INVESTIGATION ON THE FEASIBILITY OF DEVELOPING UNIFORM WATER RECYCLING CRITERIA FOR DIRECT POTABLE REUSE

STATE WATER RESOURCES CONTROL BOARD

Report to the Legislature
September 2016 - Public Review Draft

In Compliance with Water Code Section 13563

STATE OF CALIFORNIA
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Abbreviations and Acronyms

AFY	Acre-foot per year
AWWA	American Water Works Association
CalEPA	California Environmental Protection Agency
CA/NV AWWA	California-Nevada Section of AWWA
CDPH	California Department of Public Health
CEC	Constituents of Emerging Concern
CWEA	California Water Environment Association
DPR	Direct Potable Reuse
DDW	Division of Drinking Water, State Water Resources Control Board
DTSC	Department of Toxic Substances Control
IPR	Indirect Potable Reuse
LRV	Log Removal Value, a LRV of 1 equals a 10-fold removal, a LRV of 2 equals a 100-fold removal, a LRV of 6 equals a 10^6-fold removal, etc.
MGD	Million gallons a day
NWRI	National Water Research Institute
OEHHA	Office of Environmental Health Hazard Assessment
QMRA	Quantitative microbial risk assessment
RO	Reverse Osmosis filtration
RWQCB	Regional Water Quality Control Boards
SB	Senate Bill
SDWA	Safe Drinking Water Act
SWA	Surface water augmentation
SWRCB	State Water Resources Control Board (State Water Board)
SWTP	Surface water treatment plant
TOC	Total Organic Carbon
TMF	Technical, managerial, and financial capacity
USEPA	U.S. Environmental Protection Agency
UV	Ultraviolet light
WEF	Water Environment Federation
WERF	Water Environment Research Foundation
WE&RF	Water Environment & Research Foundation
WWTP	Wastewater treatment plant

Executive Summary

The population of California is projected to increase from 38 million to 50 million by the year 2049. This population increase will have a dramatic impact on the water needs of the State. To address this increased water need, the State will take a variety of actions as outlined in the Governor's California Water Action Plan, first released in 2014 and recently updated in 2016 (CA Natural Resources Agency, 2016). One component of that plan is to increase the use of recycled wastewater. The State Water Board has set a mandate of increasing the use of recycled water by 200,000 acre-foot per year (AFY) by 2020 and an additional 300,000 AFY by 2030. Although the use of recycled water for non-potable uses such as agricultural and landscape irrigation is already well established and has been regulated for decades in California, increasing the use of recycled water as a source of potable water ("potable reuse") is critical for the State to be able to meet this goal. For example, groundwater replenishment (a.k.a., groundwater recharge), which is an indirect form of potable reuse, already reuses more than 200,000 acre-feet of recycled water a year via just eight projects throughout California. Accordingly, the State Water Board revised and adopted uniform water recycling criteria for groundwater replenishment in 2014 and is in the process of establishing uniform water recycling criteria for the augmentation of surface water reservoirs used as a source of drinking water supply, which is another form of indirect potable reuse.

Legislative Mandate

In 2010, the California Legislature enacted Senate Bill (SB) 918 (Chapter 700, Statutes of 2010), which added sections 13560-13569 (Division 7, Chapter 7.3) to the Water Code regarding potable reuse of recycled water. SB 918 defined the term "direct potable reuse"[1] and directed the California Department of Public Health (CDPH) to investigate the feasibility of developing uniform water recycling criteria for direct potable reuse (DPR), convene an expert panel to study the technical and scientific issues, and provide a final report to the Legislature by December 31, 2016. The main difference between DPR and indirect potable reuse (IPR) is DPR's lack of a meaningful environmental buffer.

In 2013, the Legislature enacted SB 322 (Chapter 637, Statutes of 2013), which amended Chapter 7.3 to require that an advisory group subject to the Bagley-Keene Open Meeting Act be convened to advise the expert panel and the State Water Board in the development of the feasibility report. SB 322 additionally tasked the expert panel to assess whether additional areas of research are needed to be able to establish uniform regulatory criteria for DPR and recommend an approach for accomplishing any additional needed research in a timely manner. SB322 required that a draft report summarizing the expert panel research recommendations be prepared by June 30,

[1] "Direct potable reuse" means the planned introduction of recycled water either directly into a public water system, as defined in Section 116275 of the Health and Safety Code, or into a raw water supply immediately upstream of a water treatment plant.

2016, and a draft feasibility report be provided to the public for comment by September 1, 2016.

Experience in Direct Potable Reuse
The State Water Board reviewed DPR regulations and DPR projects nationally and internationally to determine what other regulatory approaches have been taken. There have been no regulations developed for DPR to date. There are two DPR projects currently operating worldwide as permanent sources of drinking water. The two DPR projects, one in Windhoek, Namibia, and the other in Texas, were pursued out of necessity after the communities suffered through severe drought, despite conservation efforts and efforts to find better sources of water. Both projects were constructed before there was significant guidance available on the safety of using DPR. In both cases, the regulating authority provides oversight of these projects via a site-specific permitting process rather than via a uniform regulatory process that would be applicable to other facilities.

Both projects continue to operate today under permit by regulating agencies in the absence of DPR regulations.

Independent Review
The State Water Board convened two independent groups, an expert panel of scientists and engineers, and an advisory group of stakeholders, in early 2014 to advise the State Water Board on issues related to the investigation of the feasibility of developing uniform water recycling criteria for DPR that is protective of public health. The Expert Panel was tasked with advising on public health issues and scientific and technical matters, assessing the need for additional research on DPR, and recommending an approach for completion of needed research. The Advisory Group was tasked with advising the Expert Panel and the State Water Board on relevant topics such as practical considerations for DPR criteria that are protective of public health and achievable by project proponents. The recommendations of the Expert Panel and Advisory Group established the foundation of the State Water Board's investigation and findings.

Expert Panel Findings
The Expert Panel found that it is technically feasible to develop uniform water recycling criteria for DPR in California, and that those criteria could incorporate a level of public health protection as good as or better than what is currently provided by conventional drinking water supplies and IPR. The Expert Panel found that the functionality of an environmental buffer (i.e., storage, attenuation, and response time) as provided by IPR projects was an important level of protection that would be absent in DPR projects. The Expert Panel indicated that for DPR projects, this level of protection can be addressed by enhancing the reliability of mechanical systems and treatment plant performance.

Additionally, the Expert Panel finds that there is no need for additional research to be conducted to establish criteria for DPR, but provides six research recommendations that would enhance the understanding and acceptability of DPR, and further ensure that DPR is protective of public health. The Expert Panel suggests that the research be

supported directly by the State of California, and notes that the recommended research could be done either before and/or concurrently with the development of DPR criteria. The research recommendations are summarized as follows:

1. To continue to improve on source control and final water quality monitoring, carry out an ongoing literature review to identify new compounds that may pose health risks particularly to fetuses and children from short term exposures.
2. Implement a probabilistic method (Quantitative Microbial Risk Assessment, QMRA) to confirm the necessary removal values for viruses, Cryptosporidium and Giardia based on a literature review and new pathogen data collected, and apply this method to evaluate the performance and reliability of DPR treatment trains.
3. Require monitoring of pathogens in raw wastewater to develop better empirical data on concentrations and variability.
4. Investigate the feasibility of collecting raw wastewater pathogen concentration data associated with community outbreaks of disease, and implement where possible.
5. Identify suitable options for final treatment processes that can provide some "averaging" with respect to potential chemical peaks, particularly for chemicals that have the potential to persist through advanced water treatment.
6. Develop more comprehensive analytical methods to identify unknown contaminants, particularly low molecular weight compounds potentially in wastewater that may not be removed by advanced treatment and is not presently detectable by current regulatory monitoring approaches.

While the Expert Panel believes that the absence of better information that will be provided by this research may not be an impediment to establishing uniform criteria for DPR, the State Water Board finds the research results will make a significant contribution to the development of criteria for DPR, and most importantly, will provide a higher level of certainty that the criteria are protective of public health, and therefore must be conducted concurrently with the development of DPR criteria.

Additional Knowledge Gaps

The State Water Board finds that there are additional knowledge gaps that remain before criteria can be written to address issues unique to DPR. These knowledge gaps primarily relate to the quantification of reliability, which is critical to ensuring the level of protection that otherwise would be afforded by an environmental buffer. These critical knowledge gaps must be addressed in order to develop well-crafted objective criteria that are unambiguous and enable an objective determination of compliance. The State Water Board plans to work with subject matter experts and is monitoring the progress of a number of research projects that are underway or planned that could help fill in the knowledge gaps.

Potential New Programs and Initiatives

The Expert Panel and the Advisory Group provided recommendations that will need to be addressed regarding the non-treatment barriers that are part of enhancing the safety of DPR, including source control, wastewater treatment plant optimization, advanced operator certification, and technical, managerial, and financial capacity. While these

recommendations need not be implemented before the adoption of criteria for DPR, the State Water Board must evaluate these potential new programs and initiatives that may be necessary to enhance the regulation of DPR to protect public health.

Process Going Forward

The use of recycled water for DPR has great potential but it presents very real scientific and technical challenges that must be addressed to ensure the public's health is reliably protected at all times. Given the various possible types of DPR projects, a common framework will be needed to avoid discontinuities in the risk assessment/risk management approach as progressively more difficult conditions are addressed. This report presents an assessment of the issues associated with DPR as directed by the Legislature, carefully considers the findings and recommendations of the Expert Panel and the Advisory Group, and presents a number of conclusions and recommendations that are summarized in Chapter 4 and an Implementation Plan for the development of criteria for DPR in Chapter 5.

Chapter 1. Introduction

1.1. Requirement for this Report

In 2010, the California Legislature enacted Senate Bill (SB) 918 (Chapter 700, Statutes of 2010), which added sections 13560-13569 (Division 7, Chapter 7.3) to the Water Code regarding potable reuse of recycled water. SB 918 defined the term "direct potable reuse" and directed the California Department of Public Health (CDPH) to investigate the feasibility of developing uniform water recycling criteria for direct potable reuse (DPR) and provide a final report to the Legislature by December 31, 2016. The responsibility for completing and submitting the final report to the Legislature was transferred to the State Water Resources Control Board (State Water Board) on July 1, 2014. SB 918 also required that an expert panel be convened for the purposes of advising the State Water Board on public health issues and scientific and technical matters regarding the investigation.

In 2013, the Legislature enacted SB 322 (Chapter 637, Statutes of 2013), which amended Chapter 7.3 to require that an advisory group subject to the Bagley-Keene Open Meeting Act be convened to advise the expert panel and the State Water Board in the development of the feasibility report. SB 322 additionally tasked the expert panel to assess whether additional areas of research are needed to be able to establish uniform regulatory criteria for DPR, recommend an approach for accomplishing any additional needed research in a timely manner, and provide the recommendations to the State Water Board by June 30, 2016. SB 322 required that the draft feasibility report be provided to the public for comment by September 1, 2016.

In performing the investigation of the feasibility of developing the uniform water recycling criteria for DPR, Water Code Section 13565 requires the State Water Board to consider the recommendations from the expert panel; the recommendations of the advisory group; available research regarding unregulated pollutants as developed pursuant to the State Water Board's Recycled Water Policy; the regulations and guidelines in place for DPR from jurisdictions in other states, federal government and other countries; water quality and health risk assessments associated with existing potable water supplies subject to the discharges from municipal wastewater, stormwater and agricultural runoff; and, pursuant to Water Section 13563, the results of the State Water Board's evaluation of all of the following:

(1) The availability and reliability of recycled water treatment technologies necessary to ensure the protection of public health;

(2) Multiple barriers and sequential treatment processes that may be appropriate at wastewater and water treatment facilities;

(3) Available information on health effects;

(4) Mechanisms that should be employed to protect public health if problems are found in recycled water that is being served to the public as a potable water

supply, including, but not limited to, the failure of treatment systems at the recycled water treatment facility;

(5) Monitoring needed to ensure protection of public health, including, but not limited to, the identification of appropriate indicator and surrogate constituents;

(6) Any other scientific or technical issues that may be necessary, including, but not limited to, the need for additional research.

1.2. Regulation of Recycled Water for Potable Reuse

The regulation of recycled water for potable reuse is the responsibility of the State, since there are no federal regulations for water recycling or recycled water reuse. The Porter-Cologne Water Quality Control Act, Division 7 of the California Water Code provides that CDPH shall establish uniform criteria for each varying type of use of recycled water where the use involves the protection of public health. The Drinking Water Program (DWP) within CDPH carried out the responsibility of developing uniform criteria for the use of recycled water, and continues that authority as the Division of Drinking Water (DDW) within the State Water Board when the DWP was transferred to the State Water Board on July 1, 2014.

The Regional Water Quality Control Boards (RWQCBs) are responsible for the protection of the quality of ambient surface and groundwater (i.e., lakes, rivers, and groundwater basins) up to the point where the water enters a drinking water well or surface water intake. DDW and the RWQCBs work cooperatively on regulating potable reuse projects such as those that are designed to replenish groundwater supplies or augment surface water supplies using reservoirs. The RWQCBs incorporate the DDW criteria in Water Reclamation Permits or Waste Discharge Requirements that define the requirements that a water recycling project must meet.

The State Water Board is also responsible for regulating public water systems pursuant to the federal Safe Drinking Water Act (SDWA) and the California SDWA[2] and establishing regulations that carry out the California SDWA (Titles 17 and 22 of the California Code of Regulations). DDW carries out those responsibilities including ensuring the delivery of safe drinking water from drinking water supplies such as groundwater or surface water sources that are replenished or augmented by recycled water. DDW's drinking water regulatory responsibilities include the issuance of water supply permits covering the approval of the drinking water supply, water system design and operation procedures, inspection of water systems, the enforcement of laws and regulations to assure that all public water systems routinely monitor water quality and meet current standards, and assuring notification is provided to consumers when standards are not being met. Additional information on the regulation of the water supply and water quality to promote safe drinking water by DDW and other State and local agencies can be found in the "Safe Drinking Water Plan for California" (SWRCB, 2015).

[2] Health and Safety Code, div. 104, pt. 12, ch. 4, §116270 et seq.

1.3. History of Potable Reuse in California

There has been considerable development in the planned use of recycled water to supplement drinking water supplies in California. Recycled water is obtained from municipal wastewater (sewage) treatment plants and is highly treated prior to its reuse. Recycled water may be used as an indirect source of drinking water (called indirect potable reuse, IPR), wherein recycled water is used to augment groundwater basins or surface water reservoirs that are used as sources of drinking water. The highly treated recycled water is introduced into those sources and remains within these natural bodies for some period of time, sometimes provided with additional treatment, until drawn out for use by public drinking water systems and other public and private entities that depend on these sources to meet water needs.

The planned replenishment of groundwater basins with recycled water has been practiced in California for over 50 years. The Montebello Forebay Spreading Grounds has been operated since the 1930's to replenish the groundwater basins underlying the greater Los Angeles metropolitan area with imported water and local storm water; recycled water produced by the Los Angeles County Sanitation Districts was used as an additional source of recharge water starting in 1962. Recycled water use for groundwater recharge at the Montebello Forebay has expanded from about 12,000 acre-foot per year (AFY) in 1962 to about 50,000 AFY today. The Orange County Water District, which has operated a system of groundwater injection wells at the Talbert Gap to keep seawater out of the groundwater basin underlying Orange County since 1965 using local and imported water, started using recycled water produced by Water Factory 21 in 1976 as an additional source of injection water. Less than 5,000 AFY was injected at the beginning of this potable reuse project; currently the project injects about 35,000 AFY of recycled water. Potable reuse for groundwater replenishment has expanded to 8 approved projects, mostly in southern California, that use more than 200,000 AFY of recycled water, with more than a dozen planned by local groundwater management agencies and water utilities throughout the State.

The planned augmentation of a surface water reservoir (that is used as a source of drinking water supply) with recycled water has not been implemented in California. The concept was first proposed by the City of San Diego as part of its Total Resource Recovery Project in the 1990's, and conceptually approved by the Department of Health Services in 1994. The City had conducted studies over a decade to evaluate an advanced water treatment system to produce recycled water quality suitable for discharge to the City's San Vicente Reservoir, a raw surface water reservoir, for storage and subsequent withdrawal and treatment at its Alvarado drinking water treatment plant. The City Council canceled the project in May 1999 due to public opposition. In 2009, the City of San Diego revisited surface water augmentation by initiating a demonstration project at its North City Water Reclamation Plant (WRP). The City made a renewed proposal to CDPH to use advanced treated water from the North City WRP to augment the City's San Vicente Reservoir. CDPH conceptually approved the project in 2012. In 2016, the City of San Diego revised its project proposal to instead augment the City's Miramar Reservoir, a much smaller reservoir than the San Vicente Reservoir. The State Water Board is reviewing the revised project proposal.

In February 2009, the State Water Board adopted Resolution 2009-0011, Policy for Water Quality Control for Recycled Water (Recycled Water Policy), which set a mandate of increasing the use of recycled water by 200,000 AFY by 2020 and an additional 300,000 AFY by 2030, with a goal of replacing the use of potable water with recycled water for appropriate non-potable water uses such as landscape irrigation, thereby allowing potable water supplies to be conserved for potable uses. In 2013, the Policy (SWRCB, 2013) was amended to establish a process for addressing chemicals of emerging concern (CECs) in the use of recycled water, including a research plan and a set of CEC monitoring criteria for the indirect potable reuse of recycled water for groundwater replenishment.

SB 918 required that recycled water regulations be developed for IPR, including the planned replenishment of a groundwater basin with recycled water, and the planned augmentation of a surface water reservoir used as a source of drinking water with recycled water. CDPH adopted revised regulations for groundwater replenishment in 2014, which replaced an earlier version adopted in 1978. The regulations for surface water augmentation (SWA) with recycled water are in the process of being adopted.

1.4. Direct Potable Reuse (DPR)

Water Code section 13561, established via SB 918, defines direct potable reuse (DPR) as “the planned introduction of recycled water either directly into a public water system, as defined in Health and Safety Code section 116275, or into a raw water supply immediately upstream of a water treatment plant.” The major distinction between DPR and indirect potable reuse (IPR) is that, under IPR, a meaningful environmental buffer is present between the discharge point of the recycled water into a drinking water source, and the extraction point from that source, sometimes being transmitted to a water treatment plant before distribution. As a result, in IPR projects such as groundwater replenishment or surface water augmentation with recycled water, the recycled water may be retained in the environment for an extended period of time prior to extraction. Among other things, this extended period of retention allows for action to be taken if the recycled water quality is compromised due to a treatment failure.

To compensate for the lack of an environmental barrier, DPR must depend on engineered barriers to provide an equivalent level of public health protection. These engineered barriers can include advanced treatment technologies and monitoring tools that are demonstrated to be effective and reliable. Concepts such as redundancy, robustness and resiliency are also important when evaluating the engineered barriers.

1.5. DPR Regulations and Guidance

To date, no regulations exist in the United States at the federal or the state level for DPR. There has, however, been ongoing interest regarding the planned use of treated wastewater to directly supplement water supplies, and federal and state agencies have undertaken studies, convened panels of experts to identify the issues and address questions regarding the safe use of treated wastewater to supplement water supplies, and developed general guidance documents on potable reuse, which has only within the last decade focused on DPR.

1.5.1. United States Environmental Protection Agency

The United States Environmental Protection Agency (USEPA) has studied potable reuse as early as the 1970's, convening several workshops to study the issue and commissioning the National Research Council to study the issue in the 1980's and 1990's. A 1975 EPA report (USEPA, 1975) looked at the research needs for the planned potable reuse of municipal wastewater, acknowledging that unplanned reuse is already occurring as wastewater is discharged into major river systems that are sources of potable water for downstream users. In 1980, USEPA convened a workshop (USEPA, 1982) to review and provide guidance with respect to the approaches, issues and needed research for establishing a pathway to protocol development for potable reuse criteria and for consideration of non-potable reuse options. The 1982 USEPA report acknowledged that the drinking water standards were established based on the assumption that the source water used is relatively pollution-free, and hence the development of criteria and standards for potable reuse would be necessary if the reuse of wastewater for potable purposes was to be considered. Water recycling and water reuse standards would be the responsibility of the states, not the federal government.

In 1980, USEPA published "Guidelines for Water Reuse" (USEPA, 1980) as a technical research report to develop awareness and encourage the beneficial reuse of wastewater. The 1980 report addressed the main areas of concern for water reuse, including technical issues, economic issues, legal and institutional issues, financing, and public involvement in planning, concentrating mostly on non-potable reuse, although IPR via groundwater recharge was discussed. USEPA provided updates of the "Guidelines for Water Reuse" report in 1992, 2004 and 2012. The 1992 USEPA report (USEPA, 1992) included a survey of potable reuse projects operating within the country, a compilation of state-level regulatory requirements for potable reuse, as well as an international survey of water reuse. Because most of the potable reuse projects at the time involved IPR, the report discussed DPR but did not provide any guidance on DPR. The 2004 (USEPA, 2004) and 2012 (USEPA, 2012) reports provided updates on the state of the knowledge and practice on potable reuse, including new issues such as emerging chemicals and pathogens of concern, provided new information on treatment and disinfection technologies, and updates on case studies and regulations. Each successive report addressed IPR to a greater degree, but does not provide guidelines for DPR.

1.5.2. National Research Council

The National Research Council (NRC), organized in 1916 by the National Academy of Sciences to provide scientific and technical advice on topics of national interest to governmental and other organizations, evaluated the issues relating potable reuse in the 1970's. The NRC convened the Panel on Quality Criteria for Water Reuse in 1982 at the request of USEPA, the US Department of Agriculture, and the US Army Corps of Engineers, who were studying whether the Potomac Estuary, which was heavily impacted by wastewater discharges, was suitable as a drinking water supply for Washington DC. The panel of experts made findings in a report (NRC, 1982) that outlined the scientific questions with respect to water quality criteria that should be applied to impaired sources of water such as the Potomac Estuary. The panel provided

the following perspective: *"There appears to be no scientific or societal consensus as to what constitutes an "ideal" potable water. Potability is determined by acceptability of taste and odor and the presumed absence of unacceptable adverse health effects. In the absence of an absolute, ideal water standard, the performance of a wastewater treatment facility to produce potable water should be judged in comparison with conventional drinking waters. The philosophy behind the Interim Primary Drinking Water Regulations requires that water intended for human consumption should be taken from the highest quality source that is economically feasible. Accordingly, in assessing the adequacy of water being considered for potable reuse, comparison should be made with the highest quality water that can be obtained from that locality even though that source may not be in use."*

In 1998, NRC convened the Committee to Evaluate the Viability of Augmenting Potable Water Supplies with Reclaimed Water at the request of the US Bureau of Reclamation, USEPA, the Water Environment Research Foundation (WERF), American Water Works Association Research Foundation (now Water Research Foundation), National Water Research Institute (NWRI) and several water and wastewater agencies. The Committee made findings in a report (NRC, 1998), which determined that "…*indirect potable reuse is a viable application of reclaimed water – but only when there is a careful, thorough, project-specific assessment that includes contaminant monitoring, health and safety testing, and system reliability evaluation…. Further, indirect potable reuse is an option of last resort. It should be adopted only if other measures – including other water sources, non-potable reuse, and water conservation – have been evaluated and rejected as technically or economically infeasible.*" The Committee also noted that "*Direct use of reclaimed wastewater for human consumption, without the added protection provided by storage in the environment, is not currently a viable option for public water supplies.*"

In 2012, NRC convened the Committee on the Assessment of Water Reuse as an Approach for Meeting Future Water Supply Needs at the request of USEPA, the National Science Foundation, US Bureau of Reclamation, NWRI, Water Research Foundation, and several water and wastewater agencies. The Committee revisited the issue of DPR from a new context that emphasized water supply needs for the future combined with renewed emphasis that unplanned, or de-facto reuse, is already occurring in many of the nation's surface water supplies. The Committee felt that advances in technology would improve the capability for treatment removal and monitoring such that an environmental buffer would not be needed, and supported the concept that the benefits provided by storage in natural systems can be replaced with engineered alternatives. The Committee communicated the following on the understanding of the risks: "*Health risks remain difficult to fully characterize and quantify through epidemiological or toxicological studies, but well-established principles and processes exist for estimating the risks of various water reuse applications. Absolute safety is a laudable goal of society; however, in the evaluation of safety, some degree of risk must be considered acceptable*." (NRC, 2012)

1.5.3. Texas Direct Potable Reuse Resource Document

The State of Texas, which in 2013 was the first state to approve the operation of a DPR project, does not have any regulations for DPR. The DPR projects that were, or are being approved in Texas have been evaluated on a case-by-case basis with site-specific requirements. The state commissioned a technical team to develop a guidance document that could be used as a technical resource for water utilities, consultants, and others who are considering a DPR project in the state. The "Direct Potable Reuse Resource Document" (Texas Water Development Board, 2015) presents the current understanding on the issues surrounding DPR, makes suggestions on how these issues could be addressed by a project, what information should be included in a permit application for a DPR project, and when to consult with various state regulators to discuss key issues and site-specific requirements. The document provides guidance on source control and treatment considerations for the management of pathogens and chemicals in the wastewater, gives examples of DPR treatment trains, and suggests that project proponents conduct site-specific bench scale and pilot scale studies to help determine the selection of specific treatment processes based on the site-specific wastewater quality and to help verify treatment performance.

1.5.4. New Mexico Guidelines

The State of New Mexico does not have any regulations for either indirect or direct potable reuse. The state commissioned an independent advisory panel in 2014 to study and propose a set of recommendations for DPR that the state could use to develop guidelines or regulations. The same panel is also evaluating a DPR project under consideration in the Village of Cloudcroft, New Mexico. In the 2016 "Final Report of an NWRI Independent Advisory Panel: Recommended DPR General Guidelines and Operational Requirements for New Mexico" (Crook, Cotruvo, Salveson, Stomp, & Thompson, 2016), the panel advised that DPR is feasible, and provided recommendations to the state on issues that should be considered in a DPR project. Among other things, the panel considered the technical, financial and managerial capacity (TMF) required to implement DPR projects and determined that "*small water systems present unique challenges for the State*" and "*it is clear that the complexity of the treatment processes will require significant technical support for O&M [operation and maintenance]....*" The panel suggested that New Mexico may need to consider modifying or expanding its existing TMF capacity development program required per the Safe Drinking Water Act to include public water systems considering DPR projects.

1.5.5. Water and Wastewater Research Foundations

The water industry, as represented by industry associations such as Water Environment Federation (WEF), Water Research Foundation , WateReuse Research Foundation[3], WERF, and NWRI, have also undertaken studies to help address the technical and regulatory issues associated with DPR, such as a 2010 NWRI report entitled "Regulatory Aspects of Direct Potable Reuse in California" (Crook, Regulatory Aspects

[3] The WateReuse Research Foundation and the Water Environment Research Foundation merged to establish the Water Environment & Reuse Foundation (WE&RF) in May 2016.

of Direct Potable Reuse in California - White Paper, 2010). Some of these studies convened expert panels to provide recommendations on DPR, such as a 2011 WateReuse report entitled “Direct Potable Reuse: A Path Forward” (Tchobanoglous, Leverenz, Nellor, & Crook, 2011), a 2013 WateReuse report prepared by a NWRI Independent Advisory Panel entitled “Examining the Criteria for Direct Potable Reuse” (Crook, Bull, Collins, Cotruvo, & Jakubowski, 2013), and a 2015 WateReuse report entitled “Framework for Direct Potable Reuse” (Tchobanoglous, et al., 2015) sponsored by WateReuse, American Water Works Association (AWWA), WEF, and NWRI. These reports are often cited in articles on DPR, and by other expert panels engaged in projects to advise states on DPR issues or to advise specific utilities on proposed DPR projects.

1.6. Survey of DPR Projects

Two DPR projects are recognized to be currently operating worldwide as a permanent source of drinking water for the community, one in Namibia and the other in the United States. Both projects were pursued out of necessity after the communities suffered through severe drought, and despite conservation efforts and efforts to find better sources of water, turned to DPR as the remaining alternative. Both these projects were constructed before there was any guidance available on the safety of using DPR. Both still operate today under permit by regulating agencies that do not have any DPR regulations in place. Evaluations of these projects have been done on a case-by-case basis.

1.6.1. Windhoek, Namibia, 1968 (Menge, 2006)

The longest operating DPR project is operated by the City of Windhoek, the capital of Namibia on the southwestern coast of Africa. Namibia is the driest country south of the Sahara, with an arid desert climate. Windhoek has an average annual rainfall of 14 inches, and an annual evaporation of 136 inches, resulting in a significant loss of stored surface water. Historically dependent on groundwater, the City constructed the Goreangab Dam and the Goreangab surface water treatment plant (SWTP) in 1958, to treat local river water and supply drinking water to the City. Additional surface water sources were developed further away from the City between 1970 and 1981 to meet increasing water demands. To help conserve drinking water supplies, the City’s water conservation program reduced water consumption from 185 gallons per capita per day (gpcd) in the 1980’s to 48 gpcd by 2000 (Biggs & Williams, 2008).

Windhoek grew from a population of 50,000 in 1969 to 325,000 in 2011. An increasing population, increasing water demand, and regularly occurring droughts resulted in routine water scarcity. In 1968, during a prolonged drought, the City proceeded with a plan to use secondary treated wastewater from the Gammams Waste Water Treatment Plant (WWTP) as a source of supply for its Goreangab SWTP, a 1.3 MGD (million gallons per day) drinking water treatment plant. The Goreangab SWTP continued to use secondary wastewater as a source of supply after the drought emergency passed, and effectively became a water reclamation plant, directly supplying drinking water to the City on a permanent basis. It was upgraded several times between 1969 and 1996 to

upgrade the treatment technology, improve water quality, and increase capacity, ultimately to 3.7 MGD.

In 2002, the New Goreangab Reclamation Plant (NGRP) was built to supply drinking water to the City, with a design capacity of 5.5 MGD. The new treatment train was developed based on the multiple barrier principle, with treatment and non-treatment barriers used to ensure the quality of the water. Significant non-treatment barriers employed by NGRP are the diversion of industrial wastewater away from the Gammams WWTP to aid in source control, a rigorous monitoring program, and a cap on the wastewater contribution of 35% of the total flow (Iiputa, Nikodemus, & Menge, 2008). The potable water supply portfolio for Windhoek is on average 77% surface water, 19% DPR, and 4% groundwater, but the percentage of DPR water could increase significantly during drought periods, when surface water and groundwater source capacity diminishes.

1.6.2. Big Spring, Texas, 2013

The Colorado River Municipal Water District (CRMWD) is a regional water agency that was formed in 1949 to supply water for the communities in arid west Texas, including the cities of Big Springs, Odessa, Snyder, and others, with a current combined population of about 500,000. Between 1950 and 1990, CRMWD built three dams to create surface water reservoirs storing water from the upper reaches of Texas' Colorado River, which runs about 800 miles southeast within the State of Texas before discharging into the Gulf of Mexico. CRMWD also developed four large groundwater well fields during this time. Although CRMWD's surface water reservoirs have a combined storage capacity of over 1.2 million acre-feet, recurring drought cycles often resulted in water levels dropping below intake levels or the reservoirs going dry. (Texas Water Development Board)

In the middle of an extended drought cycle that started in the 1990's, CRMWD began to consider using treated wastewater as a new water source. In 2005, CRMWD completed a feasibility study that looked at three potential regional water reclamation projects that would further treat wastewater from wastewater treatment facilities operated by the cities of Big Spring, Snyder, Midland and Odessa, to drinking water standards. (CRMWD, 2005) The selected Big Spring project would take secondary treated wastewater from the Big Spring Wastewater Treatment Plant and provide advanced wastewater treatment using microfiltration, reverse osmosis (RO), and advanced oxidation (peroxide/UV) at CRMWD's Raw Water Production Facility located nearby, with the advanced treated water pumped into CRMWD's pipeline carrying raw surface water from the E.V. Spence Reservoir. CRMWD completed the preliminary design in 2007, conducted pilot testing of the treatment train in 2009, and completed final design in 2010. CRMWD's Raw Water Production Facility started operating in May 2013, with a production capacity of 2 MGD, providing about 15% of the water flowing in the pipeline. The City of Big Spring's SWTP is the first downstream user to withdraw from the pipeline. The cities of Snyder, Odessa, Stanton, and Midland also operate SWTPs that take water downstream of that pipeline.

1.6.3. DPR as an Emergency Water Supply

In the United States, a few communities have turned to DPR as an emergency drinking water source during a drought, but discontinued DPR when the emergency ended. Chanute, Kansas (population 12,000) turned to DPR during a 1952-1957 drought, and the city operated the DPR project for seven months in 1956/57 (Crook, Regulatory Aspects of Direct Potable Reuse in California - White Paper, 2010), where disinfected secondary treated wastewater was diverted to the city's surface water treatment plant for treatment to the drinking water standards at the time.

A more recent example of DPR used as an emergency water supply is with Wichita Falls, Texas (population 100,000), where the city operated a DPR project for about 12 months in 2014/2015 during the 2010-2015 drought. Secondary treated wastewater was provided with additional treatment, which included microfiltration and RO, before the water was piped to the city's surface water treatment plant for treatment to drinking water standards. The emergency DPR project was decommissioned after the drought was over, but the city has plans to undertake a larger IPR project with surface water augmentation.

1.7. Research on Direct Potable Reuse

A number of water research foundations, institutes, and associations are supporting research projects to advance the science of DPR.

1.7.1. State Water Board

The State Water Board adopted the Recycled Water Policy in 2009 to encourage the use of recycled water. In 2009, in accordance with the Recycled Water Policy, the State Water Board convened a "blue ribbon" advisory panel (panel) to provide guidance for developing monitoring programs that assess the CECs from various water recycling practices, including IPR via groundwater replenishment and non-potable reuse. The panel report (Anderson, et al., 2010), provided conceptual frameworks for determining which CECs to monitor for and how to interpret the CEC monitoring results, applied the framework to identify a list of chemicals that should be monitored, made recommendations for monitoring specific CECs in recycled water, and made recommendations on research needs for CECs. The Recycled Water Policy requires that the panel or a similarly constituted panel be convened every five years to continue providing guidance on future State Water Board actions relating to CECs.

Following up on a panel recommendation on the development of bioanalytical techniques (or "bioassays") for assessing CECs, the State Water Board in 2011 sponsored a team of investigators to develop bioassays to identify known and unknown CECs that may potentially be found in recycled water. In the report titled "*Development of Bioanalytical Techniques for Monitoring of Constituents/Chemicals of Emerging Concern (CECs) in Recycled Water Applications for the State of California"* (SCCWRP, 2014), the investigators identified an appropriate extraction protocol for isolating and concentrating the CECs from recycled water, identified and tested currently available bioanalytical kits that could potentially be used to assess CECs in recycled water, and

suggested a framework to interpret results and assess the significance from a human health standpoint.

The State Water Board initiated a recycled water research workshop process in 2014 to identify knowledge gaps for the potential new uses of recycled water and storm water to augment existing water supplies. The workshops would provide a forum where invited experts representing water districts, sanitation districts, utilities districts, joint power authorities, cities, trade associations, research groups, federal government, and state government would collaborate to assess the current state of the science and reassess research needs, in order to develop a multi-year research plan with short and long-term goals to further recycled water research.

Topic areas discussed at the first workshop included water quality and human health; performance reliability (treatment, operations, and training); ambient water effects; and financial, environmental, and social factors of water reuse. On water quality and human health, participants agreed that research should be focused on microbes and unknown chemicals, including CECs and disinfection by-products, but that more research was needed on the assessment of chemical risks due in part to challenges posed by chemical mixtures and transformation products in the recycled water for which methods of detection and toxicity data are not currently available. Topic areas discussed at the second workshop in 2015 included chemical testing; bioanalytical screening and application of bioassays in recycled water; non-targeted analysis for CECs; source control, operations, maintenance and training; assessing CEC removal by treatment technologies; assessment of emerging and innovative technologies; and reliability and resiliency of treatment trains. A follow-up meeting occurred on August 1, 2016 between the State Water Board and WE&RF to discuss priorities and opportunities for collaboration on funding new research projects. Workshop summary reports (SWRCB, 2015) are developed and posted on the State Water Board website.

Since 2001, the State Water Board has also funded $2.65 million in water recycling research through contracts primarily with WateReuse Research Foundation (SWRCB, 2016). The research covered a broad spectrum of issues, including chemical contaminants, pathogens, treatment technologies, concentrate disposal, public perception and economics of water reuse.

1.7.2. WateReuse Research Foundation DPR Initiative

In 2009, WateReuse California developed its California DPR Initiative to help promote DPR as a viable water supply option that is safe and cost-effective, and address obstacles to DPR. In April 2010, three utility associations, WateReuse California, NWRI, and California Urban Water Agencies (CUWA) held a DPR Workshop to identify information gaps and barriers to development of potable reuse regulations in California, and help support the needs of water, wastewater and recycled water utilities in planning and prioritization of research. Also in 2010, WateReuse California and WateReuse Research Foundation sponsored a report “Direct Potable Reuse: A Path Forward” (Tchobanoglous, Leverenz, Nellor, & Crook, 2011) to provide an overview of the current understanding of issues surrounding DPR and identify the research needed to inform

the public, water utilities and regulators, so that the feasibility of DPR can be evaluated as required by SB 918.

In 2012, WateReuse Research Foundation and WateReuse California launched its California DPR Research Initiative to raise funds and conduct the necessary research to support the development of statewide criteria for DPR in California. The initial research projects were those identified as priority projects in the 2011 report, including developing guidelines for engineered storage for DPR (Project 12-06), treatment reliability (Project 11-02), monitoring for reliability and process control (Project 11-01), including a review of methods for testing the integrity of nanofiltration and RO membranes (Project 12-07), and risk reduction principles for DPR (Project 11-10).

In March and July 2014, the WateReuse Research Foundation presented an overview of the California DPR Research Initiative, the research plan, and a research status update to the Expert Panel. The Panel found that the research plan was comprehensive in addressing regulatory and utility concerns about DPR, and provided preliminary feedback on research questions that are outstanding, additional research needed, and research areas that should be strengthened.

WateReuse Research Foundation currently has about 30 projects as part of its DPR Research Initiative, with about six projects that were expected to be completed by June 2016. Most of the projects will be completed after December 31, 2016. The results of this research will provide additional information that could help in the development of criteria for DPR.

Chapter 2. Independent Review

In accordance with SB 918 and SB 322, an expert panel and an advisory group were established for the purposes of advising the State Water Board on the feasibility of developing uniform water recycling criteria for DPR. The State Water Board contracted with NWRI (Fountain Valley, CA) to help convene and administer the Expert Panel and the Advisory Group. NWRI is a nonprofit organization created in 1991 via a joint powers agreement by six southern California water and wastewater agencies to undertake research and related activities to promote the protection, maintenance, and restoration of water supplies. NWRI has extensive experience in meeting facilitation and had administered several key expert panels related to IPR. NWRI facilitated the meetings, provided administrative support for meeting planning, preparation and logistics, and facilitated the preparation of meeting reports and panel consensus reports.

2.1. Expert Panel

In 2013, the State Water Board convened a 12-member expert panel comprised of a toxicologist, engineers with experience in the treatment of drinking water supplies and knowledge of drinking water standards, a wastewater treatment engineer, an epidemiologist, a microbiologist, a chemist, and a limnologist. The panel members were selected to provide expertise in microbiology and the control of pathogenic microorganisms, microbial risk assessment, chemical occurrence in wastewater and fate in wastewater treatment, public health significance of chemicals found in wastewater and the chemical byproducts of treatment, water and wastewater treatment, quantifying the reliability of various multi-barrier systems, evaluation of health outcomes from exposure to various qualities of drinking water and the potential for illness with potable reuse. This range of expertise was needed in order to ensure a comprehensive review of all the relevant scientific and technical issues involved in the determination of whether it is feasible to develop uniform criteria for DPR.

The expert panel was tasked with advising the State Water Board on the public health issues and scientific and technical matters regarding the feasibility of developing uniform water recycling criteria for DPR, assessing the need for additional research on DPR, and recommending an approach for completion of any needed research. The State Water Board provided background information to the expert panel on the regulation of drinking water in California, the State Water Board's regulation development process, the regulation of recycled water and IPR in California, reference lists for reports and studies relevant to the investigation, focus questions that should be addressed, and other information as requested by the Expert Panel throughout the process. The Expert Panel prepared a final consensus report on the feasibility of developing criteria for DPR, included in Appendix A. The meeting reports and final draft of the Expert Panel's report are available on the State Water Board website at: http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/RW_SWA_DPRexpertpanel.shtml .

2.2. Advisory Group

The State Water Board convened an advisory group in February 2014 made up of representatives of water and wastewater agencies, environmental organizations, environmental justice organizations, public health nongovernmental organizations, ratepayer or taxpayer advocate organizations, the business community, local public health officers, the USEPA, and the State Water Board.

The Advisory Group was tasked with advising the Expert Panel regarding their scientific and technical deliberation of the feasibility of developing uniform water recycling criteria for DPR, and making recommendations to the State Water Board on relevant topics such as practical considerations for DPR criteria that are protective of public health and achievable by project proponents. The State Water Board consulted the Advisory Group, who approved the slate of Expert Panel members at their first meeting in 2014. A total of 11 quarterly Advisory Group meetings were held between 2014 and 2016 at various publicly noticed locations throughout the State. The meetings were also broadcast using web conferencing so that members of the public who were not able to attend in person can attend and participate remotely. The Advisory Group prepared a consensus report on its recommendations on the feasibility of developing criteria for DPR, included in Appendix B. The meeting agendas, meeting minutes, meeting presentations, and the Advisory Group consensus report are available on the State Water Board website at:
http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/RW_DPR_advisorygroup.shtml

Chapter 3. Feasibility of Developing Uniform Water Recycling Criteria for DPR

In carrying out the investigation into the feasibility of developing uniform water recycling criteria for DPR, Water Code Section 13566 requires the State Water Board to consider all of the following:

(a) Recommendations from the expert panel

(b) Recommendations from an advisory group

(c) Regulations and guidelines for these activities from jurisdictions in other states, the federal government, or other countries

(d) Research by the state board regarding unregulated pollutants

(e) Results of investigations pursuant to Section 13563

(f) Water quality and health risk assessments associated with existing potable water supplies subject to discharges from municipal wastewater, stormwater, and agricultural runoff

In considering all these factors, the State Water Board placed paramount importance in the recommendations of the Expert Panel. Consequently, the State Water Board identified several areas consistent with Water Code Section 13563 that the Expert Panel were asked to address in its evaluation of the feasibility of developing uniform water recycling criteria for DPR, including: 1) the availability and reliability of treatment technologies; 2) the reliability of treatment trains, including multiple barriers and sequential treatment, to ensure the protection of public health; 3) available information on health effects; 4) mechanisms that should be employed to protect public health in the event of problems such as treatment failures; and 5) monitoring needed to ensure protection of public health.

To address these areas, the Expert Panel focused their evaluation around the seven topics as listed below.

1. Potential hazards of potable reuse
2. Public health surveillance
3. Analytical methods for measuring chemical water quality
4. Application of bio-analytical tools
5. Molecular methods for assessing microbial water quality
6. Antibiotic resistant bacteria and antibiotic resistant genes
7. Quantifying treatment facility reliability, including evaluation of multiple barriers

The Expert Panel found that it is technically feasible to develop uniform water recycling criteria for DPR and that those criteria could incorporate a level of public health protection as good as, or better than what is currently provided by conventional drinking water supplies, IPR projects using groundwater replenishment, and proposed IPR projects using surface water augmentation in California. However, the Expert Panel further indicated that for DPR to provide the levels of protection afforded by IPR, the

functionality provided by the environmental buffer (i.e., storage, attenuation, and response time) for IPR must be addressed by other means for DPR. The Expert Panel indicated that for DPR, this level of protection can be addressed by enhancing the reliability of mechanical systems and treatment plant performance. The Expert Panel identified several reliability features that need to be provided in addition to requirements already specified in IPR criteria to provide those levels of protection. Those features include: 1) providing multiple, independent barriers; 2) ensuring the independent barriers represent a diverse set of processes; 3) benefits of using parallel independent treatment trains; 4) providing diversion of inadequately-treated water; 5) providing a final treatment step to "average" out any chemical peaks; 6) incorporating frequent monitoring of surrogate parameters at each step to ensure treatment processes are performing properly; and 7) developing and implementing rigorous response protocols, such as a formal Hazard Analysis Critical Control Point (HACCP) system. The Expert Panel suggested that a new formal process be established by the State Water Board to administer the periodic review of treatment performance data of permitted potable reuse projects.

The Expert Panel also cautioned that the chemical and biological stability of DPR water must be ensured, and that the introduction of DPR water into a public water system must be staged such that the reliability of treatment is well-demonstrated before the recycled water contribution into a public water system is increased. A detailed discussion of these reliability features as well as additional findings and recommendations related to reliability can be found in Section 11.1 of the Expert Panel's report.

The Expert Panel found that there is no need for additional research to be conducted to establish uniform water recycling criteria for DPR. However, the Expert Panel identified important areas related to public health that have not been addressed, and provided six research recommendations that would enhance the understanding and acceptability of DPR in California, noting that the recommendations could be undertaken either before and/or concurrently with the development of DPR criteria. The Expert Panel also felt that the research should be supported directly by the State of California, where the State Water Board and other agencies having expertise should provide oversight and direction for research efforts designed to address these areas. The six research recommendations are summarized as follows:

1. To continue to improve on source control and final water quality monitoring, carry out an ongoing literature review to identify new compounds that may pose health risks particularly to fetuses and children from short term exposures.
2. Implement a probabilistic method (Quantitative Microbial Risk Assessment, QMRA) to confirm the necessary removal values for viruses, Cryptosporidium and Giardia, based on a literature review and new pathogen data collected, and apply this method to evaluate the performance and reliability of DPR treatment trains.
3. Require monitoring of pathogens in raw wastewater to develop better empirical data on concentrations and variability.

4. Investigate the feasibility of collecting raw wastewater pathogen concentration data associated with community outbreaks of disease, and implement where possible.
5. Identify suitable options for final treatment processes that can provide some "averaging" with respect to potential chemical peaks particularly for chemicals that have the potential to persist through advanced water treatment.
6. Develop more comprehensive analytical methods to identify unknown contaminants, particularly low molecular weight compounds potentially in wastewater that may not be removed by advanced treatment and is not presently detectable by current regulatory monitoring approaches.

A detailed discussion of the rationale for these research recommendations can be found in Section 11.3 of the Expert Panel's report.

While the Expert Panel believes that the absence of better information that will be provided by this research may not be an impediment to establishing uniform criteria for DPR, the State Water Board finds the research results will make a significant contribution to the development of criteria for DPR, and most importantly, will provide a higher level of certainty that the criteria are protective of public health. Therefore, the State Water Board believes that the research must be conducted concurrently with the development of DPR criteria.

The State Water Board finds that there are additional knowledge gaps that remain before criteria can be written to address issues unique to DPR. These knowledge gaps primarily relate to the quantification of reliability, and the associated concepts such as redundancy, resiliency, and robustness, such that adequate public health protection is ensured. These issues are particularly important because the Expert Panel has identified them as critical to ensuring the level of protection that otherwise would be afforded by an environmental buffer, and the ability to quantify these concepts and translate the Expert Panel's key findings on reliability into well-crafted objective criteria that are unambiguous and enable an objective determination of compliance is fundamental to adopting criteria that adequately address the issues. Many of the Expert Panel findings on DPR performance and reliability are qualitative such as:

- The use of a DPR treatment train with multiple, independent treatment barriers that meet performance criteria greater than the public health threshold log removal value (LRV) goal for microorganisms
- Ensuring the independent treatment barriers represent a diverse set of processes in the treatment train that are capable of removing particular types of contaminants by different mechanisms
- Incorporating a final treatment process in addition to the core advanced water treatment train that can provide some "averaging" with respect to potential chemical peaks
- Developing and implementing rigorous response protocols.

These findings lead to questions that will need to be addressed. For example, what additional LRV capacity is necessary? How should treatment "diversity" be measured? How much "diversity" is necessary? How much "averaging" is necessary and how should it be specified? What criteria are necessary to ensure a "rigorous" response protocol? The Expert Panel's evaluation of treatment performance used a variety of approaches that foster an understanding of the efficacy of treatment options and show how they could be used meet the health goals. However, these concepts cannot be easily translated into quantified criteria. Metrics and specific criteria for concepts such as reliability, robustness, redundancy, and resilience must be developed.

The Expert Panel also concluded that "*Although it is prudent to include reverse osmosis in the first set of DPR projects due to the water quality benefits and performance reliability that reverse osmosis provides, proposals for DPR projects that do not employ reverse osmosis could be considered and ultimately approved by the State Water Board*." Because of the critical importance of reverse osmosis (RO) to meeting performance requirements in IPR, it is not clear how to write criteria that allow alternatives to RO while assuring no reduction of the high degree of reliability necessary for DPR. Because of the pivotal role RO would serve in DPR projects, there should be some specific reliability criteria for alternatives. The appropriate reliability metrics and criteria must be developed.

The State Water Board is monitoring the progress of a number of WE&RF research projects that are planned or underway that could help fill in the knowledge gaps. The projects of interest are included in Appendix C. Some of these projects will not be complete until 2018, and possibly later. The State Water Board plans to use a workgroup process similar to that employed in the development of groundwater replenishment regulations to address some of these remaining knowledge gaps. The State Water Board has also identified a number of research topics that should be addressed to improve the State Water Board's ability to evaluate and approve technologies for DPR, as well as some long-term research that would improve the monitoring needed to ensure protection of public health. These long term research topics are summarized in Appendix D.

It is important to recognize that there are at least three possible types of DPR projects that will have different risk profiles:

1. A project delivering recycled water to a surface water reservoir, with the reservoir providing some benefits, but lacking the full complement of benefits provided by IPR with SWA and is therefore considered DPR by the Expert Panel
2. A project delivering recycled water directly to a surface water treatment plant or a surface water reservoir, with the reservoir providing no benefits
3. A project delivering finished water to a public water system's distribution system

Each type of DPR will have its unique set of criteria. However, a common framework across the various types of DPR will help avoid discontinuities in the risk assessment/risk management approach as progressively more difficult conditions are addressed. Developing such a common framework that addresses a variety of factors,

including the complexity of treatment, the high degree of reliability required, the very short time period to detect and respond to failures and treatment plant upsets, and the lack of experience in operating DPR facilities in California, will require a deliberate and phased approach to developing DPR criteria to ensure public health protection and continued consumer confidence in the public water supply.

The Expert Panel and Advisory Group have made some recommendations regarding the non-treatment barriers that are practical considerations in the implementation of DPR, including source control, wastewater treatment plant optimization, advanced operator certification, and TMF capacity. Summarized below, the details and rationale for these recommendations can be found in the Advisory Group report as well as Chapter 10 of the Expert Panel report:

- Advanced operator certification – a stringent operations, maintenance, and monitoring program at complex DPR treatment plants must be conducted by knowledgeable and well-trained advanced certified operators in order to ensure the successful implementation of a DPR project. The State Water Board is providing technical advice and is monitoring the progress of a joint effort between the California-Nevada Section of the American Water Works Association (CA/NV AWWA) and the California Water Environment Association (CWEA) to develop a new advanced operator certification program to address this need. Developing and implementing rigorous response protocols must be fully understood and practiced by operations and management.

- Technical, managerial, and financial capacity (TMF) – the additional public health responsibilities and complexity associated with the operation, maintenance and monitoring of DPR facilities require high TMF; therefore a process must be established to evaluate the TMF of DPR project proponents.

- Wastewater treatment plant optimization – a higher quality feed water from the wastewater treatment plant can improve the operations of the downstream DPR treatment plant, to improve water quality and enhance public health protection.

- Source control – a rigorous source control program designed to control the discharge of toxic chemicals and other contaminants of human health significance to the sewer system must be implemented for any sewershed that serves as the source for DPR.

Chapter 4. Conclusions and Recommendations

The State Water Board has conducted a comprehensive review of the key issues surrounding DPR, supported by crucial scientific and technical findings and recommendations from the Expert Panel and important input on the practical aspects and stakeholder feedback from the Advisory Group. The review of DPR, the use of treated wastewater for the drinking water supply, necessarily touches on a broad array of topics, and this effort sets the foundation for future work supporting the State's continuing interest in potable reuse. The Expert Panel's report, other literature, and DDW's extensive experience with impaired drinking water sources and IPR have done much to prepare DDW to develop DPR criteria.

4.1. Conclusions

The Expert Panel has determined that it is technically feasible to develop uniform water recycling criteria for DPR; however, the Expert Panel has also identified a range of public health research needs that would enhance the understanding and acceptance of DPR in California. While the absence of better information that will be provided by this research may not be an impediment to establishing uniform criteria for DPR, the State Water Board finds a significant benefit for the research to be conducted concurrently with the development of DPR criteria, since the research and development of new innovations should enhance the development of DPR criteria that are protective of public health, while also providing sensible and practical solutions for the regulated community.

The State Water Board appreciates the Expert Panel's thorough analysis of the issues surrounding the development of uniform water recycling criteria for DPR, and while we agree generally with the conclusions reached by the Expert Panel, the State Water Board finds that some critical knowledge gaps remain regarding the ability to translate the Expert Panel's key findings on reliability into well-crafted objective criteria that are unambiguous and enable an objective determination of compliance.

The State Water Board finds that the key knowledge gaps and key research recommendations must be addressed before uniform water recycling criteria for DPR can be adopted. While the State Water Board can move ahead and start the process of developing criteria for DPR, completion of the six research recommendations and filling in the key knowledge gaps must be achieved in order to be able to successfully adopt a set of uniform water recycling criteria for DPR that is protective of public health.

A common framework across the various types of DPR will help avoid discontinuities in the risk assessment/risk management approach as progressively more difficult conditions are addressed. Accordingly, developing DPR criteria will require a deliberate and phased approach to ensure public health protection and continued consumer confidence in the public water supply.

It is also important to note that significant work is needed to address the recommendations provided by the Expert Panel and the Advisory Group regarding the

non-treatment barriers that are part of ensuring the safety of DPR, including source control, wastewater treatment plant optimization, operator certification, and technical, managerial, and financial capacity.

4.2. Recommendations – Research and Knowledge Gaps

The State Water Board has completed its investigation into the feasibility of developing uniform water recycling criteria for DPR in accordance with SB 918 and SB 322 and hereby submits the following recommendations that the State Water Board finds must be addressed in order to be able to successfully adopt a set of uniform water recycling criteria for DPR that is protective of public health. Some of these recommendations will be resource intensive and may require additional resources to administer and manage their completion within an optimal timeframe.

1. The State Water Board recommends that the development of uniform water recycling criteria for direct potable reuse be initiated concurrently with the six Expert Panel research recommendations such that the findings from these parallel efforts can be used to inform the development of criteria.

2. The State Water Board recommends that a "blue ribbon" panel be convened pursuant to the State Water Board's Recycled Water Policy to review the scientific literature and report on the current state of scientific knowledge regarding the risks of emerging constituents to public health. The panel should research the potential health risks of compounds likely to be present in recycled water that could present serious harm to health over short durations of exposure, especially chemicals that adversely affect the development of fetuses and children.

3. The State Water Board will consider probabilistic QMRA as part of criteria development for DPR, which should provide a better assessment of the performance of DPR treatment trains, provide an opportunity to identify additional effective DPR treatment trains, and result in DPR criteria that further ensure the protectiveness of DPR. The State Water Board will engage a small workgroup of subject matter experts to help develop probabilistic QMRA and determine how to incorporate this element into DPR criteria.

4. The State Water Board will work with the RWQCBs to include monitoring requirements for pathogens (i.e., Giardia cysts, Cryptosporidium oocysts, and several human viruses) in the raw (untreated) wastewater feeding potable reuse systems, using improved methods that allow for better characterization and improved precision of concentrations of pathogens, to provide more complete information on concentrations and their variability.

5. The State Water Board will work with CDPH, local health departments and wastewater agencies to investigate the feasibility of collecting pathogen concentration data for raw wastewater associated with community outbreaks of disease. If feasible, the State Water Board recommends that a process be developed to prioritize pilot projects and collect such data where possible.

6. The State Water Board recommends that short term research be conducted to identify suitable treatment options for final treatment processes that can provide some attenuation with respect to potential chemical peaks (in particular, for chemicals that have the potential to persist through advanced water treatment), which may be best conducted by the water and wastewater industry as an engineering application. The State Water Board will monitor the completion of WE&RF projects that address this research need.

7. The State Water Board recommends that the research to develop more comprehensive methods to identify low molecular weight unknown compounds for DPR, including non-targeted analysis as a screening tool, be conducted. It is an important research need that has been prioritized in the State Water Board's CEC Research Prioritization Workshops. The State Water Board will also coordinate with WE&RF and other research foundations to determine if this research project can be expedited via their research programs.

8. The State Water Board will convene technical workgroups to address the remaining knowledge gap questions regarding the development of criteria for DPR.

9. The State Water Board will continue to work with WE&RF on its DPR Research Initiative, advising its project prioritization process and serving on Project Advisory Committees.

10. The State Water Board will partner with relevant agencies within CalEPA, such as the Department of Toxic Substances and Control (DTSC) and the Office of Environmental Health Hazard Assessment (OEHHA), university research centers, and water and wastewater research foundations to develop the research projects necessary to improve the science and public health knowledge relevant to DPR.

4.3. Recommendations – DPR Program Development

The State Water Board has identified program improvements designed to address some of the non-treatment barriers related to management control that are a part of the multiple barrier concept for achieving reliability, and hereby submits the following recommendations that should be evaluated for implementation to enhance the safety of DPR as interest in the development of DPR projects grows:

11. The State Water Board will advise CA/NV AWWA and CWEA in their development of an operator certification program for advanced water treatment, and develop a strategy for implementing such a program at the State Water Board.

12. The State Water Board will establish a TMF capacity assessment process for potable reuse projects.

13. The State Water Board will work with the RWQCBs to develop a framework for optimizing WWTPs supplying a DPR project that aligns with the objectives of DPR and the RWQCBs.

14. The State Water Board will work with the RWQCBs to determine how pretreatment programs associated with DPR can be improved to address CECs, monitoring of unauthorized discharges, characterization and reduction of chemical spikes, and other concerns related to DPR.

Chapter 5. Implementation Plan

The investigation of the feasibility of developing uniform water recycling criteria for DPR has revealed a number of knowledge gaps and research recommendations that must be addressed before criteria can be adopted. The State Water Board can start developing criteria for DPR, but the following implementation recommendations in Table 1 must be addressed before criteria for DPR can be adopted.

The State Water Board has identified some program improvements designed to enhance the safety of DPR from a management control perspective that should be evaluated for implementation as interest in the development of DPR projects grows. The recommendations in Table 2 address some of the non-treatment barriers that are part of the multiple barrier concept for achieving reliability.

As key milestones are reached in the completion of research and the development of criteria, the State Water Board will inform the public and stakeholders. Additionally, the Administrative Procedure Act which guides the regulation adoption process ensures that the process is transparent and accessible by the public, with a rigorous public comment process.

Table 1: Implementation Plan – Research and Knowledge Gaps

No	Recommendation	Metric for Success	Milestones
1	The State Water Board recommends that the development of uniform water recycling criteria for direct potable reuse be initiated concurrently with the six Expert Panel research recommendations such that the findings from these parallel efforts can be used to inform the development of criteria.	DPR criteria that is protective of public health	Monitor progress of research
2	The State Water Board recommends that a "blue ribbon" panel be convened pursuant to the State Water Board's Recycled Water Policy to review the scientific literature and report on the current state of scientific knowledge regarding the risks of emerging constituents to public health. The panel should research the potential health risks of compounds likely to be present in recycled water that could present serious harm to health over short durations of exposure, especially chemicals that adversely affect the development of fetuses and children. Update the state of the science on CECs every 5 years.	Panel assessment of potential health risks of CECs in recycled water that present serious harm to health	A process to convene panel and produce reports is established
3	The State Water Board will consider probabilistic QMRA as part of criteria development for DPR, which should provide a better assessment of the performance of DPR treatment trains, provide an opportunity to identify additional effective DPR treatment trains, and result in DPR criteria that further ensure the protectiveness of DPR. The State Water Board will engage a small workgroup of subject matter experts to help develop probabilistic QMRA and determine how to incorporate this element into DPR criteria.	Implementation of QMRA via DPR criteria development	Establish QMRA process

No	Recommendation	Metric for Success	Milestones
4	The State Water Board will work with the RWQCBs to include monitoring requirements for pathogens (i.e., Giardia cysts, Cryptosporidium oocysts, and several human viruses) in the raw (untreated) wastewater feeding potable reuse systems, using improved methods that allow for better characterization and improved precision of concentrations of pathogens, to provide more complete information on concentrations and their variability.	Process for sampling, analysis, and data collection is established	Agreement with RWQCBs on process for sampling, analysis and data collection
5	The State Water Board will work with CDPH, local health departments and wastewater agencies to investigate the feasibility of collecting pathogen concentration data for raw wastewater associated with community outbreaks of disease. If feasible, the State Water Board recommends that a process be developed to prioritize pilot projects and collect such data where possible.	Process for data collection and compilation is established; evaluation of data and peer-reviewed conclusions	Monitor for community outbreaks of disease
6	The State Water Board recommends that short term research be conducted to identify suitable treatment options for final treatment processes that can provide some attenuation with respect to potential chemical peaks (in particular, for chemicals that have the potential to persist through advanced water treatment) is best conducted by the water and wastewater industry as an engineering application. The State Water Board will monitor the completion of WE&RF projects that address this research need.	Completion of research projects	Evaluate demonstration projects to assess the efficacy of these options
7	The State Water Board recommends that the research to develop more comprehensive methods to identify low molecular weight unknown compounds for DPR, including non-targeted analysis as a screening tool and bioanalytical tools, be conducted. It is an important research need that has been prioritized in the State Water Board's CEC Research Prioritization Workshops. The State Water Board will also coordinate with WE&RF and other research foundations to determine if this research project can be expedited via their research programs.	Methods developed to identify low molecular weight unknown compounds for DPR	Consider Proposition 1 funding on research efforts

No	Recommendation	Metric for Success	Milestones
8	The State Water Board will convene technical workgroups to address the remaining knowledge gap questions regarding the development of DPR criteria.	Convene workgroups and address knowledge gaps	Monitor progress of research
9	The State Water Board will continue to work with WE&RF on its DPR Research Initiative, advising its project prioritization process and serving on Project Advisory Committees.	Completion of research projects	Ongoing
10	The State Water Board will partner with relevant agencies within CalEPA, such as the Department of Toxic Substances and Control (DTSC) and the Office of Environmental Health Hazard Assessment (OEHHA), university research centers, and water and wastewater research foundations to develop the research projects necessary to improve the science and public health knowledge relevant to DPR.		Ongoing

Table 2: Implementation Plan – DPR Program Development

No	Recommendation	Metric for Success	Milestone
11	Operator certification program: the State Water Board will advise CA/NV AWWA and CWEA in their development of an operator certification program for advanced water treatment, and develop a strategy for implementing such a program at the State Water Board.	Implementation of an advanced operator certification program for DPR	Complete job analysis; identify expected range of knowledge; develop examination
12	Technical managerial and financial (TMF) capacity: the State Water Board will establish a TMF capacity assessment process for potable reuse projects.	Develop TMF capacity evaluation package	
13	Wastewater treatment plant (WWTP) optimization: the State Water Board will work with the RWQCBs to develop a framework for optimizing WWTPs supplying a DPR project that aligns with the objectives of DPR and the RWQCBs.	Implement framework for WWTP optimization for DPR	Identify proper surrogates to monitor
14	Source control: the State Water Board will work with the RWQCBs to determine how pretreatment programs associated with DPR can be improved to address CECs, monitoring of unauthorized discharges, characterization and reduction of chemical spikes, and other concerns related to DPR.	Implement pilot "advanced source control program" for DPR	Identify proper surrogates to monitor

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Appendix A: Expert Panel Report

EXPERT PANEL FINAL REPORT: Evaluation of the Feasibility of Developing Uniform Water Recycling Criteria for Direct Potable Reuse

Appendix B: Advisory Group Report

FINAL REPORT: Recommendations of the Advisory Group on the Feasibility of Developing Uniform Water Recycling Criteria for Direct Potable Reuse

Appendix C: Existing and Planned DPR Research Projects

A number of projects are underway or planned that could inform the development of criteria for DPR, including the following:

Project	Project Description
4508	Assessment of techniques to evaluate and demonstrate the safety of water from DPR treatment facilities
4536	Blending requirements for water from DPR treatment facilities
13-03	Critical Control Point assessment to quantify robustness and reliability of multiple treatment barriers of DPR scheme
13-12	Evaluation of source water control options and the impact of selected strategies on DPR
13-13	Development of an operation and maintenance plan and a training and certification framework for DPR systems
14-01	Integrated management of sensor data for real-time decision making and response
14-02	Establishing additional log reduction credits for WWTPs
14-16	Operational, monitoring, and response data from unit processes in full-scale potable reuse advanced treatment projects
14-19	Predicting RO removal of toxicologically relevant organics
15-02	Creating a roadmap for bioassay implementation in reuse waters
15-04	Characterization and treatability of TOC from DPR processes compared to surface water supplies
15-05	Developing curriculum and content for DPR operator training
15-07	Molecular methods for measuring pathogen viability/infectivity
15-10	Optimization of ozone-biological activated carbon treatment processes for potable reuse applications

Appendix D: Other Research Topics

The State Water Board has identified a number of research topics that should be addressed to improve the State Water Board's ability to evaluate and approve technologies for DPR, as well as some long-term research that would improve the monitoring needed to ensure protection of public health, including the following:

- Determine if improved RO integrity testing techniques can be developed to make it possible to receive higher log reduction credits for RO, which could result in fewer treatment processes or modified operating and monitoring requirements.

- Determine if proper membrane integrity testing can be developed and demonstrated for membrane bioreactors to eliminate the need for microfiltration or ultrafiltration treatment.

- Determine if standardized techniques can be developed for establishing advanced water treatment log removal credits.

- Investigation of possible alternative measures to the current bulk organic surrogate measures (e.g., TOC, chemical oxygen demand) for the control of trace organic compounds, which do not reflect the toxicity caused by the presence of trace organic compounds and, therefore, the safety of the reuse water.

- Evaluation of whether TOC is the appropriate surrogate to ensure the safety of reuse water relative to trace organic compounds. Determine if newer systems that target specific fractions of TOC are more appropriate.

- Investigation of surrogates to allow for real-time validation of virus removal in membrane processes. Until a real-time surrogate is developed and accepted by regulators, it will not be possible to obtain virus removal credit for most membrane processes. RO membranes typically achieve credit by observation of a surrogate such as conductivity, but that is typically limited to 1.5 to 2.0-log removal. Commercial products such as TRASAR® may be available to monitor RO performance beyond the 2.0-log from conductivity measurements but they have yet to be accepted for creditable performance by state regulatory agencies.

- Development of alternative virus surrogate parameters that exhibit similar removal relative to the contaminant of concern must be identified, tested, and validated for use in process monitoring. Frequent monitoring of surrogate parameters to ensure treatment processes are performing properly is common; however, common surrogates such as turbidity may not be sufficiently sensitive to measure changes in virus rejection.

- Evaluation of the various treatment technologies now in use for IPR and DPR to determine the optimal coupling of these technologies.

- Development of validation and verification programs to determine performance of established and alternative treatment trains. Determine the best approach for direct measurements of performance-based indicator contaminants. Establish accurate correlation of performance-based surrogates with removal mechanisms of treatment processes.

- Evaluation of full scale research on alternative measures for monitoring the microbial quality of final effluent, such as total cell counts (e.g., using flow cytometry)

The Expert Panel has identified a number of additional long-term research topics in Sections 11.2 and 11.4 of the Expert Panel report.