Urban Water Innovation Network

Sustainability Research Network

Y5: Annual Report (2019-2020)

National Science Foundation

The Urban Water Innovation Network is a Sustainability Research Network (SRN) funded by the National Science Foundation (NSF) Cooperative Agreement 1444758. The Network was established in August 2015. The Year 5 UWIN Annual Report provides a detailed summary of activities, results and accomplishments over the April 2019 – May 2020 period. The report also provides a detailed list of partners and collaborators as well as a current list of UWIN-related research products including academic publications, conference papers and proceedings, websites, models and other related products.

EXECUTIVE SUMMARY

The UWIN SRN research, educational, and engagement activities have resulted in significant scientific advancements that facilitate integration of urban water systems. These transdisciplinary activities are conducted to: 1) improve a holistic understanding of the urban water cycle; 2) evaluate technological, policy, institutional, and financial pathways toward sustainability outcomes for urban water systems; and 3) provide interdisciplinary research training opportunities for a cohort of graduate and undergraduate students across UWIN institutions.

The SRN activities engaged 39 faculty members (2 Deans, 20 professors, 5 associate professors, and 10 assistant professors, 2 instructors) from 34 academic institutions with interdisciplinary expertise, as well was 7 research scientists, 7 staff scientists, 47 graduate students, 16 undergraduate students and 7 postdoctoral research associates. Moreover, over 100 nationally renowned urban water and sustainability stakeholders from various regions across the U.S. were involved in the SRN research, engagement and educational activities. In addition, the UWIN SRN fosters ongoing collaborations with 71 organizations across the country including 11 federal/state/local government agencies, 11 non-profit organizations, 10 utility partners, 3 consulting agencies and 2 commercial/industrial firms.

The UWIN transdisciplinary activities to date have produced 165 published high impact journal publications, 28 PhD dissertations and M.S. theses, 5 book chapters, 288 conference papers/posters and presentations, 1 patent, 89 outreach and print materials, 19 software and modeling tools, 4websites, and a popular urban water webinar series offering 27 webinars (19 by UWIN researchers and 8 by regional water stakeholders). In addition, the Network has started publishing data and metadata produced via research activities, 40 datasets are currently available for download from the website. The two recently funded citizen science projects, Green Infrastructure Rapid Assessment project and the Off the Roof project, have made considerable progress and have activities currently underway.

The Network is currently conducting activities in collaboration with Howard Neukrug, UWIN External Advisory Committee member and Director of the Water Center at University of Pennsylvania, and the Philadelphia Water Department (PWD) to develop a web-tool to evaluate and adapt co-benefits/triple bottom line analysis for use in PWD's planning analysis of alternative stormwater management infrastructure. This fruitful collaborative effort will provide information on benefits and costs of green infrastructure to inform design criteria, regulations and incentive programs as well as support decision making and foster communication of benefits and costs of green infrastructure to decision makers, stakeholders and the public.

UWIN also participated in a multi-institutional collaborative effort let by Brooklyn College of the City University of New York to evaluate the resiliency of the City's stormwater and flood control infrastructure to climate change and sea level rise.

Urban Water Innovation Network

Annual Report – Year 5

CONTENTS

MAJOR GOALS

The vision of UWIN is to build an enduring research network that generates knowledge, enables innovation, and trains/supports champions of innovation for sustainable and resilient urban water systems. To implement this vision, the mission of the network is to: (i) develop technologic and sociopolitical solutions; (ii) build social capital and trusted regional leadership in six study regions; and (iii) train scientists and policy makers as champions of innovation for urban sustainability. The initial study regions include Mid-Atlantic/Baltimore, Southeast Florida/Miami, Front Range Colorado/Denver, Arizona Sun Corridor/Phoenix, Southern California/Los Angeles, and the Pacific Northwest/Portland.

Research Goals

Specifically, the overarching research goals of the UWIN SRN are to:

1. Understand responses, interactions and feedbacks between urban development patterns and the interconnected natural/socioeconomic processes (climatic, hydrologic, biogeochemical, and ecological) that impact coupled natural-human water systems;
2. Identify technological, socioeconomic, and urban water management solutions that reduce pressures, enhance resilience and maximize co-benefits in other linked systems, and measure their impacts and tradeoffs across temporal and spatial scales;
3. Explore systemic institutional frameworks required for successful transitions toward sustainable urban water systems in metropolitan regions across the U.S; and
4. Develop a national Urban Water Sustainability Blueprint by creating a conceptual framework that defines essential characteristics of sustainable urban water systems across regions, points decision makers toward best management practices, fosters peer learning and cross site comparisons, and enables agile responses to changes in driving forces that influence urban water systems.

Research activities of the network are organized in four integrated thrusts: A, B, C, and D.

Thrust A projects aim to advance fundamental knowledge about the sustainability of urban water systems, by comparing observed trends in the past with alternative future conditions. First, water supply-demand patterns under prevailing and future socioeconomic scenarios are investigated. These land and water use, land cover and socioeconomic scenarios are then used to assess responses and two-way interactions between urban form/development patterns and land-atmospheric processes in urban areas. The relationship between coupled human-natural urban water systems and regional climate, effects on urban heat islands, and the ensuing co-benefits for human health are investigated.

Using data, models, and enhanced process understanding from Thrust A, the impacts of innovative technological solutions on sustainability of water systems across ecohydrologic regions are examined under Thrust B. These solutions include: building- to community-scale resource recovery and reuse

systems, hybrid centralized-decentralized water infrastructure systems, fit-for-purpose water systems, green infrastructure, sustainable urban drainage networks (SUDS), and resilient floodplains.

Activities under Thrust C explore how cities can intentionally foster the widespread adoption of infrastructure, development patterns, consumer behaviors, and management practices that advance sustainable water management. To understand overcoming barriers to adoption of sustainable solutions, the social and behavioral systems that govern change are investigated. Components of the system include the actors, preferences, policies, institutions and other elements that shape outcomes at multiple scales from the site to the metropolis. Theories of urban change are studied to understand the social networks that shape water systems, the dynamics of household innovation, and the processes of large-scale urban change.

Thrust D activities focus on integration of data, models and products from all other themes and projects to facilitate enhanced decision making. This thrust enables synthesizing results from assessment projects under Thrust A, technological solutions under Thrust B, and socioeconomic and management solutions under Thrust C to identify viable options that provide maximum benefits at the system level. A system approach following an urban water sustainability framework is used to explore driving forces, pressures, states, impacts, and responses/solutions. This system approach explores benefits, dis-benefits, co-benefits, and tradeoffs associated with various solutions at various spatial and temporal scales. The synthesis will determine the sustainability metrics/indicators that comprise UWIN Urban Water Sustainability Blueprint.

Outreach/Stakeholder Engagement Goals

The overall goals of the stakeholder engagement components of the project are to: (i) gather feedback and input from stakeholders to ensure that UWIN science is as relevant as possible to decisions and drivers of regional concerns; (ii) compare findings from observations and analyses of stakeholder interactions across regions; (iii) use stakeholder engagement activities to serve as testbeds for tools and products developed through the project; (iv) measure the change in network composition and extent.

The overall goals of the training component are to: (i) provide adaptive management/team science skills training to UWIN researchers so that participants will become increasingly adept at working with complex transdisciplinary project teams; and (ii) provide training on skills and tools that support fostering effective communication, building cohesion, coordinating work, appreciating dependencies, aligning team members, and integrating knowledge.

Education Goals

The goals of UWIN Undergraduate Research Program (URP) are to: (i) provide a diverse group of undergraduate students mentored independent research experiences in urban water sustainability, immersing them in the challenges and rewards of transdisciplinary scholarship and helping them in their career choices and success; (ii) develop and test innovative approaches to undergraduate training in transdisciplinary, cross-site sustainability science, while also contributing to the scholarship of undergraduate education; and (iii) contribute to the UWIN research and engagement.

Specifically, student-oriented goals of the URP are to: develop strong research and inquiry skills; gain deeper knowledge in the field of urban water systems sustainability; develop skills for inter- and transdisciplinary work; understand key linkages between science and society; acquire skills in connecting scientific research to policy/management, communication, and education. The URP also contributes to personal and professional development of students to become more confident in the ability to do independent research, experience the enjoyment of working with transdisciplinary research, learn how to effectively interact with colleagues, advisors, mentors, and people outside their discipline, build positive relationships and networks to support future career development, and become reflective practitioners of scientific research and transdisciplinary science.

Mentor-oriented goals of the UWIN URP are to understand best practices to engage students in transdisciplinary research involving scientists, policymakers, and stakeholders; expand and evaluate students' thinking and understanding of science and its application to sustainable urban water systems; act as professional role models to students; and develop strong mentoring skills.

Programmatic goals of UWIN URP are to engage a diverse group of students, including race, background, type of school, career interest, and perspective; generate new knowledge and solutions for urban water sustainability that impact a broader audience; forge collaborations among researchers, regional stakeholders, students, and the global community; provide innovative and effective training for a new generation of transdisciplinary researchers prepared for the new challenges and opportunities they will encounter; and contribute to understanding of the roles that research experience and reflection play in undergraduate learning and vocational development.

Citizen Science Goals

The Network is engaged in several Citizen Science efforts, including a program on harvested rain waiter and a green infrastructure monitoring program. The major goals of the Citizen Science efforts are to:

- Contribute to UWIN science, products and participant pool
- Convene interested members of the UWIN community to explore citizen science initiatives for UWIN, and to support ongoing and new citizen science activities through exchange of ideas and resources
- Identify win-win opportunities where UWIN and other scientists, community stakeholders and members of the public can all benefit from citizen science projects

Diversity Goals

The UWIN SRN is fully committed to building a talented and diverse student cohort. The diversity activities are focused on broadening participation in urban water sustainability research through recruiting and retaining underrepresented groups through the creation of Diversity Recruitment and Retention supplements. UWIN Diversity Supplements are intended to complement existing activities and programs already in place at the Network's affiliated institutions.

- Research

    - Recruit diverse faculty, post docs, and graduate students, as applicable, to participate in UWIN research projects
    - Conduct workshops and seminars that promote a welcoming environment for diverse researchers
    - Establish a partnering program that pairs new participants with mentors/guides who have experience working with UWIN staff and projects to promote meaningful engagement in project activities
    - Identify diverse researchers to participate in dissemination activities as keynote speakers, featured presenters, etc.
    - Make presentations to minority and women engineering societies to promote awareness of the research topics amongst the traditionally underrepresented minority community
- Education & Outreach
    - Recruit diverse student participants in education programs (include participation in conferences like NSBE, SWE, SHPE, SACNAS, AISES)
    - Secure the participation of diverse researchers to be education program facilitators and provide mentoring to student participants, especially underrepresented students
    - Promote a supportive, welcoming environment for diverse participants
    - Plan community awareness events, especially, in diverse communities affected by issues related to the work of UWIN, that highlight research projects and results and promote citizen participation
    - Develop a diverse public image through the project website and other forms of media
- Engagement
    - Engage a diverse group of advisors on the overall project advisory board and regional advisory boards

MAJOR ACTIVITIES

The SRN activities were conducted in 22 research projects, a stakeholder engagement project, an Undergraduate Research Program (URP), and training opportunities for graduate and undergraduate students.

"Thrust A" Research Projects

A1-1: Quantifying vulnerability, resiliency and adaptability of US urban water supply

- Assessed shifts in regional hydroclimatic conditions of U.S. river basins in response to climate change.
- Evaluated the impacts of hydroclimatic changes on U.S. cities and agricultural regions over the 21st century.
- Developed a web tool to streamline access to U.S. hydroclimatic data at HUC8 level over the 21st century under various future climate projections, including the Variable Infiltration Capacity (VIC) model simulations with climate forcing from Multivariate Adaptive Constructed Analogs (MACA) dataset.

A1-2: Effects of changes in climate, demographics and urban form on water supply-demand equilibrium

- Analysis of survey data
- Compilation of water rates

A2-1: Land-atmosphere-hydrosphere interactions in urban terrain

- Analyzed how a strong urban heat island (UHI) might create recirculation bubbles in cities and decrease environmental quality.
- Collaborated on the development of a simplified urban heat island model that can be applied worldwide and analyzed the climatological and population drivers of the surface UHI, as well as the seasonal UHI hysteresis in various cities.
- Applied the newly developed WRF(LES)-PUCM-ParFlow model to a small test watershed in Baltimore to investigate the effect of highly-resolved urban hydrometeorological processes and three-dimensional groundwater flow on output variables such as overland flow, soil moisture, and surface temperature.

A2-2: Projecting future environmental change in urban areas

Finalized 3 manuscripts (principal result is presented under "Significant Results"):

- Examination of mean and extreme precipitation effects due to emissions of large-scale greenhouse gases, urbanization and thermal adaptation strategies (pending submission to ERL in June 2020);
- Characterizing projected human thermal exposure due to extreme temperatures owing to large-scale greenhouse gases, urbanization and population growth (submitted to PNAS and minor reviews were received two weeks ago);

- Conducted a systematic review characterizing physically-based numerical modeling of urban adaptation and developed 25 criteria to assess contextualization and reliability of each study (submitted to ERL last month).

A2-3: Assessing the thermal comfort implications of water-supported infrastructure

- Conducting national-scale assessment of urban thermal equity in collaboration with UREx SRN
- Comparison of urban green infrastructure biophysical properties with resident perceptions in Phoenix using CAP LTER data
- Assessment of water and energy affordability in the Phoenix metro area (URP project)

A2-4: Assessment and design of innovative building systems and urban infrastructure

- Analyzed data from urban radiant heat analysis with sensors we have developed
- Collaborated with Chris Swan to deploy thermal imaging to analyze vegetation surface temperatures in Baltimore
- Developed new evaporative cooling tower prototype using hydrogel in conjunction with parallel project at UA

A3-1: Variation in urban vegetation biodiversity-ecosystem functioning

- Cross site comparisons of urban vegetation – microclimate distributions
- Construction of new urban tree drought stress experimental testbed
- Evaluation of urban plant biodiversity distributions

"Thrust B" Research Projects

B1-1a: Water management solutions to enhance capacity for use of alternative water sources

- Conducted multi-objective analysis of water conservation and reuse strategies to assess tradeoffs between cost and demand reduction potential in Miami, Tucson, and Denver.
- Developed a set of indicators to measure co-benefits for water conservation and fit-for-purpose water solutions.
- Assessed carbon footprint for innovative stormwater control measures developed by ReNUWIt compared to conventional technologies.

B1-1b: Assessment of water infrastructure resilience

- Completed the simulation model for water supply infrastructure resilience to sea level rise in South Florida
- Conducted the face validation of the developed simulation model with SMEs in South Florida
- Analyzed simulation outcomes and wrote one journal and one conference paper based on this study results.

B1-2: Lifecycle assessment of urban water systems

- Completed a life-cycle assessment study of electricity demand and greenhouse gas emissions associated with the wastewater treatment systems, potable water usage, and water demand reduction strategies in Tucson, Denver, and Miami.

B2-1: Effects of green infrastructure (GI) on urban systems

- Completed modelling of several Tucson Watersheds
- Work with Earthwatch and HSBC has continued and resulted in 7 events with over 100 participants in New York, Toronto, Vancouver, CA, Chicago, and San Francisco. Turned in final report

B2-2a: Flood hydrology and rainfall frequency

- Development of storm catalogs and rainfall frequency analysis procedures using Stochastic Storm Transposition for heterogeneous urban environments.
- Development of new polarimetric rainfall algorithm for extreme rainfall events in urban environments.
- Analyses of extreme rainfall and flooding in urban environments, including 2016 and 2018 Ellicott City, Maryland floods and major flood episodes in the Houston metropolitan region.

B2-2b: Hydrology and hydraulics of urban floodplains

- A probabilistic floodplain mapping framework developed by the project team was implemented at multiple locations across UWIN cities including scenarios that implement stationary and nonstationary flood frequency analysis. A simplified, alternative approach to conduct uncertainty analysis of flood hazards was developed and evaluated against probabilistic floodplain maps derived from Monte-Carlo simulations of flood hydraulics.
- Two dimensional (2-D) hydraulic models were developed for study sites in Charlotte, NC and Tucson, AZ, and the model in Tucson, AZ was coupled with the hydrologic model of project B2-1 to evaluate the relative impact of various Green Infrastructure scenarios on flood hazards.
- Collected UAV-derived imagery to develop high-resolution topographic point clouds for 2d hydraulic model simulation of flood waves in urbanizing channel/floodplain systems. We generated digital elevation models for four successive years in the Minebank Run watershed in Towson, MD and for three successive years in the Dead Run watershed in Woodlawn, MD. Modeling scenarios are being developed to assess sensitivity of flow field to pre- vs post-restoration topography for all three watersheds, including testing the feasibility of remote sensing of roughness coefficients for hydraulic modeling. Additional hydrologic analyses are being carried out in collaboration with project B2-2a for case study of the (nominally) >1000-yr rainfall events and resulting floods in July 2016 and May 2018 in the Tiber River watershed of Ellicott City, MD.

B3-1: Flood risk to assets and socioeconomic sectors in a changing world

- Developed a nonstationary flood risk assessment model to assess chronic and acute coastal flood risks under sea level rise (SLR) scenarios.
- Applied the proposed framework to Miami-Dade County to assess chronic and acute coastal flood risks in over the range of sea-level rise scenarios for the coming decades.
- Developed a bivariate probability model to conduct flood risk assessment from computing effects of heavy precipitation and storm surge in coastal regions.

B4-1: Greywater Reuse: Pathogen Removal by a Membrane Bioreactor

- Design of greywater collection system to measure pathogen reduction. Two 250-gallon storage tank will be placed on the rooftop as source water supply to the MBR system. Each storage tank is equipped with air mixer to avoid septic conditions.
- Collaboration with Suez on integrated membrane bioreactor setup. Suez will supply Lab-scale ZeeWeed 500 membranes for this project.
- Development of testing protocols for model bacteria and viruses.

"Thrust C" Research Projects

C1-1: Understanding adoption of sustainable urban water solutions

- Completed implementation of sustainability practices survey for all 5 UWIN regions.
- Built dataset combining survey results with other explanatory variables from secondary sources.
- Conducted analysis and commenced publication of results.

C2-1: Homeowner adoption of sustainable urban water solutions

- Issues present in prior sampling were resolved and the next iteration of surveying began
- Researchers worked to redesign Choiceflow software and surveying methods
- The team continued data review and analysis, and outlined strategies for manuscript development

C3-1: Transitioning to socially equitable and environmentally just sustainable urban water systems

- Completed analyses of social vulnerability to floods hazards, household water expenditures, and health consequences of unaffordable water bills in low-income households using the Survey of Water Indicators and Socioeconomic Status of Households (SWISSH), a C3-1 survey conducted in nine UWIN study regions (n = 9,250).
- Completed analysis of interviews about health effects of unaffordable water bills in a low-income, predominantly immigrant Massachusetts city

C4-1: Financial models and strategies to support the transition to One Water

- Conducted customer survey to gauge willingness to pay for supplemental water supplies in the Palouse Basin Aquifer.
- Continued financial survey of water utility CFO's to gauge integrated management and financial outlook.
- Conducted sensitivity analysis to water demand parametric estimation methods.

"Thrust D" Research Projects

D1-1: Modeling present and future values for sustainable water management blueprint indicators

- Modeling alternative future scenarios at neighborhood scale with SWMM-5, and at the Willamette River Basin scale with Envision
- Modeling alternative future scenarios at watershed scale for Chicken Creek (HUC 12 watershed in Oregon) with UWINvision, a version of the Envision model with SWMM 5 incorporated into the model code as a plug-in
- Communicating results to stakeholders with project meetings, and to other researchers through peer-reviewed publications and presentations at professional meetings (AGU in San Francisco, ESA in Louisville Kentucky, GSA in Portland OR, and the International Geodesign Collaborative Summit, Redlands CA).

D1-2: Cross-site comparisons and contrasts across eco-hydrological regions

- Assessed co-benefits of green infrastructure in UWIN cities using the iTree tool, including air quality, carbon sequestration, cooling effects, and UV exposure.
- Collected, processed and analyzed monthly water use data from approximately 150 municipalities to characterize indoor and outdoor residential, industrial, and temporal water use patterns in U.S. cities.
- Assessed the effects of grey and green stormwater infrastructure in the New York City on flooding and combined sewer overflows over a range of climate change and sea level rise scenarios.

D1-3: Urban water decision innovation system

- Conducted a comprehensive literature review to identify One Water goals, outcomes, indicators and metrics.
- Developed a lifecycle cost assessment tool in collaboration with the Water Research Foundation to support stormwater infrastructure decisions on extent and combinations of green, hybrid green-gray and gray infrastructure practices.

Stakeholder Engagement

- Participated in design of utility operator interviews to inform UWIN One Water framework and progress rating system
- Continued background research on marketing strategies for water management and finalizing manuscript with results

- Continuing social network analysis of one UWIN urban area, South Florida, to better understand relationships and exchange of information among professionals working on climate change in region. Manuscript in preparation.

Undergraduate Research Program (URP)

- Nine undergraduate students participated in the 9-week UWIN Undergraduate Research Program (URP) during the summer of 2019.
- We recruited 10 students from a pool of 177 applicants as well as 17 mentors for URP 2020.
- We planned the 2020 program to be 100% virtual, but with students still working with mentors on similar projects to those originally envisioned for in-person mentoring.

Citizen Science

- Work with Earthwatch and HSBC on the Green Infrastructure Rapid Assessment (GIRA) project was completed in Nov. 2019 with over 200 participants in 4 US cities (New York City, Buffalo, Chicago, San Francisco) and 2 cities in Canada (Toronto, and Vacouver). In 2019, 89 datasets were collected from 71 individual bioswales (some bioswales were visited more than once). Over the life of the project, 177 datasets were collected across all study bioswales. At each bioswale, data collection was broken into 4 categories: (1) infiltration rate, (2) soil classification, (3) bioswale features and mapping, and (4) in situ data collected via Arduino sensor installation. Preliminary research findings were reported out to all city stakeholders during a remote meeting held in March 2020.
- The Off the Roof project collected roof runoff from 7 households in each of 4 cities: Fort Collins, CO (4 events), Tucson, AZ (2 events), Miami, FL (3 events), and Baltimore, MD (2 events).

SPECIFIC OBJECTIVES

The objectives of the UWIN SRN are presented for the 22 research, stakeholder engagement, and Undergraduate Research Program (URP) efforts.

"Thrust A" Research Projects

A1-1: Quantifying vulnerability, resiliency and adaptability of US urban water supply

- Develop and quantify water supply sustainability indicators
- Assess the effects of water management solutions under current and alternative future conditions

A1-2: Effects of changes in climate, demographics and urban form on water supply-demand equilibrium

- Create a database of past, present, and future household water use and prices
- Generate projections of future water demand
- Analyze past and present water prices to generate estimates of future water prices
- Assess the economic impacts of water price on regional economies
- Produce information about the economic impacts associated with regulation strategies

A2-1: Land-atmosphere-hydrosphere interactions in urban terrain

- Couple the WRF and UCM models
- Develop an enhanced representation of trees and surface-air exchanges in the WRF-UCM
- Assess the influence of urban expansion and evaporative cooling infrastructure on the urban environment

A2-2: Projecting future environmental change in urban areas

- Quantify the dynamically interactive effect of increased emissions of greenhouse gases (GHGs) and anthropogenic landscape change associated with urban expansion for the CONUS
- Examine the efficacy of locally deployed urban adaptation and mitigation solutions

A2-3: Assessing the thermal comfort implications of water-supported infrastructure

- Understand health sector perspectives on relationships between urban water systems, climate change, thermal comfort, and heat illness
- Construct a set of detailed time and activity diaries for representative urban dwellers
- Measure the microclimatic conditions experienced by urban residents
- Model how changes to water-supported urban infrastructure as well as urban climate may impact individually experienced thermal comfort for urban dwellers

A2-4: Assessment and design of innovative building systems and urban infrastructure

- Quantify localized impacts on temperature and humidity from building system interactions
- Improve characterization of building energy equipment relationships to climate and water use

- Create a method to deploy thermal cameras to measure the impact of radiation from thermal surface profiles on the heat index
- Create an improved heat index for thermal stress that better incorporates humidity, convection and radiation with the temperature

A3-1: Variation in urban vegetation biodiversity-ecosystem functioning

- Assess vegetation biodiversity distributions and vegetation density distributions throughout each UWIN region
- Evaluate effects of vegetation biodiversity and density on local cooling
- Identify trajectories of changing vegetation biodiversity, density, and ecosystem amenity trade-offs
- Conduct targeted studies of GI to evaluate importance of vegetation distributions to production of ecosystem services and associated water demands

"Thrust B" Research Projects

B1-1: Water management solutions to enhance capacity for use of alternative water sources

- Assess the effects of urban development patterns on water demand
- Assess co-benefits of alternative water management solutions, including reduction of energy demand and GHG emissions
- Assess the effects of alternative water sources, fit-for-purpose water, and conservation strategies on vulnerability, reliability and resilience of water supply systems

B1-2: Life-cycle assessment of urban water systems

- Create decision-support tools for evaluating non-traditional water sources under current and future conditions using life-cycle assessment (LCA) with regionally-appropriate data
- Characterize existing centralized gray urban water infrastructure in case-study cities to provide a baseline for comparing alternative technologies
- Connect ReNUWIt ERC and UWIN researchers doing similar research to maximize synergies

B2-1: Effects of green infrastructure on urban systems

- Understand the effects of Green Infrastructure (GI) on hazard mitigation in humid versus arid climates (efforts in arid regions focus on stormwater use while in humid regions the focus is on minimizing runoff and increasing water quality treatment)
- Assess co-benefits of GI, with a focus on heat island, shade and the support of natural and landscape vegetation in arid regions, while in humid regions focus is on aesthetic

B2-2a: Flood hydrology and rainfall frequency

- Demonstrate a predictive understanding of urban flood hydrology
- Characterize the climatology of flood-producing storm systems
- Develop and implement procedures for rainfall and flood frequency analysis

B2-2b: Hydrology and hydraulics of urban floodplains

- Create urban floodplains under uncertainty in the six study regions
- Compare and contrast the flood resiliency benefits of GI, Low Impact Development, and Sustainable Urban Drainage Systems
- Provide floodplain mapping scenarios for increased resilience to extreme events
- Provide an expanded palette for design of floodplain-greenspace networks that also increase biodiversity, moderate temperatures, cleanse air, and enhance health and happiness

B3-1: Flood risk to assets and socioeconomic sectors in a changing world

- Characterize observed and future changes in flood frequency for cities across the U.S.
- Develop a framework for assessing flood risks to assets and communities
- Assess effects of interventions and responses on the vulnerability of communities to coastal, riverine, and compound flooding

B4-1: Greywater Reuse: Pathogen Removal by a Membrane Bioreactor

- Determine the operational parameters and evaluate pathogen removal efficiency of a small membrane bioreactor (MBR) designed to treat grey water for reuse as irrigation water for urban gardens.
- Investigate the performance of a submerged MBR for pathogen removal as well as the operational parameters affecting the removal

"Thrust C" Research Projects

C1-1: Understanding adoption of sustainable urban water solutions

- Understand the nature and drivers of sustainable urban water policy learning
- Characterize the fragmentation of water governance

C2-1: Homeowner adoption of sustainable urban water solutions

- Understand how adoption decisions for sustainable urban water solutions are made
- Understand individuals' willingness to make large investments in long-term solutions and the different factors that influence willingness to pay across the selected study sites
- Understand how to empower individuals and communities to take a long-sighted view and how to encourage long-term planning and investment

C3-1: Transitioning to socially equitable and environmentally just sustainable urban water systems

- Understand inequalities in existing urban water systems
- Investigate which people and places bear more burdens and receive more benefits from current water systems and practices
- Explore expected or observed impacts and co-benefits of sustainable water solutions (i.e., One Water pathways) on underrepresented groups

C4-1: Financial models and strategies to support the transition to One Water

- Explore governance, financial strategy, economic viability, and public support perspectives of One Water
- Outline the current financial models for separate water services and the extent of their integration
- Identify instances where the current water management model works well and challenges it poses to the One Water model

"Thrust D" Research Projects

D1-1: Modeling present and future values for sustainable water management blueprint indicators

- Develop a consistent representation of the landscape change drivers, processes, and metrics for urban water system sustainability
- Develop U-envision, an alternative futures modeling framework to model future scenarios for urban water systems and to evaluate a suite of sustainability-oriented indicators
- Pilot the use of U-envision, in the Willamette Valley in Oregon

D1-2: Cross-site comparisons and contrasts across eco-hydrological regions

- Synthesize city water data and information from other projects
- Identify optimal water management solutions under deep uncertainty
- Explore tradeoffs associated with water solutions for current and alternative future scenarios
- Identify water management solutions that are most consistent with stakeholders' preferences

D1-3: Urban water decision innovation system

- Develop the Water Connect App for engaging the urban water community to contribute to the development of the UWIN Urban Water Sustainability Blueprint
- Develop web-services for characterizing urban water sustainability indicators
- Develop a multi-criteria decision analysis tool to assess social, economic, and environmental tradeoffs in meeting desired water management targets

Stakeholders & Training

- Elicit active stakeholder contribution to research and outreach
- Build social capital through network development
- Build inter-regional horizontal connections and capacity for information exchange
- Create "safe spaces" for innovation
- Elicit feedback to develop the Urban Water Sustainability Blueprint

Undergraduate Research Program (URP)

- Explore interdisciplinary questions
- Accelerate student learning and development of identity and confidence as scholars
- Promote diversity in the SRN

RESULTS

"Thrust A" Research Projects

A1-1: Quantifying vulnerability, resiliency and adaptability of US urban water supply

- Hydroclimatic characteristics of river basins in the U.S. are highly associated with their regional landform, climate, and ecosystem.
- The direction and magnitude of hydroclimatic changes in some regions vary by climate change scenarios.
- Water supply systems in the southwestern U.S. will be increasingly vulnerable to aridification of the river basins in the region under the "hot" climate change scenario.
- The increasing demand for water from municipal, agricultural, and other sectors is the key factor influencing the vulnerability of U.S. water supply systems, even when climate variability and change are considered.

A1-2: Effects of changes in climate, demographics and urban form on water supply-demand equilibrium

- Paper published with Philadelphia Water Department about their water affordability program which is called the Tiered Assistance Program (TAP)
- Analysis of responses to expenditure questions completed

A2-1: Land-atmosphere-hydrosphere interactions in urban terrain

- The study documented flow transitions between a thermal circulation bubble that traps heat and pollutants and an advective plume that ventilates the city.
- An emergent behavior patterns arises where the urban heat island is strongest in wet regions, making them more difficult to cool using green infrastructure. The same mechanisms explain the hysteresis in the annual cycle of urban surface temperatures.
- Conceptualization and coupling of land and atmospheric models could significantly influence representation of urban hydrology processes and fluxes, such as the relationships between soil moisture distribution with precipitation, slope and lateral subsurface flow of water.

A2-2: Projecting future environmental change in urban areas

- Future urbanization across US, unlike large regional thermal impacts, has negligible effect on precipitation extremes.
- Population heat exposure to extreme heat in U.S. metropolitan areas will increase by a factor of 12.7–29.5 by the end of the century, while cold exposure is projected to rise by a factor of 1.3–2.2, relative to start of century exposure.
- Systemic literature review reveals that albedo and vegetation strategies offer broadly similar magnitudes of cooling, and that trees and ground-level vegetation offer somewhat more pedestrian-level cooling per area application compared with green roofs.

A2-3: Assessing the thermal comfort implications of water-supported infrastructure

- Inequitable distributions of urban heat are the dominant pattern in cities across the country, with lower-income, racial and ethnic minority groups living in hotter parts of cities than urban counterparts. These patterns are closely related in many cities to discriminatory housing policies and zoning codes.
- In Phoenix, residents' perceptions of urban green infrastructure are closely coupled with the biophysical properties of the landscape as well as socioeconomic variables.
- Conventional benchmarks for water and energy affordability do not sufficiently represent stress, anxiety, and worry that consumers experience related to water and energy costs.

A2-4: Assessment and design of innovative building systems and urban infrastructure

- Significant error and potential bias were identified in standard methods for globe thermometer measurements in outdoor environments.
- New simulation methods were developed to characterize the variation of heat coming from different urban surfaces that includes reflection.

A3-1: Variation in urban vegetation biodiversity-ecosystem functioning

- Vegetation cooling among and within cities follows a general pattern consistent with plant stomatal response to atmospheric conditions
- Urban parks achieve a similar level of ecosystem services by selecting species with traits dependent on climate

"Thrust B" Research Projects

B1-1a: Water management solutions to enhance capacity for use of alternative water sources and B1-1b: Assessment of water infrastructure resilience

- Demand reduction potential of water conservation and reuse practices varies across regions and is primarily impacted by precipitation and irrigation demand.
- Use of stormwater to expand water supply shows large potential for water demand reduction but comes at a very high cost compared to other water conservation and reuse solutions.
- When considering tradeoffs between cost and demand reduction for traditional supplies, fit-for-purpose water solutions conducted at the single residence scale do not show as much benefit as those implemented at the multi-residential, regional, or municipal scale.

B1-2: Lifecycle assessment of urban water systems

- Over the past decade, treated wastewater volumes per person in Denver, Washington D.C., and Tucson had declined by 15-20 percent despite significant population growth.
- Of the water demand reduction strategies employed in Tucson, Denver, and Miami, roof runoff is associated with low forgone water, energy and GHG emission potential. The strategies that enable saving both water and wastewater could have a higher forgone GHG emission potential compare to strategies saving only potable water.

B2-1: Effects of green infrastructure (GI) on urban systems

- Green infrastructure (GI) must be implemented at sufficient levels based on the physiographic characteristics of the city to mitigate the effect of imperviousness on urban hydrologic response.
- Current densities of GI implementation in Tucson are insufficient to have a significant effect on flow volumes or peak flows.
- Current maintenance practices decrease infiltration in GI systems in Tucson but in other cities are related to function closer to design.

B2-2a: Flood hydrology and rainfall frequency

- Polarimetric rainfall algorithm using specific differential phase shift leads to significant improvements in estimates of extreme rainfall rates in Houston.

B2-2b: Hydrology and hydraulics of urban floodplains

- Probabilistic flood inundation maps emphasize the need to account for key uncertainties in flood hazard estimates, reveal the spatial variation in exposure likelihood, and indicate that regulatory flood hazard maps underestimate and miscommunicate their intended risk status.
- Channel morphology appears to have a dominant impact on the observed channel velocities.

B3-1: Flood risk to assets and socioeconomic sectors in a changing world

- Pacific coast regions should expect the highest major flood frequency amplification. Highest frequency amplification in minor flooding is expected along the Gulf and northeast Atlantic coasts.
- Under current sea-level conditions, expected annual damages are dominated by the exposure to occasional extreme events in Miami-Dade County. However, the expected damages from repetitive minor flooding will exceed those from extreme floods under future sea-level scenarios.

B4-1: Greywater Reuse: Pathogen Removal by a Membrane Bioreactor

- Established greywater collection, transportation, and storage plans. Grey water will be collected from three-dorm laundry rooms and mixed onsite every day. Model pathogens will be mixed into one tank to reach target concentration. The storage tank will be thoroughly disinfected between each set of pathogen experiment.
- Developed MBR testing system. We will install two lab scale MBR systems to compare the efficiencies in pathogen removal. Each system is supplied with fresh collected greywater. And water parameters will be tested continuously, and removal efficiency will be evaluated.
- Culture and testing protocols established for *E coli* and MS2

"Thrust C" Research Projects

C1-1: Understanding adoption of sustainable urban water solutions

- Meta-analysis of research shows convergence of theoretical and empirical literatures on policy change.
- Significant links exist between innovation networks, local policy networks, and routine water management activities.
- Innovations in water management take the form of experimentation across governmental and non-governmental stakeholders.

C2-1: Homeowner adoption of sustainable urban water solutions

- Across cities, factors influencing adoption include ease of adoption, costs, and environmental attitudes
- Participants report that the Choiceflow platform, the software developed for UWIN, provided an informative and innovative way to learn about the grey water technology and its implementation

C3-1: Transitioning to socially equitable and environmentally just sustainable urban water systems

- This study established that communities of color across U.S. urban areas disproportionately face challenges to water access due to unaffordable water bills that result in utilities shutting off water services to households more often than in whiter communities.
- Human responses to unaffordable water bills include use of a variety of coping strategies, such as water conservation.
- Negative mental health effects are associated with water affordability challenges. The essential need for water, its inextricable link to housing security, and fear of losing access to either was another important stressor.

C4-1: Financial models and strategies to support the transition to One Water

- Willingness to pay (~$10 per month) for water projects is improved when co-benefits, particularly wildlife habitat, are included.
- Parsimonious weather information (temperature and precipitation) may be significant to estimate household demand without the need for more advanced (e.g. ET) environmental metrics.

"Thrust D" Research Projects

D1-1: Modeling present and future values for sustainable water management blueprint indicators

- Watershed scale design of development that retains open space and riparian forest has the lowest impact on the watershed hydrologic regimes and can ameliorate but cannot entirely compensate for the impacts of climate change and population growth.
- At the neighborhood scale, both design and construction of low impact development and water harvesting / reuse can influence the relative impact of climate change and population growth.

D1-2: Cross-site comparisons and contrasts across eco-hydrological regions

- Green infrastructure can markedly change the hydrologic cycle in cities by influencing infiltration.
- Green infrastructure systems provided complimentary effects on flooding but would not substitute the effects of grey systems on combined sewer overflows in New York City.

KEY OUTCOMES

Research

The SRN activities engaged 39 faculty members (2 Deans, 20 professors, 5 associate professors, and 10 assistant professors, 2 instructors) from 34 academic institutions with interdisciplinary expertise, as well was 7 research scientists, 7 staff scientists, 47 graduate students, 16 undergraduate students and 7 postdoctoral research associates. Moreover, over 100 nationally renowned urban water and sustainability stakeholders from various regions across the U.S. were involved in the SRN research, engagement and educational activities. In addition, the UWIN SRN fosters ongoing collaborations with 71 organizations across the country including 11 federal/state/local government agencies, 11 non-profit organizations, 10 utility partners, 3 consulting agencies and 2 commercial/industrial firms.

The UWIN SRN activities has created, for the first time, an integrative assessment framework that underpins development of strategies for integrated planning and management of urban water systems, enable incorporation of decentralized regenerative technologies and infrastructure systems that enhance the resilience of water systems in cities, and enhance the co-benefits of urban water systems for improved air quality, biodiversity, readiness to climate change and extreme events, and community livability. A cyberinfrastructure is developed and piloted in several cities in the U.S. and internationally to enable communities identify solutions that best meet their need to address regional water challenges in a variety of contexts from coastal communities to high plain desserts.

The SRN transdisciplinary activities to date have produced:

- 165 high impact journal publications
- 28 PhD dissertations and M.S. theses
- 5 book chapters
- 288conference papers/posters and presentations
- 1 patent
- 89 outreach and print materials
- 19 software and modeling tools
- 4 websites
- 27 webinars
- 40 datasets

Integration Efforts

Several integrative projects were identified by project leadership to help cities transform urban water management systems through integrated approaches. UWIN established Task Forces to outline plans for the creation and development of the products listed below:

- **Sustainability Indicators**: Urban Water Sustainability Indicators are developed to provide a roadmap and compass for our collective research efforts, thus contributing to a concrete and internally consistent set of indicators is a key integrative activity within UWIN.

- **Testbed studies**: These studies are conducted to investigate technological, policy, institutional, and financial pathways that foster integrated planning and management of urban water systems, and advance transitions toward a "resource management" model, which aims to maintain or restore the natural and social capital of cities, including: reliability of water supply, water quality control, and flood control services; resilience to changes in climate, population, land use, and economic conditions; biodiversity (functional diversity); social environmental justice and equity, and community health and livability.
- **Synthesis papers**: Several cross-cutting academic publications are produced to synthesize proposed solutions to urban water issues, as identified by each project. The ongoing studies investigate: the current state of urban water systems (pressures, challenges); and socially viable and economically feasible pathways to improve the resiliency and co-benefits of urban water systems while meeting current and future needs.
- **Integrated Web Tool**: This tool is developed to enhance the capacity of decision makers to reach integrated decisions that foster One Water approaches and build sustainable urban water systems. The tool serves as a planning level tool to identify tradeoffs of integrative urban water management strategies considering economic, social, and environmental contexts. The tool is being piloted in UWIN regions with varying climatic conditions, infrastructure, decision drivers, and social preferences. Benefits and tradeoffs of various integrated water management strategies are assessed via indicators delivered by the Indicators task force.

Stakeholder Engagement

Interactions between UWIN researchers and water stakeholders from five regions (Southeast Florida, Sun Corridor, Mid-Atlantic, Pacific Northwest, and Front Range) have provided a basis for case studies on transitions toward sustainability. Analysis of qualitative data on pressures, states, and responses collected during interactions has provided insight into the challenging context of urban water management. Top pressures identified include climate change, aging infrastructure, water quality impairments, and funding limitations. Additionally, stakeholders described resistance to change and short-term perspectives among elected officials, limited understanding/awareness of water systems among decision makers, and lack of leadership on water issues as contributing to pressures. More than technological solutions, practitioners call for improved coordination in water management, strengthened communication with elected officials, and behavioral change among citizens.

The Network is currently conducting activities in collaboration with the Philadelphia Water Department (PWD) to develop a web-tool to evaluate and adapt co-benefits/triple bottom line analysis for use in PWD's planning analysis of alternative stormwater management infrastructure. This collaborative effort provides information on benefits and costs of green infrastructure to inform design criteria, regulations and incentive programs as well as support decision making and foster communication of benefits and costs of green infrastructure to decision makers, stakeholders and the public.

UWIN participated in a multi-institutional collaborative effort let by Brooklyn College of the City University of New York to evaluate the resiliency of the City's stormwater and flood control

infrastructure to climate change and sea level rise. New York City governmental stakeholder partners included the Department of Environmental Protection (DEP), Mayor's Office of Resiliency (MOR), and Emergency Management (NYCEM). The study created a citywide Hydrologic and Hydraulic (H&H) model to model flooding from stormwater in NYC. Citywide flood exposure for twenty current and future storm scenarios were simulated. The impacts of flood exposure across representative neighborhoods in across NYC. The study identified grey, green, and hybrid infrastructural systems to reduce flood exposures at both citywide and at the neighborhood scale.

Undergraduate Research Program (URP)

The URP participants are given the opportunity to perform cutting edge, transdisciplinary research of immediate relevance to people in urban areas. Students with varying research interests – social sciences, natural sciences, engineering – are placed with a team of mentors at institutions in urban areas across the nation. The program starts and ends at Colorado State University, Fort Collins, Co. The UWIN URP program engages students in three strands of activities:

- Cutting Edge Independent Research Projects
- Reflective Practice and Training Activities
- Transdisciplinary Research Activities in Urban Water Sustainability

Diversity Program

Diversity Recruitment and Retention supplements were awarded to two students for the 2019-2020 academic year and were intended complement existing activities and programs already in place at the Network's affiliated institutions.

Adriana Arcelay received supplemental support for the 2019-2020 academic year at the University of Arizona. An ideal candidate for broadening participation from traditionally underrepresented minority groups, Ms. Arcelay is a female, African-American student from a lower income background currently pursuing an MS in Hydrology at the University of Arizona. Through the supplemental UWIN support Adriana has worked on extending understanding of flood risks in rivers with non-stable beds (contributing to UWIN Project B2-2). Adriana was trained to use climate model outputs as inputs to hydrologic and hydraulic models and to estimate uncertainty in flood predictions. Her research and training is overseen by UWIN-UAZ PI Thomas Meixner, Adriana also received one semester TA position and tuition remission from the University of Arizona Department of Hydrology and Atmospheric Sciences.

Nia H. Rene was selected to receive the second diversity supplement in 2018 Unfortunately, institutional barriers prevented the reallocation of funds to a new subaward, thus UWIN was unable to financially support Miss Rene in the 2019-2020 academic year. The Network is exploring other opportunities to support Nia and her research into green infrastructure designed to assist in ushering in a new approach to urban and peri-urban water management and sustainability.

Citizen Science Program

- **Green Infrastructure Rapid Assessment (GIRA):** UWIN collaborated with Earthwatch and HSBC on the Green Infrastructure Rapid Assessment (GIRA) project with over 200 participants in 4 US cities (New York City, Buffalo, Chicago, San Francisco) and 2 cities in Canada (Toronto, and Vancouver). Data were collected from 71 bioswales (some bioswales were visited more than once). Approximately 177 datasets were collected across all study bioswales over the life of the project, including infiltration rate, soil classification, bioswale features and mapping, and in situ data collected via Arduino sensor installation.

- **Off the Roof:** The project investigates roof runoff water quality to inform treatment targets for different end-uses. Roof runoff was collected from 7 households for 4 precipitation events in Fort Collins, Tucson, Miami, and Baltimore. Result indicate that roof runoff chemical and microbial quality is highly variable across regions and sampling seasons. extensive planning and coordination is needed to enable successful roof runoff collection from the four study cities.

TRAINING & PROFESSIONAL DEVELOPMENT

Undergraduate Research Program (URP)

The URP participants are given the opportunity to perform cutting edge, transdisciplinary research of immediate relevance to people in urban areas. Students with varying research interests – social sciences, natural sciences, engineering – are placed with a team of mentors at institutions in urban areas across the nation. The program starts and ends at Colorado State University, Fort Collins, Co. The UWIN URP program engages students in three strands of activities:

- Cutting Edge Independent Research Projects
- Reflective Practice and Training Activities
- Transdisciplinary Research Activities in Urban Water Sustainability

The students who participate in the UWIN URP are part of a diverse community of scholars working together to advance understanding of complex urban water sustainability challenges. URP students conduct research under the supervision of their faculty mentors to identify potential solutions to urban water sustainability challenges in several geographical regions. They acquire both broad understanding of urban water sustainability challenges and solutions and in-depth knowledge and skills in their chosen area of research. They demonstrate mastery of core research skills: identification of a research question, design of an appropriate research methodology, processes for data collection, application of statistical analysis, and communication of results and conclusions with diverse audiences through technical writing and oral presentation. They contribute meaningful work to their teams' research and build positive relationships and networks to support their continued professional development.

URP students gain proficiency in transdisciplinary approaches to complex problem solving (stakeholder involvement and integration of diverse perspectives) and understanding of how research is translated into action. They recognize a range of employment opportunities in urban water sustainability and gain understanding of their own career interests and path. The undergraduate students participated in meetings with graduate students during the UWIN annual meeting and helped formulate ideas for improving the UWIN student experience overall.

Nine undergraduate students participated in the 2019 summer URP and were supported through this project. An additional ten undergraduate students have been selected to participate in the 2020 online summer URP.

Other undergraduate students are also involved in UWIN-related research activities. In this reporting period, 18 undergraduate students were involved in UWIN outside the URP.

Graduate Students

Over 45 graduate students are currently involved in UWIN-related research activities. While not all students are funded directly by the project, all students are contributing to the UWIN SRN goals and objectives. To date the project has generated research resulting in the completion of 13 theses and 15 dissertations.

Example training and scholarship opportunities include:

- Student training on presentations at professional meetings and conferences
- Mentorship and supervision to complete PhD dissertation and M.S. thesis projects
- Interdisciplinary team science training for graduate students
- Professional development for graduate student with job applications for faculty positions and preparation for on-campus interviews
- Graduate students training in analysis of survey data; satellite data interpretation and analysis; plant biodiversity surveys; One Water approaches; microbial analysis; stormwater control measures; water reuse; water demand reduction strategies; multi-objective optimization; and use of sustainability indicators to measure co-benefits of water conservation and reuse strategies
- Training opportunities for data science, big-data analytics, data integration, and computational statistics
- Training opportunities for decision making under deep uncertainty
- Training opportunities in network analyses research

Postdoctoral Scholars

Seven postdoctoral researchers were involved with UWIN research and training activities over the reporting period. Postdoc Maider Llaguno Munitxa will join Northeastern University as a tenure track assistant professor in the fall (School of Architecture).

Professional Development

Interdisciplinary Communication Workshop

The UWIN graduate and undergraduate research program students requested dedicated time at the 2019 annual meeting to learn about each other's research, identify connections and potential research collaborations across thrusts and regions, and better understand how the wide array of UWIN research supports an integrated One Water Approach. A full-day student workshop was designed by members of the Student Success Task Force with input from several graduate students. It was led by Dr. Deana Pennington using the Employing Model-based reasoning in Socio-environmental Synthesis (EMBeRS) approach to help facilitate development of shared understanding across disciplines. All UWIN graduate students, post-doctoral fellows and undergraduate research program students were invited to attend with housing and meals support provided.

The 23 participants found the workshop valuable and successful in achieving its goals. A majority (83% GR, 89% UG) developed new perspectives on how their research contributes to the One Water Approach and believe the workshop could lead to new or enhanced UWIN collaborations. All indicated they intended to apply what they learned in multiple contexts: 1) framing and explaining their own research; 2) collaborating on research, funding proposals and scientific articles; 3) working with stakeholder; and 4) teaching courses. Three-quarters of the graduate students indicated they would share the EMBeRS methods with others.

Workshop Leaders:

- Dr. Deana Pennington, Associate Professor of Geological Sciences, University of Texas at El Paso
- Dr. Shirley Vincent, Principal, Vincent Evaluation Consulting, LLC
- Dr. Kate Thompson, Assistant Professor of Learning Sciences, Griffith University
- Yoga Korgaonkar, UWIN PhD student, University of Arizona

Citizen Science

The participating citizen scientists in both the GIRA and Off the Roof projects have learned about water in urban systems. GIRA participants have learned how GI works and the relationship between flood water, sewer overflows and water quality in cities. One MS student (Samantha Swartz at U AZ) has been supported for her work on the project.

DISSEMINATION OF RESULTS

The UWIN research and education team members actively disseminated the products of research, education, and engagement activities via publication of high impact journal papers, presentations at various conferences, and invited lectures/seminars. These products include:

- 165 high impact journal publications available at https://www.zotero.org/groups/738723/urban_water_innovation_network_uwin/library
- 28 PhD dissertations and M.S. theses
- 5 book chapters
- 288 conference papers/posters and presentations
- 1 patent, 6 IP disclosures, and 12software copyrights
- 89 outreach and print materials available at https://erams.com/UWIN/print-materials/
- 19 software and modeling tools
- 4 websites
- 27 webinars available at https://www.youtube.com/channel/UC7nNrIUznXii6_u0axbhQrA
- 40 datasets available online at https://erams.com/UWIN/data/

A comprehensive list of these products is available from the Products Section of this progress report.

UWIN has forged partnerships with water stakeholders in 15 cities to conduct transdisciplinary research and disseminate actionable science results to communities. For example, our team led the New York City Stormwater Resiliency Study funded by NYC DEP and Mayor's Office to assess flood risks in the City and identify effective interventions. Similarly, a stakeholder workshop was conducted in Philadelphia to discuss how UWIN research and training can benefit various water programs in the city.

We have developed datasets and modeling tools that are available ale to the broader community as open-source information. Out tools are currently used by thousands of annual users. Continuous support for these tools is provided to expand their application in other regions and studies.

FUTURE PLANS (Y6-NCE)

All projects will work on reporting the results of project activities in peer reviewed journal and will present the highlights of the studies at professional meetings and conferences. While some projects have completed their activities and are graduates during this reporting period, the activities of the remaining projects are reported below.

"Thrust A" Research Projects

A1-1: Quantifying vulnerability, resiliency and adaptability of US urban water supply

- Investigate the role of water supply enhancement and water demand reduction strategies on reducing the annual and interannual vulnerability of U.S. water supply systems over a range of alternative future population, land use, and climate scenarios

- Investigate how policy and institutional agreement influence the reliability and resiliency of U.S. water supply systems in meeting current and future demands

A1-2: Effects of changes in climate, demographics and urban form on water supply-demand equilibrium

- Clean and publish water rate database on eRAMs for public use
- Complete publications specific to project activities
- Work on papers with broader UWIN research team to use completed datasets

A2-1: Land-atmosphere-hydrosphere interactions in urban terrain

- Carry out urban coupled atmosphere-land surface- subsurface simulations of Baltimore-Washington, Denver, and Portland metropolitan area using WRF-LES-PUCM-ParFlow

A2-3: Assessing the thermal comfort implications of water-supported infrastructure

- Complete analysis of health sector and emergency management interviews
- Extend urban heat mortality analysis to additional cities

A2-4: Assessment and design of innovative building systems and urban infrastructure

- Translate research finding into design conceptualization to bring the results to the urban and architectural design community and try to invoke some demonstration and change through informed generative design

A3-1: Variation in urban vegetation biodiversity-ecosystem functioning

- Continue development of urban tree drought testbed
- Expand a nascent theoretical framework of urban vegetation under the rubric of living infrastructure

"Thrust B" Research Projects

B1-1a: Water management solutions to enhance capacity for use of alternative water sources

- Conduct integrated analysis of water, wastewater, and stormwater innovations for sustainable urban development in the Globeville-Elyria-Swansia neighborhood in collaboration with UWIN team
- Enhance the Integrated Urban Water Model (IUWM) by adding co-benefits assessment module
- Assess microbial quality of stormwater

B1-2: Lifecycle assessment of urban water systems

- Continue to work on case studies using a life-cycle assessment method and water systems, energy systems, and greenhouse gas data
- Characterize the energy demand and greenhouse gas emissions associated with water treatment and wastewater treatment plants in the United States using a comprehensive survey of approximately 50 cities in the U.S.

B2-1: Effects of green infrastructure on urban systems

- Complete modelling of Tucson Auto-mall watershed
- Complete a review of current state of GI research on hydrology and water quality in cities, complete synthesis of Tucson Arizona work.

B2-2b: Hydrology and hydraulics of urban floodplains

- Combine results derived from probabilistic floodplain mapping with 2-D model scenarios to map novel flood hazard indices that improve the fundamental understanding and communication of spatial distribution of flood hazards in various UWIN regions
- Link modeling efforts with the results produced by collaborative partners to evaluate the efficacy of various green infrastructure scenarios
- Combine the results of time-series analysis of DEMs to hydraulic modeling results to predict the long-term evolution of stream restoration projects and use these results to inform future restoration efforts on how to create restoration projects that are more resilient to potential changes in hydraulic regime.

B3-1: Flood risk to assets and socioeconomic sectors in a changing world

- Develop a bivariate probability model to characterize compound flooding risks from heavy precipitation and storm surge in coastal regions under alternative climate change and sea level rise scenarios
- Apply the model to characterize compound flooding risks in various regions along the contiguous U.S. coasts
- Evaluate the effects of stormwater and flood control interventions on flood risks in a New York City sewershed

B4-1: Greywater Reuse: Pathogen Removal by a Membrane Bioreactor

- Set up the MBR system set up and train students on bacteria/virus incubation methods
- Test MBR operational parameters and test influent and effluent water quality.
- Conduct pathogen removal experiment with MBR

"Thrust C" Research Projects

C1-1: Understanding adoption of sustainable urban water solutions

- Complete survey analysis and prepare results for journal publications
- Complete papers on UWIN indicators

C2-1: Homeowner adoption of sustainable urban water solutions

- Complete data analysis
- Prepare 2-3 manuscripts and submit for publication

C3-1: Transitioning to socially equitable and environmentally just sustainable urban water systems

- Prepare the national SWISSH dataset for publication accessible to other researchers.
- Participate in creation of the Sustainable Urban Water Systems (a.k.a. "One Water Cities") Assessment Framework and Rating System

C4-1: Financial models and strategies to support the transition to One Water

- Complete the Financial survey. Complications due to COVID have delayed our progress.
- Participate in creation of the Sustainable Urban Water Systems (a.k.a. "One Water Cities") Assessment Framework and Rating System

"Thrust D" Research Projects

D1-1: Modeling present and future values for sustainable water management blueprint indicators

- Evaluate and synthesize the results of modeling future scenarios at the neighborhood scale, watershed scale
- Assess the contribution of modeling across scales to urban innovation
- Finish the groundwater studies in the Willamette watershed
- Communicate project modeling results to stakeholders and communicate project results to Portland residents through free choice learning platforms and serious game development

D1-2: Cross-site comparisons and contrasts across eco-hydrological regions

- Evaluate the effects of fit-for-purpose-use of urban water demand reduction strategies on water demand, wastewater production, and greenhouse gas emissions
- Evaluate the effects of urban water development patterns on water demands
- Assess linkages between urban land use planning and water use
- Evaluate the hydrologic performance, costs, and co-benefits of green infrastructure systems in Philadelphia, New York City, and UWIN cities Denver, Phoenix, Portland and Los Angeles

D1-3: Urban water decision innovation system

- Create web tools to enable open-source and platform independent access to project data and models
- Develop and pilot demonstration of a One Water Cities Assessment Framework and Rating System

Stakeholder Engagement

- Finalize water marketing guidance and publish
- Finalize South Florida social network analysis and publish
- Finalize UWIN project social network analysis and publish

Citizen Science Program

- All research has been completed on the GIRA project and the final report has been submitted to Earthwatch. Over the next year the research team will work on publishing the results from this work. GIRA will continue to run in NYC in collaboration with local NGOs and we will be establishing projects and collaborations to continue this work in UWIN cities (i.e. Baltimore, Tucson, Ft. Collins, and Miami).
- Off the Roof will continue to collect data and will complete data analysis and dissemination to participants in year 5.

Undergraduate Research Program

- Complete the program in 2020 and pursue funding ideas to continue the URP beyond the UWIN grant.
- Continue our efforts to provide students the opportunity to explore trans-disciplinary research skills and dispositions.
- Continue our efforts to build connections among students and within the larger UWIN community.
- Complete our education research into student learning and other outcomes from the highly innovative UWIN URP model.

COLLABORATORS & PARTNERS

Partners

During the course of this project, **UWIN has engaged over 70 organizations** including 34 academic institutions, 11 governmental agencies, 11 non-profit organizations, 10 utility partners, 2 industrial firms, and 3 consultants. A summary of our partners is provided below.

NAME	ORGANIZATION TYPE	LOCATION
Arizona Department of Health Services	State or Local Government	Phoenix, AZ
Arizona State University (UREx SRN, UAHS, 3HEAT)	Academic Institution	Tempe, AZ
Baltimore County Dept. of Environmental Protection & Sustainability	State or local Government	Baltimore, MD
Brooklyn College - City University of New York	Academic Institution	Brooklyn, NY
Carollo Engineers, Inc.	Consultant	Los Angeles, CA
Cary Institute of Ecosystem Studies	Academic Institution	Millbrook, NY
Chattahoochee River Keeper	Non-profit	Charity, GA
City of Atlanta Watershed Management	State or Local Government	Atlanta, GA
City of Fort Collins	State or Local Government	Fort Collins, CO
City of Miami	State or Local Government	Miami, FL
City of Phoenix	State or Local Government	Phoenix, AZ
City of Tempe	State or Local Government	Tempe, AZ
Colorado School of Mines	Academic Institution	Golden, CO
Colorado State University	Academic Institution	Fort Collins, CO
Decision Center for a Desert City (DCDC, phase III)	Academic Institution	Tempe, AZ
Denver Metro Wastewater Reclamation District	Utility	Denver, CO
Denver Water	Utility	Denver, CO
Earthwatch Institute	Non-profit	Boston, MA
Exxon Mobil	Industrial or Commercial Firms	Irving, TX
Florida International University	Academic Institution	Miami, FL
Fort Collins Utilities	Utility	Fort Collins, CO
Freshwater Simulations	Industrial or Commercial Firms	Portland, OR
Georgia Association of Floodplain Management	State or local Government	Atlanta, GA
Georgia State University	Academic Institution	Atlanta, GA
GreenRoots	Non-profit	Chelsea, MA
Howard University	Academic Institution	Washington, DC
Institute for Sustainable Infrastructure	Non-profit	Washington, DC
Kounkuey Design Initiative	Non-profit	Los Angeles, CA
Lanier Consulting, LLC	Consultant	Miami, FL
Maricopa County Department of Public Health	State or Local Government	Phoenix, AZ

McCormick-Taylor Consultants	Consultant	Baltimore, MD
Metro Water Reclaimation District	Utility	Denver, CO
Miami Beach Utility	Utility	Miami, FL
Miami/Dade County Water & Wastewater Dept.	Utility	Miami, FL
Michigan State University	Academic Institution	East Lansing, MI
Moscow Water	Utility	Moscow, ID
Nanjing University	Academic Institution	Nanjing, China
National Center for Atmospheric Research	Academic Institution	Boulder, CO
National Weather Service Phoenix Forecast Office	State or Local Government	Phoenix, AZ
Northeastern University	Academic Institution	Boston, MA
Northeastern University School of Law	Academic Institution	Boston, MA
Oregon State University	Academic Institution	Portland, OR
Philadelphia Water Department	Utility	Philadelphia, PA
Pima County Wastewater	Utility	Tucson, AZ
Princeton University	Academic Institution	Princeton, NJ
Sonoran Institute	Non-profit	Tucson, AZ
Southeast Florida Regional Climate Change Project	Non-profit	Miami, FL
Swiss Federal Institute of Technology Zurich, Switzerland	Academic Institution	Zurich, Switzerland
The Nature Conservancy	Non-profit	Phoenix, AZ
Torino Polytechnic	Academic Institution	Torino, Italy
Tucson Water	Utility	Tucson, AZ
United States Army Corps of Engineers	Federal Government	Mobile, AL
University at Buffalo	Academic Institution	Buffalo, NY
University College London, UK	Academic Institution	London, England
University of Arizona	Academic Institution	Tucson, AZ
University of California, Berkeley	Academic Institution	Berkeley, CA
University of California, Riverside	Academic Institution	Riverside, CA
University of Baltimore Maryland County	Academic Institution	Baltimore, MD
University of Georgia	Academic Institution	Athens, GA
University of Idaho	Academic Institution	Moscow, ID
University of Miami	Academic Institution	Miami, FL
University of Oregon	Academic Institution	Eugene, OR
University of Pennsylvania	Academic Institution	Philadelphia, PA
University of Perugia	Academic Institution	Perugia, Italy
University of Reading	Academic Institution	Reading, UK
University of Texas at Dallas	Academic Institution	Dallas, TX
UREx Sustainability Research Network	Academic Institution	Tempe, AZ
Vitalyst Health Foundation	Non-profit	Phoenix, AZ
Wayne State Universtiy	Academic Institution	Detriot, MI
Water Research Foundation	Non-profit	Alexandria, VA

Watershed Management Group	Non-profit	Tucson, AZ

Regional Stakeholder Advisory Committee Members

Front Range: Sarah Anderson, Kevin Bommer, Devon Buckels, Tom Cech, Melanie Criswell, David Erickson, Greg Fisher, Basil Hamdan, Bret Icenogle, Tracy Kaye, Jim McQuarrie, Gabriela Medina, Patrick Pfaltzgraff, Holly Piza, Dr. Florine P. Raitano, Reagan Waskom, Kevin Reidy.

Pacific Northwest: Rick Bastasch, Bobby Cochran, Jim Duggan, Stephanie Eisner, Allison Hensey, Johan Hogervorst, Hydrologist, Wayne C. Huber, Jim Meierotto, Brooke Mittermann, Karl Morgenstern, Alyssa Mucken, Bruce Roll, Carrie Sanneman, Greg Taylor, Dawn Uchiyama.

Mid-Atlantic: Kristin Baja, Jim Caldwell, Halle Van der Gaag, Jim George, Kim Grove, Benjamin H. Grumbles, Thomas Kiefer, John McCoy, Bill Stack, Steve Stewart, Anne Hairston-Strang, Frank Blanco, Jim DuBois, Kathy Chavez, Jeanne Jensen, Aminata Kilungo, Mark Hartman, Mark Holmes, Fernando Molina, Ken Seashole, Kieran Sikdar, Andy Terrey.

Southeast Florida: Jacob Coker-Dukowitz, Nichole L. Hefty, Morgan Hopkins, Jennifer Jurado, Amy Knowles, Dawn M. Meyers, Jayantha Obeysekera, Douglas Yoder.

Sun Corridor: Frank Blanco, Jim DuBois, Kathy Chavez, Jeanne Jensen, Aminata Kilungo, Mark Hartman, Mark Holmes, Mead Mier, Fernando Molina, Ken Seashole, John Shepard, Kieran Sikdar

New York: Pinar Balci, Chris Boyd, Stuart Brodsky, Edward Clerico, Simon Mettler, Philip Silva, Kenniff Vlada, Julie Welch, Michael Gubbins, Caitrin Cronin, Alan Cohn, Erin Morey, Susanne DesRoches.

Philadelphia: Dwayne Myers, Marc Cammarata, Dan Schupsky, Kelly Anderson, Stephen White, Adam Hendricks, Stephanie Chiorean, Peter Struck, Maria Antonia Andrews, Zhengxia Dou, Simon Richter Dave Arscott, William Braham, Scott Moore, Karl Russek, Erica DePalma, Carol Collier, Allison Lassiter, Russell Composto, Ken Steif, Meg Kramer, David Hewitt, Tom Daniels, Shu Yang Yang, Howard Neukrug, Swati Hegde, Julie Heffernan, Marilyn Howarth.

Citizen Science Program

Audrey Mohan (BSC), Rebecca Jorban (Rutgers Unv.), Rob Dunn (NC State Unv.), Jay Garland (EPA), Nichole Brinkman (EPA), Scott Keeley (EPA), Michael Jahne (EPA), Greg Newman (CSU/NREL), Diana Eddowes (EarthWatch), Jake Geddes (EarthWatch), Mark Chandler (EarthWatch), Anna Woodroof (EarthWatch), Lucy Triedman (EarthWatch), Caroline Nassif (EarthWatch), Caroline Dunn (EarthWatch), Gitte Venicx (EarthWatch), Paul Stanley (HSBC), Ruth Legg (HSBC), Andrew Greenspan (HSBC), Kelly Fisher (HSBC)

Undergraduate Research Program

Dr. Geoffrey Habron, Furman University, Greenville, SC; Dr. Deana Pennington, University of Texas at El Paso, El Paso, TX; Dr. Julia Svoboda Gouvea, Tufts University, Medford, MA; Dr. Kate Thompson, Griffith University, Australia; Dr. David Gosselin, University of Nebraska-Lincoln.

Other Collaborators

Dr. Fei Chen (NCAR), Mr. Mukul Tewari (IBM), Prof Sue Grimmond (Reading), Prof Nima Shokri (University of Manchester), Prof William Anderson (UT Dallas), Prof Marcus Hultmark (Princeton), Dr. Mark Chandler (Earthwatch Institute), Dr. William Eisenstein (UC Berkeley and ReNUWIt), Prof. John McCray (Colorado School of Mines and ReNUWIt), Daniel Wright (UW – Madison), Dr. Jun Wang (Unv. Iowa), An Moynihan (Pima County Flood District), David Goodrich (ARS), Irene Ogata (City of Tucson), Lucero Radonic (Michigan St. Unv.), Jayantha Obeysekera (SFWMD), William V. Sweet (NOAA), Anne Miller (CO Dept. Local Affairs), Russ Sands (Brendle Group/CWCB), Zoe Hamstead (UREx SRN), Chris Wyczalkowski (UREx SRN), Craig Fugate (Metropolitan North Georgia Water Planning District), Todd Bridges (One Concern, Engineering with Nature, USACE), Susan Beck (Georgia Dept. of Transportation), Sean Gordon (Portland State University), Vivek Shandas (Portland State University).

IMPACTS

Principal Discipline(s)

The UWIN research and engagement activities to date have advanced fundamental knowledge about driving forces, pressures and responses that influence sustainability of urban water and linked systems. Primary scientific disciplines that are involved with these activities include: urban microclimate and heat islands; climate change and extreme events; urban water demand, alternative water sources and fit-for-purpose use; vulnerability to water shortage in a changing world; vulnerability to urban flooding; urban water pollution; urban biodiversity; urban water social and policy networks; social and environmental justice implications of urban water management and extreme events; and human health and wellbeing.

The UWIN research projects have culminated in collection and creation of an unprecedented amount of data about past and present states of urban water and linked systems at local, municipal and continental scales. Additionally, our team members have developed new modeling systems that enhance the predictive capacity to assess the effects of changes in population, land use, climate, and extreme events on the vulnerability of our communities to water shortage, flooding, water pollution, extreme heat, and loss of natural capital in cities. These modeling capabilities are being used to develop appropriate adaptation and mitigation strategies that improve access to safe and clean water, resilience to extreme events, and long-term reliability of water systems and services.

Fully Coupled Representation of Urban Microclimate and Water Cycle

We have created the most complete framework to date to simultaneously model the urban water cycle and demand, the urban climate, urban energy use, and interactions thereof. The framework is being used to answer the following questions that are of central importance in the discipline:

- How does the full coupling of WRF-UCM-ParFlow affect hydrological and climatological predictions in urban terrain?
- In dry periods, urban vegetation becomes water stressed and needs irrigation, which places additional demand on water supply. What is the likelihood of such dry periods occurring at present and how will this likelihood be influenced by future climate change?
- How do climatic and energy benefits of green infrastructure facilities balance against their potential water requirements across the six metro regions that are studied in the UWIN?
- What are the effects of impervious surface area and green infrastructure on the water table location and the vulnerability of urban areas to extreme heat and drought?
- How much urban water use variability can be attributed to climatic variability and how can water demand increases associated with climate extremes be reduced?
- How do urbanization patterns, density and spatial extent influence the response of a metropolitan region to climate extremes, and thus can urban planning be used to increase urban resilience?

Our efforts are the first to robustly address these questions.

These projects also elucidate and enhance understanding of the role of urban heat in driving heat-related health outcomes. The UWIN projects have made methodological advances for environmental health and health geography, and strategies for monitoring/modeling personal heat exposure in cities. Our goal is to explore and advance the notion of personal heat exposure as a useful measurement for informing urban sustainability practices and decision-making.

Urban Biodiversity

Our data collection and modeling studies have advanced the knowledge of urban biodiversity in the context of urban microclimate variability, water availability, and development patterns.

Urban Water Supply Infrastructure, Water Demand, Alternative Water Sources, and Fit-For-Purpose Use

We have characterized and estimated current and future water yield, water supply and water demand for the contiguous United States (CONUS) to explore the vulnerability of U.S. water supply systems to shortage. These data, modeling tools and analyses reveal the effects of urbanization and climate change on water scarcity, supply reliability, and resiliency.

The newly developed, calibrated and tested Integrated Urban Water Model (IUWM) provides a significant advancement of our predictive capability to assess urban water demand management strategies and fit-for-purpose use of alternative water sources. This model can inform estimates of reliability of water resources under varying scenarios of climate, population and land use change. This model can inform estimates of reliability of water resources under varying scenarios of climate, population, and land use change.

Moreover, guidance was developed for use of alternate water sources. This guidance has been used to develop regulation for onsite water systems in California and Colorado. Another four states have regulations underway that use the developed guidance (MN, OR, WA, and HI) and two states are considering regulations (TX and AK).

The UWIN team also investigates solutions that enhance the resilience trajectories of urban water infrastructure. For example, the knowledge about dynamic responses and interactions that shape the long-term performance of dual water distribution infrastructure was advanced, including:

- The trade-offs among implementation of dual distribution systems compared to the existing singular systems
- The life-cycle cost impacts of dual water distribution system implementation as well as the existing singular water distribution systems
- The trade-off among long-term performance reliability and life-cycle costs of implementation of dual distribution systems

We have developed data showing alteration in biogeochemical and hydrologic conditions in Green Infrastructure that appears to show a positive feedback loop, e.g. as plants grow organic matter is added

and subsequently hydraulic properties are altered, which in turn encourages more plants to grow increasing organic matter.

Urban Floods

Floodplain management programs in the U.S. are widely regarded as being "broken". Our projects advance fundamental understanding of urban floodplain hydraulics and methods for characterizing uncertainty in floodplain inundation mapping while challenging the antiquated, deterministic approaches that are entrenched in U.S. floodplain management programs.

We have also developed a coherent and rigorous analytical method to estimate future return period of different categories of coastal flooding under nonstationary sea level conditions. This theoretical advancement enabled an improved assessment of coastal flood risks under different sea level rise as well as implementation of mitigation scenarios. We will next assess compounding risks from co-occurrence of storm surge and heavy precipitation.

Social and Policy Networks of Urban Water and Linked Systems

Our social, behavioral and economic research activities have created data and models that examine preferences and cognitive factors that influence decisions made within the urban water governance networks. These activities have improved our understanding of the determinants of consumer behavior and support for particular urban water management strategies and technologies, including discrepancies in how urban water innovations are perceived by different stakeholder groups. Methods are being developed that allow for simultaneous education and inquiry about adoption of new technologies, hence enabling collection of new information about individual preference and information seeking behaviors around water technologies.

Other Disciplines

Urban water and linked systems are under tremendous pressures due to limited resources and ever-increasing demands on existing systems. Population growth and urbanization influence the livability of our communities. Decisions about our water systems are made under deep uncertainty about future (e.g., climate) conditions. In response to these challenges, the UWIN research, education, and engagement programs create approaches that facilitate the transition from a "service provision" model for planning and management of water systems to a "resource management" model. The transdisciplinary UWIN activities explore technological, policy, institutional, and financial pathways toward sustainable management of water systems in a changing world. The SRN activities are conducted by researchers, scientists, students, and stakeholders from traditionally disparate disciplines, hence fostering cross disciplinary learning and innovation.

UWIN brings together perspectives and resources from 21 academic institutions with longstanding programs in water research and education, and close ties to water stakeholders across the U.S. The core competencies of our transdisciplinary team span geosciences; ecology; atmospheric sciences; water resources and environmental engineering; social, behavioral, economic and decision sciences; urban

planning and design; real estate and urban economics; mathematics and statistics; and computer sciences. The partnership integrates the expertise of investigators from historically African-American and Hispanic serving institutions, as well as educational experts experienced in societal learning and innovative approaches to education from the Cary Institute of Ecosystem Studies.

The UWIN interdisciplinary research programs enables training researchers and scientists that are familiar and comfortable with scientific terminology, approaches, and techniques from traditionally disparate areas.

For example, as a result of Dr. Sharvelle's contribution to the development of a framework for decentralized non-potable water systems, a National Blue Ribbon Commission was formed to develop a Guidebook. That guidebook has been nationally disseminated. San Francisco Public Utilities Commission has used the framework to guide development of regulations for non-potable water systems. Other jurisdictions are also working toward implementing components of the framework into their regulatory process. Consistent national guidance on regulation of decentralized non-potable water systems can increase ease of adoption of these systems with the ultimate impact of use of more local water sources.

Integrated Assessment of Urban Water and Linked Systems

Significant advancements have been made to enable integration of data and information from various water and linked systems, sectors, and domains (technological, social/policy, and financial) towards integrated assessment of urban water systems. We have developed a framework entitled "Urban Water Sustainability Blueprint" that provides a systematic approach to identification of water challenges and priorities from different lenses and perspectives, including the triple bottom line (TBL) approach, risk-based approaches, and the Drivers, Pressures, States Impacts, Responses (DPSIR) assessment. The proposed assessment framework incorporates multiple, and often conflicting, criteria in the decision-making process to ensure social viability, economic feasibility, and environmental sustainability and resiliency of proposed urban water sustainability responses.

Stakeholders & Training

Our findings extend the existing literature to add that evolution in social readiness, in the form of increasing awareness and behavioral and attitudinal shifts, is also necessary for transitions to more integrated water management approaches. Our recently published work also provides an assessment of the utility of the Pressure-State-Response model in the context of integrated urban water management.

Citizen Science

Our Citizen Science program data will help advance the field.

Undergraduate Research Program

Students' research contributed to the scientific program of mentor scientists. Some broke new ground, some developed new methods and study designs, others brought in new data and insights. We encourage students to present their results at their home institutions and at regional and national

meetings. We are also hopeful that students' projects will contribute to new proposals, new lines of inquiry and peer review publications.

Human Resources

The SRN activities engaged 39 faculty members (2 Deans, 20 professors, 5 associate professors, and 10 assistant professors, 2 instructors) from 34 academic institutions with interdisciplinary expertise, as well was 7 research scientists, 7 staff scientists, 47 graduate students, 16 undergraduate students and 7 postdoctoral research associates.

The UWIN URP has been tremendously successful in recruitment of undergraduate students from underrepresented groups for summer research training opportunities. Similarly, our regional stakeholder engagement activities facilitate two-way interactions between regional urban water managers, planners and other stakeholders with the academic team members. More than 100 regional stakeholders have been involved in our regional stakeholders meetings, both informing and learning about UWIN activities and findings.

Physical Resources

The project contributes to the environmental Resources Assessment and Management System (eRAMS) cloud computing infrastructure at Colorado State University. The computing infrastructure powers a platform for development and deployment of web-based water analytics and computationally scalable and accessible data and analysis tools.

Institutional Resources

The project contributed to the establishment of the One Water Solutions Institute at Colorado State University. The mission of the Institute is to connect our world-class research with real-world water challenges. In partnership with public, private and non-government organizations, the activities of the Institute facilitate the transition to integrated resource management across the water, food, and energy sectors.

Information Resources

Project activities create data and modeling information that are used to quantify urban water sustainability indicators using the Water Connect App. The Water Connect App, maintained by the One Water Solutions Institute at CSU, provides a single source for sharing water-related data and other resources for member cities. Users can also publish resources using the Water Connect App. Water Connect recognizes that to achieve sustainable urban water management, scientists, engineers, water managers and citizens need to access disparate data sets in order to accurately view the complete picture and respond with appropriate solutions. Water Connect fosters collaboration and promotes information sharing throughout the water community. It allows users to add their own data sets to those already publicly available. The user can control access to their data sets through setting up user groups that allow access by invitation. The web portal provides the framework, tools and guidance to

view urban water systems through several “lenses” that could include wastewater management, water supply and quality, flood protection, land use, equity, or community and environmental health. A user can add more data and therefore more “lenses”. Water challenges can no longer be addressed individually, but rather must be viewed as multi-dimensional challenges to a city with solutions developed with as many perspectives as possible. Water Connect allows communities to look at their water system through various perspectives and find innovative, dynamic solutions.

Technology Transfer

The project activities have resulted in 1 patent, 19 software technologies, and modeling tools, and 2 start-up companies. The project team members are actively pursuing additional support from the NSF iCORP and SBIR programs.

Impact on Society Beyond Science & Technology

Our regional stakeholder engagement activities engages communities across the U.S. to increase social readiness, in the form of increasing awareness and behavioral and attitudinal shifts, requisite to the transitions from management of water systems in silos to an integrated approach. Our recently published work also provides an assessment of the utility of the Pressure-State-Response model in the context of integrated urban water management.

UWIN will lead urban sustainability efforts by producing findings that alter development trends of cities across the U.S. and around the world. Achieving sustainability in urban water systems presents a problem of coupled natural-built systems that requires insights into mechanisms of transition from knowledge to action. We intend to build that linkage by focusing on the integration of coupled urban water systems to produce a toolbox of solutions that will reverberate across other systems, such as urban ecosystems, economies, and arrangements for environmental justice and equity.

The Network will result in establishment of six regional urban water sustainability hubs in highly populated urban regions across the U.S. Through time, these regional hubs, with strong network interconnectivity amongst its nodes, will serve as innovation centers to help communities transition to sustainable management of water resources. Our strategic partnership with other national and international networks involved with urban sustainability will extend our reach to more than 100 cities around the world. A key impact of UWIN is development of an Urban Water Sustainability Blueprint that is vetted by stakeholders across the U.S. and globally. This novel and transformative Blueprint will foster adaptive societal learning and assessments in response to changes in pressures on water systems to maximize resilience and co-benefits.

The global impact of this SRN can occur from the cascading effects of institutions working with other institutions in a global network focused on sustainability of urban water systems. The complexity of these systems defies stovepipe thinking and requires a systems approach. By developing the intellectual framework and messaging required to inform and build capacity among other institutions, the global impact can be large and sustained. We will develop a globally prominent Urban Water Sustainability Hub

using the Water Connect App that fosters communication and exchange of knowledge, data, and tools throughout the global community.

To date, UWIN has engaged more than 55 graduate students, 24 postdoctoral research associates and staff scientists, and several early career scientists from diverse backgrounds in research, outreach, education, and broadening participation of network activities. The Network has provided research opportunities for over 40 undergraduate students with diverse backgrounds via a creative interdisciplinary undergraduate research program.

CHANGES & ANTICIPATED PROBLEMS

No Cost Extension

Submitted on May 27, 2020; Approved May 28, 2020 (Bruce Hamilton)

Updated Project End: July 31, 2021

Justification for NSF-Approved No-Cost Extension:

The contract negotiations for establishing the cooperative agreement between NSF and CSU took several months beyond the initial start date. Similarly, several subcontracts were negotiated and executed with subaward institutions. As a requirement of these subawards, the project PI at CSU requested a 5-page project plan to describe activities at each institution with information about how the projects relate to the overall goal and objectives of the SRN. The execution of the subawards took approximately 6-months. Consequently, a majority of the subawards have remaining funds by the initial end date. The time needed to finalize the cooperative agreement and subcontracts had a cascading effect on staffing at the onset of the project. Moreover, new or updated subawards were issued during the project period. These new projects need additional time to complete their deliverables. The no-cost extension is requested to complete data analysis and graduate theses/dissertations, publish results in peer-reviewed journals, and finalize integration and synthesis or the SRN information into a Sustainable Urban Water Systems Assessment Framework and Rating System.

Plan for use of unobligated funds:

Remaining funds will be used to support graduate students, UWIN researchers and staff as well as finalize data analysis. Funds are needed to support dissemination of results in relevant peer-reviewed journals and presentation at professional conference (such as Fall AGU 2020). More time is needed for the UWIN project team to complete project integration activities developing a synthesis report, urban water sustainability indicators and rating system, and an integrated web tool, and subsequent work related to publishing and distributing the synthesis report, producing communication materials for key tools and resources, hosting a national webinar, and potentially organizing a capstone workshop. Our Undergraduate Research Program has produced invaluable data about student interest, identity, competency, and performance in this arena. Due to the Covid-19 outbreak, the 2020 URP will be moved to remote/virtual participation with minimal expenses. Therefore, we request the remaining participant support funds (approximately $43,400) to be reallocated to produce relevant journal papers. Expenses will include limited salary and a writing workshop to accelerate completion of the work.

Research Projects

Due to the 2020 COVID-19 pandemic, access to laboratories and other facilities has been restricted at the UWIN institutions. These constraints will likely alter the planned schedules for the completion of the remaining tasks. We anticipate that these circumstances will likely influence the SRN activities and may result delays in meeting the milestones and delivery of the final products. Moreover, travel restrictions could also influence completion of PhD dissertations and M.S. theses.

Stakeholder Engagement

In-person meetings with stakeholder groups were eliminated as the strategy shifted toward production of materials and interviews as means to collect data

Undergraduate Research Program

Our Undergraduate Research Program has produced invaluable data about student interest, identity, competency, and performance in this arena. Due to the Covid-19 outbreak, the 2020 URP will be moved to remote/virtual participation with minimal expenses. Therefore, we request the remaining participant support funds (approximately $43,400) to be reallocated to produce relevant journal papers. Expenses will include limited salary and a writing workshop to accelerate completion of the work.

Diversity Program

Nia H. Rene was selected to receive the second diversity supplement in 2018. Unfortunately, institutional barriers prevented the reallocation of funds to a new subaward, thus UWIN was unable to financially support Miss Rene in the 2019-2020 academic year. The Network is exploring other opportunities to support Nia and her research into green infrastructure designed to assist in ushering in a new approach to urban and peri-urban water management and sustainability.

PRODUCTS

Product Summary

Product	Total*
Book Chapters	5
Journal Articles	165
Conference Presentations	288
Patents	1
Thesis/Dissertations	28
Technologies & Models	19
Websites	4
Webinars	27
Outreach Materials	89
Data	40
Press Releases/News Articles	15
Other	12

**Figures only include published, in press and accepted materials*

Books/Book Chapters

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Journal Articles

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160. Yang J. and Bou-Zeid E. (2019) “Scale dependence of the benefits and efficiency of green and cool roofs”, Landscape and Urban Planning, 185, 127-140, DOI: 10.1016/j.landurbplan.2019.02.004.
161. Yang J. and Bou-Zeid E. (2019) “Designing sensor networks to resolve spatio-temporal urban temperature variations: fixed, mobile or hybrid?”, Environmental Research Letters, 14, 074022, DOI: 10.1088/1748-9326/ab25f8.
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164. Zhou, Z., J. A. Smith, L. Yang, M. L. Baeck, M. Chaney, M.-C. ten Veldhuis, and S. Liu, The Complexities of Urban Flood Response: Hydrologic Analyses for the Charlotte, North Carolina Metropolitan Region, Water Resources Research, 53(8), pp. 7401–7425, 2017.
165. Zhou, Z., J. A. Smith, D. B. Wright, M. L. Baeck, L. Yang, and S. Liu, Rainfall frequency analysis in a complex physiographic setting based on Stochastic Storm Transposition, Water Resources Research, 55, 2019. https://doi.org/10.1029/2018WR023567

Conference Presentations

1. Alja’fari, J., Sharvelle, S., Crall, A., Newman, G. (2019) “Off the Roof: A Citizen Science Project to Measure

the Microbial Characteristics of Roof Runoff", Hydrology Days, Fort Collins, CO
2. Anderson, Jack - Bioswales: Benefit or Burden?, Presentation at El Dia Del Agua y la Atmosfera, Department of Hydrology and Atmospheric Sciences, Tucson AZ, University of Arizona April 9,2018.
3. Anderson, Jack, Meixner Thomas, 2017, Urban bioswale characterization and design evaluation El Dia Del Agua Y Atmosfera, University of Arizona, Tucson, AZ March 27, 2017.
4. Arabi, M., Dozier, A.Q. *Combatting declining agricultural production in rapidly urbanizing semi-arid regions*. University Council on Water Resources National Institutes of Water Resources, Fort Collins, CO, June 13-15, 2017.
5. Arabi, M., Dozier, A.Q., Wostoupal, B. *Hydroeconomic modeling framework for assessing vulnerability to water demands in arid regions*. American Society of Civil Engineers, World Environmental and Water Resources Congress, Sacramento, California, May 21-25, 2017.
6. Arcelay, Adriana- Investigating impacts of projected climate change on flood risk in urban areas located along river channels, Presentation at El Dia Del Agua y la Atmosfera, Department of Hydrology and Atmospheric Sciences, Tucson AZ, University of Arizona March 25, 2019.
7. Aviv, Dorit, and Forrest Meggers. 2017. "Cooling Oculus for Desert Climate – Dynamic Structure for Evaporative Downdraft and Night Sky Cooling." Energy Procedia, CISBAT 2017 International ConferenceFuture Buildings & Districts – Energy Efficiency from Nano to Urban Scale, 122 (September): 1123–28. https://doi.org/10.1016/j.egypro.2017.07.474.
8. Batista, G. (Author & Presenter), Dozier, A. (Author), Sharvelle, S. (Author), Arabi, M. (Author), Hydrology Days 2018, "Characterization of urban water use and water demand forecasting using the Integrated Urban Water Model in Sao Paulo, Brazil," Hydrology Days, Fort Collins, CO, United States. (March 19-21, 2018).
9. Batista, Giovana (Author & Presenter), Sharvelle, S. (Author), Dozier, A. (Author), Arabi, M. (Author), 9th International Congress on Environmental Modelling and Software, "Evaluation of Water Conservation Strategies Using the Integrated Urban Water Model in Sao Paulo, Brazil," International Congress on Environmental Modelling and Software, Fort Collins, CO, United States. (June 27, 2018).
10. Bell, Emily. "Conceptualization and Measurement of Stakeholder Beliefs in Urban Water Governance" at the UA School of Government and Public Policy Saguaro Symposium, February 2017
11. Bell, Emily, Adam Henry, and Gary Pivo. "Measuring Belief Systems in Urban Water Governance" at the Midwest Political Science Association, April 2017
12. Bell, Emily, Adam Henry, and Gary Pivo. "Measuring Beliefs through Coordination Networks in Urban Water Governance" at the Political Networks Conference, June 2017
13. Bell, E A Henry and G Pivo, November 2017. APPAM 39th Annual Fall Research Conference, A Coding Frame to Link Policies and Beliefs.
14. Berkowitz, Cherrier, Downey, and Meixner. 2019. Assessing Green Infrastructure Function Across North America with Citizen Scientists and Affordable Sensors. Urban Water Innovation Network Annual Meeting 2019. Fort Collins, CO.
15. Berkowitz, A., Cherrier, J., Downey, A. and Meixner, T. 2020 Rapid Assessment & Long-Term Monitoring of Urban Green Infrastructure with Citizen Scientists. Earthwatch Green Infrastructure Citizen Science Program. Zoom.
16. Bledsoe, B.P. (2017). *Probabilistic floodplain mapping as a template for planning urban revitalization*. 17th Annual American Ecological Engineering Society Meeting.
17. Bledsoe, B.P., 2018. The Three C's of Floodplain Management. Keynote Address, 12th Annual Meeting, Georgia Association of Floodplain Management, Athens, GA 20-22 Mar.
18. Bledsoe, B., & T. Stephens. 2018. *Mapping flood hazards under uncertainty through probabilistic flood inundation maps.* Presentation, Water Environment and Reuse Foundation (WERF), 2018 Water Research Foundation Conference, Atlanta, GA, May 6-8
19. Bledsoe, B. 2018. *Addressing flooding and extreme weather with restoration efforts.* Presentation, Southeast Stream Restoration Conference – EcoStream, Asheville, NC, August 14.
20. Bledsoe, B. 2018. *The three C's of flood management.* Presentation, Vanderbilt University, Nashville, TN, November 9.
21. Bledsoe, B. 2018. *Natural and nature-based infrastructure solutions.* Presentation, Atlantic Intracoastal Waterway Association (AIWA), 2018 Annual Meeting, Charleston, SC, November 16.

22. Bledsoe, B.P. and Stephens, T.A. Informing floodplain management and hazard communication through probabilistic flood inundation maps. Presented at the 2019 Georgia Water Resources Conference, Athens, Georgia, 16-17 April.
23. Bolson, J.A. M. Sukop, G. Pivo, M. Arabi, and A. Lanier (2018). *A stakeholder-science based approach for understanding urban water sustainability challenges across the U.S.* University of Florida Water Institute 2018 Symposium, February 6-7, Gainesville, Florida. http://archives.waterinstitute.ufl.edu/symposium2018/downloads/2018BookOfAbstracts.pdf
24. Bou-Zeid, E. (2016) "Cities in the 21st century: the nexus of the climate, water and energy challenges", University of Perugia.
25. Bou-Zeid, E. (2016) "Urban monitoring of air quality: the challenges of sampling in spatially and temporally varying fields", 2016 MIRTHE+ Symposium, City College of New York, NYC.
26. Bou-Zeid, E. (2016) "Missing pieces of the puzzle: the influence of dispersive fluxes and rainfall-induced quenching on surface-atmosphere exchanges in urban areas", Brookhaven National Lab.
27. Bou-Zeid E., Li Q., and Grimmond S. (2017) "Large Eddy Simulations of Flow and Scalar Exchanges over Urban Terrain to Improve Urban Canopy Model Parameterizations", 97th American Meteorological Society Annual Meeting, Seattle , WA
28. Bou-Zeid E., Omidvar H., Li Q., Klein P.M., Mellado J.P. (2018) "Plume or bubble? The non-linear impact of an urban heat island on city-scale atmospheric circulation" Invited. Fall meeting of the American Geophysical Union, Washington DC, https://agu.confex.com/agu/fm18/meetingapp.cgi/Paper/376481
29. Bou-Zeid E., Yang J. (2018) "The location and expanse of green and cool roofs strongly modify their cooling potential" Fall meeting of the American Geophysical Union, Washington DC, https://agu.confex.com/agu/fm18/meetingapp.cgi/Paper/412776
30. Bou-Zeid E. and Yang J. (2018) Hydrological Determinants of Temperature Extremes in Cities, 2018 Annual meeting of the American Meteorological Society, Austin, TX.
31. Bou-Zeid, E., and J. Yang, (2019) "Designing sensor networks to resolve spatio-temporal urban temperature variations: fixed, mobile or hybrid?". Fall meeting of the American Geophysical Union, San Francisco, CA.
32. Bou-Zeid, E., and M. L. Munitxa, (2019) "The environmental neighborhoods of cities and their spatial extent". Fall meeting of the American Geophysical Union, San Francisco, CA.Borowy D, C Swann (2017). Identifying the processes that drive native plant community assembly patterns in urban habitats. Ecological Society of America 2017 Annual Conference.
33. Borowy D, C Swann (2017). Linking Community Assembly Processes in Experimental Urban Vacant Lot Habitats. Baltimore Ecosystem Study (BES) Annual Meeting.
34. Borowy D., Swan C.M. (2018). Annual Meeting of the Ecological Society of America, Oral Presentation, "Linking community assembly processes and patterns in experimental vacant lot habitats," Ecological Society of America, Portland, OR.
35. Borowy, D. (2018). Annual Meeting of the Baltimore Ecosystem Study, Oral Presentation, "Understanding biodiversity in the built environment," Baltimore Ecosystem Study (BES), Baltimore, MD.
36. Bozlar, M. ; Teitelbaum, E. ; Meggers, F. Liquid Desiccant-Polymeric Membrane Dehumidification System for Improved Cooling Efficiency. In International Building Physics Conference 2018; Syracuse, NY, 2018.
37. Brandi, Aldo, AM Broadbent, Matei Georgescu, Scott Krayenhoff (2020), Influence of Projected Climate Change, Urban Expansion and Adaptation Strategies on End of 21st Century Urban Boundary Layer Dynamics in the Conterminous US, 100th Meeting of the American Meteorological Society, January 16, 2020.
38. Broadbent, A. M., Krayenhoff, E. S., Georgescu M., and Sailor, D. J. Assessment of the biophysical impacts of utility-scale photovoltaics through observations and modelling. American Geophysical Union Fall Meeting, 11-15 December 2017, New Orleans, LA.
39. Broadbent, A. M., Krayenhoff, E. S., Georgescu M., and Sailor, D. J. Do photovoltaics impact local air temperature and surface energy balance? *Urban Climate Research Centre poster competition. March 2018.*Awarded* 1st Place in the Postdoctoral Researcher category

40. Broadbent, A. M., Krayenhoff, E. S., Heusinger, J., Georgescu, M (2019). Modeling the Direct Impacts of PV Systems on Surface Energy Balance and Climate in Phoenix. American Meteorological Society (AMS) conference, Phoenix, AZ 2019.
41. Broadbent, Ashley M., Matei Georgescu and E. Scott Krayenhoff (2020), Projecting End of Century Urban Population Exposure to Hot Extremes in the Continental US, 100th Meeting of the American Meteorological Society, January 16, 2020.
42. Brown, Alexander, Matthew Chiavatta, and Sarah Wrase. Michigan State University. A Spatial Analysis of Detroit Water Rates. April 9, 2018. University Undergraduate Research and Arts Forum UURAF.
43. Bruelisauer, M., Meggers, F., & Leibundgut, H. (2015). Heat Bus System to refurbish a high-rise residential building with semi-centralised high-performance chillers. In 6th International Building Physics Conference, IBPC 2015. Torino, Italy: Elsevier.
44. Chan, E., Papuga, S.A., Eklund, A. 2019. Developing tools to assess the long-term and multifunctional performance of green infrastructure: A case study in Detroit, Michigan. AGU Fall Meeting, San Francisco CA, 9-13 December 2019. Poster presentation.
45. Chinnasamy, C. V., Dozier, A., Furth, C. D., and Arabi, M. (2019). Characteristics of water use across 125 urban centers in the contiguous USA: What did we learn? AGU Hydrology Days, March 27 - 29, 2019, Fort Collins, Colorado.
46. Chinnasamy, C. V., Dozier, A., Furth, C. D., Arabi, M., and Sharvelle, S. (2019). Characteristics of Municipal End Water Uses in the Contiguous USA. 16th Annual Rocky Mountain Student Conference, May 13, 2019, Boulder, Colorado.
47. Chinnasamy, C. V., Furth, C. D., Arabi, M., Sharvelle, S., and Dozier, A. (2019). Characteristics of Municipal End-Water Uses in the Contiguous USA. 4th Annual Meeting of the Urban Water Innovation Network, July 30 – August 1, 2019, Fort Collins, Colorado.
48. Davis, M.F. and M. Sarango (2019). "Water Affordability in Massachusetts Communities: Facts and Impacts." Presented to the Massachusetts Water Resources Authority Advisory Board, Wellesley, MA, November 21, 2019.
49. Davis, M.F. and M. Sarango (2020). "Water Affordability in Massachusetts Communities: Facts and Impacts." Presented to the Massachusetts Council on Aging, Watertown, MA, February 25, 2020
50. Dell, T. (Author & Presenter), Arabi, M. (Author), 9th International Congress on Environmental Modelling and Software, "An introduction to the modeling framework and outputs of the Community-enabled Life-cycle Analysis of Stormwater Infrastructure Costs (CLASIC) tool," International Congress on Environmental Modelling and Software, Fort Collins, CO, United States. (June 25, 2018).
51. Dougherty, Benjamin. Water in the Global South and Narratives of Privatization: The Case of Brazil. Association of American Geographers (AAG) Conference. New Orleans, LA. April 9, 2018.
52. Dozier, A.Q. Wostoupal, B., Arabi, M. *Newcomers have subsidized water in the South Platte River Basin*. Hydrology Days at Colorado State University, Fort Collins, CO, Mar 19-21, 2018.
53. Dozier, A. (Author & Presenter), Arabi, M. (Author), 9th International Congress on Environmental Modelling and Software, "Optimizing water supply options for a region with urban-rural interactions," International Congress on Environmental Modelling and Software, Fort Collins, CO, United States. (June 26, 2018)
54. Eddowes, D, J. Pillich, B. Smith, J. Cherrier, T. Meixner, A. Berkowitz and M. Chandler. 2019. Using citizen science and cross sector partnerships to engage new audiences in urban sustainability initiatives. Citizen Science Association Biannual Meeting. Raleigh, NC. March 16, 2019.
55. Emler, Lori- Hydrochemical evolution of nitrogen species in semi-arid urban catchments, Presentation at El Dia Del Agua y la Atmosfera, Department of Hydrology and Atmospheric Sciences, Tucson AZ, University of Arizona March 25, 2019.
56. Fabiani C., Posello A.L., Bou-Zeid E., and Yang J (2018) "Using advanced urban canopy models to investigate the potential of thermochromic materials as urban heat island mitigation strategies" International Building Physics Conference 2018, Syracuse, NY, USA: http://amz.xcdsystem.com/476EFEC7-D8CF-7470-232B140485F971CA_abstract_File1159/FinalPaperFileUpload_283_0627023621.pdf

57. Georgescu M. (2017), UWIN – A Multi-Institutional Partnership Focused on Sustainable Urban Water Systems, July 24, 2017 (Invited Speaker at Lee Kuan Yew School of Public Policy Seminar Series, National University of Singapore, Singapore).
58. Georgescu M. (2017), Urban Climate Research and Climate Change Challenges, August 21, 2017 (Invited Speaker at the Urban Climate Summer School, University of Bucharest, Romania)
59. Georgescu M. (2017), The utility of computational modeling to address urban environmental sustainability, August 22, 2017 (Invited Speaker at the Urban Climate Summer School, University of Bucharest, Romania).
60. Georgescu M (2019), Sustainable Urban Systems – A Climatic Perspective, Monday, December 16, 2019, The National Academies of Sciences, Engineering and Medicine, Washington D.C., USA (Invited Speaker for National Academies Workshop on Advancing Urban Sustainability in China and the United States - A National Academies Workshop in Collaboration with the Chinese Academy of Sciences).
61. Georgescu M (2019), A more holistic perspective on healthy and equitable urban environments – Beyond meteorology and climate, Wednesday, October 2, 2019, University of Tsukuba, Tsukuba, Japan (Invited Speaker for Center for Computational Sciences).
62. Georgescu M (2019), An urban climate perspective on human environment interactions, Tuesday, October 1, 2019, University of Tsukuba, Tsukuba, Japan (Invited Speaker for Tsukuba Global Science Week).
63. Georgescu M (2019), Quantifying human-urban interactions: an urban climate perspective, Webinar, Thursday, August 29, 2019 (Invited Speaker for Lawrence Berkeley National Laboratory/Pacific Northwest National Laboratory Monthly Webinar Series).
64. Georgescu M (2019), Sustainable Urban Systems: An Agri-Climatic Perspective, Qinghai Normal University, Qinhgai, China, Saturday, July 13, 2019 (Invited Speaker for the 7th Landscape Sustainability Science Forum).
65. Ghanbari, Mahshid and Mazdak Arabi, Current and Future Flood Losses in the Southeast Florida, EWRI World Environmental & Water Resource Congress 2017 24 May 2017.
66. Ghanbari, Mahshid , Mazdak Arabi, Jayantha Obeysekera, William V. Sweet, Risk to Assets and Communities from Coastal Flooding: Quantifying the effect of sea level rise and flood adaptation strategies, AGU Hydrology Days 2018 19 March 2018.
67. Ghanbari, Mahshid, Mazdak Arabi, Jayantha Obeysekera, William V. Sweet, Risk to Assets and Communities from Coastal Flooding: Quantifying the effect of sea level rise and flood adaptation strategies, International Congress on Environmental Modelling and Software 2018 24-28 June 2018.
68. Ghanbari, M., Arabi, M., Obeysekera, J., & Sweet, W (2018), Coastal Flooding Risks on the Rise, AGU Fall Meeting, Washington D.C. 10-14 December 2018.
69. Ghanbari, M., Arabi, M., Obeysekera, J., & Sweet, W (2019), A Coherent Statistical Model for Coastal Flood Frequency Analysis under Nonstationary Sea Level Conditions, AGU Hydrology Days, Fort Collins, Colorado. 27-29 March 2019.
70. Ghanbari, M., Arabi, M., Obeysekera, J., & Sweet, W (2019), A Coherent Statistical Model for Coastal Flood Frequency Analysis under Nonstationary Sea Level Conditions, EWRI World Environmental & Water Resource Congress, Pittsburgh, Pennsylvania. 20-23 May 2019.
71. Ghanbari, M., Arabi, M. Kao, S.-C. (2020). Increasing Risks of Compound Flooding under Climate Change and Sea Level Rise Scenarios. Hydrology Days 2020, April 13 – 15, Fort Collins, CO.
72. Ghanbari, M., Arabi, M. (2019). Impacts of Sea Level Rise on Compound Fluvial and Coastal Flooding. American Geophysical Union Fall Meeting 2019, December 9-13, San Francisco, CA.
73. Gomez Fernandez, Edna-Liliana, Adam Henry (Co-Author), Gary Pivo (Co-Author), Andrew Sanderford (Co-Author), 2017. Association of Collegiate Schools of Planning Annual Conference, Measuring Fragmentation of Water Governance in US Cities: Theory and Evidence Examined.
74. Gomez Fernandez E. Liliana, A. Henry, and G. Pivo, August, 2017. UWIN 2nd Annual Meeting, Influence of Governmental Fragmentation in Adoption of Sustainable Policies and Innovation in Urban Water Management
75. Gomez Fernandez, Edna Liliana. "Water Sustainability Innovations through Collaborative Networks." Paper presented at Southern Political Science Association (SPSA) Annual Conference, Austin, Texas, January 2019.

76. Gomez Fernandez, Edna Liliana, Adam Douglas Henry & Gary Pivo. "Collaborative Governance in Urban Water Management in Arizona: Belief Systems, Perceptions, and Common Problems." Presented at Consortium on Collaborative Governance (CCG) Emerging Scholars Workshop, Tucson, Arizona, February 2019.
77. Gomez Fernandez, Edna Liliana Adam Douglas Henry, and Gary Pivo (2019). "Collaboration in Urban Water Management in Arizona." Political Networks Conference (Polnet). Duke University, June, 2019.
78. Greydanus, H. and M. Santelmann. 2018. Quantifying the cooling benefits of green infrastructure on air temperatures in Portland, Oregon. Abstract accepted for Ecological Society of America meeting, New Orleans, LA. August 2018.
79. Greydanus, H, Santelmann M. 2018. Ecological Society of America Annual Conference (Poster), Influence of urban green infrastructure on air temperature variability in Portland, Oregon August 2018, New Orleans, LA
80. Greydanus H., Santelmann M. 2018. Microclimate cooling of green infrastructures in Portland, Oregon. Collegiate Poster & Rapid Fire Competition. Society of Women Engineers, October 18-20 2018. Minneapolis, MN.
81. Guo, H., & Meggers, F. (2018, September 23). Analytical and Numerical Investigation on Depth and Pipe Configuration for Coaxial Borehole Heat Exchanger, A Preliminary Study. In International Building Physics Conference 2018; Syracuse, NY, 2018.
82. Guertin, D. Phillip, Yoganand Korgaonkar, I. Shea Burns, Carl Unkrich, David C. Goodrich, and William Kepner. 2016. Using AGWA and the KINEROS2 Model to Model Green Infrastructure in Two Typical Residential Lots in Prescott, AZ. Presented at: 2016 AWRA Summer Specialty Conference: GIS and Water Resources IX, Sacramento, CA, July 11-13, 2016.
83. Gupta, Neha - Comparison of Runoff Data to Assess Impact of Stormwater Green Infrastructure, Presentation at El Dia Del Agua y la Atmosfera, Department of Hydrology and Atmospheric Sciences, Tucson AZ, University of Arizona April 9,2018.
84. Gupta, Neha, and Emily Bell, 2017, Interdisciplinary dialogue to assess coupled natural and human systems, El Dia Del Agua Y Atmosfera, University of Arizona, Tucson, AZ March 27, 2017.
85. Gupta, N., Solis-Arroyo, S.S., Meixner, T., Anderson, J. and Gallo, E.L., 2018, December. Comparative Assessment of Water Quality at the Rainwater-Harvesting Basin and Neighborhood Wash Scales. In AGU Fall Meeting Abstracts.
86. Gupta, N., Meixner, T., Gallo, E.L., Canfield, E. and Spinti, R., 2018, December. Runoff increases due to urbanization in a semi-arid city. In AGU Fall Meeting Abstracts.
87. Gupta, Neha— Quantification of Runoff Response in Semi-Arid Urban Catchment – Arizona Hydrological Society Annual Symposium, Phoenix AZ, September 20, 2018.
88. Gupta, Neha - Runoff increases due to urbanization in a semi-arid city, Presentation at El Dia Del Agua y la Atmosfera, Department of Hydrology and Atmospheric Sciences, Tucson AZ, University of Arizona March 25, 2019.
89. Gupta, Neha, Stormwater Runoff Response in Semi-Arid Urban Catchment, AWWA Sustainable Water Management Conference, Tucson, AZ, April, 2019.
90. Habron G., Thompson K., Maas A., Berkowitz A. 2019. Experiential model-based reasoning for undergraduate interdisciplinary urban water synthesis. American Association of Geographers Annual Meeting, April 3rd-7th, Washington DC. Oral presentation
91. Haggerty, R., Hulse, D., Conklin, D., Santelmann, M., Wright, M. (2016). Project D1-1: UWIN Envision Modeling of Present and Future Values for Sustainable Water Management Blueprint Indicators. Urban Water Innovations Network, Annual Meeting, Ft. Collins, Colorado. August 2-4, 2016.
92. Harlan, S. L. Social Equity, Environmental Justice, and Societal Ethics Panel. Presented at the Sustainability Research Network Awardees Conference, National Science Foundation. Alexandria, VA. June 5-6, 2018.
93. Harlan, S, P Chakalian, J Declet-Barreto, D Hondula, GD Jenerette (2019). Climate Injustice in Cities: Extreme Heat and Poor Neighborhoods. American Geophysical Union. San Francisco CA December 2019
94. Harlan, S.L.,(2020) "Social Vulnerability and Perceived Risk of Floods." Invited presentation at the American Meteorological Society Annual Meeting, Boston, MA, January 12-16, 2020

95. Harrison, M., Santelmann, M., Haggerty, R. 2017. Historical Evaluation of Groundwater Responses to Underground Injection Controls in an Urban Watershed. Poster presentation American Geophysical Union Fall Meeting, New Orleans, LA. December 2017
96. Heidari, H., Arabi, M., Warziniack, T., Kao, S.-C. (2020). Assessing the Impacts of Climate Changes on the Regional Hydroclimatic Conditions of U.S River Basin over the 21st Century. Hydrology Days 2020, April 13 – 15. Fort Collins, CO.
97. Heidari, H., Arabi, M., Warziniack, T., Kao, S.-C. (2019). Changes in Hydroclimatic Characteristics of River Basins in the U.S. over the 21st Century. AGU Fall Meeting, Dec 9 – 13, San Francisco, CA.
98. Heidari, H., Arabi, M., Ghanbari, M., Warziniack, T. (2019). A Mixture Gamma-GPD Probability Model for Characterization of Water Shortage Vulnerability under Nonstationary Supply and Demand Conditions. World Environmental and water resources congress, May 19 – 23. Pittsburgh, PA.
99. Heidari, Hadi, Mazdak Arabi, Andre Dozier, Ali Tasdighi, An Analytical Framework for Assessing Municipal Vulnerability to Water Shortage and Drought Characteristics under Nonstationary Supply and Demand Conditions, AGU Hydrology Days 19 March 2018
100. Heidari, Hadi, Mazdak Arabi, Andre Dozier, Ali Tasdighi, An Analytical Framework for Assessing Water Shortage Vulnerability under Nonstationary Supply and Demand Conditions, 9th International Congress on Environmental Modelling and Software 2018 24-28 June 2018
101. Heidari, Hadi, Mazdak Arabi, Mahshid Ghanbari, A Novel Probabilistic Approach for Characterization of Municipal Water Shortage Vulnerability under Nonstationary Supply and Demand Conditions. *AGU Fall Meeting, Washington, D.C., December. 2018*
102. Heidari, Hadi, Mazdak Arabi, Mahshid Ghanbari, Travis Warziniack, Vulnerability of the City of Fort Collins Water Supply System to Water Shortage and Extended Droughts under Nonstationary Supply and Demand Conditions over the Course of the 21st Century. *AGU Hydrology Days, Fort Collins, March. 2019*
103. Heidari, Hadi, Mazdak Arabi, Mahshid Ghanbari, Travis Warziniack, A Mixture Gamma-GPD Probability Model for Characterization of Water Shortage Vulnerability under Nonstationary Supply and Demand Conditions. *World Environmental and water resources congress, Pittsburgh, May. 2019*
104. Heiden, C. (Author & Presenter), Arabi, M. (Author), 2018 AGU Fall Meeting, "A novel probabilistic approach to characterization of water quality vulnerability along Urban Gradients," American Geophysical Union, Washington, D.C., (December 10, 2018).
105. Henry, Adam, E.L. Gomez-Fernandez, and G. Pivo, March, 2017. The International Association for the Studies of the Commons. Workshop: Multi-methods Approaches for Investigating Polycentricity in Common Pool Resources.
106. Henry, A EL Gomez-Fernandez and G Pivo, November 2017. APPAM 39th Annual Fall Research Conference, A Network Approach to Understanding Fragmentation and Sustainability in Local Governance.
107. Henry, Adam. E. L. Gomez-Fernandez, and G. Pivo. February 2018. Accepted for the Annual Public Management Research Conference, in May 2018. Network-Based Measurement of Functional Fragmentation in Governance Systems: An Application to Urban Water Management
108. Henry, Adam Douglas, Lena Berger, Gary Pivo, Edna Liliana Gomez Fernandez. "Network drivers of local water sustainability innovations." Presented at 2018 Public Management Research Conference (PMRC), Singapore, June 2018.
109. Henry, Adam Douglas, Edna Liliana Gómez Fernández & Gary Pivo. "Sustainability Innovations through Collaboration in Urban Water Management." Paper presented at Association for Public Policy Analysis and Management (APPAM) Fall Research Conference, Washington, D.C., November 2018.
110. Henry, Adam Douglas, Lena Berger, Edna Liliana Gomez Fernandez & Gary Pivo. "What distinguishes local government innovators in water sustainability?" Climate Change Adaptation Science & Solutions Speaker Series, Tucson, Arizona, March 2019.
111. Henry, Adam Douglas, Edna Liliana Gomez Fernandez and Gary Pivo (2019). "Water Policy Innovations through Collaborative Governance Networks." Association for Public Policy Analysis and Management (APPAM) 41st Annual Fall Research Conference, University of Arizona, November 2019.
112. Hermosilla, Victoria — Rainwater Harvesting Infiltration Exploration Using Hydrus-1D, 2018 – Arizona Hydrological Society Annual Symposium, Phoenix AZ, September 20, 2018.

113. Hondula DM, Urban A. Detecting an urban effect in heat-related mortality records in Maricopa County, AZ. International Conference on Urban Climate, New York, NY, August 2018.
114. Hondula, David (2019). Tackling the urban heat challenge. City of Tucson 11th Annual Urban Heat Island Workshop, Tucson, AZ.
115. Horvath, A., Gursel, A. P., Chaudron, C. and Kavvada, I. (2020), "An Integrated Model of Urban Water-Wastewater-Stormwater-Energy Systems." EGU General Assembly 2020, May 4-8, 2020, Vienna (Austria)
116. Ibsen P and GD Jenerette. Effects of extreme climate on suites of functional traits in the urban forest of Southern California. Ecological Society of America, Portland, OR August 2017
117. Ibsen P, M Talal, C Swan, D Borowy, D Hondula, M Wright, and GD Jenerette. Continental scale variation in the cooling effect of urban vegetation. United States Chapter of the International Association of Landscape Ecologists. Chicago IL April 2018
118. Ibsen P, GD Jenerette, MV Santelmann, H Greydanus, D Hondula, M Wright, C Swan, D Borowy, M Sukop, T Dell, T Meixner. Regional aridity drives urban nighttime vegetation derived air cooling. American Geophysical Union. Washington DC December 2018
119. Ibsen P, GD Jenerette, LS Santiago, M Chandler, SA Shiflett (2019). Irrigated Urban Forests Shift to Anisohydric Strategies in Extreme Aridity. American Geophysical Union. San Francisco CA December 2019
120. Jenerette GD. A macroecology of urban trees. Ecological Society of America, Portland, OR August 2017.
121. Jenerette GD, J Wang, M Chandler, J Ripplinger, S Koutzoukis, C Ge, L Castro-Garcia, D Kucera, X Liu. Resolving uncertainties in the urban air quality, climate, and vegetation nexus through citizen science, satellite imagery, and atmospheric modeling. American Geophysical Union, New Orleans LA December 2017
122. Jenerette GD. Experimental landscape ecology. United States Chapter of the International Association of Landscape Ecologists. Chicago IL April 2018
123. Jenerette GD. Opportunities for urban ecology at the United States and Mexico border. Ecological Society of America Annual Meeting. New Orleans August 2018
124. Jenerette, GD (2019) From wildland urban interfaces to anthropogenic landscape systems in southern California, USA. United States Chapter of the International Association of Landscape Ecologists. Fort Collins CO April 2019
125. Jenerette GD, P Ibsen, D Kucera, S Harlan, M Georgescu (2019). A continental assessment of the urban vegetation, temperature, income nexus. American Geophysical Union. San Francisco CA December 2019
126. Johnson, A. (Author & Presenter), Swan, C. M. (Author), Annual Meeting of the Ecological Society of America, Oral Presentation, "The independent and interactive effects of plant functional and phylogenetic diversity on urban ecosystem services," Ecological Society of America, Portland, OR, (2017).
127. Joseph George, A., Arabi, M., Sharvelle, S., and Dell, T. (2019). Assess Performance of Urban Stormwater Control Measures (SCMs) under varying Maintenance Regimes. 39th Annual AGU Hydrology Days, March 27 -29, 2019, Fort Collins, CO.
128. Joseph George, A., Dell, T., and Sharvelle, S. (2018). Evaluating Uncertainty in Stormwater Control Measures (SCMs) using the EPA Storm Water Management Model linked with Markov Chain Monte-Carlo Uncertainty Technique. 9th International Congress on Environmental Modelling and Software, Modelling for Sustainable Food-Energy-Water Systems, June 24 - 28, 2018, Fort Collins, CO.
129. Keeley-LeClaire, T., Teitelbaum, E., Shim, S., Bozlar, M., Stone, H. A., & Meggers, F. (2018, September 23). Extracting Radiant Cooling From Building Exhaust Air Using the Maisotsenko Cycle Principle. 6. In International Building Physics Conference 2018; Syracuse, NY.
130. Kim, J.S. (Author & Presenter), Arabi, M. (Author), 9th International Congress on Environmental Modelling and Software, "Development of Watershed Delineation Tool Using Open Source Software Technologies," International Congress on Environmental Modelling and Software, Fort Collins, CO, United States. (June 27, 2018).
131. Kirby, T. L., A. Henry, J. Bolson, M. Sukop (2018) Regional Climate Change Adaptation Policy Network in Southeast Florida, Abstract PA11D-0818 presented at 2018 AGU Fall Meeting, Washington, D.C., 10-14 Dec. https://doi.org/10.1002/essoar.10500841.1

132. Korgaonkar, Y., Guertin, D. P., Goodrich, D. C., Unkrich, C., Kepner, W, and Burns, I. S. (2018). Modeling Urban Hydrology and Green Infrastructure using the AGWA Urban Tool and the KINEROS2 Model. In: Proceedings of the Sixth Interagency Conference on Research in the Watersheds, Shepherdstown, WV.
133. Koutzoukis S, Andrews H, S Crum, GD Jenerette. Dynamic microclimate effects of vegetation throughout a 1600 m elevation transect in Southern California, USA. Ecological Society of America, Portland, OR August 2017.
134. Koutzoukis S, GD Jenerette, M Chandler, J Wang, C Ge, and J Ripplinger. Regional and local meteorology influences high-resolution tropospheric ozone concentration in the Los Angeles Basin. American Geophysical Union, New Orleans LA December 2017
135. Krayenhoff, E.S., Georgescu, M., and M. Moustaoui. Built Expansion and Global Climate Change Drive Projected Urban Heat: Relative Magnitudes, Interactions, and Mitigation. Session: Urban Areas and Global Change, AGU Fall Meeting, 12-16 December 2016, San Francisco.
136. Krayenhoff, E.S., Georgescu, M., and M. Moustaoui. Global Climate Change and Urban Development as Drivers of Urban Heat: Relative Magnitude, Interactions, and Mitigation. Joint Session: Intersections of Global Climate Change and Urbanization, AMS 13th Symposium on the Urban Environment, 22-26 January 2017, Seattle.
137. Krayenhoff, E.S., A. Broadbent, M. Georgescu, E. Erell, A. Martilli, A. Middel, D. Sailor. 2017. Urban cooling from heat mitigation strategies: Systematic review of the numerical modeling literature. Urban Climate News, Issue 64, International Association for Urban Climate, p. 22-25.
138. Krayenhoff, E.S., Georgescu, M., and M. Moustaoui. Climates of U.S. cities in the 21st century. Annual meeting of the Urban Water Innovation Network (National Science Foundation), 31 Jul – 2 Aug 2017, Fort Collins, CO (poster). Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = No.
139. Krayenhoff, E.S. Street-level climate and dispersion in mesoscale models. Urban Meteorology and Land Surface Processes (session), Meteorology and Climate – Modeling for Air Quality Conference, UC Davis, 13-15 September 2017 (Invited Paper).
140. Krayenhoff, E.S., Georgescu, M., and M. Moustaoui. Climates of U.S. cities in the 21st century. Urban Areas and Global Change (session), American Geophysical Union Fall Meeting, 11-15 December 2017, New Orleans, LA (Invited Paper).
141. Krayenhoff, S., A.M. Broadbent, E. Erell, L. Zhao, M. Georgescu, J.A. Voogt, A. Middel, A. Martilli, D. Sailor. Urban cooling from heat mitigation strategies: Systematic review of the numerical modeling literature. Tenth International Conference on Urban Climate, 6-10 August 2018, New York, USA.
142. Kucera DC and GD Jenerette. Decadal resistance and resilience of the Los Angeles urban forest in response to drought and temperature stress. Ecological Society of America, Portland, OR August 2017
143. Kucera D and GD Jenerette (2019). The Response of Whole-City Urban Vegetation to Severe Drought in Los Angeles, CA, USA. American Geophysical Union. San Francisco CA December 2019
144. Kunnie, Mandla- Development of a database of Tucson Green Infrastructure sites, Presentation at El Dia Del Agua y la Atmosfera, Department of Hydrology and Atmospheric Sciences, Tucson AZ, University of Arizona March 25, 2019.
145. Kunnie, Mandla, Creation of Tucson GIS Green Infrastructure Database, AWWA Sustainable Water Management Conference, Tucson, AZ, April, 2019.
146. Lammers, R.W., Dell T., and Bledsoe, B.P. 2020. Integrating stormwater management and stream restoration strategies for greater water quality benefits. Poster presented at the SUSE5: The Symposium on Urbanization and Stream Ecology, Austin, TX, 12-15 Feb.
147. Lammers, R.W., Dell T., and Bledsoe, B.P. 2019. Uniting stormwater management and stream restoration strategies for greater water quality benefits. Presented at the 19th Annual Meeting of the American Ecological Engineering Society Conference: “Enabling Future Generations to Solve Our Planet’s Grand Challenges”, Asheville, North Carolina, 3-6 June.
148. Lammers R.W., Dell T., and Bledsoe B.P. 2019. Uniting stormwater management and stream restoration strategies for greater water quality benefits. Presented at the 2019 Georgia Water Resources Conference, Athens, Georgia, 16-17 April.
149. Lee, G., and A.J. Miller, 2017. Monitoring Urban Stream Restoration Efforts in Relation to Flood Behavior Along Minebank Run, Towson, MD. Abstract H31L-1629, Fall 2017 Annual Meeting, AGU, New Orleans,

LA, 11-15 Dec.
150. Lee, G. and A.J Miller, 2018. *Using SfM in creating high resolution DEMs for tracking changes in channel bed morphology and hydraulic modeling.* Abstract H43J-2614. AGU Fall Meeting 2018.
151. Lee, G. and Miller, A. 2019. Examining the Effect of Changing Floodplain/Channel Morphology on Flood Hydraulics at Minebank Run, Baltimore County, MD. Poster (H53L-1940), 2019 AGU Fall Meeting, San Francisco, CA, December 9-13.
152. Li, Q. And Bou-Zeid E. (2016), Developing Urban Surface Parameterizations for Momentum and Scalars Using Large-Eddy Simulations, 22nd Symposium on Boundary Layers and Turbulence, Salt Lake City, Utah.
153. Li, Q. And Bou-Zeid E. (2016), Contrasts Between Momentum and Scalar Exchanges Over Very Rough Surfaces, Bulletin of the American Physical Society, 61.
154. Li Q., Bou-Zeid E., and Grimmond S. (2017) "On the Momentum and Scalar Roughness Lengths of Urban Surfaces", 97th American Meteorological Society Annual Meeting, Seattle , WA.
155. Li Q., Bou-Zeid E., Yang J., Wang Z.-H. (2018) "Improving the representation of convective heat transfer in an urban canopy model", International Building Physics Conference 2018, Syracuse, NY, USA: http://amz.xcdsystem.com/476EFEC7-D8CF-7470-232B140485F971CA_abstract_File1159/FinalPaperFileUpload_424_0612122558.pdf
156. Li, Q., E. Bou-Zeid, G. G. Katul, S. B. Grimmond, and S. Zilitinkevich, 2019: "Linking Momentum and Scalar Roughness Lengths of Urban Surfaces at the Macro and Micro-scales." Fall meeting of the American Geophysical Union, San Francisco, CA.
157. Lim, T.C. and Welty, C. (2018) Spatial Considerations of Distributed Green Stormwater Infrastructure Implementation, Fall meeting of the American Geophysical Union, Washington DC, https://agu.confex.com/agu/fm18/meetingapp.cgi/Paper/424197
158. Llaguno Munitxa M., Bou-Zeid E., Bogosian B., Al Tair A., Radcliff D., Fisher S., Ryu Y. (2018) "Sensing and information technologies for the environment (SITE); hardware and software innovations in mobile sensing applications", International Building Physics Conference 2018, Syracuse, NY, USA: http://amz.xcdsystem.com/476EFEC7-D8CF-7470-232B140485F971CA_abstract_File1159/FinalPaperFileUpload_430_0630060005.pdf
159. Llaguno-Munitxa M., B. Bogosian, E. Bou-Zeid, A. Al Tair, D. Radcliff, Z. Chen, S. Fischer, Y. Ryu, J. Kim, and J. Bae (2018) Blending Hardware and Software Innovations in Mobile Urban Sensing Technologies, 2018 Annual meeting of the American Meteorological Society, Austin, TX.
160. Llaguno-Munitxa, M. and Bou-Zeid, E. (2020) "Opportunistic Mobile Urban Sensing Technologies". Annual meeting of the American Meteorological Society, Boston, MA
161. Lochet A., Berkowitz A., Vincent S., Habron G., Maas A., Gosselin D. 2018. Building transdisciplinary skills among undergraduate students through summer research experiences. Council on Undergraduate Research Biennial Conference, July 1st-3rd 2018, Arlington VA. Poster presentation.
162. Maas, Alexander (2018) Complements of the house: Estimating demand-side linkages between residential water and electricity. Western Agricultural Economics Annual Meeting. Anchorage, AK. June 24-26, 2018
163. Maas, Alexander (2018). Eliciting Preferences through Discrete Choice Experiments. Palouse Basin Aquifer Committee, Moscow, ID. October 24, 2018
164. Maas, Alexander (2019) Complements of the house: Estimating demand-side linkages between residential water and electricity. Hydrology Days, Fort Collins, CO. March 27-29, 2019
165. Maas, Alexandner (2019). Other-regarding Behavior when Common Pool Resources Have Tipping Points. Presented at Western Agricultural Economics Association annual meeting. Coeur d'Alene ID, June 2019
166. Maas, A & Koroles Awad (2019). Preferences for Alternative Water Supplies in the Pacific Northwest: A Choice Experiment. Presented at Palouse Basin Water Summit annual meeting. Pullman WA, October 2019
167. Mack, E.A. (2017) A Burgeoning Crisis? A Nationwide Assessment of the Geography of Water Affordability in the United States. Association of American Geographers (AAG) Conference. Boston.
168. Mack, Elizabeth. Human Dimensions of the Urban Water Innovation Network (U-WIN). Earth and Environmental Sciences Seminar Series, Wayne State University Colloquium. March 7, 2018.
169. Mack, E.A. An Input-Output Framework for Analyzing Consumer Responses to Changing Water Prices. North American Regional Science Association Conference. San Antonio, TX. November 7-10, 2018

170. Mack, E.A. “A Geographic Assessment of Water and Sewer Service Affordability in the Detroit Metropolitan Area.” Association of American Geographers, Washington, D.C. April 4, 2019
171. Mack, E.A. Household Expenditure Change and Cascading Effects as a Result of Increasing Costs of Water Services. North American Regional Science Conference. Pittsburgh, PA November 13-16, 2019
172. Mack, E.A. Water Rates in Detroit. Global Water Justice Summit: The Michigan Conference. Detroit Michigan. January 24-25 2020
173. Mariluz, L., J. Divalli, S.L. Harlan, L. Senier. “Collaboration between Community-Based Environmental Orgianizations and Water Resource Management Agencies: A Challenge for Achieving Water Justice.” Poster presentation at the Research, Innovation, and Scholarship Exposition (RISE), Northeastern University, April 4, 2019.
174. McWest L., Broadbent, A., Vanos, J., Georgescu, M., Middel, A. 2019. Impacts of urban tree canopy and water features on the thermal environment. American Meteorological Society 99th Annual Meeting, January 6-10 2019. Phoenix, AZ. Poster presentation.
175. Medwid, Laura. Perceptions of Water Affordability. North American Regional Science Conference. Pittsburgh, PA November 13-16, 2019.
176. Meggers, Forrest, Hongshan Guo, Eric Teitelbaum, Gideon Aschwanden, Jake Read, Nicholas Houchois, Jovan Pantelic, and Emanuele Calabrò. 2017. “The Thermoheliodome – ‘Air Conditioning’ without Conditioning the Air, Using Radiant Cooling and Indirect Evaporation.” Energy and Buildings, June. https://doi.org/10.1016/j.enbuild.2017.06.033.
177. Meggers, Forest (2019). Radiant sensing, ASHRAE 2019 summer meeting, Kansas City, MO
178. Meggers, Forest (2019). Outdoor radiant cooling, ASHRAE 2019 summer meeting, Kansas City, MO
179. Meggers, Forest (2020). Thermal Resilience, Regenerating Good, National Thai Design Week, Feb 2020, Bangkok Thailand
180. Meixner, T. 2016, Green Infrastructure as a Puzzle Piece for Water Resources in the Southwest, Presented at – Fourth Annual Kent State University Water and Land Symposium, Kent Ohio, October 6, 2016.
181. Meixner, T., Papuga, S.A., Luketich, A.M., Rockhill, T., Gallo, E.L., Anderson, J., Salgado, L., Pope, K., Gupta, N., Korgaonkar, Y. and Guertin, D.P., 2017, December. Green Infrastructure Increases Biogeochemical Responsiveness, Vegetation Growth and Decreases Runoff in a Semi-Arid City, Tucson, AZ, USA. In AGU Fall Meeting Abstracts.
182. Meixner, Thomas— Green Stormwater Infrastructure Increases Infiltration, Soil Carbon and Biogeochemical Response, 2018 – Arizona Hydrological Society Annual Symposium, Flagstaff AZ, September 7, 2018.
183. Meixner, Thomas, Green Stormwater Infrastructure Function and Interactions with Maintenance, AWWA Sustainable Water Management Conference, Tucson, AZ, April, 2019.
184. Meltzer S., Georgescu, M, Broadbent, A., Vanos, J., Middel, A. 2019. Impacts of trees on urban canyon microclimate. American Meteorological Society 99th Annual Meeting, January 6-10 2019. Phoenix, AZ. Poster presentation.
185. Miller, A.J., G. Lee, B.P. Bledsoe, and T. Stephens, 2017. Mitigation of Flood Hazards Through Modification of Urban Channels And Floodplains. Abstract H31L-1630, Fall 2017 Annual Meeting, AGU, New Orleans, LA, 11-15 Dec.
186. Miller, A.J., 2018. *Extreme floods in the Baltimore Metropolitan Region or The Myth of the 1000-Year Flood*. Wolman Club Annual Meeting, UMBC, Baltimore, MD., 1 June.
187. Miller, A.J., 2018. *Extreme floods in Ellicott City and the Baltimore Metropolitan Region*. Maryland Department of Transportation Geohazards Forum Field Trip, Keynote Speaker, Ellicott Mills Brewing Company, Ellicott City, MD., 7 August.
188. Miller, A.J., 2018. *What do we know about extreme floods in Ellicott City and the Baltimore Metropolitan Region?* Ellicott City Flash Flood Symposium, UMBC, Baltimore, MD. 7 Sept.
189. Miller, A.J., 2018. *What do we know about extreme floods in Ellicott City and the Baltimore Metropolitan Region?* Baltimore Ecosystem Study 20th Annual Meeting, University of Baltimore, Baltimore, MD., 25-26 Oct.

190. Miller, A.J., J.A. Smith, M.J. Cashman, J.J.A. Dillow, E.J Doheny, M.L. Baeck, M.M. Chaney, 2018. *Extreme floods in the Baltimore metropolitan region and the myth of the 1000-year flood.* Abstract H53F-03, Fall 2018 Annual Meeting, AGU, Washington, D.C., 10-14 Dec.
191. Neale, M., A. Dozier, S. Sharvelle, M. Arabi (2018) Identifying Optimal Water Conservation and Reuse Strategies Using and Urban Water Demand Model for a Selection of US Cities with Distinct Climatic Conditions and Land Cover Characteristics, Hydrology Days, Fort Collins, CO.
192. Neale, M., Sharvelle, S., Dozier, A., Arabi, M. (2018) "Identifying Optimal Water Conservation and Reuse Strategies Using an Urban Water Demand Model for a Selection of U.S. Cities with Distinct Climatic Conditions and Land Cover Characteristics," 9th International Congress on Environmental Modelling and Software Fort Collins, CO.
193. Neale, M., Sharvelle, S., Arabi, M. (2019) "Cost-benefit evaluation of water conservation and reuse strategies using the Integrated Urban Water Model for three U.S. cities", Hydrology Days, Fort Collins, CO.
194. Omidvar H., Bou-Zeid E., Song J., Yang J., Arwatz G., Byers C., Wang Z., Hultmark M., and Kaloush K. (2017) "Rapid Modification of Land Surface Temperature during Rainfall", 97th American Meteorological Society Annual Meeting, Seattle , WA.
195. Omidvar, H and Bou-Zeid, E and Song, J and Yang, J and Arwatz, G and Wang, Z and Hultmark, M and Kaloush, K (2017) Rapid modification of urban land surface temperature during rainfall, AGU Fall Meeting, New Orleans, LA.
196. Omidvar H. And Bou-Zeid E. (2018) "Rapid cooling of urban surfaces during rainfall: physical basis, dominant energy fluxes, and sensitivity to pavement and rainfall properties" International Building Physics Conference 2018, Syracuse, NY, USA: http://amz.xcdsystem.com/476EFEC7-D8CF-7470-232B140485F971CA_abstract_File1159/FinalPaperFileUpload_400_0628030315.pdf
197. Omidvar H., Bou-Zeid E., Li Q., Mellado J. P., Klein P. (2018). A study of city--scale atmospheric circulations, and their transition from plume to bubble. American Physical Society Division of Fluid Dynamics Meeting. Atlanta, GA, Bulletin of the American Physical Society. https://meetings.aps.org/Meeting/DFD18/Session/D34.6
198. Pantelic, J. E Teitelbaum, M Bozlar, S Kim, F Meggers, Development of moisture absorber based on hydrophilic nonporous membrane mass exchanger and alkoxylated siloxane liquid desiccant, Energy and Buildings 160, 34-43 Published, Acknowledgement: no, Peer reviewed: yes
199. Patterson, D. (Author & Presenter), Arabi, M. (Author & Presenter), Traff, K. (Author), 9th International Congress on Environmental Modelling and Software, "Workshop: eRAMS Online Tools for Integrated Resource Management," International Congress on Environmental Modelling and Software, Fort Collins, CO, United States. (June 27, 2018).
200. Poost, M. S. (Author & Presenter), Johnson, A. (Author), Swan, C. M. (Author), Ashman, T.-L. (Author), Annual Meeting of the Ecological Society of America, Poster, "Pollination in the city: Restored native species interact with spontaneous urban weeds via pollen transfer in vacant lots," Ecological Society of America, Portland, OR, (2017).
201. Puri, R., & Maas, A. (2019) Evaluating the sensitivity of residential water demand estimation to model specification and instrument choices. Presented at Universities Council of Water Resources. Snowbird UT, June 2019
202. Redican, K and E.A. Mack (2017). The Socio-Economic Impacts of Rising Water Prices using Scenario Based Modeling. Association of American Geographers (AAG) Conference. Boston. Acknowledgement of Federal Support=No
203. Rasoulkhani, K., BN Logasa, MP Reyes, A Mostafavi (2017). *Agent-based modeling framework for simulation of complex adaptive mechanisms underlying household water conservation technology adoption.* Winter Simulation Conference (WSC 2017). Las Vegas.
204. Rasoulkhani, K., BN Logasa, MP Reyes, A Mostafavi (2017). *Integrated modeling of urban water distribution infrastructure for long-term resilience assessment.* International Workshop on Computing for Civil Engineering (IWCCE). Seattle.
205. Rasoulkhani, K., J Cole, S Sharvelle, A Mostafavi (2017). *Assessment of Dual-Distribution and Decentralize Systems for Resilient Urban Water Infrastructure.* International Construction Specialty Conference. Vancouver.

206. Rasoulkhani, K., Logasa, B., Presa Reyes, M., and Mostafavi, A. (2017). Agent-based Modeling Framework for Simulation of Complex Adaptive Mechanisms Underlying Household Water Conservation Technology Adoption. ASCE International Conference on Sustainable Infrastructure, October 2017, New York, New York.
207. Rasoulkhani, K., BN Logasa, MP Reyes, A Mostafavi (2017). *Agent-based modeling framework for simulation of complex adaptive mechanisms underlying household water conservation technology adoption.* Winter Simulation Conference (WSC 2017). Las Vegas.
208. Rasoulkhani, K., MP Reyes, A Mostafavi (2017). *Emergence of Resilience from Infrastructure Dynamics: A Simulation Framework for Theory Building.* International Workshop on Computing for Civil Engineering (IWCCE 2017).
209. Rasoulkhani, K., Presa Reyes, M., and Mostafavi, A. (2017). "Emergence of Resilience from Infrastructure Dynamics: A Simulation Framework for Theory Building." ASCE International Workshop on Computing in Civil Engineering, June 2017, Seattle, WA.
210. Rasoulkhani, K., A Mostafavi (2018). *Long-term performance and life-cycle cost assessment of dual vs. singular water distribution infrastructure systems.* ASCE Construction Research Congress (CRC 2018). Seattle.
211. Rasoulkhani, K., Mostafavi, A., and Sharvelle, S. (2019). "A Computational Simulation-Based Comparison of Dual and Singular Water Distribution Infrastructure Systems for the City of Fort Collins, Colorado." ASCE International Conference on Computing in Civil Engineering, June 17–19 2019, Atlanta, GA.
212. Rasoulkhani, K., Mostafavi, A., Presa Reyes, M., and Batouli, M. (2020). "Simulation-based Assessment of Adaptive Planning in Coastal Water Supply Infrastructure Systems," ASCE Construction Research Congress 2020, March 8-10, 2020, Tempe, Arizona.
213. Ripplinger J and GD Jenerette. Dimensions of urban tree biodiversity are inversely related across continental-scale climate gradients. Ecological Society of America, Portland, OR August 2017
214. Ripplinger J, GD Jenerette, J Wang, M Chandler, C Ge, S Koutzoukis. Understanding Climate Variability of Urban Ecosystems Through the Lens of Citizen Science. American Geophysical Union, New Orleans LA December 2017
215. Rockhill, Tyler, Meixner Thomas, 2017, Investigating the relationship between hydrology and biogeochemistry in semi-arid Urban Green Infrastucture, El Dia Del Agua Y Atmosfera, University of Arizona, Tucson, AZ March 27, 2017.
216. Rochford M, Ibsen P, Jenerette D. (2016) "Species Richness and Functional Trait Diversity for Plants in Southern California's Green Infrastructure along a Climate Gradient" AGU Fall Meeting 2016. San Francisco. (Poster)
217. Santelmann, M., Haggerty, R., Hulse, D., Conklin, D., Wright, M. (2017). Project D1-1: UWIN Envision Modeling of Present and Future Values for Sustainable Water Management Blueprint Indicators. Brief prepared for Urban Water Innovations Network, Annual Meeting, Ft. Collins, Colorado. August, 2017.
218. Santelmann, M.V**.,** D. Hulse, D. Conklin, B. Fulfrost, M. Harrison, M. Wright and R. Haggerty. Multi-scale modeling of Urban Water Systems**.** UWIN Thrust C-D Webinar October 19, 2017.
219. Santelmann, M., D. Hulse, D. Conklin, B. Fulfrost, M. Harrison, M. Wright and R. Haggerty. 2017. Modeling innovation in urban water systems. American Water Resources Association meeting, Portland Oregon, Nov. 6-10 2017. (Oral Presentation)
220. Santelmann, M.V**.,** D. Hulse, D. Conklin, B. Fulfrost, M. Harrison, M. Wright and R. Haggerty. 2018. Multi-scale modeling of Urban Water Systems**.** USGS Winter Seminar Series, Portland Oregon January 23, 2018.
221. Santelmann M V, Hulse D, Wright M, Branscomb A, Enright C, Talal M and Tchintcharauli-Harrison M. 2019. International Geodesign Collaboration: Innovation in Urban Water Systems. February 2019, Redlands, CA
222. Santelmann M V, Hulse D, Wright M, Branscomb A, Enright C, Talal M and Tchintcharauli-Harrison M. 2019. International Geodesign Collaboration: Innovation in Urban Water Systems (Poster). February 2019, Redlands, CA
223. Santelmann, M.V. 2019. Evaluating biodiversity as a co-benefit of innovative water management solutions in urbanizing areas. Ecological Society of America, August 11-16, 2019, Louisville, KY.
224. Sarango, M., S. Clark, N. Faynshteyn, K. O'Donnell, S.L. Harlan (2018). *Narratives of water injustice across*

U.S. urban areas. AAG Annual Meeting. New Orleans.

225. Sarango, M., D. Kim, L. Senier, S. Harlan (2019). "Unaffordable Water in the U.S.: A Public Health & Health Equity Issue." Poster presentation at the American Public Health Association Annual Meeting, Philadelphia, PA, November 5, 2019.
226. Schoner, B., M. Wright and M. Santelmann. 2018. Integrated Urban Water Model in the Pacific Northwest. Pacific Northwest Water Research Symposium. Oregon State University. April 23-24 2018.
227. Sharvelle, S., N. Ashbolt, E. Clerico, R. Holquist, H. Leverenz and A. Olivieri (2017) *Risk Based Framework for the Development of Public Health Guidance for Decentralized Non-potable Water Systems*, WEFTEC 2017, Chicago, IL.
228. Sharvelle, S., N. Ashbolt, E. Clerico, R. Holquist, H. Leverenz and A. Olivieri (2017) *Risk Based Framework for the Development of Public Health Guidance for Decentralized Non-potable Water Systems*, International Water Association Conference on Water Reclamation and Reuse, Longbeach, CA.
229. Sharvelle, S. (2017) *Developing Guidelines for Performance of Decentralized Non-Potable Water Systems,* WE&RF Onsite Systems Workshop, Los Angeles, CA.
230. Sharvelle, S., M. Arabi, M. Sukop (2018) The National Science Foundation's Research Networks Program, Resilient Utility Coalition – Operationalizing Resilience Summit, Miami, FL.
231. Sharvelle, S., R. Luthy, P. Dillon (2019) "Urban Stormwater to Enhance Water Supply", Groundwater Protection Council, Oklahoma City, OK.
232. Smith, J.A., A.J. Miller, M.L. Baeck, M.M. Chaney, and Y.Su, 2018. *How Does it Rain Hard? The Ellicott City, Maryland Storms of 30-31 July 2016 and 27 May 2018*. Abstract H11K-1613 Fall 2018 Annual Meeting, AGU, Washington, D.C., 10-14 Dec
233. Solis-Arroyo, Sheila Comparative Assessment of Water Quality at the Rainwater-Harvesting Basin and Neighborhood-Wash Scales– Arizona Hydrological Society Annual Symposium, Phoenix AZ, September 20, 2018.
234. Stephens, T. and Bledsoe, B. (2016). An assessment framework for increased resilience to urban flooding under non-stationarity. University of Georgia Sustainability Summit. Status = Accepted; Acknowledgement of Federal Support = Yes
235. Stephens, T., B.P Bledsoe, A.J. Miller, and G. Lee, 2017. Mapping Flood Hazards Under Uncertainty Through Probabilistic Flood Inundation Maps. Abstract , Fall 2017 Annual Meeting, AGU, New Orleans, LA 11-15 Dec.
236. Stephens, T., B.P Bledsoe, A.J. Miller, and G. Lee, 2018. Mapping Flood Hazards Under Uncertainty Through Probabilistic Flood Inundation Maps. Platform Presentation, 12th Annual Meeting, Georgia Association of Floodplain Management, Athens, GA 20-22 Mar.
237. Stephens, T., & B. Bledsoe. 2018. *Mapping flood hazards under climate, land use, and geomorphic uncertainty through probabilistic flood inundation maps*. Presentation, 18th Annual Meeting of the American Ecological Engineering Society (AEES), "Ecological Engineering: Addressing Uncertainty in a Dynamic World," Houston, TX, June 12-14.
238. Stephens, T., & B. Bledsoe. 2018. *Mapping flood hazards under precipitation and land use uncertainty through probabilistic flood inundation maps*. Presentation, American Society of Civil Engineers (ASCE) International Low Impact Development Conference, Nashville, TN, August 12-15
239. Stephens, T., D. Fitzpatrick, H. Hall, & B. Bledsoe. 2018. *Confidence bounds on freeboard at stream crossings for evaluating overtopping risk*. Presentation, 8th Biennial National Hydraulic Engineering Conference (NHEC), "Advancing Hydraulic Engineering through Innovation & Resilient Design," Columbus, OH, August 28-31
240. Stephens, T., & B.P. Bledsoe. 2018. *Mapping flood hazards under climate, land use, and geomorphic uncertainty through probabilistic flood inundation maps*. Poster (EP11E-2095), 2018 AGU Fall Meeting, Washington, DC, December 10-14.
241. Stephens, T.A. and Bledsoe, B.P. 2019. Informing floodplain management and hazard communication through probabilistic flood inundation maps. Presented at the 2019 Conference of the Association of State Floodplain Managers, Cleveland, Ohio 19-23 May.
242. Stephens, T.A., and Bledsoe, B.P. The uncertainty and severity of flood hazard estimates under nonstationarity. Poster presented at the 2019 National Science Foundation Research Meeting - Urban Water Innovation Network, Fort Collins, CO, 30 July - 1 August.

243. Stuhlmacher, M., C. Wang, M. Georgescu, B. Tellman, R. Balling, N. E. Clinton, L. Collins, R. Goldblatt, G. Hansen: Toward a 30m resolution time series of historical global urban expansion: exploring variation in North American cities. Session: Urban Areas and Global Change II, AGU Fall Meeting, 12-16 December 2016, San Francisco.
244. Sukop, M.C., A.D. Henry, J. Bolson, N. Schneider, and T. Kirby (2018). *Using Social Network Analysis to Identify and Understand Linkages Between Climate-related Organizations in Southeast Florida,* University of Florida Water Institute 2018 Symposium, February 6-7, Gainesville, Florida. http://archives.waterinstitute.ufl.edu/symposium2018/downloads/2018BookOfAbstracts.pdf
245. Swartz, Samantha - Evaluating Rainwater-Harvesting Basin Curb-Cuts: How Volunteer Maintenance Impacts Infiltration Rates. Presentation at El Dia Del Agua y la Atmosfera, Department of Hydrology and Atmospheric Sciences, Tucson AZ, University of Arizona April 9,2018.
246. Swartz, Samantha- Infiltration rates of green infrastructure curb-cut basins: Finding a balance between functionality and aesthetics, Presentation at El Dia Del Agua y la Atmosfera, Department of Hydrology and Atmospheric Sciences, Tucson AZ, University of Arizona March 25, 2019.
247. Talal, M. and M. Santelmann. 2017. Vegetation biodiversity patterns and ecosystem functioning in various types of green infrastructure in Portland, OR. Poster presented at Urban Ecosystem Research Consortium. Portland, OR. February 6, 2017. Portland, OR.
248. Talal, M. and M. Santelmann. 2017. Vegetation biodiversity patterns and ecosystem functioning in various types of green infrastructure in Portland, OR. Poster presented at Urban Ecosystem Research Consortium. Portland, OR. February 6, 2017. Portland, OR.
249. Talal, M. and M. Santelmann. 2017. Vegetation biodiversity patterns and ecosystem functioning in various types of green infrastructure in Portland, OR. Poster accepted for Ecological Society of America meeting, Portland, OR. August 6, 2017.
250. Talal, M. and M. Santelmann. 2018. Plant greenness and health of various income-level neighborhoods in Portland, OR using Landsat 8 OLI/TIRS surface reflectance. Oral presentation at Urban Ecosystem Research Symposium, Portland, Oregon. Feb 5 2018.
251. Talal M, 2018. Comparison of plant greenness among neighborhoods of different income-levels in Portland, Oregon using Landsat 8 OLI/TIRS surface reflectance. Research Advances in Fisheries, Wildlife, and Ecology Symposium (Poster), April 2018, Corvallis, OR
252. Talal M. 2018. Comparison of plant greenness among neighborhoods of different income-levels in Portland, Oregon using Landsat 8 OLI/TIRS surface reflectance. Pacific Northwest Water Research Symposium (Oral), April 2018, Corvallis, OR
253. Talal, M. and M. Santelmann. 2018. Plant greenness of different income-level neighborhoods in Portland, Oregon using Landsat 8 OLI/TIRS surface reflectance. Oral presentation accepted for Ecological Society of America meeting, New Orleans, LA. August 2018. Status= ACCEPTED; Acknowledgement of Federal Support= YES; Peer-reviewed= No.
254. Talal M, Santelmann M. 2018. Comparison of plant greenness among neighborhoods of different income-levels in Portland, Oregon using Landsat 8 OLI/TIRS surface reflectance Ecological Society of America Annual Conference (Oral), August 2018, New Orleans, LA
255. Talal M, Santelmann M. 2019 Plant community composition patterns in urban parks of Portland, Oregon Urban Ecology and Conservation Symposium (Oral), February 2019, Portland, OR
256. Talal., M.L. 2019. Exploring urban parks: plant communities, visitor experiences, and manager perspectives in Portland, Oregon. Israeli Ministry of Agriculture (Invited Seminar), December 2019, Tel Aviv, Israel.
257. Talal, M.L. 2019. Exploring urban parks: plant communities, visitor experiences, and manager perspectives in Portland, Oregon. Hebrew University of Jerusalem Geography Department (Invited Seminar). November 2019, Jerusalem, Israel.
258. Talal, M.L. and M.V. Santelmann. 2019. Plant community composition patterns in urban parks of Portland, Oregon. Ecological Society of America August 11-16 2019, Louisville, KY.
259. Talal, M.L. and M.V. Santelmann. 2020. Urban park visitor preferences for vegetation – an on-site qualitative research study in Portland, Oregon. Urban Ecosystem Research Consortium Symposium, March 2, 2020, Portland, OR.
260. Talal, M.L. and M.V. Santelmann. Oregon State University. 2020. Innovations in Urban Water System.

International GeoDesign Collaborative Summit, February 21-23, 2020, Redlands, CA.
261. Talal, M.L. and M.V. Santelmann. 2020. Plant community composition patterns in urban parks of Portland, Oregon. Weizmann Institute of Science Israel Plant Ecology Conference, February 10-11, 2020, Rehovot, Israel.
262. Talebpour, M., C. Welty and E. Bou-Zeid. (2016) "Land-Atmosphere-Hydrosphere Interactions in Urban Terrains". Abstract H13C-1375 presented at the Fall 2016 Meeting of the American Geophysical Union, December 12-16, 2016, San Francisco, CA. https://agu.confex.com/agu/fm16/meetingapp.cgi/Paper/188199.
263. Talebpour M., Welty C., and Bou-Zeid E. (2018) "Modeling coupled atmospheric-hydrological processes in urban areas". Fall meeting of the American Geophysical Union, Washington DC, https://agu.confex.com/agu/fm18/meetingapp.cgi/Paper/413748
264. Talebpour M., Welty C., and Bou-Zeid E. (2019) "Development and testing an urban hyper-resolution fully-coupled subsurface-land surface-atmosphere model". 21st Annual Meeting of the Baltimore Ecosystem Study (BES) Long-Term Ecological Research Project, Baltimore, MD, USA
265. Talebpour M., Welty C., and Bou-Zeid E. (2019) "Development and evaluation of a new fully-coupled urban atmospheric-hydrological model". Fall meeting of the American Geophysical Union, San Francisco, CA, USA: https://agu.confex.com/agu/fm19/meetingapp.cgi/Paper/615914
266. Talebpour M., Welty C., and Bou-Zeid E. (2020) "A New Fully Coupled Model for Improving the Representation of Urban Heterogeneous Hygrothermal Processes". 100th Annual Meeting of the American Meteorological Society, Boston, MA, USA: https://ams.confex.com/ams/2020Annual/meetingapp.cgi/Paper/370861
267. Tchintcharauli-Harrison, M., Santelmann, M., Haggerty, R., 2019. Preliminary isotopic and hydrochemical findings of surface-groundwater dynamics in an urbanized watershed, Portland, OR: Geological Society of America Cordilleran Section Meeting, 115th, Portland, OR, Abstracts with Programs. Vol. 51, No. 4. doi: 10.1130/abs/2019CD-329864
268. Tchintcharauli-Harrison, R. Brooks, M., Haggerty, R. and M.V. Santelmann. 2019. Isotopic and Hydrochemical Investigation of Surface-Spring Water Dynamics in Urbanized Catchment, Portland, Oregon, USA. American Geophysical Union Fall Meeting, December 2019. San Francisco, CA.
269. Teitelbaum, E., Meggers, F., Scherer, G., Ramamurthy, P., Wang, L., & Bou-Zeid, E. (2015). ECCENTRIC Buildings: Evaporative Cooling in Constructed ENvelopes by Transmission and Retention Inside Casings of Buildings. In 6th International Building Physics Conference, IBPC 2015. Torino, Italy: Elsevier.
270. Teitelbaum, E., Meggers, F. Expanded Psychrometric Landscapes for New Radiant Cooling System Design and Optimization. Energy Procedia, CISBAT 2017 Conference Proceedings,
271. Teitelbaum, E., Guo, H., Read, J.R., Meggers, F. Mapping Comfort with the SMART (Spherical Motion Average Radiant Temperature) Sensor. IBPSA Building Simulation Conference, San Francisco. , Aug 7-9, 2017.
272. Teitelbaum, E., Rysanek, A., Pantelic, J., Aviv, D., Obelz, S., Luo, Y., … Meggers, F. (2018, September 23). Condensation-free radiant cooling using infrared-transparent enclosures of chilled panels. 6. International Building Physics Conference 2018; Syracuse, NY, 2018.
273. Traff, K. (Author & Presenter), Arabi, M. (Author & Presenter), 9th International Congress on Environmental Modelling and Software, "Building Containerized Environmental Models Using Continuous Integration with Jenkins and Kubernetes," International Congress on Environmental Modelling and Software, Fort Collins, CO, United States. (June 27, 2018).
274. Valencia, M.E., Jenerette D. 2018. Influence of vegetation transitions on air temperature. AGU Fall Meeting, December 2018. Washington D.C.
275. Wang, Z.H. (2016) "Urban green infrastructure: Modeling and Implications to sustainable development of cities". Nanyang Technological University, Singapore, 02 June 2016.
276. Wang, Z.H. (2016) "Climate-energy-water repercussions of urban green infrastructure". Nanjing University, Nanjing, China, 13 June 2016.
277. Waweru, D. and Cherrier. J. Natural Solutions to Urban Watershed Management: Assessing the Performance of Bioswales. 2019. Urban Water Innovation Network Annual Meeting 2019. Fort Collins, CO
278. Weller-Clarke L and GD Jenerette. Assessing sustainability trade-offs in CA rice through coupled crop and

LCA modeling. Ecological Society of America, Portland, OR August 2017

279. Wible, T. (Author & Presenter), Arabi, M. (Author), 9th International Congress on Environmental Modelling and Software, "A Web-based Healthy Watersheds Assessment Framework," International Congress on Environmental Modelling and Software, Fort Collins, CO, United States. (June 25, 2018).
280. Wible, T. (Author & Presenter), Arabi, M. (Author), 9th International Congress on Environmental Modelling and Software, "Regional Assessment of Temporal Changes in Flood Frequency and Magnitude," International Congress on Environmental Modelling and Software, Fort Collins, CO, United States. (June 28, 2018).
281. Wilder, E., R. Domond, K. Furman, L. Contorno, J. Bolson, F. Mohamed, S.L. Harlan (2018). *Barriers to sustainability: community perspectives on urban water governance.* AAG Annual Meeting. New Orleans.
282. Wostoupal, B. (Author & Presenter), Dozier, A. (Author), Arabi, M. (Author), Goemans, C. (Author), Hydrology Days 2018, "Can water conservation save agriculture?" Hydrology Days, Fort Collins, CO, United States. (March 19-21, 2018).
283. Wrase, S. and E. Mack. (2017) Underground and Overlooked: America's Wastewater Infrastructure Crisis. Michigan State University Undergraduate Research and Arts Forum (UURAF).
284. Wright, M, Santelmann, M, Hulse, D, Conklin, D, Harrison, M, Haggerty, R. 2018. H51X-1674: Multi-scale Modeling of Integrated Urban Water Management in Oregon (Poster). Presented at 2018 Fall Meeting, AGU, Washington, D.C., 3-7 Dec. 2018.
285. Wright, M., M. Santelmann, and D. Conklin 2019. Modeling Hydrologic Effects of Urbanization Using a Coupled Natural-Human Systems Model. American Geophysical Union Fall Meeting December 2019. San Francisco, CA.
286. Yang, J and Bou-Zeid, E (2017) The other side of the coin: urban heat islands as shields from extreme cold, AGU Fall Meeting, New Orleans, LA.
287. Yang J. and Bou-Zeid E. (2018) "Greening rooftops to reduce heat islands: how large is large enough?" International Building Physics Conference 2018, Syracuse, NY, USA: http://amz.xcdsystem.com/476EFEC7-D8CF-7470-232B140485F971CA_abstract_File1159/FinalPaperFileUpload_402_0619093018.pdf
288. Zahn, E., E. Bou-Zeid, J. A. Smith, M. L. Baeck, and C. Welty (2019) "Temperature Surges Caused by Hot Runoff in Urban Watersheds". Fall meeting of the American Geophysical Union, San Francisco, CA.

Patents

1. **A2-4:** *SPHERICAL-MOTION AVERAGE RADIANT TEMPERATURE SENSOR*, F Meggers, E Teitelbaum, J Read US Patent App. 15/559,218 (Approved 2020). http://puotl.technologypublisher.com/technology/20763

Thesis/Dissertations

1. Anderson, Jack, Ferre, Ty, Whitaker, Martha, and Winter, Larry. Analysis and Classification of Semi-Arid Bioswales in an Urban Setting (2018): M.S. Thesis – Hydrology, University of Arizona. Web: https://repository.arizona.edu/handle/10150/631916
2. Arcelay, Adriana (2019). Investigating Impacts of Projected Climate Change on Flood Risk in Urban Areas Located Along River Channels. M.S. Thesis, University of Arizona. Web: https://repository.arizona.edu/handle/10150/634342
3. Aviv, Dorit (2020). Design for Heat Transfer: Formal and Material Strategies to Leverage Thermodynamics in the Built Environment. PhD Dissertation. Princeton University.
4. Batista, Giovana das Gracas (2018). *Characterization of urban water use and performance evaluation of conservation practices using the Integrated Urban Water Model in São Paulo, Brazil.* M.S .Thesis: Civil and Environmental Engineering, Colorado State University. Web: https://hdl.handle.net/10217/193176
5. Cole, Jeanne Reilly (2018). A Collaborative planning framework for integrated urban water management with an application in dual water supply: a case study in Fort Collins, Colorado. PhD Dissertation: Civil and Environmental Engineering, Colorado State University. Web: https://hdl.handle.net/10217/193125
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8. Dozier, Andre (2017). Towards integrated water resources management through modeling, optimization, and stakeholder engagement with a decision support game. PhD Dissertation: Civil and Environmental Engineering, Colorado State University. Web: https://hdl.handle.net/10217/184012
9. Garlock, Genevieve (2020). The Dynamic Edge: Sea Level Rise and Waterfront Design in New York City, Undergraduate Thesis. Princeton University.
10. Gomez Fernandez, Edna Liliana (2020). Three Essays on Urban Water Management and Innovative Outcomes. PhD Dissertation, Arizona State University. Web: https://repository.arizona.edu/handle/10150/641691
11. Hermosilla, Victoria (2019). Rainwater harvesting infiltration exploration using Hydrus-1D. M.S. Thesis, University of Arizona. Web: https://repository.arizona.edu/handle/10150/634343
12. Keeley-LeClaire, Theo (2018). Evaporative-Radiant Cooling on Superhydrophilic Boehmitized Aluminum Surfaces. Undergraduate thesis, Chemical and Biological Engineering, Princeton University http://arks.princeton.edu/ark:/88435/dsp01rf55zb45b
13. Korgaonkar, Yoganand (2020). Modeling Urban Hydrology and Green Infrastructure Using the AGWA Urban Tool and the KINEROS2 Model. PhD Dissertation, University of Arizona. Web: https://repository.arizona.edu/handle/10150/636556
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16. Neale, Michael R. (2019). Assessing Tradeoffs of Urban Water Demand Reduction Strategies. M.S. Thesis: Civil and Environmental Engineering, Colorado State University. Web: https://hdl.handle.net/10217/199880
17. Omidvar, Hamidreza (2018). Heat, Air and Water: How Cities Create Their Own Hydroclimates. Ph.D. dissertation. Princeton University http://arks.princeton.edu/ark:/88435/dsp01s7526g19g
18. Puri, Roshan (2019). Evaluating the Sensitivity of Residential Water Demand Estimation to Model Specification and Instrument Choices. M.S. Thesis - Applied Economics. University of Idaho
19. Rasoulkhani, Kambiz (2020). Assessment of Urban Water Infrastructure System Resilience. Ph.D. Dissertation, Texas A&M University.
20. Rockhill, Tyler (2017). Influence of Soil Physical and Chemical Properties on Soil Co2 Flux in Semi-Arid Green Stormwater Infrastructure, M.S. Thesis - Hydrology, University of Arizona. Web: https://arizona.openrepository.com/handle/10150/626391
21. Sarango, Mariana. (2020) Keeping Our Heads above Water: Unaffordable Water, Public Health, and Equity in the United States. PhD Dissertation, Northeastern University, Boston, MA (April). Web: http://hdl.handle.net/2047/D20361356
22. Stuhlmacher, Michelle Faye (2020). Patch to Landscape and Back Again: Three Case Studies of Land System Architecture Change and Environmental Consequences from the Local to Global Scale. Arizona State University, PhD Dissertation 2020. https://search.proquest.com/openview/69c9b29a622ade17e00fc5df03fbcd55/1?pq-origsite=gscholar&cbl=18750&diss=y
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24. Talal, Michelle L. 2019. Exploring Urban Parks: Plant Communities, Visitor Experiences, and Manager Perspectives in Portland, Oregon. PhD Dissertation. Oregon State University, Corvallis, OR. Web: https://ir.library.oregonstate.edu/concern/graduate_thesis_or_dissertations/4m90f2149
25. Teitelbaum, Eric (2020). Design with Comfort: A Systems and Materials Approach to Expanded Psychrometrics. PhD Dissertation. Princeton University School of Architecture.

26. Uludere Aragon, N. Z. (2020). Underutilized spaces and marginal lands for sustainable land use: A multi-scale analysis (Order No. 27741997). PhD Dissertation. Arizona State University. Web: https://repository.asu.edu/items/56973
27. Wostoupal, B. (2018). Exploring water management tradeoffs in semiarid regions through conservation, institutions, and integrated modeling. M.S. Thesis in Civil and Environmental Engineering, Colorado State University. Web: https://hdl.handle.net/10217/191277
28. Yang, Jiachuan (2016). Urban Green Infrastructure: Modeling and Implications to Environmental Sustainability. PhD Dissertation. Arizona State University. Web: https://repository.asu.edu/items/40778

Technologies & Models

1. **A1-1:** [Software] Heidari, H., Arabi, M., Warziniack, T., Hydroclimatic Assessment Tool, https://hcat.erams.com/docs/
2. **A2-1:** Bou-Zeid group transferred to the Project A 2-2 an offline (uncoupled to WRF) urban canopy models that includes the effect of trees as well as an online one (coupled to WRF) that improves the representation of urban terrain. These models are being used in the simulation the lab or PI Matei Georgescu are doing for future cities.
    - New model for representing thermochromic materials in urban simulators
    - New approaches for designing hybrid urban sensing networks
3. **A2-4:** Evaporative cooling model built by Teitelbaum of novel membrane building facade created merging Bou-Zeid microclimate model of surface energy interactions with a subsurface model of heat transfer by evaporation behind a porous membrane.
4. **A2**-4: TRNSYS and EnergyPlus building energy simulations tools enable a dynamic iterative annual energy demand simulation platform for detailed building performance models, which can be translated into agglomerated urban performance analysis, and can output data related to energy driven evaporative cooling water use.
5. **B1-1a:** Integrated Urban Water Model (IUWM): The purpose of IUWM is to forecast urban water demand and project potential savings from conservation and use of alternative water sources over varying climatic conditions and land uses. Water supply and demand assessment under alternative climate, land use and population scenarios is an area of great interest among urban planners and water managers. The Integrated Urban Water Model (IUWM) was developed for urban water demand and savings forecasting with urban water conservation and recycling practices. The purpose of the mass balance model is to allow evaluation of alternative urban water management strategies under varying climatic conditions at a municipal or regional scale. IUWM has been deployed as an online tool and as a web service, thus enabling accessibility, ease of use and applicability at the municipal scale. IUWM facilitates the development of urban water demand forecasts through automated retrieval of publicly available data inputs through a geographical information system (GIS) interface, thus relieving the need for manual input of data. Indoor residential demands are forecast based on end-use at the census block level with population and household data retrieved from the United States census. Combined residential/commercial, industrial, and institutional (CII) irrigation demands are forecast based on daily evapotranspiration and land cover data. Water management strategies included in IUWM are:
    - Indoor conservation
    - Irrigation conservation
    - Graywater reuse for toilet flushing and irrigation
    - Stormwater capture and use
    - Wastewater treatment plant (WWTP) effluent reuse
    - More Information: http://onewatersolutions.com/our-software/tools/urban-planning/urban-water-demand-forecasting/
    - Domain: www.erams.com/iuwm
6. **B1-1a:** Community Life Cycle Assessment for Stormwater Infrastructure Tool (CLASIC): The CLASIC tool serves as a screening tool utilizing a lifecycle cost framework to support stormwater infrastructure decisions on extent and combinations of green, hybrid green-gray and gray infrastructure practices. The

tool is hosted on the eRAMS platform so that it will be geographical information system (GIS) interfaced and include interaction with national databases to upload data for the modeled area. There are three main components to the CLASIC tool outputs; life cycle costs (LCC), triple bottom line analysis (TBL) and performance (hydrologic and water quality). CLASIC is currently undergoing beta testing by user groups and will be posted as a publicly available web tool in 2019. More information: http://onewatersolutions.com/research/clasic/

7. **B1-2:** WEST/WWEST decision support tools: https://west.berkeley.edu/
8. **B2-2b:** Probabilistic floodplain mapping framework based on Monte Carlo simulations of flood hydraulics that accounts for uncertainty in model inputs and parameters.
9. **B2-2b:** Collection of UAV imagery processed using Structure from Motion (SfM) software to generate high-resolution topographic point clouds used in 2d hydraulic models of flood waves routed through pre- and post-restoration channel/floodplain systems
10. **B2-2b:** River Erosion Model (REM) http://www.github.com/rodlammers/REM
11. **D1-1:** The Freshwater Simulations group developed a version of SWMM and of EPA-NET that can be used as a web service and has delivered the model code to CSU for incorporation into their online tool set. This project is developing UWINvision, a whole watershed model built on Oregon State University's Envision modeling framework. It is the second in a series of related Envision implementations which use the Willamette River basin as their study area. The model will enable analysis of futures scenarios that include a set of plausible assumptions defined by regional stakeholders to represent future trends in urbanization and adoption of future water management technologies. The model will produce regional, basin-scale sustainability indicators to evaluate the ability of future water systems to meet desired functions and compare and evaluate outcomes for three different future scenarios.
12. **D1-2:** The Water Rights Analysis tool helped to identify and explore water rights, appropriated amounts in the Colorado region. Domain: erams.com/wra
13. **D1-2/D1-3:** [Software] Dell, T., S. Sharvelle, and M. Arabi, 2020, Community-Enabled Lifecycle Analysis of Stormwater Infrastructure Cost (CLASIC) Model, https://classic.erams.com/
14. **D1-2/D1-3:** [Software] Wible, T. and M. Arabi, 2020, River Discharge and Water Quality Analysis Tool, https://erams.com/catena/tools/water-quality/
15. **D1-2/D1-3:** [Software] Sharvelle, S. and M. Arabi, 2020, Urban Water Demand Forecasting Model, https://erams.com/catena/tools/urban-planning/urban-water-demand-forecasting/
16. **D1-2/D1-3:** [Software] Fontaine, D. and M. Arabi, 2020, Pipe Renewal Prioritization Model, https://erams.com/catena/tools/urban-planning/pipe-renewal-prioritization/
17. **D1-2/D1-3:** [Software] Wible, T., R. Morrison, and M. Arabi, 2020, River Hydraulics & Sediment Transport Model, https://erams.com/catena/tools/river-basin-planning/hydraulics/
18. **D1-2/D1-3:** [Software] Wible, T., R. Morrison, and M. Arabi, 2020, Watershed Rapid Assessment Program (WRAP) Model, https://erams.com/catena/tools/colorado-collaborative/watershed-assessment/
19. **D1-3:** The WaterConnect application was built and serves UWIN research model and data output across the nation within a geospatial interface. Domain: erams.com/water-connect. A MongoDB data store on Colorado State University holds large datasets including climate and water end-use model output. This resource is available through web-services:
    - http://csip.engr.colostate.edu:8083/csip-climate/m/prism/1.0
    - http://csip.engr.colostate.edu:8083/csip-climate/m/maca/2.0
    - http://csip.engr.colostate.edu:8083/csip-climate/m/maca/2.0
    - http://csip.engr.colostate.edu:8092/csip-daycent/m/daycent/2.0
    - https://csip.erams.com/csip-iuwm/m/iuwm/1.0

Websites

1. UWIN SRN Website: https://erams.com/UWIN/

2. UWIN YouTube Channel: https://www.youtube.com/channel/UC7nNrIUznXii6_u0axbhQrA
3. UWIN Zotero Publication Database: https://www.zotero.org/groups/urban_water_innovation_network_uwin/items
4. UWIN Urban Sustainability Data Hub: https://erams.com/UWIN/data/

Additional Products

Webinars

Webinar Series (27): In the spring of 2017 UWIN launched the Networks' first Webinar Series focused on Urban Water Innovation Research Innovations. A total of four series organized by UWIN's current research thrusts were held from April through November, 2017. The webinars include a 45-minute presentation of the specified UWIN related research, followed by a 15-minute Q&A session. The webinars were recorded and are available on the One Water Solutions Institute YouTube Channel

In the spring of 2018, we implemented the One Water Perspectives series, featuring presentations from thought leaders, regional managers, policy makers and practitioners. The series engages members of the UWIN Regional Stakeholder Advisory committees and explores activities, plans, lessons learned, and opportunities currently underway in each UWIN study region. Topics range from adaptive water supply planning and resilience infrastructure to integrated management and scenario planning as well as resource recovery, technological advancements and diffusion of innovation. The series is currently underway and will continue through the summer. These are also webinars recorded and available on the One Water Solutions Institute YouTube Channel. A total of 27 webinars, 19 research and 8 stakeholder presentations, have been published to date. More information is available here: https://erams.com/UWIN/webinars/

Outreach Materials

A variety of outreach and print materials have been published for broadly disseminating information about UWIN. The materials can be accessed from the "Product" menu on the home page of the website: https://erams.com/UWIN/print-materials/

Project Landing Pages (21): Landing pages for each of the 21 UWIN research projects were enhanced to include the projects' contacts, summary materials, imbedded webinar recordings, publications and other relevant information. You can access the individual research landing pages from the main project page: https://erams.com/UWIN/research-projects/

Project cards (21): Co-PI Santelmann of the OSU team and Sarah Millonig, UWIN Program Coordinator, developed a set of project-description cards that list every project in all four project thrusts, with concise characterization of the titles, goals and specific objectives and relevant graphics. The cards are communication tools to be used in meetings with the stakeholders, as an easy way to track and organize the complex set of projects that comprise the UWIN at the national level.

Project Catalogs (20): Sarah Millonig, UWIN Program Coordinator, developed two-page project overviews for each of the UWIN Research Projects. These documents are used during stakeholder engagement meetings and data request meetings. They are available on each project's individual landing page. In addition, an overview document was created to briefly summarize the major goals and objectives of the UWIN SRN. A comprehensive catalog is also available providing a description of both the entire program as well as the individual research projects.

Quad Summaries (23): Each project has provided a 2-page progress update summarizing major accomplishments, products and participants. These are updated annually.

Annual Reports (5): In addition to the annual report submitted to the National Science Foundation, UWIN prepares and disseminates a document containing a detailed summary of activities, results and accomplishments over the previous year. The report also provides a detailed list of partners and collaborators as well as a current list of

UWIN-related research products including academic publications, conference papers and proceedings, websites, models and other related products.

Data

Urban Sustainability Data Hub: UWIN's research activities have culminated in significant scientific advancements that enhance our understanding of urban water systems. The Network has generated extensive amounts of urban sustainability data and has been working to publish an **Urban Sustainability Data Hub**, which catalogs project metadata and provides access to data sets produced by UWIN. Each data product includes metadata and access to the raw data, once published. UWIN has partnered with the Urban Resilience to Extremes (UREx) SRN to jointly undertake and fund this effort with assistance from a post-doc shared between the two SRNs. More information is available at: https://erams.com/UWIN/data/

Currently Available Datasets

CATEGORY	TOTAL
Climate Assessment & Projections	**5**
Urban Climate Data	**6**
Water Supply & Demand	**5**
Sociopolitical Information	**4**
Microclimate	**2**
Urban Infrastructure	**4**
Green Infrastructure	**4**
Flooding	**3**
Energy Usage	**1**
Census	**2**
Land Use and Land Cover	**2**
Hydrology	**1**
UWIN Urban Water Sustainability Indicators Survey	**1**
TOTAL	**40**

Published Datasets

A2-2 (dataset):

- Krayenhoff, E. S., Moustaoui, M., Broadbent, A. M., Gupta, V., and Georgescu, M (2018). Diurnal interaction between urban expansion, climate change and adaptation in 21st century U.S. cities, Nature Climate Change, 8: 1097–1103. DOI: 10.1038/s41558-018-0320-9.

D1-1 (datasets):

- Hulse, D., Enright, C., Branscomb, A., Santelmann, M., Wright, M. 2018. Multiscale Scenario Narratives for 2060 Urban Water Management, Willamette River Basin. Institute for a Sustainable Environment, University of Oregon. Narrative description and data matrix for three alterative futures.
- Hulse, D., Enright, C., Branscomb, A., Santelmann, M., Wright, M. 2018. Land Use Land Cover for 2010 and three 2060 Alternative Future Scenarios, Chicken Creek Watershed near Sherwood, Oregon (10m raster data layers). Institute for a Sustainable Environment, University of Oregon.
- Hulse, D., Enright, C., Branscomb, A., Santelmann, M., Wright, M. 2018. Neighborhood Site Plans for 2010 and three 2060 Alternative Future Scenarios, West Sherwood Neighborhood, near Sherwood, Oregon. (polygon shapefiles). Institute for a Sustainable Environment, University of Oregon.

Other

Invited Seminars & Lectures

A2-1 (Y5):

1. Mack, E.A. Water Affordability Assessments and Solutions. Vanderbilt University October 4, 2019
2. Interview on Sirius XM Radio about Water Affordability and Conserving Water for Doctor Radio April 19, 2019

A2-2 (Y4):

3. Georgescu M (2019), Sustainable Urban Systems – A Climatic Perspective, Invited Speaker for Department of Civil and Environmental Engineering Seminar Series, University of Illinois at Urbana-Champaign, Thursday March 28, 2019 (Univ. Illinois Invited Civil and Environmental Engineering Invited Seminar speaker).
4. Georgescu M. (2018), Urban systems and Urban Climate: at odds or in sync? Monday, August 27, 2018 (Invited Presentation for Bucharest Urban Climate Summer School, Bucharest, Romania).
5. Georgescu M. (2018), The utility of computational modeling to address urban environmental sustainability, Monday, August 27, 2018 (Invited Presentation for Bucharest Urban Climate Summer School, Bucharest, Romania).
6. Krayenhoff, E.S. Can we adapt our cities to the coming heat? Department of Geography, Western University, 8 Feb 2019 (Western University Invited Seminar speaker).

A2-3 (Y4):

7. UWIN work was also acknowledged in invited presentations given by D. Hondula at the University of Georgia, University of Bucharest, and New Mexico State University.

Reports

C3-1 (Y4):

1. Contorno L., M. Sarango, S.L. Harlan. "Environmental Justice and Sustainable Urban Water Systems: Community Voices from Selected Cities in the United States." Social Science Environmental Health Research Institute, Northeastern University, Boston, MA (October 2018) www.northeastern.edu/environmentalhealth/UWIN_Report.pdf
2. Sturm, H. and M. Davis. "The Human Right to Water: A Guide to Using Freedom of Information Laws to Understand Rising Water Rates." The Northeastern University School of Law, Program on Human Rights and the Global Economy, Boston, MA (March 2019). https://lawprofessors.typepad.com/human_rights/2019/03/world-water-day-and-the-human-right-to-water-knowledge-is-power.html

Press Releases & News Articles

UWIN SRN Award – Colorado State University:

1. "CSU receives $12 million for urban water sustainability research" (2015) http://source.colostate.edu/csu-receives-12-million-for-urban-water-sustainability-research/
2. "NSF network tackles urban water problems" (2016) http://source.colostate.edu/water-water-everywhere-and-many-problems-to-solve/

A1-2:

3. "Affordable water in the US: A burgeoning crisis" (2017) https://www.sciencedaily.com/releases/2017/01/170112110851.htm
4. "Affordable water may soon dry up, especially if you live here" (2017) http://www.pbs.org/newshour/updates/affordable-water-may-soon-dry-especially-live/

A2-1:

5. "Planting Trees To Reduce Urban Heat? Works Better In Dry Climates, Study Finds" (2019) https://www.wwno.org/post/planting-trees-reduce-urban-heat-works-better-dry-climates-study-finds
6. "Solutions to urban heat differ between tropical and drier climes" (2019) https://www.nsf.gov/discoveries/disc_summ.jsp?cntn_id=299172

A2-4:

7. "Meggers wins IP Accelerator Fund to build Spherical Motion Average Radiant Temperature (SMART) building sensor and 3D thermal renderer" (2017) https://chaos.princeton.edu/2017/02/27/meggers-wins-ip-accelerator-fund-to-build-spherical-motion-average-radiant-temperature-smart-building-sensor-and-3d-thermal-renderer/

B1-1a:

8. "Report shows benefits, risks of stormwater and graywater" (2015) http://source.colostate.edu/expanding-water-supplies-report-shows-benefits-risks-of-stormwater-and-graywater/
9. "A new strategy for drought-stressed cities: graywater recycling" (2016) http://theconversation.com/a-new-strategy-for-drought-stressed-cities-graywater-recycling-56564

B1-1b:

10. "Civil engineering student's research evaluates long-term urban water infrastructure resilience" (2020) https://tees.tamu.edu/news/2018/05/civil-engineering-students-research-evaluates-long-term-urban-water-infrastructure-resilience.html

B3-1 (Y4):

11. "As Sea Levels Rise, Expect More Floods" (2019) https://eos.org/research-spotlights/as-sea-levels-rise-expect-more-floods

C4-1:

12. "Water: Underpriced, Still Expensive" (2016) http://waterfm.com/water-customer-assistance-programs-affordability/

Citizen Science:

13. "Can We Drink Rain?" (2018) http://www.kunc.org/post/can-we-drink-rain-researchers-take-look
14. "Off the Roof on SciStarter" (2018) https://scistarter.com/project/18259-Off-the-Roof

Undergraduate Research Program

15. "McNair Scholar, Takondwa Musa participates in UWIN Undergraduate Research Program | Ronald E. McNair Postbaccalaureate Achievement" (2019) https://mcnair.rutgers.edu/news/mcnair-scholar-takondwa-musa-participates-uwin-undergraduate-research-program

Awards & Scholarships

1. **A2-2 (Y4):** Broadbent, A. M., Krayenhoff, E. S., Georgescu, M., (2019). Adaptation to projected 21st century heatwaves in Atlanta, Detroit, and Phoenix. Urban Climate Research Centre Poster Event, March 2019 (**Won first prize in the Postdoctoral category**).
2. **B2-1 (Y4):** Gupta , Neha was awarded a Carson Scholarship - *https://www.carson.arizona.edu/* - this award trains students in science communication and has them present to community groups. They also write broad audience blog and publication articles.
3. **B2-1 (Y4):** My group assisted with Bo Yang (Landscape architecture professor here at Arizona) on their EPA Rainworks projects. They won Honorable Mention in the Planning Category and 2nd place in the Demonstration Category. We and UWIN were credited.

PERSONNEL

NAME	UWIN ROLE	PROJECT
Jumana Alja'fari	Graduate Student (research assistant)	B1-1a
Riley Andrade	Graduate Student (research assistant)	A2-3
Mazdak Arabi	Co-PD/PI	UWIN Director, A1-1, B3-1, D1-2, D1-3
Dorit Aviv	Graduate Student (research assistant)	A2-4
Koroles Awad	Graduate Student (research assistant)	C4-1
Mary Lynn Baeck	Staff Scientist (doctoral level)	B2-2a
Lena Berger	Postdoctoral	C1-1
Alexandra Berk	Undergraduate Student	B1-1b (URP)
Alan Berkowtiz	Co-Investigator	UWIN URP & Education Director, CS: Earthwatch GIRA project
Sierra Bettis	Undergraduate Student	B2-1
Aditi Bhaskar	Faculty	B2-1, URP Mentor
Brian Bledsoe	Co-Investigator	B2-2b, B2-2a
Jessica Bolson	Faculty	C2-1, E1-1 Stakeholder Engagement, URP Mentor
Dorothy Borowy	Graduate Student (research assistant)	A3-1
Elie Bou-Zeid	Co-PD/PI	A2-1
Aldo Brandi	Graduate Student (research assistant)	A2-2
Allan Branscomb	Staff Scientist (doctoral level)	D1-1
Ashley Broadbent	Postdoctoral	A2-2
Kevin Burgio	Staff Scientist (doctoral level)	URP Coordinator
Isabella Catalano	Undergraduate Student	A1-2
Elana Chan	Undergraduate Student	A3-1 (URP)
Molly Chaney	Graduate Student (research assistant)	B2-2a
Camille Chaudron	Staff Scientist (doctoral level)	B1-2
Jennifer Cherrier	Faculty	CS: Earthwatch GIRA project, URP Mentor
Cibi Chinnasamy	Graduate Student (research assistant)	A1-4, D1-2, D1-3
Michelle Church	Graduate Student (research assistant)	A1-2
David Conklin	Consultant	D1-1
Ryan Correa	Undergraduate Student	A2-3 (URP)
Alycia Crall	Consultant	CS: Roof Runoff Project
Jennifer Dargin	Graduate Student (research assistant)	B1-1b, URP mentor
Olaf David	Staff Scientist (doctoral level)	D1-3
Tyler Dell	Graduate Student (research assistant)	D1-2, D1-3, URP mentor
Donya Dezfooli	Graduate Student (research assistant)	D1-2, D1-3
Alisen Downey	Graduate Student (research assistant)	CS: Earthwatch GIRA project
David Dziubanski	Postdoctoral	B2-1
Chris Enright	Other professional	D1-1

Yaolin Fennell	Faculty	B4-1
Canon Furth	Graduate student (research assistant)	D1-2, B3-1
Alfy Joseph George	Graduate Student (research assistant)	D1-2
Matei Georgescu	Co-Investigator	A2-2, URP Mentor
Hamidreza Ghaffari-Nazarlou	Graduate Student (research assistant)	B4-1
Mahshid Ghanbari	Graduate student (research assistant)	B3-1
Ahmed Gharib	Graduate Student (research assistant)	A1-1, D1-2
Edna Liliana Gomez Fernandez	Graduate Student (research assistant)	C1-1
David Gosselin	Faculty	URP Consultant
Hattie Greydanus	Undergraduate Student	D1-1
Neil Grigg	Co-Investigator	C4-1
Phil Guertin	Faculty	B2-1
Hongshan Guo	Graduate Student (research assistant)	A2-4
Neha Gupta	Graduate Student (research assistant)	B2-1
Geoffrey Habron	Faculty	URP Consultant
Roy Haggerty	Co-Investigator	D1-1
Sharon Harlan	Co-Investigator	C3-1, A1-2
Hadi Heidari	Graduate student (research assistant)	A1-1
Adam Douglas Henry	Co-Investigator	C1-1
Manny Herrera	Undergraduate Student	A2-3 (URP)
Selena Hinojos	Undergraduate Student	B2-1 (URP)
David Hondula	Co-Investigator	A2-3, URP Mentor
Arpad Horvath	Co-Investigator	B1-2, B1-1
David Hulse	Co-Investigator	D1-1
Kyotaek Hwang	Postdoctoral	A3-1, URP mentor
Peter Isben	Graduate Student (research assistant)	A3-1
Darrel Jenerette	Co-Investigator	A3-1
Kimberly Jones	Co-Investigator	B4-1
Tim Kirby	Graduate Student (research assistant)	C2-1, E1-1 Stakeholder Engagement, URP mentor
Yoganand Korgaonkar	Graduate Student (research assistant)	B2-1
Dion Kucera	Graduate Student (research assistant)	A3-1
Rod Lammers	Postdoctoral	B2-2b
Gina Lee	Graduate Student (research assistant)	B2-2b
Maider Llaguno Munitxa	Postdoctoral	A2-1
Aude Lochet	Staff Scientist (doctoral level)	URP Coordinator
Alexander Maas	Co-Investigator	C4-1, URP Mentor
Elizabeth Mack	Co-Investigator	A1-2 , C3-1, A2-2
Galen Macpherson	Graduate Student (research assistant)	D1-2, D1-3
Liz Mariluz	Undergraduate Student	C3-1
Laura Medwid	Graduate Student (research assistant)	A1-2

Forrest Meggers	Co-Investigator	A2-4
Thomas Meixner	Co-Investigator	B2-1,A3-1, CS: GIRA, URP Mentor
Ariane Middel	Faculty	A2-2
Andy Miller	Co-Investigator	B2-2b
Laura Miller	Undergraduate Student	B2-2b (URP)
Sarah Millonig	Other professional	UWIN Coordinator
Mahshid Mohammad-Zadeh	Graduate Student (research assistant)	D1-2, B3-1
Ali Mostafavi	Co-Investigator	B1-1b
Takondwa Musa	Undergraduate Student	C2-1 (URP)
Michael Neale	Graduate Student (research assistant)	B1-1a
Greg Newman	Faculty	CS: Roof Runoff Project
Maggie O'Connor	Undergraduate Student	C3-1 (URP)
Shirley Papuga	Co-Investigator	A3-1
Saloni Patel	Graduate student (research assistant)	B1-1a
Dave Patterson	Other professional	D1-3
Binaya Paudel	Undergraduate Student	B4-1
Jose Pillich	Technician	CS: Earthwatch GIRA project
Gary Pivo	Co-PD/PI	UWIN Deputy Director, C1-1
Roshan Puri	Graduate Student (research assistant)	C4-1
William Rainey	Graduate student (research assistant)	D1-2
Kambiz Rasoulkhani	Graduate Student (research assistant)	B1-1b
Nia Rene	Graduate Student (research assistant)	B4-1
Sean Rucewicz	Technician	A2-4
Mary Santelmann	Co-Investigator	D1-1, A3-1, URP Mentor
Mariana Sarango	Graduate Student (research assistant)	C3-1
Sybil Sharvelle	Co-Investigator	B1-1a, B1-1b and B1-2; CS: Off the Roof; URP Mentor
James A. Smith	Co-Investigator	B2-2a
Brianne Smith	Faculty	CS: Earthwatch GIRA project
Tim Stephens	Graduate Student (research assistant)	B2-2b
Michelle Stuhlmacher	Graduate Student (research assistant)	A2-2
Yibing Su	Graduate Student (research assistant)	B2-2a
Mike Sukop	Co-PD/PI	UWIN Stakeholder Engagement Director, C2-1, C1-1,URP mentor
Chris Swan	Co-Investigator	A3-1
Samantha Swartz	Undergraduate Student	B2-1
Fatima Taha	Graduate student (research assistant)	D1-1
Michelle Talal	Graduate Student (research assistant)	D1-1, A3-1, URP Mentor
Mahdad Talebpour	Graduate Student (research assistant)	A2-1

Michael Tchintcharauli-Harrison	Graduate Student (research assistant)	D1-1
Eric Teitelbaum	Graduate Student (research assistant)	A2-4
Kate Thompson	Staff Scientist (doctoral level)	URP Consultant
Kellie Vache	Faculty	D1-1
Jennifer Vanos	Faculty	A2-2
Shirley Vincent	Consultant	UWIN Evaluator
Diane Waweru	Undergraduate Student	B2-1 (URP)
Claire Welty	Co-PD/PI	UWIN Associate Director for Research, A2-1, A2-2
Tyler Wible	Other professional	D1-3
Madison Wimberly	Undergraduate Student	A1-2
Sarah Wrase	Graduate Student (research assistant)	A1-2
Mary Wright	Graduate Student (research assistant)	A2-3
Maria Wright	Faculty	D1-1
Long Yang	Postdoctoral	B2-2a