

Beyond Lumped Inputs: Transformer Models and Spatially-Explicit Data Integration for Streamflow Forecasting in Arizona

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Abstract ID: 47

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Topic: Hydrology

Data-driven models have demonstrated remarkable success in streamflow forecasting. However, these models often rely on basin-averaged (lumped) meteorological and Earth Observation (EO) inputs, which masks the fine-scale spatial heterogeneity critical for understanding hydrological processes, especially in arid and semi-arid regions. On this notion, we investigate two key frontiers in data-driven hydrology: the adoption of more advanced architectures and the explicit integration of spatial data.

We present a comprehensive assessment across 404 USGS stream gauges in Arizona, a region characterized by semi-arid topography, diverse land cover, and highly variable hydroclimatology. Our research framework systematically compares the performance of LSTM and Transformer-based models under three distinct data integration strategies: (1) a baseline using only lumped meteorological forcings; (2) an aggregated approach incorporating basin-averaged EO data (e.g., NDVI, EVI, Snow); and (3) a spatially-explicit approach where a Convolutional Neural Network (CNN) processes gridded EO data to preserve spatial structure.

Our results yield two insights. First, the Transformer architecture consistently and significantly outperforms LSTM and Informer models across all experimental setups and forecast horizons, demonstrating its better capacity to capture long-range temporal dependencies in hydrological time series. Second, while the integration of EO data in any form provides a clear advantage over the baseline, our preliminary findings indicate that effectively encoding spatial information remains a challenge; the spatially-explicit models do not yet show a decisive performance advantage over simpler aggregated EO inputs for the region. We further find that model performance is strongly correlated with catchment properties aridity, elevation, and hydrological signatures, flashiness index, and snow fraction.

Partitioning of Soil Resources Between Dryland Shrubs and Grasses

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Topic: Hydrology

Plant-root uptake underpins the flow of water and nutrients through terrestrial ecosystems. Water and nutrients are heterogeneously distributed in soil and vary among wet and dry years. Shrubs and grasses have different root distributions extending to different soil depths. We asked three questions: (i) What are the depth profiles of root absorption of the dominant shrub and grass species of the northern Chihuahuan drylands? (ii) How do their absorption profiles change from wet to dry years? (iii) How does the absorption profile of the dominant shrub *Prosopis glandulosa* change with shrub size? Using a tracer, we measured soil-resource uptake by neighboring shrubs and grasses in the top 120 cm of the soil. Grass absorption profiles were shallower and more flexible than those of shrubs, which showed little change between dry and wet years. Shrub-rooting depth increased swiftly with size; all shrubs above the 20th percentile of aboveground volume displayed deeper absorption than grasses. We showed that shrub-grass competition for soil resources is minimal and limited to early shrub-establishment stages. Our results assist in understanding woody-plant encroachment and future plant-community structure and ecosystem functioning under a hotter, drier, and more variable climate.

Predictive Modeling of Arizona Groundwater Quality Using Transfer Learning

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Event: 2025 ASU FLOW

Topic: Hydrology

Groundwater provides 40% of Arizona's water supply. In particular, over 100,000 domestic wells serve approximately 5% of the state's population, yet the water from these private systems is largely unregulated and not systematically tested for potability. Groundwater quality in Arizona varies significantly in space and time, posing monitoring and management challenges especially in rural communities. To address this, we are developing a novel machine learning (ML) framework to predict concentration levels of key groundwater compounds (e.g., arsenic, nitrate, uranium, PFAS, chromium, selenium) across the state and proactively identify aquifers at risk of declining water quality. To overcome local data sparsity, our approach leverages transfer learning from national-scale datasets to help train a deep neural network. This multi-output model is designed to simultaneously predict the occurrence of key compounds and account for potential co-occurrence patterns between them. The model integrates over 20 geospatial predictors from climate, soil, geology, hydrology, topography, and anthropogenic datasets to make its predictions. Initial results from our spatial model generate high-resolution risk maps for the entire state. These maps highlight high-probability zones of occurrence of compounds, such as elevated arsenic in Maricopa and Yuma counties and high nitrate levels in agricultural areas, aligning with known groundwater quality issues. Explainable AI (XAI) analyses identified primary factors affecting compound occurrence, such as groundwater depth, precipitation, and land use. This framework is designed to be scalable, with ongoing work focused on developing a spatiotemporal model to predict future changes in compound levels. Ultimately, this project delivers actionable information to support ADEQ's proactive groundwater quality monitoring and decision-making related to protecting Arizona's drinking water supply.

An Extensive Statistical Characterization of High Flow Volume in Arizona to Explore the Feasibility of Flood-MAR

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Abstract ID: 44

Event: 2025 ASU FLOW

Topic: Hydrology

Flood managed aquifer recharge (or Flood-MAR) is a term recently introduced for solutions where flood water is diverted from a river to increase groundwater artificially. A key requirement to assess the feasibility of Flood-MAR at a given site is to quantify the surface water availability, for which a few definitions have been proposed based on high-flow volumes (HFV) exceeding different quantiles of daily flow and rules to preserve environmental flows. In this study, we conduct an extensive statistical characterization of various definitions of HFV across all basins at the hydrologic unit code 12 (HUC-12) level in Arizona. For this aim, we use long-term records of near-natural daily flow reconstructed with four methods for prediction in ungaged basins, including three statistical techniques and simulations with the NOAA National Water Model. We extract HFV events from the reconstructed flow time series at each site and characterize the multivariate distributions of flood volume, duration, and peak through parametric distributions and copulas. To test the procedure and assess the accuracy and uncertainty of the estimated distributions, we use more than 100 stream gages with at least 20 years of observations. This work supports the development of water management strategies aimed at augmenting groundwater resources in Arizona, a state currently under the multidecadal Millennium Drought.

Utility of Precipitation Generating Mechanisms to Model Extremes in the United States

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Event: 2025 ASU FLOW

Topic: Hydrology

Characterizing extreme precipitation (P) is key for the design of resilient hydraulic infrastructure. This task is usually performed through the statistical analysis of historical records under the assumption of a single population. In recent work, we classified the dominant generating mechanisms (GMs) of daily P at 2861 gages across the conterminous United States. The GMs include fronts (FRTs), extratropical cyclones (ETCs), tropical cyclones (TCs), atmospheric rivers (ARs), and the North American monsoon (NAM). Our analyses indicated that non-zero P and annual P maxima associated with different GMs likely belong to diverse statistical populations. In this study, we first complement the GMs by adding mesoscale convective systems (MCSs). We then fit the Generalized Pareto (GP) distribution to peak-over-threshold P series associated with each GM using a threshold invariant approach that allows the parameter comparison in space and across the GMs. We find that the shape parameter χ , controlling the distribution's right tail, is positive (i.e., the GP is heavy-tailed) at most gages and relatively higher for P associated with FRTs and NAM, and, notably, TCs, for which it exceeds 0.5. χ is instead close to zero (the GP is an exponential distribution) or even negative (the GP is bounded) for ETC, AR, and MCSs. Spatially, a lower χ is found in the Appalachians, the southeast, and the Pacific Northwest. For all GMs, the GP scale parameter α is correlated with the mean annual P. Finally, for each gage, we compare the accuracy and uncertainty of a mixture of GP distributions fitted to the two most frequent GMs with a single GP fitted to the entire sample. This work provides a framework for integrating physical drivers into the statistical analyses of extreme P, which could be expanded to incorporate climate nonstationarity.

Linking Treatment Processes to Water Quality: Understanding the Composition of Recovered Water from Urine Diversion

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Abstract ID: 42

Event: 2025 ASU FLOW

Topic: Hydrology

The majority of the southwestern US is characterized by their arid climates where water conservation is ever increasingly becoming more important to support its growing population. One such way to solve this problem is through urine diversion which separates urine from the traditional wastewater system to be treated separately. Urine is a high-nutrient waste stream that is rich in phosphorus, nitrogen, and potassium, which can be recovered as fertilizers. The water that remains after treatment has the potential for non-potable uses such as irrigation, toilet flushing, and fire protection. Previous literature has focused on the nutrient recovery but there is a gap in understanding the composition of the recovered water. During treatment, chemical addition is common in order to effectively remove the nutrients, which have the potential of altering the water chemistry. The goal of this project is to understand the link between the composition of the recovered water and the processes used in treatment. Experiments will be conducted at bench scale using real hydrolyzed urine collected from a waterless urinal with a total volume of 2 L. Throughout the treatment process, pH, conductivity, total nitrogen (TN), total organic carbon (TOC), and organic carbon will be monitored. The treatment train used is: phosphorus recovery through chemical precipitation, nitrogen recovery via air stripping, and potassium recovery through evaporation. Based on previous literature, nutrient removal isn't done to completion where these remaining nutrients and added chemicals have the potential to be in the recovered water. Depending on the concentrations of remaining constituents, further treatment may be required for the water to be suitable for non-potable uses, such as membrane filtration.

P, Pee, and People: Economic and Environmental Feasibility of Urine Diversion System Implementation in Different Building Scenarios

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Abstract ID: 41

Event: 2025 ASU FLOW

Topic: Hydrology

Agricultural producers in the Southwestern United States have faced unique challenges in recent decades, including not only increasing global fertilizer prices but also lowered water allocations. Urine could provide a solution to both issues, as it contains high concentrations of nutrients such as phosphorus (P), and the implementation of urine diversion (UD) systems can reduce water usage by wastewater appliances. However, even with successes in its technological development, UD has had limited implementation in the United States, as there is limited information on its economic and environmental feasibility in different building scenarios. This project reports on two recent studies that (1) benchmarked the phosphorus recovery potential when implementing UD in different commercial and institutional (CI) buildings, and (2) evaluated the environmental impacts of UD system design in different CI buildings using life cycle assessment (LCA). The benchmarking results showed that occupancy count and time play a significant role in phosphorus recovery potential, and that water savings from lowered flush volumes (>20% in select CI buildings) are a major co-benefit that has the largest contribution to economic savings when implementing UD systems. The LCA results showed that CI buildings with denser wastewater system layouts and greater occupant-to-appliance ratios (e.g., airports) have lowered environmental impacts from infrastructure, resulting in scenarios where fertilizer production and water savings can offset other environmental impacts, and that UD infrastructure constitutes >30% of impacts in select categories across all building types. Overall, these results provide guidelines for urban planners, building managers, facilities staff, and other relevant stakeholders on where UD is currently feasible for implementation and how UD can be made more economically and environmentally feasible in the future, providing a pathway to supplying Arizona's agriculture with local, sustainable fertilizer and greater water allocations.

Evapotranspiration and Soil Moisture Monitoring in the Upper Lake Mary Watersheds

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Event: 2025 ASU FLOW

Topic: Hydrology

The City of Flagstaff relies on the Upper Lake Mary (ULM) as a water supply for domestic and industrial use. Land use change has altered the ponderosa pine forests around ULM and increased the threat of severe wildfire in the area. Restoration projects have been planned through the Four Forest Restoration Initiative to remove trees and reduce fuel loads that spread catastrophic fires. However, the changes in hydrologic conditions resulting from forest thinning are poorly understood from an observational perspective. This study will combine the long-term dataset provided by the ULM Watershed Monitoring Program—which is supported and maintained by the City of Flagstaff—with a new instrumentation to quantify evapotranspiration (ET) and soil moisture (SM) in seven watersheds that will receive different levels of forest treatment. While the long-term data includes precipitation and discharge from each watershed, it lacks information on ET and SM from the forest canopy and the open grassland areas in the watersheds. For this purpose, our team is in the process of deploying six LiCOR LI-710 to measure ET as well as a volumetric water content probes to quantify SM in depth profiles. The experimental design includes a stationary set of instruments at a control site, along with instrumentation to be moved infrequently between the treatment watersheds. These observational efforts will also help test the TIN-based Real-Time Integrated Basin Simulator (tRIBS) which can provide spatially-distributed estimates of the water balance components in each watershed. Outcomes of this effort are expected to help forest management decisions regarding the water benefit provided through restoration projects to water supply sources.

Ensuring water sustainability and forest health in Northern Arizona watersheds using high-resolution integrated hydrological modeling (Phase -I)

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Abstract ID: 39

Event: 2025 ASU FLOW

Topic: Hydrology

High-elevation forested landscapes in the western U.S. are undergoing rapid changes driven by climate-induced shifts in forest-snow-water dynamics and by forest structural alterations from land management. With continued warming, formerly seasonal snow zones are increasingly transitioning into ephemeral snowpack areas characterized by intermittent mid-winter melt. Yet, the implications of these changes for forest and water resource sustainability remain poorly understood. This research addresses this knowledge gap by integrating field observations with coupled modeling to advance long-term forest resilience and water sustainability.

Current snowpack observations are limited by trade-offs between spatial and temporal resolution. SNOTEL provides high-frequency data but is spatially sparse and biased, whereas satellite and LiDAR offer broader spatial coverage but are temporally coarse and constrained by cloud cover or dense canopy. To overcome these limitations, we leverage a combination of datasets—including SNOTEL, satellite imagery, LiDAR, and Snowtopography (daily snow depth under varying canopy conditions)—to enhance calibration and validation of our integrated watershed model.

To support broader-scale applications, we are integrating the SnowPALM snow model with the Triangulated Irregular Network (TIN)-based Real-time Integrated Basin Simulator (tRIBS). This coupled modeling framework captures fine-scale interactions among forest cover, snowpack, and streamflow—informing decisions by stakeholders and water managers. We assess the utility of this integrated model by comparing simulations at a test site, with and without the SnowPALM component, against multiple snowpack datasets and soil moisture observations. Future efforts will extend calibration and validation to additional sites representing diverse snowpack and soil moisture conditions.

In this poster, we present preliminary results, discuss how our interdisciplinary work supports the mission of the Center for Hydrologic Innovations at Arizona State University, and demonstrate improvements over existing modeling approaches. This work contributes to broader efforts aimed at balancing watershed water yield and forest health.

Advancing Soil Organic Carbon Prediction Using Laboratory Hyperspectral Imaging and Simulated Multispectral Data

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Abstract ID: 38

Event: 2025 ASU FLOW

Topic: Hydrology

Soil Organic Carbon (SOC) plays a vital role in water retention, infiltration, and overall soil-water dynamics—key processes in sustainable watershed management, particularly in arid and semi-arid regions. This study introduces a novel laboratory-based framework that employs hyperspectral imaging (400–2500 nm), fractional-order derivatives (FODs), and machine learning to enhance SOC prediction from dried and sieved soil samples. Using Random Forest and Support Vector Regression models, we demonstrate that incorporating both spectral transformations and soil pH yields high predictive accuracy ($R^2 = 0.87$), revealing critical spectral regions for SOC estimation. To evaluate the scalability of this approach, we simulated Maxar multispectral bands from hyperspectral data and assessed performance under reduced spectral resolution. Although a drop in accuracy was observed ($R^2 \sim 0.70$), the results remain promising and suggest that high-resolution multispectral platforms could support SOC estimation if coupled with robust modeling strategies. These findings highlight the potential of high-resolution SOC prediction derived from lab-based hyperspectral data and simulated multispectral bands to support future hydrological modeling and land degradation assessments by improving the representation of soil-water interactions, particularly in data-scarce environments.

Statistical Characterization of Climate Data in a Desert Urban Environment in Phoenix, AZ

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Abstract ID: 37

Event: 2025 ASU FLOW

Topic: Hydrology

Statistical characterization of climate data in urban regions provides a strong foundation for stochastic simulations that support heat and flood mitigation, design infrastructure, and manage the power distribution network. In this study, we first develop a long-term dataset of meteorological observations at resolutions from 15 minutes to 1 hour from more than 50 weather stations in Phoenix, AZ. The variables include precipitation (P), temperature, dew point, relative humidity, wind speed (WS), wind peak (WP), wind direction, solar radiation, and barometric pressure. To ensure data quality, we apply the range, step, and persistence tests with thresholds calibrated for the monsoonal and winter storms typical of this desert region. After preprocessing, we conduct a statistical characterization of the marginal distributions for each variable and identify suitable parametric forms to describe their variability. This work provides a reliable, high-resolution dataset and a foundational statistical description of key climate variables in one of the world's largest desert urban regions. The results offer essential insights for future modeling and simulation efforts aimed at understanding climate-driven urban risks.

Evaluation and Improvement of Precipitation Products in Arizona Supporting Water Resources Planning and Management

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Event: 2025 ASU FLOW

Topic: Hydrology

Accurate long-term, high-resolution precipitation (P) products are critical for water resources planning and management. This is particularly true in the U.S. state of Arizona, which has been experiencing the Millennium Drought since ~2000 and water cuts from the Colorado River during the last three years. In this study, we first perform a multiscale evaluation in Arizona of the National Oceanic and Atmospheric Administration (NOAA) Analysis of Record for Calibration (AORC) gridded P products, available from 1979 to 2023 at 1-km, 1-hr resolution. Since AORC P is generated by merging several gridded products covering the U.S., we reconstruct each generation step to isolate distinct sources of error using several daily and hourly rain gages as reference. We conduct analyses at monthly, daily, and hourly scales at pixel level, over elevation bands, and in key basins. These comparisons are subsequently used to develop and apply bias correction techniques that incorporate terrain effect on P and better reproduce the serial and spatial correlation structures of winter and summer storms, typical of this region. We expect that the improved AORC P products will be used by state agencies in various hydroclimate and water resources management applications, as well as for the current and future iterations of the NWM in Arizona.

Optimizing Hybrid Floating Solar and Hydropower Operations for Economic Performance: A Case Study of Lake Powell

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Abstract ID: 35

Event: 2025 ASU FLOW

Topic: Hydrology

Floating solar panels are an emerging renewable energy technology that offer multiple benefits, including evaporation reduction, high power generation efficiency, potential mitigation of algal blooms, and preservation of valuable land resources. As a result, they are attracting increasing global interest. Artificial water bodies such as reservoirs are considered ideal sites for FPV installation due to their relatively controlled environments. Moreover, when integrated with hydropower reservoirs, FPV systems can leverage existing transmission infrastructure, making grid integration more straightforward, which is another factor driving research interest. Previous studies have primarily focused on the second point, but there remains a gap in understanding the operational performance of hybrid systems. In this study, we develop a stochastic optimization model to analyze the operation of the hybrid hydro-FPV system with the goal of maximizing quarterly economic revenue. The model incorporates surface solar radiation and evaporation data from the ERA5 dataset, as well as reservoir characteristics obtained from the U.S. Bureau of Reclamation (USBR). To reflect real-world operational constraints, the model applies a penalty price for days when electricity generation fails to meet contractual supply requirements. Through this framework, we derive the optimal operating strategy for hydro and solar generation under different conditions. Lake Powell is selected as the case study for model development, with the intention of extending the framework to other reservoirs in future applications.

Weather Jiu-Jitsu: Towards Adaptive Chaos Control of Weather Extremes

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Event: 2025 ASU FLOW

Topic: Hydrology

Extreme weather events present growing challenges as climate changes. “Weather Jiu Jitsu” is a proposal to nudge atmospheric circulation to redirect or defuse these extreme events by leveraging the sensitivity of chaotic atmospheric dynamics to initial conditions. We demonstrate an optimal control strategy to stabilize two low-order models of atmospheric dynamics, the Lorenz 63 (L63) and Lorenz 84 (L84). Estimated local Lyapunov exponents (LLE) are used to decide when to apply control. The timing and amplitude of nudges is solved over a forecast horizon to minimize the total energy applied, while ensuring that the trajectory remains within predefined bounds to avert undesirable consequences. The effect of multiplicative noise is considered and trajectories nudged are randomly selected from an ensemble forecast. The demonstration of controlling low-order atmospheric models in an operational context underscores the potential for adaptive chaos control of weather extremes. Implications for real world systems are discussed.

We invite collaboration to develop Weather Jiu-Jitsu as a community research platform.

Tracking *E. coli* in the Lower Gila River for Public Health Protection

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Abstract ID: 33

Event: 2025 ASU FLOW

Topic: Hydrology

The Lower Gila River at the Base and Meridian Wildlife Area, located 17 miles west of Phoenix in Maricopa County, Arizona, encompasses vital riparian and wetland ecosystems that support diverse wildlife species (Roper-Jones D., 2024). In response to increasing human activity and environmental stressors (Bureau of Land Management, n.d.), a collaborative monitoring initiative was established with the Arizona Department of Environmental Quality's Community Science Alliance and the Citizen Water Watch program. The sampling period was January to July 2025, two sites were sampled monthly for *E. coli*, total coliforms, and other water quality parameters. Preliminary results indicate average *E. coli* concentrations of 221.39 MPN/100 mL at Site 1 and 174.11 MPN/100 mL at Site 2, both within national safety standards. However, total coliform counts consistently exceeded safe levels (>2419.6 MPN/100 mL), highlighting potential health and ecological concerns. These findings underscore the necessity for ongoing monitoring to safeguard the river's ecological integrity, public health, and long-term sustainability.

Gila river. Bureau of Land Management. (n.d.-b). <https://www.blm.gov/visit/gila-river>

Circular economy for N, P and K from human urine to crops: Maximizing environmental benefits through geospatial optimization of nutrient recovery facilities

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Event: 2025 ASU FLOW

Topic: Hydrology

The primary nutrients in fertilizers—nitrogen (N), phosphorus (P), and potassium (K) (NPK)—are traditionally derived through carbon-intensive processes and rely on non-renewable feedstock sourced from geopolitically sensitive and supply-constrained regions. Transitioning to a circular economy that recovers NPK from human urine (HU) helps reduce reliance on constrained and environmentally intensive fertilizer feedstock. Existing research primarily focuses on increasing the technical efficiency and recovery rates of extracting NPK from HU. However, there has been a lack of analysis on identifying potential sources of HU in the US, locating the infrastructure to convert HU to fertilizers and transport the HU-derived fertilizers to farms.

To address this knowledge gap, we present the first geospatial optimization study aimed at maximizing environmental benefits from a circular NPK economy using HU in the U.S. We quantify HU supply from 2,600 public schools across Arizona (AZ), serving 1,095,000 students and 134,000 staff. The recovered NPK is modeled to meet the nutrient demand for 78% of crops grown across 916,000 acres of AZ cropland. The analysis applies the anticipatory- LCA framework to account for HU diversion, water savings from avoided flushing, transport of HU to recovery facilities, conversion to fertilizers, transport to farms, and waste processing along the supply chain. We explore two options for locating NPK recovery facilities: centralized and decentralized. Centralized facilities receive HU from multiple schools and extract nutrients at a larger scale. Decentralized facilities are co-located with individual schools, eliminating HU transport but operating at a smaller scale.

The results showed that HU generated in just the public schools in AZ can annually meet 2% of the N, 1.5% of the P and 1% of the K used in fertilizers in AZ. The transition to a circular NPK economy for HU-based fertilizers reduces the climate and water footprint of fertilizers in AZ by 35% and 55% respectively. In addition, the analysis will present a geospatial map containing the optimal locations of the various centralized and decentralized facilities for NPK recovery from HU in AZ.

Identifying “Attainable-ET” Benchmarks to Guide Irrigation Water Optimization in Arizona Agriculture

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Abstract ID: 31

Event: 2025 ASU FLOW

Topic: Hydrology

In Arizona, where irrigation accounts for ~72% of water demand and water supplies are stressed by prolonged drought, optimizing irrigation to reduce overall water demand is essential. Yet substantial yield variability across farms makes it difficult to pinpoint the optimal water levels that reliably sustain crop production. We introduce a spatial framework that leverages integrated remote-sensing and statistical records to map farm-scale *Attainable Evapotranspiration (ET_{at})* benchmarks across Arizona, defined as the lowest ET that still supports good yields under a given set of agro-environmental conditions. County-level USDA QuickStats yield statistics and USDA Crop Sequence Boundaries (CSB) are paired with 30 m Sentinel-2 NDVI to calibrate crop-specific yield models for major crops (corn, wheat, cotton, barley, and alfalfa). Modeled yields are aggregated to individual farm polygons and compared with county yield-per-hectare values to label each farm-year as “good” or “poor” yield. Monthly 30 m OpenET ensemble products are summed to annual depths, converted to cubic-meter volumes, and integrated over the same polygons to create a multi-year data of actual water use. For every unique combination of precipitation regime, soil taxonomy, crop type, and annual temperature, we extract the lowest ET observed among good-yield farms and assign that value as the Attainable-ET benchmark. The resulting annual farm-scale data provides a direct, spatially explicit measure of where crops already thrive with less water and where opportunities for conservation exist. The approach is also relevant for assessing the effectiveness of Arizona’s Active Management Areas (AMAs) by revealing whether policy-regulated regions are approaching optimal water-use efficiency. Our yield-modeling approach and the statewide Attainable ET benchmark maps will be presented in this session.

Weather Jiu-Jitsu: Climate Adaptation for the 21st Century

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Abstract ID: 30

Event: 2025 ASU FLOW

Topic: Hydrology

Extreme climate events, e.g., droughts, floods, heat waves, and freezes, are becoming more frequent and intense with severe global socio-economic impacts. Growing populations and economic activity leads to increased exposure to these events. Scaling existing physical, financial, and social infrastructure to provide resilience against these extreme events is daunting, as one ponders projected climate changes. Climate extremes pose a challenge even if decarbonization and geoengineering are able to regulate Earth's radiation balance.

We argue that there is an urgent need to explore a novel adaptive strategy that we call "Weather Jiu-Jitsu," which leverages the intrinsic chaotic dynamics of weather systems to subtly redirect or dissipate their destructive trajectories through precisely timed, small-energy interventions. By leveraging insights from adaptive chaos control, combined with improved observations, prediction and low-energy weather system interventions, humanity could develop a novel nature assisted global infrastructure to limit the impact of climate extremes in the 21st century. We invite discussion and collaboration to leverage the latest prediction science, including data science and deep learning, materials, science and technology for the mechanisms delivering nudges, and meteorology for understanding the chaotic dynamics that could be leveraged.

We invite collaboration to develop Weather Jiu Jitsu as a community research platform.

Where the River Speaks: Microbial Monitoring in Arizona's Lower Salt River

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Abstract ID: 29

Event: 2025 ASU FLOW

Topic: Hydrology

Arizona's rivers are essential to both human communities and ecosystems, providing critical water resources for drinking, recreation, agriculture, and wildlife. However, many of these waterways are impaired due to microbial contamination, posing risks to public and environmental health. This study focuses on the continuous monitoring of *E. coli* levels in impaired waters under the Clean Water Act, aiming to assess water quality trends and potential contamination sources. Monthly water samples are collected and analyzed for *E. coli* and total coliform at seven sites: Blue Point, Gold Field, Coon Bluff, Phon D Sutton, Granite Reef, South Canal, and North Canal, all located along the Lower Salt River and connected canals. Preliminary data from samples collected from October 2024 to July 2025 indicate elevated total coliform concentrations (> 2419.6 MPN) at Granite Reef, Gold Field, and Coon Bluff. *E. coli* levels ranged from 0 to 410.6 MPN, with notable spikes at South Canal in November 2024. The preliminary findings suggest potential contamination from runoff, recreation, or localized sources, highlighting the variability of microbial water quality across time and location. These fluctuations underscore the dynamic nature of microbial water quality and the necessity for continued volunteer-based monitoring to identify contamination sources and protect public and ecological health. By engaging citizen scientists and adhering to ADEQ's Citizen Science Program-Arizona Water Watch protocols, the data collected can guide management decisions, supplement agency-collected information, and foster a collaborative approach to sustaining Arizona's water resources.

Bridging Human Perceptions and Hydrologic Data: A Mental Modeling Approach to Water-Scarce Land Systems in a Transboundary Basin

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Abstract ID: 28

Event: 2025 ASU FLOW

Topic: Hydrology

Sustainable water governance in arid and semi-arid regions requires approaches that integrate both hydrological data and the human dimensions of resource use. This is especially critical in transboundary basins, where environmental, political, and social boundaries intersect and where water availability is both contested and vulnerable to change. AIMM (Artificial Intelligence-driven Mental Modeler) has been developed as an open-source software platform that merges stakeholder perceptions with historical water and land-use data to support integrated water resource planning. The tool allows users to construct mental models by linking predefined system components—such as groundwater levels, crop areas, or precipitation patterns—and hypothesizing causal relationships. These links are empirically estimated using a machine learning engine based on Dynamic Double Machine Learning (EconML), which uses time-series data to calculate the strength and direction of each connection. A pilot application focused on the El Paso–Ciudad Juárez region, where rapid expansion of pecan orchards—a water-intensive crop—is shifting land use patterns and intensifying stress on shared surface and groundwater supplies, including the Mesilla and Hueco Bolson aquifers. Five academic stakeholders developed mental models identifying the drivers of pecan expansion and its implications for water availability. AIMM estimated weighted connections across water, climate, and economic variables. Model structures were analyzed using graph theory indices and compared using a modified distance ratio to assess consensus and divergence. A composite group model was then constructed through matrix aggregation. This approach enables a novel form of stakeholder engagement and systems thinking that links perception with hydrologic data. Future work aims to extend AIMM to broader stakeholder groups—including irrigation districts, municipal agencies, and farmers—to support collaborative identification of leverage points and trade-offs in the pursuit of long-term water security in the region.

High-Resolution Climate Modeling to Improve Urban Flood Risk Assessment

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Abstract ID: 27

Event: 2025 ASU FLOW

Topic: Hydrology

Assessing the performance of urban stormwater infrastructure is critical to managing and mitigating urban flood risk. One aspect often overlooked in these assessments is the possible failure of parts of the stormwater pipe network that rely on pumping stations. In recent work, we developed the PSI-Cascade framework to simulate wind-induced cascading failures from power to stormwater infrastructure. A key task to increase the fidelity of the simulations with PSI-Cascade is the generation of high-resolution wind gust (WG) spatial fields, which is often limited by the low spatial coverage and temporal resolution of weather station networks. This study develops an interpolation methodology of WG observations that accounts for the high spatial heterogeneity of terrain and land cover in urban regions. The method is tested and applied in Phoenix, Arizona. WG observations from weather stations are first interpolated in space using high-resolution grids of LiDAR-derived elevation, building footprints, and land cover. Hourly observations are then downscaled to 15 minutes with a statistical technique. The utility of the interpolation method is verified by generating WG grids at 5-m and 1-h resolution from 11 storms that occurred between 2014 and 2022, which are used to apply PSI-Cascade along with the corresponding gridded precipitation fields. Outputs of PSI-Cascade are post-processed to identify city areas where stormwater pumping stations have a higher chance of failure due to wind-induced power outages, leading to significant disruption in the transportation infrastructure. This research aims to advance urban hazard modeling capabilities by addressing critical limitations in the availability of high-resolution climate data.

Effects of Different Climate Model Projections on Distributed Streamflow Simulations and Water Management Scenarios in the Colorado River Basin

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Abstract ID: 26

Event: 2025 ASU FLOW

Topic: Hydrology

The Colorado River Basin (CRB) faces unprecedented water management challenges, intensified by climate change and the ongoing 25-year Millennium Megadrought. With current operating guidelines set to expire in 2026, robust scientific insights are essential to inform future policy. This study presents an integrated modeling chain to project future streamflow across the CRB without requiring bias correction of model outputs. We use the full suite of downscaled Coupled Model Intercomparison Project Phases 5 and 6 (CMIP5 and CMIP6) climate products at 6-km resolution to force the Variable Infiltration Capacity (VIC) land surface hydrology model. Streamflow outputs from VIC are routed through the basin using the Routing Model for VIC (RVIC), enabling distributed streamflow simulations at internal channel locations. Routed streamflow from 2027–2056 are then compared across the CMIP5 and CMIP6 ensembles to evaluate differences in projected hydrologic trends during this policy-relevant period. The RVIC outputs are directly coupled with the Colorado River Simulation System (CRSS)—the water management model used for decision making in the CRB—enabling a physically consistent, bias-free assessment of how climate projections may affect basin hydrology and operations. This coupling supports the generation of credible future streamflow time series at key internal, operational locations, providing actionable insights for evaluating a range of water management scenarios. Preliminary results demonstrate how differences in climate scenarios lead to varying impacts on streamflow, reservoir storage, and hydropower generation across the basin. These findings highlight the wide inter-model variability in projected outcomes and reinforce the importance of using multi-model ensembles for robust, risk-informed planning. This integrated modeling framework offers a practical and physically grounded tool for assessing climate change impacts on distributed streamflow and water resources, supporting long-term resilience and adaptive water management in the CRB.

Utility of Flood Typing to Enhance Flood Frequency Analysis in the United States

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Abstract ID: 25

Event: 2025 ASU FLOW

Topic: Hydrology

Flood frequency analysis (FFA) is a key task for mitigating the impacts of one of the most dangerous natural disasters. Although floods are caused by different drivers, traditional FFA approaches often treat flood events as statistically homogeneous populations, an assumption that might lead to significant inaccuracies at distinct sites. This study investigates the utility of incorporating flood typing into FFA at 670 gages with near-natural daily flow observations in 1979-2020 across the United States. This was done by developing a methodological framework to (1) assign the meteorological and hydrological flood-generating mechanisms to a set of over-threshold peak flows at each gage using atmospheric and hydrologic reanalyses, (2) assess the presence of statistically different populations, and (3) compare single and mixtures of generalized Pareto distributions to model flood frequency. Preliminary results indicate the possible presence of different flood peak populations caused by atmospheric rivers and fronts, respectively, in parts of western CONUS; long and short rain caused by fronts and tropical cyclones in the east; snowmelt and rain on snow in west and central regions; monsoons and long rains in the Southwest; and excess rain and short rain in the Appalachians and New England regions. For several of these cases, goodness-of-fit metrics suggest higher performance of FFA based on mixed populations. The outcomes of this study support the improvement of national guidelines for FFA from Bulletin 17C.

Modeling the Hydrological Impacts of Vegetation Regrowth Following Thinning in Ponderosa Pine Forests

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Abstract ID: 24

Event: 2025 ASU FLOW

Topic: Hydrology

Forest treatments such as mechanical thinning and prescribed burning are widely applied across Arizona to reduce wildfire risk, restore forest structure, and improve watershed health. These treatments often result in immediate hydrological benefits – such as reduced canopy interception and transpiration – leading to increases in streamflow, soil moisture, and groundwater recharge. However, the vegetation regrowth that follows treatment can gradually diminish these benefits, although it is often overlooked in long-term planning and hydrologic modeling. This study investigates post-treatment vegetation recovery and its influence on water balance components across the Four Forest Restoration Initiative (4FRI) in northern Arizona. Using high-resolution imagery from the National Agriculture Imagery Program (NAIP; 0.6 m, biannual), we track vegetation recovery in treated ponderosa pine forests from 2007 to present. We apply multi-linear regression models to quantify trends in Normalized Difference Vegetation Index (NDVI) obtained from imagery as a function of time since treatment and precipitation, capturing patterns of understory regrowth. These NDVI-based trends are then translated into vegetation parameter grids which serve as time-varying inputs to a process-based hydrologic model – the Triangulated Irregular Network (TIN)-based Real-time Integrated Basin Simulator (tRIBS). This approach allows us to simulate how changes in vegetation recovery over time influence key water balance components, as compared to assumptions of static post-treatment conditions. By incorporating regrowth dynamics into hydrologic modeling this work supports more informed decision-making for land managers and water resource practitioners seeking to optimize forest restoration for watershed resilience and water supply.

Integrating Local Observations and Remote Sensing Data for Hydrologic Modeling in Southwestern Ponderosa Pine Forests

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Abstract ID: 23

Event: 2025 ASU FLOW

Topic: Hydrology

In the southwest United States, semiarid forests occupy the upper reaches of critical watersheds, serving as essential water sources for rural communities and metropolitan areas. In Arizona, forest thinning projects are underway to reduce tree stand density, aiming to enhance the health and resilience of these water-producing ecosystems. To assess the hydrological implications of forest thinning, the Triangulated Irregular Network (TIN)-based Real-time Integrated Basin Simulator (tRIBS) is being extensively applied. Given the model complexity, rigorous calibration and validation are essential to ensure accurate simulation of observed water and energy budgets. However, areas undergoing thinning lack sufficient hydrological observations, posing a significant challenge for this purpose. This study integrates local, ground-truth observations from ponderosa pine stands with remotely sensed data sets, including MODIS and OpenET, to evaluate the model performance over warm and cold seasons in untreated and treated conditions. In semiarid forests, accurately modeling snow-to-liquid water input (LWI) processes is crucial for predicting changes in seasonal water storage and subsequent warm-season evapotranspiration (ET). We improved the snow water equivalent (SWE) performance of the model through comparisons to Snow Telemetry (SNOTEL) data. Two eddy covariance (EC) towers located in treated and untreated ponderosa pine stands were also utilized to get estimates of warm-season ET. For this purpose, spatial model outputs within the EC tower footprint were evaluated, a first model-data comparison of this type. We also inspected spatial and temporal changes in observed surface reflectance from MODIS to test the model with respect to distributed snow presence. Remotely sensed ET from OpenET were to compare ET magnitudes and seasonality in treated and untreated conditions, offering a direct comparison with the model. This work yields an enhanced tRIBS model, specifically tuned for ponderosa pine ecosystems to provide forest managers with critical insights into how thinning practices will impact the water and energy budget of treated watersheds.

Integrated Assessment of Groundwater Storage Dynamics and Management Strategies in Arizona Under Climate and Demand Scenarios

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Abstract ID: 22

Event: 2025 ASU FLOW

Topic: Hydrology

Groundwater is a vital and often irreplaceable resource in Arizona, significantly contributing to the state's overall water supply. It favors several uses such as agriculture, the city, industry, and nature. Since the demand on water increases and climate change presents even more severe threats, it is important to realize how and to what extent the groundwater storage keeps changing and how to manage the use of this groundwater on a sustainable basis.

Within the context of the given research, we are going to develop a statewide groundwater storage projections system that will enable the assessment of groundwater levels dynamics over the past, present, and future in Arizona. This system will correlate the Arizona Department of water resources (ADWR) water supply and demand data with the sector specific water use data such as the irrigation water use, municipal and industrial meshing objects use as well as the water purposes. To verify we will use past groundwater patterns measured using valid sources of information like U.S. Geological Survey (USGS) and past hydrologic models that will corroborate our estimates.

The system will be tested and applied to determine the future ground water storage under different scenarios by putting in to consideration different climate conditions, population growth and change in the use behavior of the water. The performance of different approaches to groundwater management will be also tested, including whether the decrease in the irrigation demand, artificial recharge, and the buildup of better groundwater conservation policies are viable. Such approaches will make us realize how we can speed up or modify the act of groundwater depletion.

The extreme necessity of the coordinated statewide groundwater risk management and water management intervention is something pointed out in our results.

Differential Effects of the Colorado River Drought Declaration on Agricultural Patterns and Water Use in Central Arizona

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Abstract ID: 21

Event: 2025 ASU FLOW

Topic: Hydrology

Climate change is intensifying drought conditions in the western United States, threatening the reliability of agricultural water supplies. The Colorado River Basin (CRB), which irrigates over 4.9 million acres, has experienced severe reservoir declines, with Lake Mead losing 71% of its volume from 2000 to 2022. Following formal drought declarations and Tier 1 water cuts in 2022, Arizona agriculture encountered asymmetric impacts, driven by water rights seniority. This study evaluates the spatial and temporal impacts of Colorado River shortages on two irrigation districts in central Arizona: the Maricopa-Stanfield Irrigation and Drainage District (MSIDD), operating under junior rights, and the Ak-Chin Indian Community, holding senior tribal rights. Using high-resolution satellite imagery from Planet Labs, a Random Forest classification, and water use analysis, this study quantified changes in crop coverage, composition, and water sourcing in the two districts. Results revealed pronounced disparities in their respective responses. Ak-Chin maintained 99% of its fields under active cultivation, preserving crop diversity and rotation flexibility. Whereas, MSIDD experienced a 30% reduction in active farmland, with systematic reductions in water-intensive crops; alfalfa declined 48%, corn fell 70%, while drought-tolerant barley increased 159%. Water use analysis revealed that while Ak-Chin only used Colorado River water supply, MSIDD increased its dependence on other sources by 256% from 32 hm³ (26,000 acre-feet) in 2020 to 114 hm³ (92,000 acre-feet) in 2024, with groundwater level analysis confirming an increased extraction as water table trends reversed from rising (+0.62 m/year) to declining (-1.13 m/year). These findings document how differential water rights determine agricultural vulnerability, with senior rights holders maintaining operational stability, while junior rights holders face land fallowing and groundwater depletion. This research also shows the effectiveness of remote sensing and machine learning approaches for monitoring agricultural responses to water policy changes, offering a framework for assessing drought impacts.

Relative Roles of Fall Soil Moisture and Spring Weather on the Relationship between Snow and Streamflow in the Colorado River Basin

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Abstract ID: 20

Event: 2025 ASU FLOW

Topic: Hydrology

The Colorado River Basin (CRB) has faced prolonged drought since 2000, with recent years revealing a weakened link between snowpack and streamflow. This study investigates why near-average snowpack often fails to yield expected streamflow volumes, focusing on the influence of fall soil moisture and spring climate anomalies. Using the Variable Infiltration Capacity (VIC) model, we conducted controlled numerical experiments to isolate the effects of October soil moisture and April–June climate conditions under consistent snowpack scenarios. Results show that antecedent soil moisture accounts for approximately 74% of streamflow variability in the Upper Colorado River Basin (UCRB), while spring precipitation contributes around 24%. Initial soil moisture alone can lead to an 8.45 km³ (6.85 million acre-feet) difference in annual streamflow, with deep soil layers playing a critical role. Similarly, spring climate anomalies under similar snowpack conditions can cause up to 8.31 km³ (6.73 million acre-feet) variation in streamflow. These findings help explain the “missing snowmelt” phenomenon observed in years such as 2020 and 2021, where snowmelt replenishes soil moisture deficits or is lost to evapotranspiration rather than contributing to runoff. The study underscores the importance of incorporating soil moisture monitoring and spring climate forecasting into water management strategies to improve streamflow predictions during drought conditions.

Beyond Adaptation: Social-Ecological Transitions in Coupled Water Infrastructure under Environmental and Governance Stress

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Abstract ID: 19

Event: 2025 ASU FLOW

Topic: Hydrology

Water infrastructures in climate vulnerable regions face stress due to rising salinity and unpredictable rainfall. These environmental pressures therewithal influenced by governance challenges and driving fundamental transformations and regime shifts from historically shared surface water irrigation to privatized groundwater reliance. Despite this widespread transition, the underlying dynamics connecting environmental change, declining collective action, and infrastructure breakdown remain poorly understood. This study therefore build a coupled dynamic systems model that integrates hydrological processes, farmer behavioral adaptations, infrastructure maintenance, and institutional trust to explain how environmental and governance stressors trigger regime transitions in water systems.

Our model reveals feedback loops, through which rising surface water salinity and elite-driven salinization erode the perceived reliability of shared infrastructure, increasing exit rates toward private groundwater extraction. This behavioral shift occurs when coupled with declining infrastructure maintenance and institutional trust, accelerates aquifer depletion, reinforces social stratification, and subsides a socio-ecological trap characterized by groundwater overexploitation and degraded collective systems. The study also highlights critical thresholds and tipping points after which collective water governance begins to break down. This breakdown causes long-term changes in how water is managed and allows salty water to become more widespread in agricultural areas.

From scenario analysis, we demonstrate that recovery from such transitions requires strengthening institutional trust and targeted investments in infrastructure maintenance to reduce salinity and restore collective management. Our findings question the belief that people acting on their own can prevent larger system failures. Instead, point to the need for collective governance and action across different levels to address the problem effectively. The study thus highlights actionable takeaways and areas for policy focus to support sustainable water access under changing environmental conditions, as well as offers broad relevance for regions that rely on irrigation and are increasingly affected by both environmental stress and social challenges.

Keywords: *Water governance, Water infrastructure transitions, Regime shifts, Socio-*

ecological systems, Coupled human-water systems

Decoupling of Precipitation and Runoff: Explaining the Post 2000 Hydrological Shift in the Colorado River Basin

Authors:

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Abstract ID: 18

Event: 2025 ASU FLOW

Topic: Hydrology

Since 2000, the Upper Colorado River Basin has entered a protracted drought with warmer temperatures and lower precipitation relative to the 1900-2000 average, but—more critically—the long-standing relationship between precipitation and runoff has broken down, with identical precipitation totals now producing markedly different streamflow volumes, especially the inflows into Lake Powell. To diagnose the drivers of this hydrological shift, we developed a data-informed causal-inference framework based on statistical hypothesis testing. The framework is driven primarily by observations, while outputs from the Variable Infiltration Capacity (VIC) model are used to fill in observational gaps. The runoff coefficient (RC), defined as the ratio of runoff to precipitation, was selected to quantify their relationship. The results show that April 1st snow water equivalent (SWE) is the dominant control on the RC, explaining about 60% of its variance during the period from 1984 to 2020. Deep-layer soil moisture (SMD) emerges as the only variable with inter-annual memory, explaining an additional 25% of RC variability beyond what is explained by SWE before 2005. After 2005, however, SMD loses influence and a previously unnoticed coupling between winter temperature and summer precipitation becomes the leading secondary driver. Incorporating the interaction term alongside SWE captures 88% of observed RC fluctuations. These insights are intended to inform water resource strategies in drought-sensitive areas such as the Colorado River Basin, aiding decision-makers as they navigate the challenges of drought and climate change.

Integrating Hydrological Modeling and Remote Sensing for Monitoring and Forecasting Conditions in Forested Regions of Arizona: A Case Study of the Upper Black River

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Abstract ID: 17

Event: 2025 ASU FLOW

Topic: Hydrology

Integrating Hydrological Modeling and Remote Sensing for Monitoring and Forecasting Conditions in Forested Regions of Arizona: A Case Study of the Upper Black River

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Arizona's rapidly growing population relies heavily on snowmelt from the Salt and Verde Rivers to supply water to over 4.5 million people in metropolitan Phoenix. However, forecasting streamflow from these river systems is challenging due to highly variable weather patterns, ephemeral snowpack, and forest disturbances along the southern margin of the Colorado Plateau. This research applies a distributed hydrological model known as the Triangulated Irregular Network (TIN)-based Real-time Integrated Basin Simulator (tRIBS) to an important sub-basin of the Salt River—the Upper Black River (UBR). The model simulations utilize high-resolution LiDAR data to parameterize terrain features and vegetation structure, along with supplementary information on soil and meteorological conditions. Model snowpack conditions will be evaluated using data from a network of

SNOTEL stations and snow survey sites. Simulated snow cover fractions will be compared with remote CubeSat observations from the PlanetScope constellation. This work supports a series of airborne lidar snow surveys planned for the winter of 2025–2026, which will map spatially variable snow depth and be used to estimate snow water equivalent (SWE) in the basin. After using the surveys to further calibrate the model and build confidence in its performance, simulation outputs will be further validated against available stream gauge data. Our goal is to improve streamflow forecasts for the major reservoir systems in the Salt and Verde Rivers and bolster water security in central Arizona. This approach also offers a framework for other arid regions that rely on forest snowpacks for their water supply.

Challenges and Opportunities for Synthetic Water Distribution Models

Authors:

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Abstract ID: 16

Event: 2025 ASU FLOW

Topic: Hydrology

ABSTRACT: The expression of infrastructure as digital twins is on the rise amidst increasing possibilities of efficiency gains and the protection against vulnerabilities. Water distribution networks (WDNs), specifically, face increasing need for modernization and resilience. However, the dearth of high-resolution data on WDNs works against robust simulations. This study explores the challenges and opportunities of synthetic WDN models as a critical bridge to navigate the complexities of urban water networks. A Synthetic Infrastructure Model (SyNF) is applied to San Juan and Mayagüez, Puerto Rico to generate synthetic WDNs comprised of reservoirs, pumps, links and nodes and compare them with true data from the Puerto Rico Aqueduct and Sewer Authority (PRASA). In doing so the ability of the model to evaluate key structural and hydraulic characteristics is assessed. Results show that the synthetic model effectively captures large-scale network connectivity and spatial patterns, with moderate to strong correlations in pipe placement, nodal allocation, and pressure profiles. However, limitations are apparent in synthesizing across urban and rural morphologies, with the synthetic models overestimating nodal density in rural areas while underestimating it in urban cores. Pipe diameter distributions also diverge, with synthetic models favoring smaller pipes, impacting redundancy and criticality assessments. Opportunities for improvement include integrating population-density based allocation strategies to influence branched vs looped structure, improved handling of reservoir connections, and refining hydraulic parameters to enhance realism. These findings demonstrate the potential of synthetic WDNs as scalable tools for resilience analysis in data-scarce regions, while highlighting the need for strategies to improve the representation of socio-technical complexities and hydraulic dynamics.

Surface Water Detection in Dryland Regions using CubeSats and Machine Learning

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Abstract ID: 15

Event: 2025 ASU FLOW

Topic: Hydrology

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Commercial CubeSat constellation offers an efficient means of monitoring water presence in arid and semi-arid regions, where stream gauge coverage is often sparse or absent. Previous studies have demonstrated the use of differences in near-infrared (NIR) surface to detect water presence at 3-meter, near-daily resolution. While effective in some conditions, this method has notable limitations in densely vegetated channels and in distinguishing wet soil from flowing water. More importantly, the method requires site-specific threshold calibration with stream gauge records, which limits its transferability and scalability to different regions. To overcome these challenges, we propose a deep learning (DL) approach using a Long Short-Term Memory Convolutional Neural Network (LSTM-CNN) trained on 3-meter resolution PlanetScope imagery paired with daily streamflow records from a diverse set of USGS streams. The training dataset includes selected hydroclimatic (e.g., precipitation, temperature) and landscape features (e.g., vegetation fraction, terrain slope, aspect) to enhance model generalizability. Model performance will be evaluated against the calibrated NIR-differencing method using metrics such as precision, recall, F1-score, and IOU for water presence classification. We will also conduct ablation experiments to assess the added value of temporal memory and spatial features in improving detection accuracy under vegetation cover and during transitional hydrologic conditions. This study aims to produce a transferable and scalable DL model for surface water detection, requiring only minimal site-specific tuning. The implications are substantial for expanding streamflow regime classification and presence mapping in ungauged or poorly instrumented basins, enabling improved water resource monitoring and decision-making in dryland environments.

The Strong Impact of Precipitation Intensity on Groundwater Recharge and Terrestrial Water Storage Change in Arizona, a Typical Dryland

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Abstract ID: 14

Event: 2025 ASU FLOW

Topic: Hydrology

This study demonstrates the critical role of precipitation intensity in groundwater recharge generation and terrestrial water storage (TWS) change. We conducted two experiments driven by precipitation products with close annual totals but distinct intensity in Arizona, using the Noah-MP model with advanced soil hydrology. The experiment with higher precipitation intensity (EXP_{HI}) produces an annual groundwater recharge of 6.91 mm/year in Arizona during 2001-2020, ~15 times that of the experiment with lower precipitation intensity (EXP_{LI}). Correspondingly, EXP_{LI} produces a declining groundwater storage (GWS) trend of 0.51 mm/month, nearly triple that of EXP_{HI} . GWS change dominates the TWS trend. EXP_{LI} shows a declining TWS trend of 0.57 mm/month, nearly twice that of EXP_{HI} . Higher precipitation intensity reduces evapotranspiration and enhances infiltration and percolation, allowing more precipitation to recharge groundwater. This study underscores the need to ensure the accuracy of precipitation intensity in hydrological modeling for reliable water resources assessment and projection.

Climate Drivers of Base-flow Variability in Western U.S. Headwater Systems

Authors:

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Abstract ID: 13

Event: 2025 ASU FLOW

Topic: Hydrology

Headwater streams comprise approximately 88% of the stream network in the western United States and serve as critical sources of the nation's water supply. In the 11 western states, nearly 66% of the water originates on federal lands, with forested lands alone providing over half of this contribution. These headwaters, often situated in national forests, yield disproportionately high volumes of water and are vital for sustaining downstream ecosystems and communities. Yet many of these forests are already degraded or at risk, underscoring the vulnerability of these systems to climate stressors.

Headwater systems are especially sensitive to drought and climate change, which alter stream water balance, chemistry, and ecological function. As droughts intensify, streams increasingly rely on groundwater to maintain flow, especially during low-flow periods when base flow can become the primary source of discharge. This dependence is expected to grow under future climate scenarios. Understanding long-term trends in groundwater-supported base flow is critical for developing effective management strategies, particularly in regions like Arizona where headwater-fed rivers are essential for perennial flows, groundwater recharge, and riparian habitat resilience in an increasingly arid climate.

This study addresses these challenges by analyzing 75 years of streamflow records to quantify historical patterns and trends in base flow across western U.S. headwaters. Using base-flow separation techniques, the Mann-Kendall trend test, and the Theil-Sen estimator, we identify regional shifts in base-flow magnitude, timing, and variability, and link these patterns to key climatic drivers such as precipitation and temperature. Regional climate projections (SSP2-4.5 and SSP5-8.5) are used to estimate future base-flow responses under low- and high-emission scenarios.

Our results will provide critical insight into the past and future of groundwater-supported flows in sensitive headwater systems. By bridging the gap between regional-scale hydrologic projections and fine-scale headwater dynamics, this work informs water resource planning, habitat conservation, and climate resilience strategies for western watersheds.

Application of Bonsai Cultivation Techniques for Water-Efficient Landscaping in the Sonoran Desert

Authors:

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Abstract ID: 12

Event: 2025 ASU FLOW

Topic: Hydrology

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Unsustainable water usage is a common issue in desert cities, specifically in landscapes with non-native plants. The reliance on supplemental water and the alteration of natural environments can lead to significant harm to local wildlife, including habitat fragmentation and resource depletion. In search of more sustainable landscaping solutions, we will explore the potential of bonsai cultivation techniques when combined with native Sonoran plants. Bonsai is an ancient art form focused on creating long-term environments for plants while applying various stresses. To investigate the science behind this art form, a selection of Sonoran plants and standard bonsai trees will be monitored as they undergo the intentional stresses typically applied to bonsai. Each plant will experience one of the following stresses: soil nutrient manipulation, precise root and canopy design, and horticultural reshaping. These bonsai principles were chosen based on a previous study exploring the integration of bonsai techniques into urban environments. We will measure the rate of photosynthesis, water-use efficiency, and root/canopy growth to determine the overall health of these plants when put under various stresses. The data collected from investigating these functions will demonstrate the impact of bonsai techniques on the plant process to contribute to aesthetics in sustainable landscaping.

Closing the Water Balance of a Small Forested Watershed in Northern Arizona

Authors:

Jonna Urban, Center for Hydrologic Innovations

Abstract ID: 11

Event: 2025 ASU FLOW

Topic: Hydrology

Closing the Water Balance of a Small Forested Watershed in Northern Arizona

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AHS/ ASU Flow - Poster Session

Ponderosa pine forests are a crucial component of Arizona's water supply. However, hydrologic processes in small, forested watersheds across the southwestern U.S. remain poorly constrained due to sparse ground-based observations. In particular, the relationship between precipitation and streamflow is highly uncertain, as it is strongly influenced by temporally variable snowpack and soil moisture conditions. The objective of this study is to improve our understanding of forest hydrology in the Sycamore Creek watershed in order to inform water resource management and support long-term planning for disturbances such as wildfire and forest treatments. This work includes the analysis of historical hydrometeorological data to characterize monthly, seasonal, and annual amounts of streamflow, precipitation, and soil moisture. Freeze events have been identified by linking streamflow data to below-freezing air and soil temperatures recorded at nearby SNOTEL stations and supported by Flowtopography imagery. This process has allowed detection of stream gauging errors during freezing events in the winter months. To address this issue, we are installing a heated flume. In addition, new instrumentation in a small watershed will enhance our hydrologic monitoring efforts. These include a Cosmic Ray Neutron Sensor and a network of soil moisture probes to measure spatially integrated and point-scale soil moisture, respectively. Additional installations will include a snow water equivalent sensor, an evapotranspiration sensor, and a pyranometer. Preliminary water balance calculations using historical data indicate an overestimation of evapotranspiration, underestimation of precipitation, and seasonal inconsistencies in streamflow. Ultimately, this study aims to develop a transferable instrumentation and monitoring framework for other forested sub-basins in the Verde and Salt River basins, where accurate water balance assessment is

essential for reservoir management, hazard forecasting, and forest health.

Conceptualization of a Water Footprint Labeling (WaFL) for food in the US Grocery stores

Authors:

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Abstract ID: 10

Event: 2025 ASU FLOW

Topic: Hydrology

Diminishing water supplies and increasing water demands of the society amid climate change necessitate innovative measures of water resources management that will complement the current profile of management tools. Food production is a major water consumer in the US as well as in the rest of the world, therefore food production's water efficiency plays a critical part in water security. With the success of many precedent eco labels and the promising research in carbon footprint labels, we propose a water footprint label (WaFL) for food to be implemented in US grocery stores. Through an online survey of the US consumer population, we found that a significant percentage of consumers are to some degree receptive to the idea of a label on grocery items indicating its water consumption level. Additionally, the most preferred labeling format is a numerical label, or if a tier-system is used 3 tiers is ideal; they trust a voluntary program from USDA the most and companies self-reports the least. Meanwhile, consumers collectively are willing to pay extra for the access of the water consumption information of their groceries. The results indicated that the US consumer population is well positioned for a WaFL to inform their grocery decisions on-site, although a pre-launch campaign and follow-up monitoring and education will be essential to the successful introduction and continued improvement. We recommend further lab experiments and pilot test in grocery store settings to proof the results from this study before a label release is confidently recommended to grocery store chains, policymakers, or producers at large.

Investigation of agriculture water demand response to the Post-2026 Colorado River Operations Alternatives

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Abstract ID: 9

Event: 2025 ASU FLOW

Topic: Hydrology

As the current drought response agreement is set to expire in 2026, federal, state, and tribal stakeholders must collaborate to develop a new plan. However, these negotiations are challenged by differing views on future operations. To aid this process, the Bureau of Reclamation has published a report outlining five potential alternatives, incorporating proposals from various stakeholders. This study evaluates how agricultural water demand responds to these proposed policy changes and assesses their impacts on water availability at the local, sub-basin, and basin levels. We use a coupled modeling approach, combining the Colorado River Simulation System (CRSS) for water resource management with agent-based modeling (ABM) to simulate the dynamic responses of farmers' irrigation decisions. The CRSS operational rules are updated according to the five proposed alternatives, while the ABM utilizes a reinforcement learning algorithm to model farmers' adaptive behavior. The results of this analysis will provide critical insights to support ongoing negotiations, helping to develop a feasible, equitable, and operational solution for drought management.

Infrastructure readiness for water-positive renewable energy generation in the US

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Abstract ID: 8

Event: 2025 ASU FLOW

Topic: Hydrology

The western U.S. is rich in solar energy resources but faces growing water scarcity. Floating photovoltaics (FPV), which deploy solar panels on buoyant platforms over water reservoirs, present a dual solution for renewable energy generation and water conservation. This study evaluates infrastructure readiness for utility-scale FPV deployment by bridging the gap between national technical potential assessments and site-specific design considerations. We identify existing infrastructure—such as hydroelectric reservoirs, natural gas pipelines (for potential green hydrogen transport), and electrical grids—that could reduce capital costs and accelerate large-scale FPV adoption. By analyzing 115 reservoirs (selected from over 90,000 sites in the U.S. National Inventory of Dams), we quantify regional energy-water synergies, including renewable energy potential, capacity factors, seasonal generation variability, and evaporation savings. Our findings highlight how FPV systems in the arid and semi-arid western U.S. can leverage abundant sunlight, significant water savings, and low natural hazards (e.g., hail, high winds), while benefiting from enhanced panel efficiency due to water cooling and reduced soiling. These advantages position FPV as a promising, water-positive pathway for energy decarbonization in water-constrained regions.

Evaluating urban microclimate variability over vegetated and impervious surfaces in hot environments

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Event: 2025 ASU FLOW

Topic: Hydrology

Urban microclimates are significantly influenced by land use, particularly in arid cities where irrigated green spaces contrast sharply with surrounding impervious surfaces. To gain a better understanding of these interactions, two eddy covariance (EC) towers were deployed within Encanto Park in Phoenix, Arizona. One tower is situated in the irrigated interior of the park, while the other is at the park edge which borders a street and a large, paved area in the Arizona State Fairgrounds. EC towers provide high-frequency measurements of turbulent heat and water vapor fluxes while simultaneously monitoring key meteorological variables. Building on prior study findings that demonstrate the urban oasis effect, this research focuses on understanding the cooling benefits of the urban park through the analysis of evapotranspiration and land surface temperature (LST). Landsat-derived LST showed sharp thermal contrasts, with irrigated areas averaging 35°C as compared to 75°C at the impervious site during peak afternoon hours. Normalized Difference Vegetation Index analysis confirms vegetation density disparities, with the park maintaining values of 1.0 versus near-zero values (-0.3 to 0.1) in the paved surroundings. Initial findings show that energy partitioning at the irrigated park exhibits latent heat flux (LE) dominance, with LE exceeding net radiation at night. This energy partitioning arises from advected sensible heat from surrounding urban areas, leading to enhanced evaporative cooling that reduces sensible heat and cools the surrounding air. Our overall aim is to quantify the energy partitioning across land use contrast and how this influences the surrounding microclimates at the local scale. The insights from this study can inform sustainable urban design and water management practices in hot, arid cities.

A Holistic Modeling Approach to Enhancing Water Supply Resilience in the Colorado River Basin

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Abstract ID: 6

Event: 2025 ASU FLOW

Topic: Hydrology

The Colorado River Basin is facing intensifying stress from historic overallocation, prolonged drought, and a changing climate. Although the basin is a highly engineered system with multiple reservoirs, including Lakes Mead and Powell, its infrastructure may no longer ensure long-term resilience under escalating hydrologic and demand pressures. Addressing these challenges requires comprehensive and integrated long-term management strategies that consider the basin as a holistic system to respond to severe and prolonged droughts driven by climate change.

This research develops a decision support system using the Water Evaluation and Planning (WEAP) model to evaluate the performance of existing infrastructure and reservoir operation rules under a range of streamflow scenarios in the Colorado River Basin. The model extends beyond the basin by incorporating hydrologic and conveyance linkages to several connected watersheds (e.g., Rio Grande River Basin) and regions (e.g., Imperial Valley). Moreover, it represents the spatial distribution of demand nodes, each assigned a priority level and linked to corresponding water supply sources. This structure enables detailed analysis of allocation dynamics under different competing demands.

The model is tested for the period from 1990 to 2019, which includes key policy eras in the basin's management: 1) the pre-2007 Law of the River; 2) the 2007 Interim Shortage Guidelines; and 3) the 2019 Drought Contingency Plan. The validated model is then applied to run a range of future streamflow scenarios to assess how spatial and temporal hydroclimatic variability influences system performance. The model results provide valuable insights for decision-makers by identifying potential vulnerabilities, testing adaptation strategies, and revealing localized patterns that can inform targeted interventions (e.g., water conservation measures), region-specific investments to enhance long-term water supply resilience.

manage, and maintain it.

Evaluating System Robustness in the Western U.S. Networked Water Supply System

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Abstract ID: 5

Event: 2025 ASU FLOW

Topic: Hydrology

Large-scale water infrastructure from reservoirs to aqueducts has enabled reliable water supply across the Western U.S. This infrastructure has also reshaped the region, connected previously separate watersheds and aquifers through water transfers and shared demand nodes, effectively creating a regional water supply network. While such infrastructure systems are effective in reducing local water shortage risks during most drought events, their interconnectedness can introduce unintended vulnerabilities under long or widespread drought, including cascading failures, particularly because they are optimized based on historical variability. Since networked systems are often fragile when operating outside their historical range of variability, there is a growing need to prepare them for future uncertainties, including climate change and shifting water demand. Additionally, embedded in the design of these infrastructure systems and their operational rules are tradeoffs between local and systemic risks. However, our understanding remains limited regarding how future changes may affect water supply robustness, which operational rule adjustments could help mitigate negative impacts, and what trade-offs exist between local and system wide robustness. To address this gap, this study evaluates the robustness of a networked water supply system under scenarios of prolonged drought and changing demand using a stylized modeling approach that simplifies the network to its essential structure and behavior. The model is abstracted from the western U.S. water network, centered around the Colorado River, which has experienced unprecedented and prolonged drought, making it an ideal case for evaluating the robustness of networked water supply systems. It includes key reservoirs, conveyance infrastructure, and water users to capture the fundamental dynamics of allocation and shortage propagation. We explore how system robustness responds to various operational rule adjustments. We propose a set of performance metrics to assess robustness, including maximum shortage, percentage of demand met, and percentage of time demand met. Additionally, we investigate trade-offs between local (e.g., watershed or state-level) and systemic (e.g., basin-wide) robustness to identify potential vulnerabilities and critical weak points within the network. In sum, this study aims to provide insights into how networked water systems behave under future climate and demand changes, and how adaptive operational rules can sustain robustness over time.

Enhancing Groundwater Sustainability through Agricultural Managed Aquifer Recharge in the Phoenix Active Management Area

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Abstract ID: 4

Event: 2025 ASU FLOW

Topic: Hydrology

Groundwater depletion remains a major challenge in the Phoenix Active Management Area (AMA), driving the search for new strategies to enhance aquifer sustainability. In this study, we assess the feasibility of Agricultural Managed Aquifer Recharge (Ag-MAR) in three irrigation districts, Roosevelt, Buckeye, and Arlington, using flood flows from the Salt River. To target Ag-MAR to the areas of these irrigation districts with the highest recharge potential, we develop a Groundwater Recharge Potential Index (GWRPI) using fuzzy logic and incorporating groundwater depth below the land surface, soil saturated hydraulic conductivity, electrical conductivity, slope, and land use. Realistic recharge volumes, derived from a 20-day flood event in March 2019, were applied within Moderate to Very High GWRPI areas with Alfalfa, a flood-tolerant crop prevalent throughout the study area. Simulations were conducted using the calibrated MODFLOW-NWT groundwater flow model developed by the Arizona Department of Water Resources for the Phoenix AMA. Results show that spatially focused recharge produced significant and long-lasting groundwater benefits, with Roosevelt exhibiting the greatest response, with a groundwater elevation rise up to 11.1 ft in certain locations, due to its favorable soils and crop patterns. On average, water table rises ranged from about 2.2 ft under conservative recharge (Scenario 1) to 5.4 ft under doubled recharge (Scenario 2). Even this short-term recharge event led to aquifer improvements that persisted for multiple years compared to the baseline scenario. Sensitivity analysis revealed that increasing recharge volumes resulted in nonlinear aquifer responses, emphasizing the importance of aligning recharge strategies with local hydrogeologic and land-use conditions. This study demonstrates that spatial analysis and consideration of field-level constraints are critical for effective Ag-MAR implementation, where strategically applied recharge can strengthen groundwater resilience in Arizona and offers a transferable approach for other arid and semi-arid regions.

Understanding different flow regimes of the Grand Canyon's regional aquifer using natural tracers

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Abstract ID: 3

Event: 2025 ASU FLOW

Topic: Hydrology

High-elevation karstic aquifers fed by snowmelt are integral to supplying water for arid regions. The Grand Canyon's regional aquifer has been under-studied regarding the dynamics and differences between baseflow and snowmelt flow conditions. It is hypothesized that natural tracers collected from the water of Roaring Springs, the main water source of Grand Canyon's National Park's Transcanyon Waterline, will point to differences in snowmelt and baseflow conditions. An automatic water sampler stationed at the bottom of the Grand Canyon collects daily stable isotope samples before, during, and after snowmelt. A data logger inside Roaring Springs provides a continuous record of temperature, conductivity, and pressure. These natural tracers can point to shifts in the flow regimes of water through the regional aquifer and can identify differences between flow conditions. These data can inform when groundwater is recharging. It can also enable Grand Canyon National Park to better understand a major part of its water supply as they plan for a future where there will be less water available to provide to residents, visitors, and ecosystems.

Building and Applying a Regional Streamflow Model to Assess Water Scarcity in the Western U.S.

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Event: 2025 ASU FLOW

Topic: Hydrology

Water scarcity is a growing challenge in the Western United States, particularly in the Colorado River Basin, as population growth drives demand and aridification reduces supply. This research project focuses on developing a regional streamflow model consistent with historical spatial and temporal patterns and projected climate changes to assess the regional water supply reliability. Streamflow data from USGS and Palmer Modified Drought Severity Index (PMDI) from 1980-2017 from NOAA have been analyzed to build and refine a statistical model for streamflow. The Water Evaluation and Planning (WEAP) model will be used to model reservoir operations and withdrawals in future scenarios. This work would enable future streamflow projections in the Colorado River basin and nearby watersheds to advance sustainable planning on a regional scale using water systems analysis models. The implications of this project are in areas such as improving drinking water reliability and informing policy and infrastructure decision-making processes.

VULNERABILITY OF URBAN WATER SYSTEMS TO CHANGING DROUGHTS: THE CASE OF SANTA ROSA, CALIFORNIA

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Abstract ID: 1

Event: 2025 ASU FLOW

Topic: Hydrology

Urban areas are increasingly vulnerable to droughts due to population growth, high water demands, aging infrastructure, and climate change. This study evaluates how worsening drought characteristics, along with the speed and decisiveness of utility responses, influence the performance of urban water systems, using Santa Rosa, California as a case study. We apply a socio-hydrological model that captures delayed decision-making in response to environmental shocks to assess reliability (i.e., ratio of monthly supply to demand), rate burden, and demand burden on citizens under scenarios with increasing drought intensity, duration, and frequency. High-intensity droughts lead to the most severe shortages and the highest rate increases as the utility requires prompt investments. Longer droughts impose more sustained pressure, driving some delay in infrastructure investment and lower rates. More frequent droughts cause the system to accumulate pressure over time and further delay investments, leading to the lowest rate increments. Proactive investments in both demand management and groundwater supply expansion can maintain average reliability under worsening droughts but may not prevent sharp supply-demand imbalances in peak summer months. Groundwater plays a critical role in buffering supply, particularly in summer, but is constrained by maximum pumping capacity. Institutional factors also shape outcomes: higher institutional costs reduce average reliability and customer rates more than institutional flexibility alone. However, reducing rate burdens has minimal effect on improving reliability. Findings indicate that Santa Rosa faces vulnerability due to limited reservoir capacity, dependence on surface water, and anticipated loss of Eel River transfers.