Urban Water Innovation Network

Sustainability Research Network

Y4: Annual Report (2018–2019)

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 4 UWIN Annual Report provides a detailed summary of activities, results and accomplishments over the August 2018 – April 2019 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, 19 professors, 7 associate professors, and 11 assistant professors) from 21 academic institutions with interdisciplinary expertise, 13 research scientists, 12 staff scientists, 57 graduate students, 23 undergraduate students and 11 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.

The UWIN transdisciplinary activities to date have produced 104 published high impact journal publications, 12 PhD dissertations and M.S. theses, 4 book chapters, 217 conference papers/posters and presentations, 1 patent, 88 outreach and print materials, 12 software and modeling tools, 8 websites, 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, 36 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 recently conducted activities to add Philadelphia as an official UWIN node in March 2019. Howard Neukrug, UWIN External Advisory Committee member and Director of the Water Center at University of Pennsylvania, serves as the lead investigator for activities in the region. In addition to brining the Water Center into the Network, the Philadelphia Water Department has become actively involved in collaborations with UWIN researchers to develop a meaningful approach to addressing local urban water challenges in the city of Philadelphia.

In the last year, several UWIN researchers were promoted to faculty positions. Dr. Qi Li started as an Assistant Professor in the CEE department at Cornell University, and Dr. Jiachuan Yang started as an Assistant Professor at the Hong Kong Institute of Science and Technology. Dr. Theo Lim, started as an Assistant Professor in Urban Affairs and Planning at Virginia Tech in January 2019.

Urban Water Innovation Network

Annual Report – Year 4

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 21 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

- Alteration of hydroclimatic characteristics of HUC 8 watersheds across Continental United States (CONUS) due to climate change were quantified over the 21st century. Physiographic factors that explain the variability of hydroclimatic changes in response to climate change were explored.
- The vulnerability, reliability and resiliency of the U.S. water supply systems under the current and future climate, land use, and population scenarios were evaluated at the HUC 8 watershed scale.

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

- Survey questions related to household expenditure tradeoffs due to rising water prices were analyzed.
- A complete water rate database for regions across the U.S. was created and analyzed.
- Spatial patterns in water rates in Detroit were assessed.

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

- A new version of the coupled ParFlow-WRF model was built, which contains the most recent ParFlow and WRF codes as well as the Princeton Urban Canopy Model (PUCM).
- The ParFlow model was applied to study effects of green infrastructure on urban hydrology and water balance at the site scale.
- A computational and numerical framework with the new ParFlow-WRF was created to enable running large eddy simulation with WRF to capture higher resolution urban heterogeneous atmospheric-hydrologic interactions.
- A fast simplified model was developed to simulate how rainfall cools down urban pavements based on a previous more detailed version of the model. The simplified model was validated against field experiments. A full sensitivity analyses was conducted to deduce which urban characteristics dominate the problem.
- The WRF-PUCM mode was applied to study how green infrastructure impact urban microclimates. The results were used to compare fixed, mobile and hybrid sensing strategies in cities.

A2-2: Projecting future environmental change in urban areas

- Mean projected impacts of climate change and variability on near-surface temperatures across CONUS were analyzed using a suite of dynamically downscaled climate simulations conducted with WRF.
- Projected extreme and mean near-surface temperature and precipitation were analyzed at the city scale.
- The combined effects of urban expansion and modulation induced by decadal variability for observed temperatures over Phoenix metropolitan area were analyzed as a first step to understand large-scale versus local effects on observed evolution of historical near-surface temperatures.

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

- A national-scale assessment of urban thermal equity was conducted in collaboration with the UREx SRN.
- Comparison of urban green infrastructure biophysical properties with resident perceptions was carried out in Phoenix using CAP LTER data.
- The contribution of urban heat island effects to heat-related mortality was assessed.

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

- Efforts were conducted to link SMART Sensor and MARTY to measure urban surface geometry and radiant urban heat.
- Collaboration with Torino Polytechnic on solar driven sorption based atmospheric water capture was established.
- An architectural ray tracing urban geometry, water, and heat model was developed.

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

- Air temperature sensor networks were deployed in the UWIN study cities.
- Data on park species distributions were analyzed.
- Satellite data for more than 10 years of vegetation dynamics were compiled.

"Thrust B" Research Projects

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

- A multi-objective analysis of water conservation and reuse strategies was conducted to assess tradeoffs between cost, water demand, and household of wastewater production in Miami, Tucson, and Denver.
- Carbon footprint of innovative stormwater control measures developed by the ReNUWIt Engineering Research Center (ERC) was compared to conventional technologies**.**

B1-1b: Assessment of water infrastructure resilience

- The simulation model for dual water distribution infrastructure systems was completed.

- The performance validity of the model was examined with SMEs of City of Fort Collins Utilities.

B1-2: Lifecycle assessment of urban water systems

- The life-cycle assessment (LCA) based decision support tools (WEST and WWEST) was updated with the newest electricity and energy data.
- Preliminary baseline LCA results for Denver's wastewater system are available. Data are being analyzed to evaluate Miami's water and wastewater system as well as Tucson's wastewater system. Models for Denver and Tucson's existing water system will be developed based on literature data and submitted to those utilities for review.
- Activities were carried out to evaluate differences in implementing on-site wastewater treatment and reuse system in several neighborhoods with diverse water consumption patterns within each case study city to identify the effects of demographic, hydrologic, and other regional differences.

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

- Watershed modelling of both Bronx and High School wash has been completed. Work now focuses on variable implementation of GI in models to understand scale effect of GI within watersheds. In these watersheds as well as several others modelling of GI implementation has begun.
- Investigations of green infrastructure function and how it interacts with design and maintenance continue.
- Research efforts continue to deploy water samples and pressure transducers to monitor runoff conditions in Tucson.

B2-2a: Flood hydrology and rainfall frequency

- Storm catalogs and rainfall frequency analysis procedures using Stochastic Storm Transposition for heterogeneous urban environments were developed.
- Hurricane flood hazards in urban environments were assessed using Hurricane Harvey as a case study.
- Extreme rainfall and flooding in urban environments (including 2016 and 2018 Ellicott City, Maryland floods and extreme floods in Phoenix) were analyzed.

B2-2b: Hydrology and hydraulics of urban floodplains

- Methods for incorporating channel change in Monte-Carlo simulation of flood hydraulics were developed.
- Nonstationary flood frequency analysis techniques were implemented to develop alternative flood frequency distributions and quantify the uncertainty in discharge estimates.
- Probabilistic floodplain maps were created by conducting Monte-Carlo simulations of flood hydraulics that reflect uncertainty in river discharge, friction parameters, and channel change at McMullen Creek, Charlotte, NC.

- Additionally, methods were developed for evaluating overtopping likelihood during design events at stream crossings.
- UAV-derived imagery was collected to develop high-resolution topographic point clouds for 2d hydraulic model simulation of flood waves in urbanizing channel/floodplain systems. Digital elevation models were generated for three successive years in the Minebank Run watershed in Towson, MD and for two successive years in the Dead Run watershed in Woodlawn, MD.
- Hydraulic models were developed for Minebank Run and for Whitemarsh Run in White Marsh, MD. Modeling scenarios are being developed to assess sensitivity of flow field to pre- vs post-restoration topography for all three watersheds. 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.
- In collaborated with project C3-1, survey of respondent's flood risk perceptions, social vulnerability, and potential flood hazard exposure in nine UWIN regions was evaluated. Specifically, potential flood hazard exposure in zip code tabulation areas based on FEMA's flood insurance rate maps was calculated.

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

- A nonstationary probability model was developed to characterize the risk to compound flooding from storm surge and heavy precipitation under changing sea level conditions. The model was evaluated for major cities along the U.S. coast.
- Spatial patterns of coastal flood risks to communities by demographic and economic factors were examined in the Southeast Florida region under alternative future sea level rise scenarios.

"Thrust C" Research Projects

C1-1: Understanding adoption of sustainable urban water solutions

- Completed data collection on organizational networks and practices in a second region (Florida), and are now prepared to implement the survey in the remaining three regions.
- Completed qualitative analysis of municipal water sustainability practices, and reported results in a manuscript submitted for publication.
- Data collection on regional water and climate adaptation networks among organizations in Southeast Florida and descriptive analysis of these data were completed.

C2-1: Homeowner adoption of sustainable urban water solutions

- Online surveys focused on adoption of grey water systems disseminated to additional participants across five cities. Data collection was completed and validated.
- The team began comprehensive data review and analysis, and learned of some issues with the data, which were remedied and will be resolved in the next iteration of surveying.

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

- Geographically-referenced survey of 9,268 households in nine UWIN study regions (SWISSH) was conducted and documented. Specifically, two analyses were conducted: 1) social vulnerability and experience predictors of perceived flood risk in urban areas; and 2) comparing sustainability priorities and values of water professional stakeholders with community leaders and the general public.
- Efforts were conducted with project A1-2 on US regional estimates for multivariate indices of water use and water affordability. Also, targeted green infrastructure heat mitigation and intra-urban equity is being studied in collaboration with project A2-2.

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

- A survey of urban water users' preferences around water supply projects was conducted.
- Municipal water demand patterns were studied in collaboration with utility partners and water demand forecasting models were developed.

"Thrust D" Research Projects

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

- Designs, spatial databases, visual representations, and scenario narratives for three stakeholder-guided alternative future scenarios were completed for the Sherwood Focal Neighborhood and the Chicken Creek Watershed, a HUC-12 watershed in the urbanizing margin of Portland, OR.
- Alternative future scenarios were evaluated and compared.

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

- Monthly water use data over the 2006 and 2017 period for approximately 150 municipalities across the continental United States (CONUS) were collected and organized for calibration and testing the Integrated Urban Water Model (IUWM) model at the continental scale.
- The IUWM model was calibrated for cities across ecohydrologic regions in CONUS to produce, analyze, and assess primarily water use indicators and key performance indicators for sustainable management of urban water demands.
- A comprehensive water sustainability study was conducted at the National Western Center (NWC) campus redevelopment project in Denver, CO. The study developed water demand reduction strategies, encompassing alternative water sources and fit-for-purposes uses.
- Six "integration activities" were created to facilitate collaborative research with participants from UWIN institutions. These activities focus on cross-site comparisons and opportunities to help cities transform urban water management systems through integrated approaches.

D1-3: Urban water decision innovation system

- Efforts were initiated to integrate urban sustainability metrics and indicators from the CLASIC and IUWM tools into a comprehensive urban water sustainability rating system.
- Data produced by various UWIN research team are being collected and organized. A prototype Water Connect (water-connect.org) website was developed to upload and access city water data and models using geospatially enabled web services.

- Collaborations were forged with approximately 30 urban water managers to develop a One Water guidebook and rating system.

Stakeholder Engagement

- A protocol was designed for key informant stakeholder interviews to inform indicators and the UWIN Blueprint
- Background research was conducted on marketing strategies for water management and a manuscript with results was prepared.
- Social network analysis of one UWIN urban area, South Florida, was conducted to better understand relationships and exchange of information among professionals working on climate change in region.
- Understanding of dynamic network of climate change professionals was improved through social network analysis.

Undergraduate Research Program (URP)

- Nine undergraduate students participated in the 9-week UWIN Undergraduate Research Program (URP) during the summer of 2018.
- We recruited 9 students from a pool of 433 applicants as well as 18 mentors for URP 2019.
- Arrangements were made for students to work and live at each of the 8 host institutions involved in the 2019 program as well as scheduling students' activities during the summer.

Diversity Program

The Urban Water Innovation Network (UWIN) is highly committed to building a talented and diverse student cohort. This period, UWIN selected two students from traditionally underrepresented backgrounds to enhance and improve diversity in the Network. These Diversity Recruitment and Retention supplements complement existing activities and programs already in place at the Network's affiliated institutions.

Citizen Science

- Work with Earthwatch and HSBC on the Green Infrastructure Rapid Assessment project (formally called Sustainability Training Program, or STP, by HSBC) has continued and resulted in 7 events with over 100 participants in New York and San Francisco in the US and Toronto and Vancouver in Canada.
- 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

"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

"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

- The mixture Gamma-GPD probability model improves characterization of water shortage vulnerability.
- Land use planning and urban development patterns have profound effects on urban water demand and vulnerability to shortage.

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

- In collaboration with Philadelphia Water Department the Philadelphia water affordability program called the Tiered Assistance Program (TAP) was evaluated.
- A case study of consumer expenditures reductions due to rising water rates in Phoenix, AZ, identified spending categories where consumers would make cuts.
- Database of water rates was created for Detroit for 2010, 2015, and 2017 to analyze the rate structure of 104 water providers and the communities served.

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

- The scale of implementation of urban green infrastructure has significant impact on its benefits. Small deployments cause insignificant cooling. When implemented heterogeneously, the local impact of green infrastructure shows clear scaling with its local coverage fraction.
- Urban heat islands not only cause local warming, but under low wind conditions can create a circulation bubble that traps heat and pollutant in the city.
- Mobile sensing network vastly outperform fixed ones in generating a completely spatio-temporal map of environmental conditions in cities but both struggle to capture some of the extremes.
- Green infrastructure facilities can have the effect of shifting components of the water balance at the site scale. During the summer months when evapotranspiration exceeds direct precipitation, additional water captured by the green infrastructure contributing area enhances recharge to groundwater. This is an important change to the seasonality at the site scale, when summer months would typically see reduced recharge and reductions in storage resulting from evapotranspiration. Model results indicate that a site can discharge water to regional groundwater throughout the year.

A2-2: Projecting future environmental change in urban areas

- Interaction between projected urbanization and large-scale climate change were quantified to characterize the extent to which these two drivers of regional climate change add linearly – their sum is linearly additive during the daytime but less than their linear sum during the nighttime across most of CONUS.

- WRF simulates observed mean and extreme (99th percentile) contemporary (2000-2009) precipitation with excellent fidelity across all seasons, demonstrating its utility in investigating projected changes in precipitation owing to urbanization and climate change across CONUS.
- A combined statistical/mathematical and modeling framework was developed to assess potential saturation of the diurnal range owing to upstream urbanization remote from the observing station.

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

- Inequitable distributions of urban heat previously documented in single and few-city case studies 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
- In Phoenix, residents' perceptions of urban green infrastructure are closely coupled with the biophysical properties of the landscape as well as socioeconomic variables.
- The urban heat island has a statistically significant and independent effect on heat-related mortality aside from the well-documented main effect from ambient temperature. More than 30% of heat-related deaths in Maricopa County (AZ) may be attributable to the urban heat island effect.

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

- Mean radiant temperature varies with green-blue infrastructure by significant amounts, but we lack appropriate tools to adequately characterize the variability.
- Pavilion constructed in Singapore shows that we can shift more than 90% of cooling away for air exchanges and to isolated surfaces independent of air temperature.
- New results on desiccant indicate the capability of simple silicon oils to update water at rates equal to the best liquid desiccant to be used for water capture or energy.

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

- Cooling effect of vegetation increases with aridity throughout United States.
- Aridity is associated with changes in park plant community.

"Thrust B" Research Projects

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

- Demand reduction potential of water conservation and reuse practices varies across regions and is primarily impacted by precipitation and irrigation demand.
- Stormwater capture and use is highly effective in Miami compared to Denver and Tucson, due to high precipitation and impervious area.
- End-use efficiency (e.g. indoor appliances and irrigation) is frequently identified as part of strategies that are most cost-effective to reduce water demand.

B1-1b: Assessment of water infrastructure resilience

- The infrastructure performance of dual and singular (conventional) water distribution systems in Fort Collins, CO, were compared.
- 50-year network-level life-cycle costs of dual and singular water distribution systems in Fort Collins were estimated.
- Sensitivity of dual and singular water distribution infrastructure systems to demand fluctuations was investigated.

B1-2: Lifecycle assessment of urban water systems

- Projections for electricity mixes and associated greenhouse gas emissions were developed for each of the three case study cities for use in our LCA analysis.
- Baseline LCA results for Denver's wastewater system as well as proposed implementation scenarios for alternative water supply in three neighborhoods in Denver were created.

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

- Traditional aesthetics based green infrastructure maintenance appears to result in reduced hydraulic conductivity and thus adversely affect the design function of bioswales in arid and semi-arid cities.
- Runoff in urban catchments is significantly higher compared to nearby undeveloped watersheds at small spatial scales (less than 10 sq. km) but differences in runoff diminish at regional scale (greater than 100 sq. km).
- In work completed by an undergraduate researcher it was found that GI does lead to increased evapotranspiration and canopy cover versus trees not exposed to water additions from green infrastructure systems

B2-2a: Flood hydrology and rainfall frequency

- There is significant spatial heterogeneity in extreme rainfall across the Baltimore metropolitan area; new Stochastic Storm Transposition-based analyses capture these spatial heterogeneities.
- Spatial heterogeneities in catastrophic rainfall over Houston from Hurricane Harvey were likely linked to spatial gradients in surface roughness over the Houston metropolitan region.
- Relationships between extreme rainfall and atmospheric water vapor in the Phoenix metropolitan region exhibit pronounced nonlinearities, in contrast to standard assumptions in deriving design storms.

B2-2b: Hydrology and hydraulics of urban floodplains

- Probabilistic floodplain maps highlight spatial heterogeneities in flood hazard uncertainty and areas of elevated or hidden risk that are not made known by deterministic maps used in regulatory flood hazard assessments.
- Initial results from 2D hydraulic modeling of real flood events show expanded area of inundation following restoration and reconnection of channel with floodplain, and reduced inundation

extent, higher velocities and more flow confined to channel following channel incision by uncontrolled flooding along restored reach.

- Survey respondent's potential flood hazard exposure did not correlate with their flood risk perception; however, the relationship between social vulnerability metrics and flood risk perception were statistically significant.

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

- The assessment of coastal flood risk in Southeast Florida indicates that both chronic and acute coastal flood risks will continue to increase in the region due to the increasing frequency and intensity of coastal events as sea levels rise. Under current sea-level conditions, expected annual damages are predominantly associated with exposure to acute extreme events. However, the expected damages from chronic repetitive flooding will exceed those from extreme floods under future sea-level scenarios. The spatial distribution of future coastal flood risk by demographic factors indicates that exposure of Hispanics and Blacks as well as households with low income status to coastal flooding will increase due to inland penetration of coastal events.
- The nonstationary characterization of compound flooding indicates the increasing risks to communities and assets along the U.S. coasts from rising sea-levels.

Thrust C Research Projects

C1-1: Understanding adoption of sustainable urban water solutions

- Statistical network analysis shows that having shared belief systems about water problem severity, among other factors, predict whether organizations will cooperate.
- Local governments implement a variety of practices to pursue sustainability in addition to the types of practices commonly thought of as policy innovations: market mechanisms, regulation, and capacity building.
- The network of local governments and organizations in Southeast Florida surrounding climate change adaptation is dense and cross-sectoral; however it also shows signs of fragmentation.

C2-1: Homeowner adoption of sustainable urban water solutions

- 1500 surveys were completed across 5 cities.
- 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

- Decades of racial discrimination in urban planning shaped the inequitable distribution of basic water services and amenities that exist between white communities and communities of color today. While the history of urban development is different in each UWIN city, community

leaders reported that wealthier, white neighborhoods continue to attract greater public and private investment than predominantly minority neighborhoods, compounding historical inequities.

- Perceived risks of the likelihood and severity of floods among survey respondents in UWIN study areas were positively associated with 1) characteristics of social vulnerability, 2) previous experience with and awareness of floods, and 3) confidence in own ability to cope with a future flood disaster. Social groups that are more susceptible to environmental harms (elderly, women, ethnic minorities, and low-income people) were more fearful of floods.
- Indices derived from metrics taken from the literature on water demand are closely associated with one another and about 20% similar to estimates of water withdrawals.

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

- The relatedness of household water and electricity use was examined. The results show that price shifts in one (water or energy), meaningfully reduce consumption levels of the other. This result has implications for utility revenues and conservation.
- Sensitivity analysis was conducted on commonly used econometric models to estimate revenue and demand for water. Estimates across models are relatively stable to price instrument and weather choice. This result suggests that household-level demand can be predicted with parsimonious models - using only temperature as a weather explanatory variable - and including more complex weather variables (evapotranspiration for instance) does little to improve fit.

"Thrust D" Research Projects

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

- Results of modeling neighborhood scale water demand for the three alternative futures with IUWM indicate that higher density development, water conservation, & reuse can partially offset rising demand due to population growth and climate change. Adoption of conservation (high efficiency) practices reduced demand more than denser development or water reuse.
- Use of integrated water resource management practices can ameliorate but cannot entirely compensate for the impacts of climate change and population growth on water supply and demand.
- Integrated water management can produce significant environmental co-benefits. Results of vertebrate biodiversity modeling for the Chicken Creek Watershed indicate that; development will increase the abundance of non-native species, especially non-native mammals, however, incorporating open space as green infrastructure (i.e., maintaining riparian buffers along streams within the city and restoring wetlands as part of the conservation plan for the watershed) can improve habitat for native birds**.**

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

- Approximately 4% - 7% water conservation has been achieved across CONUS over the past two decades. The rate of conservation varies by ecohydrologic region and city population.

- The ratio of Commercial, Industrial, and Institutional (CII) to residential water demand is highly variable; but may be explained by ecohydrologic region and business activity indicators such as payrolls from economic sectors.

D1-3: Urban water decision innovation system

- The integrated urban water assessment at the National Western Center community redevelopment testbed in Denver, CO, indicated that alternative water sources and fit-for-purpose use can save more than 60% of potable water demand through landscape and technology choice, and water recycling.

KEY OUTCOMES

Research

The SRN activities engaged 39 faculty members (2 Deans, 19 professors, 7 associate professors, and 11 assistant professors) from 21 academic institutions with interdisciplinary expertise, 13 research scientists, 12 staff scientists, 57 graduate students, 23 undergraduate students and 11 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.

The SRN transdisciplinary activities to date have produced:

- 104 high impact journal publications
- 12 PhD dissertations and M.S. theses
- 4 book chapters
- 212 conference papers/posters and presentations
- 1 patent
- 88 outreach and print materials
- 12 software and modeling tools
- 8 websites
- 27 webinars
- 36 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 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. The objective of this task force is to provide guidance on how UWIN teams may engage with and contribute to the indicators

framework. We are fundamentally concerned with two sets of scientific questions: 1) How well do urban regions ("cities") perform in terms of water sustainability and equity outcomes as well as economic and environmental outcomes? 2) What pathways (including technological, institutional, and financial pathways) exist to promote greater levels of urban water sustainability? Both of these questions require a concrete and measurable set of variables that may be used as a map and compass for assessing sustainability transitions. We aim to produce a comprehensive list of indicators and manner of quantification. We also note integrative activities that researchers should participate in which link their indicator work with other task forces including test beds, the web-decision tool, and synthesis papers.

- **Testbed studies**: These studies aim 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. The activities include: (i) Evaluation of the effects of fit-for-purpose use of alternative water resources; and (ii) Understanding water flux from vegetation communities across green infrastructure types.
- **Synthesis papers**: The objective of this effort is to write cross-cutting academic papers that synthesize proposed solutions to urban water issues, as identified by each project. Participating investigators who contribute to the papers (e.g. data) will be included as co-authors. The products of the efforts will include academic synthesis papers, defined as across cities and projects/disciplines, for publication in a high-level journal(s). The ongoing studies include: 1) "Baseline/current conditions: What is the current state of urban water systems (pressures, challenges) and what does this mean for changing water management practice?"; and 2) "Future conditions: Based on the status of current systems, what changes are recommended and how do these urban water systems need to evolve to reach these recommended targets?"
- **Integrated Web Tool**: This tool is being 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. Testbed applications include a range of future conditions to identify strategies that are effective across variable conditions.

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. Regarding stakeholder-scientist interactions, participants sought practical outcomes, such as the organization of seemingly abundant scientific products into usable products.

The utility of the pressure-state-response model as a framework for data collection and analysis in the context of understanding transitions toward urban water sustainability has been considered and recommendations for future studies have been developed.

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

All students (9) in the 2018 cohort completed successful projects, presented research posters at the UWIN annual meeting, and produced a final written product. Results from program research and evaluation are being used to improve the program and research methods for 2019. Results from our research were presented at a national meeting of the Council on Undergraduate Research (CUR) in July 2018, and the Ecological Society of America (ESA) in August 2018 (see products). In addition, participants from the 2018 program presented their UWIN-related research at two professional conferences including the American Meteorological Society 99th Annual Meeting and AGU Fall Meeting (see products).

UWIN will provide the fourth Undergraduate Research Program (URP) for the summer of 2019. The size of the 2019 applicant pool increased compared to 2018 while the percentage of under-represented minorities applying to the program remained the same (24%). A highly diverse group of students, mentors, and project types was assembled for the 2019 program. For example, 67% of URP participants

are from underrepresented minorities. The pool of mentors includes 11 faculty, 1 post-doc, and 6 graduate students.

Diversity Program

This period, UWIN selected two students from traditionally underrepresented backgrounds to enhance and improve diversity in the Network. These Diversity Recruitment and Retention supplements complement existing activities and programs already in place at the Network's affiliated institutions.

Adriana Arcelay has been selected by the UWIN Diversity Committee to receive 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 will work on extending understanding of flood risks in rivers with non-stable beds (contributing to UWIN Project B2-2). Adriana will be trained to use climate model outputs as inputs to hydrologic and hydraulic models and to estimate uncertainty in flood predictions. Her research and training will be overseen by UWIN-UAZ PI Thomas Meixner, Adriana will also receive 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. Nia is a first generation African American, M.S. student in the Dept. of Earth and Environmental Sciences at Brooklyn College of the City University of New York (BC-CUNY) working under the direction of Dr. J. Cherrier. Her research focuses on the use of hybrid green infrastructure to mitigate septic pollutant loading to coastal Long Island waters to offset the recent and significant impacts of harmful algal blooms (HABs). Nia is hopeful that her research into green infrastructure will assist in ushering in a new approach to urban and peri-urban water management and sustainability.

Research Affinity Groups

While organization of UWIN research activities in research thrusts enables continuous coordination of closely related activities, a set of cross cutting affinity groups were created to enable discussions and collaborations across the four thrusts. These initial affinity groups include:

- The Green Infrastructure affinity group was formed to discuss the co-benefits and dis-benefits of GIs. This group has expanded efforts to include Paula Connolly at the GI Leadership Exchange and provide insight in regards to practitioner-identified research needs. During this reporting period Thomas Meixner (B2-1) facilitated a Green Infrastructure Rapid Assessment Watershed Management Group Learning Lab. In addition, a Cross-city Stormwater Management Comparison Database has been developed and is currently under review by members of this working group.
- A Citizen Science Affinity Group was formed in UWIN to bring together scientists and educators interested in the topic. The group met several times during the reporting period to exchange ideas and explore possible UWIN initiatives in citizen science. Two projects were selected for

funding since the group began meeting formally: Green Infrastructure Rapid Assessment (GIRA) and Off the Roof details of which are provided in the Citizen Science sections of this report.

Citizen Science Program

- Green Infrastructure Rapid Assessment (GIRA) has preliminarily shown that citizen science collected infiltration measurements compare favorably to laboratory measurements.
- 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 Students

- The entire Undergraduate Research Program aims to enhance the professional development and training of undergraduate students. The program leaders provide professional development and support the UWIN URP mentors on an ongoing basis. Nine undergraduate students participated in the 2018 summer URP and were supported through this project. An additional nine undergraduate students have been selected to participate in the 2019 summer URP.
- 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.

Undergraduate students are also involved in UWIN-related research activities outside the URP. Examples of undergraduate activities are outlined below.

- Undergraduate students were trained in water rate data collection and associated water rate information.
- High school students were mentored and trained, and participated in project A2-2 related activities. The students were co-authors in peer-reviewed publications.
- Several undergraduate students were involved projects A2-2, B1-1b, B1-2, B2-1, and B2-2b.
- Two undergraduate students work on archival data collection to support the survey efforts in project C1-1. These students have had their first exposure to scientific research in action.
- Two undergraduate students have participated in C3-1 research as part of Harlan's Water Equity Team (WET) Lab at Northeastern University from May 2018-April 2019. One undergraduate participated in C3-1 analyses at Michigan State University.
- Three undergraduates have worked on project D1-1. One worked on the IUWM modeling, calibrating the model for the Pacific Northwest using data for the Sherwood area. Another has worked on the project for two summers, first as an REU student and then through the URP program within UWIN; her work focuses on temperature and green infrastructure, between and within site variability, and the influence of vegetation cover at different scales. A final undergraduate student, at the University of Oregon also participated in development of the alternative future designs and helped develop the profile and street view representations.

Graduate Students

Over 55 graduate students are working on 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.

Postdoctoral Scholars

11 postdoctoral researchers were involved with UWIN research and training activities over the reporting period.

Professional Development

Explicit management/team science/leadership training sessions were conducted for researchers including faculty, post-doctoral associates, and graduate and undergraduate students. Numerous opportunities were provided for WUIN students, researchers, and faculty to attend professional meetings.

Other project-specific opportunities include:

- A2-1: In the last year, Qi Li started as Assistant Professor in the CEE department at Cornell University, and Jiachuan Yang started as Assistant Professor at the Hong Kong Institute of Science and Technology. Both were supported by the UWIN project. Theo Lim, who was mentored by C. Welty while he was a PhD student at U Penn carrying out ParFlow simulations on green infrastructure facilities, started as an Assistant Professor in Urban Affairs and Planning at Virginia Tech in January 2019.
- B2-1: All students participated in a stakeholder meeting in April 20, 2018 and in a stakeholder workshop on March 15 2019. These meetings have provided students with connections to

practitioners and understanding of what work in different sectors of urban hydrology and environmental problems is like. Yoganand Korgaonkar and Thomas Meixner participated in the Cross UWIN project meeting in Athens GA this past fall. Meeting was led by Brian Bledsoe and progress was made in developing cross-city modelling efforts.

- C1-1: One PhD student, Edna Liliana Gomez Fernandez, was sent to two major professional conferences, and one invited workshop for emerging scholars.
- C3-1: Harlan delivered webinar lecture on Environmental Justice delivered to 2018 URP interns, June 2018.
- Citizen Science: The participating citizen scientists in both the GIRA and Off the Roof projects have learned a lot 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 has been supported for her work on the project.
- Undergraduate Research Program: Professional development support was provided to UWIN URP mentors (faculty, postdoctoral and graduate students) on an ongoing basis.

DISSEMINATION OF RESULTS

Our team 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. A comprehensive list of these products is available from the Products section of this progress report.

The UWIN Leadership Team led the organizing and scientific committees of the 9th International Congress on Environmental Modelling and Software, which was held at Colorado State University during June 24 – 28, 2018. The theme of the congress was “Modelling for Sustainable Food-Energy-Water Systems". Approximately 450 researchers from 40 countries attended the congress. Several sessions led by UWIN members focused on urban sustainability, urban water systems, and integrated assessments. More information about the congress can be accessed at http://iemss2018.engr.colostate.edu/

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.

Other examples of our activities to disseminate results include:

- F. Meggers spent 3 months as visiting faculty at Berkeley and conducted lectures there on the relationship between outdoor climate and indoor climate modeling
- UWIN has led citizen science workshops throughout the greater Los Angeles region and presented findings at national conferences.
- The results of the dual water distribution systems study were presented to the City of Fort Collins Utility for peer review. A part of research was also presented in the Texas A&M University's Student Research Week (SRW) symposium on March 2019.
- UWIN Arizona affiliates continue to work closely with regional water (Pima Association of Governments), stormwater NGO's (Watershed Management Group), storm water (City of Tucson), environmental quality (Pima Department of Environmental Quality), and flood control (Pima Regional Flood Control District) agencies to share data, results and recommendations about how green infrastructure should be designed and maintained. The group also provided presentations to community groups (Sierra Club), the American Water Works Association and the wider public have been made that extend the impact of the work beyond the scientific community.
- UWIN research, data and findings are used as teaching examples in PhD seminars and workshops at the University of Arizona and the National University of Singapore.
- Results are disseminated though invited talks at the University of Arizona's Climate Change Adaptation Science and Solutions speaker series, and the Consortium of Collaborative Governance emerging scholar's workshop.
- Manuscript and research reports were produced for stakeholders on results from social network analysis for South Florida climate change professionals in production.
- White paper on marketing strategies for sustainable water systems is being produced.
- The financial modeling study (C4-1) formed relationships with two additional mid-sized rural utilities to conduct an interactive experiment designed to elicit residents' preferences for new water sources. Results of the study were presented to a quasi-governmental agency, The Palouse Basin Aquifer Committee, on public support for expanding water supplies. Media outreach included an article for High Country News entitled "In need of water, an Idaho town turns to its neighbors" by Emily Benson. Feb. 6, 2019.
- A webinar was held for Off the Roof Citizen Science participants. The webinar was recorded and made available to participants.

FUTURE PLANS (Year-5)

"Thrust A" Research Projects

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

- Improve representation of water allocation agreements and policy using the WEAP model
- Enhance urban water demand forecasts at the Census block group level using the IUWM model and agricultural water demand using the Daycent model

- Investigate viable technological and policy solutions for reducing the vulnerability to water shortage

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

- Enhance and publish water rate database 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

- Bou-Zeid's personnel funds ran out and no personnel will be supported at Princeton for the remainder of the project. Bou-Zeid has summer salary for the last year and will use his time to contribute to the integration activities.
- Carry out high resolution urban coupled atmosphere-land surface- subsurface simulations of Baltimore-Washington, Denver, and Portland metropolitan area using WRF-LES-PUCM-ParFlow

A2-2: Projecting future environmental change in urban areas

- Conclude analysis characterizing thermal extreme quantification across distinct cities within CONUS
- Conclude analysis assessing projected changes in extreme precipitation across CONUS
- Quantify non-local and local effects on diurnal temperature range for cities in AZ

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
- Continue cross-city analysis of urban adaptation effects on heat-related mortality

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

- Incorporate our research results into architectural design

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

- Finish data collection of urban microclimate
- Analyze satellite data for vegetation distributions
- Publish park comparison manuscript

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

- Assess performance of water conservation and reuse strategies under uncertain future scenarios (land use, climate, and population change)
- Enhance IUWM by adding co-benefits assessment module

B1-1b: Assessment of Water Infrastructure Resilience

- Present research findings in 2019 ASCE International Conference of Computing in Civil Engineering at Atlanta, GA, on June 2019.
- Complete a Ph.D. dissertation based on this research project (final defense).

B1-2: Lifecycle assessment of urban water systems

- Develop further case studies using the developed LCA model and collected data
- Document case studies

B2-1: Effects of green infrastructure on urban systems

- Develop GI scenarios in urban hydrologic models
- Provide feedback to stakeholders about implications of different practices
- Share results in the UWIN network to understand how they can be implemented in other cities
- Understand how vegetation response to GI differs across cities
- Complete comparative studies of GI implementation and their effect on urban hydrologic response

B2-2a: Flood hydrology and rainfall frequency

- Continue development and analyses of storm catalogs, especially for the Baltimore, New York and Denver metropolitan regions
- Continue urban flood studies for Baltimore, Phoenix and Tucson
- Continue climate modeling studies of extreme rainfall for the Baltimore, Phoenix/Tucson and New York City study regions

B2-2b: Hydrology and hydraulics of urban floodplains

- Develop probabilistic floodplain maps from Monte Carlo simulations at additional study sites, conduct 2-D modeling of select scenarios from Monte-Carlo simulations, and perform comparative analysis of flood hazard assessments and mitigation across regions
- Upload floodplain maps, hydraulic models, and other generated datasets to the UWIN shared data website for integration and dissemination among the UWIN team
- Conduct comparative analysis of flood-wave and flow-field response to alternative restoration strategies and to urban infrastructure affecting hydraulic response

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

- Assess rising risks of compound flooding in major coastal cities in the U.S. under sea level rise scenarios
- Assess the vulnerability of communities along the U.S. coasts to coastal flooding

- Investigate the resiliency of U.S. communities to flooding and identify effective interventions using the decision scaling framework

"Thrust C" Research Projects

C1-1: Understanding adoption of sustainable urban water solutions

- Complete data collection in Baltimore, Colorado Front Range, and Portland.
- Submit manuscript on networks and practices from the data already collected in Arizona and Florida, and (with Melanie Nagel) on network segregation in the Southeast Florida climate adaptation network.
- Coordinate UWIN Indicators integration effort and draft paper summarizing this work.

C2-1: Homeowner adoption of sustainable urban water solutions

- Resurvey additional homeowners in 5 UWIN cities
- Analyze new data
- Prepare 2 publications on data

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

- Analyze household uses and expenditures on water across socio-economic strata using SWISSH
- Submit two articles on community-based interviews (in third draft) and systematic review article of equity, justice and water for *Environmental Research Letters*
- Continue to analyze data and generate papers with A1.2, A2-2, A3-1, B2-2b, and stakeholder engagement team

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

- Work with the Water Research Foundation (WRF) to publish a financial best practices report
- Investigate customers' willingness to pay for water attributes
- Disseminate the results from financial survey to stakeholders via presentations and a emails

"Thrust D" Research Projects

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

- Model alternative future scenarios at multiple scales (Willamette River Basin; Chicken Creek Watershed; Sherwood Focal Neighborhood) and compare the outcomes across scenarios at these different scales
- Participate in preparation of synthesis papers
- Initiate test bed studies by inviting project partners to collaborate and use data we have available for alternative future scenarios developed for the Portland, Oregon region

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

- Evaluate the effects of fit-for-purpose use of alternative water resources from wastewater, stormwater, and graywater on water demand and wastewater production
- Investigate effects of water demand and drinking water infrastructure reliability, wastewater collection infrastructure reliability, and effects on rates for services and subsequent effects on affordability
- Conduct life cycle analysis of green infrastructure to evaluate benefits and co-benefits across UWIN regions

D1-3: Urban water decision innovation system

- Develop information and capacities that enable cities to identify effective strategies and viable technological, policy, institutional and financial pathways toward One Water
- Create a rating system and guidebooks including key metrics and benchmarks to assess the progression towards One Water Cities, benefits and co-benefits, and competing tradeoffs

Stakeholder Engagement

- Publish manuscript on marketing
- Publish manuscript on social network analysis
- Continue to engage in stakeholder workshops in additional regions (ex. Philadelphia) and conduct stakeholder interviews to build case studies and to continue to contribute to indicators project/ UWIN Blueprint

Citizen Science Program

- GIRA will run another full set of events, adding Chicago and repeating events in the other cities. The UWIN scientist team also will support a longer Sustainability Leadership Program event for HSBC executives in Toronto in June 2019.
- GIRA will expand to additional cities (Baltimore, Tucson, Ft. Collins, Miami?) in year 5.
- Off the Roof will continue to collect data and will complete data analysis and dissemination to participants in year 5.

Undergraduate Research Program

- Pursue 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.

COLLABORATORS & PARTNERS

Partners

During this reporting period UWIN has engaged 21 academic institutions, 11 governmental agencies, 11 non-profit organizations, 8 utility partners, 2 industrial firms, and 2 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	Academic Institution	Tempe, 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
Cary Institute of Ecosystem Studies	Other Nonprofits	Millbrook, NY
Chattahoochee River Keeper	Other Nonprofits	Charity, GA
City of Atlanta Watershed Management	State or Local Government	Atlanta, GA
City of Phoenix	State or Local Government	Phoenix, AZ
City of Tempe	State or Local Government	Tempe, AZ
City of Fort Collins	State or Local Government	Fort Collins, CO
City of Miami	State or Local Government	Miami, FL
Colorado School of Mines	Academic Institution	Golden, CO
Decision Center for a Desert City (DCDC, phase III)	Academic Institution	Tempe, AZ
Denver Water	Other - utility	Denver, CO
Denver Metro Wastewater Reclamation District	Other - utility	Denver, CO
Earthwatch Institute	Other Nonprofits	Boston, MA
Exxon Mobil	Industrial or Commercial Firms	Irving, TX
Freshwater Simulations	Industrial or Commercial Firms	Portland, OR
Florida International University	Academic Institution	Miami, FL
Fort Collins Utilities	Other - utility	Fort Collins, CO
GreenRoots	Other Nonprofits	Chelsea, MA
Georgia Association of Floodplain Management	State or local Government	Atlanta, GA
Howard University	Academic Institution	Washington, DC
Kounkuey Design Initiative	Other Nonprofits	Los Angeles, CA
Lanier Consulting, LLC	Other - consultants	Miami, FL
Maricopa County Department of Public Health	State or Local Government	Phoenix, AZ

Name	Organization Type	Location
McCormick-Taylor Consultants	Other – consultants	Baltimore, MD
Miami Beach Utility	Other - utility	Miami, FL
Miami/Dade County Water & Wastewater Dept.	Other - utility	Miami, FL
Michigan State University	Academic Institution	East Lansing, MI
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 School of Law	Academic Institution	Boston, MA
Philadelphia Water Department	Other - utility	Philadelphia, PA
Pima County Wastewater	Other - utility	Tucson, AZ
Sonoran Institute	Other Nonprofits	Tucson, AZ
Southeast Florida Regional Climate Change Project	Other Nonprofits	Miami, FL
The Nature Conservancy	Other Nonprofits	Phoenix, AZ
Torino Polytechnic	Academic Institution	Torino, Italy
Tucson Water	Other - utility	Tucson, AZ
UREx Sustainability Research Network	Academic Institution	Tempe, AZ
United States Army Corps of Engineers	Federal Government	Mobile, AL
University of California, Berkeley	Academic Institution	Berkeley, CA
University of California, Riverside	Academic Institution	Riverside, CA
University of Georgia	Academic Institution	Athens, GA
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
Vitalyst Health Foundation	Other Nonprofits	Phoenix, AZ
Water Environment & Reuse Foundation	Other Nonprofits	Alexandria, VA
Watershed Management Group	Other Nonprofits	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.

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.

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.

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.

Human Resources

The SRN activities engaged 39 faculty members (2 Deans, 19 professors, 7 associate professors, and 11 assistant professors) from 21 academic institutions with interdisciplinary expertise, 13 research

scientists, 12 staff scientists, 56 graduate students, 23 undergraduate students and 11 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 publically 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, 12 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

Research Projects

The project-specific anticipated problems stated by research team leaders are listed below.

A2-1: Effects of changes in climate, demographics and urban form on water supply-demand equilibrium

- There were issues with the water rate data collection. Students hired to do the work were not good. Sarah Wrase was reassigned to work on this and the rate data collection is now complete for select U-WIN regions. This did produce delays in the completion of this data product.

C1-1: Understanding adoption of sustainable urban water solutions

- Data collection was slower than expected. However, we are on track to have all proposed data collection for five UWIN regions complete in Year 5
- Co-I Adam Douglas Henry will expand his role in the project and will be requesting a higher amount of summer support for working on data, papers, and supervision of project tasks.

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

- The SWMM input files being prepared by CSU for the final two alternative future scenarios are slightly behind schedule, but we anticipate being able to maintain our current schedule for modeling the performance of the neighborhood designs as long as there are no further delays.
- Co-PI David Hulse has moved from the University of Oregon. As a result, ongoing work with stakeholders and the final project symposia to present results to the Stakeholder Advisory Committee will be taken on by the OSU team. We will need to retain the funds originally targeted to the University of Oregon in order to support time on the project for Maria Wright to continue to work with stakeholders as we prepare publications from the model results, to conduct watershed scale modeling with the UWINvision model for Chicken Creek, and to plan and conduct the Stakeholder Symposium.

New Project: Greywater Reuse: Pathogen Removal by a Membrane Bioreactor

- A new project has been proposed by Dr. Kimberly Jones, Howard University, to investigate decentralized water reuse systems to produce “fit for use” water to be used for irrigation purposes. A subcontract currently exists between Colorado State University and Howard University. The original subcontract included Dr. Charles Glass, who has since retired, thus a new project was developed by Dr. Jones to utilize the dedicated funds. The project will be completed by August 2021. The project will provide a useful tool for local urban gardens to ascertain the feasibility of implementing water reuse for irrigation purposes. Currently, most of

the gardens use either tap water (water hose to irrigation system) or participate in rainwater harvesting. This will be the first project to utilize reused water for irrigation.

Diversity Program

- Nia H. Rene was selected to receive the second diversity supplement. Nia is a first generation African American, M.S. student in the Dept. of Earth and Environmental Sciences at Brooklyn College of the City University of New York (BC-CUNY) working under the direction of Dr. Jennifer Cherrier. A subaward does not currently exist between Colorado State University and BC-CUNY. Thus, we are requesting approval for a new subaward with BC-CUNY to provide the supplemental funds to Nia Rene and Dr. Jennifer Cherrier. Cherrier has been highly involved in the Network over the last three years despite her lack of funding.

PRODUCTS

UWIN Products

Product Summary

Product	*Total**
Book Chapters	4
Journal Articles	104 published/in-press/accepted (4 submitted/under review/in preparation)
Conference Presentations	217
Patents	1
Thesis/Dissertations	12
Technologies & Models	12
Websites	8
Webinars	27
Outreach Materials	88
Data	36
Other	11

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

Book Chapters

1. Harlan, S.L., P. Chakalian, J. Declet-Barreto, D.M. Hondula, G.D. Jenerette (2019). Pathways to climate justice in a desert metropolis. In *People and Climate Change: Vulnerability, Adaptation, and Social Justice*, L.M. Reyes and J. Rigg (eds.) Oxford University Press. Status = Published; Acknowledgment of Federal Support = Yes; Peer Reviewed = Yes
2. Meggers, F. "Abstracting Energy" in *Energy Accounts,* Willis, D., Braham, W. W., Muramoto, K., & Barber, D. A. eds. (2016). Energy Accounts: Architectural Representations of Energy, Climate, and the Future. Routledge.
3. Santelmann, M., Gordon, S. Hulse D, Wright M, Enright C, Branscomb A, Talal, M, Tchintcharauli-Harrison M. 2019. Innovation in Urban Water Systems. In: *International GeoDesign Collaborative*; C. Steinitz and Brian Rowland Eds. ESRI Press. http://www.geodesigncollab.org (in press).
4. Sharvelle, S. E. (2018) Water Quality for Decentralized Use of Non-Potable Water Sources. *Water Quality Contributions for Women Engineers and Scientists*. Springer, (in press).

Journal Articles

1. Aliabadi, A.A., Krayenhoff, E.S., Nazarian, N. et al. Boundary-Layer Meteorol (2017) 164: 249. https://doi.org/10.1007/s10546-017-0246-1 . Status = Published; Acknowledgment of Federal Support = Yes; Peer Reviewed = Yes.

2. Barnes, M.L. and Welty, C. (2019) "Quantifying water balance components at a permeable pavement site using a coupled groundwater–surface water model" ASCE J of Hydrologic Engineering, https://doi.org/10.1061/(ASCE)HE.1943-5584.0001789 Status = Published; Acknowledgment of Federal Support = Yes; Peer Reviewed = Yes.
3. Berger, Lena, Adam Douglas Henry & Gary Pivo (2019). "Multiplexity of Local Government Actions for Urban Water Sustainability." Under review in *Environmental Research Letters*
4. Benson-Lira, V., M. Georgescu, S. Kaplan, and E. Vivoni (2016), Loss of a Lake System in a Megacity: The impact of urban expansion on seasonal meteorology in Mexico City. Journal of Geophysical Research – Atmospheres 121(7), 3079-3099. http://doi.wiley.com/10.1002/2015JD024102. Status = Published; Acknowledgment of Federal Support = Yes; Peer Reviewed = Yes.
5. Bolson, J., Sukop, M., Pivo,G., Arabi,M., Lanier, A. A stakeholder-science based approach using the National Urban Water Innovation Network as a testbed for understanding urban water sustainability challenges in the U.S. *Water Resources Research.* Status = Accepted; https://doi.org/10.1029/2017WR021191 Acknowledgment of Federal Support = Yes; Peer Reviewed = Yes.
6. Bradshaw, J., Bou-Zeid, E, and Harris, R.H. (2016) "Greenhouse gas mitigation benefits and cost-effectiveness of weatherization treatments for low-income, American, urban housing stocks", *Energy and Buildings*, 128,911-920, DOI: 10.1016/j.enbuild.2016.07.020.
7. Broadbent, A. M., Coutts, A. M., Tapper, N. J., Demuzere, M., & Beringer, J. (2017), The microscale cooling effects of water sensitive urban design and irrigation in a suburban environment. Theoretical and Applied Climatology, 1-23. Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = Yes.
8. Broadbent, A. M., Coutts, A. M., Nice, K. A., Demuzere, M., Krayenhoff, E. S., Tapper, N. J., & Wouters, H. (2019). The Air-temperature Response to Green/blue-infrastructure Evaluation Tool (TARGET v1. 0): an efficient and user-friendly model of city cooling. *Geoscientific Model Development*, *12*(2), 785-803. https://doi.org/10.5194/gmd-12-785-2019
9. Broadbent, A. M., Krayenhoff, E. S., Georgescu, M., & Sailor, D. J. (2019). The observed effects of utility-scale photovoltaics on near-surface air temperature and energy balance. *Journal of Applied Meteorology and Climatology*, (2019). https://doi.org/10.1175/JAMC-D-18-0271.1
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11. Cao, Q., D. Yu, M. Georgescu, J. Wu, and W. Wang (2018), Impacts of future urban expansion on summer climate and heat-related human health in eastern China. *Environment International*, doi: https://doi.org/10.1016/j.envint.2017.12.027, Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = Yes.
12. Cao, Q., D. Yu, M. Georgescu, and J. Wu (2018), Substantial impacts of landscape changes on summer climate with major regional differences: The case of China, *Science of the Total* Environment, https://doi.org/10.1016/j.scitotenv.2017.12.290, Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = Yes.
13. Cole, J., S. Sharvelle, D. Fourness, N. Grigg, L. Roesner, J. Haukaas (2017). Evaluation of Centralized and Decentralized Strategies for Dual Water Supply: A Case Study. ASCE Journal of Water Resources Planning and Management, 144(1): 05017017.. Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = Yes.
14. Cole, J., Sharvelle, S., Grigg, N. S., Pivo, G., Haukaas, J. (2018). Collaborative, Risk-Informed, Triple Bottom Line, Multi-Criteria Decision Analysis Planning Framework for Integrated Urban Water Management. *Water, 10*(12), 1722. https://doi.org/10.3390/w10121722 Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = Yes.
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105. Zhang, W., G. Villarini, G. A. Vecchi and J. A. Smith, (2018) Urbanization exacerbated the rainfall and flooding by Hurricane Harvey in Houston, Nature Climate Change, 563, 384 - 388, 2018. doi: 10.1038/s41586-018-0676-z
106. Zhao, Lei Oppenheimer M., Qing Z., Baldwin J., Ebi K., Bou-Zeid E.; Guan K., Liu X. (2018) "Interactions between urban heat islands and heat waves", Environmental Research Letters, 13, 034003, DOI:

10.1088/1748-9326/aa9f73. Status = Published, Acknowledgement of Federal Support = Yes, Peer Reviewed = Yes.
107. 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. Status = published. Acknowledgement = yes. Peer-reviewed =yes.
108. 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. Status = published, acknowledgment of federal support = no, peer reviewed = no.
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. Status = PUBLISHED; Acknowledgement of Federal Support = no
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. Published, Acknowledgement: no, Peer reviewed: yes
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. Bledsoe, B.P. (2017). *Probabilistic floodplain mapping as a template for planning urban revitalization*. 17th Annual American Ecological Engineering Society Meeting. Status = Accepted; Acknowledgement of Federal Support = Yes

15. 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.
16. 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
17. Bledsoe, B. 2018. *Addressing flooding and extreme weather with restoration efforts.* Presentation, Southeast Stream Restoration Conference – EcoStream, Asheville, NC, August 14.
18. Bledsoe, B. 2018. *The three C's of flood management.* Presentation, Vanderbilt University, Nashville, TN, November 9.
19. Bledsoe, B. 2018. *Natural and nature-based infrastructure solutions.* Presentation, Atlantic Intracoastal Waterway Association (AIWA), 2018 Annual Meeting, Charleston, SC, November 16.
20. 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. Status = PUBLISHED; Acknowledgement of Federal Support = No; Peer Reviewed = No. http://archives.waterinstitute.ufl.edu/symposium2018/downloads/2018BookOfAbstracts.pdf
21. Bou-Zeid, E. (2016) "Cities in the 21st century: the nexus of the climate, water and energy challenges", University of Perugia.
22. 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. Status = published, Acknowledgement of Federal Support = Yes, Peer Reviewed = No
23. 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.
24. 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
25. 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
26. 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
27. Bou-Zeid E. and Yang J. (2018) Hydrological Determinants of Temperature Extremes in Cities, 2018 Annual meeting of the American Meteorological Society, Austin, TX.
28. 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. Status = PUBLISHED; Acknowledgement of Federal Support = yes
29. Borowy D, C Swann (2017). Linking Community Assembly Processes in Experimental Urban Vacant Lot Habitats. Baltimore Ecosystem Study (BES) Annual Meeting. Status = PUBLISHED; Acknowledgement of Federal Support = yes
30. 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.
31. Borowy, D. (2018). Annual Meeting of the Baltimore Ecosystem Study, Oral Presentation, "Understanding biodiversity in the built environment," Baltimore Ecosystem Study (BES), Baltimore, MD.
32. 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.
33. 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. Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = No.
34. 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.** Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = No. ***Awarded*** 1st Place in the Postdoctoral Researcher category

35. 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.
36. 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. Acknowledgement of Federal Support=YES
37. 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. Published; Acknowledgment of Federal Support = No; Peer Reviewed = Yes
38. 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).
39. 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. Status=accepted Acknowledgement of Federal Support=YES
40. 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.
41. 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)
42. 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.
43. 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.
44. 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
45. 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). Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = No.
46. 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). Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = No.
47. 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). Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = No.
48. Ghanbari, Mahshid and Mazdak Arabi, Current and Future Flood Losses in the Southeast Florida, EWRI World Environmental & Water Resource Congress 2017 24 May 2017.
49. 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.

50. 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.
51. 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.
52. 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.
53. 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.
54. 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.
55. 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
56. Gomez Fernandez, Edna Liliana. "Water Sustainability Innovations through Collaborative Networks." Paper presented at Southern Political Science Association (SPSA) Annual Conference, Austin, Texas, January 2019.
57. 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.
58. 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. Status= ACCEPTED; Acknowledgement of Federal Support= YES; Peer-reviewed= No.
59. 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
60. 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.
61. 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.
62. 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. Status = published, Acknowledgement of Federal Support = Yes, Peer Reviewed = No
63. 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. Status = PUBLISHED; Acknowledgement of Federal Support = no
64. 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.
65. 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.
66. 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.

67. Gupta, Neha— Quantification of Runoff Response in Semi-Arid Urban Catchment – Arizona Hydrological Society Annual Symposium, Phoenix AZ, September 20, 2018.
68. 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.
69. Gupta, Neha, Stormwater Runoff Response in Semi-Arid Urban Catchment, AWWA Sustainable Water Management Conference, Tucson, AZ, April, 2019.
70. 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
71. 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.
72. 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.
73. 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. Status = PRESENTED; Acknowledgement of Federal Support= YES; Peer-reviewed= No.
74. 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
75. 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
76. 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*
77. 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*
78. 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*
79. 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).
80. 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.
81. 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.
82. 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
83. 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.
84. 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.

85. 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.
86. Hermosilla, Victoria — Rainwater Harvesting Infiltration Exploration Using Hydrus-1D, 2018 – Arizona Hydrological Society Annual Symposium, Phoenix AZ, September 20, 2018.
87. 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.
88. 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 Status = PUBLISHED; Acknowledgement of Federal Support = yes
89. 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
90. 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
91. Jenerette GD. A macroecology of urban trees. Ecological Society of America, Portland, OR August 2017. Status = PUBLISHED; Acknowledgement of Federal Support = yes
92. 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 Status = PUBLISHED; Acknowledgement of Federal Support = yes
93. Jenerette GD. Experimental landscape ecology. United States Chapter of the International Association of Landscape Ecologists. Chicago IL April 2018
94. Jenerette GD. Opportunities for urban ecology at the United States and Mexico border. Ecological Society of America Annual Meeting. New Orleans August 2018
95. 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).
96. 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.
97. 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).
98. 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
99. 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.
100. 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. Status = PUBLISHED; Acknowledgement of Federal Support = yes
101. 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 Status = PUBLISHED; Acknowledgement of Federal Support = yes
102. 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. Status = complete; Acknowledgement of Federal Support = Yes

103. 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. Status = pending; Acknowledgement of Federal Support = Yes
104. 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. Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = No.
105. 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.
106. 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). Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = No.
107. 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). Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = No
108. 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.
109. 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 Status = PUBLISHED; Acknowledgement of Federal Support = yes
110. 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.
111. Kunnie, Mandla, Creation of Tucson GIS Green Infrastructure Database, AWWA Sustainable Water Management Conference, Tucson, AZ, April, 2019.
112. 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.
113. 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.
114. 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. Status = published, Acknowledgement of Federal Support = Yes, Peer Reviewed = No
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Patents

A2-4: *SPHERICAL-MOTION AVERAGE RADIANT TEMPERATURE SENSOR*, *F Meggers, E Teitelbaum, J Read US Patent App. 15/559,218*

Thesis/Dissertations

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Technologies & Models

1. **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.
2. **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.
3. 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.

4. **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
5. **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/
6. **B1-2:** WEST/WWEST decision support tools: https://west.berkeley.edu/
7. **B2-2b:** Probabilistic floodplain mapping framework based on Monte Carlo simulations of flood hydraulics that accounts for uncertainty in model inputs and parameters.
8. **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
9. **B2-2b:** River Erosion Model (REM) http://www.github.com/rodlammers/REM
10. **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.
11. **D1-2:** The Water Rights Analysis tool helped to identify and explore water rights, appropriated amounts in the Colorado region. Domain: erams.com/wra

12. **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. Integrated Urban Water Model (IUWM) – Documentation: https://erams.com/documentation/iuwm/
2. Integrated Urban Water Model (IUWM): https://erams.com/iuwm
3. UWIN Listserv: https://lists.colostate.edu/cgi-bin/mailman/listinfo/uwin-network
4. UWIN SRN Website: https://erams.com/UWIN/
5. UWIN YouTube Channel: https://www.youtube.com/channel/UC7nNrIUznXii6_u0axbhQrA
6. UWIN Zotero Publication Database: https://www.zotero.org/groups/urban_water_innovation_network_uwin/items
7. 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 (4): 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 available. 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	**4**
Urban Climate Data	**6**
Water Supply & Demand	**4**
Sociopolitical Information	**4**
Microclimate	**2**
Urban Infrastructure	**4**
Green Infrastructure	**3**
Flooding	**2**
Energy Usage	**1**
Census	**2**
Land Use and Land Cover	**2**

Hydrology	**1**
UWIN City Indicators Survey	**1**
TOTAL	**36**

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 (Y4)

Invited Seminars & Lectures

A2-2:

- 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).
- 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).
- 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).
- 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:

- 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:

- 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

- 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

News Articles

- B3-1: "As Sea Levels Rise, Expect More Floods" EoS Earth & Space Science News, Published on 03 May 2019: https://eos.org/research-spotlights/as-sea-levels-rise-expect-more-floods

Awards & Scholarships

- A2-2: 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**).
- B2-1: 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.
- B2-1: My group assisted with Bo Yang (Landscape architecture professor here at Arizona) on their EPA Rainworks projects. They won Honorble Mention in the Planning Category and 2nd place in the Demonstration Category. We and UWIN were credited.

PERSONNEL

NAME	PROJECT ROLE	CONTRIBUTION TO NETWORK
Jumana Alja'fari	Graduate Student (research assistant)	B1-1a
Abbeygail Anders	Undergraduate Student	URP Participant
Jack Anderson	Graduate Student (research assistant)	B2-1
Riley Andrade	Graduate Student (research assistant)	A2-3
Mazdak Arabi	Co-PD/PI	UWIN Director, Project lead: A1-1, B3-1, D1-2, D1-3
Adriana Arcelay	Graduate Student (research assistant)	B2-1
Zach Argo	Undergraduate Student	A1-2
Dorit Aviv	Graduate Student (research assistant)	A2-4
Mary Lynn Baeck	Staff Scientist (doctoral level)	B2-2a
Michael Barnes	Staff Scientist (doctoral level)	A2-1
Giovana Batista	Graduate student (research assistant)	B1-1, D1-2
Alan Berkowtiz	Co-Investigator	URP Director, CS: Earthwatch GIRA project
Sierra Bettis	Undergraduate Student	B2-1
Aditi Bhaskar	Faculty	URP Mentor
Brian Bledsoe	Co-Investigator	B2-2b Project Lead, B2-2a
Annie Block	Undergraduate Student	URP Participant
Jessica Bolson	Postdoctoral	C2-1 Project Lead, E1-1 Stakeholder Engagement, URP Mentor
Dorothy Borowy	Graduate Student (research assistant)	A3-1
Elie Bou-Zeid	Co-PD/PI	A2-1 Project Lead
Aldo Brandi	Graduate Student (research assistant)	A2-2
Allan Branscomb	Staff Scientist (doctoral level)	D1-1
Ashley Broadbent	Postdoctoral	A2-2
Alexander Brown	Undergraduate Student	A1-2
Amanda Bruno	Graduate Student (research assistant)	C1-1
Molly Chaney	Graduate Student (research assistant)	B2-2a

NAME	PROJECT ROLE	CONTRIBUTION TO NETWORK
Amber Chau	Undergraduate Student	B1-2
Jacquelyn Chavez	Undergraduate Student	URP Participant
Chingwen Cheng	Faculty	A2-2
Jennifer Cherrier	Faculty	CS: Earthwatch GIRA project, URP Mentor
Matt Chiavatta	Undergraduate Student	A1-2
Michelle Church	Graduate Student (research assistant)	A1-2
Stephanie Clark	Graduate Student (research assistant)	C3-1
David Conklin	Consultant	D1-1
Lauren Contorno	Graduate Student (research assistant)	C3-1
Alycia Crall	Consultant	CS: Roof Runoff Project Volunteer Coordinator and Evaluator
Tyler Dell	Staff Scientist (doctoral level)	D1-2, D1-3
Alisen Downey	Technician	CS: Earthwatch GIRA project
Andre Dozier	Staff Scientist (doctoral level)	B1-1, D1-2, D1-3
Lori Emler	Graduate Student (research assistant)	B2-1
Chris Enright	Other professional	D1-1
Kelsi Furman	Graduate Student (research assistant)	C3-1
Canon Furth	Graduate student (research assistant)	D1-2
Erika Gallo	Staff Scientist (doctoral level)	B2-1
Matei Georgescu	Co-Investigator	A2-2 Project Lead, URP Mentor
Mahshid Ghanbari	Graduate student (research assistant)	B3-1
Katie Glodzik	Postdoctoral	E1-1 Stakeholder Engagement
Edna Liliana Gomez Fernandez	Graduate Student (research assistant)	C1-1
David Gosselin	Faculty	URP Consultant
Fiona Greer	Graduate Student (research assistant)	B1-2 Researcher, B1-1
Hattie Greydanus	Undergraduate Student	URP Participant, D1-1
Neil Grigg	Co-Investigator	C4-1
Phil Guertin	Faculty	B2-1
Hongshan Guo	Graduate Student (research assistant)	A2-4

NAME	PROJECT ROLE	CONTRIBUTION TO NETWORK
Neha Gupta	Graduate Student (research assistant)	B2-1
Aysegul P. Gursel	Postdoctoral	B1-2
Geoffrey Habron	Faculty	URP Consultant
Roy Haggerty	Co-Investigator	D1-1 Project Lead
Holly Yaryan Hall	Graduate Student (research assistant)	B2-2b
Sharon Harlan	Co-Investigator	C3-1 Project Lead, A1-2
Hadi Heidari	Graduate student (research assistant)	A1-1
Chelsey Heiden	Graduate student (research assistant)	D1-2
Adam Douglas Henry	Co-Investigator	C1-1 Project Lead
Victoria Hermosilla	Graduate Student (research assistant)	B2-1
David Hondula	Co-Investigator	A2-3 Project Lead
Arpad Horvath	Co-Investigator	B1-2 Project Lead, B1-1
David Hulse	Co-Investigator	D1-1 Project Lead
Peter Isben	Graduate Student (research assistant)	A3-1
Darrel Jenerette	Co-Investigator	A3-1 Project Lead
Kimberly Jones	Co-Investigator	Diversity Recruitment & Retention
Theo Keelye-LeClaire	Undergraduate Student	A2-4
Tim Kirby	Graduate Student (research assistant)	E1-1 Stakeholder Engagement
Yoganand Korgaonkar	Graduate Student (research assistant)	B2-1
Scott Krayenhoff	Faculty	A2-2
Dion Kucera	Graduate Student (research assistant)	A3-1
Mandla Kunnie	Undergraduate Student	B2-1
Liza Kurtz	Graduate Student (research assistant)	A2-3
Rod Lammers	Postdoctoral	B2-2b
Joome Lee	Graduate Student (research assistant)	A2-2
Gina Lee	Graduate Student (research assistant)	B2-2b
Theodore Lim	Other professional	A2-1
Maider Llaguno Munitxa	Postdoctoral	A2-1
Aude Lochet	Staff Scientist (doctoral level)	URP Coordinator

NAME	PROJECT ROLE	CONTRIBUTION TO NETWORK
Alexander Maas	Co-Investigator	C4-1 Project lead
Elizabeth Mack	Co-Investigator	A1-2 Project lead, Co-PI C3-1, A2-2
Liz Mariluz	Undergraduate Student	C3-1
Isabel McKnight	Undergraduate Student	URP Participant
Lolya McWest	Undergraduate Student	URP participant
Laura Medwid	Graduate Student (research assistant)	A1-2
Forrest Meggers	Co-Investigator	A2-4 Project Lead
Thomas Meixner	Co-Investigator	B2-1 Project Lead, CS: GIRA, URP Mentor, A3-1
Samuel Melzter	Undergraduate Student	URP participant
Ariane Middel	Faculty	A2-2
Andy Miller	Co-Investigator	B2-2b Project Lead
Sarah Millonig	Other professional	UWIN Coordinator
Fatuma Mohamed	Undergraduate Student	C3-1
Ali Mostafavi	Co-Investigator	B1-1b Project Lead, B1-1a, URP Mentor
Mohamed Moustaoui	Faculty	A2-2
Lianzheng Mu	Staff Scientist (doctoral level)	A1-2
Melanie Nagel	Postdoctoral	C1-1
Michael Neale	Graduate Student (research assistant)	B1-1a, D1-2
Victoria Nelson	Undergraduate Student	B2-2b
Greg Newman	Staff Scientist (doctoral level)	CS: Roof Runoff Project
Kiera O'Donnell	Graduate Student (research assistant)	C3-1
Hamidreza Omidvar	Graduate Student (research assistant)	A2-1
Shirley Papuga	Co-Investigator	A3-1
Jose Pillich	Technician	CS: Earthwatch GIRA project
Gary Pivo	Co-PD/PI	C1-1 Project Lead, UWIN Co-director
Amber Pulido	Undergraduate Student	URP Participant
Roshan Puri	Graduate Student (research assistant)	C4-1
William Rainey	Graduate student (research assistant)	D1-2
Kambiz Rasoulkhani	Graduate Student (research assistant)	B1-1b, URP Mentor

NAME	PROJECT ROLE	CONTRIBUTION TO NETWORK
Nia Rene	Graduate Student (research assistant)	Diversity Recruitment & Retention recipient
Julie Ripplinger	Postdoctoral	A3-1
Mary Santelmann	Co-Investigator	D1-1 Project Lead, A3-1, URP Mentor
Mariana Sarango	Graduate Student (research assistant)	C3-1
Jason Schlottman	Undergraduate Student	B2-1
Omar Shahab	Graduate student (research assistant)	D1-2
Sybil Sharvelle	Co-Investigator	B1-1a Project Lead, B1-1b, B1-2; CS: Project management for Off the Roof, URP Mentor
James A. Smith	Co-Investigator	B2-2a Project Lead
Karla Smith	Graduate Student (research assistant)	C1-1
Brianne Smith	Faculty	CS: Earthwatch GIRA project, URP Mentor
Sheila Solis-Arroyo	Undergraduate Student	B2-1
Tim Stephens	Graduate Student (research assistant)	B2-2b
Jennifer Stokes-Draut	Staff Scientist (doctoral level)	B1-2, B1-1
Michelle Stuhlmacher	Graduate Student (research assistant)	A2-2
Yibing Su	Graduate Student (research assistant)	B2-2a
Mike Sukop	Co-PD/PI	Stakeholder Engagement Project Lead, C2-1, URP Mentor
Nadia Sultan	Undergraduate Student	URP Participant
Chris Swann	Co-Investigator	A3-1
Samantha Swartz	Undergraduate Student	B2-1
Michelle Talal	Graduate Student (research assistant)	D1-1
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
Kyle Traff	Technician	D1-3
Ales Urban	Postdoctoral	A2-3

NAME	PROJECT ROLE	CONTRIBUTION TO NETWORK
Miguel Valencia	Undergraduate Student	CS: Off-the-Roof project
Jennifer Vanos	Faculty	A2-2, URP Mentor
Shirley Vincent	Consultant	UWIN External Evaluator
Meng Wang	Staff Scientist (doctoral level)	A2-2
Claire Welty	Co-PD/PI	A2-1 Project Lead, A2-2, Associate Director for Research
Jonah White	Graduate Student (research assistant)	A1-2
Tyler Wible	Technician	D1-3
Adrian Wilcox	Graduate Student (research assistant)	C1-1
Elisabeth Wilder	Graduate Student (research assistant)	C3-1
Benjamin Wostoupal	Graduate student (research assistant)	D1-2
Sarah Wrase	Graduate Student (research assistant)	A1-2, C3-1
Mary Wright	Graduate Student (research assistant)	A2-3
Maria Wright	Staff Scientist (doctoral level)	D1-1
Jiachuan Yang	Postdoctoral	A2-1
Long Yang	Postdoctoral	B2-2a