INITIAL STATEMENT OF REASONS
Surface Water Augmentation Regulations
Title 22, California Code of Regulations

SUMMARY OF PROPOSAL

The State Water Resources Control Board (State Board) proposes to adopt regulations governing the planned placement of recycled water into a surface water reservoir that is used as a *source* of domestic drinking water supply; a process known as surface water augmentation (SWA). As a *source* of drinking water supply, the treated recycled water is not being *directly* delivered to customers for human consumption; but instead, the treated recycled water in the reservoir would be subject to further treatment by a public water system's (PWS's) surface water treatment plant (SWTP) before being delivered to customers for human consumption. Existing law requires the State Board to adopt uniform water recycling criteria for SWA by December 31, 2016; subject to the condition that a statutorily mandated Expert Panel has made a finding that such criteria would adequately protect public health.

POLICY STATEMENT OVERVIEW

Problem Statement: The objective of the California Safe Drinking Water Act (SDWA) is to ensure that a PWS reliably delivers water for human consumption that is, at all times, pure, wholesome, and potable. With the limited availability of new surface water sources, the overuse of groundwater sources, the projected effect of climate change, including the potential for more frequent severe droughts, along with continued population growth, California is challenged to continue meeting the objective of the SDWA. Furthermore, in February 2009, the State Board updated its Water Recycling Policy through the adoption of Resolution No. 2009-0011[1]. The resolution includes the goal of significantly increasing the use of recycled water in California, including increasing the use of recycled water - beyond 2002 levels - by at least one million acre-feet per year by 2020, and by at least two million acre-feet per year by 2030. Indirect potable reuse (IPR) – where recycled water, after appropriate treatment, is used to ultimately supplement sources of drinking water supply utilized by a PWS – is one means to help address the aforementioned challenges. SWA is a form of IPR.

In 2010, California Senate Bill 918 was chaptered (Chapter 700), mandating the State Board[2] to adopt uniform water recycling criteria for SWA by December 31, 2016; if an

[1] http://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/2009/rs2009_0011.pdf
[2] The California Department of Public Health's authority and responsibility pertaining to this regulatory action were transferred to the State Board via 2014's Senate Bill 861 (Chapter 35). As such, applicable statutory mandates that may refer to "California Department of Public Health" or "Department" will hereinafter be referred to as "State Board" in this document.

Expert Panel, meeting applicable statutory criteria, had first made a finding that the criteria were adequately protective of public health.

Objective (Goal): The broad objective of this proposed regulatory action is to:

- Through adoption of regulations, establish uniform water recycling criteria for the planned placement of recycled water into a surface water reservoir used as a source of water supply for a PWS, such that the adherence to the criteria would result in public health being adequately protected.

Benefits: The anticipated benefits, including any nonmonetary benefit to the protection of public health and safety of California residents, worker safety, and the state's environment, from this proposed regulatory action are:

- Providing a relatively reliable, drought-proof, and sustainable option for supplementing the water in a surface water reservoir that is used as a source of domestic drinking water supply by California PWSs.
- Providing an additional means for achieving the goals for increased beneficial use of recycled water in California.
- Although the absence of SWA regulations wouldn't preclude the permitting of SWA projects, the adoption of uniform criteria in the form of SWA regulations is expected to streamline the permitting process.

EVALUATION AS TO WHETHER THE PROPOSED REGULATIONS ARE INCONSISTENT OR INCOMPATIBLE WITH EXISTING STATE REGULATIONS

The State Board evaluated this proposal as to whether the proposed regulations are inconsistent or incompatible with existing California state regulations. This evaluation included a review of California's existing regulations, potentially related to IPR by way of SWA, including the State Board's existing general regulations related to discharges to surface waters. It was determined that no other state regulation addressed the same subject matter and that this proposal was not inconsistent or incompatible with other state regulations. However, it should be noted that on June 18, 2014, the California Department of Public Health adopted regulations for another form of IPR, where recycled water is used for the purpose of replenishing groundwater basins that are used as a source of domestic drinking water supplies. For those portions of the two regulations that are comparable, the proposed SWA regulations are substantially consistent with the existing regulations for IPR through groundwater replenishment. Therefore, the State Board has determined that this proposal, if adopted, would not be inconsistent or incompatible with existing state regulations.

The proposed SWA regulations would establish *minimum* uniform water recycling criteria for the purpose of adequately protecting public health with respect to the planned placement of recycled water into a surface water reservoir that is used as a source of domestic drinking water supply. The proposed regulations would not preclude the Regional Water Quality Control Boards (Regional Boards), via their authority and responsibility, from imposing more stringent requirements when issuing a waste discharge and/or water recycling permit to water recycling agencies that may choose to engage in SWA, including having to meet National Pollutant Discharge Elimination System (NPDES) requirements established by the U.S. Environmental Protection Agency (U.S. EPA).

BACKGROUND / AUTHORITY

All suppliers of domestic water to the public are subject to regulations adopted by the U.S. EPA under the U.S. Safe Drinking Water Act (SDWA) of 1974, as amended (42 U.S.C. §300f et seq.), as well as by the State Board under the California SDWA (Health & Saf. Code, div. 104, pt. 12, ch. 4, §116270 et seq.). Pursuant to section 116270 of the Health and Safety Code, et al., it is the objective of the California SDWA for a PWS to deliver drinking water to consumers that is, at all times, pure, wholesome, and potable. The ability to meet this objective is a reflection of the water quality and quantity of a PWS's source of supply, the PWS's ability to treat the source of supply (if necessary), and the PWS's ability to deliver drinking water, all in a manner that ensures compliance with all applicable drinking water standards.

Pursuant to Water Code sections 13521 and 13562, and Health and Safety Code sections 116271 and 116375, the State Board has authority to adopt the subject regulations.

In September 2010, Senate Bill 918 (SB 918) was signed by the Governor and filed with the Secretary of State, establishing Chapter 7.3 ("Direct and Indirect Potable Reuse"), under Division 7 of the Water Code. Specific to the proposed SWA regulations and among other things, SB 918 authorized and mandated the State Board to develop and adopt uniform water recycling criteria for:

- each varying type of use of recycled water where the use involves the protection of public health (Water Code section 13521[3]).
- surface water augmentation, as defined by SB 918, by December 31, 2016, *if* an Expert Panel, convened and administered by the State Board pursuant to the bill's statutory requirements, found that the State Board's criteria would adequately protect public health (Water Code section 13562).

In addition, SB 918, along with amendments to pertinent sections of the Water Code via 2013's SB 322 (Chapter 637), required the State Board to select the Expert Panel members in consultation with an advisory group. The advisory group was mandated to consist of "no fewer than nine representatives of water and wastewater agencies, local public health officers, environmental organizations, environmental justice organizations,

[3] Although Water Code section 13521 predates SB 918, the nexus to the proposed SWA regulations was recognized by SB 918's establishment of Water Code section 13560(b).

public health nongovernmental organizations, the department, the state board, the United States Environmental Protection Agency, ratepayer or taxpayer advocate organizations, and the business community." In addition, Water Code section 13565, which was added by SB 918 and amended by SB 322, mandates that the Expert Panel, at a minimum, be comprised of:

- A toxicologist;
- An engineer licensed in the state of California 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.

On October 31, 2016, the Expert Panel made a finding that the State Board's proposed criteria were protective of public health (Appendix A, Item 1). The Expert Panel's finding states:

> *"The Expert Panel finds, in its expert opinion, that the State Board's proposed uniform water recycling criteria for surface water augmentation titled, 'Surface Water Augmentation Using Recycled Water,' as provided in Appendix B (October 12, 2016), adequately protects public health. This finding, submitted by the Expert Panel on October 31, 2016, represents the collective expert opinion of all members of the Expert Panel."*

The referenced criteria in Appendix B of the Expert Panel's finding are the SWA regulations proposed to be adopted by way of this regulatory action.

Further, as a result of SB 918 and SB 322, Water Code section 13564 requires the State Board to consider the following in its development of SWA criteria:

- The final report from the National Water Research Institute (NWRI) Independent Advisory Panel for the City of San Diego Indirect Potable Reuse/Reservoir Augmentation (IPR/RA) Demonstration Project;
- Monitoring results of research and studies regarding surface water augmentation;
- Results of demonstration studies conducted for purposes of approval of projects using surface water augmentation;
- Epidemiological studies and risk assessments associated with projects using surface water augmentation;

- Applicability of the advanced treatment technologies required for recycled water projects, including, but not limited to, indirect potable reuse for groundwater recharge projects;

- Water quality, limnology, and health risk assessments associated with existing potable water supplies subject to discharges from municipal wastewater, stormwater, and agricultural runoff;

- Recommendations of the State of California Constituents of Emerging Concern Recycled Water Policy Science Advisory Panel;

- State funded research pursuant to Water Code section 79144 and subdivision (b) of section 79145;

- Research and recommendations from the United States Environmental Protection Agency Guidelines for Water Reuse; and

- 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."

- Other relevant research and studies regarding IPR of recycled water.

Water Code section 13567, added via SB 918, also requires the SWA criteria to be consistent 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.), Division 7 of the Water Code, and the California Safe Drinking Water Act, Chapter 4 of Part 12 of Division 104 of the Health and Safety Code.

Water Code section 13560, added via SB 918, specifies that the requirements of Chapter 7.3 are not intended to delay, invalidate, or reverse any study or project, or development of regulations by the State Board, nor the Regional Board, regarding the use of recycled water for IPR for surface water augmentation, including ongoing reviews by the State Board of projects consistent with Health and Safety Code section 116551. Health and Safety Code section 116551 mandates that the State Board is not to issue a permit for a reservoir, as a source of supply for drinking water, which is augmented with recycled water, unless the State Board:

- Performs an engineering evaluation;

- Evaluates treatment technology;

- Find the recycled water used for augmentation meets all applicable maximum contaminant levels (MCLs) and secondary MCLs (SMCLs);

- Determines SWA poses no significant threat to public health; and

- Holds at least three public hearings for the purpose of obtaining public testimony, with information being made available to the public at least ten days prior to the initial hearing.

In addition to the Expert Panel review of the criteria and their finding of the criteria being protective of public health as mandated by the Water Code, Health and Safety Code section 57004 requires a regulation proposed for adoption by the State Board to undergo an external scientific peer review of the bases of the scientific portions of the regulation. This scientific peer review was necessary regardless of the Expert Panel's review because the Expert Panel was considered to have participated in the development of the scientific portions of the regulation (Health & Saf. Code § 57004(c)). Coordination and oversight of the scientific peer review was conducted by California's Environmental Protection Agency's Scientific Peer Review Program, in the Office of Research, Planning, and Performance. The scientific peer preview was completed on June 10, 2016 (Appendix A, Item 2).

The comments and recommendations received by the scientific peer reviewers where provided to the Expert Panel. As a result, the Expert Panel subsequently provided responses to the key components of the scientific peer review, with the Expert Panel's responses being documented in a memorandum dated August 3, 2016 (Appendix A, Item 3). The State Board concurs with the Expert Panel's responses. Two recommendations by the scientific peer reviewers are of note because the recommendations would result in revisions to the version of the draft SWA regulations provided to the scientific peer reviewers for review. One recommendation resulted in a change to the regulation, while the other was not supported to the extent suggested by the peer reviewer by either the State Board or the Expert Panel. Both of the recommendations pertained to the augmented reservoir requirements and are discussed in more detail within this document under the "Section 64668.30. SWSAP Augmented Reservoir Requirements" portion of the discussions.

It should be noted that the law, via SB 918 and SB 322, also mandates that the State Board perform an investigation into the feasibility of developing uniform water recycling criteria for *direct* potable reuse, and to consider (among other things) the Expert Panel's assessment and recommendations on the feasibility of developing uniform water recycling criteria for direct potable reuse. As a result, the Expert Panel developed a report on the feasibility of developing criteria for *direct* potable reuse (DPR), which also included discussions related to *indirect* potable reuse (IPR). Therefore, in developing the proposed SWA regulations the State Board reviewed and considered the Expert Panel's discussions regarding IPR, to the extent applicable to SWA[4].

In accordance with the aforementioned mandates and pursuant to Water Code sections 13521 and 13562, and Health and Safety Code sections 116271 and 116375, the State Board proposes the following changes to Title 22 of the California Code of Regulations:

[4] For access to the Expert Panel's direct potable reuse report, titled "Evaluation of the Feasibility of Developing Direct Potable Reuse Regulatory Criteria for the State of California", see http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/rw_dpr_criteria/app_a_ep_rpt.pdf.

• Amend Article 1, Chapter 3, Division 4, to amend an existing definition and establish definitions related to SWA, which includes the proposed amendment or adoption of sections summarized as follows:

- Section 60301.120 (Augmented Reservoir), defining an augmented reservoir that is used as a source of domestic drinking water supply;
- Section 60301.450 (Indicator Compound), amending an existing definition so as to not be restricted only to groundwater replenishment IPR projects, and to correct grammar;
- Section 60301.850.5 (Surface Water), clarifying that "surface water" has the same meaning as defined in Chapter 17 (existing section 64651.83).
- Section 60301.851 (Surface Water Source Augmentation Project or SWSAP), establishing a definition and a term for the type of project related to the planned augmentation of a surface water reservoir with recycled water;
- Section 60301.852 (Surface Water Source Augmentation Project Public Water System or SWSAP PWS), establishing a definition and term for a public water system choosing to participate in the planned augmentation of a surface water reservoir with recycled water,
- Section 60301.853 (Surface Water Source Augmentation Project Water Recycling Agency or SWSAP WRA), establishing a definition and term for a water recycling agency choosing to deliver recycled water for the purpose of augmenting a surface water reservoir.

• Adopt Article 5.3, Chapter 3, Division 4, to establish criteria applying to water recycling agencies involved in the planned placement of recycled water into a surface water reservoir used as a source of drinking water supply by a PWS, which includes the adoption of sections summarized as follows:

- Section 60320.300 (Application), establishing the general applicability for the requirements of the Article,
- Section 60320.301 (General Requirements), establishing general requirements, including overarching requirements and those criteria that do not fall within the more specific subject matter in subsequent sections;
- Section 60320.302 (Advanced Treatment Criteria), setting forth minimum treatment criteria and requirements for the recycled water to be delivered to an augmented reservoir;
- Section 60320.304 (Lab Analyses), establishing minimum requirements related to the analyses of chemicals and contaminants;
- Section 60320.306 (Wastewater Source Control), establishing minimum requirements and criteria related to the origin and control of raw wastewater to be ultimately treated and used for SWA projects;
- Section 60320.308 (Pathogenic Microorganism Control), establishing minimum requirements for the control of pathogenic microorganisms;
- Section 60320.312 (Regulated Contaminants and Physical Characteristics Control), establishing minimum requirements for the control of regulated contaminants and physical water quality characteristics that are commonly regulated in drinking water;

- Section 60320.320 (Additional Chemical and Contaminant Monitoring), establishing requirements for the monitoring of chemicals and contaminants beyond regulated contaminants and pathogenic microorganisms;
- Section 60320.322 (SWSAP Operation Plan), establishing minimum requirements and criteria for a water recycling agency's operation plan for a surface water source augmentation project;
- Section 60320.326 (Augmented Reservoir Monitoring), establishing the minimum monitoring requirements for an augmented reservoir;
- Section 60320.328 (Reporting), establishing water recycling agency reporting requirements, unique to SWA projects;
- Section 60320.330 (Alternatives), establishing criteria with respect to thresholds for approval for potential alternatives for the requirements established via Article 5.3.

• Adopt Article 9, Chapter 17, Division 4, establishing requirements for a PWS choosing to utilize a reservoir augmented with recycled water, summarized as follows:

- Section 64668.05 (Application), establishing the general applicability for the requirements of the Article,
- Section 64668.10 (General Requirements and Definitions), establishing definitions and general requirements for PWS choosing to participate in the planned augmentation of a surface water reservoir with recycled water;
- Section 64668.20 (Public Hearings), establishing requirements related to the need to participate in at least three public hearings prior to using an augmented reservoir as a source of supply for drinking water;
- Section 64668.30 (SWSAP Augmented Reservoir Requirements), establishing requirements pertaining to an augmented reservoir, including but not limited to baseline monitoring, theoretical retention time, and minimum criteria associated with reservoir attenuation of contaminants.

The net effect of the proposed regulations would be to establish specific regulatory criteria for general application by WRAs and PWSs choosing to engage in the planned placement of recycled water into a surface water reservoir that is used as a source of domestic drinking water supply.

None of the proposed regulations would affect California's SDWA primacy delegation granted by U.S. EPA because no federal regulations exist that specifically address SWA. The net effect of these amendments is that the proposed state regulation would not be less stringent than any existing federal regulation.

SPECIFIC DISCUSSION OF EACH PROPOSED REGULATION

The proposed regulations would be incorporated into Title 22, Division 4, of the California Code of Regulations; specifically, Article 1 and proposed Article 5.3 of Chapter 3, and proposed Article 9 of Chapter 17. The following provides a detailed discussion of the proposed regulations.

CCR TITLE 22, DIVISION 4, CHAPTER 3, ARTICLE 1 (DEFINITIONS)

Section 60301.120, Augmented Reservoir.

Section 60301.120 would be added to provide a definition of an augmented reservoir; a term used in the proposed regulation, specific to surface water augmentation. A surface water reservoir used as a source of domestic drinking water supply that also receives recycled municipal wastewater from a Surface Water Source Augmentation Project (defined in proposed section 60301.851), would be considered an "augmented reservoir."

Section 60301.450, Indicator Compound.

Section 60301.450 would be amended to delete the reference to "GRRP's" so that the definition would not be limited solely to Groundwater Replenishment Reuse Projects (defined in existing section 60301.390), which was the only type of IPR projects in use at the time the regulations for Groundwater Replenishment Reuse Projects (GRRPs) were adopted. Deleting the reference to "GRRP's" will allow the term to be used within the scope of the proposed regulations for SWA IPR projects. The section is also amended to correct grammar.

Section 60301.850.5, Surface Water.

Section 60301.850.5 would be added to establish the meaning of the term "surface water," clarifying that the term would have the same meaning as that in existing section 64651.83, Chapter 17, Division 4, Title 22.

Section 60301.851, Surface Water Source Augmentation Project or SWSAP.

Section 60301.851 would be added to establish a definition of a Surface Water Source Augmentation Project (SWSAP); a term commonly used in the proposed regulations. The definition establishes a term for projects utilized in the planned placement of recycled municipal wastewater into a surface water reservoir that is used as a source of domestic drinking water supply.

Section 60301.852, Surface Water Source Augmentation Project Public Water System or SWSAP PWS.

Section 60301.852 would be added to establish a definition of a Surface Water Source Augmentation Project Public Water System (SWSAP PWS), a term commonly used in the proposed regulations. The definition establishes a term for a particular type of public water system (PWS); specifically, a PWS choosing to engage in SWA and ultimately using an augmented reservoir as a as a source of its domestic drinking water supply. A SWSAP-PWS is also responsible for complying with the requirements of Chapter 17 to the extent they may apply. As noted in existing section 60301.680, "public water system" has the same meaning as defined in section 116275(h) of the Health and Safety Code.

Section 60301.853, Surface Water Source Augmentation Project Water Recycling Agency or SWSAP WRA.

Section 60301.853 would be added to establish a definition of a Surface Water Source Augmentation Project Water Recycling Agency (SWSAP PWS); a term commonly used in the proposed regulations. The definition establishes a term for a water recycling agency (WRA) choosing to participate (with a SWSAP PWS) in SWA and responsible for delivering recycled municipal wastewater, via a SWSAP, to a surface water reservoir, which is then used as a source of domestic drinking water supply by a SWSAP PWS. In addition to being responsible for meeting the applicable proposed requirements and operation of a SWSAP, the SWSAP WRA would be responsible for applying to the Regional Board for a permit to deliver the recycled municipal wastewater to a surface water reservoir, obtaining the permit, and complying with the terms and conditions of the permit.

CCR TITLE 22, DIVISION 4, CHAPTER 3, ARTICLE 5.3 (INDIRECT POTABLE REUSE: SURFACE WATER AUGMENTATION)

Section 60320.300, Application.

Consistent with section 13561(d) of the Water Code, section 60320.300 clarifies that the requirements of Article 5.3 would specifically apply to surface water augmentation involving the planned placement of recycled water into a surface water reservoir used as a source of domestic drinking water supply; further reiterating that the recycled water used for augmentation must be a recycled municipal wastewater, and that the regulations apply even if the reservoir, as source of drinking water supply for a PWS, is only minimally being supplemented with recycled water, or if the augmented reservoir is merely incidentally used as a source of drinking water.

Section 60320.301, General Requirements.

Section 60320.301 establishes overarching requirements and/or those that may not be specific to the other proposed sections.

Extensive coordination and communication is necessary when two (or more) separate entities, overseen and regulated by different government programs, have complicated and differing responsibilities with the shared goal of ensuring a SWSAP can augment a reservoir with recycled water in a manner that is protective of public health. Therefore, subsection (a) requires SWSAP WRAs and SWSAP PWSs to develop, and submit for review and approval, a formal joint plan prior to augmentation, signed by the individuals responsible for ensuring their entity's compliance, outlining 1) corrective actions to be taken by each entity in the event the recycled water delivered to the reservoir fails to meet the proposed requirements, and 2) the actions and procedures the SWSAP WRA will take to notify the SWSAP PWS, State Board, and appropriate Regional Board when events or actions take place that have or may adversely affect the quality of the recycled municipal wastewater delivered to the augmented reservoir. Timely and adequate notification is necessary to provide the SWSAP PWS with the ability to take appropriate remedial actions, and to allow the State Board and Regional Board to oversee the events. The State Board recognizes that, over time, a joint plan may need to be revised for a number of reasons; however, there needs to be time for adequate review of revisions by the State Board and Regional Board prior to implementation. Thus, the proposed subsection (a) requires submittal of such revised plans at least 60 days prior to the changes effectively taking place.

The cost and technical expertise necessary to install and maintain a SWSAP, in particular the advanced treatment processes, will generally be unique to a SWSAP WRA and its project. A failure to adequately possess financial, managerial, or technical capability in order to design and operate a SWSAP may result in the inability to maintain long-term sustainable compliance with the requirements for SWA established in Article 5.3, which in turn may ultimately adversely impact a PWS's ability to provide an adequate and reliable drinking water that meets drinking water standards and is protective of health. Therefore, subsection (b) requires a SWSAP WRA to demonstrate to the State Board and Regional Board, prior to engaging in such a project, that the SWSAP WRA has the financial, managerial, and technical capability to embark on a SWSAP project.

To ensure that untreated water, or treated water failing to meet the requirements of Article 5.3, is not placed into a surface water reservoir as a result of poor installation, design, or other unforeseen complications, subsection (c) requires the SWSAP WRA to first demonstrate to the State Board and Regional Board that the treatment processes are operating, and can be operated, in a manner that achieves the optimal intended function of each of the treatment processes. The start-up and commissioning process for a SWSAP will be unique to each SWSAP, not only as a result of varying treatment processes and designs, but also as a result of the variability of the quality of raw wastewater being treated and the experience of the operators. Therefore, subsection (c) requires the SWSAP WRA to include, in their engineering report required pursuant to existing section 60323, a protocol detailing the steps and actions the SWSAP WRA will take to complete the demonstration.[5]

Subsection (d) provides notice and clarifies that the State Board or Regional Board may determine compliance based on assumptions made by the State Board or Regional Board through a review of available monitoring data, in the event a SWSAP WRA fails to complete its required compliance monitoring. Averting a potential water quality compliance determination by failing to complete the required compliance monitoring in Article 5.3, does not adequately assure protection of public health.

Unexpected excursions and variability in recycled municipal wastewater quality can result in unexpected SWSAP treatment process shutdowns, as well as other problems that could adversely impact the quality and quantity of treated recycled municipal wastewater used for augmentation. As a result, to reduce the likelihood of using a wastewater of an inconsistent quality, subsection (e) requires that the recycled municipal wastewater that will be treated and used for a SWSAP by a SWSAP WRA, be from a wastewater management agency that is not in violation of the water quality requirements of its Regional Board permit; in particular, regarding the water quality requirements that pertain to surface water augmentation and the requirements of Article 3.

Subsection (f) clarifies that if a SWSAP WRA has been required by the Article or directed by the State Board or Regional Board to suspend augmentation of a reservoir, pursuant to the regulations or the State Board or Regional Board's statutory authority, the SWSAP WRA may not resume augmentation until receiving written approval from the State Board and Regional Board. To avoid repetition throughout the regulation, subsections (g) and (h) provide general clarification that all reports required by the regulations to be submitted by the SWSAP-WRA or SWSAP-PWS, are to be submitted in writing and that the term "quarter" refers to a *calendar* quarter.

Section 60320.302, Advanced Treatment Criteria.

Drinking water regulations include water quality standards for contaminants that may be commonly found in typical sources of drinking water supply. However, the drinking water regulations do not currently address many chemicals of concern that are present, or can occasionally occur, in municipal wastewater. These chemicals, lacking regulatory drinking water limits, are commonly characterized as constituents of

---

[5] Please note that section 60320.301 of the proposed regulatory text includes a grammatical correction; revising the version of the proposed regulations for which the Expert Panel made its finding (Appendix A, Item 1). In the last sentence of subsection (c), the word "to" was inserted between "pursuant" and "section."

emerging concern (CECs), and are primarily controlled with a combination of reverse osmosis and advanced oxidation treatment. In particular, relatively high concentrations of organic carbon are found in treated secondary municipal wastewater, with a correlation existing between the concentration of CECs and the measurement of bulk organic matter.

The combination of reverse osmosis (RO) treatment and a subsequent advanced oxidation process (AOP) treatment of a properly oxidized wastewater (as defined via existing section 60301.650 of Title 22) is required for surface water augmentation in order to produce water that is free of harmful concentrations of organic chemicals and produce a source of raw surface water that is *at least* as protective as other high quality surface water sources available in California. To assure this goal is achieved, the entire recycled municipal wastewater stream to be delivered to an augmented reservoir must first undergo full advanced treatment, consisting of RO and AOP treatment, in accordance with the requirements of section 60320.302.

The effectiveness of RO for CEC removal from wastewater is reported in NWRI Independent Advisory Panel for the City of San Diego Indirect Potable Reuse/Reservoir Augmentation (IPR/RA) Demonstration Project, *Advanced Water Purification Facility Study Report* (Appendix A, Item 4) A variety of RO membranes are available, with varying degrees of capability to consistently reject/remove total dissolved solids, heavy metals, organic pollutants, viruses, bacteria, and other constituents and contaminants. To ensure a SWSAP WRA utilizes membranes for RO that will adequately achieve the desired treatment goals (in particular, sufficient removal of CECs), subsection (a) establishes minimum criteria for the selection of an RO membrane to be used by a SWSAP WRA for a SWSAP. Sodium chloride rejection is commonly utilized as an overall measure of an RO membrane’s effectiveness since several of its properties (ionic charge, size of the solvated ion, etc.) reflect the rejection of the organic chemicals of concern. In addition, American Standard for Testing Materials (ASTM) International method D4194-03 is used by membrane manufacturers as a standard test method for determining the operating characteristics of RO and nanofiltration membranes.

Along with specifying minimum sodium chloride rejection criteria to be demonstrated under ASTM D4194-03 for adequately achieving the desired treatment goals, subsection (a) also specifically requires utilizing Method A (for Brackish Water Reverse Osmosis Devices) of ASTM D4194-03, which is the most directly analogous of the three methods included in the ASTM standard to treating recycled municipal wastewater. In addition, when testing under ASTM D4194-03, specific test conditions are commonly used and reported by manufacturers when membranes are to be used for potable reuse. The narrower and/or more specific test conditions are established in paragraphs (A) through (E) of subsection (a), which help ensure membranes are tested in the same manner, with comparable results indicating the membranes’ ability to adequately reject the types of organic chemicals found in municipal wastewater.

To verify proper installation and to demonstrate the intended general effectiveness of the RO membrane under full operating conditions, paragraph (2) requires the SWSAP WRA to monitor the membrane permeate during the first 20 weeks of operation to ensure that no more than five percent of the sample results have total organic carbon (TOC) concentrations greater than 0.25 mg/L, with monitoring occurring no less frequently than weekly.

While subsection (a) establishes criteria for ensuring proper RO membrane selection and initial installation and operation, subsection (b) establishes requirements of the SWSAP WRA to ensure the RO membranes are operating as intended on an on-going basis. Because there are a number of parameters that may be monitored to confirm that the membrane is performing as designed and intended, subsection (b) allows the SWSAP WRA to propose the manner in which they intend on monitoring membrane integrity. However, the proposal, which is subject to State Board review and approval, must include at least one form of continuous monitoring, along with the corresponding surrogate and/or operational parameter limits and alarm settings that will indicate when a membrane's integrity has been compromised so that appropriate corrective action may be taken in a timely manner.

Although RO treatment largely meets the treatment goals for most contaminants and/or CECs, there are certain chemicals that are not well removed by RO treatment alone, and AOP treatment is required to address such chemicals. For example, N-nitrosodimethylamine (NDMA) and 1,4-dioxane - two contaminants for which notification levels (NLs) have been established pursuant to Health and Safety Code section 116455 - are non-ionic constituents with very small molecular weights that are not substantially removed via RO treatment alone, but is effectively addressed by AOP. In general, RO and AOP in combination do not provide multiple barrier treatment for *each* chemical that may be problematic; however, RO and AOP treatment offer dissimilar treatment mechanisms to mitigate unknown organic chemical contaminants. To address chemicals *like* NDMA and 1,4-dioxane (i.e., chemicals similarly reduced with AOP treatment, without NDMA and 1,4-dioxane necessarily being present), AOP treatment is required.

The effectiveness of AOP for CEC reduction is reported in NWRI Independent Advisory Panel for the City of San Diego Indirect Potable Reuse/Reservoir Augmentation (IPR/RA) Demonstration Project's, *Advanced Water Purification Facility Study Report* (Appendix A, Item 5). Because the effectiveness of AOP treatment is dosage-dependent, in order to ensure an AOP treatment process is designed to be substantively effective, subsection (c) requires the SWSAP WRA to demonstrate that the AOP treatment is designed and will be operated to achieve no less than what would be required to provide at least a 0.5-$\log_{10}$ reduction of 1,4-dioxane; a minimum treatment threshold found to be effective and utilized at several groundwater replenishment IPR projects (Appendix A, Item 6). In other words, even in the absence of 1,4-dioxane, a SWSAP WRA must utilize AOP treatment capable of providing as robust a barrier as an AOP treatment that *would* reduce 1,4-dioxane by at least 0.5-$\log_{10}$, *if* it was present.

Recognizing that there may be varying types and configurations of AOP treatment available to achieve the treatment standard (equivalent to no less than 0.5-$\log_{10}$ reduction of 1,4-dioxane), the regulation does not require a specific type or configuration for AOP treatment. Rather, the SWSAP WRA is required to demonstrate that its chosen design will achieve the treatment standard. A protocol is required to be submitted to the State Board, for review and approval, describing the means in which the SWSAP WRA intends to demonstrate that its AOP treatment will achieve the treatment standard. The demonstration need not be full-scale, but if not, the protocol must describe how the bench-scale testing or pilot testing will accurately translate and scale-up to full-scale operation.

As with the RO treatment, the AOP treatment design protocol must include at least one form of continuous monitoring, along with the corresponding surrogate and/or operational parameter limits and alarm settings that will indicate when the AOP's process integrity has been compromised, so that appropriate corrective action may subsequently be taken in a quick and timely manner. Subsection (d) requires the full-scale operation of the AOP treatment to be operated in accordance with the design having met the requirements of subsection (c), including the continuous monitoring of the surrogate and/or operational parameters identified and demonstrated pursuant to subsection (c).

Subsections (e) and (f) require the SWSAP WRA, within 60 days after completing the first 12-months of the full-scale operation of the AOP and RO treatment, to submit a report to the State Board and Regional Board for the purpose of summarizing the effectiveness of each treatment process in achieving the treatment goals, confirming the correlation between the monitoring parameters and treatment operation and constituent reductions, and identifying any problems that may have occurred and the subsequent corrective action. The reports are necessary because they will inform the State Board and Regional Board in a manner that helps assure effective and efficient implementation of the treatment requirements for SWA.

To ensure the RO and AOP treatment processes continue to be operated, on an on-going basis, in the manner for which they were designed, subsections (g) and (h) establish operational standards based on the results of on-going monitoring. Under subsection (g), on a quarterly basis using monitoring results for the quarter, the SWSAP WRA is required to calculate the percent of excursions from the thresholds that were identified as being indicative of effective RO and AOP treatment operation. That said, one could not necessarily conclude that a failure to meet a surrogate and/or operational standards would necessarily result in effluent being produced that may not ultimately be adequately protective of public health. However, an inability to consistently meet the surrogate and/or operational standards could be an indication of poor RO and AOP treatment operation; increasing the likelihood that the effluent produced could be substandard.

Therefore, if more than 10 percent of the results for a quarter exceed a surrogate and/or operational standard, the SWSAP WRA is required to submit a report to the State Board and Regional Board that identifies the reason(s) for the excursions and describes the corrective actions taken (or to be taken). The report must be submitted within 45 days of the end of the quarter in question, which provides ample time to evaluate the data, perform the necessary calculations, and take corrective action or evaluate the nature of the problems causing the excursions and how they may be addressed. The SWSAP WRA will also be required to consult with the State Board and Regional Board regarding the excursions and, if directed, comply with an alternative monitoring plan that may better determine the extent of the problem and how it may be corrected, which could include more extensive monitoring.

Under subsection (h), on a monthly basis the SWSAP WRA is required to monitor for contaminants having MCLs and NLs. Similarly, as noted above, the failure of RO and AOP treatment to produce an effluent meeting MCLs and NLs would be indicative of potentially poor treatment operation, increasing the likelihood that the effluent produced could be substandard. To avoid unnecessary redundant monitoring, the monthly operational monitoring for MCLs and NLs may be used for the compliance monitoring of MCLs and NLs required pursuant to section 60320.312 and 60320.320, respectively. After no less than 12 consecutive months of monthly operational monitoring for MCLs and NLs with no excursions, thus indicating good operation of the advanced treatment operations for MCLs and NLs, the SWSAP WRA may apply to the State Board and Regional Board to reduce the monitoring frequency to no less frequent than quarterly.

Section 60320.304, Lab Analyses.

Section 60320.304 addresses laboratory analyses of the recycled municipal wastewater used for augmentation of a reservoir used as a source of drinking water. To ensure the highly treated wastewater is treated adequately for the protection of public health, it is necessary that the chemicals monitored be analyzed by laboratories using analytical methods that are capable of detecting and quantifying the levels of contaminants at appropriate levels.

Subsection (a) applies to contaminants that have MCLs (primary and secondary MCLs), which are regulatory standards that apply to drinking water. Consistent with other sources of water intended to become drinking water supplies, subsection (a) requires drinking water methods to be used when analyzing regulated drinking water contaminants (i.e. those with MCLs). Drinking water methods are able to detect and quantify contaminants at lower concentrations than wastewater methods, and are therefore more appropriate for monitoring water that is to be used as a source of drinking water. Wastewater that is not intended for human consumption is generally subject to laboratory analyses using methods designed for monitoring wastewater discharges for environmental protection and for compliance with federal and state environmental regulations, with the focus not necessarily being related to those who consume the water.

Laboratories that perform analyses of contaminants and chemicals for regulatory purposes in California's water supplies - including drinking water, wastewater, and water in the environment, such as groundwater and surface water - are required to be certified by the State Board for such analyses. The State Board, through its Environmental Laboratory Accreditation Program (ELAP), is responsible for certifying the laboratories in accordance with the Environmental Laboratory Accreditation Act (Health & Saf. Code § 100825, et seq.). Certification ensures that analyses are performed using appropriate methods, equipment, and personnel, and that appropriate quality assurance of the analytical procedures leading to results is occurring. Although laboratories seeking to perform such analyses are aware of the requirement for certification by ELAP, subsection (a) ensures that the SWSAP WRA is aware of the requirement.

Subsection (b) applies to chemicals that do not have MCLs, such as those required via the additional chemical monitoring requirements of section 60320.320 (e.g. CECs, those with NLs, etc.), the surrogate and/or operational constituents required to be monitored pursuant to section 60320.302 (if applicable), and other chemicals that are not regulated in drinking water supplies. Because the analytical methods may vary from being fairly well-accepted and commonly used to being relatively new, and the analyses for such unregulated constituents may significantly vary, subsection (b) requires the SWSAP WRA to identify, in their Operation Plan (required pursuant to section 60320.322), the method of analyses to be used for unregulated contaminants. Subsection (b) ensures that the SWSAP WRA appropriately addresses the analytical methods used to assess the presence of those chemicals.

Section 60320.306, Wastewater Source Control.

Section 60320.306 establishes requirements regarding the source of wastewater to be treated and ultimately used for augmenting a surface water reservoir used as a source of drinking water. The overall intent of section 60320.306 is to ensure the quality of recycled wastewater to be used in a surface water augmentation project is relatively predictable and public health is adequately protected as a result of the subsequent treatment.

As such, subsections (a) and (b), in combination with subsection (e) in section 60320.301, establish general requirements to minimize the chemical discharge burden of the wastewater on the treatment processes, and to reduce the uncertainty and variability of chemicals in the wastewater. The concept for the requirements is analogous to the source water assessments that are required for new sources of drinking water and the steps taken for protection of existing drinking water sources, which are helpful for minimizing drinking water source contamination.

Subsection (a) requires that the recycled municipal wastewater used for a SWSAP must have originated from a wastewater management agency that has a program in place that controls the chemicals in its wastewater through industrial pretreatment and pollutant source control. The primary purpose of the requirement is to ensure that adequate consideration is given to the quality of the wastewater so that subsequent treatment will not be compromised by unknown contaminants, nor compromised by chemicals that are present in concentrations that may be too high to be adequately removed by treatment processes. In addition, such a program should provide insight regarding the origin of particular contaminants that may be problematic.

While wastewater management agencies typically administer industrial pretreatment programs, the need for a more extensive pollutant source control program is important to help ensure the reliable availability of a wastewater source that is consistently of a quality amenable to treatment. In addition, a proper pollutant source control program can provide the information needed to take corrective actions. Subsection (b) sets forth the minimum steps that are to be addressed in the pollutant source control programs. The assessment of the fate of chemicals and contaminants enables predictions to be made about the adequacy of pretreatment and treatment steps, while source investigations and monitoring allow verification of the environmental fate assessment. The emphasis on State Board or Regional Board specified chemicals or constituents ensures that the source control program will focus on substances of human health concern. The outreach program to dischargers is intended to inform and educate them about the importance of and need to limit their chemical releases, in terms of both quality and quantity into the wastewater treatment facility; therefore, providing more certainty about the types and amounts of chemicals being released. The requirement for a current inventory of chemicals and contaminants assures necessary consideration is given with respect to information on the types and amounts of chemicals and contaminants in the wastewater and any potential adjustments to treatment are necessary to address particular contaminants.

Together, the requirements of section 60320.306 and section 60320.301(e) are intended to result in a well-characterized wastewater, which will enable proper treatment design and operation for the purpose of augmenting reservoirs that are used as a source of drinking water.

Section 60320.308, Pathogenic Microorganism Control.

Section 60320.308 establishes requirements to address pathogenic organisms present in the municipal wastewater that is to be treated and used for augmenting a reservoir that is used as a drinking water source. As with any source of drinking water, pathogenic microorganisms pose significant acute health risks, if left untreated.

Although protection of public health for some contaminants can be addressed by way of the establishment of water quality standards (e.g., MCLs for regulated contaminants, as in section 60320.312), establishing water quality standards for pathogenic organisms is not feasible or practicable due to the scope of pathogenic organisms and the inability to measure, in a practical manner, the concentration of organisms at the low levels that correspond to acceptable illness risks. Therefore, similar to CECs being addressed by way of the establishment of treatment objectives and standards (section 60320.302), pathogenic microorganisms are to be addressed via the establishment of treatment objectives and standards.

The framework for the approach used to determine the treatment objectives for pathogenic microorganisms was as follows: 1) Identify the classes of waterborne pathogens of greatest concern to public health from exposure to drinking water; 2) identify acceptable risk-based concentrations for those pathogens; 3) Determine the concentrations of those pathogens in untreated wastewater, and; 4) Determine the necessary reduction of those pathogens that must be achieved through treatment (i.e. the ratio of the concentration of pathogens considered to be safe for drinking water to the concentration observed in raw wastewater).

Once these steps are completed, a minimum required reduction of pathogenic organisms (via the classes of pathogens identified) can be required as an overall treatment objective for assuring a drinking water is ultimately produced that is adequately protective of public health, consistent with current drinking water standards. The raw sewage pathogen density was selected as the initial point for the $\log_{10}$ reduction calculation, rather than primary or secondary effluent, because of the broad range in organism reduction effectiveness for the various wastewater treatment technologies in use.

To that end, enteric virus, *Giardia* cyst, and *Cryptosporidium* oocyst were the classes of pathogenic microorganisms selected for control largely because they are the organisms targeted in the Federal and California surface water treatment regulations for drinking water, since they are known to be the pathogens of greatest concern to human health. It should also be noted that although the treatment objective refers specifically to enteric virus, *Giardia* cyst, and *Cryptosporidium* oocyst pathogenic organisms (or classes of organisms), other pathogenic organisms will be controlled in the process as well, including bacteria.

The acceptable risk-based concentration in drinking water for the pathogens were consistent with the U.S. EPA’s allowable drinking water densities (Appendix A, Item 7), which are intended to limit the annual risk of infection to 1 in 10,000 in drinking water. The raw wastewater levels for virus and *Giardia* were identified from a premier textbook on water recycling (Appendix A, Item 8), using the upper end of the reported range for each organism. The raw wastewater level for *Cryptosporidium* oocyst was obtained from studies done in Norway and Australia (Appendix A, Items 9 and 10). The peak organism densities were selected from the studies and rounded up to one significant figure. These raw wastewater levels are considered the highest organism densities that are expected in raw municipal sewage. The maximum raw sewage pathogen density was used, rather than the 95th percentile density (or some other percentile), to provide further confidence that the public would be protected during worst-case wastewater pathogen occurrences. Table 1 summarizes the outcome of the overall approach used.

Table 1

	Enteric virus	***Giardia* cysts**	***Cryptosporidium* oocysts**
Raw sewage maximum density	1×10^5 virus/L	1×10^5 cysts/L	1×10^4 oocysts/L
Tolerable drinking water density	2.2×10^{-7} virus/L	6.8×10^{-6} cysts/L	1.7×10^{-6} oocysts/L
Ratio of drinking water to sewage density	2.2×10^{-12}	6.8×10^{-11}	1.7×10^{-10}
Required $\log_{10}$ reduction	12	10	10

For each pathogen, the overall required $\log_{10}$ reduction was calculated by dividing the tolerable drinking water density by the raw sewage density, and rounding the logarithm (base 10) of the result to the nearest whole number. As a result, through treatment alone (including the SWTP); for enteric viruses, the concentration of enteric viruses will be reduced by no less than 99.9999999999 percent before being distributed as a drinking water, while *Giardia* cysts and C*ryptosporidium* oocysts will be reduced by no less than 99.99999999 percent.

The regulation requires that the recycled water treatment processes achieve at least 8-$\log_{10}$ enteric virus, 7-$\log_{10}$ *Giardia* cyst, and 8-$\log_{10}$ *Cryptosporidium* oocyst reduction prior to discharge into the reservoir. The PWS's SWTP, as required by existing state and federal drinking water standards, will provide the remainder of the total required $\log_{10}$ reduction for each organism (no less than 4-$\log_{10}$ enteric virus, 3-$\log_{10}$ *Giardia* cyst, and 2-$\log_{10}$ *Cryptosporidium* oocyst reduction). This differential $\log_{10}$ reduction required of a SWSAP treatment train is identified in paragraph (1) of subsection (a). These $\log_{10}$ reductions are required when the first option in proposed section 64668.30(c), Article 9 of Chapter 17, has been chosen [subsection (c)(**1**)].

The second option in proposed section 64668.30(c) [subsection (c)(**2**)], Article 9 of Chapter 17, requires an extra $\log_{10}$ of reduction for each pathogenic organism prior to delivery of the recycled water to the reservoir, as a balance to the less conservative nature of the second option in 64668.30(c). Therefore, for consistency with the requirements of section 64668.30(c)(2), paragraph (2) of subsection (a) therefore requires an extra $\log_{10}$ reduction for each pathogen organism for those choosing to utilize the option identified in section 64668.30(c)(2), Article 9 of Chapter 17. Similarly, under paragraph (3), further log_{10} reductions may be required for a SWSAP PWS for approval of reducing its theoretical retention time pursuant to section 64668.30(b)(2)(D), Article 9 of Chapter 17.

Although all validated treatment barriers between the raw sewage and finished drinking water may be credited toward the total log_{10} reduction required, for each of the log_{10} reduction requirements in section 60320.308(a), the credit for an individual treatment process is limited to 6- log_{10}. This addresses two concerns: (1) the unacceptability of organism challenge tests to demonstrate greater than 6-log_{10} reduction and, (2) to limit reliance on an individual treatment process, thereby ensuring a meaningful multi-barrier treatment approach. In addition, to ensure several individual treatment processes will be utilized that have a substantive log_{10} reduction capacity, the recycled water's treatment train is required to have at least three individual treatment processes accredited with no less than 1.0-log_{10} reduction.

Multi-barrier treatment to control a contaminant can achieve a number of desirable objectives that will improve the overall reliability of a treatment scheme. The multi-barrier concept is utilized and imbedded in federal and state drinking water standards. Should one treatment barrier fail, others should still be effective. Additionally, a water quality challenge that impairs the performance of one treatment barrier may not affect a dissimilar barrier.

The multiple barrier principle is a widely accepted concept, common to surface water treatment and some groundwater treatment, as described in the World Health Organization's *Guidelines for Drinking-Water Quality* (Appendix A, Item 11). The importance of the multiple barrier concept as it pertains to potable reuse projects is also addressed in the National Research Council's report on *Water Reuse: Potential for Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater*[6].

Subsection (b) requires the SWSAP WRA to demonstrate that its SWSAP treatment processes can reliably achieve the log_{10} reductions required in subsection (a). To gain credit toward meeting the log_{10} reduction requirements, the SWSAP WRA must provide evidence to the State Board for any treatment process for which the SWSAP WRA and/or SWSAP PWS intends to seek credit toward meeting the log_{10} reduction requirements in subsection (a). The evidence is to be compiled into a written report and submitted to the State Board for review and approval. As a minimum form of quality assurance, the report is required to be prepared by engineer licensed in California with at least five years of experience, as a licensed engineer, in wastewater treatment and public water supply, including the evaluation of treatment processes for pathogen control. Recognizing that the log_{10} reduction capabilities of treatment processes vary significantly - from well-known and widely documented, to unknown and in need of direct validation utilizing challenge tests – the evidence to be provided may vary as well,

[6] National Research Council's report on *Water Reuse: Potential for Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater* is available at: http://www.nap.edu/catalog/13303/water-reuse-potential-for-expanding-the-nations-water-supply-through.

including challenge tests, industry studies, or log_{10} reductions previously accredited by the State Board for an identical or substantially similar treatment process.

The ability of a treatment process to reliably achieve the log_{10} reductions required in subsection (a) is not limited to evidence provided that the chosen treatment processes are capable of achieving the accredited log_{10} reductions; on-going verification that the treatment processes are operating as designed is also necessary. Therefore, subsection (b) also requires the SWSAP WRA to identify the means by which the treatment processes will be verified as operating as intended, on an on-going basis during operation, in order to achieve the minimum log_{10} reduction required under subsection (a). The on-going monitoring to be used to verify performance, which may vary depending on the type of treatment and verification used, is to be included in the SWSAP WRA's Operation Plan (required pursuant to section 60320.322).

Subsection (c) addresses potential instances of lapses in operation and/or treatment that may be an indication of inconsistencies in operation, or operational issues that may potentially lead to more significant treatment lapses if left unaddressed. Because an SWSAP is producing water that will reside in an environment (a surface water reservoir) where it can disperse with and be attenuated by other previously acceptable drinking water sources already in the reservoir, brief and moderate lapses in treatment can be tolerated. However, with the treatment monitoring required of these projects, rapid (within 24 hours) identification, investigation, and initiation of corrective actions of an operational problem are expected. If the lapse in operation exceeds the duration criteria specified in the subsection (c), notification to the State Board and Regional Board agencies, as well as all public water systems utilizing the augmented reservoir as a source of drinking water, is required to take place within 24 hours of knowledge of the incident(s). Public water systems need to be informed of the problems so that they can take any additional mitigating actions necessary to ensure the protection of public health. Notification of the State Board and Regional Board is necessary for regulatory agency oversight, a review of project treatment reliability and operation, and confirmation of identification of the problem and corrective actions. Failures of a shorter duration are to be reported to the Regional Board no later than ten days after the month in which the incident(s) occurred.

As previously noted, the 8-log_{10} enteric virus, 7-log_{10} *Giardia* cyst, and 8-log_{10} *Cryptosporidium* oocyst reduction criteria are intended to produce a source of drinking water as treatable as the existing source (the surface water reservoir prior to augmentation with treated recycled water), with no greater pathogenic organism load. With care taken to conservatively determine the log_{10} reductions necessary to achieve safe drinking water during worst-case conditions, some flexibility is allowed in meeting the overall organism log_{10} reduction objective. This is a condition not unlike the fluctuations expected in natural surface water sources. The criteria are designed to assure a safe, treatable source of water for a SWTP, not the uniformly high quality required of finished drinking water.

Subsection (d) identifies requirements associated with operational lapses of a more significant nature, where the lapse of pathogenic organism removal potentially poses a risk that may be unsafe. The trigger level identified is where the required pathogen reduction is not met within 2-log_{10} of the specified log_{10}-reduction required pursuant to subsection (a)(1), (a)(2), or (a)(3), depending on the option chosen pursuant to section 64468.30(c), Article 9 of Chapter 17. The 2-log_{10} reduction failure threshold would be considered significant in light of the fact that the treatment process is producing a *source* of drinking water (yet, not a drinking water directly distributed to consumers). As a result, within 24 hours of the SWSAP WRA being aware of the incident (via corresponding alarm limits identified in the SWSAP WRA's Operation Plan), the SWSAP WRA is required to notify the State Board, Regional Board, and each SWSAP PWS utilizing the augmented reservoir of the incident. In addition, the SWSAP WRA is required to discontinue delivery of recycled municipal wastewater to the surface water reservoir, unless directed otherwise by the State Board and the Regional Board.

Section 60320.312, Regulated Contaminants and Physical Characteristics Control.

The use of treatment techniques, such as those required in sections 60320.302 and 60320.308, are ideal for addressing some contaminants and chemicals (e.g. pathogenic organisms, CECs, etc.) where, for example, on-going analyses of such constituents are not practical and/or health risks have yet to be adequately identified. However, treatment techniques are unnecessary when standards and practical analytical methods exist for a contaminant. Section 60320.312 addresses the control of contaminants and physical characteristics for the planned placement of recycled water into a surface water reservoir used as a source of water supply, when drinking water standards exist for contaminants and physical characteristics.

Subsections (a) and (b) require an SWSAP WRA to monitor for contaminants and constituents for which drinking water standards exist. Because the treated recycled water is being used to supplement a source of drinking water (i.e., a surface water reservoir), it is cogent to require the effluent of an SWSAP to be monitored for the same contaminants required to be monitored of typical drinking water sources, and to verify whether the concentrations remain below the drinking water standards and that the existing surface water reservoir has not been degraded as a source of drinking water.

Subsection (a) identifies the specific contaminants to be monitored in the recycled municipal wastewater to be delivered to the augmented reservoir, which are contaminants for which drinking water standards exist. Consistent with monitoring requirements for drinking water sources considered to be vulnerable to contamination, subsection (a) requires the SWSAP WRA to conduct quarterly monitoring of the recycled municipal wastewater delivered to the augmented reservoir. Although public water systems typically monitor disinfection byproducts within the distribution system, rather than within the source of drinking water (and will still be required to do so under drinking water requirements for public water systems), it doesn't negate the need to ensure the source of drinking water will not be degraded with such contaminants, nor potentially adversely impact the public water system's ability to ultimately meet all applicable drinking water standards. This holds true for lead and copper as well, which under drinking water regulations are also monitored at locations (consumers' taps) other than drinking water sources. It should be noted that the addition of advanced treated water into a source of drinking water may ultimately affect the corrosive nature of the drinking water supplied and, therefore, the public water system will need to conscientiously assess potential impacts and implement the requirements of the existing Lead and Copper Rule under Chapter 17.5. This concern, as well as others related to the introduction of advanced treatment water through the PWS's SWTP and distribution system is also addressed in the proposed requirements of Article 9, Chapter 17 (see section 64668.30).

While subsection (a) identifies MCLs for drinking water contaminants that pose a risk to human health, subsection (b) requires monitoring of constituents having SMCLs (secondary MCLs), which are identified in two tables (64449-A and 64449-B) located in existing section 64449 of Chapter 15. Secondary drinking water standards, although not health-based standards, primarily address the physical characteristics of water and are required to be met by public water systems in the drinking water provided to consumers. As such, the recycled municipal wastewater is also required to be monitored for secondary drinking water standards at least annually. The requirement parallels the requirements of drinking water sources that must be monitored periodically for chemicals and characteristics having secondary standards.

Subsection (c) describes the actions to be taken in the event the results of the monitoring of the recycled municipal wastewater required in subsection (a) exceed an MCL or action level (for lead and copper, as established in Chapter 17.5). An exceedance of an MCL or action level prompts a requirement to take a follow-up sample, as confirmation of the initial elevated result. Some contaminants are considered to have risks associated with health effects that may become apparent relatively soon after exposure to the contaminant (short-term exposure contaminants), while other contaminants are associated with risks resulting from a long period of exposure (long-term exposure contaminants), typically 70 years or more. Drinking water standards for short-term exposure contaminants establish responses to exceedances that are more immediate than the long-term exposure contaminants. Regulatory responses to long-term exposure contaminants are generally based on exceedances of the running annual averages of follow-up results.

Therefore, reflecting a similar approach, paragraph (1) establishes follow-up actions for recycled municipal wastewater exceedances associated with short exposure risks; with paragraph (2) establishing follow-up actions for exceedances associated with long exposure risks. As a result, paragraph (1) includes the requirement that a SWSAP WRA promptly notify the State Board and Regional Board of exceedances and initiate weekly monitoring for the contaminant and, if the running four-week average of weekly results exceeds (or would exceed) the contaminant's MCL or action level, the SWSAP

WRA would be required to immediately suspend the delivery of recycled municipal wastewater to the augmented reservoir. Monitoring for the contaminant must continue until monitoring confirms the problem has been addressed (i.e., four consecutive results meet the drinking water standard).

Although paragraph (2) of subsection (c) similarly requires initiation of weekly monitoring for confirmed exceedances, follow-up actions and notification are less immediate where, for example, a longer period of exceedances (a running four-week average exceeds an MCL for sixteen consecutive weeks) may result in being required to suspend the delivery of recycled municipal wastewater to the augmented reservoir (subparagraph (B)). That said, prior to that point, the SWSAP WRA would be required to take actions (report with schedule for corrective actions) if the running four-week average is exceeded. Monitoring for the contaminant must continue until monitoring confirms the problem has been addressed (i.e., four consecutive results meet the drinking water standard).

Subsection (d) describes the requirements for actions following an exceedance of a secondary MCL. Although conceptually similar to subsection (c), with exceedances prompting an increase in monitoring frequencies and reporting to the State Board and Regional Board, the less stringent nature of the requirements in subsection (d) reflects the fact that secondary MCLs are not health-based contaminants.

Although attenuation will occur within the reservoir to blunt the impact of exceedances to a degree not generally afforded to a public water system directly serving drinking water, the necessity for a SWSAP to meet MCLs and action levels is also reflective of reliably providing effective treatment, in addition to not degrading the existing surface water source of drinking water used by a public water system and enabling the public water system to ultimately meet drinking water standards.

Because of the unique nature of asbestos and its fibers, including its presence in water generally being associated with pipe construction, subsection (e) allows for relief from the frequency of monitoring for asbestos required under subsection (a). To be allowed the reduced monitoring, the SWSAP WRA must provide evidence that asbestos contamination is not a concern by having results below the asbestos detection limit for at least four consecutive quarters of monitoring.

Section 60320.320, Additional Chemical and Contaminant Monitoring.

Sources of drinking water in California are subject to periodic on-going monitoring of chemicals and contaminants – more so when the source is vulnerable to contamination or there is a known presence of contaminants. This monitoring occurs even though subsequent treatment processes may remove or reduce the contaminants to levels considered to be protective of public health. The specific chemicals and contaminants required to be monitored under drinking water standards are largely determined from the likelihood of their presence in typical sources of drinking water, along with associated health risks. Ultimately, for IPR projects such as surface water augmentation, the initial source is municipal wastewater; an atypical source of drinking water. As a result, it is prudent and consistent to have monitoring requirements specific to those additional chemicals and contaminants that may be present in municipal wastewater. Section 60320.320 establishes requirements for chemicals and contaminant monitoring, beyond those commonly required of drinking water (e.g., the regulated contaminants in section 60320.312). The monitoring of additional chemicals and contaminants is necessary to assure and confirm protection of public health, address the uncertainty regarding the presence of unregulated contaminants, affirm the efficacy of the treatment processes, and to potentially help determine the origin of their presence if found in the augmented reservoir.

Subsection (a) identifies two classes of chemicals - which are not typically required to be monitored under drinking water standards - to be monitored in the recycled municipal wastewater delivered to an augmented reservoir. Quarterly monitoring is required (as in subsection (b)), which is substantially consistent with the frequency at which vulnerable sources are monitored under drinking water standards.

Paragraph (1) of subsection (a) requires monitoring of chemicals specified by the State Board from the list of Priority Toxic Pollutants found in Title 40, section 131.38, of the Code of Federal Regulations. Waste dischargers are already required to monitor for applicable Priority Toxic Pollutants and some are already required to be monitored pursuant to these proposed regulations since they may also be regulated drinking water contaminants. Based primarily on the State Board's review of the SWSAP engineering report, specific pollutants will be required to be monitored in the recycled municipal wastewater delivered to the augmented reservoir.

Paragraph (2) requires monitoring for other additional chemicals, identified as potentially present in the municipal wastewater as a result of a review of the SWSAP engineering report and/or the results of the assessment performed pursuant to proposed section 60320.306(b)(1). The engineering report or the assessment may identify a chemical or chemicals associated with a particular industrial application which, for example, discharges to the wastewater treatment facility. Additionally, in order to help discern the origin of contaminants that may be present in the reservoir, the contaminants specified to be monitored may include those related to the reservoir monitoring required by section 60320.326.

Subsection (b) includes an additional group of contaminants to be monitored on a quarterly basis; those with NL that have been established by the State Board. NLs are health-based advisory levels that have been established by the State Board for contaminants in drinking water and for which MCLs have not been established. NLs largely serve as a precautionary measure for a contaminant that may be ultimately be considered a candidate for the establishment of an MCL, but have not yet undergone or completed the regulatory MCL-setting process. With NLs being health-based advisory levels and public water systems being required, pursuant to section 116455 of the Health and Safety Code, to take specific actions in the event of an exceedance of a NL (e.g., notifying the PWSs governing body and the PWSs that are directly supplied with that drinking water), it is prudent to require the monitoring of NLs and to take specific actions if an NL is exceeded.

NLs may be found on the State Board's Web site[7] and the State Board, under this proposed regulation, will identify individual contaminants having NLs for which monitoring will be required, based on project-specific information (as with proposed subsection (a)). Experience and knowledge gained from regulating groundwater replenishment projects, another form of IPR, will also play a role in identifying the contaminants having NLs to be monitored.

As with section 60320.312, if an NL is exceeded, the SWSAP WRA is required to undertake confirmation monitoring and, if necessary based on the results, initiate weekly monitoring for the contaminant until the running four-week average does not exceed the NL and the State Board and Regional Board has determined monitoring is no longer necessary. Paragraphs (1) and (2) of subsection (b), respectively, establish the actions to be taken in the event a running four-week average exceeds an NL and if the running four-week average is exceeded for sixteen consecutive weeks. Paralleling the Health and Safety Code (where notification is required for NL exceedances) and the general triggers for MCL exceedances under proposed section 60320.312, the SWSAP WRA will be required to notify the Regional Board and State Board in a report that includes identification of the reason for the exceedance and the corrective actions to be taken. Where monitoring indicates a more persistent issue (i.e., a running four-week average is exceeded for sixteen consecutive weeks), a SWSAP WRA is also required to quickly notify (within 48 hours) each PWS utilizing the augmented reservoir of the exceedance.

Subsection (c) enables the SWSAP WRA to reduce the quarterly monitoring required in subsections (a) and (b) to annually, following the State Board's review of monitoring results indicating that such chemicals and contaminants are not detected or, if detected, are consistently only at very low levels that would not be of concern. At a minimum, monitoring results for the most recent two years of operation would be necessary to determine that chemicals or contaminants are not present at levels of concern.

Subsection (d) requires annual monitoring of State Board-specified or Regional Board-specified indicator compounds. Broadly, the monitoring of indicator compounds, whose presence may not necessarily have a *direct* public concern, can be used to inform the State Board and Regional Board (as well as the SWSAP WRA) about the overall ability of treatment to adequately remove chemicals of a small molecular size that may be relatively resistant to treatment and/or removal from wastewater. An indicator compound is defined in more detail via existing section 60301.450 of Article 1, with its definition being proposed to be non-substantively amended to be inclusive for SWA

[7] http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/NotificationLevels.shtml

projects. Indicator compounds may vary on a case-by-case basis, depending largely on the wastewater and treatment processes used by a SWSAP. The specified indicator compounds will be based on a review of the engineering report for the particular SWSAP and the inventory provided via the requirements of section 60320.306(b)(4); yet, may be limited by the availability of test methods for such chemicals and the ability the chemicals to characterize the performance of the treatment process, as noted in paragraphs (1) through (4).

Subsection (e) establishes a general requirement (aside from the reporting otherwise specifically required in the section) regarding the reporting of chemicals or contaminants detected as a result of the monitoring required in this section (section 60320.320). In addition, subsection (e) requires that a SWSAP WRA monitor the recycled municipal wastewater delivered to the reservoir for other chemicals or contaminants that may be detected pursuant to the reservoir monitoring required in section 60320.326, if directed to do so by the State Board or Regional Board. Such monitoring and reporting can inform the regulating agencies of the fate, transport, and/or origins of particular chemicals and contaminants, as part of the agencies' oversight of SWSAPs.

Section 60320.322, SWSAP Operation Plan.

The final effluent of a SWSAP's treatment processes will eventually be delivered to a reservoir used as a source of drinking water by a PWS. Thus, the overall treatment system or scheme ultimately leading to a drinking water provided to consumer will also include subsequent treatment via the PWS's SWTP, which is subject to existing state and federal requirements. As a result, the wastewater treatment processes producing the effluent are part of the system of treatment processes utilized to ultimately produce a drinking water for human consumption. Under existing section 64661 ("Operation Plan") of Chapter 17, a PWS operating a SWTP must develop and operate the SWTP in a manner "designed to produce the optimal water quality from the treatment process." Likewise, proposed section 60320.322 requires a SWSAP WRA to develop an Operation Plan for the SWSAP operated by the SWSAP WRA.

Subsection (a) establishes the general requirements and elements associated with an Operation Plan, including minimum requirements for the content of the Operation Plan. In order to achieve one of the overall goals of developing an Operation Plan that could be a valuable tool for new personnel (or regulatory personnel) to fully understand the day-to-day operation of the SWSAP, and ensure consistent operation, the content may need to expand beyond those identified in subsection (a). This would include, at a minimum, identifying and describing the operations, maintenance, analytical methods, the monitoring necessary for the SWSAP to meet the requirements of the Article, and the reporting of monitoring results to the State Board and Regional Board. The content of the Operation Plan is to also include the elements of the training required pursuant to subsection (b), which are generally not applicable to the operation of a wastewater treatment facility, but necessary when providing drinking water.

With the understanding that changes in operation of a SWSAP (e.g., ‘fine-tuning’ and changes in equipment) may occur, subsection (a) includes the general requirement that a SWSAP WRA maintain and implement an Operation Plan that reflects current operation of the SWSAP. Subsection (a) also includes general requirements associated with regulatory oversight of a SWSAP, such as submitting, for review and approval, an Operation Plan prior to operation of a SWSAP and making the Operation Plan readily available for review by State Board and/or Regional Board personnel.

As previously suggested, while operator certification requirements for wastewater treatment plants currently exists, there currently are no operator certification requirements directly specific to the advanced, and potentially unique, treatment processes necessary to meet the requirements of proposed Article 5.3; in particular, those associated with proposed sections 60320.302 and 60320.308. In addition, wastewater treatment plant operators may have relatively limited knowledge regarding drinking water regulations and the potential adverse health effects associated with consumption of drinking water that fails to meet such drinking water regulations. Knowledge and training in this regard will raise operator awareness in support of conscientious operation of a SWSAP by the operators. Therefore, subsection (b) requires a SWSAP WRA to demonstrate that its personnel operating and overseeing the SWSAP operations have been appropriately trained, as noted in paragraphs (1) through (3).

Subsections (c) and (d) extend upon, and make more specific, the general requirements in subsection (a) regarding the SWSAP WRA’s development and maintenance of its Operation Plan. Subsection (c) requires that the SWSAP be operated, at all times, in a manner that achieves optimal reduction of all contaminants and chemicals, particularly those noted in paragraphs (1) through (3); namely, pathogenic contaminants, regulated contaminants, and the additional chemicals and contaminants in section 60320.320. Optimal treatment is expected during the first year of operation – i.e., once delivery of treated recycled water begins, which follows the ‘commissioning’ of the SWSAP alluded to in proposed section 60320.301(c) – and at all times thereafter when augmentation of the reservoir occurs. Recognizing that revisions to the Operation Plan may occur from time to time in order to, for example, more fully describe and identify the operations necessary to ensure full optimal treatment, subsection (d) requires the SWSAP WRA to continually update the Operation Plan as such revisions are made and to submit the revised Operation Plan to the State Board and Regional Board for review. A six-month timeframe provides ample time for the preparation and submittal of a post-operation Operation Plan, supplementing the pre-operation Operation Plan submittal required pursuant to subsection (a).

Section 60320.326, Augmented Reservoir Monitoring.

Section 60320.326 establishes requirements for the monitoring of a reservoir that is intended to be used, and is used, as an augmented reservoir for a surface water source augmentation project (SWSAP). Subsection (a) requires the identification of locations within the reservoir to be used for monitoring. Because the burden of ensuring that most of the augmented reservoir requirements are being met lies with the SWSAP PWS (e.g., proposed sections 64668.10 and 64668.30, Chapter 17), along with the need to understand the intended operational use of the reservoir by the SWSAP PWS (e.g., from where the water will be withdrawn by the SWSAP PWS), it will be necessary for the SWSAP WRA to coordinate with the SWSAP PWS to satisfactorily meet the proposed requirements pertaining to monitoring locations in the reservoir. Because a SWSAP may impact a significant volume of the reservoir, and ultimately the entire reservoir, paragraphs (1) through (3) specify the minimum criteria associated with selection of reservoir monitoring locations, such that the monitoring locations identified are collectively representative of the volume of the reservoir impacted by the SWSAP.

Subsection (b) establishes a requirement to perform monthly water quality monitoring of a surface water reservoir, for no less than 24 consecutive months prior to initiating augmentation of the reservoir. The purpose of the monitoring is to establish a water quality baseline for the reservoir, prior to the delivery of advanced treated recycled water to the reservoir. Establishing a water quality baseline provides a means of identifying changes that may occur in the reservoir (including those that may be beneficial) as a result of the SWSAP and, similarly, to potentially identify the origin of such water quality changes (i.e., to exclude or include the SWSAP as the origin). Subsection (b) identifies a number of particular constituents to be monitored that may change, or be a catalyst for change, as a result of the addition of highly treated water into the reservoir. In addition, the SWSAP WRA will be required to have the monthly samples analyzed for the presence of project-specific chemicals and contaminants. The 24-month minimum timeframe is intended to provide a baseline that adequately portrays a reservoir’s seasonal and operational variations, and is consistent with the minimum timeframe requirement of operation of a reservoir as an approved surface water source found in proposed section 64668.30(a).

To effectuate the overall reason for the requirements of subsection (b) noted above – namely, to identify impacts of the SWSAP on the reservoir - subsection (c) requires that the monitoring required pursuant to subsection (b) continue for no less than 24 months *after* the augmentation of the recycled water has begun, in order to have a means of comparison with the baseline reservoir water quality *prior* to augmentation. In addition, early identification of impacts on the reservoir’s water quality will provide a basis for the SWSAP PWS to make any necessary adjustments in operation of its SWTP, assuring a reliable supply of a drinking water to its customers that meets all drinking water standards. Recognizing that the impacts on a reservoir, as a result of the SWSAP, may be minimal and/or well-understood and stabilized, subsection (d) allows the SWSAP WRA to apply for a reduction in the otherwise on-going monthly monitoring required pursuant to subsection (c). On the other hand, it's also recognized that more frequent monitoring or the addition of specific constituents to the monitoring regime required in subsection (b), (c), or (d) may be necessary depending on new knowledge, potential concerns, or unique project-specific characteristics. Therefore, subsection (e) establishes a broad requirement for a SWSAP WRA to monitor for State Board-specified chemicals or contaminants, at the locations and frequencies specified by the State Board.

Section 60320.328, Reporting.

Section 60320.328 establishes requirements for specific reports to be submitted by the SWSAP WRA to the State Board and Regional Board. Development of such reports requires the SWSAP WRA to assess and contemplate its SWSAP, and make available a summary of relevant information to each SWSAP PWS. In addition, the reports may be utilized by the State Board and Regional Board when overseeing a SWSAP WRA, as well as providing a summary of updates to the State Board and Regional Board.

The report required pursuant to subsection (a) is required to be submitted each year, no later than July 1st, covering the previous year's operation. Each SWSAP PWS affected by the SWSAP is to be notified of the availability of the report, allowing the SWSAP PWS to review the report as the SWSAP PWS sees fit. Paragraphs (1) through (7) describe the minimum content of the report, which focuses on compliance summaries, corrective actions taken or to be taken, water quality assessments, changes operation and/or treatment, recycled water used and planned usage, along with a summary of the SWSAP WRA's actions taken with respect to ensuring the quality of the raw wastewater is acceptable, controlled, and meeting the requirements of sections 60320.306 and 60320.301(e). It is necessary that the report, with the information being technical in nature and largely related to engineering aspects of a SWSAP, be prepared by an engineer licensed in California and experienced in the fields of wastewater treatment and public water supply.

Existing section 60323, Title 22, requires all entities supplying recycled water for reuse projects (which would include a SWSAP) to have a State Board-approved engineering report. Due to the complex nature of an SWSAP, the on-going need to ensure protection of public health, and the need for the State Board and Regional Board to have an engineering report that reflects relatively recent operations and finding, subsection (b) requires the SWSAP WRA to update its engineering report no less often than every five years and submit the updated report to the State Board and Regional Board.

Section 60320.330, Alternatives.

The development of treatment processes associated with the removal of contaminants of concern to public health, as well as the means of assessing the reliability and efficacy of such treatment processes, is dynamic. As a result, section 60320.330 recognizes this circumstance by allowing alternatives to the requirements of Article 5.3. Any substantive alternative would result in a change in operation that could potentially impact a project's ability to be protective of public health and, therefore, if the change is significantly different from the process or approach presented to the public by way of section 64668.20 of Article 9 (Public Hearings), a public hearing may be prudent.

Therefore, as required in paragraphs (1) through (3) of subsection (a), before being allowed to utilize an alternative, the SWSAP WRA is required to (1) demonstrate that the alternative would provide an equivalent (or better) level of protection of public health than what would be required otherwise via the proposed regulations, (2) receive written approval from the State Board prior to implementing the alternative, and, (3) if directed by the State Board or Regional Board, conduct a public hearing on the proposed alternative.

In addition, as previously noted, section 13562(a)(2) of the Water Code mandates that an Expert Panel, convened by the State Board, make a finding that the SWA criteria adequately protect public health. Therefore, because of the prospective nature of section 60320.330 allowing alternatives – where an alternative may be considered without the Expert Panel being able to contemplate the specific alternative at the time of their approval of these regulations - subsection (b) requires an independent scientific advisory panel, similar in composition to the Expert Panel, to review the SWSAP WRA's demonstration required in subsection (a).

CCR TITLE 22, DIVISION 4, CHAPTER 17, ARTICLE 9 (INDIRECT POTABLE REUSE: SURFACE WATER AUGMENTATION)

Section 64668.05, Application.

Chapter 17 establishes requirements for a PWS using approved surface waters as a source of supply for treatment, with the effluent ultimately supplied as a drinking water. Because IPR through SWA involves the planned placement of recycled municipal wastewater into a surface water reservoir that is used as a source of domestic drinking water supply by a PWS, the supplemental requirements for a PWS choosing to use a reservoir augmented with recycled water are proposed to be added to Chapter 17, under newly proposed Article 9. This application is provided in proposed section 64668.05.

Section 64668.10, General Requirements and Definitions.

Section 64668.10 establishes general requirements and definitions pertaining to proposed Article 9 and a PWS choosing to engage in a SWSAP and utilize an augmented reservoir as a source of supply. Subsection (a) provides definitions for the terms “Augmented Reservoir”, “Surface Water Source Augmentation Project” (or “SWSAP”), “Surface Water Source Augmentation Project Public Water System” (or “SWSAP PWS”), and "Surface Water Source Augmentation Project Water Recycling Agency” (or “SWSAP WRA"), consistent with the proposed definitions in Chapter 3 for IPR SWA projects.

Subsection (b), consistent with section 116550(a) of the Health and Safety Code, requires a PWS wishing to use an augmented reservoir to first submit an application for a permit or permit amendment. In addition, a SWSAP PWS is required to have an approved joint plan with the SWSAP WRA, for the reasons previously noted in this document in the discussion of proposed section 60320.301. The existing requirements of Chapter 17 [section 64660(c)(2) and section 64661] for a PWS operating a SWTP include the development of an emergency plan and operations plan. Because a SWSAP impacts a PWS operations and emergency actions, a SWSAP PWS is required to update its emergency plan and operations plan, accordingly. The portions of the joint plan associated with the PWS emergency and operations plan will need to be included in the revised plans.

In addition, utilizing recycled water as a source of supply for a PWS presents unique challenges with respect to potential contaminating events that may impact the surface water reservoir, which will be the source of supply to the PWS SWTP. Such events may need quick, well-planned, remedial actions on the part of the PWS, often in conjunction with the SWSAP WRA, to ensure the PWS is capable of continuing to reliably provide a safe and wholesome supply of drinking water, which may include the need to provide an alternative supply or additional treatment. The general conditions that must be contemplated, which the PWS must be prepared to address, are described in paragraphs (1) through (3) of subsection (b), including the surface water reservoir receiving water failing to meet the requirements of section 60320.308(d), which would be considered a significant treatment failure event involving pathogenic organisms.

To demonstrate the ability to comply with the requirements of the proposed regulations, ranging from reservoir monitoring to necessary flow rates and reservoir volumes, the SWSAP PWS will need to have sufficient direct, or in some cases indirect, control over the operation of the reservoir. Subsection (c) requires that the PWS must have such control. To further enhance oversight of a SWSAP, Subsection (d) requires the SWSAP PWS to immediately notify the State Board upon learning of the SWSAP WRA failing to comply with the SWSAP WRA’s permit or a requirement of proposed Article 5.3, Chapter 3.

Section 64668.20. Public Hearings.

Section 116551(b) of the Health and Safety Code mandates that, prior to issuing a permit or permit amendment to a PWS for utilizing a reservoir as a drinking water supply that is directly augmented with recycled water, the State Board must hold at least three noticed public hearings in the area where recycled water is proposed to be used or supplied for human consumption. The primary purpose of holding the public hearings is to receive public testimony on the proposed use. Section 64668.20 establishes requirements of the PWS SWSAP related to the statutory mandate.

Subsection (a) establishes general requirements regarding the purpose and nature of the information to be presented to the public. To properly educate and inform the public about the proposed project, in a manner in which the public can provide well-informed comments and questions during the hearing, subsection (a) includes a framework for the minimum information to be provided. Further information may be needed to properly elucidate the nature of a SWSAP to the public.

As mentioned in subsection (a), subsection (b) would also require the information to be provided on the SWSAP PWS Web site, as well as requiring the information to be provided at a repository that allows public access to the information (e.g. a public library). The Internet is commonly used as a viable means of reliably and effectively providing information to the public. To allow the public ample time to review the information prior to the hearing, the information is required to be available to the public for no less than 30 days before the hearing(s). Subsections (c) and (d) establish the minimum necessary actions to be taken and logistics to be followed by the SWSAP PWS regarding the availability of the information and the notification of the public with respect to the information to be presented at the public hearings.

Section 64668.30. SWSAP Augmented Reservoir Requirements.

As previously noted (Background/Authority section of this document), comments and recommendations were received by scientific peer reviewers for the proposed regulations as a result of the mandate of section 57004, Health and Safety Code. Two recommendations received via the scientific peer review process are of note because the recommendations suggested revisions to the version of the proposed SWA regulations that were provided to the reviewers. Both of the recommendations were provided by Dr. Scott Wells, professor of Civil and Environmental Engineering at Portland State University, and pertain to the subjects addressed by proposed section 64668.30. Dr. Wells's recommendations may be found on page 4 of his submittal dated May 5, 2016 (Appendix A, Item 2). One recommendation – regarding the proposed minimum theoretical retention limit – is not being proposed to be adopted by the State Board for the reasons noted below in the subsection (b) discussion. The other recommendation – regarding the need for external peer review for tracer and hydrodynamic modeling studies – was accepted, resulting in the addition of proposed subsection (f).

Section 64668.30 establishes requirements pertaining specifically to the use of a reservoir as an augmented reservoir. Because a SWSAP PWS's involvement with and use of a SWSAP includes additional responsibilities to those of a PWS treating an otherwise approved surface water, it is imperative that a prospective SWSAP PWS first establish the ability to treat the surface water (sans a SWSAP) in a manner that reliably provides drinking water meeting all drinking water standards, under varying conditions and circumstances. As a result, subsection (a) requires that PWS operate a SWTP for a minimum timeframe of five-years before the PWS may be allowed to engage in a SWSAP. That said, the State Board recognizes that circumstances may exist where a PWS, on a case-by-case basis, may be able to demonstrate such ability in a shorter timeframe. However, consistent with the baseline monitoring requirements in proposed section 60320.326 (Chapter 3), the PWS must have been reliably operating a SWTP for no less than two years prior to engaging in a SWA project.

The differentiation between an IPR project and a DPR project is that an IPR project provides a meaningful robust environmental buffer as a component of public health protection. For a surface water augmentation reservoir, the benefits of the reservoir as an environmental buffer lie primarily in the form of contaminant attenuation to mitigate the potential consequences of a SWSAP treatment failure. As a result, the attenuation is not considered part of the treatment technology train and may not be used as credit to meet the other proposed regulatory requirements associated with contaminant control and removal for SWA projects. To ensure the reservoir provides a meaningful environmental buffer, two types of requirements associated with the robustness of a reservoir are proposed in subsections (b) and (c); the former largely operational and the latter performance-based.

Subsection (b) establishes a requirement that a reservoir to be used for augmentation must initially provide a theoretical retention time of at least 180 days, with the SWSAP PWS subsequently having the option of submitting an application to be approved for a reduced minimum theoretical retention time of no less than 60 days (two months). Dr. Scott Wells recommended eliminating the theoretical retention time minimum of six months as a criterion for compliance. In support of his recommendation, Dr. Wells illustrated that the overall theoretical retention time of a reservoir, and the amount of dilution occurring within the reservoir, may not always have a strong relationship and therefore a theoretical retention time criterion would provide no additional protective benefit relative to the proposed dilution/attenuation criteria of subsection (c).

Although the State Board doesn't disagree with Dr. Wells' analysis, the purpose of the theoretical retention time requirement is not to supplement the proposed dilution requirements found in subsection (c). Where the performance-based requirements in subsection (c) address the need for a rigorously quantified direct dilution of the recycled water delivered to the reservoir, the minimum theoretical retention time requirement in subsection (b) establishes a simple operational criterion as a means of assuring the reservoir would be of sufficient size to be able to provide greater opportunity and options for responding to and potentially mitigating significant treatment failures. Having both operational and performance-based criteria assures the reservoir will be a resilient, robust, and meaningful environmental buffer – one that that will significantly reduce the likelihood of adverse impacts from treatment failures. In addition to the basic hydraulic operation benefits established by way of the requirements of subsection (b), the requirements of a minimum theoretical retention time, in combination with performance criteria in subsection (c), also help distinguish an *indirect* potable reuse project (like a SWSAP) from a *direct* potable reuse project. Establishing a distinction between indirect potable reuse and direct potable reuse is consistent with Chapter 7.3, Division 7, of the Water Code.

The State Board's position regarding the inclusion of a minimum theoretical retention time, in contrast to Dr. Wells's recommendation, is well-supported by the findings of the Expert Panel. The Expert Panel - in their memorandum responding to the scientific peer reviewers' comments (Appendix A, Item 3, pages 7 and 8) – addresses, in detail, Dr. Wells's recommendation to eliminate the minimum theoretical retention time criteria. Therefore, for the reasons noted above and consistent with the Expert Panel's findings, the State Board has retained criteria for a minimum theoretical retention time.

It should be noted, however, that the draft regulation reviewed by Dr. Wells allowed the minimum theoretical retention time to be reduced from six months to four months and that the current proposed regulation allows the minimum theoretical retention time to be reduced to 60 days (two months). This reduction in the allowed minimum theoretical retention time (from four months to two months) was made to allow further flexibility for projects, on a case-by-case basis (see discussion below regarding subsection (b)(2)), and is consistent with the Expert Panel's finding in their DPR report, where the Expert Panel considered a project having less than two months theoretical retention time to be DPR, rather than IRP (Appendix A, Item 12).

A monthly determination compliance with the minimum theoretical retention time requirement is sufficient to assure that the reservoir is being operated to maintain sufficient volume to mitigate treatment failures. Paragraph (1) of subsection (b) requires a SWSAP PWS with a theoretical retention time determined to be less than its approved minimum theoretical retention time to report the deficiency to the State Board and Regional Board, along with descriptions of corrective actions taken to ensure that future theoretical retention times will be no less than the approved minimum theoretical retention time.

As noted in subsection (b), an *initial* approved minimum theoretical retention time may be no less than 180 days. However, after operation at an initial approved minimum theoretical retention time, paragraph (2) allows the SWSAP PWS to apply for a reduced on-going approved minimum theoretical retention time; but the reduction may not be less than 60 days. The SWSAP PWS application is required to include the information listed in subparagraphs (A) through (F), which is the minimum information needed by the State Board to be reviewed and taken into consideration prior to approving a reduced minimum theoretical retention time less than 180 days. The information listed in subparagraphs (A) through (F) will provide the State Board with information that may be relevant to the potential impacts of a shorter minimum theoretical retention time. On a case-by-case basis – after weighing the information individually and in total regarding demonstrated reliability of treatment and mitigating circumstances unique to a particular SWSAP - the State Board may approve a shorter minimum theoretical retention time. Per subparagraph (F), the SWSAP PWS is required to demonstrate to the State Board that the reduced minimum theoretical retention time will be at least as protective of public health as otherwise required. The SWSAP PWS may be required to have the demonstration reviewed by an independent scientific advisory panel approved by the State Board to provide the State Board with additional scientific insights regarding the potential consequences of reducing the theoretical retention time.

As previously noted, the performance-based requirements in subsection (c) address the need for a rigorously quantified direct dilution of the recycled water delivered to the reservoir. This is to be achieved by the SWSAP PWS demonstrating to the State Board, using tracer studies and hydrodynamic modeling, that a 1:100 dilution will be achieved under all operating conditions such that the volume of water withdrawn from the reservoir, at the inlet of the SWTP, contains no more than one percent (1:100 dilution) of recycled water that was delivered during a 24-hour period (see subsection (c)(1)).

As an alternative, under subsection (c)(2), the SWSAP PWS may similarly demonstrate that the inlet of the SWTP contains no more than ten percent (1:10 dilution) of recycled water that was delivered during a 24-hour period - *if* the recycled water delivered to the reservoir was subjected to an *additional* treatment process providing at least 1-$\log_{10}$ reduction (for each) of enteric virus, *Giardia* cysts, and *Cryptosporidium* oocysts. Although the additional treatment need not be a treatment process unique or different from the other treatment processes, it must be independent and not reliant on the other treatment processes. In this way, the 1-$\log_{10}$ additional treatment balances the dilution being reduced to 1:10 – which may be considered as being 1-$\log_{10}$ less than a 1:100 dilution - while still providing a minimum standard for a meaningful environmental buffer via dilution. Thus, the option in subsection (c)(2) is comparable to the 1:100 dilution requirement in (c)(1). Although the additional treatment process will be designed and operated by the SWSAP WRA, the SWSAP PWS will be responsible for demonstrating, to the State Board, compliance with the requirements related to the additional treatment alternative. This is a further example of the importance of strong communication between the SWSAP WRA and the SWSAP PWS.

To demonstrate compliance with subsection (c), the SWSAP PWS will need to rely on extensive hydrodynamic modeling. Since hydrodynamic modeling is a simulation, it’s important to ensure and verify the accuracy of the hydrodynamic modeling using data gathered under actual conditions. Therefore, subsection (d) requires a SWSAP PWS to verify its hydrodynamic modeling by conducting a tracer study under hydraulic conditions representative of normal operations. The SWSAP PWS must initiate the tracer study prior to the end of the sixth month of operation, utilizing an added tracer. The six-month timeframe provides time to develop a tracer study protocol, which must be reviewed and approved by the State Board.

Recognizing that changes in operation of the reservoir may substantially impact the hydraulic characterization that was used to demonstrate compliance with subsection (c), subsection (e) requires a SWSAP PWS to notify the State Board of such changes prior to initiating the changes. The SWSAP PWS will have to demonstrate to the State Board that the hydraulic characterization used to assure compliance with section 64668.30, in particular subsection (c), remains accurate and valid under the proposed new operating conditions. If not, the SWSAP PWS may be required by the State Board to again demonstrate compliance, per subsections (c) and/or (d).

As noted, the second recommendation made by Dr. Wells – regarding the need for external peer review for tracer and hydrodynamic modeling studies – was accepted, resulting in proposed subsection (f). The use of tracer studies and hydraulic modeling is essential for providing an accurate hydraulic characterization of a reservoir and to demonstrate compliance with subsection (c). This process is complex and involves expertise that may be beyond a regulatory agency's expertise, and requires that the process and its result be confirmed. The Expert Panel's review of Dr. Wells's recommendation substantiates the need for requiring the review by an independent scientific advisory panel. To ensure the State Board has available all the information necessary to make well-informed decisions regarding a SWSAP PWS's demonstration of compliance with subsection (c), a SWSAP PWS is required to allow State Board representatives to join in all independent scientific advisory panel discussions.

Changes in the quality of water being treated by a SWTP can affect the facility's treatment processes and the operation of the treatment plant, even if the source water being treated may be of a higher quality. Likewise, the subsequent introduction of advanced treatment water (after going through the SWTP) into the distribution system of a PWS may impact the chemical and/or microbial stability of the drinking water provided to the consumers. As a result, subsection (g) requires a SWSAP PWS to assess and address potential impacts resulting from the introduction of advanced treated water, as an increasing fraction of advanced treated water is introduced to the SWTP and the SWSAP PWS's distribution system.

REASONABLE ALTERNATIVE STANDARDS

The State Board has determined that no reasonable alternative considered or otherwise identified and brought to its attention would be more effective in carrying out the purpose for which this action is proposed, would be as effective and less burdensome to the regulated water systems and affected private persons, or would be more cost-effective to the regulated water systems and affected private persons, yet equally effective in implementing statutory requirements or other provisions of law, than the proposed action.

EVALUATION REGARDING INCONSISTENCY OR INCOMPATABILITY WITH EXISTING STATE REGULATIONS

The State Board evaluated this proposal as to whether the proposed regulations are inconsistent or incompatible with existing California state regulations. This evaluation included a review of California's existing regulations, potentially related to IPR by way of SWA, including the State Board's existing general regulations. It was determined that no other state regulation addressed the same subject matter and that this proposal was not inconsistent or incompatible with other state regulations. However, it should be noted that on June 18, 2014, the California Department of Public Health adopted regulations for another form of IPR, where recycled water is used for the purpose of replenishing groundwater basins that are used as a source of domestic drinking water supplies. For those portions comparable, the proposed SWA regulations are substantially consistent with the existing regulations for IPR through groundwater replenishment. Therefore, the State Board has determined that this proposal, if adopted, would not be inconsistent or incompatible with existing state regulations.

ECONOMIC IMPACT ANALYSIS

The State Board has prepared the following Economic Impact Analysis pursuant to Gov. Code sec. 11346.3(b)(1)(A)-(D):

No existing or future member of the regulated community is required or compelled to engage in surface water augmentation as a result of the proposed regulations, and no member of the regulated community is currently engaged in surface water augmentation. In addition, under existing authority and through the existing permitting processes of the regulatory agencies that would be issuing permits for surface water augmentation projects, the criteria in the proposed regulations would be required of the regulated community via such permits, even in the absence of the adoption of the regulations. The proposed regulations do not impose any additional requirements on members of the regulated community that may choose to engage in surface water augmentation. The proposed regulations serve to help streamline the permitting process through the adoption of uniform criteria, as mandated by Water Code section 13562.

- The creation or elimination of jobs within the State of California: The requirements previously summarized should not have any affect in that there would not be any significant change in the regulated community or regulatory agency personnel associated with the adoption of the proposed regulations.
- The creation of new businesses or the elimination of existing businesses within the State of California: The nature of the drinking water and recycled water industry is such that the adoption of this proposed regulation would not result in the creation or elimination of businesses. The members of the regulated community that may choose to engage in surface water augmentation would be public entities providing public services, as opposed to business enterprises. The impact of the proposed regulations on new businesses or the elimination of existing businesses would be insignificant.
- The expansion of businesses currently doing business within the State of California: The proposed regulation applies to the drinking water and recycled water industry only and should not have any effect on the expansion of businesses within the State of California.
- The benefits of the regulation to the health and welfare of California residents, worker safety, and the state's environment: The State Board has made a determination that the proposed regulations would streamline a process for ensuring the protection of the public's health and welfare through the adoption of the proposed regulations, with no adverse impacts to worker safety or California's environment.

SIGNIFICANT STATEWIDE ADVERSE ECONOMIC IMPACT DIRECTLY AFFECTING BUSINESS, INCLUDING ABILITY TO COMPETE

The State Board has determined that the proposed regulatory action would have no significant adverse economic impact on California business enterprises and individuals, including the ability of California businesses to compete with businesses in other states. The proposed regulations apply only to water recycling agencies and public water systems choosing to engage in surface water augmentation and include no requirements that would not otherwise be required of the entities through existing statutory authority and mandates. Additionally, pursuant to Government Code section 11342.610, utilities such as public water systems and water recycling agencies are exempt from the definition of a small business. The members of the regulated community that may choose to engage in surface water augmentation would be public entities providing public services, as opposed to business enterprises.

EFFECT ON SMALL BUSINESS

The State Board has determined that the proposed regulations would not affect small business because Government Code chapter 3.5, article 2, section 11342.610 excludes drinking water utilities from the definition of small business, and the proposed regulations do not apply to small businesses.

REPORTING REQUIREMENTS

The State Board has determined that the proposed regulations would not require reports from businesses.

STATE WATER POLICY CODE SECTION 106.3 CONSIDERATION

In establishing and adopting the proposed regulations, the State Board considered the statewide policy set forth in section 106.3 of the Water Code and determined the proposed regulations will further the stated policy.

DUPLICATION OR CONFLICTS WITH FEDERAL REGULATIONS

The proposed regulations do not unnecessarily duplicate or conflict with federal regulations. A review of the Code of Federal Regulations did not indicate the existence of duplicative or conflicting law.

COMMONLY USED ACRONYMS AND TERMS

AOP - Advanced Oxidation Process

ASTM - American Society for Testing Materials

CCR - California Code of Regulations

CEC - Constituents of Emerging Concern

DPR - Direct Potable Use

ELAP - Environmental Laboratory Accreditation Program

U.S. EPA - United States Environmental Protection Agency

IPR - Indirect Potable Use

MCL - Maximum Contaminant Level

NL - Notification Level

NWRI - National Water Research Institute

PWS - Public Water System

RO - Reverse Osmosis

Regional Board - Regional Water Quality Control Board

SDWA - Safe Water Drinking Act

SMCL - Secondary Maximum Contaminant Level

SWA - Surface Water Augmentation

State Board - State Water Resources Control Board

SWSAP - Surface Water Source Augmentation Project

SWSAP PWS - Surface Water Source Augmentation Project Public Water System

SWSAP WRA - Surface Water Source Augmentation Project Water Recycling Agency

SWTP- Surface Water Treatment Plant

WRA - Water Recycling Agency

APPENDIX A

DOCUMENTS RELIED UPON

1. Expert Panel finding of State Board Surface Water Augmentation criteria to be protective of public health (October 31, 2016): See attached.

2. Peer Review mandated via Health and Safety Code section 57004: Documents pertaining to the State Board's submittal for peer review and peer reviewer's comments may be accessed via http://www.swrcb.ca.gov/water_issues/programs/peer_review/. See attached.

3. Expert Panel response to Peer Review mandated via Health and Safety Code section 57004 (August 2016). See attached.

4. *Advanced Water Purification Facility Study Report*, January 2013, pages 2-53 to 2-64, Section 2, Demonstration Facility Description and Observations, Constituents of Emerging Concern, CEC Performance Indicator Monitoring, Table 2-24 CEC Potential Indicator Characterization Results, RO Removal.
http://www.sandiego.gov/water/purewater/pdf/projectreports/section2demonstration.pdf

5. Ibid, pages 2-24 to 2-27, Section 2 Demonstration Facility Description and Observations, 2.3.3 UV Disinfection and Advanced Oxidation.

6. *West Basin Municipal Water District, Advisory Panel Findings and Recommendations, Seawater Barrier Water Conservation Project Phase III.* Final Report, May 15, 2001. See attached

7. LongTerm2 Surface Water Treatment Rule, [Federal Register: January 5, 2006 (Volume 71, Number 3)][Rules and Regulations] [Page 653-702] – using the high infectivity rate. http://www.gpo.gov/fdsys/pkg/FR-2006-01-05/pdf/06-4.pdf

8. *Water Reuse*, Metcalf and Eddy, 2007, Table 3-7, "Microorganism concentrations found in untreated wastewater and the corresponding median infectious dose." See attached.

9. "Occurrence of *Cryptosporidium* Oocysts and *Giardia* Cysts in Sewage in Norway", Robertson, L. J., L. Hermansen, and B. K. Gjerde (2006), Appl Environ Microbiol 72(8): 5297–5303. http://aem.asm.org/content/72/8/5297.full.pdf+html

10. "Observed and Predicted Oocyst Concentration Distributions as the Starting Point for Quantitative Microbial Risk Analysis of Tertiary Treatment", Melbourne Water (2011): See attached.

11. *Guidelines for Drinking-Water Quality,* World Health Organization: http://apps.who.int/iris/bitstream/10665/44584/1/9789241548151_eng.pdf

12. *"Evaluation of the Feasibility of Developing Uniform Water Recycling Criteria for Direct Potable Reuse"*, Expert Panel, Chapter 9, page 227. See attached.

13. American Standard for Testing Materials (ASTM) International method D4194-03 is available via https://www.astm.org/Standards/D4194.htm

APPENDIX A – DOCUMENTS RELIED UPON

Reference No. 1

Expert Panel finding of State Board Surface Water Augmentation criteria to be protective of public health (October 31, 2016)

October 31, 2016

NATIONAL WATER RESEARCH INSTITUTE
EXPERT PANEL

Expert Panel Finding on California State Water Resources Control Board's Proposed Uniform Water Recycling Criteria for Surface Water Augmentation

PREPARED FOR:

California State Water Resources Control Board

PREPARED BY:

The Expert Panel convened pursuant to California Water Code, sections 13562(a)(2) and 13565(a).
www.nwri-usa.org/ca-panel.htm

FOREWORD AND FINDING

In 2013 and pursuant to its contracts with the California Department of Public Health[1] and State Water Resources Control Board (State Board), the National Water Research Institute (NWRI) formed an independent, third-party, expert panel (Expert Panel) to 1) advise the State Board on public health issues, as well as scientific and technical matters, regarding development of uniform water recycling criteria for surface water augmentation and to 2) adopt a finding as to whether the State Board's proposed uniform water recycling criteria for surface water augmentation would be adequately protective of public health. The Expert Panel was formed by NWRI on behalf of the State Board pursuant to California Water Code, section 13565 (a) and (d). Appendix A provides the names, titles, and biographies for each Expert Panel member.

The Expert Panel is a requirement of the California Water Code, sections 13562(a)(2) and 13565(a). As mandated, the Expert Panel was convened and administered for the purposes of advising the State Board "on public health issues and scientific and technical matters regarding development of uniform water recycling criteria for indirect potable reuse through surface water augmentation."[2] In addition, the State Board must "develop and adopt uniform water recycling criteria for surface water augmentation" on or before December 31, 2016.[3] The Expert Panel 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 may be adopted.[4]

The Expert Panel met 12 times between March 2014 and July 2015 to examine relevant data, case studies, and reports. The Expert Panel also reviewed and provided recommendations on draft versions (initial version dated July 2014) of the proposed criteria titled "Surface Water Augmentation Using Recycled Water," which was developed by State Board staff. Each meeting resulted in an Expert Panel report that was submitted to State Board staff and made available for public access via NWRI's and the State Board's websites[5].

The Expert Panel finds, in its expert opinion, that the State Board's proposed uniform water recycling criteria for surface water augmentation titled, "Surface Water Augmentation Using Recycled Water," as provided in Appendix B (October 12, 2016), adequately protects public health. This finding, submitted by the Expert Panel on October 31, 2016, represents the collective expert opinion of all members of the Expert Panel.

---

[1] On July 1, 2014, via Senate Bill 861, Ch. 35, the authority, duties, powers, purposes, functions, responsibilities, and jurisdiction of the California Department of Public Health pertaining to this matter were transferred to the State Water Resources Control Board.

[2] California Water Code, section 13565(a)(1)

[3] California Water Code, section 13562(a)(2)(A)

[4] California Water Code, section 13562(a)(2)(B)

[5] http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/RW_SWA_DPRexpertpanel.shtml

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

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

James Crook, Ph.D., P.E.
Panel Co-Chair
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.
U.S. Environmental Protection Agency
(Durham, NC)

CONTENTS

---

1. INTRODUCTION

In 2013, the National Water Research Institute (NWRI) of Fountain Valley, California, appointed state and national water industry professionals to an independent, third-party Expert Panel (Panel) to provide advice to the State of California on developing water recycling criteria for indirect potable reuse (IPR) through surface water augmentation (SWA). The 12-member Panel was formed on behalf of the State Water Resources Control Board (State Board) and is administered by NWRI. The Panel is a requirement of the California Water Code, Section 13560-13569.

As mandated in the Water Code, the California Department of Public Health (now the State Board) "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." In addition, the Water Code requires the State Board to "develop and adopt uniform water recycling criteria for surface water augmentation" on or before December 31, 2016. The Panel 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.

To fulfill this task, the Panel met 12times between March 2014 and July 2015 in various locations throughout California. These meetings were attended by Panel members, State Board staff, NWRI staff, staff from water utilities throughout the state, and other interested parties. During these meetings, the Panel examined relevant data, case studies, and reports. The Panel also reviewed and provided recommendations on draft versions of the proposed criteria titled "Surface Water Augmentation Using Recycled Water," which was developed by State Board staff. Each meeting resulted in a Panel report that was submitted to the State Board and made available for public access on the NWRI and State Board websites.[6]

1.1 Background Regarding IPR via SWA

Following the initial approval of the City of San Diego's IPR proposal to augment a surface water reservoir, the Division of Drinking Water and Environmental Management of the California Department of Public Health (now referred to as the State Board Division of Drinking Water) and the Department of Water Resources convened the California Potable Reuse Committee to identify the conditions necessary for safe SWA throughout California. In 1996, the California Potable Reuse Committee produced the document, "A Proposed Framework for Regulating the Indirect Potable Reuse of Advanced Treated Reclaimed Water by Surface Water Augmentation" (California Potable Reuse Committee, 1996). Subsequently, the California Recycled Water Task Force was created by statute in 2001 and was tasked, in part, to evaluate the need to reconvene the California Potable Reuse Committee to update their findings in the Framework.

In the report entitled "Water Recycling 2030 – Recommendations of California's Recycled Water Task Force" (State of California, 2003), the Task Force concluded[7] that it was not necessary to revisit the 1996

---

[6] http://www.nwri-usa.org/ca-panel.htm
http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/RW_SWA_DPRexpertpanel.shtml

[7] See Recommendation 6.3 of "Water Recycling 2030 – Recommendations of California's Recycled Water Task Force" (State of California, 2003).

Framework and the State should be able to make determinations regarding IPR based on the following publications:

- "Report of the Scientific Advisory Panel on Groundwater Recharge with Reclaimed Water" (State of California, 1987).
- "Issues in Potable Reuse" (National Research Council, 1998).
- "A Proposed Framework for Regulating the Indirect Potable Reuse of Advanced Treated Reclaimed Water by Surface Water Augmentation" (California Potable Reuse Committee, 1996).
- CDPH draft groundwater replenishment regulations (August 5, 2008)[8].

1.2 Summary of Proposed 1996 Framework for Regulating Indirect Potable Reuse by Surface Water Augmentation

The California Potable Reuse Committee examined the feasibility and safety of potable reuse of recycled water following advanced treatment. In the 1996 Proposed Framework document, committee members concluded that planned IPR of advanced treated recycled water using surface water reservoirs is feasible under the following six specific criteria:

- Application of Best Available Technology in advanced wastewater treatment with the treatment plants meeting operating criteria.
- Maintenance of appropriate retention times based on reservoir dynamics.
- Maintenance of advanced wastewater treatment plant reliability to consistently meet primary microbiological, chemical, and physical drinking water standards.
- SWA projects using advanced treated recycled water must comply with applicable State of California criteria for groundwater recharge for direct injection with recycled water.
- Maintenance of reservoir quality.
- Provision for an effective source control program.

Other project approval considerations identified in the Framework included recommendations for:

- Independent Monitoring Oversight Authority. This authority would be appointed by CDPH (now the State Board) and Regional Water Quality Control Board (RWQCB) to provide a third-party review of the operational, regulatory, and environmental issues associated with the project.
- Coordination. Coordination between water reclamation agencies, regulatory agencies, and agencies responsible for public water systems should be instituted in both formal and informal channels.

[8] Revised groundwater replenishment regulations were subsequently adopted by CDPH and became effective on June 18, 2014 (California Code of Regulations, 2016).

- Operator Training and Certification. Operator training and certification programs must ensure reliable operation of advanced treatment facilities.
- Source Aesthetic Quality. Use of advanced treated recycled water should not negatively impact the aesthetics (taste, odor, and appearance) or consumer acceptance of the public drinking water supply.

2. INDIRECT POTABLE REUSE THROUGH SURFACE WATER AUGMENTATION

IPR through groundwater replenishment (also known as groundwater recharge) with advanced treated water has been a long-standing practice in California. California's draft regulations for IPR through groundwater replenishment have gone through many revisions in the last 28 years and were eventually adopted in 2014 (California Code of Regulations, 2016). As another form of IPR for which there is significant historical experience, groundwater replenishment provides some of the basis for the development of the criteria for planned IPR of advanced treated water by SWA.

The treatment and water quality management approach considered by the Panel for SWA is similar to the approach used for groundwater replenishment, and both types of IPR are illustrated in Figure 1. SWA consists of introducing municipal wastewater that receives secondary, tertiary, and advanced treatment into a reservoir serving as a raw water source of domestic drinking water supply. The advanced treated water would be commingled with the water within the reservoir. The commingled water would then, after appropriate dilution and retention times, receive treatment in a conventional surface water treatment plant, consistent with the U.S. and California Safe Drinking Water Acts and their implementing regulations, before introduction into a public water system's potable water distribution system.

The most important issues surrounding the planned IPR of advanced treated water include: 1) maintenance of advanced water treatment facility (ATWF) performance and reliability of a high water quality; and 2) inclusion of an environmental buffer (as defined in the proposed SWA criteria contained in Appendix B). Water quality is influenced by every unit process in the process train. Water quality at any point in the system process depends on the performance and reliability of the preceding processes. The design and operation of the ATWF to provide multiple safety barriers are critical to ensure consistent and reliable production of high-quality source water.

In Figure 1(c), a surface water reservoir serves as the environmental buffer. It is important to note that, considering the existing statutes and current regulatory framework in California, when a project is operated such that the reservoir cannot or does not provide the dilution and retention time prescribed in the criteria, the proposed project would be considered a direct potable reuse (DPR) project, rather than an IPR project. To date, the State has not developed criteria for DPR.

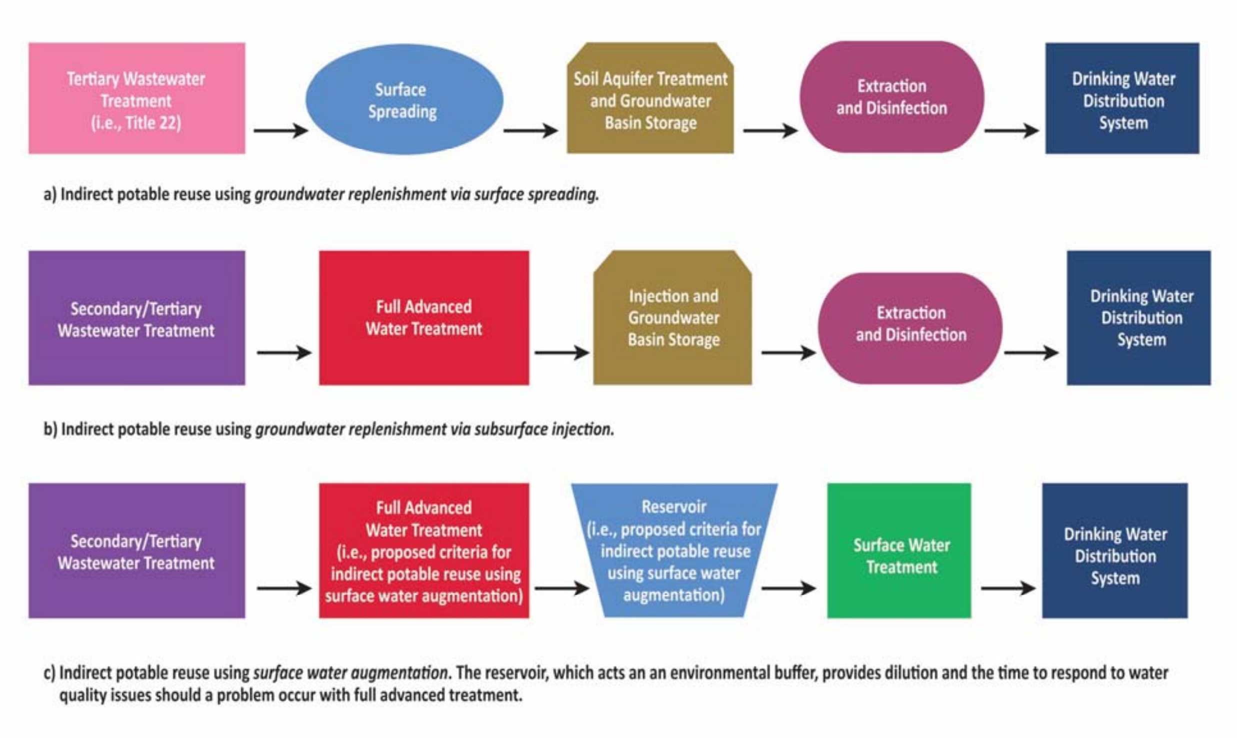


Figure 1: **Schematics of indirect potable reuse in California using groundwater replenishment (a,b) and surface water augmentation (c). The environmental buffer is represented by a groundwater aquifer in (a) and (b), and by a reservoir in (c). Wastewater treatment could include either secondary or tertiary treatment. Tertiary treated wastewater per Title 22 involves well oxidized, filtered, and disinfected wastewater. Soil aquifer treatment involves the percolation of water through the vadose zone, which provides soil treatment. In California, full advanced treatment per Title 22 requires reverse osmosis and advanced oxidation. Drinking water treatment for surface water meets California drinking water standards (Olivieri et al., 2016).**

3. PANEL FINDING

The Panel discussions to date included the following:

- 1996 Framework document developed by the California Potable Reuse Committee.
- 1998 and 2012 National Research Council reports on potable reuse (National Research Council, 1998; National Research Council, 2012).
- 2014 CDPH groundwater replenishment regulations (California Code of Regulations2016).
- Other pertinent information from a review of the literature.
- Detailed review of the first draft proposed IPR-SWA criteria (provided to the Panel in July 2014) developed by State Board staff as well as responses to Panel questions and comments by DDW staff are contained in the Panel meeting reports.
- The Expert Panel final report to the State Water Resources Control Board "*Evaluation of the Feasibility of Developing Uniform Water Recycling Criteria for Direct Potable Reuse*," August 2016.
- Review of the proposed draft IPR-SWA criteria (Appendix B) dated October 12, 2016.

The results of the Panel discussions and recommendations are provided in Panel reports. While the Panel agrees with the California Potable Reuse Committee report, new research and advances in treatment technologies and monitoring techniques over the past 20 years have advanced the science and understanding of IPR projects and was considered by the Panel. Further, an additional 20 years of experience with IPR through groundwater replenishment has added significant knowledge and confidence to the design, operation, and management of IPR projects.

The Panel's review and discussions of the IPR groundwater replenishment regulations as related to IPR-SWA criteria and the Panel review and discussions of the first and subsequent draft SWA criteria resulted in revisions and clarifications to the draft SWA criteria. Appendix B includes the draft SWA criteria (October 12, 2016) developed in response to the Panel's comments and recommendations. Per its charge, the Panel finds, in its expert opinion, that the October 12, 2016, proposed IPR-SWA criteria for "Surface Water Augmentation Using Recycled Water" (see Appendix B) adequately protects public health.

4. REFERENCES

California Code of Regulations. 2016. *Water Recycling Criteria*, Title 22, Division 4, Chapter 3, California Code of Regulations, Sacramento, CA. https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=IE8ADB4F0D4B911DE8879F88E8B0DAAAE&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default)

California Potable Reuse Committee. 1996. *A Proposed Framework for Regulating the INDIRECT POTABLE REUSE of Advanced Treated Reclaimed Water by SURFACE WATER AUGMENTATION IN CALIFORNIA.* California Department of Water Resources, Sacramento, CA (January 1996).

National Research Council. 1998. *Issues in Potable Reuse: The Viability of Augmenting Drinking Water Supplies with Reclaimed Water.* National Research Council of the National Academies, National Academy Press, Washington, D.C.

National Research Council. 2012. *Water Reuse: Potential for Expanding the Nation's Water Supply through Reuse of Municipal Wastewater.* National Research Council of the National Academies, National Academy Press, Washington, D.C.

Olivieri, A.W., J. Crook, M.A. Anderson, R.J. Bull, J.E. Drewes, C.N. Haas, W. Jakubowski, P.L. McCarty, K.L. Nelson, J.B. Rose, D.L. Sedlak, and T.J. Wade (2016). *Expert Panel Final Report: Evaluation of the Feasibility of Developing Uniform Water Recycling Criteria for Direct Potable Reuse*. Prepared August 2016 by the National Water Research Institute for the State Water Resources Control Board, Sacramento, CA.

State of California. 1987. *Report of the Scientific Advisory Panel on Groundwater Recharge with Reclaimed Water.* G. Robeck (ed.). State of California Department of Water Resources, Sacramento, CA.

State of California. 2003. *Water Recycling 2030: Recommendations of California's Recycled Water Task Force.* California Department of Water Resources, Sacramento, CA.

Tchobanoglous, G., J. Cotruvo, J. Crook, E. McDonald, A. Olivieri, A. Salveson, and R.S. Trussell. 2015. *Framework for Direct Potable Reuse*. WateReuse, Alexandria, VA.

APPENDIX A: PANEL 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., BCEE (Panel Co-Chair)
Environmental Engineering Consultant (Boston, MA)

Jim Crook is an environmental engineering consultant (Boston, MA) 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 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 elected as a Water Environment Federation Fellow in 2014 and 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.

APPENDIX B: PROPOSED DDW IPR-SWA CRITERIA

SBDDW-16-02
Surface Water Augmentation Using Recycle Water
October 12, 2016

TITLE 22, CALIFORNIA CODE OF REGULATIONS

DIVISION 4, CHAPTER 3

ARTICLE 1. Definitions

Adopt Section 60301.120 as follows:

§60301.120. Augmented Reservoir.

"Augmented Reservoir" means a surface water reservoir used as a source of domestic drinking water supply that receives recycled municipal wastewater from a Surface Water Source Augmentation Project (SWSAP).

NOTE: Authority cited: Sections 13521 and 13562, Water Code; and Section 116271, Health and Safety Code. Reference: Sections 13520, 13522, 13522.5, 13523, 13523.1, 13524, 13560, 13561, 13564 and 13565, Water Code; and Section 116551, Health and Safety Code.

Amend Section 60301.450 as follows:

§60301.450. Indicator Compound.

"Indicator Compound" means an individual chemical in ~~a GRRP's~~ municipal wastewater that represents the physical, chemical, and biodegradable characteristics of a specific family of trace organic chemicals; is present in concentrations that provide information relative to the environmental fate and transport of those chemicals; may be used to monitor the efficiency of trace organic compound~~s~~ removal by treatment processes; and provides an indication of treatment process failure.

NOTE: Authority cited: Sections 13521, 13562 and 13562.5, Water Code; and Section~~s~~ ~~131052 and 131200~~116271, Health and Safety Code. Reference: Sections 13520, 13522, 13522.5, 13523, 13523.1, 13524, 13560, 13561 and 13562.5, Water Code.

Adopt Section 60301.850.5 as follows:

§60301.850.5. Surface Water.

As used in this Article and Article 5.3 of this Chapter, "Surface Water" has the same meaning as defined in section 64651.83 of Chapter 17.

NOTE: Authority cited: Sections 13521 and 13562, Water Code; and Section 116271, Health and Safety Code. Reference: Sections 13520, 13522, 13522.5, 13523, 13523.1, 13524, 13560, 13561, 13564 and 13565, Water Code; and Section 116551, Health and Safety Code.

Adopt Section 60301.851 as follows:

§60301.851. Surface Water Source Augmentation Project or SWSAP.

"Surface Water Source Augmentation Project" or "SWSAP" means a project involving the planned placement of recycled municipal wastewater into a surface water reservoir that is used as a source of domestic drinking water supply, for the purpose of supplementing the source of domestic drinking water supply.

NOTE: Authority cited: Sections 13521 and 13562, Water Code; and Section 116271, Health and Safety Code. Reference: Sections 13520, 13522, 13522.5, 13523, 13523.1, 13524, 13560, 13561, 13564 and 13565, Water Code; and Section 116551, Health and Safety Code.

Adopt Section 60301.852 as follows:

§60301.852. Surface Water Source Augmentation Project Public Water System or SWSAP PWS.

"Surface Water Source Augmentation Project Public Water System" or "SWSAP PWS" means a public water system that plans to utilize or is utilizing an augmented reservoir as a source of drinking water and is responsible for complying with the requirements of Chapter 17 and the applicable requirements of this Chapter.

NOTE: Authority cited: Sections 13521 and 13562, Water Code; and Section 116271, Health and Safety Code. Reference: Sections 13520, 13522, 13522.5, 13523, 13523.1, 13524, 13560, 13561, 13564 and 13565, Water Code; and Section 116551, Health and Safety Code.

Adopt Section 60301.853 as follows:

§60301.853. Surface Water Source Augmentation Project Water Recycling Agency or SWSAP WRA.

"Surface Water Source Augmentation Project Water Recycling Agency" or "SWSAP WRA" means an agency that is subject to a Regional Water Quality Board's (Regional Board's) water-recycling requirements applicable to a Surface Water Source Augmentation Project (SWSAP) and is, in whole or part, responsible for applying to the Regional Board for a permit, obtaining a permit, the operation of a SWSAP, and complying with the terms and conditions of the Regional Board permit and the requirements of this Chapter.

NOTE: Authority cited: Sections 13521 and 13562, Water Code; and Section 116271, Health and Safety Code. Reference: Sections 13520, 13522, 13522.5, 13523, 13523.1, 13524, 13560, 13561, 13564 and 13565, Water Code; and Section 116551, Health and Safety Code.

ARTICLE 5.3. Indirect Potable Reuse: Surface Water Augmentation

Adopt Section 64320.300 as follows:

Section 64320.300. Application.

The requirements of this Article apply to a Surface Water Source Augmentation Project Water Recycling Agency (SWSAP WRA) involved in the planned placement of recycled municipal wastewater into a surface water reservoir that is used, in whole or in part, as a source of domestic drinking water supply by a public water system pursuant to Article 9, Chapter 17, of this Division.

Adopt Section 60320.301 as follows:

§60320.301. General Requirements.

(a) Prior to augmentation of a surface water reservoir using a SWSAP, each SWSAP WRA and each SWSAP PWS participating in the SWSAP shall submit a joint plan to the State Board and Regional Board for review and written approval. At a minimum, the joint plan shall address the elements in paragraphs (1) and (2) below. The joint plan shall be signed by each person with authority or responsibility to operate the SWSAP, comply with the requirements of this Article, and ensure that each SWAP WRA and SWAP PWS implements the actions designated in the joint plan. In the event of any subsequent change in applicable authority, responsibility, operation, or ownership of a SWSAP WRA or SWSAP PWS, including the addition of any SWSAP WRA or SWSAP PWS participant in the SWSAP, a revised joint plan shall be submitted to the State Board and Regional Board for review and written approval, and the revised joint plan shall be signed by all participants. A revised joint plan shall also be submitted to reflect any change in the information provided pursuant to paragraphs (1) and (2) below, and to address any State Board or Regional Board concerns. A revised joint plan required by this section shall be submitted not less than sixty (60) days prior to the effective date of any change required by this section to be addressed in a revised joint plan.

(1) Corrective actions to be taken in the event that a delivery of recycled municipal wastewater from the SWSAP to an augmented reservoir fails to meet the water quality requirements of this Article.

(2) The procedures a SWSAP WRA will implement for notifying a SWSAP PWS, State Board, and Regional Board of:

(A) operational changes that may adversely affect the quality of the recycled municipal wastewater to be delivered to an augmented reservoir, and

(B) the events and corresponding corrective actions required to be identified in paragraph (1).

(b) Prior to design and operation of a SWSAP, a SWSAP WRA shall demonstrate to the State Board and Regional Board that the SWSAP WRA possesses adequate financial, managerial, and technical capability to assure compliance with this Article.

(c) Prior to augmentation of a surface water reservoir using a SWSAP, a SWSAP WRA shall demonstrate to the State Board and Regional Board that all treatment processes are installed and can be operated by the SWSAP WRA, as designed, to achieve their intended function. A protocol describing the actions to be taken to meet this subsection shall be included in the engineering report submitted pursuant section 60323, Article 7 of Chapter 3.

(d) If a SWSAP WRA fails to complete compliance monitoring required by this Article, compliance may be determined by the State Board or Regional Board based on monitoring data available to, and assumptions made by, the State Board or Regional Board.

(e) A SWSAP WRA shall ensure that the recycled municipal wastewater used for a SWSAP is from a wastewater management agency that is not in violation of the effluent limits or water quality requirements that pertain to surface water augmentation pursuant to this Article, as incorporated in the wastewater management agency's Regional Board permit.

(f) When a SWSAP WRA has been required by this Article or directed by the State Board or Regional Board to suspend augmentation of a surface water reservoir for any reason, augmentation of the surface water reservoir shall not resume until the SWSAP WRA has obtained written authorization to resume augmentation of the reservoir from the State Board and Regional Board.

(g) Reports required by this Article to be submitted by a SWSAP WRA or SWSAP PWS to the Regional Board or State Board shall be in writing.

(h) Unless specified otherwise, the term "quarter", as used in this Article, refers to a calendar quarter.

NOTE: Authority cited: Sections 13521 and 13562, Water Code; and Section 116271, Health and Safety Code. Reference: Sections 13520, 13522, 13522.5, 13523, 13523.1, 13524, 13560, 13561, 13564 and 13565, Water Code; and Section 116551, Health and Safety Code.

Adopt Section 60320.302 as follows:

§60320.302. Advanced Treatment Criteria.

A SWSAP WRA shall ensure the continuous treatment, with full advanced treatment meeting the criteria in this section, of the entire recycled municipal wastewater stream prior to its delivery to an augmented reservoir. Full advanced treatment is the treatment of an oxidized wastewater, as defined in section 60301.650, using a reverse osmosis and an oxidation treatment process that, at a minimum, meets the criteria of this section.

(a) A SWSAP WRA shall select for use a reverse osmosis membrane such that:

(1) each membrane element used in the SWSAP has achieved a minimum rejection of sodium chloride of no less than 99.0 percent (99.0%) and an average (nominal) rejection of sodium chloride of no less than 99.2 percent (99.2%), as

demonstrated through Method A of ASTM International's method D4194-03 (2014) using the following substitute test conditions:

(A) a recovery of permeate of no less than 15 percent (15%);

(B) sodium chloride rejection is based on three or more successive measurements, after flushing and following at least 30 minutes of operation having demonstrated that rejection has stabilized;

(C) an influent pH no less than 6.5 and no greater than 8.0;

(D) an influent sodium chloride concentration of no greater than 2,000 mg/L, to be verified prior to the start of testing; and

(E) an applied pressure no greater than 225 pounds per square inch (psi); and

(2) during the first twenty weeks of full-scale operation the membrane produces a permeate with no more than five percent (5%) of the sample results having TOC concentrations greater than 0.25 mg/L (or an alternative surrogate parameter and corresponding limit approved by the State Board), as verified through monitoring no less frequent than weekly.

(b) For the reverse osmosis treatment process, a SWSAP WRA shall propose, for State Board review and written approval, on-going performance monitoring (e.g., conductivity, TOC, etc.) that indicates when the integrity of the process has been compromised. The proposal shall include at least one form of continuous monitoring, as well as the associated surrogate and/or operational parameter limits and alarm settings that indicate when the integrity has been compromised.

(c) To demonstrate a sufficient oxidation treatment process has been designed for implementation, the SWSAP WRA shall conduct testing demonstrating that an oxidation treatment process will provide no less than 0.5-$\log_{10}$ (69 percent) reduction of 1,4-dioxane.

(1) A SWSAP WRA shall submit a testing protocol, as well as the subsequent results, to the State Board for review and written approval. The testing shall include challenge or spiking tests, using 1,4-dioxane, to demonstrate the proposed oxidation

treatment process will achieve the minimum 0.5-log_{10} reduction under the proposed oxidation treatment process's normal full-scale operating conditions.

(2) A SWSAP WRA shall establish, and submit to the State Board for review and written approval, surrogate and/or operational parameters that indicate whether the minimum 0.5-log_{10} 1,4-dioxane reduction design criterion is being met. At least one surrogate or operational parameter shall be capable of being monitored continuously, recorded, and have associated alarms that indicate when the process is not operating as designed.

(d) During full-scale operation of the oxidation treatment process designed pursuant to subsection (c), a SWSAP WRA shall continuously monitor the surrogate and/or operational parameters established pursuant to subsection (c)(2). A SWSAP WRA shall implement, in full-scale operation, the oxidation treatment process as designed pursuant to subsection (c).

(e) Within sixty (60) days after completing the first 12-months of full-scale operational monitoring pursuant to subsection (d), a SWSAP WRA shall submit a report to the State Board and Regional Board that includes:

(1) results of surrogate and/or operational parameter monitoring conducted pursuant to subsection (d);

(2) a description of the efficacy of the surrogate and/or operational parameters to reflect the reduction criterion for 1,4-dioxane; and

(3) a description of actions taken, or yet to be taken, if any of the following occurred during the first 12 months of operation:

(A) the 1,4-dioxane reduction did not meet the associated design criteria in subsection (c), as indicated by the on-going continuous operational surrogate and/or operational parameter monitoring;

(B) if 1,4-dioxane was present, the continuous surrogate and/or operational parameter monitoring failed to correspond to the reduction criterion for 1,4-dioxane; and

(C) any failure, interruption, or other incident that may have resulted in insufficient oxidation treatment having occurred.

(f) Within sixty (60) days after completing the initial 12 months of operation of the reverse osmosis process (or alternative process approved pursuant to 60320.330), a SWSAP WRA shall submit a report to the State Board and Regional Board describing the effectiveness of the treatment, process failures that occurred, and actions taken in the event the on-going monitoring, conducted pursuant to subsection (b), indicated that process integrity was compromised.

(g) Each quarter, a SWSAP WRA shall calculate what percent of results of the quarter's monitoring, conducted pursuant to subsections (b) and (d), did not meet the surrogate and/or operational parameter limits established to assure proper on-going performance of the reverse osmosis and oxidation processes. If the percent is greater than ten, within forty-five (45) days after the end of the quarter a SWSAP WRA shall:

(1) submit a report to the State Board and Regional Board that identifies the reason(s) for the failure, if known, and describes the corrective actions planned or taken to reduce the percent to ten percent (10%) or less; and

(2) consult with the State Board and Regional Board and, if directed by the State Board or Regional Board, comply with an alternative monitoring plan approved by the State Board and Regional Board.

(h) Each month a SWSAP WRA shall collect samples representative of the effluent of the advanced treatment process under normal operating conditions and have the samples analyzed for contaminants having MCLs and notification levels (NLs). After 12 consecutive months with no results exceeding an MCL or NL, a SWSAP WRA may apply to the State Board and Regional Board for a reduced monitoring frequency. The reduced monitoring frequency shall be no less than quarterly. Monitoring conducted pursuant to this subsection may be used in lieu of the monitoring (for the same contaminants) required pursuant to sections 60320.312 and 60320.320. The effluent of the advanced treatment process may not exceed an MCL.

NOTE: Authority cited: Sections 13521 and 13562, Water Code; and Section 116271, Health and Safety Code. Reference: Sections 13520, 13522, 13522.5, 13523, 13523.1, 13524, 13560, 13561, 13564 and 13565, Water Code; and Section 116551, Health and Safety Code.

Adopt Section 60320.304 as follows:

§60320.304. Lab Analyses.

(a) An analysis for a contaminant having a primary or secondary MCL shall be performed using a drinking water method approved by the State Board for the contaminant, by a laboratory that at the time of the analysis has a valid certificate from the State Board for the analytical method used.

(b) Analyses for chemicals other than those having primary or secondary MCLs shall be described in the SWSAP WRA's Operation Plan prepared pursuant to section 60320.322.

NOTE: Authority cited: Sections 13521 and 13562, Water Code; and Section 116271, Health and Safety Code. Reference: Sections 13520, 13522, 13522.5, 13523, 13523.1, 13524, 13560, 13561, 13564 and 13565, Water Code; and Section 116551, Health and Safety Code.

Adopt Section 60320.306 as follows:

§60320.306. Wastewater Source Control.

A SWSAP WRA shall ensure that the recycled municipal wastewater used for a SWSAP shall be from a wastewater management agency that:

(a) administers an industrial pretreatment and pollutant source control program; and

(b) implements and maintains a source control program that includes, at a minimum;

(1) an assessment of the fate of State Board-specified and Regional Board-specified chemicals and contaminants through the wastewater and recycled municipal wastewater treatment systems,

(2) chemical and contaminant source investigations and monitoring that focuses on State Board-specified and Regional Board-specified chemicals and contaminants,

(3) an outreach program to industrial, commercial, and residential communities within the portions of the sewage collection agency's service area that flows into the water reclamation plant subsequently supplying the SWSAP, for the purpose of managing and minimizing the discharge of chemicals and contaminants at the source, and

(4) a current inventory of chemicals and contaminants identified and evaluated pursuant to this section, including new chemicals and contaminants resulting from new sources or changes to existing sources, that may be discharged into the wastewater collection system.

NOTE: Authority cited: Sections 13521 and 13562, Water Code; and Section 116271, Health and Safety Code. Reference: Sections 13520, 13522, 13522.5, 13523, 13523.1, 13524, 13560, 13561, 13564 and 13565, Water Code; and Section 116551, Health and Safety Code.

Adopt Section 60320.308 as follows:

§60320.308. Pathogenic Microorganism Control.

(a) A SWSAP WRA shall design and operate SWSAP treatment processes such that the recycled municipal wastewater delivered to an augmented reservoir for use by a SWSAP PWS receives treatment as follows:

(1) For a SWSAP PWS implementing the requirements of section 64668.30(c)(1) of Chapter 17, the treatment train shall reliably achieve at least 8-$\log_{10}$ enteric virus reduction, 7-$\log_{10}$ *Giardia* cyst reduction, and 8-$\log_{10}$ *Cryptosporidium* oocyst reduction, consisting of at least two separate treatment processes for each pathogen (i.e., enteric virus, *Giardia* cyst, or *Cryptosporidium* oocyst). A separate treatment process may be

credited with no more than 6-log_{10} reduction, with at least two processes each being credited with no less than 1.0-log_{10} reduction.

(2) For a SWSAP PWS implementing the requirements of section 64668.30(c)(2) of Chapter 17, the treatment train shall reliably achieve at least 9-log_{10} enteric virus reduction, 8-log_{10} *Giardia* cyst reduction, and 9-log_{10} *Cryptosporidium* oocyst reduction, consisting of at least three separate treatment processes for each pathogen (i.e., enteric virus, *Giardia* cyst, or *Cryptosporidium* oocyst). A separate treatment process may be credited with no more than 6-log_{10} reduction, with at least three processes each being credited with no less than 1.0-log_{10} reduction.

(3) The State Board may increase the minimum enteric virus, *Giardia* cyst, and *Cryptosporidium* oocyst log_{10} reductions required in paragraphs (1) and (2) as a result of a SWSAP PWS relying on additional treatment to obtain State Board approval of an alternative minimum theoretical retention time pursuant section 64668.30(b) of Chapter 17.

(b) The SWSAP WRA shall validate each of the treatment processes used to meet the requirements in subsection (a) for their log reduction by submitting a report for the State Board's review and written approval, or by using a challenge test approved by the State Board, that provides evidence of the treatment process's ability to reliably and consistently achieve the log reduction. The report and/or challenge test shall be prepared by engineer licensed in California with at least five years of experience, as a licensed engineer, in wastewater treatment and public water supply, including the evaluation of treatment processes for pathogen control. The SWSAP WRA shall propose and include in its Operations Plan prepared pursuant to section 60320.322, on-going monitoring using the pathogenic microorganism of concern or a microbial, chemical, or physical surrogate parameter(s) that verifies the performance of each treatment process's ability to achieve its credited log reduction.

(c) If the applicable pathogen reduction in subsection (a) is not met based on the on-going monitoring required pursuant to subsection (b), within 24 hours of its knowledge of an occurrence, the SWSAP WRA shall investigate the cause and initiate corrective actions. If there is a failure to meet the pathogen reduction criteria longer than 4 consecutive hours or more than a total of 8 hours during any 7-day period, the SWSAP WRA shall, within 24 hours of its knowledge of such a failure, notify the State Board, Regional Board, and each SWSAP PWS utilizing the augmented reservoir. Failures of shorter duration shall be reported to the Regional Board no later than 10 days after the month in which the failure occurred.

(d) The SWSAP WRA shall, within 24 hours of its knowledge, notify the State Board, Regional Board, and each SWSAP PWS utilizing the augmented reservoir and, unless directed otherwise by the State Board and the Regional Board, discontinue delivery of recycled municipal wastewater to the SWSAP augmented reservoir if:

(1) pursuant to the pathogen reduction requirements in subsection (a)(1), the effectiveness of the treatment train to reduce enteric virus is less than 6-$\log_{10}$, *Giardia* cysts reduction is less than 5-$\log_{10}$, or *Cryptosporidium* oocysts reduction is less than 6-$\log_{10}$,

(2) pursuant to the pathogen reduction requirements in subsection (a)(2), the effectiveness of the treatment train to reduce enteric virus is less than 7-$\log_{10}$, *Giardia* cysts reduction is less than 6-$\log_{10}$, or *Cryptosporidium* oocysts reduction is less than 7-$\log_{10}$, or

(3) effectiveness of the treatment train to reduce enteric virus, *Giardia* cysts, or *Cryptosporidium* oocysts is less than a $\log_{10}$ reduction value derived from deducting 2-$\log_{10}$ from each of the minimum enteric virus, *Giardia* cyst, and *Cryptosporidium* oocyst $\log_{10}$ reductions required pursuant to subsection (a)(3).

NOTE: Authority cited: Sections 13521 and 13562, Water Code; and Section 116271, Health and Safety Code. Reference: Sections 13520, 13522, 13522.5, 13523, 13523.1, 13524, 13560, 13561, 13564 and 13565, Water Code; and Section 116551, Health and Safety Code.

Adopt Section 60320.312 as follows:

§60320.312. Regulated Contaminants and Physical Characteristics Control.

(a) Each quarter a SWSAP WRA shall collect samples (grab or 24-hour composite) representative of the recycled municipal wastewater delivered to the augmented reservoir and have the samples analyzed for:

(1) the inorganic chemicals in Table 64431-A, Chapter 15;

(2) the radionuclide chemicals in Tables 64442 and 64443, Chapter 15;

(3) the organic chemicals in Table 64444-A, Chapter 15;

(4) the disinfection byproducts in Table 64533-A, Chapter 15.5; and

(5) lead and copper.

(b) Each year, in the same quarter, the SWSAP WRA shall collect at least one representative sample (grab or 24-hour composite) of the recycled municipal wastewater delivered to the augmented reservoir and have the sample(s) analyzed for the secondary drinking water contaminants in Tables 64449-A and 64449-B of Chapter 15.

(c) If a result of the monitoring performed pursuant to subsection (a) exceeds a contaminant's MCL or action level (for lead and copper), the SWSAP WRA shall collect another sample within 72 hours of notification of the result and have it analyzed for the contaminant as confirmation.

(1) For a contaminant whose compliance with its MCL or action level is not based on a running annual average, if the average of the initial and confirmation sample exceeds the contaminant's MCL or action level, or the confirmation sample is not collected and analyzed pursuant to this subsection, the SWSAP WRA shall notify the State Board and Regional Board within 24 hours and initiate weekly monitoring until four consecutive weekly results are below the contaminant's MCL or action level. If at any time a result causes, or would cause, a running four-week average of weekly results to exceed the contaminant's MCL or action level, the SWSAP WRA shall notify the State Board, each SWSAP PWS utilizing the augmented reservoir, and Regional Board within

24 hours and immediately suspend delivery of the recycled municipal wastewater to the augmented reservoir.

(2) For a contaminant whose compliance with its MCL is based on a running annual average, if the average of the initial and confirmation sample exceeds the contaminant's MCL, or a confirmation sample is not collected and analyzed pursuant to this subsection, the SWSAP WRA shall initiate weekly monitoring for the contaminant until the running four-week average of results no longer exceeds the contaminant's MCL.

(A) If the running four-week average exceeds the contaminant's MCL, a SWSAP WRA shall describe the reason(s) for the exceedance and provide a schedule for completion of corrective actions in a report submitted to the State Board and Regional Board no later than 45 days following the quarter in which the exceedance occurred.

(B) If the running four-week average exceeds the contaminant's MCL for sixteen consecutive weeks, a SWSAP WRA shall notify the State Board, Regional Board, and each SWSAP PWS utilizing the augmented reservoir within 48 hours of knowledge of the exceedance and, if directed by the State Board or Regional Board, suspend delivery of the recycled municipal wastewater to the augmented reservoir.

(d) If the annual average of the results of the monitoring performed pursuant to subsection (b) exceeds a contaminant's secondary MCL in Table 64449-A or the upper limit in Table 64449-B, the SWSAP WRA shall initiate quarterly monitoring of the recycled municipal wastewater for the contaminant and, if the running annual average of quarterly-averaged results exceeds a contaminant's secondary MCL or upper limit, describe the reason(s) for the exceedance and any corrective actions taken a report submitted to the Regional Board no later than 45 days following the quarter in which the exceedance occurred, with a copy concurrently provided to the State Board. The annual monitoring in subsection (b) may resume if the running annual average of quarterly results does not exceed a contaminant's secondary MCL or upper limit.

(e) If four consecutive quarterly results for asbestos are below the detection limit in Table 64432-A for asbestos, monitoring for asbestos may be reduced to one sample every three years. Quarterly monitoring shall resume if asbestos is detected.

NOTE: Authority cited: Sections 13521 and 13562, Water Code; and Section 116271, Health and Safety Code. Reference: Sections 13520, 13522, 13522.5, 13523, 13523.1, 13524, 13560, 13561, 13564, 13565 and 13567, Water Code; and Section 116551, Health and Safety Code.

Adopt Section 60320.320 as follows:

§60320.320. Additional Chemical and Contaminant Monitoring.

(a) Each quarter, a SWSAP WRA shall sample and analyze the recycled municipal wastewater delivered to the augmented reservoir, for the following:

(1) Priority Toxic Pollutants (chemicals listed in 40 CFR section 131.38, “Establishment of numeric criteria for priority toxic pollutants for the State of California”, as the foregoing may be amended) specified by the State Board, based on the State Board’s review of the SWSAP engineering report; and

(2) Chemicals specified by the State Board, based on its review of the SWSAP engineering report, the results of the augmented reservoir monitoring conducted pursuant to section 60320.326, and the results of the assessment performed pursuant to section 60320.306(b)(1).

(b) Each quarter, a SWSAP WRA shall sample and analyze the recycled municipal wastewater delivered to the augmented reservoir for State Board-specified chemicals having notification levels (NLs). If a result exceeds an NL, within 72 hours of notification of the result the SWSAP WRA shall collect another sample and have it analyzed for the contaminant as confirmation. If the average of the initial and confirmation sample exceeds the contaminant’s NL, or a confirmation sample is not collected and analyzed pursuant to this subsection, the SWSAP WRA shall initiate weekly monitoring for the contaminant until the running four-week average of results does not exceed the NL and the State Board and Regional Board determine weekly monitoring may cease.

(1) If a running four-week average exceeds the contaminant's NL, the SWSAP WRA shall describe the reason(s) for the exceedance and provide a schedule for completion of corrective actions in a report submitted to the Regional Board no later than 45 days following the quarter in which the exceedance occurred, with a copy concurrently provided to the State Board.

(2) If a running four-week average exceeds the contaminant's NL for sixteen consecutive weeks, the SWSAP WRA shall notify the State Board, Regional Board, and each SWSAP PWS utilizing the augmented reservoir within 48 hours of knowledge of the exceedance.

(c) A SWSAP WRA may reduce monitoring for the chemicals in this section to once each year following State Board written approval based on the State Board's review of no less than the most recent two years of results of the monitoring performed pursuant to this section.

(d) Each year, the SWSAP WRA shall monitor the recycled municipal wastewater delivered to the augmented reservoir for indicator compounds specified by the State Board or Regional Board based on the following:

(1) a review of the SWSAP WRA's engineering report;

(2) the inventory developed pursuant to section 60320.306(b)(4);

(3) an indicator compound's ability to characterize the performance of the treatment processes for removal of chemicals; and

(4) the availability of a test method for a chemical.

(e) A chemical or contaminant detected as a result of monitoring conducted pursuant to this section shall be reported to the State Board and Regional Board no later than the end of the quarter following the quarter in which the SWSAP WRA is notified of the results. If directed by the State Board or Regional Board, the SWSAP WRA shall monitor the recycled municipal wastewater delivered to the augmented reservoir for chemicals or contaminants detected pursuant to section 60320.326.

NOTE: Authority cited: Sections 13521 and 13562, Water Code; and Section 116271, Health and Safety Code. Reference: Sections 13520, 13522, 13522.5, 13523, 13523.1, 13524, 13560, 13561, 13564 and 13565, Water Code; and Section 116551, Health and Safety Code.

Adopt Section 60320.322 as follows:

§60320.322. SWSAP Operation Plan.

(a) Prior to operation of a SWSAP, a SWSAP WRA shall submit an Operation Plan to the State Board and Regional Board and receive written approval of the plan from the State Board and Regional Board. At a minimum, the Operation Plan shall identify and describe the operations, maintenance, analytical methods, monitoring necessary for the SWSAP to meet the requirements of this Article, and the reporting of monitoring results to the State Board and Regional Board. The plan shall also identify an on-going training program that includes the elements of the training required pursuant to subsection (b) of this section. A SWSAP WRA shall implement the Operation Plan and update the Operation Plan to ensure that the Operation Plan is, at all times, representative of the current operations, maintenance, and monitoring of the SWSAP. The SWSAP WRA shall make the Operation Plan immediately available to the State Board or Regional Board for review upon request.

(b) Prior to operation of a SWSAP, a SWSAP WRA shall, at a minimum, demonstrate to the State Board and Regional Board that the personnel operating and overseeing the SWSAP operations have received training in the following:

(1) The proper operation of the treatment processes utilized pursuant to sections 60320.302 and 60320.308;

(2) The California Safe Drinking Water Act and its implementing regulations; and

(3) The potential adverse health effects associated with the consumption of drinking water that does not meet California drinking water standards.

(c) At all times recycled municipal wastewater is delivered to the augmented reservoir, the SWSAP WRA shall ensure that all treatment processes are operated in a manner that provides optimal reduction of all chemicals and contaminants including:

(1) microbial contaminants;

(2) regulated contaminants identified in section 60320.312; and

(3) chemicals and contaminants required pursuant to section 60320.320.

(d) Within six months following the first year of optimizing treatment processes pursuant to subsection (c) and anytime thereafter operations are optimized that result in a change in operation, the SWSAP WRA shall update the SWSAP Operation Plan to include the changes in operational procedures and submit the Operation Plan to the State Board and Regional Board for review.

NOTE: Authority cited: Sections 13521 and 13562, Water Code; and Section 116271, Health and Safety Code. Reference: Sections 13520, 13522, 13522.5, 13523, 13523.1, 13524, 13560, 13561, 13564 and 13565, Water Code; and Section 116551, Health and Safety Code.

Adopt Section 60320.326 as follows:

§60320.326. Augmented Reservoir Monitoring.

(a) Prior to augmentation of a surface water reservoir using a SWSAP, the SWSAP WRA, in coordination with the SWSAP PWS, shall identify monitoring locations in the augmented reservoir, for State Board review and written approval. The identified monitoring locations must be representative, throughout the volume of the surface water reservoir impacted by the SWSAP, at a minimum, of the following:

(1) Differing water quality conditions across the horizontal extent of the surface water reservoir;

(2) Each level in the surface water reservoir corresponding to the depths in which water may be withdrawn; and

(3) The surface water reservoir's epilimnion and hypolimnion.

(b) Prior to augmentation of a surface water reservoir using a SWSAP, each month, the SWSAP WRA shall collect samples for no less than 24 consecutive months, from the monitoring locations established pursuant to subsection (a). The samples shall be analyzed for the contaminants in tables 64449-A and B of Chapter 15, total organic carbon (TOC), total nitrogen, total coliform bacteria, temperature, dissolved oxygen, chlorophyll a, total and dissolved phosphorus, and other State Board-specified chemicals and contaminants based on a review of the SWSAP WRA's engineering report and the results of the assessment performed pursuant to section 60320.306(b)(1).

(c) The SWSAP WRA shall continue to conduct monthly monitoring pursuant to subsection (b) for no less than the initial 24 months a SWSAP WRA is delivering recycled municipal wastewater to an augmented reservoir. In addition, the on-going monitoring required by this section shall include State Board-specified chemicals and contaminants based on SWSAP operations and the results of recycled municipal wastewater monitoring conducted pursuant to this Article.

(d) After completion of the 24-months of monthly monitoring conducted pursuant to subsection (c), a SWSAP WRA may apply to the State Board for reduced on-going monitoring. The SWSAP WRA shall obtain State-Board written approval prior to implementation of the reduced monitoring. The reduced on-going monitoring frequency may be no less than once every 12 months.

(e) Notwithstanding subsection (b), (c), and (d), a SWSAP WRA shall monitor for any State Board-specified chemicals or contaminants, at the locations and frequencies specified by the State Board.

NOTE: Authority cited: Sections 13521 and 13562, Water Code; and Section 116271, Health and Safety Code. Reference: Sections 13520, 13522, 13522.5, 13523, 13523.1, 13524, 13560, 13561, 13564 and 13565, Water Code; and Section 116551, Health and Safety Code.

Adopt Section 60320.328 as follows:

§60320.328. Reporting.

(a) By July 1st of each year, a SWSAP WRA shall provide a report to the State Board and Regional Board, and make a copy of the report available to each SWSAP PWS affected by the SWSAP. Each SWSAP PWS shall be notified by direct mail and/or electronic mail of the availability of the report. The report shall be prepared by an engineer licensed in California and experienced in the fields of wastewater treatment and public water supply. The report shall include the following:

(1) A summary of the SWSAP compliance status with the monitoring requirements and criteria of this Article during the previous calendar year;

(2) For any violations of this Article during the previous calendar year;

(A) the date, duration, and nature of the violation,

(B) a summary of any corrective actions and/or suspensions of delivery of recycled municipal wastewater to an augmented reservoir resulting from a violation, and

(C) if uncorrected, a schedule for and summary of all remedial actions;

(3) Any detections of monitored chemicals or contaminants, and any observed trends in the monitoring results of the augmented reservoir required pursuant to section 60320.326;

(4) A description of any changes in the operation of any unit processes or facilities;

(5) A description of any anticipated changes, along with an evaluation of the expected impact of the changes on subsequent unit processes;

(6) The estimated quantity and quality of the recycled municipal wastewater to be delivered for the next calendar year, as well as the quantity delivered during the previous three years; and

(7) A summary of the measures taken to comply with section 60320.306 and 60320.301(e), and the effectiveness of the implementation of the measures.

(b) No less frequently than every five years from the date of the initial approval of the engineering report required pursuant to section 60323, Article 7 of Chapter 3, the

SWSAP WRA shall update the engineering report to address any SWSAP changes from the previous engineering report, and submit the report to the State Board and Regional Board. The update shall include, but not be limited to, the anticipated increases in delivery of recycled municipal wastewater and a description of the expected impact the increase will have on the SWSAP WRA's ability to meet the requirements of this Article.

NOTE: Authority cited: Sections 13521 and 13562, Water Code; and Section 116271, Health and Safety Code. Reference: Sections 13520, 13522, 13522.5, 13523, 13523.1, 13524, 13560, 13561, 13564 and 13565, Water Code; and Section 116551, Health and Safety Code.

Adopt Section 60320.330 as follows:

§60320.330. Alternatives.

(a) A SWSAP WRA may use an alternative to a requirement in this Article if the SWSAP WRA:

(1) demonstrates to the State Board that the proposed alternative provides an equivalent or better level of performance with respect to the efficacy and reliability of the removal of contaminants of concern to public health, and ensures at least the same level of protection to public health;

(2) receives written approval from the State Board prior to implementation of the alternative; and

(3) if required by the State Board or Regional Board, conducts a public hearing on the proposed alternative, disseminates information to the public, and receives public comments.

(b) The demonstration in subsection (a)(1) shall include the results of a review of the proposed alternative by an independent scientific advisory panel, approved by the State Board, that includes, but is not limited to, a toxicologist, a limnologist, an engineer licensed in California with at least three years of experience in wastewater treatment and public drinking water supply, a microbiologist, and a chemist.

NOTE: Authority cited: Sections 13521 and 13562, Water Code; and Section 116271, Health and Safety Code. Reference: Sections 13520, 13522, 13522.5, 13523, 13523.1, 13524, 13560, 13561, 13564 and 13565, Water Code; and Section 116551, Health and Safety Code.

DIVISION 4, CHAPTER 17

ARTICLE 9. Indirect Potable Reuse: Surface Water Augmentation

Adopt Section 64668.05 as follows:

Section 64668.05. Application.

In addition to meeting the applicable requirements of this Chapter, a water supplier whose approved surface water source of supply is augmented utilizing a Surface Water Source Augmentation Project (SWSAP) shall meet the requirements of this Article and the applicable requirements of Article 5.3 of Chapter 3. For the purpose of this Article, the water supplier shall be referred to as a Surface Water Source Augmentation Project Public Water System (SWSAP PWS).

Adopt Section 64668.10 as follows:

Section 64668.10. General Requirements and Definitions.

(a) Unless noted otherwise, as used in this Article, the following terms are defined as follows:

(1) “Augmented Reservoir” has the same meaning as defined in section 60301.120, Article 1, Chapter 3.

(2) “Surface Water Source Augmentation Project” or “SWSAP” has the same meaning as defined in section 60301.851, Article 1, Chapter 3.

(3) “Surface Water Source Augmentation Project Public Water System” or “SWSAP PWS” has the same meaning as defined in section 60301.852, Article 1, Chapter 3.

(4) "Surface Water Source Augmentation Project Water Recycling Agency” or “SWSAP WRA" has the same meaning as defined in section 60301.853, Article 1, Chapter 3.

(b) Prior to using an augmented reservoir as a source of supply, a SWSAP PWS shall submit an application for a domestic water supply permit or permit amendment, and have an approved joint plan with a SWSAP WRA, as required pursuant to section

60320.301(a) of Article 5.3, Chapter 3. The SWSAP PWS shall revise its emergency plan and operations plan required pursuant to sections 64660(c)(2) and 64661 to include the elements of the joint plan and, at a minimum, include the means of providing an alternative source of domestic water supply, a State Board-approved treatment mechanism, or other actions to be taken, to ensure a reliable supply of water is delivered that meets all drinking water standards, in the event that the surface water from the augmented reservoir, as a result of a SWSAP:

(1) Could not be or has not been 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, as determined by the State Board; or

(3) Receives water that fails to meet the requirements of section 60320.308(d) of Article 5.3, Chapter 3.

(c) A SWSAP PWS shall demonstrate to the State Board and Regional Board that the SWSAP PWS has sufficient control over the operation of an augmented reservoir to ensure its ability to comply with the requirements of this Article and the applicable requirements in Article 5.3 of Chapter 3.

(d) A SWSAP PWS with knowledge of a SWSAP WRA failing to meet a requirement of the SWSAP WRA's permit or a requirement of Chapter 3, Article 5.3, shall immediately notify the State Board.

NOTE: Authority cited: Sections 13521 and 13562, Water Code; and Sections 116271 and 116375, Health and Safety Code. Reference: Sections 13520, 13522, 13522.5, 13523, 13523.1, 13524, 13560, 13561, 13564, 13565 and 13567, Water Code; and Sections 116275, 116365, 116375, 116385, 116390, 116400, 116525, 116530, 116535, 116540, 116550, 116551, and 116735, Health and Safety Code.

Adopt Section 64668.20 as follows:

§64668.20. Public Hearings.

A SWSAP PWS may not use an augmented reservoir without a domestic water supply permit or permit amendment for the use of the augmented reservoir as an approved surface water source, and unless the SWSAP PWS facilitates at least three public hearings held by the State Board and the SWSAP PWS does the following:

(a) In coordination with and with the assistance of the SWSAP WRA, develop information to be provided to the public at the public hearings and on the SWSAP PWS's Internet Web site. The information shall include, but not be limited to:

(1) descriptions of the SWSAP;

(2) identification of the municipal wastewater source for the SWSAP;

(3) descriptions of the treatment processes, monitoring, contingency plans; and

(4) the anticipated State Board and Regional Board permit provisions applicable to the SWSAP.

(b) Provide the State Board, for its review and written approval, the information the SWSAP PWS develops pursuant to subsection (a). Following the State Board's approval of the information, the SWSAP PWS shall place the information on a Web site managed and operated by the SWSAP PWS, and in a repository (such as a local public library) in a manner that provides at least 30 days of public access to the information prior to each public hearing. For each of the public hearings, the SWSAP PWS shall make copies of the information available to the public.

(c) No less than 30 days prior to placing the information required pursuant to subsections (a) and (b) in a repository, notify its customers and all public water systems that may receive drinking water impacted by the SWSAP of the following;

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

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

(3) the purpose of the public hearing and the repository, along with a brief description of the project,

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

(5) the date, time, and location of the public hearing; and

(d) Deliver the public notification required pursuant to subsection (c), in a manner to reach all public water systems and persons whose source of drinking water may be impacted by the SWSAP. The manner of delivery shall be by direct mail and using one or more of the following methods:

(1) local newspaper(s) publication of general circulation; and/or

(2) television and/or radio broadcast locally.

NOTE: Authority cited: Sections 13521 and 13562, Water Code; and Sections 116271 and 116375, Health and Safety Code. Reference: Sections 13520, 13522, 13522.5, 13523, 13523.1, 13524, 13560, 13561, 13564, 13565 and 13567, Water Code; and Sections 116275, 116365, 116375, 116385, 116390, 116400, 116530, 116535, 116550, 116551, and 116735, Health and Safety Code.

Adopt Section 64668.30 as follows:

§64668.30. SWSAP Augmented Reservoir Requirements.

(a) The SWSAP PWS shall ensure that prior to augmentation of a surface water reservoir by a SWSAP, the surface water reservoir to be used as an augmented reservoir was in operation as an approved surface water supply pursuant to this Chapter for a period of time sufficient to establish a baseline record of the surface water reservoir's raw water quality, including but not limited to the monitoring required pursuant to section 60320.326 of Chapter 3, and treated drinking water quality. A surface water reservoir shall have been operating as an approved surface water source for at least five years prior to receiving recycled municipal wastewater from a SWSAP, unless approved otherwise in writing by the State Board, but in no case less than two years.

(b) The SWSAP PWS shall ensure that a surface water reservoir used as an augmented reservoir has a minimum theoretical retention time of no less than that which has been approved by the State Board. Monthly, the SWSAP PWS shall calculate and record the theoretical retention time. The theoretical retention time shall be the value (in units of days) resulting from dividing the volume of water in the surface water reservoir at the end of each month, by the total outflow from the surface water reservoir during the corresponding month. The total outflow shall include, but not be limited to, all outflows and withdrawals from the surface water reservoir. An initial approved minimum theoretical retention time may be no less than 180 days.

(1) If a month's theoretical retention time is determined to be less than its approved theoretical retention time, the SWSAP PWS shall, by the end of the subsequent month, submit a report to the State Board and Regional Board describing the corrective actions to be taken to ensure future theoretical retention times will be no less than its approved theoretical retention time.

(2) A SWSAP PWS may apply to the State Board, for written approval, for a reduced on-going alternative minimum theoretical retention time of less than 180 days, but no less than 60 days. The SWSAP PWS's application shall include all information requested by the State Board for its consideration of a proposed alternative minimum theoretical retention time, including the following:

(A) Evidence that the SWSAP PWS and SWSAP WRA have reliably and consistently met the requirements of this Article and Article 5.3, Chapter 3, under varying operating conditions;

(B) At the proposed alternative minimum theoretical retention time; the maximum anticipated recycled municipal wastewater flow to the surface water reservoir, the total anticipated outflows from the reservoir, and the total available flows of approved reservoir sources of supply;

(C) The maximum percent, by volume, of recycled municipal wastewater that will be delivered to the surface water reservoir during any 24-hour period, in accordance with subsection (c), at the proposed alternative minimum theoretical retention time;

(D) A description of total proposed treatment and total $\log_{10}$ reduction for enteric virus, *Giardia* cysts, and *Cryptosporidium* oocysts. For proposed alternative minimum theoretical retention times less than 120 days, no less than one $\log_{10}$ reduction of such pathogens beyond that otherwise required pursuant to this Article and Article 5.3, Chapter 3, shall be provided;

(E) The ability to adequately respond to potential SWSAP treatment failures in a timely manner, such that there is no interruption of drinking water, meeting all applicable standards, supplied to customers; and

(F) A demonstration that the alternative minimum theoretical retention time provides, based on information provided pursuant to this paragraph (paragraph (2)), an equivalent or better level of protection of public health than otherwise required pursuant to this Article and Article 5.3, Chapter 3. If required by the State Board, the SWSAP PWS's demonstration shall include a review by an independent scientific advisory panel approved by the State Board.

(c) Prior to augmentation and whenever requested to do so by the State Board, the SWSAP PWS shall demonstrate to the State Board, utilizing tracer studies and hydrodynamic modeling, that at all times under all operating conditions, the volume of water withdrawn from the augmented reservoir to be ultimately supplied for human consumption contains no more than:

(1) one percent, by volume, of recycled municipal wastewater that was delivered to the surface water reservoir during any 24-hour period, or

(2) ten percent, by volume, of recycled municipal wastewater that was delivered to the surface water reservoir during any 24-hour period, with the recycled municipal wastewater delivered by the SWSAP WRA having been subjected to additional treatment producing no less than a 1-$\log_{10}$ reduction of enteric virus, *Giardia* cysts, and *Cryptosporidium* oocysts, as noted pursuant to section 60320.308(a)(2). With regard to the additional treatment:

(A) The additional treatment need not be a unique type of process from other treatment processes utilized by the SWSAP WRA to meet the requirements of section 60320.308, but shall be independent of and not reliant on the other treatment processes.

(B) The SWSAP PWS, in consultation with the SWSAP WRA, shall obtain the additional treatment process information necessary for demonstrating that the requirements of section 60320.308(a)(2) of Chapter 3 and this paragraph will be met.

(d) To verify that the requirements of subsection (c) are being met, within the first six months of operation, under hydraulic conditions representative of normal SWSAP operations, the SWSAP PWS shall initiate a tracer study utilizing an added tracer. The results of the tracer study shall be used to validate the hydrodynamic modeling required in subsection (c). Prior to performing the tracer study, the SWSAP PWS shall submit a tracer study protocol for State Board review and written approval. The SWSAP PWS shall perform the verification required by this subsection whenever requested by the State Board.

(e) Notwithstanding a change in operation allowed pursuant to the SWSAP PWS's domestic water supply permit, prior to initiating a change in operation, including physical changes to the surface water reservoir, that may impact the hydraulic characterization utilized to determine compliance with the requirements of this section, the SWSAP PWS shall notify the State Board and;

(1) demonstrate that the hydraulic characterization used to comply with this section remains valid under the changed operation, or

(2) if requested by the State Board, demonstrate compliance pursuant to this section under the new hydraulic conditions.

(f) Unless directed otherwise by the State Board, a SWSAP PWS shall utilize an independent scientific advisory panel to meet the requirements of this section pertaining to the hydraulic characterization of the reservoir, including tracer study verifications and hydraulic modeling used to demonstrate compliance with subsection (c). The independent scientific advisory panel shall be approved by the State Board and include, at a minimum, a limnologist with experience modelling the hydraulic characterization of surface water reservoirs, or a limnologist and an individual with experience modelling the hydraulic characterization of surface water reservoirs. The SWSAP PWS shall allow

State Board representatives, as guests, to join all independent scientific advisory panel meetings and discussions.

(g) Prior to augmentation of a surface water reservoir using a SWSAP, a SWSAP PWS shall submit a plan, for State Board review and approval, describing the actions the SWSAP PWS will take to assess and address potential impacts resulting from the introduction of advanced treated water into the SWSAP PWS's surface water treatment plant and, indirectly, into the drinking water distribution system. At a minimum, the plan shall address:

(1) maintaining chemical and microbial stability in the drinking water distribution system as the drinking water quality changes with anticipated increasing fractions of advanced treated water;

(2) maintaining treatment effectiveness throughout the surface water treatment plant as the source water quality changes with anticipated increasing fractions of advanced treated water in the reservoir;

(3) assessments to be performed prior to and during operation of the SWSAP with respect to paragraphs (1) and (2); and

(4) assessment outcomes of which the SWSAP PWS will notify the State Board.

NOTE: Authority cited: Sections 13521 and 13562, Water Code; and Sections 116271 and 116375, Health and Safety Code. Reference: Sections 13520, 13522, 13522.5, 13523, 13523.1, 13524, 13560, 13561, 13564, 13565 and 13567, Water Code; and Sections 116275, 116365, 116375, 116385, 116390, 116400, 116530, 116535, 116550, 116551, and 116735, Health and Safety Code.

APPENDIX A – DOCUMENTS RELIED UPON

Reference No. 2

Peer Review mandated via Health and Safety Code section 57004: Documents pertaining to the State Board's submittal for peer review and peer reviewer's comments may be accessed via http://www.swrcb.ca.gov/water_issues/programs/peer_review/.

Portland State UNIVERSITY

Masseh College of Engineering and Computer Science
Department of Civil and Environmental Engineering
Post Office Box 751 503-725-4276 tel
Portland, Oregon 97207-0751 503-725-5950 fax
wellss@pdx.edu

May 5, 2016

Gerald W. Bowes, Ph.D.
Manager, Cal/EPA Scientific Peer Review Program
Office of Research, Planning and Performance
State Water Resources Control Board
1001 I Street, 16th Floor
Sacramento, CA 95814

Dear Dr. Bowes:

Attached is the external peer review for the proposed uniform water recycling criteria for indirect potable reuse through surface water augmentation. Initially I had thought that review point 6 would be under my purview, but it is more linked to review points 3-5 than 7-10 which form the basis of my expertise. Please let me know if you have questions on the enclosed review.

Truly,

Scott A. Wells, Ph.D., P.E.
Professor of Civil and Environmental Engineering

Review of the proposed uniform water recycling criteria for indirect potable reuse through surface water augmentation

Scott A. Wells, Ph.D. P.E.

May 5, 2016

Contents

Introduction

This review is based on points 7-10 in the Scientific Assumptions, Findings and Conclusions to be Addressed by Peer Reviewers:

> 7. The reservoir will enhance the reliability of a SWA project by mixing each portion of the recycled water flow, including any off-spec recycled water, with a large volume of water that meets the water quality requirements for a surface water source. (Ref §64668.30. SWSAP Augmented Reservoir Requirements)
>
> 8. Mixing a batch of inadequately treated recycled water in the reservoir with other water such that a 24-hour batch of off-spec water cannot be more than 10% of the water withdrawn from the reservoir at any time is a significant reliability benefit for a potable reuse project. (Ref §64668.30. SWSAP Augmented Reservoir Requirements)
>
> 9. Hydrodynamic modeling is a means of characterizing the capacity of a reservoir to attenuate the effect of treatment failures by mixing off-spec water with reservoir water. (Ref §64668.30. SWSAP Augmented Reservoir Requirements)
>
> 10. The theoretical retention time (TRT) of the reservoir is a valuable measure of the reservoir's potential to provide the required mixing and provide a meaningful barrier to inadequately treated recycled water reaching the public water system (Ref §64668.30. SWSAP Augmented Reservoir Requirements)

A short comment on each review point will be made followed by two recommendations.

Comments on Review Points 7-10

Reservoirs enhance reliability of SWA project

The storage reservoir provides a buffer to the treatment plant effluent allowing for mixing to reduce the impact of potential pathogens. The issue is how effective is the storage reservoir in providing a public health benefit when the discharging wastewater treatment plant no longer is able to provide adequate treatment. This logically leads to criteria for the next 3 points, 8-10, in the list of review points for consideration.

Mixing untreated recycled water in reservoir

Setting a minimum dilution requirement provides a buffer for the wastewater discharge especially since this rule must also be in addition to the log reduction, i.e., at least a 9-log10 enteric virus reduction, 8-log10 Giardia cyst reduction, and 9-log10 Cryptosporidium oocyst reduction (§60320.308). The minimum dilution is set at 1% by volume or 10% with additional wastewater treatment. The basic idea is to provide a minimum dilution requirement for the untreated or 'off-spec' wastewater which is reasonable.

Hydrodynamic modeling used to characterize the reservoir

Hydrodynamic modeling of the reservoir and a tracer study to verify the model is an essential part of determining dilution estimates. Even though the tracer study can only evaluate a limited set of conditions, the hydrodynamic model can be used to explore different scenarios under different meteorological and hydrologic periods. A series of guidelines though should be specified with regard to tracer studies and the modeling itself. These include requiring an outside peer review of the model study and dye study and setting worst-case scenarios for performing a dye study, for example during stratification period in the summer when hydrologic inflows may be low and water consumption is high.

Theoretical detention time potential of reservoir

§64668.30 states:

> (b) The SWSAP PWS shall ensure that a surface water reservoir used as an augmented reservoir has a theoretical retention time of no less than six months. Monthly, the SWSAP PWS shall calculate and record the theoretical retention time. The theoretical retention time shall be the value (in units of months) resulting from dividing the volume of water in the surface water reservoir at the end of each month, by the total outflow from the surface water reservoir during the corresponding month. The total outflow shall include, but not be limited to, all outflows and withdrawals from the surface water reservoir.

It is unclear why there is a theoretical detention time of 6 months for the overall reservoir since the overall retention time may or may not have any relationship with the amount of dilution occurring in a reservoir system. The rule implies that this provides more protection. Even though this metric is simple, the retention time of the reservoir is often not predictive of being in compliance with project treatment goals.

Recommendations

My recommendations are as follows:

1. Eliminate the theoretical retention time of a minimum of 6 months as a criterion for compliance.
2. Add the need for external peer-review for the tracer and hydrodynamic modeling studies.

The reasons for these recommendations are discussed below.

Theoretical retention time of a minimum of 6 months as a criterion for compliance

Since a theoretical retention time (TRT) of a reservoir of a minimum of 6 months may not be related to meeting the standards for dilution compliance, this requirement is not protective. Since hydrodynamic modeling is already required, the TRT of a reservoir being a minimum of 6 months does not provide any additional protective benefit.

The TRT is computed from the following formula:

$$TheoreticalRetentionTime = \frac{Reservoir\ volume}{Total\ outflow}$$

Hence, a low theoretical retention time may imply (1) a low reservoir volume and hence low dilution capacity, or (2) a large total outflow (possibly with a large inflow) and hence a high dilution capacity since the treatment plant inflow is mixed with large inflows. But if the reservoir volume decreases significantly during high outflows (implying small inflows), this could make meeting dilution requirements even more difficult.

Because of this ambiguity in using the TRT, it does not provide any redundancy in protection and as a result could be omitted from the surface water rule.

As an example, consider a hypothetical case for a reservoir in California that is evaluating adding a wastewater source to a reservoir. The reservoir has multiple withdrawals at the dam including a municipal water withdrawal (ranging from 2-10 m^3/s). A wastewater inflow was added to a reservoir model with a conservative tracer to evaluate predicted dilution at the municipal intake and explore the issue of whether the theoretical detention time is a useful criterion for protecting the municipal water intake from too little dilution from the wastewater discharge. The volume of the reservoir is approximately 7E8 m3 with average inflows and outflows averaging about 90 m^3/s for the high flow year and 51 m^3/s for the low flow year. Figure 1 shows the plan view segments (not geo-referenced) and the location of the dam, the 3 model branches, and the wastewater inflow. The wastewater inflow is located about 20 km from the dam with a constant flow rate of 1 m^3/s and an effluent tracer concentration of 100 mg/l. Figure 2 shows a side view of the vertical layers of the main upper branch ending at the dam.

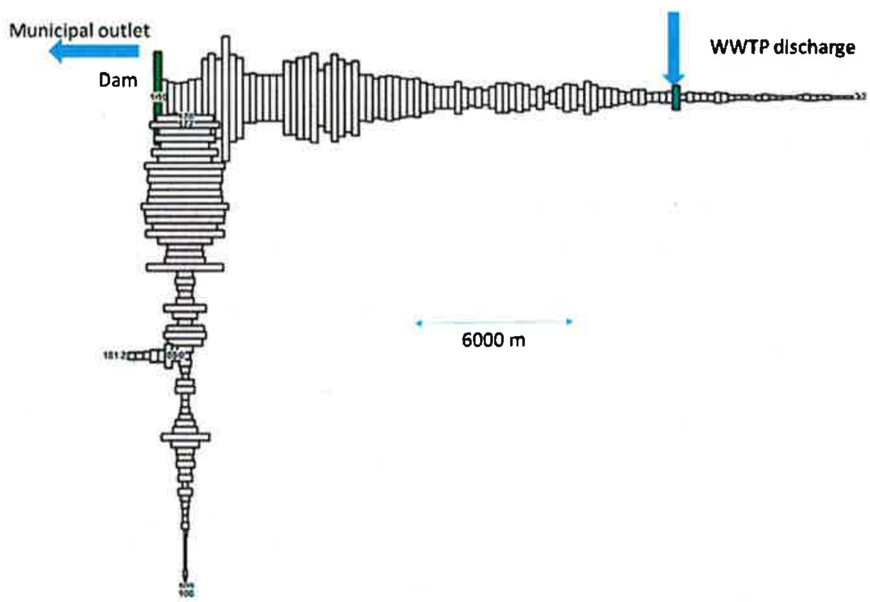


Figure 1 Segment grid for 2D CE-QUAL-W2 reservoir. Segment surface widths are shown. The green downstream section is the dam where the municipal outlet is located.

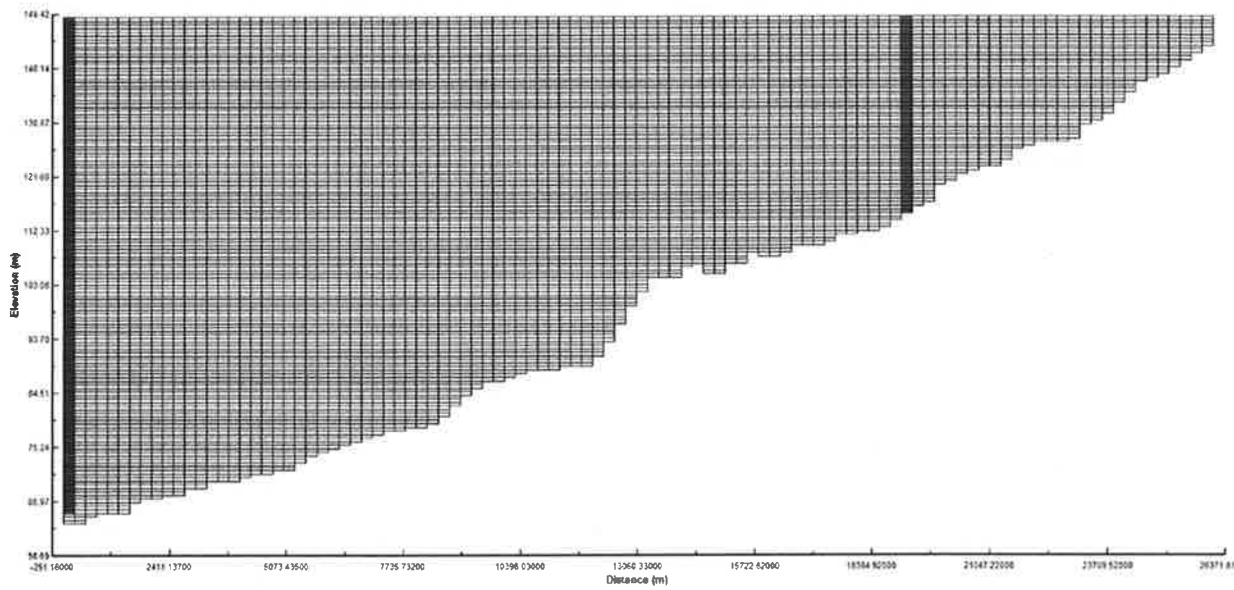


Figure 2. Side view of vertical layers in the upper model branch. The dam (shaded in green) is on the downstream end (left side) and the treatment plant discharge is about 20 km upstream of the dam (also shaded in green).

The model assumes well-mixing of the wastewater in the width of the reservoir as if there was a diffuser that mixed the waste across the channel. The wastewater was assumed to be at 15°C, and the inflow was placed at a corresponding vertical density level at this part of the reservoir. This is a hypothetical discharge but includes using realistic reservoir inflow and outflow rates and meteorological conditions. Model predictions of temperature stratification and destratification dynamics in the reservoir are realistic.

Note Figure 3 where the predicted concentration of wastewater in the water treatment plant influent is predicted during a calendar year (2003) where the yearly average detention time is only 3 months. A 1 mg/l influent concentration in the water treatment plant is a mixing of 1/100 or 1%. If this is the goal, then for most of the year, until October (around Julian day 1000) the 1% guideline is met even with a TRT less than 6 months. The large spike in October above 1% occurs as a result of high outflows, low inflows (low mixing potential), and the subsequent lowering of water levels. Figures 4 and 5 show the thermal regime and concentration of wastewater effluent in the reservoir during this time period (around October 2003) where mixing dilution is over 1%. During this period, inflows are low, the wastewater treatment plant discharge collects near the bottom of the discharge point and is drawn out by the high outflow. This shows that TRT is not a predictor of low mixing efficiency but could imply just the opposite as seen in the beginning of the year (January-June). As these processes are site-specific and complicated by interplays of inflow, storage, outflow and stratification conditions, the TRT is not an adequate predictor for protection of the water intake.

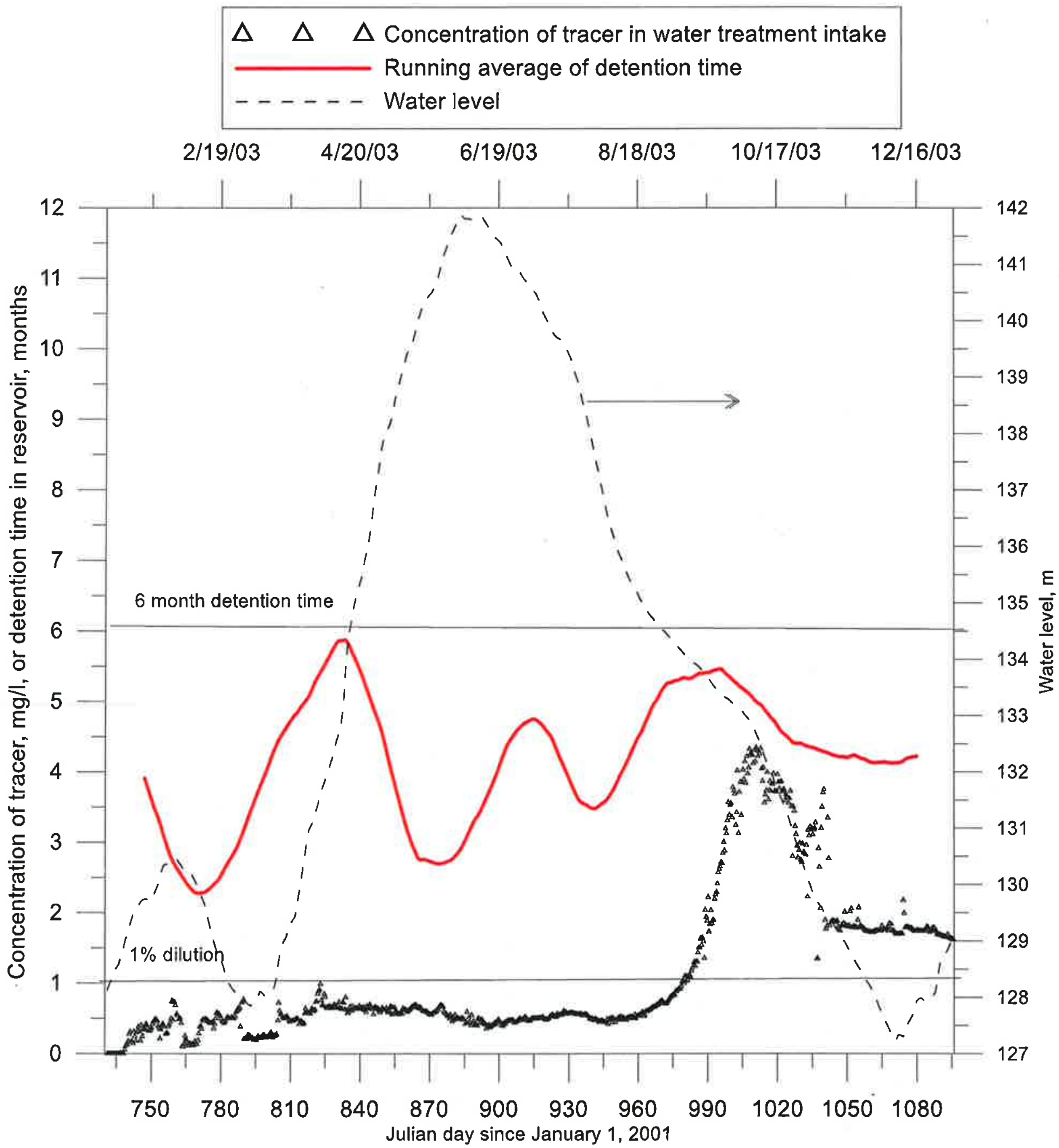


Figure 3. Predicted concentration at municipal inlet, detention time and water level in reservoir with high yearly inflows in 2003.

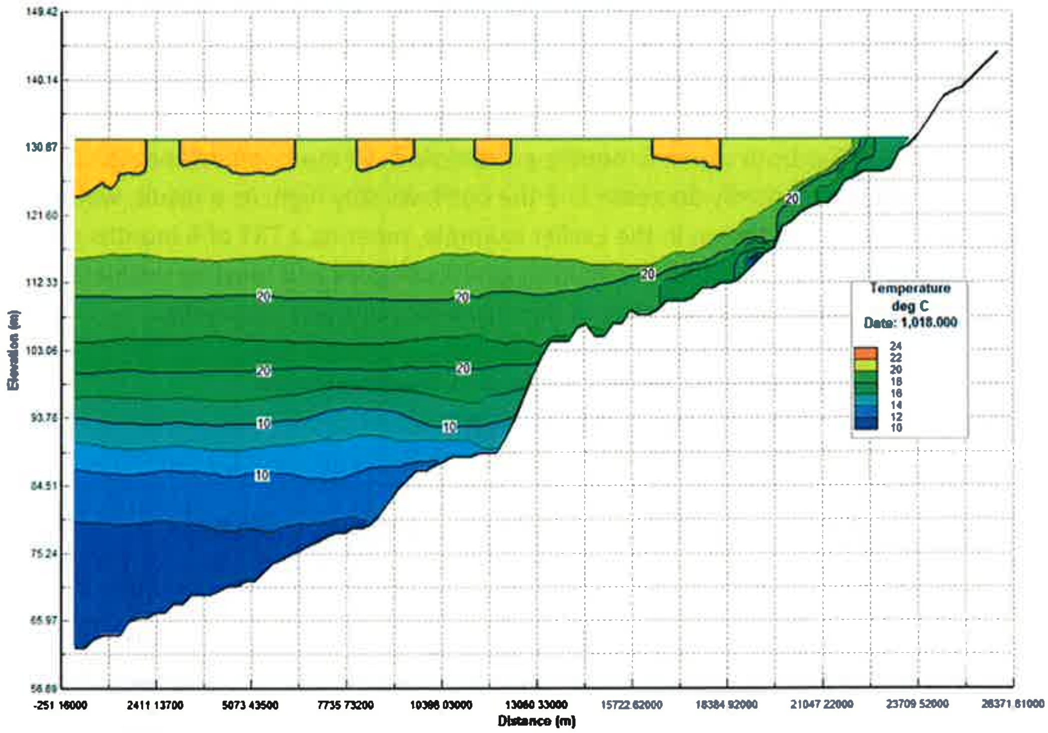


Figure 4. Temperature regime in October 2003.

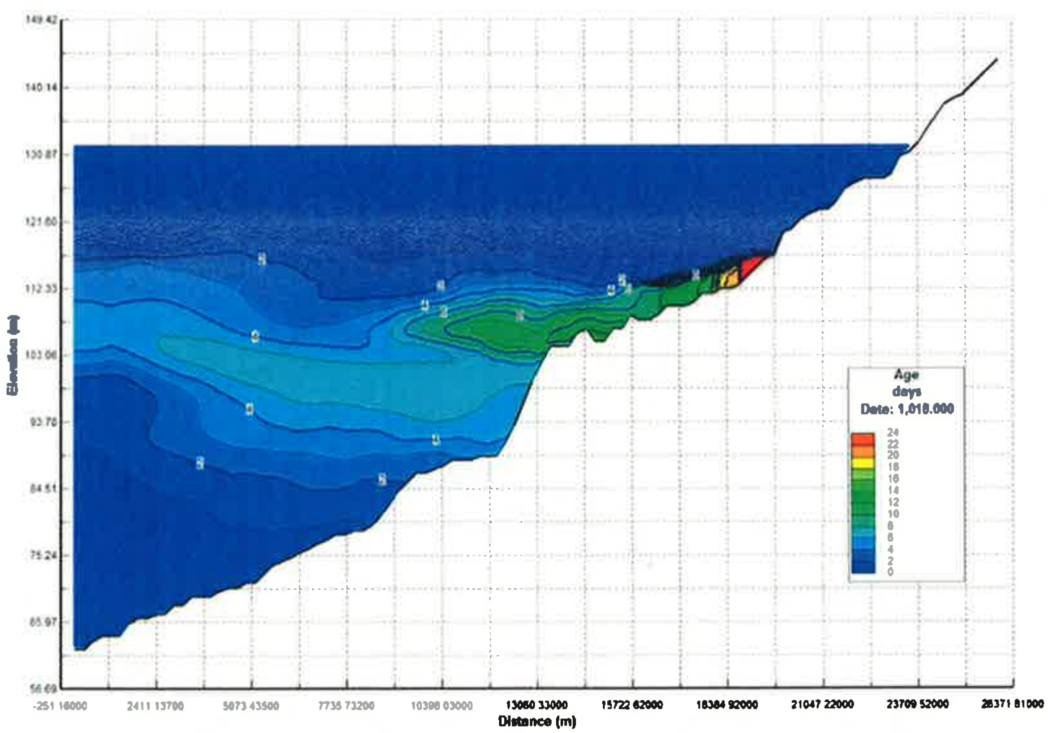


Figure 5. Concentration of tracer in reservoir in October 2003. Inflow concentration was at 100 mg/l and at a temperature of 15°C.

Consider another example for the same reservoir but during a different hydrological regime where the average yearly detention time is 5.3 months. In Figure 6, the wastewater tracer concentration in the water intake is shown along with retention time and water level over a calendar year (2001). The 1% mixing of wastewater effluent to influent water goal is met until about Julian day 180 (June 2001). During this period of time the TRT is both above 6 months and below it. Of more importance is that late in the year, after June, the inflows markedly decrease and the outflows stay high. As a result, water levels decrease significantly. Hence, as shown in the earlier example, meeting a TRT of 6 months is not related to meeting the 1% mixing goal. Meeting the dilution goal is complex and must be evaluated with complex mathematical models and an understanding of flow dynamics of these reservoirs.

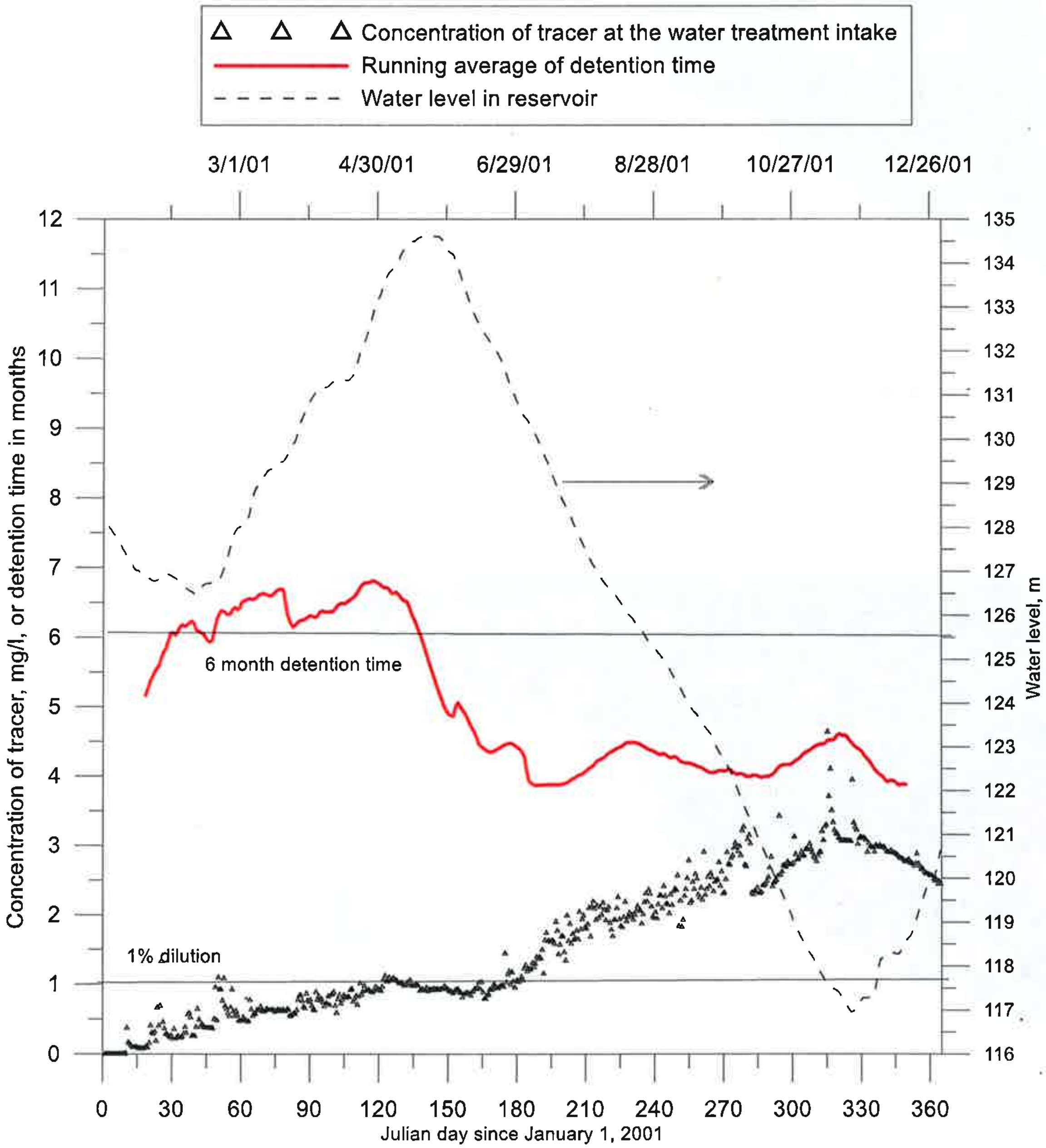


Figure 6. Predicted concentration at municipal inlet, detention time and water level in reservoir with average yearly inflows.

External peer-review for the tracer and hydrodynamic modeling studies

As demonstrated in the prior example, hydrodynamic modeling and analyses of dilution capacity are complex and require external peer-review.

Estimating the potential mixing of wastewater entering a water treatment intake means understanding the physical path of the wastewater flow, the potential for short-circuiting, and the impacts of stratification and water level changes on dilution efficiency. This requires (1) dilution/mixing tests and (2) hydrodynamic modeling.

Mixing/dilution tests

Sometimes performing mixing tests on reservoirs can be challenging because of issues (real or perceived) with toxicity (Smart, 1984) in an active drinking water supply. During the San Vicente Reservoir tests (Flow Science, 2012a), lanthanum chloride was used as the tracer.

For a tracer released with the wastewater effluent, the concentration of the tracer peak and the timing of the peak at the water intake show the mixing potential for the specific situation of the test. The usefulness of these data is that this information can be used to verify the performance of a numerical model. The hydrodynamic model can then be used to explore other critical inflow, water level, hydrological and/or meteorological conditions.

Hydrodynamic modeling

Models for water quality and hydrodynamic studies have been used frequently in assessing how to meet water quality standards and in assessing water body performance in meeting water quality targets. There are many models available which have been used in these studies. Lists of models that are used have been cited in Janssen et al. (2015) and Mooij et al. (2014) besides others that are available. These models can range from fully mixed to 1D vertical to 2D longitudinal-vertical or 2D horizontal to fully 3D models of hydrodynamics and water quality.

Because of the importance of computing dilution in the receiving reservoir, fully-mixed and 1D models over-average or over-mix inflows in the receiving reservoir and would not be conservative in estimating dilution. Depending on the circumstances of the reservoir and the wastewater inflow, 2D longitudinal-vertical (and quasi-3D), 2D horizontal (if receiving waters do not stratify), and 3D models could be used to predict dilution if care is taken to understand the implications of each model on predicted dilution within the reservoir. A verification of the model dilution with a tracer study would be an important exercise to assess the model's ability to capture the correct dilution.

Because of the complexities of hydrodynamics in the receiving reservoir during tracer tests and modeling studies, peer review of the tracer test and modeling study is recommended as part of the rule for compliance.

Good modeling practice (Van Waveren, et. al. 2000) includes checklists for peer review that can be very helpful in evaluating the applicability of a model to a given application including mass balance checks. Very few models include checks of mass balances within their code. These tests if not provided by the model, need to be provided by the model user to verify and validate the modeling study. This is the minimum approach to ensuring model accuracy. The National Research Council (2007) includes "peer review" as part of the model evaluation process and recommends evaluation of any modeling tool for the following items:

1. Get the correct result
2. Get the correct result for the right reasons
3. Transparency

EPA (2015) also includes guidelines for peer review and states the reason for the peer review of the model:

> "Peer review is conducted to ensure that activities are technically defensible, competently performed, properly documented and consistent with established quality criteria. Peer review is an in-depth assessment of the assumptions, calculations, extrapolations, alternate interpretations, methodology, acceptance criteria and conclusions pertaining to the scientific or technical work product, and of the documentation that supports them."

As an example of what type of peer review comments could be provided, a cursory review of the San Vicente Reservoir study by Flow Science (2012a, 2012b) is provided below.

Example of San Vicente Reservoir Study

The documentation for peer review provided one example of a modeling approach from San Vicente Reservoir conducted by Flow Science (2012a, 2012b). They used the 3D model ELCOM/CAEDYM after initially using the 1D model DYRESM. A cursory review of this study found several aspects that could be used as a basis for further analysis or investigation:

1. The ELCOM hydrodynamic model used in this study is based on the model of Casulli and Cheng (1992) and uses the hydrostatic assumption. Whenever outlet hydraulics are an important part of withdrawals and the model uses the hydrostatic assumption, in order to obtain the correct water quality for reservoir outlets (such as inflows to a water treatment plant) some form of selective withdrawal scheme should be used (Jin-suo et al., 2013).
2. Sensitivity to the turbulence model is also an important part of a complex 2D or 3D model. It is not clear in the Flow Science (2012a) model whether a simple eddy viscosity model where the user specifies eddy viscosity or a more advanced model was used. Sensitivity of the model results to the type of eddy viscosity used is usually critical in predicting internal currents in the model. Documentation on that sensitivity would ensure understanding the idea of getting the right result for the right reason and whether the model is able to predict a wide-variety of hydrologic and flow conditions.
3. A mass balance check that the model conserves mass of the tracer is an important aspect of verifying the conservation of mass principle as employed in the numerical model.

References

Annette B.G. Janssen, George B. Arhonditsis, Arthur Beusen, Karsten Bolding, Louise Bruce, Jorn Bruggeman, Raoul-Marie Couture, Andrea S. Downing, J. Alex Elliott, Marieke A. Frassl, Gideon Gal, Daan J. Gerla, Matthew R. Hipsey, Fenjuan Hu, Stephen C. Ives, Jan H. Janse, Erik Jeppesen, Klaus D. Jöhnk, David Kneis, Xiangzhen Kong, Jan J. Kuiper, Moritz K. Lehmann, Carsten Lemmen, Deniz Özkundak, Thomas Petzoldt, Karsten Rinke, Barbara J. Robson, René Sachs, Sebastiaan A. Schep, Martin Schmid, Huub Scholten, Sven Teurlincx, Dennis Trolle, Tineke A. Troost, Anne A. Van Dam, Luuk P.A. Van Gerven, Mariska Weijerman, Scott A. Wells, Wolf M. Mooij (2015) Exploring, exploiting and evolving diversity of aquatic ecosystem models: a community perspective, Aquatic Ecology, Volume 49, Issue 4 (2015), Pages 513-548, DOI 10.1007/s10452-015-9544-1.

Casulli, Vincenzo and Cheng, Ralph T. (1992), "Semi-implicit finite difference methods for three-dimensional shallow water flow," International Journal for Numerical Methods in Fluids, 15, 629-48.

Cole, T. and Wells, S.A. (2014) "CE-QUAL-W2: A Two-Dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model, Version 3.71" Department of Civil and Environmental Engineering, Portland State University, Portland, OR.

Flow Science (2012a) Reservoir Augmentation Demonstration Project: Limnology and Reservoir Detention Study of San Vicente Reservoir - Calibration of the Water Quality Model, Prepared for City of San Diego 600 B Street, Suite 600, San Diego, CA 92101.

Flow Science (2012b) Water Purification Demonstration Project: Limnology and Reservoir Detention Study of San Vicente Reservoir - Hydrodynamic Modeling Study, Prepared for City of San Diego 600 B Street, Suite 600, San Diego, CA 92101.

Jin-suo Lu, Wei Zhang & Xian Guo (2013) Extensive Selective Withdrawal Theory and Verification using CFD Simulation, Engineering Applications of Computational Fluid Mechanics, 7:4, 433-440

Mooij WM, Trolle D, Jeppesen E, Arhonditsis G, Belolipetsky PV, Chitamwebwa DBR, Degermendzhy AG, DeAngelis DL, De Senerpont Domis LN, Downing AS, Elliott JA, Fragoso Jr CR, Gaedke U, Genova SN, Gulati RD, Håkanson L, Hamilton DP, Hipsey MR, 't Hoen J, Hülsmann S, Los FJ, Makler-Pick V, Petzoldt T, Prokopkin IG, Rinke K, Schep SA, Tominaga K, Van Dam AA, Van Nes EH, Wells SA and Janse JH (2010) "Challenges and opportunities for integrating lake ecosystem modelling approaches," Aquatic Ecology: DOI:10.1007/s10452-010-9339-3, 44(3): 633-667.

National Research Council (2007) Models in Environmental Regulatory Decision Making, Committee on Models in the Regulatory Decision Process, Board on Environmental Studies and Toxicology, Division on Earth and Life Studies, National Academy of Sciences, Washington D.C.

Smart, P. L. (1984) A review of the toxicity of twelve fluorescent dyes used for water tracing. *The National Speleological Society Bulletin*, 46: 21, 1984.

Van Waveren, R. H., S. Groot, H. Scholten, F. Van Geer, H. Wösten, R. Koeze and J. Noort (2000) Good Modelling Practice Handbook, STOWA report 99-05 Dutch Dept. of Public Works, Institute for Inland Water Management and Waste Water Treatment, report 99.036 ISBN 90-5773-056-1

U.S. Environmental Protection Agency (2015) Peer Review Handbook, 4th Edition, Prepared for the U.S. Environmental Protection Agency under the direction of the EPA Peer Review Advisory Group Science and Technology Policy Council U.S. Environmental Protection Agency Washington, D.C.

UCLA Engineering
HENRY SAMUELI SCHOOL OF ENGINEERING AND APPLIED SCIENCE
Civil and Environmental Engineering Department

Shaily Mahendra, Ph.D.
Associate Professor & Samueli Fellow
5732C Boelter Hall
Los Angeles, CA 90095
Telephone: (310) 794-9850
E-mail: mahendra@seas.ucla.edu

To: Dr. Gerald W. Bowes
Manager, Cal/EPA Scientific Peer Review Program
Office of Research, Planning and Performance
State Water Resources Control Board
1001 "I" Street, 16th Floor
Sacramento, California 95814

From: Dr. Shaily Mahendra
Associate Professor and Samueli Fellow
Department of Civil and Environmental Engineering
5732C Boelter Hall
University of California
Los Angeles, CA 90095-1593

Date: June 10, 2016

External Peer Review of Proposed Uniform Water Recycling Criteria for Indirect Potable Reuse Through Surface Water Augmentation

I have carefully reviewed the "Description of scientific assumptions, findings, and conclusions of the Proposed Uniform Water Recycling Criteria for Indirect Potable Reuse Through Surface Water Augmentation" in the Appendix 2. I have also read the Excerpts of California Water Code sections 13560-13569 (Appendix 4) and the Draft Regulations (Appendix 5). I have followed the guidance to external scientific reviewers provided by the staff under the Supplement to Cal/EPA External Scientific Peer Review Guidelines - Exhibit F in Cal/EPA Interagency Agreement with University of California. My review will address the scientific assumptions, findings, and conclusions numbers 1 and 2 as well as the overall perspective.

Please feel free to contact me if there are any questions I may answer.

Respectfully submitted,

Shaily Mahendra

Shaily Mahendra
Associate Professor
UCLA Engineering

1. *Reducing concentrations of organic constituents of emerging concern (CECs) to levels found in high quality conventional sources is a water quality objective for those constituents that is adequately protective of public health. (Ref §60320.302. Advanced Treatment Criteria)*
   The challenges in creating enforceable regulatory limits on contaminants including 1,4-dioxane and NDMA are extremely difficult due to the evolving toxicological and analytical knowledge on these CECs. In general, the approach used for reducing the CEC concentrations appears reasonable given the limited data available regarding their occurrence and public health impacts. The comparison with high quality conventional sources is presented well, but the selection of 10mg/L organic carbon needs to be better supported. Furthermore, municipal wastewater effluent discharges are a potential source of 1,4-dioxane in receiving water bodies.[1] Operating under the assumption of five percent contribution into water sources places the maximum effluent 1,4-dioxane concentrations at 20 µg/L to maintain compliance with current notification levels of 1.0 µg/L. Interestingly, a recent study of the Cape Fear River watershed in North Carolina found that 1,4-dioxane concentrations varied from 1.3 – 1,405 µg/L depending on the community being served.[2] This magnitude of variation makes it difficult to determine whether 5% is an appropriate minimal dilution factor for the protection of public health for CECs like 1,4-dioxane. Another somewhat weak assumption is that the correlation between bulk organic surrogates for CECs are enough to use for monitoring. I reviewed the linked report, but there was inadequate discussion and referenced studies confirming the correlation between the measurements, so my review primarily focused on the dilution factor in SWA.

2. *A combination of reverse osmosis (RO) treatment and an advanced oxidation process (AOP) will accomplish the water quality objective with respect to organic constituents of emerging concern. (Ref §60320.302. Advanced Treatment Criteria)*

   The incidence of CECs is increasing with recent advancements in analytical detection methods and better understanding of sources and mechanisms of formation of NDMA and 1,4-dioxane in treated water. Recent analyses of 1,4-dioxane in public supply wells show a national average detection rate of 13%.[3] Similarly, NDMA was detected in the effluent of 34% of the chloramine plants tested.[4] Other nitrosamines may be formed as disinfection byproducts, but NDMA was the most frequently detected nitrosamine during UCMR3, accounting for 95% of the nitrosamine detections. While the evolving toxicology of CECs and piecemeal of regulatory standards among state agencies and federal and international bodies creates uncertainty, establishment of stringent action levels for selected CECs is imminent, and will require aggressive treatment of both conventional and recycled/reclaimed water supplies. Despite the high cost and high energy requirements, advanced water treatment using a combination of RO/AOP is recognized as an effective treatment strategy for trace CECs like NDMA, perfluoroalkyl and polyfluoroalkyl substances (PFAS), and 1,4-dioxane in drinking water.[5] It has been reported that RO and AOP can decrease NDMA to below 10 ng/L, which is a likely to be established as federal MCL in the near future. The diverse physical and chemical properties of CECs unquestionably require multiple treatment trains approach. The effectiveness of AOP treatment can be negatively impacted by multiple compounds in contaminated water streams competing for the hydroxyl radicals.[6] Additionally, the combined approach would be ideal for contaminants like 1,4-dioxane and PFAS that are not efficiently removed from water by RO and UV treatment, but are more susceptible to degradation by hydroxyl radicals and other reactive oxygen species. The combined treatment approach should be an effective strategy to minimize effluent discharges in excess of regulatory limits on CECs. However, rigorous studies must be conducted to identify the CEC degradation products in various water chemistries, especially with humic substances, undergoing various AOP treatments, e.g., UV/H_2O_2 or UV/O_3. The toxicological effects of CEC degradation products on human health as well as indicator organisms in the aquatic environment need to be evaluated prior to implementing the SWA guidelines.

References:

1. Stepien, D.K.; Diehl, P.; Helm, J.; Thoms, A.; Püttmann, W. Fate of 1,4-dioxane in the aquatic environment: From sewage to drinking water. *Water Research* 2014, 48, 406-419.
2. Sun, M.; Lopez-Velandia, C.; Knappe, D. R. Determination of 1,4-Dioxane in the Cape Fear River Watershed by Heated Purge-and-Trap Preconcentration and Gas Chromatography-Mass Spectrometry. *Environmental Science & Technology* 2016, 50, 2246-2254.
3. Mohr, T. K. G. Santa Clara Valley Water District. *Presentation to Association of California Water Agencies Safe Drinking Water Committee,* August 15, 2013, Los Angeles, CA.
4. Russell, C. G.; Blute, N. K.; Via, S.; Wu, X.; Chowdhury, Z. Nationwide Assessment of Nitrosamine Occurrence and Trends. *Journal - American Water Works Association* 2012, 104, E205-E217.
5. Suthersan, S.; Quinnan, J.; Horst, J.; Ross, I.; Kalve, E.; Bell, C.; Pancras, T. Making Strides in the Management of Emerging Contaminants. *Groundwater Monitoring & Remediation* 2016, 36, 15–25.
6. Eberle, D.; Ball, R.; Boving, T. B. Peroxone activated persulfate treatment of 1,4-dioxane in the presence of chlorinated solvent co-contaminants. *Chemosphere* 2016, 144, 728-735.

Charles P. Gerba, PhD.
The WEST Center
The University of Arizona

May 23, 2016

Review of for Indirect Potable Reuse through Surface3 Water
"Proposed Recycling Criteria for Indirect Potable Reuse through Surface3 Water

3. Treatment that provides a 12 log enteric virus, 10-log Giardia cysts, and 10-log Cryptosporidium oocyst reduction for portable reuse projects will ensure microbiologically safe drinking water (Ref 60320.308. Pathogenic Microorganism Control)

I believe in general that the assumptions on pathogen reduction by treatment process are generally conservative at this time. However, there are certain limitations in these estimates that should require a reevaluation in the future based upon new data on the concentration of pathogens in untreated wastewater.

The 12 log removal requirement used for pathogen reduction is based on data on the estimated concentration of pathogens in a 1996 published document (Metcalf and Eddy, 2007). Since that time significant advances have made in our ability to detect and quantify viruses in untreated sewage and the levels of viruses may be significantly greater than the maximum of 10^6 per liter on which this requirement was based (Metcalf and Eddy, 2007). In addition many new viruses have been discovered which can be excreted in fecal material and urine (La Rosa et al, 2012). For example, adenoviruses and Aichiviruses have been detected in concentrations as great as 10^8 to 10^9 per liter (Kitajima et al., 2014; Hata et al., 2012; Girones et al., 2010). These are just two of now more than 150 different types known viruses which can occur in wastewater. Also water conservation efforts (i.e. increased use of low flush toilets and washing machines which use less water) will result in increasing concentrations of viruses and other pathogens in domestic wastewater. For these reasons the estimates for a 12 log reduction should be revisited on a regular basis to ensure the desired risk level from viruses is achieved.

References

Girones, R., Ferrus, M. A., Alonso, J. L., Rodriguez-Manzano, J., Calgua, B., Correa, A. A., Hundesa, Carratala, A. and Bofill-Mas, S. 2010. Molecular detection of pathogens in water; The pros and cons of molecular techniques. Water Research. 44:4325-4349.

Hata, A., Kitajima, M. and Katayama, H. 2012. Occurrence and reduction of human viruses, F-specific RNA coliphage genogroups and microbial indicators at a full-scale wastewater treatment plant in Japan. Journal of Applied Microbiology. 114:545-554.

Kitajima, M., Iker, B. C., Pepper, I. L. and Gerba, C. P. 2014. Relative abundance and treatment reduction of viruses during wastewater treatment processes – identification of potential viral indicators. Science of the Total Environment. 489:290-296.

La Rosa, G., Fratini, M., Libera,S. D., Iaconell, M.I. and Muscillo, M. 2012. Emerging and potentially emerging viruses in water environments. Ann Ist Super Sanità . 48: 397-406.

Metcalf and Eddy. 2007. Water Reuse. Issues, Technologies and Applications. McGraw Hill, NY.

Pons-Salort, M, Parker, E.P. and Grassly, N.C. 2015. The epidemiology of non-polio enteroviruses: recent advances and outstanding questions. Current Opinions Infectious Disease 28:479-487.

4. The criteria that ensure multi-barrier treatment will promote the use of reliable, resilient, and robust treatment train for the control of microorganisms, (Ref 60320.308. Pathogenic Microorganism Control).

I believe the assumptions made for the removal of pathogens by the different barriers are conservative at this time. Placing a limit on the removal for one treatment processes of 6-log is also conservative and prevents over extrapolation of what can be measured for removal by a given processes i.e. laboratory assessment of treatment processes can generally measure a 4 to 6 log reduction of a pathogen.

5. The progressive actions to be taken in the event recycled water treatment falls to provide the full organism log reductions are adequate to ensure a microbiologically acceptable source for a surface water treatment plant. (Ref 60320.308. Pathogenic Microorganism Control).

The requirements stated for failure to provide full organism log reductions appear adequate given the buffer capacity of the reservoir and dilution likely in the reservoir.

6. A surface water treatment plant will continue the minimum organism log reductions required by the surface water treatment regulations when its source water becomes part of a surface water augmentation project. (Red 60302.208. Pathogenic Microorganism Control).

The draft regulation relies on modeling for some compliance determinations over seen by the limnology subgroup done for the City of San Diego. Modeling the fate of pathogens in reservoirs can be challenging because microorganisms are particulates and not solutes. Differences among the different types of pathogens (protozoa, bacteria, viruses) in density, shape, hydrophobicity, charge and size can result in significant differences in how they will become distributed in a reservoir (Brookes et al., 2004; 2005). The two studies referenced did not use microbial tracers or other type of particulate tracers (e.g.

fluorescent beads) (Flow Science, 2012a; 2012b). One model showed good agreement with temperature and conductivity, and utilized a (lanthanum chloride) tracer which exhibited a significant amount of tracer loss due to coagulation/flocculation and settling during the study. The other used simulations of various "hypothetical tracers". These approaches may not totally reflect the behavior of particulate pathogens within a reservoir. It is recommended that microbial tracers such as coliphages be used in the future to add assurances that these modeling approaches reflect the behavior of at least viral pathogens.

References

Brookes, J. D., Antenucci, J., Hipseyb, M., Burch, M. D., Ashbolt, N. J. and Ferguson, C. 2004. Fate and transport of pathogens in lakes and reservoirs. Environment International 30: 741– 759.

Brookes, J. D., Hipsey, M. R., Burch, M. D., Regel, R. H., Linden, L. G., Ferguson, C. M. and Antenucci, J. P. 2005. Relative value of surrogate indicators for detecting pathogens in lakes and reservoirs. Environmental Science and Technology. 39: 8614-8621.

Flow Science. 2012a. Water Purification Demonstration Project: Limnology and Reservoir Detention Study of San Vicente Reservoir - Hydrodynamic Modeling Study. Harrisonburg, VA

Flow Science. 2012b. Reservoir Augmentation Demonstration Project: Limnology and Reservoir Detention Study of San Vicente Reservoir - Calibration of the Water Quality Model. Harrisonburg, VA

10. The theoretical retention time (TRT) of the reservoir is a valuable measure of the reservoir's potential to provide the required mixing and provide a meaningful barrier to inadequately treated recycled water reaching the public water system (Ref 64668.30. SWSAP Augmented Reservoir Requirements).

It is important to recognize this is only a theoretical retention time and may not reflect the behavior of all pathogens, because of differences in shape, size, density etc. For example, hydrophobic properties of some microorganisms may result in their accumulation at the air water interface and not be diluted in the same manner as microorganisms less hydrophobic (Armanious et al., 2016).

Reference

Armanious, A. Aeppli,M., Jacak, R., Refardt, D.,Sigstam, T., Kohn, T. and Michael Sander. 2016. Viruses at Solid–Water Interfaces: A Systematic Assessment of Interactions Driving Adsorption. Environmental Science and Technology. 50:732-743.

The Big Picture

I think it needs to be recognized that assumptions on setting overall reductions for pathogens by treatment processes will always be a moving target. New viruses which are excreted in both the feces and urine are recognized every year. How effectively these viruses are removed by treatment processes is unknown. In addition, this increases the known concentration of total viruses in untreated wastewater, thus bringing into question if a 12 log removal for viruses is enough for reclaimed wastewater treatment systems designed to produce potable water. Based on current scientific knowledge I believe the assumptions used in the risk assessment to develop the proposed regulations are conservative.

Date: 9 May 2016
Mong Hoo LIM
Chief Water Quality Specialist
PUB Singapore

EXTERNAL PEER REVIEW OF PROPOSED UNIFORM WATER RECYCLING CRITERIA FOR INDIRECT POTABLE REUSE THROUGH SURFACE WATER AUGMENTATION

Preface

Water reuse is an important component for water sustainability and there is an increasing urgency for its implementation as water scarcity has become more severe. However, there are health risks and concerns associated with water reuse, and rules and regulations to address the risks and concerns are generally lacking. It is highly commendable that the State Water Resources Control Board of California is taking the lead in developing uniform water recycling criteria for indirect potable reuse through surface water augmentation and I feel privileged to be invited as a reviewer. Singapore has implemented indirect potable reuse in the local context since 2003 and the background is given below. I sincerely hope that with my experience in Singapore, I can contribute to the development of the water recycling criteria.

Singapore is a water-stressed nation. Although it has abundant rainfall, its small land area limits its capability to collect and store the rainfall. In the United Nations World Water Development Report (2003), Singapore was ranked 171th among a list of 182 countries in terms of fresh water availability. PUB, the Singapore's national water agency which is responsible for the collection, production, distribution and reclamation of water in Singapore, has turned the vulnerabilities of water shortage into opportunities to achieve water sustainability through a holistic integrated water resource management which anchors on the fundamentals: adequate sources to meet demand through source diversification including water reuse, and an effective management of water demand. Singapore now has 4 sources of water supply, called the 4 National Taps and they are: imported water from Malaysia, water from local water catchments, NEWater (reclaimed water purified from wastewater effluent) and desalinated seawater. With its holistic integrated water resource management for water sustainability, PUB won the Stockholm Industry Water Award in 2007.

Under the Singapore's water reuse programme, wastewater effluent that would otherwise be discharged into the sea, is further treated with advanced membrane technology (micro/ultrafiltration, followed by Reverse osmosis and UV disinfection) to produce purified water called NEWater. NEWater is used by industrial and commercial premises for non-potable purposes and a small percentage of NEWater (2-5%) is discharged into raw water reservoirs for indirect potable reuse. Production of NEWater provides a strategic additional water source which is a key step towards Singapore's water sustainability. NEWater also has the advantage of being independent of changing climate and extreme weather situations such as droughts. It augments resilience to Singapore's water supply, achieves the multiplier effect of water yield through recycling, and frees up the potable water previously used for non-potable purposes to meet increasing potable water demand.

Water quality management for water safety of the 4 National Taps in Singapore is undertaken by PUB Water Quality Office headed by the Chief Water Quality Specialist. To ensure the quality of water supply, the Water Quality Office has put in place a comprehensive water monitoring programme from source to tap which include water in waterways, NEWater, raw water in the reservoirs, treated water produced by waterworks, drinking water in the distribution networks and at customers' taps.

- Mong Hoo LIM

1. Reducing concentrations of organic constituents of emerging concern (CECs) to levels found in high quality conventional sources is a water quality objective for those constituents that is adequately protective of public health. (Ref §60320.302. Advanced Treatment Criteria)

Typically, there can be about 10 mg/L of organic carbon in treated (secondary) municipal wastewater. This organic matter could potentially contain chemicals at concentrations of human health concern and for which no drinking water standard exists. These chemicals are commonly characterized as constituents of emerging concern (CECs).

The draft regulation objective is to reduce the concentration of CECs to levels below those found in good conventional surface water sources available in California, such as the Colorado River and State Water Project. The total municipal wastewater discharge contribution is less than five percent of the total flow, as an annual average, for these two sources. There are many communities nationwide using water sources with a municipal wastewater contribution of five percent or greater. The U.S. Environmental Protection Agency (U.S. EPA) has not yet targeted the CECs for regulation.

The State Water Resources Control Board's Science Advisory Panel report on *Monitoring Strategies for CECs in Recycled Water* Section 8.3 Indicator Compounds and Surrogate Parameters for Treatment Performance Assessment, page 65, provides discussion and referenced studies confirming correlation between measurement of bulk organic matter in wastewater as surrogates for CECs. The Science Advisory Panel report is available at: http://www.waterboards.ca.gov/water_issues/programs/water_recycling_policy/docs/cec_monitoring_rpt.pdf

Comments:

I understand that the statement on "confirming correlation between measurement of bulk organic matter in wastewater as surrogate for CECs" mentioned in paragraph 3 above is deduced from some specific studies and I assume that "wastewater" mentioned is treated (secondary) wastewater effluent (about some 10 mg/L of organic matter) and not the original wastewater. In the context of recycled water which is RO permeate, its baseline bulk organic concentration is still relatively high compared to concentrations of CECs. Hence, it may not be sensitive to detect an increase in concentration of CECs which are normally at very low levels, e.g., in ng/L or low µg/L, but yet, pose a concern at these levels. As an illustration, the total organic carbon concentration of recycled wastewater, i.e., the RO permeate, is around 80 - 100 µg/L with a normal fluctuation of about 10 µg/L (based on Singapore's experience), and taking NDMA as an example, at the Notification Level of 10 ng/L, the carbon content is only 3.2 ng/L which is 0.003 µg/L. Hence, the bulk organic concentration will not be sensitive to indicate the change in NDMA's concentration. Similar argument applies for a situation when the increase of all CECs amounts to a total quantum of low µg/L. Therefore, the bulk organic concentration of the RO permeate is a good indication of RO performance for removal of bulk organic matter but may not be sensitive to the extent of indicating CECs removal rate by the RO, or the concentrations of CECs in the RO permeate. Notwithstanding, it is important to evaluate the individual concentration of CECs found in the RO permeate with a correct perspective, weighing against the level at which the compound will pose a health concern.

I wish to commend the good approach mentioned in the report on *Monitoring Strategies for CECs in Recycled Water* Section 8.3 Indicator Compounds and Surrogate Parameters for Treatment Performance Assessment, page 65 (line 11 of Section 8.3), i.e., "Thus, to ensure proper performance of unit operations regarding the removal of CECs , a combination of appropriate surrogate parameters and performance indicator CECs should be selected that are tailored to monitor the removal efficiency of individual unit processes comprising an overall treatment train". In the Singapore's experience, Silica, nitrate, ammonia and conductivity are also monitored for indication of aging of RO membrane.

In the discussion of potable water reuse, direct or indirect mode, concern of CECs is general circling around PPCPs. However, it is inevitable that industrial chemicals in treated or untreated industrial effluent are also discharged into municipal sewers and may also be present in secondary wastewater effluent and hence need to be taken into consideration, for example, dichloromethane at levels exceeding drinking water standards can be of concern as its removal by RO membrane is not high. Hence, it is also important to pay attention to this class of chemicals. In Singapore, besides routine sampling, online VOC sensors are placed in sewers to monitor the quality of sewage.

Notwithstanding, noting that the intended purpose is for indirect potable reuse and there is a tight monitoring regime for indicator CEC in addition to the multi-barrier approach in the subsequent processes, e.g., a 1:100 dilution in augmented reservoir, measurement of bulk organic matter in wastewater, RO permeate, in combination of other appropriate surrogate parameters and performance indicator CECs as mentioned in the abovementioned report. This approach, in my opinion, is the current best available practice.

2. A combination of reverse osmosis (RO) treatment and an advanced oxidation process (AOP) will accomplish the water quality objective with respect to organic constituents of emerging concern. (Ref §60320.302. Advanced Treatment Criteria)

A combination of RO and AOP treatment are being required (§60320.302. Advanced Treatment Criteria) to meet the CEC objective. Although RO permeate largely meets the goal there are certain chemicals (e.g. 1, 4-dioxane and NDMA) that are not well removed and the AOP is required to address those certain chemicals not well treated by RO. Although RO and AOP in combination do not provide multiple barriers to each problematic chemical type, they do offer dissimilar treatment mechanisms that are likely to attenuate unknown organic chemical contaminants.

The effectiveness of RO for CEC removal from wastewater is reported in National Water Research Institute (NWRI) Independent Advisory Panel for the City of San Diego Indirect Potable Reuse/Reservoir Augmentation (IPR/RA) Demonstration Project, *Advanced Water Purification Facility Study Report*, January 2013, pages 2-53 to 2-64, Section 2 emonstration Facility Description and Observations, Constituents of Emerging Concern, CEC Performance Indicator Monitoring, Table 2-24 CEC Potential Indicator Characterization Results, RO Removal. This report can be found at:
http://www.sandiego.gov/water/purewater/pdf/projectreports/section2demonstration.pdf

The effectiveness of AOP for CEC reduction is reported in National Water Research Institute (NWRI) Independent Advisory Panel for the City of San Diego Indirect Potable Reuse/Reservoir Augmentation (IPR/RA) Demonstration Project, *Advanced Water*

Purification Facility Study Report, January 2013, pages 2-24 to 2-27, Section 2 Demonstration Facility Description and Observations, 2.3.3 UV Disinfection and Advanced Oxidation. This report can be found at:
http://www.sandiego.gov/water/purewater/pdf/projectreports/section2demonstration.pdf

This combination of treatment processes is required for injection projects in the California regulations for groundwater replenishment indirect potable reuse (CCR, Title 22, §60320.201). The *Groundwater Replenishment System 2008 Annual Report* of Orange County Water District provides evidence that the required treatment processes can be operated to produce the intended water quality. This report can be found at:
http://www.ocwd.com/media/3489/2008_gwrs-annual-report_final.pdf

Comments:

I agree that a combination of RO and AOP treatment is required to meet the CEC objective. It is noted from the technical report (*Advanced Water Purification Facility Study Report*, January 2013, pages 2-24 to 2-27, Section 2 Demonstration Facility Description and Observations, 2.3.3 UV Disinfection and Advanced Oxidation) that the AOP is of UV-H2O2 type which besides oxidation, also provided photolysis action which can significantly remove NDMA. Other AOP treatment can be of ozone-H2O2 of which the removal rate for NDMA may not be as effective. Nevertheless, it is noted that there is a requirement to meet the 10 ng/L Notification Level for NDMA.

Although there may be controversies about the metabolites generated by AOP which may be harmful to health at sufficient dosage, the concentrations of these metabolites generated are likely to be in trace levels that the subsequent 1:100 dilution in the augmented reservoir will likely nullify the health impacts.

It is observed that the revised regulations stipulate "(Page 6 of 29: **§60320.302 Advanced Treatment Criteria**)….. Full advance treatment is the treatment of an oxidized wastewater, as defined in section 60301.650, using a reverse osmosis and an oxidation treatment process that, at a minimum, meet the criteria of this section "). From implementation perspective, my view is that if the purpose of oxidation is to set a barrier to remove known and unknown trace organics of which some are very persistent in nature that require advanced oxidation, stating "an oxidation treatment process" is perhaps too general and may not be able to achieve the objective. Although there is a statement of "at a minimum, meet the criteria of this section", the challenge is the ability or non-ability to demonstrate such, hence it may lead to subsequent ambiguity in the implementation. Perhaps, an option is to consider using a more specific term, for example "advanced oxidation process" or other equivalent term of "oxidation process with oxidative power which is equivalent to….." etc.

It is noted that there is a provision in the proposed regulation for other equivalent or better performance technologies (page 22 of 29 "§60320.330 Alternatives"). This has given a flexibility for adoption of other equivalent or better treatment technologies if proven as such. For example, granular activated carbon filtration which is a physical sorption process and not a chemical process that may introduce metabolites, may be a feasible option.

6. A surface water treatment plant will continue to provide the minimum organism log reductions required by the surface water treatment regulations when its source water becomes part of a surface water augmentation project. (Ref §60320.308. Pathogenic Microorganism Control)

Implicit in the regulation's approach to control pathogens is the conclusion that the minimum organism reductions required under the State and Federal surface water treatment regulations for a surface water treatment plant (SWTP) (4-log enteric virus, 3-log *Giardia* cyst, and 2-log *Cryptosporidium* oocyst) can be credited toward the 12-log enteric virus, 10-log *Giardia* cyst, and 10-log *Cryptosporidium* oocyst reduction requirement. This conclusion determines the log reductions required of the recycled water discharged into reservoir to avoid degradation of the reservoir as a drinking water source (the difference between the overall log reduction and what the SWTP provides), as well as determining the role the SWTP will play in meeting the overall log reduction treatment objective.

The SWTP treating water from a reservoir has been approved for that use because it was designed to deal with the reservoir water quality. That water would contain particulates and possibly particulate associated microorganisms. Recycled water discharged to the reservoir will be RO/AOP effluent and may ultimately constitute nearly all of the impounded water for some reservoirs. It is concluded that the existing SWTP will work effectively to achieve at least the minimum pathogen LRVs required by the State and Federal surface water treatment regulations because the reservoir water will come to resemble the natural water typically successfully treated by the SWTR (sans SWA with recycled water), by being exposed to surface runoff and the suspension of particulate matter due to wind, turnover, and recreational activities.

Final rule of Long Term 2 Enhanced Surface Water Treatment Rule is available at:
https://www.gpo.gov/fdsys/pkg/FR-2006-01-05/pdf/06-4.pdf

Comments:

SWTP is required under the State and Federal surface water treatment regulations to have minimum reduction of 4-log enteric virus, 3-log *Giardia* cyst, and 2-log *Cryptosporidium* oocyst. The SWTP receiving water from augmented reservoir is therefore need to have or designed to have these pathogen LRVs. It is also reasonable to expect the recycled water discharged into the reservoir (RO/AOP effluent) will come to resemble the natural water typically successfully treated by the SWTR by being exposed to surface runoff and the suspension of particulate matter due to wind, turnover, and recreational activities.

7. The reservoir will enhance the reliability of a SWA project by mixing each portion of the recycled water flow, including any off-spec recycled water, with a large volume of water that meets the water quality requirements for a surface water source. (Ref §64668.30. SWSAP Augmented Reservoir Requirements)

The reservoir in a SWA project must provide a real public health benefit to meaningfully distinguish SWA from direct potable reuse as both are defined in the California Water Code.

According to the California Water Code SWA places the recycled water into a reservoir used by a surface water treatment plant (SWTP) whereas direct potable reuse can introduce the water immediately upstream of a SWTP (or directly into a public drinking water system). For a very small reservoir or where recycled water enters the reservoir near the abstraction point, the two forms of potable reuse would be functionally indistinguishable.

In the event that there is a short-term failure of the wastewater treatment to meet the quality objectives, the reservoir provides the opportunity to mix off-spec water with a relatively large volume of suitable source water. By mixing the off-spec water with suitable source water, the reservoir will dilute the excessive contaminants and attenuate the effect of the treatment failure. This "suitable source water" in the reservoir can be approved surface water sources, either from the reservoir watershed or imported water, or recycled water that was previously discharged to the reservoir and met the treatment objective. This mixing benefit is only available for failures of limited duration because frequent or prolonged discharges of off-spec water could exhaust the diluent capacity of the reservoir. Operational requirements in the regulation ensure that treatment failures will be promptly identified and corrected.

Comments:

Dilution of off-spec water in the augmented reservoir is an effective barrier to counter a short-term failure of the wastewater treatment. It is important to highlight that the mixing benefit is only available for failure of limited duration because frequent or prolonged discharges of off-spec water could exhaust the diluent capacity of the reservoir. In this respect, it is essential to have effective water quality monitoring program for the recycled water as well as the water in the reservoir.

Wastewater can contain discharges from industries and the constituents are of different nature compared with water in a natural reservoir. These wastewater constituents, including the unknown unknowns, may not be completely removed by the RO/AOP processes. The augmented reservoir which also receive natural run-off can provide the mixing benefit to alleviate any impacts caused by the residual of the abovementioned wastewater constituents. On the other hand, the RO/AOP effluent has very low organic content and can provide a benefit to reduce the organic concentration in the augmented reservoir, thereby reduce the risks of formation of excessive DBPs in the SWTP that draw water from the augmented reservoir.

APPENDIX A – DOCUMENTS RELIED UPON

Reference No. 3

Expert Panel response to Peer Review mandated via Health and Safety Code section 57004 (August 2016).

NWRI National Water Research Institute

Memorandum

Jeffrey J. Mosher
Executive Director

E-mail: jmosher@NWRI-USA.org

18700 Ward Street
P.O. Box 8096
Fountain Valley, California
92728-8096

(714) 378-3278
Fax: (714) 378-3375

To: Mike McKibben, P.E.
Jing-Tying Chao, P.E.
Division of Drinking Water
State Water Resources Control Board
1001 I Street
Sacramento, CA 95814

From: **Expert Panel (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**

Adam Olivieri, Dr.P.H., P.E., EOA, Inc.
James Crook, Ph.D., P.E., Environmental Engineering Consultant
Expert Panel Co-Chairs

Jeffrey J. Mosher, National Water Research Institute
Expert Panel Administrator

Subject: Expert Panel (Panel) Response to Key External (Peer) Reviewer Comments on DDW staff's Proposed Draft IPR-SWA Criteria (under SWRCB Agreement No. 13-21041)

Date: August 3, 2016

On behalf of the Expert Panel (Panel), the National Water Research Institute (NWRI) is pleased to transmit this memorandum to the California State Water Resources Control Board (State Water Board) regarding the Panel's review and response to key items in the comments received from the State Water Board's External (Peer) Reviewers on the Division of Drinking Water (DDW) staff's proposed draft indirect potable reuse (IPR)-surface water augmentation (SWA) criteria.

The Panel has reviewed the Peer Reviewers' comments on the proposed draft IPR-SWA criteria and acknowledges and thanks the Peer Reviewers for their careful reviews. In this memorandum, the Panel has provided its responses to key comments and suggestions from the Peer Reviewers.

Expert Panel Response to Peer Reviewer Comments:

A. Dr. Shaily Mahendra (University of California, Los Angeles)

Dr. Shaily Mahendra focused her comments on elements 1 and 2 of the proposed draft SWA criteria concerning the treatment of contaminants of emerging concern (CECs).

1. Reducing concentrations of organic constituents of emerging concern (CECs) to levels found in high quality conventional sources is a water quality objective for those constituents that are adequately protective of public health. (Ref §60320.302. Advanced Treatment Criteria)

Dr. Mahendra acknowledged the challenges in creating enforceable regulatory limits on contaminants such as 1,4-dioxane and NDMA, and considered the approach used for reducing concentrations of organic contaminants to be reasonable, but indicated that the selection of 10 milligrams per liter (mg/L) of organic carbon needed further support. As a point of clarification, 10 mg/L of organic carbon in secondary effluent was not a "selected value," but simply a statement indicating what is typically observed in water sources. This value is offered to provide an example of "currently acceptable" sources. Nevertheless, it would be useful to document this value and provide an estimate of a range of concentrations that typically are encountered.

Dr. Mahendra's second point is that the scenario described does not take into account the large variation in the concentrations of certain CECs, quoting as an example a range of 1.3 to 1,405 micrograms (µg) of 1,4-dioxane per liter (L) (apparently in secondary or tertiary wastewater effluent). As an example, she contends that concentrations would have to be less than 20 µg/L in the effluent for a dilution of 95 percent to bring the concentration of 1,4-dioxane to a value below the notification level. Variations in concentrations of organic contaminants of this magnitude in secondary wastewater effluents could be a challenge to surface water treatment plants (SWTPs). It should be noted that the Panel recognized the removal of 1,4-dioxane and other uncharged, low molecular weight compounds is not correlated with total organic carbon (TOC) removal because the compound is not well removed in the unit process that most effectively reduces TOC (i.e., reverse osmosis). In fact, this is one of the reasons that advanced oxidation processes (AOPs) are employed in most IPR projects. As is addressed elsewhere, it is important that a facility producing advanced treated water (ATW) for any potable reuse project has a robust source protection program AND has characterized the concentration variability for organic contaminants, especially those that are capable of penetrating key treatment barriers. In the case of 1,4-dioxane and other uncharged, low molecular weight compounds that may be discharged by commercial and industrial sources, partial removal of concentration spikes will occur that will reduce the amount of dilution needed to comply with guidelines. Steps designed to address this concern include understanding the variability in contaminant concentrations, maintaining control over the sewershed, operating a reliable advanced water treatment facility (AWTF) with multiple, independent barriers, operating a robust monitoring program (covering unit performance and mechanical reliability), and employing a rigorous monitoring response program.

2. A combination of reverse osmosis (RO) treatment and an advanced oxidation process (AOP) will accomplish the water quality objective with respect to organic constituents of emerging concern. (Ref §60320.302. Advanced Treatment Criteria).

Dr. Mahendra makes several observations of importance in considering the effectiveness of combined RO and AOP treatment for the removal of CECs. She notes that "RO/AOP is recognized as an effective treatment strategy for trace CECs like NDMA, perfluoroalkyl and polyfluoroalkyl substances (PFAS), and 1,4-dioxane in drinking water" and concludes that "the combined treatment approach should be an effective strategy to minimize effluent discharges in excess of regulatory limits on CECs." Regarding her comment that the effectiveness of AOP can be compromised by multiple compounds that compete for hydroxyl radicals, the Panel suggests that such competition would not significantly impact the performance of the AOP because the process is used on RO permeate that normally includes very low concentrations of dissolved organic compounds (DOC) or other compounds that would compete for hydroxyl radicals. In fact, hydrogen peroxide is expected to be the main sink for hydroxyl radicals under the conditions in RO permeate, even if several trace organic compounds are present in the permeate simultaneously. The efficiency of the AOP would only be compromised by a pulse of a very high concentration of contaminants in the RO permeate, and such pulses would likely be identified as "off-spec" water.

It is also suggested that the CEC degradation products of AOP be quantified and an evaluation of their health hazards be conducted. It is important to recognize that the concentrations of precursor compounds expected in RO permeate are very low and that those compounds mainly consist of the neutral, low molecular weight compounds discussed above. This produces an upper limit on the concentrations of byproducts, as well as possible precursors; therefore, this problem is not as broad as seems to be implied. Although future research may lead to the identification of some yet-to-be-discovered byproducts of the oxidation of these compounds that are extremely toxic, it is difficult to imagine a compound being created by AOP that is a greater hazard than NDMA. These statements are not meant to discourage future research on AOP transformation products, but rather that research should be done in a very selective way with compounds that are relatively abundant and are poorly removed by RO and whose chemistry is such that a problem can be predicted rather than spending a substantial amount of resources in a broad research effort that is thought to address a minor problem. It is the opinion of the Panel that this is not something that needs to be pursued prior to implementing the IPR-SWA criteria.

B. Dr. Mong Hoo Lim (Chief Water Quality Specialist, Public Utilities Board, Singapore)

Dr. Lim provided a helpful summary of Singapore's NEWater program followed by comments on elements 1, 2, 6 and 7 of the proposed draft IPR-SWA criteria concerning the treatment of CECs (elements 1 and 2), pathogen removal at a SWTP (element 6), and dilution requirement for the reservoir (element 7).

> *1. Reducing concentrations of organic constituents of emerging concern (CECs) to levels found in high quality conventional sources is a water quality objective for those constituents that are adequately protective of public health. (Ref §60320.302. Advanced Treatment Criteria)*

Dr. Lim comments that bulk organic carbon concentration in RO permeate is a good indication of RO performance for the removal of bulk organic matter, but cautions that TOC may not be sensitive enough to establish CEC removal by RO or concentrations of CECs in the RO permeate. The Panel concurs with this comment, having proposed TOC only as a broad performance indicator, and recommended monitoring of NDMA and other select CECs in the advanced water treatment train.

Dr. Lim also identifies the potential challenges resulting from the discharge of chlorinated solvents and other industrial chemicals into the sewer system, and recommends the use of online volatile organic compound (VOC) monitors deployed across the sewerage conveyance system. This approach is included in Singapore's monitoring program and is a valuable suggestion. Source control within the sewershed is of utmost importance and chemical discharge is an issue that has been considered in some detail in the Panel's discussion of monitoring and operations; however, the Panel declined to recommend the use of the VOC detection method because online TOC monitoring and other approaches to source control can achieve the same objectives. Dr. Lim opined that the requirements and approach described within the draft criteria represented current best available practices.

> *2. A combination of reverse osmosis (RO) treatment and an advanced oxidation process (AOP) will accomplish the water quality objective with respect to organic constituents of emerging concern. (Ref §60320.302. Advanced Treatment Criteria)*

Dr. Lim agrees that a combination of RO and AOP treatment is required to meet the CEC objective, and points out a potential need to be more specific about the nature of the oxidation treatment process that is used. The Panel agrees with that statement, but believes it is better handled through the engineering report submitted by the project sponsors. Dr. Lim also agreed with the Panel that the "metabolites" (more properly labeled transformation products) of AOP likely are to be present in such low concentrations as to be a trivial issue, especially given the required 1:100 dilution required of SWA water introduced into a reservoir. Dr. Lim also noted the treatment alternatives clause; this clause is a valuable feature of the draft criteria as alternatives to AOP might be more efficient and less costly depending upon the contaminant profile observed in a given plant's RO permeate.

> *6. A surface water treatment plant will continue to provide the minimum organism log reductions required by the surface water treatment regulations when its source water becomes part of a surface water augmentation project. (Ref §60320.308. Pathogenic Microorganism Control)*

Dr. Lim supports the 4-3-2 log reductions for virus, *Giardia,* and *Cryptosporidium* at the SWTP, recognizing that ATW discharged to the reservoir would likely come to resemble natural waters successfully treated by the Surface Water Treatment Rule.

> *7. The reservoir will enhance the reliability of a SWA project by mixing each portion of the recycled water flow, including an off-spec recycled water, with a large volume of water that meets the water quality requirements for a surface water source (Ref §64658.30. SWSAP Augmented Reservoir Requirements)*

Dr. Lim indicates that the dilution of off-spec water in the augmented reservoir provides an effective barrier to counter the short-term failure of advanced water treatment, but notes that frequent or prolonged off-spec discharges could exhaust the diluent capacity of the reservoir and highlights the importance of a robust monitoring program both at the AWTF and at the reservoir. The Panel certainly agrees with these statements and believes that the State Water Board has experience in implementing rigorous compliance programs to avoid this possible outcome.

C. Dr. Charles Gerba (University of Arizona)

Dr. Charles Gerba addressed elements 3, 4, 5, and 6 of the proposed draft IPR-SWA, focusing on pathogen removal at the AWTF (elements 3, 4, and 5), and at the SWTP (element 6).

> *3. Treatment that provides a 12 log enteric virus, 10-log* Giardia *cysts, and 10-log* Cryptosporidium *oocyst reduction for potable reuse projects will ensure microbiologically safe drinking water (Ref 60320.308. Pathogenic Microorganism Control)*

Dr. Gerba stated that these assumptions on pathogen reduction by treatment processes are conservative, but noted that enhanced analytical capabilities have identified both a larger number of types of viruses and higher concentrations and, thus, suggested a reevaluation of 12-10-10 in the future based upon new pathogen concentration data for untreated wastewater. The Panel agrees and discussed this issue in the draft Panel Report on *Evaluating the Feasibility of Developing Uniform Water Recycling Criteria for Direct Potable Reuse* that has now been submitted to the State Water Board.

> *4. The criteria that ensure multi-barrier treatment will promote the use of a reliable, resilient, and robust treatment train for the control of microorganisms, (Ref 60320.308. Pathogenic Microorganism Control).*

Dr. Gerba stated that the assumptions made for removal of pathogens by different barriers are conservative, and endorsed the 6-log limit that could be assigned to a given treatment process based upon the constraints of direct laboratory measurements. The Panel concurs with his assessment.

> *5. The progressive actions to be taken in the event recycled water treatment fails to provide the full organism log reductions are adequate to ensure a microbiologically acceptable source for a surface water treatment plant. (Ref 60320.308. Pathogenic Microorganism Control).*

Dr. Gerba stated that the actions proposed in the draft IPR-SWA criteria if treatment fails to provide the full organism log reductions are adequate to ensure a microbially acceptable source water for a SWTP. The Panel concurs with his assessment.

> *6. A surface water treatment plant will continue the minimum organism log reductions required by the surface water treatment regulations when its source water becomes part of a surface water augmentation project. (Ref 60302.208. Pathogenic Microorganism Control).*

Dr. Gerba recognized the role that modeling plays in defining compliance of the reservoir as an effective environmental buffer, but commented that chemical tracers may not totally reflect the behavior of particulate pathogens and suggested that coliphages be used as tracers for viral pathogens. The Panel suggests that the small size of viruses (20 to 100 nanometers [nm]) limits Stokes settling velocities such that settling is not an important transport process for free viruses; therefore, they can be reasonably represented by soluble tracers subject to advective, convective, and dispersive transport. The Panel agrees that aggregation and flocculation, in some cases, may be important and that, in such cases, vertical settling also could be a factor, although increased settling lowers the overall lifetime of particles in the water column and thus might be expected to reduce concentrations at the reservoir outlet and delivered to the SWTP. Practical issues also may arise from implementing a tracer study using a very large quantity of coliphages released to a surface water reservoir.

D. Dr. Scott Wells (Portland State University)

Dr. Scott Wells submitted a thoughtful peer-review of elements 7 - 10 of the proposed draft IPR-SWA criteria as provided in the Peer-Review Request Package, focusing on reservoir capacity to enhance reliability in SWA (element #7), a minimum dilution requirement (element #8), the role of hydrodynamic modeling (#9), and theoretical detention time (element #10).

> *7. The reservoir will enhance the reliability of a SWA project by mixing each portion of the recycled water flow, including any off-spec recycled water, with a large volume of water that meets the water quality requirements for a surface water source. (Ref §64668.30. SWSAP Augmented Reservoir Requirements)*

Dr. Wells described the role of the reservoir as a buffer for treatment plant effluent, allowing mixing and dilution, and then focused his comments on the subsequent elements of the draft IPR-SWA criteria below.

> *8. Mixing a batch of inadequately treated recycled water in the reservoir with other water such that a 24-hour batch of off-spec water cannot be more than 10 % of the water withdrawn from the reservoir at any time is a significant reliability benefit for a potable reuse project. (Ref §64668.30. SWSAP Augmented Reservoir Requirements)*

Dr. Wells supported the notion of a minimum dilution requirement for off-spec water and concluded this approach is reasonable.

> *9. Hydrodynamic modeling is a means of characterizing the capacity of a reservoir to attenuate the effect of treatment failures by mixing off-spec water with reservoir water. (Ref §64668.30. SWSAP Augmented Reservoir Requirements)*

Dr. Wells identified the limitations to tracer studies and highlighted the capability of hydrodynamic modeling to explore different meteorological and hydrological conditions. He recommended that a series of guidelines be developed for the tracer studies and modeling work, including outside peer review for these studies. This forms one of his two recommendations that the Panel considers in greater detail below.

10. The theoretical retention time (TRT) of the reservoir is a valuable measure of the reservoir's potential to provide the required mixing and provide a meaningful barrier to inadequately treated recycled water reaching the public water system (Ref §64668.30. SWSAP Augmented Reservoir Requirements)

Dr. Wells stated that it was unclear why a theoretical detention time was specified since detention time may or may not have any relationship with the amount of dilution achieved in the reservoir. This element of the draft IPR-SWA criteria leads to his second more substantive recommendation, which the Panel further considers below.

Dr. Wells then outlined in detail the rationale for his two specific recommendations:

a) Eliminate the theoretical retention time of a minimum of 6 months as a criterion for compliance.
b) Add the need for external peer-review for the tracer and hydrodynamic modeling studies.

<u>a. Theoretical hydraulic retention time</u> - Dr. Wells states on p.4, l.15-19 that "It is unclear why there is a theoretical detention time of 6 months for the overall reservoir since the overall retention time may or may not have any relationship with the amount of dilution occurring in a reservoir system. The rule implies that this provides more protection. Even though this metric is simple, the retention time of the reservoir is often not predictive of being in compliance with the project treatment goals." He further states that on p.4, l.26-29 that "Since a theoretical retention time (TRT) of a reservoir of 6 months may not be related to meeting the standards for dilution compliance, this requirement is not protective. Since hydrodynamic modeling is already required, the TRT of a reservoir being a minimum of 6 months does not provide any additional protective benefit."

He then provides a detailed critique of the theoretical detention time of a reservoir (p.4-9) using a two-dimensional laterally-averaged simulation and correctly highlights that average TRT and dilution are not necessarily strongly related (e.g., Figures 3 and 5), supporting his conclusion that a TRT of 6 months does not provide additional protective benefit beyond the dilution requirement.

While the Panel agrees that TRT and dilution are not necessarily strongly related and, on that basis, also agrees that TRT provides no additional protective benefit relative to the dilution criteria, TRT is not being proposed in the draft regulations as an additional dilution/performance criterion for the reservoir.

The *performance criterion* for the reservoir in an IPR-SWA project is the minimum requirement of 1:100 dilution (or 1:10 dilution with 1-log additional treatment for all pathogens) achieved at all times as demonstrated through calibrated hydrodynamic modeling. While TRT can be a useful simple screening tool (e.g., to estimate the average time off-spec water may remain in a reservoir following an upset at an AWTF and the amount of dilution that may be achieved under well-mixed conditions), its fundamental purpose in the proposed draft regulations is to serve as an *operational criterion* for the reservoir, placing limits on the basic hydraulic operation of the reservoir (specifically outflow rate relative to reservoir volume). Having both *operational* and *performance* criteria was deemed to provide greater assurance of the effective, reliable, and resilient operation of an IPR-SWA project. For example, the requirement of a 1:10 dilution with 1-log additional treatment could be met with a well-mixed reservoir with a TRT of only 10 days that would export within 5 hours 2 percent of the contaminant mass in a 24-hour pulse of off-spec water to the downstream treatment plant. This solution provides little time to respond to a treatment plant failure and weakens the role of the surface water reservoir as a meaningful environmental buffer. Incorporating a minimum TRT in the regulations provides a simple criterion – unique from the dilution/performance criterion – that places constraints on reservoir operation and helps ensure the role of the reservoir as a robust environmental buffer in IPR-SWA. Thus, the Panel respectfully disagrees on the recommendation to remove TRT as a compliance criterion.

b. External Peer Review for Tracer and Hydrodynamic Modeling Studies - Dr. Wells makes a compelling case for the external peer review of modeling and tracer studies. Demonstrating the robustness and effectiveness of the reservoir as an environmental buffer hinges on a carefully calibrated hydrodynamic model that, in turn, is dependent upon a well-planned and executed tracer study. The Panel agrees with Dr. Wells on the necessity for externally peer-reviewed model and tracer studies as part of IPR-SWA project design and approval.

APPENDIX A – DOCUMENTS RELIED UPON

Reference No. 4 & 5

Advanced Water Purification Facility Study Report, January 2013, pages 2-53 to 2-64, Section 2, Demonstration Facility Description and Observations, Constituents of Emerging Concern, CEC Performance Indicator Monitoring, Table 2-24 CEC Potential Indicator Characterization Results, RO Removal.
http://www.sandiego.gov/water/purewater/pdf/projectreports/section2demonstration.pdf

APPENDIX A – DOCUMENTS RELIED UPON

Reference No. 6

West Basin Municipal Water District, Advisory Panel Findings and Recommendations, Seawater Barrier Water Conservation Project Phase III. Final Report, May 15, 2001.

McGuire
Environmental
Consultants, Inc.

"Quality services that ensure safe drinking water"

May 15, 2001

Mr. Richard A. Nagel
West Basin MWD
17140 S. Avalon Blvd. #210
Carson, CA 90746-1296

Dear Mr. Nagel:

The purpose of this letter is to transmit to you the attached report entitled "West Basin Municipal Water District Advisory Panel Findings and Recommendations, May 15, 2001, Seawater Barrier Water Conservation Project: Phase III." It has been a pleasure working with you and your staff on this important project.

If the panel can be of any further assistance, please contact us.

Very truly yours,

Michael J. McGuire, Ph.D.

I:\WinWord Data\Central West Basin Expert\West Basin Final Report\Transmittal Letter.doc

1919 Santa Monica Blvd. Suite 200 Santa Monica, CA 90404-1950 Telephone (310) 829-1441 Fax (310) 829-2155

FINAL REPORT

West Basin Municipal Water District
Advisory Panel
Findings and Recommendations
May 15, 2001

Seawater Barrier Water Conservation Project:
Phase III

INTRODUCTION

In an effort to make best use of water resources in the arid Southern California region, the West Basin Municipal Water District (WBMWD) is proposing to increase the percentage of recycled water delivered to the seawater barrier from 50% to 100%. An Advisory Panel comprised of five experts in the fields of water quality, public health, groundwater transport and water/wastewater treatment was convened in November 2000 to review the project and make recommendations to WBMWD. In a memorandum dated November 2, 2000, The Panel Chair summarized the charge to the Panel. The four key tasks of the Panel were:

- Review several documents including portions of the engineering report for the project and determine if the documents sufficiently describe the project
- Evaluate the water quality data presented to the Panel and judge its completeness as it relates to the Panel's need to form an expert opinion on the project
- Evaluate the proposal to increase from 50 percent to 100 percent the amount of recycled water as the source of water for injection into the seawater barrier
- Provide the Panel's collective opinion on the efficacy and advisability of increasing the amount of recycled water in the barrier from the perspective of public health protection

The Panel met on three occasions in open, technical workshops—November 15, 2000, December 19, 2000 and March 14, 2001. The technical workshops were followed by executive sessions where the Panel reviewed the presentations made, formed questions for later investigation and began formulating its final recommendations. The Panel also met with WBMWD staff on February 7, 2001 to discuss details of the barrier operation and water quality investigations ongoing by WBMWD staff and consultants. Before, during and after all of these meetings, the Panel reviewed dozens of reports and data presentations.

This report summarizes the Panel's conclusions, findings and recommendations.

CONCLUSION

The Seawater Barrier Water Conservation Expert Panel unanimously supports the West Basin Municipal Water District's proposal to increase the percentage of recycled water delivered to the seawater barrier from 50% towards 100%, providing it is conducted in a step-wise process, and incorporates additional treatment barriers for protection, close communication with the California Department of Health Services, significant monitoring, and key decision milestones.

FINDINGS

1. Microfiltration/Reverse Osmosis (MF/RO) treatment of secondary wastewater, as practiced in the West Basin plant, provides an excellent process train for producing reclaimed water for use in the seawater barrier and as a source for indirect potable reuse after groundwater recharge. These processes include microfiltration to remove particles and pathogens, composite membrane reverse osmosis for removing dissolved inorganic and organic molecules, aeration (recarbonation) for removal of remaining volatile organics, and ultraviolet radiation for further disinfection and removal of trace organic compounds. Thus, the treatment train provides multiple barriers for removal of potentially hazardous chemicals and pathogens.

2. The seawater barrier has been in operation using recycled water since 1995. The current operations permit allows injection water to be comprised of a maximum of 50% recycled water with the balance made up from imported water from the Metropolitan Water District of Southern California (MWD). The Panel finds that there are compelling reasons to continue operation of the seawater barrier using recycled water, and that the use of highly purified, recycled water in the seawater barrier is a significant source of potable water supply for wells in the near vicinity of the ocean. Operation of the seawater barrier is essential for the protection of the West Basin groundwater basin. Thus, an increase in the percentage of recycled water for the seawater barrier project would provide:

    - A continued, critical resource protection function by limiting the amount of seawater that can contaminate the fresh water in the basin
    - An additional source of water supply for human consumption

3. Indirect potable use of recycled water necessitates the use of multiple barriers for protection of human health from hazardous chemicals and pathogens, similar to that afforded by the natural physical, chemical, and biological processes that occur with time following discharge of treated wastewaters to rivers and streams used by downstream users as drinking water supplies—see attached figure.

4. Long travel time through porous media in an aquifer is one of the important protective barriers for recycled water. The travel time for recycled water injected into the seawater barrier to the first potable water supply well is estimated to be on the order of years. However, this should be verified through measurements of groundwater from nearby monitoring wells as well as from extraction wells. Numerical modeling results show that the time period for the currently used potable water supply wells in the West Basin to come under 100% influence of water injected into the barrier is estimated to be on the order of

several decades. This estimate should be continually refined based on water quality data obtained from sampling wells located for monitoring the influence of seawater barrier recharge water.

5. The current requirement of 50% blending of recycled water before injection was based upon the use of older reverse osmosis technology that was capable of removing total organic carbon (TOC) to about 1 mg/L. However, the newer composite membranes currently used at the WBMUD consistently remove TOC to about one-fifth of that value or about 0.2 mg/L. A further disinfection barrier is then provided with the use of ultraviolet radiation. Use of these newer treatment processes will significantly enhance performance capabilities and justify the suggested step-wise increase in recycle water use towards the 100% level.

6. The most complete trace organic analysis reasonably available in the drinking water community has been performed on recycled water from Train 3 at the West Basin plant (with limited replication), and no organics of public health concern have been found.

7. A comparison of the analyses of organics in the WBMWD MF/RO plant (followed by ultraviolet [UV] light treatment) product water with product water from MWD showed that neither of these waters contained detectable trace organics of public health concern.

8. Future improvements in trace analytical chemistry (for both organics and inorganics) may make it possible to detect concentrations of contaminants that are not known to be present at this time at low part-per-billion or part-per-trillion levels. Should this occur, the public health significance of these contaminants will have to be addressed.

9. The Panel believes that multiple treatment barriers to chemical and biological contaminants are necessary between the Hyperion effluent and potable water consumed by the public using water from the West Basin; the attached diagram reflects such multiple barriers and equates these barriers with natural processes in the environment which purify water sources. The Panel believes that an additional barrier should be added to the current and anticipated process train—advanced oxidation by the addition of hydrogen peroxide in the presence of UV light to produce the hydroxyl radical to oxidize trace organics that may be present.

10. The possibility exists that scientific advances, such as in water chemistry and biology, may uncover new contaminants of concern in recycled or imported waters that are not adequately addressed by the multiple barriers being provided or proposed. If additional process treatment steps are found not to address such an unforeseen problem adequately, then wellhead treatment could ultimately be required to protect public health.

11. A review of the data comparing the disinfection byproducts (DBPs) formation potential of MF/RO water with water from existing production wells indicates that an increase in recycled water will decrease the DBPs formed. MF/RO producing lower levels of DBPs will decrease the DBP risks to public health for water injected into the barrier.

12. NDMA concentrations in the MF/RO treated water can be adequately removed with UV light technology. The high UV light energy required for NDMA destruction provides a further significant barrier to viruses, bacteria and other pathogens.

13. Currently, the West Basin plant uses about 10% of the effluent from the Hyperion wastewater treatment plant as its source of supply. A high degree of communication exists between the Hyperion plant and the West Basin facility so that news of any process upsets at Hyperion that might affect the product water at the West Basin plant can and should be readily transmitted.

14. The City of Los Angeles has in place an industrial waste pretreatment program to reduce the impacts of industrial wastewater discharges on the operation of the Hyperion plant; however, the program was never designed to prevent compounds of human health concern from being discharged into the sewer system.

15. The West Basin aquifers experience a wide range of oxidation-reduction (redox) conditions that appear to be natural phenomena; parts of the West Basin have naturally reduced conditions in the groundwater as measured by the presence of ammonia, sulfide and/or reduced forms of iron and manganese.

16. It is apparent that the existing seawater barrier, while mostly effective, still allows several thousand acre-feet of seawater to intrude into the basin annually; the Panel is concerned that the continued degradation of this highly valuable resource is continuing. The Panel feels that the appropriate agencies should take whatever steps are necessary to restore "protective elevations" or any other measures in the basin to prevent any future encroachment.

RECOMMENDATIONS

1. The Expert Panel supports WBMWD's proposal to increase the percentage of recycled water to the seawater barrier. However, this should not be done in a single step. The Panel suggests the increases be conducted step-wise, the first being from 50% to 75%. Before, during and after this increase, WBMWD should incorporate a comprehensive monitoring program that would track impacts on monitoring wells and potable wells. If no physical or chemical problems or public health concerns are determined after a reasonable trial period, the percentage of recycled water could be increased from 75% towards 100% in appropriate steps as indicated by the data collected during the first and subsequent steps. Comprehensive monitoring should continue after each step. The monitoring should include both the observation wells near the barrier as well as selected water purveyor supply wells. The groundwater model should be periodically updated as new data become available and the predictive estimates of timing, quantity and quality of recharge to the inland well fields should be refined.

2. Trains 1 and 2 in the WBMWD plant should be replaced with MF/RO/UV technology; any increase in the plant capacity for the seawater barrier supply should employ the MF/RO/UV processes, which include aeration through recarbonation. Any water produced for potable purposes from the West Basin plant should be treated with UV light to reduce the concentration of NDMA below the current Action Level of 20 ng/L and should include

hydrogen peroxide addition to provide additional protection from other possible remaining trace organics.

3. A comprehensive monitoring program during the period following an increase in percent recycled water to the barrier should include:

   - Quarterly TIC analysis of MF/RO/UV process train effluent prior to injection into the barrier
   - Initiation of frequent monitoring of the MF/RO/UV process train effluent for pharmaceutically active compounds (PhAC), when such analytical methods are offered by commercial laboratories
   - Continued close attention to drinking water Title 22 analyses on product water; monitor for Unregulated Contaminant Monitoring Rule (UCMR) compounds on a frequent basis; frequency may be reduced for given chemicals upon clear demonstration that they do not exist in the product water
   - Monitoring of key water quality parameters to determine the percentage of recycled water reaching monitoring and production wells—if possible development of a simple tracer analysis (minor constituents, ratios of major and/or minor ions) that would help track the arrival of recycled water at the monitoring and production wells
   - A more detailed assessment and tracking of the redox condition of the West Basin, particularly that portion under the direct influence of recycled water recharge; tracking the presence of ammonia and its oxidation to nitrite and nitrate would be an important component of such a monitoring program
   - Because it is important to define both the areal and vertical extent of the barrier injection water as well as the continuing seawater intrusion, it may be necessary to construct additional monitoring wells if "data gaps" exist in sensitive areas of the basin.

4. WBMWD working in concert with the County of Los Angeles, Department of Public Works should urge that any improvements in the seawater barrier be made to eliminate to the maximum degree economically possible the continued leakage of seawater into the basin.

5. Because of industrial components in discharges to the Los Angeles sewer system, the City of Los Angeles and WBMWD should begin discussions on possible modifications to the sewer discharge requirements to take into account the ultimate use of the highly treated Hyperion effluent as a source of potable water.

6. WBMWD should consult with the California Department of Health Services, the Orange County Water District, and MWD regarding the most appropriate analytical procedures for the TIC analyses. Routine comparisons of the MF/RO/UV/H2O2 product water with the alternate source of dilution water from MWD should be continued.

ADVISORY PANEL MEMBERS

Dr. Michael J. McGuire, Chair
President, McGuire Environmental Consultants, Inc.

Dr. Harvey Collins
Former Deputy Director of Public Health Programs and
Former Chief, Division of Drinking Water and Environmental Management, California Department of Health Services

Dr. David Jenkins
Professor in the Graduate School, University of California at Berkeley

Dr. Perry McCarty
Professor Emeritus, Stanford University

Dr. Dennis Williams
President, GEOSCIENCE Support Services, Inc.
Ground Water Hydrologist

APPENDIX A – DOCUMENTS RELIED UPON

Reference No. 7

LongTerm2 Surface Water Treatment Rule, [Federal Register: January 5, 2006 (Volume 71, Number 3)][Rules and Regulations] [Page 653-702] – using the high infectivity rate. http://www.gpo.gov/fdsys/pkg/FR-2006-01-05/pdf/06-4.pdf

APPENDIX A – DOCUMENTS RELIED UPON

Reference No. 8

Water Reuse, Metcalf and Eddy, 2007, Table 3-7, "Microorganism concentrations found in untreated wastewater and the corresponding median infectious dose."

nisms in wastewater are from
l industrial sources. Additional
system is presented in the next

unicipal wastewater are shown
fectious dose. Note that a wide
are encountered in the field, and
cal dose needed to cause disease

beach, and (b) health warning
of Orange County Sanitation

Table 3-7
Microorganism concentrations found in untreated wastewater and the corresponding median infectious dose[a]

Organism	Concentration in raw wastewater, MPN/100 mL[b]	Median infectious dose number (N_{50})
Bacteria		
Bacteroides	10^7–10^{10}	
Coliform, total	10^7–10^9	
Coliform, fecal[c]	10^5–10^8	10^6–10^{10}
Clostridium perfringens	10^3–10^5	1–10^{10}
Enterococci	10^4–10^5	
Fecal streptococci	10^4–10^6	
Pseudomonas aeruginosa	10^3–10^6	
Shigella	10^0–10^3	10–20
Salmonella	10^2–10^4	
Protozoa		
Cryptosporidium parvum oocysts	10^1–10^5	1–10
Entamoeba histolytica cysts	10^0–10^5	10–20
Giardia lamblia cysts	10^1–10^4	< 20
Helminth		
Ova	10^0–10^3	
Ascaris lumbricoides		1–10
Virus		
Enteric virus	10^3–10^4	1–10
Coliphage	10^2–10^4	

[a]Adapted in part from; Feacham et al. (1983); NRC (1996); Crook (1992).
[b]MPN = most probable number.
[c]*Echerichia coli* (enteropathogenic).

in humans (see Fig. 3-8). There is also a wide person-to-person variation in the N_{50} dose, depending on the overall health of the individual, genetic factors, the age of the person, and whether the immune system is compromised, which is represented by reporting the N_{50} dose as a range of values. The subject of median infectious dose is considered further in Chap. 5.

Pathogens in Treated Wastewater

The occurrence and concentration of pathogenic microorganisms in treated municipal wastewater depends on a number of factors including (1) the number of organisms in the untreated wastewater, (2) the level of treatment, (3) the treatment technologies employed, and (4) the regulatory requirements. A discussion on the level of treatment and the available treatment technologies is presented first, followed by information on the pathogens in treated wastewater. Treatment technologies are discussed in great detail in Part 3 of this textbook.

Treatment Levels and Technologies

Methods of treatment in which the application of physical forces predominate are known as *unit operations*. Methods of treatment in which the removal of contaminants is brought about by chemical or biological reactions are known as *unit processes*. At the

APPENDIX A – DOCUMENTS RELIED UPON

Reference No. 9

Occurrence of *Cryptosporidium* Oocysts and *Giardia* Cysts in Sewage in Norway", Robertson, L. J., L. Hermansen, and B. K. Gjerde (2006), Appl Environ Microbiol 72(8): 5297–5303. http://aem.asm.org/content/72/8/5297.full.pdf+html

APPENDIX A – DOCUMENTS RELIED UPON

Reference No. 10

Observed and Predicted Oocyst Concentration Distributions as the Starting Point for Quantitative Microbial Risk Analysis of Tertiary Treatment", Melbourne Water (2011).

Observed and Predicted Oocyst Concentration Distributions as the Starting Point for Quantitative Microbial Risk Analysis of Tertiary Treatment

Prepared for: **Melbourne Water**

by: **Tetra Tech, Inc.**

Project manager: **Tom Hargy**
(thomas.hargy@tetratech.com)

Technical lead: Tim Bartand
(timothy.bartrand@tetratech.com)

Revision 2

28 June 2011

Executive summary

Quantitative microbial risk assessment (QMRA) is increasingly used in assessment and design of water and wastewater treatment facilities, including facilities treating water for various types of reuse. QMRA provides direct connection between source water quality, treatment efficiency, and human health outcomes and, when used correctly, allows exploration of average and extreme conditions and attendant human health implications. Because QMRA estimates risks directly, its use in plant design or assessment provides an alternative to safety factors whose selection may be arbitrary and unrelated to human health risks.

This report describes preliminary analyses and model development for QMRA analysis of the Melbourne Water Eastern Treatment Plant. Analyses were conducted to allow comparison of simulated secondary effluent *Cryptosporidium* oocyst concentrations with observed oocyst concentrations. Those comparisons allowed assessment of whether the observed raw sewage oocyst concentrations (used with predicted secondary treatment plant removal values) or the secondary effluent concentrations are best for use as source terms in quantitative microbial risk analysis (QMRA) of the ETP's tertiary treatment process.

Basic statistical analyses were conducted on a relatively large (n > 70) set of samples collected from multiple locations along the current ETP activated sludge treatment process. Data were generally fit best by log normal distributions for the raw sewage, primary effluent and settled secondary effluent. Only modest removal of oocysts was observed across the primary treatment, whereas consistent removal (average around 0.83 $\log_{10}$ (oocyst/L)) was observed between the raw sewage and the secondary effluent samples. Method percent recovery was normally distributed for samples of raw sewage, but not for samples from the secondary effluent. Based on a non-parametric statistical test, recovery efficiencies for raw sewage and secondary effluent samples were not significantly different.

The distribution of log removal values (LRV) across the entire secondary treatment process was estimated based on reported raw sewage and secondary effluent oocyst concentrations. Several techniques were used to generate LRV distributions, including pairing samples by date (samples collected from the secondary effluent one day after the raw sewage samples were collected), by rank within their distribution, randomly, and using two bootstrap procedures. Each technique had associated shortcomings. Pairing lagged and random samples resulted in unrealistic negative removal (i.e. an apparent increase in oocyst concentration) across the plant, while the ranked samples resulted in no unrealistic outcomes. Randomly-paired samples resulted in gross overpredictions of variability in the LRV, whereas ranked bootstrap pairs may have underestimated variability. We are concerned that any of these methods, because they do not consider the impact of important plant operating conditions such as suspended solids concentration or volumetric flow rate, could result in LRV predictions inconsistent with actual plant operations for at least a portion of the LRV distribution.

Secondary effluent oocyst concentration distribution was predicted using the LRV distributions estimated as described above and using the raw sewage oocyst concentration as the source water oocyst distribution. The procedure used to make the estimations is similar to the procedure that would be used in a detailed QMRA of the treatment process. The predicted secondary effluent oocyst concentration distributions were compared to the observed oocyst distribution for the secondary effluent. The lagged sample model performed reasonably well, reproducing the mean for the secondary effluent oocyst concentration distribution but overpredicting the high portion of the oocyst distribution. The ranked pairs model underpredicted the variability in secondary effluent oocyst concentration whereas a model using a bootstrap distribution of average LRVs significantly underpredicted variability in secondary effluent oocyst concentration.

These results support a conclusion that while statistical analyses can lead to reasonable models for predicting secondary effluent oocyst concentration, none of those models dependably predicts the *Cryptosporidium* oocyst concentration distribution over the range of conditions expected at the ETP. Thus, the observed secondary effluent oocyst distribution appears to be a more dependable starting point for QMRA analyses of the planned tertiary treatment than values predicted used LRV distributions and raw oocyst concentrations. Given the consistent observation of oocysts in the secondary effluent and similar range of recovery observed for raw sewage and secondary effluent samples, detection sensitivity does not preclude use of observed secondary effluent oocyst concentration rather than raw sewage oocyst concentration as a starting point for QMRA.

Background

The Australian Guidelines for Water Recycling (AGWR) adopts a risk-based approach to assure appropriate quality of recycled water with respect to human health. Conceptually, this approach involves characterising the microbial risks in the source water, identifying the intended end uses for the recycled water and associated exposure provisions, and determining the level of microbial reduction required to achieve the nominated tolerable health risk to recycled water users. Accurate characterisation of both the microbial hazards in the water and effectiveness of respective treatment barriers are critical inputs into the risk-based calculations.

As noted in the Australian Guidelines for Water Recycling (Environment Protection and Heritage Council et al. 2006), there is no single correct way to conduct risk analyses and hazard assessments of recycled water (page 33). Though the precise configuration of a risk model of the Melbourne Water (MW) Eastern Treatment Plant (ETP) is, as yet, not chosen, a framework inclusive of all of the data elements listed in the guideline (with the exceptions of preventive measures to be applied at the site of use or discharge of the recycled water and ecological impacts) is likely to be similar to the framework shown in Figure 1.

Accurately characterizing the pathogen source is an essential step in developing quantitative microbial risk assessment (QMRA) models. The source characterization strongly influences the magnitude of risk predicted and, if the source is characterized with a distribution, the source strongly influences the variability in predicted risk. Depending upon the type of model employed, the source must accurately characterize both the central tendency and the probability distribution of pathogen densities. In Figure 1, two alternative source characterizations for a hypothetical QMRA model of the MW ETP *Cryptosporidium* removal are shown. In alternative 1 the raw sewage oocyst density distribution and knowledge about the treatment (Log removal value [LRV]) distribution in secondary treatment are used to generate a predicted distribution of oocysts in the tertiary treatment influent water. In alternative 2 the source for a QMRA model of tertiary treated water from the ETP is the observed distribution of pathogen (for the purposes of this report *Cryptosporidium*) densities from secondary treatment.

Using the oocyst density in the raw sewage might prove advantageous if secondary effluent oocyst concentrations were frequently below detection limits (BDL) or if there were relatively few samples of secondary effluent from which to characterize the distribution of oocyst concentrations. For example, Eisenberg et al. (2008) based estimates of pathogen densities on raw sewage pathogen distributions and assumed performance of unit processes because pathogen densities were low in biosolids and could not be characterized. The process models developed in that study accounted for the high variability related to the very different contact times possible within the treatment process. Those models could not, however, be validated since a suitable data set describing pathogen occurrence in biosolids was not available; in that study the treatment model was validated via determination that all predicted biosolids pathogen levels were below detection limits.

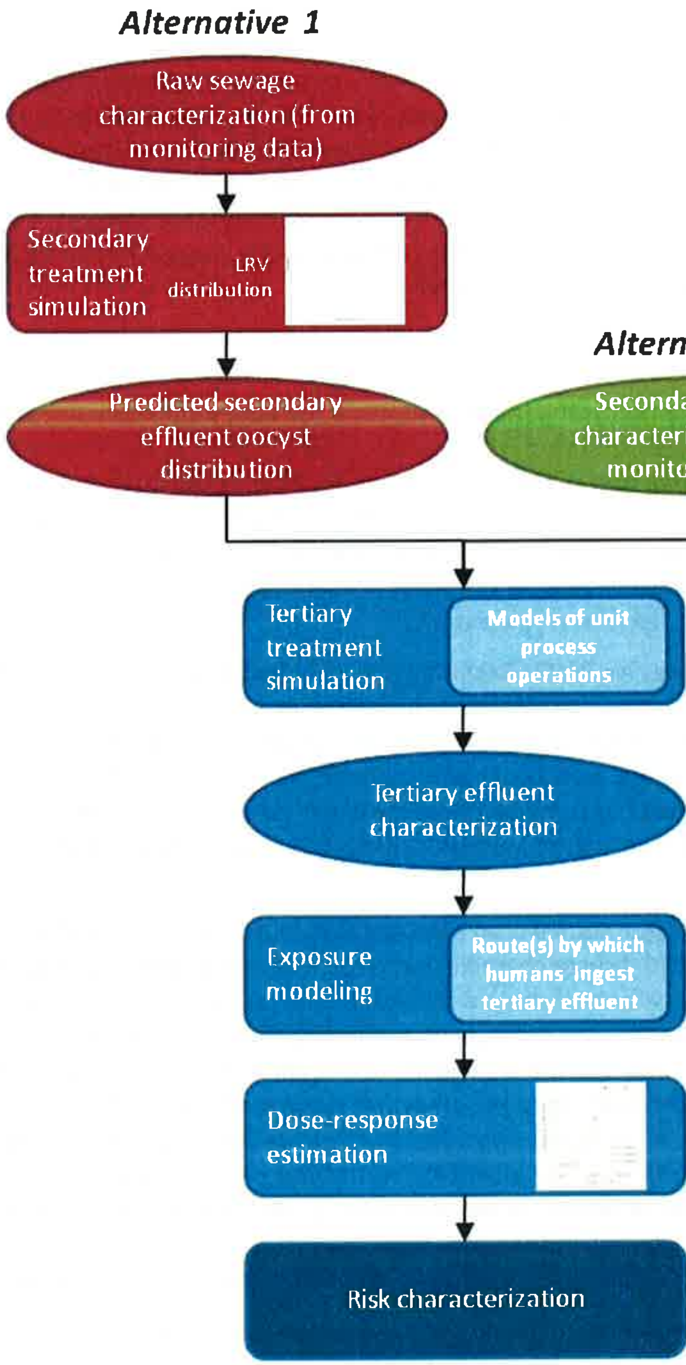


Figure 1. Possible risk assessment framework showing alternative source water choices

Both the raw sewage oocyst concentration and the secondary treatment simulation shown in the alternative 1 branch of Figure 1 are subject to uncertainty (sampling and measurement errors) and variability including variations in influent oocyst concentrations in raw sewage, variations in contact time through the treatment process, and variations in process performance with operational factors such as suspended solids concentration and loading rates. Correlation of secondary treatment performance with influent water quality (and possibly oocyst concentration as a covariate) is possible. Given these considerations, alternative 1 appears subject to greater uncertainty and variability than alternative 2.

In this report relatively large datasets of *Cryptosporidium* densities from samples collected at multiple locations along the secondary treatment process are used to generate candidate distributions for LRV and then predict oocyst concentration distribution in the secondary effluent (source term for a QMRA model of tertiary treatment). In a preliminary section, basic statistical analyses are conducted on the data, including assessment of the distribution of oocysts in the raw sewage and secondary effluent. These parametric distributions of oocyst densities could be employed in QMRA models that include predictions of the frequency and magnitude of extreme events (Smeets et al. 2008). After the basic statistics are described, alternative techniques for developing distributions of LRV across secondary treatment are described and the LRV distributions are assessed against expected process performance. Next, raw sewage oocyst concentration distribution and the alternative characterizations of LRV are used to produce predicted distributions of oocyst concentrations in the secondary effluent (Alternative 1 in Figure 1). Predicted values are compared with observed values. Finally, an overall assessment of alternative 1 and 2 for generating source data for use in a QMRA model of tertiary treatment is presented.

Preliminary data analyses

Preliminary data analyses included the following:

- basic characterization of data
- tests to determine whether corrected oocyst concentration data are normally or log-normally distributed
- determination of whether recovery is normally distributed, and
- comparison of the distribution of oocyst densities among different sample locations.

Basic statistics were generated for *Cryptosporidium* oocyst concentrations corrected by accompanying recovery data in raw sewage, primary effluent, secondary effluent and forebay inlet (a sample location in close proximity to discharge from secondary treatment). In this characterization, the following methods were used:

1. Raw sewage data is available for the period February 2003 – November 2010 while forebay inlet data is available for June 2007 – November 2010. The raw sewage data was truncated to June 2007 – November 2010 representing the period for which raw sewage and forebay inlet data is available.
2. All values below detection limit (BDL, field qualifier value of "<") were set to half[1] of the detection limit.
3. Duplicate data (samples taken at the same date and time) were averaged.
4. If at least one of the duplicate data points was below DL then the averaged value was assumed to be below DL
5. All oocyst concentrations are corrected for method recovery determined by matrix spike analyses.
6. Data without associated recovery (e.g., with recovery < DL) were excluded from analyses.

[1] Representation of an unknown, BDL concentration with half the detection limit is a common practice, but has little theoretical support. Basic statistics are generated under this assumption. A more rigorous treatment of BDL data is found on page 9 in the section detailing development of parametric distributions describing oocyst occurrence at sample locations.

Recoveries were reported with nearly all *Cryptosporidium* oocyst density data and used to produce corrected estimates for oocyst density. Recoveries observed at the raw sewage and forebay inlet locations (the two locations of primary interest in this study) are summarized in Table 1.

Table 1. Recovery statistics for the raw sewage and forebay locations

Location	Total n	No. data below DL[1]	Truncated data set n	Minimum (%)	25th percentile (%)	Mean (%)	STD (%)	Median (%)	75th percentile (%)	95th percentile (%)	Maximum (%)
raw sewage	135	27	108	8.5	24	37.3	17.1	37.5	48	68.8	81
forebay inlet	132	3	129	10	21.5	30.8	13	29	40	53	65

[1] Recovery below DL (<10%) was not included in this summary

The average recovery data were initially checked for normality. Tests indicate that the raw sewage ($p=0.04$) and forebay inlet ($p=0.03$) are not normally distributed. Because recoveries from the two locations were not normally distributed, the Wilcoxon rank test was used to compare the recovery between the two sites. With a p-value of 0.01, the recoveries for the raw sewage and forebay inlet were found to be significantly different. Recoveries were not found to be normally distributed for the primary effluent location (p-value < 0.01).

Basic statistics describing corrected oocyst concentrations at each of three sample locations in secondary treatment are shown in Table 2 and Figure 2[2]. Clear reductions in oocyst concentration are observed across secondary treatment, though not across primary treatment. It should be noted that comparison of individual statistics of the raw sewage and primary effluent oocyst concentration distributions do not provide an accurate description of removal and that in other statistical tests described below low removal was observed across primary treatment. Low removal across primary treatment but significant overall removal is consistent with the findings of Medema et al. (1998), who noted that oocysts attach readily to particles in sewage and are removed via sedimentation, depending on the size and settling velocity of the particles.

The data distributions at the raw sewage, primary effluent and forebay inlet locations (Figure 2) were tested for normality (Shapiro-Wilk test). With a p-value of less than 0.01 all of the three datasets were shown to be not normally distributed. The data for all locations were found to be highly skewed. The three datasets were also tested for the log normal distribution. Under the assumption that below detection limit (BDL) data assume the value of half the detection limit, none of the datasets was log-

[2] Statistical tests demonstrated that, despite the proximity of the locations, the secondary effluent and forebay inlet concentrations distributions differed, likely because the sample collection date ranges for the two locations did not overlap. Consequently only forebay inlet samples were used to characterize effluent from secondary treatment. Statistics used to compare the secondary inlet and forebay locations are presented in the Appendix to this report.

normally distributed (p-value ≤ 0.01) with the exception of the data for the forebay inlet (p-value = 0.77). When data below the detection limit were excluded from analysis, the corrected oocyst density at the primary effluent (p-value=0.22), forebay inlet (p-value=0.27), and primary effluent (p-value=0.09) were found to be log-normally distributed.

Table 2. Basic statistics describing corrected oocyst concentration at sample locations

Statistics	Raw Sewage		Primary Effluent		Forebay Inlet	
Data coverage	Jun2007 - Nov2010		Mar2008 - Nov2010		Jun2007 - Nov2010	
No. data points[1]	108‡		114		129†	
No. duplicate data[2]	6		6		7	
No. data below DL[3]	42		32		6	
oocyst concentration	oocysts/L	Log_{10} (oocysts/L)	oocysts/L	Log_{10} (oocysts/L)	oocysts/L	Log_{10} (oocysts/L)
Minimum	20	1.30	19.5	1.29	0.3	-0.52
25th percentile	53.5	1.73	56.8	1.75	8.7	0.94
Mean	500	2.70	954	2.98	114.1	2.15
Standard deviation	1087	0.59	1998	0.72	230.7	0.74
Median	161	2.21	225	2.35	32.1	1.51
75th percentile	368	2.57	763	2.88	102	2.01
95th percentile	3465	3.54	5388	3.73	6660	2.82
Maximum	6875	3.84	13000	4.11	1546	3.19

†One value was flagged as "NR"

‡Two values were flagged as "no result"

1 Number of data points include only data with associated recovery and corresponding data coverage listed

2 Duplicated data were averaged and included in this summary

3 Oocyst count data below DL were set to half of the detection limit and included in this summary

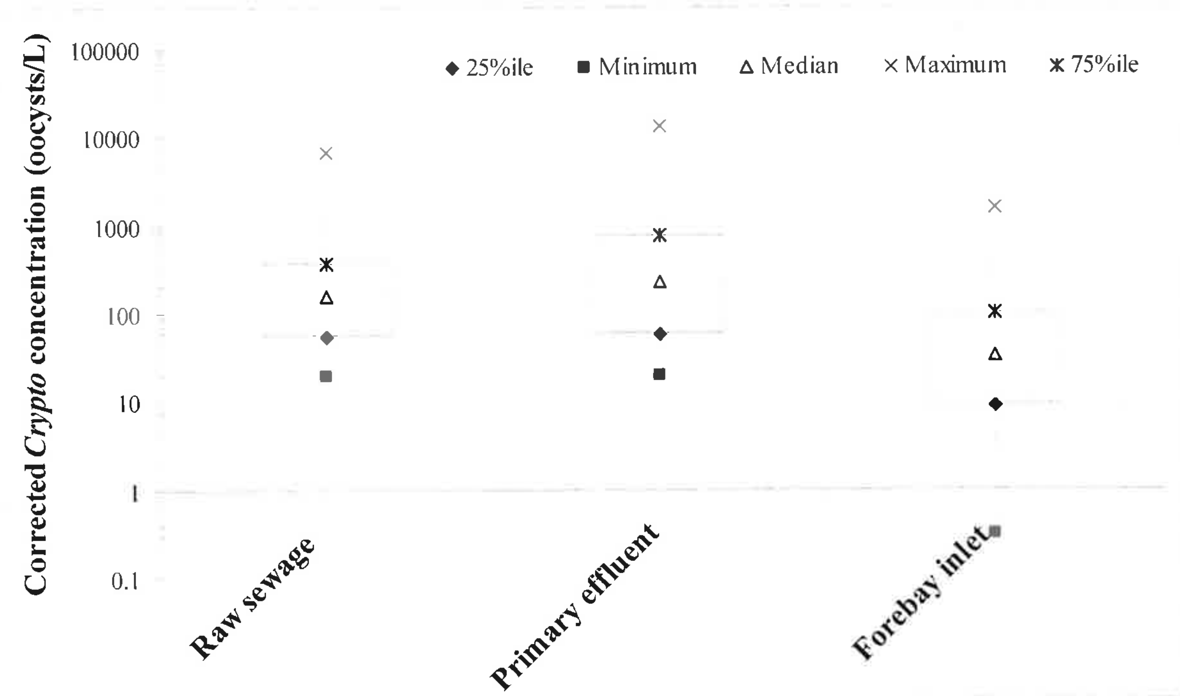


Figure 2. Box and whiskers plot summarizing corrected *Cryptosporidium* concentration at three Melbourne Water Eastern Treatment Plant locations

Because the best fit distribution for data was ambiguous, the non-parametric Wilcoxon rank test was used to compare oocyst data for the raw sewage, primary effluent, and forebay inlet sites. The results, shown in Table 3, demonstrate that there were differences for all pair-wise comparisons except the raw sewage and the primary effluent locations, indicating those two datasets are from the same distribution.

Table 3. Wilcoxon rank test results comparing three ETP locations (corrected oocyst concentrations)

Site 1 × Site 2	p-value	Differences? (Yes or No)
Raw sewage × primary effluent	0.13	No
Raw sewage × forebay inlet	<0.01	Yes
Primary effluent × forebay inlet	<0.01	Yes

The arithmetic and geometric mean for the daily corrected *Cryptosporidium* oocyst concentration for forebay and raw sewage are provided in Table 4. These values are provided mainly as reference and to allow comparison of oocyst concentrations at those locations with those observed in other facilities.

Table 4. Geometric and arithmetic means for daily average corrected *Cryptosporidium* density at the raw sewage and forebay locations

Location	Number of records	Arithmetic Mean		Geometric Mean	
		oocysts/L	$\log_{10}$(oocysts/L)	oocysts/L	$\log_{10}$(oocysts/L)
Raw sewage	94	561	2.75	198	2.30
Forebay inlet	113	126.3	2.10	34.3	1.54

Haas et al. (1999) suggest fitting distributions to data with BDL data using maximum likelihood estimation (mle) with a modified likelihood function in which the probability of BDL data is replaced with the cumulative density function evaluated at the detection limit. Mathematically, the likelihood function may be written

$$L = \prod_{i=1}^{n} [f(x_i;\beta)]^{\delta_i} [F(x \ ;\beta)]^{(1-\delta_i)} \quad [1]$$

and the corresponding deviance may be written

$$-2\ln(L) = -2\sum_{i=1}^{n} \{\delta_i [\ln(f(x_i;\beta)) + (1-\delta_i)\ln(F(x_i;\beta))]\} \quad [2]$$

where L denotes likelihood, x_i are the data being fit to the distribution (either the observed value or the reported detection limit), δ is 1 for data above the detection limit and 0 for data below the detection limit, f and F are the probability density function and cumulative density function to which the data are being fit, and β s a vector of parameters for the distribution (e.g., the mean and standard deviation of a normal distribution).

In QMRA, parametric distributions provide a means for exploring extreme conditions or conditions outside those typically encountered during data collection. Five distributions—the normal, lognormal, gamma, log-gamma, and Weibull—were fit to the raw sewage, primary effluent and forebay inlet data via maximum likelihood. In each case the distribution parameters were those that optimized the deviance (equation 2). Because all of the models considered had the same number of parameters, the model with the lowest deviance was selected as the best fit. Because different references parameterize the gamma, log-gamma and Weibull differently, the parameterizations used in this study (and as presented by DeVore 1990) are provided below.

The gamma and log-gamma distributions are given by

$$f(x;\alpha,\beta) = \begin{cases} \dfrac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta} & x \geq 0 \\ 0 & \text{otherwise} \end{cases} \quad [3]$$

where α is the shape parameter and β is the scale parameter. For the gamma distribution x is the *Cryptosporidium* oocyst corrected concentration and for the log-gamma distribution x is the $\log_{10}$-transformed oocyst concentration. The Weibull probability density function is given by

$$f(x;\alpha,\beta) = \begin{cases} \dfrac{\alpha}{\beta^{\alpha}} x^{\alpha-1} e^{-(x/\beta)^{\alpha}} & x \geq 0 \\ 0 & \text{otherwise} \end{cases} \quad [4]$$

Models, deviances and fitted parameters are provided in Table 5 for the raw sewage, Table 6 for the primary effluent and Table 7 for the forebay inlet (secondary effluent).

Table 5. Summary of fits of raw sewage *Cryptosporidium* oocyst data to candidate distributions

Distribution	-2 ln(*L*)	Parameters
Normal	4111	$\hat{\mu} = 51.4$, $\hat{\sigma} = 1688$
Log-normal	784	$\hat{\mu} = 2.27$, $\hat{\sigma} = 0.61$
Gamma	3790	$\hat{\alpha} = 0.29$, $\hat{\beta} = 1830$
Log-gamma	811	$\hat{\alpha} = 6.87$, $\hat{\beta} = 0.31$
Weibull	787	$\hat{\alpha} = 2.85$, $\hat{\beta} = 2.33$

Table 6. Summary of fits of primary effluent *Cryptosporidium* oocyst data to candidate distributions

Distribution	-2 ln(*L*)	Parameters
Normal	3711	$\hat{\mu} = 350$, $\hat{\sigma} = 2310$
Log-normal	684	$\hat{\mu} = 2.15$, $\hat{\sigma} = 0.95$
Gamma	3380	$\hat{\alpha} = 0.29$, $\hat{\beta} = 2900$
Log-gamma	711	$\hat{\alpha} = 5.93$, $\hat{\beta} = 0.37$
Weibull	688	$\hat{\alpha} = 2.74$, $\hat{\beta} = 2.47$

Table 7. Summary of fits of forebay *Cryptosporidium* oocyst data to candidate distributions

Distribution	-2 ln(*L*)	Parameters
Normal	3513	$\hat{\mu} = 104$, $\hat{\sigma} = 234$
Log-normal	614	$\hat{\mu} = 1.44$, $\hat{\sigma} = 0.77$
Gamma	2857	$\hat{\alpha} = 0.44$, $\hat{\beta} = 248$
Log-gamma	732	$\hat{\alpha} = 2.01$, $\hat{\beta} = 0.72$
Weibull	689	$\hat{\alpha} = 1.82$, $\hat{\beta} = 1.60$

For all three locations the log-normal distribution provided the best fit. The Weibull (without the data log-transformed) provided a fit only slightly worse. On the basis of the log-normal distribution best-fit parameters, an average LRV of 0.83 was observed between the raw sewage and the secondary effluent. The log-normal distribution with parameters $\hat{\mu} = 1.44$ and $\hat{\sigma} = 0.77$ describes the occurrence of oocysts in secondary effluent (at the forebay inlet), inclusive of extreme values, and is suitable for use in QMRA analyses of tertiary treatment at the ETP.

LRV distributions

As demonstrated by Smeets et al. (2008), accurate characterizations of LRV for either unit operations or for treatment processes depend upon the appropriate pairing of inlet and effluent concentrations. As noted by the authors, pairing samples collected at the same time can result in misleading inferences regarding pathogen removal, including apparent increase in number of pathogenic organisms during treatment. Ideally reactor hydraulics and mixing should be included in evaluations of LRV, as proposed in the integrated disinfection design framework (IDDF) (Bellamy et al. 1998). In the absence of the detailed models and data required for using the IDDF, the approaches demonstrated by Smeets and colleagues provide several alternatives for generating LRV distributions. In this study, those distributions are compared with an assumed uniform LRV of 0.5, as suggested in the Department of Health Victoria Draft guidelines for validating treatment processes for pathogen reduction (Supporting Class A water recycling schemes in Victoria) (Department of Health Victoria 2010).

Smeets et al. (2008) compared three approaches for using data sets of process influent and effluent pathogen data to establish distributions of reactor performance. The authors advocate use of a distribution rather than a fixed value based on average conditions at reactor influent and effluent or values of some confidence intervals of the influent and effluent distributions. This is because LRV distributions allow estimation of risks related to extreme events and, in some cases, risks analyses have demonstrated that extreme events may dominate risks. Smeets and colleagues compared three approaches for using *Campylobacter* monitoring data for characterizing drinking water treatment process performance in a QMRA framework. Analyses were performed on paired samples of raw and treated water. Data were paired based on the following:

- same sample time;
- random pairing; and
- rank within non-parametric distribution.

We conducted analyses similar to those conducted by Smeets et al. (2008) in an attempt to develop a "best" characterization of LRV between the raw sewage sample point and the forebay influent point (settled secondary effluent). Those LRV distributions were then used to estimate secondary effluent oocyst concentration distributions as they would be estimated in a QMRA model of the secondary treatment process.

This section begins with generation of non-parametric distributions of LRV over secondary treatment. The LRV distribution is estimated using different pairings of observed raw and forebay *Cryptosporidium* concentrations. Those LRV distributions are compared with each other on the basis of plausibility (e.g. are unrealistically high or low removals observed in the distribution) and on the basis of variance. Though the magnitude of variations in LRV are not known, it is anticipated that LRV varies with plant operating conditions such as loading rate, suspended solids concentration, and possibly oocyst concentration. To generate LRV distributions, the following pairings of influent and effluent data were done:

- one-day lag in sample collection time for raw sewage and forebay locations (selected to approximate hydraulic residence time between the sample locations);
- pairing of influent and effluent samples by rank;
- random pairing of influent and effluent samples;

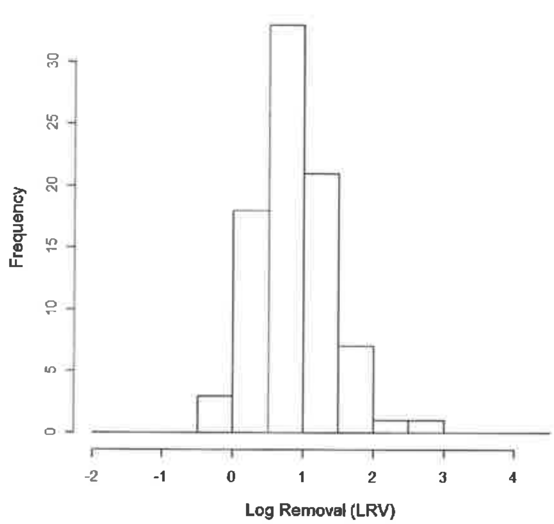
- pairing of inlet and effluent distributions generated by bootstrap, with samples paired by rank; and
- pairing of mean LRV of bootstrap samples paired by rank.

Use of lagged samples is consistent with the methodology described in the Department of Health Victoria Draft guidelines for validating treatment processes for pathogen reduction (Supporting Class A water recycling schemes in Victoria) (Department of Health Victoria 2010) and represents an improvement in analysis of samples collected at the same time, in that samples collected at lagged times are more likely to be related to each other. However, as suggested by Eisenberg et al. (2008), actual residence times within wastewater plants are widely variable, with well-mixed processes such as activated sludge unit operations best characterized by exponential distributions in residence time. Given this variability, the likelihood of exactly pairing related samples appears to be low. Smeets et al. (2008) suggest pairing by rank as a reasonable alternative because this procedure is less prone to result in the unlikely observation of a higher concentration of pathogens after treatment than before treatment compared to when pairing samples collected at the same time. One complication associated with pairing by rank is that samples with low pathogen numbers are associated with high uncertainty (sampling uncertainty) and LRV estimates made on the basis of those samples might be less certain than LRV estimates made using data in the mid- and high-ranges of the distribution. Random pairings of influent and effluent concentration were not expected to result in a reasonable distribution of LRV, but were included to provide a full range of LRV distributions to compare.

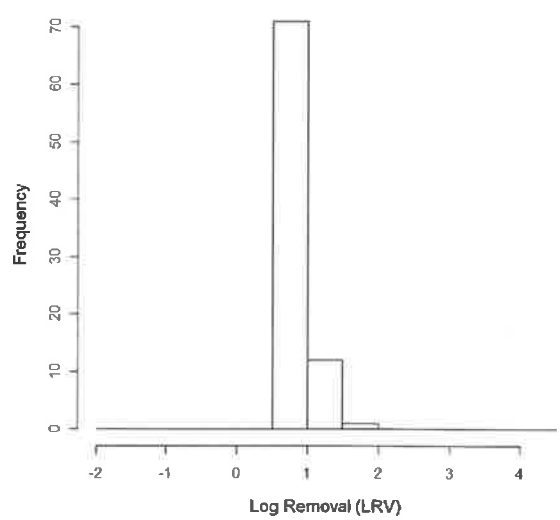
Two bootstrapping procedures were conducted to provide additional information on the likely variability and range of LRV. Bootstrapping may be thought of as a set of numerical experiments that replicate the sampling that was conducted to provide the data used in this report (Efron and Tibshirani 1993). Bootstrapping is a well-established practice and is commonly used in QMRA for developing non-parametric distributions of variables as well as for generating confidence intervals of statistics such as parameter estimates. In the first use of bootstrap in this report, the distributions of LRV for 10000 bootstrap replicates of the raw sewage and forebay inlet corrected oocyst concentration data were produced by pairing influent and effluent data by rank within their respective bootstrap replicates. Bootstrap sample sizes were the same number of samples taken at the forebay inlet, which had fewer samples than were taken for the raw sewage. The second application of bootstrap involved averaging the LRVs for each of the bootstrap replicates. This produced an estimate of mean LRV and its confidence interval over all anticipated operating conditions.

Histograms showing LRV distributions for the pairing strategies are found in Figure 3 and summary statistics describing the distributions are presented in Table 8. As noted above, because significant differences were noted for *Cryptosporidium* concentrations at the secondary effluent and forebay locations, all comparison were made between the raw sewage and forebay locations (which had more data points than the secondary effluent location). LRVs and predictions of secondary effluent concentrations were conducted for corrected and uncorrected *Cryptosporidium* oocyst concentrations, though only the results of analyses with the corrected data are shown here.

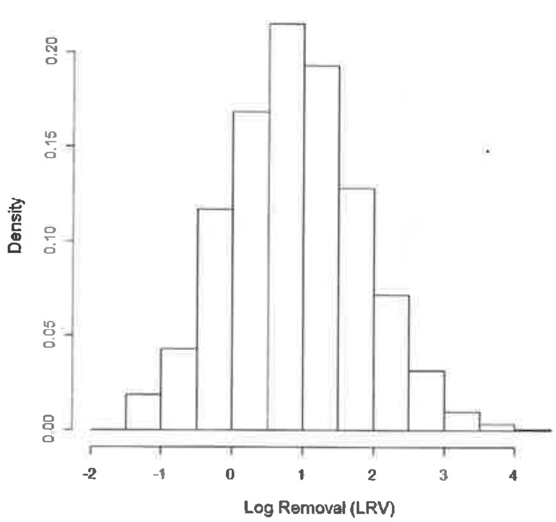
Histogram of LRV, lagged samples



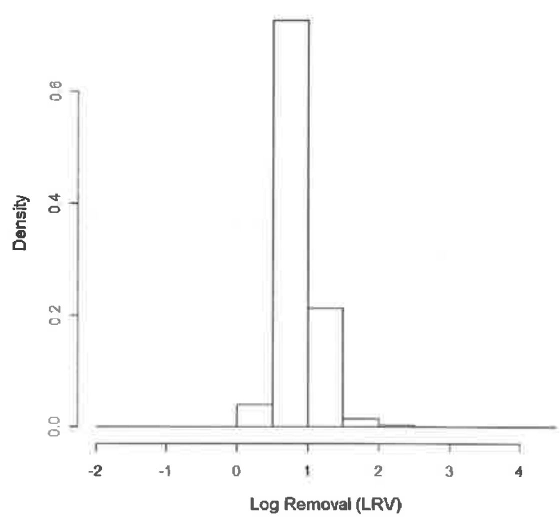
Histogram of LRV, ranked samples



Histogram of LRV, randomly-paired samples



Histogram of LRV, ranked bootstrap samples



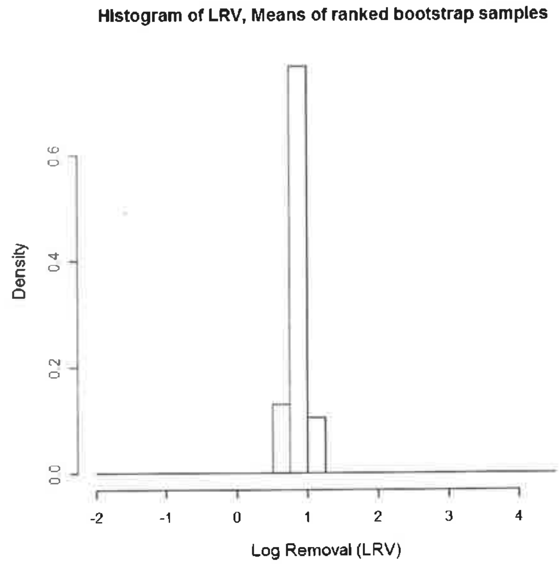


Figure 3. Histograms of LRVs associated with pairing strategies

Table 8. Summary of LRV outcomes for different pairing strategies

	Pairing Strategy				
Parameter	**Lagged samples**	**Ranked samples**	**Random pairs**	**Bootstrap samples**	**Bootstrap means**
Mean LRV	0.87	0.87	0.88	0.87	0.87
LRV Variance	0.25	0.039	0.85	0.061	0.011

The different pairing strategies have a profound influence on the distribution of LRVs predicted using the wastewater treatment plant influent raw sewage) and effluent (forebay inlet) data. As anticipated based on the characterization of the LRV distributions, the lagged and random sample pairings both resulted in some degree of higher effluent *Cryptosporidium* concentration than influent concentration, with the randomly-paired samples associated with this misleading result most often. This finding calls into question use of a low (say 5th) percentile LRV based on lagged samples for characterizing removal. When low removal are associated with low influent *Cryptosporidium* density, uncertainty in both the influent and effluent *Cryptosporidium* density may result in inaccurate characterization of plant performance. The lagged sample pairing exhibits greater variability than the ranked sample strategy, but significantly less than samples paired randomly. The distribution based on mean LRVs for ranked bootstrap samples exhibits an unrealistically-low level of variability. The ranked distribution exhibits greater skew than the lagged sample and randomly paired LRV distributions. In summary, the ranked sample distribution and distributions generated using bootstrapping of ranked samples largely overcome anomalous process performance characterizations, but might not accurately portray the variability observed in the system.

Predicted and observed secondary effluent *Cryptosporidium* concentration

The LRV distributions presented above were used in concert with the distribution of *Cryptosporidium* in raw sewage to produce estimates of secondary effluent *Cryptosporidium* concentration for comparison with observed values. This procedure is similar to calculations that could be used as part of QMRA analyses of process performance—though in many cases a less detailed representation of process performance (e.g., mean, 5th percentile, and 95th percentile) may be used if the intent of the QMRA analysis is screening risks, or if the QMRA objective is to establish mean conditions and not to explore extreme events. The results of these simulations are compared to the observed distribution of oocysts in the settled secondary effluent. This comparison allows validation (or rejection) of the models.

Six simulations were conducted for comparison of predicted results to observed oocyst concentration distribution in the secondary effluent (forebay inlet). Those simulations were:

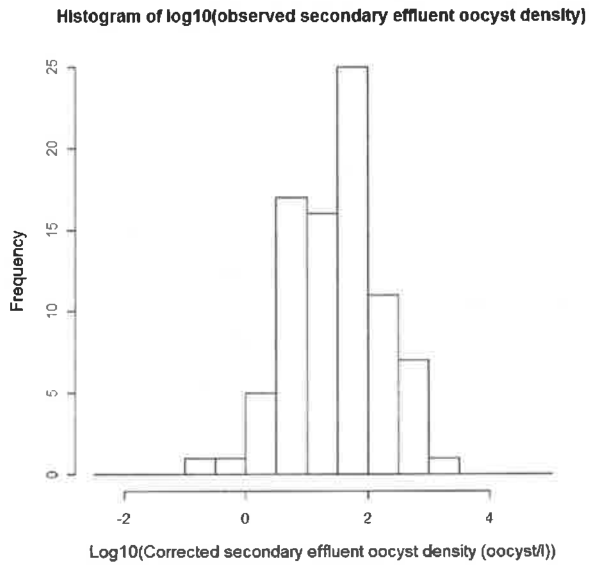
1. direct use of raw sewage oocyst concentration and an assumption of a 0.5 log reduction across the wastewater treatment process
2. Monte Carlo simulation in which raw sewage oocyst densities were drawn from the observed values and LRV was drawn from the lagged samples LRV distribution
3. Monte Carlo simulation in which raw sewage oocyst densities were drawn from the observed values and LRV was drawn from the ranked samples LRV distribution
4. Monte Carlo simulation in which raw sewage oocyst densities were drawn from the observed values and LRV was drawn from the randomly paired samples LRV distribution
5. Monte Carlo simulation in which raw sewage oocyst densities were drawn from the observed values and LRV was drawn from the bootstrapped ranked samples LRV distribution
6. Monte Carlo simulation in which raw sewage oocyst densities were drawn from the observed values and LRV was drawn from the averaged bootstrapped ranked samples LRV distribution.

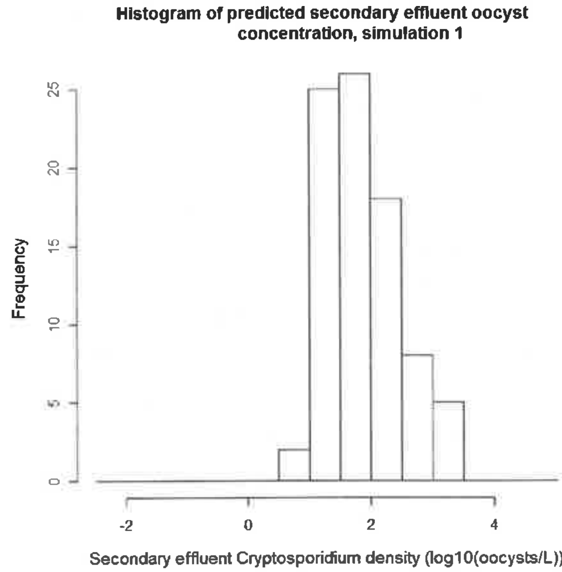
Monte Carlo simulation refers to a simulation in which parameters are repeatedly drawn from distributions describing their occurrence and used to generate a large number of results. The distribution of those results is the set of eventualities consistent with the model and data and its statistics (e.g., 95th percentile confidence interval) are used in risk characterization. In this study, with the exception of the first simulation the Monte Carlo simulation model is

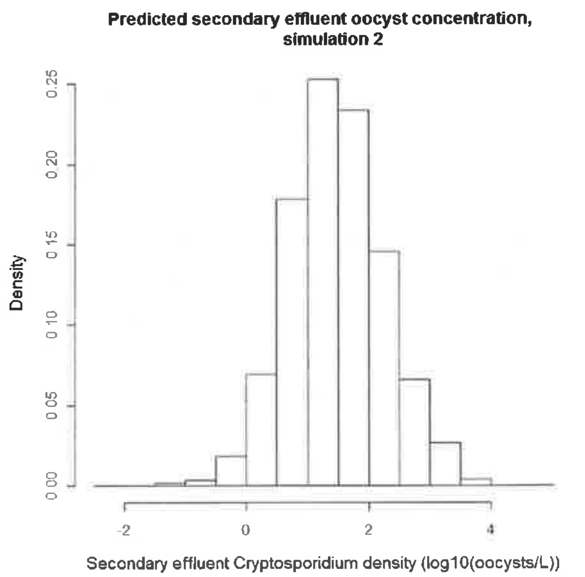
$$\log_{10} C_{FB} = \log_{10} C_{RS} - LRV \quad [5]$$

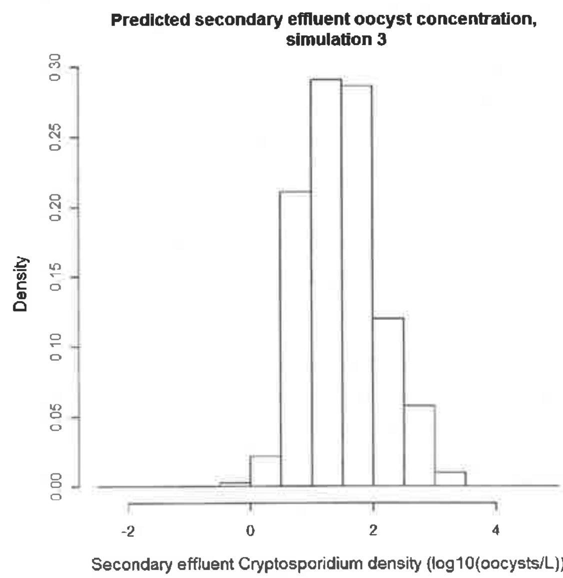
where C_{FB} is oocyst concentration at the forebay inlet and C_{RS} is oocyst concentration in the raw sewage. In the Monte Carlo simulations C_{RS} and LRV are random variables drawn from the distributions described in the list of simulations numbered 1-6 above.

Histograms showing predicted effluent concentration distributions (as $\log_{10}$(oocyst concentration)) are shown in Figure 4 and distribution statistics are summarized in Table 9. The observed oocyst density is presented as the first panel in Figure 4.


Histogram of log10(observed secondary effluent oocyst density)
Frequency
0
5
10
15
20
25
-2
0
2
4
Log10(Corrected secondary effluent oocyst density (oocyst/l))


Histogram of predicted secondary effluent oocyst concentration, simulation 1
Frequency
0
5
10
15
20
25
-2
0
2
4
Secondary effluent Cryptosporidium density (log10(oocysts/L))


Predicted secondary effluent oocyst concentration, simulation 2
Density
0.00
0.05
0.10
0.15
0.20
0.25
-2
0
2
4
Secondary effluent Cryptosporidium density (log10(oocysts/L))


Predicted secondary effluent oocyst concentration, simulation 3
Density
0.00
0.05
0.10
0.15
0.20
0.25
0.30
-2
0
2
4
Secondary effluent Cryptosporidium density (log10(oocysts/L))

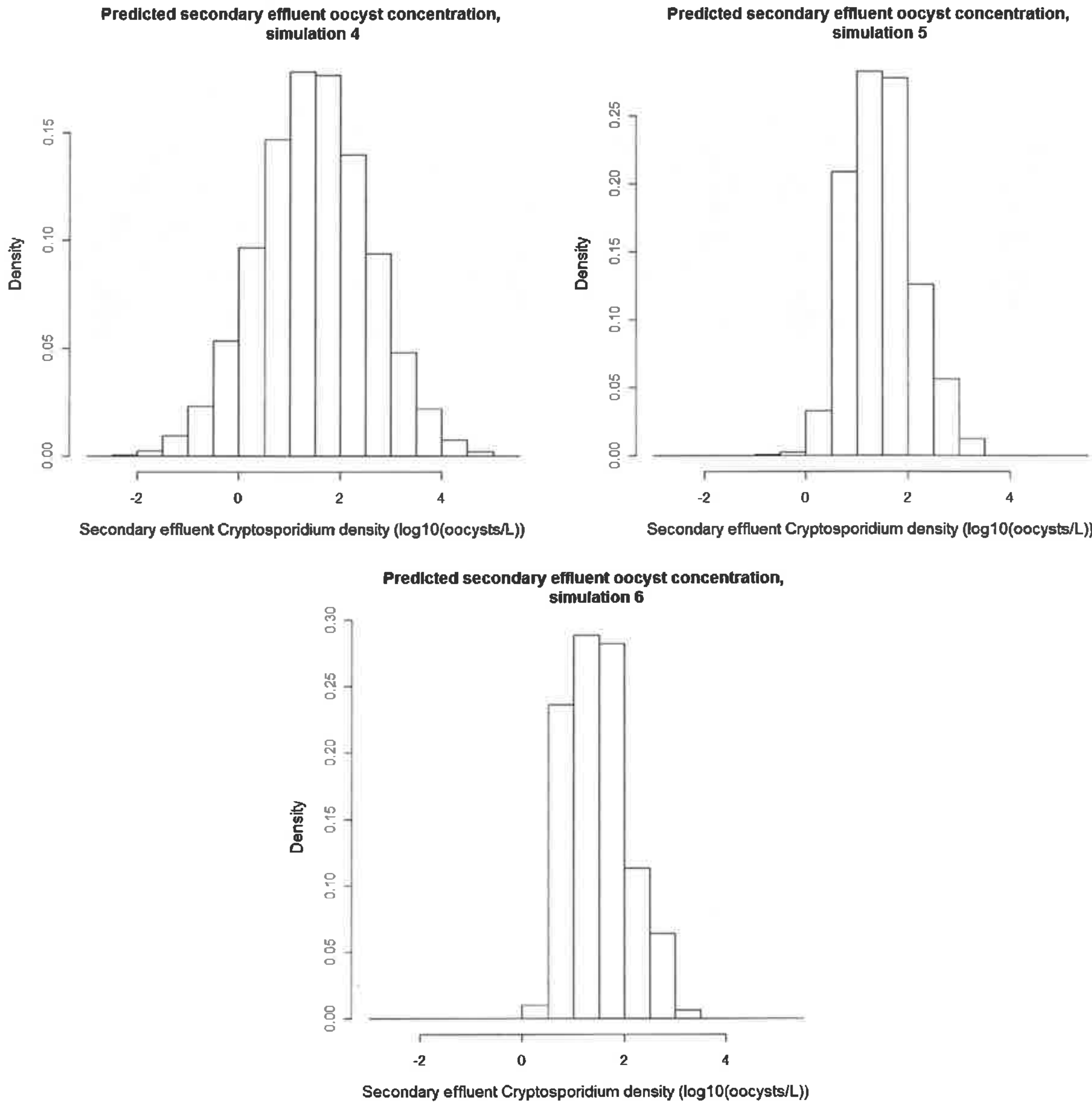


Figure 4. Observed and predicted distributions of oocysts in the secondary effluent

Table 9. Summary of predicted secondary settled effluent concentration distributions

	Observed and Predicted Secondary effluent Log_{10}(*Cryptosporidium* concentrations)†						
Parameter	Observed	LRV = 0.5 (simulation 1)	Lagged samples (simulation 2)	Ranked samples (simulation 3)	Random pairs (simulation 4)	Bootstrap samples (simulation 5)	Bootstrap LRV means (simulation 6)
Mean density	1.48	1.85	1.48	1.49	1.47	1.48	1.48
Variance	0.53	0.34	0.59	0.37	1.18	0.39	0.34
5th quantile	0.40	1.05	0.24	0.63	-0.33	0.57	0.65
95th quantile	2.74	3.07	2.81	2.68	3.26	2.67	2.67

† Note that the results reported for observed effluent density differ from those reported in Table 2 because only samples for which both raw sewage and forebay inlet had recovery above the DL were included in this analysis.

The predicted oocyst distributions are evaluated against the observed secondary effluent oocyst distribution. This comparison is a validation of the LRV models, since the observed values are the most direct measure of system performance. The default assumption of a uniform 0.5 log removal appears to underestimate the typical removal of the ETP and significantly overestimates the 5th quantile value of effluent oocyst density. Although the lagged pairs distribution (simulation 2) appears more in line with the observed values, it is prone to overpredicting the highest (extreme) oocyst densities. While the ranked pairs distribution range is more in line with the observed data, the distribution has an overall lower variability. As expected, the random pairs distribution range is much wider than that of the observed distribution, while the two bootstrapped distributions are similar to that of the ranked pairs.

Discussion

Accurate depiction of source data is essential for developing a QMRA with meaningful results that will be able to predict risks over the range of operating conditions, including those associated with extreme events. As demonstrated in this report, while some approaches for simulating wastewater treatment at the ETP reproduce the effluent *Cryptosporidium* distribution reasonably well, each of the approaches is subject to drawbacks that could result in inaccurate characterization of either the range or variability in oocyst densities in the effluent. These inaccuracies are problematic because (1) their use in assessing extreme events is questionable, and (2) because they might lead to misleading QMRA findings and difficulties in developing subsequent risk management strategies.

For the ETP, one potential motivation for using raw sewage concentrations, as opposed to secondary effluent concentrations, as the basis (source term) of QMRA analyses could be that higher numbers of oocysts are likely to be present in the raw sewage. This could lead to more facile measurement of oocysts at that location. Analysis of the raw and treated sewage oocyst concentrations and recoveries for the ETP indicate that the raw sewage oocyst concentrations may be no easier to measure than those in the treated wastewater. The number of BDL samples in the raw sewage and secondary effluent are not significantly different from each other; the recoveries for the two stations are also not statistically different. Thus the uncertainty and potential bias associated with use of raw sewage data and a characterization of wastewater treatment performance rather than direct use of observed plant effluent water quality is not offset by a reduction uncertainty in oocyst concentration in the secondary effluent and the head of the tertiary treatment processes.

These findings lead us to suggest the direct use of observed secondary effluent *Cryptosporidium* oocyst densities as the starting point for QMRA analyses of the tertiary treatment processes. Note that this suggested approach does not preclude conducting parallel QMRA analyses of the wastewater treatment process as part of an overall risk management strategy. Such analyses could be performed to develop an improved understanding of plant performance and to allow improved characterization of the variability of the treatment process.

References

Bellamy, W. D., G. R. Finch and C. N. Haas 1998. Integrated disinfection design framework. AWWA Research Foundation Denver, CO

Department of Health Victoria 2010. Draft guidelines for validating treatment processes for pathogen reduction supporting Class A water recycling schemes in Victoria. Department of Health. Melbourne, VIC Date.

DeVore, J. L. 1990. Probability and Statistics for Engineering and the Sciences. Belmont, CA, Duxbury Press.

Efron, B. and R. J. Tibshirani 1993. An Introduction to the Bootstrap. New York, Chapman and Hall.

Eisenberg, J. N. S., K. Moore, J. A. Soller, D. Eisenberg and J. M. J. Colford 2008. Microbial risk assessment framework for exposure to amended sludge projects. Environmental Health Perspectives 116(6):727-733.

Environment Protection and Heritage Council, The Natural Resource Management Ministerial Council and The Australian Health Ministers' Conference 2006. Australian Guideline for Water Recycling: Managing Health and Environmental Risks (Phase 1). Canberra, Australia

Haas, C. N., J. B. Rose and C. P. Gerba 1999. Quantitative Microbial Risk Assessment. New York, John Wiley and Sons.

Medema, G. J., F. M. Schets, P. F. M. Teunis and A. H. Havelaar 1998. Sedimentation of free and attached Cryptosporidium oocysts and giardia cysts in water. Applied and Environmental Microbiology 64(11):4460–4466.

Smeets, P. W. M. H., Y. J. Dullemont, P. H. A. J. M. VanGelder, J. C. Van Dijk and G. J. Medema 2008. Improved methods for modeling drinking water treatment in quantitative microbial risk assessment; a case study of *Campylobacter* reduction by filtration and ozonation. Journal of Water and Health 6(3):301-314.

Appendix

The data distribution for the secondary effluent sample location was tested for normality (Shapiro-Wilk test). With a p-value of less than 0.01 the secondary effluent dataset was shown to be not normally distributed. Under the assumption that below detection limit (BDL) data assume the value of half the detection limit, the secondary effluent location (p-value = 0.92) was determined to be log-normally distributed. When data below the detection limit were excluded from analysis, the corrected oocyst density at the secondary effluent was found to be log-normally distributed (p-values of 0.37).

A T-test was used to assess whether the forebay and secondary effluent data could be pooled. As shown in previous sections, the log-transformed data for these two locations are normally distributed which made possible the use a parametric test for comparing these two sites. The T-test indicated the log-transformed data for the two sites were significantly different (p-value = 0.01), despite their close proximity in the treatment train and although no processes expected to remove oocysts occurs between the sample locations. The difference between the data sets is likely because data were collected during non-overlapping time periods. Because the data were found to differ, they were not pooled and calculations for determining LRV were made excluding secondary effluent *Cryptosporidium* oocyst data.

APPENDIX A – DOCUMENTS RELIED UPON

Reference No. 11

Guidelines for Drinking-Water Quality, World Health Organization.
http://apps.who.int/iris/bitstream/10665/44584/1/9789241548151_eng.pdf

APPENDIX A – DOCUMENTS RELIED UPON

Reference No. 12

“Evaluation of the Feasibility of Developing Uniform Water Recycling Criteria for Direct Potable Reuse”, Expert Panel, Chapter 9, page 227.

As noted in **Section 1.1.3** in **Chapter 1**, about two-thirds of the population of California receives drinking water from the State Water Project (SWP), which is fed by water from the Delta. Twelve wastewater treatment plants (WWTPs) discharge to the Delta, and many others discharge to its tributaries. Currently, the average volume of dry weather wastewater discharge reaching the Delta is around 350 mgd; it is expected to increase in the future (SWPCA, 2011). Notably, efforts are underway to improve the quality of wastewater reaching the Delta, including upgrading WWTPs to include granular media filtration (SWPCA, 2011).

All California SWP contractors completed monitoring required by the Long Term 2 Enhanced Surface Water Treatment Rule, the results of which are documented in SWPCA (2011). The results have been classified in Bin 1, representing low *Cryptosporidium* levels (i.e., a running annual average of less than 0.075 oocysts per liter); therefore, no additional action related to reducing *Cryptosporidium* concentration is required at this time.

9.1.2 Scenario 2: Indirect Potable Reuse with an Environmental Buffer with Reduced Retention Time (the "Gap")

As discussed in **Section 1.1.2** in **Chapter 1**, all current and proposed regulations for indirect potable reuse (IPR) in the State of California include the use of a regulatory-defined environmental buffer; however there are likely to be potential potable reuse projects where an environmental buffer is available, but does not meet the proposed operational and performance criteria for an IPR project using surface water augmentation (SWA). This scenario addresses such a situation.

The proposed criteria for IPR using SWA include (1) an operational criterion of a monthly-average theoretical hydraulic residence time of at least 4 to 6 months and (2) a performance criterion requiring the dilution of a 1-day pulse of "off-spec" water of at least 1:100 or of 1:10 when an additional 1-$\log_{10}$ reduction of each pathogen (i.e., virus, *Cryptosporidium* oocysts, and *Giardia* cysts) is provided by the AWTF (NWRI, 2015a,b). These criteria ensure that a substantial environmental buffer is in place to provide the following three benefits:

- Storage of advanced treated water for subsequent potable reuse.
- Attenuation (e.g., by dilution and die-off) of any contaminants that may evade sufficient treatment.
- Time to respond to treatment plant upsets during production.

Notably, the proposed criteria for IPR projects using SWA do not include an alternatives clause (NWRI, 2015b) like that in the regulations for IPR using groundwater replenishment (CCR, 2015), where a project may be allowed to use an alternative to ***any*** requirement if it "assures at least the same level of protection to public health." Consequently, an IPR project for SWA using an environmental buffer that does not meet regulatory criteria would be defined as DPR. This situation creates a regulatory "Gap" between IPR projects with smaller environmental buffers and DPR projects with no environmental buffers. Based on the previous analysis of an environmental buffer conducted by the Expert Panel as part of its review of proposed criteria for IPR using SWA (NWRI, 2015a,b), the Expert Panel considers IPR projects with a theoretical hydraulic retention time of <2 months to be a DPR project (i.e., the Gap between IPR using SWA and DPR covers projects with theoretical hydraulic retention times of ≥2 months and <4 months). See **Section 1.1.2** of **Chapter 1** for more information.