The UWIN Annual Report provides a detailed summary of activities, results and accomplishments. 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.

Urban Water Innovation Network

Annual Report

2016-2017

Mazdak Arabi, UWIN Director

Urban Water Innovation Network
Annual Report

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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.

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.

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. More specifically, Year Two engagement goals emphasize understanding decisions in our regions to: enhance understanding of regions' water sustainability decisions; focus discussions on decisions and barriers to implementing sustainability strategies; and implement a survey to gather data on decisions.

MAJOR ACTIVITIES

Research activities of the network are organized in four integrated thrusts: A, B, C, and D. A complete list of projects, lead investigator and links to individual project webpages is located in Appendix A.

Thrust A – assesses baseline conditions for sustainability. These projects aim to advance fundamental knowledge about the sustainability of urban water systems, by comparing observed trends in the past with alternative future conditions.

Thrust B – design and discover innovative technological solutions for sustainable urban water. 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.

Thrust C – innovative transitions for sustainable water management. 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.

Thrust D – evaluate impacts, tradeoffs and co-benefits of innovative technologies. 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.

Thrust A Research Projects

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

- Quantified changes in water supply for 4-digit HUCs across the Contiguous United States
- Simulated trans-basin water transfers at the 4-digit HUC level for the CONUS
- Quantified current and future water demands from various sectors at the county-level

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

- Collected and analyzed current water prices for water providers in UWIN regions
- Analyzed regional water output multipliers from the IMPLAN data
- Created a “water pressures” index for UWIN regions
- Collected bond ratings and other financial information from utilities
- Designed survey questions to elicit customer responses to water availability

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

- Completed the development of high resolution large eddy simulations over urban topographies
- Improved representations of land-atmosphere exchanges of heat and water over urban terrain
- Developed a novel model for thermal energy of urban pavements following rainfall
- Completed a study on the interaction between Urban Heat Islands and Cold Waves

A2-2: Projecting future environmental change in urban areas

- Created regional climate datasets for the CONUS
- Quantified effects of projected greenhouse gas-induced climate change, urban expansion and their dynamic interaction on temperature and precipitation
- Quantified the effects of cool roof and green roof implementations on near surface thermal climate amelioration
- Added a representation of trees into the standard single layer urban canopy model

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

- Analyzed the EPA's Consolidated Human Activity Database to understand time-activity patterns
- Analyzed travel activity model data to estimate thermal comfort
- Conducted microclimate measurements using evaporative cooling "misters" for human thermal comfort

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

- Continued the development of radiant heat sensors to analyze heat stress
- Continued research on the ability to deploy water on membranes or superhydrophelic surfaces to cool building walls

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

- Sampled biodiversity from multiple green infrastructure types in Los Angeles and Baltimore
- Began identifying environmental sensor deployment plans for further analysis of green infrastructure

Thrust B Research Projects

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

- Developed a triple bottom line (TBL) framework to support decision making toward integrated urban water management
- Applied the Integrated Urban Water Model (IUWM) to evaluate water conservation and reuse strategies in study regions
- Developed an agent-based model to understand factors (demographic, regulations, social networks, etc.) that influence household adoption of water conservation technologies
- Created a dynamic simulation model to investigate the long-term performance of water distribution networks

B1-2: Lifecycle assessment of urban water systems

- Collected information on the local energy mix in the study regions
- Prepared data and methods to update tools for life cycle assessment of water systems

B2-1: Effects of green infrastructure on urban systems

- Developed data and modeling capacities that enable modeling the water balance at the lot-scale and optimizing green infrastructure designs to support environmental and water sustainability

B2-2a: Flood hydrology and rainfall frequency

- Implemented the Stochastic Storm Transposition (SST) analyses for rainfall frequency analysis
- Developed polarimetric rainfall algorithms for extreme rainfall events
- Created high-resolution rainfall and rain gage datasets for the study areas
- Performed flood hydroclimatology studies for the study regions
- Assessed the regional climatology of extreme flood-producing storms
- Improved urbanized land surface models for assessing land-atmosphere interactions and their impact on urban rainfall climatology

B2-2b: Hydrology and hydraulics of urban floodplains

- Evaluated variation in floodplain roughness and its effects on modeling uncertainty
- Began to conduct 2-D hydraulic modeling for evaluating novel methods to incorporate bridges and other in-stream structures in 2-D hydraulic models

- Developed high-resolution digital elevation models to quantify modifications of channel geometry after flooding events
- Developed a 2-D hydraulic modeling to investigate scenarios representing pre- and post-flood hydraulic conditions

B3-1: Flood Risk to Assets and Socioeconomic Sectors in a Changing World

- Developed a framework for assessing flood risk to assets and communities from riverine and tidal flooding, storm surge, and compound flooding events
- Developed analytical methods for spatial disaggregation of flood risk
- Quantified flood risks in the Southeast Florida region

Thrust C Research Projects:

C1-1: Understanding adoption of sustainable urban water solutions

- Completed a protocol for defining local water organizations and governments
- Developed a search protocol to identifying grey literature related to water policy decisions and innovations
- Developed a pilot survey instrument to measure water governance practices, beliefs of policy participants, as well as networks between organizations involved in water governance
- Used network analysis to develop a unique index of fragmentation in water governance systems

C2-1: Homeowner adoption of sustainable urban water solutions

- Developed text documents, articles, videos, and images that will be incorporated into the Choiceflow platform for conducting urban water technology adoption experiments

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

- Conducted a survey of UWIN researchers about major inequities in urban water systems
- Scanned several national household surveys on water and consumer expenditures, risk perceptions of water hazards, and adaptive behaviors
- Designed a guide and iterative sampling strategy for interviews with community organizations

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

- Developed a database of financial systems from organizations that have started the transition to integrated urban water systems
- Assessed the drivers and effectiveness of financing efforts in the case study utilities
- Prepared a survey to collect information from financial and utility managers about funding mechanisms and financial models for integrated urban water systems

Thrust D Research Projects

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

- Implemented the widely-used urban stormwater model to be deployed as web services
- Evaluated alternative spatial geometries for modeling urban hydrologic response units
- Began defining the three alternative future scenarios that will be the focus of modeling efforts

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

- Assessed changes in flood frequency, duration and intensity in cities across the U.S.
- Assessed changes in drought frequency, duration and intensity
- Assessed watershed health indicators for urban areas

D1-3: Urban water decision innovation system

- Developed the first draft of the UWIN Urban Water Sustainability Blueprint
- Developed and implemented the Water Connect app, which provides the framework, tools and guidance to view urban water systems through several “lenses”

Education, Outreach & Engagement

Stakeholders & Training

- Conducted 2017 Stakeholder meetings in UWIN regions to understand policy, institutional, and financial pathways for transitioning to integrated urban water systems
- Provided training on effective Team Science, active listening, and leadership styles

Undergraduate Research Program

- Completed post-program surveys by student participants and mentors
- Supported students in completing their research papers
- Planned and advertised the 2017 UWIN URP
- Completed the 2017 student selection and orientation
- Analyzed results from 2016 mentor and student surveys
- Analyzed the 2016 educational outcomes from the case-study

SPECIFIC OBJECTIVES

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

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 from storm surge, tidal and riverine flooding
- Examine the effects of flooding on communities and economic sectors

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

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 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

RESULTS

Research

Consumers' water bill is likely to increase for many communities across the U.S. in the upcoming decades, making water unaffordable for nearly one-third of American households.

Indoor and outdoor water conservation and alternative water sources from graywater, stormwater and wastewater could substantially reduce projected future water shortage vulnerability. However, institutional barriers, particularly water rights in the West, impede innovative approaches for the development of these strategies at the municipal and regional scales.

Fort Collins Case Study

A framework was developed to support decisions to move toward integrated urban water management. The framework was successfully applied in a case study in the City of Fort Collins to evaluate separate supply of raw and potable water including alternatives for decentralized water supply. Early results from the analysis of dual water supply systems in the City of Fort Collins indicate substantial benefits of separate supply of water for potable use that can be realized without notable financial burden.

Centralized alternatives for water supply were found to be favorable in the City of Fort Collins compared to point of use or neighborhood treatment to supply potable water. This result could be different in areas where water is not gravity supplied. Results from application of IUWM in the City of Fort Collins showed high potential for water demand reduction associated with reducing irrigation demand via installation of drought tolerant landscape and efficient irrigation systems.

Urban growth scenarios with transitioning low density development to medium and high density development in Fort Collins were estimated to reduce total water demand. While this change in land use increases indoor demand, outdoor demand is predicted to be substantially reduced due to decreases in irrigated area.

Factors (e.g., socio-demographic factors, social network structures, and price structure) that influence households' behaviors related to water conservation technology adoption were explored. The results showed that the effectiveness of renewal strategies and capital funding levels in improving the resilience of water systems vary based on the network attributes (e.g. physical attributes and demand).

Urban Flooding

"Collapsing" thunderstorm systems are important flood agents for urban areas of the eastern U.S. There is little evidence that flash flood producing thunderstorm systems "split" as they approach urban areas. Spatial heterogeneities of flash flood producing rainfall over Baltimore are linked to interaction of the Bay Breeze circulation and Urban Heat Island circulation; spatial heterogeneities are manifested in Lagrangian storm properties. These results have important implications for implementation of stochastic storm transposition methods that address spatial heterogeneities over urban regions.

The frequency of tidal flooding in coastal regions in the U.S. has increased over the last century. While the social and economic consequences of single extreme flooding events far exceed those of tidal flooding, the long term damages from repeated tidal flooding exceeds potential damages due to extreme flooding in many coastal regions in the U.S.

The exposure to flooding and damages vary substantially at smaller spatial scales, even within a city. Understanding the spatial variability of flood exposure and damage is essential to adequately characterize impacts on communities and economic sectors.

Urbanization, Green Infrastructure & Heat Island Effects

Current surface-air exchange schemes in the Urban Canopy Model (UCM) are lacking, and need to be improved. In particular, important differences between the momentum and heat transport and between turbulent and dispersive transport in urban environments are at present completely ignored in UCMs. Our fine scale LES studies enable the development of much more realistic surface-atmosphere urban exchange schemes that will be implemented in WRF.

Heat waves intensify during the nighttime under cold wave conditions. This shelters the city from extreme cold and has positive health implications that offsets and may surpass the negative impacts of the Urban Heat Island during the summer time.

Implementation of urban green infrastructure has significant impact on urban energy-water nexus not only in the canopy layer, but extended to the overlying atmospheric boundary layers (up to 2 km in elevation). Effective urban landscape planning for sustainable water solutions must take into account the size effect.

We examined the effects of projected urban expansion over the 21st century on summer near surface air temperature which are shown to differ between start-of-century and projected end-of-century global climates. This difference results in the interaction effect, which is of smaller magnitude than the effect of urban expansion and varies between positive and negative values regionally. Cool roofs exert a 1-3K cooling influence across urbanized areas, and their uniform application can offset warming due to urban expansion in most regions. Cool roofs also reduce summertime convective precipitation across the U.S. Atlantic coast, consistent with previous work using earlier versions of WRF.

We determined that quantification of the thermal comfort benefits of evaporative cooling "misters" is highly sensitive to the heat stress/exposure variable of interest (e.g., temperature versus heat index versus wet bulb globe temperature).

Stakeholder Engagement

The focus of engagement activities was on developing regional UWIN relationships with stakeholders in the study regions, collecting data on urban water systems concerns, obtaining feedback to align UWIN research with stakeholder interests and needs, and expanding the network. The core stakeholder engagement team (SET) planned and attended all regional meetings along with the respective regional research teams. The traveling SET planned and facilitated all meetings to ensure uniform meeting structure and data collection for comparative purposes across regions.

A facilitated brainstorming activity was designed to maximize opportunity for conversation among the stakeholders, collect information quickly, and promote thought-provoking discussion. The question framing the activity was composed of 6 parts: What are the most serious threats to those systems? What are the key strengths of the region's water, wastewater, and stormwater systems? What major economic, social, or ecological problems are caused by those systems? What approaches have already been successful in addressing threats and impacts? What possible solutions not being widely tried deserve a closer look? What are the major impediments to implementing solutions?

Of the challenges described in pre-workshop survey responses, climate change, or climate-change-related impacts were the most frequently described challenge for three study regions: Southeast Florida, the Sun Corridor, and the Pacific Northwest. In Southeast Florida, climate concerns center around impacts of sea-level rise. The Sun Corridor stakeholders' concerns focus on drought, extreme events, and water availability in the future. The most commonly described challenges for the Front Range include water quality impacts and population growth, followed by climate change. In the Front Range, the relationship between supply and demand for water, where demand is expected to be greater than supply, is exacerbated by growing regional populations and land use change. Climate impacts upon the supply side of this relationship are also a major concern for the region as they are reliant upon snow melt for water supply. In the Mid-Atlantic, water quality concerns, particularly relating to Chesapeake Bay and the ability to meet total maximum daily load (TMDL) regulations, were greatest, and aging infrastructure and stormwater management were tied for the next most often described challenges.

Education & Outreach

UWIN engaged stakeholders in Los Angeles, San Francisco, and New York City to expand the network to other cities and regions across the U.S. As a result, a strong working relationship has been established with city water practitioners, managers and policy makers in these regions.

Expanding upon previous stakeholder engagement activities, UWIN held a 1/2 day workshop with the City of Los Angeles One Water LA group to discuss collaborative efforts and priority research needs for the region. UWIN held a 1/2 day workshop with the City of New Work water managers to discuss collaborative efforts and priority research needs for the region.

UWIN team members participated in numerous stakeholder meetings and research conferences to promote integrated water management and increase understanding of One Water technological, policy, and financial pathways. The following education and outreach activities were accomplished in Year Two:

- Increased the capacity of UWIN researchers for collaborative research via regional team science training activities
- Initiated weekly research webinar series, sessions are available on the UWIN YouTube channel (see products)
- Developed project cards and 2-page overview for use at stakeholder meetings, trainings and outreach events (see products)
- Created public product library of UWIN-related research publications (see products)

Undergraduate Research Program (URP)

UWIN provided the second Undergraduate Research Program (URP) for the summer of 2017. 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 2017 UWIN URP program engages students in three strands of activities:

- **Cutting Edge Independent Research Projects:** Working closely with mentor scientists, students delineate a research question and hypotheses, develop and implement a project, analyze data, give a poster presentation at the UWIN full-network annual meeting, and write a research report. Students are also encouraged to produce a research paper for publication in a peer reviewed journal and to present their results at a national conference.
- **Reflective Practice and Training Activities:** Skill building workshops and seminars support student learning. Students participate in in-person and virtual sessions in scientific writing, transdisciplinary science, ethics in sustainability, strategies for effective communication, and future options in study and work.
- **Transdisciplinary Research Activities in Urban Water Sustainability:** Students explore how to promote sustainable management of urban water systems by working with a team of disciplinary experts. They are encouraged to look beyond their own discipline as well. Students participate in workshops and seminars led by experts from different fields. A Forum on Opportunities in Urban Water Sustainability Research and Applications will showcase examples of natural science, engineering, and social science in action.

The 2017 URP projects are:

- Project 1- Variation in Vegetation's Influence on Urban Climate. Darrel Jenerette (University of California Riverside) and Thomas Meixner (University of Arizona)
- Project 2- Evaluating Options for Management of Urban Flood Hazards. Andrew Miller (University of Maryland Baltimore County)
- Project 3- Water Resources and Heat Emergencies. David M. Hondula (Arizona State University)
- Project 4- Natural Solutions for Urban Watershed Sustainability. Jennifer Cherrier and Brianne Smith (Brooklyn College of the City University of New York
- Project 5- Visualizing Urban Water Sustainability Indicators within a Video Game for Collecting Water Management Ideas from Gamers. Mazdak Arabi and Andre Dozier (Colorado State University)
- Project 6- Water Affordability Case Studies. Elizabeth Mack (Michigan State University)
- Project 7- Transitions to Socially Equitable and Environmentally Just Sustainable Urban Water Systems. Sharon Harlan (Northeastern University)

- Project 8- Characterizing the Urban Energy Water Nexus through Modeling and Data Analysis. Forrest Meggers (Princeton University), Sybil Sharvelle (Colorado State University) and Elie Bou-Zeid (Princeton University)
- Project 9- System-of-Systems Analysis of Water Infrastructure Resilience under Climate Change Impacts. Ali Mostafavi (Texas A&M)

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 affinity groups include:

- A city water-energy nexus affinity group was formed to discuss topics related to the linkages between water and energy at building to municipal scales, and win-win solutions for energy and water conservation, resource recovery and reuse. The group is considering: 1) further study of the cascade of thermal energy available from wastewater and also the relationship to biogas production; and 2) studying the relationship of local climate to water emissions and consumptive use in the city as well as local thermal exchanges with people and thermal stress impacts.
- The Green Infrastructure affinity group was formed to discuss the co-benefits and dis-benefits of GIs.
- 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. Initiatives under consideration include: 1) A protocol to quantify the sustainability of a school or home water budget; 2) Water quality comparisons across space and trends over time and interpreted through a curriculum module; 3) Roof runoff water quality characterization; 4) Microclimates, temperature and vegetation; 5) Green infrastructure; and 6) Water gaming projects.

Program Evaluation

UWIN external education evaluator Dr. Shirley Vincent conducted a thorough evaluation of UWIN education, outreach, and engagement activities. The evaluations were submitted to the UWIN management team for improvement of network education and broadening participation activities.

For example, in a report titled “UWIN Professional Development: Team Science Adaptive Management Skills, Year One Evaluation Report, August 2015 - December 2016”, Dr. Vincent described the outcomes of the training efforts in detail. Some highlights are given here:

- The majority of workshop participants reported that the workshop experience influenced their thinking about participating in and managing interdisciplinary and transdisciplinary research projects.
- Forty-two individuals completed the training. Attendees were 50% graduate students, 38% research principal investigators, 10% institute and program staff, and 2% postdoctoral researchers.
- The participants are diverse in terms of areas of research/scholarship: 38% engineering, 30% physical sciences, 14% interdisciplinary (i.e. environmental science, sustainability), 11% social sciences and less than 3% each for life sciences, natural resources, and computer and mathematical sciences. The cohort was 62% male, 78% white and 70% US born. Compared with national graduate student

demographic data reported by NSF, the UWIN graduate student participant demographics had more diversity in race/ethnicity.

TRAINING & PROFESSIONAL DEVELOPMENT

Undergraduate Students

The entire Undergraduate Research Program is geared toward the professional development and training of undergraduate students. The program leaders provide professional development and support the UWIN URP mentors on an ongoing basis. Ten undergraduate students participated in the 2016 summer URP and were supported through this project. One 2016 URP student, Mary Plauche (Georgia College and State University), is currently applying for graduate school and a NSF fellowship to support her graduate studies. An additional ten undergraduate students have been selected to participate in the 2017 summer URP.

Five additional undergraduate students are involved in UWIN-related research activities outside the URP.

Graduate Students

Over 40 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. Examples of graduate student activities include:

- Three graduate students obtained training and experience in designing and executing a study protocol that assesses urban biodiversity and its connection to urban hydrology and ecosystem services.
- One PhD UWIN-supported student contributed to the study on dual water supply systems in the City of Fort Collins, CO and development of a framework to support integrated urban water management. This student has gained knowledge on urban water systems and has developed capacity for decision support, including development of a framework to support decisions for urban water systems. The student has been able to successfully integrate knowledge from the social sciences with decision making in engineering, gaining important skills to be successful in the 21st century job market.
- In Academic Year 2016-2017, four Northeastern Sociology PhD students, one Population Health PhD student, and one Sociology MA student worked in Harlan's lab on planning and developing the interview study. These students are part of the Social Science Environmental Health Research Institute and also involved in UWIN-related research activities.
- We are training graduate students on the software and the technology in order to conduct UWIN-related experiments. In addition, we are connecting graduate students across projects who might be conducting similar projects to expand the breadth and scope of what they are learning through participation in UWIN research.
- Yoganand Korgaonkar participated in a summer training workshop held on July 11-29, 2016 at the University of Texas at El Paso. The National Science Foundation-funded Employing Model-Based Reasoning in Socio-Environmental Synthesis (EMBeRS) project hosted ten PhD students from diverse disciplines to participate in two weeks of specialized training on conducting interdisciplinary research in teams.

- In November 2016, Gina Lee (UMBC) and Tim Stephens (University of Georgia) participated in a training workshop in downtown Baltimore for users of the 2d version of HECRAS. The information conveyed in the workshop will assist both PhD students in developing hydraulic models for flood simulation in their respective urban watersheds.
- A PhD research assistant attended the 2017 UWIN regional engagement meeting and Team Science Training as well as a Political Networks descriptive and inferential workshop.
- Research assistant Maria Wright participated in a hydrologic modeling course, including completion of a project on use of SWMM5.

Postdoctoral Scholars

The hiring of Dr. Scott Krayenhoff has allowed for significant opportunities for training and professional development vis-à-vis one-on-one mentorship through PI Georgescu. The overarching goal is to foster an environment in which Dr. Krayenhoff continues to evolve as (1) a creative and productive scholar, (2) assumes the role of a qualified and desirable contributor to and leader of interdisciplinary research teams, (3) continues his development as an effective written and oral communicator, (4) assumes status as an inspiring mentor to undergraduate and graduate students, (5) and attains experience as a skilled developer of research grants and proposals.

Dr. Jiachuan Yang was hired and started as Postdoctoral Scholar (PDS) at Princeton working full time on this project in January 2017. PDS Maider Llaguno-Munitxa started at Princeton in April 2017; while she is not supported by the project, her work is related to urban data visualization and will interact with the project significantly. All these participants are advancing their education and scientific training in urban science through their work on the project.

Dr. Alex Maas was hired as a postdoctoral research associate at Colorado State University to evaluate financial models/pathways for integration of urban water systems. He has been closely involved with the UWIN Summer URP.

Professional Development

Explicit half-day adaptive management/team science/leadership training sessions have been deployed in each region where a stakeholder meeting has been held. These opportunities have been made available to researchers including faculty, post-doctoral associates, and graduate students. Researchers from other NSF-funded projects such as WSC have been invited to join as well when space is available.

We also formed a “Whole Watershed Model” workgroup (led by Conklin and Wright) in an effort to expand capacity among the team to run U-envision and develop collaborations with other Envision related research projects. Team members (Harrison, Wright, Conklin, Fulfrost, Dalrymple, and Santelmann) have participated in this group along with several graduate students and researchers from Portland State University (Alex Nagel and Dan Larson) and Colorado State University (Tyler Dell).

DISSEMINATION OF RESULTS

UWIN conducted six regional stakeholder engagement meetings in Miami, Phoenix, Baltimore, Portland, Denver, and New York City. These meetings facilitated interactions amongst UWIN researchers in the regions as well as key water stockholders with deep knowledge of regional water challenges, success stories, and solutions.

UWIN participated in the Water Now Alliance meeting in April 2017 to get feedback from water managers, planners, and policy makers, and also promote integrated water management and One Water approaches.

UWIN broadly disseminated the results and products via peer reviewed journal publications, conference proceedings and presentations at international conferences, and invited lectures by various members of the team. Moreover, the project website is continuously updated with new materials and information that can be consumed by the Network audiences. Please see the list of reported products for more information.

Dr. Arabi presented the UWIN Urban Water Sustainability Blueprint and One Water purpose, principles, and pathways at numerous professional meetings, including Water Alliance 2017 Summit and AGU Fall meeting. The UWIN management team coordinated and presented webinars on the Water Connect App and other tools developed by the UWIN team members. Weekly online research seminars were held that are open to the broader urban water research community.

Several media outlets, including USA Today and PBS, extensively covered the content of the water affordability study by Dr. Mack.

Dr. Georgescu served as Panelist for a Monthly Water Climate Briefing at the invitation of ASU's Decision Center for a Desert City (DCDC). The panel discussion was moderated by DCDC's Director Dave White and dialogue centered on biophysical aspects of regional hydroclimate effects associated with urban expansion. The full video of the panel discussion is available at: https://vimeo.com/145519301

Dr. Georgescu appeared on the Arizona PBS TV Show named Arizona Horizon, hosted by Ted Simons, on August 18, 2015, to discuss the U-WIN consortium of 14 academic institutions focused on characterizing and increasing resilience of water systems. The show aired live but may also be viewed from the PBS archive from the following: http://www.azpbs.org/arizonahorizon/detailvid.php?id=15676

Dr. Bou-Zeid gave invited oral presentations on this work at the University of Perugia in Italy, at Brookhaven National Lab, and at a Symposium on Regional Air Quality Monitoring in New York City. He also participated in a panel at the Princeton club in New York on the topic of resilient and sustainable cities. PI Bou-Zeid also gave a talk in the lecture series "Science on Saturday" at the Princeton Plasma Physics Lab, a series targeting a broad audience with a particular focus on high school students. The video is available at http://www.pppl.gov/events/science-saturday-cities-21st-century-nexus-climate-water-and-energy-challenges

PhD student Hamidreza Omidvar and Elie Bou-Zeid gave 2 talks on the project work at the Annual Meeting of the American Meteorological Society in Seattle in January of 2017.

PhD student Mahdad Talebpour and Dr. Claire Welty (with Elie Bou-Zeid as a co-author) gave a poster presentation of the conceptual model for coupling of ParFlow and WRF for urban domains at the 2016 Fall meeting of the American Geophysical Union.

The UWIN team working on Green Infrastructure and flood control topics maintains regular communication with local governments, NGOs, and other stakeholders. Dr. Meixner made a presentation to the 2017 One Water Summit (organized by the US Water Alliance) in New Orleans regarding the use of GI to enable better utilization of storm water in the region.

Drs. Mack and Harlan organized a session on Social Equity, Environmental Justice and Urban Water Systems (#4455) at the Annual Meeting of the American Geographers Association in Boston, April 5-9, 2017.

A packet of case-studies from WRF, WERF, and the EPA was compiled and sent to stakeholders in the Sun Corridor Region. Our survey is meant to elicit input from stakeholders, but it also provides some material and will foster thought about financing integrated water management.

The results of UWIN stakeholder engagement meetings in the form of preliminary summaries of findings in each region are available on the project website. A manuscript is ready for submission.

Dr. Berkowitz disseminated preliminary results of the URP through the NSF Biology REU Site Directors' network (meeting in Arlington, VA May 2017), the Ecological Society of America, and a newly funded RCN-UBE looking at the outcomes of immersive field-based research programs.

FUTURE PLANS (Year-3)

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

- Revise municipal water demand estimates from county-level to block group level for the CONUS
- Improve climate change data for water supply assessment via collaborations with Project A2-2
- Improve water shortage vulnerability assessments for the CONUS and top 100 most populated cities in the U.S.

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

- Collect past water prices from individual providers in all UWIN regions
- Develop a water demand index and assess economic impacts from water price increases

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

- Integrate "offline" improvements in urban modeling into WRF-UCM, test the improved model
- Investigate the thermal dynamics of runoff for urban surfaces and identify best ways to represent these processes in coarse models
- Apply the new WRF-UCM model for a wide range of scenario analysis including urban expansion, xeric versus mesic landscaping, regional tree and shading effects
- Develop ParFlow models to study integrated urban hydrological processes under varying development patterns

A2-2 Projecting future environmental change in urban areas

- Analyze simulation results from modeling studies on interactive effect of increased emissions of greenhouse gases (GHGs) and anthropogenic landscape change associated with urban expansion for the CONUS
- Conduct high resolution simulations (1-2km) to assess locally deployed urban adaptation and mitigation solutions for the six study regions using the NCAR Yellowstone supercomputer

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

- Complete literature review regarding urban water use and thermal comfort
- Implement the iButton temperature sensor network in Phoenix along with complementary thermal and visible imaging
- Analyze household interviews related to water use during heatwave power failure scenarios
- Extract subset of pedestrian travel data from MAG activity data for thermal assessment
- Conduct practitioner interviews on water use during emergency scenarios

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

- Expand data collection on urban form and systems in NYC
- Develop new tools to improve characterizations of energy-water relationships
- Use the analysis framework for the mean radiant temperature in urban spaces to demonstrate potential effects on the level of thermal stress felt by urban dwellers
- Examine the relationship of thermal stress with the availability of green and blue infrastructure

A3-1 Variation in urban vegetation biodiversity-ecosystem functioning

- Finalize the deployment plan for air temperature sensor networks across UWIN regions
- Engage with citizen scientists in air temperature sensor networks

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

- Calibrate the IUWM model to investigate multiple scenarios of water conservation and reuse, land use change, population growth and climate change
- Develop and evaluate urban water sustainability metrics related to urban water demand management strategies
- Conduct uncertainty analysis to assess the importance of performance metrics and stakeholder preferences on appropriate infrastructure options
- Assess the resilience of urban water infrastructure systems under chronic and acute stressors such as population change, aging infrastructure, and funding constraints
- Corroborate the results of resilience assessment via data collection from Subject Matter Experts
- Conduct the resilience assessment study in other UWIN cities (upon the availability of data)

B1-2 Lifecycle assessment of urban water systems

- Analyze the baseline operational energy and GHG effects of urban water systems
- Continue developing the scope for collaborative research among ReNUWIt ERC and UWIN teams

B2-1 Effects of green infrastructure on urban systems

- Continue working with local stakeholders, collecting monitoring data and complete modeling of several Tucson watersheds

B2-2A Flood hydrology and rainfall frequency

- Continue with data set development tasks, hydroclimatology studies and development of hydrologic models for urban flooding.

B2-2B Hydrology and hydraulics of urban floodplains

- Develop 1-D and 2-D hydraulic models in multiple UWIN regions
- Enhance Monte-Carlo simulations with the 1-D hydraulic models to improve representation of spatial heterogeneity of roughness, variability in river discharge, and channel change
- Explore various methods of generating and depicting probabilistic floodplain maps
- Collaborate with C3-1 to develop a household survey regarding water risk and incorporate the results of the survey into mapping flood hazards

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

- Investigate risks to riverine and coastal flooding for UWIN cities and other major regions across the U.S. using the assessment framework developed during the previous reporting period
- Develop a methodology to forecast changes in riverine flood frequency under future climate change scenarios

C1-1 Understanding adoption of sustainable urban water solutions

- Pilot survey with LWOs in one municipality, code the results to develop a larger snowball sample for surrounding municipalities
- Revise survey based on pilot results and implement in one UWIN study area (Sun Corridor, Arizona)
- Compile complete sample frame for all UWIN regions, to be used for survey implementation in the following project period

C2-1 Homeowner adoption of sustainable urban water solutions

- Conduct the first ChoiceFlow consumer behavior experiment, which will include surveys evaluating likelihood of adoption and willingness to pay for graywater infrastructure at the homeowner scale across the UWIN case study sites
- Make decisions and prepare materials for the next round of experiments to be conducted using Choiceflow

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

- Conduct interviews with community organizations in the UWIN study regions
- Deploy the household survey
- Submit paper on systematic literature review of environmental justice issues related to urban water systems

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

- Conduct a survey of financial officers and management staff in water service organizations
- Categorize drivers, obstacles and results of case studies

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

- Represent the "current course" scenario developed by our stakeholder group, and focus on modeling water budget and indicators related to stormwater runoff and sewer performance
- Engage with regional stakeholders to define assumptions for the Current Course future scenario including implementation of green infrastructure and graywater reuse
- Begin adaptation of the EPANET model for implementation in U-envision and by CSU as a web service

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

- Evaluate the effects of alternative urban water demand management strategies, including graywater, stormwater, wastewater, and indoor/outdoor conservation at city block group level for the CONUS
- Evaluate the effects of alternative urban water demand management strategies under future climate, land use, and population scenarios in UWIN regions
- Evaluate decadal changes in flood frequency, drought frequency and water quality along urban streams in UWIN regions

D1-3 Urban water decision innovation system

- Complete urban water data services for UWIN regions and major cities in the CONUS
- Publish the first draft of UWIN Urban Water Sustainability Blueprint as a wiki

Stakeholders & Training

- Re-evaluate engagement goals and processes to focus more closely on the development of the project's blueprint/roadmap
- Engage strategic partners in the US Water Alliance, Water Now Alliance, and The Nature Conservancy

URP

- Offer the URP in 2017 for 10 students, each working at a different UWIN institution

COLLABORATORS & PARTNERS

Partners

Name	Organization Type	Location
Arizona Department of Health Services	State or Local Government	Phoenix, AZ
Arizona State University	Academic Institution	Tempe, AR
Arizona State University (UREx SRN, UAHS, 3HEAT)	Academic Institution	Tempe, AZ
Cary Institute of Ecosystem Studies	Other Nonprofits	Millbrook, NY
Chattahoochee River Keeper	Other Nonprofits	Charity, GA
City of Atlanta Watershed Management	Academic Institution	Atlanta, GA
City of Phoenix	State or Local Government	Phoenix, AZ
Decision Center for a Desert City (DCDC, phase III)	Academic Institution	Tempe, AZ
Earthwatch Institute	Other Nonprofits	Boston, MA
Florida International University	Academic Institution	Miami, FL
Howard University	Academic Institution	Washington, DC
Kounkuey Design Initiative	Other Nonprofits	Los Angeles, CA
Lanier Consulting, LLC	Industrial or Commercial Firms	Miami, FL
Maricopa County Department of Public Health	State or Local Government	Phoenix, AZ
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
The Nature Conservancy	Other Nonprofits	Phoenix, AZ
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 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

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, PhD, Frank Blanco, Jim DuBois, Kathy Chavez, Jeanne Jensen, Aminata Kilungo, Mark Hartman, Mark Holmes,Mead Mier, 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

Undergraduate Research Program

Dr. Geoffrey Habron, Warren Wilson College, Asheville, NC; 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.

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, Assistant Professor (Madison, WI).

IMPACTS

Principal Discipline(s)

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

- This project advances fundamental knowledge and methodology for characterization of vulnerability and resilience indicators under deep uncertainty.

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

- The project will develop the most complete framework to date that will simultaneously model the urban water cycle and demand, the urban climate, urban energy use, and how these three aspects are coupled.

A2-2 Projecting future environmental change in urban areas

- Effects of urban expansion under future climate differ from those under present climate, leading to a small interaction effect. Uniform application of heat mitigation implementations under projected future climates have similar qualitative impacts to those under present climates, but differ quantitatively. Our efforts are the first to robustly quantify these effects, which help assess the degree of urban warming over the coming century in CONUS as well as the efficacy of common heat mitigation strategies and the magnitude of their unintended consequences (e.g., on precipitation) under future climates.

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

- Project impacts are beginning to be realized. We are anticipating methodological advances for environmental health and health geography, and have included these perspectives in a manuscript in press at Environmental Health Perspectives related to measurement strategies for personal heat exposure. 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.

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

- We are expanding the field of research to academics working in the energy water nexus, both in the area of climate and latent heat transfer related disciplines as well as in the field of water infrastructure considerations of waste heat and energy generation.

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

- This project advances the science of urban water sustainability and resilience through the following avenues: (i) understanding the dynamic behaviors and interactions that shape the resilience landscape of water infrastructure; (2) identifying innovative technological, infrastructure, and planning solutions and policies that potentially enhance the resilience trajectories of urban water infrastructure; and (3) exploring the fundamental characteristics of resilient water infrastructure.

B2-2B Hydrology and hydraulics of urban floodplains

- Floodplain management programs in the US are widely regarded as being "broken." This project will 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 US floodplain management programs.

C1-1 Understanding adoption of sustainable urban water solutions

- Training future scholars in Government and Public Policy

C2-1 Homeowner adoption of sustainable urban water solutions

- The project develops a new method that allows for simultaneous education and inquiry about adoption of new technologies. This method allows us to collect new information about individual preference and information seeking behaviors around water technologies.

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

- This project is adapting Envision, an alternative futures modeling framework developed at OSU, to model a 'common core' set of urban water system phenomena. U-envision will perform spatially and temporally explicit simulations of future urban water resource use within the context of co-evolving population, climate, land use, and governance. The project will advance hydrologic modeling by developing new U-envision "plugin" models related specifically to the urban water system, including "lite" versions of popular software for modeling storm and wastewater networks (SWMM) and water distribution piping systems (EPA-NET).

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

- The project develops methods for cross-site learning via bottom-up and top-down mathematical optimizations techniques. A compute game is developed to enable data collection for bottom-up optimization. The combination of the two approaches enables identification of biases in decision making by machine learning, human biases, and demographics.

D1-3 Urban water decision innovation system

- Numerous technological advancements in commuting are made to enable computational scalability of data and modeling services for climatic, hydrological, and water quality assessments.

URP

- Most students and mentors reported that the students' research contributed to the scientific program of scientists. Some broke new ground, some developed new methods and study designs, others brought in new data and insights. We are hoping that students' projects will contribute to new proposals, new lines of inquiry and peer review publications. Beyond this, we would like to encourage students to present their results at their home institutions and at regional and national meetings.

Other Disciplines

UWIN brings together perspectives and resources from 16 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 group 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.

Human Resources

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

Physical Resources

The project contributes to the environmental Resources Assessment and Management System (eRAMS) cloud computing infrastructure at Colorado State University.

Institutional Resources

The project contributes to the One Water Solutions Institute at Colorado State University.

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 app 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 will result in several patent applications, copyrights disclosures, and technology transfers over the next 3 years.

Impact on Society Beyond Science & Technology

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, would 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.

Over the five year project period, UWIN will engage more than 25 PhD students, 5 postdoctoral research associates, and several early career scientists from diverse backgrounds in research, outreach, education, and broadening participation of network activities. The Network will provide research opportunities for 50 undergraduates with diverse backgrounds via a creative interdisciplinary undergraduate research program.

CHANGES & ANTICIPATED PROBLEMS

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

- One of the students working on the project had medical issues this semester which reduced the number of person hours worked on the project. Once the person recovers, they are expected to return to full person hours.

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

- PI Bou-Zeid intended to hire a postdoc in the summer of 2016, but the candidate he selected and who is outstanding for the job will not finish his Ph.D. and be able to start his postdoc until after January 1 , 2017.

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

- Through a related project (NSF Hazards-SEES) we have discovered a new interesting thread of research related to water supply/access during power failures and heat emergencies, and intend to allocate resources to analyze data collected from that project with a focus on water issues.
- Ariane Middel is departing Arizona State University in summer 2017 to take a tenure-track position at Temple University; collaboration is expected to continue as planned. Dr. Middel's new location and proximity to other UWIN cities offers the opportunity for more cross-city comparative analysis.

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

- Adding more consideration for potential of heat and thermal energy available from wastewater after investigations and collaborations developed during summer URP program, which was not explicitly mentioned in initial project plan, but related to energy recovery opportunities for buildings and communities.

C2-1 Homeowner adoption of sustainable urban water solutions

- The population of the experiment is taking a bit longer than anticipated to coordinate, however most of the videos, interviews, and articles needed to conduct our first experiment have been created/collected and we expect no further delays.

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

- One of the students working on the project had medical issues this semester which reduced the number of person hours worked on the project. Once the person recovers, they are expected to return to full person hours.

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

- Our project is tightly linked with project D1-2, which is developing methods and algorithms to calculate water sustainability indicators for different UWIN regions. Their approach includes development of "virtual" networks representing wastewater and stormwater networks that can be used on eRAMS with SWMM to explore benefits of the adoption of green infrastructure. Project plans include the use of these virtual networks from CSU in our modeling with U-envision, delays in receiving the virtual network input files at CSU could delay progress in our modelling of the alternative future scenarios. We plan to work closely with CSU to facilitate the delivery of the products we need for U-envision model development. Communications and ongoing discussions with CSU project members of modelling using U-envision and SWMM (through the Whole Watershed Modelling group) is one action we are taking to help avoid this problem. As an interim "work-around" we are also using actual input files for SWMM obtained from Portland Bureau of Environmental Services to test performance of SWMM-lite within U-envision.

Stakeholder Engagement

- The project's original plan for tripling the size of each regional stakeholder group by soliciting 3 suggested new participants from each original participant was misguided and failed to produce the originally desired number of new participants. However, subsequent experience with smaller groups has indicated that the desired results can be obtained – perhaps even more readily – in the smaller group format.

PRODUCTS

Books/Book Chapters

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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.

Journal Papers

Aliabadi, A.A., E.S. Krayenhoff, N. Nazarian, P.R. Armstrong, A. Afshari, and L.K. Norford. Effects of roof edge roughness on air temperature and pollutant concentration in urban canyons. Boundary-Layer Meteorology doi:10.1007/s10546-017-0246-1 . Status = Published; Acknowledgment of Federal Support = Yes; Peer Reviewed = Yes.

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.

Cao, Q., D. Yu, M. Georgescu, J. Wu (2016), Impacts of urbanization on summer climate in China: An assessment with coupled land-atmospheric modeling, J. Geophys. Res. Atmos, doi: 10.1002/2016JD025210, 121(18), 10,505-10,521. http://onlinelibrary.wiley.com/doi/10.1002/2016JD025210/full Status = Published; Acknowledgment of Federal Support = Yes; Peer Reviewed = Yes.

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Shim, S., Shin, S., Meggers, F., Bou-Zeid, E., & Stone, H. A. (2016). Controlled evaporative cooling on a superhydrophilic surface: building a green wall. In Bulletin of the American Physical Society (Vol. 61–20). Portland, Oregon. Retrieved from http://meetings.aps.org/Meeting/DFD16/Session/R2.6 Status = Published; Acknowledgment of Federal Support = No; Peer Reviewed = Yes

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residential neighborhood of Phoenix, Arizona, Journal of Geophysical Research: Atmospheres, 122:3317-3329. Status = Published; Acknowledgment of Federal Support = Yes; Peer Reviewed = Yes.

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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.

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Bell, Emily, Adam Henry, and Gary Pivo. “Measuring Beliefs through Coordination Networks in Urban Water

Governance” at the Political Networks Conference, June 2017

Bell, Emily, Adam Henry, and Gary Pivo. “Measuring Belief Systems in Urban Water Governance" at the Midwest Political Science Association, April 2017

Bou-Zeid, E. (2016) “Cities in the 21st century: the nexus of the climate, water and energy challenges”, University of Perugia.

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

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.

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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

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

Li, Q. And Bou-Zeid E. (2016), Contrasts Between Momentum and Scalar Exchanges Over Very Rough Surfaces, Bulletin of the American Physical Society, 61. Status = published, Acknowledgement of Federal Support = Yes, Peer Reviewed = No

Li Q., Bou-Zeid E., and Grimmond S. (2017) “On the Momentum and Scalar Roughness Lengths of Urban Surfaces”, 97th American Meteorological Society Annual Meeting, Seattle , WA.

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Stuhlmacher, M., C. Wang, M. Georgescu, B. Tellman, R. Balling, N. E. Clinton, L. Collins, R. Goldblatt, G. Hansen: Toward a 30m resolution time series of historical global urban expansion: exploring variation in North American cities. Session: Urban Areas and Global Change II, AGU Fall Meeting, 12-16 December 2016, San Francisco. Status = complete; Acknowledgement of Federal Support = Yes

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Teitelbaum, E., Meggers, F., Scherer, G., Ramamurthy, P., Wang, L., & Bou-Zeid, E. (2015). ECCENTRIC Buildings: Evaporative Cooling in Constructed ENvelopes by Transmission and Retention Inside Casings of Buildings. In 6th International Building Physics Conference, IBPC 2015. Torino, Italy: Elsevier. Published; Acknowledgment of Federal Support = No; Peer Reviewed = Yes

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Wang, Z.H. (2016) "Urban green infrastructure: Modeling and Implications to sustainable development of cities". Nanyang Technological University, Singapore, 02 June 2016. Status = published, Acknowledgement of Federal Support = Yes, Peer Reviewed = No

Wrase, S. and E. Mack. (2017) Underground and Overlooked: America's Wastewater Infrastructure Crisis. Michigan State University Undergraduate Research and Arts Forum (UURAF). Acknowledgement of Federal Support=No

Patents

Provisional Patent filed for Spherical Motion Average Radiant Temperature (SMART) Sensor

Provisional Patent filed for membrane desiccant dehumidification system

Thesis/Dissertations

Jiachuan Yang (2016) "Urban Green Infrastructure: Modeling and Implications to Environmental Sustainability", Arizona State University

Qi Li (2016) "Scalar and Momentum transport over Complex Surfaces" Princeton University

Technologies or Techniques

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.

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.
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.

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

Domain: www.erams.com/iuwm
www.erams.com/documentation/iuwm

D1-1: The Freshwater Simulations group of the project team developed a version of SWMM 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 U-envision, 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 is a whole watershed model (WWM) – it attempts to represent, in a temporally and spatially explicit way, all the processes which significantly affect the supply and demand for water within an entire watershed, in this case the Willamette River basin (WRB) in western Oregon. In addition, the U-envision model will explicitly represent portions of the piped water networks within the WRB's two largest metropolitan areas, Portland and Eugene-Springfield. 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 use sustainability indicators to evaluate the ability of future water systems to meet desired functions and, in the case of U-envision, help compare and evaluate outcomes for different futures scenarios.

Websites

Integrated Urban Water Model (IUWM) – Documentation: https://erams.com/documentation/iuwm/

Integrated Urban Water Model (IUWM): https://erams.com/iuwm

UWIN Listserv: https://lists.colostate.edu/cgi-bin/mailman/listinfo/uwin-network

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

UWIN YouTube Channel: https://www.youtube.com/channel/UC7nNrIUznXii6_u0axbhQrA

UWIN Zotero Publication Database:
https://www.zotero.org/groups/urban_water_innovation_network_uwin/items

Other Products

Project cards: 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 Overviews: 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.

A1-2: Special Issue of Region Magazine from the Regional Studies Association about Urban Infrastructure. This issue contains 5 articles from the UWIN project, currently in review.

A2-1: Bou-Zeid, E. (2016) "Cities in the 21st century: the nexus of the climate, water and energy challenges", University of Perugia, Talk.

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, Talk.

A2-3: Forthcoming article in Regions Magazine special UWIN supplement organized by Liz Mack; citation details TBA. Publication expected in summer 2017. Co-authors Hondula, Middel, Vanos, Kaiser, Herdt STATUS = Awaiting publication; Acknowledgement = YES; Peer Reviewed = NO

C3-1: Mack and Harlan organized a session on Social Equity, Environmental Justice and Urban Water Systems (#4455) at the Annual Meeting of the American Geographers Association in Boston, April 5-9, 2017. Status = Not published; Acknowledgment of Federal Support = Yes; Peer Reviewed = No. Student presentations from C3-1:

- Kyle Redican, Socio-Economic Impacts of Water Pricing using Scenario Based Modeling
- Stephanie Clark, Sharon Harlan, Elizabeth Mack, Systematic Review of Peer-Reviewed Literature on Urban Water Pressures and Environmental Justice in the United States
- Mariana Sarango, Exposure to Flood Hazards by Race & Ethnicity in Boston, MA

Appendix A: Project Table

Project	Abbreviated Title	PI	Lead Institution	Project Webpage
A1-1	Water Scarcity, Supply Vulnerability & Resiliency	Jorge Ramirez	Colorado State University	https://erams.com/UWIN/a1-1
A1-2	Socioeconomics of Water	Elizabeth Mack	University of Michigan	https://erams.com/UWIN/a1-2-msu/
A2-1	Next Generation Urban Modeling	Elie Bou-Zeid	Princeton University	https://erams.com/UWIN/a2-1/
A2-2	Project Future Change in Urban Areas	Matei Georgescu	Arizona State University	https://erams.com/UWIN/a2-2/
A2-3	Thermal Comfort of Water-supported Infrastructure	Dave Hondula	Arizona State University	https://erams.com/UWIN/a2-3/
A2-4	Innovative Building Systems & Urban Infrastructure	Forrest Meggers	Princeton University	https://erams.com/UWIN/a2-4/
A3-1	Urban Vegetation Biodiversity & Ecosystem Functioning	Darrel Jenerette	University of Califorina - Riverside	https://erams.com/UWIN/a3-1/
B1-1a	Alternative Water Sources & IUWM	Sybil Sharvelle	Colorado State University	https://erams.com/UWIN/b1-1-csu/
B1-1b	Water Infrastructure Resilience	Ali Mostafavi	Texas A&M University	https://erams.com/UWIN/b1-1-tamu/
B1-2	Life-cycle Assessment of Urban Water Systems	Arpad Horvath	University of Califorina - Berkeley	https://erams.com/UWIN/b1-2/
B2-1	Impact of Green Infrastructure in Urban Systems	Tom Meixner	University of Arizona	https://erams.com/UWIN/b2-1/
B2-2a	Flood Hydrology and Rainfall Frequency	James A. Smith	Princeton University	https://erams.com/UWIN/b2-2a/
B2-2b	Hydrology and Hydraulics of Urban Floodplains	Brian Bledsoe	University of Georgia	https://erams.com/UWIN/b2-2b/
B3-1	Flood Risk to Assets and Socioeconomic Sectors	Mazdak Arabi	Colorado State University	https://erams.com/UWIN/b3-1/
C1-1	Adoption of Sustainable Water Solutions	Gary Pivo	University of Arizona	https://erams.com/UWIN/c1-1/
C2-1	Homeowner adoption of new technologies	Jessica Bolson	Florida International University	https://erams.com/UWIN/c2-1/
C3-1	Social Equity & Environmental Justice (SEEJ)	Sharon Harlan	Northeastern University	https://erams.com/UWIN/c3-1/
C4-1	Financial Challenge to the One Water Transition	Neil Grigg	Colorado State University	https://erams.com/UWIN/c4-1/
D1-1	UWIN Envision Modeling	Roy Haggerty	Oregon State University	https://erams.com/UWIN/d1-1/
D2-1	Cross-site Comparisons and Contrasts	Mazdak Arabi	Colorado State University	https://erams.com/UWIN/d1-2/
D3-1	Decision Innovation Systems	Mazdak Arabi	Colorado State University	https://erams.com/UWIN/d1-3/
E1-1	Undergraduate Research Program	Alan Berkowitz	Cary Institute of Ecosystem Studies	https://erams.com/UWIN/urp/
E2-1	Stakeholder Engagement Program	Mike Sukop	Florida International University	https://erams.com/UWIN/stakeholders/
E3-1	Team Science Skills	Alicia Lanier	Lanier Consulting	N/A
E4-1	Diversity Program	Kimberly Jones,	Howard University	N/A