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Table of Contents

Table of Contents Continued

Presenter Index

A

B

C

D

E

F

G

H

J

K

L

M

Planning for the Future of the Colorado River

John Schmidt, Professor, Janet Quinney Lawson Chair in Colorado River Studies, Utah State University

A warming climate is predicted to cause decreased runoff in the Colorado River basin, especially from the Rocky Mountains whose snowmelt comprises most of the stream flow of the mainstem river. One aspect of the impending decrease in watershed runoff is that water-supply managers will be forced to make decisions about where to store declining water supplies, especially in years of protracted drought. Should water be primarily stored in upstream reservoirs where evaporation is less or in Lakes Powell and Mead that produce large amounts of hydroelectricity? Should water be primarily stored in Lake Powell, in Lake Mead, or in equal amounts in both reservoirs? Decisions about keeping some reservoirs relatively full and others relatively empty have the potential to drastically change some of the existing novel aquatic ecosystems that have developed since construction of the large reservoirs of the Colorado River watershed.

BIO: John (Jack) C. Schmidt is Janet Quinney Lawson Chair in Colorado River Studies at Utah State University. He leads the Center for Colorado River Studies and has been on the faculty for more than 25 years. His research is focused on describing the geomorphic history of western rivers and developing programs for rehabilitation of degraded ecosystems. Between 2011 and 2014, he served as Chief of the USGS/Grand Canyon Monitoring and Research Center.

Finding Context

Robert Davies, Associate Professor of Professional Practice, Department of Physics, Utah State University

As scientists, citizens, and policymakers continue to plan our water future, it is more important than ever that these discussions take place — and these decisions are made — through a lens that recognizes and includes all pieces of the puzzle. “If a problem is too big to be solved” said Dwight Eisenhower, “make it bigger.” In this talk I will make the problem bigger; in doing so, I hope to enlarge the solution space dramatically. I will overview a developing framework of Planetary Boundaries and Social Foundations — a framework that encompasses the full context of the issues this conference seeks to address. What are the environmental challenges that are co-extant with water; what are the concomitant social challenges; and what are the solution pathways that synergistically address, rather than exacerbate, other environmental and social challenges.

BIO: Robert Davies is Professor of Professional Practice in the Physics Department at Utah State University, where he focuses on global environmental change and critical science communication. Over the past decade, Rob has developed and delivered hundreds of public lectures on climate change and human sustainability. Rob is also co-creator of The Crossroads Project, a “performance science” collaboration that has been performed for audiences across the nation on the critically important topic of human sustainability and vibrancy. Rob is a past associate of the Utah Climate Center; has served as a scientific liaison for NASA on the International Space Station Project; as a project scientist with Utah State University’s Space Dynamics Laboratory; and an officer and meteorologist in the United States Air Force.

Plenary Sessions

Jackson Webster, UCOWR Warren A. Hall Medal Award Recipient
Professor Emeritus of Ecology, Virginia Tech

BIO: Jack Webster grew up in Indiana and attended Wabash College where he majored in biology and minored in mathematics. He started graduate school at the University of Tennessee, but after three years in the Army, he went to the University of Georgia to study ecosystem modeling with Dr. Bernard Patten. His research was on nutrient dynamics in streams at Coweeta Hydrologic Laboratory. Webster went to Virginia Tech after completing his Ph.D. and was on the faculty for 40 years until retiring in 2015. At Virginia Tech, he taught Freshwater Ecology, Ecology, Ecosystem Dynamics, Stream Ecology, and Modelling Stream Ecosystems. He also taught summer courses at Flathead Lake Biological Station in Montana and Highlands Biological Station in North Carolina. During his career, he mentored 17 masters and 9 Ph.D. students. Webster has published over 165 scientific articles including a recent book on watershed response to clearcutting. Most of his publications have been on ecosystem processes in streams and stream modelling. He conducted much of his research at Coweeta, and he continues to analyze data and write papers about Coweeta streams and watersheds. Webster was active in several professional societies, especially the Society for Freshwater Science. He was on the Editorial Board for Ecology and Ecological Monographs and was an Associate Editor for the Journal of the North American Benthological Society and for Freshwater Biology..

Impact of Water Conservation on Long-Term Drought
Amy Vickers, President, Amy Vickers & Associates, Inc.

Dramatic news headlines about the damages wrought by drought, such as perilously low reservoir levels, dried up rivers and wildlife die-offs easily grab the public's emotion, but too often they divert attention away from drought solutions: efficient water use. Indeed, drought can inflict serious pain, but how much is due to Nature's folly versus human failure, specifically water managers and public officials who fail to act early and aggressively in implementing water-saving steps that could avert drought costs? Effective conservation programs can enable water supply systems to not only withstand short- and long-term droughts but moreover can ensure ample water supplies far out into the future. Several major U.S. water suppliers have permanently reduced demands by over 25% with conservation while also increasing their drought resistance. This plenary will present an overview of the efficiency of water use today among residential, commercial, industrial, and agricultural water users as well as the state-of-the-art in water conservation and efficiency technology, policy, and practice. From highly effective urban lawn irrigation schedules and infrastructure leakage reduction to the latest in atmospheric water generation, agricultural water reuse, and smart meter technologies, the impact of water efficiency in mitigating if not averting drought will be discussed.

BIO: Amy Vickers is a nationally recognized water conservation and efficiency expert, engineer, and author of the award-winning Handbook of Water Use and Conservation: Homes, Landscapes, Businesses, Industries, Farms (WaterPlow Press). President of Amy Vickers & Associates, Inc., an independent research and consulting practice based in Amherst, Massachusetts, she has advised over 125 public and private water utilities, organizations, and industries across the United States, Canada, England, Eastern Europe, South Africa, and the Middle East. A prolific writer, Amy has published more than 100 technical papers and articles in professional publications and other media. Most recently, she is a contributing chapter author in Drought and Water Crises: Integrating Science, Management, and Policy, Second Edition (CRC Press/Taylor & Francis Group, 2018). Amy is also the author of the first U.S. national water efficiency standards for plumbing fixtures that were adopted under the U.S. Energy Policy Act of 1992, a measure that is saving the United States an estimated 7 to 9 billion gallons of water daily. She has a MS in Engineering from Dartmouth College and BA in Philosophy from New York University.

Urban Water Demand Trends and the Future of American Water Use

Peter Mayer, Principal, Water Demand Management

Water demand across the U.S. is lower today than it has been for years, a direct result of intentional water conservation and demand management programs and policies implemented across all sectors. This talk will explore how changes in water demand have been accomplished and what water planners and managers should expect in the coming years.

BIO: Peter Mayer is a professional engineer and urban water expert in the areas of water use, water efficiency, demand management, and water resource planning. For more than 20 years, Peter's work has focused on urban water management, researching water use patterns, assessing the impact of water rate structures, evaluating water efficiency measures and programs, forecasting future demand with and without conservation, preparing water demand management plans, and conducting water supply scenario analysis. Peter was the lead author for the Water Research Foundation (WRF) "Residential End Uses of Water" studies published in 1999 and 2016 and a key contributor to the companion "Commercial and Institutional End Uses of Water" study. In 2017 Peter published ground breaking research on peak demand management through advanced irrigation control. Peter is currently leading three research studies for WRF and the Alliance for Water Efficiency (AWE) on meter sizing, outdoor water savings, and drought response, developing demand management plans with New York City Department of Environmental Protection, and a team member consultant for the Colorado State Water Supply Initiate. In 2016, Peter testified as an expert witness on municipal and industrial water use at the U.S. Supreme Court (FL v. GA, 142 Original) on behalf of the State of Georgia. In 2013, Peter founded WaterDM – Water Demand Management. WaterDM's current clients include: the New York City Water Board, Colorado Water Conservation Board, AWE, Rachio, WRF, and Northern Water. Throughout his career Peter has worked with more than 100 water providers across the United States, Canada, and Australia. Peter is vice chair of the AWWA Customer Metering and Practices committee, and he chaired the subcommittee that prepared the 3rd edition of AWWA's M22 Sizing of Water Service Lines and Meters manual and is leading the effort to prepare the 4th edition. He is a four time winner of AWWA and ASCE Journal "Best Paper" awards. Peter earned his MS in water resources engineering from the University of Colorado in Boulder and holds a BS from Oberlin College.

Understanding the Causes and Impacts of Groundwater Depletion

John Tracy, Texas A&M AgriLife Research - TWRI
(Authors: J. Tracy, L.F. Konikow, J. Johnson, S. Sibray, Z. Sheng, D. Porter)

Groundwater is the Earth's most extracted raw material, with almost 1,000 cubic kilometers per year (km^3/yr) (800 million acre-feet per year) of groundwater pumped from aquifers around the world. About 70% of groundwater withdrawals worldwide are used to support agricultural production systems, and within the United States, about 65% of groundwater withdrawals are used for irrigating croplands. In arid and semi-arid areas, groundwater is often the only consistent source of water, with some areas using over 90% of withdrawals for irrigated agriculture. In these regions, the use of groundwater typically far exceeds the rate at which groundwater is naturally replenished, indicating that these critical groundwater resources are being slowly depleted. Within the United States, groundwater depletion has occurred in many important agricultural production regions, including the Great Plains Region (Nebraska, Colorado, Oklahoma, New Mexico and northern Texas) which has experienced the greatest long-term depletion, the Central Valley of California which is currently experiencing the highest groundwater depletion intensity, the Mississippi Embayment Aquifer (Mississippi River lowlands bordering Arkansas and Mississippi), aquifers in southern Arizona, and smaller aquifers in many western states. The most obvious consequences of depleting groundwater resources are the loss of a long term water supply and the increased costs of pumping groundwater as the water table declines below the ground surface. However, there are many other consequences associated with groundwater depletion, including the loss of the productivity of groundwater production wells (possibly requiring the construction of new wells), the depletion of the flow of water in rivers, creeks and lakes which are hydrologically connected to groundwater aquifers, the shifting and subsidence of land surfaces that can occur when groundwater is extracted from aquifers, and the intrusion of high saline, or poor quality, water from other subsurface formations. This paper provides an overview of the drivers of groundwater depletion, the wide range of impacts that groundwater depletion cause, and approaches that can be used to slow or arrest the rate of depletion, relying on case studies from a number of aquifers across the western United States.

Linking Landscape Hydrologic Processes to Spring Ecosystem Dynamics

Nathan Reaver, University of Florida

In many of Florida's spring-fed rivers, benthic and periphytic algae abundance are increasing and, in some cases, replacing once-dominant aquatic rooted vascular plant communities, which are critical to ecosystem structure and function. These shifts in primary producer communities have occurred contemporaneously with increases in nitrogen concentration and declines in discharge. While much research has focused on the role of nutrients in driving this change, in-channel hydrodynamics are also known to control vascular plant and algal abundances and their interactions. A hypothesized driver of observed vegetation shifts is a reduction in the hydraulic control of algal abundance, induced by declines in spring discharge. Understanding the relationships between hydrology and primary producers is essential for developing ecologically relevant flow regulations. Critically, the processes and interactions embedded within the hydraulic control hypothesis span a large range of spatial and temporal scales, cascading from the landscape scale, to the river reach scale, to the organism scale. Recognizing this scale-interdependence, this study tests the hydraulic control hypothesis using a multi-scale observational, experimental, and modeling approach. First, landscape-scale drivers of spring discharge generation were investigated using the Budyko framework. Landscape-scale processes were linked to reach-scale hydraulic processes using tracer experiments, allowing for the development of specific quantitative relationships between discharge and flow velocities. Reach-scale processes were linked to primary producer community structure and dynamic using observational and experimental tests for critical threshold velocities for primary producer abundance. Finally, results from all scales were combined into a modeling framework and applied to a single spring run, the Silver River. Model results suggest that primary producer community shifts in the Silver River can be associated with discharge declines driven by declines in landscape-scale aquifer recharge. This implies that restoration of discharge may reverse primary producer changes in springs where the dominant driver is hydraulic control.

Perennial Crop Dynamics May Affect Groundwater Sustainability

Bradley Franklin, School of Public Policy, University of California-Riverside
(Authors: B. Franklin, K. Schwabe, K. Knapp, L. Levers)

During California's extreme drought from 2010-2016, there was a shift in irrigation from annual to perennial crops, increasing already high reliance on groundwater. Since California passed the Sustainable Groundwater Management Act (SGMA), no economic modelling has investigated the potential effect of perennials on groundwater levels. An integrated model of Kern County is developed here with both groundwater and perennial crop dynamics. Water scenarios are used to investigate the impacts of surface water reductions and perennial prices on land and groundwater use. The results indicate perennial irrigation leads to faster aquifer draw-down compared with models lacking perennial crop dynamics.

Models of Nutrient Biogeochemical Processes Derived from Hyporheic Zone Studies in Coastal California Watersheds

Barry Hibbs, California State University, Los Angeles
(Authors: M. DeHoyos, D. Puga)

Hyporheic zone is the interstitial environment contained in streambeds and streambanks below and adjacent to streams, where active fluid flux and biogeochemical cycling occurs during surface/subsurface interactions. The watersheds we investigated feed into marine environments in coastal Southern California. Earlier studies by researchers suggested reaction with geologic strata by percolating groundwater may be an important source of nutrients (P and N) during dry weather flow conditions (2 weeks after any rain event), where the Miocene marine shales are the dominant substrate comprised of the Monterey-Modelo formation. Our studies in the same watersheds suggested urban runoff of both tap and primarily recycled water is a major contributing factor for nutrient loading, although some geologic input is also evident. We have further addressed the issue by studying hyporheic zone processes in creeks receiving tap water runoff and recycled water runoff, and in other creeks in undeveloped areas that do not receive any urban runoff. In natural creeks with no urban runoff from tap or recycled water, nutrients are low in concentration in hyporheic zone (< 0.5 mg/L NO_3-N, < 0.2 mg/L NH_3-N, < 0.3 mg/L PO_4). Where streams receive urban runoff from tap only, the concentrations of nutrients are also low, and are generally very similar in concentration to what was found in the natural streams. Where streams receive runoff from recycled water, concentrations of nutrients in hyporheic zone are variable, with about 65% of samples containing low nitrate (< 0.5 mg/L NO_3-N), moderate to moderately high ammonium (0.4 to 1.5 mg/L NH_3-N), and moderately-high orthophosphate (0.5 to 8 mg/L PO_4). Stream flows in natural and tap-fed streams contain low concentrations of nutrients, very similar to the concentrations found in the connected hyporheic zone. Where streams receive recycled water due to leakage from urban landscapes, the flows usually contain moderate nitrate (0.4 to 3.0 mg/L NO_3-N), low ammonium (< 0.3 mg/L NH_3-N), and moderate orthophosphate (0.4 to 1.5 mg/L PO_4). The data indicate, where recycled water is used, nutrient loading occurs and important biogeochemical processes take place in the hyporheic zone, including dissimilatory nitrate reduction (producing ammonium) and gradual accumulation of phosphate by evapotranspiration and sorption/desorption processes. Environmental isotopes are presented in this paper as supporting evidence of these processes.

Session 2, Between Science and Policy: Toward Closing the Gap between Scientists and Policy-Makers in the Water-Energy-Food Nexus

Modeling the Uptake and Spread of Technological and Institutional Innovations in Managed Storage for a FEW System

Daniel Mueller, Washington State University
(Authors: M. Goldsby, D. Mueller, H. Roshan, S. Hoard, J. Padowski)

There is a push for developing models to test the efficacy of potential policy and technological innovations in managing Food-Energy-Water (FEW) security. To model the effects of those innovations, it is tempting to compare scenarios where the innovation is applied in a binary manner. However, the assumption that innovations are adopted wholesale and all at once is unrealistic. As such, there is a need to model a more gradual uptake of innovations to provide more accurate and realistic predictions. As a baseline, we use the Community Assets and Attributes Model (CAAM) originally developed to assess community suitability for aviation biofuel facilities through quantification of social assets. The CAAM provides county level measurements for social, cultural, human, and political capitals. We test the hypothesis that counties in the Columbia River Basin with higher levels of community capitals are more likely to adopt innovations early. From that baseline, we further hypothesize that the spread from early adoption to later adoptions can be represented using an agent-based framework, where individual counties are treated as agents. Agent-based modeling offers one strategy for understanding the collective impact and dynamics of individual or autonomous decisions, and how innovation adoption may spread through a community or network. To validate the model we use data from existing case studies where counties have adopted new policy or technological innovations to meet new requirements regarding in-stream flow regulations, which we will present. Future directions include using the model to more realistically represent and predict the spread of innovations in FEW storage management in accordance with the ColumbiaFew Project.

Produced Water Reuse and Recycling in Oklahoma

David Lampert, Oklahoma State University
(Author: H. Atoufi)

The development of oil and gas wells requires water resources for drilling and fracturing prior to production, and additional water is consumed in secondary and enhanced recovery operations. Wastewater is produced along with the oil and gas that must be separated from the products and then either re-injected, applied to land, or treated and discharged. This “produced water” from oil and gas operations varies widely in quality but often exhibits high concentrations of salts, oils and greases, heavy metals, and other organic compounds depending on both the characteristics of the formation and the technologies used in recovery operations. The recent expansion in oil and gas production throughout the United States has simultaneously increased freshwater consumption and produced water generation. Produced waters from oil and gas operations pose risks to the environment and therefore must be either treated or disposed of via underground injection. Recent studies have provided evidence that underground injection of produced water induces seismic activity in Oklahoma. Reusing the produced waters from oil and gas operations provides a potential mechanism to alleviate strains on water resources. The State of Oklahoma recently passed House Bill 3055 that sets an ambitious target to consume no more water in 2060 than had been consumed in 2010. To identify potential opportunities for reuse and recycling of produced waters, the Governor of Oklahoma formed the Water for 2060 Produced Water Working Group (PWWG). The PWWG is a fact-finding work group to look at ways that water produced in oil and natural gas operations may be recycled or reused instead of being injected into underground disposal wells. The PWWG has been charged with identifying regulatory, technical, and economic barriers to produced water reuse as well as looking at opportunities and challenges associated with treating produced water for beneficial uses, such as industrial use, or crop irrigation. This presentation will provide an overview of produced water management and preliminary findings from the PWWG study.

Session 2, Between Science and Policy: Toward Closing the Gap between Scientists and Policy-Makers in the Water-Energy-Food Nexus

Toward Understanding the Level of Convergence between Researchers and Stakeholders Perspectives on Issues Related to Water-Energy-Food (WEF) Challenges: The Case of San Antonio, Texas

Bryce Hannibal, Texas A&M University
(Authors: B. Daher, B. Hannibal, R. Mohtar, K. Portney)

The past decade witnessed growth in research on interconnected resource challenges, primarily focused on quantification of their interconnections, and more recently with greater focus on their social, economic, and policy dimensions. Despite this move towards inter and trans-disciplinary research, which fosters greater cross-departmental collaborations among research groups, little work has been done to investigate the convergence of perspectives of those academic research groups with the respective stakeholders in their regions of study, regarding issues related to resource challenges they face. In this paper, we focus on the case of San Antonio, Texas, which represents a resource hotspot characterized by rapid urbanization, growing energy production in its Eagle Ford Shale Play, and growing agricultural activity. We administered a questionnaire which learns about the perspectives of researchers at Texas A&M's Water-Energy-Food (WEF) Nexus Initiative and WEF stakeholders representing governmental, non-governmental, and business organizations from the San Antonio Region, in an effort to understand their level of convergence over various resource related issues facing the region. Seventy-one responses were received comprising researchers (31 of 71 respondents), and other regional stakeholders from governmental, non-governmental, and business organizations working in the water, energy, or food sectors (40 of 71 respondents). This paper specifically aims to: 1) identify the level of convergence between researchers and other WEF stakeholders in San Antonio on issues related to the Region's water, energy, and food challenges; 2) identify the level of communication existing between WEF stakeholders themselves, compared to the level of communication with members of the research community; and 3) identify barriers to and opportunities for improving communication between San Antonio WEF stakeholders and the researchers involved with studying the issues they face. We find aspects of convergence between researchers and stakeholders perspectives regarding issues related to water, energy, and food in the region. We also find aspects of convergence between both groups over the potential of "Aquifer Storage and Recovery" in addressing the region's future water challenges. Modest levels of communication is reported between researcher and regional stakeholder groups with other water, energy, and food stakeholders in the region. Both groups converge over the potential role of "increased communication" and "sharing information between agencies" in improving cooperation towards addressing the region's interconnected resource challenges. In order to allow for that to be possible, institutional mechanisms and resource allocation for such activities needs to be revisited.

Life Cycle Water Consumption for Transportation Fuel Production in the U.S.

David Lampert, Oklahoma State University

Water and energy resources are fundamental to life on Earth and essential for economic production activities. Energy and water sustainability must be analyzed holistically because the production of energy consumes water, while the treatment and distribution of water consumes energy. Water is required for irrigation in the development of biofuels, to create reservoirs for hydroelectric power plants, for extraction of raw materials such as petroleum and natural gas, and for cooling and processing in facilities such as thermoelectric power plants and refineries. This presentation will provide a comparison of the life cycle water consumption from various fuel production pathways in the United States. The results indicate that market penetration of alternative transportation fuels has the potential to increase freshwater resource consumption. These impacts must be weighed against potential benefits of decreased greenhouse gas and fossil energy consumption. The presentation will also highlight emerging challenges in energy-water systems analysis including the importance of regionality, co-product allocation, and consistent system boundaries when comparing the water intensity of alternative fuels.

The Blue City: Urban Metabolism and the Energy-Water Nexus

Christopher Chini, University of Illinois

Water resources and their embedded energy are critical components of the urban environment, but a lack of data can often hinder water resources analyses. Drinking water and wastewater utilities across the country collect vast amounts of data for their internal accounting and quality control purposes. But where are all these data? In comparison, energy utilities in the United States report their data to the Energy Information Administration (EIA), created in the aftermath of the 1970s energy crisis. Existing methods of obtaining comprehensive data rely on open records requests, which are time intensive and often perpetuate data gaps due to responsiveness. We contacted over 250 drinking water and wastewater utilities across the United States requesting drinking water and wastewater treated volume and embedded energy data. Through this effort, we create a national database of primary data from water utilities, allowing for the development of conservation benchmarks, and providing opportunities for urban water resources sustainability at the national level. On average, U.S. drinking water utilities treat 560 liters per capita per day (lpcd) and U.S. wastewater utilities treat 500 lpcd. To treat this volume of water, an average of 0.34 kWh/m^3 for drinking water and 0.43 kWh/m^3 for wastewater services are required. The results of this data collection effort both motivate the need for a centralized water resources utility database and provide opportunities for evaluating spatial and temporal trends in water resource consumption and embedded energy.

Texas Watershed Steward Program

Michael Kuitu, Texas A&M AgriLife Extension
(Authors: J. Mowrer, W. Ling, D. Gholson)

Stakeholder participation is paramount in planning and implementing effective water quality and watershed management efforts. Individuals who live, work, and recreate in a watershed know it best and can drive local actions to improve and protect their water resources. However, many stakeholders are not well informed about local water resource issues, watershed processes, or potential management strategies. In fact, most individuals are unaware of whether water quality issues exist in their area and, more importantly, how they as individuals can make a difference. The Texas Watershed Steward (TWS) program was developed to address this need by providing training on the fundamentals of watersheds and watershed management. TWS is designed to educate stakeholders about their watershed, potential impairments, and steps that can be taken to protect and improve water quality. The curriculum provides a comprehensive summary of water quality management in Texas and is delivered using a team approach through a blend of PowerPoint modules, interactive stations, and hands on demonstrations. Since the first workshop was held in December 2007, 106 TWS educational events have been delivered in watersheds throughout Texas, reaching a total of 4,487 people as of January 2019. Pre/Post-program test data not only show a 33% increase in participants' knowledge concerning water quality and watershed management, but also 64% of attendees report they intend to adopt behaviors to protect or improve water quality. Evaluation data collected from participants six months after attending a workshop indicate more than 75% of respondents have adopted one or more best management practices. Implementation of the TWS program has facilitated initiation of new water quality improvement projects, increased stakeholder involvement in existing watershed protection efforts, and has motivated individual citizens to take greater personal responsibility for the protection of their water resources.

The Ups and Downs of Watershed Protection Plan Implementation

Ward Ling, Texas A&M AgriLife Extension

Stakeholder participation is critical to successful watershed planning and implementation. In some cases, simple steps could be taken to help promote participation of stakeholders, which ultimately leads to successful implementation. Examples provided from implementation of a Watershed Protection Plan in a central Texas creek will demonstrate how the use of grant funds led to a combination of, what could be termed as successes and setbacks, as well as, lessons learned. In addition, in order for implementation to be most effective, a wide audience should be engaged. This is only achieved through diligent "preplanning" of educational programs, field days, and other events in the watershed. Finally, to improve the success of watershed based plan implementation success, water resource management agencies should value the investment of local stakeholders, and allow use of federal funds for meals and refreshments at development and implementation events to lessen the burden on stakeholders who are donating significant personal and/or professional time to support a government process.

Successful Watershed Management in the Midwest: Getting to Scale

Rebecca Power, University of Wisconsin-Madison
(Authors: R. Power, A.R.P. Vishweshwer)

After decades of experience and research in watershed management, much has been learned about developing and implementing successful watershed initiatives that improve environmental and social outcomes. However, currently available water quality data from United States Environmental Protection Agency shows that 51% of assessed rivers and streams; 70% of assessed lakes, reservoirs, and ponds; 79% of assessed bays and estuaries; 73% of assessed coastal shoreline; 92% of assessed ocean and near coastal waters; 48% of assessed wetlands; 98% of assessed Great Lakes shoreline; and 100% of assessed Great Lakes open waters are impaired. Nitrogen, phosphorus, mercury, and polychlorinated biphenyls are among the most common causes of impairment. Given the current condition of Midwest water resources and the complexity of actions needed to achieve lasting success, deliberate efforts need to be made to implement watershed management across larger geographies in a robust way. This presentation summarizes a new white paper that offers a vision and theory of change for how successful watershed management systems can be scaled up across the Midwest. It (a) proposes a primary unit of watershed management that can be scaled up and sustained over time, b) articulates the necessary elements to foster and support the scale-up efforts, and (c) proposes actionable strategies for operationalizing the scale-up effort. This white paper is informed by two sources of data: (a) Peer and nonpeer reviewed literature and (b) watershed experts who attended a summit in November 2017 and (c) follow-up conversations with these and other experts in conservation and water resource management. While the white paper focuses the cases and recommendations of this paper in the Midwestern U.S., we hope that some of the recommendations will have applicability in other regions of the U.S. and to the field of watershed management as a whole.

Oklahoma's Perspectives on Water Issues and Implications to Water Education Programs

Kevin Wagner, Oklahoma Water Resources Center, Oklahoma State University
(Authors: K. Wagner, C. Eck, B. Chapagain, O. Joshi)

In 2008, the Oklahoma Cooperative Extension Service facilitated a statewide random sample survey of Oklahomans to evaluate citizen awareness, attitudes and willingness to act on water issues. In 2018, the survey was re-issued by the Oklahoma Water Resources Center to a random sample of Oklahomans. Over 400 surveys were returned representing a 23% response rate. In addition to the statewide survey of the public, we also surveyed water professionals and college students at Oklahoma State University to assess differences between these populations. The public generally did not consider water quantity or climate change a concern. Instead, clean water is of greatest concern to the public. Clean drinking water, clean rivers/lakes, and clean groundwater were the public's top three water issues in both 2008 and 2018. Further, the public felt that their ground and surface water was of slightly lower quality in 2018. In 2018, fewer respondents felt surface water quality was good/excellent and more felt it was poor/unacceptable than in 2008. Despite this, the public felt that their drinking water was safe to consume. Numerous opportunities for education were identified. Respondents of both the 2008 and 2018 survey generally preferred receiving water information via printed materials (i.e. fact sheets, bulletins, brochures) and watching television coverage. However, educated users, along with those dissatisfied with their drinking water and those on private systems, are more likely to prefer action based learning methods (i.e. volunteer, participate in training). We will present these and other preliminary results of the 2018 survey, examine changes from 2008 to 2018, assess differences between the three groups surveyed, and discuss potential implications of survey results to agency and university education programs.

Session 4, Panel Discussion: Connecting Land and Water: Research in the Colorado River Basin

Coordination of land and water use decisions is critical if we are to meet the current and future water needs of communities, economies, and environments in the rapidly urbanizing American West. Greater coordination is also needed among researchers and between researchers and practitioners to identify, implement, and share research goals, funding opportunities, and future directions for integrating land and water research that could lead to creating and facilitating sustainable land and water policies. Help us develop a research network focused on advancing the state of research and practice on linking water and land research, policy, and management in the West.

Panel organizers:
Faith Sternlieb, Lincoln Institute of Land Policy
Ashley Hullinger, University of Arizona Water Resources Research Center

Panelists include:
Sharon B. Megdal, University of Arizona Water Resources Research Center
Gretel Follingstad, University of Colorado, Denver
David Kreamer, University of Nevada, Las Vegas
Ginger Paige, University of Wyoming
Joanna Endter-Wada, Utah State University
David DuBois, New Mexico State University

The following abstracts were submitted to this session:

Bridging Land and Water: Building Common Ground and Collaborative Settings in Rural Watersheds

Sharon B. Megdal, University of Arizona Water Resources Research Center
(Authors: A. Hullinger, S.B. Megdal)

The University of Arizona Water Resources Research Center will contribute lessons learned from working as a bridging organization in rural watersheds of Arizona, connecting land and water issues with action-oriented co-generation of knowledge. Bridging organizations serve key roles as translators between available research and the land and water management groups that would use this information. Through process design that is grounded in contextual regional policies, relevant issues, and current research, a bridging organization can facilitate productive dialogue among unaligned and possibly oppositional opinions about land and water management. Ongoing engagement is critical to building trust, establishing common ground, and co-generating knowledge, with the end goal of enhancing community water resilience.

Connecting Research with Water Resource Management in the Colorado River Basin: Some Approaches Investigated in Wyoming

Ginger Paige, University of Wyoming

Understanding how external drivers, climate and management, impact eco-hydrologic function and water availability is critical in the Colorado River Basin (CRB). The Colorado River is a critical water resource for seven western states. However, it is over allocated and currently in its 19th year of drought. Wyoming is one of the four upper basin states collaborating on a drought contingency plan for the CRB. Research and collaborations in the Upper Green River Basin in Wyoming (a headwater of the CRB) are focused on 1) improved data collection efforts to quantify water use and availability within the basin; 2) measurement and modeling of hydrologic response to climate and management practices; and 3) assessing water conservation and drought mitigation efforts and their impacts on land and water resources. This talk will highlight those on-going efforts, the drought contingency plan and discuss implications for land and water management and improved policy development for the CRB moving forward.

Session 4, Panel Discussion: Connecting Land and Water: Research in the Colorado River Basin

Water Demand Forecasting on Colorado's Growing Front Range

Gretel Follingstad, University of Colorado, Denver
(Authors: G. Follingstad, A. Troy)

Urban growth simulation models provide an important tool to help water managers project water use into the future. Typically, urban growth models are used to look at outputs such as land conversion, traffic congestion, energy use or pollution. But only recently have such models been used as a vehicle to assess future water consumption under baseline and alternative (e.g. climate change and land pricing policies) scenarios (Polebitski and Palmer 2010; Polebitski, Palmer, and Waddell 2010). Although such analyses are in their infancy, this research will expand upon the few existing studies that have already integrated urban growth models with water consumption models. This research aims to model future water consumption in response to urban growth into prairie lands along Colorado's urban Front Range. The project will use outputs from DRCOG's UrbanSim model to simulate future growth through the year 2040, which is the current end year of the model. The project will include modeling Denver (which is growing into the eastern plains through its airport zone annexation) and Aurora, a neighboring plains jurisdiction. The project will look at different types of housing development scenarios with a primary focus on outdoor irrigation requirements of varied landscape designs. The project will estimate household level irrigation water consumption based on regressions of Denver Water customer data related to vegetation water use data. These irrigation coefficients are an important component to determining the baseline water supply and demand scenario (current status-quo) and formulating alternative scenarios such as the extent to which climate change would increase evapotranspiration rates. In addition, the research will assess the overall water footprint of different development types (Single Family- Large, Typical, Small, Multifamily, 3-Story Walkup, Mid-Range Multifamily, High Density Multifamily) based on Denver Water Use data.

Assessment of historical and projected drought variability in the Great Plains

Laurent Ahiablame, UC Agriculture & Natural Resources
(Authors: J. Comer, L. Ahiablame, L. Perkins, P. Johnson)

Disturbances, such as grazing and fire, in Northern Great Plains grasslands, can influence soil hydrological processes. This study assessed the impact of intense winter grazing and wildfire on soil moisture, temperature, and infiltration rates in the western South Dakota grasslands. Three blocks of experimental pastures subdivided each into three plots (three intense winter grazed, three burned by wildfire, and three controls). The control plots are non-burned and non-intense-winter grazed grasslands, and the blocks were different from each other with hillslope and plant species composition. The plots were monitored over two growing seasons after the disturbances (wildfire burning and intense winter grazing) occurred. Preliminary data indicate that the control pastures have higher soil moisture content than that of the burned and intense winter grazed treatment pastures. Disturbance did not influence infiltration and soil temperature; however, infiltration time was slightly higher in intense winter grazed pasture while soil temperature was slightly higher in wildfire burned pasture than in the other pastures.

Salton Sea Solutions: Water Markets

Lucia Levers, University of Minnesota
(Authors: L. Levers, K. Schwabe, T. Skaggs, D. Story)

The Salton Sea, California's largest lake, is the site of a looming ecological and human health disaster due to the loss of nearly all alternative wetland habitat and increased playa exposure. The Sea serves as a rest stop for millions of Pacific Flyway migratory birds, and year-round habitat for endangered and sensitive species. Playa contributes to human health damages via airborne pollutants. As a terminal and drainage water fed lake, the Sea is shrinking and becoming more saline as inflows decrease, partly because of the 2003 federal-state-local agreement (i.e., Quantification Settlement Agreement) that allowed the transfer of large amounts of irrigation water to urban users. In 2017, mitigation transfers, intended to slow the Sea's decline, stopped. Inflows will further decrease, accelerating salinization and shrinking, resulting in tens of billions of dollars of estimated damages. Proposals to address these concerns include: an as yet unfunded plan by the State of California to alter the shape and size of the Sea, international ocean water importation, and purchasing water from agricultural users. Using a recently developed regional hydro-economic model of the region that accounts for essential field-level agro-hydrologic processes related to crop production, irrigation, and salinity, we evaluate the cost-effectiveness of three possible water purchase programs considered for "saving" the Salton Sea: fallowing additional farmland, improving irrigation efficiency, and direct leasing. Results indicate that both fallowing and direct lease programs are capable of generating significant environmental water flows with relatively small decreases in agricultural production and no appreciable decrease in grower profits. We then compare these possible solutions to a controversial program being considered by the state to import water from the Sea of Cortés to the Salton Sea. We find that an in-region transfer of water from agriculture is substantially less expensive and significantly more expedient than an international importation plan.

Circular Buffer Strips to Conserve Water and Improve Water Use Efficiency of Center Pivot Irrigated Agriculture in the Southern High Plains

Sangu Angadi, New Mexico State University
(Authors: S. Angadi, S. Begna, P. Singh, P. Gowda, M.R. Umesh, G. Marek)

Irrigation well outputs in the Southern High Plains are reducing with Declining Ogallala aquifer. Most farmers are not able to irrigate their entire pivot and part of their pivot is used for rainfed cropping. In spite of significant improvements in irrigation technologies, water cycle of irrigated pivot is low because the system cannot conserve high intensity rainfall due to poor infiltration rates, frequent small irrigation amounts make pivots as hot spots for evaporation losses, low organic matter has reduced soil water holding capacity, and entire soil profile is not used for storing moisture in production process. A long term research project of rearranging unirrigated part of the pivot into circular buffer strips of perennial grasses alternating with crop strips to improve many ecosystem services including water cycle was initiated at Agricultural Research Center at Clovis in 2016. Corn was used as a test crop. Microclimate, soil moisture and crop biomass and seed yield will be summarized in the presentation.

Unimpaired Hydrologic Metric Scaling for California Streams

Karl Christensen, Utah State University
(Authors: K. Christensen, B. Lane)

River ecosystems are controlled in part by natural variation in the flow regime. Streamflow alterations that impair these natural variations often have negative impacts for aquatic species. Unimpaired flow metrics can inform environmental water management goals to maintain and restore river ecosystems by restoring critical aspects of the natural flow regime, but unimpaired daily streamflow data is not always readily available. Statistical time series scaling approaches present an opportunity to estimate unimpaired flow metrics at ungauged locations to better address environmental water management objectives. This study evaluates a suite of scaling approaches for their ability to estimate ecologically significant daily unimpaired flows metrics. Scaling methods such as the drainage area ratio and standardization by means were compared with scaling methods using recently developed dimensionless reference hydrographs and modeled monthly flows. Performance of alternative scaling approaches was evaluated based on their ability to predict flow metrics derived from the model unimpaired daily streamflow time series across hydrologic settings and climate conditions. Results in an application to the State of California demonstrate the utility of hydrologic stratification to improve statistical scaling methods and indicate that different scaling approaches are better suited to estimate different daily flow metrics. Aggregated dimensionless reference hydographs accounted for spatial and inter-annual variability better than a single index gauge for improved representation across large regions. This is the first known example of combining readily available stream classifications and stream class stratified reference hydrographs to refine scaling relationships and better capture timing patterns across a large heterogeneous region. This study can inform a future selection process to choose the best scaling approaches for a given study region based on he specific flow metrics of interest, hydrologic settings present, and reference gauge density and distribution. Better prediction of unimpaired daily flow metrics will lead to more accurate streamflow regime characterization and better flow management decisions.

Brandywine and the Piedmont: Restoration and Revival of America's Most Historic Small Watershed

Jerry Kauffman, University of Delaware

The Brandywine River falls a thousand feet from the Appalachian Piedmont in Pennsylvania downstream past William Penn's 1682 arc boundary to tidewater to provide the sole source of drinking water for Wilmington, the largest city in Delaware. In the centuries since the 1777 Battle of the Brandywine (the largest battle of the American Revolution), the 1802 founding of the DuPont gun powder mills along a river with a higher fall than Niagara, and the 20th Century American art of the Wyeths, the Brandywine has suffered from industrial pollution from chemical plants and agricultural runoff from the 2nd most valuable farm county in the Keystone State. But in the decades since the Clean Water Act Amendments of the 1970s, the Brandywine has been on a rebound with improvements in the fishable dissolved oxygen standard and the swimmable bacteria standard that has brought kayakers and the anadromous American shad and striped bass back to the State that was formerly known for the three "C's: chemicals, corporations, and chickens. This is the story of the restoration and revival of Brandywine River in what National Geographic has called America's most historic small watershed.

Session 6, Panel Discussion: Informing the Future of Water Resources Programing Through Integration of the Social and Natural Sciences and Enhanced Trans-Organizational Collaboration

The USGS Water Resources Research Act Program: Integrating University and Federal Research, Outreach, and Education

Earl A. Greene, USGS Water Resources Research Act Program

Meeting imperatives for our nation's water resources requires the adoption of the best-available science coupled with the effective transfer of technology to water users and managers at multiple scales. Accurate assessment and monitoring of water resources is critical for day to day management but also increasingly needed to predict and address extreme hydrologic events, such as floods or extended drought. The United States Geological Survey (USGS) Water Resources Research Act Program (WRRAP) is a unique federal-state partnership composed of a legislatively authorized national network of 54 institutes or centers embedded at our nation's universities. Fifty-four WRRAP institutes provide water-related services in the 50 states as well as the District of Columbia, Puerto Rico, the U.S. Virgin Islands, and Guam. Collectively, the institutes are organized as the National Institutes for Water Resources (NIWR). The program's university-based institutes and centers bring to bear the capacity of our nation's higher-education enterprise on water-related issues. The structure of WRRAP promotes institute flexibility and agility in addressing emerging water resources issues adaptable to local cultures, institutions of governance, and regional socio-economic and physical conditions. This structure facilitates key programmatic features: stakeholder-driven science (research); outreach and engagement; and workforce development and water literacy through education and training of students and scientists. The WRRAP communicates research results and facilitates technology transfer among and between federal agencies, localities, states, the public, and other users of water-related technology and information. This engagement is achieved through traditional outreach and extension models as well as newer models, such as the co-production approach. In fulfilling its mandates, the WRRAP has trained or supported over 10,500 students and funded thousands of research projects addressing water resources; connected our nation's university enterprise to the USGS Mission and vice versa; and, amplified federal funding dollars through non-federal matching funds toward sustainable, safe, and secure water resources.

The NOAA National Sea Grant College Program and USGS Water Resources Research Act Program - A Natural Partnership

Darren T. Lerner, University of Hawaii Water Resources Research Center
(Authors: D.T. Lerner, M.J. Donohue, E.A. Greene, K. Bareford)

Enhanced collaboration among organizations with water-related missions has the potential to increase society's ability to manage freshwater resources as well as react to water-related concerns such as drought, pollution, and water access and security. Inter-organizational connectivity can also serve to integrate the social and natural sciences while establishing a nexus among government, academia, industry, and community; providing synergistic pathways toward seeding water-related solutions innovation. Two organizations founded on a federal-state partnership model, with programs or institutes embedded and administered at our nation's universities, exemplify these opportunities. The United States (U.S.) National Oceanic and Atmospheric Administration (NOAA) National Sea Grant College Program and U.S. Geological Survey Water Resources Research Act Program (WRRAP) have complimentary legislative mandates, similar organizational structures, and conduct applied research, education, and extension. In 2015, we initiated exploration of options and mechanisms with which to develop partnerships at state, regional, and national levels between Sea Grant and WRRAP. Efforts included regional engagement of state directors of both programs, as well as their respective federal leaders, to share programmatic foci and "best practices," as well as identify synergies. Regional meetings have been conducted in the Pacific, Gulf of Mexico, Great Lakes, and Mid-Atlantic regions, with additional meetings planned for the Northeast and Southeast. These meetings have also stimulated trans-organizational engagement among Sea Grant and WRRAP with the NOAA National Water Center and University of Alabama, Alabama Water Institute as well as the NOAA Water Team. Considerations associated with this nascent partnership have illustrated the value, but also commonplace barriers, to inter-organizational collaboration. Some potential barriers are: entrenched institutional identities and cultures and the complexities of federal and state funding mechanisms. Nonetheless, leveraging capacity among organizations to amplify available resources and increase productivity, while developing innovative solutions to water-related issues, is a judicious and rewarding approach.

Session 6, Panel Discussion: Informing the Future of Water Resources Programing Through Integration of the Social and Natural Sciences and Enhanced Trans-Organizational Collaboration

Bridging the Water Information Gap: The National Water Extension Program

Karen Bareford, NOAA and University of Alabama

Too much water, too little water, or water of poor quality endangers life, property, economies, and ecosystems. These threats to water security arise from numerous factors, including increased water demand from population growth and weather- and water-related impacts of climate variability and change. Unfortunately, threats to water security are intensifying, and risk exposure is difficult to predict. In light of increasing efforts across the federal government, including the U.S. National Oceanic and Atmospheric Administration (NOAA), and greater university enterprise to better address water threats, the NOAA National Weather Service Office of Water Prediction, The National Sea Grant College Program, and the University of Alabama have combined efforts to create a National Water Extension Program (NWEP). The trans-organizational structure of the NWEP establishes and codifies a framework from which collaboration across administrative lines provides water data in comprehensive formats to enhance the capacity of organizations, communities, and citizens. The NWEP is based out of the National Water Center, located on The University of Alabama campus in Tuscaloosa; but is tasked to work nationally to support water-related extension on local, regional, and national scales. The aim of the program is to foster collaboration among the diverse organizations, communities, and stakeholders who require water-related data and tools to support their decision-making processes. Coupling traditional professional extension with innovative modeling and other cutting-edge technologies, the goal of the NWEP is to facilitate the delivery, transfer, and interpretation of information and technology resources to users. The technological advances currently under development will enable access to greater amounts of data, in a variety of formats, that will inform more accurate and efficient vital short- and long-term decisions. Providing such tools will allow individuals, governmental entities, emergency response personnel, resource managers, and businesses to plan for and protect citizens, water resources, property, and the long-term sustainability of public health and the economy.

A Trans-Disciplinary Faculty Cluster Hire in Energy and Water Sustainability: Developing Actionable Scholarship via Collaboration and Diversity

Mary J. Donohue, University of Hawaii Water Resources Research Center
(Authors: M.J. Donohue, D.T. Lerner)

The management of water resources to achieve desirable outcomes for municipalities, industry, indigenous cultural practices, natural systems and wildlife, recreation, and other uses is complex and spans multiple disciplines. Traditionally, university-level scholarship in water-related disciplines has been conducted in "silos," resulting in large part from the formal school, departmental, and unit structures of academia, both physical and cultural. Integration of research across disciplines is increasingly recognized as advantageous as evidenced in part by funding opportunities that mandate inter-, multi-, or trans-disciplinary approaches. The functional integration of the results of such scholarship and associated development of actionable management practices is less common. To address the above, a cluster hire was established in 2013 at the University of Hawaiʻi at Manoa with a focus on energy and water sustainability. Seven tenure-track faculty representing six disciplines and five colleges were hired. Disciplines included microbiology, economics, architecture, engineering, urban and regional planning, and natural resource management. Common to each faculty member was a joint appointment in their respective locus of tenure (e.g. engineering) at 75% and a 25% appointment in the University of Hawaiʻi Sea Grant College Program. Sea Grant is the cluster's nexus and codifies the research to outreach and technology transfer ethos of Sea Grant within the cohort. Further enriching the cluster is the diversity of faculty recruited including five women, three of which are of native Hawaiian ancestry. The faculty cluster has proven successful in integrating and applying scholarship via trans-disciplinary grants, research, and student mentoring and training. Further, the joint appointments with Sea Grant and associated professional outreach opportunities have been embraced by the cluster and resulted in meaningful connections with community, including native Hawaiian communities. The success of this non-traditional hiring model is also evidenced by the achievement to date of tenure by two of the seven faculty, with an additional three faculty expected to be awarded tenure in 2019.

Agricultural Water Management Decisions in Ungauged Semi-arid Watersheds: Value of Remote Sensing Integrated Hydrologic Modeling

Manashi Paul, University of Maryland, College Park
(Authors: M. Paul, M. Negahban-Azar)

Intensified climate variability, depleting groundwater and escalating water demand creates severe stress on high-quality water sources used for agricultural irrigation. The water scarcity exacts a necessity to evaluate various water conservation techniques and explore non-traditional water sources to save freshwater and sustain food production. However, before the implementation of agricultural management practices, it is necessary to evaluate the ecological and economical effects on the watershed scale using agro-hydrological model. It becomes more challenging to calibrate and validate the hydrological model and simulate accurate hydrologic information for poorly gauged or ungauged watershed. The objective of this study was to provide a complete assessment of the agriculture water budget using a hydrological model Soil and Water Assessment Tool (SWAT) with the application of remotely sensed leaf area index (LAI) for a large complex watershed. An agricultural dominant (37.4%) San Joaquin watershed in the Center Valley of California was selected where major croplands are almond (10.35%), vineyard (8.2%), alfalfa (4.2%), winter wheat (2.6%), tomatoes (2.4%) and cotton (2.3%). Deficit irrigation (DI), conveyance improvement (CI), precise irrigation (PI), wastewater reuse (WWR), and their combinations were evaluated as different scenarios. The potential non-traditional water source scenario was developed through recycled water from wastewater treatment plant as a valuable alternative for emergency agricultural water (e.g., drought season) and to reduce irrigation water extraction. For each scenario, crop water use and environmental flow (ex. surface runoff and groundwater) were estimated for the cash crop like almond and vineyard. The primary results showed that, in the almond dominated subbasin, WWR scenario could reduce 14.2% of irrigated water use where PI, DI and CI scenarios can reduce 2.4%, 13.8%, and 3.7% respectively compared to the baseline. The outcomes from this study will provide information for agricultural water resource management and facilitate future studies focusing on developing a decision-making tool.

Impacts of Variable Irrigation Regimes on Cotton Yield and Fiber Quality

Saleh Taghvaeian, Oklahoma State University
(Authors: J. Stivers, R. Boman)

Irrigation water used by the agricultural sector accounts for 70-90% of the total global water use and produces almost 50% of the crop production value. Recent climatic extremes and rapid growth in food and water demands have placed pressure on the agricultural community across the globe to improve the management of their water resources. Throughout the southern USA, upland cotton is a major crop. Meeting the economic demand in this area while dealing with variable climate and water scarcity issues requires the optimization of irrigation management and a better understanding of cotton responses to variable irrigation rates. In this study, the crop yield and fiber quality effects upon cotton under variable irrigation application rates of no irrigation (NI), reduced irrigation (RI), and full irrigation (FI) were evaluated for a site in central Oklahoma during three years. The lint and seed yields were both found to increase with irrigation application rates. However, the fiber quality parameters showed no response to the variable irrigation. The relationships between yield (seed and lint) and applied water (irrigation + precipitation) were not significant. On the other hand, positive and statistically significant linear relationships were found between yield components and crop evapotranspiration, with coefficients of determinations of 0.63 and 0.69 for lint and seed yields, respectively. No significant relationships were determined for fiber quality parameters versus applied water or crop evapotranspiration.

Scarcity Amidst Plenty: Can Farm-level Profitable Water Conservation Practices Reverse the Decline of the Mississippi River Alluvial Aquifer in the Delta?

Nicolas Quintana Ashwell, Mississippi State University, Delta Research and Extension Center

Annual rainfall is high in the Mississippi Delta (1325-1340 mm per year) but low during crop production months. Irrigation is used to deliver the water required to achieve crops' fully-watered yields. Despite abundant (seemingly available) surface water, the Misssissippi river, groundwater is the main source of for irrigation. Data from the U.S. Geological Survey (USGS) indicate that decline in the Mississippi River Valley alluvial aquifer (MRVA) is noticeable in parts of the Delta. The estimated decline exceeds 300,000 acre-feet annually—an unsustainable rate. Flood irrigation is the prevalent choice of farmers in the region. The traditional style of managing this irrigation system is associated with high levels of water over-application that translates into low levels of water use efficiency. Field experiments at Mississippi State University's Delta Research and Extension Center (DREC) indicate that the adoption of water conservation practices results in significant reductions in the amounts of water applied without negative incidence on yields. Furthermore, practices such as Computerized Hole Selection (CHS), soil moisture sensors, surge valves, and identification of better irrigation-event triggering parameters; result in significant cost savings at the field level; i.e., profitable water conservation. However, the increases in water use efficiency resulting from adopting the prescribed conservation practices result in reductions in runoffs and (possibly) return flows to the aquifer. If return flows are significant or if runoffs are re-used in the system, conserving water on the field may not reduce the rate of decline of the aquifer. Furthermore, if the conservation practices make irrigation more profitable, it may increase the irrigated acreage at rates that may result in faster aquifer depletion. This research project employs data from DREC, the Yazoo Mississippi Delta Joint Water Management District (YMD), and USGS; to assess the potential to profitably slow-down the rate of decline of the MRVA in the Delta.

Conservation Management Practices in Mid-southern, USA Corn Production

Dave Spencer, Mississippi State University
(Authors: D. Spencer, J. Krutz, M. Locke, C. Bryant)

The Mississippi River Valley Alluvial Aquifer has the third highest rate of withdrawal of any aquifer in the United States with 98% of withdrawals used for agricultural irrigation in the Mid-Southern, USA. Low irrigation efficiencies have contributed to the decline of the MRVAA's water levels, demonstrating that current irrigation practices are not sustainable. This study investigates whether cover crops may be incorporated into agricultural production systems to reduce water use and improve infiltration. Studies were established in Stoneville, MS in 2017 and 2018 to determine the effects of four cover crops on irrigation application efficiency, runoff, and off-site nutrient and sediment transport under furrow irrigation and simulated rainfall. Experimental design is a randomized complete block with four replications. Treatments include a reduced till/no cover (as a control), reduced tillage with cereal rye (*Secale cereal* L.), reduced tillage with Austrian winter pea (*Pisum sativum* L.), reduced tillage with tillage radish (*Raphanus sativus* L.), reduced tillage with crimson clover (*Trifolium incarnatum* L.), and no till/no cover. Under furrow irrigation, runoff volume decreased from 2017 to 2018 by 24.8 and 12.3% in the no till/no cover and tillage radish treatments, respectively. Additional results, including infiltration under rainfall simulation and nutrient and sediment transport for both simulated rainfall and furrow irrigation, will be presented as well.

Increasing Mid-southern USA Furrow-Irrigation Application Efficiency through Conservation Production Systems

Corey Bryant, Mississippi State University
(Authors: C. Bryant, L.J. Krutz, M.A. Locke, B.R. Golden, D.B. Reynolds, T. Irby)

In Mid-Southern USA soybean (*Glycine max* L.) production supplemental irrigation is necessary to ensure consistent yields and profitability during periods of drought. Furrow-irrigation accounts for approximately 80% of regional irrigation systems; yet it is one of the most inefficient methods of delivering irrigations to a field. As many environmental limitations prevent the implementation of high efficiency irrigation systems adaptations to current irrigation practices must be found to increase irrigation application efficiency. This study sought to quantify the effects of conservation tillage and cover crops on furrow advance time, runoff volume, infiltration volume, irrigation water use efficiency and irrigation application efficiency in Mid-Southern USA furrow-irrigation systems. Seven treatments arranged in a randomized complete block (n=3) included conventional tillage/winter fallow (CT/WF), reduced tillage/winter fallow (RT/WF), reduced tillage with sub-soiling (RT/SS), reduced tillage/cereal rye (*Secale cereale* L.) cover crop (RT/RC), reduced tillage/tillage radish (*Raphanus sativus* L.) cover crop (RT/TR), zone tillage/winter fallow (ZT/WF), and zone tillage/tillage radish cover crop (ZT/TR). Experimental units were hydrologically separated and instrumented to mass balance irrigation water. Zone tillage systems increased furrow advance time 67% compared to CT/WF ($P < 0.0001$). Runoff and infiltration volumes were 62% greater and 43% less, respectively, in CT/WF and RT/WF compared to all other conservation practices ($P < 0.0001$). However, irrigation water use efficiency was reduced by at least 8% compared to RT/SS ($P = 0.0453$). Overall, irrigation application efficiency was reduced by 43% in CT/WF and RT/WF systems ($P < 0.0001$).

Three Rivers QUEST – Ohio Basin Monitoring

Melissa O'Neal, West Virginia Water Research Institute

The West Virginia Water Research Institute (WVWRI), a program of the National Research Center for Coal and Energy at West Virginia University, has been actively researching water-related issues since 1967. USGS 104b seed funding received in 2009 by the West Virginia Water Research Institute (WVWRI) provided the launch for water quality monitoring and management in the Monongahela River. By 2012, This successful program expanded to become 3 Rivers QUEST (3RQ), a partnership including Duquesne University and Wheeling Jesuit University to monitor the Allegheny and upper Ohio Rivers. A sampling network of 54 sampling stations was established including the mainstems of the three rivers and their major tributaries. To date, over 5,700 (1,618 Allegheny; 1,252 Ohio; 2,920 Monongahela) samples have been collected and analyzed. This data set has already been used by Industry, USEPA Region 3, Pennsylvania and West Virginia to develop a discharge management program for coal mines that resulted in a Clean Water Act sec. 303 delisting of the upper Monongahela River for TDS and sulfate. Various watershed groups contribute data to 3RQs WATERS database as well as participate in Roundtable meetings. The upper Ohio River basin has been heavily developed for both coal, power and shale gas production with implications for public health due to increasing halogen (Cl, Br) inputs to municipal source waters. Understanding more about the quality of our surface waters as they relate to the intakes of our municipal water treatment plants directly benefits public health. 3RQ Targeted studies have been conducted upon citizen requests to look at radiologicals at mine discharges and total trihalomethane in schools. REACH Roundtables provide an opportunity for groups to share information and collaborate on projects.

Effect of Surface Coal Mine Reforestation on Soil Water Chemistry

Amir Hass, West Virginia State University
(Authors: A. Hass, J.G. Skousen, R. Cantrell)

Proper reclamation of surface coal mining sites is essential for adequate restoration of ecosystem services, such as clean water. In this study we present results of soil water chemistry in reforested experimental site in southern West Virginia. The effect of Forestry Reclamation Approach practices (FRA), namely the use of oxidized vs reduced sandstone spoils as topsoil replacement material, and loose vs compacted placement thereof are evaluated 12 years after reclamation. Two large FRA experimental plots (ca. 2.8 hectare each) were established in 2005 using brown sandstone or gray sandstone spoils as topsoil replacement material. Each plot was further split into two subplots where the material was compacted or loosely placed. Shallow wells and zero-tension pan lysimeters (at 30 to 80 cm deep) were installed near three random locations within each treatment plot (spoil type x placement practice) during early spring of 2017. Water samples were collected weekly during 2017 and 2018 growing seasons and analyzed for elemental and ionic composition, total alkalinity, and total and organic and inorganic carbon. Dissolve oxygen, pH, temperature, and redox potential were measured in-situ using multi-parameter probe (Xylem Inc.). Episodes of high total dissolved solids, in excess of regulatory thresholds (300-500 µS cm^{-1}), were coupled with high alkalinity, circumneutral pH, and low redox potential. Redox-, rather than acid-promote dissolution appear to govern soil water chemistry in these sites. Results of the two-year study are discussed and water composition is compared to on-site surface runoff water, and to soil water in adjacent, non-disturbed native forest.

Exceedence of Maximum Contaminant Level Drinking Water Standards in Grand Canyon Springs and Implications for Future Monitoring

David Kreamer, University of Nevada, Las Vegas

Historical information from 1950 to 2017 on Grand Canyon spring water quality and quantity was examined to determine the number of times the U.S. Environmental Protection Agency's Maximum Contaminant Levels (MCLs) for drinking water standards were exceeded, and the factors that might influence water quality in the springs. MCLs are the legal threshold limit on the amount of a substance permissible in public water systems under the Safe Drinking Water Act. MCLs were exceeded at least 136 times in Grand Canyon springs over the 67 years evaluated, with arsenic concentrations exceeding the MCLs most frequently (78 times). MCL concentrations were also exceeded for beryllium, uranium, cadmium, lead and mercury. Locations for the highest concentrations of these elements included Pumpkin Spring, Monument Spring, Horn Spring, Big Spring and Milkweed Spring. Many of the exceedences were recorded from springs issuing from the Redwall-Muav aquifer stratigraphic region. Some isotopic analyses suggest anthropogenic influence on water quality. The highest historical arsenic concentration was reported as 350 times the MCL, the highest beryllium concentration was 32 times the standard, uranium over 13 times higher, cadmium over 3 times exceeding the drinking water level, lead over twice the level, and mercury 1.9 times the MCL. The more stringent Maximum Contaminant Level Goals (MCLGs) for drinking water quality, which are the levels for drinking water which are associated with no or minimal risk, were exceeded regularly in spring water samples. Examining the data further, many of the exact locations of sampling for each spring were not consistent through the years, nor were meteorological and hydrological conditions before and during sampling. These spatial and temporal inconsistencies in sampling, along with large data gaps, make trend and correlation analysis difficult.

Three Rivers QUEST (3RQ) REACH 4Schools STREAMing

Melissa O'Neal, West Virginia Water Research Institute

The West Virginia Water Research Institute (WVWRI), a program of the National Research Center for Coal and Energy at West Virginia University, has been actively researching water-related issues since 1967. When municipal water authorities were puzzled by the sudden increase of total dissolved solids (TDS) in late 2008, it was in the interest of WVWRI to find out what might be causing the changes in the water chemistry of the Monongahela River. While numerous programs existed that monitored water quality, the data collected was either too sporadic or the studies did not include TDS. In response to the need for TDS data, routine monitoring on the mainstem of the Monongahela and mouths of major tributaries began in 2009 with funding through USGS and WVWRI. In 2011, thanks to funding by the Colcom Foundation, the Three Rivers QUEST (3RQ) program was initiated by partnering with Duquesne University, Wheeling Jesuit University and the Iron Furnace Chapter of Trout Unlimited. Geographically, the 3RQ Partners monitor mainstem and mouths of major tributaries along the Allegheny, Monongahela and Ohio Rivers. In addition to routine monitoring monthly at 42 stations, 3RQ Partners have utilized Targeted Study funds to investigate community water quality concerns over such things as radiologicals in mine discharge and total trihalomethane in schools. The REACH component of the program engages local watershed groups with data management and roundtable events. REACH 4Schools (R4S) program launched in mid-2017 with a grant from the Pennsylvania Department of Environmental Protection Environmental Education Grants Program. R4S is an educational framework that engages students in monitoring water quality within the Allegheny, Monongahela, and upper Ohio River Basins. Middle and high school students who participate in the project become involved by collecting data, either continuous by deploying data loggers, and/or discrete by obtaining physical samples for chemical analysis. Students learned the importance of quality assurance/quality control, chain-of-custody, collecting grab samples for lab analysis, and how to utilize HACH kits for stream-side chemical analysis. R4S students are engaged in many topics, such as general water quality, water chemistry, and chemistry as it relates to biology, aquatic biology, water sampling, environmental principles, ecology, data analysis, data entry, and database management. Students entered data into 3RQs WATERS database. Resultant data is displayed to the public via 3RQ data map. R4S STREAMing (Science Technology RIVERS Engineering Art and Math) contest funded by EQT engaged students in building a Weebly website, creating YouTube videos and developing content for booklets to be distributed throughout their communities. Conveying the importance of water quality data to the public through varied content. Students also provided presentations at symposiums.

Session 9, Panel Discussion: Sustainable Water Resources for Irrigated Agriculture

Panel organizers:
John Tracy, Texas A&M AgriLife Research - TWRI
Bill Hargrove, University of Texas at El Paso
Zhuping Sheng, Texas AgriLife Research

Panelists include:
Bill Hargrove, University of Texas at El Paso
Ali Mirchi, Oklahoma State University
Alex Mayer, Michigan Tech University
Zhuping Sheng, Texas AgriLife Research

The following abstracts were submitted to this session:

Evaluating Water Scarcity under Climate Change with a Basin Scale Model

Alex Mayer, Michigan Tech University
(Authors: A. Mayer, D. Gutzler, D. Pennington, F. Ward)

The semi-arid Middle Rio Grande basin, extending from Elephant Butte reservoir, New Mexico, to the confluence with the Rio Conchos along the Texas-Chihuahua border, regularly experiences water scarcity, as evidenced by falling groundwater levels and unreliable surface water supplies. Our team has developed complementary water balance and hydro-economic optimization models to investigate potential solutions for managing water supplies and demands under uncertain, but potentially daunting, climatic and water demand conditions. The basic hydrologic elements of the models include aquifers, surface water reservoirs, and the Rio Grande. Major water users represented in the models include urban centers, with total population exceeding two million, and several irrigation districts in three states and two countries. The models were calibrated based on historical observations of surface water storage and flow. Future water use is determined in the water balance model by projecting historical water use patterns into the future. The hydro-economic model determines water use, based on maximizing the net present value of water summed over time and water-using sectors. Future climate scenarios were used as input to the models to assess impacts on water availability and economic outcomes under various shortages and adaptation measures. Future climatologies were formulated by obtaining US Bureau of Reclamation (USBoR) projections of inflows to Elephant Butte reservoir and adjusting the inflows based on historical patterns of upstream water use. The USBoR inflow projections are bias-adjusted versions of the CMIP5 set of more than 80 climate model projections for the region. Results imply that surface water supply variability (and unreliability) will continue to increase, putting greater pressure on groundwater supplies. Imposition of groundwater extraction limits results in greater short-term economic losses to agricultural users, relative to no-limit extraction conditions, because urban suppliers have more flexibility in water source options. We will describe key simplifications and assumptions in the models.

Evaluating Salinity and Other Water Quality Concerns with SWAT

Zhuping Sheng, Texas AgriLife Research
(Authors: E. Ayana, Z. Sheng, R. Srinivasan, A. Mirchi, S. Ahn)

Much of the Rio Grande water is known to be allocated for agricultural, municipal and industrial water supplies which has apparently affected the salt balance. Fresh water delivered from the Elephant Butte Reservoir during the irrigation season has a TDS of 550 mg L^{-1} on average, while the highest salinity of the Rio Grande occurs in the section from Fort Quitman to Presidio (3,200 mg L^{-1} on average). Elevated salinity in water not only limits the variety of crops, but also salt accumulation in agricultural fields, which in turn impacts crop yield. A SWAT hydrologic model has been developed to supplement the agronomic and economic analysis for water portfolio diversification and increasing agriculture viability in the basin. We are investigating how alternative water use can extend basin freshwater availability; crops and cultivars suitable for alternative water sources; and salinity loads. This includes manipulations of cropping systems, irrigation systems, salinity management and timing of cropping. We are exploring a statistical approach to examine if any relationship exists between observed salinity and stream flow. The existence of such a relationship can potentially be used to estimate salinity levels for different future scenarios and thereby estimate crop yields as well. This presentation will focus on the findings of the statistical analysis of salinity and flow observations along the reach of the Rio Grande between El Paso and Presidio. The other approach using a salinity chemistry and transport module for SWAT being developed by Colorado State University will also be discussed. The findings are expected to provide guidelines for water resources and salinity management under changing climate.

Session 10, CUAHSI Water Data Services Workshop

Facilitated by CUAHSI and led by Christina Bandaragoda. This workshop continues into Session 15. Participants attended both sessions.

About the workshop:
CUAHSI's Water Data Services are free, open-access, and available to everyone. Learn how these services can help you and your team:

- Develop data management plans, which are now required by most funders.
- Discover and find a broad array of water data-time series, samples, spatial coverages, and more.
- Use CUAHSI apps and tools for expediting and documenting workflows.
- Share your data within a group and publish your data with a DOI.

Session 11, Tips and Tools for Effective Visualization, Design, and Communication of Your Research

Facilitators:
Nicole Wilkinson McIntosh, NC Water Resources Research Institute;
Walt Gurley, Data & Visualization Librarian at NC State University

Designed for students, faculty, and professionals, this workshop emphasizes effective visualization, design, and communication of your research. We will focus on poster and oral presentations for conferences, as well as overall principles for narrowing the focus of your communication, conveying key points to diverse audiences, the role of narrative in your communication, as well as fundamental design principles for visual media (posters, print, and PowerPoint presentations) that have a significant impact on how your material is received by viewers. The session will consist of presentations, group exercises, and constructive critiques of content to reinforce design principles and before and after examples of presentation materials.

Stochastic Analysis of Cover Crops and Conservation Tillage Practices in Louisiana Soybean Production under Risk

Naveen Adusumilli, LSU AgCenter
(Authors: N.Adusumilli, S. Dodla, H. Wang, M. Deliberto)

Stochastic efficiency with respect to a function (SERF) is used to rank conservation practices and place an upper and lower bound on their value. Production data and yield of soybeans over three years are collected from demonstration plots. The data are used to build cumulative distribution functions of returns for cover crop practices, single and mixtures, combined with conservation tillage practices. The methodology examines the most-risk efficient suite of practices in terms of maximizing economic profitability across a range of risk-aversion preferences. Analysis of Louisiana data indicated that for the continuous non-irrigated soybean cropping system, no-till combined with the cover crop is equally preferred to conventional till with cover crops at higher levels of risk aversion. However, at lower levels of risk aversion, conventional till with hairy vetch was the most preferred system. The analysis provides a methodology to compare multiple conservation practices simultaneously with consideration to risk, providing an assessment of the value of conservation in their production region.

A Dry-Year Option for Irrigation in the Texas Lower Rio Grande Valley

Ron Lacewell, Texas A&M AgriLife
(Authors: N. Sinha, R. Lacewell, L. Ribera)

The Lower Rio Grande Valley is increasingly subjected to erratic water deliveries plus the water is shared with Mexico. To address assurance of water for urban communities, an analysis of a market solution termed a Dry-Year option was devised whereby irrigation could be withheld in case of an expected water shortage. Urban has first priority for water. But the urban water is delivered on the back of agriculture irrigation water. Therefore, in case agriculture irrigation water is not available, there is no water to get urban water to the cities (this agriculture water is called push water). To address this, a system was devised similar to one in place for the Edwards Aquifer, call a Dry-Year Option. This is a multi-year agreement between a city and agriculture, say five year contract. Agriculture is offered a contract and it includes an annual payment (option) regardless of whether the water is needed or not. But in the case of an expected shortfall then the option can be called in which case the farmer will not use the agreed amount of water and be paid for not irrigating. That water then is available as “push water” to get the urban supply to the discharge points of the city. The timing of notification of calling the option to not irrigate is sufficiently early so that crops can be planted to be produced rainfed or dryland. The payment schedule is designed to make the farmer slightly better off than if they irrigated in those cases where the option is called. For this exercise the option value was set at $50 per acre foot and then if the option is called an additional $150 per acre foot is paid. The system is successful for the Edward Aquifer Authority but much more challenging for South Texas.

Crop Diversification and Critical Stage Based Irrigation to Sustain the Ogallala Aquifer

Sangu Angadi, New Mexico State University
(Authors: S. Angadi, S. Begna, S. Singh, K. Katuwal, P. Singh, J. Singh)

Declining Ogallala aquifer is threatening irrigated agriculture and rural economy in the Southern Great Plain. Diversifying well adopted, low water using, stress tolerant, low input alternative crops can help in reducing irrigation water use. Further, understanding water use by these alternative crops during different growth stages under different water availabilities will assist in relating water use to seed yield formation in these diverse crops. That information can help manage alternative crops with less water. Diverse crops like winter and spring canola, safflower and guar were evaluated in different years at Agricultural Science Center at Clovis, New Mexico State University. Irrigation treatments included pre-season irrigation to rewet the profile, while in season irrigation treatments included irrigation during all growth stages, no irrigation during vegetative growth stage, no irrigation during reproductive growth stage and no irrigation after establishment. Crops responded differently to stress during reproductive stage. Seed yield of more stress tolerant crops like safflower and guar were less affected by skipping irrigation during reproductive stage compared to vegetative stage, in contrast winter and spring canola yields were more affected by skipping irrigation at reproductive stage. Root system and drought physiology of crops seems to affect these responses. Results from all trials will be summarized to assess crop diversification benefit to sustainability of Ogallala Aquifer.

Evaluation of Agricultural Best Management Practices on Groundwater Recharge

Glenn O'Neil, Institute of Water Research - Michigan State University
(Author: J. Asher)

Groundwater is a critical hydrologic resource in Michigan. Over 250 million gallons are withdrawn every day for use in agriculture and industry. It provides drinking water to 45% of the state's residents and helps regulate water temperature in sensitive stream habitats. Numerous studies have evaluated the impact of agricultural best management practices (BMPs) on surface water quality, but few have specifically explored how such practices affect the volume of water infiltrating the soil and recharging aquifers. This project is utilizing the Soil and Water Assessment Tool (SWAT) to evaluate how effective certain agricultural BMPs are at reducing runoff and facilitating groundwater recharge. The project's study area is the Maple River watershed of in central Michigan, a region heavily dependent on agriculture. The authors are building a SWAT model of the watershed and will calibrate it to baseflow conditions at stream gauges to zero in on the signal from groundwater recharge in the hydrograph. The authors will then run the calibrated model through a suite of scenarios simulating various BMPs, including conservation tillage, cover crops, conservation crop rotations, filter strips, drainage water management, and pasture, among others. The geographic scope of the BMP adoption in these scenarios will cover the entire watershed so that the spatial variability of the practices' impacts can be analyzed. The authors anticipate that conservation tillage, drainage water management, and pasture practices will facilitate greater recharge than cover crop or filter strips.

Testing Pivot Irrigation Innovations on Utah Farms

Matt Yost, Utah State University

Potential solutions for conserving water in agriculture include improving irrigation efficiency. The potential of two advanced irrigation systems, low energy precision application (LEPA) and precision mobile drip irrigation (MDI), are being evaluated to assess how they might improve irrigation uniformity and efficiency and conserve water at three alfalfa fields and one corn field in Utah in 2018 and 2019. Yield, crop quality, and crop profits will be measured and combined with comprehensive soil moisture data, to assess the viability of these advanced irrigation systems.

The Role of Data Standardization in Support of Water Governance: An Ongoing Data Integration Experiment in the Western U.S.

Sara Larsen, Western States Water Council
(Authors: S. Larsen, A. Abdallah, T. Willardson)

Effective water governance allows participating interests to put forward their economic, political, ecological, and social objectives to arrive at joint resolutions to common concerns. A significant part of developing communication channels between governance parties is the discovery of terms and concepts that have been adopted over time by those contributing to the conversation. The creation of a shared understanding and a community vocabulary can be a lengthy endeavor but is an important step for productive conversation. Aside from supporting institutional missions, operations, and research questions, data have a functional role in support of effective water governance. Having ample, clear, documented data of good quality facilitates effective water governance conversations. Conversely, lack of abundant, clear supporting data is a barrier to effective governance, especially if there are issues of trust, accountability, and/or transparency between the parties. Similar to the discovery of conversational terms, heterogeneous datasets provided for review by the group would likely have greater value for discussion if they utilized standard terms, semantic meanings, spatial and temporal scales, data provenance, methodologies, traceability, etc. The Western States Water Council (WSWC) is one such water governance body - a collaborative forum for its western state agency members to articulate concerns and share solutions to common water resource management issues. Over decades of discussion, an appreciation for the unique administrative approaches and terms used by contributing members has allowed for a common vocabulary, but very little has been done to develop a corresponding standardization of the unique datasets generated by western water agencies (e.g., water rights, permits, water planning/projections, withdrawals, consumptive use, water pricing, water rates, and regulatory/institutional constraints at play in specific locations). WSWC's initiation of the Water Data Exchange (WaDE) has allowed for the discovery of datasets that are most commonly generated by its members, and their individual vocabularies. It has also allowed for the development of a standardized, machine-readable format for the most commonly generated datasets that don't readily fit into existing water data standards. In this talk, WSWC will discuss the importance of data standardization and integration, and how it can effectively support governance. Likewise, governance bodies can foster and utilize data standardization efforts to achieve better collaboration.

Effects of Point and Non-point Sources on Water Quality Short-term Assessment at the Kanawha River, West Virginia

Fernando Rojano, West Virginia State University
(Authors: F. Rojano, D.H. Huber, I.R. Ugwuanyi, V.L. Noundou, A.L. Kemajou)

Field measurements of the variables associated to water quality in a river were investigated in an area stressed by mining, agriculture, urban and industrial activities, which contribute several pollutants to the Kanawha river through point and non-point sources. To determine the status of the water quality along 52 kilometers of the river, four locations were chosen and collected data during the winter period (December, 2017-March, 2018). At each of the four locations one sonde was placed monitoring: temperature, conductivity, oxido-reduction potential, pH, chloride, ammonium, nitrate, dissolved oxygen and turbidity. The collected data served to identify the local impact of storms in the dynamics of each of the variables, as well as the definition of the point and non-point sources. The point sources followed the integration of all the tributaries to the Kanawha river, by being networked through the principles of hydrodynamics. On the other hand, non-point sources were identified through the HSPF program provided by the EPA, integrating information from meteorological stations, impervious and pervious areas, type of vegetation, type of soil, topography and land use. Hydrodynamics and hydrologic approaches were then joined to predict water quality along the river. Additionally, this study includes a discussion about the various factors determining accuracy on the predictions once deduces the contributions of the point and non-point sources with the aim to describe the water quality conditions.

Moving Water Quality Monitoring into the 21st Century: Timely Assessment of Minnesota's 10,000 Lakes Using Satellite Imagery

Jeffery Peterson, University of Minnesota
(Authors: L. Olmanson, B. Page, D. Porter, M. Bauer, P. Brezonik, J. Peterson)

To ensure the health and sustainability of Minnesota's 10,000+ lakes, novel and comprehensive monitoring strategies to complement conventional field sampling are necessary for effective management. For the past 20 years, we have demonstrated the effectiveness of image processing techniques for mapping lake water clarity and colored dissolved organic matter (CDOM) using Landsat satellite imagery. Here, we demonstrate the implementation of our mapping practices into an automated high performance computing (HPC) pipeline with the purpose to seamlessly generate statewide satellite data products for lake water quality monitoring and management purposes. These calibrated water quality maps, including Secchi depth (SD), CDOM, chlorophyll-a, and suspended solids (SS), rely heavily on field validated datasets to account for the dynamics of optically complex lake systems of the region. To this end, sampling efforts in the summer months constrain uncertainties between satellite and surface-water measurements. As new field validation data become available at season-end, scripted modules within the processing chain are modified accordingly and applied to incoming and previously processed imagery to determine whether any resulting water quality product models need modification. The resulting data will be made available to the public in an online lake map viewer linked to a spatial database that will allow for statistical summaries at different delineations and time windows, temporal analysis and animations of water quality variables. This unique data source will dramatically improve data-driven resource management decisions and will help inform agencies about evolving water quality conditions statewide. In terms of decision-making, the production of frequent data on water clarity, chlorophyll-a, CDOM, and SS on lakes across Minnesota will enable water quality and fisheries managers to better understand lake ecosystems. The improved understanding will yield societal benefits by helping managers identify the most effective strategies to protect water quality and improve models for increased fisheries production.

Hydrodynamic and Sediment Transport Modeling of a Large, Shallow Lake in the Semi-arid West

Nicholas von Stackelberg, Utah Department of Environmental Quality
(Authors: N. von Stackelberg, M. Barber, J. Su)

This study investigated the hydrodynamics and sediment transport within Utah Lake, a large, shallow, freshwater lake with a surface area of 380 square kilometers and an average depth of 3.2 meters. The circulation pattern and currents in shallow lakes are strongly influenced by wind speed and direction, and the resuspension of sediments results from both wind-induced currents and wave action on the lake bottom. A 3-dimensional model utilizing the Environmental Fluid Dynamics Code (EFDC) was built to simulate these processes over a 10-year historical time period (Water Year 2006-2015). Aspects of the lake's hydrodynamics that were considered included the water balance, water surface elevation, evapotranspiration, ice cover and hydrologic connection between the bays and the main lake. The ability of various properties of the cohesive sediments to predict sediment deposition and resuspension in the lake was evaluated. The results of the study have implications on water clarity, internal phosphorus cycling, formation of harmful algal blooms (HAB), and future lake restoration efforts.

Using HydroShare for FAIR Data Management: Improving Opportunities for Data Reuse and the Reproducibility of Research Results

Jeffery Horsburgh, Utah State University
(Authors: J. Horsburgh, D.G. Tarboton, A. Castronova, The HydroShare Development Team)

Over the past several years, the scientific community has pushed for better methods, tools and infrastructure to support reuse of scientific data and to better enable the reproducibility of scientific research. This push was motivated by a need to achieve greater transparency in the scientific process and trust in research findings. As a result, a diverse set of stakeholders representing academia, industry, funding agencies, and scholarly publishers came together to develop and endorse a set of principles for making scientific data Findable, Accessible, Interoperable, and Reusable (FAIR). These principles place specific focus on enhancing the ability of computers to find and use the data, but also aim to facilitate data reuse by people. In this presentation, we will describe how the online HydroShare repository and its associated meta(data) models and tools have been designed to support the FAIR principles. HydroShare is a web-based hydrologic information system operated by the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) that was designed to support a collaborative and holistic approach to data management. HydroShare includes a domain-specific data and model repository that supports transparency in the scientific process by enabling researchers to easily share and publish products resulting from their research – not just the scientific publication summarizing a study, but also the data, models, and workflow scripts used to create the scientific publication and reproduce the results therein. HydroShare also includes a Jupyter Hub computational environment that can be used for developing and executing Jupyter Notebooks using the Python or R code languages, enabling students and other researchers to reproduce analyses shared by the original authors. Together, the repository and computational environment serve as a platform for collaboration that integrates data storage, organization, discovery, analysis, and computation, and that allows researchers to employ services beyond their desktop computer in their analyses, while improving their ability to collaborate and reproduce results. We will discuss how HydroShare enables best practices for uploading and describing datasets, for linking datasets with publications that use them, and for promoting data reuse and reproducibility through sharing of data, models, and scripts that encode the scientific workflow. The HydroShare system is available at http://www.hydroshare.org.

Session 14, Human Induced Planetary Change - The Broader View of Climate Change Adaptation and its Implications for Water Resources Management I

Forecasting Streamflow in Every River in the World using Global Climate Models

Dan Ames, Brigham Young University
(Authors: D. Tarboton, J. Nelson, N. Jones)

Welcome to the age of the Water Data Deluge – certainly the most amazing period in human history to be a water resources scientist or environmental engineer! It is a peculiar and amazing time characterized by the creation, on a daily basis, of massive quantities of data and information that dwarf the world's complete water data catalog of only a decade or two earlier. It is a time when an individual scientist with the most basic and inexpensive hardware and software can build a data collection network that can generate a veritable flood of information about the environment. So, what do we do with all of this data? How do we store, retrieve, visualize, document, cite, and make sense of environmental observations that quickly grow from the hundreds of thousands of values to the millions of values? What do we do when these counts escalate into to the billions or trillions of observations? Certainly, a new generation of cyberinfrastructure is needed to help manage and interpret such data. The National Science Foundation has funded a series of projects and programs centered on improved scientific cyberinfrastructure with the goal of creating a large ecosystem of tools and technologies that can help address these problems. This presentation will examine two such projects presently underway at Brigham Young University, including HydroShare: a system for community collaboration and data sharing in the cloud; and Tethys Platform: open source tools for rapid development and deployment of water and environmental web apps.

Adapting to Extreme Hydrologic Events in the Bear River Basin

Connely Baldwin, PacifiCorp

Extreme hydrologic events in the Bear River basin in Utah, Idaho and Wyoming have been occurring more regularly as single-year high flow events punctuating a background of persistent drought. The operational impacts of this type of regime for irrigation users in the basin will be presented. As usual, attribution to human-induced planetary change is difficult and will not be attempted, but the implications for adapting to this type of regime on an ongoing basis are discussed.

Water Management and Policy Innovations in a Changing Climate: Integration of Resource, Hazard, and Stewardship Considerations

Shaleen Jain, University of Maine
(Authors: S. Jain, A. Lausier, M. Beyene, N. Dhakal, N. Abdullah, A. Aljoda)

Water resources management and policy (WRMP) has evolved to achieve a high level of sophistication stemming from developments in systems analysis, stochastic and physical hydrology. Recent recognition of the important role of climate variability and change and climate-induced nonstationarities has illuminated concerns with respect to the adequacy of current WRMP approaches, as well as the need to integrate climate-hydrology-ecology to better realize goals linked to water resources sustainability. In this presentation, I discuss some emerging research questions facing water resources sustainability concerns, and present examples from place-based studies that seek to deliver usable knowledge in support of decision-making and policy. Examples include the changes in seasonality of extreme rainfall and their impacts on coastal communities, legacy contaminant releases from glaciers, adaptive water policy design in a "Apple-converted-space" changing climate, and anticipating climate-induced thresholds in lake-watershed systems. Some ideas to refocus water research and decision-making within a stewardship approach are also discussed.

Session 14, Human Induced Planetary Change - The Broader View of Climate Change Adaptation and its Implications for Water Resources Management I

Water Futures - Planning and Management Considering the Relative Roles of Technological, Social and Climate Change

Upmanu Lall, Columbia University

There has been much interest in Climate Change Adaptation and a lot of interesting research has emerged as to potential water resources impacts and how to manage them. Over the last 5 decades, we have also witnessed significant changes in population demographics (declining as well as rapidly growing cities), social values, and technologies. A very limited consideration of these factors is evident in historical planning and management of water systems, yet these issues are potentially as important as climatic uncertainties, especially if the emphasis shifts from large centralized infrastructure to distributed infrastructure that may be locally or centrally managed (as we see emerging in the renewable energy field). I plan to discuss how one could start approaching the planning and design of such systems considering a framework of sequential decisions that considers actions that need to be taken as a system component "fails" due to a climatic, social or demographic event or change, and different types of uncertainties are resolved in specific ways and to different degrees.

Decision Framework for Infrastructure Sequencing (DFIS): A Holistic Approach for Regional Water Supply Planning

Tirusew Asefa, Tampa Bay Water

Tampa Bay Water has unequivocal obligation to meet the regions water supply need today and in the future. Its six Member Governments (three Cities and three Counties) provide water for a customer base of over 2.5 million people. The agency does this through a delicate balance of environmental needs, cost, and sustainability. Increasingly competitive demands for small percentage of rainfall (5%) that can become supply sources and are susceptible to rise in future temperature, increasing demand for water by both residents and environment led the agency to look at "out of the box" decision support tools in guiding water resource allocation and planning for, when, and how much water the area needs. For example, recently completed multi-year Master Water Plan study looked at a variety of projects including understanding the complex interaction between demand and supply in the region, state-of-the practice demand management approaches targeting both passive and activity efficiency measures that could be implemented as a fraction of the cost of new water supply projects, a residual risk management tool that guides agency's operation during times of rare but extreme drought, and optimization of existing resources. Currently, the agency is embarking on a Decision Framework for Infrastructure Sequencing (DFIS) project that seeks to develop an infrastructure pathway for select MWP projects to balance level of service, sustainability, and financial responsibility using a variety of system metrics. DFIS tries to link short-term operation to long-term planning through development and monitoring of decision triggers to bring new infrastructures "just in time".

Session 15, CUAHSI Water Data Services Workshop, Continued

Facilitated by CUAHSI and led by Christina Bandaragoda. This workshop is a continuation of Session 10. Participants attended both sessions.

About the workshop:
CUAHSI's Water Data Services are free, open-access, and available to everyone. Learn how these services can help you and your team:

- Develop data management plans, which are now required by most funders.
- Discover and find a broad array of water data-time series, samples, spatial coverages, and more.
- Use CUAHSI apps and tools for expediting and documenting workflows.
- Share your data within a group and publish your data with a DOI.

Session 16, Panel Discussion: Stakeholder Engagement in Answering to Water Quality and Quantity Problems

Increasingly biophysical science is being asked to provide best management practices as well as a scientific basis for regulatory actions. A USDA funded project that attempts to address how best to present and conduct biophysical research to obtain stakeholder buy-in will be discussed. The research project is being conducted in five study locations located in three different states and focuses on water quantity and quality issues. Our project is premised on the notion that water quantity and quality issues can be better approached through a process where stakeholders, communities, scientists, and experts collaboratively identify, investigate, and solve water issues. We will provide an overview of the project from the perspective of the biophysical scientists called on to provide research-based data to answer the questions raised by the process.

Panel organizers:
Shad Nelson, Texas A&M University Kingsville
Chittaranjan Ray, Nebraska Water Center
Clinton Williams, USDA-ARS, US Arid-Land Agricultural Research Center

Panelists include:
Shad Nelson, Texas A&M University Kingsville
Chittaranjan Ray, Nebraska Water Center
Clinton Williams, USDA-ARS, US Arid-Land Agricultural Research Center
Daran Rudnick, University of Nebraska - Lincoln

Session 17, Water Resource Development and Environmental Quality in Developing Communities

Technical, Economic, and Social Viability of Low-cost Biochar for Agricultural Stormwater Treatment

Nathan Howell, West Texas A&M University
(Authors: N. Howell, T. Agreda)

As the world increases in population, with the highest growth in the developing world more stress has been put on local environmental resources. Increasing human populations requires a larger food supply and more housing. In addition to meeting basic human needs, locations of increasing populations experience rising expectations for higher standards of living which often comes in the form of more food variety. One great area of stress as a result of all of these trends is agriculture. Pressure exists for agriculture to expand into areas which were lightly used before or were not used at all. Other areas will experience pressure to intensify their cropping systems. While there are ways for agricultural expansion to occur which are more sustainable (e.g., no-till farming, organic fertilizers, integrated pest management), the reality is that many farming practices that can result in larger pollutant mass loads in runoff are likely to continue. These pollutant loads can and will diminish groundwater and surface water quality. While local communities may wish to mitigate these negative effects of runoff, they also feel the economic pressure to increase food and wealth. One large area of interest in developing communities as a solution to many problems is pyrolyzed biomass or biochar. Biochar is a highly recalcitrant "hard carbon" with properties similar in some respects to activated carbon but that can often be made for at a much lower cost and simpler technology. Biochar can be made from virtually any type of local biomass. Crop residue and animal waste is a desirable biomass source for biochar because the production of biochar can solve multiple problems. Biochar creation can produce a product which can remove pollutants from water while at the same converting what would otherwise be a waste into a useful product with real value. In this presentation, we will explore experimental results from some common dyes on developing world biochars. We used dyes that can be surrogates for the removal potential of these biochars for many classes of water pollutants. The biochars themselves are made from six crop residues which are globally very common—rice husk, cotton hulls, wheat straw, pecan shells, peanut shells, and coconut fiber. We developed kinetic rate laws for pollutant uptake on the biochar and also adsorption isotherms. Using this information, we performed some design calculations on biochar quantities, treatment residence times, and placements of biochar-infused stormwater interceptors to predict their treatment effectiveness. We then examined what the economic cost of the interceptors in the developing world. Finally, we used what is known about developing world rural agriculture to provide recommendations on how one might succeed in actually getting communities to adopt these stormwater treatment practices.

Water Resource Development - Lessons Learned from the Kansas Ogallala Aquifer

Bill Golden, Kansas State University
(Authors: B. Golden, B. Guerrero)

Water resources development is generally considered a way to generate economic growth in developing countries. The development of water resources for irrigation, hydro electric power and rural water supplies, often look good on paper and are justified by positive cost-benefit analysis yet result in negative unintended consequences. The Ogallala aquifer underlies about 112 million acres, in parts of eight states, including: Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas and Wyoming. In Kansas, rapid development of the aquifer started in the 1950s and continued thru the 1990s and resulted in the irrigation of approximately 3 million acres – and in some areas, the aquifer being over appropriated by greater than 50%. Kansas is currently doing a great job of monitoring the aquifer and developing innovative conservation schemes. However, as Sophocleous (2009) stated we have learned most of our lessons about natural resource uses and conservation through a process that can be described as "education by disaster". While the Western Kansas economy may get to sustainability it may be sustaining an economy without the Ogallala Aquifer. This presentation reviews some of the lessons learned from the Kansas-Ogallala experience: the need to get all stakeholders involved and review all economic and sociologic impacts prior to development; to adequately determine sustainability requirements; to insure there is local control with state oversight; how to establish monitoring and reporting requirements; and the need to consider future generations.

Session 17, Water Resource Development and Environmental Quality in Developing Communities

Stakeholder Perceptions of the Importance of Groundwater for Sustaining Communities

Bridget Guerrero, West Texas A&M University
(Authors: B. Guerrero, M. Sanderson, S. Lauer, B. Golden, M. Vestal)

The Ogallala Aquifer is the largest freshwater aquifer in the world and is the main source of water for agriculture, which is a main economic driver in the Ogallala Aquifer Region (OAR). The aquifer underlies eight states with varying levels of saturated thickness and recharge levels across the region. The northern part of the region experiences both more rainfall and better recharge while the southern portion of the region is semi-arid with little to no recharge. The development of this water resource greatly increased agricultural productivity and economic activity in the region in the mid to late 1900's. However, rapidly depleting water supplies and adverse climate impacts are likely to reduce crop production in the future, which could cause adverse effects on both agricultural revenue and local communities. The Ogallala Water Coordinated Agriculture Project is a multi-disciplinary collaborative effort funded by USDA-NIFA and is focused on developing and sharing practical, science-supported information relevant to best management practices for optimizing water use across the eight-state region. One objective of this study is to identify the social values and beliefs driving on-farm decisions about natural resource use and adaptive management. A structured survey was used to elicit responses from stakeholders in the region to measure risk perceptions and norms related to the state of the Ogallala Aquifer. A random sample of producers across the states included in the study were identified through a subcontract arrangement with the National Agricultural Statistics Service. The survey was administered in February of 2018 and was sent to 7,712 agricultural producers in 227 counties across six states. The response rate was 15.9% with 1,226 producers responding. Results will be presented and are expected to generate lively discussion. Descriptive results will include stakeholder perceptions on the current state of the aquifer, if conservation needs to occur, why conservation does not or cannot occur, and what producers would change in their operation if they were faced with reduced water availability. These discussion points will be related to the importance of water availability in developing communities and sustaining established communities.

Hydrophilanthropy Gone Wrong: How Well-meaning Scientists Can Make the Situation Worse

David Kreamer, University of Nevada, Las Vegas

Hydrology is a field that naturally and directly lends itself to making the world better, by improving water supply and water quality both to people and ecosystems, and by diminishing global sanitation problems. Many hydrologists therefore have the opportunity, if not the inclination, for philanthropic acts and activities. However, the implementation of positive water and sanitation (WASH) projects in the Economically Developing World on a local level is fraught with obstacles, often brought on by the wide-ranging situational contexts of each project. For example, a survey of 21 African nations (Rural Water Supply Network Work Plan, January 2009-December 2011) reported that 36% of installed well pumps were non-functional. Specific plans for water and sanitary development can make scientific sense, but violate the local village political and social order, not be sustainable, use inappropriate technology, and even negatively impact the original project goals. Conversely, local expectations may not make scientific sense, and blind implementation of WASH schemes can lead to long lasting ill-effects. Even if scientific considerations and local social context are in agreement, the way a project is implemented can evoke community unrest. Many well-intentioned scientists (let's not call them "do-gooders") are limited in the time they can spend assisting an overseas community, therefore alternate future scenarios for the future and sustainability of WASH activities, in their absence, must be considered. Other factors, such as the source and transportation of materials, documentation and data archiving, observing cultural norms in dress and religious rituals, and obtaining stakeholder "buy-in", can all directly affect the ultimate success of a WASH project.

Evaluating Sources and Quantifying Differences in Soil *E. coli* Occurrence in Minimally Impacted Catchments

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Fecal water resource contamination is a critical problem contributing to millions of water-borne illnesses contracted by humans annually. *Escherichia coli* and other fecal indicator bacteria are used as surrogate measures to estimate potential for human pathogen presence in surface waters. Reducing their presence in watersheds is the focus of nonpoint source management prescribed in areas where elevated *E. coli* concentrations exist; however, knowing specific sources of *E. coli* is required before they can be effectively managed. This is challenging as all birds and mammals are *E. coli* sources. Bacterial source tracking (BST) has been used to identify contributing sources of *E. coli* in many watersheds and has aided water quality managers in addressing potential pollution issues. While useful, this approach is not perfect as unidentified sources are almost always noted. Additionally, an increasing number of cases in published literature document the presence of endemic or naturalized species of fecal indicator bacteria in soil environments that cannot be traced back to recent fecal contamination. To evaluate the potential for soil to serve as a source of *E. coli*, research conducted on three minimally impacted watersheds (ungrazed native rangeland, ungrazed cropland, managed hay pasture) compared the quantity and source of *E. coli* in soils and surface runoff. Comparison of *E. coli* DNA isolated from soils to isolates housed in the Texas *E. coli* BST Library allowed contributing sources of *E. coli* at these sites to be identified. Results demonstrate that a variety of *E. coli* sources contribute to intensively managed lands. Land use and wildlife presence seemingly influence *E. coli* source presence; however, source composition differences between watersheds are not strongly defined. Findings were unexpected and suggest that wildlife and other creatures may translocate *E. coli* from excluded sources onto managed landscapes. Results demonstrate challenges faced when managing *E. coli* loading in a watershed and highlight the need to account for background sources in water quality management efforts.

Identification of Factors Affecting Fecal Pollution in Beaver Lake Reservoir

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Standard methods for the evaluation of recreational water quality rely on generic bacterial indicators such as *Escherichia coli*. However, *E. coli* does not provide enough information to determine fecal source or public health risk. The study objective was to determine factors influencing the presence of *E. coli* and host-specific markers (HSM) from upstream to downstream in Beaver Lake Reservoir (BLR). From February 2014 to September 2015, 420 base flow and rain event samples were collected from seven sites—two sites from streams (White River [WR] and War Eagle Creek) draining into BLR and five sites from within BLR. Each sample was analyzed for *E. coli* and by quantitative polymerase chain reaction for HSM related to human, bovine, and poultry. The data indicate that overall levels of *E. coli* were significantly greater in the WR and significantly lower at the most downstream sampling location in BLR. *Escherichia coli* is more likely present during spring (adjusted odds ratio [aOR] = 1.86), at the WR sampling site (aOR = 3.39), or during a rain event (aOR = 2.73). Moreover, the HSM HumM2 is more likely present (aOR = 1.99) when *E. coli* is present. These same factors were associated with *E. coli* concentrations >126 most probable number 100 mL^{-1} (aOR = 2.76–12.48), except the poultry marker CL was more likely associated (aOR = 3.81) than HumM2. This study revealed that both seasonal and locational factors are important variables for fecal pollution in BLR. Moreover, these same factors may apply to fecal pollution in man-made reservoirs within similar types of watersheds across the United States, as well as internationally.

Streambed Sediment and *E. coli*: Variability, Attachment, and the Impact of Riparian Management

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Pathogens are the number one cause of impairments in streams and rivers within the United States. Streambed sediments can be a major reservoir of fecal indicator bacteria, including *E. coli*, in surface water bodies. These microbes can resuspend into the water column via disturbance from storms, wildlife, recreation, etc. and contribute to water quality impairments. A series of studies have been conducted to examine temporal and spatial distributions of *E. coli* in sediments, their attachment rates both within the water column and within the sediment, as well as the impact of riparian area management on the sediment and water *E. coli* concentrations. Five sets of 25 sediment samples were collected to examine the spatial variability at a single location. The results showed skewed distributions with pockets of higher concentrations generally located at the edge of the stream with the exception of the cattle crossing. In terms of the seasonal variability, higher concentrations are more often seen in the latter half of the summer months (July, August, September), but this is not universally observed. Unsurprisingly, greater attachment rates were observed in the sediment with up to 95% of *E. coli* attached to settleable particles, whereas less than 30% of E. coli were attached to settleable particles in the water column. Lastly, seasonal riparian area management practices appear to not only decrease E. coli concentrations in the water column, but also provide reduced E. coli concentrations in the streambed sediments.

Microbial Community Dynamics in a Karst Aquifer System and Proximal Surface Stream in Northwest Arkansas

Kristen Gibson, University of Arkansas
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Northwest Arkansas has well-developed karst systems, with numerous sinking streams and springs. Karst conduits enable contaminants to enter groundwater systems, degrading the water quality and destroying fragile karst ecosystems. The purpose of this research is to compare the difference between microbial communities within two different settings, a karst aquifer and a surface stream. Three sampling sites within Blowing Springs Cave (BSC) were selected from downstream to upstream. Similarly, sampling sites within Little Sugar Creek (LSC) were labeled from upstream to downstream (LSC1, LSC2, LSC3, LSC4) spanning both rural and urban settings with BSC intersecting LSC between sites LSC2 and LSC3. Both water and sediment samples were collected at each site on 14 sampling days from March to November 2016. Water samples were collected 5 cm below the surface using sterile 500mL Nalgene bottles, and sediment samples were collected from shallow areas approximately 10 cm below the surface using Whirl-Pak bags. One hundred-mL of each water sample were used for *E. coli* detection and enumeration using the IDEXX Quanti-tray⍰ 2000 system with Colilert™ reagent to determine the Most Probable Number (MPN). For total genomic DNA (gDNA), 200 mL of each water sample was filtered through a 0.2 µm, 47 mm Supor-200 filter membrane to capture total bacterial cells followed by gDNA extraction. For sediment the gDNA was extracted by mixing 5 g of sediment with 5 g of 4-mm sterile glass beads and 45 mL of an extraction solution. The sample was centrifuged at 5000 rpm for 10 min, the pellet resuspended, and gDNA extraction followed. The 16S rRNA was amplified to build a sequencing library targeting the V4 region of the 16S rRNA. The median *E. coli* value for the sites at BSC was 40.15 MPN/mL with samples never exceeding the secondary contact limit, 2050 MPN/ 100 mL. The values ranged from 0.9 to 920.8 MPN/100mL during the study period. For LSC, the median *E. coli* concentration was 120.4 MPN/100mL, with values ranging from 4.1 to 2419.6 MPN/100mL. These values exceed primary and secondary contact limits at various times of the year. The metagenomics analysis was conducted on 181 samples resulting in a mean raw count per sample of 28,270 counts. The results showed diversity was greatest between the water and sediment followed by the locations. Microbial communities in water and sediment were distinctly different in terms of community membership (presence/absence) and structure (relative abundance). These key differences are likely due to the natural habitat of specific microorganisms, which are dependent on the favorable conditions of the environment and nutrients that are provided in these environments. The major bacterial communities identified in this study were the genera *Acinetobacter*, *Pseudomonas*, *Flavobacterium*, *Clostridium* and two unclassified genera from the families *Bacillaceae* and *Enterobacteriaceae*.

Implications of Climate Variability and Change for Water Resources Management across the Conterminous US

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Precipitation, temperature and wind determine water availability (e.g., streamflow) and water that is needed for human activities (e.g., irrigation demands). Water security is thus strongly affected by patterns in space and time of climate variability and change. Additionally, water allocation relies on water in rivers and streams, reservoirs, or groundwater, inducing other correlation in space and time. For instance, limited precipitations may be mitigated through stored water (temporal) or diversion (spatial) or may on the contrary result in larger problems because of reduced flows downstream. We propose a quantification of the water allocation risks as a function of climate signal. We perform this assessment using a linear optimization model built for the conterminous US at the county-scale comprising a water demand model for the agricultural, industrial, energetic and public supply sectors. Super-imposed to the county-scale grid is a surface water network with 23’000 nodes representing rivers, lakes, reservoirs, canals and diversions. Optimal allocation strategies are identified by formulating an optimization problem minimizing risks of failures to provide water to the sector. To study the impact of climate patterns, the optimization is run for a climatic data set reproducing the last 60 years, comprising temperature and precipitation, and their impacts on water demands for the agricultural sector and run-off contribution to streams. In addition to the quantification of the risks associated to current allocation strategies for past climate variability, the model framework allows to assess mitigation strategies such as coordination in water operations, the value of reservoirs or the potential of flexible water rights. Constraints are added or withdrawn to compare various management policies such as limiting collaborations between counties at various scales, or by simulating various extraction policies on groundwater to mitigate water availability. Many data limitations impair the model. It however permits the propagation of the correlation structures in climate events through the water systems to assess the spatial and temporal consequences of drought events. Because the political scale is used to formulate the model, the results quantify the value of water management policies to climate signal, and thus constitute a framework to evaluate water governance strategies developed to respond to climate stress both at the policy and the infrastructural level.

Long Term Climate Change Impacts on Arid Groundwater Basins - Environmental Issues Related to Aquifer Flow Capacity

Barry Hibbs, California State University, Los Angeles

This paper reviews environmental and hydrological problems associated with long term climate change and flow capacity in arid groundwater basins. Flow capacity is defined as the maximum amount of water that a flow system can transmit. The phrase “rejected recharge” typically is applied to an aquifer at flow capacity where precipitation infiltration or other sources of potential recharge exceed the capacity of the saturated zone to accept additional recharge. Usually this results in regional saturation of the water table near land surface. The characteristics of a flow system that influence flow capacity are moisture availability, slope of the terrain, and permeability of the aquifer. Moisture is not available for flow capacity to be established in most arid aquifers. Climatological change as a result of global warming or cooling may cause an arid system to reach flow capacity. Paleohydrologic evidence of flow capacity in arid aquifers is observed in the southwestern Basin and Range province. Flow capacity was established in some of these aquifers during the pluvial periods of the late Pleistocene Epoch, when precipitation was higher. Recent concerns about global warming and climate change intensify concerns about possible effects of flow capacity on groundwater quality. Abandoned landfills and radioactive waste and other long term disposal sites could become inundated, creating a potentially threatening environmental problem. In addition, where flow capacity was achieved along basin floors several thousand years ago, basin floor salts were precipitated in phreatic playas. Playa salts may remain in soils and may not be completely leached for tens of thousands of years as climate becomes drier and as water tables fall. These salts can be long term sources of salinity enrichment in groundwater basins due to leaching. Hydrologists often focus on deeper sources of salinity in groundwater basins and should recognize historical presence of phreatic playas that may be a more prominent source of salinity. Finally, land surface elevation regulates maximum hydrologic head in interconnected groundwater basins. Loss of flow capacity, formerly achieved in groundwater basins, may result in completely different groundwater flow trajectories as aquifers equilibrate to falling hydraulic head. Water chemistry and water ages in groundwater basins must factor in changing relationships between basins due to loss of flow capacity, with vestiges of water types resulting from historic interbasin groundwater flow processes that are no longer occurring.

Session 19, Human Induced Planetary Change - The Broader View of Climate Change Adaptation and its Implications for Water Resources Management II

Evapotranspiration Adjustment Factor Study: Reducing Water Waste in Landscape Plantings

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Water conservation in urban landscapes in California is critical due to a limited water supply, cyclical droughts, climate change, and population increases. The population of California is expected to increase from 39 million to 60 million by 2050. The majority of growth in Southern California expected to occur in inland areas where the cost of living is lower than along the coast. Due to larger lot sizes in inland areas and the warmer climate, evapotranspiration (ET) rates are significantly higher than along the coast and more water is required for irrigation. Water use and plant health at 30 professionally-managed landscape sites (parks, country clubs, university grounds, business parks, etc.) in six climate zones across California were measured before and after site managers received intensive hands-on training by our project team to reduce water loss. Training included how to schedule irrigations based on climate and plant water needs and how to determine sprinkler system precipitation rates and improve the distribution uniformity (evenness of applied water across the site) of the sprinkler system to reduce water loss. Training also included how to check for system leaks, equipment failure, head misalignment, pressure irregularities, and other common issues. The total amount of water used at each site was measured by water meters (21 sites) or sensors (9 sites) and recorded monthly for 24 months. The sites were inspected quarterly by project personnel who made sprinkler repairs as needed and evaluated plant health and canopy coverage the first year. At the end of the first year, managers of sites that exceeded an ETAF of 0.7 were asked to reduce their water budgets to 0.7 the second year. Coincidentally, mandatory emergency water restrictions were imposed by the state during the second year of the study contributing to adherence. Twenty-one of the 30 sites significantly reduced water use without a reduction of plant health or aesthetics. Failures to conserve water at the remaining sites was due to lapses in consistently adopting ‘best management practice’ taught during the first year, personnel changes, and undetected system leaks. Some sites realized a 50% or greater reduction in water use without compromised plant health or appearance. Since approximately 50% of all water used in the urban sector of California is directed at irrigating large professionally maintained landscapes and smaller residential plantings impacts from our study are noteworthy. With recent further reduction from 0.70 Evapotranspiration Adjustment Factor (ETAF) to 0.45 ETAF (new commercial landscapes) and to 0.55 ETAF (new residential landscapes) we estimate that implementing ‘best management practices’ demonstrated at our project sites could save between 1.3 million to 2.9 million acre-feet of water per year in California.

Observed Changes in Upper Rio Grande Snowpack Water Storage and Snowmelt Timing: 1980 to 2018

Emile Elias, USDA ARS SW Climate Hub (Authors: E. Elias, D. James, S. Heimel)

One of the most widely anticipated impacts of climate change on the hydrological cycle of western watersheds is earlier snow melt. Observational studies and hydrological modeling efforts predict diminished snowpack and earlier peak streamflow in watersheds across the western United States. Here we use snow course data of the snowpack telemetry (SNOTEL) network from 16 stations in the Upper Rio Grande watershed with the longest data record (~40-years). Trend analyses with various methodologies (parametric, mann-kendall and regional kendall) and time-windows (1980 to 2018 and 1984 to 2018) augment previous modeling studies. We anticipate that since the observable impacts of climate change are occurring in many sectors, observed data may show a decreasing trend in maximum water equivaled of the snowpack (SWE), earlier snowmelt, shifts in the snowmelt window and a more rapid snowmelt (fewer days between peak snowpack and no snowpack). Trend analyses between 1980 and 2018 show the maximum annual water content in snowpack is decreasing, the snowpack is melting earlier and the date of the maximum SWE is earlier in the year. However, the number of days between the peak snowpack and no snowpack did not change – indicating that the snowpack was not melting faster. The early 1980’s was an anomalous wet time, so we tested trends from 1984 to 2018 and found trends similar to those reported using linear regression. Maximum SWE declined in 11 of 16 watersheds, maximum SWE was reached earlier in 10 of 16 watersheds and the snowmelt window was earlier in 10 of 16 watersheds. Trends for the 1980 to 2018 and the 1984 to 2018 timeframes were similar, despite controlling for an anomalously wet early 1980’s. The regional kendall test reflects these trends with significantly decreasing maximum annual SWE, earlier arrival of maximum SWE and an earlier snowmelt window. Over the 40 years of measured snowpack data results indicate that snowmelt is 16 days to 5 weeks earlier, similar to modeling studies comparing a 40 to 70-year timeframe (1999 to midcentury)

Session 20, Introducing & Exploring SMERGE: An Improved Historical U.S. Soil Moisture Product

Presenters:
Dannele Peck, USDA Northern Plains Climate Hub
Ken Tobin, Texas A&M International University
Julian Reyes, USDA Southwest Climate Hub

Accurate historical estimates of root-zone soil moisture are critical for research and management related to drought monitoring, flood forecasting, agricultural production, wildfire risk, and more. SoilMERGE (SMERGE) is a new product that provides improved historical estimates of root-zone soil moisture (0-40 cm) for the continental United States, spanning nearly four decades (1979 to 2015), at a 0.125o spatial resolution, and on a daily time-step. The SMERGE product is developed by merging NLDAS land surface model output with surface satellite retrievals from the European Space Agency Climate Change Initiative. Therefore, unlike other soil moisture products, SMERGE exhibits the strengths of both approaches—modeling and remote-sensing—merged together into one data product. More details can be found at http://www.tamiu.edu/cees/smerge/overview.shtml. To enhance SMERGE's usefulness to water resource researchers and managers, this panel session (with later audience participation) will open by introducing the audience to SMERGE, then providing them with a hands-on tutorial for accessing and visualizing the data using NASA's Giovanni portal (https://giovanni.gsfc.nasa.gov/giovanni/#service=TmAvMp&starttime=&endtime=&dataKeyword=SMERGE_RZSM0_40CM). The session will continue with a lightning talk from an early-adopter describing their research application of SMERGE in agriculture. Other proposed applications of SMERGE will also be shared, such as its use in improving river flood-forecasting, wildfire risk modeling, or invasive plant species distribution modeling. The session will conclude with an interactive dialog with the audience to gather their feedback and ideas for improving the product.

INFEWS Uncertainties to Solutions: Alternative Futures to Address Agricultural Runoff for Magic Valley, Idaho

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In 2017, the U.S. Census Bureau announced Idaho to be the fastest growing state by population in the country. As these trends continue, this growth can have various impacts on socio-ecological systems such as increased development, pressure exerted on agricultural production, and increased effects of urban stream syndrome. Various scenarios, driven by stakeholders, can help to effectively guide the designs of our green infrastructure networks. This project evokes stakeholder-defined key issues addressed within a National Science Foundation (NSF) funded project in Idaho's Magic Valley. Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS) is an interdisciplinary research initiative seeking to address issues concerning drought, water demand, water quality, and food security by using a stakeholder-driven alternative futures framework (Steinitz, 2012). Researchers within the project seek to operationalize stakeholder-driven assumptions for various scenarios utilizing the planning and suitability of effective Conservation Agriculture Best Management Practices (BMPs) addressing water availability for the Magic Valley in Idaho. The project will utilize an alternative futures methodology to interpret and represent rural and urban green infrastructure interventions at various locations within the watershed. This approach has the potential to operate at various scales and, through this project, we seek to construct the narrative at both the landscape and the site scale. The results aim to inform policy makers, planners, developers, and landscape architects about the efficiencies of various BMP types through a framework for planning and design. These outputs will also depict modeled landscape change via various scenario solutions. The stakeholder group will substantiate plausible solutions and scenarios for the Valley, which will guide the green infrastructure network. Once validated, we will focus on the siting, selecting, and sizing of three different structural BMP networks to address water quality, water quantity, soil health, provision of habitat, and inclusion of public green space.

A Socio-hydrologic Vulnerability Index and Hotspot Map for the Columbia River Basin

Paris Edwards, University of Idaho

Water systems are the lifeblood of the Columbia River Basin (CRB), sustaining habitats, cultures, and economies throughout the region. The Basin is experiencing a calamitous combination of increasing water demand and declining snowpack, with limited water storage infrastructure. The resulting changes to water availability and timing have broad but unequal impacts on interconnected social and hydrologic systems. We use principal component analysis to isolate key indicators and compare relative social and physical vulnerability at the subbasin scale (HUC 8) using an index approach. Social vulnerability variables are aggregated from Census block groups to help identify concentrations of sensitive populations within the Basin. These variables include age, education, poverty status, race, etc. Similarly, hydrologic variables such as flow variability, precipitation and temperature variability, potential groundwater storage capacity, water quality, etc. are evaluated to assess potential exposure to future water loss. A spatially explicit hotspot map of the combined socio-hydrologic assessment provides a tool for visualizing patterns of systemic vulnerability to water loss across the CRB. A primary goal of this research is to provide a jumping off point for examining resilience and vulnerability at finer scales and to ultimately contribute to providing policy and management-relevant information pertinent to community scale adaptation.

Understanding Drought Impacts on Agricultural Water Use in the Walla Walla River Basin

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Understanding how droughts impact water budgets at watershed scales is essential for effective water management solutions. This is especially true in agricultural areas where evapotranspiration accounts for significant amounts of the overall water budgets. Using the Walla Walla River Basin (a subbasin of the Columbia River Basin) as a test case, we investigated the similarities and the differences in consumptive use of irrigated crops during the 2015 drought year compared to with the drought-free years of 2014 and 2016 using the Mapping Evapotranspiration at high Resolution with Internalized Calibration (METRIC) model. Use of Landsat images in combination with the surface energy balance algorithm of METRIC gives estimates of actual Evapotranspiration (ET) over large areas. A total of 58 cloud-free images from 2014 through 2016 were used in combination with the Legrow, Washington Agrimet weather station (legw) for the analysis purpose. The Legrow Agrimet station lies inside the basin and was used as the ground weather station for the calibration and reference ET calculation purposes. With this information, the change in the ET due to water shortage can easily be detected, which helps in finding the impact of drought with respect to consumptive water use. It is expected that the consumptive use of water significantly drops during the 2015 drought year compared to the drought-free periods. This information will be extremely valuable to watershed managers trying to plan future water storage and trading projects. Our findings will also further highlight the potential of the METRIC model in the detection of water shortages.

Comparative Minimum Instream Flows across States and Provinces in the Columbia River Basin: Resilience in the Face of Climate Change

Adam Wicks-Arshack, University of Idaho
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Throughout the Columbia River basin, water resource managers are increasingly charged with the competing tasks of balancing an ever growing demand on consumptive, out of stream, water uses with a mandate to preserve instream flows for environmental, recreational and aesthetic purposes. Management decisions and water rights that designate a minimum quantity of water to remain in a flowing body of water are known as minimum instream flows. However, due to varying approaches by state governments and a lack of readily available data, monitoring and enforcement efforts have yet to realize the legal weight of instream flow protections in the Columbia River basin. Here, we present a minimum instream flow database and interactive mapping tool that monitors streamflow levels as they relate to over 1500 designated minimum instream flows throughout the Pacific Northwest. The online map and database empowers water users, managers and stakeholders to analyze historical streamflow data, real-time flows and future predicted flows under various climate change scenarios. Using several key metrics, this tool enables a quantitative legal analysis to evaluate governance approaches used by states and sub-basins and assesses resilience to a changing flow regime in the face of climate change.

Assessment and Characterization of Hybrid Mesoporous Material MCM with Titanium Dioxide for Water Treatment

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In the current study, a new method was developed to synthesize the hybrid mesoporous material with metallic oxides, MCM-48 with TiO_2, at an improved efficiency and reduced cost. The results have shown an over 95% adsorption efficiency for trace metals for the hybrid MCM-48 with TiO_2 materials, and a significantly improved maximum adsorption capacity compared to pure MCM-48. Its unique hybrid structured allows the polluted water to pass through the strong yet highly permeable structure of mesoporous material, while gives enough time for the pollutants to react with the TiO_2 infused on the porous structure so that the polluted water can be treated without introducing secondary pollutants. The microstructures of the MCM-48 with and without TiO_2 are characterized using SEM with EDS and Porosimiter. The effectiveness of wastewater treatment is measured using Inductively Couple Plasma-Mass Spectrometer (ICP-MS). The significant improvements observed here is likely due to the infused TiO_2 to the base MCM-48 structure, which also agree with the authors' previous finding. It is noticed that, while the higher concentration of TiO_2 has a positive impact on the adsorption of trace metals, the higher concentration of Ti source does not necessarily yield significantly higher concentration of TiO_2 in the final product. Future study is needed to further explore this hybrid mesoporous material for other pollutants treatment, and to obtain a further understanding of its mechanisms.

Application and Quick Removal of Powdered Activated Carbon by a Cloth Media Filtration System: A Feasibility Study

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Wastewater treatment using Powdered Activated Carbon (PAC) is a promising technology to adsorb various pollutants from waste streams. But it's commercial application in the wastewater treatment plant (WWTP) remains a challenge due to the lack of effective technology for quick application, mixing and then removal from the same flow. Typically, a WWTP uses long retention time (requiring large basins) for PAC removal resulting in large footprints and extra space. In recent years, Cloth Media Filtration (CMF) has become popular in WWTPs mainly in the filtration process due to its ease of operation and maintenance. This study examines the commercial feasibility of (i) inline PAC injection, (ii) its mixing using the air-diffusion method and then (iii) removal by CMF from the same flow stream. A pilot-scale CMF system was designed and installed in a municipal WWTP at Panama City, Florida, U.S.A. The results showed excellent performance of the CMF (with needlefelt fabric) system. The removal of commercially available PACs was more than 70% within a short time (8.15-minute residence time) up to a PAC dose of 32.2 mg/L at a flow rate of 30 L/s. Additionally, filtration time (ranging from 29 to 82 minutes) and backwash time (ranging from 7 to 11 minutes) showed that the designed CMF system can be considered as an acceptable means for PAC removal in commercial WWTP.

Biobeads as Substrate to Capture and Reuse of Nutrients from Agriculture-runoff

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Agricultural nonpoint source pollution such as nitrate and phosphorus loading in receiving water is a major contributor to water quality problems. It indeed leads to algal blooms and hypoxia. Water bodies in hypoxic state are expensive to treat and constitute a concern for human health. In this regard, low-cost and renewable water treatment technologies are warranted to reduce nutrient loading to receiving waters. Herein, we explore the feasibility of polysaccharides to capture nitrate and phosphate from surface and subsurface drainage water. Porous beads based on alginate and iota-carrageenan have been prepared and used as nutrient adsorption media. Since the charge groups of alginate and iota-carrageenan carboxylate groups (COO^-) and sulfate groups (SO_3^-), respectively interact well with nitrate and phosphorus residues, the two selected polysaccharides are able to effectively capture nitrate and phosphate from the water. The outcome offers an elegant, novel and inexpensive opportunity of utilizing polysaccharide-based beads to capture nutrients leaving the field and mitigate water quality issues. Polysaccharides are biodegradable and thus beads loaded with nutrients are recyclable as fertilizers for crop applications.

CWSRF Loans - Do They Work?

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The Clean Water State Revolving Fund (CWSRF) is a federal program that has capitalized loan funds in each state for a wide variety of improvement projects, primarily related to publicly owned treatment works (POTWs). Since 1990, New York State's CWSRF has provided over $28.5 billion in low- or no-cost financing to municipalities for water quality projects, yet comprehensive monitoring and evaluation of water quality improvements associated with those projects has not occurred. This project examines 189 POTWs in New York that have received CWSRF-financing and attempts to link these projects to measurable improvements in effluent quality. In other words, is this federal loan program effective in New York? Information regarding CWSRF-financed projects that occurred between Federal Fiscal Years 2010-2017 was acquired from the New York State Environmental Facilities Corporation, the state agency charged with administering the CWSRF. Monthly water pollutant data for four commonly reported parameters was obtained via the U.S. Environmental Protection Agency's Water Pollutant Loading Tool. Using a statistical modeling approach, we compare effluent quality trends at facilities where financed projects were completed to facilities that applied for but did not receive financing. Independent, explanatory variables included in our model were chosen to reflect general facility characteristics, such as design flow and capacity utilization rate, operational and engineering process control characteristics that were hypothesized to be important drivers of effluent water quality, as well as variables reflecting financial aspects of each project. Using the results, we identify specific project types that may be associated with demonstrable water quality improvements and discuss the overall effectiveness of the CWSRF program in delivering results in New York.

Determining the Responses of Mountainous Watersheds for Water Supply under Future Climate Change Scenarios

Mohammad Hasan, University of Utah
(Authors: M. Hasan, M.E. Barber)

Mountainous watersheds play significant roles in terms of water supply for many cities and their surrounding areas in the world. Understanding the responses of mountainous watersheds under different future climate change scenario is essential for the improvement of sustainable planning efforts related to future water supply and demand forecasting. In this study, stream flow models for eight mountainous watersheds of the Jordan River, Utah are developed at basin scale using Distributed Hydrologic Soil Vegetation model (DHSVM) for a future ten-year period (2035 to 2044) taking Representative Concentration Pathway (RCP) 6.0 scenario into consideration. A dynamically downscaled hourly climate data at 4km resolution for RCP 6.0 scenario has been used to predict the responses of the watersheds for the said period. The areas of the watersheds vary from 7 square miles to 50 square miles and the elevations range from 8,000 feet to 11,500 feet. DHSVM uses many soils and vegetation parameters out of which the most sensitive soil parameters are exponent for the change of lateral conductivity with depth, the rate of lateral and vertical hydraulic conductivity, porosity and wilting point whereas the most sensitive vegetation parameters are leaf area index (LAI), vegetation height, and maximum and minimum stomatal resistance. The models have been developed using 30m resolution DEM, 2011 NLCD land cover map and SSURGO soil map of the watersheds. The models are calibrated for three years (1998 – 2001) using the observed meteorological data from the nearby SNOTEL sites and weather stations and validated against the historical discharge for ten years from water year (WY) 2005 to 2015. The results of the study would provide a clear idea about the future contribution of mountainous watersheds to the Jordan River as well as the difference between the historical and the future contribution. Total demand of Salt Lake City and surrounding areas for the future time period will also be estimated to calculate how much of the demand would be fulfilled by the mountainous watersheds which would help the decision maker to plan the water supply aforehand.

A Water Quality and Climate Change Impact Modeling on Small Scale Watershed Based on Limited Climate Data Availability

Richard C. Peralta, Utah State University
(Authors: K. Asghari, R.C. Peralta, S. Kamali)

We implemented a data-driven method for predicting nitrate and phosphate concentrations in surface water discharging from a Great Basin inter-mountain watershed. The flow enters a reservoir before reaching Salt Lake City. The current and future qualities of water entering the urban area via surface water and recharging groundwater is important to the population, planners and managers. Despite the existence of a large diversity of physically-based models to perform water quality assessments, the lack of physical and qualitative parameters existing in small-scale basins has questioned their usefulness and effective performances. Thus, it is recommended to evaluate other techniques that can provide reasonable evaluation of water quality using limited data available. We employ the modeling approach of Support Vector Regression (SVR), a black-box learning algorithm that is a form of Support Vector Machine (SVM) and is built on limited quality parameters available in the study area for both quality simulation and downscaling the regional climate models (RCMs) datasets. In the SVR construction, the most closely related key factors to representative target variables (phosphate and nitrate) were extracted by Gamma test. The limited spatial and temporal data of 2016 and 2017 water-year was used to calibrate and validate the approach for the Red Butte Creek (RBC) watershed located in Salt Lake Valley, Utah. The two quality parameters (Nitrate and Phosphate) were predicted with high coefficient of efficiencies (0.7727 and 0.6206) and low RMSE (0.0036 and 0.0040) in validation phases, respectively. We applied the same SVR structured model to measure the impact of future climate scenarios on two quality parameters. For selected Inter-governmental Panel for Climate Change (IPCC) scenarios, three RCMs datasets were derived and adopted to downscale the mean areal precipitation and temperature for selected watershed. The analysis highlights the importance and suitability of SVR approach for predicting water quality values and assessing the future climate change impact on quality parameters.

Water Quality Simulations over the Jordan River through the Water Quality Assessment Simulation Program (WASP)

Juhn-Yuan Su, University of Utah

Significant portions of the Jordan River system, an approximate 85-kilometer, 51-mile reach spanning from Utah Lake to the Great Salt Lake, have been indicated as impaired by the Utah Department of Environmental Quality for particular water quality constituents. Such impairment affects the performance of the system, impacting environmental processes (e.g., aquatic life, nutrients, etc.) and societal characteristics (e.g., water use) along the system. At the same time, while such impairment requires significant remedies (e.g., water quality modeling, TMDL load allocations, etc.) for optimizing the performance of the system, comprehensive yet detailed understanding of the system, involving environmental processes, atmospheric characteristics, societal inputs, etc. seems required. In this exercise, a modeling framework has been implemented toward assessing the water quantity and quality performance of the Jordan River system subject to historical followed by futuristic societal (e.g., land use development) and atmospheric (e.g., climate change) characteristics. For this exercise, the water quality performance along the Jordan River is evaluated through simulations of selected water quality constituents (e.g., nitrogen species, phosphorus species, dissolved oxygen, etc.) under the Water Quality Assessment Simulation Program (WASP; Version 8 and above), incorporating model inputs from other models involved under such framework (e.g., GoldSim, SWMM, EFDC, etc.). Such simulations are conducted over an extended historical baseline period, from October 1, 2000 to September 30, 2009, with applications of three climate change projections described by the representative concentration pathways (RCPs). The results from the simulations will be evaluated for assessing the historical characteristics of the Jordan River, which will be extended as the basis for simulating the water quality performance of the system subject to futuristic societal (e.g., land use scenarios) and atmospheric (e.g., climate change) projections.

Evidence-based Decision Making in a Post-truth World

Christopher Scott, University of Arizona

Research leading to policy – the conventional approach to evidence-based decision-making – needs to be reinvented in an increasingly “post-truth” world. We have seen the growth of contentious policy debates on water resources and environmental challenges where researchers and academicians in general are not central to policy formulation. There is a critical need to refine and reinvent science-policy co-production approaches, with significantly greater reliance on key priorities identified by resource-management agencies, civil society, the public, and indeed, even through political and electoral processes. This provides greater likelihood of – but by no means ensures – policy adoption. Key to the process is engagement, both outreach (translational science and effective communication) and also inreach (establishing applied-science objectives and methods with policy-makers substantiated by research outside the academy). I ask whether post-truth is the new institutional normal. Drawing on work at the University of Arizona by the Udall Center for Studies in Public Policy and others across a range of contexts, I assess water management in Arizona and the Southwest and adaptive management under conditions of water scarcity and climate variability and change in the Americas and South Asia. My aim is to illustrate the potentials, breakthroughs, and pitfalls inherent in policy engagement beyond the academy walls, concluding by distilling lessons with broader relevance.

NIFA's IBCE Kicks around Some New Twists for Programming in Water

James Dobrowolski, USDA National Institute of Food and Agriculture

USDA NIFA's Institute for Bioenergy, Climate and Environment (IBCE) envision shared goals for water that lead to sustainable, resilient agroecosystems supporting healthy people and vibrant communities. Subject to the demands of the US Farm Bill, USDA and NIFA Strategic Plans, IBCE could: 1) *Improve and develop innovative tools and practices to enhance decision-making to promote resilient agroecosystems* by making precision agriculture more precise through the adoption of newly available technologies; growing crops that benefit from deficit irrigation in areas of the US prone to drought, irregular water deliveries or rapidly varying climates; solving the salinity issue associated with long-term irrigation and/or irrigation with nontraditional water sources; defining soil health for locations suited to grow crops eaten fresh and relate the concept to long-term sustainable agriculture; and assisting producers/stakeholders to conjunctively manage groundwater and surface water. 2) *Strengthen partnerships/collaborations* by training NIFA staff to address private matching of public awards with a variety of partners (both for- and non-profit companies, international entities, other federal, state and local agencies) through MOUs, reimbursable agreements and other mechanisms; promoting more inter-agency collaboration such as NSF's INFEWS/SiTS or contests with USDOE; encouraging local workshops led by National Program Leaders (NPLs) and Program Specialists (PS) to bring inter- and intra-agency colleagues together around key new technologies. 3) *Improve the understanding of interactions between the natural and social sciences to alter the bias across NIFA* by including a social, economic, policy or human geography priority in each Request for Applications (RFA); highlighting the results of social research (e.g., survey work); require outreach professionals to understand the difference between information transfer and adoption/behavior change; strengthen the linkage between IBCE and NIFA education programs. 4) *Support research to improve the resiliency of managed systems* by understanding that all systems are managed to some degree—which systems to emphasize/improve; continuing to request research, outreach/education that deals with mitigation and adaptation of agriculture and natural resources management to a widely varying climate; knowing enough about how drought triggers are negotiated or backed by science; predicting resiliency across fields, watersheds and landscapes. 5) *Prepare universities and others to better formulate **transdisciplinary** research, outreach/education* by properly conceptualizing interdisciplinary research involving scientific and non-scientific sources to meet the complex challenges of society; making transdisciplinary research a familiar activity of students before they are forced to risk all as faculty.

Managing Interdisciplinary Teams: Lessons Learned from Coupled Natural and Human Systems Modeling in Lake Catchments

Kelly Cobourn, Virginia Tech
(Authors: R. Henson, K. Cobourn, C. Carey, K. Weathers, K. Farrell, N. Ward)

Interdisciplinary team science is increasingly common in fields such as ecology and water resource management, where it is used to investigate the multifaceted and reciprocal interactions between humans and their environment. We present lessons learned from one such research project, a coupled natural and human systems (CNHS) modeling effort focused on freshwater lakes. Over the past three years, our team has grappled with challenges arising from large team size, geographically distributed researchers, complex interdisciplinary integration, and more. Drawing on frameworks established in the literature, we delve into the lessons we have learned in practical, day-to-day team management. How do we move datasets from one sub-team to the next? How do we formalize our expectations for collaborative manuscript writing? Which management techniques have been most successful? Our answers to these questions contribute to the growing body of Science of Team Science knowledge. They highlight the types of challenges that arise in interdisciplinary team science in the field of ecology, and identify potential strategies teams may use to address them. Ultimately, we seek to support effective and efficient collaborative team science in order to advance the state of CNHS modeling. Such advancement will help the scientific community move toward developing a holistic understanding of complex freshwater systems and support policy development and management of these scarce resources.

Purdue's Efforts and Experiences to Increase Hiring, Retention, Development, and Success of Women and Minorities in STEM Faculty Positions

Natalie Carroll, Purdue University

The focus of this talk is to present a university-level effort to increase recruiting, retention and advancement of women faculty in STEM positions. The policies, procedures, and practices developed can increase diversity and inclusion in all levels of programming and in all interdisciplinary work. Some years ago it became clear that although there were increasing rates of success in recruiting white women faculty into tenure-track positions in STEM-related departments, there was a significant, long-standing difficulty in recruiting and keeping underrepresented minority women into these same STEM tenure-track positions. Inclusive and widespread discussions with STEM and non-STEM faculty (both men and women and at different ranks), diversity staff, administrators, cultural center directors, and analysis of campus STEM faculty data and climate survey information, revealed three clear areas that required focused and centralized coordination and research capacity in order to: 1) recruit underrepresented minority women to STEM faculty positions; 2) increase the success and retention of STEM women faculty; and 3) expand the leadership development opportunities for STEM faculty women so that they are prepared for departmental, center, college and university leadership. The university received funding (five-years, $4 million) from the National Science Foundation (NSF) Advance Program to increase campus coordination and empowerment from the highest levels of leadership in order to realize the fullest measure of institutional transformation. They created the *Center for Faculty Success* to enable systemic coordination, targeted research, and comprehensive evaluation to inform us of programmatic impacts and will strongly inform the shaping of institutional policy. The strategic portfolio of initiatives under the three integrated goals and the effectiveness of specific institutional remediation efforts will be discussed.

Water Supply and Demand Forecast for the Columbia River Basin

Jonathan Yoder, School of Economics Sciences, Washington State University
(Authors: J. Adam, M. Barik)

The Columbia River Basin is intensively managed to meet a range of competing demands for water, and is essential for the growth and enhancement of the region. Every five years the Washington State Legislature requires an updated long-term forecast of water supply and water demand. The latest Forecast used integrated biophysical-economic modeling to explore the impact of projected climate change, crop mix changes, and changes in water availability on water supply and demand by 2035 (http://www.ecy.wa.gov/programs/wr/cwp/2016Forecast.html). Warmer temperatures, wetter winters and springs, smaller and earlier snowmelt peaks are projected. While annual water supplies are projected to increase across the Basin (+15% (±8%)), timing will shift earlier: unregulated supply is projected to decrease 10% (±8%) from June-October, and increase 31% (±9%) from November-May. Climatic change is projected to lead to a 5% (± 1%) decrease in irrigation water demand, assuming irrigated acreage remains constant. Projected changes in crop mix (e.g. shift towards more water-use efficient crops) would further decrease demand, resulting in a 7% (± 1%) decrease. Although these annual supply and demand projections appear encouraging, there are important caveats to consider, including: Future producer or agency decisions, such as increases in double-cropping and increased irrigated acreage resulting from planned water storage projects, could lead to increased demand for irrigation water. These results reflect median years, while vulnerability to future climatic changes will be most apparent in drought years, generally expected to occur more frequently in the future. Frequency and magnitude of curtailments in the spring are projected to increase in some watersheds, likely because the shift in demand is expected to occur faster than the shift in supply. Future forecasts will build on this work and may look more closely at these issues, as well as improving estimates of municipal and hydropower water needs, and the potential impacts of changes to the Columbia River Treaty with Canada.

On the Frontier of Water Rights: Beneficial Use and Relinquishment in Settling the Columbia River Basin

Nicholas A. Potter, Washington State University
(Authors: N. Potter, J. Yoder)

An economic frontier can be thought of as a shockwave that increases economic rents as it passes through. As rents increase, property rights are more clearly defined and enforced. In the arid west, this shockwave took the form of irrigation and rail, which made previously unvaluable land economically viable to settlers. Property rights for water correspondingly developed into what became known as the Prior Appropriations doctrine. Rights are filled in order of seniority and are for a specified diversion amount that is applied in some beneficial use. Institutional path dependence suggests that while prior appropriations is considered to be an inefficient mechanism for modern allocation of scarce water, it arose as a solution to problems faced by frontier settlers. For example, under prior appropriations, cohesive groups could self-govern and disparate groups could negotiate contracts to solve the coordination problem of constructing irrigation infrastructure. Yet to our knowledge a key component of prior appropriations, the idea of beneficial use and forfeiture, has not been explained. Under forfeiture, the portion of a water right that goes unused is subject to relinquishment in a policy known as “use-it-or-lose-it”. Relinquishment is considered an impediment to modern water markets, since a right is subject to relinquishment during adjudication or before a transaction. In this paper, we explain how beneficial use and relinquishment sought to maximize the productive use of water as the frontier moved through the arid west, focusing on the Columbia River Basin. We propose an economic model that demonstrates how beneficial use and relinquishment solve problems of speculation and monopoly or abandoned and unworked claims while still allowing users the freedom to apply their water in its most productive capacity. The model provides policy suggestions for water rights in new frontier areas.

Technology for Trade: A Conceptual Framework to Improve Water Use for Agriculture and Beyond

Kirti Rajagopalan, Washington State University
(Authors: K. Rajagopalan, J. Yoder)

Water reallocation is an important means to ensure that water resources are applied to the best and highest valued uses, within agriculture and across competing uses. Water markets can be powerful tools to facilitate this reallocation and increase the productive value of water. While water market activity is increasing in certain locations across the western United States, water markets are currently hindered by multiple information-related constraints and transaction costs that limit market efficacy, and can even exacerbate resource misallocation relative to no market at all. We introduce a conceptual framework to mitigate these constraints and improve water use efficiencies by capitalizing on three synergistic emerging technologies – improved seasonal water forecasting, automated consumptive use monitoring, and "smart" markets for leasing and trading water. The framework also considers the technology-institution nexus which is critical for identifying barriers to adoption, how they may be overcome in complex environments, and critical system interdependencies. Ultimately, the framework facilitates the assessment of the value of technology adoption and institutional changes for improving water use and its economic benefits.

Modeling Reservoir Operators as Autonomous Agents Provides Opportunities to Elicit How Discretion is Exercised in Balancing Competing Objectives

Alejandro Flores, Boise State University
(Authors: K.E. Kaiser, A.N. Flores)

Modeling the management of operation of reservoir systems necessitates integrating complex social and hydrologic dynamics. Simulation of these coupled natural-and-human systems requires characterizing decision-making processes of relevant actors, mechanisms through which they exert control on the biophysical stocks and flows, their ability to react and adapt to regional environmental conditions, and the plausible behaviors in response to changes in those conditions. Agent based models (ABMs) are useful tools for simulating these complex adaptive systems because they provide relatively straightforward ways to dynamically link models of biophysical systems and the decisions that exert controls on stocks and flows of those systems. In this work we present the development of an agent-based model designed to simulate the operation along the Boise River Basin reservoir system in southwest Idaho, USA. Precipitation in the upper basin supplies 90% of the surface water used in the basin, thus managers of the reservoir system (located in the upper basin) must balance flood control for the metropolitan area with water supply for downstream agricultural and hydropower use. Our model is encoded with information provided by the U.S. Army Corps of Engineers Water Control Manual for the reservoir system, which lays out reservoir outflows based on operational targets that change based on reservoir status and time of year. Engagement with key stakeholders of reservoir system operation reveals that a number of additional operating criteria are imposed, at the discretion of the managers, to address additional targets that often relate to downstream ecological integrity. We conduct a suite of numerical experiments that test alternative hypotheses about how this discretion is exercised and compare modeled reservoir storage and outflow to observed for a 20-year period of record. Comparing the simulated and actual storage and outflow for these alternative scenarios provides key insights into how reservoir operators exercise their discretionary authority under different circumstances. In doing so, these experiments lead to important conclusions about how to represent reservoir management using ABMs. In an effort to envision how to extend this place-specific model and recognizing variability in agent behavior across systems makes development of ABMs challenging, we conducted a review of extant literature applying ABMs to water management. From this review we synthesize groupings of agent typologies found in the literature that possess similar functional roles, management objectives, and decision-making strategies. We propose that such functional typologies can simplify the representation of water management across river basins and increase transferability and scaling of ABMs.

Session 26, Panel Discussion: Illinois Stakeholder Implementation of the Nutrient Loss Reduction Strategy I

Illinois Farmer Implementation of the Nutrient Loss Reduction Strategy

Lauren Lurkins, Illinois Farm Bureau
(Authors: L. Lurkins, L. Ramsey)

Since 2015, Illinois Farm Bureau (IFB) has contributed to the impressive statewide effort to implement the Illinois Nutrient Loss Reduction Strategy (NLRS). Through leadership and participation from our farmer members across the state, IFB has been able to make meaningful contributions toward water quality improvements in Illinois. From 2016 to present, IFB has committed approximately $1 million of its own funding to build and maintain its sustainability programs. This is in addition to the on-farm actions of individual farmers and landowners. For the past several years, IFB has made it an organizational priority to lead on environmental issues, most notably, the NLRS. Our NLRS efforts focus in four primary areas: 1) education and outreach; 2) supporting research initiatives; 3) supporting implementation efforts; and 4) demonstrating progress. This presentation will highlight the details of new partnerships and initiatives that have been formed based on farmer-generated ideas and solutions that all would not have been possible without the framework of the NLRS.

POTW Efforts and Collaborations on the Illinois Nutrient Loss Reduction Strategy

Albert Cox, Metropolitan Water Reclamation District of Greater Chicago
(Authors: A. Cox, J. Kozak, G. Tian, O. Oladeji, D. Qin, R. Manner)

Since the release of the Illinois Nutrient Loss Reduction Strategy (Strategy), POTWs in Illinois have taken a very proactive approach in implementing a wide range of efforts to contribute to the nutrient loss reduction goals outlined in the Strategy. The efforts are focused on reducing phosphorus (P) discharge and have resulted in significant capital and operational investments, either voluntarily or as required by NPDES permits. The approaches include facility upgrades and retrofits, investments in watershed-based activities, and establishing partnerships with various stakeholders. Most POTWs are implementing biological phosphorus removal (Bio-P) systems to contribute to the goals of the Strategy and comply with permit discharge limits. As an example, the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC), the largest POTW in the state, has embarked on a three-pronged approach to nutrient reduction, which includes nutrient removal, nutrient recovery, and leadership in statewide collaborations. At its facilities, the MWRDGC has implemented Bio-P at two of its seven water reclamation plants (WRP), the Stickney and Kirie WRPs, which resulted in significant reductions in P discharged from these plants. The MWRDGC installed the largest P recovery facility in the United States at its Stickney WRP, and is conducting pilot-scale studies on the use of microalgae for nutrient recovery from its O'Brien WRP. As the MWRDGC recognizes that the goals of the Strategy could be achieved more effectively through a collaborative approach, MWRDGC has made available some of the agricultural fields at its 13,000-acre site located in Fulton County, Illinois to demonstrate the benefits of collaboration. The effort includes a nutrient loss reduction program at this site to foster collaboration between various stakeholders on the development and demonstration of agricultural best management practices for nutrient loss reduction. The project now engages collaborations with University of Illinois, Illinois Central College, Illinois Sustainability and Technology Center, and the Illinois and Fulton County Farm Bureaus. Research and demonstration projects including outreach programs are supported by these collaborators, including the Illinois Nutrient Research and Education Council. This presentation will highlight some of the facility upgrade projects undertaken by MWRDGC and other POTWs and some of the results of the stakeholder collaborations.

Session 26, Panel Discussion: Illinois Stakeholder Implementation of the Nutrient Loss Reduction Strategy I

Environmental Community Activity to Support and Implement the Illinois Nutrient Loss Reduction Strategy

Cindy Skrukrud, Sierra Club, Illinois Chapter

Illinois' environmental community helped develop the state's 2015 nutrient loss reduction strategy (https://www2.illinois.gov/epa/topics/water-quality/watershed-management/excess-nutrients/Pages/nutrient-loss-reduction-strategy.aspx) and is an active participant in the implementation of the strategy. As our sector desires clean and healthy waters both within Illinois and downstream to the Gulf of Mexico, it is critical that Illinois' strategy calls for reductions in nutrient loads leaving the state along with cleanup of nutrient problems in rivers, lakes and streams within the state. We recognize that reaching these goals can only be achieved over time and through partnership with other stakeholders at both the local watershed and the statewide level. At the watershed level, both staff and volunteers from environmental organizations are leaders and participants in watershed groups. We were instrumental in forming groups such as the Fox River Study Group (http://www.foxriverstudygroup.org/) and the Squaw Creek Clean Water Alliance, which are addressing algae problems in a major river and the watershed feeding a small glacial lake, respectively. Sierra Club volunteers also participate in many other watershed groups throughout the state. Prairie Rivers Network and the Illinois Chapter of the Sierra Club worked with the Illinois Association of Wastewater Agencies and the Illinois EPA to develop a 2018 agreement to reduce phosphorus inputs from municipal wastewater treatment plants by 2030, giving treatment plant operators time to make the substantial process and equipment changes needed. Sierra Club also worked with agricultural partners to establish the Illinois Nutrient Research and Education Council (https://illinoisnrec.org/) in 2012 which funds research and education programs ($10 million to-date) to aid Illinois farmers in understanding and adopting practices that optimize fertilizer uptake into crops and reduce nutrient loss to our state's waterways. We work with other stakeholders to continue to improve the biennial reporting of the progress in nutrient loss reduction that is underway at facilities, in communities and on farms throughout Illinois and to adapt our efforts in order to meet the strategy's interim and ultimate reduction goals. Hundreds of members of environmental organizations are calling for the clean water infrastructure investments needed at the state and local levels in order to achieve the strategy's goals. They are championing both the grey and green infrastructure needed to reduce nutrient pollution from wastewater discharges and urban and agricultural runoff. Their voices amplify the efforts of the coalition of stakeholders implementing the strategy and ensure that leaders at the community and state levels understand the importance of this undertaking to Illinois citizens.

Promoting Instream Flows in Western States

Belize Lane, Utah State University
(Authors: B. Lane, D. Rosenberg)

Public support for instream flow policies is growing because of changing cultural and economic values for ecosystems, recreation, and aesthetics, a changing climate, and mounting awareness of the ecological consequences of traditional western water management. Agriculture accounts for approximately 90% of western water use, but that proportion is declining rapidly to supply growing urban populations. This major shift in water demands represents both an opportunity to increase instream uses and a challenge as efficiency and conservation measures can decrease critical return flows to rivers and negatively impact ecosystems. With the fastest growing population, second driest conditions, and some of the highest water use rates, the state of Utah exemplifies several key challenges and opportunities for instream water management in western states. Major constraints on the entities that can own or lease instream flows, allowable instream purposes, and persistently high transaction costs have resulted in very few successful instream water rights transfers under the existing laws. This presentation outlines available tools to promote instream flows within the Utah water rights system and identifies key implementation challenges. Two case studies in northern Utah illustrate technical and legislative opportunities to promote instream flows both within and outside the current water rights system.

A Modular Integrated Modeling Framework for Ecohydraulic Analysis

Fengwei Hung, Utah State University
(Authors: F. Hung, B. Morgan, B. Lane)

Human activities including irrigation, hydropower generation and municipal water withdrawal have drastically altered natural flow regimes, posing a severe threat to aquatic ecosystems. Recognizing these negative impacts, water managers are increasingly allocating environmental flows to maintain river ecosystem integrity while supporting human water demands. A pressing challenge is assessing the ecological impacts of streamflow alteration to determine how much water can be diverted while still maintaining ecosystem functions. We attempt to address this challenge by developing transferable approaches that integrate geomorphology, hydrology, hydraulics, and ecosystem to inform water resource management. More specifically, we develop an integrated framework for river management that includes modules of terrain generation, hydrodynamic simulation, a habitat suitability assessment, and performance metric development. The terrain and hydrodynamic modules can provide detailed hydraulic information, which incorporated with habitat suitability criteria, will inform unique hydro-suitability relationships for a variety of aquatic species and ecosystem functions. The hydro-suitability curves can also be aggregated in time by user-defined performance metrics (e.g. resilience and vulnerability) to allow direct comparison of various flow scenarios. This framework enables the user to generate their own model components (e.g. terrain, ecohydraulic objectives, flow scenarios) and incorporate existing datasets into the modeling framework when they become available. These modularized tools are generalized for river management at the reach scale and can be applied across river systems with variable hydraulic and hydrologic characteristics. We will apply this framework to the South Fork Eel River Basin in northern California, to inform decisions on environmental flow allocation.

Characterizing Streamflow and Temperature Patterns on the Blacksmith Fork River to Determine Impacts of Summer Dewatering

Madison Alger, Utah State University
(Authors: M. Alger, B. Lane)

Water supply in the intermountain west is increasingly limited and uncertain due to climate change as well as growing and shifting demands. Agriculture is the largest water user across the intermountain west. In agriculture dominated streams, irrigation diversions can drive extremely low baseflows or full channel dewatering during the growing season. Summer dewatering is occurring more frequently and for longer periods, driving changes in streamflow and temperature patterns that negatively impact fish and other aquatic species. Additionally, there is mounting societal interest in instream flows to support recreation, aquatic species, and aesthetic value. A case study of the Blacksmith Fork River in northern Utah demonstrates opportunities and challenges to improve instream water management. This study characterizes streamflow and temperature patterns through a dry summer and develops quantitative relationships between streamflow and temperature in space and time to inform instream flow management efforts. The study area was heavily instrumented to collect temperature, streamflow, and aquatic macroinvertebrate data. The significance of antecedent climate conditions, surface water – groundwater interactions, and canal diversions is assessed. This study informs both local and regional water management efforts to maintain healthy river ecosystems and avoid dewatering while continuing to support irrigated agriculture.

Climate Impacts on Drought in the Ganges Delta, Bangladesh

Sonia Murshed, Utah State University
(Authors: S. Murshed, J.J. Kaluarachchi)

Drought forecasting is crucial in the Ganges Delta of Bangladesh which is an agriculture-dominated region. Upstream water diversions from the Ganges River is reducing the surface water availability at the downstream delta area. It also increases salinity intrusion towards inland, making water unsuitable for irrigation. This study addresses the potential drought conditions considering climate variability and climate change. Drought hazards were assessed with observed (1949-2015) and projected (2016-2100) climate data. Observed data were collected from Bangladesh Meteorological Department. We used three regional climate models, i.e., RCA 4, REMO2009 and RegCM 4-4 and two emission scenarios of RCP 4.5 and RCP 8.5 to assess future changes in drought characterization. A total number of 15 rainfall and temperature indices were calculated to depict climate variability and changes. We also estimated the standardized precipitation index (SPI) and the standardized precipitation evapotranspiration index (SPEI) to understand the consequences of climate change on drought hazards. These results show that the study area is heading towards a warmer climate. Contribution from extreme rainfall (95th and 99th percentile) along with simple daily intensity index is decreasing. This decreasing trend of rainfall is found to be similar for the future climate projections. In addition, both SPI and SPEI show higher numbers of extreme drier conditions, indicating more frequent droughts in the future. Reliable information on droughts is essential for proper water and irrigation management. These findings will help decision-makers to take necessary precautions to sustain agriculture of this drought-prone region.

Session 28, Panel Discussion: How to Have a Successful Grant Proposal: Insight from Syntheses of the USDA-NIFA Water and Climate Portfolios

We have been evaluating the USDA-NIFA Water and Climate portfolios for the last several years. As this work concludes, we will share insights about the impacts of these portfolios, how to build a successful grant team, how to maximize the effectiveness of capacity funding that land grant universities receive, and much more.

Panel organizers:
Mike O'Neill, University of Connecticut
Linda Prokopy, Purdue University
Sarah Church, Purdue University
Laura Esman, Purdue University
Jackie Getson, Purdue University

Panelists include:
Jim Dobrowolski, USDA National Institute of Food and Agriculture
Mike O'Neill, University of Connecticut
Linda Prokopy, Purdue University

US Army Plans for Water Security to Sustain Critical Missions

Elisabeth Jenicek, US Army Engineer Research and Development Center
(Authors: E. Jenicek, A. Hur, V. Heath, M. Mithaiwala)

For Army installations, water supply represents a critical resource for which there is no substitute. Water utilities are subject to disruption from a variety of natural and man-made hazards, risks and disasters. Any interruption in supply will result in degraded training, reduced readiness of Soldiers and their equipment, impacted force projection, industrial base disruptions, and reduced quality of life for Soldiers, military families, and civilians. The Army's Installation Energy and Water Security Policy, established requirements to sustain critical mission capabilities and to mitigate risks posed by energy and water disruptions affecting installations. This mandate includes coordinating vulnerability and risk assessments of potential disruptions and implementing adequate responses to mitigate identified risks. Specifically, installations must be capable of providing necessary energy and water for a minimum of 14 days for critical missions. Other requirements include identifying installation-critical energy/water requirements, defining energy/water security risks, prioritizing mitigation actions, and developing projects that close energy/water security gaps and reduce risk. The Engineer Research and Development Center is developing one of the Army's first Installation Energy and Water Plans (IEWP) at Fort Bragg, NC, a key force projection platform, to meet this policy. They've developed tools to help create or update IEWPs. These tools will help answer the questions: What is the range and scale of potential water disruptions?; What is the current readiness of installations to address a near-term disruption in water supply?; What are the categories of water demand on an installation, ranging from mission critical to non-essential?; and, What are the potential sources of back-up supply, what category of demand can they meet, and what additional treatment capabilities will be required to use them? The first group of priority 1 installations must prepare IEWPs by the end of Fiscal Year 2019, with remaining IEWPs due by the end of 2021.

Getting to Know Your Audience: A Performance-based Approach to Residential Outdoor Water Conservation

Ronald A. Kaiser, Texas A&M University
(Authors: A. Lewis, C.P. Khedun, R.A. Kaiser)

Public drinking water systems are an integral part of urban infrastructure and it would be difficult to imagine life in the United States without them. An estimated 283 million people, or 87 percent of the country's population, currently rely on public water supplies for domestic use. Despite population growth, public-supply water use has undergone a nationwide downward trend, owing largely to increasingly efficient indoor water appliances such as low-flow toilets, showerheads, dishwashers and washing machines. While municipal indoor per capita water use has declined through improved appliance efficiency, the largest urban end uses continue to be outdoors, chiefly landscape irrigation. Urban water conservation programs have shifted accordingly towards reducing landscape watering. Outdoor water use varies nationally and regionally and is affected by climatic conditions and automated irrigation systems. Studies have indicated that single-family households without automated irrigations systems tend to apply much less water than their landscapes theoretically require. Hence, applying more water than a landscape needs (overwatering) is inefficient and wasteful of water. In order to maintain them in a healthy condition, many homeowners invest substantially on irrigation systems and water. However, consumers who irrigate for too long or too often, or are unaware of misdirected or broken sprinklers, leaking or broken pipes, or loss due to wind and evaporation, tend to overwater. Addressing this ubiquitous waste of drinking water is important as water providers increasingly face supply constraints and costly infrastructural improvements amid growing demand. This study explores how residential overwatering varied for 15,000 single-family homeowners in the City of College Station, Texas. For each household, monthly outdoor water usage was computed by subtracting an average of monthly usage during the winter and thereby compared with weather conditions and an irrigation budget. Landscape irrigation needs were based on evapotranspiration and rainfall from a network of 8 sensors over the period 2015-2018. Preliminary findings have shown that not all overwatering is equally shared. Most households that overwater do so infrequently, and those that overwater often also are responsible for most of the volume wasted. Findings from this study can help water utilities develop more effective water conservation strategies and interventions.

Evaluating the Sensitivity of Residential Water Demand Estimation to Model Specification and Instrument Choices

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Past studies have estimated residential water with different econometric model choices. Inconsistency in the choice of the price signal, its instruments, and appropriate weather variables have offered qualitatively different estimates of price elasticity — both elastic (>1) and inelastic (<1) — in the water demand literature. This distinction is important because elasticity estimates are critical in creating efficient and effective water conservation and management practices. Also, accurate demand responses to price changes help water utilities stabilize and anticipate future revenue, which requires appropriate model specification. However, specifying residential water demand with appropriate model (under IBR) is challenging for three reasons: 1) there is an ongoing debate over the appropriate price signal on residential water bills, 2) little theoretical motivation exists for determining which weather variables affect demand, and 3) simultaneity issues in estimation require the use of instruments, which vary within the literature. In this paper, we elucidate the effects of model choices on elasticity by systematically varying the specification of price, instruments, and weather variables across a suite of models. As found in other work, our results suggest that households respond to the average price. For the choice of weather, we find relatively stable estimates, implying that choices in weather variables (average versus maximum daily temperature, for example) have little (or no) impact on elasticity estimates. However, when a model is specified only with precipitation variables, elasticity estimates are qualitatively different (>1) and model fit is worse, which suggests that, so long as a temperature variable is included, parsimonious models can provide consistent and efficient estimates, thereby reducing the need for more in-depth measurements (air pressure, humidity, wind speed, for instances) offered by advanced weather stations. Similarly, we find a negligible impact of different price instruments on elasticity. Understanding the implications of these results provide guidance to future researchers for if and how to include different weather metrics while modelling residential water demand, and ultimately help water managers and stakeholders establish appropriate water price and predict revenue while satisfying households demand.

Colorado River Drought Contingency Planning and What it Means for Municipal, Tribal, and Agricultural Water Users in Arizona

Sharon B. Megdal, University of Arizona Water Resources Research Center

The Colorado River is a critical water resource for seven states, including the host state for this conference, and the Republic of Mexico. Long-term drought conditions and over-allocation of river supplies has the probability of a shortage being declared in 2020 at over 50 percent. What does shortage mean for Arizona, particularly Central Arizona, home to fifth largest city in the U.S., a vibrant agricultural sector, and several Indian Nations? How did Arizona work through the very thorny issues of how to spread the pain of significant cutbacks to surface water deliveries through the Central Arizona Project? This presentation will speak to the thorny issues that Arizona, along with other states, has had to work through in order to develop a Drought Contingency Plan for the Lower Colorado River Basin. The presentation will draw upon presenter Sharon Megdal's years of experience in the academic sector as well over 10 years as a member of the Central Arizona Project board of directors. It will focus on the water policy creativity and give-and-take necessary for addressing water resource shortfalls due to extreme climate conditions juxtaposed with a growing economy and water demands.

Urban Response to Prolonged Drought in the Las Vegas Region

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(Authors: D. Bennett, K. Sovocool)

The Las Vegas, Nevada, region is one of the nation's fastest growing population centers. It is also the driest major city in North America and heavily reliant on the Colorado River. Since 2000, the Colorado River has been experiencing prolonged drought, producing just 75 percent of historically-average runoff. The reduction in flow has resulted in depletion of both Lakes Powell and Mead and has policy consequences for seven Western states and Mexico. There is a high potential for declaration of a shortage on the river, resulting in mandatory reductions of the allocations for Arizona, California and Nevada. The prospect of reduced allocations has spurred additional conservation efforts. This presentation will review southern Nevada's response to the early drought conditions and explain recent and proposed drought response measures to further reduce consumptive demand.

Agricultural Best Management Practices to Limit Nutrient Export in Southern Illinois

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The Illinois Nutrient Loss Reduction Strategy has established goals for a 15% reduction in nitrogen and 25% reduction in phosphorus by 2025. To achieve these goals a multitude of in-field and edge-of-field Best Management Practices (BMPs) have been developed and implemented across the Illinois landscape to reduce sediment and nutrient loading to streams. Individual BMPs have been proven as effective tools for soil, water, and nutrient management, but not all of them have been assessed based on secondary impacts aside from their intended uses/designs, over the long term, and some are relatively new practices. Research at Southern Illinois University (SIU) has focused on addressing these questions for 4 different best management practices. The longest ongoing project has focused on the impacts that cover crops and tillage have on water quality at both the field and watershed scales. Leguminous (hairy vetch, *Vicia villosa*) and non-leguminous (cereal rye, *Secale cereal*; oat, *Avena sativa*; Radish, *Raphanus raphanistrum* subsp. sativus) were compared over the past 5 years and have shown noteworthy impacts on crop yields and water quality. Two new projects are focused on tile drainage management using saturated buffers and water and sediment control basins (WASCoBs). A new "pitch fork" design of a saturated buffer was installed to do a side-by-side comparison with the standard saturated buffer NRCS practice (Code 604). The WASCoB project will incorporate cover crops into their design and be monitored for water quality and crop yields over the next 5 years. The 4th project is investigating the influence of gypsum (calcium sulfate dihydrate), a by-product of coal burning for electric power generation, on phosphorus levels in surface runoff and grain yields in agricultural soils. Results from these projects will help farmers make sound economic and environmental decisions for sustainable management of Illinois farmlands.

Applying Research: Cover Crops in the Field and Policy

Jonathan Coppess, University of Illinois at Urbana-Champaign

The Agriculture Improvement Act of 2018 reauthorized American farm policy. It is commonly referred to as the farm bill and is the latest in more than eighty years of federal policies to assist farmers with low crop prices, yield risks and natural resource concerns. One of the most pressing natural resource concerns for row-crop production in the Midwest is the loss of nitrate-nitrogen from farm fields that impacts water quality in rivers, lakes and the Gulf of Mexico. Agriculture is one of the main sources of nitrate-nitrogen in water bodies. One method of reducing nutrient losses from fall application is by use of winter cover crops in place of a conventional, bare fallow method which leaves unused inorganic nitrogen vulnerable to losses, but farmer adoption has been slow. One of the challenges for widespread cover crop adoption involves the added risk and management complexities for the operation, particularly during crucial windows for planting the cash crop in the spring. Cover crop adoption and addressing nutrient loss for water quality provides an excellent example of the need for the application of agricultural research in both the fields and federal farm policy. In the fields, one example is the development of web-based decision support tools that can translate research for cover crops by providing up-to-date, hyper-localized and easy-to-use information to manage the cover crops and reduce the risk of adoption. For federal policy, conservation programs authorized by the farm bill provide limited cost-share assistance for cover crops, as well as the potential for annual income assistance payments that could help with cover crop adoption. Federal policies could be revised to better support farmers in adopting cover cropping practices. Fully integrated farm policy, for example, would seek to appropriately cover the short-term costs of cover cropping, as well as helping the farmer to manage the risk of practice adoption for yields and income or profitability; a blend of farm support policy and conservation policy that encourages innovation and the search for managing costs or economic efficiencies such as by pegging conservation assistance to crop prices.

Impact of Subsurface Drainage on Field-scale Hydrology and Crop Production

Rabin Bhattarai, University of Illinois at Urbana-Champaign
(Authors: R. Bhattarai, H. Jeong, R. Cooke)

Subsurface drainage (tile) drainage improves crop yields on poorly drained soil, while it could deteriorate downstream water quality. Although there have been many efforts on improving our understanding of the effects of tile drainage design and management, very limited studies have comprehensively investigated the impact of tile spacing and depth on nutrient loss from tile-drained fields and the crop productivity. Moreover, the results of the limited studies have not been conclusive. In this study, we seek to shed light on the controversial outcomes and provide a clearer picture of the impact of tile spacing and depth. We installed and instrumented nine experimental sites having three different combinations of tile spacing and depth with three replicates. We analyzed one and half years' monitoring results of hydrological responses and crop production on the experimental sites to answer the question: how does change in tile depth and spacing variation impact subsurface hydrology, nutrient loss, and crop production?

Toward a Regional Phosphorus (Re)cycle in the U.S. Midwest

Andrew Margenot, University of Illinois at Urbana-Champaign

Redirecting anthropogenic waste phosphorus (P) flows from receiving water bodies to high P demand agricultural fields offers a triple win: reduce point-source P discharges, meet agricultural P needs, and – depending on the speciation of rP– mitigate P losses from agriculture. We illustrate the potential of recovered P (rP) production in the Midwest from diverse waste steams and its re-use in agricultural fields, using struvite and phytin as example rPs. The yield and composition of rP differs greatly among livestock, municipal, and grain milling waste streams due to the speciation of P and presence of co-precipitating ions and molecules. Solubility of rP presents key tensions between engineered P recovery and agronomic re-use because it defines both the ability to separate organic and inorganic P from aqueous streams and the crop-availability of rP added to soil. The crop availability of P contained in struvite and phytin is governed by distinct abiotic and biotic processes that are crop- and soil-specific. On the other hand, the low water solubility inherent to rP could be leveraged to decrease P losses from agricultural fields. Matching rP species to appropriate agricultural production systems is key for the development of sustainable and financially viable regional exchanges of rP from wastewater treatment and bioprocessors to agricultural end-users.

Cover Crop Impact on Nitrogen Fate and Cash Crop Yield

Richard Roth, Purdue University
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It has been estimated that agricultural sources contribute more than 70 percent of the nitrogen and phosphorus delivered to the Gulf. Therefore, the objectives of this study were to investigate the impact of cover crops (CC) on the distribution of inorganic nitrogen (N) in the soil profile and on the load and concentration of nitrate in subsurface tile water. This experiment was conducted at the Illinois State University Nutrient Management Field Station, in Lexington, IL. Treatments include a zero control (no N fertilizer and no cover crop), fall dominated N application (70% fall, 30% spring) with and without CC, and a spring dominated N application (20% fall, 80% spring) with and without CC. All treatment received the same rate of phosphorus as diammonium phosphorus in the fall. Automated water samplers (ISCO 6712) were programmed to collect samples that were then analyzed for nitrate and ammonium concentrations. Spring cover crop sampling revealed an average biomass of 1,815 kg ha^{-1}. Over the course of the study, CC integration resulted significantly less soil nitrate at the lower depths of the soil profile near the tile-drainage location. Despite, N application timing CC reduced nitrate loading via tile-drainage by 41-52%. Thus, data from this study proves that CC inclusion as an in-field best management practice to reduce nitrate loss is effective across the spectrum of fertilizer N application management in the Upper Mississippi River Basin.

Satellite Data-driven Modeling of Field Scale Evapotranspiration in Croplands Using the MOD16 Algorithm Framework

Colin Brust, University of Montana
(Authors: M. He, J.S. Kimball, C. Brust, M. Maneta)

Evapotranspiration (ET) is a key variable linking the global water, carbon and energy cycles, while accurate ET estimates are crucial for understanding cropland water use in context with agricultural management. Satellite remote sensing provides spatially and temporally continuous information that can be used for global ET estimation. The NASA MODIS MOD16A2 operational product provides 500-m 8-day global ET estimates extending from 2001 to present. However, reliable estimates for delineating field level cropland ET patterns are lacking. In this investigation, we modified the MOD16 global algorithm to better represent cropland ET by calibrating model parameters according to C3 and C4 crop types, and incorporating finer scale satellite vegetation inputs to derive 30-m cropland ET estimates over the continental USA (CONUS). Similar overlapping enhanced vegetation index (EVI) records from Landsat and MODIS were used to generate a continuous 30-m 8-day fused EVI and ET record extending from 2008 to 2017 over CONUS croplands. The satellite-based ET estimates were compared with tower based ET observations over different crop types, and more traditional cropland actual ET (AET) estimates derived from reference ET and crop-specific coefficients. The new satellite based 30-m cropland ET estimates (ET_{30m}) corresponded favorably with both tower ET observations (ET_{flux}; R^2=0.69, RMSE=0.70 mm d^{-1}, bias=0.04 mm d^{-1}) and the baseline global MOD16A2 ET product (ET_{MOD16}). The ET_{30m} results also showed better performance against the ET_{flux} observations than ET_{MOD16} (R^2=0.54, RMSE= 0.82 mm d^{-1}) or AET (R^2=0.52, RMSE=2.47 mm d^{-1}) for monitoring CONUS croplands. The spatial and temporal patterns of the ET_{30m} results show enhanced delineation of agricultural water use, including impacts from variable climate, cropland area and diversity. The resulting ET_{30m} record is suitable for operational applications promoting more effective agricultural water management and food security.

Weather Fluctuations, Expectation Formation, and Short-run Behavioral Responses to Climate Change

Kelly Cobourn, Virginia Tech
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One premise adopted in most studies on climate change impacts is that weather fluctuations affect economic outcomes contemporaneously. However, under certain circumstances the impact of weather fluctuations in the current year can be carried over into the future. Using agricultural production as an example, we empirically investigate how expectations are formed and updated over previous realizations of weather, and how farmers adjust and adapt their decision-making in response. Many agricultural production decisions are made prior to the realization of weather, and these *ex ante* decisions require farmers to use subjective expectations over climate. If farmers' subjective expectations are disproportionately influenced by most recent weather realizations, then the resulting economic decisions become sub-optimal as farmers over-adjust to short-run weather shocks, which incurs potential economic losses. Our empirical analysis examines how past weather shocks, i.e., deviations from climate normals, affect two *ex ante* agricultural production decisions: acreage and crop-allocation decisions. We use farm-level data for an irrigated, multi-crop agricultural system in the Eastern Snake River Plain of Idaho, where we combine remote-sensing observations on land use and crop allocation decisions with other geo-referenced datasets, including weather, water rights, and water curtailments. We use a panel fixed-effect regression model, and include multiple lags of non-linear temperature, precipitation, and surface water availability as independent variables. Our results indicate that previous shocks in weather and surface water availability significantly affect both acreage and crop-allocation decisions. These results provide evidence to reject the hypothesis that farmers form expectations on climate solely from long-run climate normals. Instead, our results support alternative expectation-formation heuristics to various degrees. We find that the timing of weather and water shocks affect farmers' adaptation strategies, consistent with the availability heuristic. We also present evidence that farmers adopt the reinforcement learning, when making inferences on future climate. This study makes several contributions to the existing literature. First, our study complements the literature on climate impact by demonstrating a mechanism through which past weather fluctuations may affect future economic decisions and outcomes. Second, our study emphasizes the need to incorporate short-run behavioral responses into assessments of climate change impacts. We show that weather fluctuations create the potential for an over-adjustment cost when farmers overreact to short-run weather signals, and are particularly relevant given that climate models project a change in long-run averages as well as increased variation, which will likely increase this over-adjustment cost.

Evaluating the Spatial Distribution of Drought Impacts in Montana using a Remote Sensing-driven Hydro-economic Model

Marco Maneta, University of Montana
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Anticipating agricultural water demand, land reallocation, and impact on farm revenues associated with different policy or climate constraints is a challenge for water managers and for policy makers. While current integrated hydro-economic models based on programming methods provide estimates of farmer reactions to water constraints and the hydrologic consequences of these reactions, they have important shortcomings such as the high cost of data collection surveys necessary to calibrate the model, biases associated with inadequate farm sampling, infrequent calibration updates, or model overfitting, among other problems. Here we present a novel integrated hydro-economic modeling package that couples a full description of the hydrologic cycle at the regional scale with an economic model of agricultural production and water use based on mathematical programming methods. The model is driven by satellite remote sensing and other hydro-climatologic and economic information from public databases. Satellite-based remote sensing imagery provide free and accessible spatially and temporally continuous observations of vegetation greening that can be used to retrieve crop type, yield, or crop water use necessary for model calibration. Model calibration is performed recursively every year by assimilating remote sensing information using a Bayesian filter. Recursive calibration permits to detect gradual changes in the hydrologic system or in the economic behavior of farmers and adjust model parameters accordingly. Remote sensing estimates of agricultural activity eliminate the sampling bias of the surveys, reduce operational costs, and permit state-wide model applications. We use this model to investigate how farmers reallocate agricultural land and water in the state of Montana under drought conditions, and how farmer choices impact streamflows and exacerbate the negative effect of drought on downstream users.

Achieving Groundwater Sustainability in the San Joaquin Valley: A Hydro-economic Approach

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Groundwater in California has historically contributed from 40 to 60 percent of the total applied water in irrigated agriculture. This source has also served as the main buffer against surface water shortages during droughts. As a common pool resource, groundwater has been overdrafted for decades particularly in areas in that rely on water imports for irrigation or runoff is less abundant like in the San Joaquin Valley, one of the largest agricultural regions in the world. The 2012-2016 drought catalyzed groundwater legislation and in 2014, the Sustainable Groundwater Management Act (SGMA) became one of the most comprehensive regulations in California's water history. SGMA requires critically overdrafted basins to reach sustainability in various forms including water balance by 2040. This paper presents the potential economic costs for agriculture and related sectors in the San Joaquin Valley in its gliding path towards groundwater sustainability. A hydro-economic approach connecting models of agricultural production and water use, groundwater, and land use data in the San Joaquin Valley has been employed. The roles of markets and enhanced water supplies is also explored.

Current State-of-the-Art Satellite Remote Sensing Tools for Agricultural Drought Monitoring

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The development of satellite remote sensing tools for agricultural drought monitoring and early warning has rapidly evolved over the past decade to provide a suite of tools that characterize several parts of the hydrologic cycle that are related to the development and progression this natural hazard. Several remote sensing-based drought monitoring tools for the continental United States will be presented that assess environmental conditions that include vegetation health, evapotranspiration, soil moisture and groundwater. Examples will provided in support of the U.S. Drought Monitor (USDM). The development of satellite-based, composite drought indicators such as the Vegetation Drought Response Index (VegDRI) and the Quick Drought Response Index (QuickDRI) will also be discussed, as well as current and future research directions in satellite remote sensing of drought.

Calibrating NMR Logging for Estimating Hydraulic Conductivity in Glacial Aquifers

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Accurately characterizing hydrogeologic parameters that control groundwater flow is essential for developing models necessary for groundwater management. While there are multiple methods for measuring hydraulic conductivity (*K*) in aquifers, many require time consuming, expensive field work or extensive calibration. Nuclear magnetic resonance (NMR) logging could provide a way to rapidly estimate *K* vertically at submeter resolution. NMR logging tools characterize the amount of water and properties of the water-filled porosity in a cylinder outside of the disturbed zone of a well. Unfortunately, NMR logging relies on models that require calibration to accurately measure *K*. These models were developed by the petroleum industry for measuring the permeability of reservoir formations, and comparatively little work has been done to assess the suitability of these models for groundwater applications. Here we investigate the use of NMR logging in the Glacial Aquifer System of the northern United States, an important national water supply that provides water to 41 million people. At two field sites each with two wells in southcentral Wisconsin we combine NMR logging with adjacent measurements of *K* from a direct push permeameter (DPP) to estimate the necessary NMR calibration constants. The link between NMR and *K* depends on an empirical relation between porosity (ϕ) and a measure of the surface-to-volume ratio derived from the NMR measurement, the relaxation time, T_{2ML}. We use the Schlumberger-Doll Research (SDR) equation, $K_{NMR} = b\varphi^m T_{2ML}{}^n$ and explore possible values of b, m and n. Using two statistical methods, Markov chain Monte Carlo (MCMC) and bootstrapping, we find the optimal values for each well given the DPP data. Our optimal values of *b* are lower than those found at other aquifer sites in Kansas and Washington, possibly indicating that the glacial sediments are more consolidated. The optimal value for *m* is 1. Values for *n* are typically 1 or 2 indicating NMR relaxation in either the slow or fast-diffusion regime respectively. We find the slow-diffusion regime (*n*= 1) is optimal for one of the field sites, and the fast-diffusion regime (*n*= 2) for the other. Using these empirical constants in most cases gives us an NMR-derived K that differs by a factor of 2-3 from the DPP-measured K. Calibrating NMR models of *K* in the glacial aquifer system will improve our understanding of the link between NMR and *K* and improve future estimates of *K* in glacial sediments.

Recharging Near-surface Aquifers using Low-cost Direct Push Wells: A Case Study in the Lower Republican River Basin, Kansas

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Aquifer storage and recovery (ASR) is the artificial recharge and temporary storage of water in an aquifer when water is abundant, and recovery of all or a portion of that water when it is needed. Recently, interest in ASR has increased due to various concerns such as declining groundwater resources, vulnerability of surface water supplies to contamination and reservoir sedimentation, and unfavorable projections of future climate change. In this study, we evaluated a new recharge method for ASR in near-surface unconsolidated aquifers using small-diameter, low-cost wells installed with direct-push (DP) technology. The effectiveness of a DP well for ASR was compared with a surface infiltration basin at a field site in the Lower Republic River basin, north-central Kansas. Initial DP-based characterization of the shallow, unconsolidated subsurface indicated that both the vadose and saturated zones have many low permeability silt and clay layers constraining vertical flow. The performance of the surface basin as a recharge approach was poor at the test site due to the presence of a continuous clay layer at a depth of 1.5 to 3 m, which prevented the downward movement of infiltrated water and significantly reduced the recharge capacity of the basin. The DP well, on the other hand, penetrated through this clay layer and was able to recharge water at a much higher rate without use of a pump (water moved by gravity alone). Most importantly, the costs of the DP well, including both the construction and land costs, were only a small fraction of those for the infiltration basin. The low cost of DP wells can significantly expand the applicability of ASR as a water resources management tool to regions with limited resources, such as many small municipalities and rural communities. Our field results have clearly demonstrated the great potential of DP wells as a new recharge option for ASR projects in near-surface unconsolidated aquifers.

Application of a Bioaccessibility-based Method for Pyrethroid Insecticides: A Case Study

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Pyrethroids are a class of widely-used insecticides that can be transported from terrestrial applications to aquatic systems via runoff. Pyrethroids are detrimental to stream ecosystems due to their overt toxicity to sediment-dwelling invertebrates, and the risk of pyrethroid exposure tends to be greater in urban landscapes. In this collaborative project, we assessed total and bioaccessible pyrethroids in the sediments collected during the 2016 Northeastern Stream Quality Assessment. In this work, 49 stream sediments were surveyed for nine current-use pyrethroids using two extraction methods: total pyrethroid concentrations were determined by exhaustive chemical extraction, and bioaccessible pyrethroid concentrations were determined by single-point Tenax extraction. Total and bioaccessible pyrethroids were detected in the majority of sites (76% and 67%, respectively), and this detection frequency was similar to other metropolitan areas in the United States. The average total concentration of pyrethroids across all sites was 259 ng/g organic carbon (OC), while the average bioaccessible concentration was smaller, 43.9 ng/g OC. Sediment toxicity was assessed using amphipod bioassays, and in contrast to higher detection frequency, only 28% and 15% of sediments caused a decrease in amphipod biomass and survival, respectively. Bifenthrin was the most commonly detected pyrethroid in sediments. As confirmation, a temperature-based focused toxicity identification evaluation was used to support pyrethroids as the causal factor for toxicity. Sediment toxicity was equally well-predicted by total and bioaccessible pyrethroid concentrations expressed as toxic units. This work suggested that while pyrethroid contamination is widespread in urban streams in the northeastern United States, bioaccessibility-based methods, such as Tenax extraction, are a useful complementary technique that can help explain sediment toxicity results.

Does the Use of a Sediment Holding Time Bias Laboratory Bioassay Results?

Michael Lydy, Southern Illinois University Carbondale
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The adverse effects of hydrophobic organic compound (HOC) exposure in field sediments are often assessed using laboratory-based bioassays. After sediment samples are collected, current protocols state the sediments are stored at 4^{o}C, prior to beginning the bioassays. While a sediment holding time is common practice, its influence on the reliability of bioassay results is largely unknown, especially for current-use HOCs, such as pyrethroid insecticides. The toxicity to and bioaccumulation by aquatic invertebrates relates to the concentration of HOCs in the rapidly-desorbing phase of the sediment, i.e. the bioaccessible concentrations. Single-point Tenax extraction is a bioaccessibility-based method that can estimate bioaccessible concentrations with sufficient temporal resolution to track changes in concentrations during recommended sediment holding times. In this study, repeated measurements of bioaccessible concentrations and amphipod survival and growth were made as a function of sediment holding time using pyrethroid-contaminated field sediments. Similarly, bioaccessible concentrations and bioaccumulation were measured in oligochaetes as a comparison using the legacy HOCs, polychlorinated biphenyls (PCBs). While the bioaccessible and bioaccumulated PCB concentrations did not change significantly through 244 d of holding time, the bioaccessible pyrethroid concentrations were more varied. Depending on when pyrethroid-contaminated sediments were sampled, the bioaccessible pyrethroid concentrations showed first-order loss with half-lives ranging from 3 to 45 d of holding, or slower, linear decreases in concentrations (up to 14% decrease over 180 d). These findings suggest that for recently deposited contaminants, holding the sediments prior to bioassays has the potential to bias toxicity estimates.

Session 32, The USGS Water Resources Research Act National Competitive Grants Program (104G): What Have We Learned in the Last 10 Years?

Using Weathering Geochemistry to Understand Sources of Stream Flow Generation in Streams Traversing Mountain-basin Transitions in the Upper Missouri Watershed

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In many watersheds of the western United States, high-relief mountain headwaters drain to low-relief intermountain basins, providing water critical to human infrastructure that typically dominates the intermountain basin. The resulting patterns of exchange among streams, irrigation canals, soil water, and groundwater, in turn control water quality and sustain the spatiotemporal distribution of recharge necessary to support groundwater use and streamflow generation during dry periods. Understanding how these exchanges ultimately contribute to the hydrologic storage necessary for streamflow generation will be critical for predicting how a changing climate will influence the coupled human-natural systems of the western United States. Here, we explore the spatiotemporal distribution of surface-subsurface exchange along longitudinal synoptic transects of water quality in the Gallatin River Watershed, including a mountain-headwater process domain (Hyalite Canyon) and its mountain front transition to an intermountain-basin process domain (Gallatin Valley). In Hyalite Canyon, we use strontium and uranium concentrations and their isotopic ratios (^{87}Sr/^{86}Sr and ^{234U}/^{238}U activity ratios) as indicators of variability in water-rock interaction, and we subsequently apply mixing analyses to demonstrate how these tracers are uniquely useful to differentiate sources of streamflow generation from aquifers associated with differing lithologic units along the canyon. Also in Hyalite Canyon, we compare longitudinal patterns of d^{18}O and d^{2}H in precipitation, snowpack, and stream water to infer seasonal patterns in connectivity between streamflow generation and precipitation or snowmelt. Finally, patterns in ^{87}Sr/^{86}Sr and ^{234}U/^{238}U activity ratios from Hyalite Canyon into the Gallatin Valley become more uniform from the mountain front to the watershed outlet. This homogenization suggests increasing contributions from an alluvial groundwater reservoir that is a well-mixed combination of recharge sources along the mountain front, and is also subject to further evolution in water quality driven by human infrastructure and infiltration through soils. Hydrologic concerns in the western US now demand that we understand the processes that provide sustainable water resources. Most conventional watershed hydrologic models were designed to predict the response of watersheds to precipitation, and thus their ability to predict low flow in dry seasons is often suspect. More spatially explicit studies of surface-subsurface exchanges, such as those presented here, will allow development of a new generation of watershed-scale hydrologic models that incorporate the groundwater dynamics necessary to understand reliability of dry season streamflows under future climate conditions.

Pathogen Monitoring and Quantitative Microbial Risk Assessment of Secondary Water in Cache Valley, UT

Jennifer Weidhaas, University of Utah
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Diminished water supplies have resulted in increased use of secondary water for irrigation, including the use of treated municipal wastewater. Treatment plant effluent, secondary water systems, and irrigated vegetable crops in Cache Valley, UT were tested for the presence of bacterial, protozoan, and viral pathogens by culture-based and quantitative polymerase chain reaction (qPCR) based methods. Culture-based results indicate the secondary water quality decreases after release from the wastewater treatment plant, and in some irrigation plots exceeds the *Escherichia coli* geometric mean of 126 CFU per 100 mL set by the FDA Food Safety Modernization Act guidelines for agriculture water. Furthermore, qPCR analysis of residential and farm secondary waterlines, and irrigated vegetables reveals the presence of viruses (norovirus genotype I and human adenovirus serotypes 40 and 41), protozoans *(giardia* spp.) and bacteria (*E. coli*, *Salmonella* spp., and *Enterococcus faecalis*). Mean qPCR results for samples collected from Hyrum, UT secondary waterlines are the following: norovirus G1 (0.2 average gene copy/L), human adenovirus S40/41 (0.7 average gene copy/mL), *Giardia* spp. (1.8 average gene copy/mL), *E. coli* (146.2 average gene copy/mL), *Salmonella* spp. (0.1 average gene copy/mL), and *E. faecalis* (480.6 average gene copy/mL). A quantitative microbial risk assessment of exposure to waterborne pathogens from ingestion of water adhered to or taken up by irrigated vegetables and accidental ingestion scenarios was calculated using Monte Carlo estimation methods on the culture and qPCR results.

Monitoring Pharmaceuticals and Personal Care Products in Secondary Water Distribution: Risks to Human and Environmental Health

R. Ryan Dupont, Utah State University
(Authors: L. Ahmadi, K.T. Duodu, R.R. Dupont, J.E. McLean)

In various municipalities in Utah, treated municipal wastewater is used during the irrigation season for urban and agricultural irrigation. Hyrum City located in Northern Utah has one of the most advanced wastewater treatment systems in the state and discharges its effluent into a pressurized secondary water distribution system for use of the residents during the irrigation season. Some of Hyrum residents use the reclaimed water for irrigating their lawns, filling their pools, and growing vegetables. This USDA-NIFA funded project investigates quantification and detection of 12 pharmaceuticals and personal care products (PPCPs) in reclaimed water used for urban irrigation, in order to study and manage the risks associated with reuse of treated wastewater for the wide range of individuals exposed to it. Accordingly, various influent, effluent, distribution system, irrigation water, soil and plant samples were taken throughout the Hyrum system during two consecutive years and analyzed for 12 PPCPs. The 12 PPCPs include: Acetaminophen, Caffeine, DEET, Sulfamethoxazole, B-Estradiol, Estrone, Progesterone, Gemfibrozil, Carbamazepine, Triclosan, Fluoxetine and Tris-(2-chloroethyl) Phosphate. Quantification of these PPCPs in water samples was done using a Solid Phase Extraction method and a Triple Quad LC/MS System. After lyophilizing the soil and plant samples and using an Accelerated Solvent Extraction method, a similar approach to water samples was used for PPCP detection and quantification in the collected solids. The results of PPCP removal by the Hyrum Treatment Plant, along with the PPCP concentrations in irrigation water, in the distribution line, in soil and in a wide variety of vegetables (squash, cucumber, tomato, and etc.) grown with reclaimed water will be presented. The potential risks of reuse practices based on the quantitative PPCP results will be discussed.

Session 33, Water Reuse in Utah: Exploring Opportunities and Risks through Engineering, Extension, and Social Science

Water Reuse in Utah - Is it your Water to Reuse?

Niel Allen, Utah State University

Water Reuse is a great tool, but requires careful consideration due to water rights, water quality permits, and implementation requirements. In many areas, discharged wastewater is reused for agricultural irrigation and other purposes by valid historic water rights. The Water Reuse Act established legal and regulatory processes to protect water users and the environment. The reuse of water requires the approval by State Engineer's water rights office and due process to protect existing water uses and users. The Utah Water Reuse Act requires that proposed water reuses are consistent with the underlying water right, the water reuse does not enlarge the underlying water right, and any return flow requirement of the underlying water right is satisfied. The reuse can be by a public agency who holds the water right, reuse by another party through a change in water right or existing water right, or by a contract. In all cases, the reuse is subject to the water right process of the state. Additionally, all discharges are subject to compliance to water quality standards and discharge permits, and reuse is subject to State Water Quality regulations and Board decisions. Examples of water reuse for conserving water and improving water quality will be presented that meet the Utah Water Code provisions and protecting existing water rights.

Public Perspectives in Northern Utah on Water Reuse in Secondary Water Systems

Courtney Flint, Utah State University
(Authors: C. Flint, K. Koci)

Diminished water supplies in the United States have led water managers to incorporate alternative water sources in local water provision, including the reuse of treated municipal wastewater (also known as reclaimed or reused water). While relatively advanced treatment methods are often used to remove contaminants from municipal wastewater, questions remain about the potential for possible harmful contaminants to exist in reused water even after treatment. Local stakeholders' perspectives regarding reused water are essential to fully understand the implications of these water provision changes at the local level. This study evaluates residents' perceptions of risk regarding water reuse for residential irrigation purposes in Cache Valley, Utah. We conducted a survey in Hyrum, Utah (where reclaimed water is used in residential secondary water distribution) and Logan, Utah (where there is no residential water reuse). Results of this survey offer insight into how residents in Hyrum use reclaimed water, whether they perceive risk associated with specific reclaimed water uses, and general public acceptability of residential and agricultural water reuse. We also compared risk perceptions and acceptability of reclaimed water use between Hyrum and Logan. Findings suggest that Hyrum and Logan respondents generally support the idea of reusing treated wastewater for agricultural and residential irrigation. They have a range of perspectives on potential health risks involved with using reclaimed water for irrigation. Those who had *not* heard of reusing treated wastewater for irrigation were more likely to agree there is *no* health risk involved. Additionally, findings suggest that respondents' health risk perceptions correlate with reclaimed water use, with landscaping seen as the most common and safest reclaimed water use. While some households do use reused water for children's play and swimming pools, the majority of respondents do not see these uses as safe. We will present further details from the survey analysis and implications for managing water reuse with local constituents.

Session 33, Water Reuse in Utah: Exploring Opportunities and Risks through Engineering, Extension, and Social Science

Variations in Water Reuse Practices in Utah

Hillary K. Fishler, Utah State University
(Authors: H.K. Fishler, C.G. Flint, L.N. Allen)

Water reuse has been acknowledged as a way to manage increasing demand for water and diminishing water supplies. Utah is the second driest state in the union, with a growing population that will stress available water sources for uses as culinary drinking water, for agriculture, residential irrigation, industry, and returns to the Great Salt Lake. Across the state, municipalities and water districts are considering and beginning to adopt novel solutions to assist in the conservation of water for the future. A number of these municipalities are pursuing wastewater reuse to alleviate symptoms of water scarcity and to maintain quality of life for residents. This research utilizes qualitative interviews with municipal water providers, water conservancy districts, water treatment operators, and other decision makers across the state of Utah, to examine water treatment and reuse strategies and decisions. We explore varied water reuse practices in the state that differs by available water treatment technology, available water sources, unique water access policy, land use history, current hazards and environmental challenges, water user typologies, and reported secondary use needs. While current literature states that inception of reuse practices depend on public acceptance, technology, and economic viability, our findings suggest that across Utah, the drivers and barriers are more nuanced. We will explore the varied reported water reuse objectives across municipalities in Utah, their intersections with water conservancy districts, regional variations, and key takeaways in planning for the future of water reuse within Utah. An overview of ongoing reuse activities from this study will be available in an updated version of the 2005 Water Reuse in Utah report.

Leveraging Soil Health for Watershed Health

Ann Lewandowski, University of Minnesota Water Resources Center

Soil plays a pivotal role in the water cycle, mediating evapotranspiration, surface and subsurface water flow, and the transport and transformation of nutrients, pollutants, and other water constituents. Soil health -- the capacity of soil to perform these and other functions – is altered by land management practices, making soil health management a means to alter water quality and flow. Yet this tool for water resource management has been underutilized. This presentation summarizes the types of activities happening in the Midwestern United States to advance adoption of soil health management systems, and offers guidelines to increase the use of soil health management as a means to water resource management. Examples of important activities are farmer-led councils and soil health teams to facilitate peer learning in several states, the Conservation Cropping Systems Initiative to train conservation professionals in Indiana, the Minnesota Office for Soil Health to strengthen local initiatives, the North Central Region Water Network's Soil Health Nexus, and several others. Together, these efforts unite the individual projects with a watershed-scale planning approach. Several elements are needed to expand these types of activities and to make a more effective connection between soil health and improved water resources. Most importantly, researchers and managers need a watershed view of soil health that goes beyond the more common field- or point-scale view. Linking processes at different scales has implications for how we prioritize, plan, and implement soil health management systems in contrast to other types of water resource management projects. The objective of this presentation is to lay groundwork for a soil health session at the 2020 UCOWR conference.

Integrated Best Management Practices of Terraces, Cover Crops, and No-Tillage for Managing Nutrient Loss

Gurbir Singh, Southern Illinois University/University of Missouri
(Authors: G. Singh, K.A. Nelson)

Increased emphasis on implementation of conservation practices [terraces, conservation tillage including no-till or reduced tillage, and cover crops (CC)] have led to the integration of best management practices (IBMPs). However, research on IBMPs is limited. Therefore, a field trial was established at the University of Missouri Grace Greenley Research Center near Leonard, Missouri to evaluate the effects of terraces with landscape positions and CCs on soil health parameters, CC biomass accrual and no-till corn (*Zea mays* L.) -soybean [*Glycine max* (L.) Merr] yields. Additionally, total suspended solids (TSS), nitrate-N (NO_3-N), and total phosphorus (TP) export and discharge was also evaluated from terrace with or without CCs. Six parallel terraces were installed at 36.5 m spacing with each consisting of an individual underground tile outlet. Soybean was planted in 2016 and 2018, and a CC blend was overseeded at R6. Corn was planted in 2017 and cereal rye (Secale cereal L.) CC was drill-seeded after corn harvest. Soil health parameters had significant ($p<0.10$) year by landscape position interactions for Mg, K, total organic C, and clay content. Each of these parameters was same among landscape positions before terrace construction, and at least one of the landscape positions differed following terrace construction. Cover crop in terraces reduced soybean and corn grain yield by 12 and 6% in 2016 and 2017, respectively, and increased soybean yield 4% in 2018. Crop yield was greatest at the shoulder landscape position and lowest in the channel in all years. Terraces with CCs reduced TSS from 363 to 4713 g ha^{-1}, TP from 2 to 90 g ha^{-1}, NO_3-N from 147 to 3407 g ha^{-1}, and discharge from 41 to 81 m^3 ha^{-1} compared to no CC terraces. Two-year cumulative TSS, NO_3-N, and discharge from CC terraces was 41, 52, and 43% lower than the terraces with no CC. Cover crops did not affect cumulative TP loss. Cover crops were an effective tool for reducing discharge and nutrient loss in a no-till tile-terrace field.

Alternative Practices to Reduce Nutrient Pollution: A Bio-economic Spatial Model

Lucia Levers, University of Minnesota
(Authors: L. Levers, B. Dalzell, J. Peterson)

The Mississippi River Basin includes some of the most productive agricultural lands in the world, and much of the landscape is dominated by corn and soybeans. These crops are harvested in the fall and fields are typically left barren through the winter. Under this management, excess nitrogen fertilizer can be delivered to streams and rivers, ultimately contributing to local and regional water quality degradation, including the hypoxic zone in the Gulf of Mexico. Potential remedies to this problem include introduction of winter cover crops, or establishing perennial cover such as switchgrass or prairie restoration. To evaluate these alternatives, we combined a biophysical watershed model (SWAT) with an agro-economic optimization programming approach; our framework simulates policy driven land use and environmental effluent shifts. While it is common to evaluate the impacts of farm management practices at a fine resolution, many management decisions are made at the scale of the farm field—suggesting that there may be a spatial disconnect between managing for environmentally and/or economically optimum outcomes vs. managing in a manner that is practicable. As such, we employ a novel and more realistic management unit approach, in addition to shifts at the HRU (hydrologic response unit) level. We applied our framework to Beaver Creek watershed, a tributary of the Minnesota River Basin and simulated land management changes required to achieve nitrogen reduction benchmarks. We found that while perennial crops are more environmentally beneficial, strategically located cover crops can be used as the sole practice to achieve significant environmental benchmarks. As the management unit increases in size, the loss of potential profit to the farmer increases as well. Additionally, high levels of precipitation greatly influence the environmental damages as well as the relative amount of alternative practices needed to reach nutrient reduction goals. This suggests climate change projected for our study area will make nutrient reduction ever more difficult to achieve.

The Role of Systems Thinking in Early Adopter Conservation Behaviors: Implications for Middle Adopters

Linda S. Prokopy, Purdue University
(Authors: S. Church, J. Arbuckle, K. Floress, B. Gramig)

This presentation includes results from a completed review and meta-analysis of 35 years (1982-2017) of quantitative and qualitative social science research papers that have examined motivations of and barriers to adoption of conservation practices in US agriculture. The proposed study updates and greatly expands on previous work that has reviewed BMP adoption. This meta-analysis: (1) reviews all appropriate studies published during the timeframe, (2) accommodates a number of advances in this field of study such as the growth of qualitative research with farmers, and (3) focuses on both barriers to and motivations for adoption. All U.S. studies found in the peer-reviewed literature, theses/dissertations, and grey literature since the early 1980s were reviewed for potential inclusion in this meta-analysis and review. Papers were identified through database literature searches. The project investigators employed vote-count meta-analysis and qualitative coding methods to identify patterns and trends in the literature. After a brief discussion of the study's methodology, the speakers will present study findings and discuss implications for conservation outreach and education as well as suggestions for future adoption studies.

Meta-Review of Barriers and Motivations for Farmers to Adopt Conservation Practices

Linda S. Prokopy, Purdue University
(Authors: S. Church, J. Lu, L.S. Prokopy)

To address critical water quality problems, significant public and private sector resources have been directed to promoting and supporting the adoption of conservation practices and systems-level conservation approaches. Cover crops, in particular, have been a focus of outreach and policy efforts due to their multiple benefits for crop production, carbon sequestration, soil health, and water quality. Indiana is a national leader in cover crop adoption. We hypothesize that Indiana's state and local agencies have emphasized a systems approach to conservation planning and farm management, which has been successful in reaching early adopters. We contend that the systems approach to conservation adoption is not a salient message to middle adopters, thus adoption (particularly cover crops) remains stagnant. In this talk, we report data from producer surveys administered in three Indiana watersheds – St Marys, Big Pine, and Upper White – as well as preliminary data from producer and conservation staff interviews in two watersheds – Big Pine and Upper White. We found that producers who adopted either cover crops, a conservation plan, or conservation tillage were more likely to be systems thinkers than non-adopters. Interview data indicate similar findings. These results have significant implications for conservation planners who work to enroll additional acreage in conservation and conservation programs – a whole farm systems approach to conservation messaging may not be an effective method for middle adopters.

Session 35, Tools and Resources for Coping with the Impacts of Drought and Water Scarcity in a Changing Climate

What is the United States Drought Monitor and How Does it Identify Drought

Brian Fuchs, National Drought Mitigation Center

The United States Drought Monitor (USDM) (Svoboda et al., 2002) has become the go-to resource for the weekly objective assessment of drought in the United States and continues to be used more and more by stakeholders and federal agencies for a variety of decision-making activities. When the USDM was developed in 1999, the largest limiting factor was the regular availability of data that covered the United States in a near-real time capacity. Only a handful of drought-related indices and indicators were available each week, and most were being disseminated at a very coarse climate division scale. One of the many strengths of the USDM is that the process of making the weekly map has been flexible, allowing it to evolve over time and incorporate new data as they have become available. For the researchers who are developing these new types of data, the USDM in turn enables them to see the data being used in a very useful and scientific manner. From the early beginnings of using coarse climate-division-based data, the USDM currently is incorporating a number of gridded data that are available at a very high resolution. New tools such as the Evaporative Stress Index (ESI), the Evaporative Demand Drought Index (EDDI), and the Vegetation Drought Response Index (VegDRI), as well as numerous satellite-based products and gridded data products, have allowed the USDM process to evolve to produce the map at a finer resolution than when it started. By adding several dozen sources of subjective data to feed into the "convergence of evidence" approach that is the basis of the strength of the USDM, the USDM process is flexible enough to incorporate any number of inputs into assessments.

Drought in New Mexico - Challenges and Opportunities for Characterizing and Communicating Drought Impacts

Dave DuBois, New Mexico State University

Characterizing and communicating drought never comes easy. Common with other western states, New Mexico has over a 10,000 feet elevation difference between the mountain peaks of the north and the Permian Basin of the southeast. That comes with a host of challenges in dealing with many climate zones, land covers, and land uses. Another challenge that we deal with is balancing the short-term drought impacts less than a few months with longer ones lasting years. Finding the impacts that are important to the user of the data is critical. Intentionally engaging our media partners throughout the process has been an important part of our work in communication. The increasing role of social media in promoting current events including drought is noted. I found working with the CoCoRaHS observing community worked well where we requested them to submit condition reporting reports. Every state addresses drought assessment and reporting different and in New Mexico we provide updates to the US Drought Monitor as a team consisting of the National Weather Service and the New Mexico State Climate Office who are supported by many federal, state, municipal, and tribal staff providing data. During the process we work with the users of our drought assessment such as the US Drought Monitor, agricultural communities, state agencies, and the media. The USDA Southwest Climate Hub and Farm Service Administration agents were played key roles in both tracking drought and communicating it to our various groups. I will use 2018 as a case study to illustrate how snow drought in the high elevations of northern New Mexico and southwest Colorado intensified drought that lasted more than a year later. One of the methods to communicate this was finding an analog year in the past to compare and contrast. By the end of 2018 the Four Corners remained dry while the rest of the state received enough precipitation to improve short-term drought.

Session 35, Tools and Resources for Coping with the Impacts of Drought and Water Scarcity in a Changing Climate

Using Ecological Site Information to Develop Drought Response Strategies

Emile Elias, USDA ARS, SW Climate Hub
(Authors: J. Brown, E. Elias, J. Reyes, C. Steele, A. Wyndam)

Ecological Sites (ES) are interpretive groupings of static soil properties with unique climate, geomorphic and edaphic properties. They can be mapped using National Cooperative Soil Survey tools and are supported by standardized, databased descriptions that include spatial biophysical attributes (e.g. soil depth, texture) and temporal behaviors (e.g. vegetation dynamics, disturbance responses). In this project, we used ecological site information to evaluate the potential impact of drought conditions and to develop potential response strategies in two Major Land Resource Areas (MLRAs). MLRA 69 in SE Colorado is characterized by mollisols, short grass prairie vegetation and extensive livestock grazing/dryland small grains. MLRA 41 in SE Arizona is characterized by aridisols, desert shrub/oak woodland/desert grassland vegetation and is used for livestock grazing. We developed drought vulnerability assessment criteria to rank impacts on specific management units and to serve as a basis for developing strategic responses. The primary threat of drought in MLRA 69 is reduced livestock forage and mid-term suppression of forage production post-drought, including ranch-level economic impacts. Soils and vegetation are relatively well-adapted to drought and have substantial capacity for recovery, but economic stability is more fragile. MLRA 41 has experienced, and continues to, experience short, medium and long-term drought impacts. Short term impacts include reduced forage production; medium term impacts are primarily suppressed forage production post-drought; and long-term impacts include grass to shrub transitions and soil degradation. Within each MLRA, there were substantial differences among ES, both in terms of reduction of forage production and in long-term recovery post drought. These differences offer opportunities for managers to develop drought responses by selectively destocking management units as drought progresses and restocking post drought.

Grass-Cast: A New Tool to Inform Drought Management in the West

Dannele Peck, USDA Northern Plains Climate Hub
(Authors: W. Parton, M. Hartman, J. Derner, D. Peck, B. Fuchs, W. Smith)

The USDA Northern Plains Climate Hub facilitates communication and collaboration between agricultural producers and researchers, particularly those with expertise in climate and agriculture. By engaging scientists in conversations with producers and their trusted technical advisers (e.g., University Extension professionals and USDA Service Center staff), the relevance and usability of research outputs can be dramatically improved. This engagement process was crucial in the development of a new Grassland Productivity Forecast or “Grass-Cast,” which can help ranchers in the Great Plains better anticipate and prepare for drought and associated shortages in summer grazing resources. Grass-Cast uses over 30 years of historical data on weather and vegetation growth—combined with seasonal precipitation forecasts—to predict if rangelands in individual counties are likely to produce above-normal, near-normal, or below-normal amounts of vegetation. Grass-Cast was first released to the public in 2018 for the Northern Great Plains, and to the Southern Great Plains in 2019. Work is now underway to develop Grass-Cast for the Southwest region of the United States. We provide an overview of the modeling process used to produce Grass-Cast, which involves a process-based ecological model, historical weather data, sub-seasonal climate outlooks, remotely-sensed NDVI data, and long-term measurements of above-ground net primary productivity. We then discuss how ranchers and other rangeland managers can use Grass-Cast to help inform and carry out their drought management plans. Finally, we describe the process used to engage stakeholders in the design of Grass-Cast, which made it more relevant and thus of greater interest for potential adoption/use.

Assessment of UAV Flight Times for Estimation of Daily High Resolution Evapotranspiration in Complex Agricultural Canopy Environments

Ayman Nassar, Utah State University
(Authors: A. Nassar, A. Torres-Rua, M. McKee, W. Kustas, C. Coopmans, H. Nieto, L. Hipps)

Evapotranspiration (ET) is a key variable for irrigation water management, with significant importance in drought-stricken areas as California, the West US and high value crops. The advent of UAV technology with similar technology as satellites' allows for the estimation of high-resolution ET at crop row spacing. While current UAV ET research looks to match satellite overpass time (~10:30 AM local time for Landsat), occurrence of cloud or high wind speeds, can restrict UAV flights and affect remote sensing data quality. In addition, ET estimates acquired by remote sensing platforms are instantaneous ET (mm/hr), which are translated to daily scale (mm/day), assuming the instantaneous ET ratio is constant along the day. While this assumption can be considered valid for full cover crops (alfalfa, corn), temperature regimes (linear surface temperature gradient in the morning, nonlinear in the afternoon) in complex agricultural environment may not fulfill this assumption along the day. In this study, high resolution multispectral and thermal UAV at different times of day in multiple seasons are used to identify the sensitivity of daily ET to time of data acquisition. Data from collection campaigns conducted during multiple years and times of day (morning, Landsat overpass and afternoon) by the Utah State University AggieAir UAV Program over a commercial vineyard located near Lodi, California as part of the USDA Agricultural Research Service Grape Remote Sensing Atmospheric Profile and Evapotranspiration eXperiment (GRAPEX) Project are used. Landsat-harmonized optical along with atmospherically calibrated thermal imagery data from UAV at 10 cm and 60 cm are used. A thoroughly tested Two-Source Surface Energy Balance Model (TSEB2T) model is used to estimate and validate instantaneous and daily ET using eddy covariance measurements. The procedure and analysis for the different times of the day and crop seasonal pattern are presented and discussed.

Western WERA - Watershed Processes and Human Water Systems

Sam Fernald, New Mexico State University

This is a group panel to explore new directions for the new western WERA - Wateshed Processes and Human Water Systems. It involves speakers from all western states. They will give presentations about their areas of expertise. A moderated discussion will explore directions for the new WERA.

Resiliency Analysis of Stormwater Drainage System under Climate and Landuse Changes in Jordan River Watershed

Muhammad Imran Chaudhry, University of Utah

In this research, an SWMM model is developed for stormwater quality and quantity of the Jordan River watershed, Utah. The objective of this research is to study the impact of the future climate change scenarios encompassing the four AR5 climate projections and provide inputs to other models (EFDC, GoldSim, DHSVM, and WASP) to create a system dynamic model of the integrated urban water system for the Salt Lake City metropolitan area. Along with the climate change scenarios future land use changes are studied and implementation of BMP/LID to achieve water quality and quantity as per Utah Pollutant Discharge Elimination System (UPDES). The expected results are the temporal and spatial variations in stormwater runoff quality and quantity.

Agriculture as a System for Managed Aquifer Recharge for Drylands by Restoring Hydrologic Connectivity to Floodplains and Aquifers in Watersheds

Connie Maxwell, New Mexico Water Resources Research Institute
(Authors: C. Maxwell, S. Langarudi, A.S. Fernald, J.P. King, D. Cadol, A. Faist)

In the American Southwest, what underlies both drought and increased flooding as social crises is a water storage problem. Less winter precipitation has diminished snowpacks and the resulting spring runoff. Reduced soil infiltration capacity coupled with increased precipitation intensity has increased runoff energies and the resulting catastrophic flooding. Alternative water management strategies that replenish groundwater and soil storage systems have increasingly become critical. Maximizing available water storage will require land managers to develop innovative solutions to handle stormwater supplies that arrive in fewer and increasingly intense monsoonal bursts. Historically, floods along the Rio Grande River network in New Mexico were more connected to more richly vegetated floodplains, which resulted in watersheds retaining more their water and soil resources. Agriculture supported that natural dynamic through systems of stormwater harvesting and by spreading flood flow onto floodplains (floodplain connectivity) which resulted in infiltration into shallow (aquifer connectivity). Today management has lost many of these system functions, and communities are seeking solutions to watersheds "leaking" their resources of water and soil. A broad group of stakeholders in Southern New Mexico are collaboratively facing the related challenges of severe water scarcity and erosion from drying uplands in watershed clogging valley irrigation systems and riparian areas. To predict how much ecological restoration it would take to turn degradation trends around, we developed a remote sensing and system dynamics modeling approach to identify and predict high priority areas for restoring an optimum level of floodplain and aquifer connectivity. We synthesized hydrologic flow data, satellite images, spatially explicit models, and generalized linear models into a system dynamics model to predict landscape behavior responses. The evaluation resulted in identification of interventions with the potential to achieve a target level of ecosystem service benefits. Nearly forty percent of the global land surface is managed in agriculture, and with potential innovative adaptation, agriculture can once again become a system for recharging our aquifers and restoring our watersheds.

California Climate Smart Agriculture

Laurent Ahiablame, University of California, Agriculture and Natural Resources
(Author: D. Parker)

The University of California, Agriculture and Natural Resources is developing a Climate Smart Agriculture program, much like University of California Statewide Integrated Pest Management program, that is distributed across the state and focused on implementing on-farm solutions to mitigate and adapt to climate change. Mitigation impacts and contributions include information distribution, voluntary adoption and assisting growers when applying to the California Department of Food and Agriculture's (CDFA) incentive programs and activities such as soil health, nutrient management, irrigation management, on-farm composting and manure management. The program will assemble a cohort of UC ANR Community Education Specialists that are located in 10 counties throughout the state. The cohort will provide information to growers, application assistance to growers to support CDFA's technical incentive programs and assist in research, extension and outreach on implementation of climate smart farming and ranching management practices. The program will serve as a conduit between discovery and implementation of these climate smart farming practices. The interagency coordination is intended to provide a strong communication and collaboration linkage between the University of California and the California Department of Food and Agriculture and amongst the cohort teams with the common goals of learning from each other and applying new research findings into practical management practices.

Public Perceptions of Flood Risk and Infrastructure Options

Jamie McEvoy, Montana State University
(Authors: J. McEvoy, E.A. Shanahan, N. Bergmann, E.D. Raile)

This lightning talk will discuss public perceptions of two infrastructure options for responding to flood risks in Montana. The first option is replacing existing levees. The City of Miles City, MT initiated a Section 205 study with the U.S. Army Corps of Engineers (USACE) which will identify alternatives for addressing the flood risk to the community. USACE is proposing a new levee to replace the existing levee which does not meet the standards required by the Federal Emergency Management Agency (FEMA). A second flood response option that is being promoted in other areas of MT by non-governmental organizations, including The Nature Conservancy, is the construction of "beaver mimicry" structures. In contrast to hard engineering solutions (e.g., levees), these projects use flexible, local, low-cost materials to reconnect streams with their floodplains and capture spring runoff in the floodplain. These responses have different effects on watershed processes, including groundwater storage. This presentation will focus on residents' public perception of a new levee in Miles City and landowners' perception of beaver mimicry projects in Beaverhead County, MT.

Improving the Predictability of Actual Evapotranspiration across Different Climates and Land Uses

Fabian Nippgen, University of Wyoming
(Authors: F. Nippgen, M. Ross, P. Stoy)

Evapotranspiration is a central component of the water balance and is needed to efficiently manage water resources. Quantifying evapotranspiration usually relies on complex models or expensive measurements. For this reason, annual evapotranspiration is often calculated as the residual of the water balance with change in storage assumed to be negligible. However, more recent research suggests this methodology overestimates the variability in annual evapotranspiration. We address the need for better predictability of evapotranspiration with a comprehensive analysis of the worldwide FLUXNET network of eddy covariance towers. We test different machine learning algorithms for predicting annual evapotranspiration across different climates and land uses with a special focus on the Intermountain West.

A Holistic Approach to Study Watershed-Riparian Systems in Oregon

Carlos Ochoa, Oregon State University

An improved understanding of ecohydrologic connections is critical for improving land management decisions in water-scarce regions of the western United States. For this study, conducted in a semiarid (358 mm) rangeland location in central Oregon, we evaluated precipitation-interception-soil moisture dynamics at the plot scale and characterized surface water and groundwater relations across the landscape including areas with and without western juniper (*Juniperus occidentalis*). Results from this study show that juniper woodlands intercepted up to 46% of total precipitation, altering soil moisture distribution under the canopy and in the interspace. Results indicate that precipitation reaching the ground can rapidly percolate through the soil profile and into the shallow aquifer, and that strong hydrologic connections between surface and groundwater components exist during winter precipitation and snowmelt runoff seasons.

Use of Eco-hydrologic Indicators in Assessing Differences in Watershed Hydrologic Response in Wyoming

Ginger Paige, University of Wyoming

The partitioning of water within watershed systems is a complex relationship between the dominant drivers (climate and management) and the watershed characteristics that can affect the eco-hydrologic responses. The hydrologic response of a watershed system may change in response to acute “natural” drivers (e.g., severe drought, wildfire), or significant immediate management actions (e.g., changes in dominant water use, implementation of large structures - dams) or change incrementally over longer-time scales due to the non-stationarity of climate. This “lightning” talk will look at eco-hydrologic indicators (e.g., lag-time, Precipitation/Evapotranspiration, Precipitation/runoff) in two watersheds in WY and their shifts relative to each other and over time.

Session 37, Panel Discussion: Water-Efficient Cities and Schools Ready to Meet Our Water-Short Future

Amidst today's unending reports of severe droughts, climate change, and dire prognostications about the world's threatened water supplies, too often missing in this collective handwringing is attention to solutions. How can we, and how must we, do more with less water in the years ahead? How much water is used–and wasted–in our cities, schools, and infrastructure? How much water can be saved with conservation and reuse? Are universities and colleges addressing these issues with their students and faculty, and how many schools "walk the talk" with active water saving programs? What roles and responsibilities should universities and colleges play in educating water professionals, researchers, technicians, and policy makers to meet our looming water supply and quality challenges?

To address these challenging questions, this panel discussion will include a water conservation manager and statistician from a major U.S. water supplier, a university educator/sustainability program leader, and a college water efficiency program educator and curriculum developer, all of whom have realized significant water savings from conservation programs in cities and schools, several of which have won awards.

Panel discussion topics will include:

- City of Dallas, Texas. How did Dallas become a national leader in saving water? How much water have they saved from conservation, and how were these savings achieved, e.g., technologies and policies? What are Dallas's "lessons learned" to help other cities and communities realize a water-efficient future?
- UConn/Storrs. How much water has been saved by the University of Connecticut/Storrs award-winning sustainability program? What drove UConn to achieve those water savings, and what were the benefits and costs? What key actions can universities and colleges take to save water on campus?
- Lane Community College (Oregon). What college and university level curricula and programs are needed to educate and train future generations of water efficiency professionals (engineers and planners), technicians, and policy makers? How has Lane's water efficiency program evolved, and where are their graduates now? What are the career prospects in water conservation and efficiency, and what skills and degrees are needed?

Panel organizer:
Amy Vickers, Amy Vickers & Associates, Inc.

Panelists include:
Holly R. Holt-Torres, Water Conservation Division Manager, Dallas Environmental Quality & Sustainability, City of Dallas
James McGuire, Director of the Office of Environmental Quality and Sustainability, City of Dallas
Michael P. O'Neill, Ph.D., Associate Dean & Associate Director, UConn Extension, University of Connecticut/Storrs
Roger Ebbage, CEM, Adjunct Faculty, Energy and Water Education Programs, Lane Community College (OR)

Session 38, Harmful Algal Blooms

The Evolving Legal Landscape for Nutrient Pollution and Harmful Algal Blooms

Catherine Janasie, National Sea Grant Law Center

2018 was a particularly bad year for harmful algal blooms (HABs). In June 2018, the city of Salem, Oregon, which obtains its drinking water from Detroit Lake, found dangerous levels of cyanotoxins in its water supply. The result was a “do not drink” water advisory that lasted for weeks, and the Oregon Health Authority implemented a rule requiring certain larger drinking water systems that use surface water to regularly test for cyanotoxins. At the opposite end of the country, Florida experienced its worst HAB in decades. As a result, Congress passed bipartisan legislation to combat HABSs, which President Trump signed in early 2019. The recent legislation updated the 1998 Harmful Algal Bloom and Hypoxia Research and Control Act (HABHRCA). Complementing this law are 2015 Amendments to the Safe Drinking Water Act that required the U.S. Environmental Protection Agency (EPA) to develop a strategic plan targeted at managing the risks of algal toxins in drinking water supplies. The EPA released Health Advisories for microcystins and cylindrospermopsin in 2015 and an Unregulated Contaminant Monitoring Rule for 30 contaminants, including 10 cyanotoxins, in 2016. Despite this Congressional attention, the regulation of nutrient pollution remains challenging. In December 2018, the EPA and U.S. Army Corps of Engineers proposed a new Waters of the United States (WOTUS) rule under the Clean Water Act (CWA) that could significantly curtail the reach of the CWA to regulate nutrient pollution. Due to the federal government shutdown, though, the proposed rule remains in limbo, as does the Obama Administration’s 2015 WOTUS Rule, which has been entrenched in litigation since being finalized. Also in limbo is the EPA’s 2016 Draft Human Health Recreational Ambient Water Quality Criteria for microcystins and cylindrospermopsin, which has yet to be finalized by the agency. This talk will provide an overview of the evolving legal landscape for nutrient pollution and HABs. In addition to providing a brief summary of existing laws, this talk will discuss the impact of litigation on Trump Administration rulemaking and previous actions taken by the Obama Administration.

Satellite Remote Sensing of Harmful Algal Blooms in the Southern Great Plains

Abubakarr Mansaray, Oklahoma Water Resources Center
(Authors: A. Mansaray, S. Stoodley, A. Dzialowski, K. Wagner, N. Torbick)

A major goal of water quality monitoring is to detect pollution related events, such as harmful algal blooms (HABs), and guide management decisions. A major challenge to this is the timeliness of detection and our ability to assess the spatial extent of pollution events and impacts. In Grand Lake O’ The Cherokees, HABs became a public health concern in July 2011 when an advisory for non-body contact included the Fourth of July holiday. This created the need to develop new strategies for timely detection of HABs. Satellite remote sensing provides the opportunity to achieve this goal. Our research integrated in situ water quality data with Landsat data and machine learning to build a tool allowing automated detection of HABs in the Grand Lake Watershed. In situ water quality data were collected from four reservoirs in Oklahoma and Kansas to develop indices for algae and turbidity as input into the HABs monitoring tool. The tool utilizes Python programming language to extract Landsat data from the U.S. Geological Survey website and interpret the data to indicate HAB conditions as high, medium, and low. Our goal now is to expand this tool to provide high resolution early warning systems for HABs throughout the region. Further studies are planned to utilize a tiered approach to integrate additional satellite platforms, unmanned aerial systems, and unmanned surface vessels to increase the reliability and timeliness of HABs detection and characterization in the region.

Comparison of Harmful Algal Blooms in Large Eastern and Western U.S. Lakes

John Bratton, LimnoTech
(Authors: J. Bratton, R. Lambert, J. Ibershoff, E. Verhamme, J. Wolfe, D. Dilks)

Harmful algal blooms (HABs), particularly of cyanobacteria, are commonly reported from many large lakes, particularly those that are shallow or that include shallow embayments. Recent blooms in western Lake Erie, Utah Lake, and Lake Okeechobee impacted drinking water, recreation, and irrigation. Current research has shown common factors among these blooms, as well as important distinctions, which are important to understanding their occurrence and possible mitigation. Shallow lakes or lakes with restricted embayments tend to retain nutrients in sediment that can cause internal loading which can fuel blooms for months. Such lakes also warm quickly and flush slowly, which favors rapid growth and persistence of blooms once they have begun. Laboratory and field experiments have indicated that phosphorus has a dominant role in bloom formation, but that nitrogen may also be important, particularly because of its relationship with toxin production in cyanobacteria such as *Microcystis*. Because of contrasts in watershed and lake processes in western lakes versus eastern lakes, effective HAB mitigation approaches may differ substantially in these settings. The relative role of nutrient loading from atmospheric deposition and runoff from snowmelt at higher elevations in western lakes, is contrasted with the importance of nutrient loading from agriculture in the east, especially from former wetland areas that have been hydrologically modified. Loading from wastewater may be important in either setting, where sufficient urban development exists to create substantial loads.

MN HAB Group: Responding to Proliferating Blue-green Algae in Minnesota Lakes

Shahram Missaghi, University of Minnesota Extension

Minnesota communities are facing potential negative environmental, health, and economic consequences of harmful and toxic algae. Freshwater Harmful Algal Blooms (HABs), formed primarily by toxin-producing strains of blue-green algae, pose specific and serious health risks to animals and people through contact with affected waters and through ingestion of algae and toxins in water, particularly when communities depend on lakes for swimming beaches or drinking water, as is the case for approximately 20% of the residents of Minnesota. Over the past three years, the MN HAB Group, a collaborative research team and funded in parts from the Environment and Natural Resource Trust Fund, has worked to develop an understanding on how to detect, track and predict the development and persistence of freshwater harmful algal blooms in Minnesota lakes. The Group has also facilitated collaboration and communication in research, education, training, and statewide outreach through an annual MN HAB Workshop sponsored by the University of Minnesota. To date, the Workshop has provided training to over 100 water resources students, professionals, and practitioners. As part of our presentation, we will also share information on algae bloom terminology, with a focus on blue-green algae in Minnesota lakes, while sharing our updates on advanced monitoring and modeling research. We also showcase the newly developed MN HAB Educational Trailer, a mobile educational unit that offers hands-on experience space and learning opportunities around HABs in MN lakes - for water resources professionals as well as the general public. The session participants will be invited to explore how we can better increase our understanding of blue-green algae in general in and discuss how we can work together and learn from each other to increase the resiliency of all of our communities to the potential for toxic algae breakouts.

Connecting Extension and Water Resources Research Institutes to Advance Harmful Algal Bloom Research and Outreach

Chad Cook, University of Wisconsin-Madison, Division of Extension
(Author: M. Miller)

Harmful Algal Blooms (HABs), or blue green algae, are naturally occurring; however, their frequency and intensity are increasing. Excess nutrients create a “greening” effect with the growth of algae, which challenges healthy ecosystem functionality. The largest of these water impairments is the hypoxic zone in the Gulf of Mexico due to runoff from the upriver states in the Mississippi River Basin. Lake Erie has also seen frequent and impactful blooms in recent years. Local water impairments, such as the Toledo, Ohio drinking water crisis in 2014, demonstrate the significant water damages that can occur if the issue is left without scientific remediation. Land Grant University-based Water Resources Research Institutes (WRRIs) focus on research related to local water issues. In 2017, WRRIs in the Mississippi River Basin recognized HABs as an emerging threat to the region. In an effort led by the Iowa Water Center, nine WRRIs aligned to focus their 2018 call for competitive seed grant funds on HABs. This resulted in 15 new research projects throughout the Mississippi River Basin. These projects, as well as another 30 funded between 2014-2017, have been catalogued to identify commonalities and major themes in order to coordinate and inform current and future research efforts. In 2018, this initiative led to the formation, with support from the North Central Region Water Network, of a twelve-state team partnering WRRIs and Cooperative Extension to assess current HABs outreach and education efforts and establish uniform recommendations for the North Central region. Extension, also associated with Land Grant Universities, is often on the front lines of communicating research-based information to stakeholders. This team sought to inventory the available literature from WRRI-sponsored HABs research, identify gaps in Extension HABs publications and outreach, and bring Extension and WRRIs together to assess programming needs. Using HABs as the focal issue, this initiative underscores the benefits of connecting the WRRIs, with their focus on research related to local water issues, to Extension, which is on the front lines of providing research-based information to stakeholders. This partnership is critical to providing the best public service. This presentation will provide an overview of this partnering effort, highlight some of the challenges and successes, and review some of the recommendations resulting from the discussions related to HABs research and outreach in the North Central Region.

Occurrence of Microcystin (or Lack Thereof) across a Nutrient Gradient in Ozark Streams

Brian Haggard, Arkansas Water Resources Center
(Authors: B. Austin, D. Lee, B. Haggard)

Most harmful algal bloom (HAB) studies in freshwater systems have centered around lakes and ponds, while relatively few studies have focused on the presence of algal toxins in streams. The purpose of this study was to document the occurrence of microcystin, a common cyanotoxin associated with HABs, within Ozark streams in Northwest Arkansas. Throughout the summer and early fall of 2018, 20 streams were sampled approximately bi-weekly for sestonic and periphytic microcystin and chlorophyll a (CHL *a*). Additionally, water samples were collected and analyzed for anions, total nitrogen (TN), and total phosphorus (TP). The streams sampled represented a nutrient gradient with mean TN and TP concentrations ranging from 0.46 to 3.70 mg L^{-1} and from 0.011 to 0.107 mg L^{-1}, respectively. Microcystin was detected in both the water and periphyton samples, with microcystin ranging from <0.1 to 0.4 µg L^{-1} in water samples and from <0.1 to 14.7 µg m^{-2} in periphyton slurries. Measured concentrations in 97% of water samples and 76% of periphyton slurries were below the reporting limits of 0.3 µg L^{-1} and both decreased throughout the summer. Sestonic CHL *a* was also low ranging from 0.01 to 11.93 µg L-1. Neither sestonic microcystin nor CHL *a* were related to either TN or TP during this study. Periphytic algal biomass was positively related to both TN (R=0.622; P=0.010) and TP (R=0.688; P=0.003). However, microcystin in the periphyton slurry was only related to periphyton ash free dry mass (R=0.516; P=0.041). All water column microcystin concentrations were well below the current EPA recreation standard of 4.0 µg L^{-1}.

Drought Insights from Retrospective Analyses of Federal Crop Insurance Payments and Causes of Loss

Julian Reyes, USDA Southwest Climate Hub (Authors: J. Reyes, C. Steele, E. Elias)

Over $100 billion worth of crops was insured through the Federal crop insurance program in 2017 alone. The U.S. Department of Agriculture (USDA) Risk Management Agency (RMA) oversees this program, which provides a financial safety net for farmers given price declines and weather-related perils. The reasons for crop loss (i.e., causes of loss) are an important component of crop insurance, and can provide information on risk management and future adaptation efforts. The synthesis and analysis of existing 'big data' in the agricultural sector can yield additional insights of such knowledge, as well as increase the overall collective value of these data. The creation of the USDA Climate Hub network prioritizes information synthesis and decision support tools by developing and delivering science-based information and technologies to agricultural and natural resource managers to enable climate-informed decision-making. As part of this, Hubs work across USDA agencies to synthesize existing information to meet the needs of our ultimate stakeholders - farmers, ranchers, and land managers. First, we describe an initial retrospective analysis at multiple spatial and temporal scales over the United States. Nationally, drought was the top two cause of loss since 2001, and was responsible for over 40% of nationwide climate-related crop loss payments. Regional differences in top causes of loss related to drought demonstrate the complex interactions of biophysical, climatic, socio-economic, and geo-political factors. Next, we explore how drought-induced crop loss payments are linked with other drought indicators such as the Palmer Drought Severity Index, U.S. Drought Monitor Categories, and events from the Drought Impact Reporter. Finally, we showcase the AgRisk Viewer, a web-based tool developed to more effectively deliver crop insurance data to our partners and stakeholders for increased accessibility, discoverability, and usability. Ultimately, we envision the project supporting adaptation in high production risk areas and agroecosystem resilience.

Islands of Resilience: Community Challenges and Responses to the 2018 Colorado Plateau Exceptional Drought

Emile Elias, USDA ARS SW Climate Hub
(Authors: E. Elias, C. Steele, J. Reyes, D. Brown, S. Behery, E. Weight)

Exceptional drought persisted over the Colorado Plateau and adjacent regions for nearly all 2018. This area serves as the headwaters for major rivers including tributaries to the Colorado River and the Rio Grande. Historic agriculture, extensive public lands, and recreation and tourism were impacted by unprecedented drought. We explore factors conferring community resilience in the context of drought typology and impact time-frame. Drought typology includes 1) meteorological drought (precipitation deficit), 2) agricultural drought (soil moisture deficit), 3) hydrological drought (deficit in water resources), and 4) socioeconomic drought (when the former definitions impact the supply and demand of goods). Impact time-frame includes short-term impacts lasting weeks to months and long-term impacts potentially lasting a year or more. Specific short-term impacts observed in 2018 include dry stock tanks, limited forage quantity and quality and the immediate response to the 416 fire, which burned 55,000 acres in the San Juan National Forest over 61 days. Longer-term impacts of the 2018 drought include local and regional diminished water supply, poor water quality, fish kills, post-fire mudslides in the burn scar and producer decisions to permanently transition out of agriculture. Community drought resilience efforts began in January, when dismal snowpack led to community leader meetings followed by drought informational meetings with irrigators. Water-specific factors conferring resilience include plentiful initial reservoir water storage, sophisticated irrigation system planning, owning senior water rights or having access to groundwater, and establishment of shortage sharing agreements (e.g. Animas River irrigators). As drought conditions continued, producers hauled water for livestock and wildlife. Others had to fallow lower-value crops and hand-water high-value crops. Local service-based organizations (Good Food Collective and Spring Creek Horse Rescue) and established supportive relationships between land-owner and rancher led to resilience in specific instances. Geographically decoupled water sources from demands led to longer-term, distant impacts of exceptional drought in this headwaters region. Throughout the drought webinars featuring weather and climate experts provided updates which were used by local managers and the media to communicate drought progress and resources.

Recent Streamflow Declines and Snow Drought in Upper Rio Grande Tributary Basins

Caitriana Steele, USDA Southwest Climate Hub
(Authors: C. Steele, E. Elias, J. Reyes)

To understand how future climate change will impact agricultural communities in the southwest, it is essential that we know how water availability has varied in the past. Over the last half-century, there has been a trend of declining streamflow across the southwestern United States. For rivers such as the Rio Grande, with more than 65% of the native flow originating as snowpack in mountainous headwaters, this trend has been driven by changes in winter precipitation, decreasing snow water equivalent (SWE), rising temperatures and earlier spring snowmelt. Researchers have already documented how lower SWE contributes to reduced streamflow volume from the entire Upper Rio Grande (URG) headwaters to the state line between Colorado and New Mexico. In this paper, we analyze the relationship between SWE and streamflow volume over the last 30 - 40 years at a finer spatial scale, looking at individual high elevation watersheds in New Mexico that contain tributaries of the Rio Grande. In addition, we use longer-term datasets to identify years of snow drought that resulted from significantly lower winter precipitation. Two years of critically low snowpack (2002 and 2018) provide insights into potential future snow drought scenarios. We intend to use these findings to summarize potential impacts from climate change on the rural, acequia communities who live in and cultivate the narrow valleys situated just below the high elevation watersheds.

Environmental Systems Management Class: From Lecture to Flipped to Online

Natalie Carroll, Purdue University

The goal of the *Environmental Systems Management* class is to introduce students to a variety of environmental topics, concerns, and solutions. This course originally followed a traditional lecture format until 2013 when the instructor began using "flipped" classroom methodology. This required a drastic reduction in traditional lectures, replaced by more active student involvement during class time. Students were required to prepare for each class by completing an assignment. They then engaged during class in hands-on activities, team exploration, discussions, and other interactive study to explore the assignment more deeply. The flipped classroom methodology worked well when students came to class prepared and engaged during class. Those who did not prepare were detrimental to the class and were more likely to complain about the flipped class methodology. Then in 2017, the instructor developed nine online lectures because of a time conflict. Students reported that they liked the online lecture, particularly the flexibility it allowed in both speed of presentation and when they accessed the material. None of the students reported difficulty in learning the information online. Because of the nature of the course, the overwhelming positive response by students to the nine online lectures, and the university administration's desire for more online offerings, the instructor petitioned the departmental curriculum committee to teach the class totally online in 2018. Online lectures included slides (similar to Power Point), reading, and some calculations. Students were required to take a quiz after each lecture to show that they understood the fundamental concepts presented and had completed the assignments. The lectures were posted Monday morning and students had until Saturday evening at 7pm to complete two lectures for each week. A Midterm and Final were given using "ProctorTrack," software that videotapes the students while they were taking these exam. Areas of concern about student integrity are flagged for the instructor to watch and determine if the student cheated. The online class was a success. Five students who were student-teaching in schools across the state and were particularly happy to be able to take the course during their semester away from campus. Enrollment increased from about 25 to 45 (80%). Comparing grades between the online and face-to-face indicated that learning was about the same as in previous years. The GPA spread was slightly lower for the online class than in previous years. The instructor suspects that was because students were more likely to skip online lectures, possibly because they forgot, than classroom lectures.

Elucidating Source Waters and Hydrochemical Processes in a Protected Ecological Habitat

Alfredo Estrada, California State University, Los Angeles
(Authors: A. Estrada, D. Stone, J. Garrison, B. Hibbs, S. Tovar, L. Zuniga)

A wetland and lake fed by a series of springs in Deep Springs Valley, Inyo County, CA lies at the center of our investigation. Deep Springs creates the riparian habitat for the California black toad (*Anaraxsus exsul*). The toad's range lies entirely within the Deep Springs Valley and the toad is listed as threatened by the CA Department of Fish and Wildlife. The black toad is affected by hydrology and hydrogeology of environments due to their reliance upon water for reproduction, unshelled eggs, and highly permeable skin. The black toad's habitat requires presence of water year round from permanent springs; which is necessary for the black toad's breeding and egg laying. This project contributes to knowledge of recharge sources in an undeveloped arid basin by integrating water isotopes, nutrients, and standard hydrochemical parameters to decipher flowpaths and understanding of hydrochemical facies and water types. Three distinct groundwater types feeding the springs and surrounding wetland have been identified by an earlier USGS study (1965) that used standard inorganic constituents only. Based on USGS data, our hypotheses of origin of these distinct water types is: 1) three or more recharge sources from different areas achieving independent chemistry from recharge area to discharge areas at the springs; and 2) one, or at most two recharge sources, and reaction of water with different geologic facies (e.g., rocks only, or rocks and playa sediments) to achieve different chemistry. Our initial studies show that an artesian system feeding into the Deep Springs Playa is characterized by very low sulfate (< 3 mg/L SO_4), high ammonium (3 to 8 mg/L NH_4), and moderately high phosphate (0.4 to 3 mg/L PO_4). The other nearby springs contain moderate sulfate (50 to 125 mg/L SO_4), low ammonium (< 0.03 mg/L NH_4), and low phosphate (< 0.15 mg/L PO_4). Stable water isotopes vary narrowly in all of these samples from -15.30 to -15.90 delta O18 and -117 to -122 delta D, with most samples varying by less than 2 per mil delta D. These data imply a common source of recharge water, and chemistry of groundwater that evolves more as a result of hypothesis 2 above. Moderate reducing conditions in artesian sediments account for sulfate loss through reduction and higher solubility of ammonium and orthophosphate. Future work will emphasize collecting additional redox sensitive hydrochemical parameters and trace elements, and use of additional environmental isotopes to examine hydrogeological processes and redox conditions.

Delineating Beaver Impoundments with High Resolution Imagery and Machine Learning

Kyle Fitch, University of Wyoming
(Authors: K. Fitch, F. Nippgen)

In a semi-arid, snowmelt dominated landscape, low discharge is common throughout the summer months with many streams falling dry. Beaver dams have the potential to store water at the surface for long periods of time and then release it during the dry summer period. However, little is known about the exact effects of beaver impoundments on the hydrology in snow-dominated semi-arid systems and the spatial and temporal dynamics of beaver ponds. This project is focused on the Crow Creek and South Lodgepole Creek watersheds in the Laramie Range of Southeastern Wyoming. The granite capped topography extends 60 miles North-South and encapsulates the Medicine Bow-Routt National forest, where beavers are common throughout this protected region. We use National Agricultural Imagery Program (NAIP) imagery (sampled in 2003, 2008, and every 3 years between 2009 and 2018) to identify and delineate beaver impoundments throughout the Laramie range and track their development in space and time. Understanding the spatial and temporal dynamics of beaver dams in the Laramie Range is a crucial first step to understanding how impoundments affect hydrologic regimes in semi-arid climates.

The Two-Stage Saturated Buffer: Integrating the Use of Cover Crops into Saturated Buffer Designs for Nitrogen Mitigation in Southern Illinois Agriculture Systems

John Gale, Southern Illinois University Carbondale
(Authors: J. Gale, J.E. Schoonover, K.W.J. Williard, J. Crim)

Nitrate leaching from Midwestern agricultural fields has received growing attention and requires immediate action to adapt, or develop, best management practices (BMPs) to reduce impacts on the environment. Nitrate can enter streams and cause local water quality impairment issues and increase the size of the hypoxic zone in the Gulf of Mexico. To date, there have been many BMPs proposed to attenuate nutrients and trap sediments along field borders and within agricultural fields. Both saturated riparian buffers (SRBs) and cover crops have proven to be effective BMPs for nitrogen management in row crop agricultural areas. This research seeks to quantify nitrate leaching from three drainage scenarios in a tile-drained system: 1.) control (a grassed buffer with no tile diversion), 2.) standard saturated buffer (a diversion draining through a grassed buffer), and 3.) two-stage saturated buffer that drains into both a cover crop strip (stage 1, diversion 1) and a grassed buffer (stage 2, diversion 2). This research is one of the first to blend the two BMPs into one management design used for assessing nitrogen management in row crop agriculture. Discharge and nitrate concentrations have been measured bi-weekly at each SRB using AgriDrain control boxes equipped with HOBO sensors for accurate measurement. Preliminary results have shown that the SRBs reduced outflow volumes in addition to reducing nitrate loads. Both cover crop and grass buffers have had higher nitrate concentrations than the field wells due to the lateral lines in the saturated buffer systems effectively conveying water towards the wells in the vegetated buffers. However, an elevated water table in the two-stage saturated buffer has caused the tile diversion lines to become saturated at times which has negatively affected its performance compared to the traditional saturated buffer. Findings from this study may be used by farmers and land managers to guide future nutrient management decisions.

Detecting Tile Drainage Systems in Low Relief Land Using High Resolution LiDAR Terrain Data

Rui Gao, Utah State University
(Authors: R. Gao, R. Zeng)

Tile drainage systems are fundamental agricultural infrastructures that improve food production in farmlands where groundwater table reaches the root zone. The drainage system has converted the Midwest from wetland to one of the most fertile agricultural lands in the world and enhanced food and biofuel production, while altering flow pathways and residence time, creating new hydrologic response regimes, and driving environmental changes in sediment dynamics, nutrient cycling and aquatic ecosystems. A comprehensive knowledge of drainage systems is vital for integrated management of water and agricultural land. However, current estimation of drainage systems is limited in accuracy and spatial resolution, making it inappropriate to be represented in regional hydrologic models. This study aims at providing a regional map for artificial drainage systems from sub-meter LiDAR terrain data. Because of the high-resolution data, traditional watershed delineation tools not only cost more time but also hardly delineate the watershed since the flow direction cannot be judged accurately when the elevation of the adjacent grids are same. To overcome the technique challenges and reduce computational expense, we propose a filtering approach to detect artificial drainage systems. We will delineate potential drainage ditch features by ridge/curvature filtering techniques with parameters tailored for artificial drainages. Commission errors will be filtered out by land use and land cover map. The drainage ditch network skeleton will be connected as a network of artificial drainage system, which will be further connected to natural river network. Additionally, artificial drainage open ditch channel geometry will be captured by projecting the detect drainage network back to the LiDAR terrain map. The detected drainage systems will provide fundamental information for hydrologic and hydraulic modeling. Further, the detected drainage map will serve as training and validating benchmarks to develop regression models to estimate artificial drainage system in regions with no LiDAR data.

Snow to Streams: Using Thermal Infrared Imagery to Better Understand Snowmelt Dynamics and Runoff

Cole Green-Smith, University of Wyoming, Watershed Management/Hydrology
(Authors: C. Green-Smith, F. Nippgen)

Today, agriculture, industry, municipalities and other stakeholders encounter complex issues with water as a resource. Since most of the intermountain west’s water is derived through mountainous snow-dominated systems, it is relevant to focus on the processes that convert snowpack to streamflow in order to better evaluate water availability. Despite the importance, it is still not fully understood how snowmelt becomes streamflow. Some factors that contribute to the complexity of these topics are high spatial variability of topography and land cover of subalpine systems that in turn lead to high spatial heterogeneity in snow accumulation and subsequent water inputs to the ground. It has proven difficult to sufficiently instrument even small watersheds to capture this high degree of spatial variability. New methods and approaches are needed to attempt a more thorough understanding of how snowmelt affects runoff source areas in complex terrain. This work focuses on the snowmelt period in a small, sub-alpine, snow-dominated watershed in the Snowy Range of Southeast Wyoming. We use an unmanned aerial vehicle (UAV) coupled with a thermal infrared (TIR) camera to produce thermal imagery for identifying spatial variability in soil and surface saturation during the snow melt period. We couple this imagery with information from three nests of shallow soil moisture sensors, streamflow, and snow-course data to assess the potential of TIR imagery to track runoff source areas through space and time.

Satellite-Based Record of Changes in Ice Cover of Utah Lake

Carly Hansen, University of Utah
(Authors: C. Hansen, N. Von Stackelberg)

Ice cover and ice-free periods impact aquatic habitats and have an important role in ecological processes and surface-atmospheric interactions. It can also serve as a useful indicator of local changes in climate, reflecting changing patterns in seasonal air temperature. Utah Lake currently lacks a consistent record of ice cover characteristics, making it difficult to evaluate trends or patterns or how ice cover relates to seasonal climate conditions. The relationships between climate (especially air temperature) and ice cover is especially important for shallow lakes like Utah Lake. Using historical imagery from multiple satellites, we constructed a record of ice cover characteristics for Utah Lake and used this record to evaluate important characteristics such as timing of ice-on, break-up, duration, and spatial extent of ice cover. With the historical record, we are able to compare the observed patterns to trends found in other regions in the northern hemisphere over the same time period. We also compare ice cover trends to several atmospheric variables measured by meteorological stations and remote sensing to explore how trends in ice cover compare to local climate trends.

Elasticity in the Colorado River Basin Using the Budyko Method

Amber S. Jones, Utah State University
(Authors: A.S. Jones, M. Alger, B. Lane)

As a critical source of water for the southwestern United States, the Colorado River is the subject of interstate compacts, international treaties, and numerous agreements that regulate its flow, storage, and diversions. Climate change and aridification cause concern for the future of the Colorado River, and a drought contingency plan for basin the was recently negotiated and authorized by Congress. Process-based hydrologic models have been used to assess the sensitivity to increasing temperature and changes in precipitation throughout the basin under multiple climate change scenarios. As an alternative, the relatively simple Budyko model based on the long-term water balance can be effective at assessing the sensitivity of runoff to changes in other components of the water balance (e.g., precipitation and potential evapotranspiration). The Budyko curve indicates the energy or water limitation on evapotranspiration, and provides a reference for partitioning precipitation to runoff. For this presentation, we used Budyko based methods to determine the sensitivity of runoff to temperature increases and elasticity of runoff to changes in precipitation for 29 subcatchments in the Colorado River Basin. For each subcatchment, we determined the aridity index and the watershed storage parameter. Results show distinctions between watersheds driven by snowmelt hydrology in the Upper Basin and those driven by summer monsoonal storms located in the Lower Basin. In particular, the Paria River and the Little Colorado River subbasins are sensitive to changes in precipitation and temperature. The results from this method are consistent with sensitivity and elasticity ranges determined by other studies for the Colorado Basin.

Water Quality and Agronomic Impacts of Gypsum Applications in Southern Illinois

Harpreet Kaur, Southern Illinois University Carbondale
(Authors: H. Kaur, K.W.J. Williard, J.E. Schoonover, J. Snyder, G. Singh)

The eutrophication of aquatic systems due to diffuse pollution of agricultural phosphorus (P) is a world-wide water quality problem. It is critical to develop effective practices to keep nutrients in the soil and prevent their loss in runoff to maintain and improve water quality. Gypsum is a potential tool that has been researched in other Midwestern states but not in Illinois and found to be a reliable practice to reduce phosphate leaching. The project is being conducted at two scales to test two objectives: gypsum's impact on water quality and gypsum's impact on grain yields. Surface runoff flumes have been established on a high P level field on the SIU University Farms to assess the effects of gypsum application rate on the water quality of surface runoff. After each significant rain event, surface runoff samples are collected and analyzed in the lab for dissolved phosphate, total phosphorus, nitrate, sulfate, and total suspended solids. To assess gypsum's impact on yield, we established a replicated large-scale field study on three producers' farms in the medium P supplying soils of southern Illinois. This study includes four treatments: gypsum (1 ton/acre), calcium (lime), sulfur (ammonium sulfate), and a control (no gypsum, calcium or sulfur) to determine which element in gypsum may be impacting yield. The impact of gypsum applications on soil physical properties will also be assessed. The economic cost of the gypsum addition and practicality of farmer adoption will be evaluated through a partial budget analysis. This research is planned for four years and is supported by Illinois Nutrient Research and Education Council.

Irrigation Initiation Timing Influence on Soybean Yield and Net Returns in Mississippi

Gurpreet Kaur, Mississippi State University
(Authors: H.C. Pringle, L.L. Falconer, D.K. Fisher, G. Kaur, L.J. Krutz)

Water withdrawal for agricultural use from Mississippi River valley alluvial aquifer exceeds aquifer recharge, resulting in decline in groundwater levels. Efficient irrigation scheduling will aid in conservation efforts to sustain groundwater resources. A study was conducted on Sharkey clay soil in Mississippi Delta from 2012 to 2015 to develop irrigation initiation recommendations for furrow irrigated soybean. Irrigation was initiated multiple times (I1, I2, I3, I4, I5) during the growing season and soybean yield and net return were determined to evaluate the effectiveness of each irrigation initiation timing. The first irrigation initiation timing (I1) commenced when soil water potential (SWP) readings were in the range of -30 to -50 kPa. Once the first irrigation initiation timing began, subsequent irrigation initiation timings were initiated 5 d apart. At these irrigation initiation timings, growth stage, soil water potential, and soil water deficit (SWD) were compared to determine parameter or combination of parameters that consistently provided the greatest soybean yields and net returns. All irrigation initiation timings provided higher soybean yield and net returns than non-irrigated treatment, except for one of soybean variety used in 2014. The growth stage, SWP and SWD for last initiation timing that did not statistically reduce yield or net returns compared to the maximum yielding initiation timing in different years' ranges from V7 to R2, -45 to -107 kPa, and 48 to 115 mm, respectively. Our results indicate that monitoring one parameter or use of a single trigger value is not sufficient to optimize irrigation scheduling in order to maximize soybean yield with the least amount of water every year. Monitoring one or more parameters (e.g., leaf water potential, air temperature, solar radiation) is needed in combination with soil moisture to quantify the abiotic stresses on the plant.

Enhancement of the Aquifer Recharge Factor in DRASTIC Model using SWAT and GIS Techniques

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The robustness of groundwater vulnerability assessment using the conventional DRASTIC model is highly dependent on the quality of the input data. The current research aims at examining the improvement of the Aquifer Recharge Factor (R) factor by utilizing and incorporating both the SWAT model and GIS techniques. Two approaches were used to compare the use of conventional recharge map versus a SWAT-based recharge map in the DRASTIC model as to account for the level of aquifer vulnerability. To prepare a more accurate recharge map, ArcSWAT was used by utilizing four main factors (Land Use, Soil Cover including vegetation, Slope of surface and Weather). The remaining DRASTIC factor was prepared based on the conventional method with reliable data and two final DRASTIC outputs were developed. The results indicated that the newly developed approach using the SWAT model for recharging map has resulted in a better resolution of DRASTIC vulnerability classes where the resolution was enhanced by 54%.

Python Tools for Automated Integration of Hydrologic Data into Watershed Models

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Watershed models such as the Hydrological Simulation Program in Fortran (HSPF) are used extensively for the assessment of water quantity and water quality issues including droughts, flooding, nutrients, and total maximum daily loads of pollutants. Such models rely on extensive data including streamflow, climatology, land use, and hydrography to simulate water budgets and pollutant concentrations throughout a study area. The construction of a watershed model is a difficult and time-consuming process as it requires compilation of extensive quantities of data into formatted files followed by a simultaneous fitting of many uncertain parameters. Because of these complications, studies are often limited to calibration periods of only a few years even when analyzing long time-scale issues such as climate and land use changes and are difficult or impossible to reproduce. Public data sources are readily available online, but integration into a consistent form is a time-consuming and inefficient process. Advances in the development of free and open source software tools and availability of online data create opportunities to automatically gather, process and aggregate data needed to answer water resources questions. This presentation will discuss a completely open-source Python packages that gathers hydrologic data from sources including from the internet and uses it to automate the construction of a watershed model.

The “Waters of the US” Rule and Wetland Conversion Rates

Christopher Lant, Utah State University

As of this writing, a proposed rule has been promulgated that greatly restricts the definition of Waters of the United States, thus removing Federal protection of wetlands that are not adjacent to navigable waters. This paper presents an analysis of wetland conversions from 1955-2009 included in the National Wetland Inventory in order to assess the on-the-ground impact of this rule. While conversion of wetlands to non-agricultural purposes have persisted, the five U.S. national wetland inventory reports spanning 1955-2009 show a large decline in the rate of conversion of wetlands for agriculture, especially from the mid-1970s to the mid-1990s. Through regression and path analysis, this study identifies primary policy and economic drivers of this decline in wetland conversions. The Clean Water Act §404 is strongly and negatively related to conversion rates, reducing conversions by 234,000 acres per year since its enactment. Crop prices also affect wetland conversions both directly, by influencing returns to investments for conversion, and indirectly, by influencing Conservation and Wetland Reserve Program enrollments as well as the regulatory impact of Swampbuster. Along with the proportion of wetlands remaining, these factors explain 90-94 percent of the annual variation in total wetland conversions, agricultural conversions, and conversion of forested and emergent wetlands.

Sensitivity of Closed-basin Mountain Lakes to Climate Change and Implications for Interstate Water Compacts in the West

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Mountain lakes help to maintain baseflow of rivers by gradually releasing snowmelt-derived water through surface and subsurface hydrologic connections between lakes and streams. Snowpack and the timing of snowmelt primarily control mountain lake volumes and patterns of seasonal water loss, which leads to variability in the contributions of lake water to streams through time due to changes in hydroclimate. Closed-basin mountain lakes (those without surface inlets or outlets) can undergo substantial seasonal water loss and are highly sensitive to changes in the volume and timing of spring snowmelt, but the importance of seasonally varying lakes to streamflow and their sensitivity to climate change remains unclear. By conducting geophysical surveys and measuring water-level fluctuations of lakes in the Medicine Bow Mountains of Wyoming we find that 1) closed-basin lakes can lose up to 99% of their volumes each year, 2) the lakes recharge groundwater by losing most of their water to seepage, and 3) lake-derived groundwater likely contributes to streams through subsurface hydrologic connections. Further, radiocarbon ages of basal sediments show that lakes with seasonally varying water levels in the Medicine Bow Mountains formed only after 5 ka. Based on results from a lake-level database for North America, timing of high lake levels in the Medicine Bow Mountains coincides with high lake levels across the West after 5 ka and suggests that the climate of the mid-Holocene (roughly 9-6 ka) reduced mountain lake abundance relative to today. Mean global temperatures are predicted to exceed those of the mid-Holocene, however, and although mountain lakes will continue to store water past the melt season, their volumes may decrease and storage may not persist into the fall. Reduced lake-stream connectivity may result in diminished streamflow, particularly in fall when the pulse of snowmelt has passed and when lake-derived water represents a larger proportion of baseflow in streams. Consequently, appropriations of interstate watercourses, such as the Laramie River, will require modification due to altered water availability in coming decades. The Laramie River receives snowmelt-derived water from the Medicine Bow Mountains and was the first watercourse in the U.S. to undergo an interstate appropriation. Rising temperatures will likely decrease storage of snowmelt in lakes in the Medicine Bow Mountains and diminish late-season contributions of lake-derived water to the Laramie River. Evaluating the potential for reduced flow in the Laramie River therefore provides a valuable opportunity to study the implications of climate change on interstate water compacts throughout the West.

Spatiotemporal Analysis of Precipitation and Water Use in Contiguous U.S.

Jason Levi Manley, Utah State University
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Fresh water is one of the most vital natural resources on earth. It is therefore paramount that civilization achieve sustainable development by dynamically balancing fresh water supply with demand. This study analyzes the historical spatiotemporal trends of precipitation and water use for the Contiguous United States (CONUS). Information about the spatiotemporal variability trends of precipitation (the main water source) and water uses from various sectors will provide support for water resources management and conservation. This study adopts the concept of gravitational center to calculate the first-order spatial moment of precipitation, and water withdrawals, in CONUS. We calculate the annual and monthly gravitational center of precipitation from gridded PRISM climate data for 1895-2017. We also calculate the gravitational centers of main water withdrawal categories (e.g., irrigation, thermoelectricity, and public supply) based on the five-year USGS county-level water use data between 1985 and 2015. By showing the trajectories of gravitational center, this study illustrates the inter- and intra-annual spatial variability of precipitation and the long-term trend of water uses. Insights from this study will add understanding to the climatic and anthropogenic forcing of water supply and consumption in CONUS to provide insights for sustainable water resources management.

Treating One Waste Stream with Another: Spent Grow Mats as a Carbon Source for Denitrification of Hydroponic Wastewater

Gina Riggio, University of Arkansas
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This study will investigate the feasibility of leaching organic carbon from spent soil-free horticultural grow mats to fuel the heterotrophic denitrification of high nitrate-N hydroponic greenhouse wastewater. The objective is to determine if one waste stream can be treated with another, to both improve the life cycle cost of soil-free growth media and mitigate eutrophication in waterbodies that receive nitrogen-rich greenhouse wastewater. Two types of grow mat materials (hemp and wood fiber) will be compared, at 3:1 and 2:1 carbon to nitrogen ratios. Grow mats will be obtained from a shelf style microgreen growing system, with microgreen roots left over from harvest still embedded in the mats. Hydroponic wastewater will be obtained from a bench-scale deep water raft culture (DWC) system used to grow lettuce. Denitrifying bacteria starter culture for the biological filter will be obtained as activated sludge from a local wastewater treatment plant and allowed to establish in a high-nitrate synthetic wastewater mixture of known composition. Removal efficiency from DWC wastewater will be compared to distilled water and the synthetic wastewater used to establish the biological filter. Removal efficiency will be calculated using pre- and post-treatment measurements of organic carbon (fBOD5) and nitrate nitrogen. Experiments will be performed in triplicate at two different retention times. Multiple regression analysis will be performed to detect any relationship between carbon:nitrogen ratios, water retention time, and nitrate removal efficiency.

Investigating Wildfire Trends in California over 32 Years

John Salguero, California State University, Los Angeles
(Authors: J. Salguero, J. Li, A. Farahmand, J.T. Reager)

Wildfires in the United States (US) during the last several decades have become larger with greater frequency. This noteworthy trend can affect fire regimes throughout the US in the near future. A fire regime is the pattern of fires that are established in an environment over an extended time period and can be characterized by frequency, spatial pattern, seasonality, and intensity. California is a suitable area to investigate changing fire regimes because of its location, the western frontier of the US, known to have had an increase in forest wildfire activity. This increase in activity can be attributed to factors such as warmer spring and summer temperatures, reduced precipitation, and earlier spring snow melts. Therefore, it is important to understand California's dynamic fire regimes in order to minimize negative impacts on the environment, society, and economy. This study uses observations from the Monitoring Trends in Burn Severity (MTBS) database. This database provides records on large fire events that are 500 acres or greater in the east coast and that are 1000 acres or greater in the west coast. Linear regression analyses were carried out to understand how fire regimes have developed in the Northern California and Southern California GACC (Geographic Area Coordination Center) regions over a 33-year span, from 1984 to 2016. Slightly increasing trends were discovered in both GACC regions in the study period. These findings will help develop a robust seasonal to sub-seasonal forecasting capacity for wildfires in California.

Cover Crops: Solution to Sediment and Nutrient Loss? A Paired Watershed Study

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(Authors: A. Sharma, J.E. Schoonover, K.W.J. Williard, G. Singh, J. Crim, J. Snyder)

Use of cover crops, to manage the loss of sediments and nutrients caused by surface and sub-surface flow is a commonly used best management practice in the midwestern United States. Until recently, plot level studies were the primary method for evaluating the impact of cover crops on water quality. Singh. et. al. (2018) established one of the few watershed scale studies that focused on analyzing stream water quality and discharge in a stream that drained fields in cover crops. The objective of the study is to quantify the potential of cover crops in improving water quality at watershed scale. The project will undergo continuous monitoring of two watersheds to analyze changes in the water quality and stream discharge from a no-till corn/soybean rotation with cereal rye (*Secale cereal*) and hairy vetch (*Vicia villosa*) as the winter cover crops in the treatment watershed. The study site located at Southern Illinois University, Carbondale, IL, will evaluate the sediment, phosphate, nitrate, ammonia, total N, and dissolved organic carbon exports from the paired watershed using ISCO automated water samplers. The study design is a paired watershed design where watershed #1 (42ha) will be the treatment watershed and is under mixed land use of 66.4% cropland, 30.3% forested cover and 3.3% impervious surface. Watershed #2, the control watershed, has a total area of 27 ha with its area comprising 91% cropland, 6.6% forested cover, and 2.4% impervious surface. Calibration data of 3 years and treatment period of 2 years will be used as reference to perform the study to determine if the water quality results are similar between the two watersheds, or if new patterns emerge. Data for water quality (major anions including nitrate and phosphate) will be determined from field sample collection and laboratory analysis while the regression equation from the calibration period will be in used to predict the data if a treatment did not occur and compare it to observed data in the treatment watershed. The overall difference in actual and predicted results will serve as base for realizing the impacts of the cover crop treatment on water quality and stream discharge.

Long-term Drainage, Subirrigation, and Tile Spacing Effect on Corn Production

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Flooding and drought are the most damaging abiotic stresses affecting corn production in the United States. To combat these stresses subsurface tile drainage systems were used in conjunction with water-level control structures for subirrigation in northeast Missouri. The objective of this research was to evaluate yield variability and plant population of two subsurface drain tile spacings (6.1 and 12.2 m) at 3.05 m intervals from the tile lines for a claypan soil. Seventeen-year long-term (2002-2018) corn production data was classified in to normal, wet, and dry years based on precipitation received during the growing season Yields and plant populations were determined at 3.05 m intervals above and between the 6.1 and 12.2 m tile lines and were compared to non-drained (ND) and non-drained delayed planting (NDDP) controls. For all data, average yields increased 27% (2.01 Mg/ha) with DO at a 6.1 m spacing compared to the non-drained controlled. DSI at a 6.1 m spacing increased yields 38% (2.77 Mg/ha) compared the non-drained control. In dry years, yields above a 6.1 m spaced tile line were 74% greater than between the tile lines, while yields above the tile lines were three times greater than the ND control. Grain yield variability generally decreased from a dry to a normal year. Narrower drain tile spacings with subirrigations may need to be installed to reduce grain yield variability in dry and wet environments, but the cost-effectiveness of these systems needs to be determined.

Impact of Cover Crops on Nitrate and Phosphate Leaching in the Vadose Zone

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Cover crops (CCs) have been promoted as a practice to limit nutrient leaching, especially during the dormant season. The winter fallow period is a critical time for leaching of nutrients, since winter precipitation has a great potential to flush nutrients from the soil profile. A replicated plot study was established in 2014 to monitor nutrient leaching with pan lysimeters in different CCs and tillage rotations at the Southern Illinois University Carbondale research farm. The experimental design was completely randomized with two tillage practices, conventional tillage (CT) and no tillage (NT) and three different rotation treatments, corn-noCC-soybean-noCC (CncSnc), corn-cereal rye-soybean-hairy vetch (CcrShv) and corn-cereal rye-soybean-oats+radish (CcrSor). Pan lysimeters were installed in each plot below the A horizon which varied around 22-30 cm in depth. Soil solution was sampled weekly or biweekly depending on precipitation patterns and analyzed for nitrate and dissolved reactive phosphate. During the cash crop season 2015, the rotations CcrShv and CcrSor with hairy vetch and oats+radish as preceding CCs resulted in 89% (37.73 vs 19.96 kg ha^{-1}) and 68% (33.46 vs 19.96 kg ha^{-1}) more nitrate-N leaching than the CncSnc rotation. This may be due to excess mineralized nitrogen from the cover crop biomass being available prior to the primary nitrogen uptake window of the cash crop. Yet, in the CC season in spring 2016, cereal rye CC in CcrShv and CcrSor reduced nitrate-N leaching by 84% (0.68 kg ha^{-1}) and 78% (0.63 kg ha^{-1}) compared to the CncSnc, respectively, under the CT system. Dissolved reactive phosphate (DRP) leaching loss was reduced by 73 and 87% in rotation CcrShv under no-tillage compared to rotation CncSnc under conventional tillage after cash crop harvesting in cash crop season 2016 and 2017, respectively. Our study highlights the role of different cover crops species in limiting nutrient leaching and the importance of timing the release of nitrogen from cover crop biomass to meet nitrogen demands of subsequent cash crops.