Urban Water Innovation Network (UWIN)

Transitioning toward sustainable urban water systems

Research
Innovating technological and management solutions for integrated urban water systems

Education
Training champions of innovation for sustainable urban water systems and resilient cities

Engagement
Creating an agile network of researchers, educators and stakeholders to understand water challenges and solutions

Global water crises are the biggest threats facing the planet in the 21st century.

The vision of UWIN is to build an enduring research network that fosters innovation of integrated urban water solutions and trains champions of innovation.

To implement this vision, our mission is to: develop technologic and sociopolitical solutions; build social capital and trusted regional leadership in regions across the United Sates; and train scientists and policy makers as champions of innovation for urban sustainability.

UWIN is a consortium of several academic institutions along with key partners 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.

UWIN activities encompass six U.S. regions with varying eco-hydrologic and climatic regimes ranging from coastal moist mid-latitude climates of the Mid-Atlantic to the subtropical semi-arid deserts of the Southwest. These regions also represent a wide spectrum of demographic, cultural and policy settings. Such diversity enables cross-site assessments to explore locally appropriate sustainable technological, sociopolitical and management solutions across regions undergoing various development trajectories.

Urban Water Solutions

UWIN activities foster integrated management of urban water systems, where:

- The urban water cycle is considered a single integrated system
- All urban water flows are recognized as potential resources
- Effects on flooding, water quality, wetlands, watercourses, estuaries and coastal waters are recognized
- Co-benefits for other urban outcomes (e.g. livability and equity) are considered

Our research activities aim to create knowledge and increase fundamental understanding of challenges to urban water systems, and find solutions to enhance preparedness for responding to water crises in regions across the United States.

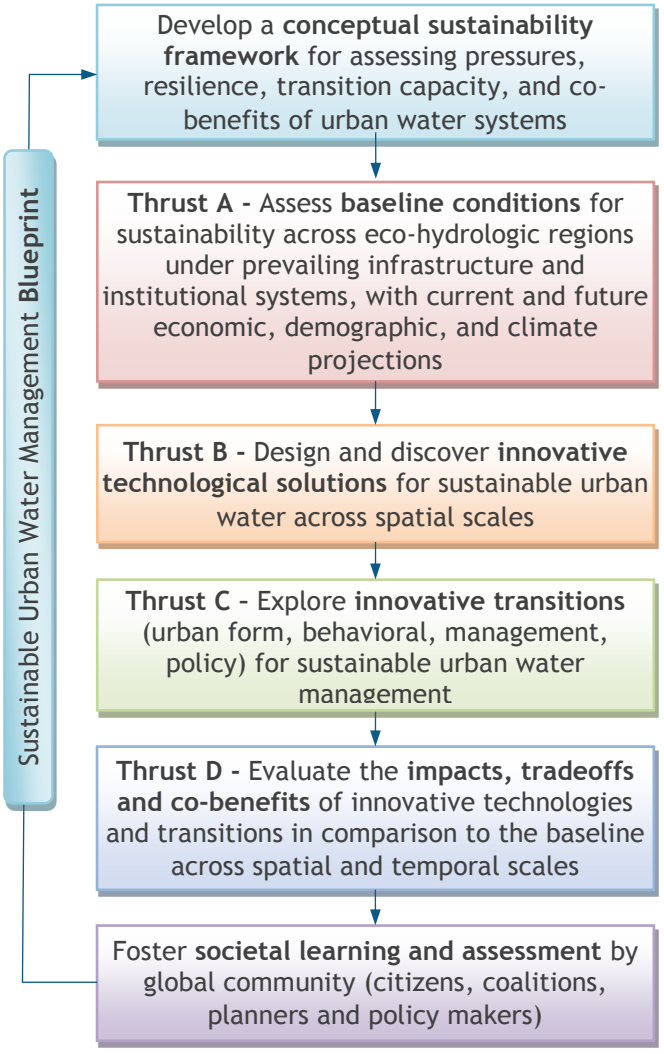
The UWIN research and engagement framework guides the development of an ambitious research agenda while ensuring flexibility in response to societal needs through stakeholder engagement and societal learning processes.

The first research thrust of UWIN (Thrust A) enhances fundamental knowledge of coupled physical and socioeconomic processes and feedbacks for baseline (observed past) and future (scenario-based) conditions that govern urban water systems. Assessments are conducted at spatial scales ranging from individual buildings to entire metro regions, focused on observed past (1950-current), mid-century (2040-2060) and end of century (2080-2100) periods.

This enhanced understanding guides design and discovery of alternative technological and management solutions that are economically feasible, socially viable, and environmentally effective (Thrust B).

Exploring pathways that facilitate transitions from current infrastructure and institutions to sustainable solutions is the focus of Thrust C.

A decision innovation dashboard is being developed under Thrust D activities that tracks and rates options for both top-down and bottom-up optimization of urban water systems via stakeholder engagement.



The goal of UWIN engagement is to better understand challenges that threaten urban water systems, perspectives on management of urban water systems, success stories, and solutions in a changing world.

Our engagement activities aim to understand challenges that confront urban water systems. These challenges are complex, nuanced, and dynamic, while influencing how elected officials and water service utility managers balance multiple, and often conflicting, perspectives on management of their urban water systems.

Because of complex interactions between the natural, built, social and economic environments coupled with changing climate patterns and the fragmented nature of governance, elected officials and managers rely on data analytics and models to navigate uncertainty as they search for feasible infrastructure solutions.

Understanding the complexity of the interactions between natural, built, and human systems is at the core of UWIN activities.

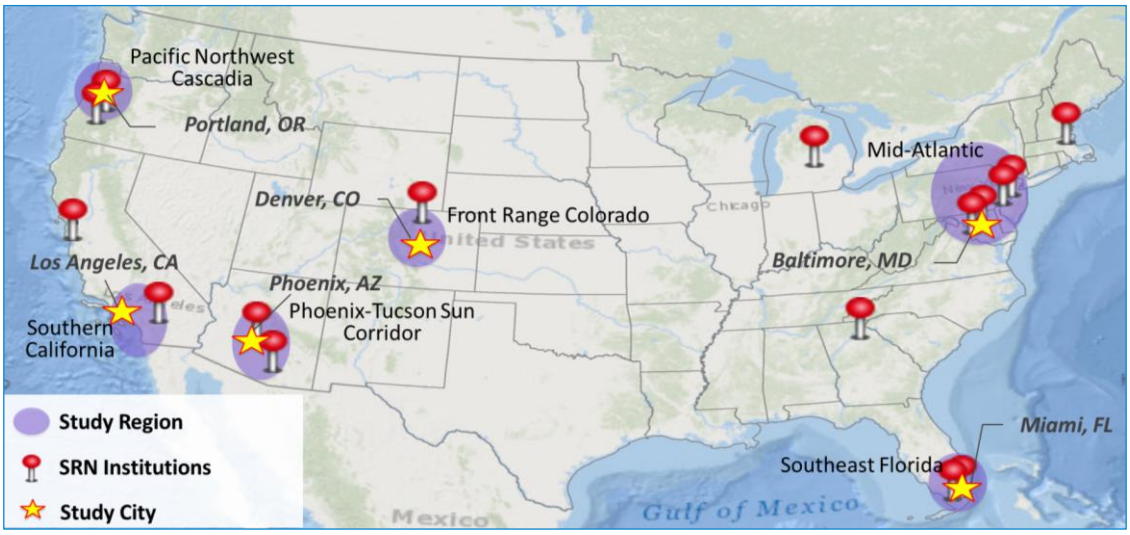
- Elicit active stakeholder contribution to research and outreach
- Build social capital through network development
- Build inter-regional connections and capacity for information exchange
- Create “safe spaces” for innovation
- Develop the Urban Water Sustainability Blueprint

Our interactions with the broader scientific and stakeholder community aim to:

- Understand realistic climate change scenarios and implications for urban water systems across the United States
- Identify risks to water quality
- Identify risks to water quantity
- Understand how contaminants form and travel through potable water distribution systems
- Understand flooding risk concerns
- Understand the implications of assumptions made in modeling scenarios including boundary conditions and factors of safety
- Analyze trade-offs among risks and the costs of avoided damages associated with flooding or water quality failures
- Integrate social, economic, and environmental considerations with technical analysis, including the financing of infrastructure
- Create scenarios to allow adaptable implementation of infrastructure design
- Enable tailored model development with site specific data to address concerns of communities across UWIN regions
- Address aging infrastructure conditions in light of the risk of failure, land use changes, or other conditions

UWIN Regions

The diversity of UWIN regions provides the opportunity to work across eco-hydrologic regions from Miami, Florida, with the world's highest value of assets exposed to sea level rise and coastal processes, to the Willamette region in Oregon where climate thresholds have already altered interconnected hydrologic, biogeochemical, and ecological processes. Inclusion of distinct eco-hydrologic regions gives national and international relevance to UWIN approaches and solutions. The same set of highly linked projects are conducted in each of the study regions to evaluate a consistent set of issues, hence allowing cross-site comparison. A similar degree of diversity in governmental approaches, demographics and other social metrics is evident across the regions, which fosters generalizable findings from our social research and learning agenda.



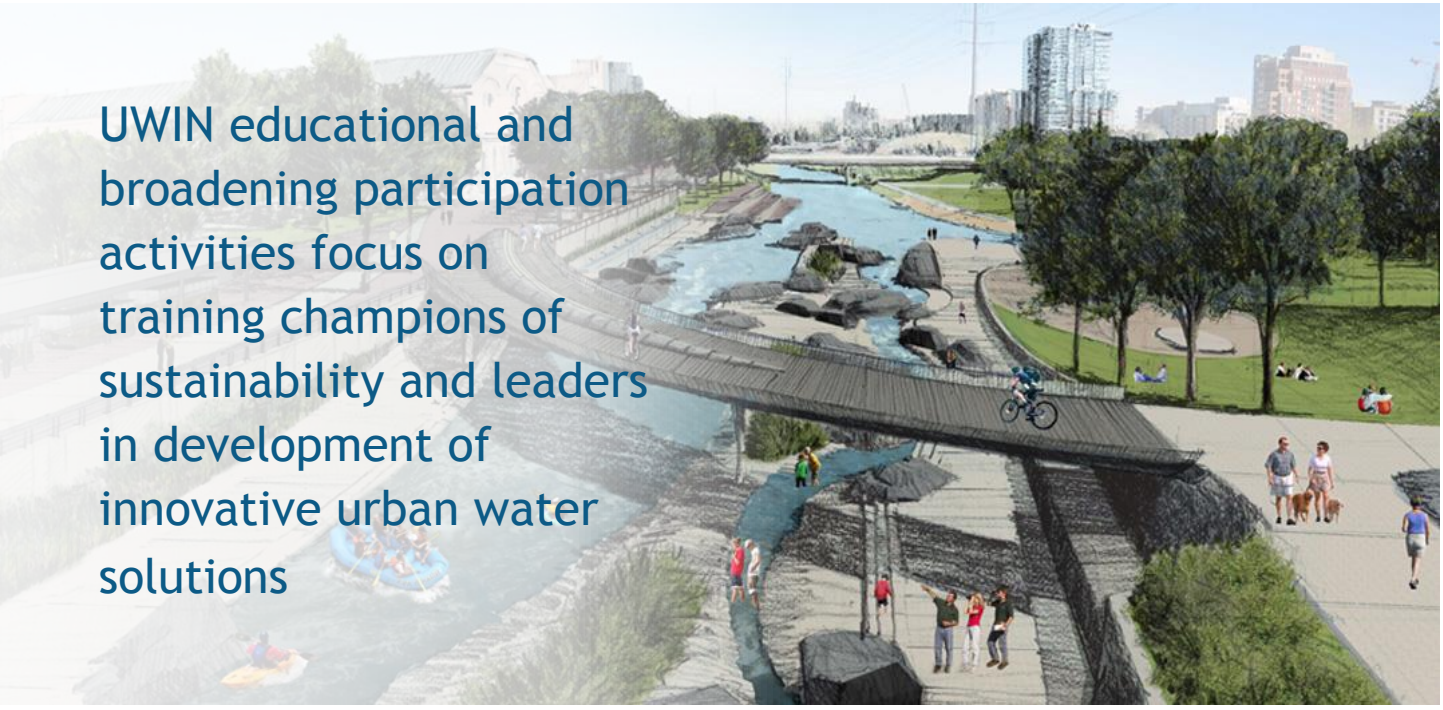
UWIN leverages existing resources from prior national and regional investments.

The network activities build on an unprecedented amount of hydro-climatic, ecological, socioeconomic and institutional data and models available from existing sustainability efforts across the U.S., including two NSF-funded urban Long Term Ecology Research Networks (LTERs), five NSF/USDA-NIFA funded Water Sustainability and Climate (WSC) projects, and the NSF-funded ReNUWIt Engineering Research Center, all of which are UWIN partners.

Urban Water Sustainability Blueprint

A key product of UWIN is a blueprint for urban water sustainability. Once developed, this blueprint will define the essential characteristics of coupled natural-built urban water systems and their sustainability to point decision makers toward the most appropriate options and transition pathways for reducing pressures, enhancing resilience, and maximizing co-benefits. The blueprint will feature common indicators to enable classification of urban water systems in cities across the U.S. and globally. The study regions and cities are used as observatories to identify key sustainability indicators.

UWIN is a World Class Research Network Building on Robust Data and State-of-the-Art Analytics in Testbeds Across the United States.



UWIN educational and broadening participation activities focus on training champions of sustainability and leaders in development of innovative urban water solutions

Undergraduate Research Program

UWIN offers a Sustainable Urban Water Interdisciplinary Undergraduate Research Program (URP) where students are placed with a team of mentors the different UWIN cities. Students work on individual research projects in an area of concentration, while also interacting with other students and mentors in different disciplines in the national network. In this way, students develop disciplinary and place-based depth while also learning across the socio-environmental spectrum and across broader spatial scales. A key goal is to support interested students to learn about and get engaged with research on solutions for sustainable urban water systems.

Research Experiences for Teachers

To foster K-12 education in sustainable urban water systems, an onsite Sustainable Urban Water Interdisciplinary Research Experiences for Teachers (RET) program is offered with the expectation of building long-term collaborative relationships between K-12 STEM teachers and the university research community. The program and partnerships it builds helps K-12 teachers translate their research experiences and new knowledge into classroom activities, helping to create the next generation of cross-disciplinary research scientists.

Citizen Science Program

UWIN is engaging in multiple citizen science efforts, including a program on Residential and School Ecosystem Water Budgets. UWIN research team will begin developing protocols later this year, building on campus water budget curricula for schools so citizens can quantify the sustainability of their school or home water budgets.

Additional Citizen Science involvement includes coordinating with existing water monitoring efforts in/near each city to create a project-wide dataset of water quality comparisons in space and trends over time.

Urban Water Sustainability MOOC

UWIN offers an Urban Water Sustainability Massive Open Online Course (MOOC) for teaching and engagement of graduate students, as well as the broader water community. The goal is to reach interested students across the nation and around the world, with the additional objective of recruiting students and postdoctoral fellows into the research network.

Thrust A - Interactions and feedbacks between urban development and interconnected natural/socioeconomic processes

Project A1-1: A multi-scale, multi-model dynamical-probabilistic approach to quantifying vulnerability, resiliency and adaptability of U.S. urban water systems to climatic and socio-economic variability

This project explores the effects of urbanization on water scarcity, supply vulnerability and resiliency.

Project A1-2: Effects of changes in climate, demographics, and urban form on water supply-demand equilibrium, economic growth, and social equity and equal opportunity

This project evaluates the economic effects of water price increases on household income, regional income and employment, and business output.

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

The objective of this project is to develop the next-generation urban modeling system to assess the water demand and cooling effects of urban canopy; the complex water-climate-energy repercussions of green infrastructure systems; and thermal comfort in the urban outdoor space.

Project A2-2: Land-atmosphere-hydrosphere interactions: projecting future environmental change in urban areas

This project quantifies combined and interacting effects of urban expansion and greenhouse gas emissions on urban hydroclimate for the mid- and end-of-century continental U.S.

Project A2-3: Assessing the thermal comfort implications of water-supported urban infrastructure at the human scale

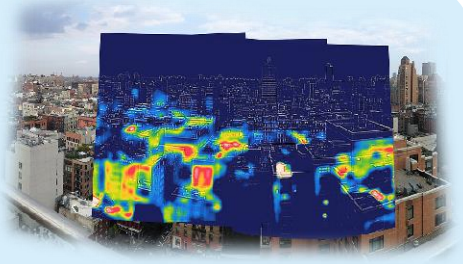
This project investigates what will happen to the thermal comfort of urban dwellers, and the associated risks of heat related illness, in the face of changes to urban water systems driven by climatic variability and infrastructure modification.

Project A2-4: Assessment and design of innovative building systems and urban infrastructure to mediate impacts on the urban water cycle, heat island, and regional climate

This project creates new knowledge about the interactions between building systems and the urban environment with the water-energy nexus, and identifies alternative solutions for mitigation of water, heat and energy stress through architecture and urban design.

Project A3-1: Continental scale variation in urban vegetation biodiversity – ecosystem functioning

This project focuses on the quantification of urban biodiversity and ecosystem functioning and assessments of potential trajectories for these components in UWIN regions under current and future climatic conditions.



This research thrust hinges on enhancing our fundamental understanding and characterization of the sustainability of urban water systems, by comparing observed trends in the past with alternative future land and water use, population, and climate scenarios. The projects under this thrust are organized in three themes.

Theme A1 projects characterize water supply-demand patterns under future socioeconomic scenarios. Land and water use, land cover and socioeconomic scenarios are used to assess two-way interactions and feedback between urban form and development patterns and land-atmospheric processes.

Theme A2 projects assess the impacts of urban water systems on urban heat island and the regional climate, and the ensuing co-benefits for human health.

Theme A3 projects examine effects of changes in climate, population, demographics, and policy on hydrologic and ecological processes over the observed past and future assessment periods.

Using data, models, and enhanced process understanding from Thrust A, Thrust B projects develop and measure the effects of innovative technological solutions that can enhance the sustainability of water systems across eco-hydrologic regions. These solutions include building- to community-scale resource recovery and reuse systems (Theme B1), green infrastructure, sustainable urban drainage networks, and floodplains (Theme B2).

The assessment of effects and tradeoffs for these solutions include all four components of the Urban Water Blueprint and are conducted for the observed and future assessment periods.

The solutions that are examined include:

- Urban water conservation systems
- Fit for purpose water systems, including graywater and stormwater
- Water recovery and recycling systems
- Energy and heat recovery systems
- Green infrastructure
- Sustainable urban drainage networks (SUDS)

Thrust B - Innovative infrastructure and technological solutions to enhance resilience of urban water systems and co-benefits

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

The goal of this project is to investigate the role of alternative water management solutions (including decentralized systems) in response to external pressures on urban water systems in UWIN regions. Specific objectives of the study are to: (i) assess the effects of various scales (building- to neighborhood-level) and configurations of water management solutions on reliability and resilience of water supply under population growth, land use, and climate pressures; (ii) assess co-benefits of alternative water management solutions across different geographic regions, including reduction of energy demand and GHG emissions, and (iii) estimate effects of alternative water management solutions to improve sustainability indicators across different regions.

Project B1-2: Spatially- and temporally-informed life-cycle assessment of urban water systems

This project evaluates UWIN-identified urban water innovations using life-cycle assessment (LCA) to assess energy use and emissions within a city/region and the broader economy. Objectives of the study are to: (i) develop decision-support tools for evaluating non-traditional water sources under current and future conditions using life-cycle assessment (LCA) with regionally-appropriate data; and (ii) characterize existing centralized gray urban water infrastructure in case-study cities to provide a baseline for comparing alternative technologies.

Project B2-1: Comparative study of Green Infrastructure (GI) effects across UWIN Urban Systems

This project seeks to understand how the direct benefits of GI might scale from point to city levels. The optimal density of GI to maximize water quality and water quantity ecosystem services as well as other ecosystem services is investigated based on climate (precipitation regime –amount, intensity, and frequency). The project examines the effectiveness of centralized and distributed GI systems in regions with varying climatic conditions ranging from dry to humid, and gentle to intense regimes.

Project B2-2: Flood hydrology and rainfall frequency, and urban floodplains

In this project, the hydrology, hydro-meteorology and hydro-climatology of urban flooding are examined through numerical modeling and data-driven studies that focus on urban watersheds in the UWIN regions. The broad objective of this study is to develop a predictive understanding of urban flood hydrology that can be used to assess the effectiveness of “urban water solutions”, especially GI technologies, in reducing flood hazards. This project also addresses the interactions between flood flows and urban channels, floodplains and riparian zones as influenced by urban infrastructure and efforts to mitigate effects of urban development, e.g. GI and low impact development (LID), on flood response and other environmental consequences.

Thrust C – Explore innovative transitions (urban form, behavioral, management, policy) for sustainable urban water management

Project C1-1: Understanding adoption of sustainable urban water solutions

This project seeks to characterize and understand the adoption of sustainable urban water practices in U.S. urban areas and to discover how changes toward more sustainable practices can be deliberately facilitated. Such practices may be adopted by public and private water agencies, public transportation, open space and land use planning agencies, private land developers and property owners, and industrial water users.

Project C2-1: Understanding homeowner adoption of new technologies for sustainable water management using dynamic information acceleration

The purpose of this project is to understand how adoption decisions are made by exploring the ability of dynamic information acceleration (DII) to model how future adoption decisions might be reached, and their likely outcomes. The data that emerge from a DII application include not just overall assessments of likely willingness to adopt as a function of experimental manipulations in information content, but also the structure of the information gathering process that leads to that decision. Additionally, the research addresses another fundamental challenge to making cities more sustainable, which is how to get individuals and communities to take a long-sighted view and how to encourage long-term planning and investment.

Project C3-1: Transitioning to socially equitable and environmentally just sustainable (SEEJ) urban water systems

This project seeks to understand how sustainable technological and behavioral solutions for water systems promote equitable and just urban outcomes. A geo-referenced Household Survey of Pressures, Indicators, and Solutions examines how water pricing policies affect people over the entire socio-economic spectrum and how people perceive water-related pressure points and risks with respect to their health, safety, and livelihoods in the local socio-economic and cultural contexts. A Social Equity and Environmental Justice Database is developed to build capacity for designing technological solutions for community-scale water conservation, green infrastructure, and flood protection.

Project C4-1: Making the One Water transition – Financial challenges and opportunities of moving from service provision to resource management

This project investigates viable financial models that would facilitate incorporation of the triple bottom line in valuation of water systems. The research addresses affordability and equity in water systems, and develops non-traditional revenue sources that include developing a circular economy. As Water Service Providers take on the challenge of managing water as one resource, a key impediment is that current financial and legal structures are based on a service provision model. This research project develops and evaluates a 'resource management' business model recognizing that water is a valuable urban amenity and is an important element of the livability of the community.

Thrust C projects explore how cities can intentionally foster the widespread adoption of infrastructure, development patterns, consumer behaviors, and management practices that advance sustainable water management. Existing approaches are persistent and path-dependent, locked into established practices, rules and cultures. Overcoming barriers requires insight into the social and behavioral systems that govern change because the barriers are more socio-institutional than technical.

Components of the system include the actors, preferences, policies, institutions and other elements that shape outcomes at multiple scales from building to metro region levels.

A particular emphasis of the projects in Thrust C is to understand best practices for integration of urban planning with urban water management.

Research activities under Thrust D focus on integration of UWIN data, models and products to facilitate enhanced decision making. This thrust enables synthesizing results from other projects to identify viable solutions that provide maximum benefits at the system level. A system approach is used to explore impacts, benefits, and tradeoffs associated with various urban water solutions.

The assessments define, characterize and quantify the UWIN Urban Water Sustainability Blueprint indicators. The syntheses questions include:

- What institutional agreements facilitate/impede sustainable management of urban water?
- What are tradeoffs associated with various infrastructure and technological solutions?
- How do tradeoffs vary across spatial and temporal scales within a city or across cities?
- How are urbanization responses interconnected spatially and temporally?
- What are general patterns in the relationship between the urban landscape and water availability, vulnerability and resiliency?

Thrust D – Evaluate the impacts, tradeoffs and co-benefits of innovative technologies and transitions

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

This project will quantify a set of "blueprint indicators" used to compare baseline and alternative future scenarios. Scenarios are driven by changes in population, land use, and climate, and influenced by different policies, management, and water innovations (informed by stakeholder workshops). An alternative futures modeling framework is used to model future scenarios for urban water systems in the Willamette Valley, OR that reflect the key drivers and influence of relevant policy and management strategies. Outputs include transferable modeling and stakeholder engagement approaches, a set of future scenarios for the Willamette Valley, and model outputs representing landscape dynamics and water innovation impacts at decadal time steps

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

Two optimization approaches are used to explore tradeoffs associated with urban water management solutions across scales: (i) top-down optimization; and (ii) bottom-up optimization. For the top-down approach, novel multi-criteria optimization tools are used to explore optimal system-level solutions for urban water management under uncertainty.

Implementation of top-down optimization approaches may be hindered by failure to engage stakeholders in the decision making process from the outset. As an alternative, a bottom-up approach is used to identify best solutions from alternatives that are created by stakeholders. Our annual stakeholder meetings are anticipated to bring together approximately 500 stakeholders from various regions in the U.S. These meetings are used as a means to generate a large number of urban water management scenarios for each of the UWIN regions. Then, best solutions from the stakeholder alternatives are identified and compared with the solutions form the top-down approach.

Project D1-3: Urban water decision innovation system

A cloud based system is developed to deploy urban water analytics that are developed by UWIN projects and partners. The system is designed using the environmental Resource Assessment and Management System (eRAMS) and is called Urban-Water Resources Assessment Program (Urban-WRAP). The system provides computationally scalable, accessible, and platform independent web services for the assessment of the UWIN urban water sustainability indicators in regions across the U.S. A governing rule for the development of the decision innovation system is that complexity is analyzed comprehensively, but decision information is presented to communities and regulators in understandable forms to support informed choices.

A World Class Partnership

With support from the National Science Foundation, Colorado State University leads the effort to establish the Urban Water Innovation Network (UWIN). The mission of UWIN is to create technological, institutional, and management solutions to help communities increase the resilience of their water systems and enhance preparedness for responding to water crises. UWIN builds on long-standing programs at CSU for research and training, and trusted leadership in all facets of water resources. These programs include urban water conservation, sustainable urban drainage systems and flood control, drought management, pollution control, water resources planning and management, ecological engineering, climate sciences and urban biodiversity. The UWIN consortium includes:

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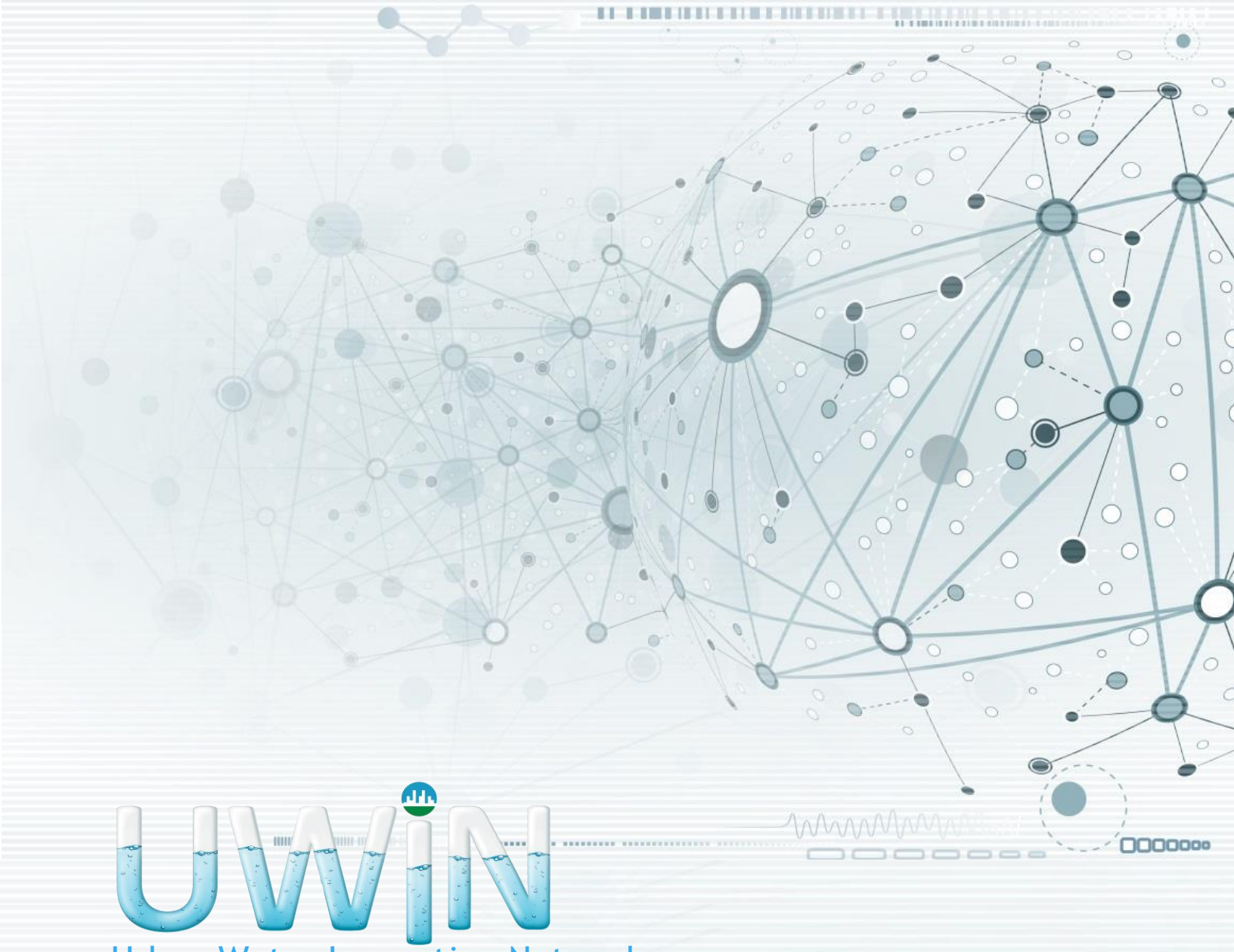

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