2017 ANNUAL REPORT

Utah Water Research Laboratory

UtahStateUniversity

Message from the Director

Mac McKee
UWRL Director

Water management is much more complex than many people realize. Good water management involves an awareness of information from a huge range of disciplines—from how a single water molecule behaves to the constraints and opportunities created by state or national water laws and policies. As water engineers, we must be in touch with both ends of that spectrum. This is what we have always done and continue to do at the Utah Water Research Laboratory (UWRL). Our water experts continue to push boundaries to advance the field of water resources management, in all its complexity.

In this report we highlight just four of the 224 active research projects conducted at the UWRL over the past year. Technology continues to play a significant role in water resources management. Our researchers are using advanced remote sensing technology in a NASA-funded project to improve evapotranspiration estimates that in turn affect crop health and irrigation water efficiency in high-value precision agriculture industries such as E&J Gallo wine grape vineyards in California.

Our hydraulic structures engineers were contacted by the State of California to construct and analyze a large-scale physical model of the damaged spillway at Oroville Dam, the tallest dam in the US. Their efforts helped California state officials and dam managers ensure that the repair plans for the spillway would perform safely and as intended.

Here in Utah our researchers are finding new ways to identify water conservation opportunities for non-residential urban water users and investigating new ways to deal with the challenges of storm water—from identifying the best plants to use in storm water detention basins for removing pollutants, to testing new green infrastructure systems and developing models to predict and evaluate the effectiveness of managed aquifer recharge.

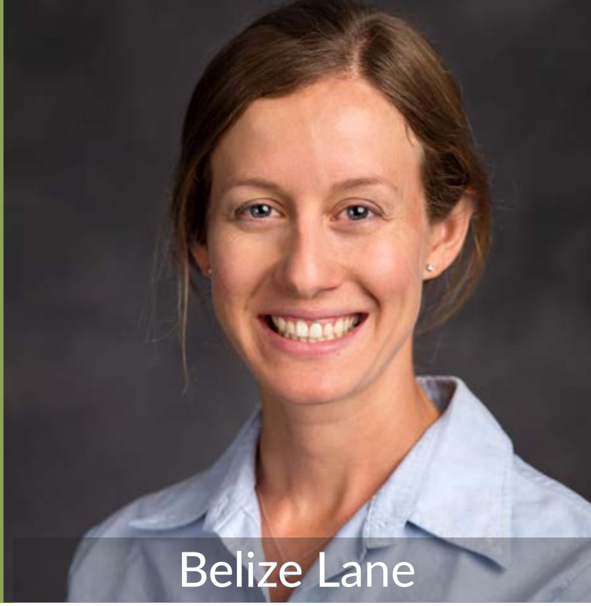
This report is only a brief snapshot of the wide range of research ongoing at the UWRL. For more information, please visit our website at:

http://uwrl.usu.edu/

Photo by Tyler King

Contents

The 4 UWRL welcomes new faculty members



Belize Lane

Assistant Professor

Expertise: Hydrology / Water Resources

Belize joins the UWRL from UC Davis. Her expertise is at the intersection of hydrology and water resources management, with an emphasis on improving river management for both human and environmental objectives. Her recent research has focused on linking surface hydrology, fluvial geomorphology, and river ecology to improve basic scientific understanding of river systems while directly informing watershed management applications. When not studying rivers, she enjoys rafting them. She has rafted the headwaters of the Amazon in Peru (Maranon), the headwaters of the Brahmaputra in norther India (Siang), the Grand Canyon (Colorado), as well as rivers in Costa Rica, Chile, Oregon, Idaho, and California. ■

Alfonso Torres-Rua

Assistant Professor

Expertise: Agricultural Remote Sensing Analytics

Alfonso hails from Peru but earned his MS and PhD right here at USU. His research and expertise include remote sensing data (unmanned aerial vehicles [UAVs] and satellites) production and analysis for agricultural water management, with emphasis on spatial crop status and water use estimation and monitoring, as well as water resources analysis at spatial and temporal scales. Recent research has focused on evapotranspiration, irrigation, remote sensing, soil moisture, and using high-resolution UAV and satellite imagery for studies and models at large and small scales. Alfonso oversees AggieAir analytics procedures and research for scientific and practical applications. ■

Tianfang Xu

Research Assistant Professor

Expertise: Groundwater

Tianfang started her engineering journey at Nanjing University in China, a journey that led her next to the University of Illinois at Urbana-Champaign, and then on to a research position at Michigan State University. Her research centers on model-data fusion, combining process-based models with data-driven methods, to improve predictive capability and understanding of water resources systems, in particular, under human adaptations and global change. Recent projects include integrated modeling of surface and ground water, using remote sensing and machine learning for crop irrigation monitoring and yield prediction, and HPC-enabled uncertainty quantification for hydrologic models. ■

Ruijie Zeng

Assistant Professor

Expertise: Data Mining / Water Resources Systems

Ruijie first studied hydraulic engineering at Tsinghua University in China, followed by two graduate degrees at the University of Illinois at Urbana-Champaign. His research focuses on understanding watersheds as coupled nature-human systems, in particular how hydroclimatic processes change due to irrigation development at watershed and regional scales. He also works on water resources system analysis, with an emphasis on using data mining techniques to provide better decision-making support for water resources planning and management. ■

AggieAir:
out of the shadows

AggieAir taking off over an E&J Gallo vineyard in Sonoma County, CA


Story photos by Jessica Griffiths

Around 1 million acres of California's Central Valley are dedicated to grape production, which contributes some $6 billion to the state's economy. Other high value crops, including, fruit and nut orchards, represent an additional 2.6 million acres with an economic impact of around $10 billion. There is no question that the growers want to ensure that their processes are as efficient as possible.

Drs. Alfonso Torres-Rua and Mac McKee (UWRL) and Dr. Lawrence Hipps (USU Agricultural Experiment Station) are currently working with the USDA's Agricultural Research Service (ARS) and E&J Gallo Winery, along with a number of other agencies and stakeholders, on a 3-year NASA-funded study that will help wine grape growers in California to:

- Improve the accuracy of the maps and models that estimate irrigation water use,
- Identify vine health issues related to water stress and other crop factors, and
- Explore the effect of shadows and vine canopy heterogeneity on evapotranspiration (ET) estimates.

The project combines the benefits of ground-based sensors, satellite imagery, and very high-resolution remote sensing (RS) data from AggieAir, the unmanned aerial system (UAS) developed at the UWRL, to help growers determine where to apply water for optimal crop yield

10-cm pixel size allows AggieAir images to reveal so much information that vineyard managers can determine the status of a single grapevine.

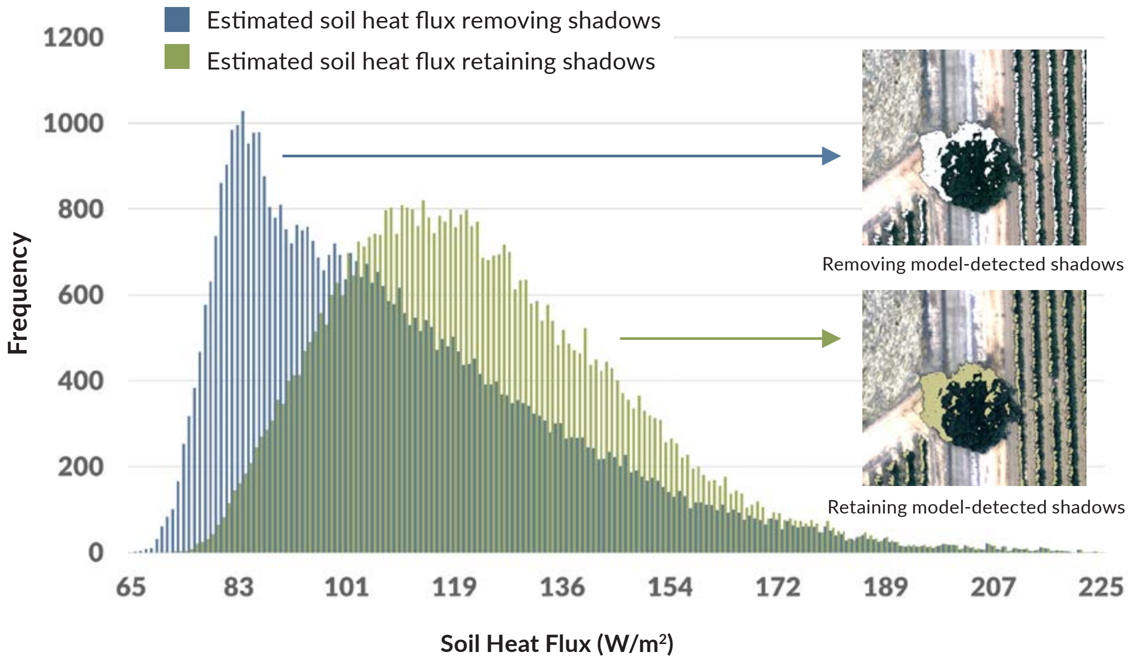
without over- or under-watering areas with different needs. The research team is also working to develop sophisticated new tools to more accurately estimate a number of crop parameters.

Pushing the Boundaries

Traditional RS data sources such as Landsat satellites (with a 30-m pixel size) don't directly detect small details like the shadows cast by the vegetation canopy, so their effect on evapotranspiration (ET) and soil moisture estimates, for example the cooling effect of shadows on plants and soils, still lurks unseen in the data.

AggieAir's 10-cm pixel size, on the other hand, reveals so much information that vineyard managers can determine the status of a single grapevine. That is good when managers wish to identify diseased or dead vines or create increasingly

AggieAir imagery over an E&J Gallo vineyard near Lodi, CA



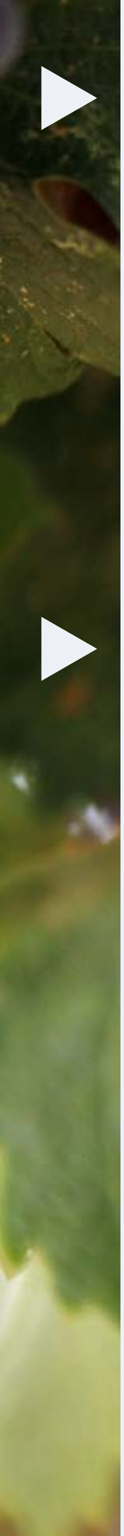
accurate ET or vine canopy estimates, but the visibility of those fine details can also be a nuisance. Since the darkened areas reflect less light energy, valuable data can be lost in the shadows, which can introduce potential classification and calculation errors. Determining the best way to deal with shadows in high-resolution RS data is pushing the boundaries of current practice and understanding.

Out of the Shadows

By analyzing the data, Torres-Rua and his team, including graduate student Mahyar Aboutalebi, have verified that the shaded and sunlit sides of the vines behave very differently, and those differences change over the course of the day depending on sunlight intensity and angle. The impacts of these differences on ET estimates that use energy balance models and high-resolution remote sensing data can be significant.

These researchers are working toward successfully applying high-resolution energy balance modeling techniques to acquire ET estimates using fine-resolution UAS-based data. While a great deal of research is still needed, the goal is coming into view with the emerging ability of AggieAir's UAV-based RS technologies to acquire high-resolution, scientific-grade spectral data in three dimensions, high-resolution digital elevation (DEM) and digital surface (DSM) model data, and point cloud data that are both dense and accurate. The result will be powerful new precision agriculture tools with the ability to benefit not only California wine grape growers, but Utah farmers as well.


Ian Gowing and Daniel Robinson prepare AggieAir Minion for flight



About the NASA project

- **Project Title:** Monitoring Vineyard Water Use and Vine Water Status with Land Surface Temperature for Improved and Sustainable Water Management from Field to Regional Scales

- **Full Award:** $1.3 million

- **USU/UWRL Award:** ~$140,000 annually for 3 years

- **Study Dates:** Feb 2017 – Jan 2020

- **Funding Agency:** U.S. National Aeronautics & Space Administration (NASA, grant #NNX17AF51G)

- **Study Locations:** 3 E&J Gallo vineyard sites across middle to northern California with differing topography / soil conditions / environments

---

About AggieAir

- AggieAir is an on-demand airborne remote sensing platform developed at the UWRL to advance the capabilities of small unmanned aerial vehicles in providing high-resolution, multi-spectral imagery and scientific data for hydrologic and other research.

- **Project Data Sources:** Landsat, ESA Sentinel, and Planet (small) satellites, ARS, E&J Gallo, and high-quality ground data. This summer, data from the new thermal camera aboard the International Space Station will be added.

- **New AggieAir BluJay platform** can stay airborne for 200 minutes without landing or recharging. This makes coordinating flight times with various satellite overpasses much easier, allowing researchers to capture a "moment in time."

- **Improved performance:** With all new avionics and wiring, BluJay can fly 1 sq. mi in 12 minutes. New optical filters provide 6 spectral bands in 3 cameras. The added spectral bands improve the ability to see plant diseases. The same technology will also help researchers track algae blooms in lakes right here in Utah.

- **AggieAir leaders** are helping to develop Utah's UAS industry. Director Cal Coopmans is also president of the Mountain West Unmanned Systems Alliance, which is currently providing support to local and state organizations to create a major UAS test site in Utah.

Collaborators in this NASA-funded project include:

- USDA-ARS Hydrology and Remote Sensing Laboratory (Project Lead)
- NASA-Marshall Space Flight Center (Co-I)
- Utah State University/ Utah Water Research Laboratory (Co-I)
- USDA-ARS National Laboratory for Agriculture and The Environment (Collaborator)
- E&J Gallo Winery (Co-I, partner, end-user)
- National Grape & Wine Initiative (stakeholder, supporter)
- Almond Board of California (stakeholder, supporter)

Oroville Dam Spillway Model:

helping the tallest dam in the United States recover from a near disaster

Project lead engineer Michael Johnson in front of the 1:50 scale model of the damaged spillway

Story photos by Matt Jensen.

On February 21, 2017, the Oroville Dam spillway on Lake Oroville in California broke apart as operators released water in an attempt to lower lake levels amid extremely high rainfall. As officials raced to assess the situation and made plans to begin repairs, the California Department of Water Resources (DWR) commissioned engineers at the Utah Water Research laboratory (UWRL) to construct a 1:50 scale physical model of the damaged spillway and the replacement spillway design.

The physical model would assist the hydraulic design team assembled by the DWR in their efforts to ensure that the new spillway at the Oroville site performs safely and has the capacity to pass the required flood releases. Physical models are considered state-of-the-art and provide valuable information to engineers to help them develop the best designs possible. The UWRL has been modeling hydraulic structures for more than 50 years to improve designs, reduce costs, and increase safety.

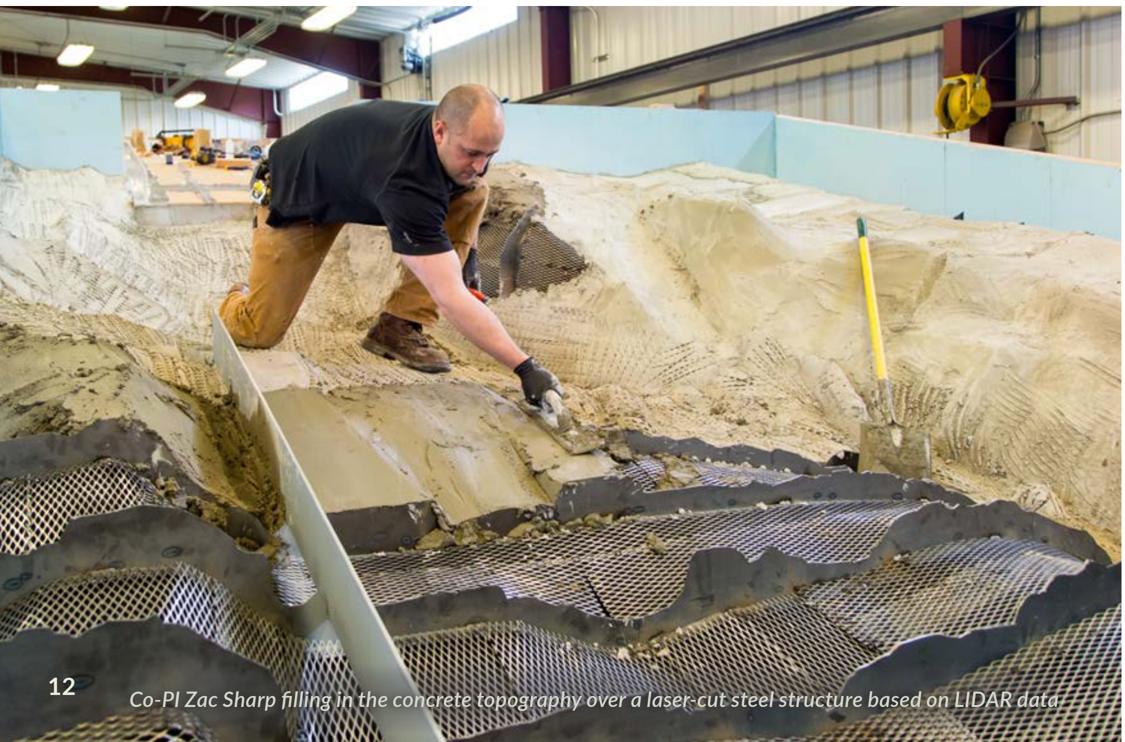
Modeling Projects

Lead engineers Dr. Michael Johnson and Dr. Zachary Sharp, along with their team of 15 engineers and technicians, constructed the approximately 100-foot-long by 60-foot-wide model in just 40 days.

After modeling the damaged spillway, Johnson's team revised the model to test the replacement spillway design. The revised model also tested an aerator at the transition from structural concrete to roller compacted concrete that would aerate the flow, protecting the spillway should it be needed for operation in the interim between construction seasons. That feature may or may not be implemented, but understanding the performance of the aerator through the modeling process provides confidence to engineers and operators as they move forward with repairs.

Project lead, Michael Johnson says of this project, "We have been honored to work with the impressive group of people from so many disciplines that the DWR assembled to accomplish this work. The public can have full confidence in the new structure, which is expected to serve for many decades to come."

Now that the main spillway work is nearly complete, the UWRL research team is beginning another modeling project that will test the proposed design for repairs to further stabilize the Oroville Dam emergency spillway. ■



Co-PI Zac Sharp filling in the concrete topography over a laser-cut steel structure based on LIDAR data

UWRL Media Day

With the widespread media attention surrounding the Oroville Dam spillway damage and the repair efforts, the UWRL held a media day on June 16, 2017 for members of the press to see the model first-hand and ask questions. Read more at:

uwrl.usu.edu/news/oroville-dam

About Oroville Dam

- An **earthen** embankment dam
- Stores **3.5 million** acre-feet of water
- Used for **water supply, flood control,** and **hydroelectricity**
- Tallest dam in the US at **770** ft
- Completed in **1968**

About the Model

- Scale **1:50**
- **~100** ft long and **60** ft wide, simulating a dam and spillway area of over **4.4 million** sq ft
- **7,030+** gallons per minute in the model simulate flow of **277,000** cubic feet per second in the prototype
- **15** ft of elevation change in the scale model simulates **~750** ft of elevation change in the original spillway
- **Wood, acrylic, steel,** and **concrete** construction
- **~20,000** lbs of concrete to form the topography
- **LIDAR** topography was imported to **CAD** to create cross sections
- **Steel** cross sections were then cut out using a **laser cutter**
- **15** engineers and technicians constructed the model in **40** days
- Budgeted cost = **$277,000**

1:50 scale model of the damaged spillway

Mike Johnson demonstrating the revised model for members of the media

5-minute data recorded for one manufacturing customer shows the potential to separate indoor and outdoor water uses based on time of day.

Focus on

UTAH:

Photo by Nour Atallah

Non-Residential Water Metering: identifying new conservation opportunities

Nearly all urban water use monitoring, modeling, and conservation research has focused on a large but relatively homogenous group of residential water users. Although non-residential business and commercial establishments, industries, and institutions use significant volumes of water, their diversity has made them difficult to monitor and study because their water use varies in terms of amount, timing, location, and other factors.

With the emergence of newer “smart” meters, water use now can be measured and recorded at a very high temporal frequency. Smart meters can help determine total water use, timing, and component end uses to better understand current water use practices by non-residential users.

Drs. David Rosenberg and Jeff Horsburgh and MS student Nour Atallah are using these data records to identify water-saving opportunities that will help meet Utah’s water conservation goals. In their current study, they are working with the Logan City Public Works Department to evaluate six local non-residential users in Cache Valley, including manufacturing, printing, and assisted living facilities, to:

- Expand current water metering methods
- Enhance existing monitoring data
- Estimate peak demand and the timing of demands
- Demonstrate and test methods to identify conservation opportunities

Thus far, the team has successfully installed metering equipment at multiple facilities in Logan, Utah, and recorded water use at five-minute and five-second intervals for up to five months. Initial analysis of the five-minute data recorded for one customer shows the potential to separate indoor and outdoor uses based on time of day. For instance, a major increase in water use at ~10:00 p.m. on most days indicates outdoor landscape watering.

This project builds on prior research that identified water use differences by gender in public restrooms at USU and synergistic actions households can take to save water and energy. The data collected for this project can help the water providers and agencies like the Utah Division of Drinking Water better understand water demands of non-residential establishments and help cities better target water conservation actions to non-residential customers. ■

Optimizing Storm Water Management: vegetation selection, harvesting strategies, and managed aquifer recharge

Storm water runoff from Utah's city streets, major industrial facilities, and residential neighborhoods can be a significant source of water pollution to receiving water bodies and, potentially, to municipal water supplies. At the same time, increasing population and climate patterns that indicate a larger proportion of precipitation as rain rather than snowpack in the future have water managers looking for ways to protect and expand water supplies.

Dr. Ryan Dupont is collaborating with the Logan City Public Works and Salt Lake City Public Utilities departments to conduct a range of multidisciplinary research that is providing critical, locally generated storm water system performance data for these decision makers.

Vegetated Storm Water Basins

Storm water detention basins are often used as a means of reducing flooding and managing polluted runoff. One recent project is identifying the effectiveness of local plant species to optimize nutrient and metal removal in these vegetated storm water management systems. This study measured biomass production and water quality improvement in both a controlled greenhouse environment and at a field demonstration study site at the Green Meadows subdivision in Logan, Utah. Researchers quantified water and pollutant uptake for seven plant species in the laboratory under simulated rainfall events. The field demonstration site used three of these plant species, as well as naturally propagated plant species and non-vegetated control plots. The study team quantified plant growth and measured contaminant (nutrients and metals) removal in response to periodic storm water events through plant harvesting.

Sedges were found to be optimal plants to improve the water quality of storm runoff in arid northern Utah. Twice per year harvesting maximized nutrient removal from the system, while single seasonal harvesting was sufficient for maximizing metal uptake. Total containment of storm water generated at the demonstration site continues to result in 100% pollutant removal from surface water discharge.

Green Infrastructure Systems

Other studies are underway to investigate the effectiveness of green infrastructure systems such as modified conventional curb and gutter, utilizing curb cuts and bio-swales that completely eliminate storm water discharge into the collection system for storms up to 2 inches in depth.

Total containment of storm water generated at the demonstration site continues to result in pollutant removal at

100%

Data collected at a SLC Public Utilities site also showed no overflow and complete retention of all parking lot runoff at the site, but soil pore water lysimeters and soil samples at one Logan site and sampling wells below the filtration layer at the SLC Public Utilities site indicated pollution infiltrating the underlying groundwater. While these pollutant concentrations were low, groundwater quality remains a concern, especially at the SLC Public Utilities site. Analyses will be expanded to include microbial contaminants of human health interest.

EPA Aquifer Recharge Project

A three-phase EPA funded project (R835824) is evaluating green infrastructure performance in capturing and treating storm water and storing it via groundwater recharge, including:

- Phase 1: Monitoring and documenting existing, diverse managed aquifer recharge (MAR) storm water harvesting options for recharge potential and contaminant removal and transformation for a range of relevant field conditions

- Phase 2: Integrating storm water modeling approaches to predict changes in aquifer storage, groundwater and surface water flow and quality, and human health and ecosystem services resulting from storm water management that maximizes storm water harvesting

- Phase 3: Assessing stakeholder attitudes and preferences concerning MAR for storm water harvesting and collaborating with stakeholders to identify, select, and evaluate MAR storm water harvesting outcomes for the Salt Lake Valley using the integrated Phase 2 modeling approach

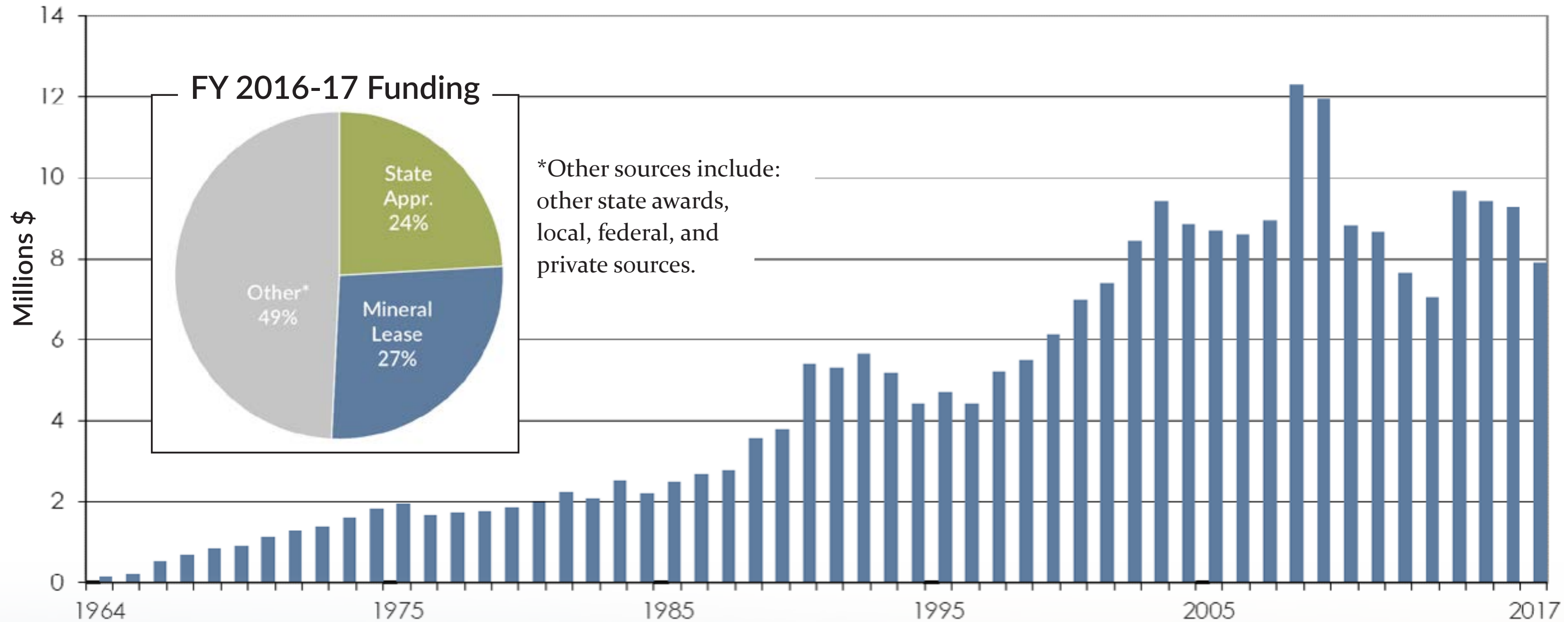
Balancing storm water quality and quantity priorities is a daunting challenge, but these studies are providing critical information to Utah municipalities and counties that are responsible for meeting new EPA storm water management permit requirements. ■

Photo by Trixie Rife

Curb cut and bioswale green infrastructure feature in Logan, Utah

FY16-17 Financial/Academic Summary

UWRL Funding History:



Research and Training Products:

224
Active projects

164
Scholarly presentations at professional conferences

153
Scholarly publications in peer reviewed journals

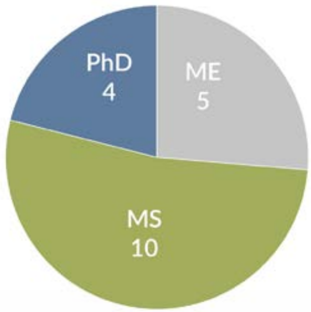
15
Short courses

Student Outcomes:

43
Graduate research assistantships funded

78
Undergraduate students supported

19
Graduate degrees granted



$7,904,781

Total Annual Expenditures FY 16-17

UtahState University
UTAH WATER RESEARCH LABORATORY

8200 Old Main Hill, Logan, UT 84322-8200 • (435) 797-3155
uwrl.receptionist@usu.edu • http://uwrl.usu.edu

Publication editor, Carri Richards; Vineyard photos, Jessica Griffiths