



Memorandum

Date: February 16, 2022

To: Wendy Steffensen
Environmental Project Manager, LOTT Clean Water Alliance

From: James Crook, PhD, PE, Panel Chair
Kevin M. Hardy, JD, Executive Director, NWRI

Subject: NWRI Independent Expert Advisory Panel for LOTT RWIS
Panel Meeting 5 Recommendations

The National Water Research Institute (NWRI) is pleased to provide this memorandum from the NWRI Peer Review Panel to review the LOTT Clean Water Alliance Reclaimed Water Infiltration Study (RWIS) project. The Panel met online on November 2, 2021, to review presentations on the Human Health Risk Assessment (HHRA) from the LOTT project team.

The purpose of the NWRI Panel is to provide a third-party peer review of the technical, scientific, regulatory, and policy aspects of the RWIS project. Results of the study will be used to help policymakers make informed decisions about reclaimed water treatment and use in the future.

NOTE: NWRI transmitted a draft memorandum to the LOTT Study Team on November 23, 2021. The Study Team responses are in blue text throughout this final document.

NWRI Peer Review Panel Members

- Chair: James Crook, PhD, PE, BCEE, Environmental Engineering Consultant
- Paul Anderson, PhD, ARCADIS
- Michael Dodd, PhD, University of Washington
- Michael Kenrick, PE, LHG, Geoengineers
- Edward Kolodziej, PhD, University of Washington
- John Stark, PhD, Washington State University

Kevin M. Hardy • Executive Director • khardy@nwri-usa.org • www.nwri-usa.org

JPA MEMBERS: Inland Empire Utilities Agency • Irvine Ranch Water District • Los Angeles Department of Water and Power • Orange County Sanitation District • Orange County Water District • West Basin Municipal Water District



More information about NWRI is provided in Appendix A. More information about the Panel members is in Appendix B. The agenda for the meeting is in Appendix C. A list of meeting attendees is in Appendix D.

Pre-Meeting Review Materials

The Panel thanks the LOTT project team for providing the following excellent project materials to review before the meeting:

- Human Health Risk Assessment–LOTT RWIS, prepared by Intertox (October 15, 2021)
- Ecological Risk Assessment–LOTT RWIS, prepared by Windward (October 19, 2021)

Panel Findings and Recommendations

The principal findings and recommendations of the Panel are based on the presentations about the HHRA that were given by the project team at Meeting 5 on November 2, 2021. The Panel appreciates the high quality of the project team’s presentations and reports.

The Panel was given 12 questions, which are addressed in this technical memorandum. The following section lists the questions that LOTT provided, followed by Panel responses and recommendations. Additional comments and recommendations that are not addressed by the questions follow in a later section of this memo.

Peer Review Questions on Human Health Risk Assessment

1. **Given the study findings, how would you describe the relative safety of infiltration of this reclaimed water?**

Panel Response: Based on the findings of the human health risk assessment (HHRA) and other similar studies, the Panel finds that the infiltration of reclaimed water is generally considered to be a safe use or application of the resource from a human health protection standpoint.

STUDY TEAM RESPONSE: [Comment noted.](#)

2. **Given the layers of conservative assumptions used in both the fate and transport model and the risk assessments (RAs), do the model and the RAs result in findings that over-estimate risk compared to what is typically done in risk assessments?**

Panel Response: Due to the layers of conservative assumptions used in both the fate and transport model and the HHRA, the findings are far more likely to overestimate risk than underestimate risk, as is the case with most HHRA. The multiple conservative assumptions used in this HHRA are generally consistent with other risk assessments. The researchers relied on empirical analyses of fate and transport modeling and ended up with attenuation



factors (AFs) based on monitoring data, not on mechanistic or attenuation models. This is a reasonable approach that embraces the range of attenuation observed in the aquifer.

Attenuation factor modeling is still uncertain in some cases. Over long distances or long times, the accuracy of the AF becomes very meaningful and is a source of long-term uncertainty.

A summary table of assumptions used to develop AFs and estimate exposure point concentrations at 200 feet would help the Panel and others understand the effect of AFs on predicted concentrations. For example, the HHRA states that people using tap or well water “would be exposed to the maximum estimated concentration in the aquifer regardless of distance from source” (second paragraph of Section 3.5). Understanding the key assumptions used to derive the maximum estimated concentration would add important clarity to the report. The Panel understands that maximum refers to the predicted concentration at the closest modeled distance from the source (200 feet), which would be the highest predicted concentration given that concentrations of many compounds will be lower at greater modeled distances from the source given greater time for attenuation.

In particular, one item that is still a bit unclear is whether maximum 95 percent upper confidence level (UCL) or average reclaimed water concentrations were used as the initial (source concentration) values in determining AFs for subsequent exposure point concentrations (EPCs) modeling. From the June 2021 and November 2021 project team presentations and the Fate and Transport and HHRA documents, it seems like either 95 percent UCL or maximum measured reclaimed water concentrations were used as starting/source concentrations to obtain maximum modeled EPCs in the overall EPC modeling that uses AFs.

However, looking back at the Residual Chemical Fate and Transport Analysis report document, it is not clear if the values used to determine the AFs were also 95 percent or maximum values, as that report appears to refer to average values. (Apologies if the answer to this was provided in the documentation but overlooked.) The Panel asked about AF calculations, specifically, if using 95 percent UCL or maximum reclaimed water concentrations instead of average concentrations might artificially steepen the slope of the AF line in the near-source (less than 200 feet) region. Would this method lead to overestimating attenuation near the source compared to concentrations that would be obtained if starting with average reclaimed water concentrations?

The Panel recognizes that even if this is the case, such an effect would likely be offset, to some extent, by using 95 percent UCL or maximum values as starting values in the overall EPC modeling.

Even if attenuation is assumed to be faster in the near-source region starting with higher assumed source concentrations in the EPC, the predictions are likely conservative overall.



However, some clarification on this point would be very helpful in assessing the potential importance of AF assumptions in predicting EPCs for certain attenuated chemicals, in particular for 1,4-dioxane. The predicted lifetime excess cancer risk for 1,4-dioxane from tap water ingestion approaches the one in one million *de minimis* risk threshold for the residential reasonable maximum exposure (RME) scenario for the shallow aquifer.

The Panel appreciates that information about input concentrations and modeling assumptions has been presented in past reports. However, given that the HHRA draws on key findings presented in those reports, the Panel believes that summarizing key assumptions in the HHRA report will improve transparency of the HHRA process.

Given the information presented during the November 2, 2021, meeting, the Panel believes the AF/EPC modeling is sufficiently conservative, particularly for N-nitrosodimethylamine (NDMA) and perfluoropentanoic acid (PFPeA). As stated in the HHRA, even at greater distances and travel times, the two compounds show minimal attenuation.

In places, the report is vague in communicating actual detected concentrations that are used for modeling. Additional clarity on reporting concentrations and communicating how the model is applied would be beneficial.

STUDY TEAM RESPONSE: It is important to distinguish how the starting point reclaimed water concentrations were derived for the attenuation factor (AF) versus the exposure point concentration (EPC) calculations, as the methodology is different. Here are the key differences, which we intend to summarize in the HHRA to provide clarity as requested in this comment. Details are provided in the technical memorandum, *Residual Chemical Fate and Transport Analysis (Task 2.1.5), October 14, 2021* (referred to hereafter as the F&T memo).

- AF calculations. See Section 3.4 and Appendix F of the F&T memo. In general, the average reclaimed water concentration [C] over the four sampling events associated with the tracer test was used to define the starting point concentration for deriving AFs. (Exceptions were carbamazepine, quinoline, and TDCPP, where only one sampling period of data was used due to limited data in the other sampling events.) This was done so that we had synchronous sets of reclaimed water and downgradient groundwater quality samples at locations that we could relate to travel times. It would not have been appropriate to consider all of our reclaimed water data (i.e., inclusive of the Task 1 2014/2015 data) for this purpose, as that reclaimed water quality was not paired with groundwater monitoring data.
- EPC calculations. See Section 4.2 of the F&T memo. In contrast to the AF approach, here we considered all reclaimed water data, including that from the Task 1 2014/2015 sampling events. With a broader data set, this is where we were able to use the 95 percent UCL of the arithmetic mean. In cases where data were insufficient for that,



we used the maximum observed concentration to remain health protective in our assumptions.

3. One reason for the study was the lack of research on this topic in similar temperate climates.

3a. How consistent are this study's findings to studies done elsewhere?

Panel Response: There have been several studies in the United States and elsewhere for groundwater recharge projects similar to the LOTT project. The findings from this study on aquifer water quality changes and associated risks to the public caused by adding reclaimed water via spreading basins is consistent with major studies conducted in California and elsewhere on health-significant constituent presence and reduction in the underground aquifers.

STUDY TEAM RESPONSE: Comment noted.

3b. What does that mean for the need to conduct future research? Is it reasonable to look to studies done elsewhere for information about new or different chemicals of interest (COIs) in the future?

Panel Response: Yes, it is reasonable to look at studies being conducted elsewhere to help identify constituents of emerging concern (CECs) and whether they pose a potential human health risk. The potential human health effects of per- and polyfluoroalkyl substances (PFAS) as a class of contaminants are notable, given that science is still identifying all the chemicals in this class that may occur in wastewater treatment streams. Other sources of COIs in the watershed (such as residential septic systems) and their contributions to COIs in groundwater need to be accounted for. Information on other chemical classes will expand as more data are gathered in the future and our understanding of how these chemicals interact with each other improves.

Mixtures of COIs may represent an unquantified risk because there are likely a number of structurally related compounds (such as total nitrosamines and total organic fluorine) that may have similar effects or modes of action. We currently do not have perfect knowledge of what chemicals are present in complex mixtures like treated wastewater effluent, which poses some uncertainties. These uncertainties present opportunities for research.

STUDY TEAM RESPONSE: Comment noted.

• Questions 4 through 11 are related to the chemicals NDMA and PFPeA

Panel Response: This section contains comments on NDMA and PFPeA because those compounds have estimated upper bound risks reported to be greater than the Environmental Protection Agency (EPA) *de minimis* cancer risk of 1×10^{-6} (one in one million) and hazard index (HI) of one. As discussed in the November 2, 2021, Panel



meeting, EPA risk assessment guidance recommends reporting estimated risk to one significant figure. Following such guidance, the non-cancer risk for PFPeA would equal the EPA allowable HI of one, and PFPeA would not be identified as posing a potentially unacceptable upper bound non-cancer risk. The upper bound lifetime cancer risk for NDMA would be 3×10^{-6} . That is above the EPA *de minimis* allowable risk, but at the low end of the allowable risk range. Given the many conservative assumptions used in the HHRA and the uncertainty associated with many of those assumptions, the Panel recommends reporting estimated potential risks to one significant figure to better represent the degree of confidence associated with the risk estimates.

STUDY TEAM RESPONSE: We will retain our approach of calculating risk to two significant figures, consistent with other similar efforts. However, we will add discussion in the text regarding the alternative approach of reporting results to one significant figure with a reference to the Panel-cited EPA guidance document.

4. Is the risk analysis done here similar to analyses done in other studies?

Panel Response: Yes. The risk analysis done for this project is conservative and is consistent with those done for other studies. It is protective of public health.

STUDY TEAM RESPONSE: Comment noted.

5. Is relative risk appropriately portrayed?

Panel Response: If this question is asking whether the comparison of estimated risk to the EPA Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Resource Conservation and Recovery Act (RCRA) allowable risk range of 1×10^{-6} to 1×10^{-4} is appropriate, the Panel agrees that the allowable risk range represents one set of benchmarks that can be used to provide perspective about the estimated risks.

Other benchmarks are also available and should be included in the report, including the range of allowable risk associated with EPA Maximum Contaminant Levels (MCLs). The MCLs represent risks that are assumed by the EPA to be allowable in a drinking water supply, which is the same type of exposure being evaluated in the HHRA. A comparison to other potential sources of human health risk can also be included in the report.

STUDY TEAM RESPONSE: We will include a table of existing relevant water quality criteria (e.g., state or federal), including MCLs, in the report for the eight chemicals of interest for comparison to the estimated water concentrations. However, we note that because MCLs are established based on other criteria in addition to health risk (e.g., policy, feasibility, background exposures), the ranges of allowable risks associated with MCLs can vary widely and may exceed the RCRA allowable risk range for cancer of 1×10^{-6} to 1×10^{-4} . The HHRA, in contrast, follows standard EPA risk assessment methodologies to characterize ranges of potential human health risks exclusive of policy or feasibility considerations, so a



comparison of estimated risks to the 1×10^{-6} to 1×10^{-4} range is appropriate here. We do not think including a discussion of the risk ranges considered to be acceptable based on MCLs should be included in the HHRA but could be a valuable part of future discussions to, for example, support risk communication or cost/benefit analyses.

In several places, the HHRA report refers to the evaluation as determining whether residual chemicals in recharge water pose a significant human health risk. From the point of view of relative risk, use of the word “significant” to characterize risks that are being estimated overstates the likely outcome of this and most other HHRAs. It might be better to refer to the evaluation as determining whether residual chemicals in recharge water pose a potentially *unacceptable* risk to human health. Even risks above the EPA allowable risk range are not necessarily significant, as they may be smaller than other risks that are considered not to be significant.

STUDY TEAM RESPONSE: In order to avoid statements regarding the significance or acceptability of risk to interested parties, we will revise the HHRA to state that “estimated potential risks are within/below/exceed the EPA’s allowable risk range” and leave the interpretation of whether such risks are acceptable to be made by the reader.

In Section 5.2.1, the HHRA report states that the estimated excess lifetime cancer risk of 2.9×10^{-6} can be interpreted as the probability of 2.9 persons out of one million developing cancer if exposed over the course of their lifetime at the rate assumed by the HHRA. That is not actually true. As stated in earlier sections of the HHRA, most of the exposure assumptions and the toxicity assumptions are upper bounds, designed to overstate rather than understate potential risk. Thus, the 2.9×10^{-6} is an upper bound estimate of cancer risk.

The actual number of persons that may develop cancer is almost certainly lower than 2.9 in one million and may even be zero (EPA 1986, 2004). The report should clarify this explanation of the risk estimates to help readers understand that the estimated risks are upper bounds, not best estimates.

STUDY TEAM RESPONSE: We will expand on our explanation of this in the report.

The scale of the y-axis on Figures 5–1 through 5–4 could be changed from linear to log to better show the relative risk of all eight compounds included in the HHRA. As presented, the figures could be interpreted to indicate that the risks associated with many compounds are only slightly below allowable risk benchmarks. Most are substantially lower. The figures could also be improved by showing not just the EPA *de minimis* cancer risk targets, but the entire allowable risk range. That would help readers understand that even the highest estimated risks are at the low end of the range. And finally, it might help to include the central tendency estimated risks to provide additional perspective about the range of risks.



STUDY TEAM RESPONSE: We will likely retain the use of linear plots for presentation of some information, for ease in communication with non-technical audiences. However, we agree that inclusion of figures to show estimated risks relative to the allowable risk range could aid the reader in understanding how the risks compare, and we will include a figure of this type in the report. Given the intent to clearly show the upper and lower limits of this range, it is likely that this figure will be presented in log scale.

6. Given the layers of conservative assumptions used in the modeling, would you suggest any refinements to better estimate EPCs of these two chemicals (e.g., NDMA and PFPeA)?

Panel Response: The Panel suggests a probabilistic risk assessment to better characterize and quantify the range of potential risk, which will help inform the cost benefit analysis.

STUDY TEAM RESPONSE: To provide additional perspective of ranges of potential risk, we intend to include a probabilistic risk assessment, but only for NDMA and PFPeA and for only the resident exposure scenario, consistent with the EPA's recommendations for a tiered approach to risk assessment. This approach consists of starting with screening level, deterministic assessments using conservative (health protective) point estimate assumptions intended not to underestimate risk and proceeding through more resource-intensive analyses such as a probabilistic risk assessment (PRA) for those chemicals, scenarios, and/or pathways that are of most concern, such as those that exceed allowable risk thresholds (EPA 2014¹, EPA 2021²).

7. The exposure point concentrations for NDMA and PFPeA were calculated using the 95 percent Upper Confidence Limit of all reclaimed water detections. Is this practice considered standard? In light of the fact that NDMA was not detected in approximately half of the reclaimed water samplings, does this method bias the findings?

Panel Response: It is not surprising to see some variability in occurrence sampling; many factors can influence detected concentrations. The information about the 95 percent upper confidence limit (UCL) is an excellent example of the kind of information that could be presented in the summary table suggested in the response to Question 2.

It is unclear from the question whether the 95 percent UCL was calculated using only the detected concentrations or if it used all the concentrations, including non-detects. If only detected concentrations were used, that would represent a deviation from the common practice of including non-detects with an assumed concentration and, depending upon

¹ <https://www.epa.gov/sites/default/files/2014-11/documents/raf-pra-faq-final.pdf>

² <https://www.epa.gov/expobox/exposure-assessment-tools-tiers-and-types-deterministic-and-probabilistic-assessments>



detection limit, could introduce bias. Typically, non-detects are assumed to have a concentration of one-half the detection limit. If non-detects were included in the calculation of the 95 percent UCL, it is unclear from the question (or the report) what concentration was used to represent the non-detects. This key information and assumptions should also be included in the HHRA to help readers track concentrations throughout the report, including how non-detects were considered and used.

STUDY TEAM RESPONSE: For our calculation of the 95 percent UCL of the arithmetic mean, only data points representing detections were used. We reran the calculation using ProUCL software for NDMA and PFPeA including non-detects, assuming a concentration of one-half the detection limit (DL). This resulted in no change to the 95 percent UCL result as reported to the number of significant figures shown.

8. Given the layers of conservative assumptions in the HHRA, would you suggest any refinements to more accurately assess risk from these two chemicals?

Panel Response: The Panel suggests a probabilistic risk assessment, which may inform the cost benefit analysis.

STUDY TEAM RESPONSE: We intend to include a probabilistic risk assessment (as supplemental to the deterministic risk assessment) for NDMA and PFPeA for the residential exposure scenario, as noted above.

9. Given the levels of risk or hazard estimated for NDMA or PFPeA and the layers of conservative assumptions in the HHRA, as well as levels of risk that are considered significant in other studies, do you consider the estimated risks to be significant? Do you have suggestions for communicating the relative significance of these risks?

Panel Response: See the response to Question 5 regarding communicating the relative significance of the estimated risks.

The Panel did not reach consensus on whether the estimated risks can be considered significant or not. If exceeding the *de minimis* allowable risk level of 1×10^{-6} is assumed to represent significance, then the risks are significant. If the full EPA risk range is used, or if the risk range associated with MCLs is used, the risks are relatively low and are not significant. Hence the value of presenting multiple measures and perspectives about allowable risk, including the risks associated with exposure from other common sources such as use of household chemicals, diet, etc.

It is important to recognize that some of the chemicals included in the HHRA may have similar modes of action. If the hazard index of PFPeA is around 1, there may be other related chemicals with similar modes of action that might increase the estimated non-cancer risk associated with this class of compounds. To the extent that individual



PFAS compounds are assumed to have a similar mode of action, it might be helpful to sum the hazard indices of the individual PFAS compounds and discuss the resulting PFAS class hazard index in the uncertainty section, keeping in mind the upper-bound nature of the estimated exposures and risks.

STUDY TEAM RESPONSE: As indicated above in the response to Comment 5, we will include a table of existing relevant water criteria (including MCLs) to provide additional perspective on relative risks and also explore inclusion of additional figures to show how estimated risks compare to allowable risk ranges. Also, the inclusion of a probabilistic risk assessment for the resident exposure scenario for NDMA and PFPeA, as discussed in the response to Comment 6, will provide additional information about the ranges of potential risks. We included discussion of potential exposures to NDMA and PFPeA from other sources in Section 5.3.4 (Comparison of Exposure from Other Sources) of the HHRA, and discussion of potential additive effects of PFAS compounds in Section 5.3.5 (Potential Additive Effects of PFAS Compounds) of the HHRA.

10. What are your thoughts on the need for continued monitoring, additional treatment, or other measures regarding NDMA or PFPeA?

Panel Response: Consistent with practices at other similar systems, the Panel recommends more monitoring to evaluate trends over time and space. More details also are needed on the suggested advanced treatment options in the HHRA, which refers to two specific treatment options. Are the costs based on the two options that LOTT is considering? What is the best-estimate risk?

Similar projects often default to quarterly monitoring for high-priority compounds and annual monitoring for broader screening of compounds. The Panel would like to see more frequent monitoring for these classes of compounds and general screening of effluent quality, in particular for total nitrosamines and PFAS. Quarterly sampling of reclaimed water and twice a year sampling in some downgradient wells is typical for long-term monitoring.

STUDY TEAM RESPONSE: Comment noted.

11. Are other reclaimed water utilities/facilities taking specific steps regarding NDMA or PFPeA?

Panel Response: Yes. Other reclaimed water utilities/facilities are taking specific steps for NDMA when it is present at slightly higher concentrations than those observed here. This is at the borderline to mandated treatment, depending on exactly what the concentrations are. Other facilities are taking steps to reduce nitrosamines in infiltration water as needed.

PFAS is a large issue in Orange County, California, and elsewhere. Wellhead treatment in Orange County is beginning and some sites are being studied for a Centers for Disease



Control study on PFAS to understand the extent of contamination and the degree of management needed.

STUDY TEAM RESPONSE: Comment noted.

12. The Panel commented on a partial draft of the Ecological Risk Assessment (ERA) previously and had no substantive comment. Are there any concerns with the draft final ERA?

Panel Response: The Panel would like to see more information on fipronil, if available. In particular, what assumptions were modified, or what new data were used that decreased estimated fipronil exposure from concentrations presented in the draft ERA? Estimated fipronil exposure is now below the toxicity reference value (TRV). The Panel would like more information, because fipronil undergoes very little attenuation in aquifers and is considered to be relatively toxic and persistent.

NOTE: The Panel commented in the last report that fipronil is generally considered to be a relatively hydrophobic sorbate with a moderately high log K and stronger binding to soil/media, so please check and consider its potential for long-range groundwater transport carefully, especially if environmental predictions are based on extrapolating results across many decades. This recommendation also applies to the comment about clarification of the classifications of Category 2 compounds in the hydrogeologic study/fate and transport analysis section of the memo.

STUDY TEAM RESPONSE: See Section 5 (pp. 5–3 and 5–4) of the F&T memo for the updated information on fipronil, including data from the literature. In subsequent communications, the Panel recommended considering information from [Fipronil: environmental fate, ecotoxicology, and human health concerns](#), by Colin C. D. Tingle, Joachim A. Rother, Charles F. Dewhurst, Sasha Lauer, and William J. King (published in *Rev Environ Contam Toxicol* 2003;176:1–66, <https://pubmed.ncbi.nlm.nih.gov/12442503/>).

The Study Team reviewed the paper and determined that no modification was needed to the characterization of fipronil in the final F&T memo, for these reasons: 1. Tingle et al., note that because of its high affinity to soils, fipronil typically stays within the first few centimeters of soil and leaching to groundwater is practically nonexistent; and, 2. Although Tingle et al., presents a wider range of degradation rates than was considered in the F&T memo, fipronil in reclaimed water recharged at Hawks Prairie is still calculated to degrade to well below threshold concentrations of potential concern before reaching local creeks. Although no change was made to the F&T memo or the ERA with regard to fipronil, the Panel has noted that not all degradation products have been considered in this study (including such products related to fipronil, which are also discussed in Tingle et al.), so the ERA has been revised to include a new subsection (6.1.2.2) to discuss uncertainty related to degradation products.



Additional Panel Comments and Recommendations

The Panel appreciated the discussion of PFAS and potential contribution to class toxicity in the HHRA (Section 5.3.5) and would like to see a similar discussion for total nitrosamines.

STUDY TEAM RESPONSE: We did not obtain sufficient data during the sampling phases of this effort to provide that kind of discussion at this time.

Section 4.0 contains a great deal of information on evaluating the toxicity of compounds. Some information is general, such as the application of uncertainty factors to the no observed adverse effects levels to derive acceptable daily intakes (ADIs). Some information is very detailed, such as the discussion of the derivation of ADIs for primidone. The HHRA could be made more accessible to readers by moving much of this discussion to an appendix and providing a brief summary in Section 4.0.

STUDY TEAM RESPONSE: Comment noted.

Conclusion

The purpose of the NWRI Panel is to provide an independent, third-party expert peer review of the technical, scientific, regulatory, and policy aspects of the HHRA for the LOTT RWIS project.

The Panel thanks the project team for the presentations and looks forward to any questions or requests for clarification.

Please direct questions to Suzanne Sharkey, Project Manager, at ssharkey@nwri-usa.org.



Appendix A • About NWRI

Disclaimer

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

About NWRI

A 501c3 nonprofit organization, 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.

For more information, please contact:

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Appendix B • Panel Member Biographies

Chair: James Crook, PhD, PE, is an environmental engineer with more than 45 years of experience in state government and consulting engineering arenas, serving public and private sectors in the United States and abroad. He has authored more than 100 publications and is an internationally recognized expert in water reclamation and 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. He currently serves on several advisory panels and committees sponsored by NWRI and others. Among his honors, he was selected as the American Academy of Environmental Engineers 2002 Kappe Lecturer and the WaterReuse Association's 2005 Person of the Year. In 2016 he received the California WaterReuse Presidential Award. Crook received both an MS and PhD in Environmental Engineering from University of Cincinnati, and a BS in Civil Engineering from University of Massachusetts.

Paul Anderson, PhD, is Vice President and Principal Scientist for ARCADIS US, Inc. Since 2000, Paul Anderson has researched the presence and effects of pharmaceutical ingredients and personal care products in surface water. His research began with developing a screening level model that predicts the concentration of human pharmaceuticals and other compounds released from wastewater treatment plants. He helped develop a database that summarizes peer-reviewed literature on aquatic toxicity, environmental fate in surface water, and treatment plant removal of pharmaceuticals.

Anderson has over 35 years of experience in human health and ecological risk assessment. He has a PhD and an MA in Biology from Harvard University and a BA in Biology from Boston University.

Michael Dodd, PhD, is an Associate Professor in the Department of Civil and Environmental Engineering and an Adjunct Associate Professor in the Department of Environmental and Occupational Health Sciences at the University of Washington (UW). Dodd's research focuses on characterizing chemical and photochemical redox processes in aquatic systems, particularly in eliminating pollutants and pathogens during water and wastewater treatment. Focus areas include modeling the behavior of chemical and microbiological contaminants during chemical oxidation and disinfection processes, developing assays to quantify the impacts of such processes, and engineering novel approaches to centralized and decentralized water treatment. Dodd has a PhD in Environmental Sciences from the Swiss Federal Institute of Technology–Zurich (ETH–Zurich), an MS in Environmental Engineering and a BS in Civil Engineering from Georgia Institute of Technology.

Michael Kenrick, PE, LHG, is Senior Consultant Hydrogeologist with GeoEngineers in Redmond, Washington. Since the Covid pandemic, Kenrick has been working remotely from



his new home in Devon, England. His expertise includes aquifer hydraulics, well testing; groundwater modeling; infiltration, flow and seepage; percolation and recharge; groundwater chemistry and quality; and water rights assessments. Kenrick trained as a civil engineer and hydrogeologist and has applied knowledge from a career serving commercial and municipal clients in key water-related sectors including groundwater, water supply, stormwater infiltration, artificial recharge, water reuse, dewatering for the mining and construction industries, and environmental assessment. He gained experience in the UK, Europe, Africa, and Asia before moving to Seattle in 1985, where he honed hydrogeologic methods for groundwater issues in the Pacific Northwest.

Edward Kolodziej, PhD is Associate Professor at the University of Washington, where he holds joint appointments in the Division of Sciences and Mathematics (UW Tacoma) and the Department of Civil and Environmental Engineering (UW Seattle). He works on a variety of local and regional water quality issues, especially those focused on organic contaminants, through The Center for Urban Waters in Tacoma, WA. Kolodziej's interests include water quality and contaminant fate in natural and engineered systems, especially focusing on interdisciplinary approaches to complex environmental issues affecting water and ecosystem health. His research has been published in *Science*, and featured in news media such as *Nature*, *Scientific American*, *U.S. News and World Report*, *Yahoo Health News*, *BBC Radio's "Inside Science"*, and the *Huffington Post* among others. Kolodziej earned an MS and PhD in Environmental Engineering at University of California at Berkeley, and a BS in Chemical Engineering from the Johns Hopkins University.

John Stark, PhD is a Professor of Ecotoxicology and Director of the Washington Stormwater Center at the Washington State University Research and Extension Center in Puyallup. His research addresses the development of hazard and risk assessment for aquatic organisms in rivers and streams in the Pacific Northwest. Stark is an expert in population modeling and has developed population-level risk assessments based on matrix and differential equation models. Recent projects involve determination of the effects of stormwater on salmon, zebra fish, and aquatic invertebrate health and assessing the impact of pesticides on endangered butterflies. Stark holds a PhD in Entomology and Pesticide Toxicology from University of Hawaii, an MS in Entomology from Louisiana State University, and undergraduate degrees in biology and forest biology from S.U.N.Y. and Syracuse University, respectively.



Appendix C • Meeting Agenda



Independent Expert Advisory Panel for LOTT Clean Water Alliance Reclaimed Water Infiltration Study

Meeting 5

November 2, 2021

Location

GoToMeeting
See Outlook invite for login information

Contacts

Suzanne Sharkey: 949.258.2093
Mary Collins: 206.380.1930

Meeting Objectives

- Brief the Panel and receive feedback on the final Human Health Risk Assessment
- Facilitate interaction between the Panel, the LOTT project team, and the Science Task Force
- Allow working time for the Panel to begin writing the draft meeting report

OPEN STAKEHOLDER WORKSHOP: 11:00 am to 1:00 pm

11:00 am	Welcome, introductions, and review meeting objectives and agenda	Kevin Hardy, NWRI, and Jim Crook, Panel Chair
11:10 am	Project status update	Wendy Steffensen, LOTT
11:20 am	Introduction to HHRA	Jeff Hansen, HDR
11:30 am	HHRA Update and Changes	Gretchen Bruce, Intertox
12:15 pm	Panel Q & A	Facilitated by Jim Crook
12:50 pm	Wrap up with Science Task Force	

CLOSED PANEL WORKING SESSION: 1:00 pm to 2:00 pm

1:00 pm	Closed Panel session	Facilitated by Jim Crook
2:00 pm	Adjourn	

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Peer Review Questions on Human Health Risk Assessment (HHRA)

1. Given the study findings, how would you describe the relative safety of infiltration of this reclaimed water?
2. Given the layers of conservative assumptions used in both the fate and transport model and the RAs, do the model and the RAs result in findings that over-estimate risk compared to what is typically done in risk assessments?
3. One reason for the study was the lack of research on this topic in similar temperate climates.
 - o 3a. How consistent are this study's findings to studies done elsewhere?
 - o 3b. What does that mean for the need to conduct future research? Is it reasonable to look to studies done elsewhere for information about new or different COIs in the future?

Questions 4 through 11 are related to the chemicals NDMA and PFPeA:

4. Is the risk analysis done here similar to analyses done in other studies?
5. Is relative risk appropriately portrayed?
6. Given the layers of conservative assumptions used in the modeling, would you suggest any refinements to better estimate EPCs of these two chemicals?
7. The exposure point concentrations for NDMA and PFPeA were calculated using the 95% Upper Confidence Limit of all reclaimed water detections. Is this practice considered standard? In light of the fact that NDMA was not detected in approximately half of the reclaimed water samplings, does this method bias the findings?
8. Given the layers of conservative assumptions in the HHRA, would you suggest any refinements to more accurately assess risk from these two chemicals?
9. Given the levels of risk or hazard estimated for NDMA or PFPeA and the layers of conservative assumptions in the HHRA, as well as levels of risk that are considered significant in other studies, do you consider the estimated risks to be significant? Do you have suggestions for communicating the relative significance of these risks?
10. What are your thoughts on the need for continued monitoring, additional treatment, or other measures regarding NDMA or PFPeA?
11. Are other reclaimed water utilities/facilities taking specific steps regarding NDMA or PFPeA?
12. Peer Review commented on a partial draft of the Ecological Risk Assessment (ERA) previously and had no substantive comment. Are there any concerns with the draft final ERA?



Appendix D • Meeting Attendees

Steven Boessow

Gretchen Bruce

Erin Conine

Lisa Dennis–Perez

Carrie Gillum

Jeff Hansen

Kevin Hansen

Bob Jacobs

Matt Kennelly

Joanne Lind

Christine Marbet

Koenraad Marien

Shane McDonald

Hans Qiu

Julie Rector

Art Starry

Wendy Steffensen

Jay Swift

Tyle Zuchowski

NWRI Panel Members

James Crook, Panel Chair

Paul Anderson

Michael Dodd

Michael Kenrick

Edward Kolodziej

John Stark

NWRI Staff

Kevin Hardy, Executive Director

Mary Collins

Natalie Roberts

Suzanne Sharkey