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WATER SCIENCE AND TECHNOLOGY BOARD

Management and Adaptation to Aridification in the Western U.S.

November 15, 2021

OPEN SESSION MATERIALS

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Management and Adaptation to Aridification in the Western United States

Fall Event of the
Water Science and Technology Board

Frequent and severe drought is the new normal for the western U.S. The long-term climate outlook for the western U.S. is one of aridification, and the subsequent impact on water availability will necessitate innovative solutions to manage constrained water supply and demand. These solutions will be a portfolio of new technologies, bold social adaption, policy and legal frameworks, and economic incentives. The western U.S. is not isolated in its management of aridification, and there are lessons to be learned from other arid regions of the globe. Similarly, global policy and markets – particularly international trade – both influence and are impacted by the decisions made in the western U.S. The successful management of and adaptation to aridification requires a holistic approach that embraces the complexity of the hydrologic, socioeconomic, and political dynamics in flux from local to global scales.

This meeting will provide a 20-year outlook of the tough decisions and strategies needed to manage and adapt to aridification in the Western U.S. The meeting will offer an overview of our current understanding of the hydrologic system in the western U.S. with an emphasis on the existing response to aridification and will highlight forward-looking opportunities – and challenges – that span socioeconomic adaptation strategies to technology-driven solutions.

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Monday, November 15 , 2021
Open Session
All times ET

12:00 PM	**Welcome, Introductions, and Meeting Objectives** *Cathy Kling, WSTB Chair*
12:10 PM	**KEYNOTES** **Hydrologic and Socioeconomic Outlook in the Western U.S.** *Moderator: Dave Wegner, WSTB Member*

Objective: Provide an overview of aridification in the Western U.S. and potential socioeconomic impacts, as critical context for meeting discussions on adaptation strategies

	Evolving Water Science and Related Policy Issues in a Rapidly Changing American West *Brad Udall, Colorado State University* **Going for Groundwater: Causes, Consequences and Responses to a Critical Sustainability Challenge** *Tom Hertel, Purdue University*
12:45 PM	**Q&A with Keynote Speakers**

1:00 PM	**Socioeconomic Adaptation Strategies—Flash Talks** *Moderator: Newsha Ajami, WSTB Member*
	The Innovation Moment for Water Governance and Policy Solutions in the West *Dave White, Arizona State University* **Industry Impacts of Pricing Groundwater** *Ellen Bruno, University of California, Berkeley* **Water Law and Workarounds - Ingredients of Success** *Anne Castle, Water Policy Group* **Climate Change Effects and Adaptation in Agriculture** *Bruce McCarl, Texas A&M University* **Water Justice** *Susana DeAnda, Community Water Center*
1:50 PM	**Panel Discussion with Speakers on Socioeconomic Adaptation Strategies** *Moderator: Newsha Ajami, WSTB Member*
2:15 PM	**BREAK**
2:45 PM	**Technology-Based Strategies—Flash Talks** *Moderator: Venkat Lakshmi, WSTB Member*
	Geophysical Imaging of the Subsurface for the Selection of Recharge Sites *Rosemary Knight, Stanford University* **Emerging Technologies for Water Reuse** *George Tchobanoglous, University of California, Davis* **High-Resolution Remote Sensing to Characterize Agronomic Processes Across Scales** *Elia Scudiero, University of California, Riverside* **Prospects and Challenges of Desalination Technologies** *Menachem Elimelech, Yale University* **Overview of the Portfolio of Technology-Based Solutions** *Peter Gleick, Pacific Institute*

3:35 PM	**Panel Discussion with Speakers on Technology-Based Strategies** *Moderator: Venkat Lakshmi, WSTB Member*
4:00 PM	**Closing Panel Discussion: Promising Strategies for the Next 20-50 Years** *Moderator: Jordan Fischbach, WSTB Member*
	Panelists: Brad Udall, Colorado State University; Peter Gleick, Pacific Institute; Anne Castle, Water Policy Group; Tom Hertel, Purdue University; Susana DeAnda, Community Water Center
ADJOURN DAY 1 5:00 PM	

SPEAKER BIOS

Ellen Bruno is an Assistant Cooperative Extension Specialist in the Department of Agricultural and Resource Economics at the University of California, Berkeley. She conducts research and outreach on economic and policy issues relevant to California's agriculture and natural resources, with a particular focus on groundwater. She holds a B.S. in Management Science from the University of California, San Diego and an M.S. and Ph.D. in Agricultural and Resource Economics from the University of California, Davis.

Anne Castle is a Senior Fellow at the Getches-Wilkinson Center for Natural Resources at the University of Colorado, focusing on western water issues including Colorado River operational policy and the integration of tribal water interests. She is a founding member of the Water Policy Group. Prior to joining the University of Colorado, she was Assistant Secretary for Water and Science at the U.S. Department of the Interior (DOI), where she oversaw water and science policy for the Department and had responsibility for the U.S. Bureau of Reclamation and the U.S. Geological Survey. While at DOI, Ms. Castle spearheaded the Department's WaterSMART program and provided hands-on leadership on Colorado River issues, including a ground-breaking agreement between the U.S. and Mexico. She is the President of the Board of Directors of the Colorado Water Trust and serves on several boards or advisory committees, including Western Resource Advocates, Airborne Snow Observatory, Stanford University's Water in the West program, and the Colorado River Water and Tribes Initiative, where she is co-leading an initiative on universal access to water on Indian reservations. She received her J.D. from the University of Colorado Boulder.

Susana De Anda is Co-Founder and Executive Director of the Community Water Center. She is a seasoned community organizer and has received numerous awards and recognitions. Her experience includes planning and organizing positions at the Center on Race, Poverty and the Environment, the County of Merced Planning Department, the Santa Barbara County Water Agency, and the Santa Barbara non-profit Community Environmental Council. She served for the past few years on the Community Funding Board of the Grassroots Fund through the Rose Foundation for Communities and the Environment, Tulare County Water Commission and on the Board of Directors of the Tulare County United Way. She currently serves on the Advisory Council for the Water Solutions Network and is a Steering Committee Member on the Water Equity and Climate Resilience Caucus. She is also a Co-Founder and member of the board of Water Education for Latino Leaders (WELL). She earned a B.A. from the University of California, Santa Barbara while completing a double major in Environmental Studies and Geography.

Menachem Elimelech is the Sterling Professor of Chemical and Environmental Engineering at Yale University. His research focuses on membrane-based technologies at the water-energy nexus, materials for next-generation desalination and water purification membranes, and environmental applications of nanomaterials. He was the recipient of numerous awards in recognition of his research contributions. Notable among these awards are the Clarke Prize for excellence in water research, election to the U.S. National Academy of Engineering, Eni Prize for 'Protection of the Environment,' and election to the Chinese Academy of Engineering. He has advised 43 Ph.D. students and 41 postdoctoral researchers, many of whom hold leading positions in academia and industry. In recognition of his excellence in teaching and mentoring, he has received the W.M. Keck Foundation Engineering Teaching Excellence Award, the Yale University Graduate Mentoring Award, and the Yale University Postdoctoral Mentoring Prize. Dr. Elimelech received his Ph.D. in Environmental Engineering from The Johns Hopkins University

Peter Gleick is Co-Founder and President Emeritus of the Pacific Institute in California, an independent research institute creating and advancing solutions to global water problems. Dr. Gleick is one of the world's leading experts on freshwater resources and a hydroclimatologist focused on climate change, water and conflict, and the human right to water – work used by the United Nations and in human rights court cases. He pioneered the concepts of the "soft path for water" and "peak water" and has worked extensively on issues related to water and international security, including developing the Water Conflict Chronology – the comprehensive database of violence associated with freshwater resources and systems. He is author of many scientific papers and thirteen books, including *The World's Water* series*, Bottled and Sold,* and *A 21st Century US Water Policy.* Dr. Gleick is a MacArthur Fellow, member of the U.S. National Academy of Sciences, winner of the 2018 Carl Sagan Prize for Science Popularization, and served two terms on the National Academy of Sciences, Engineering, and Medicine's Water Science and Technology Board. He received his B.S. in Engineering and Applied Science from Yale University and his M.S. and Ph.D. in Energy and Resources from the University of California, Berkeley.

Thomas W. Hertel is a Distinguished Professor of Agricultural Economics at Purdue University. His research and teaching focuses on international trade, food, and environmental security. He is a Fellow and Past-President of the Agricultural and Applied Economics Association (AAEA), Fellow of the American Academy for the Advancement of Science, Honorary Life Member of the International Association of Agricultural Economists, and the Founder and Executive Director of the Global Trade Analysis Project. Dr. Hertel has received a number of AAEA awards, including Outstanding Graduate Teacher, Publication of Enduring Quality, Distinguished Policy Contribution, Outstanding Journal Article, and Quality of Communication. His research has also been recognized by the Australian Agricultural and Resource Economics Association (Best Journal Article) and the Ecological Society of America (Sustainability Science Award). Dr. Hertel received his B.A. in Economics from the University of North Carolina at Chapel Hill, M.S. in Public and International Affairs from Princeton University, and Ph.D. in Applied Economics from Cornell University.

Rosemary Knight is the George L. Harrington Professor of Earth Sciences at Stanford University. She has worked for more than 30 years on the challenge of using geophysical methods to characterize groundwater systems. She has founded, with Adam Pidlisecky, the Center for Groundwater Evaluation and Management with the vision of advancing and promoting the use of geophysical methods through the development of partnerships with water agencies. Collaboration with local and state agencies—moving "knowledge into action"—remains central to Dr. Knight's work. At Stanford, she has served as Department Chair, Associate Vice-Provost for Graduate Education, on the University Budget Group for 15 years, and as Chair of the Faculty Senate. Dr. Knight has been active within the Society of Exploration Geophysicists (SEG) and has been recognized by the SEG with awards for research, teaching, and service. Within the American Geophysical Union, Dr. Knight was the founding Chair of the Near-Surface Geophysics Focus Group and has served as an Associate Editor for *Water Resources Research* and the *Journal of Geophysical Research*. She received her B.S. and M.S. in Geological Sciences from Queen's University in Kingston, Ontario, Canada and her Ph.D. in Geophysics from Stanford University.

Bruce A. McCarl is University Distinguished Professor, Presidential Impact Fellow, Regents Professor, Senior AgriLife Research Fellow, and Professor of Agricultural Economics at Texas A&M University. Dr. McCarl works on economic implications of global climate change and greenhouse gas emission reduction and the food/energy water Nexus as well as forestry and agricultural policy design, biofuels, mathematical programming, and risk analysis. He is the author of over 300 journal articles and more than 500 other papers and presentations. He has been involved with over $90 million in sponsored research. Prior to Texas A&M, he was at Oregon State and Purdue Universities. He is a Fellow of the Agricultural and Applied Economics Association and a fellow of both the Western and Southern Agricultural Economics Associations. He was part of the Intergovernmental Panel on Climate Change that was co-recipient of the 2007 Nobel Peace Prize. He earned his B.S. in Business Statistics from the University of Colorado and Ph.D. in Management Science from Pennsylvania State University.

Elia Scudiero is a Research Agronomist at the Environmental Sciences Department of the University of California, Riverside with a joint appointment at the U.S. Department of Agriculture's (USDA) Agricultural Research Service U.S. Salinity Laboratory. Dr. Scudiero's Digital Agronomy Lab specializes in the use of near-ground and remote sensing measurements to study soil and crop processes across scales to support sustainable site-specific agriculture management. His research is funded by a variety of federal, state, and commodity-board funding programs. He is the Principal Investigator of a USDA-National Institute of Food and Agriculture Sustainable Agricultural System project on Artificial Intelligence for Sustainable Water, Nutrient, Salinity, and Pest Management in the Western U.S. He received his B.S. and M.S. in Environmental Sciences and Technology and Ph.D. in Crop Science from the University of Padua, Italy.

George Tchobanoglous taught courses on water and wastewater treatment and solid waste management at the University of California, Davis , where he is Professor Emeritus in the Department of Civil and Environmental Engineering. He has authored or coauthored over 600 publications, including 23 textbooks and 8 reference books. He has also presented more than 625 lectures on various environmental engineering subjects. He was inducted into the National Academy of Engineering. He is also a member of the European Academy of Sciences and Arts and was elected a Corresponding Member of the Academy of Athens. Tchobanoglous received a B.S. in Civil Engineering from the University of the Pacific, an M.S. in Sanitary Engineering from the University of California, Berkeley, and a Ph.D. in Environmental Engineering from Stanford University.

Bradley H. Udall is a Senior Water and Climate Research Scientist/Scholar at Colorado State University's Colorado Water Center. His expertise includes hydrology and related policy issues of the American West, with a focus on the Colorado River. He has authored climate change assessments for the Bureau of Reclamation and the state of Colorado. Mr. Udall was a co-author of the 2009 and 2019 National Climate Assessments and a contributing author to the 2014 Intergovernmental Panel on Climate Change 5th Assessment. He has written several peer-reviewed papers on the impacts of climate change on the Colorado River, including "The 21st Century Colorado River Hot Drought and Implications for the Future," which attributed part of the decline in Colorado River flows to rising temperatures. He has testified in both the U.S. Senate and U.S. House of Representatives on the impacts of climate change of water resources. He has received the Climate Science Service Award from the California Department of Water Resources for his work in facilitating interactions between water managers and scientists and the Partner in Conservation Award from the Department of Interior. He formerly served on the American Water Works Association Research Foundation expert panel on climate change. His work was recently featured on CBS's *60 Minutes*. He received his B.E. in Environmental Engineering from Stanford University and MBA from Colorado State University.

Dave White currently serves as Deputy Director of the Global Institute of Sustainability and Innovation, Professor in the School of Community Resources and Development, Director of the Decision Center for a Desert City, and Interim Director of the Rob and Melani Walton Sustainability Solutions Service at Arizona State University (ASU). Since joining ASU, he has helped lead its evolution into one of the world's leading universities for global impact. Dr. White is internationally-recognized for his contributions to science in support of sustainability. He has published more than 60 peer-reviewed articles advancing numerous fields, including decision science, science and technology studies, sustainability science, and water resources management. His work has also been covered in popular media including *The New York Times*, *Washington Post*, *Wall Street Journal*, and National Public Radio. Dr. White is an inaugural Fellow of the PLuS Alliance, with joint appointments across ASU, Kings College London, and the University of New South Wales in Sydney, Australia. He received his B.S. in History from George Mason University, his M.S. in Resource Recreation and Tourism from the University of Idaho, and his Ph.D. in Forestry from Virginia Polytechnic Institute and State University.

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Water Science and Technology Board (WSTB)

Statement of Task

The Water Science and Technology Board serves as the focal point for studies related to water resources at the National Academies. The board works to improve the scientific and technological foundation for addressing national- and regional-level questions and issues associated with efficient management, development, and use of water resources in natural and engineered environments. WSTB studies may assume a wide, systematic perspective of water and related resources or focus on specific aspects of water infrastructure and related engineering aspects. Scientific, engineering, economic, institutional, legal, and social aspects of water resources thus all represent areas of interest and potential investigations for the WSTB.

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CATHERINE L. KLING, NAS, Chair, is the Tisch University Professor of Environmental, Energy, and Resource Economics in the Dyson School of Applied Economics at Cornell University and the Faculty Director of the Atkinson Center for a Sustainable Future. She specializes in the economic valuation of ecosystem services and the integrated assessment modeling for water quality modeling. Dr. Kling currently chairs the National Academies of Sciences, Engineering, and Medicine's Water Science and Technology Board and is a member of the PNAS editorial board. She has been a member of nine Academies study committees, including several focused on water resources and agricultural issues. She served as president of the Association of Environmental and Resource Economists, held editorial positions at ten economics journals, and has published over 100 journal articles and book chapters. She is currently the editor of the Review of Environmental Economics and Policy. She is an elected Fellow of the Association of Environmental and Resources Economists, the Agricultural and Applied Economics Association, and the American Association for the Advancement of Science. She is also a University Fellow at Resources for the Future, a member of the National Academy of Sciences, and has served for ten years on EPA's Science Advisory Board. She received her B.A. in business and economics from the University of Iowa and Ph.D. in economics from the University of Maryland, College Park.

NEWSHA K. AJAMI is the director of Urban Water Policy with Stanford University's Water in the West program. A leading expert in sustainable water resource management, water policy, innovation, and financing, and the water-energy-food nexus, her research throughout the years has been interdisciplinary and impact driven, focusing on the improvement of the science-policy-stakeholder interface by incorporating social and economic measures and effective communication. Dr. Ajami is a two-term gubernatorial appointee to the Bay Area Regional Water Quality Control Board. Before joining Stanford, she worked as a senior scholar at the Pacific Institute, and served as a Science and Technology fellow at the California State Senate's Natural Resources and Water Committee where she worked on various water and energy related legislation. She has published many highly cited peer-reviewed articles, coauthored two books, and contributed opinion pieces to the New York Times, San Jose Mercury and the Sacramento Bee. She was the recipient of the 2005 National Science Foundation award for AMS Science and Policy Colloquium and ICSC-World Laboratory Hydrologic Science and Water Resources Fellowship from 2000 to 2003. Dr. Ajami received her Ph.D. in civil and environmental engineering from the University of California, Irvine, an M.S. in hydrology and water resources from the University of Arizona, and a B.S. in civil and environmental engineering from Tehran Polytechnic.

PEDRO J. ALVAREZ, NAE, is the George R. Brown Professor of Civil and Environmental Engineering at Rice University where he also serves as founding director of the NSF Engineering Research Center on Nanotechnology-Enabled Water Treatment. His research interests include environmental implications and applications of nanotechnology, bioremediation, fate and transport of toxic chemicals, water footprint of biofuels, water treatment and reuse, and antibiotic resistance control. He is the 2012 Clarke

Prize Laureate and also won the American Academy of Environmental Engineers and Scientists' Grand Prize for Excellence in Environmental Engineering and Science. Past honors include president of the Association of Environmental Engineering and Science Professors (AEESP), the Perry McCarty AEESP Founders' Award for Outstanding Contributions to Environmental Engineering Education and Practice, the AEESP Frontiers in Research Award, the Water Environment Foundation McKee Medal for Groundwater Protection, the Strategic Environmental Research and Development Program's Cleanup Project of the Year award, the Brown and Caldwell Lifetime Achievement Award for Site Remediation, the American Society of Civil Engineers' Simon Freese Award, and various best paper awards with his students. He is an associate editor of Environmental Science and Technology and previously served on the scientific advisory board of the EPA and of the advisory committee of the NSF Engineering Directorate. Professor Alvarez was elected to the National Academy of Engineering for outstanding contributions to the practice and pedagogy of bioremediation and environmental nanotechnology. Professor Alvarez received his B.Eng. in civil engineering from McGill University and M.S. and Ph.D. degrees in environmental engineering from the University of Michigan.

JONATHAN D. ARTHUR, P.G. is the Executive Director of the American Geosciences Institute. From 2009 through June 2021, Dr. Arthur served as the State Geologist of Florida and Director of the Florida Geological Survey. His research in aquifer vulnerability and metals mobilization during artificial recharge has informed environmental policy and management, and he holds a keen interest in geoscience policy, public engagement, and application of geosciences to address societal and environmental concerns. Dr. Arthur is a Fellow of the Geological Society of America, and recipient of the John T. Galey, Sr. Memorial Public Service Award from the American Institute of Professional Geologists. He has served as president of the Association of American State Geologists and the Florida Association of Professional Geologists, and other leadership roles in the geoscience community. Dr. Arthur has served on four National Academy of Sciences committees related to aquifer system dynamics and habitat conservation, and has given congressional briefings and testimony, numerous invited presentations, keynotes, and international workshops. He earned his Ph.D. in geology from Florida State University.

RUTH L. BERKELMAN (NAM) is the Rollins Professor Emerita in Epidemiology at Emory University and has held appointments in the departments of epidemiology, global health, and medicine, and the Emory Ethics Institute. She is an international expert in infectious diseases and public health policy, and has engaged on issues related to waterborne disease. She has investigated outbreaks, has conducted research, and has led policy discussions on the prevention and control of legionellosis. Before coming to Emory, she served in many positions, including the Deputy Director of the National Center for Infectious Diseases, Centers for Disease Control and Prevention (CDC). She retired as an Assistant Surgeon General after 20 years with the U.S. Public Health Service. Dr. Berkelman has served on various committees and boards including the HHS National Biodefense Science Board, the NRC Board of Life Sciences, and the Princeton University Board of Trustees. She is a member of the National Academy of Medicine and the American Academy of Microbiology, and is currently serving on the External Advisory Board for the College of Public Health and Health Professions, University of Florida. She holds an A.B. degree from Princeton University and an M.D. from Harvard Medical School. She is board certified in pediatrics and internal medicine.

JORDAN R. FISCHBACH is the director of planning and policy research at The Water Institute of the Gulf. Before joining the Water Institute, Fischbach was co-director of the RAND Climate Resilience Center, a senior policy researcher at the RAND Corporation, and an affiliate faculty member at the Pardee RAND Graduate School. Since 2010, Fischbach has led RAND research focused on climate adaptation, urban resilience, water resources management, coastal planning, and post-disaster recovery. For the past 10 years, Fischbach has been the principal investigator for the Coastal Louisiana Risk Assessment (CLARA) modeling effort, which provides next-level modeling capabilities for Louisiana Coastal Protection and Restoration Authority to efficiently estimate flood risk under a wide range of future environmental, operational, and growth uncertainties and with various proposed projects in place. Fischbach's other work includes serving as a co-investigator for the NOAA Mid-Atlantic Regional Integrated Sciences and Assessments (MARISA) center, which has the goal to support the effective utilization of climate science and the building of adaptive capacity and resilience to climate variability and change in the Mid-Atlantic region. Fischbach was previously principal investigator on a project to evaluate of the economic, social, and ecosystem benefits and costs of a range of green stormwater infrastructure proposals for Pittsburgh's Negley Run watershed. The project applied simulation modeling and Robust Decision Making to evaluate large-scale green infrastructure designs—developed by the U.S. Army Corps of Engineers Pittsburgh District—across a range of uncertain climate futures. He received his B.A. in history from Columbia University and his M.Phil. and Ph.D. in policy analysis from Pardee RAND Graduate School.

ELLEN GILINSKY is president of Ellen Gilinsky, LLC, which she started in January 2017 to work with government, industry, and the private sector on finding environmental solutions to water challenges. As part of the Obama Administration from 2011 through 2016, she was the associate deputy assistant administrator for water at the Environmental Protection Agency where she played a key role in water programs at the federal, state, and local levels working closely with diverse stakeholders in the water quality, quantity, and agriculture sectors and serving as co-chair of the Mississippi River/Gulf of Mexico Hypoxia Task Force. Prior to this appointment, Dr. Gilinsky served as director of the Water Division at the Virginia Department of Environmental Quality, and in the early 1980s she was part of Virginia's Chesapeake Bay Program staff. In addition, she has 12 years of experience as an environmental consultant at several regional and national environmental engineering firms. She has been a past president of the Association of Clean Water Administrators and held a past gubernatorial appointment to the State Advisory Board of the Virginia Water Resources Research Center. She currently serves as a board member of River Network and the Soil and Water Conservation Society and holds a gubernatorial appointment to the Science and Technical Advisory Committee of the Chesapeake Bay Program. Dr. Gilinsky received her B.A. in biology from the University of Pennsylvania and her Ph.D. in zoology with a concentration in aquatic ecology from the University of North Carolina at Chapel Hill.

WENDY D. GRAHAM is the Carl S. Swisher Eminent Scholar in Water Resources in the Department of Agricultural and Biological Engineering, and Director of the Water Institute, at the University of Florida, Gainesville. Her areas of specialization include integrated hydrologic modeling, groundwater resources evaluation and remediation, evaluation of impacts of agricultural production on surface and groundwater

quality, evaluation of impacts of climate variability and climate change on hydrologic systems, and stochastic modeling and data assimilation. Dr. Graham is a member of the Florida Agricultural Water Policy Advisory Council. She served three terms on the National Academies' Committee on Independent Scientific Review of Everglades Restoration Progress as well as on the Review of EPA's Economic Analysis of Final Water Quality Standards for Nutrients in Lakes and Flowing Waters in Florida. She has a B.S. in environmental engineering from the University of Florida, and a Ph.D. in civil engineering from the Massachusetts Institute of Technology.

ROBERT M. HIRSCH is a research hydrologist emeritus at the U.S. Geological Survey (having retired in 2018). As a research hydrologist, the focus of his research is on the description and understanding of long-term variability and change in surface-water quality and streamflow. From 1994 through May 2008, he served as the Chief Hydrologist of the USGS. In this capacity, Dr. Hirsch was responsible for all USGS water science programs, which encompass research and monitoring of the nation's groundwater and surface water resources including issues of water quantity as well as quality. Dr. Hirsch has received numerous honors from the federal government and from non-governmental organizations, including the 2006 American Water Resources Association's William C. Ackermann Medal for Excellence in Water Management, selected to be the Walter Langbein Lecturer of the American Geophysical Union in 2017, and has twice been conferred the rank of Meritorious Senior Executive by the U.S. President. He is co-author of the textbook *Statistical Methods in Water Resources*. Dr. Hirsch has served on two Academies committees, including the *Committee to Review the NYC DEP Operations Support Tool*. Dr. Hirsch received a B.A. in geology from Earlham College, an M.S. in geology from University of Washington, and a Ph.D. in environmental engineering from the Johns Hopkins University.

VENKATARAMAN LAKSHMI is a professor in the Department of Engineering Systems and Environment at the University of Virginia. He served as the Cox Visiting Professor of Earth Sciences at Stanford University 2006-2007 and 2015-2016 and Program Director for Hydrologic Sciences at the National Science Foundation 2017-2019. His research interests are in the areas of land surface hydrology, hydrometeorology, hydro-climatology and land-atmospheric-ecological interactions studies using modeling and remote sensing. Between 1995 and 1999 he worked at the NASA Goddard Space Flight Center as a research scientist in the Laboratory for the Atmospheres. Dr. Lakshmi is a fellow of the American Society of Civil Engineers (ASCE) and has over 100 peer-reviewed articles and 400 presentations. He has advised over 30 graduate students. He has served as editor for Eos, associate editor of Water Resources Research, Journal of Hydrologic Engineering, Journal of Hydrology and Journal of Geophysical Research and currently is serving as Editor of the Vadose Zone Journal. He is the founding editor-in-chief of the Remote Sensing in Earth System Science (a Springer publication). He has served on the board of directors of the Consortium of Universities for the Advancement of Hydrological Sciences, the AGU Hydrological Sciences Executive Council and the co-chair for the Program Committee of the Hydrology Section for the AGU Fall Meeting. He recently served on the National Academies Panel for the Decadal Survey of Earth Observations from Space (NASA) (2016-2018) and as chair of the planning committee for Groundwater Recharge and Flow: Approaches and Challenges for Monitoring and Modeling Using

Remotely Sensed Data (NGA) (2018-2019). He received his Ph.D. in Civil and Environmental Engineering from Princeton University in 1996.

MARK W. LeCHEVALLIER has worked since 1985 for American Water, a water utility operating in 40 states and Canada that serves over 15 million people. Dr. LeChevallier is currently a Vice President and Chief Science Advisor at the American Water Corporate Center in Voorhees, NJ. In this capacity he is involved in the research and development, innovation, and environmental compliance and stewardship program for the company. His research areas have included bacterial regrowth, disinfection of biofilms, corrosion, AOC measurement techniques, biological treatment, Mycobacterium, microbial recovery and identification, modeling and impact of pressure transients on water quality, and detection, treatment and survival of Giardia and Cryptosporidium. He has authored or coauthored over 100 research papers. He was the recipient of the George Warren Fuller award in 1997 from the New Jersey section of the American Water Works Association, the Abel Wolman Award from the American Water Works Association in 2012, and the A.P. Black award for research from the American Water Works Association in 2015. He received his BS and MS in microbiology from Oregon State University. He worked as a Research Associate at Montana State University, where he received his Ph.D. in microbiology.

CAMILLE PANNU is a visiting assistant clinical professor of law at the University of California, Irvine School of Law's Community and Economic Development Clinic. Prior to joining the University of California, Irvine, Pannu served as the inaugural director of the Aoki Water Justice Clinic at the University of California, Davis School of Law where she combined transactional law, policy advocacy, and strategic research to ensure low-income communities receive clean, safe, and affordable drinking water. Prior to UC Davis, Professor Pannu served as an Equal Justice Works Fellow in the southern San Joaquin Valley where she partnered with low-income communities of color to address poverty and racial and environmental inequality. Her project provided direct transactional legal services and support to Valley communities who sought to establish “green-collar” worker cooperatives, community-owned enterprises, and essential infrastructure projects (water, wastewater, energy, roads). Her research focuses on structural racism, poverty, and environmental inequality in low-income, rural, and unincorporated communities. Her work interrogates how groups leverage power through corporate law and local government to assert control over shared environmental resources and essential infrastructure. Pannu received her B.A. in international political economy and J.D. with a certificate in environmental law from the University of California, Berkeley.

DAVID L. SEDLAK, NAE, is the Plato Malozemoff Professor in the Department of Civil & Environmental Engineering at the University of California, Berkeley where he is also the co-Director of the Berkeley Water Center and the Deputy Director of the National Science Foundation's Engineering Research Center on Reinventing the Nation's Urban Water Infrastructure (ReNUWIt). His areas of research include analytical methods for measuring organic compounds in water, fate of chemical contaminants in water recycling systems, environmental photochemistry, and ecological engineering. He has received several notable awards including the Fulbright Senior Scholar Award in 2003, Paul Busch Award for Innovation in Water Quality Engineering in 2003 and the NSF CAREER Award in 1997. Dr. Sedlak received a B.S. in

environmental science from Cornell University and a Ph.D. in water chemistry from the University of Wisconsin, Madison.

JENNIFER TANK is the Galla Professor of Biological Sciences at the University of Notre Dame and director of the Notre Dame Environmental Change Initiative (ND-ECI). Dr. Tank is an aquatic ecologist and biogeochemist who studies how nutrients and particles move through streams and rivers with a focus on restoration and conservation efforts that improve the structure and function of flowing waters. Her research informs management and policy of freshwaters especially around water quality in agricultural landscapes. Her federally-funded research program includes grants from the U.S. Department of Agriculture, National Science Foundation, Department of Defense, and the Environmental Protection Agency. She has published >160 journal articles and this work has been cited >17,000 times. She also serves as an associate editor for two journals: Biogeochemistry and Limnology and Oceanography Letters. Dr. Tank is also committed to science leadership and translation, which grew out of her participation as a 2013 Leopold Leadership Fellow. She was the 2018-19 president of the Society for Freshwater Science and was recently elected a 2020 AAAS Fellow. For the National Academies of Sciences, Engineering, and Medicine, she served on the consensus study Future Water Priorities for the Nation: Directions for the U.S. Geological Survey Water Mission Area. She earned her Ph.D. in ecology from Virginia Polytechnic Institute and State University.

DAVID WEGNER is a senior scientist at Woolpert Engineering. He is retired from a senior staff position on water, energy and transportation committees in the U.S. House of Representatives. In that position he worked on legislation that directly affected administration policy and federal agency actions related to the U.S. Army Corps of Engineers, the Department of the Interior, the Environmental Protection Agency, Bonneville Power, Tennessee Valley Authority, and the Department of Energy. Prior to serving in Washington, D.C. he worked for over 20 years for the Department of the Interior managing water and science programs in the Colorado River basin and the Grand Canyon. During his tenure at DOI he was instrumental in formulating the Adaptive Management approach for other river systems impacted by dams and river operations. For 14 years he built a private international environmental company that focused on global water issues. Currently he works as a senior scientist for science for Woolpert Engineering and provides input and strategic counsel to NASA/JPL, academic institutions, members of Congress and staff, and international organizations focused on water, energy, coastal and climate issues. Mr. Wegner is a frequent lecturer on the use of science in natural resource management and on the history of western water. He is on the boards of the Glen Canyon Institute, the Sonoran Institute and CalCom Solar. Mr. Wegner received his M.S. in engineering/fluvial geomorphology from Colorado State University.

P. KAY WHITLOCK, PE, D.WRE, F.ASCE, Vice President, manages multi-disciplinary water resource projects for Christopher B. Burke Engineering, Ltd. (CBBEL), a full service civil engineering firm specializing in municipal, water resources, traffic, construction, environmental, and mechanical engineering with multiple offices in Illinois and Indiana. Ms. Whitlock has more than 50 years of experience in the areas of water resource management, stormwater management, flood control, water and natural resource engineering, federal, state and local funding, and legislative testimony for project authorizations. Ms.

Whitlock was the water resources lead for the Master Civil Engineer team for the O'Hare Modernization Program (OMP) from 2003-2019. She now handles drainage and permitting for the O'Hare International Airport new terminal development. Prior to this, Ms. Whitlock served at a number of public water resource agencies, including the Santa Clara Valley Water District, DuPage County, Illinois and the Illinois Division of Water Resources. Kay currently serves as the Legislative Chair for the Illinois Association of Stormwater and Floodplain Management. She has made presentations on Water Resources Engineering throughout the United States and around the world, including China and Lebanon; and has been recruited multiple times through the years to speak on Professional Ethics in Engineering. Ms. Whitlock earned her B.S. degree in Agricultural Engineering from the University of Illinois, Urbana-Champaign and her M.A from the University of Illinois, Springfield and is a graduate of University of Mississippi's Management Training Institute. She is a Registered Professional Engineer in Illinois and a Diplomate Water Resources Engineer.

Past Meeting Topics

Water Science and Technology Board

- May 2021: Federal Agency and Congressional Priorities for Water Science, Technology, and Policy
- Oct 2020: Exploring Pressing Issues at the Interface of Water Science and Environmental Justice
- May 2020: Wastewater Monitoring for COVID-19 Disease Surveillance/Reopening During COVID-19: Ensuring Safe Water Supplies at the Building Scale
- Nov 2019: Conversations with WSTB Core Sponsors and Other Federal Agency Liaisons
- Jun 2019: Federal and State Perspectives on U.S. Water Resources: Groundwater Quality and Quantity and Other Water Challenges
- Nov 2018: Connecting Climate, Weather, and Water – Status, Challenges, and Needs for Subseasonal-to-Seasonal Forecasting for Water Use and Management (joint w/BASC)
- May 2018: Environmental Dynamics and Exposure Pathways of Subsurface Contaminants, Part 4 of 4
- Dec 2017: Water Issues for the Nation
- Apr 2016: America's Drinking Water: Risks and Challenges/Tile Drains: Understanding and Mitigating the Impacts on the Nation's Streams