Appendix C: Compilation of Ideas/Actions from the Literature

NATIONAL WATER REUSE
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Appendix C: Compilation of Ideas/Actions from the Literature and List of Literature Sources

Appendix C provides the results of a primary review of literature identified using targeted literature searches. High-level actions from the literature are organized by the Strategic Objectives outlined in the draft Action Plan.

Disclaimer

The literature reviewed herein is not exhaustive. It is intended to serve as a high-level sampling of available literature that EPA and its water reuse partners were aware of and received by July 1, 2019. Actions are not listed in order of significance.

Section 2.1—Enable Consideration of Water Reuse with Integrated and Collaborative Action at the Watershed Scale

- Create tools so that communities can "set the foundation" to start implementing an IWRM (or ONE Water) approach in their region/basin/city. This phase kicks off the entire IWRM planning approach by defining what IWRM means to your entity, identifying a core group of critical partners, and assessing the needs and opportunities that your IWRM approach would address (United States Water Alliance, 2019a,b; WRF, 2017a).
- Support an integrated water management approach to address site-specific conditions and objectives; no one reuse strategy fits all communities (CUWA, 2019; WE&RF, 2017a; Kunz et al., 2015; AWWA, 2014; NRC, 2012; U.S. EPA, 2012a).
- Identify ways to encourage flexibility at the local level so legislation or codes related to water reuse (including permitting) enable implementation of the reuse strategy that best fits the needs of the local community (CUWA, 2019; WateReuse California, 2019; WRF, 2019b; Pacific Institute, 2018; CUWA, 2017; State of California, 2016; Freedman and Enssle, 2015; Kunz et al., 2015). Include consideration of flow and life cycle assessment (WRF, 2019c; CUWA, 2019; Ghimire et al., 2019; AWWA, 2017; CUWA, 2017; Tran et al., 2017; National Academies of Sciences Engineering and Medicine, 2016; Wiener et al., 2016). Areas where revision is needed include: local regulations that require all water meet potable standards, plumbing codes related to dual piping, stringent permitting and inspection requirements for recycled water, change petition processes, the use of alternative treatment trains, and raw water and treated drinking water augmentation (WateReuse California, 2019; Freedman and Enssle, 2015).
- Conduct analysis to understand impacts of water conservation and reuse on downstream water supplies (NRC, 1996) under future population scenarios, considering that contributions of wastewater in receiving streams are likely to increase under current population projections and migration trends – additionally how will the likely associated increase in salinity and other effects on water quality affect water reuse applications (NRC, 2012).
    - Consider how policies can account for a holistic view of the water service sustainability tradeoffs and potential benefits, including the beneficial use of stormwater (California Water Boards, 2018; Cashman et al., 2018; Pacific Institute, 2018; Cashman et al., 2017; Cashman et al., 2016; National Academies of Sciences Engineering and Medicine, 2016).

- Support and/or identify policy innovations to create appropriate incentives to capture watershed-based environmental benefits of agricultural application of recycled water. Specifically, states/locales' reuse regulations need to be coordinated with irrigation water quality requirements (within the watershed and existing conveyance infrastructure when possible) (WRF, 2019b).
- Conduct an analysis to understand the non-monetized costs and benefits of reuse to help planners and regional managers understand benefits of water reuse within IWRM. For example, reuse coupled with conservation can reduce seasonal peak demands to potable systems, thereby reducing capital/op costs and stretching potable supplies. These benefits can be challenging to quantify prior to implementing a project and documenting performance (NRC, 2012).
- Support collaboration between communities and industrial water facilities, which are some of the highest volume water users in the United States and offer a key partnership for municipalities looking for reclaimed water off-takers (Bluefield Research, 2017).
- Utilize a framework that outlines a strategy for systematically identifying and incorporating the costs and benefits of water management strategies into decision making. The framework could be used by the public sector, for example, when evaluating which water supply/supplies or water quality interventions to pursue. Or, it could be used by the private sector, when assessing which projects to invest in within their value chains or as part of their philanthropic activities (Pacific Institute, 2019).

Section 2.2—Coordinate and Integrate Federal, State, Tribal, and Local Water Reuse Programs and Policies

- Assess the potential harmonization of regulations across agencies. Regulatory inconsistency between agencies is cited as an impediment to reuse by studies and stakeholders (WRF, 2019b; U.S. EPA, 2018a; Bluefield Research, 2017; U.S. EPA, 1972).
- *Add to the NPDES Action*:
    - Consider the development of "umbrella permits' so that a WRRF wishing to deliver reuse water to agriculture does not need to apply for a new NPDES permit solely because the discharge point to the same waterbody has changed (e.g. moved from the centralized WRRF location to somewhere near agricultural lands) (WEF, 2018b).
- Consider modifying SDWA's structure or implementation to increase public confidence in all potable supplies and ensure appropriate controls exist in reuse projects; adjustment to consider treatment or monitoring for effluent-dominated source waters (e.g. water reuse) would respond to concerns raised by state/local regulators and advisory panels (NRC, 2012).
- Develop policies to account for water shortages over 10-year time frames (U.S. GAO, 2014).
- Conduct an exploratory analysis of regulatory and policy incentives and/or clarifications to encourage additional reuse of industrial water (U.S. EPA, 2018e). The industry is adept at dealing with a regulated environment and will pursue creative uses of water (and produced water), if it makes financial sense (WRF, 2018e; WE&RF, 2016c; Colorado Energy Office & Colorado Mesa University, 2014).
- Consider the establishment of structures for ongoing regulatory oversight to ensure compliance of onsite non-potable projects. Oversight is essential to protect public health and sustain safety and

reliability by meeting regulatory standards and permit requirements (United States Water Alliance, 2018).

- Develop new regulatory programs to authorize and manage beneficial use of produced water, particularly reuse outside the oil and gas industry, as programs specific to these uses are not well developed. Legal and regulatory considerations include determining state water rights and applicable regulations such as those relating to water quality standards and permitting (Groundwater Protection Council, 2019).
- Determine the applicability of current centralized waste treatment effluent guidelines to oil and gas operations interested in water reuse applications (U.S. EPA, 2018b).

Section 2.3—Compile and Refine Fit for Purpose Specifications

- Develop a risk-based regulatory framework to both maintain quality and increase confidence in reuse as a safe alternative. As part of this effort, develop a new quality assurance framework for water reuse and establish health benchmarks for various uses of recycled water (Groundwater Protection Council, 2019; Nappier et al., 2018; Soller et al., 2018; Tasker et al., 2018; U.S. EPA, 2018a; WRF, 2018c; United States Water Alliance, 2017a; WE&RF, 2017b; National Academies of Sciences Engineering and Medicine, 2016; USAPHC, 2014).
    - As part of this effort, identify better indicators and surrogates that can be used to monitor process performance in reuse scenarios and develop online real-time or near real-time analytical monitoring techniques for their measurement (Schoen et al., 2018; Soller et al., 2018; WateReuse Colorado, 2018b; WRF, 2018d; AWWA, 2017; Jahne et al., 2017; United States Water Alliance, 2017a; WE&RF, 2017b, 2016d; NRC, 2012). This will have the additional benefit of reducing unnecessary treatment costs (California Water Boards, 2018).
    - Both microbial contaminants and contaminants of emerging concern, such as xenobiotics and pharmaceuticals (e.g., carbamaxepine), should be considered in risk frameworks (Ibekwe et al., 2018; Sheikh, 2017; Paltiel et al., 2016).
- Utilize a framework as a planning support tool to reveal the environmental impacts (e.g., greenhouse gas emissions, energy consumption) of integrating decentralized non-potable reuse with existing centralized wastewater infrastructure, which can be adapted to evaluate different treatment technology scales for reuse (Kavvada et al., 2016).
- Identify risks associated with the unintended or inappropriate uses of reclaimed water (Danforth et al., 2019; Rahm and Riha, 2014; NRC, 2012). For example:
    - Understand cross-connection contamination or unacceptable reclaimed water sources for a future use (NRC, 2012).
    - Consider subtle changes associated with wastewater derived compounds (e.g., reports of treated wastewater causing severe lesions and developmental alterations in amphibians, which are not common sentinel testing organisms in the Whole Effluent Toxicity (WET) testing paradigm) (NRC, 2012).
    - Endorse an implementation framework to ensure public health protection through reuse of industrial water (Groundwater Protection Council, 2019; Colorado General Assembly, 2018; WE&RF, 2016c; U.S. EPA, 2012c, 1980). Industrial water recycling requirements can be site-

    specific and must be based on careful evaluations of process requirements (Groundwater Protection Council, 2019; WE&RF, 2016c; Colorado Energy Office & Colorado Mesa University, 2014; Argonne National Laboratory, 2007; U.S. EPA, 1980).

    - Continue researching the risks of unconventional oil and gas, which can vary on a site-specific basis. This work should include consideration of emerging chemicals of concern, exposure, and impact on health (including chronic toxicity) and the environment (e.g., sediments, plants) associated with produced water (U.S. EPA, 2019; Hull et al., 2018; U.S. EPA, 2018b, e; Blewett et al., 2017; Chen et al., 2017; He et al., 2017; Orem et al., 2017; Pica et al., 2017; Silva et al., 2017; Shonkoff et al., 2016; Torres et al., 2016; Colorado Energy Office & Colorado Mesa University, 2014; Skalak et al., 2014). For produced water treated to achieve acceptable TDS (salinity) limits, non-saline toxicity may still pose residual risks that must be understood and managed (Danforth et al., 2019).
    - Support monitoring and data collection related to water resource risks as part of the planning process for oil and gas development (Rahm and Riha, 2014).

- Conduct pilot project with respect to risks associated with produced water use for dust suppression and other current practices (Colorado Energy Office & Colorado Mesa University, 2014). (could be potentially funded under the EPA START GRANT).
- Develop a better understanding of pathogen removal efficiencies and establish default performance levels for various wastewater treatment processes for use in risk assessments in potable and non-potable reuse projects (Schoen et al., 2018; WateReuse Colorado, 2018a, b, d; Jahne et al., 2017; NRC, 2012). This will have the additional benefit of reducing unnecessary treatment costs (California Water Boards, 2018; WE&RF, 2017b).
- Retrofit existing wastewater treatment plants as a model for reuse project development (Bluefield Research, 2017).

Section 2.4—Promote Technology Development, Deployment, and Validation

- Develop standardized guidance (or best practices) for design and operation of engineered natural systems (e.g. environmental buffers employed in reuse projects) so that (a) their performance can be quantifiably compared to engineered unit processes and (b) designs can be adjusted to ensure uniform protection offered by one natural system/environmental buffer versus another (Attwater and Derry, 2017; NRC, 2012).
- Conduct an assessment of what technologies can be applied to water reclamation so that new plants can recover energy and use resources most efficiently (NRC, 2012).
- Increase investment in the agriculture/water quality nexus. Investments in research and in the development of new technologies targeting water quality, and plant and soil protection, may reduce or eliminate impediments relating to water quality (Wall et al., 2019; WRF, 2019b; USDA, 2016; Medina et al., 2015; O'Neill and Dobrowoiski, 2005; NRC, 1996).
- Improve monitoring and implementation of new technologies for urban runoff capture and infiltration practices, which are necessary to protect local drinking water supplies. Advances in sensing and forecasting can make stormwater capture more dynamic through interconnectivity and real-time decision making (Luthy et al., 2019; Luthy and Sedlak, 2018; U.S. EPA, 2018d).

- Research and quantify the specific process modifications needed for reuse projects for contaminants found to increase in concentration owing to the use of specific treatment processes (salinity, NDMA, aluminum, recalcitrant organic nitrogen, bromate, and other DBPs) (Danforth et al., 2019; WRF, 2017b). Sodium and boron can impair agricultural/landscape irrigation if not treated to specific baselines; a systematic review of treatment systems can determine where systems matching fit for purpose can be improved and/or made less expensive (NRC, 2012).

- Explore the use of various treatment trains and combinations of treatment technologies to clean effluent before it is blended with existing water supplies. There is no single technology solution for wastewater reuse and a range of treatment technologies is often required (Bluefield Research, 2017).

- Consider the use of technologies (such as evaporation) to remove total dissolved solids that use waste heat from other industrial sources that, where co-located. The use of these technologies can significantly reduce the costs of treatment of oil and gas extraction wastes (U.S. EPA, 2018b).

- Specific Literature R&D requests:
    - R&D in salinity reduction and point-of-use treatment for application of reuse water in irrigation. Cost effective methods to reduce salinity and meet disinfection requirements may foster greater adoption of reuse (WRF, 2019a).
    - R&D to reduce cost of targeted NH3/ammonium (not nitrate) removal, which must occur if water is used to stock a recreational lake, engineered wetland, coastal marsh, or woodlands (toxic to aquatic life) (NRC, 2012).
    - Increase R&D of technologies that will allow industrial water to be reused, specifically including brine disposal (WRF, 2019c; U.S. EPA, 2019; WateReuse California, 2019; Silva et al., 2017; Colorado Energy Office & Colorado Mesa University, 2014).
    - R&D to develop and validate standardized methods for analyzing industrial/oil and gas related chemicals for use in water quality monitoring (Shonkoff et al., 2016).
    - R&D to support mobile treatment plants to potentially make nonindustrial uses [of oil and gas produced water] more feasible, both logistically and financially. In many basins, mobile plants are used to some degree or on a preliminary basis; more widespread use will require funding support and collaborative investment (Bluefield Research, 2017; Colorado Energy Office & Colorado Mesa University, 2014).
    - R&D for new technologies (e.g., sensors) can be used to address continuous monitoring to ensure adequate performance (United States Water Alliance, 2017a; WE&RF, 2017b; Western Resource Advocates, 2017; National Academies of Sciences Engineering and Medicine, 2016; Freedman and Enssle, 2015; U.S. EPA, 2012b).
    - R&D to develop alternative measures to reflect the toxicity caused by the presence of trace organic compounds (TrOCs) (WRF, 2017a) and other oil and gas-related chemicals (Shonkoff et al., 2016).
    - R&D to develop techniques to assess produced water quality characteristics that overcome the challenges that hypersaline or corrosive produced waters pose to routine analytical methods (Danforth et al., 2019). More research is needed to understand the complex chemistry of hydraulic fracturing fluids, wastewaters, and treatment methods and efficacy

    for removal of organic compounds in produced water, which can vary by operator, geologic formation, and fluid age (Butkovskyi et al., 2018; Luek et al., 2018; Silva et al., 2017).

  - R&D summary of needs for power plant cooling water (Argonne National Laboratory, 2007).

Section 2.5—Improve Availability of Water Information

- Develop an operational database to better understand common failure modes at DPR facilities and impacts on water quality to allow for more effective design of resilience strategies (WRF, 2018c; WHO, 2017; WE&RF, 2016a; WateReuse Association, 2015). The industry would benefit from the compilation and analysis of data from existing potable reuse facilities (WRF, 2017b).
- Develop a centralized database with information on the amount of wastewater reused by states. Include data from smaller systems (WEF, 2018a).
- A more effective mechanism for the compilation and sharing of AWTF operation and performance data (plant design, process performance, operation practices, and mechanical reliability) should be compiled in a consistent format and made accessible in a timely manner to all interested WateReuse 135 parties. Data can be used to assess current practices, as well as inform and potentially promote new designs (WateReuse Association, 2015).
- Establish a database on effluent and surface waters impaired by TDS at the national level, which would help farmers make water management decisions when addressing increasingly-brackish groundwater supplies (WRF, 2019b).
- Create a mechanism for utilities to report data on agricultural reuse practices in publicly accessible formats that facilitate analysis. Federal and state databases on water management and reuse are an important research asset (WRF, 2019b).
- Gather and share trusted, accessible information about produced water, including baseline data and the rapidly-evolving technologies for treating and re-using produced water. Emphasize principles of joint data collection, monitoring, and conveying such data to stakeholders in accessible ways. Education institutions and a structure for such data-sharing could play important roles (Colorado Energy Office & Colorado Mesa University, 2014).
- Reporting of produced water chemical composition should be expanded in frequency and cover more chemicals used in hydraulic fracturing fluids. Produced water management practices should be oriented towards safer and more sustainable options such as reuse and recycling, but with adequate controls in place to ensure their safety and reliability (Chittick and Srebotnjak, 2017).
- Public information about the chemicals and effects on health associated with onshore unconventional oil and gas production is incomplete because some are considered confidential, which has created mistrust towards the industry (Torres et al., 2016).
- Establish a program for source water monitoring and pretreatment and programs for the control of pathogens and chemical risks with the goal of protecting public health and safety (AWWA, 2018).

Section 2.6—Facilitate Financial Support for Water Reuse

- Quantify the non-monetized costs and benefits of potable and nonpotable water reuse compared with other water supply sources to enhance water management decision making (NRC, 2012). For example:
    - Consider balance between crop restriction and wastewater application techniques with respect to overall costs (WHO, 1989). Include a triple bottom line cost benefit analysis to compare nontraditional water sources (WRF, 2018a).
    - Document the non-monetized costs and benefits of reuse projects in comparative cost analyses of water supply alternatives. EPA's WEAP model might provide a useful tool for this effort (NRC, 2012; U.S. EPA, 2012b).
    - Quantify the non-monetized costs and benefits of potable and non-potable water reuse compared with other water supply sources to enhance water management decision making (NRC, 2012).
- Identify (or compile) non-traditional funding mechanisms that allow greater efficiency to implement water reuse into management plans (Public Policy Institute of California (PPIC), 2019; WateReuse California, 2019; Colorado General Assembly, 2018; River Network, 2018; Bluefield Research, 2017; United States Water Alliance, 2017b; WRF, 2017a; Perrone and Rohde, 2016; State of California, 2016; Colorado Energy Office & Colorado Mesa University, 2014; U.S. EPA, 2012b; NRC, 1996). These may include: a credit trading program (Colorado General Assembly, 2018; United States Water Alliance, 2017b; Colorado Energy Office & Colorado Mesa University, 2014; NRC, 1996), collaborative funding models (River Network, 2018; United States Water Alliance, 2017b; NRC, 1996), public-private partnerships (P3s) (Colorado General Assembly, 2018; WRF, 2017a; U.S. EPA, 2012b), EPA innovation grants (Colorado General Assembly, 2018; WRF, 2017a; U.S. EPA, 2012b), grants from the Bureau of Reclamation to support drought mitigation projects (Bluefield Research, 2017), low cost financing for recycled water projects (State of California, 2016), fees from developers and non-residential properties (Colorado General Assembly, 2018; WRF, 2017a; U.S. EPA, 2012b), inclusion of operation and maintenance of nonpotable on-site systems in the total cost of the building (and thus covered by the property owner) (Pacific Institute, 2018), the sale of green bonds (WateReuse California, 2019; Bluefield Research, 2017), state revolving and WIFIA funds (Bluefield Research, 2017), and make compelling cases to increase rates (WRF, 2017a).
- Target financial support/subsidies for reuse projects to small farms. Smaller farms' irrigation practices are disproportionately affected during surface and groundwater shortages, which are major drivers of reuse (WRF, 2019b). Economic challenges are the greatest barrier to successful project implementation on farms. High costs of distribution systems (pipelines) present a significant challenge (Bischel et al., 2012).
- Leverage the Water Security Grand Challenge funding to advance transformational technology and innovation to meet the global need for safe, secure, and affordable water (U.S. DOE, 2018).
- Leverage investments in advanced water treatment as an alternative to plant upgrades (CUWA, 2019; WE&RF, 2017a). Consider adjustment of rate structure to equitably distribute cost of service to existing and future purveyors (AWWA, 2014).
- Incentivize innovative water exchange arrangements and innovation in water and wastewater treatment and recycled water infrastructure (WateReuse California, 2019).

- Provide a recycled water rate structure discounted from potable water rates (Bischel et al., 2012).

Section 2.7—Integrate and Coordinate Research on Water Reuse

- Issue a challenge to develop approaches for using industrial water to meet the demands of future water availability (Colorado General Assembly, 2018; U.S. EPA, 2018e).
- Explore the impacts and potential opportunities for utilizing recycled water for agricultural irrigation presented by the FDA Food Safety Modernization Act (FSMA) Produce Safety rule (WRF, 2018a).
- Engage the National Academies to set a national research agenda to examine institutional challenges to potable reuse and provide funding to meet those challenges as well as the Water Research Foundation, which funds a suite of research projects focused on both potable and nonpotable reuse (WRF, 2019a; U.S. EPA, 2018c).

Section 2.8—Improve Outreach and Communication on Water Reuse

- Produce more science and highlight success stories across states relating to recycled water for food crop irrigation, to aid state regulators considering expansion of water reuse permitted use in agriculture (WRF, 2019b). In particular, document case examples of agricultural reuse in coastal areas, especially those driven by saltwater intrusion and/or coastal subsidence, that are not typically considered as strong opportunities for reuse (e.g. Puget Sound) (WRF, 2019b). Additionally:
    - Help farmers understand the nutrient content potential of recycled water, particularly in areas adjacent to POTWs that do not remove nutrients (78%) or do discharge to nutrient-impaired waterbodies (1500). It will be important to convey that existing POTW effluent could supply 17% of irrigation needs in the west and 75% of seasonal irrigation needs in the east (WRF, 2019b).
- Help develop public relations campaigns to alleviate public concern and minimize risks associated with a reduction in sales from irrigation with recycled water (WEF, 2018b).
- Develop mechanisms to ensure utilities and regulators have the ability to learn about emerging topics in water reuse, because not all have the professional development budget to purchase access to journal articles and reports (WRF, 2019b). Regional conferences (such as the Idaho Water Reuse Conference) have proven to be an effective forum for learning about neighboring states successes, challenges, and approaches to regulation (WRF, 2019b).
- Invest in water knowledge, including improved public understanding of a region's available water supplies and the full costs/benefits associated with water supply alternatives, both to increase general public awareness/support/understanding of the value of water, and to enable more efficient processes for the evaluation of specific reuse projects (Bischel et al., 2012; NRC, 2012). (This could include K-12 educational programs)
    - Promote collaborative and cooperative outreach with a uniform message and consistent terminology to facilitate public acceptance of potable reuse. For example, develop school educational programs for grades 1 through 12 that address source control issues related to potable reuse (AWWA, 2018; WRF, 2017a; AWWA, 2016; Millan et al., 2015; AWWA, 2014). Make the natural water cycle part of the conversation (include aspects of WWTP/DWTP/reuse) (AWWA, 2016).

- Develop public outreach for future planned potable projects. Outreach efforts should be applied early, include set goals, engage the media, use consistent terminology, avoid the use of jargon, confront misinformation as soon as it is encountered, education about emerging technologies, and provide information to the public about constituents of concern and acceptable discharges to the sewer (AWWA, 2018; U.S. EPA, 2018a; WHO, 2017; WRF, 2017a; AWWA, 2016, 2014; NRC, 2012). Mainstreaming planned potable reuse will require building legitimacy, planning within an integrated water context, enacting a robust communications strategy, and appropriate regulatory environment (CUWA, 2019; WE&RF, 2017a; NRC, 2012; U.S. EPA, 2012a). Could also apply to outreach to other use applications:
    - Develop materials/help states, locales, and industry closely collaborate with local tribes when considering or planning to employ snowmaking using recycled water, when applicable (Leao and Tecle, 2003).
    - Help decision-makers at all levels identify and understand relevant receptors and potential adverse effects at the individual, population, and community level for a particular use [of produced water] (Danforth et al., 2019).
- Document successful applications of reuse/recycle technology at industrial installations (Colorado Energy Office & Colorado Mesa University, 2014).
- Develop best practices for communicating relative risk and develop effective guidance for improving risk communication around exposure to contaminants of emerging concern that might be found in reclaimed water (ACWA & ASDWA, 2019).

Section 2.9—Support a Talented and Dynamic Workforce

- Develop operator training and licensure/certification programs specifically for DPR facilities (WRF, 2019a; WateReuse Colorado, 2018a, b, c, d; WRF, 2018b; WE&RF, 2017a; WRF, 2017b; WE&RF, 2016a, b, d; WateReuse Association, 2015; AWWA, 2014).
- Create recognition awards and certification programs for reuse facilities (Freedman and Enssle, 2015).
- Provide guidance on requirements for ability to manage complex water projects, technical understanding, and operator licensing needed for potable reuse projects (WE&RF, 2017a; WateReuse Association, 2015; AWWA, 2014).

Section 2.10—Develop Water Reuse Metrics that Support Goals and Measure Progress

- Conduct an analysis of de-facto potable water reuse to quantify the number of people possibly exposed to wastewater constituents/in quantifiable concentrations; such as study has not been done for nearly 40 years (NRC, 2012).
- Redo the analyses to understand coastal discharges as a percent of total discharges, to better understand the extent of public supplies potentially saved by reusing instead of discharging to oceans/estuaries (WateReuse California, 2019; NRC, 2012).
- Support development of real-time nutrient measurements. Real-time data on nutrient concentrations are needed to adaptively manage recycled water to accommodate the variability in

evapotranspiration rate and fertilization needs throughout a crop's production cycle (WRF, 2019a; Soller et al., 2018; WRF, 2018d).

- Perform and publish studies to better-characterize opportunities for reuse specifically in small communities (WRF, 2019a, b). Most data indicating proximity of POTWs to irrigable land are based on large-community POTW data that is self-reported, such as the Clean Watersheds Needs Survey (WRF, 2019b).
- Coordinate and incorporate the following recommendations concerning analysis of Clean Watersheds Needs Survey data (WRF, 2019b):
    1. Spray irrigation (land application) represents a major gap in accounting for agricultural water reuse. Further review of the CWNS data revealed inconsistencies between states and POTWs in how these data are reported. How many of the POTWs reporting spray irrigation are growing a crop? Those that are not currently growing crops represent an opportunity to increase food or fodder production with no or little additional investment in infrastructure (WRF, 2019b).
    2. Disinfection appears to be under-reported in the CWNS data, but is an important determinant in the type of crops that can be irrigated with recycled water. Further clarification is needed to identify the actual prevalence of disinfection (WRF, 2019b).
    3. The CWNS class 'reuse for irrigation' does not distinguish between reuse for landscape irrigation and reuse for agricultural irrigation. Future surveys should provide further distinction between these classes (WRF, 2019b).
    4. Data on unit processes present at a facility are useful for evaluating the potential for a given facility to produce water suitable for reuse. However, reporting rates for these variables are low. Higher response rates would facilitate a more complete analysis of these data (WRF, 2019b).
    5. The class 'advanced treatment' could be made more useful for evaluating the potential for recycled supply if the data included a variable indicating the presence of membrane processes or other technologies which would meet requirements for 'filtration' (WRF, 2019b).

Other potential ideas

- Related to water rights:
    - States should clarify water rights laws (for example, the right to use aquifers as reuse supply storage; and the rights and interests of downstream interests), so that those interested in reuse can efficiently understand whether they may proceed in acquiring necessary water rights/permits and implementing their projects (Bluefield Research, 2017; NRC, 2012).
    - Clarify/address water rights regarding stormwater in most western states. Points requiring clarification include the acquisition of water rights as a requirement for large-scale stormwater capture and use projects, and water rights may limit widespread implementation of smaller-scale stormwater and graywater projects for consumptive uses

    (California Water Boards, 2018; AWWA, 2017; Bluefield Research, 2017; National Academies of Sciences Engineering and Medicine, 2016).

  - Clarify/address water rights and water sharing related to the use of produced water, particularly reuse outside the oil and gas industry (Groundwater Protection Council, 2019). Midstream water operations and other forms of water sharing are typically outside traditional state oil and gas regulatory frameworks and require state authorization and oversight for activities that are not associated with other permitted oil and gas operations (Groundwater Protection Council, 2019).
  - Clarify water rights specifically to facilitate trading of reclaimed water and/or trades offsetting one supply of water with reuse water will enable more surface water augmentation (NRC, 2012).
- Related to snowmaking:
  - Conduct extensive monitoring to determine the impacts of snowmaking with recycled water on regional water resources, vegetation, and wildlife resources (Szpaczynski, 2019; Kursky and Tecle, 2015; Niraula and Tecle, 2006; Leao and Tecle, 2003).
- Related to climate change:
  - Consider the impact of climate change on droughts, rainfall distribution, and storm intensity, which impact wastewater flow and volume of water available for reuse (Public Policy Institute of California (PPIC), 2019; WateReuse California, 2019; Attwater and Derry, 2017; Bluefield Research, 2017; Tran et al., 2017).
  - Climate change might necessitate the need to develop new, drought proof water supplies (Public Policy Institute of California (PPIC), 2019; Bluefield Research, 2017).

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