NATIONAL WATER RESEARCH INSTITUTE

Volume I

Final Report

of the March 5, 2014, Conference Call Meeting of the

Expert Panel

for the

California Department of Public Health (Agreement No. 13-21041)

on

Development of Water Recycling Criteria for Indirect Potable Reuse through Surface Water Augmentation and the Feasibility of Developing Criteria for Direct Potable Reuse

June 12, 2014
Fountain Valley, California

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

ABOUT NWRI

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

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Publication Number: NWRI-2014-05

ACKNOWLEDGMENTS

The Expert Panel on "Development of Water Recycling Criteria for Indirect Potable Reuse through Surface Water Augmentation and the Feasibility of Developing Criteria for Direct Potable Reuse" (Panel) was formed at the request of the California Department of Public Health (CDPH). Financial support for the Panel is being provided by CDPH through Agreement No. 13-21041.

The Panel would like to thank CDPH staff for the information, materials, and suggestions received from CDPH as part of the first Panel Meeting, which is the focus of this Panel Report. In particular, the Panel thanks Mr. Randy Barnard, Mr. Mark Bartson, Mr. Brian Bernados, Mr. Bruce Burton, Mr. Robert Hultquist, and Dr. David Spath of CDPH for their assistance. The Panel also appreciates the support of Mr. Bruce Burton, Chief of the Northern California Drinking Field Operations Branch, who serves as the CDPH project representative on this effort.

In addition, the Panel thanks the National Water Research Institute for administering and organizing the Panel's efforts. The Panel would also like to recognize the WateReuse Research Foundation, WateReuse California, and Water Research Foundation for participating in the first Panel Meeting and providing valuable information on current and future potable reuse research projects.

DISCLAIMER

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

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ACRONYMS

CDPH	California Department of Public Health
CT	Concentration × time
DPR	Direct potable reuse
FAT	Full advanced treatment
HACCP	Hazard analysis and critical control points
IPR	Indirect potable reuse
NDMA	N-Nitrosodimethylamine
NWRI	National Water Research Institute
PI	Principal Investigator
RO	Reverse osmosis
SCCWRP	Southern California Coastal Water Research Project
SFEI	San Francisco Estuary Institute
WRRF	WateReuse Research Foundation

1. PURPOSE AND HISTORY OF THE PANEL

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

The Panel has been formed on behalf of the California Department of Public Health (CDPH) and is administered by NWRI.

Specifically, the Panel is charged with the following:

1. Advise CDPH on public health issues and scientific and technical matters regarding the development of surface water augmentation (IPR) criteria.
2. Advise CDPH on public health issues and scientific and technical matters regarding the feasibility of developing criteria for DPR.
3. Assess what, if any, additional areas of research are needed for establishing criteria for DPR.

1.1 Project Background

The California Water Code Section 13563[1] requires that CDPH, on or before December 31, 2016, shall investigate and report to the Legislature on the feasibility of developing uniform water recycling criteria for DPR. Furthermore, on or before December 31, 2016, CDPH shall develop and adopt Water Recycling Criteria for surface water augmentation. CDPH shall not adopt the criteria unless and until an Expert Panel adopts a finding that the proposed criteria would adequately protect public health.

Therefore, CDPH is charged with convening and administering an Expert Panel "for the purposes of advising the Department on public health issues and scientific and technical matters regarding development of uniform water recycling criteria for indirect potable reuse through surface water augmentation and investigation of the feasibility of developing uniform water recycling criteria for direct potable reuse."

Water Code Section 13565 also requires that the Panel "shall assess what, if any, additional areas of research are needed to be able to establish uniform regulatory criteria for DPR. The Panel shall then recommend an approach for accomplishing any additional needed research regarding uniform criteria for DPR in a timely manner."

[1] http://www.leginfo.ca.gov/cgi-bin/displaycode?section=wat&group=13001-14000&file=13560-13569 (last accessed June 12, 2014).

1.2 Panel Members

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

Panel members include:

- *Panel Chair:* R. Rhodes Trussell, Ph.D., P.E., Trussell Technologies, Inc. (Pasadena, CA)[2]
- 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)
- Adam Olivieri, Dr.P.H., P.E., EOA, Inc. (Oakland, CA)
- Joan B. Rose, Ph.D., Michigan State University (East Lansing, MI)
- David Sedlak, Ph.D., University of California, Berkeley (Berkeley, CA)
- Tim Wade, Ph.D., United States Environmental Protection Agency (Durham, NC)

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

[2] Rhodes Trussell resigned from the Expert Panel effective June 5. 2014.

2. PANEL MEETING

A half-day meeting of the Expert Panel was held on March 5, 2014, from 9:00 am to 1:00 pm (Pacific Standard Time) using web-enabled conference call services. This meeting represents the first time the Panel has met. The specific focus of this meeting was to learn about CDPH's mandate, review the current version of the *California Direct Potable Reuse Initiative Research Plan* and other current DPR research activities, and comment upon what, if any, additional areas of research are needed for establishing criteria for DPR.

2.1 Background Material

Prior to the meeting, CDPH provided the following background material to the Expert Panel:

- *California Direct Potable Reuse Initiative Research Plan* (dated February 25, 2014), prepared by WateReuse Research Foundation (WRRF) and WateReuse California. Sections include:
    - Section 1: Background, Drivers, and Participants of the DPR Initiative
    - Section 2: Research Path to Achieve DPR Initiative's Goal
    - Section 3: Current WateReuse Research Foundation DPR Research Projects
    - Section 4: Future Research and Next Steps

- A list of proposed questions for the Panel to consider in reviewing the *California Direct Potable Reuse Initiative Research Plan*, including:
    1. Does the Research Plan appropriately define the needed DPR research?
    2. Is the framework presented in the Plan appropriate (i.e., regulatory, utility, and community concerns)?
    3. Can the Panel identify any substantial gaps in the research framework, including the current research and proposed future research?
    4. Does the Panel have other comments for WateReuse Research Foundation and WateReuse California as it implements the Plan?
    5. How would the Panel like to be updated in the future on the status of the research efforts?

- *California Water Code Section 13560-13569*, which is relevant to potable reuse and the Panel's effort.

2.2 Meeting Agenda

Staff from NWRI and CDPH collaborated on the development of an agenda for the web-enabled conference call Panel meeting, which is included in Appendix C. The agenda was based on meeting the following specific objectives:

1. Provide an overview of CDPH's mandate regarding the Panel.
2. Review the Panel's scope of work.
3. Review DPR research efforts to date and comment on future research needs.

The first half of the conference call was devoted to presentations by CDPH and NWRI on the Expert Panel process and tasks, as well as CDPH's statutory mandates and interest in DPR. The next hour included presentations by project managers on current and planned research efforts in potable reuse and DPR.

Specifically, presentations included:

- Potable Reuse Statutory Mandates and Tasks
- Overview of Panel Process
- Regulating Potable Reuse
- Questions and Research Issues
- Direct Potable Reuse Initiative
- Overview of Current DPR Research

Time was allowed for questions and discussion between CDPH staff, research project managers, and Panel members following each presentation and throughout an open discussion held during the latter half of the meeting. The Panel then met in a closed session to develop a draft report outline, which is expanded upon in this report.

2.3 Meeting Attendees

All Panel members were able to participate on the conference call meeting, though Dick Bull, Joan Rose, and David Sedlak missed portions of the call due to scheduling conflicts. Other attendees included NWRI staff, CDPH staff, and water reuse research representatives. A complete list of Panel meeting attendees is included in Appendix D.

3. COMMENTS

Some California municipalities are actively engaged in considering DPR at the present time. In support of this effort, WRRF, California WateReuse Association, and others are working together to conduct and coordinate a substantial research effort addressing DPR issues that have been identified thus far. This Expert Panel is charged with assessing additional areas of research needed to establish uniform regulatory criteria for DPR and recommending an approach for accomplishing any needed research in a timely manner. The Panel has also been asked, at the outset of its deliberations, to provide comments on current research efforts being undertaken. To this end, at its first teleconference meeting, the Panel heard presentations on regulatory requirements, research plans, and current research activities from CDPH, California WateReuse, and WRRF.

The Panel has not had significant time to deliberate on the issues in DPR or to develop a consensus among its members on the research needs that emanate from them; therefore, it should be understood that the Panel's views on some issues may further evolve during future deliberations and specific recommendation may result. Nevertheless, as the efforts previously mentioned are contemporary with the Panel's activities, timely feedback from the Panel is necessary. The following comments, which were generated and briefly reviewed by Panel members, represent a summary of the issues on the Panel's mind as they begin deliberations, and are provided to help WRRF strengthen its research plan and for CDPH's consideration.

The principal comments derived from the material presented and discussed during the conference call meeting are provided below. They are organized under the following categories:

- General Comments
- CDPH Mandate and Panel Process
- Comments about the Research Plan
- Panel's Response to Research Plan Questions

3.1 General Comments

- The Panel would like to receive copies of reports completed by WRRF on DPR-related topics (PDF files are preferred, when possible).

- The Panel would also like to receive a copy of Policy Memorandum 97-005 on "extremely impaired water sources" (as mentioned by Bob Hultquist of CDPH).

- The Panel encourages the development of a website to provide the Panel with useful presentations and deliverables.

- The Panel noted that the formal reports from newly awarded and future research projects may not be available in time to be useful toward the Panel review process; yet, in many cases, significant work may be completed or underway. The Panel is interested in finding an effective way to include an up-to-date understanding of this ongoing research in its

deliberations. The Panel discussed receiving periodic updates, early materials, or presentations at future Panel meetings.

- The Panel would like to receive information regarding out-of-spec behavior reported for IPR projects and drinking water treatment plants throughout the State. The Panel is particularly interested in incidences of compromise in the removal of pathogens, including the process used to discover breakthrough (if any). Such information could be provided in the form of a summary or in the form of case studies that include information like the process train used, type of incident or compound, response and response time, information provided to the public, public reaction, overall costs, and other relevant factors (such as risk factors, detection methods, potential surrogates, response measures, public outreach, and so on). Where IPR projects are specifically concerned, an example might be the Orange County Water District's response to the occurrence of N-Nitrosodimethylamine (NDMA), 1,4-dioxane, tritium, and acetone.

- The Panel notes that peer-reviewed publications have greater credibility than industry research reports and encourages WRRF and its principal investigators (PIs) to consider producing peer-reviewed publications.

3.2 CDPH Mandate and Panel Process

- The Panel would like clarification of certain terms, which appear to be key elements of the State's mandate, including: "adequately protective of public health," "feasibility," "acceptable risk," and "DPR." The Panel would like to address these issues in detail at the next meeting, and would appreciate a presentation from CDPH discussing their perspective.

- Regarding surface water augmentation criteria, the Occoquan Reservoir Project operated by UOSA in Virginia and the Lake Lanier Project operated by the F. Wayne Hill Water Resources Center near Atlanta, Georgia, are other projects of interest. Information on the status of DPR projects elsewhere, particularly Windhoek, Namibia, and Big Spring, Texas, would also be useful to the Panel. The Panel would like to hear a presentation addressing these projects.

- As the Panel understands it, the purpose of the Advisory Committee is to provide insight and support to the Panel. To facilitate productive interaction, the Panel recommends that a liaison from the Advisory Committee, such as the Committee Chair, be invited to attend the public portions of future Panel meetings. A direct dialogue between the Panel and the Advisory Committee may also prove useful in the future.

3.3 Comments about the Research Plan

The Panel would like to commend WRRF and WateReuse California for their efforts with the DPR Initiative. Overall, the research plan is comprehensive and thorough, especially in regards to addressing regulatory and utility concerns about DPR. The results of these research projects are highly anticipated.

3.3.1 General

- The feasibility of DPR depends, in part, on how it fits with other alternatives to expand the State's water resources through recycling of municipal wastewater effluents.

- It is not clear to everyone that DPR must be pursued to meet the State's water resource needs. The Panel requests a review of the data that provide the basis for a water resource economic case of DPR for the State of California.

- Doing away with the environmental buffer in potable reuse projects may represent a significant change. River flow and movement through the ground are both effective in removing many contaminants from water.

- Reaction times and processes involved in the environment may be quite different from those in conventional treatment processes. Environmental buffers do not just create a barrier, but they can also be an effective treatment process for some contaminants. This issue needs consideration when evaluating the feasibility of DPR.

- A comparison of the long-term impacts on water resources is needed between a few large IPR plants that redirect water back into the overall California raw water supply versus a smaller number of DPR plants built across the state.

3.3.2 Research on Pathogens

In potable reuse projects, as wastewater sources and finished drinking water become closer together (in either time or space), the concern about protection from momentary lapses in pathogen control becomes increasingly important.

- The Panel suggests that the following questions about pathogen control, as provided by CDPH, become the subject of a future study:

    - Is the available monitoring (including perhaps of surrogates) sensitive and rapid enough to tell us when the organism reduction goal is not being met?
    - How do we quantify the overall reliability of the treatment scheme?
    - How consistently must the treatment meet the organism log-reduction goal?
    - Multiple redundant barriers minimize the chance of a complete failure of treatment. How do we determine the necessary number and capability of the redundant barriers?
    - Are there Critical Control Points for key pathogens that can be identified and monitored?

- Information on pathogen levels in raw wastewater is limited. Industry surveys should be conducted using peer-reviewed methods and techniques to characterize the pathogen levels in raw sewage, in different populations, throughout the seasons, and during local episodes of illness. New technology that provides high throughput, multiple pathogen identification, detection of emerging pathogens, and/or better quantification may be valuable in achieving this objective.

- Research needs to be conducted to document and quantify the removal of pathogens in different biological wastewater treatment processes. In the absence of that research, many advanced water treatment plants will likely be built with more treatment than is needed to establish removal credits.

- A better understanding of the microbial community that exists in advanced treated water is needed, and how a stable microbiological community can be maintained throughout the distribution system when DPR is employed. It is important to ensure that new ecological niches are not being created for the proliferation of opportunistic pathogens. Emerging methods for measuring, monitoring, and managing the microbial community during storage and distribution of recycled water should be evaluated.

3.3.3 Research to Address Regulatory Concerns

Other key differences between IPR and DPR are the consequences of process failures. Therefore, both failure analysis and reliability analysis will be important.

- There is a need to define and describe the concept of "safe." The word "safe" has different meanings to members of the community than it does to engineers who design facilities. Regulators often end up in the middle, making judgments about what is safe. The Panel sees the potential for a research project on better defining, communicating, and describing the concept of "safe." Will an annual risk of infection of 10^{-4} for potable water (for example, for pathogens) be the goal or are more safety factors necessary?

- Regardless of how effective, reliable, robust, redundant, and resilient the system is, we should be prepared for circumstances where it fails. Certainly, every precaution should be taken to prevent failure, but work is needed on what should be done in light of failure when it does occur (e.g., how to identify it, how will we respond to it, and how it will be communicated?). Simply put, this consideration needs to be more explicitly addressed in the research.

- The concept of "resilience" has not been formally developed in potable reuse. Indications are this will be addressed by additional redundancy (e.g., log removals) in the treatment system to mitigate the effects of system failures. A rational basis is needed for determining how much redundancy is required, or systems will be predictably over-engineered with attendant costs in terms of redundant or substitute unit processes and space within a treatment plant to accommodate redundant systems. Therefore, a methodology based upon experience with the failure of unit processes in potable reuse system needs to be developed. There is a wealth of experience with the unit processes used in IPR (which are, for the most part, identical with those anticipated for use in DPR). If sufficient data are available from this experience, it should be straightforward to collect the data and develop a generic model (i.e., one that can be adapted to any given treatment train) for use in assessing the actual need for redundant treatment systems to maintain the accepted risk reduction goals through failures of different extents, durations, and severity. If the data are not available, it can be generated. Although likely more

important for microbial agents, such a model should be useful for defining the flexibility of treatment processes to remove specific compounds of proven health concern. In both cases, it should be possible to determine the response time for bringing redundant treatment online in the case of failures. Some problems will be small enough to address by taking the malfunctioning component offline, while others may require shutting down a significant fraction of unit processes required for a particular treatment. Whatever the degree of treatment failure that entails should include documentation of critical questions relating to the degree of impairment and variation in time required to make appropriate repairs, as well as the extent to which key components of established health concern in a particular water source are not being removed. This will allow a clear documentation of the extent to which public health protection may be diminished during failures in the treatment process that are inevitable. The impacts on risk are likely to be minimal for documentable health risks, and are unlikely to be remedied by arbitrarily increasing the assignment of additional logs of removal to a treatment train.

- A key component of defining the "consistency of treatment" is to understand the variability that occurs within each unit process in a treatment train and incorporate this variability into a quality assurance analysis. The WRRF 13-03 Project on "Critical Control Point Assessment to Quantify Robustness and Reliability of Multiple Treatment Barriers of DPR Scheme" is expected to compile data from actual facilities on the variability of an entire treatment train. The Panel would like to receive more information about this new project, including the experimental plan.

- At present, as an industry, we do not understand what makes a barrier redundant or independent. It is a research need. Full-scale monitoring should assess what makes it redundant for contaminants of interest.

- What treatment trains are considered equivalent to full advanced treatment (FAT)? It is unclear to the Panel if other treatment trains are being considered by CDPH or if FAT is the gold standard. Also, what types of scale should these schemes have (e.g., oversight, financial, etc.)?

- The Panel suggests examining the experiences of the food industry.

- A more thorough evaluation may be warranted of the experiences of other DPR schemes (like Windhoek) and their response strategies. It may be useful to expand this effort to include surface water treatment plants using source water that receive a significant amount of wastewater discharge.

3.3.4 Research to Address Utility Concerns

- A more comprehensive economic analysis of potable reuse is needed. This analysis should consider factors such as the drought-proof nature of potable reuse and benefits of a diversified water supply portfolio. Research may exist to help assess when DPR projects should be selected over traditional water supply projects.

- The Panel anticipates that issues pertaining to energy, such as costs, conservation, and recovery, may be adequately addressed in the upcoming WRRF 14-03 project titled "Developing Methodology of Comprehensive (Fiscal/Triple Bottom Line) Analysis of Alternative Water Supply Projects Compared to DPR." Keeping the Panel updated on the progress of this project will be helpful.

- The Panel would like to see more information regarding requirements and the need for providing blending for DPR and surface water augmentation projects that might differ from CDPH's groundwater recharge draft regulations (i.e., source water used for blending, location of blending, accounting [the recycled water contribution concept averaged over several years]).

- The Panel would like more information regarding the potential of non-reverse osmosis (RO) treatment options being suggested to eliminate the need for brine disposal. RO removes a significant number of contaminants from water. Would DPR without RO eliminate an important barrier?

3.3.5 Research to Address Community Concerns

The Panel would like to provide the following suggestions to broaden the "Community Concerns" portion of the DPR research effort, increase transparency, and address information gaps:

- We need to consider how other industries (like air travel, food processing, and nuclear power) have addressed questions about safety and confidence with the public. What systems have these industries created to ensure quality? Can we modify or apply them to DPR?

- It will be important to discuss openly with the public other water supply options that may be available besides DPR (e.g., IPR, desalination, tradeoffs with agricultural, etc.).

- Selecting straightforward, transparent terminology to describe the DPR process is a step in the right direction. However, a more comprehensive plan is needed to address the concerns of opponents and community members who feel alienated; terminology alone will not be enough to lessen their fears.

- The composition, disposal, and environmental impacts of RO reject probably warrant further consideration as well.

- Some speak as if treated drinking water is sterile, whereas in reality, it contains varying concentrations of microorganisms, most of which are believed to be benign. This misperception will need to be addressed when communicating the safety of DPR projects to the public and stakeholders. The concept of the "water microbiome" may provide a means of understanding and communicating this idea

- Clarification is needed as to how the products of the research to address community concerns will be used and by whom. For instance, will a rapid response team be necessary for DPR projects? In recent times, we have seen the emergence of pathogens and chemicals (e.g., *Giardia, Cryptosporidium, Legionella,* HIV, prions, emerging disinfection byproducts, etc.) that have been of concern to health professionals and the community. Some of these have been serious problems, while others have posed little, if any, risk to water supplies. Consideration should be given to developing a mechanism for addressing process treatment failures, community outbreaks of illness, newly identified chemical contaminants and pathogens, and social issues in a timely manner. Developing this mechanism might require maintaining a list of on-call experts in a variety of fields, as well as deciding which agency or group should be responsible for coordinating the rapid response team.

3.3.6 Health Research

More effort should be devoted to health research. Suggestions include:

- A first priority should be the design of study(s) to assess changes in infectious disease rates when DPR is initiated. An approach has been suggested by other NWRI Panels for various IPR projects. Generally, such studies should be set up with county or state health departments in areas where activities may be ongoing. Ongoing standard surveillance activities should be leveraged to establish baseline rates of illness (e.g., hospital visitations, emergency room visits, school absenteeism, and calls to nurse hotlines). The DPR system should not be the sole focus of investigation, but rather tied in with a broader surveillance of disease outbreaks in the area. It should also be integrated into these projects as one of the variables examined. A pilot project should be funded that investigates the feasibility of such an effort with the appropriate public health authorities in areas where DPR is likely to be initiated. It is important that actual studies be initiated prior to the introduction of DPR.

- Efforts on diseases that might result from chemical exposure are also possible, but would require much more work in designing an approach. The key to how such studies can be conducted is the selection of appropriate health endpoints. This may mean some divergence from studying classical health endpoints, but focusing on biomarkers that are dependable indicators of increased risk for such endpoints

- Public health surveillance is a key component of any IPR or DPR project and should be adequately addressed. During the City of San Diego Health Effects Study (c.1992), a baseline was developed on pertinent morbidity and mortality data so that a basis of comparison would be available to the City if potable reuse became a reality. The Panel can be provided relevant historical background work from San Diego, if needed. Also, taste and odor complaints should be tracked, monitored, and evaluated.

3.3.7 Chemicals of Emerging Concern (CECs)

- It appears that several of the proposed DPR Initiative projects imply that additional bio-

analytical screening assays are needed for CECs. The DPR Initiative team should dialogue with staff from both the Southern California Coastal Water Research Project (SCCWRP) and San Francisco Estuary Institute (SFEI) regarding ongoing research in California involving the use of such assays for certain CECs. In addition, other organizations and agencies, such as the State Water Resources Control Board, are involved with research projects to evaluate bio-analytical tools. These outside efforts should be incorporated into the Panel's review process and DPR Initiative (for instance, include a presentation on the results of these projects at a future Panel meeting).

- The Panel encourages the DPR Initiative team to read the brief review on antibiotics and antibiotic resistance in the April 2012 SCCWRP report on *Monitoring Strategy for Chemicals of Emerging Concern (CECs) in California Aquatic Ecosystems: Recommendations of a Science Advisory Panel* (see Section 4.3 and Appendix F of the report, which can be found on the SCCWRP website[3]).

3.3.8 Hazard Analysis and Critical Control Points (HACCP)

The Hazard Analysis and Critical Control Points (HACCP) framework deserves consideration. As follow up:

- The Panel would like to receive more information about the ongoing WRRF 13-03 Project on "Critical Control Point Assessment to Quantify Robustness and Reliability of Multiple Treatment Barriers of DPR Scheme." It is understood that the project is in the early stages and the first progress report is pending. In the meantime, the Panel would find it helpful to receive the experimental plan for WRRF 13-03.

- Though some Panel members have concerns about validation and calibration, the Panel is also interested in the workshop results for the WateReuse-10-07 Project on "Bio-Analytical Techniques to Assess the Potential Human Health Impacts of Reclaimed Water."

3.3.9 Application of Research

The Panel would like to learn more about the plan to transition the results from research to application. How will operators make the tools work? Will the tools be practical? Will the test results provide usable information (quality of information) that is a reliable guide to whether treatment needs to be improved (if possible) or water wasted? Can the results be interpreted or explained to the public?

[3] http://www.sccwrp.org/ResearchAreas/Contaminants/ContaminantsOfEmergingConcern/EcosystemsAdvisoryPanel.aspx

3.4 Panel's Response to Research Plan Questions

1. ***Does the Research Plan appropriately define the needed DPR research?***

   The Panel believes that the DPR Research Plan is comprehensive and thorough, especially in regards to addressing regulatory and utility concerns about DPR. The results of the research projects will assist in providing regulators and utilities with the information they may need as they consider implementing DPR. The comments provided in this Panel Report are intended to help strengthen the Research Plan.

2. ***Is the framework presented in the Plan appropriate (i.e., regulatory, utility, and community concerns)?***

   The Panel believes that the framework summarized in the DPR Research Plan for addressing regulatory, utility, and community concerns is suitable for the intended purpose. The Panel provided additional comments in this Panel Report on areas in the Research Plan that may need to be strengthened, such as focusing on health research.

3. ***Can the Panel identify any substantial gaps in the research framework, including the current research and proposed future research?***

   In the time allotted for the current review, the Panel was unable to conduct a comprehensive analysis of gaps in the proposed research framework or list of current and future projects. The comments above provide a preliminary assessment of gaps and suggestions for additional research. The Panel suggests that the status of current research efforts be reviewed at Panel meetings with research organizations to maintain a dialogue on current and future research efforts.

4. ***Does the Panel have other comments for WRRF and WateReuse California as it implements the Plan?***

   In addition to the comments provided in this Panel report, the Panel would like to learn more about the plan to transition the results from research to application. How will utilities make use of the results and tools? The interpretation indicators and surrogates (either as water parameters or as indicators of health risk) must be specified, justified, and validated. Prioritization is also of interest. What should be done first? Why? And how? Pilot and field studies are an essential component of translational science for the water industry, and that type of follow up might be needed.

5. ***How would the Panel like to be updated in the future on the status of the research efforts?***

   The Panel would benefit from updates on current or upcoming research efforts, including early materials (as discussed in Section 3.1 of this report). Perhaps there could be a briefing or summary of the conference call meetings held between WRRF and its project PIs for the DPR Initiative.

APPENDIX A: Panel Background

About NWRI

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

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

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

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

About NWRI Panels

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

The NWRI Panel process provides numerous benefits, including:

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

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

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

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

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

Examples of recent NWRI Panels include:

- **Developing Proposed Direct Potable Reuse Operational Procedures and Guidelines for New Mexico** for the New Mexico Environment Department (NM)
- **Monterey Peninsula Groundwater Replenishment Project** for the Monterey Regional Water Pollution Control Agency (CA)
- **Groundwater Recharge Scientific Study** for the LOTT Clean Water Alliance (WA)
- **Groundwater Replenishment System Program Review** for the Orange County Water District (CA)
- **Examining the Criteria for Direct Potable Reuse** for Trussell Technologies (CA) and WateReuse Research Foundation (VA)
- **Evaluating Potable Reuse** for the Santa Clara Valley Water District (CA)
- **Indirect Potable Reuse/Reservoir Augmentation Project Review** for the City of San Diego (CA)
- **BDOC as a Surrogate for Organics Removal in Groundwater Recharge** for the California Department of Public Health (CA)
- **Effluent Master Plan** for Tucson Water (AZ)
- **Groundwater Replenishment Project Review** for the Los Angeles Department of Water and Power (CA)

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

APPENDIX B: Panel Member Biographies

R. Rhodes Trussell, Ph.D., P.E., DEE – Panel Chair
Chairman and CEO
Trussell Technologies, Inc. (Pasadena, CA)

Rhodes Trussell is recognized worldwide as an authority in methods and criteria for water quality and in the development of advanced processes for treating water or wastewater to achieve the highest standards. A Civil and Corrosion Engineer with over 35 years of experience, he has worked on the process design for dozens of treatment plants ranging in size from 1 to 900 million gallons per day in capacity. At present, he is Chairman and CEO of Trussell Technologies, Inc., an environmental engineering firm that focuses on the quality and treatment of water and wastewater. He is also active on numerous boards and committees, such as serving as Chair of the Water Science and Technology Board for the National Academies (1999-2006), Chair of the Research Advisory Committee for the WateReuse Research Foundation, and Member of the Water Environment Research Foundation Board of Directors. Just recently, he retired from the U.S. Environmental Protection Agency's Science Advisory Board after 17 years of service. He was also named as the 2013 recipient of the NWRI Athalie Richardson Irvine Clarke Prize for excellence in water research. Trussell received a B.S. in Civil Engineering and both an M.S. and Ph.D. in Sanitary Engineering from the University of California, Berkeley.

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.

Adam Olivieri, Dr. P.H.., P.E.
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.

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 C: Meeting Agenda

NATIONAL WATER RESEARCH INSTITUTE

Expert Panel Conference Call

California Department of Public Health: Development of Water Recycling Criteria for Indirect Potable Reuse through Surface Water Augmentation and the Feasibility of Developing Criteria for Direct Potable Reuse

REVISED FINAL Conference Call Meeting Agenda

March 5, 2014 ♦ 9:00 am to 1:00 pm (Pacific Time)

Conference Call Logistics
See email for "GoToMeeting" web information
Call-in number: 1-877-339-0022
*Passcode: *1948184**

Contacts:
Brandi Caskey (NWRI Office)
(714) 378-3278

Meeting Objectives:

- Provide an overview of CDPH's mandate regarding the Expert Panel.
- Review the Panel's scope of work.
- Review DPR research efforts to date and future research needs.

Wednesday, March 5, 2014

9:00 am	Welcome and Introductions	Jeff Mosher, NWRI
9:10 am	Review Agenda and Purpose of Meeting	Rhodes Trussell, Panel Chair
CDPH Perspective and Panel Overview		
9:20 am	Statuary Mandates and Specific Tasks of the Panel	Bruce Burton, CDPH
9:35 am	Overview of Panel Process	Jeff Mosher
9:50 am	Briefing on Potable Reuse in California	Bob Hultquist, CDPH Brian Bernados, CDPH
Review of DPR Research		
10:20 am	WateReuse DPR Initiative and "Research Plan" Overview	David Smith, WateReuse California

10:35 am	Overview of Current and Future DPR Research Projects	Julie Minton Stefani McGregor Justin Mattingly WateReuse Research Foundation
11:30 am	Open Discussion on DPR Research Efforts	Rhodes Trussell
Panel Discussion		
12:00 noon	Closed Panel Discussion	Rhodes Trussell
1:00 pm	**ADJOURN**	

APPENDIX D: Meeting Attendees

Panel Members:

- *Panel Chair:* R. Rhodes Trussell, Ph.D., P.E., DEE, Trussell Technologies, Inc. (Pasadena, CA)
- 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)
- Adam Olivieri, Dr.P.H., P.E., EOA, Inc. (Oakland, CA)
- Joan B. Rose, Ph.D., Michigan State University (East Lansing, MI)
- David Sedlak, Ph.D., University of California, Berkeley (Berkeley, CA)
- Tim Wade, Ph.D., United States Environmental Protection Agency (Durham, NC)

National Water Research Institute:

- Brandi Caskey, Events Manager
- Jeff Mosher, Executive Director
- Gina Vartanian, Outreach and Communications Manager

California Department of Public Health:

- Randy Barnard, Recycled Water Treatment Specialist
- Mark Bartson, Chief, Technical Operations Section
- Brian Bernados, Technical Specialist
- Bruce Burton, Chief, Northern California Drinking Field Operations Branch
- Bob Hultquist, Drinking Water Program Expert
- Dave Spath, Drinking Water Program Expert

WateReuse Representatives:

- Mark LeChevallier, American Water (WRRF RAC Chair)
- Justin Mattingly, WateReuse Research Foundation
- Stefani McGregor, WateReuse Research Foundation
- Wade Miller, WateReuse Research Foundation
- Julie Minton, WateReuse Research Foundation
- David Smith, WateReuse California

Water Research Foundation:

- Chris Rayburn, Water Research Foundation