California Water Boards
Protecting California's Water

Recycled Water Research Needs in California

Workshop Summary

Prepared by the

Southern California Coastal Water Research Project (SCCWRP),
the WateReuse Research Foundation, and
the National Water Research Institute (NWRI)

Workshop hosted by the
California State Water Resources Control Board

Held at the

Southern California Coastal Water Research Project Authority
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Contents

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Executive Summary

The California State Water Resources Control Board (State Water Board) held a workshop on October 29, 2014 to enhance interaction among the many water quality management agencies affected by transition of drinking water oversight from the California Department of Public Health to the newly created State Water Board Division of Drinking Water. The workshop focused on developing shared research priorities for water reuse and stormwater capture, and included 57 invited leaders from stormwater, wastewater treatment and drinking water entities, as well as staff from the State Water Board and Regional Water Quality Control Boards (collectively, Water Boards). The workshop considered issues associated with direct potable reuse, indirect potable reuse and surface water augmentation, and was organized around four research themes: (1) water quality and human health, (2) performance reliability (treatment, operations and training), (3) ambient water effects and (4) financial, environmental and social considerations. Participants were provided summaries of present knowledge and research needs within each theme area and were asked to help prioritize those needs. The following is a general summary of input received; please note that not all participants agreed with all statements below.

1) **Water Quality and Human Health**

   Participants generally agreed that microbes and unknown chemicals are the primary targets on which research should be focused, and felt that assessment of chemical risks needed more research attention. Participants generally endorsed research on bioanalytical screening tools to determine if they are needed to supplement current monitoring, but also expressed concern that this research theme is still in its infancy and would require considerable investment to determine its applicability to recycled water. Many participants also expressed confidence in current monitoring approaches and were reluctant to express strong opinions on the need for supplemental monitoring tools.

2) **Performance Reliability (Treatment, Operations, and Training)**

   Participants generally agreed there is a strong link between performance reliability and water quality and public health protection. In addition, participants highlighted the need for water agencies to have the Technical, Managerial and Financial (TMF) capacity to implement potable reuse. Key areas of research included assessing treatment effectiveness, understanding appropriate operations, evaluating monitoring schemes, and emphasizing the importance of staff training for operating advance treatment technologies. Consistent with a multiple barrier concept for public health protection, specific areas of research were varied and ranged from source control to new advanced technologies to operator certification.

3) **Ambient Water Effects**

   Participants agreed with the general research needs identified in the overview presentation: (1) effects of stream flow reduction as stormwater is captured or wastewater effluent is reassigned to drinking water, (2) effects of increased constituent concentrations in the smaller volume of discharged water and (3) environmental fate of compounds during groundwater recharge or surface water augmentation. Among these themes, participants identified effects on stream flow as the highest research priority. Specifically, participants identified the need to improve understanding of flow-ecology relationships and the potential impacts of stormwater capture and wastewater diversions on stream ecology. Participants noted that these ecological demands will need to be balanced with other desired uses, and with water rights considerations.

4) **Financial, Environmental and Social Considerations**
   Participants generally agreed that a holistic analysis of sustainability factors for water reuse (versus traditional water sources) is necessary to ensure that the proper level of treatment is employed without expending unnecessary funds, energy, and greenhouse gas emissions for overtreatment. Workshop participants identified the greatest research need around public acceptance of reuse, including research on terminology used to communicate both inside and outside the industry. Participants also focused on the need for economic research, examining whether reuse needs to be incentivized and how much to value diversifying the water supply.

Participants generally agreed that research priorities across these four thematic areas differed for water reuse/stormwater capture in general, versus those for direct potable reuse. When considering general water reuse/capture, participants identified the ambient effects as the highest-priority research area, followed by human health research. When participants were asked to consider research needs associated with direct potable reuse, a majority of participants identified protection of human health as the highest research priority, followed by performance reliability. Participants agreed the workshop was a positive unifying event for California's water management community, but also recognized that it was only a first step, as the invitees were high-level managers. State Water Board staff expressed interest in following up with additional workshops focused on the high-priority thematic areas, but targeted toward participation by subject-area experts.

Introduction

On July 1, 2014, responsibility for drinking water oversight in the State of California transitioned from the California Department of Public Health to the newly created Division of Drinking Water within the State Water Board. This transition was intended to consolidate water quality management within a single organization and create an entity that simultaneously considers drinking water, ambient discharge and water reuse. This transition has led to enhanced interaction among a number of water quality management groups, several of which have had limited previous interaction.

To assist in this transition and create a community of water quality management agencies, the State Water Board convened a workshop on October 29, 2014, in Costa Mesa, CA. The workshop focused on developing research priorities to help enhance management of recapture and reuse of stormwater and municipally treated wastewater. The workshop attendees included 54 leaders from a cross-section of stormwater, wastewater treatment and drinking water entities, including State Water Board staff (see Appendix A for list of attendees).

The workshop was organized around four research themes:

- Thematic Topic 1: Water Quality and Human Health
- Thematic Topic 2: Performance Reliability (Treatment, Operations and Training)
- Thematic Topic 3: Ambient Water Effects
- Thematic Topic 4: Financial, Environmental and Social Considerations

The morning session included presentations describing the present state of knowledge and some research needs associated with each topic (see Appendix B for the workshop agenda). These presentations were provided by three research organizations that helped support the meeting (the WateReuse Research Foundation, the National Water Research Institute and the Southern California Coastal Water Research Project Authority), with handouts on these topics provided to meeting participants ahead of the workshop (see Appendix C for the write-ups).

The afternoon session included breakout sessions intended to enhance interaction among workshop participants and explore areas of consensus. There were four breakout sessions corresponding to the four research thematic areas. Workshop attendees participated in all four breakout sessions, rotating among them every 30 minutes. The composition of attendees in each breakout session was shuffled every 30 minutes to facilitate maximum interaction among workshop participants. A facilitator for each breakout theme served to integrate findings among the rotations.

The goal of the breakout sessions was to assess the level of agreement or interest in the research priorities within each theme. Participants were asked to address the following questions in each breakout session:

- Was the state of the knowledge for each research theme sufficiently captured in the research summary documents and the presentations?
- Are there important or additional research needs that were not identified in the summary documents?

- Which identified research themes should receive the highest priority?
- Which identified research topics within the themes should receive the highest priority?

The workshop finished in plenary session, with presentations about the breakout session outcomes and a discussion about research priorities across the thematic areas.

This workshop report includes five main sections, one describing outcomes for each of the thematic breakout sessions and one describing the final plenary discussion.

Breakout Session 1: Water Quality and Human Health

Group Leaders: Mike Wehner (Orange County Water District) and Keith Maruya (SCCWRP)

Overview

This research theme focuses on the potential for enhancing monitoring for recycled water to ensure that treatment systems are effective at protecting human health. The overview presentation identified two focal areas for monitoring: (1) pathogens that can pose an acute health risk, and (2) chemicals, including contaminants of emerging concern (CECs), that may pose a chronic health risk. Health protection in both of these areas is presently achieved using multiple barriers of water treatment combined with surrogate measures and indicator bacteria or chemicals to ensure treatment efficacy. However, increasingly sensitive, specific and rapid molecular methods are being developed for measurement of microbial water quality. Similarly, bioanalytical tools that screen for the presence and effects of chemicals in water show promise in expanding the scope and robustness of the current chemical-specific monitoring approach. Significant challenges must be overcome for either approach to be implemented for potable reuse or drinking water applications.

Research Priorities

Generally, workshop participants agreed with the overview presentation's premise: Microbes and unknown chemicals, including CECs and disinfection by-products (DBPs), are the primary targets on which research should be focused. Of these, participants felt by a 2 to 1 margin that assessment of chemical risks needed more research attention than assessment of microbes. The participants felt this way because current and future known and unknown chemicals may pose a greater challenge than pathogens to assess and manage. In particular, the participants indicated that the chemical-specific risk paradigm may not keep pace with the discovery of new CECs or DBPs, and is not intended to address chemical mixtures, including transformation products, some of which cannot be monitored using currently available methods.

Many participants endorsed more research on the use of bioanalytical screening tools to determine if they are needed to supplement current monitoring. While there was support for this research direction, there was also concern this was a research theme that is still in its infancy and that would require considerable investment to determine if it would be possible to implement bioanalytical screening tools for recycled water. Comments from participants indicated that adoption of this approach, if feasible, would require development and validation of *in vitro* bioassays focused on multiple biological endpoints that could be related to chronic human health risks.

Participants also agreed on the need to determine whether a practical implementation strategy for bioassay screening could be developed in drinking water or recycled water applications. To assess the feasibility and value of a bioanalytical approach, a substantial investment in laboratory training will be needed, participants said. Experts at U.S. EPA and other leading toxicological risk authorities should be consulted regarding the interpretation of *in vitro* bioassay results in recycled water and drinking water, and regarding which bioanalytical tools could be standardized for use by water laboratories. Research is also needed to develop guidance on how bioassays could be used in conjunction with chemical monitoring, since biomonitoring tools will not replace chemical testing and may actually trigger additional testing to investigate the chemical causes of biological responses observed with *in vitro* tests.

The potential interpretation of bioassay results relative to human health risk needs to be studied to determine what is feasible. If bioassays could be applied in a water setting, guidance on appropriate follow-up measures in response to bioassay screening results would be needed to inform decisions regarding potential changes to current treatment or source-control strategies. Before large investments are made in bioassays, the potential benefits and difficulty in development of methods, interpretation of results, and implementation in water facilities would need to be reviewed in detail.

Participants felt a lesser need for research to develop new methods for measuring pathogens. They felt this way because they had higher confidence that microbial risks (other than emerging pathogens) are adequately mitigated by current treatment, monitoring and risk-assessment practices. In addition, several participants voiced concern that the quantitative polymerase chain reaction methods that are the focus of most present research are confounded by measuring both viable and non-viable organisms, which could be particularly problematic for sustaining public confidence because of the risk of false positive results.

Additional Topics Discussed

Many participants expressed confidence in current monitoring requirements, including online performance monitoring, and were reluctant to express strong opinions on the topic of supplemental monitoring tools, citing a desire to better understand the topic and/or to defer to the opinions of independent experts. Participants suggested that many of the questions that were posed to them should be posed to topical experts, such as those serving on the State Water Board’s Expert Panel on Direct Potable Reuse and Reservoir Augmentation.

Breakout Session 2: Performance Reliability (Treatment, Operations and Training)

Group Leader: Jeff Mosher (National Water Research Institute)

Overview

This research theme focuses on performance reliability for potable reuse systems. The purpose of evaluating performance is to ensure that treatment systems will protect public health from the risks of chemicals and pathogens. The overview presentation focused on four areas of assessment: (1) treatment effectiveness, (2) operations, (3) monitoring schemes and (4) staff training.

The foundation for performance reliability is the *multiple barrier concept*, which includes protocols for treatment barriers along with technical, operational and managerial barriers. The goals of implementing performance reliability measures (such as multiple barriers) are to prevent contamination at the source, enhance treatment performance, safeguard water quality, and ensure protection of public health.

Direct Potable Reuse (DPR) differs from Indirect Potable Reuse (IPR) in a significant way: The DPR treatment process does not include an environment buffer such as a groundwater basin or a surface water reservoir, whereas the IPR process does. Instead of an environment buffer, DPR would incorporate other measures such an engineering storage buffer, redundant treatment and performance monitoring to ensure water quality. In addition, the DPR treatment process requires other safeguard measures that provide adequate time to react in case of a lapse in the water treatment operation.

Research Priorities

Several areas were universally acknowledged as important for potable reuse:

- All IPR and DPR systems must meet stringent criteria for select chemicals and pathogens.
- The multiple barrier concept provides significant protection of public health.
- Quality control in potable reuse projects can be achieved through monitoring and operational procedures.
- Quality assurance can be achieved through multiple barriers, assessment of treatment reliability through surrogate monitoring, and sound operations.
- Established design and operational principles are available to ensure water quality.
- DPR that is protective of public health can be achieved through appropriate treatment strategies, technical controls, online monitoring devices and operational controls.
- The State Water Board’s Expert Panel on DPR can review many of the technical areas associated with performance reliability.

Workshop participants generally agreed that performance reliability is a critical component of planning, designing and implementing DPR, and they acknowledged the critical link between performance reliability, water quality and public health protection. In addition, the participants agreed that the water industry has the capability and tools to implement DPR, although this capability needs to be assessed for each agency. Participants described this capability in terms of Technical, Managerial and Financial (TMF) capacity, which provided a useful lens to view priorities. Although there is overlap among these three areas and although most of the research priorities are in the technical area, it was acknowledged that TMF is a key concept in evaluating and implementing DPR systems.

Workshop participants discussed a wide range of research priorities related to performance reliability, and identified the following key areas:

- **Source control programs for potable reuse:** Source control programs for DPR must focus not only on pre-treatment, but also on protecting public health by controlling industrial chemicals in the collection system. An additional consideration is controlling for salinity for operational and treatment cost reasons. A standard approach to source control may enhance the effectiveness of DPR and may also increase public confidence and acceptance.

- **Facility operations:** Effective operations will be critical for the success of DPR, and first steps include identifying and addressing potential treatment lapses and maintaining effective response times. There is also a need to develop contingency plans (e.g., guidance and model language for permits) and Standard Operating Procedures (SOPs), including approaches for response times. Treatment performance, monitoring and operational requirements (including SOPs) can be documented in operation, monitoring and maintenance plans, and the long-term viability and consistency of facilities (e.g., 20 years of operations) should be assessed in terms of the role of operations and maintenance.

- **Operators and operator training:** Operator training for advanced treatment technologies is needed. Training could be provided by current facilities for operators of planned facilities, and development of a mentor program for operators should be considered. In addition, it would be useful to document the day-to-day needs and activities for operators of advanced treatment facilities. In the future, it may be advisable to require an operator certification program; this certification could build upon current certification programs for water, wastewater and stormwater. Also in the future, it may be advisable to unify all water-resources certifications into one program and/or create a partnership between the state and nonprofit certification programs. Alternatively, other ways to streamline current certification programs may be identified.

- **Wastewater treatment:** Wastewater treatment facilities can be reassessed with the goal of potable reuse as the end use, and more effective treatments should be evaluated, such as membrane bioreactors (MBRs) for wastewater treatment. Also to be considered is optimizing wastewater treatment processes for the purpose of further advanced treatment. This improved monitoring of wastewater processes would benefit operations, operators and reliability.

- **Advanced water treatment:** The performance reliability of advanced treatment processes for removing chemicals and pathogens should be assessed, and understanding of advanced treatments, such as Advanced Oxidation Processes (AOP), should be improved to optimize performance and adoption of these systems. A validation program would be helpful in assessing new technologies.

- **Facility design:** Treatment failures and response times can be minimized through use of the "4R" concept (reliability, robustness, resiliency, and redundancy) in the design of both recycled water and drinking water treatment facilities; however, guidance on the "4R" concept needs to be developed. In addition, the use of surrogates and indicators for treatment performance, including novel approaches, must be validated. Also to be considered are using surrogates for pinpointing treatment issues and optimizing use of real-time Critical Control Point procedures, which can identify treatment lapses and assist operators in running advanced treatment facilities. New technologies also should be evaluated, including alternatives to full advanced treatment for potable reuse, and use of distributed treatment for recycled water (i.e., scalping facilities) should be investigated to assess benefits and advantages. Other design features should be evaluated for enhanced water quality and treatment reliability, including elimination of return flows, denitrification and flow equalization.

- **Performance and water quality monitoring:** Opportunities for additional or enhanced performance monitoring, including online monitoring for the control of pathogens (acute risk) and chemicals (chronic risk) should be explored. The use of surrogate monitoring and the Critical Control Point approach can provide the information needed to ensure treatment performance and water quality. However, for monitoring to be effective, the methods must (1) be available commercially, (2) consist of standardized protocols with adequate QA/QC and (3) generate meaningful results. Additional monitoring may avoid the need for redundant treatment and enhance public acceptance.

- **Concentrate management:** The labor and expense required to manage concentrate produced by reverse osmosis (RO) can be significant, especially for inland projects, and can delay implementation. RO concentrate (which may require additional treatment) must be better managed to maximize recycling of water. Also, the effects of discharging RO concentrate through ocean outfalls needs to be studied.

Additional Topics Discussed

Workshop participants expressed confidence in current performance reliability, including treatment reliability, performance monitoring capabilities, and plant operations. However, participants recognized that additional treatment and monitoring reliability are required for DPR because of the absence of the environmental buffer. As a result, participants focused on identifying enhancements, such as increased treatment reliability from new treatment technologies and schemes. They were also interested in advances in performance monitoring to ensure treatment reliability and to detect excursions as quickly as possible. Workshop participants suggested that many of the technical questions could be addressed by the State Water Board's Expert Panel on Direct Potable Reuse and Reservoir Augmentation.

Additional topics mentioned included (1) understanding the loss of the environmental buffer, (2) water reliability as a goal and (3) the need for basin plan amendments. In addition, participants said that research results must inform DPR implementation, regulations and permits.

Breakout Session 3: Ambient Water Effects

Group Leader: Eric Stein (SCCWRP)

Overview

This research theme focuses on potential effects on the ambient environment associated with increased wastewater reuse or increased capture and use of stormwater. The overview presentation identified three potential areas of effect: (1) reductions in stream flow as stormwater is captured or wastewater effluent is reassigned to drinking water, (2) changes in constituent concentrations as treated water is transferred to the drinking water system, which would cause the wastewater effluent to contain a similar amount of contaminants in a smaller volume (i.e. less dilution), and (3) environmental fate of compounds present in recycled water as it is used for groundwater recharge of aquifers or surface water augmentation in various types of drinking water reservoirs as part of indirect potable reuse.

Research Priorities

Workshop participants agreed with the three general categories identified in the overview presentation and did not identify additional major needs within this research theme. Among the three themes, the breakout groups identified potential flow effects as the highest priority. Specifically, they identified the need to improve understanding of flow-ecology relationships for a range of appropriate biological endpoints. Understanding the potential impacts of diversions on stream ecology will allow identification of ecologically sustainable flows (both high flow and low flow) that will protect sensitive species and habitats. These ecological demands will need to be balanced with other uses and with water rights considerations. Participants said exploration of this topic should include wildlife and resource agencies, such as the U.S. Fish and Wildlife Service and California Department of Fish and Wildlife. Specific issues raised for this topic included:

- The need to set appropriate targets in consideration of temporal variability in flow associated with short-term drought cycles and longer-term climate change
- The need to study the effects of conservation practices on reduced runoff
- The need to consider discharge water concentration effects of recycled water augmentation on biological endpoints; these may be analogous issues for wetlands and estuarine habitat, but should be considered after stream flow-ecology relationships have been better defined

Improved understanding of flow-ecology relationships will allow for development of an integrated framework for considering all Beneficial Uses for a given stream in concert, as a way of reducing conflicts between competing uses (e.g. habitat needs vs. recreational needs vs. human consumption needs). The goal is to provide a mechanism for flexibility in meeting ambient water requirements to accommodate multiple beneficial uses and reconcile potentially competing uses. Ultimately, this process could include development of a hierarchy of use priorities. This process would need to be conducted separately for coastal and non-coastal discharges.

The second priority area identified by participants was the need to characterize concentrate and assess the potential effects of concentrate on natural communities. This analysis would likely need to be done separately for discharges to the ocean, to streams or to estuaries. The goal is to understand the composition of concentrate, the fate of plumes and the effect of more concentrated plumes on benthic communities. Specific issues raised for this topic included:

- Understanding the ambient effect of CECs and disinfection byproducts that may be concentrated in discharges
- Improving modeling of the fate of more buoyant plumes
- Exploring the potential effects of discharge on localized hypoxia

The participants also identified a need to research opportunities for treatment and/or reuse of concentrate, including alternative disposal options such as dewatering for landfill disposal or deep injection of concentrates.

Additional Topics Discussed

In addition to the two priority areas identified above, the participants identified several topics that they felt were important, but that did not rise to the same level as the two priority areas. The most overarching issue identified was the need to change the entire paradigm of how recycled water issues are considered and communicated. This change would allow the water management community to eliminate stigmatizing recycled water by taking the perspective that all water is recycled and by developing common standards for all water, regardless of its source. The participants also identified the need to improve the integration of agriculture and/or industrial uses into the discussion of water reuse and ambient effects. A discussion of these uses would allow an exploration of how to maximize reuse of secondary or tertiary treated water for other purposes (e.g. agriculture), freeing up capacity of municipal or environmental uses of recycled water. Finally, there was interest in exploring options for appropriate locations for storage of stormwater. For example, what would be the potential ecological implications of storage within river corridors? Similarly, would increased recharge of stormwater intensify the risk of mobilization of legacy or natural contaminants present in soil and subsurface?

Ultimately, participants stressed the need to take a watershed perspective in considering ambient effects. This view will allow a focus on managing watersheds as cohesive units and on using the most appropriate strategies in the right locations to manage overall watershed health.

Breakout Session 4: Financial, Environmental and Social Factors of Water Reuse

Group Leaders: Melissa Meeker and Julie Minton (WateReuse Research Foundation)

Overview

To fully evaluate water supply options, a “triple bottom line” (TBL) approach should be taken to consider the financial, environmental and social factors. This holistic analysis factors in the sustainability influences (which may be positive or negative; see Table 1) that water reuse poses versus traditional water sources. By using a TBL framework, decision-makers can help ensure that the end-use need for water quality corresponds to the proper level of treatment without expending unnecessary funds, energy and GHG emissions or generating other social costs (fit for purpose). A social aspect that must be expanded when considering reuse projects is the public acceptance of such projects. A public outreach and engagement program is key to community acceptance of a reuse project.

Table 1: Triple Bottom Line Summary

	Factors	Impacts
Financial	• Capital construction costs • Operations and maintenance costs • Energy usage	Costs for reuse are highly site-specific in how they can compare to other supply options. Options like desalination and importing water have very high energy requirements and costs. The cost of water reuse varies depending on the location, but is often competitive (if not the most economical).
Environmental	• Wastewater discharges • Concentrate disposal • GHG emissions • Water diversions • Climate change resiliency	Water reuse has the potential to greatly reduce or eliminate wastewater discharges. For RO applications, there can be issues in concentrate disposal. Reuse has the potential to reduce water diversions from one ecosystem to help preserve local environments.
Social	• Local economic impact • Supply reliability • Aesthetics • Quality of life	Reuse creates a local supply of water to be used for a variety of purposes to bolster the local economy while reducing dependence on other sources, such as imported water. Reuse can help support irrigation for parks and other recreational activities to improve the local quality of life.

Research Priorities

While the pre-workshop writeup and workshop presentation covered the financial, environmental and social aspects of water reuse, workshop participants focused most of their attention on the public acceptance of such projects, agreeing that this aspect required the most attention to foster the success of reuse.

There were many themes discussed to better engage and inform the public. The participants agreed that terminology used to communicate about water reuse, both inside and outside the industry, must be consistent and used consistently. Participants said it is important to convey a simple message, but at the same time, offer enough technical information to lead to public trust in this "fit-for-purpose" end product. The water management community must be consistent and positive with the language used (e.g. use "purified water" rather than "recycled water"). To help convey its message, the industry should recruit champion advocates, particularly children (by inserting water reuse as a topic in school curriculum), young adults (who can spread the message via social media), and environmental groups (that can communicate environmental benefits). The industry should also identify and target its least supportive groups (e.g. the elderly, mothers of small children) with these positive messages about the sustainable, safe practice of reuse.

Several recommended actionable items were developed and supported by the participants:

- Participants embraced the idea of a water bottling station that would use advanced purified water (full advanced treated water) as a supply to fill water bottles. Participants agreed on the importance of bottling the water to demonstrate the taste and appearance of this water, but cautioned that bottling would send mixed messages, as bottled water does not send a sustainability message.
- Because of perception concerns surrounding a water bottling station, participants also developed an idea for a reality television documentary that would focus on a small community using advanced purified water as its drinking water source.
- Participants agreed that as advanced purified water moves closer to becoming a drinking water source, it should first be offered in government buildings, demonstrating to the public that the groups responsible for regulating and approving this practice are completely confident in its safety.

Participants also identified additional research topics to be considered under the financial, environmental and social factors of reuse:

- Agricultural research is critical in California, and a TBL analysis should be completed for that end use.
- There are numerous financial constraints to reuse, as it can be expensive to implement if only looking at costs alone and not benefits. Does reuse need to be incentivized or streamlined to make it cost-competitive? Or is it a larger issue of the value of water in general? How should this be addressed?
- The economic impact of water scarcity and allocations should be quantified. What is the value of diversifying a water supply?
- The rate of retirement of water/wastewater utility professionals appears to be greater than the need for hiring. How does the industry appeal to and more effectively recruit the younger generations?

Plenary Summary

The final workshop session brought together all participants to hear the breakout-session summaries and to discuss prioritization across the research themes. The summary presentations, which were provided by the session moderators, were intended to convey an overview of the research priorities discussed during the four breakout sessions.

Prioritization among areas was determined by vote during the session. Participants agreed that research priorities differed for water reuse/recapture in general, versus those for direct potable reuse; prioritization was accomplished in two separate votes.

When considering general water reuse/recapture, the greatest number of participants identified ambient water effects as the most important research area, followed closely by human health research. However, these research priorities shifted when participants were asked to consider only research needs associated with direct potable reuse. In this case, a majority of participants identified human health as the highest priority, followed by performance reliability.

<u>Votes for general water reuse research</u>

	First priority	Second priority
Water quality and human health	12	**22**
Performance reliability (Treatment, Operations, and Training)	11	10
Ambient water effects	**18**	5
Triple bottom line	6	6

<u>Votes for general water reuse research</u>

	First priority	Second priority
Water quality and human health	**26**	14
Performance reliability (Treatment, Operations, and Training)	14	**21**
Ambient water effects	2	1
Triple bottom line	1	7

The workshop concluded with participants agreeing that the workshop was as a useful unifying event for California's water management community. Vicky Whitney of the State Water Board, the workshop's hostess, noted that it was timely because water reuse is gaining traction in the State and with the transfer of drinking water program to the State Water Board. She added that having a shared community vision for recycled water research needs will assist with moving forward with implementation of water reuse and stormwater projects in the State. Ms. Whitney also recognized that the workshop was only a first step toward a collaborative approach, as the invitees were all high-level managers. She indicated State Water Board interest in following up with additional workshops focused on the priority thematic areas identified here, but targeted toward participation by subject-area experts.

Appendix A: Meeting Attendees

Name	Title	Organization	E-mail Address
Barnard, Randy	Senior Sanitary Engineer	State Water Board	Randy.barnard@waterboards.ca.gov
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Appendix B: Meeting Agenda

State Water Resources Control Board

Recycled Water Research Needs Workshop

Final Agenda

October 29, 2014

Location

SCCWRP Meeting Room
3535 Harbor Blvd
Costa Mesa, CA 92626

Meeting Goals

- Provide an opportunity for Water Board executive managers and research organizations to meet decision makers from the drinking water, wastewater, and storm water agencies who are potential suppliers and distributers of recycled and reused water.
- Bring together recycled water producers and water supply agencies to identify research gaps that should be addressed to ensure water supplies from these sources are safe for people and the environment.

9:00 am	Welcome, Charge, and Introductions	Elizabeth Haven State Water Board
9:20 am	Overview of State Board Activities	Jonathan Bishop State Water Board
9:50 am	Thematic Topic 1: Water Quality and Human Health	Mike Wehner Orange County Water District
10:20 am	Thematic Topic 2: Performance Reliability) (Treatment, Operations, and Training)	Jeff Mosher National Water Research Institute
10:50 am	Thematic Topic 3: Ambient Water Effects	Eric Stein SCCWRP
11:20 am	Thematic Topic 4: Financial, Environmental, and Social Factors of Water Reuse	Julie Minton WateReuse Research Foundation

11:50 am	Instructions for afternoon Breakout Sessions -4 groups -Rotation between the 4 themes	Steve Weisberg SCCWRP
12:00 noon	LUNCH (ON-SITE)	
1:00 pm	Breakout Session #1	Rooms A, B, C, D
-		
1:30 pm	Breakout Session #2	Rooms A, B, C, D
-		
2:00 pm	Breakout Session #3	Rooms A, B, C, D
-		
2:30 pm	BREAK	
3:00 pm	Breakout Session #4	Rooms A, B, C, D
-		
3:30 pm	Report Out and Wrap Up	Victoria Whitney State Water Board

Appendix C: Thematic Topic Pre-Meeting Write-Ups

Thematic Topic #1: Water Quality and Human Health

Definition of the Topic:

Wastewater has been introduced into drinking water supply sources for centuries. For instance, treated wastewater is discharged into river systems that contribute to downstream drinking water supplies all throughout the U.S. (this practice is referred to as *de facto* water reuse). Public health risks associated with drinking water supplies (including supplies affected by *de facto* water reuse) have been virtually eliminated due to advances in filtration and disinfection. As an example, indirect potable reuse (IPR) has been successfully practiced in California for more than 50 years, with studies verifying the safety of using recycled water to recharge groundwater supplies.

Direct potable reuse (DPR) could provide the State with greater flexibility in using recycled water by enhancing existing reuse strategies aimed at augmenting water supplies. Because DPR reduces the need for environmental buffers (i.e. storage prior to reuse), it may require additional treatment, operational control, and monitoring, including real-time (or near real-time) monitoring, to ensure the performance of the treatment systems and quality of the treated water. Two classes of constituents are of particular interest due to their potential effects on human health: pathogens and residual chemicals (such as disinfection byproducts and constituents of emerging concern [CECs]). Recent requirements established for IPR in California call for the log reduction of viruses and protozoa between raw sewage and the final product water distributed to consumers. Furthermore, a select number of chemicals and process control surrogates have been identified for monitoring recycled water. These requirements are in addition to the need to comply with drinking water Maximum Contaminant Levels (MCLs) for substances with a defined risk level.

Summary of the Issue:

Current regulatory and monitoring paradigms for drinking water have proven effective in preventing acute human health impacts due to pathogens. Risks due to microorganisms are well-characterized by considering human dose-response data for target microbes (e.g., *Cryptosporidium* and norovirus) so that treatment techniques that control these targets can be reasonably applied to a wider group of related pathogens. Because monitoring methods for many pathogens can be slow, insensitive, and/or imprecise, surrogates are routinely used to demonstrate the operational integrity of treatment barriers and ensure acceptable water quality. For DPR, additional monitoring schemes and approaches would be beneficial for validating treatment performance and water quality.

Chemicals can be measured at low concentrations, including well below levels of human health concern, although advanced instrumentation and expertise are required. Full advanced treatment (i.e., microfiltration, reserves osmosis, and advanced oxidation processes) for recycled water is effective in reducing trace organic compounds, as shown through direct chemical analyses and total organic carbon (TOC) concentrations in treated water. The performance of these treatment processes are validated using online and real-time surrogate measures.

Developing conventional dose-response relationships for chemicals using animal models to assign risk thresholds is slow, cumbersome, and expensive. The addition of a risk framework for assessing large numbers of trace organic compounds could help improve the evaluation of the human health significance of chemicals. In addition, evaluating possible impacts of mixtures of chemicals, including unknowns and metabolites (for which we do not yet have analytical methods), is an area of research interest.

State of the Knowledge:

DPR monitoring can be enhanced to improve the operational integrity of treatment barriers, which would result in water quality with an acceptable risk for chemicals and pathogens. Doing so would involve the following advancements:

- Development of better indicators and surrogates.
- Use of Critical Control Points for process control for validating the operations of treatment processes.

Pathogen monitoring may also be enhanced through the use of molecular methods for pathogen measurements. The state of pathogen measurement using molecular methods, such as polymerase chain reaction (PCR) based technologies, is expanding rapidly. These methods may shorten the response time from days to hours. They also provide the potential opportunity for analytical automation and incorporating such technology into a continuous-flow measurement system. However, these technologies are still being developed for many pathogens of potential interest and are not sensitive enough to ensure the detection of pathogens that are of concern at very low concentrations. PCR-based techniques do not provide information about the infectivity of pathogens, indicators detected, or the level of risk for the population.

For chemicals, detection methods are continually being developed and/or improved to measure new chemicals or existing chemicals at lower levels of detection. Bioanalytical tools that screen for biological activity are being developed to complement the analysis of individual chemical measurements. These tools, however, have their challenges: they are still in their early stages of development for many potential biological endpoints of interest; can only measure the activity of certain chemicals; may be unable to assess activity at low concentrations; and cannot address all biological endpoints of interest. In addition, they would require a set of accompanying diagnostic tools and a new interpretive framework to make bioassay outputs useful. For instance, a screening response could be used to trigger a more detailed analysis, including chemical analysis for specific chemicals or chemical groups that are causing the screening response.

Research Needs:

- Evaluate the efficacy of current monitoring tools for DPR to address the following questions:
  - Are indicators and surrogate measures adequate to represent the effectiveness of treatment processes to control microbial and chemical risks?
  - Could additional indicators and surrogate measures be employed to better define risk and, therefore, better optimize the application of treatment and monitoring resources?
  - What are appropriate Critical Control Points, and how effective is this monitoring strategy?
- Verify the performance of multiple barriers in reducing chemical and microbial hazards to levels that are protective of human health. Are these barriers sufficiently robust and timely to divert off-

spec water so that it does not pose a health risk to consumers? Can pathogen log removal credits for treatment barriers be better characterized?

- Develop a strategy for assessing the usefulness of PCR-based techniques in a DPR scheme to address the following:
    - Automated large volume method for PCR detection of pathogens of interest (especially viruses and protozoa).
    - Validation of pathogen methods with inter-laboratory evaluations and different water matrices.
    - Validation of unit processes and surrogates for pathogen and CEC removal.
- While bioassays may present an opportunity to assess the presence of chemicals in recycled water, they are in the initial stages of development. One possible next step could be to further investigate bioassays for use as indicators of initial triggers in toxicity pathways. If research advances are made, future efforts may involve:
    - Developing a chemical risk paradigm to interpret bioassay monitoring data.
    - Developing and validating bioanalytical tools (screening level) and non-targeted analytical methods (diagnostics) to inform the CEC risk paradigm and verify treatment performance.

Thematic Topic #2: Performance Reliability (Treatment, Operations, and Training)

Definition of the Topic:

Fundamental to potable reuse is the reliability of treatment performance, which is needed to ensure the protection of public health. Reliability is built upon effective treatment, along with appropriate operations, monitoring, and trained staff. Underlying performance is a multiple barrier concept, which has been the cornerstone of the drinking water programs. It consists of coordinated technical, operational, and managerial barriers that help prevent contaminants at the source, enhance treatment, and ensure a safe supply of potable water. Significant protection is provided when a diversity of independent barriers are combined in series. This configuration provides two critical elements: redundancy (which prevents the failure of a single barrier from causing a failure of the entire system) and robustness (or the use of a diversity of barriers to address the diversity of potential contaminants). The use of multiple and diverse barriers results in a high overall level of reliability. In addition, appropriate monitoring and sound operations, including trained and knowledgeable operators, ensures treatment performance and water quality.

State of the Knowledge:

In California, two types of indirect potable reuse (IPR) are possible for groundwater recharge: (1) spreading of tertiary treated wastewater, and (2) spreading or injection of full advanced treated (FAT) waters that have been further treated via reverse osmosis and advanced oxidation. A third option is IPR via reservoir augmentation. All IPR systems must meet stringent chemical and pathogen criteria. The key difference between direct potable reuse (DPR) and IPR is that DPR eliminates the use of an environmental buffer (i.e., aquifer or reservoir). Removing the environmental buffer raises three important questions:

1) Is an engineered storage buffer needed?
2) What treatment performance monitoring requirements are needed to evaluate quality assurance?
3) What is the role of redundancy and robustness in a treatment train without an environmental buffer?

To ensure a significant level of protection for potable reuse systems, the following management, operational, and technological barriers are employed:

- Source control, including industrial source control, monitoring, and consumer, business and industrial sector education.
- Wastewater treatment, equalization, and monitoring.
- Advanced treatment and monitoring (reverse osmosis, advanced oxidation, disinfection).
- Optional drinking water treatment.
- Engineered buffer and/or monitoring.

A consistent potable water reuse quality should be achieved through appropriate and proven treatment strategies (e.g., FAT), technical controls (e.g., alarms, inspections, standard procedures), online monitoring devices (e.g., turbidity, total organic carbon [TOC], residual chlorine), and operational controls to react to upsets and variability. Similar to drinking water systems, quality control in potable reuse projects is provided by monitoring and operational response plans. Quality assurance is provided through multiple barriers and an assessment of treatment reliability. Established design and operational principles are used to ensure water quality.

As with drinking water facilities, water quality monitoring for potable water reuse involves the monitoring of bulk parameters (surrogates) and indicators to ensure the proper performance of unit processes. Monitoring consists of: 1) on-line monitoring devices (turbidity, chlorine residual, pH, and TOC), and 2) measurements using grab or composite samples (ammonia, nitrate, TOC, and *E. coli*) to ensure the quality of the finished water. These practices follow standards and protocols similar to those applied in drinking water treatment.

Current wastewater and drinking water operator certification programs define criteria and provide the minimum qualifications for certification. However, these two programs do not address advanced treatments used in FAT systems. At present, utilities and agencies with these needs provide the appropriate training and experience. Treatment performance, monitoring, and operational requirements are documented in Operation, Monitoring, and Maintenance Plans for potable reuse systems.

Summary of the Issues:

DPR can be protective of human health if adequate protection through *treatment, monitoring, and operations* is engineered within the system. Specific areas include the following:

- **Source control programs** for the wastewater collection systems are needed to address the control of substances not compatible with potable water reuse systems.
- **Other design features** should be evaluated, including: optimization of wastewater treatment; elimination of return flows; denitrification; flow equalization; and improved performance monitoring.
- **Strategies for incorporating reliability and resilience** into system design and operations are needed. Strategies should address the variability of processes, treatment lapses, and operator error. One approach for operational reliability is the use of Critical Control Points (CCPs), which involves operating processes under specific conditions to ensure a certain level of treatment is achieved.
- Currently, a **"4R" approach** has been proposed for DPR that defines the *reliability* of the system in terms of *resilience*, *robustness*, and *redundancy*. Applying this concept has the potential to ensure public health protection through the proper design and operation of DPR systems.
- In the future, **new technologies** may improve capabilities for both monitoring and treatment. These innovations will increase performance reliability for potable reuse.
- An appropriate online monitoring scheme is not feasible to provide real-time monitoring of all constituents of concern. However, **surrogate and indicator constituents** can be used to assess performance reliability of key unit process in place of direct measurements for all constituents of interest.
- **Monitoring and operation plans** are needed to address variability, equipment lapses, and operator error.
- Robust **operator training** is needed for DPR facilities to address advanced treatments and monitoring schemes, as well as meet appropriate response times in case of failures.

Research Needs:

- Assess the resiliency and interdependency of unit treatment processes (i.e., trace the failure and impacts).
  - Evaluate the removal efficiency of trace organic compounds of potential public health concern through FAT.
  - Predict the removal of compounds that may be precursors of disinfection byproducts.
  - A key component of defining the "consistency of treatment" is to understand the variability occurring within each unit process. More understanding is needed of what makes a barrier redundant or independent.
  - Use CCP assessments to quantify the robustness and reliability of multiple treatment barriers of DPR.

- Develop a process to evaluate and validate new and innovative technologies.
  - What treatment trains are considered equivalent to FAT?
  - More information is needed on the potential of non-reverse osmosis treatment options to eliminate the need for brine disposal.

- Document and quantify the removal of pathogens.
  - Limited information exists on pathogen levels in raw wastewater.

    - Evaluate the removal of pathogens in different biological wastewater treatment processes.
    - Better understand microbial communities that exist in treated water facilities.

- Regardless of how effective, reliable, robust, and redundant the system is, the treatment plant and delivery system must be prepared for circumstances where it fails (this is described as resiliency).
    - Evaluate information on out-of-spec behavior for IPR projects in the U.S. and the impact on water quality.

- A plan is needed to transition the results of research to application.

- Develop training for operators for DPR facilities.

Thematic Topic #3: Ambient Water Effects

Definition of the Topic:

In addition to human health concerns, increased recycled water use may have consequences for the ambient environment. Changes in the amount, timing, and duration of discharges to streams and the ocean have the potential to affect biological communities by altering flow patterns and the concentrations of constituents present or being discharged into the environment. A need exists to develop a decision-making framework for balancing ecological needs against the goals of increasing sustainable water use.

Summary of the Issue:

Meeting the State of California's goals of sustainable local water supplies will require increased reuse of wastewater and the development of the capacity to reuse stormwater; however, each of these strategies could result in effects on the ambient environment.

The California Recycled Water Policy includes a goal of increasing stormwater reuse by 500,000 acre feet by 2020 and 1 million acre feet by 2030. Stormwater reuse could take many forms, from capturing peak flows for reuse to increased use of low flows and urban runoff. Increased stormwater reuse will alter flow characteristics, which has the potential for both positive and negative effects on stream environments. Ecological effects could be of greatest concern in streams that support important fishery resources, sensitive species, or habitats that rely on specific flow requirements. However, it will also be important to understand how changes in flow affect biological indicators, such as benthic invertebrates, that are routinely used for assessment and compliance purposes. On the positive side, reducing the amount of stormwater and/or urban runoff entering streams may be an important strategy for meeting existing water quality goals, such as Total Maximum Daily Loads (TMDLs) or Hydromodification Management requirements.

The increased reuse of wastewater may result in ambient effects in streams, estuaries, and the ocean. Urban runoff and wastewater effluent have replaced groundwater accretion, including spring flow, as the predominant sources of base flow in many urban streams and rivers. Ecological stress associated with decreased flows may occur with increased wastewater and stormwater reuse. However, the knowledge of flow-based impacts is minimal, particularly regarding arid streams where reuse needs are greatest. Increased wastewater recycling may also affect the ocean environment as the volume of wastewater discharged to the ocean decreases, but the mass of discharged constituents remains the same. The result could be increased concentrations of plume constituents, including salts, contaminants, or reclamation/disinfection byproducts, potentially altering the current fate and transport of plumes (and, likely, resulting in impacts to biota).

State of the Knowledge:

Many studies have demonstrated that alterations of flow regime can be associated with changes in fish, amphibian, and macroinvertebrate communities. Although a basic understanding of the relationship between flow alteration and ecological response exists, few studies have provided mechanistic evidence on how specific ecological metrics respond to various degrees of flow alteration necessary for establishing instream flow requirements. Many states, including California, are beginning to use the *Ecological Limits of Hydrologic Alteration* (ELOHA) framework to support regional flow management programs. The States of New Jersey, Pennsylvania, and Ohio have recently proposed instream flow requirements based on this framework, and California is currently conducting ELOHA-based flow-ecology studies in the Sacramento-San Joaquin region (for fish) and in Southern California (for benthic macroinvertebrates). These studies will form a foundation for developing instream flow management programs that could be applied to recycled water policies.

Current wastewater outfalls are based on design flows that may be reduced by as much as two- to ten-fold, due to enhanced reuse. Outfall plume mixing and dilution has been a well-studied topic, and public domain models exist to support the recalculation of initial dilution (a critical element of regulatory compliance). However, the accuracy of the model may need validation if flows are sufficiently reduced to decrease full functionality of outfall engineering. There is also a need to increase our understanding of plume fate and transport because changes in density may alter current plume exposure due to varying buoyancy characteristics, advection distance from the outfall, and water column mixing or particle settling. Plume tracking to assess ecosystem exposure is less readily developed than initial dilution models, and wastewater agencies are just now developing and implementing new technology to quantitatively define plume presence in near-real time. Finally, current ecological effects from outfall plumes are relatively well-studied and routine monitoring approaches can assess any potential detrimental ecosystem impacts, although constituents of emerging concern may require unique approaches.

Research Needs:

1. Develop an assessment and management framework for considering effects on the ambient environment as part of recycled water polices. Include mechanisms to increase coordination among public and *private* agencies and programs.

2. Develop flow-ecology relationships to protect desired beneficial uses:
    a. Sensitive species.
    b. Fisheries.
    c. Benthic invertebrates and other bioassessment targets (e.g., algae).

3. Develop models to better predict how reduced flow may affect stream morphology in terms of the potential management of hydromodification effects.

4. Conduct studies to determine how recycled water practices can be designed to optimize flow management and application of best management practices to help meet water quality objectives.

5. Refine existing models (both Nearfield and regional circulation) and *in situ* measurements to assess the initial dilution and fate and transport of more concentrated (denser) wastewater plumes.

6. Investigate the effects of contaminants of emerging concern (including nanoparticles) on in-stream and marine and estuarine receiving water biological communities. Expand research on short- and long-terms effects of "new" constituents on biological communities:
    a. Chronic effects of higher salts and brines on marine benthic communities.
    b. Toxicity and bioaccumulation of advanced oxidation processes and disinfection byproducts on marine benthic communities.

Thematic Topic #4: Financial, Environmental, and Social Factors of Water Reuse

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Definition of the Topic:

Water reuse provides a reliable, climate-independent local source of supply. While scientific and technological advances can address public health and water quality concerns regarding the implementation of water reuse projects, secondary issues must be acknowledged and addressed when considering the viability and acceptance of specific activities. A "triple bottom line" (TBL) approach should be taken to evaluate the financial, environmental, and social factors of various water supply options being considered. This holistic analysis factors in the sustainability influences (which may be positive or negative) that water reuse poses versus traditional water sources. Equally (if not more important), a public outreach and engagement campaign is key to community acceptance of a reuse project.

Important factors considered under a TBL approach should include:
- Cost of treatment between potable water and reuse water.
- Energy requirements.

- Associated greenhouse gas (GHG) emissions.
- Environmental benefits/impacts from reduced wastewater discharge due to water reuse activities.
- Various social benefits (including supply reliability, enhanced green space, and sustainable design).

These costs and benefits will be evaluated individually for affordability, compatibility, and other criteria, but they should also be considered in a cumulative nature to determine how each variable will affect the regional water resources equation. Another social aspect that is worthy of significant attention is public acceptance, which is critical to launching and maintaining water reuse projects. While the quality of reuse water is safe and fit for its intended use, the public can have trouble overcoming apprehension over the source of this supply. Outreach and engagement are key components of the success of water reuse projects.

State of the Knowledge:

Evaluating the true cost of a specific water supply necessitates using a TBL perspective by taking the full financial, environmental, and social factors into consideration. By using a TBL framework, decision makers can help ensure that the end-use need for water quality corresponds to the proper level of treatment without expending unnecessary funds, energy, and GHG emissions or generating other social costs (WRRF-10-01). For end-users that do not require potable water (e.g. irrigation, some industrial uses), costs and resources can be conserved through appropriate planning and management of the water supply.

A major driver for the cost of water is energy consumption, both in treatment and conveyance from the water source to end user. Different sources of water have different energy requirements. For instance, imported water requires considerable energy to move it in sufficient quantity from its source to where it is needed. Desalination, on the other hand, may be used locally, but requires large amounts of energy to separate salt from water. Along with the financial cost of energy consumption, the associated GHG emissions result is a significant environmental cost. Tools exist (e.g., Water-Energy Simulator WRRF-08-16) that allow users to evaluate the energy and GHG implications of population growth, impact of climate change, development of alternative water and energy sources, and water treatment improvements resulting from stricter water-quality guidelines and emerging contaminants.

Environmental impacts can also significantly influence how decision makers evaluate different water treatment and supply options. Because reclaimed water is locally sourced for local use, it reduces the need for water transfers from one region to another. For example, if reuse is further expanded in California, it has the potential to reduce the need for imported water from the San Joaquin Delta in the north, thereby supporting the natural flow of water in the delta. This would allow for greater protection of endangered species (like the delta smelt), potential restoration of native salmon populations, and decreased tension between agricultural interests in the Central Valley and environmental groups. In addition, indirect potable reuse (IPR) applications can protect and enhance existing reservoirs and aquifers against depletion. An IPR project, the Groundwater Replenishment System in Orange County pumps half it's produced water into injection wells to prevent seawater intrusion from contaminating the groundwater basin. In this case and others, recycled water improves the quality of its receiving water; however, impacts from reduced flows must be considered.

In general, barring any unforeseen regulatory changes, the cost of treating wastewater and drinking water can be expected to follow historical trends. In terms of water reuse, this predictability-of-cost is especially valuable because it can allow a utility to accurately predict the cost of maintaining a reliable stream of water that can be used for a variety of purposes. Drought and the uncertainty surrounding the future availability of water gives additional economic value to the inherent reliability of water reuse by allowing industry and other users to be able to better project future costs. There is also an associated social value with avoiding future water restrictions and having the assurance of a stable source of water in the future.

In terms of public perception and acceptance of reuse, local, state, and national campaigns have been successful through engagement on the water cycle and importance of quality (rather than the source). Utilities (particularly in California) have learned that proactive, robust outreach with simple messages and broad reach are worthwhile. Willingness to accept wastewater as an adequate source often varies on the environmental buffer and final end use. There is a statewide movement in California for direct potable reuse (DPR); through effective messaging, DPR can become an accepted source of potable water in the future (WRRF-13-02).

A summary of the TBL is provided in Table 1.

Table 1: Triple Bottom Line Summary

	Factors	Impacts
Financial	• Capital Construction Costs • Operations and Maintenance • Energy Usage	Costs for reuse are highly site-specific in how they can compare to other supply options. Options like desalination and importing water have very high energy requirements and costs. The cost of water reuse varies depending on the location, but is often competitive (if not most economical).
Environmental	• Wastewater Discharges • Brine Disposal • GHG Emissions • Water Diversions • Climate Change Resiliency	Water reuse has the potential to greatly reduce or eliminate wastewater discharges. For RO applications, there can be issues in brine disposal. Reuse has the potential to reduce water diversions from one ecosystem to help preserve local environments.
Social	• Local Economic Impact • Supply Reliability • Aesthetics • Quality of Life	Reuse creates a local supply of water to be used for a variety of purposes to bolster the local economy while reducing dependence on other sources, like imported water. Reuse can help support irrigation for parks and other recreational activities to improve the local quality of life.

Research and Program Needs:

- Full evaluation to quantify (place a dollar value on) the non-monetary environmental and social impacts of water reuse compared to traditional sources of water.
- Full accounting of energy use and GHG emissions associated with water reuse, along with traditional water sources.
- Low-energy treatment options to decrease the cost and carbon footprint of water reuse.
- Integrating the need for climate change adaptation into a water reuse strategy.
- Public campaign on the value of water and viable options for a resilient water supply.
- Communication strategies to better engage stakeholders and the public on the benefits of water reuse, including DPR.