NATIONAL WATER RESEARCH INSTITUTE

Volume I

Expert Panel on the Development of Water Recycling Criteria for Indirect Potable Reuse (IPR) through Surface Water Augmentation and the Feasibility of Developing Criteria for Direct Potable Reuse (DPR)

for the

State Water Resources Control Board
Division of Drinking Water
(Agreement No. 13-21041)

Final Panel Meeting Report: Surface Water Augmentation Regulation Concept Review

Based on a Panel Meeting Held December 11-12, 2014
(Meeting #3)

February 18, 2015
Fountain Valley, California

www.nwri-usa.org/ca-panel.htm

ABOUT NWRI

A 501c3 nonprofit organization, the National Water Research Institute (NWRI) was founded in 1991 by a group of California water agencies in partnership with the Joan Irvine Smith and Athalie R. Clarke Foundation to promote the protection, maintenance, and restoration of water supplies and to protect public health and improve the environment. NWRI's member agencies include Inland Empire Utilities Agency, Irvine Ranch Water District, Los Angeles Department of Water and Power, Orange County Sanitation District, Orange County Water District, and West Basin Municipal Water District.

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The Drinking Water Program was officially transferred from CDPH to the State Water Resources Control Board (State Board) and renamed as the Division of Drinking Water (DDW) on July 1, 2014. Financial support for the Panel is being provided by DDW through Agreement No. 13-21041.

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In addition, the Panel thanks the National Water Research Institute for administering and organizing the Panel's efforts. The Panel would also like to recognize the WateReuse Research Foundation and members of the State Board's Direct Potable Reuse (DPR) Advisory Committee for participating in the third Panel Meeting.

DISCLAIMER

This report was prepared by an NWRI Expert Panel (Panel), which is administered by the National Water Research Institute (NWRI). Any opinions, findings, conclusions, or recommendations expressed in this report were prepared by the Panel. This report was published for informational purposes.

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ACRONYMS

AF	Acre foot
AOP	Advanced oxidation process
AWT	Advanced water treatment
CDPH	California Department of Public Health
CFSTR	Continuous Flow Stirred Tank Reactor
CWA	Clean Water Act
CWC	California Water Code
DDW	State Water Resources Control Board Division of Drinking Water
DPR	Direct potable reuse
GAC	Granular activated carbon
EPA	U.S. Environmental Protection Agency
IPR	Indirect potable reuse
LRV	Log reduction value
MCL	Maximum contaminant level
MF	Microfiltration
mgd	Million gallons per day
NL	Notification level
NPDES	National Pollutant Discharge Elimination System
NRC	National Research Council
NWRI	National Water Research Institute
RO	Reverse osmosis
SDWA	Safe Drinking Water Act
State Board	State Water Resources Control Board
SVR	San Vicente Reservoir
SWA	Surface water augmentation
SWSAP	Surface water source augmentation project
TDS	Total dissolved solids
TorC	Trace organic chemical
WRRF	WateReuse Research Foundation

1. Purpose of the Report

The purpose of this report is to provide the State Water Resources Control Board (State Board) with the Expert Panel's discussions from their December 11-12, 2014, meeting on the information presented by State Board staff regarding the initial draft document titled, "Surface Water Augmentation IPR Preliminary California Regulation Concept," prepared by the State Board and dated July 2014. In addition, the Panel report also includes some very preliminary statements and recommendations regarding the Panel's intended approach to address the Panel's charge relative to indirect potable reuse (IPR).

2. Purpose and History of the Panel

In 2013, the National Water Research Institute (NWRI) of Fountain Valley, California, a 501c3 nonprofit, appointed state and national water industry experts to an independent, third-party Expert Panel to provide advice to the State of California on developing Water Recycling Criteria for IPR through surface water augmentation (SWA) and determining the feasibility of developing criteria for direct potable reuse (DPR).

The Panel was originally formed on behalf of the Drinking Water Program of the California Department of Public Health (CDPH). As of July 1, 2014, the Drinking Water Program was officially transferred from CDPH to the State Board and renamed as the Division of Drinking Water (DDW); therefore, hereafter, CDPH will be referred to as the State Board in this report. The Panel for the State Board is being administered by NWRI.

2.1 Panel Charge

The specific purpose of the Panel is provided in Chapter 7.3 – entitled "Direct and Indirect Potable Reuse" – of the California Water Code[1]. The exact wording is as follows:

> 13565. (a) (1) On or before February 15, 2014, the department shall convene and administer an expert panel for purposes of advising the department on public health issues and scientific and technical matters regarding development of uniform water recycling criteria for indirect potable reuse through surface water augmentation and investigation of the feasibility of developing uniform water recycling criteria for direct potable reuse. The expert panel shall assess what, if any, additional areas of research are needed to be able to establish uniform regulatory criteria for direct potable reuse. The expert panel shall then recommend an approach for accomplishing any additional needed research regarding uniform criteria for direct potable reuse in a timely manner.

With respect to SWA, the Panel's charge – as stated in Section 13562 of the California Water Code – is as follows:

> (B) Prior to adopting uniform water recycling criteria for surface water augmentation, the department shall submit the proposed criteria to the expert panel convened pursuant to subdivision (a) of Section 13565. The expert panel shall review the proposed criteria and shall adopt a finding as to whether, in its expert opinion, the proposed criteria would adequately protect public health.

[1] Appendix A contains a copy of Chapter 7.3 of the California Water Code, effective January 1, 2014. http://www.leginfo.ca.gov/cgi-bin/displaycode?section=wat&group=13001-14000&file=13560-13569 (last accessed October 6, 2014).

Please refer to Chapter 7.3 of the California Water Code (Appendix A) for a description of State Board and Panel activities as pertaining to this effort.

2.2 Panel Members

The Panel is made up of 12 individuals who meet the California Water Code Section 13565 requirement that the Panel "shall be comprised, at a minimum, of a toxicologist, an engineer licensed in the state with at least three years' experience in wastewater treatment, an engineer licensed in the state with at least three years' experience in treatment of drinking water supplies and knowledge of drinking water standards, an epidemiologist, a limnologist, a microbiologist, and a chemist."

Panel members include:

- *Panel Co-Chair:* Adam Olivieri, Dr.P.H., P.E., EOA, Inc. (Oakland, CA)
- *Panel Co-Chair:* James Crook, Ph.D., P.E., Water Reuse and Environmental Engineering Consultant (Boston, MA)
- Michael Anderson, Ph.D., University of California, Riverside (Riverside, CA)
- Richard Bull, Ph.D., MoBull Consulting (Richland, WA)
- Dr.-Ing. Jörg E. Drewes, Technische Universität München (Munich, Germany)
- Charles Haas, Ph.D., Drexel University (Philadelphia, PA)
- Walter Jakubowski, M.S.., WaltJay Consulting (Spokane, Washington)
- Perry McCarty, Sc.D., Stanford University (Stanford, CA)
- Kara Nelson, Ph.D., University of California, Berkeley (Berkeley, CA)
- Joan B. Rose, Ph.D., Michigan State University (East Lansing, MI)
- David Sedlak, Ph.D., University of California, Berkeley (Berkeley, CA)
- Tim Wade, Ph.D., United States Environmental Protection Agency (Durham, NC)

Background information about the NWRI Panel process can be found in Appendix B, and brief biographies of the Panel members can be found in Appendix C. Further information about the Panel can also be found on the NWRI website at www.nwri-usa.org/ca-panel.htm.

3. Panel Meeting

A two-day meeting of the Panel was held on December 11-12, 2014, at the City of San Diego's North City Water Reclamation Plant in San Diego, California. The specific focus of the meeting was to continue to review the State Board's draft SWA Criteria, better understand the intent and technical basis of the draft criteria, and receive an update on DPR research efforts to date.

3.1 Background Material

Prior to the meeting, the following background material was provided to the Panel:

- The State Board's Response to *Draft Final Panel Meeting Report: Panel's Initial Discussions on the Draft Surface Water Augmentation IPR Preliminary California Regulation Concept (Dated July 2014) – Volume I*, prepared October 6, 2014, by the Expert Panel on the Development of Water Recycling Criteria for Indirect Potable Reuse through Surface Water Augmentation and the Feasibility of Developing Criteria for Direct Potable Reuse.

- *California Direct Potable Reuse Initiative "Reporting on Significant Progress"* (dated Fall 2014/Winter 2015), prepared by the WateReuse Research Foundation (WRRF) and WateReuse California.

These background materials are also provided in Volume II of this report.

3.2 Meeting Agenda and Logistics

Staff from NWRI, the co-chairs of the Panel, and the State Board collaborated on the development of an agenda for the Panel meeting, which is included in Appendix D. The agenda was based on meeting the following specific objectives:

1. Continue to review the State Board's draft criteria for SWA, specifically focused on the draft reservoir criteria.
2. Receive a technical briefing on the City of San Diego's modeling efforts that formed the basis for the State's proposed reservoir criteria.
3. Translate the modeling results to draft criteria.
4. Discuss with the State Board's DDW staff their comments and interpretation of the Panel's draft report covering the July 24-25, 2014, Panel meeting.
5. Review comments of the State Board's DPR Advisory Committee.
6. Receive an update on DPR Research Initiative efforts to date.

The first day included presentations by the City of San Diego staff and consultants (as noted below), as well as updates on the State Board's DPR Advisory Committee and on current and planned research efforts in potable reuse.

Specifically, presentations included:

- Pure Water San Diego IPR/Surface Water Augmentation Project Overview
- San Vicente Reservoir Modeling Studies
- State Board Staff's Response to the Panel's Comments on the Preliminary Surface Water Augmentation Criteria (Reservoir Criteria)
- State Board Staff's Response to the Panel's Comments on the Preliminary Surface Water Augmentation Criteria (Pathogens and Treatment Criteria)
- DPR Advisory Committee Update
- Overview of California DPR Research Initiative Efforts

The slide presentations are provided in Volume III of this report.

Time was allowed for questions and discussion between State Board staff, research project managers, and Panel members following each presentation and throughout an open discussion held during the meeting.

The Panel met in a closed session on the second day to initiate review and discussions on the draft SWA criteria. Other topics covered, time permitting, included the City of San Diego's project efforts, comments of the DPR Advisory Committee, and questions regarding developing a framework for the review of the feasibility of DPR criteria.

3.3 Meeting Attendees

All Panel members participated at the meeting with the exception of Dr. David Sedlak and Dr. Kara Nelson (due to scheduling conflicts). Other attendees included NWRI staff, State Board staff, water reuse research representatives, and utility representatives. A complete list of Panel meeting attendees is included in Appendix E.

4. SUMMARY OF PANEL KEY COMMENTS AND RECOMMENDATIONS

A key focus of this Panel meeting was to continue to review the initial draft *Surface Water Augmentation IPR Preliminary California Regulation Concept* (dated July 2014) and better understand the intent and technical basis of the SWA draft reservoir criteria. Based on Panel discussions, the Panel organized comments and recommendations under the following topics:

- General Comments
- State Board's Response to the Draft Final Panel Meeting Report Prepared October 6, 2014
- Surface Water Augmentation Criteria

4.1 General Comments

The comments in this section focus on the overarching concepts and understandings that will guide and govern the Panel's approach to conducting the review of IPR criteria for SWA (and, eventually, DPR) as required by the California Water Code.

- The Panel commends the effort by the State of California, specifically the State Board's DDW, to develop SWA regulations for IPR, which could help communities throughout California, supplement existing drinking water sources, improve the reliability of existing water supplies, and facilitate additional potable reuse in communities throughout California and the United States.

- As per California Water Code Section 13560-13569, the Panel recognizes that the State Board has been mandated to "develop and adopt uniform water recycling criteria for surface water augmentation" on or before December 31, 2016. Further, the Panel understands that it is charged to "review the proposed criteria and shall adopt a finding as to whether, in its expert opinion, the proposed criteria would adequately protect public health" before the criteria are adopted.

4.2 State Board's Response to the Draft Final Panel Meeting Report Prepared October 6, 2014

The Panel appreciates the comments provided by the State Board staff on the *Draft Final Panel Meeting Report: Panel's Initial Discussions on the Draft Surface Water Augmentation IPR Preliminary California Regulation Concept (Dated July 2014) – Volume I*, prepared October 6, 2014, by the Panel. The comments helped clarify many issues. The Panel will appropriately revise the Draft Final Report and provide the Final Report to State Board staff.

4.3 Surface Water Augmentation Criteria – Proposed Reservoir Criteria

The main focus of the Panel's discussion was on the reservoir criteria. The State Board staff provided four independent (and not necessarily equivalent) proposed options for reservoir criteria (see the list below).

a) A minimum 100:1 dilution of a 24-hour production of recycled water with reservoir water.
b) A minimum 60-day retention of recycled water in the reservoir.
c) A minimum 10:1 dilution of a 24-hour production of recycled water with reservoir water and a minimum 30-day retention of recycled water in the reservoir.
d) A minimum 10:1 dilution of a 24-hour production of recycled water with suitable reservoir water and a 1-log reduction of each organism, in addition to the reductions required in (the pathogen required log reduction value [LRV] sections).

4.3.1 Summary of the Panel's Understanding of State Board Staff's Draft SWA Reservoir Criteria Assumptions

Based, in part, on discussions with State Board staff at the December 11-12, 2014, Panel meeting and review of the State Board staff's responses to comments on the Panel's October 6, 2014, report, the Panel understands that the State Board staff assumptions used to develop and support the criteria are as follows:

1- The primary benefit of the reservoir is to ensure **improved treatment scheme reliability** as part of a planned SWA project (California Water Code Section 13561) where the reservoir is used to provide a source of domestic water supply that receives additional treatment consistent with the State of California drinking water regulations.

2- The reservoir is the key component used to distinguish an IPR-SWA project from a DPR project.

3- Improved reliability is defined as the provision of **residence time** of the advanced treated water in the reservoir, allowing for a **response time** to mitigate potential advanced treatment plant failures.
   a. Residence time is defined as the time for 2 percent of the advanced treated water to pass out of the reservoir into the drinking water treatment plant.

4- The reservoir **dilution** requirement is also included to mitigate potential advanced treatment plant failures.
   a. Dilution factor of 1:10 is defined as one part advanced treated water into nine parts reservoir water.
   b. Dilution factor of 1:100 is defined as one part advanced treated water into 99 parts reservoir water.
   c. Dilution is assumed to be needed to address an inadequately-treated water occurrence over a 24-hour period.

5- The four reservoir options noted above assume some combination of dilution, log reduction for viruses, and residence time (also based on the log reduction for viruses).

6- All four options are based on the assumption that an advanced treatment plant failure producing inadequately-treated water will occur and be detected and corrected within 24 hours.

7- Pathogen reduction credit in the reservoir.
   a. Virus reduction credit may be provided per a separate section.
   b. The project sponsor may also apply for pathogen reduction credit for other pathogens on a case-by-case basis.

4.3.2 Additional Panel Understandings Based on Review of California Groundwater Recharge IPR regulations

1- The California regulations (Title 22, Division 4, California Code of Regulations) for groundwater recharge IPR projects address both microbial pathogens and chemical contaminants.

2- For microbial pathogens, the groundwater recharge regulations require that groundwater recharge projects, prior to distribution for potable uses, provide treatment to achieve at least 12-log enteric virus reduction, 10-log *Giardia* cyst reduction, and 10-log *Cryptosporidium* oocyst reduction.

   a. The above groundwater treatment log reductions can be interpreted and applied to SWA-IPR projects as follows:

      i. Advanced treated water released to the reservoir achieves at least 8-log enteric virus reduction, 7-log *Giardia* cyst reduction, and 8-log *Cryptosporidium* oocyst reduction.
      ii. Drinking water treatment for surface water supplies provides at least 4-log enteric virus reduction, 3-log *Giardia* cyst reduction, and 2-log *Cryptosporidium* oocyst[2,3] reduction.
      iii. No additional reductions are provided for in the reservoir unless specifically requested and demonstrated by the SWA-IPR project sponsor, as previously noted.

   b. The groundwater regulations also include limits for chemical constituents (e.g., maximum contaminant levels [MCLs], notification levels [NLs], and other constituents specified by the State Board) and monitoring requirements for contaminants/parameters that would also apply to SWA-IPR projects.

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[2] The SDWA public health risk goal for surface waters and groundwaters under the direct influence of surface waters is to be achieved through installing sufficient treatment[2] technologies to achieve log removal[2] of *Cryptosporidium* ranging from 2 (disinfection only with source < 0.01 oocyst/L) to 3 (conventional surface drinking water filtration and disinfection treatment) to 5.5, depending upon the concentrations of cryptosporidium measured in 24-monthly source water samplings.

[3] The SDWA also allows for water supplies that can demonstrate low risk of *Cryptosporidium c*ontamination that wish to avoid filtration can meet requirements by utilizing two disinfectants that can control *Cryptosporidium*, such as ozone, ultraviolet (UV) light, or chlorine dioxide.

4.3.3 Panel Observations

1- The dilution terminology is confusing and does not follow standard engineering practice nomenclature.

2- Dilution needs to be carefully and clearly defined.
   a. Based on the December 11-12, 2014, Panel meeting, the Panel understands that dilution is tied to the need to mitigate inadequately-treated water occurring at some unknown frequency during advanced water treatment operations, for a duration of up to 24 hours, and at an unknown concentration of unspecified pollutants.

3- Installation of a diffuser at the inlet could help the reservoir meet the dilution requirement.

4- Retention time needs to be carefully and clearly defined.
   a. The working assumption is that tracer studies need to be designed and conducted to understand the worst-case condition.
   b. Modeling will need to be done.
   c. Need to represent the conservative nature of tracer.
   d. Need to define the probability that worst-case reservoir dynamics will occur.

5- If all four reservoir criteria are independent and acceptable, then it is reasonable to assume that a SWA-IPR project could be designed, operated, and approved to meet more than one of the reservoir options during specific crucial times of the year.

5. Panel Conclusions and Recommendations on the SWA Draft Reservoir Criteria

The Panel – after lengthy discussion and deliberation at the December 11-12, 2014, meeting and the subsequent review of the additional technical information prepared by Panel member Dr. Michael Anderson (see Appendix F) – provides the following comments and recommendations regarding the proposed reservoir criteria.

5.1 Comments on the Proposed Reservoir Criteria

In this section, text on the reservoir criteria from the State Board's draft SWA regulation concept has been inserted for ease of reference, followed by specific Panel comments. The following 18 comments are provided based on the analysis contained in Appendix F. Note that indented text represents the numbered Panel comments.

Reservoir Criteria from the July 2014 draft SWA Regulation

§64601. General Criteria for Determining the Suitability of a Reservoir Used as a Source of Domestic Water for Augmentation with Recycled Water.

(a) Reservoirs receiving a discharge of recycled water as part of a SWSAP must have been in operation as an approved surface water (§ 64651.10) for a sufficient period of time to establish a baseline record of reservoir raw water quality and treated drinking water quality. In no case shall the reservoir been operating as an approved surface water for less than five years prior to the discharge of recycled water.

> Panel Comment #1: This is a reasonable requirement with a sound rationale.

(b) The public water system using the reservoir as a domestic water source must have sufficient control over the operation of the reservoir to assure their ability to comply with the requirements of this Article.

> Panel Comment #2: This is a reasonable requirement with a sound rationale.

§64602. Retention and/or Mixing of Recycled Water in the Reservoir.

(a) The reservoir must achieve one of the following between the discharge of the recycled water[4] into the reservoir and its abstraction as a surface water source:

- A minimum 100:1 dilution of a 24-hour ~~one week~~ production of recycled water with suitable reservoir water
- A minimum 60-day retention of recycled water in the reservoir

[4] Recycled water, as used herein, is wastewater treated to the degree that it is suitable for discharge to a qualifying drinking water source reservoir.

- A minimum10:1 dilution of a 24-hour ~~one week~~ production of recycled water with suitable reservoir water and a minimum 30-day retention of recycled water in the reservoir
- A minimum10:1 dilution of a 24-hour ~~one week~~ production of recycled water with suitable reservoir water and a 1-log reduction of each organism in addition to the reductions required in section(s) (??)

> Panel Comment #3: Dilution, retention (e.g., t_2), and LRV values are not independent criteria. As indicated in the "Conceptual Framework-Screening Model" document in Appendix F, dilution factors and t_2 values are both linearly related to the reservoir hydraulic retention time (t_r) under the Continuous Flow Stirred Tank Reactor (CFSTR) approximation for the winter well-mixed period and volumetric steady-state. Modest relaxation of these assumptions does not substantively change the results of the calculations presented therein and the autocorrelation that exists between these attributes. Moreover, it was demonstrated that large t_2 values are met only for very large reservoirs with long hydraulic retention times (e.g., a t_2 value of 60 days would require a theoretical t_r of 8.3 years, while also yielding a 1:3,000 dilution, while a 30-day t_2 value yields a theoretical 1:1,500 dilution and t_r value of 4.1 years). Short-circuiting can greatly lower the actual dilution and t_2 values. Thus, while travel time/time-to-react is a useful concept, it would be difficult for a reservoir receiving SWA to meet t_2 values of 30 to 60 days under conditions when the water column is mixed (often two or more months each winter). Revisions of these four criteria that include eliminating the 60-day t_2 and 30-day t_2 plus 1-log dilution criteria have been incorporated in the Panel's proposed edits to the SWA criteria (See Section 5.2). The general requirement for a minimum theoretical hydraulic retention time from (d) below is proposed as an alternative to a specific t_2 value(s).

Reservoir water suitable for diluent credit must be from reservoir watershed runoff, imported water that has been approved as a surface water source, or recycled water meeting the requirements of section(s) …[5]

> Panel Comment #4: This is a reasonable requirement with a sound rationale.

Recycled water may only be discharged into the reservoir when less than one percent[6] of the reservoir water is recycled water that did not meet the requirements of section(s) …[6]

> Panel Comment #5: This is a reasonable requirement with a sound rationale.

The recycled water retention time in the reservoir is determined by the elapsed time at which two percent of any volume[7,8] of discharged recycled water has been abstracted.

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[5]The treatment requirements for organisms and unregulated trace organic chemicals (TrOCs).
[6]One percent at SVR, after steady-state is achieved, would allow 1-month of off-spec discharge over 8 years (V/Q=8 years.), an average of 3.65 days/year.
[7]T2 was approved by staff, but we may want to consider lag time.
[8]Volume of the tracer is the measure used in the SWTR, although concentration is used in the groundwater recharge IPR criteria (it says "any volume" because the volume should not matter).

Panel Comment #6: This definition is adequate, although it does potentially add some confusion distinguishing between a theoretical hydraulic residence time and a recycled water retention time. As indicated in (a) above, it is recommended that criteria defining minimum t_2 values be removed from the draft criteria, obviating the need for this text.

(c) Where a thermocline is used as a reservoir feature to help meet the retention time requirements in (a):

Panel Comment #7: As indicated in the "Conceptual Framework-Screening Model" document in Appendix F, reliance on the thermocline to achieve dilution and/or t_2 retention time requirements is thought to be a difficult operational strategy and one that imposes severe constraints for use in SWA given the greatest availability of recycled water during the winter, costs of the construction and operation of the advanced water treatment plant, and costs related to the development of conveyances. A 1:10 dilution of a 1-day production of recycled water and 1-log reduction by an independent treatment process provides a much more cost-effective and flexible scheme for minimizing potential health risks resulting from SWA. Removing the use of the thermocline from the draft criteria is recommended (see Appendix F).

(i) The recycled water discharge must be above the thermocline and the withdrawal for drinking water use must be below the thermocline.

Panel Comment #8: See above comments in (c).

(ii) Water shall not be abstracted from the reservoir for the duration of the relevant retention time option from subsection (a) once stratification is reestablished. The engineering report must identify criteria for determining when the thermocline has been reestablished.

Panel Comment #9: See above comments in (c). Moreover, reference to use of the thermocline adds unnecessary complications to the draft criteria.

(d) The recycled municipal wastewater shall be retained in the reservoir for a theoretical retention time of at least twelve months prior to withdrawal for use as a drinking water supply. The theoretical retention time shall be determined monthly by taking the volume of the impounded water at the end of the month and dividing by one month and the total outflow from the reservoir during the month, including overflow and withdrawals for water use.

Panel Comment #10: As previously noted, theoretical hydraulic retention time, t_r, is an important property useful in defining, at a screening level, the potential suitability of a reservoir for SWA. It is recognized, however, that t_r values can obscure important hydrodynamic, design, and operational factors that ultimately govern the true dilution and travel time/time to react for any particular proposed SWA project. There is possible value in retaining a minimum t_r value as a way to set some bounds on the transport time/time to react from (a) above and on the size of potential SWA projects. For example, requiring a 1-year t_r value at an outflow rate equivalent to a typical wastewater treatment plant flow of 15 million gallons per day (mgd) would require a reservoir that is 16,800 acre-feet in volume and would provide a t_2 value of 7.3 days under the winter CFSTR approximation. At the same time, however, this requirement would likely reduce the usefulness of the fourth draft reservoir criteria that requires only 1:10 dilution and 1-log reduction by an independent treatment process 1-log additional treatment. That is, under the CFSTR approximation, a 1-year t_r value would yield a 1:365 dilution of a 1-day pulse of inadequately-treated water, thus yielding a theoretical dilution factor that is 36 times larger than 1:10 dilution. Thus, a 1-year t_r requirement may exclude some systems that would be likely candidates for the 1:10 alternative criterion. All this being said, a t_r value of 4 to 6 months might be a reasonable compromise, achieving a theoretical dilution of approximately 1:120 to 1:180 and theoretical t_2 values of 2.4 to 3.6 days. It is highly unlikely that such reservoirs could reliably meet the 1:100 dilution criterion, but could plausibly attain 1:10 dilution.

(e) Based on possible changes in reservoir hydrodynamics since the most recent tracer study or model study, the Division of Drinking Water Quality may require a SWSAP's project sponsor to demonstrate that the reservoir hydraulic characterization used to comply with this section remain valid.

Panel Comment #11: This is a reasonable requirement with a sound rationale.

(f) To verify that the retention time requirements in subsection (a) is being met, prior to the end of the sixth month of operation under hydraulic conditions representative of normal SWSAP operations the SWSAP shall initiate a tracer study utilizing an added tracer. The Division of Drinking Water Quality must approve the tracer test protocol.

Panel Comment #12: A tracer test should be included, although requiring this after approval and operation for 6 months or more of an SWSAP could place the utility in a tenuous situation – what if the dilution requirement is not met? If the project was approved under the 1:100 criteria, one could suppose that the State Board would require 1-log additional reduction by an independent treatment process be added so that the SWSAP conforms to the 1:10 and 1-log additional treatment criterion. This requirement would certainly be an important performance test with potentially costly implications. The practical effect of this might be for projects to design for the 1:10 and 1-log additional reduction by an independent treatment process. A tracer test should be required as part of the application/permit process.

§64603. Siting of the Point of Recycled Water Discharge to the Reservoir.
The location of the point of SWSAP discharge into the reservoir shall be sited to enable compliance with the retention time requirements of subsection (a). The location shall be based on three-dimensional hydrodynamic modeling of the reservoir.

Panel Comment #13: This requirement seems overly prescriptive. A SWSAP should be held to requirements that protect public health without micromanaging it. These details should be considered in the engineering report and SWA application. See Section 5.2 for proposed revisions.

§64603. Reservoir LRVs

(a) For each month the recycled water is retained in the reservoir as demonstrated with a tracer study or numerical model the recycled municipal wastewater will be credited with 1-log virus reduction. The protocol used to establish the reservoir retention time shall be approved by the Division of Drinking Water Quality. Reservoir LRVs for organisms may be approved by submitting a report for the Division of Drinking Water Quality's review and approval, or by using a challenge test approved by the Division of Drinking Water Quality, that provides evidence of the reservoir's ability to reliably and consistently achieve the log reduction

Panel Comment #14: The complexity of demonstrating LRVs under all circumstances (summer/winter, high turbidity/low turbidity, short-circuiting, etc.) for all possible pathogens would make this pathway to compliance a difficult one with a high burden of proof. It is suggested that LRVs not be explicitly included as a compliance pathway, and rather accept inactivation and loss occurring in the reservoir simply as an added margin of safety. See Section 5.2 for proposed revisions.

§64604. Public Hearings.

(a) Three public hearings for a SWSAP shall be held by public water systems using the SWSAP as a source of supply prior to the Division of Drinking Water Quality's submittal of recommendations regarding the SWSAP to the RWQCB or SWRCB, or approving the SWSAP as an approved source in a public water system permit. The SWSAP water-recycling agency shall participate in the hearings for the purpose of presenting information on the recycled water source, treatment, monitoring, and anticipated SWRCB or RWQCB permit provisions. Prior to a public hearing, the public water system(s) and SWSAP water-recycling agency shall provide the Division of Drinking Water Quality, for review and approval, the information the public water system(s) and SWSAP water-recycling agency intends to present at the hearing and on the Internet. Following the Division of Drinking Water Quality's approval of the information, the SWSAP water recycling agency shall place the information on the Internet and in a repository that provides at least thirty days of public access to the information prior to the public hearings.

Panel Comment #15: This is a reasonable requirement with a sound rationale.

(b) Prior to placing the information required pursuant to subsection (a) in a repository, the SWSAP shall:

- (1) Notify the public of the following;
  - (A) the location and hours of operation of the repository,
  - (B) the Internet address where the information may be viewed,
  - (C) the purpose of the repository and public hearing,
  - (D) the manner in which the public can provide comments, and
  - (E) the date, time, and location of the public hearing.

(2) Notify all public water systems that can receive water, directly of indirectly, including through emergency connections, from the SWSAP.

Panel Comment #16: This is a reasonable requirement with a sound rationale.

(c) Unless directed otherwise by the Division of Drinking Water Quality, the public notification made pursuant to subsection (b)(2) shall be by direct mail and the notification made pursuant to (b)(1) shall be by one or more of the following methods delivered in a manner to reach persons whose source of drinking water may be impacted by the SWSAP:

(1) Local newspaper(s) publication;
(2) Mailed or direct delivery of a newsletter;
(3) Conspicuously placed statement in water bills; or
(4) Television and/or radio.

NOTE: Authority cited: §116551 H&S Code

Panel Comment #17: This is a reasonable requirement with a sound rationale.

§64605. Alternative Source of Supply

Prior to operation of a new SWSAP, or during the first year of operation after [*insert effective date*] for an existing SWSAP, the public water system(s) using the augmented reservoir as a source shall have a Division of Drinking Water Quality approved plan that provides an alternative source of domestic water supply, or a Division of Drinking Water Quality approved treatment mechanism in the event that the water withdrawn from the augmented reservoir, as a result of the SWSAP;

(1) Is not being treated to meet California drinking water standards,
(2) Has been degraded to the degree that it is no longer a safe source of drinking water, or
(3) Receives water that fails to meet subsection 60320.010(c).

Panel Comment #18: This is a reasonable requirement with a sound rationale.

5.2 Recommendations to Modify the Reservoir Criteria

Based on the above Panel comments, the Panel prepared the following recommended edits to the proposed criteria inserted below.

Title 22, CALIFORNIA CODE OF REGULATIONS
DIVISION 4. ENVIRONMENTAL HEALTH
CHAPTER 17. SURFACE WATER TREATMENT

Article ?. Surface Water Reservoirs Augmented with Recycled Water

§64601. General Criteria for Determining the Suitability of a Reservoir Used as a Source of Domestic Water for Augmentation with Recycled Water.

(a) Reservoirs receiving a discharge of recycled water as part of a SWSAP must have been in operation as an approved surface water (§ 64651.10) for a sufficient period of time to establish a baseline record of reservoir raw water quality and treated drinking water quality. In no case shall the reservoir been operating as an approved surface water for less than five years prior to the discharge of recycled water.

(b) The public water system using the reservoir as a domestic water source must have sufficient control over the operation of the reservoir to assure their ability to comply with the requirements of this Article.

§64602. Retention and Mixing of Recycled Water in the Reservoir.

Implementation of SWA in a source drinking water reservoir requires that several criteria be met:

(a) The reservoir must have a theoretical retention time of at least 6 months. The theoretical retention time shall be determined monthly by taking the volume of the impounded water at the end of the month and dividing by one month and the total outflow from the reservoir during the month, including overflow and withdrawals for water use. The average time that recycled municipal wastewater is retained in the reservoir shall thus be at least six months prior to withdrawal for use as a drinking water supply.

~~(b) The SWSAP sponsor must be able to demonstrate that a 1-day (24-h) input pulse results in:~~

~~(i) a concentration in the reservoir withdrawal that is no greater than 1% of the recycled water effluent concentration (i.e., ensuring at all times at least a 100-fold dilution of any contaminants resulting from a treatment failure during full advanced treatment), or~~

~~(ii) a concentration in the reservoir withdrawal that is no greater than 10% of the recycled water effluent concentration (i.e., 10-fold dilution) and, through treatment, additional 1-log pathogen reductions beyond the reductions required in §60321.003.~~

(b). The SWSAP sponsor must be able to demonstrate that:

(i) the volume of water withdrawn from the reservoir on any given day contains no more than 1% by volume of recycled municipal wastewater added to the reservoir on any single previous day, or

(ii) the volume of water withdrawn from the water on any given day contains no more than 10% by volume of recycled municipal wastewater added to the reservoir on any single previous day and in addition has a 1-log pathogen treatment reduction (by an independent treatment process? All three pathogens? And where?) ~~beyond the reductions required in §60321.003.~~

~~(a) The reservoir must achieve one of the following between the discharge of the recycled water[9] into the reservoir and its abstraction as a surface water source:~~

- ~~A minimum 100:1 dilution of a one week production of recycled water with suitable reservoir water~~
- ~~A minimum 60-day retention of recycled water in the reservoir~~
- ~~A minimum10:1 dilution of a one week production of recycled water with suitable reservoir water and a minimum 30-day retention of recycled water in the reservoir~~
- ~~A minimum10:1 dilution of a one week production of recycled water with suitable reservoir water and a 1-log reduction of each organism in addition to the reductions required in section(s) (??)~~

(c) Reservoir water suitable for receipt of recycled water ~~diluent credit~~ must be from reservoir watershed runoff, imported water that has been approved as a surface water source, or recycled water meeting the requirements of §60321~~section(s) …~~[10]

(d) Recycled water may only be discharged into the reservoir when less than one percent[11] of the reservoir water is recycled water that did not meet the requirements of §60321~~section(s) …~~[3]

~~The recycled water retention time in the reservoir is determined by the elapsed time at which two percent of any volume[12,13] of discharged recycled water has been abstracted.~~

~~(c) Where a thermocline is used as a reservoir feature to help meet the retention time requirements in (a):~~

~~(i) The recycled water discharge must be above the thermocline and the withdrawal for drinking water use must be below the thermocline.~~

~~(ii) Water shall not be abstracted from the reservoir for the duration of the relevant retention time option from subsection (a) once stratification is reestablished. The engineering report must identify criteria for determining when the thermocline has been reestablished.~~

~~9 recycled water, as used herein, is wastewater treated to the degree that it is suitable for discharge to a qualifying drinking water source reservoir~~

10 The treatment requirements for organisms and unregulated TrOCs.

11 One percent at SVR, after steady state is achieved, would allow 1-month of off-spec discharge over 8 years (V/Q=8 yrs.), an average of 3.65 days/yr.

~~12 T2 was approved by staff but we may want to consider lag time~~

~~13 volume of the tracer is the measure used in the SWTR, although concentration is used in the groundwater recharge IPR criteria (It says "any volume" because the volume should not matter)~~

~~(d) The recycled municipal wastewater shall be retained in the reservoir for a theoretical retention time of at least twelve months prior to withdrawal for use as a drinking water supply. The theoretical retention time shall be determined monthly by taking the volume of the impounded water at the end of the month and dividing by one month and the total outflow from the reservoir during the month, including overflow and withdrawals for water use.~~

~~(e) Based on possible changes in reservoir hydrodynamics since the most recent tracer study or model study, the Division of Drinking Water Quality may require a SWSAP's project sponsor to demonstrate that the reservoir hydraulic characterization used to comply with this section remain valid.~~

(e~~f~~) To verify that the dilution ~~retention time~~ requirement~~s~~ in subsection (a) is being met, prior to the end of the sixth month of operation under hydraulic conditions representative of normal SWSAP operations the SWSAP shall initiate a tracer study utilizing an added tracer. The Division of Drinking Water ~~Quality~~ must approve the tracer test protocol. The Division of Drinking Water must also be notified of significant changes in SWA and reservoir operation beyond those in the project permit; the DDW may require a SWSAP's project sponsor to demonstrate that the reservoir hydraulic characterization used to comply with this section remains valid.

~~**§64603. Sitting of the Point of Recycled Water Discharge to the Reservoir.**~~
~~The location of the point of SWSAP discharge into the reservoir shall be sited to enable compliance with the retention time requirements of subsection (a). The location shall be based on three-dimensional hydrodynamic modeling of the reservoir.~~

~~**§64603. Reservoir LRVs**~~
~~(a) For each month the recycled water is retained in the reservoir as demonstrated with a tracer study or numerical model the recycled municipal wastewater will be credited with 1-log virus reduction. The protocol used to establish the reservoir retention time shall be approved by the Division of Drinking Water Quality. Reservoir LRVs for organisms may be approved~~

~~by submitting a report for the Division of Drinking Water Quality's review and approval, or by using a challenge test approved by the Division of Drinking Water Quality, that provides evidence of the reservoir's ability to reliably and consistently achieve the log reduction~~

§646~~0~~34. Public Hearings.
(a) Three public hearings for a SWSAP shall be held by public water systems using the SWSAP as a source of supply prior to the Division of Drinking Water ~~Quality~~'s submittal of recommendations regarding the SWSAP to the RWQCB or SWRCB, or approving the SWSAP as an approved source in a public water system permit. The SWSAP water-recycling agency shall participate in the hearings for the purpose of presenting information on the recycled water source, treatment, monitoring, and anticipated SWRCB or RWQCB permit provisions. Prior to a public hearing, the public water

system(s) and SWSAP water-recycling agency shall provide the Division of Drinking Water ~~Quality~~, for review and approval, the information the public water system(s) and SWSAP water-recycling agency intends to present at the hearing and on the Internet. Following the Division of Drinking Water ~~Quality~~'s approval of the information, the SWSAP water recycling agency shall place the information on the Internet and in a repository that provides at least thirty days of public access to the information prior to the public hearings.

(b) Prior to placing the information required pursuant to subsection (a) in a repository, the SWSAP shall:

(1) Notify the public of the following;

(A) the location and hours of operation of the repository,

(B) the Internet address where the information may be viewed,

(C) the purpose of the repository and public hearing,

(D) the manner in which the public can provide comments, and

(E) the date, time, and location of the public hearing.

(2) Notify all public water systems that can receive water, directly of indirectly, including through emergency connections, from the SWSAP.

(c) Unless directed otherwise by the Division of Drinking Water ~~Quality~~, the public notification made pursuant to subsection (b)(2) shall be by direct mail and the notification made pursuant to (b)(1) shall be by one or more of the following methods delivered in a manner to reach persons whose source of drinking water may be impacted by the SWSAP:

(1) Local newspaper(s) publication;

(2) Mailed or direct delivery of a newsletter;

(3) Conspicuously placed statement in water bills; or

(4) Television and/or radio.

NOTE: Authority cited: §116551 H&S Code

§646~~05~~4. Alternative Source of Supply

Prior to operation of a new SWSAP, or during the first year of operation after [*insert effective date*] for an existing SWSAP, the public water system(s) using the augmented reservoir as a source shall have a Division of Drinking Water ~~Quality~~ approved plan that provides an alternative source of domestic water supply, or a Division of Drinking Water ~~Quality~~ approved treatment mechanism in the event that the water withdrawn from the augmented reservoir, as a result of the SWSAP:

~~;~~

(1) Is not being treated to meet California drinking water standards,

(2) Has been degraded to the degree that it is no longer a safe source of drinking water, or

~~(1) Has been degraded to the degree that it is no longer a safe source of drinking water, or~~

(3) Receives water that fails to meet subsection 60320.010(c).

CALIFORNIA WATER CODE
CHAPTER 7.3 DIRECT AND INDIRECT POTABLE REUSE
SECTION 13560-13569

13560. The Legislature finds and declares the following:

(a) In February 2009, the state board unanimously adopted, as Resolution No. 2009-0011, an updated water recycling policy, which includes the goal of increasing the use of recycled water in the state over 2002 levels by at least 1,000,000 acre-feet per year by 2020 and by at least 2,000,000 acre-feet per year by 2030.

(b) Section 13521 requires the department to establish uniform statewide recycling criteria for each varying type of use of recycled water where the use involves the protection of public health.

(c) The use of recycled water for indirect potable reuse is critical to achieving the state board's goals for increased use of recycled water in the state. If direct potable reuse can be demonstrated to be safe and feasible, implementing direct potable reuse would further aid in achieving the state board's recycling goals.

(d) Although there has been much scientific research on public health issues associated with indirect potable reuse through groundwater recharge, there are a number of significant unanswered questions regarding indirect potable reuse through surface water augmentation and direct potable reuse.

(e) Achievement of the state's goals depends on the timely development of uniform statewide recycling criteria for indirect and direct potable water reuse.

(f) This chapter is not intended to delay, invalidate, or reverse any study or project, or development of regulations by the department, the state board, or the regional boards regarding the use of recycled water for indirect potable reuse for groundwater recharge, surface water augmentation, or direct potable reuse.

(g) This chapter shall not be construed to delay, invalidate, or reverse the department's ongoing review of projects consistent with Section 116551 of the Health and Safety Code.

13561. For purposes of this chapter, the following terms have the following meanings:

(a) "Department" means the State Department of Public Health.

(b) "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.

(c) "Indirect potable reuse for groundwater recharge" means the planned use of recycled water for replenishment of a groundwater basin or an aquifer that has been designated as a source of water supply for a public water system, as defined in Section 116275 of the Health and Safety Code.

(d) "Surface water augmentation" means the planned placement of recycled water into a surface water reservoir used as a source of domestic drinking water supply.

(e) "Uniform water recycling criteria" has the same meaning as in Section 13521.

13561.5. The state board shall enter into an agreement with the department to assist in implementing this chapter.

13562. (a) (1) On or before December 31, 2013, the department shall adopt uniform water recycling criteria for indirect potable reuse for groundwater recharge.

(2) (A) Except as provided in subparagraph (C), on or before December 31, 2016, the department shall develop and adopt uniform water recycling criteria for surface water augmentation.

(B) Prior to adopting uniform water recycling criteria for surface water augmentation, the department shall submit the proposed criteria to the expert panel convened pursuant to subdivision (a) of Section 13565. The expert panel shall review the proposed criteria and shall adopt a finding as to whether, in its expert opinion, the proposed criteria would adequately protect public health.

(C) The department shall not adopt uniform water recycling criteria for surface water augmentation pursuant to subparagraph (A), unless and until the expert panel adopts a finding that the proposed criteria would adequately protect public health.

(b) Adoption of uniform water recycling criteria by the department is subject to the requirements of Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of Title 2 of the Government Code.

13562.5. Notwithstanding any other law, no later than June 30, 2014, the department shall adopt, by emergency regulations in accordance with Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of Title 2 of the Government Code, requirements for groundwater replenishment using recycled water. The adoption of these regulations is an emergency and shall be considered by the Office of Administrative Law as necessary for the immediate preservation of the public peace, health, safety, and general welfare. Notwithstanding Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of Title 2 of the Government Code, emergency regulations adopted by the department pursuant to this section shall not be subject to review by the Office of Administrative Law and shall remain in effect until revised by the department.

13563. (a) (1) On or before December 31, 2016, the department, in consultation with the state board, shall investigate and report to the Legislature on the feasibility of developing uniform water recycling criteria for direct potable reuse.

(2) The department shall complete a public review draft of its report by September 1, 2016. The department shall provide the public not less than 45 days to review and comment on the public review draft.

(3) The department shall provide a final report to the Legislature

by December 31, 2016. The department shall make the final report available to the public.

(b) In conducting the investigation pursuant to subdivision (a), the department shall examine 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.

(c) (1) Notwithstanding Section 10231.5 of the Government Code, the requirement for submitting a report imposed under paragraph (3) of subdivision (a) is inoperative on December 31, 2020.

(2) A report to be submitted pursuant to paragraph (3) of subdivision (a) shall be submitted in compliance with Section 9795 of the Government Code.

13563.5. (a) The department, in consultation with the state board, shall report to the Legislature as part of the annual budget process, in each year from 2011 to 2016, inclusive, on the progress towards developing and adopting uniform water recycling criteria for surface water augmentation and its investigation of the feasibility of developing uniform water recycling criteria for direct potable reuse.

(b) (1) A written report submitted pursuant to subdivision (a) shall be submitted in compliance with Section 9795 of the Government Code.

(2) Pursuant to Section 10231.5 of the Government Code, this section is repealed on January 1, 2017.

13564. In developing uniform water recycling criteria for surface water augmentation, the department shall consider all of the following:

(a) The final report from the National Water Research Institute Independent Advisory Panel for the City of San Diego Indirect Potable Reuse/Reservoir Augmentation (IPR/RA) Demonstration Project.

(b) Monitoring results of research and studies regarding surface water augmentation.

(c) Results of demonstration studies conducted for purposes of approval of projects using surface water augmentation.

(d) Epidemiological studies and risk assessments associated with projects using surface water augmentation.

(e) Applicability of the advanced treatment technologies required for recycled water projects, including, but not limited to, indirect potable reuse for groundwater recharge projects.

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

(g) Recommendations of the State of California Constituents of Emerging Concern Recycled Water Policy Science Advisory Panel.

(h) State funded research pursuant to Section 79144 and subdivision (b) of Section 79145.

(i) Research and recommendations from the United States Environmental Protection Agency Guidelines for Water Reuse.

(j) The National Research Council of the National Academies' report titled "Water Reuse: Potential for Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater."

(k) Other relevant research and studies regarding indirect potable reuse of recycled water.

13565. (a) (1) On or before February 15, 2014, the department shall convene and administer an expert panel for purposes of advising the department on public health issues and scientific and technical matters regarding development of uniform water recycling criteria for indirect potable reuse through surface water augmentation and investigation of the feasibility of developing uniform water recycling criteria for direct potable reuse. The expert panel shall assess what, if any, additional areas of research are needed to be able to establish uniform regulatory criteria for direct potable reuse. The expert panel shall then recommend an approach for accomplishing any additional needed research regarding uniform criteria for direct potable reuse in a timely manner.

(2) The expert panel shall be comprised, at a minimum, of a toxicologist, an engineer licensed in the state with at least three years' experience in wastewater treatment, an engineer licensed in the state with at least three years' experience in treatment of drinking water supplies and knowledge of drinking water standards, an epidemiologist, a limnologist, a microbiologist, and a chemist. The department, in consultation with the advisory group and the state board, shall select the expert panel members.

(3) Members of the expert panel may be reimbursed for reasonable and necessary travel expenses.

(b) (1) On or before January 15, 2014, the department shall convene an advisory group, task force, or other group, comprised of no fewer than nine representatives of water and wastewater agencies, local public health officers, environmental organizations, environmental justice organizations, public health nongovernmental organizations, the department, the state board, the United States Environmental Protection Agency, ratepayer or taxpayer advocate organizations, and the business community, to advise the expert panel regarding the development of uniform water recycling criteria for direct potable reuse and the draft report required by Section 13563. The department, in consultation with the state board, shall select the advisory group members.

(2) Environmental, environmental justice, and public health nongovernmental organization representative members of the advisory group, task force, or other group may be reimbursed for reasonable and necessary travel expenses.

(3) In order to ensure public transparency, the advisory group established pursuant to paragraph (1) shall be subject to the Bagley-Keene Open Meeting Act (Article 9 (commencing with Section 11120) of Chapter 1 of Part 1 of Division 3 of Title 2 of the

Government Code).

(c) On or before June 30, 2016, the department shall prepare a draft report summarizing the recommendations of the expert panel.

(d) The department may contract with a public university or other research institution with experience in convening expert panels on water quality or potable reuse to meet all or part of the requirements of this section should the department find that the research institution is better able to fulfill the requirements of this section by the required date.

13566. In performing its investigation of the feasibility of developing the uniform water recycling criteria for direct potable reuse, the department shall consider all of the following:

(a) Recommendations from the expert panel appointed pursuant to subdivision (a) of Section 13565.

(b) Recommendations from an advisory group, task force, or other group appointed by the department pursuant to subdivision (b) of Section 13565.

(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, as developed pursuant to Section 10 of the recycled water policy adopted by state board Resolution No. 2009-0011.

(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.

13567. An action authorized pursuant to this chapter shall be consistent, to the extent applicable, with the federal Clean Water Act (33 U.S.C. Sec. 1251 et seq.), the federal Safe Drinking Water Act (42 U.S.C. Sec. 300f et seq.), this division, and the California Safe Drinking Water Act (Chapter 4 (commencing with Section 116270) of Part 12 of Division 104 of the Health and Safety Code).

13569. The department may accept funds from nonstate sources and may expend these funds, upon appropriation by the Legislature, for the purposes of this chapter.

About NWRI

For over 20 years, NWRI – a science-based 501c3 nonprofit located in Fountain Valley, California – has sponsored projects and programs to improve water quality, protect public health and the environment, and create safe, new sources of water. NWRI specializes in working with researchers across the country, such as laboratories at universities and water agencies, and are guided by a Research Advisory Board (representing national expertise in water, wastewater, and water reuse) and a six-member Board of Directors (representing water and wastewater agencies in Southern California).

Through NWRI's research program, NWRI supports multi-disciplinary research projects with partners and collaborators that pertain to treatment and monitoring, water quality assessment, knowledge management, and exploratory research. Altogether, NWRI's research program has produced over 300 publications and conference presentations.

NWRI also promotes better science and technology through extensive outreach and educational activities, which includes facilitating workshops and conferences and publishing White Papers, guidance manuals, and other informational material.

More information on NWRI can be found online at www.nwri-usa.org.

About NWRI Panels

NWRI also specializes in facilitating Independent Advisory Panels on behalf of water and wastewater utilities, as well as local, county, and state government agencies, to provide credible, objective review of scientific studies and projects in the water industry. NWRI Panels consist of academics, industry professionals, government representatives, and independent consultants who are experts in their fields.

The NWRI Panel process provides numerous benefits, including:

- Third-party review and evaluation.
- Scientific and technical advice by leading experts.
- Assistance with challenging scientific questions and regulatory requirements.
- Validation of proposed project objectives.
- Increased credibility with stakeholders and the public.
- Support of sound public-policy decisions.

NWRI has extensive experience in developing, coordinating, facilitating, and managing expert Panels. Efforts include:

- Selecting individuals with the appropriate expertise, background, credibility, and level of commitment to serve as Panel members.

- Facilitating hands-on Panel meetings held at the project's site or location.
- Providing written report(s) prepared by the Panel that focus on findings and comments of various technical, scientific, and public health aspects of the project or study.

Over the past 5 years, NWRI has coordinated the efforts of over 20 Panels for water and wastewater utilities, city and state agencies, and consulting firms. Many of these Panels have dealt with projects or policies involving groundwater replenishment and potable (indirect and direct) reuse. Specifically, these Panels have provided peer review of a wide range of scientific and technical areas related water quality and monitoring, constituents of emerging concern, treatment technologies and operations, public health, hydrogeology, water reuse criteria and regulatory requirements, and outreach, among others.

Examples of recent NWRI Panels include:

- **Development of Water Recycling Criteria for Indirect Potable Reuse through Surface Water Augmentation and the Feasibility of Developing Criteria for Direct Potable Reuse** for the State Water Resources control Board Division of Drinking Water (CA)
- **Evaluating Water Quality Testing at the Silicon Valley Advanced Water Purification Center for Future Potable Reuse Applications** for the Santa Clara Valley Water District (CA)
- **Developing Proposed Direct Potable Reuse Operational Procedures and Guidelines for New Mexico** for the New Mexico Environment Department (NM)
- **Monterey Peninsula Groundwater Replenishment Project** for the Monterey Regional Water Pollution Control Agency (CA)
- **Groundwater Recharge Scientific Study** for the LOTT Clean Water Alliance (WA)
- **Groundwater Replenishment System Program Review** for the Orange County Water District (CA)
- **Examining the Criteria for Direct Potable Reuse** for Trussell Technologies (CA) and WateReuse Research Foundation (VA)
- **Evaluating Potable Reuse** for the Santa Clara Valley Water District (CA)
- **Indirect Potable Reuse/Reservoir Augmentation Project Review** for the City of San Diego (CA)
- **BDOC as a Surrogate for Organics Removal in Groundwater Recharge** for the California Department of Public Health (CA)
- **Recycled Water Master Plan** for Tucson Water (AZ)
- **Groundwater Replenishment Project Review** for the Los Angeles Department of Water and Power (CA)

More information about the NWRI Independent Advisory Panel Program can be found on the NWRI website at http://nwri-usa.org/Panels.htm.

APPENDIX C: Panel Member Biographies

Adam Olivieri, Dr.PH, P.E. (Panel Co-Chair)
Vice President
EOA Inc. (Oakland, CA)

Adam Olivieri has 35 years of experience in the technical and regulatory aspects of water recycling, groundwater contamination by hazardous materials, water quality and public health risk assessments, water quality planning, wastewater facility planning, urban runoff management, and on-site waste treatment systems. He has gained this experience through working as a staff engineer with the California Regional Water Quality Control Board (San Francisco Bay Region), as staff specialist (and Post-doc fellow) with the School of Public Health at the University of California, Berkeley, project manager/researcher for the Public Health Institute, and as a consulting engineer. He is currently the Vice president of EOA, Inc., where he manages a variety of projects, including serving as Santa Clara County Urban Runoff Program's Manager since 1998. Olivieri is also the author or co-author of numerous technical publications and project reports. He received a B.S. in Civil Engineering from the University of Connecticut, an M.S. in Civil and Sanitary Engineering from the University of Connecticut, and both an MPH and Dr.PH in Environmental Health Sciences from University of California, Berkeley.

James Crook, Ph.D., P.E. (Panel Co-Chair)
Water Reuse and Environmental Engineering Consultant (Boston, MA)

Jim Crook is an environmental engineer with more than 40 years of experience in state government and consulting engineering arenas, serving public and private sectors in the U.S. and abroad. He has authored more than 100 publications and is an internationally recognized expert in water reclamation and reuse. He has been involved in numerous projects and research activities involving public health, regulations and permitting, water quality, risk assessment, treatment technology, and all facets of water reuse. Crook spent 15 years directing the California Department of Health Services' water reuse program, during which time he developed California's first comprehensive water reuse criteria. He also spent 15 years with consulting firms overseeing water reuse activities and is now an independent consultant specializing in water reuse. He currently serves on several advisory panels and committees sponsored by NWRI and others. Among his honors, he was selected as the American Academy of Environmental Engineers' 2002 Kappe Lecturer and the WateReuse Association's 2005 Person of the Year. Crook received a B.S. in Civil Engineering from the University of Massachusetts and both an M.S. and Ph.D. in Environmental Engineering from the University of Cincinnati.

Michael Anderson, Ph.D.
Professor of Applied Limnology and Environmental Chemistry and Chair
Department of Environmental Sciences

University of California, Riverside (Riverside, CA)

Michael Anderson, a Professor of Applied Limnology and Environmental Chemistry, has taught courses at the University of California, Riverside, since 1990. His research focus includes water and soil sciences, with particular emphasis in applied limnology and lake/reservoir management; surface water quality and modeling; fate of contaminants in waters, soils, and sediments; and environmental chemistry. Current research projects include laboratory, field, and modeling studies in support of the development of species conservation habitat at the Salton Sea, sponsored by the California DWR and DFG, and a survey of organochlorine pesticides and Polychlorinated Biphenyls (PCBs) in McGrath Lake that is funded by the Los Angeles Regional Water Quality Control Board. He and his students also recently completed studies quantifying the abundance and distribution of quagga mussel veligers in the reservoirs of the Colorado River Aqueduct, as well as assessing the ecological and biological conditions at Lake Elsinore. In addition, he has served on various panels and workgroups, including as member of the California Department of Water Resource's Salton Sea Hydrologic Technical Workgroup (2007-2008). Anderson received a B.S. in Biology from Illinois Benedictine College, M.S. in Environmental Studies from Bemidji State University, and Ph.D. in Environmental Chemistry from Virginia Tech.

Richard Bull, Ph.D.
Consulting Toxicologist
MoBull Consulting (Richland, WA)

Since 2000, Richard Bull has been a Consulting Toxicologist with MoBull Consulting, where he conducts studies on the chemical problems encountered in water for water utilities, as well as federal, state, and local governments. Bull is a Professor Emeritus at Washington State University, where he maintains Adjunct Professor appointments in the College of Pharmacy and the Department of Environmental Science. Formerly, he served as a senior staff scientist at DOE's Pacific Northwest National Laboratory, Professor of Pharmacology/Toxicology at Washington State University, and Director of the Toxicology and Microbiology Division in the Cincinnati Laboratories for the U.S. Environmental Protection Agency. Bull has published extensively on research on central nervous system effects of heavy metals, the carcinogenic and toxicological effects of disinfectants and disinfection by-products, halogenated solvents, acrylamide, and other contaminants of drinking water. He has also served on many international scientific committees convened by the National Academy of Sciences, World Health Organization, and International Agency for Research on Cancer regarding various contaminants of drinking water. Bull received a B.S. in Pharmacy from the University of Washington and a Ph.D. in Pharmacology from the University of California, San Francisco.

Dr.-Ing. Jörg E. Drewes
Chair Professor, Chair of Urban Water Systems Engineering
Technische Universität München (Munich, Germany)

Jörg Drewes joined the Technische Universität München in 2013. Prior, he was a professor in the Department of Civil and Environmental Engineering at Colorado School of Mines (CSM), where he taught from 2001 to 2013. While at CSM, he served as the Director of Research for the National Science Foundation's Engineering Research Center *ReNUWIt* (which included Stanford University, University of California Berkeley, New Mexico State University, and CSM). He also served as Co-Director of CSM's Advanced Water Technology Center (AQWATEC). Drewes is actively involved in research in the areas of energy efficient water treatment and non-potable and potable water reuse. Current research interests include treatment technologies leading to potable reuse and the fate and transport of persistent organic compounds in these systems. He has published more than 250 journal papers, book contributions, and conference proceedings, and served on National Research Council Committees on *Water Reuse as an Approach for Meeting Future Water Supply Needs* and *Onsite Reuse of Graywater and Stormwater*. He also currently serves as Chair of the International Water Association (IWA) Water Reuse Specialist Group. Drewes received a Cand. Ing. (B.S.), Dipl. Ing. (M.S.), and Doctorate (Dr.-Ing.) in Environmental Engineering from the Technical University of Berlin, Germany.

Charles Haas, Ph.D.
Department Head, L.D. Betz Professor of Environmental Engineering
Drexel University (Philadelphia, PA)

Charles Haas is the Department Head of the Civil, Architectural, and Environmental Engineering at Drexel University since 1991. He is also the L.D. Betz Professor of Environmental Engineering and Director of the Drexel Engineering Cities Initiative. Prior to joining Drexel, he served on the faculties of Rensselaer Polytechnic Institute and the Illinois Institute of Technology. Haas specializes in water treatment, risk assessment, environmental modeling and statistics, microbiology, and environmental health. He received a B.S. in Biology and M.S. in Environmental Engineering, both from the Illinois Institute of Technology. He also received a Ph.D. in Environmental Engineering from the University of Illinois at Urbana-Champaign.

Walter Jakubowski, M.S.
Consultant
WaltJay Consulting (Spokane, WA)

Walter Jakubowski has degrees in Pharmacy from Brooklyn College of Pharmacy, Long Island University; in microbiology from Oregon State University, and graduate training in epidemiology from the University of Minnesota. He has research publications on hospital pharmacy; on microorganisms in oysters and clams under the federal Shellfish Sanitation Program, and more than 40 peer-reviewed publications on determining the health effects and public health significance of pathogens, especially intestinal protozoa and viruses, in drinking water, waste water and municipal sewage sludge. He has served as a consultant to the World

Health Organization on pathogenic intestinal protozoa (for development of the International Drinking Water Guidelines), and to the Pan-American Health Organization on environmental virus methods. He was instrumental in conducting the first international symposium on *Legionella* and Legionnaire's Disease at the Centers for Disease Control. He has more than 48 years of experience working with waterborne pathogens, especially enteric viruses, *Giardia* and *Cryptosporidium.* He initiated landmark studies on the human infectious dose of *Cryptosporidium* and chaired the Joint Task Group on Pathogenic Intestinal Protozoa for *Standard Methods for the Examination of Water and Waste Water* from 1978 to 2005. He was a charter member of U.S. EPA's Pathogen Equivalency Committee and served on that committee until his retirement from the U.S. Public Health Service/Environmental Protection Agency in 1997. Since then, he has been practicing as a private consultant while serving on various professional committees, panels, and boards.

Perry McCarty, Sc.D.
Silas H. Palmer Professor of Civil and Environmental Engr. Emeritus
Stanford University (Stanford, CA)

Perry McCarty is the Silas H. Palmer Professor of Civil and Environmental Engineering Emeritus at Stanford University. McCarty received the Clarke Prize Award in 1997 for his significant contributions to the areas of water treatment, reclamation, groundwater recharge, and water chemistry and microbiology. He is universally recognized for his research on understanding contaminant behavior in groundwater aquifers and sediments. McCarty has received numerous honors, including being elected to the National Academy of Engineering and American Academy of Arts and Sciences, as well as receiving an honorary doctorate from the Colorado School of Mines. He was also awarded the John and Alice Tyler Prize for Environmental Achievement in 1992 and the Stockholm Water Prize in 2007. McCarty received his B.S. from Wayne State University, and both his M.S. and Sc.D. from Massachusetts Institute of Technology.

Kara Nelson, Ph.D.
Professor
University of California, Berkeley (Berkeley, CA)

Kara Nelson is a Professor in Civil and Environmental Engineering at the University of California, Berkeley. She received her B.A. degree in biophysics from U.C. Berkeley, her M.S.E. degree in environmental engineering from the University of Washington, and her Ph.D. in environmental engineering from U.C. Davis. Her research program addresses critical issues at the intersection of public health and the environment, with a focus on reducing the threat posed by waterborne pathogens by improving our engineering infrastructure to make it more effective, affordable, as well as maximize its environmental benefits. Specific research areas include mechanisms of pathogen inactivation, molecular techniques for pathogen detection, optimizing treatment processes, water reuse, and challenges with providing safe drinking water and sanitation in the developing world. Dr. Nelson has published over 50 articles in peer-reviewed journals, including two invited reviews, and one book chapter. She is the Director of Graduate Education at the National Science Foundation Engineering Research Center for Reinventing our Nation's Urban Water Infrastructure (ReNUWIt), the faculty leader of the Research Thrust Area on Safe Water and Sanitation at Berkeley Water Center. Dr. Nelson was awarded the Presidential Early Career Award for Scientists and Engineers (PECASE) at a ceremony in the White House in 2004. This award is the nation's highest honor for scientists in the early stages of their career.

Joan B. Rose, Ph.D.
Homer Nowlin Endowed Chair for Water Research
Michigan State University (East Lansing, MI)

Joan Rose, a professor at Michigan State University, has made groundbreaking advances in understanding water quality and protecting public health for more than 20 years and has published over 300 articles. She is widely regarded as the world's foremost authority on the microorganism *Cryptosporidium* and was the first person to present a method for detecting this pathogen in water supplies. She examines full-scale water treatment systems for the removal of pathogens. In 2001, she received the Athalie Richardson Irvine Clarke Prize from NWRI for her advances in microbial water-quality issues. She served as the Chair of the Science Advisory Board for the U.S. Environmental Protection Agency's Drinking Water Committee for 4 years, and currently serves on the Science Advisory Board for the Great Lakes. In addition, she is Co-Director of the Center for Water Sciences (which includes work with the Great Lakes and Human Health Center of the National Oceanic & Atmospheric Administration) at Michigan State University, where she is also Director of the Center for Advancing Microbial Risk Assessment. Rose received a B.S. in Microbiology from the University of Arizona, an M.S. in Microbiology from the University of Wyoming, and a Ph.D. in Microbiology from the University of Arizona.

David Sedlak, Ph.D.
Malozemoff Professor, Department of Civil and Environmental Engineering
University of California, Berkeley (Berkeley, CA)

David Sedlak is a Professor of Civil and Environmental Engineering at the University of California, Berkeley. He is also Co-Director of the Berkeley Water Center and Deputy Director of the National Science Foundation's Engineering Research Center for Reinventing the Nation's Urban Water Infrastructure (ReNUWIt). His research focus is on the fate of chemical contaminants, with the long-term goal of developing cost-effective, safe, and sustainable systems to manage water resources. Sedlak's previous experience includes Staff Scientist at ENVIRON Corporation and membership on the National Research Council's Committee on Water Reuse. He has individually or co-authored over 70 peer-reviewed publications, among many other publications and presentations. Sedlak published a book in 2014 called "Water 4.0: The Past, Present, and Future of The World's Most Vital Resource," where he points out that most of the population gives little thought to the hidden systems that bring us water and take it away and how these marvels of engineering face challenges that cannot be solved without a fundamental change to our relationship with water. Sedlak received a B.S. in Environmental Science from Cornell University and a Ph.D. in Water Chemistry from the University of Wisconsin.

Tim Wade, Ph.D.
Epidemiology Branch Chief
United States Environmental Protection Agency (Durham, NC)

Tim Wade is the Epidemiology Branch Chief at the United States Environmental Protection Agency (U.S. EPA) and Assistant Professor of Epidemiology at the University of North Carolina, Chapel Hill. Wade has been working with the U.S. EPA since 2005, conducting a series of epidemiologic studies to evaluate the health effects of arsenic exposure in well water in Inner Mongolia. As Branch Chief, Wade determines research priorities, directs staff and post-doctoral students, and manages an annual budget of over $1 million annually. In 2011, Wade received the EPA Office of Water Bronze Medal for his exceptional service to the Office of Water in the development of recreational water quality criteria. He received a B.A. in Biological Science from California Polytechnic at Pomona, a B.A. in Psychobiology from Claremont McKenna College, and both an MPH and Ph.D. in Epidemiology from the University of California at Berkeley.

NATIONAL WATER RESEARCH INSTITUTE

Expert Panel

SWRCB's Division of Drinking Water (DDW)
Development of Water Recycling Criteria for
Indirect Potable Reuse through Surface Water Augmentation and the
Feasibility of Developing Criteria for Direct Potable Reuse

Meeting #3 Agenda
December 11-12, 2014

LOCATION	**CONTACTS**
City of San Diego's	Jeff Mosher (Cell)
North City Water Reclamation Plant	714-705-3722
4949 Eastgate Mall	Jaime Lumia (NWRI Office)
San Diego, CA 92121	(714) 378-3278

Meeting Objectives:

- Continue to review DDW draft criteria for surface water augmentation.
- Receive technical briefing from City of San Diego's modeling efforts that formed the basis for state's proposed criteria.
- Translate the modeling results to draft criteria.
- Discuss with DDW the intent of the surface water augmentation criteria, including the reservoir criteria, and the technical basis for the criteria
- Review comments of the DDW DPR Advisory Committee.
- Receive an update on DPR Research Initiative efforts to date.

Thursday, December 11, 2014 (Open Session)

8:30 am	1. Welcome and Introductions	Jeff Mosher, NWRI
8:45 am	2. Review Agenda and Meeting Objectives	Adam Olivieri and Jim Crook, Panel Co-Chairs
9:00 am	3. Summary Overview of Meeting 2 recommendations (see Panel Report Section 4.7 – Recommendations and Next Steps)	Co-Chairs and Jeff Mosher, NWRI

City of San Diego Reservoir Modeling Efforts

9:15 am	4. Pure Water San Diego IPR/Surface Water Augmentation Project Overview	Marsi Steirer and Jeff Pasek, City of San Diego
10:00 am	Panel Discussion	Co-Chairs
10:15 am	Break	
10:30 am	5. San Vicente Reservoir Modeling Studies	Imad Hannoun, Water Quality Solutions
11:30 am	Panel Discussion	Co-Chairs
12:00 pm	LUNCH	

Review Draft DDW Surface Water Augmentation Criteria

12:30 pm	6. DDW's Response to the Panel's Comments on the Preliminary Surface Water Augmentation Criteria (Reservoir Criteria)	Bob Hultquist and DDW Staff
1:00 pm	Panel Discussion	Co-Chairs
2:00 pm	BREAK	
2:15 pm	7. Continue to Review DDW Responses (Pathogens and Treatment Criteria)	Bob Hultquist and DDW Staff
3:00 pm	Panel Discussion	Co-Chairs
3:45 pm	8. DPR Advisory Committee Update	Mike Wehner, OCWD
4:15 pm	9. Overview of DPR Initiative Efforts	Julie Minton, WateReuse Research Foundation
4:45 pm	Panel Discussion and Wrap-up	Co-Chairs
5:00 pm	ADJOURN	

Friday, December 12, 2014 (Closed Session)

8:30 am	Welcome and Introductions	Co-Chairs
8:45 am	DDW – Possible Panel Questions	Panel and Bob Hultquist

Closed Session Starts 9:45 am

9:45 am	Review: ● City of San Diego Project Efforts ● Surface Water Augmentation Criteria ● Advisory Committee Comments ● DPR Criteria Questions ● March 2015 Meeting Agenda	
12:00 noon	LUNCH	
12:45 pm	Continue Panel Discussions	Co-Chairs
2:15 pm	Wrap-Up, Schedule, Assignments, and Next Steps	Co-Chairs
2:45 pm	ADJOURN	

APPENDIX E: Meeting Attendees

Panel Members:

- *Panel Co-Chair:* Adam Olivieri, Dr.P.H., P.E., EOA, Inc. (Oakland, CA)
- *Panel Co-Chair:* James Crook, Ph.D., P.E., Water Reuse and Environmental Engineering Consultant (Boston, MA)
- Michael Anderson, Ph.D., University of California, Riverside (Riverside, CA)
- Richard Bull, Ph.D., MoBull Consulting (Richland, WA)
- Dr.-Ing. Jörg E. Drewes, Technische Universität München (Munich, Germany)
- Charles Haas, Ph.D., Drexel University (Philadelphia, PA)
- Walter Jakubowski, M.S., WaltJay Consulting (Spokane, Washington)
- Perry McCarty, Sc.D., Stanford University (Stanford, CA)
- Kara Nelson, Ph.D., University of California, Berkeley (Berkeley, CA) (on phone)
- Joan B. Rose, Ph.D., Michigan State University (East Lansing, MI)
- Tim Wade, Ph.D., United States Environmental Protection Agency (Durham, NC)

National Water Research Institute:

- Suzanne Faubl, Water Resources Scientist and Project Manager
- Jeff Mosher, Executive Director

State Water Resources Control Board, Division of Drinking Water:

- Randy Barnard, P.E., Recycled Water Treatment Specialist
- Brian Bernados, P.E., Technical Specialist
- Bob Hultquist, P.E., Drinking Water Program Expert
- Karen Larsen (on phone)
- Mike McKibben, P.E., Senior Engineer

WateReuse Research Foundation:

- Julie Minton

Utility Representatives:

- Amy Dorman, City of San Diego
- Albert Lau, P.E., Director of Engineering and Planning, Padre Dam Municipal Water District
- Jeff Pasek, Watershed Manager, City of San Diego
- Bill Pearce, City of San Diego
- Marsi Steirer, Deputy Director, City of San Diego
- Toby Roy, Water Resources Manager, San Diego County Water Authority
- Anthony Van, City of San Diego
- Mike Wehner (Advisory Committee Member), Assistant General Manager, Orange County Water District

Others:

- Kevin Alexander, Hazen and Sawyer

- Lynn Grijalva, Hazen and Sawyer
- Imad Hannoun, Water Quality Solutions
- Brian Pecson, Trussell Technologies, Inc.
- Seval Sen, RMC Water and Environment
- Shane Trussell, Ph.D., P.E., BCEE, President, Trussell Technologies, Inc.

Appendix F: Surface Water Augmentation-Indirect Potable Reuse: A Simple Conceptual Framework and Screening Model (Prepared By Michael Anderson)

<u>Rationale and Criteria</u>

The California State Water Resources Control Board (State Board) Division of Drinking Water (DDW) (formerly the California Department of Public Health) has developed regulations governing groundwater recharge with highly treated wastewater for subsequent extraction and distribution as a potable supply. In many settings, a suitable groundwater basin with appropriate capacity, water quality, and hydraulic properties may not be available. The City of San Diego has proposed augmenting the San Vicente Reservoir (SVR) with 15,000 AF/year of advanced treated wastewater and is exploring additional inputs to both the SVR and Otay Reservoir near Chula Vista. In support of this effort, the City of San Diego has been engaged in two parallel studies:

i. Development of an advanced treatment demonstration project to assess performance and reliability; and
ii. Reservoir hydrodynamic and water quality modeling.

The City has constructed and has been operating a 1-mgd advanced water treatment (AWT) pilot plant that includes microfiltration, reverse osmosis, and advanced oxidation with ultraviolet light and hydrogen peroxide (UV/H_2O_2), similar to Orange County's Groundwater Replenishment System. Surface water modeling has played an important role in developing the proposed project, and has been used to help quantify the effectiveness, benefits, limitations, and constraints of the SVR for storage of highly treated wastewater and as an environmental barrier. This document specifically considers the use of a surface water reservoir for IPR.

A primary consideration for the reservoir is that it is effective for both storage and as an environmental barrier. In the absence of significant and demonstrable benefit(s) of the reservoir, the *indirect* feature of this type of potable reuse comes into question. Therefore, an initial criterion that becomes relevant is the average hydraulic residence time (t_r), which is simply:

$$t_r = \frac{V}{Q_{out}} \qquad (1)$$

where V is the volume and Q_{out} is the flow rate out of the reservoir. That is, if reservoir storage volume is low and/or outflow rates are high, added recycled water would have a short residence within the reservoir, and at sufficiently short times would effectively serve as a conduit linking wastewater to drinking water facilities and the potable supply. An important initial consideration then is simply what is an appropriate mean residence time? Draft groundwater regulations stipulated 6 months residence time in the aquifer prior to withdrawal of recycled water, although revised regulations now require 2 months residence time. It is recognized, however, that the hydrodynamics and mixing of a surface water reservoir are fundamentally different than that in a groundwater basin.

The mean residence time can be important from two distinct perspectives. First of all, the amount of dilution, expressed as a dilution factor (C_{in}/C_r), which can be achieved for a pulse of contaminant in wastewater (e.g., representing a treatment failure), can be shown to be related to the mean hydraulic residence time by:

$$\textit{Dilution factor} = \frac{C_{in}}{C_r} = \frac{t_r}{\Delta t} \tag{2}$$

where C_{in} is the influent concentration, C_r, is the reservoir concentration (after input and mixing), and Δt is the duration of influent contaminant pulse. This simple equation holds for well-mixed conditions and volumetric steady-state where recycled water inflows are balanced by outflows (i.e., the reservoir is represented as a continuous flow stirred tank reactor [CFSTR]), although modest relaxation of these assumptions do no substantially change the results. Assuming a pulse duration of 1 day, the dilution factor (C_{in}/C_r) increases linearly with t_r, with a value of 10 (for a dilution of 1:10 or 1-log dilution) of a 1-day event for a reservoir with a mean t_r value of 10 days, and 100 (for a dilution of 1:100 or 2-log dilution) for a reservoir with t_r of 100 d (Figure 1, solid line). Reduction in the duration of the input to 0.5 days yields two times greater dilution factors at any given t_r value, while an increase in pulse duration to 2 days results in correspondingly lower dilution factor values (Figure 1, dot-dash and dashed lines, respectively).

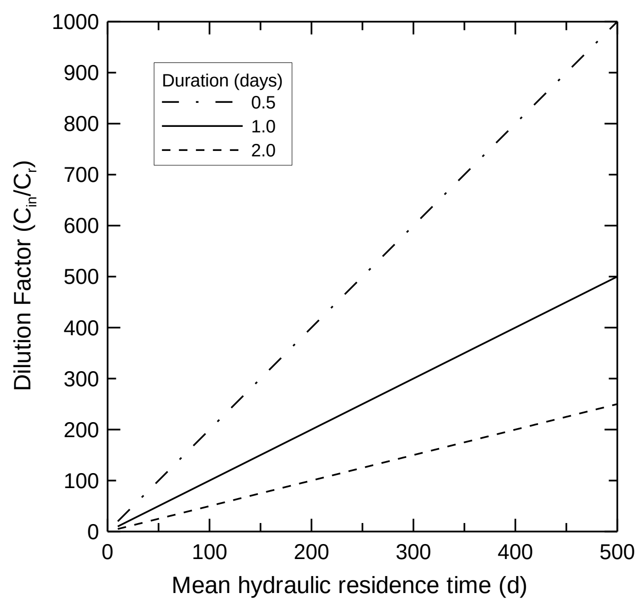

Figure 1. Dilution factor as a function of mean hydraulic residence time and duration of input pulse of degraded water (reservoir represented as a CFSTR).

Beyond dilution, the mean hydraulic residence time also governs the time available to react to a treatment failure and for a contaminant to be removed from the reservoir via inactivation, photolysis, volatilization, or other loss process. Contaminant loss is generally described as a first-order process, with concentrations decreasing exponentially over time. Therefore, a long hydraulic detention time not only yields a high amount of dilution for a short duration input, but it also provides time to react to a treatment failure while also allowing time for *in situ* treatment and contaminant removal.

The time to react to an unplanned discharge of inadequately-treated (off-spec) water into a reservoir is an important factor. To serve as an effective environmental barrier, the reservoir should provide ample time to implement corrective actions and prevent off-spec water from being delivered to a downstream surface water treatment plant. For a well-mixed reservoir, such as found during the winter months in warm monomictic lakes, the travel time/time-to-react (t_x) also varies with the mean hydraulic residence time and with the fraction (x) of off-spec water extracted from the reservoir. At low values of x, t_x is approximated by:

$$t_x \simeq x\, t_r \tag{3}$$

From Equation 3, we see that the travel time/time-to-react increases approximately linearly with the hydraulic residence time of the reservoir and with the fraction of off-spec water extracted. At the limit, it will take longer than the hydraulic residence time of the reservoir to elapse before the full volume of off-spec water is transported through the reservoir. Conversely, it will take a short interval of time before a small fraction of off-spec water is extracted from the reservoir. As an example, one calculates that it would take 1.0 day for 2 percent of off-spec water to be withdrawn from a well-mixed reservoir at steady-state with a mean residence time of 50 days.

From the above considerations, it is clear that the hydraulic residence time of the reservoir can play a central role in defining the suitability of a water body as an environmental buffer for SWA/IPR: it determines both the (i) amount of dilution that can be achieved under ideal well-mixed conditions, and (ii) travel time/time-to-react to an unplanned or off-spec discharge, with both of these attributes increasing linearly with increasing t_r (Equations 2 and 3).

<u>Consideration in the Context of Draft Criteria</u>

The draft criteria* (§64602[a]) stipulate that the reservoir must provide one of the following (Hultquist, 2014):

- A minimum 1:100 dilution of a 1-day production of recycled water with reservoir water.
- A minimum 60-day travel time, defined here as t_2, the elapsed time at which 2 percent of any volume of discharged recycled water has been abstracted.
- A minimum 1:10 dilution of a 1-day production with reservoir water and a minimum 30-day t_2 travel time.
- A minimum 1:10 dilution of a 1-day production with reservoir water and a redundant 1-log reduction of each organism.

*(*Dilution values in the original draft criteria have been rewritten here in more conventional notation.)*

The draft criteria (§64602[d]) also require a theoretical retention time of at least 12 months prior to the withdrawal of recycled municipal wastewater for use as a drinking water sources.

Demonstration of compliance with one or more of these draft requirements (§64602[a]) will help ensure that the reservoir serves as an adequate environmental buffer in SWA. Moreover, it will be useful for utilities to conduct a preliminary screening/feasibility analysis prior to engaging in more detailed studies. Given the central role of the hydraulic residence time in defining the amount of dilution achieved and the travel time/time-to-react under well-mixed conditions from the preceding section, one sees a strong relationship between all these criteria. As a result, under idealized uniform mixed conditions and volumetric steady-state, a t_r requirement of 12 months also defines the theoretical amount of dilution of a 1-day pulse of out of compliance water (1:365), as well as the t_2 value (7.3 days). In a similar way, a reservoir with a 100-day residence time, achieving a theoretical 1:100 dilution of a 1-day pulse of off-spec water will have a t_2 value of 2 days, and a reservoir achieving a 1:10 dilution will have a t_2 value of 0.2 days under idealized conditions.

It is recognized that recycled water inflows would result in the development of near-field plumes and potential for short-circuiting, so idealized mixed conditions would be actually be rare, but over slightly larger spatial dimensions and longer time frames, mixed conditions are often present in warm monomictic reservoirs in Southern California and elsewhere for 2 months or more during the winter season when the greatest availability of recycled water is often found. The purpose for the above analysis is to develop a conceptual framework and screening model to assess the potential suitability of a reservoir for SWA. For systems conforming to criteria under theoretical conditions, it will be necessary for utilities to then assess more rigorously under actual field and operational conditions the capacity to meet requirements, in particular the potential for short-circuiting of flow, and conditions during the winter as well as during the summer when thermal stratification may be present.

Utilities, therefore, have three parameters potentially under their operational control to help meet a set of criteria: the volume of their reservoir (V), the outflow rate (Q_{out}), and duration of a pulse of off-spec water (Δt). Assuming operation throughout the year, including the winter well-mixed period, maintenance of either a large reservoir volume or a low relative outflow rate allows one to regulate the hydraulic residence and, thus, the amount of dilution (Equation 2) and travel time/time-to-react (Equation. 3). For a given t_r value, greater dilution (and travel times) can also be achieved by reducing the possible duration of a pulse of off-spec water; this could arguably be achieved through redundant online monitoring and fail-safe controls at the advanced treatment facility. Given the range of different contaminants that could enter the reservoir if some component of the advanced treatment system were to fail, and differences in contaminant persistence, reservoir water quality and other factors, *in situ* removal was not included in the assessment. Moreover, this analysis explicitly considers projects that would be expected to be operated throughout the year, and is focused on the winter period when criteria would be most difficult to meet. The benefit of thermal stratification for dilution and time-to-react in reservoirs that withdraw water from the hypolimnion is significant, although the duration and strength of stratification even for a single reservoir can vary relatively widely depending upon meteorological and hydraulic conditions. Thus, reliance upon thermal stratification and operation of SWA based exclusively upon it is thought to be difficult to achieve, while at the same time imposing unrealistic constraints on operation by the project utilities.

<u>San Vicente Reservoir</u>

As an example, some simple analytical calculations were conducted for the SVR, currently under consideration for SWA, in the context of the preliminary draft criteria. The base case, defined in detailed hydrodynamic simulation studies as approximately 155,000-AF volume, will be used, with some seasonal changes in volume, but no net annual drawdown, and three recycled water flow rates (13.3, 27, and 68 mgd) (Pasek and Hannoun, 2014). Using the simple fully mixed assumption (and volumetric steady-state with recycled water inflows balanced by outflows), the theoretical amount of dilution and t_2 values associated with a 1-day pulse into the base-case 155,000-AF reservoir at the three different proposed recycled water flow rates are summarized in Table 1. At a flow rate of 13.3 mgd (40.8 AF/day), the theoretical residence time of recycled water in the reservoir exceeds 10 years, and SVR can achieve up to 1:3,797 dilution of a 1-day pulse of degraded recycled water at this flow rate (see Table 1). The corresponding t_2 value (assuming mixing of a 1-day pulse through the entire reservoir volume) was 76.0 days. This scenario fully met all four of the draft SWA criteria. Doubling the recycled water flow to 27 mgd, under steady-state conditions, lowered by one-half the theoretical hydraulic residence time (from 10.4 to 5.1 years) and t_2 value (from 76.0 to 37.2 days) (see Table 1). At this flow rate, even assuming complete mixing of the pulse, SVR failed to meet the $t_2 \geq 60$ day criteria, although draft criteria require only that one of the four criteria be met. The highest flow rate (68 mgd) yielded the lowest theoretical hydraulic residence time (2.0 years), dilution rate (1:743), and t_2 value (14.6 days) (see Table 1). Under this scenario, only the 1:100 dilution and 1:10 dilution with 1-log redundant treatment criteria were met.

Table 1. San Vicente Reservoir Operated under Base-Case Conditions (155,000 AF Nominal Volume) and Theoretical Mixed Water Column

Flow (mgd)	Flow (AF/day)	t_r (yr)	Dilution of 1-Day Pulse	t_2 (d)	1:100	$t_2 \geq 60$ d	1:10 & $t_2 \geq 30$ d	1:10 & 1-log
13.3	40.8	10.4	1:3797	76.0	✓	✓	✓	✓
27	82.9	5.1	1:1871	37.2	✓		✓	✓
68	208.7	2.0	1:743	14.6	✓			✓

The values presented in Table 1 represent ideal conditions for the well-mixed SVR. By completely and instantaneously mixing the recycled water into the reservoir, the reservoir is treated as a continuous-flow stirred tank reactor (with no reaction); hydrodynamic simulations demonstrate that such mixing is not routinely achieved in SVR. Rather, complex transport and mixing often occurs as a result of wind-forcing, convection, and other processes that can allow for short-circuiting in which recycled water is quickly transported from discharge point to intake. Thus, such processes could yield concentrations at the intake that are higher and dilution factors lower than those presented in Table 1 and, in fact, could fall below the minimum 1:100 dilution specified in the draft SWA criteria. Dilution in this context becomes imprecise, if not somewhat ambiguous; for this reason, the *"minimum 1:100 dilution of a 1-day production of recycled water"* criteria is thought to be more accurately defined as *"the concentration at the drinking water intake that is less than 1 percent of the maximum concentration of a 1-day pulse of contaminants in recycled water."* Such a definition requires that the reservoir provide at least 2-log dilution under all conditions, including hydrodynamic conditions with rapid transport from discharge to intake with limited mixing into the reservoir.

<u>Conclusions</u>

The theoretic hydraulic residence time of a reservoir was shown to govern the amount of dilution that can be achieved in a reservoir, as well as the time for 2 percent (t_2) (or other percentage) of recycled water to be withdrawn from a reservoir under well-mixed, steady-state conditions. Such conditions represent a theoretical limit that is useful, at a screening level, in defining the amount of dilution and the t_2 value for a reservoir receiving recycled water for comparison with draft SWA criteria.

References

Hultquist, B. (2014). *Surface Water Augmentation: Draft Criteria Elements.* Presented at NWRI-Expert Panel meeting, July 28, 2014, San Diego, CA.

Pasek, J., and I. Hannoun (2014). *San Vicente and Otay Reservoirs Modeling Investigations.* Presented at NWRI Expert Panel meeting, July 28, 2014, San Diego, CA.