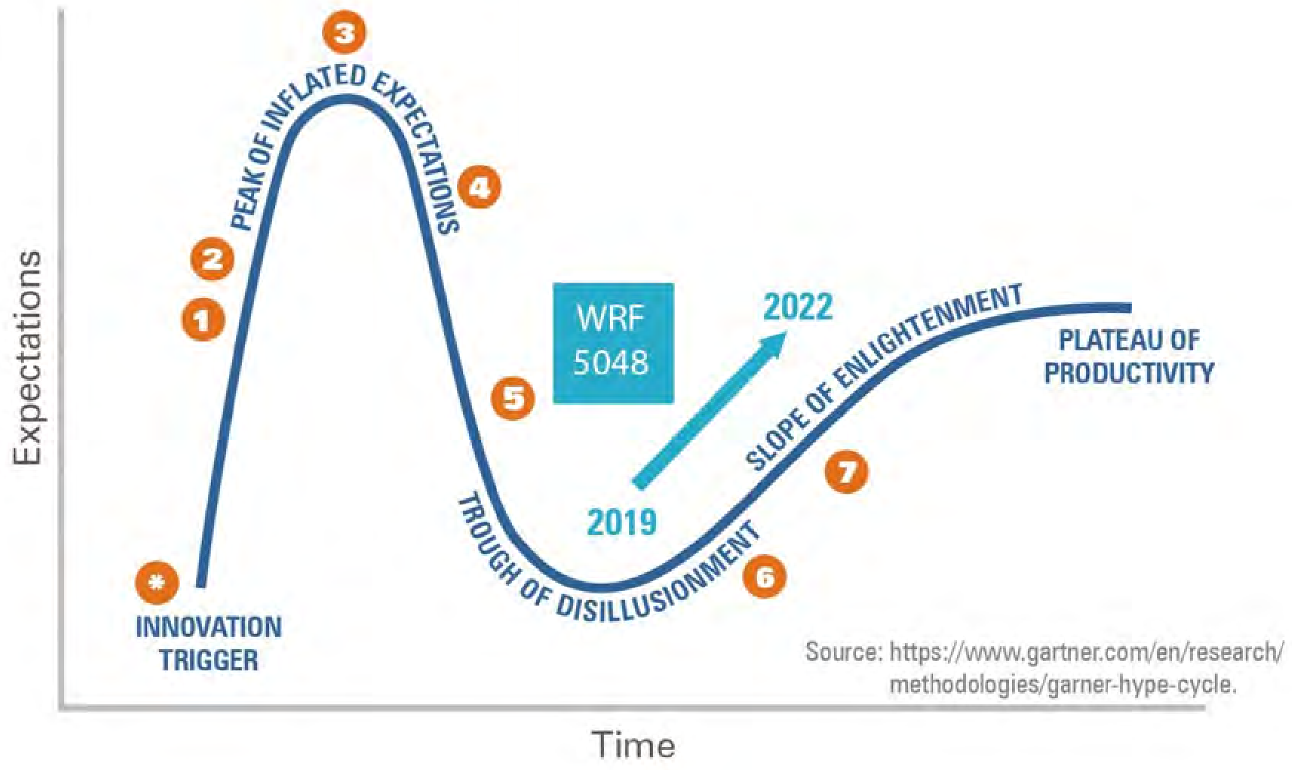
(c) The source control program must be audited by an independent party at least every five years. The audit shall use the "Control Authority Pretreatment Audit Checklist and Instructions", EPA, 833-B-10-001, February 2010.

(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:

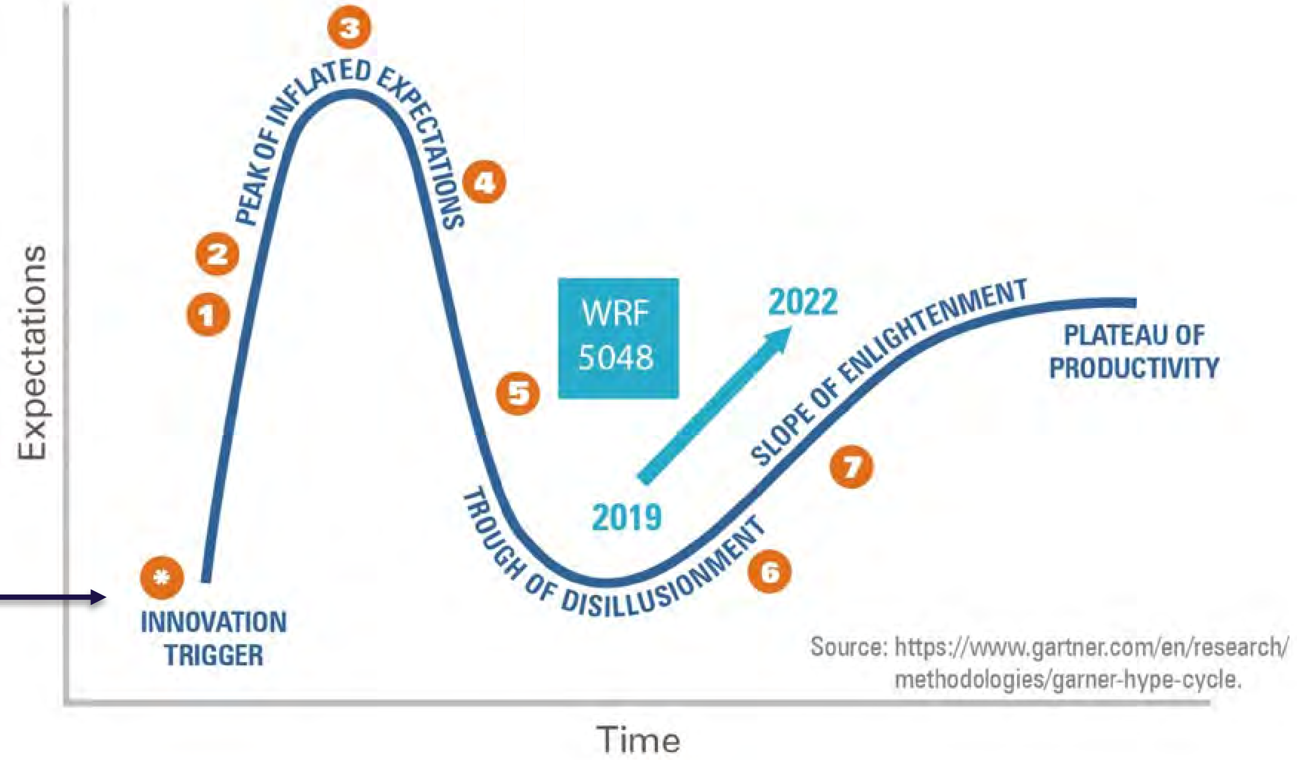
(1) On-line monitoring instrumentation at critical locations that measure surrogate(s) that may indicate a chemical peak;

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

California Water Boards

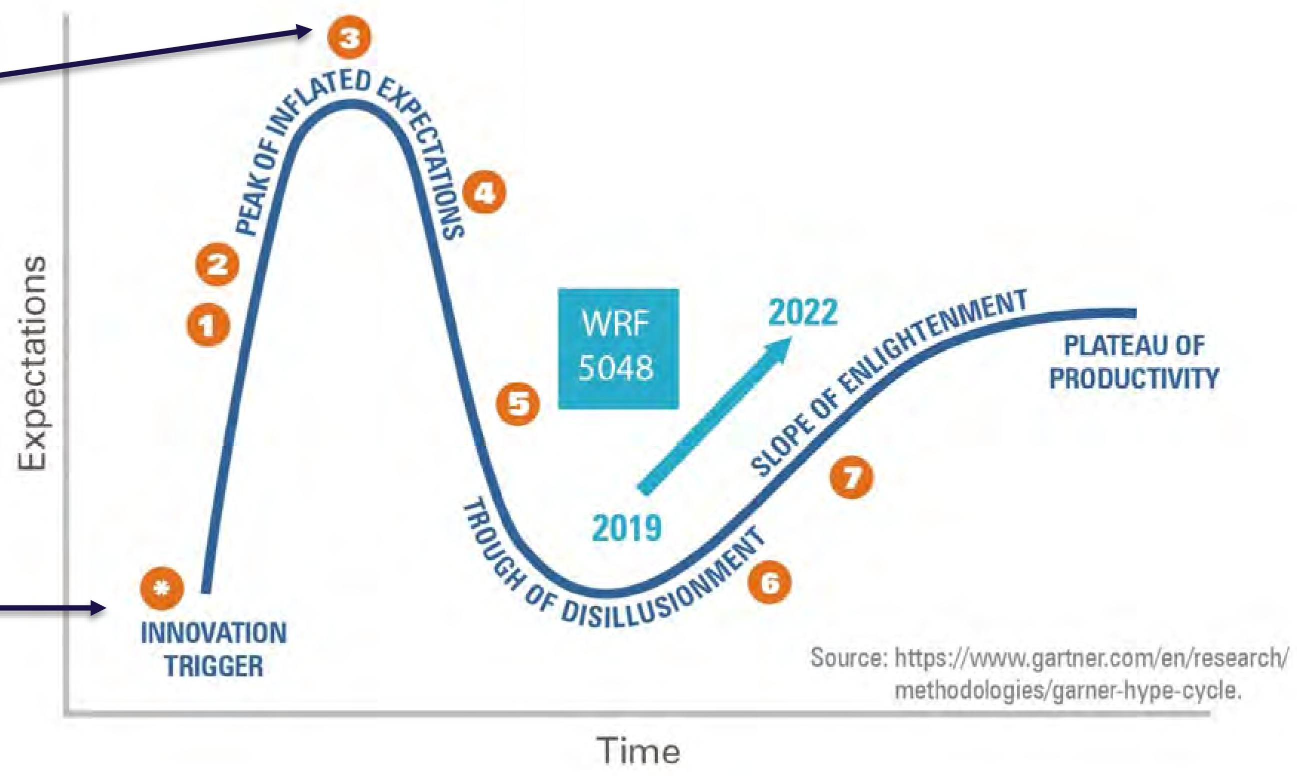

Expectations
PEAK OF INFLATED EXPECTATIONS
WRF
5048
2022
2019
SLOPE OF ENLIGHTENMENT
PLATEAU OF
PRODUCTIVITY
TROUGH OF DISILLUSIONMENT
INNOVATION
TRIGGER
Source: https://www.gartner.com/en/research/
methodologies/garner-hype-cycle.
Time

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)

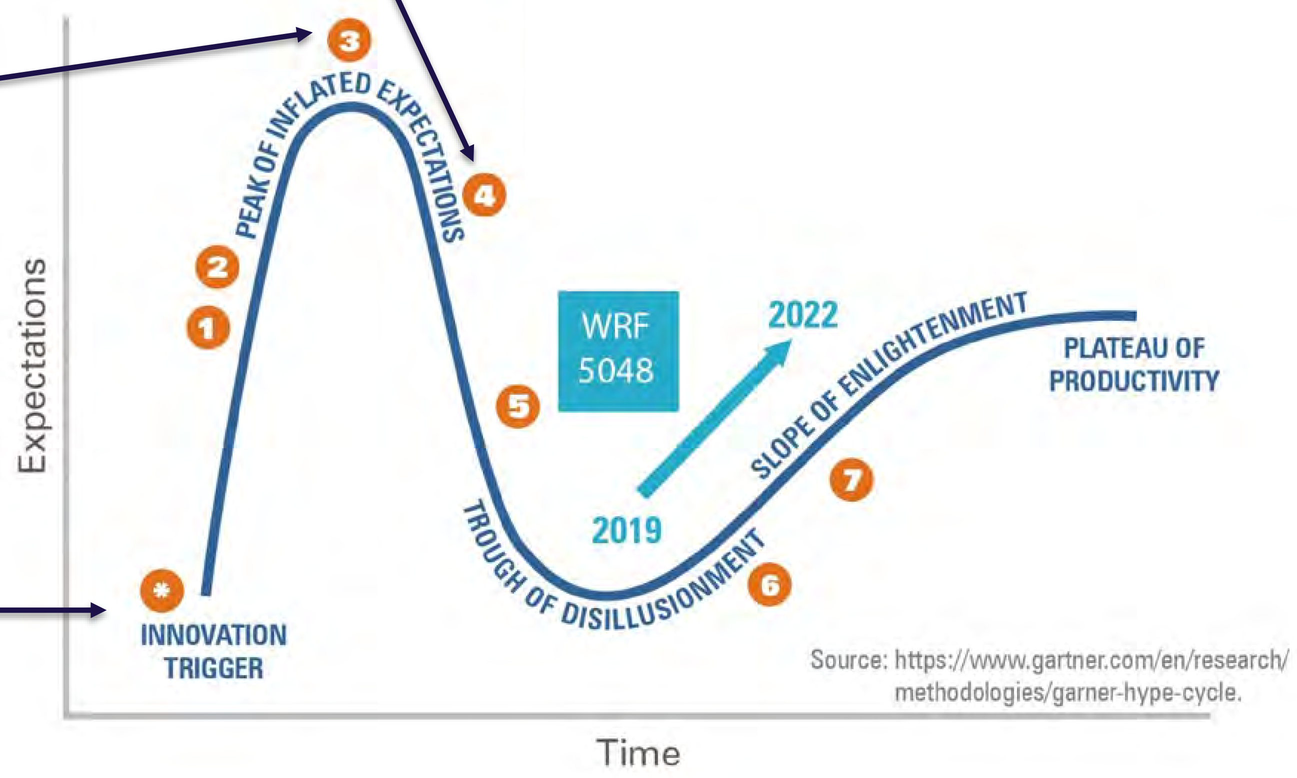
Idea conceived to use real-time sewershed monitoring for potable reuse



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

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

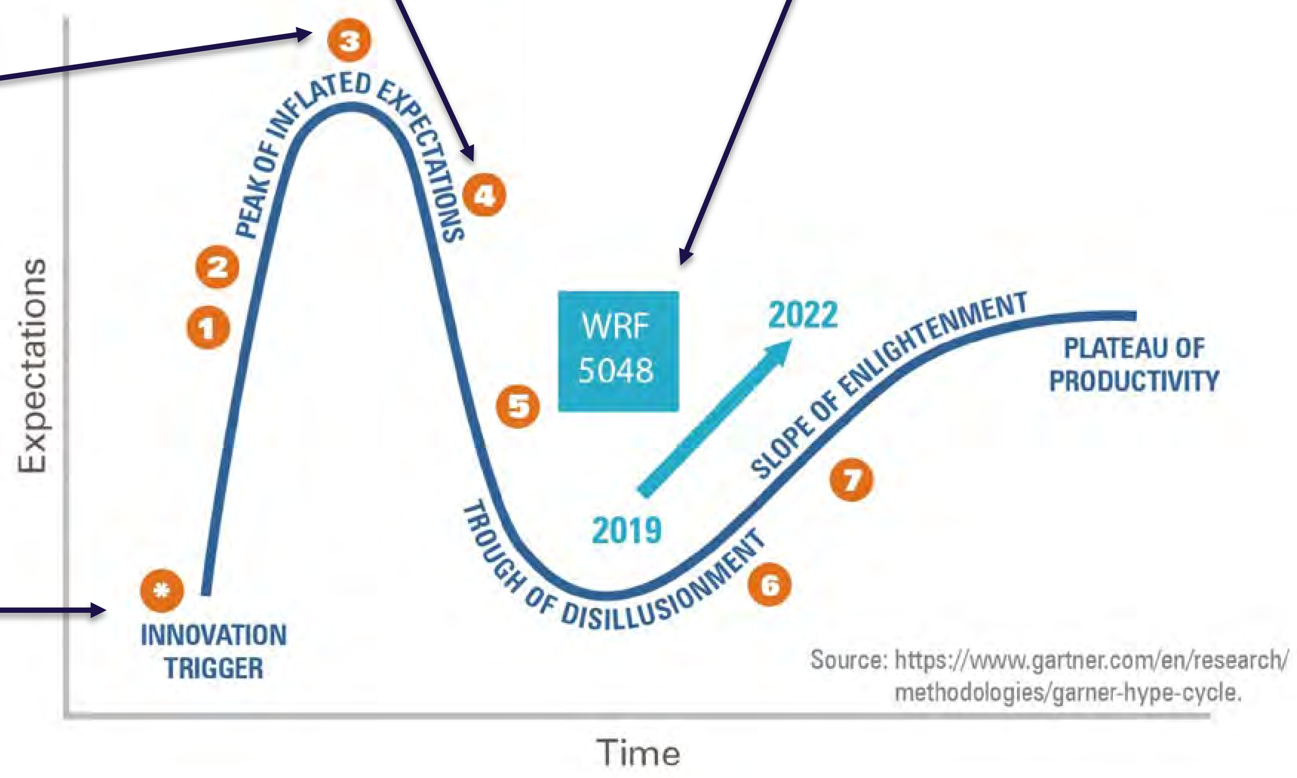
Idea conceived to use real-time sewershed monitoring for potable reuse



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

This project:
balance, realism, practical guidance

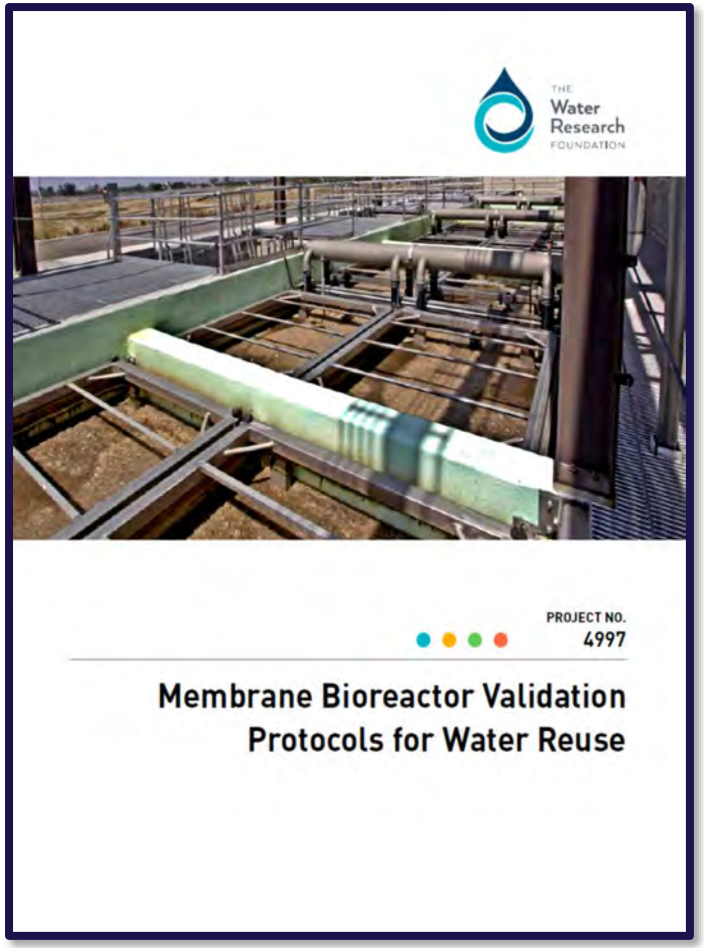
Sensors for broader variety of water quality parameters become available
(optical, specific metals, automated GC/MS)

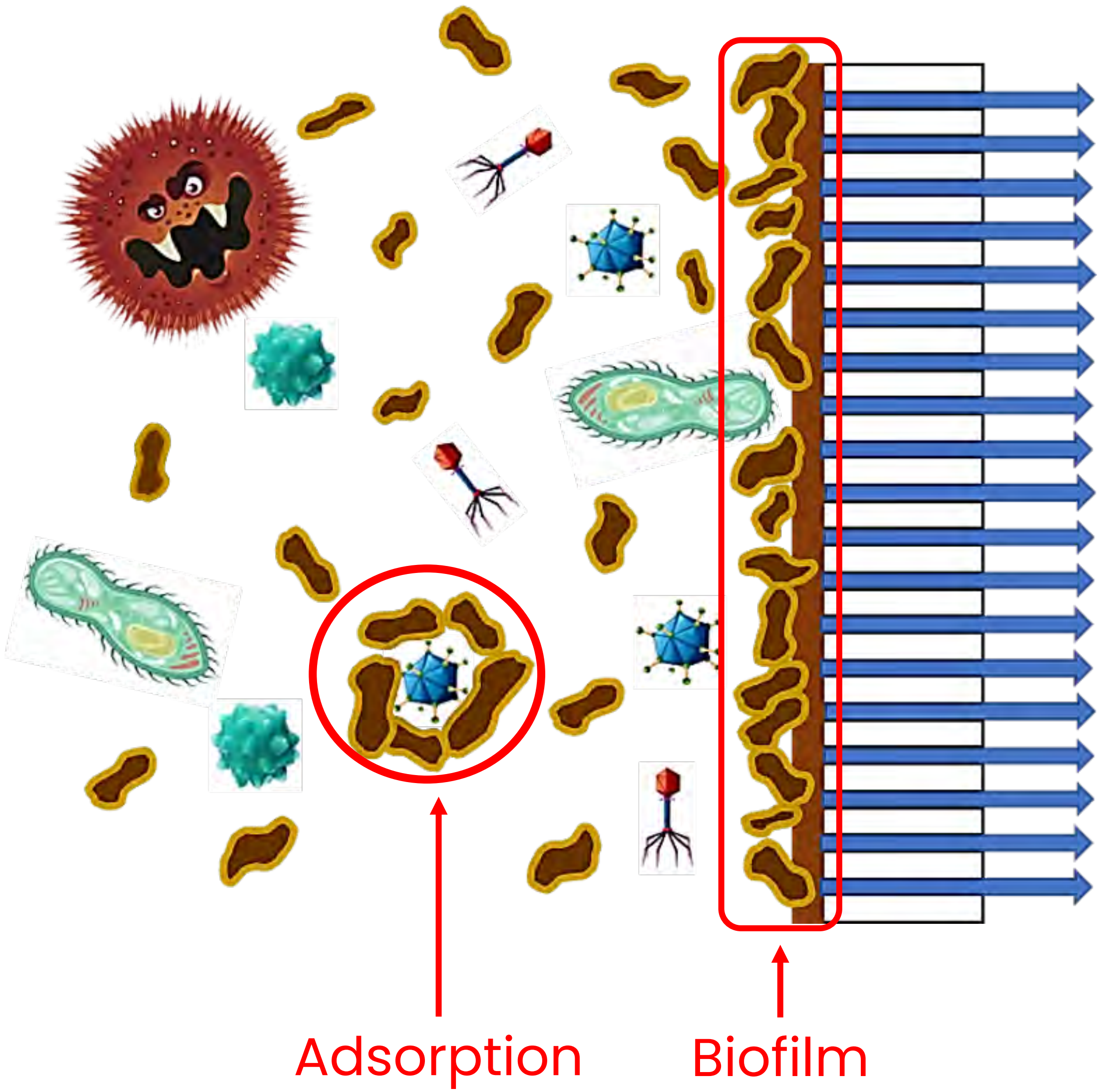


Idea conceived to use real-time sewershed monitoring for potable reuse

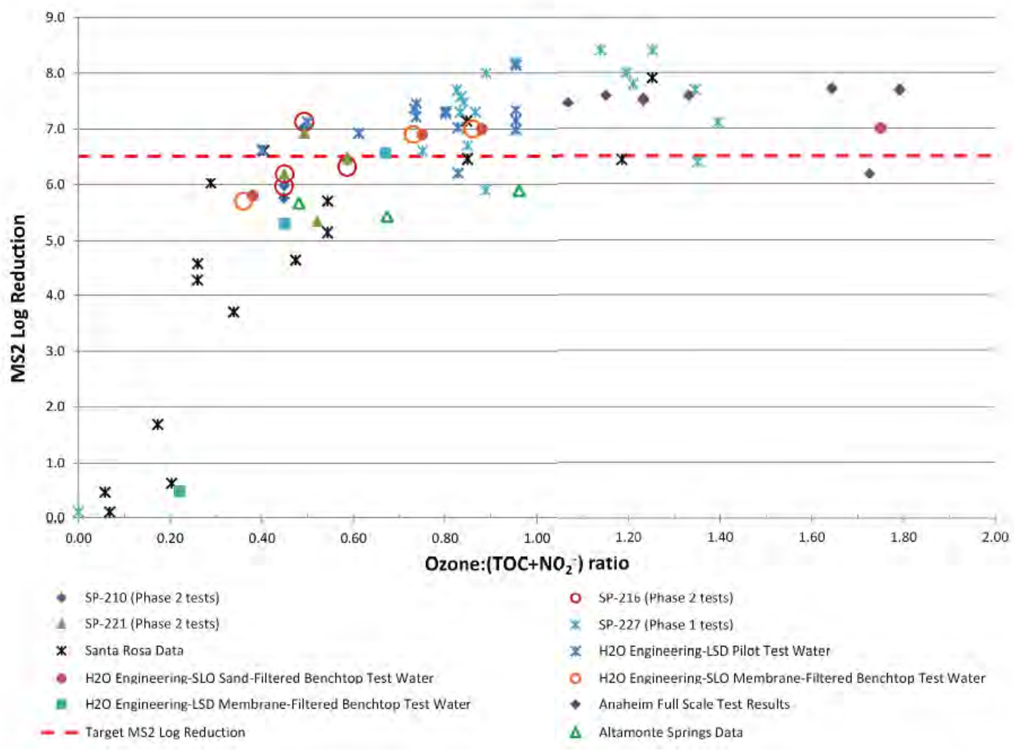
Pathogen Removal Performance and Surrogates

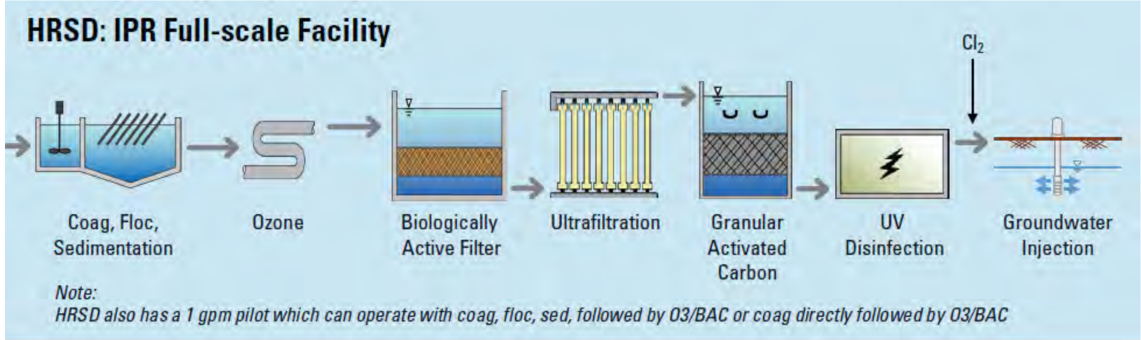
MBRs Remove Pathogens, but WRF 4997 & 4959 Defined How They Do It



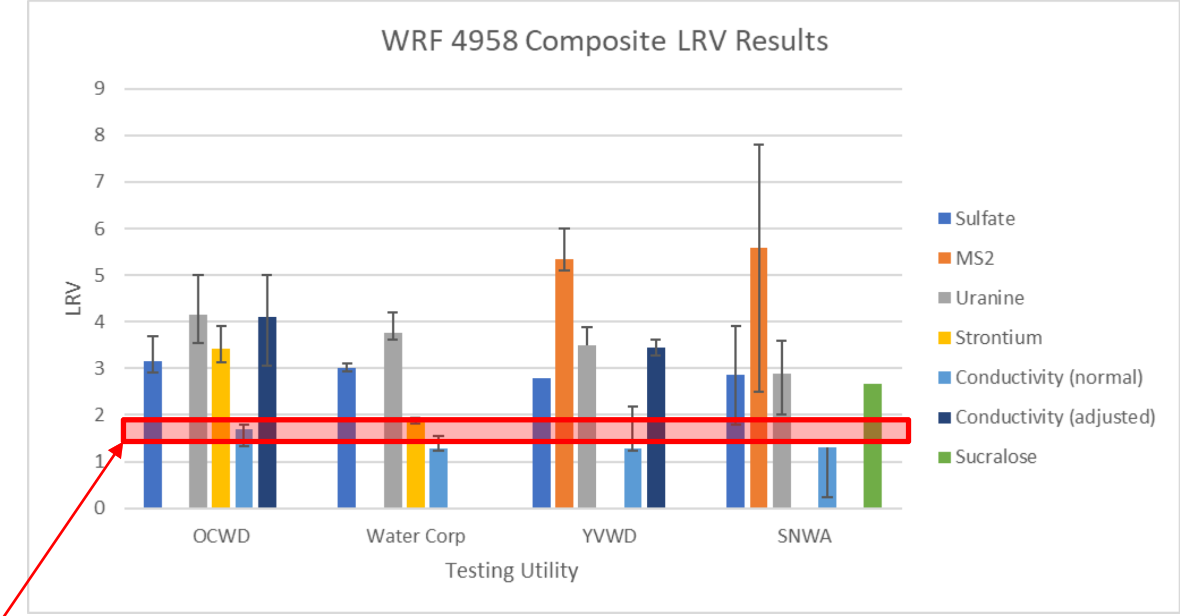


Ozone is a Fabulous Virus and Bacteria Disinfectant, and Biofiltration Can Provide a Pathogen Barrier…WRF 5129 Will Define Performance and Monitoring



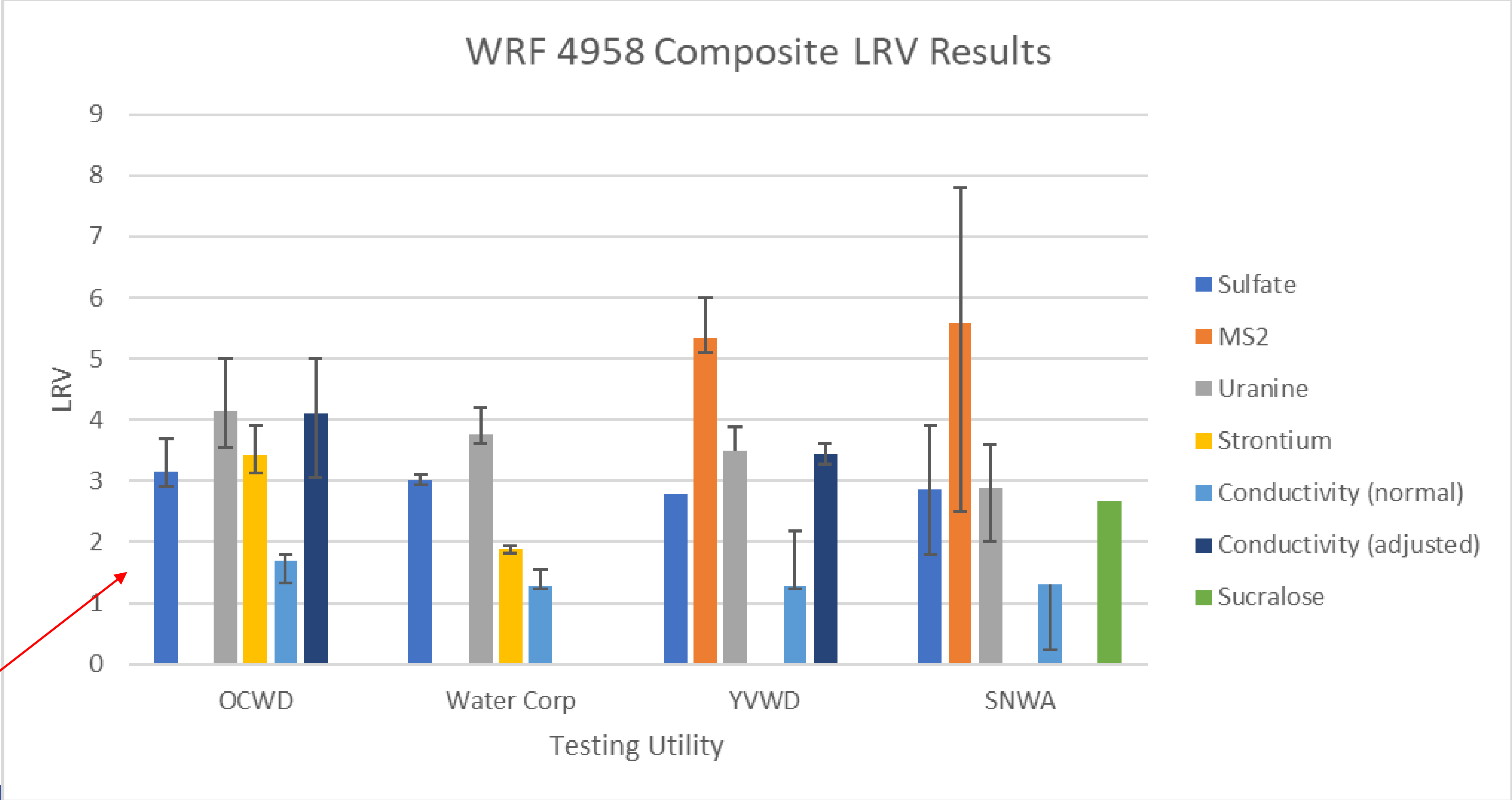


RO Removes Salt, TOC, and All Pathogens to a Significant Level…But WRF 4958 is Detailing the Proper Surrogates to Correlate with LRV



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!

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

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, Hikaru Iso, Shotaro Torii, Yasuhiro Matsui, Hiroyuki Katayama

Trace Chemical Monitoring

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

- O3: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

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

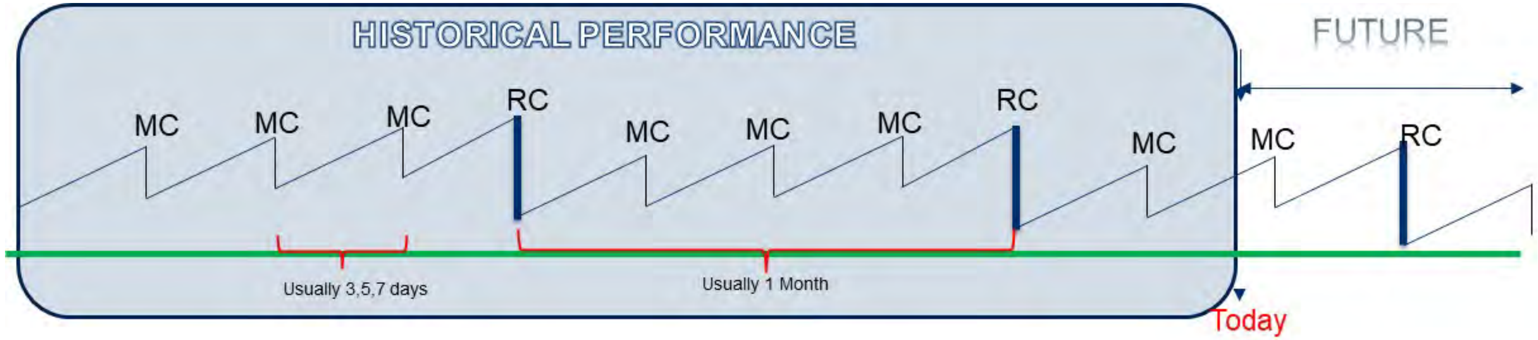
Activated Sludge is Well Proven, but AI/ML for Potable Reuse is Just Beginning


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

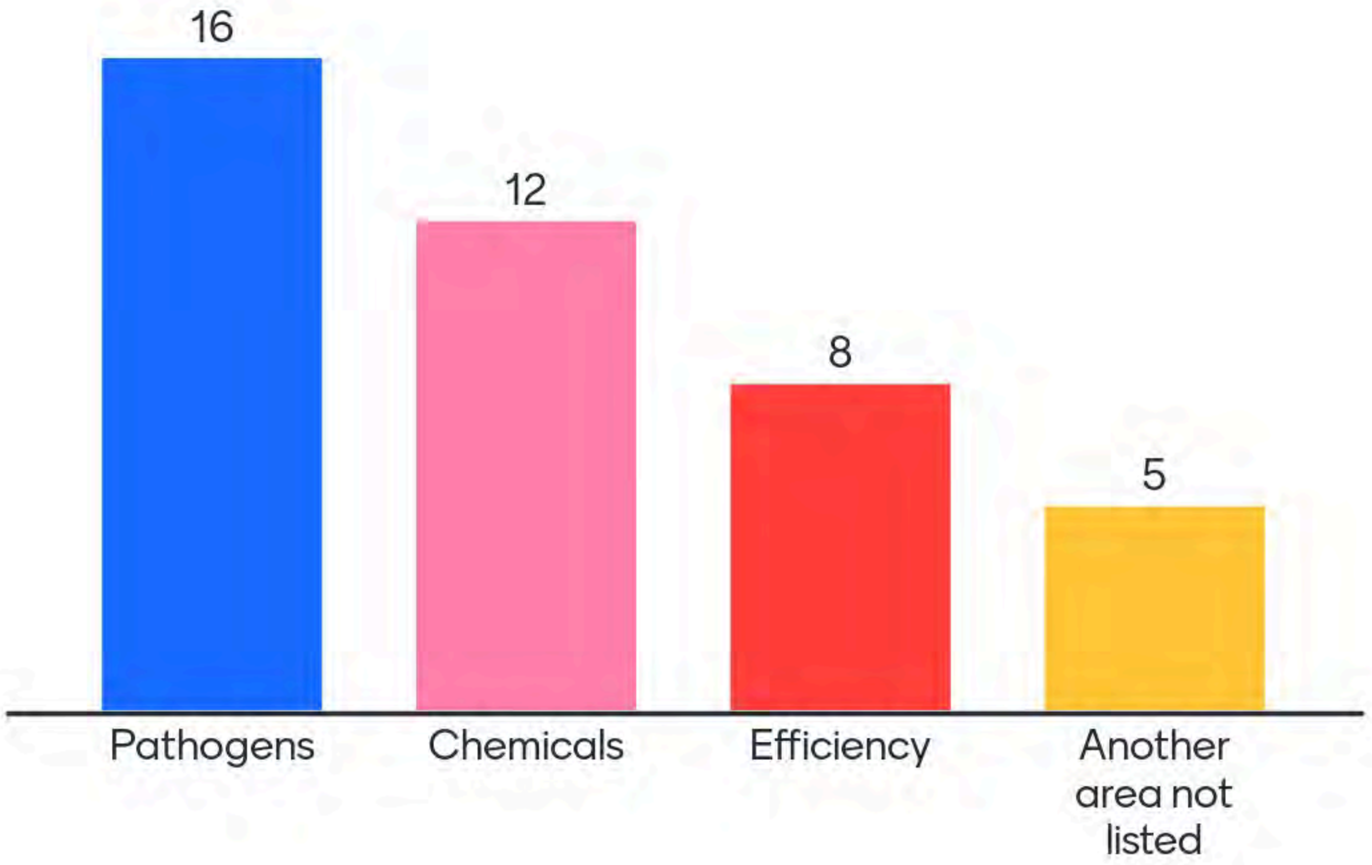
- **Real Time Pathogen Monitoring Demonstration Testing**
  - ✓ Builds Upon NWRI Efforts
  - ✓ Identifies Analytical Methods for (near) Real Time Monitoring of Different Pathogens and Surrogates
  - ✓ Includes Online Demonstration
  - ✓ $350,000

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?



Mentimeter

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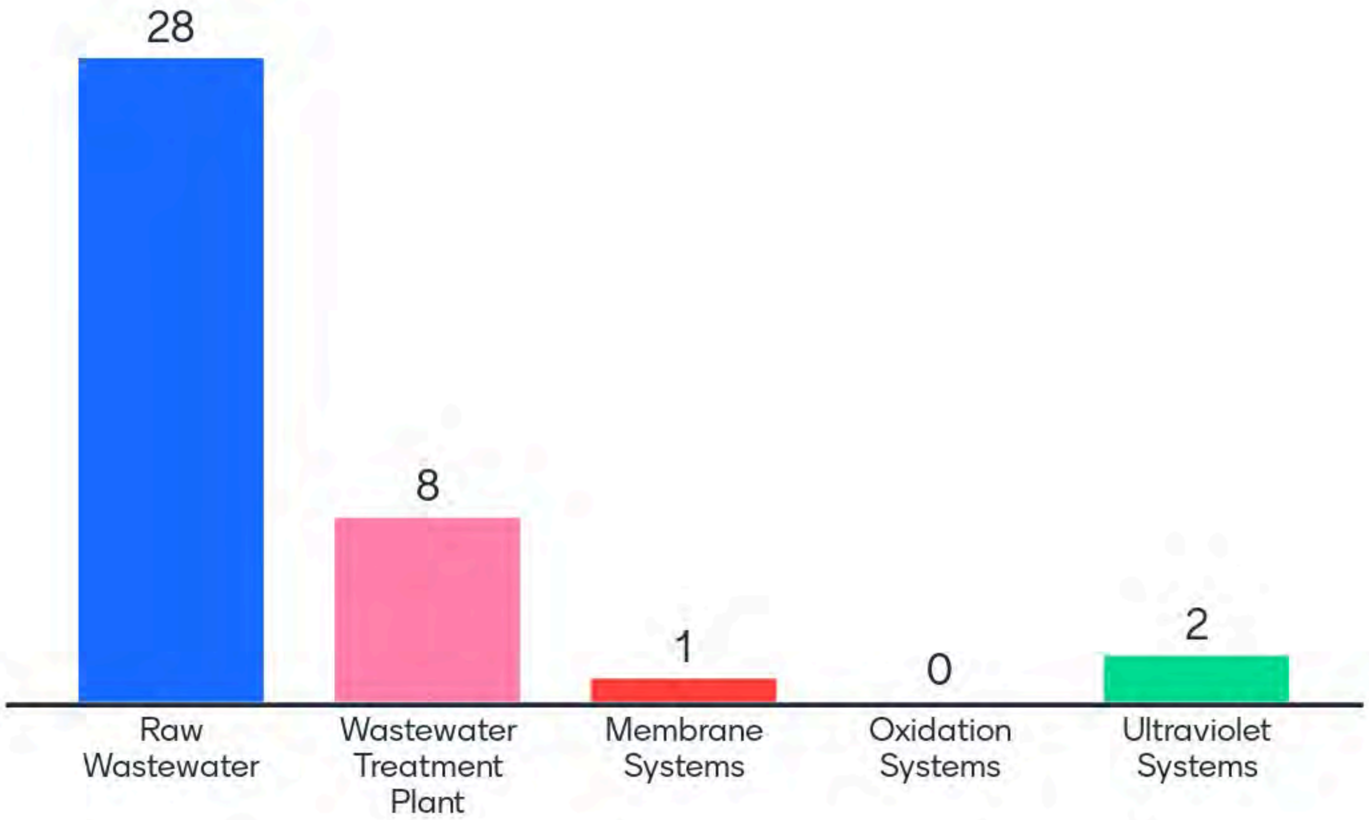
What part of the treatment process poses the greatest risk?

Mentimeter



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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

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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

WRF Provides LOTS of Decision Support

In 3 Major Categories

1. Applied engineering & science
2. Synthesis report(s) on reuse R&D
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WRF Provides LOTS of Decision Support

<u>In 3 Major Categories</u>

1. Basic engineering research
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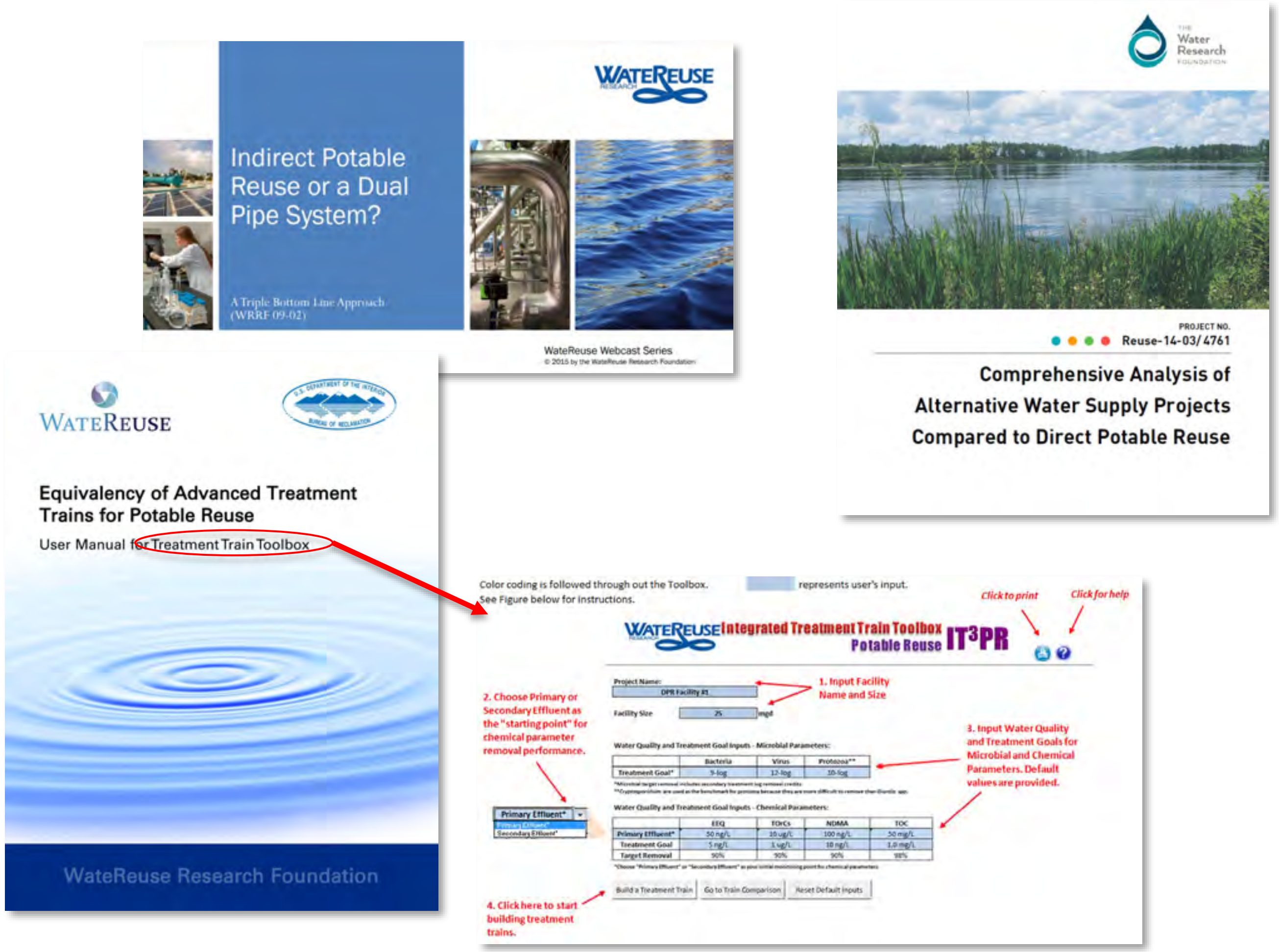


WRF Provides LOTS of Decision Support

In 3 Major Categories

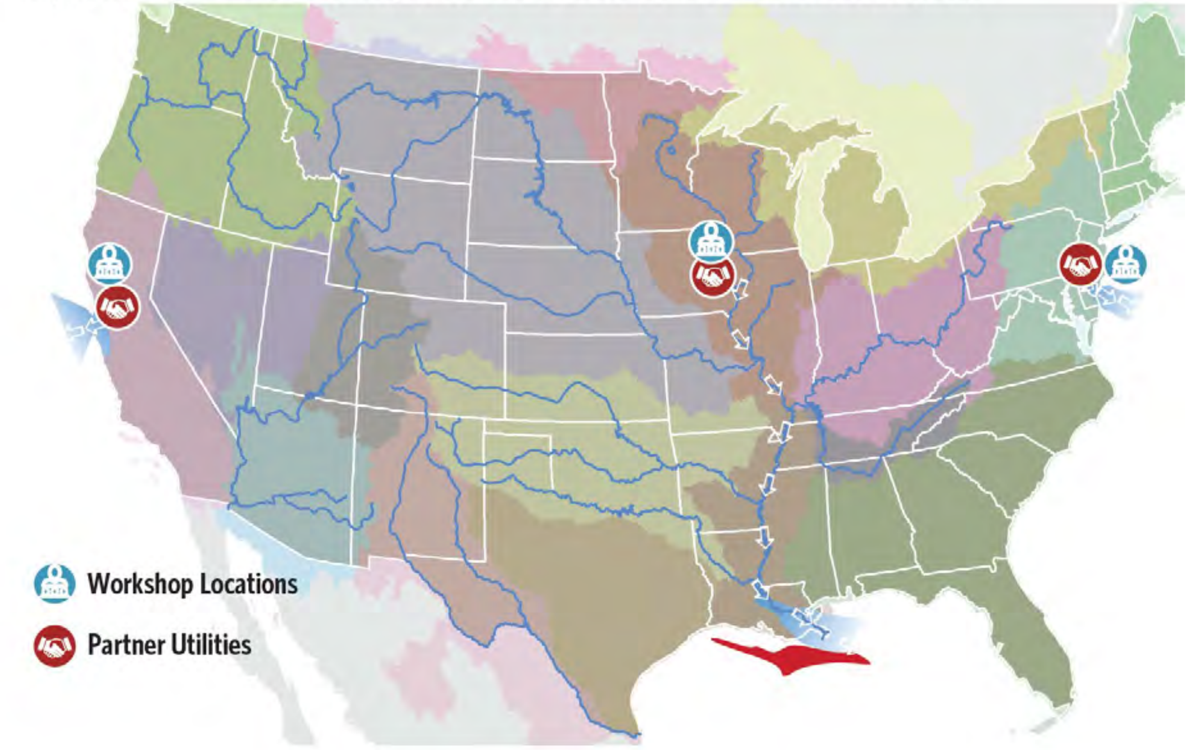
1. Basic engineering research
2. Synthesis report(s) on reuse R&D
3. Decision support **guidance & tools**

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



THE Water Research FOUNDATION

IOWA SOYBEAN Association

CEDAR RAPIDS City of Five Seasons

PHILADELPHIA WATER DEPARTMENT

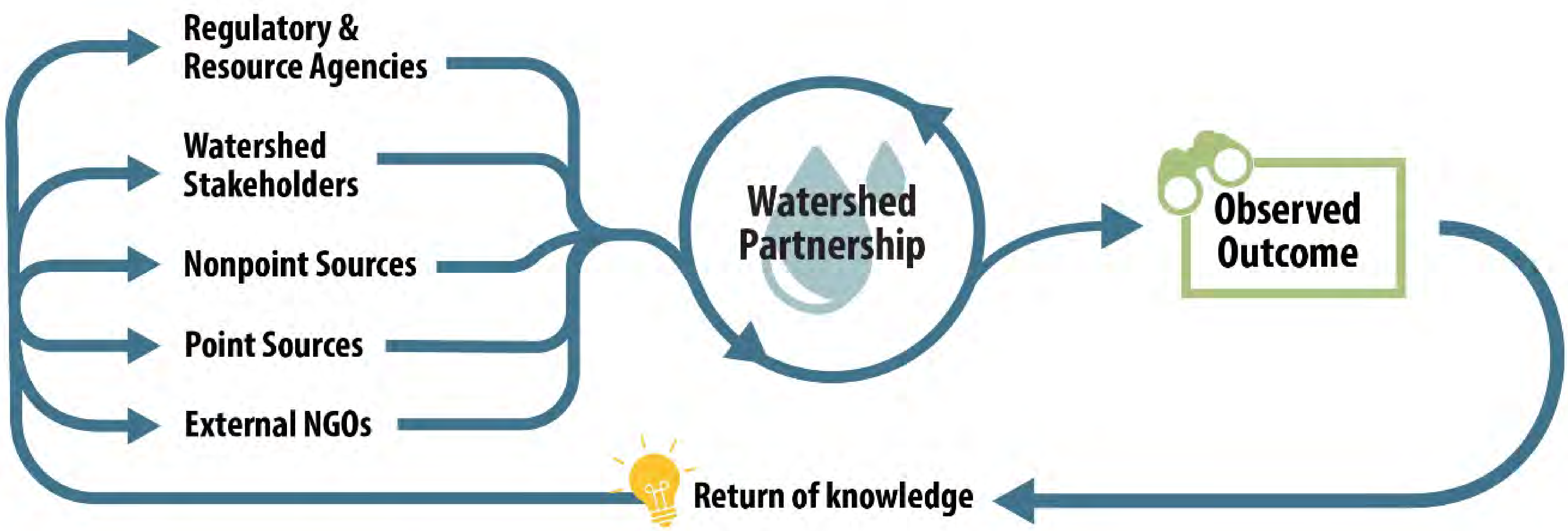
BACWA BAY AREA CLEAN WATER AGENCIES

HDR

LimnoTech

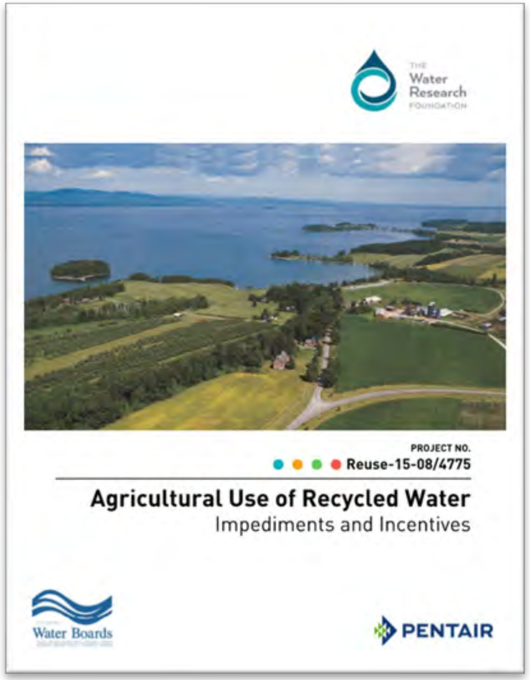
UNIVERSITÉ LAVAL

Optimal Watershed Partnership to Yield Water Quality Improvements through Adaptive Management



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

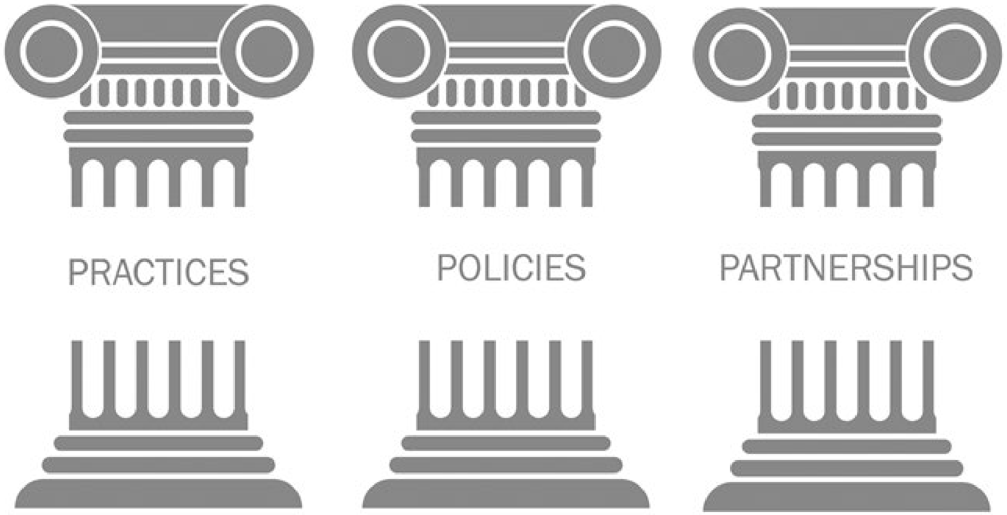
- Water Quality
- Water Quantity
- Technology
- Regulatory & Institutional
- Economic & Financial
- Outreach & Coordination
- Supply/Demand Imbalance
- Perceived Risks
- Food System Supply Chain Complexities



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

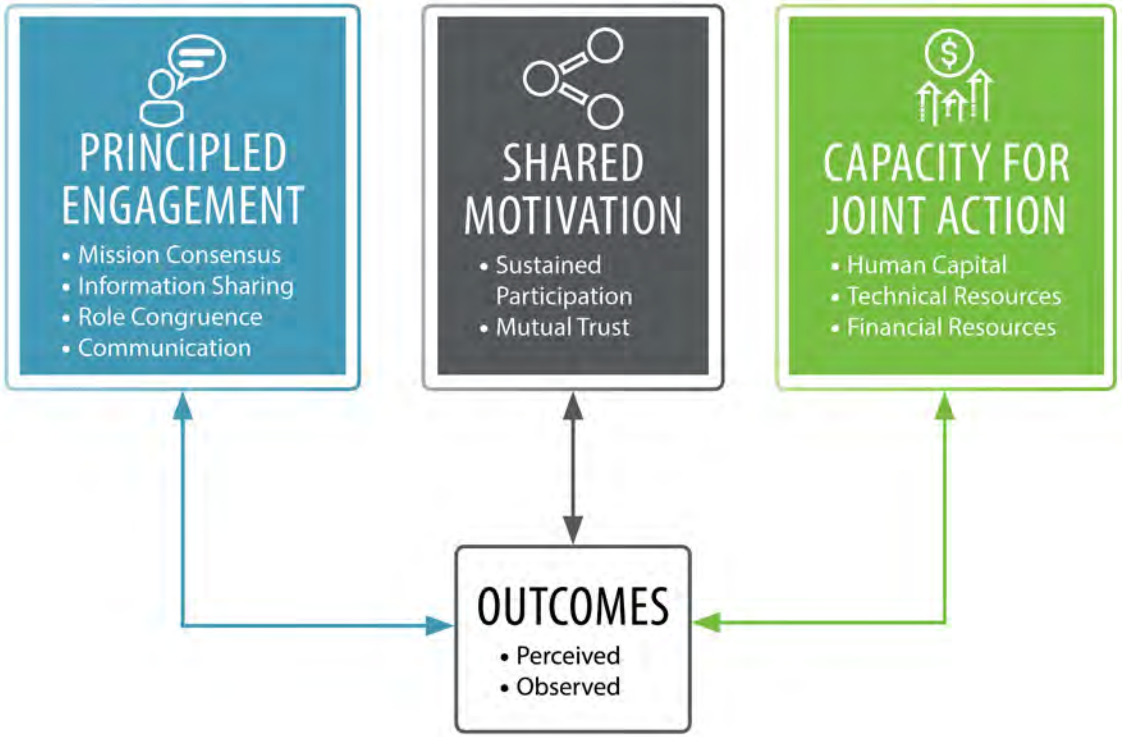


- Practices
  - Nutrient Removal Treatment
  - Best Management Practices
- Policies
  - Regulatory Frameworks
  - Watershed Governance
- Partnerships
  - Collaboration
  - Leadership

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

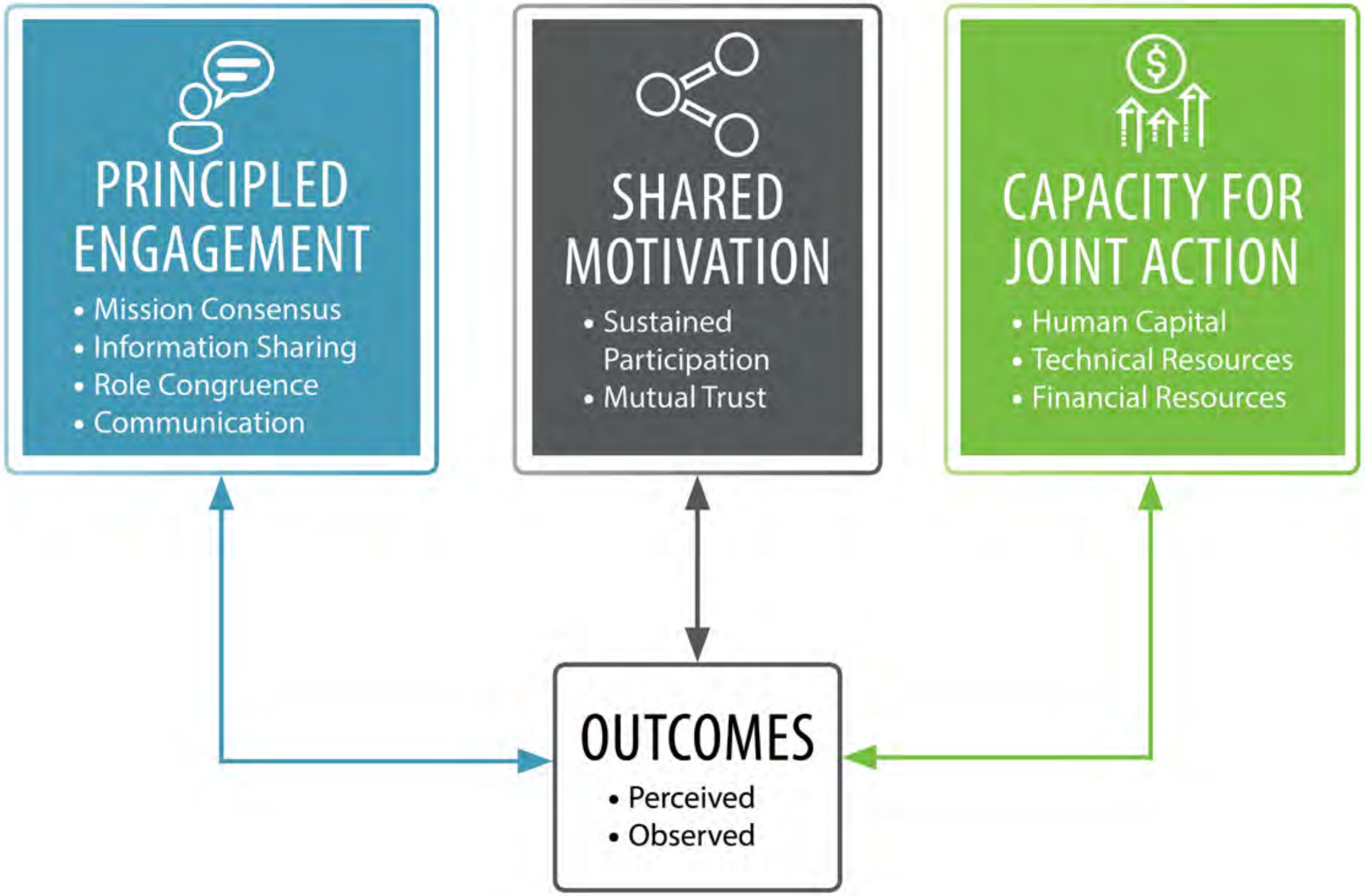
Biddle, 2017

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

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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

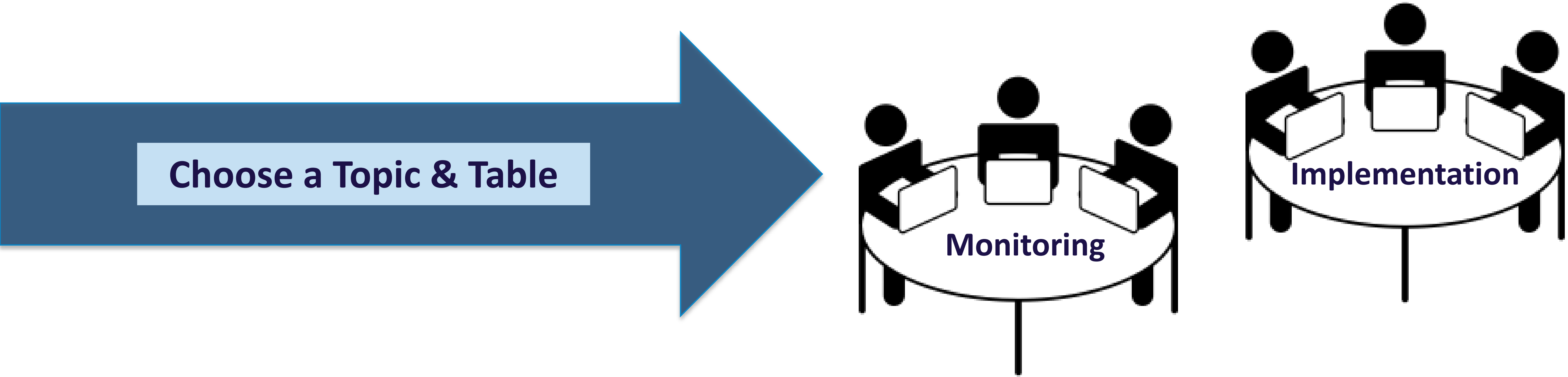
Pinar Balci, NYDEP

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

Appendix B

Project Concepts Developed During Facilitated Breakout Sessions

Source Water

1. Assessment of membrane fouling/foulants to inform source control, pretreatment, and/or wastewater treatment
    a. First step: identify the foulants on membranes (RO)
    b. Send step: investigate potential to address through source control, pretreatment, and wastewater treatment
    c. Examine tradeoffs in energy usage/efficiency, cap cost, operational costs, scalability
2. Implications of occasional secondary wastewater source waters on potable reuse
    a. What are the broader impacts of Inflow and Infiltration (I&I) into wastewater collection systems, including stormwater, and capture of dry weather flows.
    b. How should the implications inform design of wastewater treatment and advanced treatment facilities.
3. Managing reuse based on impacts of CSOs.
    a. How should reuse projects be planned/managed based on CSO issues.
    b. How to continue to operate reuse program during these events.
    c. What are changes and/or challenges for WQ
4. Treatability of co-produced water for reuse
    a. Co-produced water can vary widely due to sites and extraction approaches.
    b. In particular, some co-produced water is very saline.
    c. Also, co-produced water is often poorly characterized.
    d. The "receptor" (e.g., application) defines the end use (e.g., fit for purpose)
    e. Subtopic: suitability of co-produced water for potable reuse
5. Impact of stormwater's water quality of municipal wastewater reuse
    a. How does inclusion of stormwater in wastewater facilities impact chemical water quality, treatability?
    b. What is the consistency of water quality?
    c. What are the special and temporal variability and impact on reuse?
6. Impact and management of wastewater sidestreams for reuse.
    a. The water quality of sidestreams is challenging and sending back to the head of the wastewater treatment plan reintroduces those constituents back to the wastewater flows.
    b. Disposal of sidestreams to landfills is being restricted.
    c. What are the potential WQ impacts to the reuse project?
    d. Are there treatability issues?
7. Source water characterization of industrial discharges and impacted on municipal wastewater.
    a. Examine industrial discharges to wastewater collections systems.
    b. Assess impact on municipal wastewater treatment processes and reuse WQ.
    c. What are potential source control opportunities?
8. Pretreatment for industrial programs to improve reuse
    a. Get a better handle on WQ from industrial dischargers
    b. Develop guidance for implementing local limits to protect reuse projects
    c. Develop appropriate pretreatment best practices (best management practices)
    d. How does source control save costs and provide other benefits (e.g., WQ)
    e. Are are surrogate compounds that can be used?

   f. Subtopic: Treatability or treatment performance impacts
9. Assess completing needs for wastewater facilities
   a. Including
      i. Energy recovery
      ii. Nutrient recovery
      iii. Water reuse
      iv. Environmental stewardship
   b. How can multiple needs be managed?
   c. Are there unintended consequences?
   d. How to support a circular economy?
10. Economic tradeoffs of treatment steps
   a. Where is biggest bang for buck?
      i. Source control
      ii. Pretreatment
      iii. WW treatment (NDN)
      iv. Advanced treatment
   b. Use of offsets?
11. Economic, Water Quality, Operations and Energy Impacts of Full Nitrifying vs. non-Nitrifying wastewater treatment plants
   a. Phase 1: desktop study
   b. Budget: $150,000
12. Economic Impacts of Enhanced Source Control on Local Industries
   c. What are the costs of enhanced source control on local economy when undertaking a potable reuse project?
   d. Budget: $150,000
13. Impacts of Organics Management and Treatment Processes (e.g. Co-digestion) on IPR/DPR
   e. Problem Statement: Wastewater utilities are processing more organics (consolidated sludge, food wastes) for multiple benefits. We need to know more on the IPR/DPR impacts of the sidestreams and treatment within the wastewater treatment plants
   f. High carb wastes include: FOGs, food waste, food processing wastes, etc.
14. Evaluate the Impacts of New/Innovative Wastewater Treatment Processes on Source Water Quality
   g. Problem Statement: New processes are being developed for wastewater treatment plants. The impacts of these processes on source water for potable reuse is unknown.
      i. Example processes: AGS, MBBR, MABR, MBR, etc.
   h. Desktop study to identify processes of interest after specific processes are identified ($200,000)
   i. Maybe some piloting ($200,000)
15. Onsite Potable Reuse Needs (Smaller Sewershed Challenges)
   a. Problem Statement: Lack of characterization between smaller onsite potable reuse and large system potable reuse. Given the ongoing push for potable reuse to meet green certifications like LEED and Living Buildings.

  b. Research Objectives: Characterize the differences between large source and smaller limited source water and treatment XXX? To develop challenges and pros and cons of the two approaches.

16. Building National Consensus Then a Database to Identify Presences, Variability, and Concentrations of Constituents in Source Waters
    c. Chemistry/biology
    d. Enhance understanding
        i. Local limits and needs for monitoring/sensors
17. Impacts of Sidestreams as a Component of Source Water for Potable Reuse
    a. Objectives: 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
    b. Approach: 1 year bench-scale testing at minimum, but pilot preferred
        i. Budget/duration: $350k – 2 years
18. Public health and process benefits of nitrification as pretreatment to an AWPF
    a. Objectives: 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
    b. Budget/duration: $200k – 1 year
19. Flow Equalization for Potable Reuse
    e. Objectives: 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
    f. Budget/duration: $200k – 1 year

Treatment

1. Quantifying Energy Demand Associated with Alternative Water Supplies
    a. Problem Statement: In developing a project approach, we need to understand the associated energy costs and be able to communicate it to the public.
        i. For example: IPR vs DPR, imported water vs. DPR
    b. Objectives: quantify energy use for different water sourcing, treatment and distribution. Create accounting methos.
    c. Budget: $200,000
2. Developing a Standard Protocol for Wastewater Treatment Effluent Characterization

   a. Problem statement: We need a standard process to determine the level of treatment needed to characterize secondary effluent source water. Processes vary, source water varies so treatment needed varies. Probability of occurrence. Analogous to MBR LRVs.
   b. Objectives: Develop standard method for characterizing level of treatment. Get the data and do the math.
   c. Budget: $500,000
3. Optimizing Process and Energy Efficiency in Potable Reuse
   a. Problem statement: System are built based on water quality treatment goals (i.e. chemicals, pathogens). We need to assess systems based on the energy impacts of the design. With that information, informed multi-benefit design decisions can be made.
   b. Objectives: Understand the measurement and standards in place. Assess treatment train over-design gaps. Analysis vs. alternative sources
   c. Budget: $349,999
4. Best practices of monitoring pathogens in potable reuse (intricacies of measurements in various different water qualities)
5. Impacts of process design on pathogen LRVs in Membrane Bioreactors
6. Development of surrogate monitoring for pathogens in Membrane Bioreactors (building on the output from 4959)
7. Review of nature-based systems and their role in potable reuse
8. Understanding the nature and impact of biofiltration biology
9. Treatment options for tough to treat wastewater streams (centrate, intermittent wasting, ...) and the impact on effluent quality and downstream unit operations.
10. Treatment Trains working together - understand the impacts of upstream treatment on downstream unit operations
11. Fate of PFAS across the treatment train - lessons learned in potable reuse
12. Alternative Approaches to Improve Energy Conservation for Energy Reduction
    a. Problem statement: Potable reuse requires additional processes that increase the energy footprint.
    b. Objectives: Identify major energy drivers and mechanisms of energy use. Compare public health risk tradeoffs with lower carbon footprint. Survey of wastewater treatment plants and advanced water purification facilities.
    c. Budget: $100,000 to $200,000
13. Monitoring Treatment of Toxic Industrial Pollutants
    a. Problem statement: Are pass through chemicals present at significant concentrations to cause public health risk? If so, how are they treated?
    b. Objectives: Evaluate multiple sites and bench test bio effluents with concentrations above certain thresholds. Spiking tests with selected chemicals
    c. Budget: $250,000
14. Ozone LVR for Potable Reuse
    d. Problem statement: Ozone is a critical virus barrier yet there’s a lack of literature on pathogen and surrogate ozone disinfection kinetics in the wastewater matrix.
    e. Objectives: Determine which virus should be used to establish LVRs. Perform an occurrence study of viruses and surrogates. Review epidemiology literature. Perform dose/response testing looking at indigenous and spiked/seeded pathogens.
    f. Budget: $300,000

15. Alternative Treatment Processes: Reimagining Advanced Water Treatment
    g. Problem Statement: The focus on reverse osmosis and ozone/biologically active filtration treatment may have blinded us to other processes and approaches available and/or used in surface water treatment (e.g., titanium oxide, new oxidants, pasteurization)
    h. Objectives: Identify processes and strategies that can address critical contaminants and advanced water treatment objectives. Perform literature review and hold workshops.
    i. Budget: $150,000
16. Energy Minimization + Innovation vs. Safety/Reliability:
    a. Question: Given the projected demand for potable reuse, how can we reduce overall energy footprint moving forward?
    b. Objective: Develop "big picture" strategies to reduce energy footprint from facility siting, planning, secondary treatment, advanced treatment, blending, WTP, and distribution
    c. Budget: $350,000
    d. Partners: WEF, AWWA
17. Potable Reuse Specific Treatment Guidelines:
    e. Question: How do we know how much ozone treatment we need to achieve disinfection goals?
    f. Objective: Develop a protocol for establishing LRVs for ozone (with and without peroxide) when the dissolved ozone residual is either very low or zero
    g. Budget: $350,000
    h. Partners: AWWA, EPA

Monitoring

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1. Incorporate Risk Assessment to Target and/or Prioritize Monitoring
    a. Tie to critical control point framework
    b. How can risk assessment methods inform prioritization of determining where and how to monitor?
    c. State of the science: where do we need risk assessment
2. Keeping Up with the Instruments and Monitoring Effectiveness
    a. How reliable are the existing sensing technologies?
        i. Within collection system, wastewater treatment plants, drinking water treatment plans
    b. State of the science review, look at surrogate indicators
    c. Are the instruments we have capable to deliver the results we need?
        i. In light of the realities of these waste streams
        ii. Variability in flow characteristics
3. What are the methods that we can use to identify the low probability/high threat events that can disrupt system operations?
    a. Disrupt biological treatment
    b. Pass through reverse osmosis and filters
4. How can artificial intelligence and machine learning approaches be used for process optimization/management of data for system risk management?

  a. Variable flow monitoring (e.g., through pretreatment, dischargers)

5. Adapting PCR Methods for near-real time monitoring
    a. Evaluate the virus reduction credits for various treatment processes
    b. What are the best indicators/surrogates?
    c. Compare the results with culture-based methodology
    d. Track with online surrogates
    e. Evaluate the required sample volumes
    f. Budget: $300,000
6. Benefits of VOC Monitoring in wastewater treatment effluent for control and detection of low molecular weight organic spikes
    g. Budget: $250,000
7. Accessible Monitoring for Small Systems
    h. Study looking at existing monitoring tools
        i. Frequency, methods, location
    i. Evaluate the costs/benefits of putting together a monitoring train. What is the cost of an extra log credit and can it be obtained more easily through a different method (treatment vs. monitoring)?
    j. Budget: $100,000 to 150,000
8. Early Warning System for Operational Efficiency
    a. Problem statement: Current monitoring is focused on parameters impacting public health. However, there are compounds that could impact operations that do no impact public health (i.e., food grade glue).
    b. Objectives: Identify compounds that could cause problems that would affect each treatment process of interest
9. Identify Alternative Water Sources to Augment Wastewater Flows for Reuse and Associated Monitoring Needs
    c. Problem statement: Fully integrating stormwater into sewer system creates a combined sewer problem. However, additional sources such as stormwater can be collected to expand water supply
    d. Research objective: To determine monitoring points and operational triggers that don't compromise the integrity of the reuse system while maximizing water supply
10. Guidance Document for Advanced Treatment Monitoring and Implementation
    e. Problem statement: There is no consistency in monitoring equipment requirements (e.g., location of instrumentation, methodologies, data frequency, etc.)
    f. Research objective: Provide greater consistency in guidelines for instrumentation
11. Finding Correlations Between Raw Wastewater Quality and Potable Reuse Risk
    a. Builds Upon WRF 5048 and 4960
    b. Identifies Chemical Pollutants that Pose Risk to Purification Trains
    c. Determines Correlations Between Target Chemical and Surrogates
    d. Budget: $250,000
12. Real Time Pathogen Monitoring Demonstration Testing
    e. Builds Upon NWRI Efforts
    f. Identifies Analytical Methods for (near) Real Time Monitoring of Different Pathogens and Surrogates

   g. Includes Online Demonstration
   h. Budget: $350,000
13. Evaluation of Chemical Spikes in RO Permeate and Post RO Ozone/BAC Evaluation
   i. Detect Chemical Pollutants That Pass Through RO
   j. Determine Risk and Treatability Through Ozone/BAC
   k. Budget: $350,000
14. Use of AI/ML for Potable Reuse Water Quality, Efficiency, and Risk Minimization
   l. Builds Upon MWD, USBR, NAWI grants
   m. Identifies Approaches to Improve Efficiency and Protect Water Quality
   n. Includes Operations Engagement
   o. $250,000
15. Better understanding CECs for potable reuse: Non-Targeted Analysis (NTA) Method Robustness Study.
16. Risk Assessment of Potable Use of Recycled Water to Support Public Review and Acceptance.

Implementation

1. Building Public Trust in Reuse Programs
   a. Communications; specific to trust profile of utilities
   b. Specific to constituents of concern; exposure pathways; blind sampling/comparison to other utilities; yuck factor – simple language
2. Partnerships
   a. Leverage nutrient management holistic approach for improved
   b. Key success factors in partnerships
   c. How to identify co-benefits
   d. WRF4974
3. Consumer confidence report for CWA
   a. What does public expect to see?
   b. What indicators matter to public?
   c. What chemicals in reuse can be communicated to share w message with public?
4. Create business case for reuse programs
   a. Establish and quantify costs and benefits (ranges?)
   b. Document and quantify risks (i.e., climate change, water availability, reg limits)
5. Workforce development needs
   a. How does AI change staffing needs?
   b. Process efficiencies
6. Interagency Collaboration for Reuse: Understanding Successes, Failures, and Guidance
   a. Problem statement: Institutional and cultural silos exist. Financial and rate challenges exist. These barriers can slow or halt reuse projects. There is a lack of wholistic thinking.
   b. Research objectives: pull together case studies, successful and unsuccessful
   c. Identify pinch points and barriers
   d. Include: examination of cultural barriers, equity, who were the champions
   e. Case studies cover multiple agency types
   f. Funding issues, operations (rates)

    g. Develop guidance or framework (could be part of separate project, if so, increase project budget)
    h. Budget: $100,000 to $200,000
7. What to expect when you're birthing a water reuse project: Frequently asked questions for/from stakeholders
    i. Problem statement: Agencies don't understand stakeholder concerns that might arise as they implement reuse
    j. Objectives:
        i. Help agencies know what they don't know
        ii. Understand the playing field
        iii. Review of utilities' FAQs by stakeholders (surveys & case studies)
        iv. Develop FAQ guide for stakeholders, including separation by groups: ag, industry, rate payers, others.
        v. Include info that utilities can provide them
8. Understanding the impediments to potable reuse
    a. Compare and contrast society "acceptance" of solids recycling, energy conservation
9. Case studies/examples marketing programs
10. What should we really be concerned about? Defining an acceptable level of risk for:
    b. Environmental health
    c. Public Health
    d. Economic
11. How do we challenge the concept / mindset that potable reuse is too expensive?
    e. We need to drive innovation to develop technologies that minimize our need to "take things out"
12. Framework to bring together state regulators / state program to promote responsible reuse implementation
    f. Problem statement: state programs (and state regulators) are a mosaic of policies / approaches that would benefit from alignment
    g. Objective: To ensure that state regulators (water + wastewater) engage in an informed manner to research and rule making
    h. Budget: $100K
    i. Volunteers: NWRI
13. Brine Management: Regional Approaches
    a. What are drivers? (e.g. brine line, brine minimization, resource recovery)
    b. Regional cooperatives
    c. Regulatory drivers in the future
14. Impacts of Regionalization of Wastewater Treatment Facilities on Recycled Water
    d. Reducing wastewater flows
    e. Increase solids in collection system
    f. Regional benefits and/or solutions (I.e., storage)
    g. Outcome: framework for regional cooperation and partnerships (water, wastewater, stormwater)
15. Alignment of local, state, and federal institutions
    h. Identify areas of common ground

        i. Identify inefficiencies and proactively address
    i. Keep differences (innovation alive!)
    j. Case studies, white papers
    k. Steps for developing reuse programs
    l. WRAP, CA Action Plan, local agencies
16. Impacts of water rights in pursuing reuse projects
    m. Poor WQ in one location
    n. Good WQ leaving the location
    o. Water rights with wastewater
        i. Impediments to reuse
        ii. Stranded assets
    p. e.g. 212 analyze discharge flows (changes)
17. “Inreach Approaches” for
    q. Planning and implementation
    r. Listening to community groups
    s. Best practices includes DAC/underserved communities in project planning to inform decision making

Appendix C

Follow-Up Prioritization Survey

Developing a Nationwide Water Reuse Research Roadmap Workshop

Follow-Up Prioritization Survey

Listed below are research projects that were developed during the Sunday afternoon Workshop: Developing a Nationwide Water Reuse Research Roadmap. Research projects are organized into four broad categories: Source Water, Treatment, Monitoring, and Implementation.

We invite you to review and prioritize your top 4 projects in each category to help inform WRF's future project planning and in support of the Water Reuse Action Plan's research strategy (WRAP Action 7.2).

1. **Source Water Research Projects**

Please select your top 4 projects

- ☐ Assessment of Membrane Fouling / Foulants to Inform Source Control, Pretreatment, and/or Wastewater treatment
- ☐ Implications of Occasional Secondary Wastewater Source Waters on Potable Reuse
- ☐ Managing Reuse Based on Impacts of Combined Sewer Overflows
- ☐ Treatability of Co-produced Water for Reuse
- ☐ Impact of Stormwater's Water Quality on Municipal Wastewater Reuse
- ☐ Impact and Management of Wastewater Sidestreams for Reuse
- ☐ Source Water Characterization of Industrial Discharges and Impacts on Municipal Wastewater
- ☐ Pretreatment for Industrial Programs to Improve Reuse
- ☐ Assess Competing Needs for Wastewater Facilities
- ☐ Economic, Water Quality, Operations, and Energy Impacts on Advanced Water Treatment Facilities of Full Nitrifying vs. non-Nitrifying source water
- ☐ Impacts of Enhanced Source Control on Local Industries
- ☐ Impacts of Organics Management and Treatment Processes on IPR/DPR

- ☐ Evaluate the Impacts of New/Innovative Wastewater Treatment Processes on Source Water Quality
- ☐ Onsite Potable Reuse Needs (Smaller Sewershed Challenges)
- ☐ Building National Consensus on (and Database of) the Presence, Variability, and Concentrations of Constituents in Source Waters
- ☐ Public Health and Process Benefits of Nitrification as a Pretreatment to an AWPF
- ☐ Flow Equalization for Potable Reuse

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2. **Treatment Research Projects**

Please select your top 4 projects

- ☐ Quantifying Energy Demand Associated with Alternative Water Supplies
- ☐ Developing a Standard Protocol for Wastewater Treatment Effluent Characterization
- ☐ Optimizing Process and Energy Efficiency in Potable Reuse
- ☐ Alternative Approaches to Improve Energy Conservation for Energy Reduction
- ☐ Pass-through Chemicals' Occurrence and Related Public Health Risk
- ☐ Viral Surrogates for Ozone Log Removal Values (LRV) for Potable Reuse
- ☐ Alternative Treatment Processes: Reimagining Advanced Water Treatment Trains
- ☐ Balancing the Competing Objectives of Energy Minimization and Innovation with Safety and Reliability

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3. **Monitoring Research Projects**

Please select your top 4 projects

- ☐ Evaluation of Chemical Spikes in RO Permeate and Post RO Ozone/BAC
- ☐ Finding Correlations Between Raw Wastewater Quality and Potable Reuse Risk
- ☐ Monitoring Strategy to Incorporate Stormwater as a Reuse Source
- ☐ Use of AI / Machine Learning for Potable Reuse Water Quality, Efficiency, and Risk Minimization
- ☐ Adapting PCR Methods for Real Time / Near Real Time Monitoring
- ☐ Demonstration Testing (building on NWRI Efforts) for Real Time / Near Real Time Monitoring
- ☐ VOC Monitoring for Control and Detection of Low Molecular Weight Organic Spikes

- ☐ Monitoring of Compounds that Affect Operations but are not Harmful (e.g. food grade glue)
- ☐ Wastewater Effluent Early Warning System - Assessing Low Probability / High Threat Events
- ☐ Accessible Monitoring for Small Systems (relevant tech, cost/benefit)
- ☐ Guidance Document for Advanced Treatment Monitoring and Implementation / Keeping Up with the Instruments and Monitoring Effectiveness
- ☐ Better understanding CECs for potable reuse: Non-Targeted Analysis (NTA) Method Robustness Study

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4. Implementation Research Projects

Please select your top 4 projects

- ☐ Building Public Trust In Reuse Programs (Specific To Constituents Of Concern; Exposure Pathways; Blind Sampling/Comparison To Other Utilities)
- ☐ Developing Consumer Confidence Reports / Project Water Quality Reports for Recycled Water Projects
- ☐ How To Create Business Case For Reuse Programs (Establishing and Quantifying Costs and Benefits, and Document and Quantify Risks)
- ☐ Identifying Changing Workforce Development Needs For Reuse & Innovation
- ☐ Interagency Collaboration For Reuse: Understanding Successes, Failures, And Guidance
- ☐ FAQ To Expect When You're Implementing A Water Reuse Project
- ☐ Case Studies/Examples Of Reuse Marketing Programs
- ☐ Defining An Acceptable Level Of Risk for reuse Projects (Environmental Health, Public Health, Economic)
- ☐ How Do We Challenge The Concept / Mindset That Potable Reuse Is Too Expensive?
- ☐ Framework To Bring Together Local, State Regulators / State Programs, And Federal Agencies To Promote Responsible Reuse Implementation and Identify Alignment / Inefficiencies
- ☐ Regional Approaches To Brine Management
- ☐ Impacts Of Regionalization Of Wastewater Treatment Facilities On Recycled Water Project Implementation
- ☐ Impacts Of Water Rights In Pursuing Reuse Projects
- ☐ Outreach Approaches For Including Disadvantaged Communities / Underserved Communities In Project Planning

- [ ] Guidance for Construction of Interagency Agreement for Potable Reuse Projects
- [ ] Risk Assessment of Potable Use of Recycled Water to Support Public Review and Acceptance (includes outreach toolkit)

5. If you would like to suggest a water reuse research project idea related to **potable reuse** that is not listed above, please write it in the blank below:

6. If you would like to suggest a water reuse research project idea related to **non-potable reuse** that is not listed above, please write it in the blank below:

Submit

0%

Appendix D

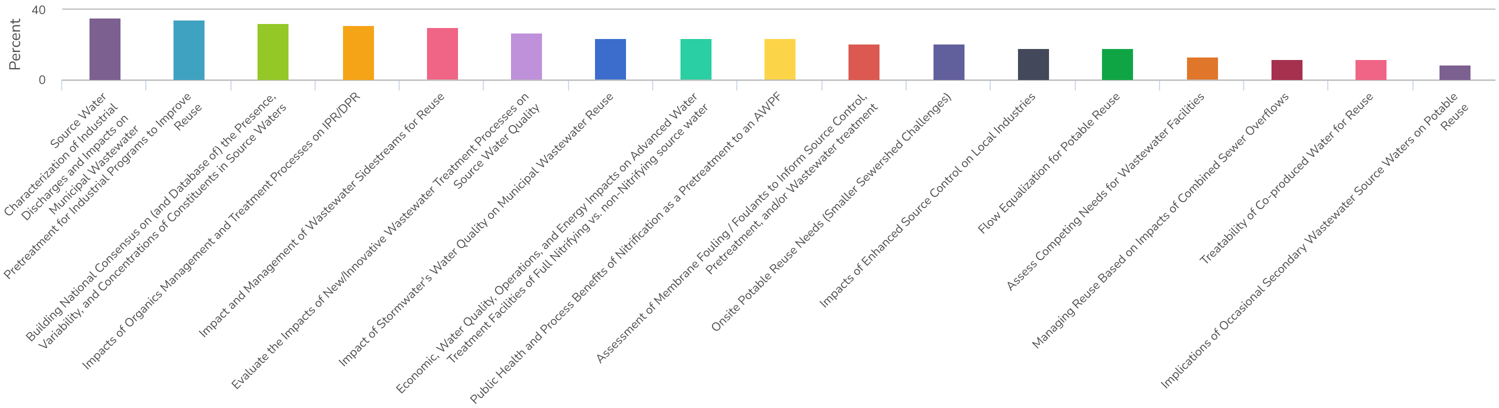
Follow-Up Prioritization Survey Results

Developing a Nationwide Water Reuse Research Roadmap Workshop Survey Results

Response Counts

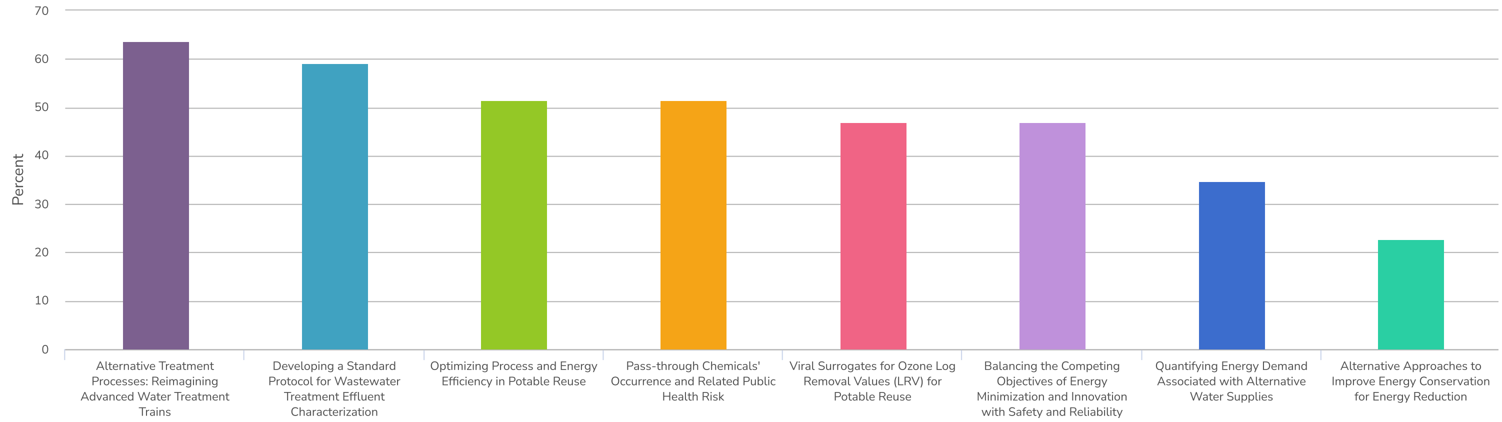
Completion Rate:	**100%**	
	Complete	68
		Totals: 68

1. Source Water Research Projects - Please select your top 4 projects



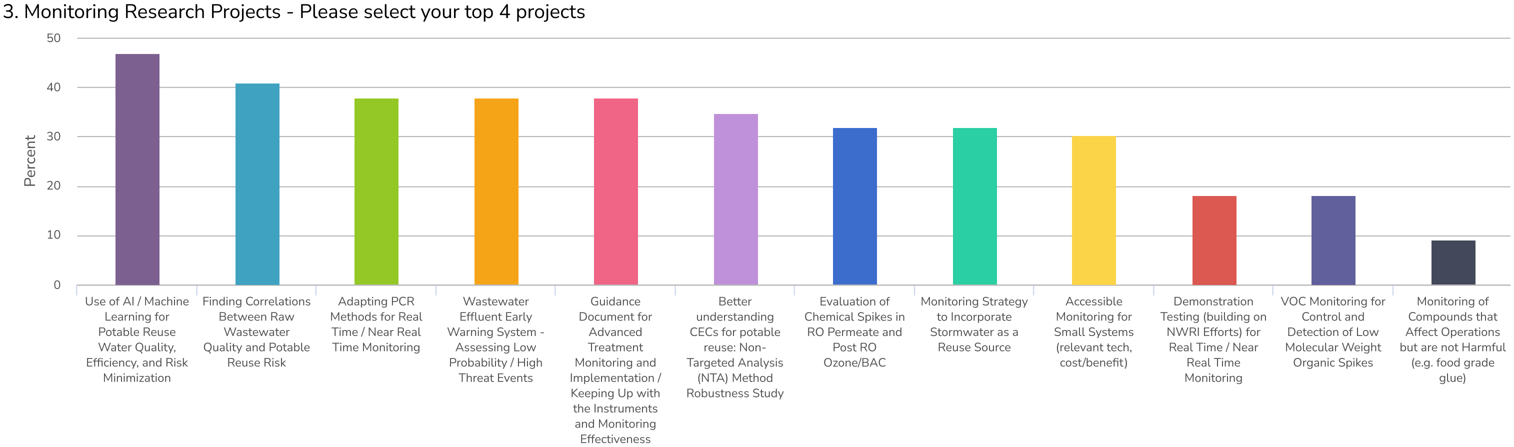
Value	Percent	Responses
Source Water Characterization of Industrial Discharges and Impacts on Municipal Wastewater	35.8%	24
Pretreatment for Industrial Programs to Improve Reuse	34.3%	23
Building National Consensus on (and Database of) the Presence, Variability, and Concentrations of Constituents in Source Waters	32.8%	22
Impacts of Organics Management and Treatment Processes on IPR/DPR	31.3%	21
Impact and Management of Wastewater Sidestreams for Reuse	29.9%	20
Evaluate the Impacts of New/Innovative Wastewater Treatment Processes on Source Water Quality	26.9%	18
Impact of Stormwater's Water Quality on Municipal Wastewater Reuse	23.9%	16
Economic, Water Quality, Operations, and Energy Impacts on Advanced Water Treatment Facilities of Full Nitrifying vs. non-Nitrifying source water	23.9%	16
Public Health and Process Benefits of Nitrification as a Pretreatment to an AWPF	23.9%	16
Assessment of Membrane Fouling / Foulants to Inform Source Control, Pretreatment, and/or Wastewater treatment	20.9%	14
Onsite Potable Reuse Needs (Smaller Sewershed Challenges)	20.9%	14
Impacts of Enhanced Source Control on Local Industries	17.9%	12
Flow Equalization for Potable Reuse	17.9%	12
Assess Competing Needs for Wastewater Facilities	13.4%	9
Managing Reuse Based on Impacts of Combined Sewer Overflows	11.9%	8
Treatability of Co-produced Water for Reuse	11.9%	8
Implications of Occasional Secondary Wastewater Source Waters on Potable Reuse	9.0%	6

2. Treatment Research Projects - Please select your top 4 projects



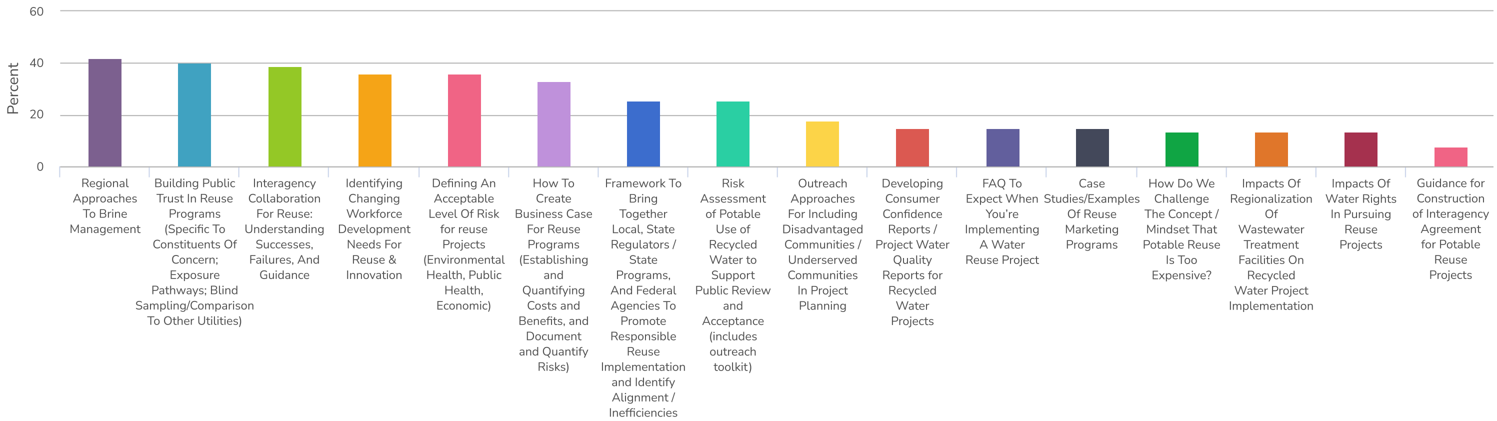
Value	Percent	Responses
Alternative Treatment Processes: Reimagining Advanced Water Treatment Trains	63.6%	42
Developing a Standard Protocol for Wastewater Treatment Effluent Characterization	59.1%	39
Optimizing Process and Energy Efficiency in Potable Reuse	51.5%	34
Pass-through Chemicals' Occurrence and Related Public Health Risk	51.5%	34
Viral Surrogates for Ozone Log Removal Values (LRV) for Potable Reuse	47.0%	31
Balancing the Competing Objectives of Energy Minimization and Innovation with Safety and Reliability	47.0%	31
Quantifying Energy Demand Associated with Alternative Water Supplies	34.8%	23
Alternative Approaches to Improve Energy Conservation for Energy Reduction	22.7%	15

3. Monitoring Research Projects - Please select your top 4 projects



Value	Percent	Responses
Use of AI / Machine Learning for Potable Reuse Water Quality, Efficiency, and Risk Minimization	47.0%	31
Finding Correlations Between Raw Wastewater Quality and Potable Reuse Risk	40.9%	27
Adapting PCR Methods for Real Time / Near Real Time Monitoring	37.9%	25
Wastewater Effluent Early Warning System - Assessing Low Probability / High Threat Events	37.9%	25
Guidance Document for Advanced Treatment Monitoring and Implementation / Keeping Up with the Instruments and Monitoring Effectiveness	37.9%	25
Better understanding CECs for potable reuse: Non-Targeted Analysis (NTA) Method Robustness Study	34.8%	23
Evaluation of Chemical Spikes in RO Permeate and Post RO Ozone/BAC	31.8%	21
Monitoring Strategy to Incorporate Stormwater as a Reuse Source	31.8%	21
Accessible Monitoring for Small Systems (relevant tech, cost/benefit)	30.3%	20
Demonstration Testing (building on NWRI Efforts) for Real Time / Near Real Time Monitoring	18.2%	12
VOC Monitoring for Control and Detection of Low Molecular Weight Organic Spikes	18.2%	12
Monitoring of Compounds that Affect Operations but are not Harmful (e.g. food grade glue)	9.1%	6

4. Implementation Research Projects - Please select your top 4 projects



Value	Percent	Responses
Regional Approaches To Brine Management	41.8%	28
Building Public Trust In Reuse Programs (Specific To Constituents Of Concern; Exposure Pathways; Blind Sampling/Comparison To Other Utilities)	40.3%	27
Interagency Collaboration For Reuse: Understanding Successes, Failures, And Guidance	38.8%	26
Identifying Changing Workforce Development Needs For Reuse & Innovation	35.8%	24
Defining An Acceptable Level Of Risk for reuse Projects (Environmental Health, Public Health, Economic)	35.8%	24
How To Create Business Case For Reuse Programs (Establishing and Quantifying Costs and Benefits, and Document and Quantify Risks)	32.8%	22
Framework To Bring Together Local, State Regulators / State Programs, And Federal Agencies To Promote Responsible Reuse Implementation and Identify Alignment / Inefficiencies	25.4%	17
Risk Assessment of Potable Use of Recycled Water to Support Public Review and Acceptance (includes outreach toolkit)	25.4%	17
Outreach Approaches For Including Disadvantaged Communities / Underserved Communities In Project Planning	17.9%	12
Developing Consumer Confidence Reports / Project Water Quality Reports for Recycled Water Projects	14.9%	10
FAQ To Expect When You're Implementing A Water Reuse Project	14.9%	10
Case Studies/Examples Of Reuse Marketing Programs	14.9%	10
How Do We Challenge The Concept / Mindset That Potable Reuse Is Too Expensive?	13.4%	9
Impacts Of Regionalization Of Wastewater Treatment Facilities On Recycled Water Project Implementation	13.4%	9
Impacts Of Water Rights In Pursuing Reuse Projects	13.4%	9
Guidance for Construction of Interagency Agreement for Potable Reuse Projects	7.5%	5

5. If you would like to suggest a water reuse research project idea related to potable reuse that is not listed above, please write it in the blank below:

Hide Responses ▾

ResponseID	Response
6	Consortium to bring synergies and lessons learned state by state potable reuse experiences
10	Source control for PFAS and other CECs through outreach to industries.
21	BAC acclimation: strategies for improving acclimation timing and performance
26	Compare costs/benefits of implementing potable reuse projects with costs/benefits of offsetting demand for potable water through implementation of non-potable reuse projects.
29	Engineered and Nature Based Biological Treatment Processes/Systems/Systems of Systems that Support Potable Reuse - critical knowledge for the regulators and the utilities to better understand the capabilities of their existing systems and for avoiding the prescriptive treatment trains incorporated into regulations.
34	The psychology and sociology of water recycling. Understanding how individuals and communities process information.
42	IN TREATMENT - from our group that didn't seem to make the list ... 1. Best practices of monitoring pathogens in potable reuse (intricacies of measurements in various different water qualities) 2. Impacts of process design on pathogen LRVs in Membrane Bioreactors 3. Development of surrogate monitoring for pathogens in Membrane Bioreactors (building on the output from 4959) 4. Review of nature based systems and their role in potable reuse 5. Understanding the nature and impact of biofiltration biology 6. Treatment options for tough to treat wastewater streams (centrate, intermittent wasting, ...) and the impact on effluent quality and downstream unit operations. 7. Treatment Trains working together - understand the impacts of upstream treatment on downstream unit operations 8. Fate of PFAS across the treatment train - leasons learned in potable reuse
54	High levels of reduction of moleclar targets (including ARGs and viruses)
61	- Epidemiological studies of locations where potable reuse has been implemented - artificial buffer best practices - Potable reuse blends and distribution system integrity - IPR: avoiding mobilization of contaminants in groundwater IPR projects

ResponseID	Response
63	Rapid and automated culture-based microbial monitoring for treatment processes.
65	Best practices for potable reuse of wastewater.
66	Serious gaming for potable reuse implementation involving all stakeholders.

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6. If you would like to suggest a water reuse research project idea related to non-potable reuse that is not listed above, please write it in the blank below:

Hide Responses ▾

ResponseID	Response
10	Protecting groundwater quality when irrigating above agronomy rates with reuse water.
26	Parallel to the evaluation of multi-agency collaboration challenges/strategies in WRAP Action 2.16 focusing on wastewater reuse, evaluate multi-agency collaboration challenges and strategies focusing on stormwater capture and use (which could consider both potable and non-potable uses of captured stormwater)
29	Development of multi-benefit projects in the age of climate change and circular economy - putting together the tailored building blocks for our communities to achieve sustainable and resilient resources -- water reuse (Potable and Non Potable) is a critical enabler at the center of this framework.
54	Accumulation and release of microbes by BAC
60	more RO concentrate info. options etc for those of use who do not live by an ocean
61	- Economic framework evaluation of distributed greywater systems / on-site reuse vs. scalping plants vs. regional reuse plants. - Regulatory impacts of higher concentration outfalls due to conservation and reuse.
65	Removal of pharmaceutical medications from wastewater before disposal or use on irrigation.

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