

2023 ANNUAL REPORT

Utah Water Research Laboratory

UTAH STATE UNIVERSITY®

Message from the Director



David Tarboton
UWRL Director

Water resources in Utah and around the globe continue to become more variable. Climate change is affecting rivers and river ecosystems, agriculture irrigation, and the Great Salt Lake. The Utah Water Research Laboratory always has a thumb on the pulse of water, and our recent research focuses on the needs of the state and others with similar environments.

A huge hurdle to overcome in implementing research-based solutions at the Great Salt Lake is a lack of continual, well-documented data. Without upstream monitoring and salt balance samples, air quality metrics and lakebed measurements, strategies will remain incomplete. The Great Salt Lake Strike Team was created in 2022 to bring together experts and data to evaluate potential solutions. The team just released its first updated summary since its original policy assessment report last year. The research is clear: no one solution will save our Great Salt Lake.

UWRL researchers are utilizing their areas of expertise to study many different facets of the lake's situation, bringing much needed data to the table.

Mirroring the need for increased data is a need for more detailed models to predict how our water will continue to respond to climate change. Sediment buildup from floods and wildfire can cause damage to infrastructure and wildlife habitat. UWRL faculty member Colin Phillips is developing a physics-based model for river channels. His work utilizes high-resolution lidar topography to extract the river's geometry and track it over time to improve predictions of river instability.

UWRL's AggieAir researchers are harnessing cutting-edge drone technology to improve not only water management at orchards and farms, but crop yield as well by getting detailed information about crop water usage into the hands of growers. Faculty member Alfonso Torres-Rua is working with California's Almond Board to reduce the strain on water resources while maintaining the stress needed for a tree to produce well. Working with computer scientists, he aims to eliminate the processing time between flight and results so growers can make water-conscious irrigation choices every day.

The projects highlighted in this report are just a slice of the research the lab is conducting to address water needs across the state and globe. I am gratified to see the focus Utah has on water, and the UWRL is dedicated to research and develop future solutions. ■

For more information, please visit our website:

<http://uwrl.usu.edu/>



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The Great Salt Lake: addressing concerns from precipitation to pollution



Photo courtesy USU

Hardly a week goes by without a news story on the Great Salt Lake. Concerns over toxic dust, salinity balance, and water levels populate every conversation about Utah's precious terminal lake, all issues that have been exacerbated by climate change and increased diversion of river water that used to flow straight to the lake.

Great Salt Lake Strike Team

With environmental groups, concerned citizens, and Utah policy makers searching for solutions, the Great Salt Lake Strike Team was formed to focus on protective measures and potential solutions. The Strike Team is made up of experts from Utah State University, the University of Utah, and state agency leaders and experts. Two UWRL faculty members—David Tarboton and Bethany Neilson—add their hydrology expertise to the Strike Team's toolkit. The team does not advocate, but functions as a technical, policy-advising entity to help the state find the best paths forward to overcome current hurdles.

The Strike Team has been engaging in research since 2022, and their recent 2023 report highlights the need for many data-driven solutions to restore the lake. The 2023 water year contributed a significant amount of water to the Great Salt Lake Basin, which had positive effects on lake levels. However, improved monitoring systems and management strategies are still needed to ensure that water saved through management and conservation efforts is shepherded past diversions to reach the lake.

Dust Working Group

Another collaborative group is focusing on a specific aspect of the Great Salt Lake and its impacts on the surrounding cities: dust generated from the dry lakebed. This dust working group is made up of researchers from Utah State University, the University of Utah, Westminster College, Brigham Young University, Salt Lake Community College, and Weber State, along with the Utah Division of Air Quality. The group is sharing research and communicating efforts to understand the science behind the dust plumes, potential toxicity, and the potential impact on Utah's population.

"The group has been remarkable in putting everybody in the same room," said USU professor Randy Martin. "Everybody's got different thoughts and ideas."

While one is looking at chemical signatures, another is researching wind patterns or population impacts. Analyzing several dust events over several years enables researchers to see what the impacts are to wider populations. The collaboration elevates the scientific understanding of GSL dust events and the potential hazards involved.

Other Research Efforts

With the Strike Team focused on informing policy makers on overarching issues and the dust working group communicating air quality research, other UWRL researchers are working on addressing a range of broadly identified concerns:

Tracking Water Inflow

Limited data complicates the tracking of water deliveries to the GSL, despite a focus on raising lake levels. USU is working on a gaging and infrastructure gap analysis with the Utah Division of Water Rights to help prioritize new river and diversion monitoring stations. According to Bethany Neilson, the 2023 snow year didn't raise lake levels as much as people had hoped due to previous drought years and the runoff first filling reservoirs and groundwater stores. "We made progress last year," Neilson said. "But we need to continue to establish the best practices for conserving and tracking water to the lake." Increasing measurement sites and improving information sharing ensures transparency for water rights users and enhances water resources management.



A Flood of Data

Overcoming challenges at the lake requires sifting through a flood of data to increase access for researchers and decision makers. Jeff Horsburgh is tackling this important cyberinfrastructure pillar. He is conducting a hydroinformatics and technology gap analysis for the Utah Division of Water Rights to help them update and scale their system to meet increasing needs for data collection and management. "They need a modern and robust data system," Horsburgh said. "Not just to support the data they already have, but also to meet the needs of new data collection programs." With all eyes on water rights and the lake, Horsburgh is making recommendations to help state agencies support new data priorities.



Farmland Irrigation

"To have more water in the Great Salt Lake, you have to reduce the amount of water being depleted or consumed," says Burdette Barker. His focus is on estimating water depletion on farms through evapotranspiration. Being able to quantify water going into the air helps water users and state managers understand how much water can be leased to various sources. One method of reducing farm evapotranspiration is subsurface drip lines. Barker is comparing the depletion of water on alfalfa fields using these buried lines against other forms of irrigation. The goal is to be the most productive with the water used.





Lakebed Toxins

Sierra Young and Joan McLean are studying how the cycle of wetting and drying of the shoreline affects toxin mobilization. Their focus is on arsenic because it rises to the surface with rewetting instead of staying buried in the sediment. They concluded that arsenic concentrations are higher when the playa (lakebed) is wetter. When the shoreline dries out during the summer months, the toxin has the potential to become airborne via harmful dust. Seasonal lake level and shoreline fluctuations are normal, but Young and McLean stressed that raising the lake levels will be important for keep more of the playa covered so this harmful toxin stays buried where it belongs.



Salinity Balance

Salinity is mostly determined by fluctuating water levels and water exchanges between the lake arms. Master's student Diana Dunn is working with Brian Crookston to create a salt balance model of the south arm; work that is complicated by data availability. Dunn warns, "modeling the lake is a challenge because it requires combining data from different sources and filling gaps in the record. We need to collect data at a higher frequency and with greater coordination among data collectors." Dunn's model is being developed with the best data available and can be improved as more data is received. Using her work, the state can test management strategies to preserve healthy salinity levels.



Air Quality

As the wind blows dust from the lake into surrounding cities, the likelihood of citizens inhaling toxic elements increases tenfold. Chlorine and bromine are highly reactive halogens that destroy our protective ozone layer. In a recent study, Randy Martin observed halogen levels near the GSL to determine where they might be coming from. The likely source is the nearby US Magnesium plant. The plant stopped operation last year for maintenance, which gave researchers a chance to observe levels without that major source. Martin hopes to extend the study when US Magnesium resumes operations to see what added impact it has on air quality in the region.

Changing Channels: climate impacts on rivers

Extrême and variable weather continues to rock our ecosystems as climate change disrupts the regular patterns of precipitation our rivers are accustomed to. Bigger storms result in more frequent flooding and landslides, and increased drought enhances the threat of wildfire, vegetation loss, and extreme erosion.

We rely on these mountain rivers as sources of drinking water, hydropower generation, recreation, and irrigation. But we don't have any way to predict or assess how rivers will respond to climate change in the future, which has implications for water resources and infrastructure. We need dynamic models for our rivers as climate continues to destabilize.

Analyzing in High Res

Assistant professor Colin Phillips and his team are utilizing high-resolution

lidar topography to develop a physics-based model of river channels, looking to see how sensitive they are to shifting changes in climate.

First, the team had to develop the tools to extract river geometry from the topography data. This let them look at river features in a new and highly detailed way.

Then they analyzed the data to identify and quantify changes due to natural variability and changes resulting in instability and erosion.

In looking at Strawberry River after wildfire and flood, they found that sections of the river with debris flows resulted in significant erosion of roads in the area. The sediment buildup from extreme weather events poses a great risk to infrastructure and wildlife habitat

as the river's channel undergoes drastic changes.

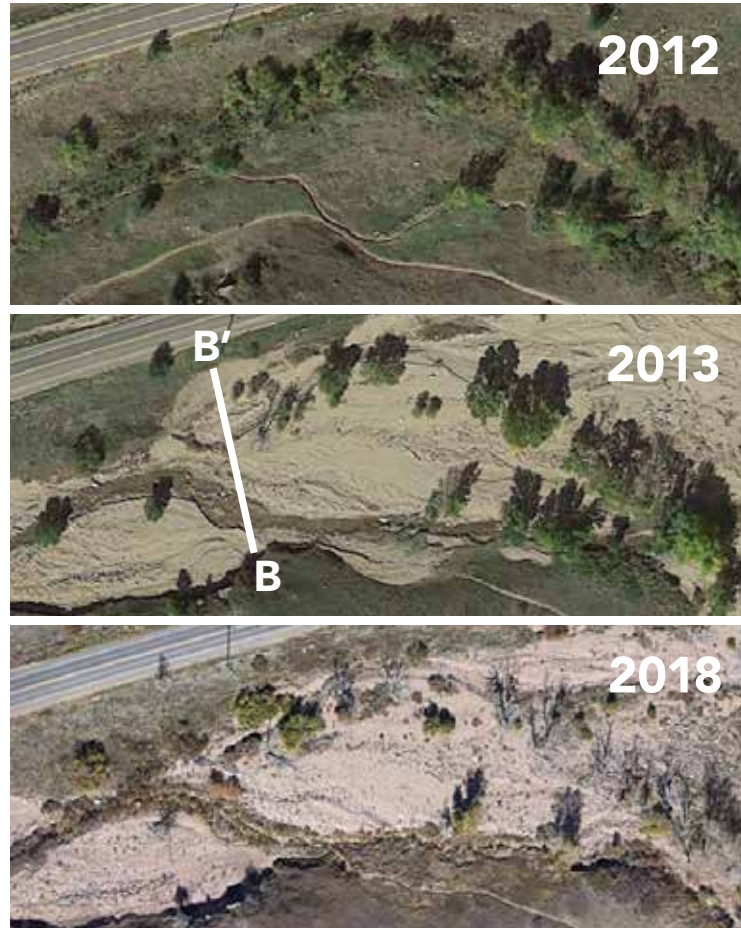
Improving Models

Two students on Phillips' team took a closer look at river channel geometry to improve predictions of change on a larger and more variable scale. Where before, only a few cross-sections of a river were used to inform the model, using this lidar topography allows for continuous measurements.

With the data from 65 rivers, they found that the degree to which a river deviates from its course is positively correlated with the flood duration. The longer the flood, the greater the change in the river channel geometry. Rivers are wider where floods occur for more of the year. The more time spent in flood, the wider and shallower the channel becomes.



Fourmile Canyon Creek, CO widened 30 meters during the 2013 Boulder Floods, and the effects were still present in 2018.



Creek photos courtesy Colin Phillips; river photo courtesy UWRL

With these discoveries, researchers now have a framework for understanding how climatic or engineered changes could alter river geometry, affecting flood risk and habitats.

Predicting and assessing river susceptibility to significant change is vital to developing mitigation strategies. Phillips is looking further to automate the analysis of high-res lidar topography and perform physical experiments at the UWRL to improve predictions and understand the factors that lead to river instability. ■

Further Reading:

Threshold constraints on the size, shape and stability of alluvial rivers.

<https://www.nature.com/articles/s43017-022-00282-z>

National Science Foundation Award

<https://bit.ly/49ar1YE>





“
We know the science.
We know how to
interpret the data
captured. Why not put
that knowledge inside a
computer in the drone?
”

Towards Real Time Water Data for Almond Orchards, Vineyards, and Irrigated Lands

Unmanned aerial vehicles (UAVs), or drones, are fast becoming an essential part of agriculture, and AggieAir researchers are a driving force behind using this technology to manage water and increase yield. They are working to get the data from the drones and into the hands of the growers in real time.

Alfonso Torres-Rua and a team of scientists from Utah State University, University of California, US Department of Agriculture (USDA)–Agriculture Research Service, and E&J Gallo, among others, have surveyed several crops using drone technology. They began with grapes in California, studying the water use at vineyards. That project is expanding to Israel with collaborators from Ben Gurion University and to Chile with University of Talca. AggieAir will use its expertise to compare regional water use.

Concurrently with a project for almond orchards, the team is also looking at tart cherry production in a project funded by USDA–National Institute of Food and Agriculture and at turfgrass quality for the US Golf Association. The advantages of utilizing this technology for agriculture optimization and water conservation spreads across different crops and climates.

Since the beginning of this research in 2011, the same knowledge and expertise in UAVs has been used, studied, and

tweaked for every agricultural project, highlighting its versatility. “The same technology, the same data, has served so many different purposes,” Torres said.

Acres of Almonds

California is the number one producer of almonds. The state provides 80% of the world’s almonds, but the industry lost two billion dollars in the market due to water scarcity and climate change. Almonds require a significant amount of water to grow, and as the price of water goes up and accessibility goes down, producers need more accurate ways to schedule their irrigation and conserve as much water as possible. Funded by the Almond

Board of California, Torres is working with other institutions and disciplines to improve water management for the almond groves and increase yield.

Their project goal is to estimate the current amount of water and stress per tree using different levels of technology and then integrate that technology into existing irrigation equipment on almond farms. Adequate management of stress levels on a tree actually increases the quality of nuts. Stress is produced by giving the tree just enough water for growth but not too much.

Torres and the AggieAir team travel to California during key moments of the



growing period: fruit formation, mid-development, and before harvest. Their collaborators in California conduct more frequent data collection visits to the study sites and fly smaller commercial drones almost weekly to provide continual data for the season. When Torres flies an AggieAir drone over the field, he can see the characteristics of every tree in the orchard, including canopy size, location density, and water use. This information is tree-specific, which means producers or orchard managers can quantify how much to irrigate each section/valve—no more, no less.

Putting Data in Use

Growers already have the ability to vary water applications in different parts of their orchard, but detailed information about their trees is needed in order to fully utilize this technology and make their field more water-conscious.

The data Torres gathers on this specific project is used to improve existing algorithms that will generate information on water status and stress. This simplifies the monitoring process and reduces excess water usage. He's also able to coordinate his flights with satellite overpasses and uses both to develop estimates of evapotranspiration (water

evaporated from the soil or expelled from the plants) at the scale of a single tree.

But with all of this incredible data, there's still a problem:

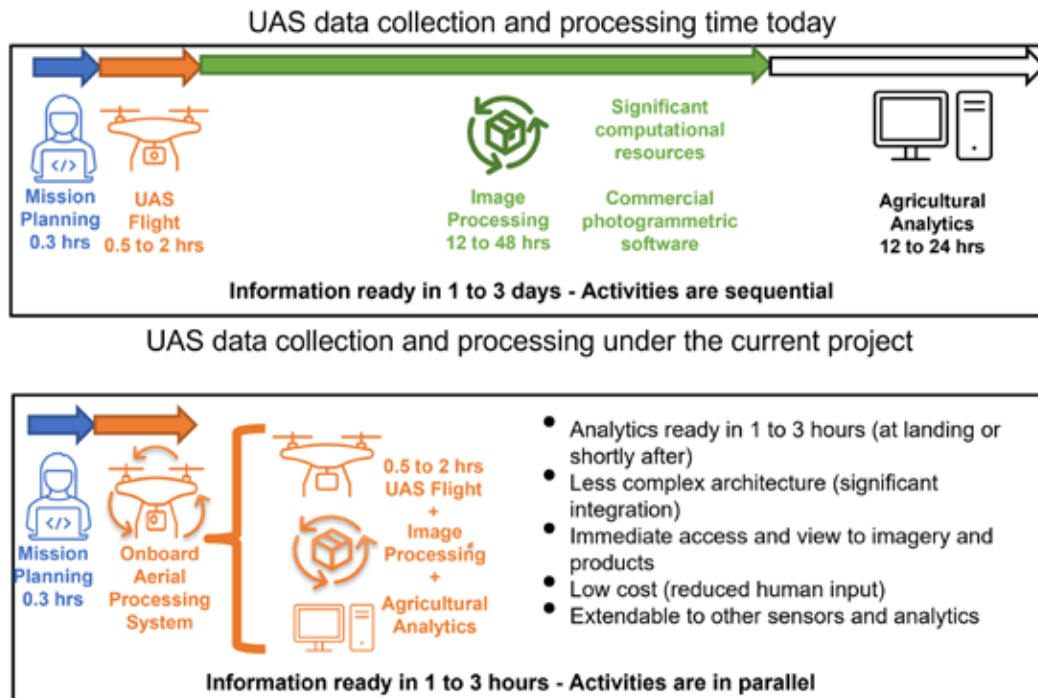
A single flight from an AggieAir UAV can capture half a terabyte of data that takes days to process. This is why it isn't common to see farmers flying drones by themselves. It's an expensive, heavy, and long process. By the time the data is ready to use, the information is obsolete and needs have changed. Torres said managers would need this data once a week to be able to generalize their irrigation needs.

And that problem is exactly what his team is working on across all of their projects.

Real Time

"We know the science," Torres said. "We know how to interpret the data captured by the drone. Why not put that knowledge inside a computer in the drone?"

With AggieAir's unique expertise and access to perform experimental research on an unprecedented scale, USU researchers, Steve Petruzza, Calvin Coopmans and Alfonso Torres-Rua and their students are working on eliminating the time gap between raw flight and processed data. In other words, they want the information in real time.



“We’re hoping that with these projects, we will have everything we need to create that ultimate product that will make drone information accessible to producers,” Torres said.

Their team already has a prototype and are only 2–3 years away from a working prototype. The process is difficult: they’ve had to develop the knowledge of how to interpret the data and then develop models that work inside drone technology. But the results will be instant, usable data for field and orchard managers so they can plan their weekly irrigation, saving water and increasing crop production at the same time.

Eventually, Torres hopes to see this technology in the hands of the growers themselves, able to fly a drone over their field and adjust their irrigation systems whenever they need to, “no PhD needed.”

Torres looks forward to the next generation of drone technology with an appreciation for all they’ve been able to accomplish so far. “We think of that moment—the drone use in agriculture will change forever. And that’s being done here, in this little corner in the mountains.”

Further Reading:

The Grape Remote sensing Atmospheric Profile and Evapotranspiration eXperiment (GRAPEX) (Bulletin of the American Meteorological Society): <https://bit.ly/3O7AnMK>

GRAPEX grapevine project website <https://bit.ly/47Opdn3>

The Tree-crop Remote sensing of Evapotranspiration eXperiment (T-REX) (Bulletin of the American Meteorological Society): <https://bit.ly/42fDxUy>

T-REX almond project website <https://www.t-rexproject.com/about-the-project>

Story photos courtesy Alfonso Torrués-Rúa





Water Conservation in the Home

Drought conditions in Utah and across many parts of the nation highlight the need for smart home water metering systems. Standard water use data, like what municipal companies use to charge water bills, typically only record monthly water use and don't show peak water-use times, volumes, or types. Frequent and accurate data is important for informing water managers and helping homeowners reduce and optimize their water usage.

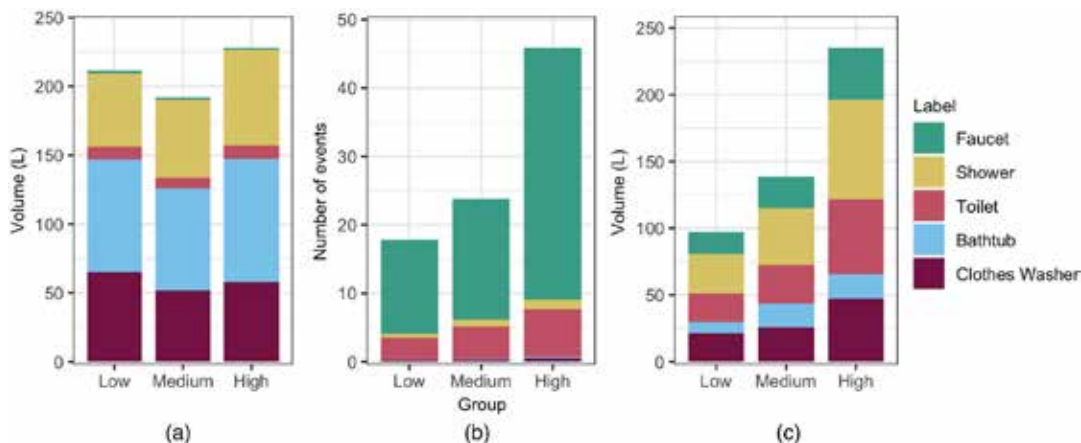
Associate Professor Jeff Horsburgh and his students gathered and analyzed detailed data on indoor (toilets, faucets, showers, bathtubs, clothes washers) and outdoor (irrigation via hose or sprinklers) water use for homes in Logan and Providence, Utah.

Their new data collection devices provide a finer scale to better understand how much water each appliance and irrigation system is using. In particular, they can separate and classify water use data into individual end-use events, such as a shower or a load of laundry. The results provide opportunities for water conservation.

Conserve Indoors

The data in the graph above show showers were the largest consumer, averaging 30.9% of daily water consumption, followed by toilets at 22.1%. Faucets were the highest performing category, which may be explained by their being the most likely to be frequently replaced.

Individuals can conserve water by replacing or adjusting toilets and



Indoor water use summary by group for low, medium, and high water users: (a) average water use volume per event occurrence; (b) average number of events per capita per day; and (c) average daily indoor water use per capita and distribution among end uses.

showerheads to be more efficient. The data on shower length also shows room to conserve in shortening showers to 10 minutes or less.

Conserve Outdoors

The data revealed a strong correlation between automated sprinkler systems and higher water use. Households can reduce their irrigated landscape to conserve water by replacing turf with water-conscious plants.

Additionally, the recommended times for irrigating to reduce evaporation loss are in the early morning or late evening. Irrigating during these times will increase the efficiency of the sprinkler system.

Patterns and differences in water use varied over time for individual homes, and understanding this variability is important

in reducing assumptions about water use and in helping water utilities and decision makers better understand how and when water is being used. Placing these results in the hands of residential water users provides them with the opportunity to make informed changes to their water use behavior and assist in their community's conservation efforts. ■

The data shown in this article first appeared in the following journal article: [https://doi.10.1061/\(ASCE\)WR.1943-5452.0001633](https://doi.10.1061/(ASCE)WR.1943-5452.0001633)

Read more in our research briefs:

An open-source, semisupervised water end-use disaggregation and classification tool. <https://bit.ly/49d1rSR>

Variability in consumption and end uses of water for residential users. <https://bit.ly/3vQS6l9>

Awards and Achievements

Photo courtesy UWRL



David Rosenberg

ASCE Planning and Management Council Service to the Profession

David Rosenberg received this Service to the

Profession Award from the American Society of Civil Engineers. Rosenberg was awarded for establishing a new journal program to reproduce results and creating an open repository of water resources teaching materials.



Colin Phillips

USU Eldon J. Gardner Teacher of the Year

Colin Phillips won the Eldon J. Gardner Teacher of the Year Award

from the USU College of Engineering. This award recognizes excellent teaching at the university. The awardee is chosen by a committee of students, faculty, and administrative representatives.



David Tarboton

USU D. Wynne Thorne Career Research

David Tarboton, director of the UWRL, received the D. Wynne Thorne Career

Research Award from USU. This award is a premiere research recognition given to a senior faculty member who produced a significant portion of their research at USU.

The following represent some of the many projects and grants awarded to UWRL faculty in FY 22–23:

- ▶ Monitoring cyanotoxin levels in Utah water bodies and assessing qPCR analysis methods. (*Utah Division of Water Quality, Hou*)
- ▶ Remote sensing of wine-grapevine transpiration for improving water use and yield of vines. (*US Department of Agriculture: Agricultural Research Service, Torres*)
- ▶ Post-wildfire infrastructure risk management assessment for Grizzly Creek (*Bureau of Land Management, Lane*)
- ▶ Flow characteristics modeling of lower elevation at Lake Mead Intake No. 3 and pumping station. (*Barfuss*)
- ▶ Hydroinformatics gap analysis for the Utah Division of Water Rights and its water data. (*Utah Division of Water Rights, Horsburgh*)
- ▶ Measurement and telemetry gap analysis for the Great Salt Lake and its water gains and losses. (*Utah Division of Water Rights, Neilson*)
- ▶ Physical modeling of a second raise of Dog River Ram and Spillway. (*Crookston*)



Karem Meza won first place with her poster presentation on evapotranspiration on urban turfgrass.

Her project focused on using UAV remote sensing to analyze urban turfgrass quality, particularly on golf courses. Her research looks to quantify the relationship between water use and turfgrass quality. Using drones, water managers will be able to adjust irrigation to maintain good quality turfgrass while conserving our water resources during drought.



Abby Englund and Abby Johnson, both students at the UWRL, were part of the environmental design team that took second place at the Water Environment Federation's Technical Exhibition Conference.

The competition is based on problems relating to the protection of the circular water economy. Their design was a removal treatment process for per- and polyfluoroalkyl substances (PFAS) in the East Canyon Water Reclamation Facility in Park City, Utah.

Faculty Promotions

Three UWRL professors were promoted to associate professor with tenure:

Brian Crookston

Belize Lane

Alfonso Torres-Rua

New Faces

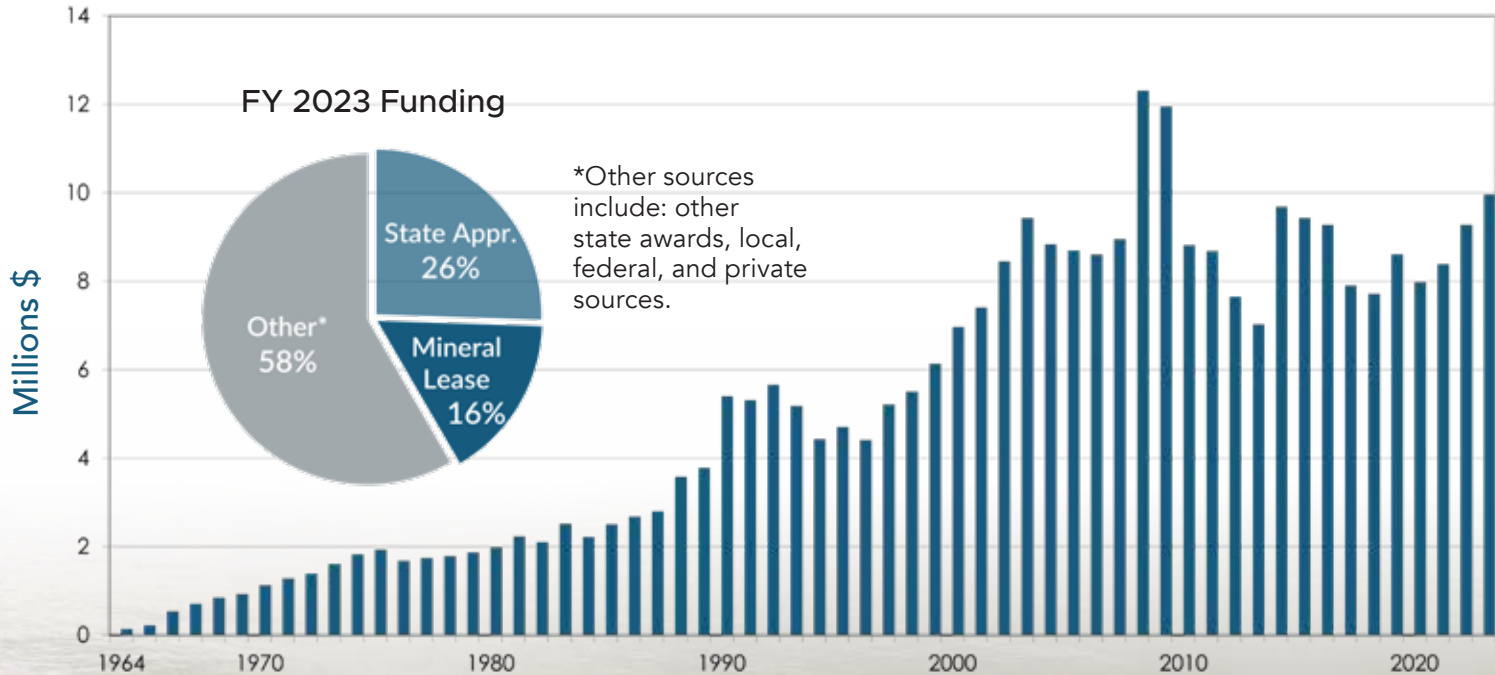
Ashton Decker joined the UWRL this year as a receptionist. She is the face of the lab for our visitors and new students.

Alyssa Regis has joined the UWRL community as a communications specialist. She publishes outreach material and acts as the lab's photographer.

Jamie Stubbs recently joined the UWRL as a business assistant. Her main focus is business affairs for the hydraulics area. ■

FY 2023 Financial/Academic Summary

UWRL Funding History:



\$9,959,079

Total Annual Expenditures FY 2023

Research and Training Products:

180

Active projects

58

Scholarly publications in
peer-reviewed journals

30

Short courses peer
& trainings

Student Outcomes:

49

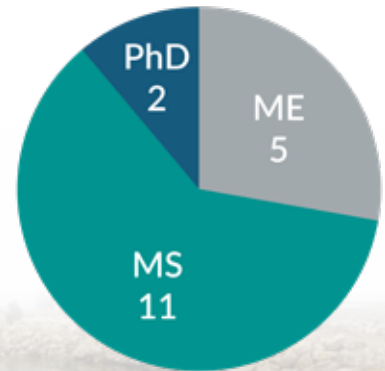
Graduate research
assistantships funded

74

Undergraduate students
supported

18

Graduate degrees
granted





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Great Salt Lake photos courtesy USU

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