FY 2020-21
Mineral Lease Fund Report

Utah Water Research Laboratory

for

Office of the Legislative Fiscal Analyst
State Capitol Complex
House Building, Suite W310
Salt Lake City, UT 84114

by

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Utah Water Research Laboratory
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Foreword

Water is a precious and scarce resource in the State of Utah and ongoing research to understand and manage the many issues associated with providing safe water for drinking, ensuring sufficient water for irrigation, municipalities, industries, and the environment, and enabling economic development is critical. This report describes the work funded by Mineral Lease funds (MLF) during fiscal year 2020–21 (FY 21) at the Utah Water Research Laboratory (UWRL) in pursuit of its mission to generate the knowledge needed to solve water problems through research and help the State meet its water needs now and in the future. The projects described in this report focus on cutting-edge research to find practical solutions to some of the most pressing water related problems facing Utah. The research ongoing at the UWRL includes work on innovative sensing to measure and manage flows and water use, assess water and air quality, identify emerging threats (e.g., from pharmaceuticals, cyantoxins, and invasive species) and research ways to address them. Current water resources research is addressing the occurrence of drought in river systems critical for the State of Utah, such as the Colorado River Basin, where for the first time the US Bureau of Reclamation declared a water shortage in summer 2021. Several projects focus on the Logan River as an observatory and microcosm for study that facilitates development of the understanding needed to solve problems throughout Utah, and beyond. Other research is advancing our understanding of the hydrology and water resources implications of fires, which have increased across the Western US, and the effects a changing climate has on snow, the predominant source of water in Utah.

To support our mission, the UWRL receives 2¼% of deposits made to the Mineral Lease (ML) Account, "to be used for activities… having as a purpose the development… of water resources in the State of Utah." With this basic support, UWRL is able to leverage significant funding from other public and private sources to enhance the scope and impact of our projects. Over $4.5 million in project funding from other sources in FY 21 has provided additional opportunities for finding solutions to State water issues as well as contributing to economic growth. The UWRL also expands the benefits of its projects through collaborations and partnerships with local, state, and federal agencies. As one of the oldest, most respected and unique University-based water research facilities, the UWRL's goals and mission remain the same: to provide data, tools, and solutions to better manage and use the limited water and land resources of the State. We look forward to many more decades of service to Utah's citizens.

In compliance with House Bill 103 passed during the 1993 Legislature General Session, this report provides a brief description of the UWRL's MLF-supported active research, training, and service projects over the past fiscal year, along with an accounting of the ML funds for FY 21, budgeted expenditures for FY 22, and planned expenditures for FY 23. The projects are organized into broad areas of activity that address a spectrum of high-priority water resources needs and issues in the State. Each project includes a statement of the project purpose, the specific benefits to the citizens of Utah, and areas benefited.

The UWRL is pleased to submit this year's report to the Legislature through the Office of the Legislative Fiscal Analyst, and to the Community and Economic Development Appropriation Subcommittee of the Legislature, which reviews this report as part of its normal budgetary process.

We welcome any comments or questions that result from these reviews.

David Tarboton, UWRL Director

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Section 1

Introduction

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History of the Utah Water Research Laboratory

The Utah legislature authorized the establishment of the UWRL at Utah State University in 1959 as an important component of the State of Utah's commitment to water resources research, assuring cutting-edge solutions to the State's water problems. Today, the UWRL continues its service as one of the oldest and most respected university-based facilities performing research and providing practical solutions to the most pressing problems facing Utah, and indeed our nation and the world.

Water is often referred to as the lifeblood of Utah. As we look to the future, it is important to recall how important water resources have always been to the prosperity and quality of life of Utah's citizens. This was evident in the vision of our State leaders when USU was established as the State's Land Grant University in 1888, and water, and particularly irrigation science and the engineering of water works, were of foremost importance as curricular and research components. During the following several decades, water resources education and research were mainly carried out by faculty and students in the relevant academic departments and by the Engineering and Ag Experiment Stations. In 1957, George Dewey Clyde, former Dean of Engineering at USU, was elected the 10th Governor of Utah, serving two terms until 1965. During his tenure, he strongly supported research on best practices for using and protecting Utah's precious water resources, including funding and breaking ground for construction of the Utah Water Research Laboratory in 1963. The following year, 1964, Congress approved the Water Resources Research Act that created a water research institute in every state. The Utah institute, known as the Utah Center for Water Resources Research (UCWRR), was established at the UWRL as part of a national network of water research institutes.

As an acknowledged world leader in water engineering, the opening of the new Utah Water Research Laboratory building in 1965 provided the State and USU with a world-class research facility to support the work of faculty, students, and water professionals from across the state and around the world. The Laboratory's facilities include one of the best hydraulics laboratories in the United States and a unique erosion testing facility with a large rainfall simulator. In 1981, an extensive remodeling project added an environmental quality laboratory wing, significantly upgrading facilities and equipment needed for water quality testing and research. In 2009, the UWRL completed a hydraulics modeling and testing laboratory in order to support expanded hydraulics research activities associated with releases from dams (and related hydraulic phenomena, such as venting) and the design of hydraulic structures in Utah, such as the irrigation lift stations on Utah Lake. Today, the UWRL has a total of more than 113,000 square feet of state-of-the-art laboratory, computer, and office space. This continued growth and productivity over the past 56 years has allowed the UWRL to have a significant state, national, and worldwide impact in water resources research and applications.

Productivity

In order to leverage the expertise of the UWRL, our faculty collaborate with colleagues from various USU departments, as well as faculty from other institutions and professionals from the private sector and government agencies in Utah and elsewhere. Several of our faculty members, including a former UWRL Director, have been awarded the Utah Governor's Medal for Science and Technology. In addition, our faculty have received many national honors and recognitions, and served on numerous state, national, and international engineering and science panels and committees.

In addition to our research role, the UWRL is involved in university graduate and undergraduate education through the inclusion of students in hands-on projects, part-time employment, and research assistantships. Graduate student involvement in research leading to masters and doctoral degrees prepares them to enter the workforce as trained water professionals. Undergraduate students involved in UWRL research projects gain skills and experience for their future careers.

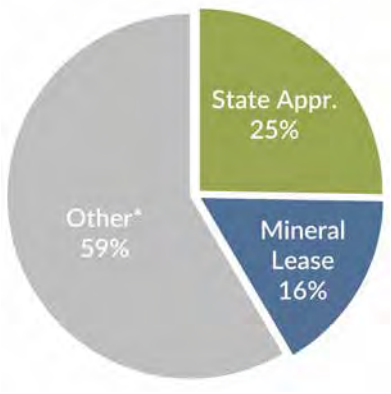
As students graduate and are hired by Utah employers, they become effective means of technology transfer from the UWRL to Utah's water and environmental organizations. Technology and information are also transferred through collaborating and partnering with engineers, scientists, and managers of the Utah Department of Natural Resources, Water Resources Division, the Utah Department of Environmental Quality, the twelve Utah local health departments, and several large water user districts and associations.

The table below summarizes the productivity of the Lab in terms of research, education, outreach, and training**.** The total research funding through the UWRL in FY 21 of over $8 million makes it one of the largest university based institutes in the nation.

UWRL Financial/Academic Summary FY 21	
Number of Active Projects	176
Dollar Value of Active Projects	$8,386,868
Scholarly Publications in Peer-Reviewed Journals	68
Scholarly Presentations at Professional Conferences	72
Outreach Activities FY 21	
Short Courses and Field Training	34
UWRL Student Support FY 21	
Graduate Students Supported	63
Undergraduate Students Supported	47
Degrees Granted FY 21	
Doctor of Philosophy (PhD)	2
Master of Science (MS)	21
Master of Engineering (ME)	4

Research Program Structure and Organization

The research programs of the Utah Water Research Laboratory (UWRL) directly address current and future water resources needs of the state, and most are relevant to national and worldwide issues as well. The State of Utah provides state-appropriated funds (SAF) and Mineral Lease funds (MLF) for research support at the UWRL. These funds directly target problems facing the State of Utah. In FY 21, MLF funding of just over $1.36 million accounted for 16% of total UWRL expenditures. With additional funding from federal, private, and other state sources (as shown in the pie chart), the total UWRL expenditures for FY 21 were over $8.38 million.



UWRL Funding FY 21

The UWRL's MLF projects are organized into five major research program areas:

- Environmental
- Hydraulics
- Measurements, Sensing, and Information Systems
- Water Education, Outreach, and Technology Transfer
- Water Resources

The individual projects are under the direction of UWRL researchers and involve collaboration with other departments at Utah State University including:

- Civil and Environmental Engineering (College of Engineering)
- Electrical and Computer Engineering (College of Engineering)
- Biological Engineering (College of Engineering)
- Engineering Education (College of Engineering)
- Watershed Sciences (College of Natural Resources)
- Plants Soils and Climate (College of Agriculture and Applied Sciences)

The overall UWRL research, education, and training activities related to Mineral Lease funding are very diverse, as is indicated by the project summaries in this report. However, the totality of the UWRL's programs, taking into account state funds and our external contracts and grants, is even broader. We continue to be involved in advancing hydrologic information systems for data management in support of transparent and reproducible research. At several field sites, we are investigating hydro-climatological processes. Our hydraulics, erosion control, and environmental quality laboratories are involved with a range of experimental work and service projects that utilize our unique facilities. Computer models, remote sensing, geographic information systems, digital terrain models, expert systems, and many other modern technologies are developed and applied in the research projects and are used to develop tools for use by water and environmental managers and professionals in Utah. We have hired a new faculty member in the area of environmental and intelligent systems, with an emphasis on using robotic systems to monitor environmental processes, and we have searches underway for one groundwater and two environmental faculty members.

The UWRL also prepares guidance materials for use by practitioners. Some projects are relatively small in scope while others involve interdisciplinary teams and collaboration with multiple agencies and with the private sector. Most of our projects also include an outreach component, engaging our staff in public and professional service, technology and information transfer, and public education. UWRL faculty are part of a recently established National Science Foundation Institute for Geospatial Understanding through an Integrative Discovery Environment (I-GUIDE). The research in this institute is pursuing an understanding of the complex interactions involved in climate-related disasters where we cannot just look at a single discipline or a single place where a disaster may occur but need to understand how increased vulnerability of our infrastructure, such as aging dams, makes economic sectors like manufacturing and transportation more vulnerable. The institute is bringing experts from many fields together to tackle these challenges holistically.

Management of USGS 104 Program for State Benefit

The Water Resources Research Act of 1964 created a national network of Water Resources Research Institutes (WRRIs) in the United States and an allotment program providing funds for the institutes, called the Section 104 Program. The Utah Institute, known as the Utah Center for Water Resources Research (UCWRR), is located at the Utah Water Research Laboratory (UWRL). Currently, the Section 104 Program receives federal funds of $125,000 through the U.S. Geological Survey (USGS) that are required to be matched 2:1 with non-federal funds. State ML funds are used for much of this match. This year, the base grant, in combination with ML funds, directly benefits the State of Utah in the following areas:

1. Developing new tools and technologies for generating real-time maps of thermal and multispectral sUAS (drone) data to improve access to spatial information for local, state, and federal agencies and other aerial data stakeholders. Such information is crucial to addressing immediate water challenges at the intersections of urban, agricultural, and natural areas, including, drought, wildfire, changes in weather patterns, irrigation management, etc.
2. Quantifying the impact of reservoir sedimentation from wildfires on water security using bathymetric surveys and aerial imagery over Utah reservoirs. Reservoir sedimentation is a leading concern in many areas worldwide, including northern Utah. Sediment reduces the capacity and useful life of reservoirs over time. However, sediment predictions do not currently consider wildfire-related sediment, which can further diminish reservoir capacity and longevity. Accurate current water capacity and decadal sedimentation rates for reservoirs will help water managers to manage water scarcity challenges.
3. Developing microplastic sampling methodologies and investigating the fate of microplastics in wildland environments using the Logan River watershed as an example of other human-impacted mountainous areas in the Intermountain West. Microplastics are ubiquitous downstream of human activity and have been found around the globe, yet little is known about microplastic concentrations in remote mountainous environments from, for example, atmospheric transport of microplastic and aquatic transport from mountainous freshwaters to urban centers.
4. Furthering the conversation on water strategies for managing the threatened Great Salt Lake (GSL) ecosystem. This project will create an advisory committee and conduct a scientific survey to assess the views of residents of the GSL watershed and other Utah residents to inform stakeholders in their efforts to maintain the health of the GSL, its wetlands, and the human communities that surround it.

Relevancy and Benefits of the Mineral Lease Fund

As one of the driest states in the union, the LIFE BLOOD of Utah's economy and quality of life is WATER. Our average precipitation of only 13 inches of water per year, mostly in the form of winter snowfall, must meet the State's economic, social, and environmental water needs throughout hot, dry summer periods. As has often been emphasized by our state leaders over many decades, water is indeed the essential resource needed to sustain Utah's quality of life and economic vitality. The State's investment in its water resources through the ML fund is critically important to finding the best technologies and methods to protect, manage, and wisely use our precious water for the benefit of all Utah's citizens.

Research Program Planning and Project Selection

The goal of the UWRL research programs is to identify and develop projects that will help to assure Utah's ability to meet the water needs of its citizens and economy in the future. This requires a broad and deep understanding of surface and groundwater resources in the context of climate change and environmental variability, the complex physical and biological processes that affect water quantity and quality, and the dynamic interaction of human activity in land and water use in our arid environment.

In order to focus research on problems and needs that are both relevant and current, UWRL engineers and scientists work closely with state and local government agencies and are actively involved with and serve on many state and local organizations, committees, and boards, as well as a wide range of local, state, national and international professional organizations. These associations give UWRL researchers influence in and a greater understanding of critical water-related research efforts around the nation and the world that are applicable to Utah. Participation in various professional water and environmental organizations helps to bring recognition and external project funding to the state and provides exposure to worldwide research and best practices. In return, this helps the UWRL to identify current and future research needs that will affect our state and assures that projects are relevant to Utah.

The UWRL Director, Associate Directors and faculty members meet periodically with state and federal agency managers and personnel from local water organizations to discuss research needs and identify opportunities for the UWRL to respond to these needs. The UWRL has engaged with many State agencies and other local, state, regional, and national organizations over the past few years, serving on committees and boards and connecting professionally. Some of these include:

State of Utah Agencies

- Department of Environmental Quality (Harmful Algal Blooms Team, Jordan River TMDL Advisory Committee, Long term Stormwater Management Group, Air Quality Board, Division of Water Quality, Drinking Water Board, Drinking Water Operator's Certification Commission, Water Operators Certification Commission,)
- Department of Natural Resources (Division of Water Resources, Agricultural Water Optimization Task Force)
- Governor's Office of Management and Budget – Agriculture Water

Local Agencies and Organizations

- Cache County Solid Waste Advisory Board
- Cache Clean Air Consortium

- Cache County State Implementation Plan Team
- Cache Environmental Flows Group
- Crockett Canal Company Technical Advisory Board
- Logan City (Air Quality Board, Renewable Energy/Conservation Advisory Board, Water & Wastewater Board)
- Logan Island Canal Company
- Logan River Task Force
- Logan River Water Users
- Salt Lake City Corporation
- OpenET Colorado River Basin Working Group

Other State and National Agencies and Organizations

- California Water Quality Monitoring Council, Environmental Flows Strategic Workgroup
- California Data Science Advisory Panel
- FEMA Guidelines for Best Design and Inspection Practices for Spillways
- FEMA Dam Intervention Initiative Advisory Board
- National Dam Safety Review Board
- NOAA National Water Center Community Advisory Committee for Water Prediction
- United Kingdom Natural Environmental Research Council

Professional Organizations

- Air and Waste Management Association – Industrial Wastewater Treatment Waste Management, Federal Facilities Committees
- American Geophysical Union (AGU)
- American Institute for Medical and Biomedical Engineering
- American Society of Civil Engineers (ASCE), Environmental Water Resources Institute (EWRI)
- American Water Resources Association (AWRA)
- American Water Works Association (AWWA)
- Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI)
- European Working Group on Overflowing and Overtopping Erosion
- Hydraulic Structures Committee of IAHR
- Institute of Biological Engineering, Steering Council
- National Institutes for Water Resources (NIWR)
- National Inventory of Low-head Dams, Joint Task Committee
- National Onsite Wastewater Recycling Association
- National Society of Black Engineers
- Northeast Biotechnology Center and Consortium
- United States Society on Dams, spillways committee
- Utah Onsite Wastewater Association
- Water Environment Association of Utah – Biosolids Committee
- Water Environment Federation – Residual and Biosolids Committee
- Western States Water Council, OpenET Colorado River Basin Working Group

Mineral Lease Fund Expenditures

The table below summarizes the actual, budgeted, and planned expenditures of ML funds allocated to the UWRL for FY 2021 through FY 2023 for research projects in the five major Program Areas. UWRL administration and technology transfer expenditures account for approximately 13% of total MLF budgeted and planned expenditures.

Mineral Lease Fund Expenditures: Research Program Area	Actual FY2021	Budgeted FY2022	Planned FY2023
Administration	$176,061	$181,343	$186,783
Environmental	$542,598	$615,949	$605,376
Hydraulics	$80,709	$166,099	$155,634
Measurement, Sensing and Information Systems	$75,747	$174,776	$187,570
Water Education, Outreach and Technology Transfer	$104,455	$203,233	$201,093
Water Resources	$383,567	$470,800	$475,744
TOTALS	**$1,363,137**	**$1,812,200**	**$1,812,200**

Expenditures differ from budgeted amounts due to fluctuations in the actual amount of ML funds received and due to the time required to properly plan and spend funds received. Funds received are, as noted above, 2.25% of deposits made to the Utah ML account. The $1,363,137 expenditure was less than budgeted last year due to lower state deposits. The budgeted $1,812,200 for this and next year reflects what is budgeted for the UWRL from MLF in the Utah State Legislature higher education base budget. Recognizing that the state deposits received will be different from this budgeted amount, the project budget planning for each program area includes amounts for undesignated research projects, which are projects that will only be started if actual ML deposits are sufficient.

A detailed breakdown of the expenditures for each project within these Research Program Areas is presented in the Research Project Summaries section of this report.

Benefits to the State of Utah

ML funding is often used as leverage to acquire additional support from other sources, which allows us to perform even more research in the State. Every one of Utah's counties have benefited from one or more of the UWRL projects conducted during the past year.

The following gives a general overview of some of the recent and current benefits produced by ML funded projects by Program Research Area. The Research Project Summaries section of the report describes specific State benefits from each research project.

Environmental

This program emphasizes an integrated engineering and science approach to managing and improving the quality of our land, water, and air resources. The program includes engineering approaches for the treatment and reclamation, recycling, and reuse of municipal and industrial wastewater and biosolids and the sustainable management of stormwater for its capture and reuse using green infrastructure approaches. The fate of emerging contaminants in biosolids, soils and crops, and the risks that these emerging contaminants pose to human health and the environment are also topics of active research. In addition to the research on water and land processes, this area also includes work on contaminant uptake into plants and indoor and outdoor air quality problems in the state, including PM2.5 and ozone associated winter inversions and vehicle emissions. This research encompasses diverse areas of specialization, including environmental engineering, environmental chemistry, environmental microbiology, chemical engineering, soil science, photochemistry, aerosol chemistry, plant science, and modeling. Additionally, this year many UWRL faculty have participated in cutting-edge collaborative research into mapping the SARS-CoV-19 virus in domestic wastewater distribution systems, survivability of the virus through municipal wastewater treatment plants, and the presence of the virus on short-range and long-range ambient aerosols.

Hydraulics

The UWRL uses numerical and scaled physical models to evaluate and optimize hydraulic structure design and performance. Hydraulic structure modeling projects include, but are not limited to, dams, reservoirs, spillways, canals, pipelines, tanks, power stations, pump stations, tunnels, and diversion structures.

The hydraulics group also performs calibrations and tests on valves, pumps, flow meters and other hydraulic equipment to assist worldwide manufacturers and users.

Measurements, Sensing, and Information Systems

To be effective, water and environmental managers must have access to relevant data. Sometimes, these data must be available in real-time to support decision-making. The UWRL is a leader in developing advanced monitoring and sensing systems for collecting environmental and water-related data along with cyberinfrastructure for managing the resulting data and interfacing with user-driven decision support systems for water and environmental planning and management. Another significant area of research focuses on the use of remote sensing technology and data to improve water, agricultural, and environmental resources management. This includes the UWRL's development of a unique unmanned aerial remote sensing system (AggieAir™). These small aircraft are programmed to fly over research sites, such as farm fields, wetlands, rivers, and riparian environments collecting multispectral high-resolution imagery. These data are then analyzed using innovative image processing techniques and used to enable more efficient irrigation of crops, identification and management of invasive vegetation, and for improved water and environmental management.

Water Education, Outreach, and Technology Transfer

The mission of the UWRL also involves outreach activities related to public service, information dissemination, technology transfer, and short courses. These activities provide benefit to Utah's state and local agencies, elected officials, citizens, and the nation. Projects conducted by the UWRL in this program area, including many funded from sources other than Mineral Lease Funds, have substantial education, outreach, and training components. Resources provided by Mineral Lease moneys are sometimes used to enhance the development of technologies, training modules or educational materials, and are often used to provide technical support to Utah's state and local agencies on water-related issues. The Utah On-Site Wastewater Treatment Training Program at the UWRL offers on-site wastewater training in support of the State of Utah certification program for on-site wastewater treatment professionals. Additional information can be found at https://uwrl.usu.edu/research/owt. Undergraduate and graduate students also participate in projects that involve hands-on, real-world activities.

Water Resources

This diverse program has strengths in both the theoretical and the applied aspects of hydrology and water resources. Hydrologic research includes hydrologic-related data collection and modeling that focuses on rainfall and evapotranspiration processes, snow hydrology, floods, droughts, terminal lakes, erosion and sediment transport, surface water quality and temperature, and groundwater/surface water connectivity. Water Resources management research areas include water conservation, river basin planning, reservoir operating policies, habitat monitoring and restoration, urban water management, and land use change. This program area also addresses various institutional and legal aspects of water, such as water rights transfers, water banking, distributed water demand and supply modeling, and cost allocation and user fee determination.

Information Dissemination

UWRL information dissemination activities include the publication of research results in professional journals, distribution of information on various UWRL and UCWRR web pages and newsletters, presentations before various professional societies at organization and association meetings both in the state and around the country, and sponsorship and participation in numerous short courses and training programs.

The UWRL web page (http://uwrl.usu.edu) provides general information about the UWRL and its personnel and, from time-to-time, a feature article on different research projects, faculty, and students at the UWRL.

Professional Service

UWRL Faculty are active professionally, and serve on state and local advisory panels to provide technical expertise, input, and review of water-related issues. Faculty also participate in and organize conferences, sessions, and workshops with professional societies. The also serve as journal peer reviewers and editors and assist funding agencies with proposal reviews. UWRL personnel are frequently invited to provide technical and informational presentations before state and national professional groups. Through this work they serve the profession and remain current on emerging research. Key UWRL faculty service activities include the following:

Utah Boards/Committees	Other State/Local Boards/Committees
Utah Department of Environmental Quality – Harmful Algal Blooms Team – Jordan River TMDL Advisory Committee – Long-term Stormwater Management Work Group – Utah Air Quality Board – Utah Drinking Water Board – Utah Water Operators Certification Commission Utah Division of Water Quality Nutrient Criteria Development Core Advisory Team Utah Division of Water Resources, Utah Agricultural Water Optimization Task Force (UDWR)	Cache County Solid Waste Advisory Board Cache County Implementation Plan Team Logan City Renewable Energy and Conservation Advisory Board Logan City Water Board Logan River Task Force Logan River Water Users Crocket Avenue Project Technical Advisory Board NOAA National Water Center Community Advisory Committee for Water Prediction OpenET Colorado River Basin Working Group Water Environment Association of Utah – Biosolids Committee
Peer Review Journal Articles	**Professional Leadership and Service**
Environmental Modelling & Software Journal, editorial board Environmental Engineering Science Environmental Science and Technology Hydrological Processes, associate editor Journal of the American Water Resources Association Journal of Coastal and Hydraulic Structures, editor Journal of Biological Engineering, editorial board Journal of Environmental Management Journal of Environmental Chemistry and Toxicity Journal of Water Resources Planning and Management, ASCE, associate and reproducibility editor Water Environment Federation Research WIREs Water, associate editor	American Geophysical Union Publications Committee Cache Environmental Flows Group Overtopping Protection at Dams and Levees Seminar Series, team leadership Society of PhotoOptical Instrumentation Engineers Conference Committee Technical Standards in Drone Technology (ASABE) United States Society on Dams Committees Utah Onsite Wastewater Association Conference Planning Committee Utah Water Users Workshop
Proposal/Program Review	
NASA Research Opportunities in Space and Earth Science program review panel National Science Foundation. Review panels and postdoctoral program USDA NIFA Proposal Review Board	

UWRL: Solving Today's Water Problems by Looking to the Future

Our planet is clearly experiencing staggering water problems driven by increased climatic variability and extreme climate driven events; an expanding population with growing demands for water, food, and energy; and the need to protect valuable environmental resources. Uncertainty about our water availability and quality in the face of these pressures underscores the need for forward-thinking research that results in practical solutions. The UWRL has evolved into a diverse center of excellence for generating knowledge related to water challenges. It fills an important role in the US and global community of water research facilities, with the interdisciplinary expertise to develop better ways to measure, monitor, model, understand, and manage 21st century water resources. Good water management recognizes the value of information from many disciplines—from how a single water molecule behaves to the constraints and opportunities created by state or national water laws and policies. Through its support of the UWRL, Utah is investing both in the creation of new knowledge and in the next generation of water engineers and experts that are critical to the ability of our state and the nation to deal with these water challenges now and the future. As the UWRL looks forward to another year of service to Utah, we are proud to acknowledge all the dedicated people, past and present, who have contributed to the UWRL's achievements and its outstanding reputation for water research and education.

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Section 2

Administration, Advisory Support and Special Equipment

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Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds

Administration: Area	Actual FY2021	Budgeted FY2022	Planned FY2023
Businss Services Office	$91,201	$93,937	$96,755
Communications and Outreach Office	$52,262	$53,830	$55,445
UWRL Administration	$32,598	$33,576	$34,583
TOTALS	**$176,061**	**$181,343**	**$186,783**

Administration and Advisory Support and Special Equipment

The Administrative Officers of the UWRL are responsible for managing the facilities and budget of the lab and overseeing the diverse projects conducted by faculty and their students. The Director and Associate Directors of the UWRL also work to maintain liaison with water planning and management officials across the state. Frequently, faculty from the UWRL are invited to serve on committees or provide technical or advisory support on water problems by various state or local agencies and, to the extent that it lies within the mission of the UWRL to provide such input, ML funds are sometimes used to cover expenses required to support these activities. Additionally, when research needs arise that require specialized equipment that cannot be made available through other means, MLF resources are sometimes used to acquire these equipment items critical for Utah-based research.

Administration of the MLF Program

The costs of administering the MLF program at the Utah Water Research Laboratory are deliberately held as low as possible, so as to maximize the direct research supported by ML funds. Collaboration with water managers and policy makers in state and local agencies identifies where applied research can contribute toward the solution of critical water resources problems. MLF money spent on administration at the UWRL provides some salary support for the UWRL Director and Associate Directors and supports the administration of the USGS 104(b) program funding that comes to the state. FY 21 administrative costs represented approximately 2.4% of total UWRL MLF expenditures.

Outreach and Business Support

Overall, annual research expenditures for the UWRL have generally fluctuated between $ 8 and $ 9 million, and at any point in time, around 200 active research contracts are administered at the UWRL. These projects require significant support from the UWRL Business Office in the form of accounting and financial oversight. Further, the UWRL Publications Office provides support for outreach activities (such as the production of presentations, maintenance of the UWRL and UCWRR web pages, etc.). MLF expenditures in FY 21 on these support activities accounted for 10.5% of total MLF funding.

Advisory Support on Water Problems

The UWRL receives many requests for advice and collaborative help on various water problems in the state and provides support, sometimes from MLF sources, to defray travel costs so UWRL faculty can participate in meetings in the state to coordinate UWRL activities with ongoing water problems, identify and seek funding for new applied research in the state, and provide expert advice on current water issues faced by various state and local agencies. These activities, if any, are enumerated in the Project Summaries section.

Section 3

Project Summaries

Research Project Summary Categories

This section of the report provides a summary of each project and its benefits to the state and areas benefited. The projects are organized into the previously noted program areas as follows:

- Environmental
- Hydraulics
- Measurements, Sensing, and Information Systems
- Water Education Outreach and Technology Transfer
- Water Resources

Environmental

ACTUAL, BUDGETED AND PLANNED EXPENDITURES OF MINERAL LEASE FUNDS

ENVIRONMENTAL: PI	Project Name	Actual FY2021	Budgeted FY2022	Planned FY2023
Doucette, W.	Evaluating Plant Uptake and Distribution of 4,4' Methylenedianiline in Tomato, Soybean and Wheat Plants	$63,059		
Dupont, R.	Evaluation of the Presence, Fate and Exposure Pathways of PFAS Compounds in Northern Utah Communities	$63,113	$65,006	$66,956
Dupont, R.	Field Sampling of COVID-19 in Wastewater to Manage Outbreaks and Disease Transmission	$35,429	$36,492	$37,587
Dupont, R.	Documenting Human Health Impacts from Exposure to Microbial and Chemical Hazards in Reclaimed Wastewater used in Urban Agriculture	$38,969		
Martin, R.	Air Quality Ammonia Studies (Vehicle Emissions) and Airborne COVID Studies	$53,042		
McFarland, M.	Use of Magnetite to Improve Settling and Effluent Quality in Wastewater Treatment Plants	$67,446	$69,469	$71,553
McLean, J.	Advanced analytical support for research efforts in environmental quality	$39,755	$40,948	$42,176
McLean, J.	Drought-Driven Changes to Winter Wheat Root Exudation	$27,684	$28,514	$29,369
McLean, J.	Impact of Metals and Metal Ions on Soils and Plants	$27,684	$28,514	$29,369
Moor, K.	Nitrite Radicals in Agricultural Runoff Receiving Surface Waters	$36,050	$37,131	$38,245
Sims, J.	Mitigation of Methane Emissions from Anthropogenic Sources	$17,296	$17,815	$18,349
Sims, R.	Wastewater Treatment: Nutrient Removal using Biofilm Microalgae	$24,168	$24,893	$25,640
Stevens, D.	Assessment and Modeling of Cyanotoxin Presence and Occurrence Risk in Utah Surface Waters	$48,903	$50,370	$51,881
	Designated projects		*$71,797*	*$73,951*
	Undesignated research projects in program area		*$145,000*	*$120,300*
	TOTALS	**$542,598**	**$615,949**	**$605,376**

Evaluating Plant Uptake and Distribution of 4,4'-Methylenedianiline in Tomato, Soybean and Wheat Plants

Project Description:

Need and Purpose

4,4'-Methylenedianiline (MDA) is an important industrial chemical used mainly in the production of polyurethane. It is an organic base that is toxic and detrimental to human health. Polyurethane is durable, but it can degrade in soils, where MDA can then be released and potentially taken up by plants and move into the food chain. The most likely routes of plant contamination in a soil environment are through degradation of polyurethane or by polyurethane-coated controlled-release fertilizers. If not rapidly biodegraded or irreversibly sorbed, or with a continual discharge to the soil, 4,4'-MDA could be taken up by plant roots and transferred to the above-ground tissues , creating a risk of exposure for humans and animals.

The goal of this project was to determine the transpiration stream concentration factor (TSCF) values for 4,4'-MDA and a butyl MDA carbamate (test substances), and for pyrene and caffeine (reference substances) in three plants species (tomato, soybean and wheat) as function of root zone pH using short-term exposures of roots contained within a pressurized chamber test system. The TSCF values as well as tissue-specific bioaccumulation values were also determined using long-term 14C- 4,4'-MDA exposures to roots of these same intact plant species grown from seedling to maturity. Experimental data can accurately quantify the plant uptake of these compounds to increase understanding of the distribution of these contaminants within a plant and to assess associated risks of contamination. The concern and uncertainty regarding plant uptake, in addition to the implications of chronic exposure to small doses and a feasible route of exposure, underscore the importance of understanding the behavior of MDA in plants, especially those used as food.

Benefits to the State

This project helped to determine the risk of MDA associated with the use of polyurethane-coated fertilizers and may also assist in development of improved fertilizers or agricultural practices to mitigate the potential for human exposure, such as limiting its use to crops that are raised for their above ground tissue rather than roots or tubers.

Findings/Results

The TSCF of MDA was determined using pressure chamber and intact plant methods. In intact plants, wheat had a higher 14C- MDA TSCF than both soybean and tomato plants. The differences among plant species may be due to physiological differences. The intact plant results for tomato and soybean were found to be statistically equivalent to the

Principal Investigators:

William Doucette (PI)

Students:

Jeffrey Wight (MS)

Partners/Collaborators:

USU: Crop Physiology Laboratory
National: International Isocyanates Institution

Geographic Areas:

Study Areas: Logan, UT

Areas Benefited: Any agricultural area in Utah

Contacts:

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Publications:

Wight, Jeffrey. 2022. *Evaluating Plant Uptake of 4.4'-Methylenedianiline,* Master of Science in Environmental Engineering thesis, Utah State University, All Graduate Theses and Dissertations 8374. https://digitalcommons.usu.edu/etd/8374

results of the pressure chamber experiment. In intact plants, the 14C-MDA concentrations found in above-ground tissue were highest in the leaves, followed by the stems, and then the tomato fruit or wheat head. However, the concentration in the roots was much higher than in above ground tissue. The root concentration factor (RCF) of 14C-MDA was larger than all other compounds used in this experiment, including the highly hydrophobic compound, pyrene, implying that root strong sorption processes may limit transport of 14C-MDA to above ground tissue.

The average TSCF values for 14C-MDA derived from hydroponically grown and intact wheat plants were slightly higher than corresponding values from soybean and tomato plants. This could be due to differences in metabolic capacities across the three plant species; however, metabolites were not identified or quantified to confirm this hypothesis. The average intact plant TSCF value for soybean was equivalent to that obtained from the pressure chamber method, while the value for tomato was slightly higher.

The TSCF of 14C-MDA in tomato plants were also determined using the pressure chamber method. The average TSCF value obtained using non-labelled 4,4'-MDA was significantly lower than that obtained using 14C- 4,4'-MDA. The average pressure chamber-derived TSCF value for the butyl MDA carbamate was 0.008 in the tomato at pH 7.8. The 4,4'-MDA and butyl MDA carbamate substances did not exhibit the expected correlation of TSCF with their log Kow values, suggesting that the aromatic diamine substance (4,4'-MDA) has a higher potential for sorption to the roots than does the aromatic monoamine substance (butyl MDA carbamate).

Comparisons between intact plant and pressure chamber-derived TSCF values determined for the same plant species and in the same study have not been previously reported in the literature. The overall distributions of 14C within the three plants species were similar, with the concentrations in the root greater than in the leaves and stems, which were further greater than in fruit. Tomato fruit concentrations were generally 5-10 times less than those in leaves but the concentrations of 14C in the wheat heads were only less than the wheat leaf concentrations by a factor of two or less.

Learning that a chemical, such as MDA, with aromatic amines will sorb strongly enough to roots to limit transport to the rest of the plant is invaluable as this behavior could also be observed in other similar compounds, though this will likely need to be determined experimentally first. Further research could help in identifying the true mechanism of sorption to the roots and in constructing predictive models for plant uptake. The results from this research add to knowledge useful for determining the risk of MDA contamination associated with the use of polyurethane coated fertilizers.

Work Plan FY 21–22

This project is complete.

Evaluation of the Presence, Fate and Exposure Pathways of PFAS Compounds in Northern Utah Communities

Project Description:

Need and Purpose

PFAS compounds represent a wide range of polyflorinated alkyl substances that have been used in consumer products and firefighting foams since the 1940s because of their heat and water-resistant properties. These chemicals are persistent in the environment and in the human body and have recently been associated with significant adverse human health effects, including increased cholesterol levels, low infant birth rates, cancer, and adverse effects on the immune system and on thyroid hormone production. Significant PFAS levels detected in surface and groundwater in Michigan and growing health effects evidence have resulted in a lifetime health advisory level in drinking water of 70 ng/L proposed by EPA in 2019 to limit human exposure to PFAS compounds. In this project we generate PFAS concentration data for various potential exposure routes of PFAS in northern Utah (municipal wastewater treatment plant effluent used for secondary irrigation, municipal landfill leachate, wet deposition) and evaluate potential human risks via direct exposure to secondary water, recreational contact, and ingestion of fruits and vegetables irrigated with treated effluent and contaminated rainwater.

Benefits to the State

Project results describe PFAS fate and transformation in wastewater treatment plants and lagoons and document potential risks of PFAS compounds in reclaimed wastewater, recreational settings impacted by precipitation and landfill leachate influences, and produce grown in urban gardens with reuse water. Treatment and reuse options limiting PFAS risks will be identified, if necessary, providing essential information to those communities considering development of water reuse projects in the future. Results can be broadly applied to other semi-rural regions in the State with water scarcity issues driving the development of treated wastewater for secondary water reuse.

Findings/Results

We developed sample processing/extraction and analytical methods to identify and quantify 24 different PFAS compounds in a wide variety of environmentally relevant samples. Quantitation in field samples has focused on C4-C9 carboxylic and sulfonic acids because of their relatively low Method Reporting Limits (MRLs) below 40 ng/L and because they have been routinely detected in samples analyzed in this study. Compounds > C9 rarely appear and tend to have MRLs at 40 ng/L and above. A range of PFAS compounds have been identified in both wastewater influent and treated effluent samples, in vegetables irrigated with secondary water, in some rainwater samples, and

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Joan E. McLean (Co-PI)

Technicians:

Joshua Hortin (Researcher II)
Ruiwen Chen (Researcher II)

Students:

Simon Kozik (MS)

Partners/Collaborators:

Local: Hyrum Wastewater Treatment Plant

Geographic Areas:

Study Areas: Logan, Wellsville, and Hyrum, Utah

Cache County Utah

Areas Benefited: Other areas within Utah currently utilizing or planning water reuse projects

Contacts:

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Presentations:

Kozik, S., R. Chen, J. Hortin, J.E. McLean, R.R. Dupont. 2021. *Evaluating the Presence and Exposure Risk of PFAS Compounds in a Rural Setting.* Presented in a Live Virtual Session at the 114th Air and Waste Management Association Annual Conference and Exhibit, June 14, Orlando, FL. Paper #983667

in landfill leachate and leachate pond sediment samples collected throughout Cache Valley. Figure 1 (top) shows the concentration of ten commonly detected PFAS isomers in local wastewater effluent samples compared to those quantified in the San Francisco municipal treatment plant serving a much larger population. This figure clearly indicates that wastewater PFAS concentrations are comparable in both highly urban and rural/peri-urban areas, making risks of exposure by this route universal. The figure also shows the accumulation of some PFAS compounds (esp. PFOA) in soils with a history (≈ 20 years) of irrigation with reclaimed wastewater, and that these PFAS compounds have been shown to find their way into edible portions of vegetables grown in these soils (top figure). Low but measurable concentrations of these PFAS compounds have also been found in rainwater collected from throughout Cache Valley, and work is continuing to estimate the contribution of rainwater versus reclaimed wastewater to the levels found in both background and irrigated soils for refined risk assessment calculations.

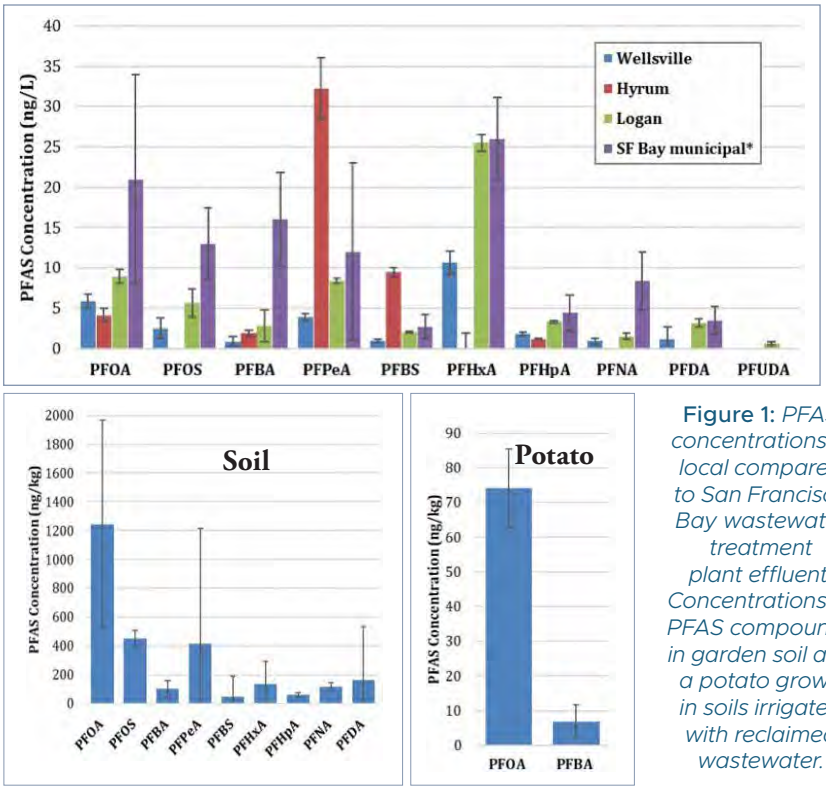

Figure 1: *PFAS concentrations in local compared to San Francisco Bay wastewater treatment plant effluent. Concentrations of PFAS compounds in garden soil and a potato grown in soils irrigated with reclaimed wastewater.*

Work Plan FY 21–22

We will complete wastewater reuse system sampling to include biosolids from the Hyrum treatment plant that are applied to adjacent farmland; analyze a wide range of fruits and vegetables irrigated with reclaimed wastewater in Hyrum compared to concentrations from background sites throughout the valley; and sample and analyze rainwater within the Cache Valley and at a background site in Logan Canyon to assess the contribution of wet deposition to PFAS loadings within the region.

Field Sampling of COVID-19 in Wastewater to Manage Outbreaks and Disease Transmission

Project Description:

Need and Purpose

The COVID-19 pandemic has taken a significant toll on human life and has been a significant economic burden throughout the world. Utah and Utah State University, in particular, have not been immune to the pandemic's effects, which caused disruptions to learning and academic life on campus throughout 2020. This project developed and validated methods for sampling student housing units on the USU residential campuses to provide early warning of asymptomatic or pre-symptomatic individuals in USU housing so that residents in those units could be screened, isolated, and quarantined as necessary to contain the spread of the virus on USU residential campuses.

Benefits to the State

Sampling methods developed in this project have been used and validated at USU's main campus, as well as at the Price and Blanding campuses, and results from the monitoring of collected samples by USU's Biological Engineering Department have provided the necessary information to detect and contain the spread of COVID-19 on these campuses and throughout the communities that host these institutions. The methods are applicable at other locations throughout the State where concentrated housing units or housing areas can benefit from early detection of infected individuals before symptoms of the infection might appear. Early detection and prevention of the spread of this virus are critical to containing viral transmission and the potentially high costs of treatment and severe health and economic consequences.

Findings/Results

A total of 27 sampling locations were established in manholes servicing student housing units throughout the three USU campuses. Composite wastewater samples were collected one to two times per week from each location for processing and detection of COVID-19 viral remnant levels in the sampled wastewater. Samples collected prior to all students returning to campus in fall 2020 showed very low levels of viral load in the wastewater. Upon the return of students to campus, viral levels increased significantly, and this rapid increase in concentration prompted the testing of occupants in several housing units, which resulted in the detection and isolation of six asymptomatic individuals in a building population of approximately 400 occupants. An additional spike in later in the semester prompted additional occupant screening and isolation in several housing units. In one location, a spike identified through wastewater screening efforts

Principal Investigators:

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Students:

Mariah Brotherson (BS)
Abby Englund (BS)
Grant Mauk (BS)

Partners/Collaborators:

Local: USU Facilities, Risk Management, Biological Engineering

USU Eastern, USU Blanding

Logan City Environmental Department

Hyrum Wastewater Treatment Plant

Geographic Areas:

Study Areas: USU main campus, USU Eastern in Price, USU Blanding, and adjacent communities

Areas Benefited: Other areas throughout the State that can benefit from early detection for containment of the spread of COVID

Contacts:

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Presentations:

Dupont, R.R. 2020. *Field sampling for COVID-19 in wastewater.* Training presentation to USU Eastern and USU Blanding campus representatives outlining sampling methods, sample handling procedures, operation and maintenance requirements, sampling pitfalls and solutions, etc. September 4, 2020. UWRL

led to the detection of more than twenty asymptomatic individuals from a building population of approximately 500 residents.

The use of wastewater screening for the collection of composite samples from potentially infected individuals in USU housing units was able to detect viral load from pre- or asymptomatic individuals, allowing the directed and strategic screening and isolation of those individuals to limit the spread of COVID-19 during a time of high national and statewide viral transmission rates. Results suggest that variable viral loadings from individuals at various stages of infection and recovery can be observed from sample populations, making this a screening method at best. It has been demonstrated, however, to be an effective tool in directing the more expensive testing of individuals contributing to these wastewater signals in an unbiased and strategic way.

Work Plan FY 21–22

This project will continue into FY 21–22. The continued monitoring of student housing units will aid in the response to evolving COVID variants and the continued effort to effectively control the spread of COVID within the USU residential campuses and surrounding communities.

Figure 1: *(A) Wastewater sampling at the main Logan campus, (B) autosampler used for wastewater monitoring, (C) typical manhole configuration for sampling of multiple housing units, and (D) bottles in autosampler units for sample collection over time.*

Documenting Human Health Impacts from Exposure to Microbial and Chemical Hazards in Reclaimed Wastewater used in Urban Agriculture

Project Description:

Need and Purpose

Diminishing water supplies have resulted in an increased use of alternative water sources for agriculture, including treated municipal wastewater (reclaimed water). Twenty million hectares in 50 countries worldwide were irrigated with reclaimed water in 2010. As public expectations for local agricultural food systems grow and demands on traditional agricultural water supplies increase, safely managed reclaimed wastewater sources could become an essential component of future sustainable food production systems.

To accurately estimate human health risk from the use of reclaimed wastewater in urban and peri-urban agricultural settings, we must consider multiple exposure routes, additivity of chemical risk, and the complexity of the pathogenic community that may exist in reclaimed water. Cache Valley, Utah, is an ideal location for such a study as reclaimed wastewater use is widespread (involving wastewater from 85% of the Valley's population) and is distributed and applied in a wide range of ways, representing a broad range of potential exposure pathways over the entire urban/peri-urban/rural spectrum. Further, WWTPs using various treatment technologies are readily available in the Valley.

Benefits to the State

The project increased the understanding of the risks of using of nontraditional waters (i.e., reclaimed wastewater) for agriculture and the potential human health exposures and risks at watershed scales, while also engaging, educating, and reducing the risks to affected community members and stakeholders.

Findings/Results

We monitored and quantified the removal efficiency of a range of pharmaceuticals and personal care products (PPCPs) and microbial pathogens produced by a wide range of treatment technologies existing in the Cache Valley. We also performed monitoring to determine the fate of these PPCPs and pathogens within the reclaimed water distribution system in the Hyrum, Utah, community, utilizing state-of-the-practice wastewater treatment technology. Finally, we quantified the PPCP and pathogen levels in irrigation water applied to forage and feed crops, and home gardens during the reporting period, as well as soils and plant tissue, to expand the database of pollutant uptake and concentration in crops, and exposures levels during secondary water use for irrigation. Reductions in concentrations of some PPCPs were observed within the secondary water distribution system, contrary to pathogen data, which showed regrowth of bacteria and stable viral concentrations as reuse water moves through the pressurized distribution system.

Principal Investigators:

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Joan E. McLean
Randal Martin
Courtney Flint
Niel Allen
Jennifer Weidhaas (UofU)

Students:

Leila Ahmadi (postdoc)
Kristin B. Koci (PhD)
Kwame T. Duodo (MS)
M.S. Olsen (MS)

Partners/Collaborators:

Local: Hyrum, UT, Logan, UT, Wellsville, UT Public Works and Environmental Departments

National: USDA NIFA program

Geographic Areas:

Study Areas: Hyrum, Logan, Wellsville, Cache County

Areas Benefited: Other areas in Utah using or considering the use of reclaimed water for industrial agriculture or urban secondary water uses

Contacts:

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Publications:

This project resulted in 2 publications, 17 scholarly presentations, 2 MS theses, and numerous data sets

Datasets:

The following data sets will be anonymously archived within two years at HydroShare.org

- PPCP and microbial pathogen data generated from influent and effluent sampling from three wastewater treatment plants in Northern Utah between 2017 and 2019
- Secondary water distribution system PPCP and microbial pathogen sampling during irrigation season 2017 to 2019 in Hyrum Utah
- Secondary water tap, home garden vegetable, and home garden soil samples collected from Hyrum Utah, 2017 and 2018
- Citizen response to perceived health and safety risk of the use of reclaimed water in urban agriculture collected from select respondents in Hyrum and Logan Utah during summer/fall 2018

We completed an analysis of Key Informant Interviews to evaluate perceptions and experiences related to local reclaimed water use by water providers. Results from both Hyrum, and the "control" group in Logan were summarized and reported in two project newsletters distributed to interested survey respondents in both communities.

Findings confirm that the main risk associated with the reuse water from the Hyrum secondary water system is exposure to microbial pathogens rather than PPCPs. The PPCP risk analysis indicated that PPCP exposure represents a de minimis risk to potentially exposed Hyrum residents under worst case exposure conditions of direct ingestion of secondary irrigation water or home garden vegetables irrigated with this water. A Quantitative Microbial Risk Assessment (QMRA) was completed for a range of microbial pathogens, and results from this analysis indicated that (1) the probability of illness from eating raw foods irrigated with reclaimed water was higher than the baseline US illness rate for all pathogens studied, (2) the probability of illness from direct ingestion of secondary water was higher than the reference risk benchmark for Salmonella spp., and (3) for a bioaerosol inhalation route, probability was higher for human adenovirus and Legionella pneumophila. These microbial pathogen risk results suggest that they are the key risk parameters for reclaimed wastewater use for Hyrum secondary irrigation and that risk reduction measures should focus on improved management of the secondary water system to reduce pathogen regrowth and subsequent exposure.

Figure 1: *Vegetation sampling from gardens irrigated with reclaimed water.*

We communicated finding to the advisory board, water system providers and irrigators, and published two Extension Fact Sheets. These focused on identifying effective, low to no-cost options (use of chlorine prior to reuse water entering the secondary water distribution system, produce washing post-harvest, wait time post irrigation prior to harvest, etc.) for the reduction of microbial pathogen exposure and risk from secondary water use.

Work Plan FY 21–22

This project is complete.

Air Quality Ammonia Studies (Vehicle Emissions) and Airborne COVID Studies

Project Description:

Need and Purpose

Previous research and regulatory work have shown vehicle emissions are the dominant emission sources for Utah's direct and precursor pollutants. Additionally, it has become apparent that current air pollutant emission inventories underestimate available ambient ammonia (NH3), a key component of our local/regional PM2.5 (ammonium nitrate). State-wide photochemical modeling attempts must be artificially enriched by two to six times to adequately predict observed ambient concentrations. Separately, as the COVID-19 pandemic spread throughout the country and Utah, the need to understand the long-range and local transmission modes became apparent. As a part of this effort, Martin became involved in several studies examining the potential for long-range transport of the SARS-Co-2 virus via attachment to air-borne particles and the potential for virus-laden aerosols associated with municipal wastewater treatment. This summary combines two projects funded via the Utah Division of Air Quality (UDAQ) and Mineral Lease funds to expand the overall scope of the research.

Benefits to the State

Accurately assessing the ambient NH3 and other relevant pollutants and their emissions from sources relevant to the fleets and conditions of northern Utah will help to identify their significance, particularly under wintertime, inverted conditions. Successful tracking of the airborne SARS-CoV-2 virus would help establish source attributions and could lead to mitigation scenarios.

Findings/Results

At the conclusion of the on-road automobile ammonia emissions study, over 50 light-duty gasoline and diesel vehicles were tested on-road for ammonia and related pollutant emissions. The fleet-averaged ammonia emissions were found to be 55.6 mg/mile, which would yield an estimated 1,497 metric tons of NH3 per year from passenger vehicles along the Wasatch Front. As shown in Figure 1 below, this represents a 43% increase above the current EPA emissions inventory. The magnitude of the ammonia emissions was also found to be strongly correlated with vehicle age and mileage, with older, higher-mile vehicles typically showing higher NH3 emissions.

Some of the ambient deposition (NADP and other samples) were found to contain SARS-Cov-2 RNA, but the spatial detection seemed locationally inconsistent. Air parcel back trajectory analysis is being conducted to see if any patterns can be identified when viral RNA was detected. Several aerosol and in situ (process stream) samples were collected from the Hyrum

Principal Investigators:

Randal S. Martin, USU/UWRL (Co-PI),
Joe Thomas UDAQ, WSU NCAST (Co-PI),
John Sohl, WSU,
Janice Brahney, USU,
Keith Roper, USU (Co-PI)

Students:

Motasem Abualqumboz (MS)

Partners/Collaborators:

Local: Logan, Cache County, UT; Wasatch Front, UT

State/National: Utah Division of Air Quality, UT Air Monitoring Center; Some national implications

Geographic Areas:

Study Areas: Most automobile emissions testing conducted at the UWRL and at Weber State University's National Center for Automotive Science and Technology (WSU/NCAST). Nationwide aerosol and precipitation samples obtained through cooperative agreements with the National Atmospheric Deposition (NADP) and other related networks.

Areas Benefited: Northern Utah will see the most direct/immediate benefit. UDAQ will also use the results in planning future mitigation and modeling strategies. The COVID studies will benefit all of Utah and will also have national implications.

Contacts:

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Publications:

- Abualqumboz, M. 2021. *Ammonia Emission Assessment from Gasoline and Diesel Engines under Utah Specific Conditions* All Graduate Theses and Dissertations. 8243. https://digitalcommons.usu.edu/etd/8243
- A manuscript is in final preparation for submission to the Journal of the Air & Waste Management Association (JAWMA)
- A manuscript is in preparation on the airborne and in situ COIVD measurements from the Hyrum Wastewater Treatment Plant

Datasets:

None are publicly available at this time, but they can be obtained through contact with Randal Martin

Wastewater Treatment Plant (HWWTP). The data are still being compiled and analyzed; however, aqueous-borne SARS-CoV-2 RNA was found at several location throughout the WWTP process, including the effluent, but no RNA was detected in the aerosol collected from within the plant facilities.

Work Plan FY 21–22

The current phase of the automobile emissions studies ended in summer 2021. As previously noted, the PI has become involved with potential long-range COVID transport studies, COVID associated with wastewater treatment, and related potential for biological aerosol releases. Also initiated during the early portions of the 21/22 FY will be studies associated with the emissions and ambient concentrations of an important emerging pollutant class known as PFAS (per- and polyfluoroalkyl substances).

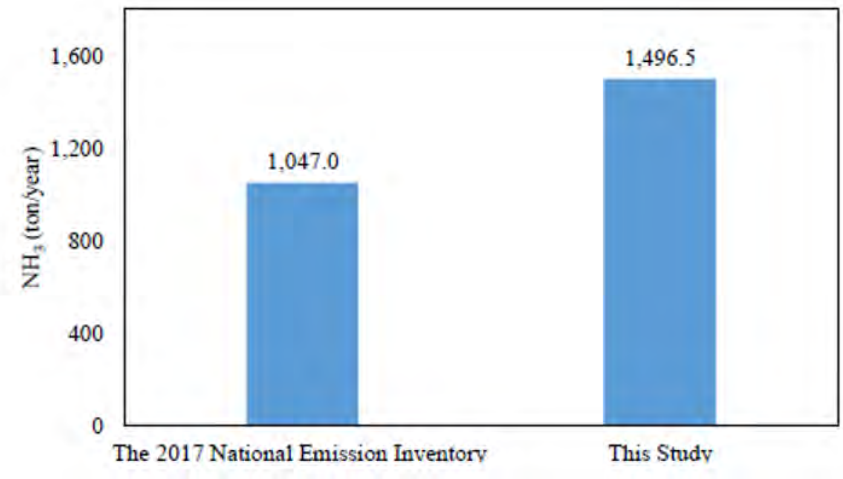

Figure 1: *Wasatch Front NH3 emission rates according to the USEPA (2017 NEI) and this study.*

Use of Magnetite to Improve Settling and Effluent Quality in Wastewater Treatment Plants

PROJECT DESCRIPTION:

Need and Purpose

The City of Logan is in the process of upgrading its wastewater treatment facility from a lagoon system to a mechanical facility in order to meet the new phosphorus and ammonia effluent limits imposed by the Utah Division of Water Quality (Carollo, 2015). The new treatment plant will use the 3-Stage Bardenpho process with BioMag® Technology, which adds magnetite to the secondary treatment process. BioMag® was chosen because it would enable Logan City to build a facility with a much smaller footprint than a conventional 3-Stage Bardenpho wastewater treatment facility as the soils in the area where the new plant will stand would not be able to support a conventional facility due to its size. Magnetite is an iron ore mineral with a specific gravity of about 5.2, which is much higher than the specific gravity of water and of individual biological floc particles. The high specific gravity of magnetite is expected to increase the settling velocity of the biological floc in the settling tanks, thereby improving their efficiency and enabling smaller sized tanks to be used. Magnetite is also said to improve the quality of effluent from wastewater treatment facilities (Evoqua, 2017).

This research is investigating the effectiveness of magnetite in wastewater treatment in terms of Biological Nutrient Removal (BNR) and the use of the wasted solids containing magnetite in processes such as anaerobic digestion (for facilities that digest their sludge anaerobically). The information obtained should help the City of Logan to have a clearer picture of what to expect with the new treatment plant in terms of biological nutrient removal and also provide information on how the magnetite in the sludge would affect the gas composition in case they decide to digest their sludge anaerobically in the future.

Benefits to the State

This work can:

- reduce the initial capital cost of erecting larger new facilities to meet more stringent effluent quality standards, and reduce operation and maintenance costs
- Improve capacity of existing wastewater treatment facilities, thus eliminating the need to erect entirely new facilities to meet effluent quality requirements
- Improve effluent quality from wastewater treatment facilities to meet requirements imposed by the Division of Water Quality
- Possibly reduce hydrogen sulfide production, its corrosion effect on metal, and toxicity to humans (for facilities that digest their sludge anaerobically to produce biogas).

PRINCIPAL INVESTIGATORS:

Michael McFarland (PI)

STUDENTS:

Patricia Ayaa (PhD)

PARTNERS/COLLABORATORS:

Local: Holly Daines, Mayor, Logan City

Issa Hamud, Environmental Director, Logan City

Jim Harps, Wastewater Director, Logan City

Tom Jensen, Sewer and Water Board, Logan City

GEOGRAPHIC AREAS:

Study Areas: Logan, Utah

Areas Benefited: Logan, Utah and other cities with similar wastewater treatment needs

CONTACTS:

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Publications:

- Ayaa, P., and McFarland, M. 2021. *Effect of Magnetite on Anaerobic Digester Biogas, Hydrogen Sulfide, Digester Effluent and Related Processes*. Journal of Environmental Engineering, https://doi.org/10.1061/(ASCE)EE.1943-7870.0001947
- Ayaa, P., Stevens, D.K., and McFarland, M. 2020. *Estimating the Effect of Magnetite on Nitrogen and Phosphorus Removal using Intervention Analysis*. Journal of Environmental Engineering, 10.1061/(ASCE) EE.19437870.0001780. https://ascelibrary.org/doi/pdf/10.1061/%28ASCE%29EE.1943-7870. 0001780

Findings/Results

Research on the effects of magnetite in anaerobic digestion is still on-going, and so far, findings demonstrate that magnetite added to the anaerobic digestion process reduces the concentration of hydrogen sulfide gas in the biogas produced (Figure 1). Since the last MLF report (2020–2021), another peer reviewed publications associated with the use of magnetite under anaerobic digester conditions has been accepted and published.

Work Plan FY 21–22

Plans for the next fiscal year include:

1. Completing the on-going research on the effect of magnetite in the anaerobic digestion process
2. Conducting research into the use of bioenergetics to model interspecies electron transfer during magnetite application in the methane fermentation process. This will be the subject of the next published paper.

Figure 1: *Anaerobic Digester System at Central Valley Water Reclamation Plant (Salt Lake City, Utah).*

Advanced Analytical Support for Research Efforts in Environmental Quality

Project Description:

Need and Purpose

The Environmental Quality Laboratory provides technology, expertise, services, and training in advanced analytical science supporting today's water and environmental students, researchers, and stakeholders. Environmental research at the EQL emphasizes an integrated engineering and science approach to the environmental quality of land, water, and air. A multidisciplinary group of engineers and scientists conducts basic and applied laboratory and field research aimed at understanding and finding sustainable solutions to water challenges that occur in the innumerable interactions between humans and water. These pressing challenges include monitoring and preventing harmful algal blooms and cyanotoxin production, monitoring the presence of pharmaceuticals, personal care products, and fluorinated

Figure 1: *Sampling for PFAS at Logan Landfill (top L); harmful algal bloom at Mantua reservoir (2021) (credit: Utah Department of Environmental Quality) (top center); examining wheat roots under drought stress (top R). air sampler for PFAS compounds (bottom).*

Principal Investigators:

Joan E. McLean (PI)
Joshua Hortin (Researcher II)
Ruiwen Chen (Researcher II)

Partners/Collaborators:

Academic: Various USU departments

Local: Bear River Health Department

Geographic Areas:

Study Areas: The indicated challenges affect a range of stakeholders throughout Utah

Areas Benefited: All counties in Utah

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substances in reused wastewater, through secondary water systems and into soils and crops; monitoring pesticides and adjuvants in water, soil, plants, and pollen; monitoring airborne fluorinated substances, especially those arising from landfills; investigating the breakdown of plastics and microplastics in the environment; monitoring pollutant loading from stormwater; monitoring wastewater for COVID-19 DNA; and other urgent matters that arise.

Benefits to the State

Provide advanced analytical support to researchers across the USU campus and to state and local agencies.

Findings/Results

Analytical procedures have been developed for:

- pharmaceutical and personal care products (PPCPs) in water, soil and plants
- pesticides and adjuvants in water and soil
- Per- and polyfluorinated alkyl substances (PFAS) in water, soil, plants and air
- Cyanotoxins in drinking and ambient waters
- Plant and rhizosphere metabolites
- Low detection limits for nutrient (P and N) in water
- Trace element analysis.

Methods have been developed for faculty researchers in the USU departments of Natural Resources, Chemistry, Civil and Environmental Engineering, Biological Engineering, and Plants, Soils and Climate, as well as the Bear River Health Department.

Work Plan FY 21–22

Continue to develop advanced analytical methods to serve the research needs of with the Utah Water Research Laboratory faculty and the USU campus. Advanced analytical methods will also support various agencies in Utah.

Figure 1: *UWRL Environmental Quality Laboratory advanced analytical equipment*

Drought-Driven Changes to Winter Wheat Root Exudation

Project Description:

Need and Purpose

In late 2020, >80% of Utah entered a state of extreme drought, a condition not seen since 2003 according to the United States Drought Monitor. The drought intensified into an exceptional drought for 57–70% of the state through July 2021 (Figure 1), a condition not observed in Utah the past 21 years, resulting in USDA disaster designations in all 29 Utah counties and the complete loss of many dryland wheat fields.

Drought-related agricultural losses are expected to continue in the face of climate change, so farmers need strategies to increase crop resilience. One strategy being tested by this laboratory and researchers nationwide is the application of nanoparticle micronutrients to soil (Potter et al. 2021). Plants acquire micronutrients through root exudation of specific organic acids, but drought can alter root exudation. Plants also provide root exudates to attract beneficial root-colonizing bacteria.

In order to fully understand the mechanisms by which micronutrient nanoparticles enhance plant drought tolerance, studies of the exudation patterns of common Utah dryland crops, such as winter wheat, are needed.

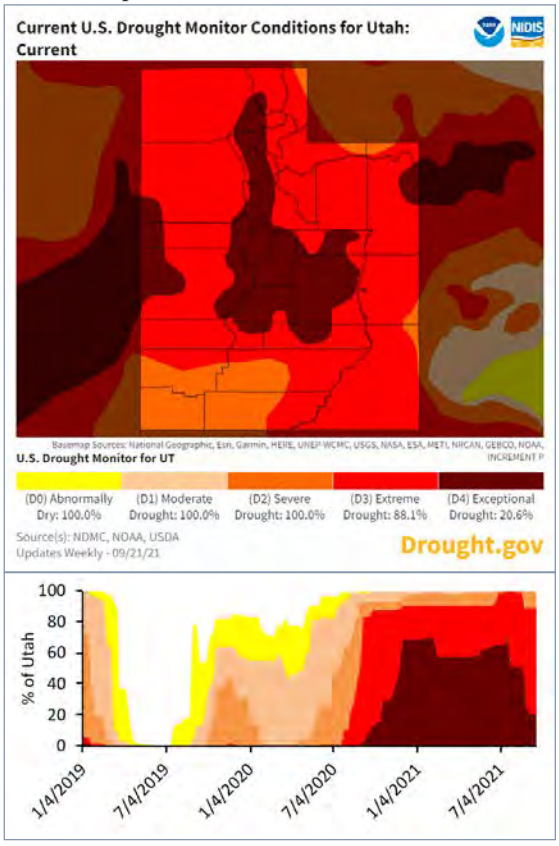

Figure 1: *Current and historical U.S. Drought Monitor conditions for Utah.*

Benefits to the State

Strategies to reduce crop losses from drought, particularly in dryland systems, will benefit farmers throughout Utah and improve water resources management.

Principal Investigators:

Joan E. McLean (PI)
Anne Anderson (Biology)
David Britt (Biological Engineering)
Astrid Jacobson (Plants, Soils, and Climate)
Joshua Hortin (Researcher II)

Students:

Dakota Sparks(MS)

Partners/Collaborators:

National: In support of USDA funding

Geographic Areas:

Study Areas: Counties with agricultural operations

Areas Benefited: All counties in Utah

Contacts:

Joan E. McLean
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Publications:

Potter, M., Deakin, J., Cartwright, A., Hortin, J., Sparks, D., Anderson, A. J., McLean, J. E., Jacobson, A., and Britt, D. W. 2021. *Absence of nanoparticle-induced drought tolerance in nutrient sufficient wheat seedlings*. Environmental Science and Technology. doi.org/10.1021/acs.est.1c00453

Findings/Results

Drought increases root exudation of organic and amino acids when roots are colonized by a beneficial bacterium. Increased root exudates imply that levels of dissolved micronutrients from nanoparticle supplementation, particularly copper-based treatments, will also increase. Results: The bacterium, Pseudomonas chlororaphis O6 (PcO6), originally isolated from the roots of a Cache Valley dryland wheat farm, is an aggressive root colonizer, and drought did not impede the colonization of the roots in these experiments. PcO6 metabolizes ~50–95% of the organic and amino acids provided by the plant roots. However, under drought, more organic and amino acids were detected even in the presence of PcO6, suggesting that the plants produce more root exudates under stress and/or the PcO6 slow their metabolism. Figure 2 shows an example of a particular root exudate, glycine betaine, which is known to play a role in plant drought tolerance. Glycine betaine around the roots was lower when PcO6 were present than when absent, but it was over 15 times higher in a droughted system with PcO6 than a watered system with PcO6. Most other root exudates followed a similar pattern. Preliminary evidence from our colleagues shows that winter wheat recovers more strongly after a drought period when glycine betaine is present in the rooting zone. Thus, the increase in root exudates could be beneficial for crop recovery. Additionally, the presence of organic and amino acids in the rooting zone will attract beneficial microbes and enhance the solubility of micronutrient fertilizers.

Work Plan FY 21–22

We will publish the results of this research in a peer-reviewed journal, which provide insight into other MLF-funded projects. We will also investigate the roles of specific root exudates in the scientific literature to determine the importance of other root exudate shifts observed under drought, which will help determine if more research in this area is needed.

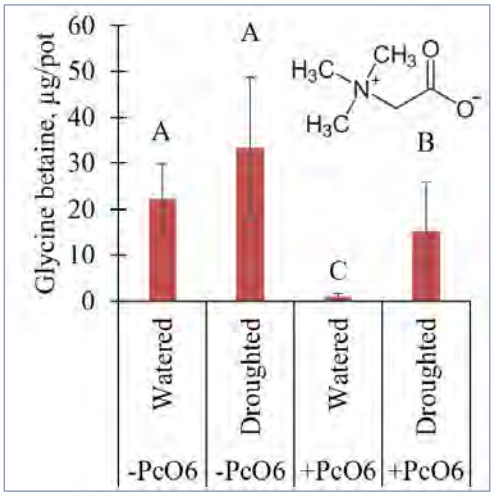

Figure 2: *Current and historical U.S. Drought Monitor conditions for Utah.*

Impact of Metals and Metal Ions on Soils and Plants

Project Description:

Need and Purpose

Copper oxide nanoparticles (CuO NPs) are potential crop antifungals, antimicrobials, fertilizers, and drought resistance treatments. Plants need copper (Cu) as a micronutrient, but elevated levels of bioavailable Cu are highly toxic to plants and their associated microbes. Plants and microbes signal, defend against competition, and acquire micronutrients by releasing organic chemicals that dissolve minerals, including CuO NPs. These NPs have low solubility in pure water, but dissolved organic carbon (DOC) binds to Cu, which drives NPs dissolution. The pH also plays a significant role in dissolution, with CuO NPs being most soluble under acidic conditions. Plants and microbes exude various types and quantities of chemicals depending on the soil properties, plant species, microbial community structure, and environmental stresses, thus altering the CuO NPs' solubility and influencing plant Cu uptake.

We evaluated the interactions of soil-derived organic matter, Utah-bred winter wheat root exudates, and native microbial exudates on the dissolution of CuO NPs using three Utah soils. The different origins and management practices of these soils alter the pH, the soil organic matter quantity and characteristics, and the microbial population and composition. Previous research used a single bacterium and only alkaline soils to examine the impact of wheat-bacterium interactions on CuO NP solubility. In current efforts, we are evaluating entire soil microbial communities, alkaline and acidic soils, the differing soil-derived organic matters, and the wheat on the solubility of CuO NPs in alkaline agricultural soils (pH 8, "ArgM" and "OrgM"), and acidic grassland soil (pH 6.5, "TWDEF"). We observed the whole soil-bacteria-wheat system impact on CuO NP solubility and the soil-wheat system alone through filtration of the microbes from the soil solution.

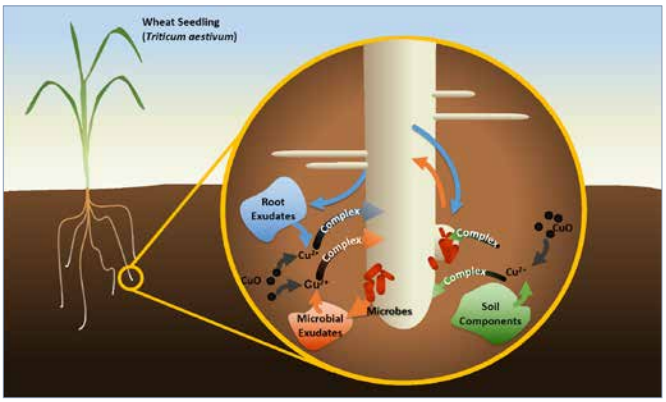

Figure 1: *Root and microbial exudates increase dissolution of CuO NPs more than soil components.*

Principal Investigators:

Joan E. McLean (PI)
Anne Anderson (Biological Engineering)
David Britt (Biological Engineering)
Astrid Jacobson (Plants, Soils, and Climate)
Joshua Hortin (Researcher II)

Students:

Dakota Sparks (MS)
Grant Mauk (undergraduate)

Partners/Collaborators:

National: In support of National Science Foundation funding

Geographic Areas:

Study Areas: Counties with abandoned and active mining operations, counties with industrial operations, and counties with agricultural operations

Areas Benefited: All counties in Utah

Contacts:

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Publications:

Dakota Sparks will complete his thesis work in February 2022 and publish the results in a peer-reviewed journal.

Benefits to the State

Results directly benefit Utah counties with current metal contamination from abandoned and active hard rock mining and related industrial operations by protecting environmental quality and human health related to metal exposure. CuO NPs may benefit counties with agricultural operations as the pesticidal and drought resistance-stimulating properties of the NPs are developed, particularly as drought and opportunistic pathogens increase in frequency.

Findings/Results

Exudates released by roots overcome the inherent soil properties of pH and soil organic matter and are the driving factor of CuO NP dissolution. The presence of native soil microbes modifies root exudates and corresponding NP solubility, which can be useful for developing strategies to control the solubility of CuO NPs benefit plant-microbial health (Figure 1).

We grew wheat in sand with the addition of pore waters from three Utah soils and native microbes either present or absent in the soils. Soil pH and organic matter concentration and composition varied. The CuO NPs dose was 30 mg Cu/kg sand. Wheat grew for 10 days, and the sand pore water was extracted and analyzed for DOC composition and CuO dissolution.

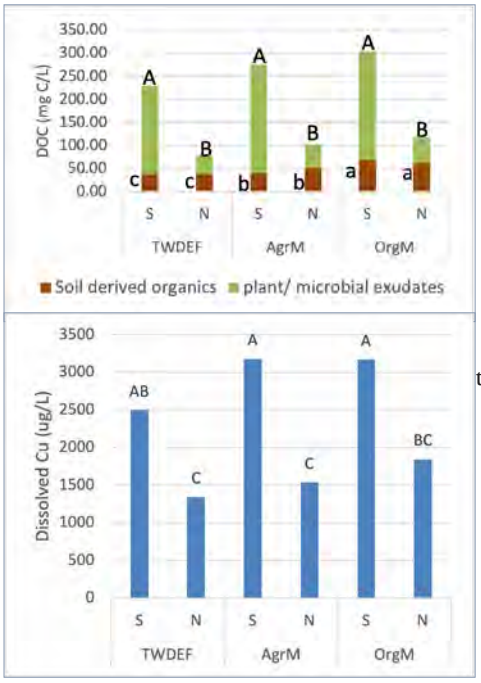

Figure 2: *Amount and composition of dissolved organic carbon (DOC) at harvest (A) and dissolved Cu (B) in treatments of three soil pore waters and two microbial conditions. Matching letters within the figures represents the measurements being statistically equivalent based on Tukey's HSD test.*

Figure 2A shows the composition of the DOC from the pore water at harvest. The organically managed (OrgM) soil had the most soil-derived organic matter, while the grassland soil, TWDEF, had the least. Whether with native microbes or without, the DOC concentration increased to the same level across all soil types. Microbes decreased plant-derived DOC concentrations due to microbial metabolism, but the soil-derived DOC was not affected by microbial activity. Figure 1B represents the dissolved Cu found in the pore waters. Despite differences in soil DOC concentrations, CuO NP solubility was the same for soils within the same microbial conditions (presence or lack of microbes). Thus, consumption of plant-derived organic carbon decreased the solubility of CuO NPs.

Work Plan FY 21–22

To further this work, the research team will seek additional funding.

Nitrite Radicals in Agricultural Runoff Receiving Surface Waters

Project Description:

Need and Purpose

Agricultural runoff is a major source of pollution in surface waters, resulting in a net input of various organic contaminants (e.g., pesticides, herbicides, antibiotics) and nutrients such as nitrogen and phosphorous. These contaminants can have serious impacts on water quality. The input of nitrogen from agricultural runoff can cause major algal blooms that deplete oxygen in surface waters and harm aquatic life. The input of nitrogen, as nitrate, can also impact the broader fate of organic pollutants in surface waters. In a sunlit surface water, nitrate interacts with sunlight to generate reactive intermediates that react with organic co-contaminants from agricultural runoff—such as the aforementioned pesticides, herbicides, and antibiotics—degrading these compounds and removing them from the environment. Nitrate may thus play a role in the environmental fate of organic contaminants associated with agricultural runoff.

One of the key reactive intermediates that is formed from nitrate in sunlit surface waters is the nitrite radical. This radical has been shown to react with a small set of organic contaminants, but its reactivity trends have not yet been established. This needs to be addressed because nitrite radical reactions may form highly nitrated and nitrosated organic compounds, which are highly toxic byproducts. This project is determining the reactivity of nitrite radicals with a range of organic contaminants. Knowing how nitrite radicals interact with contaminants will help us ultimately predict the transformation products formed in agricultural runoff receiving waters

Benefits to the State

This project is deepening our understanding of how pollutants degrade in sunlit surface waters and the broader impacts of agricultural runoff on surface waters. By determining reactive trends of nitrite radicals, we can predict potential toxic byproducts to protect environmental and human health related to the exposure of nitrated organic contaminants. This project impacts the large portions of Utah that engage in agricultural production.

Findings/Results

A critical instrument in this project is our transient absorption spectrometer, which we will use to measure the reactivity of nitrite radicals with organic contaminants. We installed the laser system and confirmed that it works properly, using a photochemical reaction—quenching triplet-excited 2-acetonaphthenone with 2,4,6-trimethlyphenol—as a validation experiment. We found excellent agreement between our

Principal Investigators:

Kyle J. Moor (PI)

Students:

Monika Madhiyan (PhD)

Geographic Areas:

Study Areas: Counties with agricultural operations

Areas Benefited: All of Utah

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measured value and the literature, indicating that our laser system works properly. We are now attempting to observe nitrite radicals on our laser system, optimizing the laser measurements by changing the experimental conditions with a focus on how we produce nitrite radicals.

Work Plan FY 21–22

This project only recently started and is expected to continue in FY21–22. We have not yet observed nitrite radicals on our laser system at this point. Our next major milestone will be observation of nitrite radicals, confirming that we are in fact monitoring nitrite radicals by measuring nitrite radical reactivity with phenol, a well-established reaction that has previously been reported. We will then screen a set of organic contaminants to measure the reactivity of nitrite radicals and determine how chemical structure impacts reactivity. We will also investigate the formation pathways of nitrite radicals from different components in agricultural runoff such as dissolved organic matter.

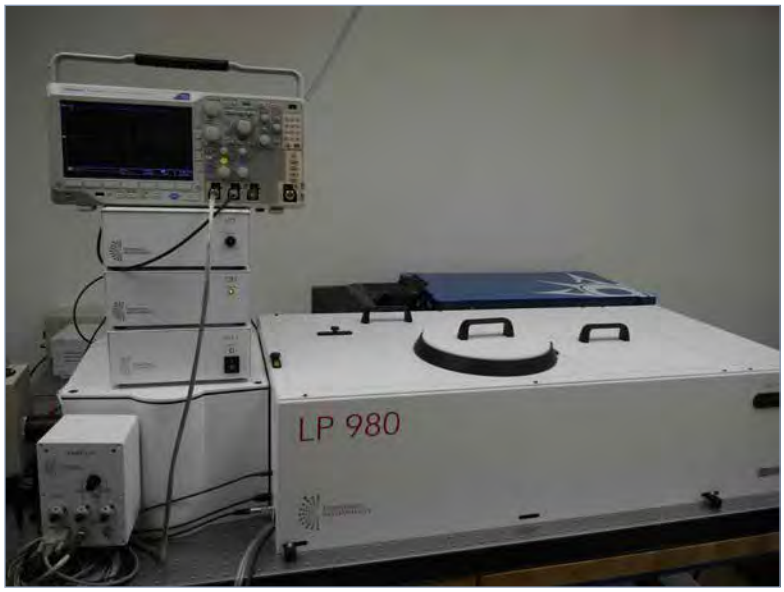

Figure 1: *Transient absorption spectrometer used to measure reactivity of nitrite radicals.*

Mitigation of Methane Emissions from Anthropogenic Sources

Project Description:

Need and Purpose

Increasing atmospheric greenhouse gas (GHG) concentrations have necessitated development of methods to not only reduce GHG emissions, but to also increase GHG treatment. Carbon dioxide (CO_2) emissions receive the majority of attention given to GHGs, but pound for pound, methane (CH_4) is over twenty-five times more effective than CO_2 at trapping heat in the atmosphere over a 100-year period. CH_4 is the second largest contributor to the total global atmospheric greenhouse effect, accounting for approximately 20 percent of global emissions on a CO_2 equivalent basis. Globally, CH_4 emissions in 2020 were estimated by the EPA to be 9,390 million metric tons of CO_2 equivalent.

Atmospheric CH_4 levels reached above 1850 ppb in 2018, over 2.5 times higher than the estimated pre-industrial equilibrium value in 1750. The large increase in the atmospheric concentrations in that time frame can be mostly attributed to anthropogenic emissions, which include agriculture, energy industry, and waste from homes and businesses, among other sources. In agriculture, the production of CH_4 emissions is largely tied to enteric fermentation by domestic livestock, which includes animals that produce CH_4 as part of their digestive process. In the energy industry natural gas and petroleum are large sources of CH_4 emissions. Methane is the primary constituent of natural gas and is emitted during many phases of natural gas production processes. Oil and coal production are also industry sectors that produce large quantities of CH_4 emissions. With regards to waste from homes and businesses, CH_4 is generated as waste decomposes in landfills and wastewater treatment, as well as in composting. Anthropogenic CH_4 emissions for the decade 2008–2017 were estimated to have increased nearly 10% from the previous decade.

In addition, methane contributes to the formation of NH_4NO_3, which is a major component of particulate matter less than 2.5 microns ($PM_{2.5}$). $PM_{2.5}$ is an important air contaminant that contributes to poor air quality in Cache Valley and in other areas of Utah during winter inversions. In this project, we investigate the efficacy of a potential method to mitigate the impacts of methane produced from anthropogenic sources such as landfills, wastewater treatment sites, mining, and agriculture (Figure 1).

Benefits to the State

The project will provide direct benefit to the State of Utah, especially the Cache Valley area, by targeting local anthropogenic methane sources for methane emission reduction. This can potentially reduce the amount of methane that is a precursor for the formation of $PM_{2.5}$, as well as GHG.

Principal Investigators:

Judith L. Sims (PI)
Charles Miller
Ronald Sims

Students:

Jace Parkinson (MS)

Geographic Areas:

Study Areas: Cache County

Areas Benefited: Areas of Utah where air quality problems or large amounts of methane are generated

Contacts:

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PUBLICATIONS:

- Parkinson, Jace, 2021. *Methane Emission Treatment and Potential Upcycling using Methylomicrobium alcaliphilum*. All Graduate Plan B and other Reports. 1573. https://digitalcommons.usu.edu/gradreports/1573

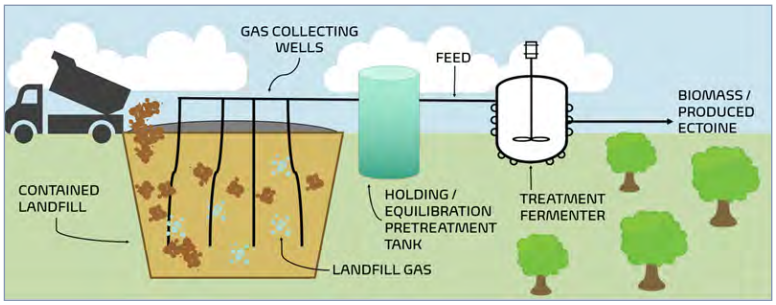

Figure 1: *Preliminary design visual for a M. alcaliphilum based method of landfill gas treatment.*

Findings/Results

Anthropogenic methane emissions are harmful to the environment and can be difficult to treat. Use of M. alcaliphilum for bioremediation of methane looks to be one of the most promising methods of reducing the negative environmental impacts of methane emissions while simultaneously providing an economic incentive through the production of ectoine, a high value by-product. Successful bioreactor design for M. alcaliphilum based methane treatment requires biokinetic constants and microbial growth information. Methods were established for determining biokinetic constants, including growth rate, biomass yield, specific methane consumption rate, and a correlation between methane oxidation and carbon dioxide production for M. alcaliphilum. Values determined for these constants were used to provide a preliminary engineering design for treating methane emissions from the North Valley Landfill in Cache County, Utah. M. alcaliphilum, an obligate methanotroph, was evaluated for use in bioreactors for oxidizing anthropogenic methane emissions. Bench scale culture of M. alcaliphilum yielded biological constants including growth rate, biomass yield on substrate, apparent yield on substrate, and specific methane degradation rate. Using the EPA LandGEM tool to generate emission predictions for the North Valley Landfill, in Cache County, Utah, a preliminary engineering design model for treatment of methane emissions was developed. The model estimated treatment of over 800,000 m^3 methane emitted from approximately 280,000 Mg of waste using 250 kg of M. alcaliphilum contained in reactors sized at a total liquid phase volume of 50,000 L.

WORK PLAN FY 21–22

We will continue to investigate the capability of M. alcaliphilum to grow and to degrade methane in dilute methane environments, as is common in most anthropogenic methane emission sources such as landfills (less than 20% methane by volume in gas phase). We will also calculate the methane degradation rate and ectoine production rate by M. alcaliphilum under batch conditions.

Wastewater Treatment: Nutrient Removal using Biofilm Microalgae

Project Description:

Need and Purpose

Nutrient management in water resource recovery facilities (WRRF) in Utah has been mandated by the Utah Department of Environmental Quality in response to national legislation to improve the water quality of receiver systems including rivers, lakes, and reservoirs, mitigation eutrophication, and recycle nutrients. This project helps in achieving these goals through a new technology developed by the Sustainable Waste to Bioproducts Engineering Center (SWBEC): a rotating algae biofilm reactor (RABR) that removes nitrogen and phosphorus from wastewater through cultivation of biofilm microalgae that can be harvested and recycled into value bioproducts. Specifically, this project will test a process called luxury phosphorus uptake (LPU) using the RABR technology, where more phosphorus can be removed from wastewater than is needed for basic functions of the biofilm microalgae used for treatment to reduce the phosphorus concentration in the reclaimed water from 3.5 mg/L to 0.3 mg/L at the Central Valley Water Reclamation Facility (CVWRF) in South Salt Lake City, the largest WRRF in Utah, which treats approximately 60 million gallons per day.

Benefits to the State

SWBEC at USU is currently working with WesTech, a major environmental technology firm, and the Central Valley Water Reclamation Facility (CVWRF), the largest water reclamation facility in the State of Utah, to test, at pilot scale, the application of LPU with the RABR technology at the CVWRF for treatment of wastewater and production of value bioproducts by recycling nutrients out of the water that can cause eutrophication in Utah Lake and other water bodies in Utah. The phosphorus enriched algae biomass can be used to produce value bioproducts to enhance the Utah economy including high phosphorus fertilizer, fire retardant, and feedstock for biocrude and bioplastic production. Results will also directly benefit the CVWRF and other water reclamation facilities in the State of Utah by helping to meet Utah standards.

Findings/Results

Results include the following:

1. Identified microalgae species that exhibit luxury phosphorus uptake (LPU) in WRRF but have not been tested in biofilm systems
2. Identified environmental factors that affect LPU, including sunlight intensity, temperature, and how long the water is in contact with the LPU microalgae

Principal Investigators:

Ronald C. Sims (PI)

Students:

Dylan Ellis (MS)

Partners/Collaborators:

Local: Logan City

State: Utah Department of Environmental Quality

Business/Industry: WesTech Engineering SLC and Central Valley Water Reclamation Facility SLC

Geographic Areas:

Study Areas: State of Utah water resource recovery facilities

Areas Benefited: Both rural and urban areas would benefit from the results of this project because municipal wastewater from all areas of the State of Utah could be improved with the technology being tested.

Contacts:

Ronald C. Sims
435.797.3156
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Presentations:

- Ellis, D. and R. Sims. 2021. *Luxury Phosphorus Uptake in Biofilm Microalgae Treating Municipal Wastewater Anaerobic Digester Pressate*. Poster presentation at the Institute of Biological Engineering National Conference, April 2021
- Ellis, D., G. Jones, J. Zhao, and R. Sims. 2021. *Analytical and Data-Driven Models to Predict Algae Biofilm Growth in Wastewater Treatment*. Poster presentation at the National Conference on Undergraduate Research, April 2021

3. Constructed a model pilot scale rotating algae biofilm reactor (RABR) to test LPU at the Central Valley Water Reclamation Facility
4. Implemented the model pilot scale RABR at the Central Valley Water Reclamation Facility (CVWRF) for field testing using anaerobic digester effluent
5. Presented at two national conferences

The model RABR for testing LPU at the Central Valley Water Reclamation Facility is shown in the photograph.

Work Plan FY 21–22

In FY 21-22, the project will utilize the pilot-scale RABR at the CVWRF and in greenhouse conditions to test the treatment at scale-up sizes for removing phosphorus through luxury phosphorus uptake (LUP) from municipal wastewater and will measure the resulting biomass that can serve as feedstock for recycling nutrients into high value bioproducts.

Figure 1: *Testing unit for phosphorus removal from wastewater at the Central Valley Water Reclamation Facility in South Salt Lake City.*

Assessment and Modeling of Cyanotoxin Presence and Occurrence Risk in Utah Surface Waters

Project Description:

Need and Purpose

Cyanotoxins are chemicals and chemical classes produced by cyanobacteria. These phototrophic bacteria contain chlorophyll and a blue pigment and are found primarily in lakes, oceans, and reservoirs. Many cyanobacteria can get the nitrogen they need directly from the atmosphere and are abundant in Utah lakes and reservoirs with excess phosphorus, especially in late summer and autumn. Cyanotoxins are among the more potent natural poisons that affect nervous system and liver function in mammals, including humans. Some evidence suggests links between cyanotoxins and neurological disorders such as Lou Gehrig's disease. At a recent meeting of state water administrators, cyanotoxins were listed as one of the top three concerns in drinking water systems nationwide.

Historically, microcystins in Utah water supplies have been rare, though not absent. A well-publicized cyanobacteria bloom in Utah Lake in fall 2014 resulted in the death of a swimming dog, which created a stir in news and social media outlets and prompted a response by the State of Utah Department of Environmental Quality. Cyanobacteria blooms have been reported in several Utah reservoirs used for drinking water supplies, such as Scofield (Carbon), Mantua (Box Elder), and Pineview (Weber) reservoirs. Additional water suppliers have noted cyanobacteria blooms in late summer and fall in their source waters. A 2007 US EPA lake survey found that samples from 8 out of 28 Utah reservoirs showed a moderate to high risk for exposure to cyanotoxins.

This project has conducted a literature review of cyanobacteria and cyanotoxin modeling and is currently coordinating with drinking water utilities to determine need for and set up programs that monitor and assess cyanotoxin risk and determine data needs, monitoring and assessing key selected Utah drinking water utilities, and performing initial laboratory and kinetic modeling work for cyanobacterial growth and toxin release under a variety of environmental conditions.

Benefits to the State

Benefits include guidance for developing long-term cyanotoxin monitoring programs, preliminary data collection and database development for cyanotoxin-related information, and an assessment of current cyanotoxin risk in water supplies that also identifies problem supplies at risk of an increasing cyanotoxin presence.

Findings/Results

We completed a literature review of mathematical models for cyanobacteria growth and cyanotoxin production. We worked with the State of Utah and the Bear River Health Department (BRHD) to monitor and identify cyanobacteria in Utah waters

Principal Investigators:

David Stevens (PI)
Joan McLean (PI)

Students:

Jade Echard (EEP)
Brent Jacobson (EEP)

Partners/Collaborators:

UWRL: Josh Hortin

Local: Bear River Health Dept.
Brigham City, UT
Scofield, UT
Pineview, UT

State: Kate Naleway, Utah Division of Water Quality

Eva Nieminski, Utah Division of Drinking Water

Geographic Areas:

Study Areas: Cache, Box Elder, Carbon, Weber, Morgan, and Washington counties

Areas Benefited: Drinking water utilities statewide will benefit from this work

Contacts:

David Stevens
435.797.3229
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Publications:

Echard, J. 2021. *A review of harmful algal bloom prediction models for lakes and reservoirs.* All Graduate Plan B and other Reports. 1519. https://digitalcommons.usu.edu/gradreports/1519

and assess the levels of toxin in recreational waters and drinking water supplies. As part of their extensive cyanobacteria monitoring program at many Utah reservoirs and lakes, the Division of Water Quality (DWQ) obtained samples of cyanobacterial blooms so we could isolate individual cyanobacterial species. Microscopic analysis confirmed the presence of three toxin-producing species: Aphanizomenon flos aquae (neurotoxin, hepatotoxin), Dolichospermum (Anabaena. neurotoxin), and Microcystis (neurotoxins and hepatotoxins). The BRHD samples from six lakes and reservoirs in May-September contained the toxins anatoxin-a, microsystins, and cylindrospermopsin. The concentrations of two of the three classes of cyanotoxins were below detection limits in most cases, but Mantua surface waters showed anatoxin-a and two systems (Mantua and Pioneer Park) showed microcystin levels high enough to cause concern.

The DWQ samples were used to identify types of cyanobacteria and to isolate specific types of organisms for growth in microcosms using serial dilution techniques. Attempts to develop static cultures were not successful for any of the dilutions. However, later shake cultures are more promising and appear to sustain growth with simulated sunlight over 50% of the day.

Work Plan FY 21–22

A publication based on the completed literature review will be submitted to a peer-reviewed journal. Monitoring and laboratory studies will continue through the duration of the project. Those studies will produce an improved kinetic model for growth and toxin production from at least one of the three cyanobacteria types listed.

Figure 1: *Monitoring at Mantua Reservoir (shown above) and at other lakes and rivers in Cache, Box Elder, and Rich counties will continue through October 2021 and will resume in spring 2022 (after lake thaws).*

HYDRAULICS

ACTUAL, BUDGETED AND PLANNED EXPENDITURES OF MINERAL LEASE FUNDS

HYDRAULICS: PI	Project Name	Actual FY2021	Budgeted FY2022	Planned FY2023
Crookston, B.	Hydraulic Design Guidance for Stepped Spillways	$3,649	$3,758	$3,871
Crookston, B.	New Design and Analysis Guidance Regarding Potential Scour of Hydraulic Structures Located in Canals, Rivers, Dams and Levees	$3,649		
Johnson, M.	Hydraulic Research on Flow Measurement on the Exit of a Tee Junction with Converging Flow	$12,181		
Johnson, M.	Hydraulic Research on Flow Measurement Downstream of a Bifurcating Tee Junction	$18,416		
Phillips, C.	High-resolution River Dynamics	$36,050	$37,132	$38,246
Sharp, Z.	Improving the Hydraulics of Urban Flooding	$6,764	$6,967	
	Designated projects		*$63,242*	*$71,017*
	Undesignated research projects in program area		*$55,000*	*$42,500*
	TOTALS	**$80,709**	**$166,099**	**$155,634**

Hydraulic Design Guidance for Stepped Spillways

PROJECT DESCRIPTION:

Need and Purpose

Spillway rehabilitation is needed in Utah and in the USA as existing infrastructure ages and design standards are modernized. A stepped chute with and without a labyrinth crest provides a spillway rehabilitation alternative which is economical and does not require a large footprint. Due to limited research, however, the exact implications of a stepped chute with a labyrinth crest or with inclined steps are unknown. However, labyrinth weirs and stepped chutes are known to dissipate energy, introduce aeration, and increase turbulence within the flow. Combinations of stepped chutes with labyrinth crests present challenging design needs. Furthermore, modern construction techniques for stepped chutes often include inclined steps. This research seeks to identify design guidance for such spillways, including factors such as sidewall height, length-to-flow uniformity, and energy dissipation.

Benefits to the State

This research is of benefit to the State of Utah and others as it provides important design guidelines for this specific spillway type. To date, we have had interest from Utah, the US Army Corps of Engineering, the US Department of Agriculture, the US Bureau of Reclamation, and private consultancies and universities.

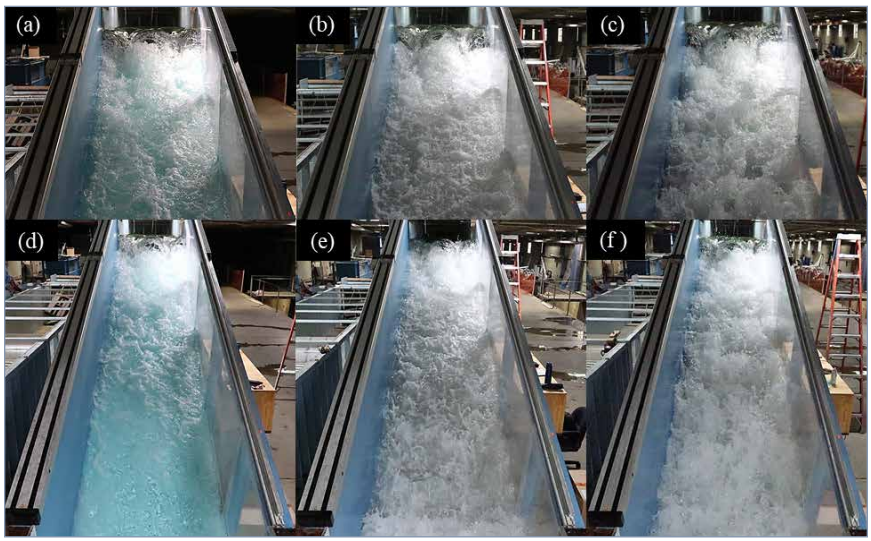

Figure 1: *Flow pattern comparison for Q=285.0 l/s between (a and d) h=0.0 mm, (b and e) h=101.6 mm, and (c and f) h=203.2 mm.*

PRINCIPAL INVESTIGATORS:

Brian Crookston PhD, PE

STUDENTS:

Megh Raj KC (PhD),
Kade Flake (MS)

PARTNERS/COLLABORATORS:

Academia: University of New South Wales

GEOGRAPHIC AREAS:

Study Areas: All work was conducted in the Hydraulics Laboratory of the Utah Water Research Laboratory at Utah State University

Areas Benefited: Flood control infrastructure, water supply storage in reservoirs, etc.

CONTACTS:

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PUBLICATIONS:

- Flake, Crookston and Felder, (Under Review). *Flow non-uniformity and energy dissipation in a stepped chute with a labyrinth crest*.
- Flake, Crookston, and Felder, (Under Review). *Air-water flow properties of mild-sloping stepped chute with a labyrinth crest*.

WEBSITES:

https://uwrl.usu.edu/hydraulics/

Findings/Results

Detailed documentation of the two-phase flow and air-water properties in the stepped chute. The results thus far have concluded the sidewall height can be appropriately sized using existing methods when the maximum flow depth, occurring at the chute entrance, is used. Aeration, initiated by the labyrinth weir, plays a critical role in achieving uniform flow farther upstream. A stepped spillway with a labyrinth crest appears to dissipate less energy compared to a stepped spillway with a linear crest.

WORK PLAN FY 21–22

Currently, the design process assumes no difference in performance between a vertical face step and an inclined step. Some preliminary academic work from Australia on inclined step geometry, not representative of actual construction geometries, indicates that this is not the case and is not a conservative assumption. No testing has been performed for inclined step geometry as constructed in the field. Therefore, the work will focus on inclined steps for a chute geometry, which is representative of placement of RCC overlays for stepped chutes where formwork would not be used and the downstream edges are left at a 45-degree angle. The primary questions to be answered are how the inclined step geometry affects air-water flow properties down the chute and identifying the key behaviors of interest to engineers and scientists, such as flow bulking, required sidewall heights, velocity profiles, void fractions, turbulence, and energy dissipated along the chute, and residual energy at the toe of the structure. Direct comparisons to the existing USU data set with vertical step faces are planned.

Table 1: *A tentative test matrix for FY 2022.*

h (mm)	Q (l/s)	h/d_c	F	F^*	$R(x10^5)$	$We(x10^3)$
101.6	140.0	0.81	2.1 to 5.1	2.7	0.90 to 1.64	4.2 to 8.0
101.6	285.0	0.51	1.5 to 4.8	5.3	1.85 to 3.28	8.9 to 17.9
101.6	425.0	0.39	1.4 to 4.6	8.0	2.84 to 5.52	15.1 to 31.2
101.6	565.0	0.32	1.5 to 4.3	10.6	3.38 to 7.54	21.2 to 42.1
203.2	140.0	1.62	2.1 to 4.7	0.9	0.70 to 1.56	3.2 to 7.9
203.2	285.0	1.02	2.2 to 4.5	1.9	2.21 to 2.62	10.3 to 17.6
203.2	425.0	0.77	1.9 to 4.6	2.8	2.97 to 4.54	14.3 to 29.0
203.2	565.0	0.64	1.8 to 4.5	3.7	3.44 to 6.25	20.5 to 38.4

The results of this study are of high interest to the dam safety community within the State of Utah as well as other private and state entities in the USA, USACE, Reclamation, FERC, TVA, FEMA dam safety programs, and the international community. Australian academics in particular is keen to see the results and wish to collaborate.

New Design and Analysis Guidance Regarding Potential Scour of Hydraulic Structures Located in Canals, Rivers, Dams and Levees

PROJECT DESCRIPTION:

Need and Purpose

Looking at the immediate future, Utah is at a crossroad with historic growth, which will require significant changes in the State's water infrastructure—both in new construction and rehabilitation. Many Utah communities that historically have been centered around agriculture have become more urbanized, and the state's high-population density corridor has continued to grow. This growth naturally puts increased demands on water infrastructure and the environment.

One consequence of growth is an increased demand for flood protection since development can modify catchment response to snowmelt and rainfall and, in some instances, construction has occurred within Utah's floodplains. Direct evidence indicates that the number of flood-related incidents in Utah and the USA is increasing. A critical component to in-stream and flood-related infrastructure is foundation protection during normal operation and flood events. Local scour can undermine footings and slabs, which could potentially result in structural failure and instability. The DMAD (Delta, Melville, Abraham, and Deseret) Reservoir in Utah experienced a dam failure due to local scour in 1983 and is currently being rehabilitated. According to Utah Dam Safety Engineer Everett Taylor, the State of Utah is in need of additional guidance for predicting local scour at many hydraulic structures.

One particular flood control structure, the piano key weir, is being constructed in many locations around the globe due to its cost effectiveness and hydraulic performance. Studies related to scour performance at these structures would be useful for estimating eroded volumes, scour-hole geometries, temporal evolution, and equilibrium scour depths. Knowing a maximum depth of scour is particularly useful for sizing cutoff walls where this type of concrete structure terminates.

Figure 1: A scour morphology and foundation protection experiment at Utah Water Research Laboratory supporting general research and projects.

PRINCIPAL INVESTIGATORS:

Brian M. Crookston (PI)

STUDENTS:

Wyatt Lantz (MS)

PARTNERS/COLLABORATORS:

State: Everett Taylor, Utah Department of Natural resources, Division of Water Rights

GEOGRAPHIC AREAS:

Study Areas: All work was conducted in the Hydraulics Lab of the Utah Water Research Laboratory at Utah State University

Areas Benefited: Potentially any canal, river, dam, or levee with this type of structure

CONTACTS:

Brian Mark Crookston
(435) 797-0247
brian.crookston@usu.edu

PUBLICATIONS:

- Lantz, W., Crookston, B.M., and M. Palermo (2021). *Apron and cutoff wall scour protection for Piano Key Weirs*, Water by MPDI,13(7). https://doi.org/10.3390/w13172332 IF. 3.103. https://www.mdpi.com/2073-4441/13/17/2332/htm
- Lantz, W., Crookston, B.M., and M. Palermo (In Press). *Evolution of local scour downstream of type A PK weir in non-cohesive sediments*. Journal of Hydrology and Hydromechanics, IF. 2.011

PRESENTATIONS:

Lantz, W., Palermo, M., and B.M. Crookston. (2020). *Flood infrastructure: Localized scour at piano key weirs*, Dam Safety 2020, Palm Springs, CA.

WEBSITES:

https://uwrl.usu.edu/hydraulics/

Benefits to the State

This research is of benefit to the State of Utah and others as it provides important design guidelines for piano key weirs.

Findings/Results

The temporal evolution and maximum scour geometries were quantified. A conference paper to ASDSO was completed (with an award) along with two journal publications and a master's thesis.

WORK PLAN FY 21–22

This project is complete.

Figure 2: *Scour morphology and foundation protection experiments at Utah Water Research Laboratory supporting general research and projects.*

Hydraulic Research on Flow Measurement on the Exit of a Tee Junction with Converging Flow

PROJECT DESCRIPTION:

Need and Purpose

An increasing population in the state, country, and world also increases the need to measure water resources. Graduate student Eliot Naulu conducted research to improve flow measurement. The project is beneficial as it improves understanding of combining flow upstream of a Venturi flow meter, which may be used in local water treatment and supply systems.

Benefits to the State

This project supported a student's research focused on resource management and monitoring. In cases where flow measurement accuracy is important, for example in water treatment systems, flow meter performance is critical to accurate measurement. In some installations, installing a flow meter in piping that is not ideal may be necessary. Naulu conducted research to demonstrate how flow measurement could be improved despite an adverse piping installation. Naulu has now accepted employment within the State of Utah and is a contributing member of its population. He is using his expertise to provide benefit to the citizens of the state through the various projects he is working on and can employ the findings of his research where applicable now and in the future.

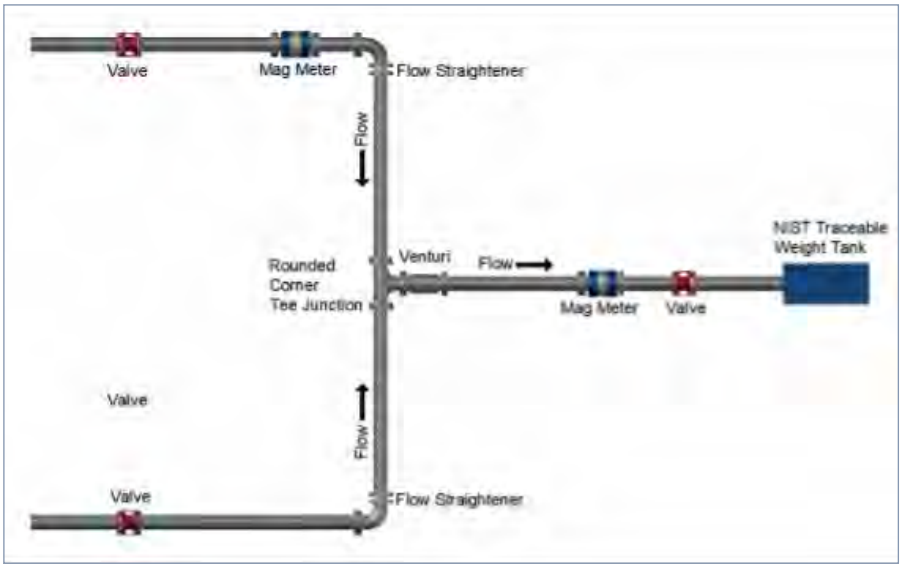

Figure 1: *Conceptual metering installation.*

PRINCIPAL INVESTIGATORS:

Michael C. Johnson (PI)

STUDENTS:

Eliot Naulu (MS)

PARTNERS/COLLABORATORS:

Business/Industry: BIF

GEOGRAPHIC AREAS:

Study Areas: Cache County

Areas Benefited: Any water treatment or distribution system in the State of Utah may benefit from the findings of this study

CONTACTS:

Michael C. Johnson
435.797.3176
michael.johnson@usu.edu

PUBLICATIONS:

- Naulu, E. 2021. *Venturi Meter Performance When Installed on the Exit of a Tee Junction with Converging Flow*. All Graduate Theses and Dissertations. 8150. https://digitalcommons.usu.edu/etd/8150
- Naulu, E., M.C. Johnson, Z.B. Sharp. 2021. *Venturi Meter Performance When Installed on the Exit of a Tee Junction with Converging Flow.* Journal paper in preparation

Findings/Results

The research showed how combining flow in a tee upstream from a Venturi flow meter impacts the measurement performance of the meter.

WORK PLAN FY 21–22

Data collection and analysis is complete, and findings are being prepared for publication in a peer-reviewed article.

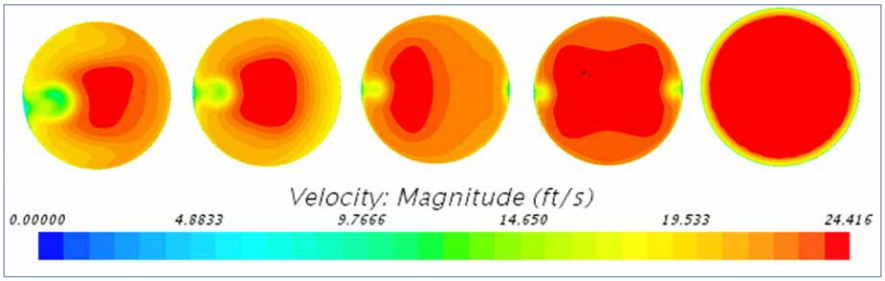

Figure 2: *Flow profiles of Venturi meter's inlet for flow splits at 0D. From left to right: 100/0, 80/20, 60/40, 50/50, Straight-line.*

Hydraulic Research on Flow Measurement Downstream of a Bifurcating Tee Junction

PROJECT DESCRIPTION:

Need and Purpose

An increasing population in the state, country, and world, also increases the need to measure water resources. Graduate Student Matt Day conducted research to improve flow measurement. The project is beneficial as it advances understanding of combining flow upstream of a Venturi flow meter, which may be used in local water treatment and supply systems.

Benefits to the State

This project supported a student's research focused on resource management and monitoring. In cases where flow measurement accuracy is important, for example in water treatment systems, flow meter performance is critical to accurate measurement. In some installations, installing a flow meter in piping that is not ideal may be necessary. Day conducted research to demonstrate how flow measurement could be improved despite an adverse piping installation. Day is using his expertise to benefit to the citizens of the state through the various projects he is working on and can employ the findings of his research where applicable now and in the future.

Findings/Results

The research showed how combining flow in a tee upstream of a Venturi flow meter impacts the measurement performance of the meter.

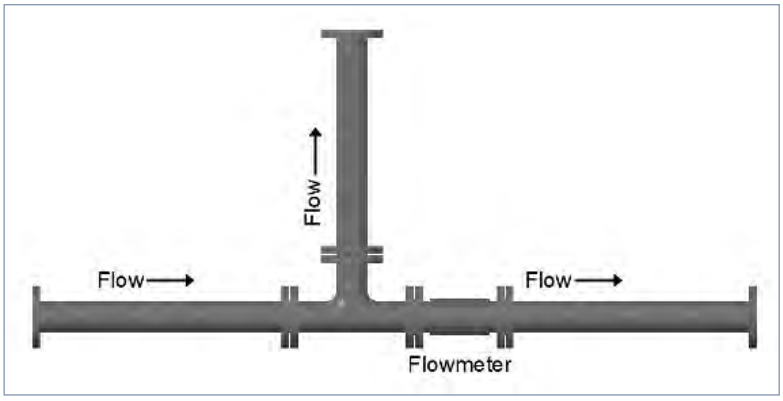

Figure 1: *Conceptual metering installation showing how flow is split.*

PRINCIPAL INVESTIGATORS:

Michael C. Johnson (PI)

STUDENTS:

Matt Day (MS)

PARTNERS/COLLABORATORS:

Business/Industry: BIF

GEOGRAPHIC AREAS:

Study Areas: Cache County

Areas Benefited: Any water treatment or distribution system in the State of Utah may benefit from the findings of this study

CONTACTS:

Michael C. Johnson
435.797.3176
michael.johnson@usu.edu

PUBLICATIONS:

- Day, M. 2021. *Classical Venturi Meter Performance Downstream of the Through Leg of a Tee Junction*. All Graduate Theses and Dissertations. 8257. https://digitalcommons.usu.edu/etd/8257
- Day, M., M.C. Johnson, Z.B. Sharp. 2021. *Classical Venturi Meter Performance Downstream of a Bifurcating Tee Junction.* Journal paper in preparation

WORK PLAN FY 21–22

Data collection and analysis is complete, and findings are being prepared for publication in a peer-reviewed article.

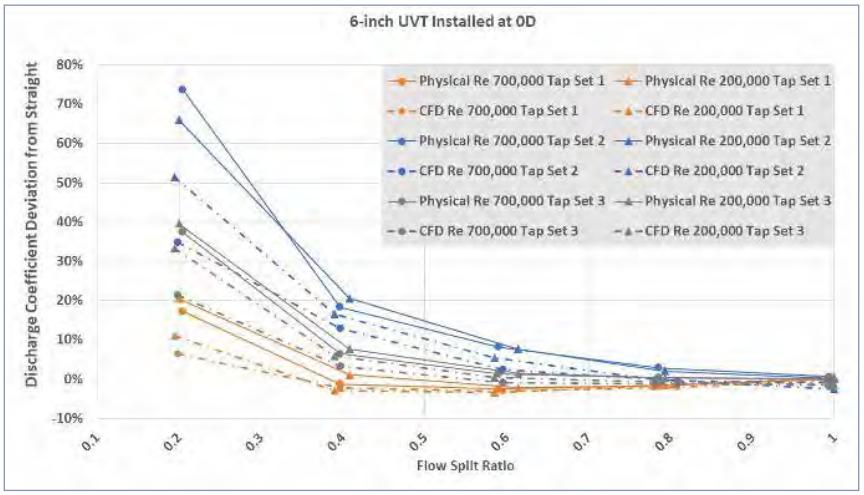

Figure 2: *Deviation of discharge from straight for 6-inch UVT Venturi meter.*

High-resolution River Dynamics

PROJECT DESCRIPTION:

Need and Purpose

Rivers are critical freshwater sources for drinking water, hydropower generation, recreation, and irrigation. Rivers also pose significant hazards to life and property through flooding and via the reduction of water quality from excess erosion and stormwater runoff. Flooding hazards and potential for erosion result from a combination of the size of a river channel and the regional climate, which dictates the amount of water supplied to the watershed over a storm or snowmelt period. Effective river management requires an understanding of how rivers set their shape and size with respect to their watershed, land use conditions, and current and future regional climate.

Benefits to the State

The extraction and quantification of river geometry from high-resolution topography and large datasets yields a predictive model for river geometry and stability in the face of changing conditions. These analyses represent the foundation from which predictive models for water quality and flooding hazards will be developed. The state of Utah faces an uncertain water future as drought results in diminished water resources, but the limited rainfall is predicted to increase in intensity. This combination of more intense rainfall over drier climates, compounded with increasing wildfire, results in increased erosion and reduced water quality within the critical water source regions. Prediction and greater understanding of these hazards will allow for the development of successful mitigation strategies.

Findings/Results

We compiled a large (>1000) river reach dataset to test and validate competing models for the size of rivers. Using this dataset, we found that natural river reaches are adjusted such that the flow that fills the channel prior to flooding is just above the force required to erode the riverbanks. These observations provide the necessary data to validate a prior engineering model for the size and formation of rivers, and we propose this model as the standard baseline from which to assess river form. Fine sediment within rivers results in turbidity, decreased water quality, and the infilling of reservoirs. The transport of fine sediment within a river is determined by the size of the river (larger rivers carry more material). Using the identified baseline model for river channel size, we were able to synthesize over 400,000 records of fine sediment transport from across the United States into a singular set of relations, which could form the basis of a predictive water quality model and inform mitigation strategies for reservoir siltation.

PRINCIPAL INVESTIGATORS:

Colin Phillips (PI)

STUDENTS:

Gabriel Benitez (MS)

PARTNERS/COLLABORATORS:

Local: Logan River Observatory

GEOGRAPHIC AREAS:

Study Areas: Logan River watershed and +1000 distributed freshwater sites throughout the country

Areas Benefited: Watersheds across the country

CONTACTS:

Colin Phillips
435.797.0938
colin.phillips@usu.edu

DATASETS:

Phillips, C. B. 2021. *Alluvial River Bankfull Downstream Hydraulic Geometry*, HydroShare, http://www.hydroshare.org/resource/fa5503b04af343ffbaf33d5a15cb2579

Within the Logan River we are analyzing high-resolution topography of the Logan River to automate the extraction of high-resolution river geometry, which can be used with the standard model described above to enhance predictions at the local level and reduce the need for time-intensive field surveys. The extraction of high-resolution river geometry forms the basis for flood risk and river aquatic habitat models.

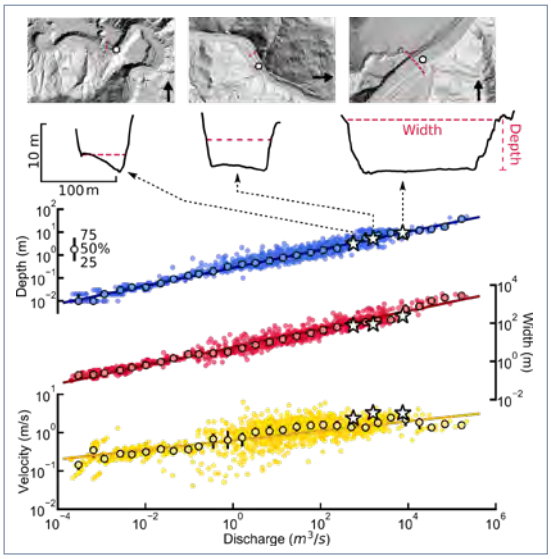

Figure 1: *River geometry (depth & width) and flow measurements (velocity) compiled for model validation.*

WORK PLAN FY 21–22

During the coming year, we will complete the site high-resolution river geometry work within the Logan River and combine these data with observations of water quality parameters (temperature, turbidity) and assess how land use and the underlying geology may cause river geometry to deviate from the standard model.

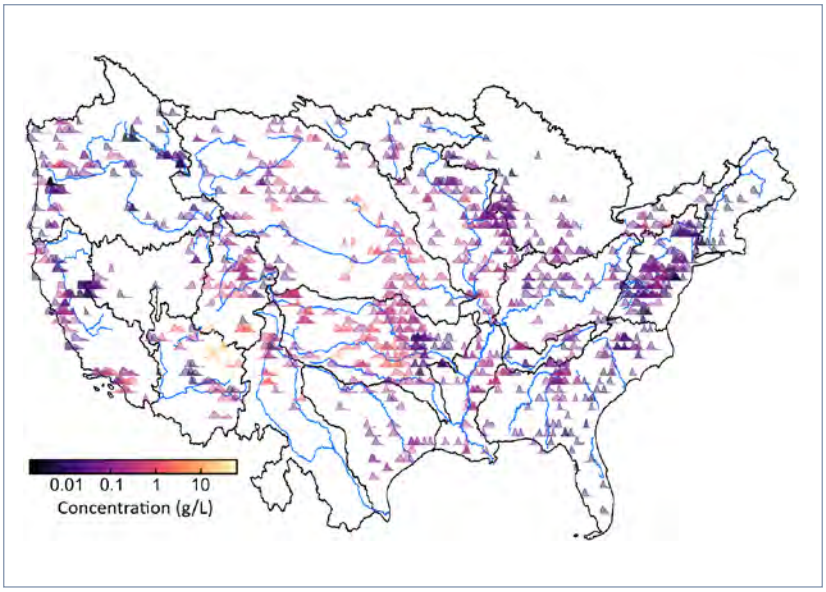

Figure 2: *Suspended sediment database for the United States. Color represents the concentration in grams per liter. The highest concentrations in the nation are located in southern Utah and northern Arizona.*

Improving the Hydraulics of Urban Flooding

PROJECT DESCRIPTION:

Need and Purpose

In most river systems, the initial flooding location is the same with every flood event. Flooding occurs when water flows over the riverbanks and can cause property damage or injury and death to people and animals. Flood prediction improvements can help eliminate flood damage in multiple ways. First, with a proper warning, flood mitigation efforts can be implemented to keep flow in the riverbanks. Second, with proper warning, people and animals can be evacuated and kept safe. Third, and a large focus of this research, if the portion of the river (or structure, culvert, bridge, etc.) that causes the flooding can be identified, it potentially can be fixed to prevent flooding in that area.

Current methods for determining flood boundaries in urban areas involves using topography and bathymetry data sets for an urban river and its flood zone. With that data set, a 1D HEC-RAS model can be set up and run, making a number of assumptions. The 1D HEC-RAS models are very accurate and efficient for long river reaches; however, the weakness of the 1D model is predicting the performance of control structures and other choke points in the river that may cause flooding. To accurately model control structures or other choke points in urban rivers with a 1D model, the modeler must know a rating curve for that choke point. If that information is not available, then the modeler is left to guess. The 2D HEC-RAS model is an improvement over the 1D model in that it allows the user to let the model calculate the rating curve at control structures. The 2D model is also efficient and, in some instances, accurate for predicting rating curves of choke points. An improvement over the 2D model is a full 3D computational fluid dynamics (CFD) model, which can offer accurate rating curve information for various structures and choke points in urban rivers.

This research explores a site-specific location within Logan City limits that is the first place to flood and compares the results of 1D, 2D, and 3D models for predicting that flood event. The research also investigates the cause of the flooding and recommends economic fixes the city can implement to prevent the flood event from occurring.

Benefits to the State

Every city in Utah could implement this new approach to investigating their flood boundaries and be better prepared for future flooding. Logan City will receive all site-specific data and reporting that is completed in this project for the location of their most sensitive flood zone.

PRINCIPAL INVESTIGATORS:

Zachary Sharp, PhD, PE (PI)

STUDENTS:

Taylor Kesler (MS)

PARTNERS/COLLABORATORS:

Local: Logan, UT

GEOGRAPHIC AREAS:

Study Areas: All modeling work was completed at the Utah Water Research Laboratory at Utah State University

Areas Benefited: Potentially any city at risk of flooding

CONTACTS:

Zachary B. Sharp
435.797.3167
zac.sharp@usu.edu

PUBLICATIONS:

A publication of the work will be completed by the end of the year.

Findings/Results

At this point in the research, the 1D and 2D HEC-RAS modeling is complete, and the CFD modeling is ongoing. The results of the HEC-RAS modeling show that the 2D model predicts a much larger flood area.

WORK PLAN FY 21–22

This project will finish by December 2021. The only part of the project yet to be completed is the CFD portion of the work. When that is complete, the results of the full 3D model will be compared to the 1D and 2D model results.

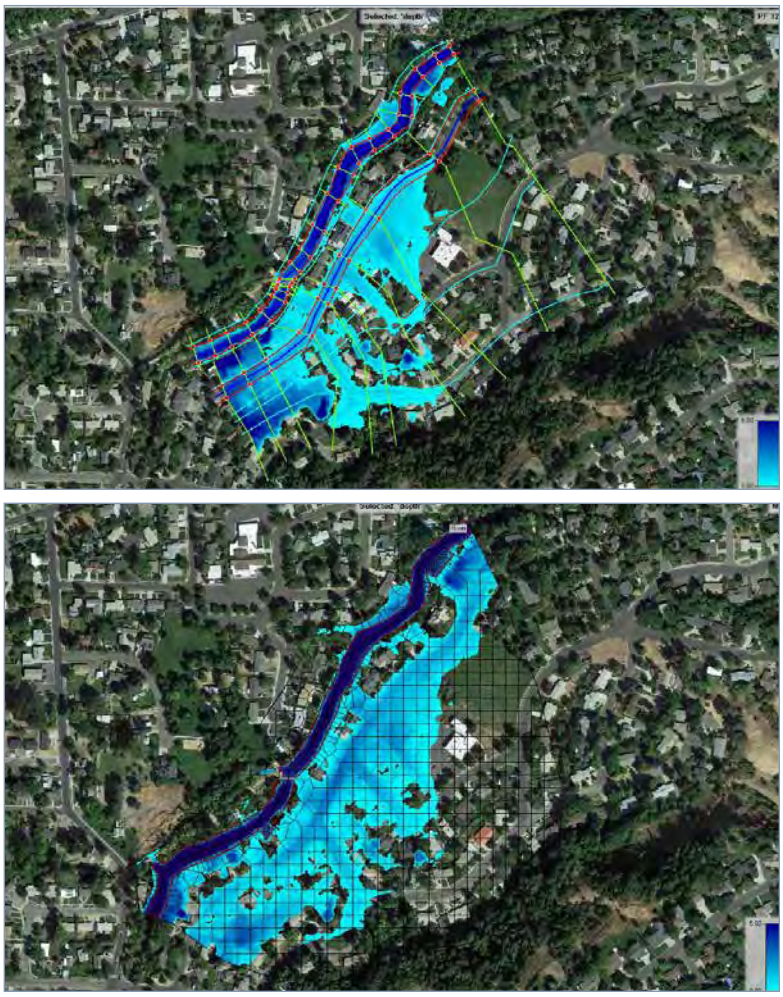

Figure 1: *1D and 2D HEC-RAS results.*

Measurement, Sensing and Information Systems

Actual, Budgeted and Planned Expenditures of Mineral Lease Funds

Measurement, Sensing and Information Systems: PI	Project Name	Actual FY2021	Budgeted FY2022	Planned FY2023
Coopmans, C.	Development of an Inexpensive UAV for Remote Sensing in Water Management and Natural Resources Management	$53,257	$54,854	$56,500
Gowing, I.	Bee Habitat Vegetation Classification using Extremely High Resolution Imagery using an Unmanned Aerial Vehicle (UAV)	$5,251		
Gowing, I.	Mapping Invasive Aquatic Weed (*Eurasian Watermilfoil*) in Browns Pont, Utah, using an Unmanned Aerial Vehicle (UAV)	$5,251	$19,753	$20,345
Horsburgh, J.	Cyberinfrastructure for Intelligent Water Supply	$11,988	$19,753	$20,345
	Designated projects			
	Undesignated research projects in program area		*$80,416*	*$90,380*
	TOTALS	**$75,747**	**$174,776**	**$187,570**

Development of an Inexpensive UAV for Remote Sensing in Water Management and Natural Resources Management

Project Description:

Need and Purpose

Many current sources of remote sensing (e.g. manned aircraft and satellite platforms) are too expensive, have low spatial resolution, or are not activated frequently enough to be practical for many applications. A low-cost, small unmanned aerial system (sUAS) called AggieAir can fill this need for actionable aerial information by providing low-cost, multispectral aerial imagery and other scientific data quickly and frequently. In addition, the AggieAir platform design is not dependent on a runway for takeoff and landing, which enables it to be launched almost anywhere. Some examples of applications that have benefitted from AggieAir include agriculture, riparian habitat mapping, road and highway surface monitoring, wetland mapping, and fish and wildlife tracking.

Benefits to the State

The data produced by AggieAir have the potential to help save water in Utah by offering farmers and scientists a low-cost solution to mapping crop soil moisture for more efficient irrigation and other natural resource management challenges. This data can also help canal operators to manage water more effectively or wetland managers to manage invasive plant species. If these invasive plant species are left unchecked, they can take over native plant species, destroy bird habitat, and use excessive amounts of water. AggieAir can also provide new jobs and economic growth to the state of Utah. The long-term goal for the AggieAir system is to eventually create a business within the state of Utah and market this technology. AggieAir's technology also brings greater focus on the State's position in aerospace, unmanned systems, and the civil uses of remote sensing technologies in agriculture. The AggieAir lab and its students, employees, and capabilities have served as a resource at Utah State University for more than a decade, supporting STEM undergraduate recruiting, senior design projects, and student-driven research of all kinds, as well as STEM outreach and education programs such as NSF GearUP, Engineering State, Drone education at EAA AirVenture, National Intercollegiate Flying Association, Civil Air Patrol training, Women in Aviation, etc.

Findings/Results

In the past year, AggieAir has prepared the technology and used its fleet of GreatBlue aircraft (and others) to map vineyards, collect air quality data, and fly scientific missions in many locations for many purposes. Introduced last year, the 55-pound hybrid 'quadplane' drone "GreatBlue" is the culmination of more than 15-years of AggieAir platform (aircraft) and payload development. Much of the past year was spent on continuing upgrades to GreatBlue,

Principal Investigators:

Calvin Coopmans (PI)
Ian Gowing (Co-PI)
Alfonso Torres-Rua (Co-PI)

Partners/Collaborators:

Business/Industry: Deseret UAS, ArcTech Charge, Fortem Inc., Northrop Grumman

USU: Professors Scott Budge, Baron Wesemann, Steve Petruzza, Patrick Belmont

Geographic Areas:

Study Areas: Most of the test flights took place at our test site near Cache Junction, UT, where The FAA granted AggieAir official approval to conduct flights (FAA Form 7711-1 2013-WSA-63). In the past year, AggieAir has also flown at other Utah sites and in California (partnered with E&J Gallo Wineries)

Areas Benefited: All counties in the state could benefit

Contacts:

Calvin Coopmans
(435) 764 4579
cal.coopmans@usu.edu

Websites:

https://aggieair.usu.edu/

including a higher-quality autopilot system that allows for finer control in flight and new research possibilities based on modern software capabilities, in addition to test flights and AggieAir service center missions. For the 6th successive year, AggieAir collected valuable agricultural data in California during another intensive campaign in collaboration with other world-class groups such as the USDA ARS, NASA, and E&J Gallo wineries. In addition, GreatBlue was used to collect air quality samples for two Northrop Grumman's static rocket motor test fires, including NASA's FSB-1 booster for the Space Launch System (see Figure 1, also video at https://youtu.be/xGvsiO-siiY).

Work Plan FY 21–22

AggieAir plans to continue missions within and outside the state of Utah, such as mapping Utah reservoirs and studying California almond farms, furthering world-class research and integrating new science and technology into Utah through partnerships. Built on now established large-scale, stable flight, AggieAir is also actively working on streamlining and improving the aerial data processing pipeline to allow for near-real-time data delivery (mapping), which will lead to many new research applications and opportunities, aircrafts, and student experiences.

Figure 1: *The view from under USU/UWRL AggieAir's GreatBlue flying over Northrop Grumman/NASA's FSB-1 solid-rocket booster static test fire.*

Publications:

- C. Coopmans, S. Brimhall, R. Goodman, and S. Petruzza, *Scientific Timely, Actionable Robotic Data Operating System (Stardos): Architecture And Progress*, in Autonomous Air and Ground Sensing Systems for Agricultural Optimization and Phenotyping VI, Apr. 2021, 11747. https://doi.org/10.1117/12.2588009
- A. F. Torres-Rua et al., *Estimation of evapotranspiration and energy fluxes using a deep learning-based high-resolution emissivity model and the two-source energy balance model with sUAS information*, in Autonomous air and ground sensing systems for agricultural optimization and phenotyping v, 2020, vol. 11414, https://doi.org/10.1117/12.2558824
- A. Nassar et al., *To what extent does the eddy covariance footprint cutoff influence the estimation of surface energy fluxes using two source energy balance model and high-resolution imagery in commercial vineyards?,* in Autonomous air and ground sensing systems for agricultural optimization and phenotyping v, 2020, vol. 11414, https://doi.org/10.1117/12.2558777
- A. Nassar et al., *Influence of model grid size on the estimation of surface fluxes using the two source energy balance model and sUAS imagery in vineyards*, Remote Sensing, vol. 12, no. 3, p. 342, 2020. https://www.mdpi.com/2072-4292/12/3/342

Bee Habitat Vegetation Classification using Extremely High-Resolution Imagery using an Unmanned Aerial Vehicle (UAV)

Project Description:

Need and Purpose

The United States Department of Agriculture (USDA) contracted with the AggieAir Service Center, Utah State University, to capture extremely high-resolution multi-spectral imagery at the USDA Bee Research station, Logan, Utah. The high-resolution imagery will be used by USDA to detect and classify vegetation community species types within the 0.6 acres surveyed. A DJI Matrice Pro 600 UAV with a MicaSense Altum 6 band camera was flown at 10 m above ground level to capture imagery at 0.5-cm pixel resolution. Propeller Aeropoint self-GPS-ing aerial targets were deployed throughout the study area to assist with orthorectification of the final mosaic. Prior to the survey area being flown, 21 quadrats measuring 1m by 1m were placed within the surveyed area and plant communities / species types were identified by USDA to assist with image classification.

Benefits to the State

Utah has significant forest and reserve/natural areas that can be synergistically used for bee habitat, increments of native or wild bee population, and honey production. This research looks into the use of unmanned aerial technology to identify and quantify native vegetation flower types and quantity.

Findings/Results

A UAV flight at very low elevation (10m above ground level) was performed over the USDA ARS Logan site to determine and evaluate the capabilities of a multispectral + thermal sensors camera and to generate multiple products (natural images, infrared images, thermal maps, plant height) that can help with identification and counting of flowers within the site.

Figure 1: *DJI Matrice Pro 600 over the USDA ARS Logan site.*

Principal Investigators:

Ian Gowing (PI)
Shannon Syrstad (Co-PI)
Alfonso Torres-Rua (Co-PI)

Partners/Collaborators:

Federal: Jonathan Koch, USDA

Geographic Areas:

Study Areas: Cache County

Areas Benefited: Cache County and statewide

Contacts:

Ian Gowing
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ian.gowing@usu.edu

Websites:

https://uwrl.usu.edu/aggieair/uav-service-center/index

Work Plan FY 21–22

This project is now complete and all final products including a fully orthorectified mosaic, digital elevation model, point cloud data, a classification vegetation map based on data provided were delivered to the USDA.

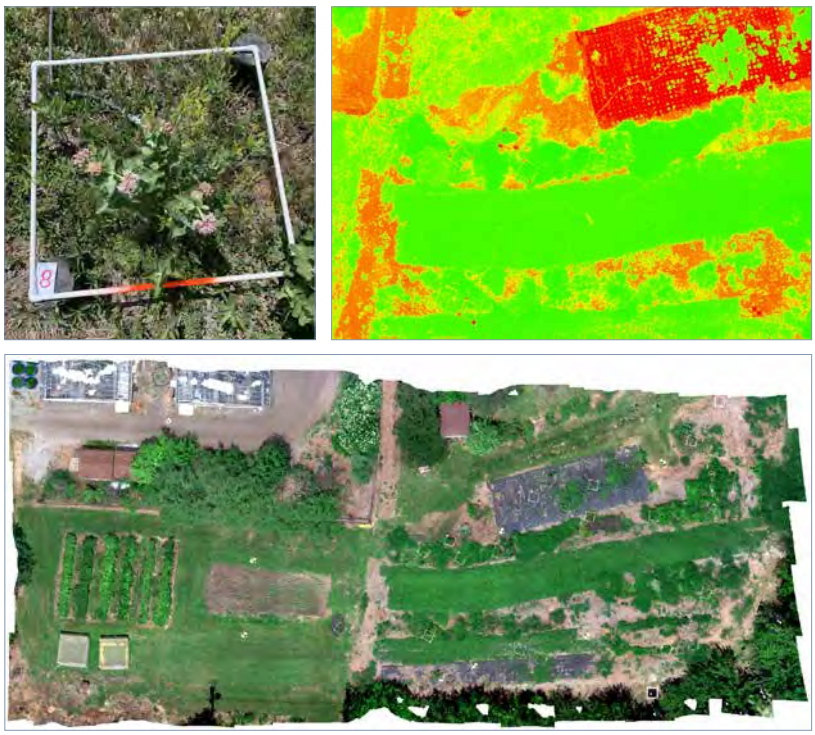

Figure 2: *Quadrat used in image classification detection (top L); NDVI image of surveyed plot (top R); final reflectance mosaic of surveyed plot (bottom).*

Mapping Invasive Aquatic Weed (Eurasian Watermilfoil) in Browns Pond, Utah, Using an Unmanned Aerial Vehicle (UAV)

Project Description:

Need and Purpose

The Utah Department of Natural Resources, Division of Wildlife Resources, contracted with the AggieAir Service Center, Utah State University, to capture multi-spectral high-resolution aerial imagery of Eurasian Watermilfoil ((Myriophyllum spicatum) over Browns Pond (North & South), Uintah County, Utah, using a DJI Matrice Pro 600 (UAV). Watermilfoil is a non-native invasive aquatic plant that out-competes all native vegetation, has little nutritional value, and reduces invertebrate abundance and diversity. The data and analysis provided by the AggieAir Service center are expected to significantly improve the information content to UDWR in terms of aquatic species diversity and extent within each pond, as well as providing detailed data to calculate the effectiveness of the proposed herbicide treatment in eradicating watermilfoil.

Figure 1: *Browns Pond North with DJI Matrice Pro 600.*

Two UAV flights have been planned to capture multi-spectral high-resolution imagery over Browns Pond North and South, before and after the proposed herbicide treatment plan to target and eradicate Eurasian Watermilfoil. The imagery will be used initially to map the presence and percent quantity of both emergent and submerged aquatic vegetation. After the initial aerial survey is complete, ground truthing data will be collected at both ponds to properly train computer models to identify aquatic species within the imagery. Both ponds will then undergo the proposed herbicide treatment plan arranged by UDWR. A second aerial survey will take place to capture up-to-date imagery. Using both sets of imagery and the ground sampling data, a change detection process will provide UDWR with accurate data illustrating the composition of aquatic vegetation within each pond before and after the treatment program. The data will also illustrate the effectiveness of the overall treatment plan and highlight any potential areas within either pond that may have been missed.

Benefits to the State

The results from this study will provide valuable data to UDWR for monitoring the effectiveness of their treatment plans to eradicate invasive aquatic vegetation in open water bodies. The use of this UAV technology to

Principal Investigators:

Ian Gowing (PI)
Shannon Syrstad (Co-PI)
Alfonso Torres-Rua (Co-PI)

Partners/Collaborators:

State: Richard Gibbs, Utah Division of Wildlife Resources

Geographic Areas:

Study Areas: Browns Pond (North & South), Uintah County, Utah

Areas Benefited: Uintah County

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Websites:

https://uwrl.usu.edu/aggieair/uav-service-center/index

map and monitor invasive aquatic weeds at very high resolution is an effective tool that both state and local agencies throughout the state of Utah can use.

Findings/Results

The first UAV flights over Browns Pond, North and South, took place August 25, 2021. The imagery was processed and full reflectance orthomosaics were produced. The first flight imagery was sectioned into six generic categories using the spectral uniqueness and isodata cluster unsupervised classification method. Within each generic category, 50 random points were generated to serve as sampling points for ground truthing. This method creates a random, yet equally represented, set of data collection points that can represent the spectrally different areas well enough. The data collected at the sampling points is used in the supervised classification process.

Work Plan FY 21–22

We anticipate that the herbicide treatment plan will take place towards the end of September 2021. Approximately four weeks after the treatment plan, a second series of UAV flights will take place to capture post-treatment imagery. Analysis and report writing will continue through to December 2021.

Figure 2: *Browns Pond North, Uintah County, Utah (top); Browns Pond North mosaic (bottom L); Browns Pond South mosaic (bottom R).*

Cyberinfrastructure for Intelligent Water Supply

Project Description:

Need and Purpose

High-resolution water-use data collection using smart water meters promises to enhance our ability to characterize water demand and water use behavior, estimate peak water usage, reduce undetected leaks, and improve urban water management. However, obtaining high-temporal-resolution data at a scale larger than a few houses presents challenges in terms of data collection, storage, management, and processing. This research is advancing smart water metering and supporting cyberinfrastructure for building the scientific data and knowledge base to sustainably manage urban water supplies.

Benefits to the State

In Utah and the western U.S., many urban water management challenges stem from quickly growing populations, highly allocated water supplies for both human and environmental uses, and variable water availability related to drought. Mitigating these pressures and ensuring the sustainability of urban water supplies will require new data and analytics that provide detailed, actionable information for optimizing the planning, design, and operation of water management infrastructure. We are quickly moving to a new paradigm where precise accounting and management of urban water consumption is necessary for a sustainable water future. This project is working to better enable this by advancing the human- and cyber-infrastructure available for building and managing next generation smart metering systems and their resultant data.

Figure 1: *The custom smart water meter datalogger designed and developed by the project for collecting high-resolution water use data on existing residential water meters.*

Findings/Results

We developed a low-cost datalogger (~$100) that can be deployed on existing water meters to collect high-temporal-resolution data without affecting the functionality of the meter. Using these dataloggers, we completed two detailed smart water metering and water use behavior studies: one in USU's single student housing complexes and one with participating residential homes in Logan City and Providence City, UT. Using the data collected

Principal Investigators:

Jeffery S. Horsburgh (PI)

Students:

Nour Attallah (PhD)
Camilo Bastidas (PhD)
Joseph Brewer (MS)

Partners/Collaborators:

Local: Logan City, UT
Providence City, UT
Utah State University Housing and Facilities Departments

National: National Science Foundation

Geographic Areas:

Study Areas: Logan City, UT and Providence City, UT

Areas Benefited: Although our data collection activities have focused on the cities of Logan and Providence in Cache County, we anticipate that our results will be applicable statewide and beyond

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Websites:

CIWS server and code at:
https://github.com/UCHIC

from participating residential homes, we developed a computer algorithm to identify individual water use events and classify them by end use type (e.g., toilets, faucets, showers, etc.). We then developed a more advanced datalogger capable of collecting data and running the classification algorithm in the field, effectively converting existing water meters into "smart" computational nodes rather than requiring expensive transmission of high data volumes and resource-intensive central post-processing of data. Using the detailed water-end-use data, we studied the timing and distribution of water use behavior within participating homes to better understand and quantify indoor and outdoor water use. We created cyberinfrastructure to automate management of high-resolution data collected as part of our residential smart water metering studies. We deployed and tested our cyberinfrastructure in a production environment, demonstrating successful management of the large volume of data produced by our field data collection activities. This project has created multiple opportunities for training students, including the following: (1) support for two PhD and one MS student; (2) an undergraduate monitoring program where students worked on independent data collection and research projects using the data collection infrastructure we have established; (3) teaching modules for CEE courses designed to teach students how to manage, read, manipulate, subset, summarize, and visualize high-resolution water use data collected using our water meter dataloggers, introduce machine learning concepts in Python, and analyze geospatial patterns in urban water use; and (4) a student data visualization challenge using high-resolution water-use datasets produced by this project.

Figure 2: *USU PhD students Camilo Bastidas and Nour Attallah install a smart water metering data logger on a residential water meter in Logan, UT.*

Work Plan FY 21–22

We will finalize a refinement to our smart water metering datalogger that will enable it to record full-pulse-resolution data (i.e., individual time-stamped pulses) from existing water meters to more accurately identify and classify individual water use events and use the high-resolution water-use data collected to develop an advanced water demand modeling tool that addresses deficiencies in existing water demand modeling approaches.

Datasets:

Related data resources:

- http://www.hydroshare.org/resource/2081d6098f3e4569bce119174a78f10e
- https://doi.org/10.4211/hs.4de42db6485f47b290bd9e17b017bb51
- http://www.hydroshare.org/resource/0b72cddfc51c45b188e0e6cd8927227e
- https://doi.org/10.4211/hs.aaa7246437144f2390411ef9f2f4ebd0
- http://www.hydroshare.org/resource/b6bbdcd9b120430b9a54974a798961f1

Publications:

- Bastidas Pacheco, C.J., Horsburgh, J.S., Tracy, R.J. 2020. *A low-cost, open source monitoring system for collecting high-resolution water use data on magnetically-driven residential water meters*, Sensors, 20(13), 3655, https://doi.org/10.3390/s20133655
- Brewer, J.C. 2020. *Characterizing Water and Water-Related Energy Use in Multi-Unit Residential Structures with High Resolution Smart Metering Data*, All Graduate Theses and Dissertations, 7976, https://doi.org/10.26076/669a-93b0
- Attallah, N., Rosenberg, D.E., Horsburgh, J.S. 2021. *Water end use disaggregation for six non-residential facilities in the City of Logan, UT, USA*, Journal of Water Resources Planning and Management, 147(7), https://doi.org/10.1061/(ASCE)WR.1943-5452.0001367
- Bastidas Pacheco, C.J., Brewer, J.C., Horsburgh, J.S., Caraballo, J. 2021. *An open source cyberinfrastructure for collecting, processing, storing and accessing high temporal resolution residential water use data*, Environmental Modelling & Software, 144, 105137, https://doi.org/10.1016/j.envsoft.2021.105137
- Attallah, N.A., Horsburgh, J.S., Beckwith, Jr., A.S., Tracy, R.J. 2021. *Residential water meters as edge computing nodes: Disaggregating end uses and creating actionable information at the edge*, Sensors, 21(16), 5310, https://doi.org/10.3390/s21165310

Water Education, Outreach and Technology Transfer

Actual, Budgeted and Planned Expenditures of Mineral Lease Funds

Water Education, Outreach and Technology Transfer: PI	Project Name	Actual FY2021	Budgeted FY2022	Planned FY2023
Dupont, R.	Logan City Renewable Energy and Sustainability Advisory Board (RESAB)	$3,000	$3,090	$3,183
Rosenberg, D.	Make Water Research Results More Reproducible	$23,616	$24,325	$25,055
Sims, J.	Development of an On-Site Demonstration Site at the Ash Creek Special Service District	$10,347	$10,657	$10,977
Sims, J.	Utah On-Site Wastewater Treatment Training Program	$20,347	$20,957	$21,586
Stevens, D.	State of Utah Operators Certification Commission	$3,000	$3,090	$3,183
Stevens, D.	Center of Excellence for Water (Egypt)	$21,905	$22,562	$23,239
Tullis, B.	State of Utah Drinking Water Board	$22,240	$19,753	$20,345
	Designated projects		*$5,969*	*$6,148*
	Undesignated research projects in program area		*$92,830*	*$87,377*
	TOTALS	**$104,455**	**$203,233**	**$201,093**

Logan City Renewable Energy and Sustainability Advisory Board (RESAB)

Project Description:

Need and Purpose

The mission of the Logan City Renewable Energy and Sustainability Advisory Board (RESAB) is to provide advice and technical assistance related to the conservation and efficient use of resources, to assist in transitioning the City of Logan toward a renewable energy portfolio that is secure, diverse, and cost-effective; promotes security of the environment; and addresses climate change action.

RECAB's goals include:

1. Reduce residential energy consumption (per capita) over the next 10 years
2. Improve energy efficiency of commercial and public customers
3. Implement demand-side management (DSM) programs with residential, commercial, and public customers
4. Identify and research potential sources of renewable energy for Logan City
5. Identify and promote green building standards
6. Identify and promote alternative forms of public transportation
7. Promote public education on issues of energy supply security, energy cost security, and environmental security
8. Reduce carbon emissions and assist Logan City with carbon emission study.

Benefits to the State

The RESAB provides Logan City with technical expertise and experience on the potential of new renewable energy sources, carbon emission estimates, carbon emission reductions, and public education. Dupont attends monthly meetings of the Logan RESAB, provides comments and input on renewable energy and waste management issues that arise, and has responded to special requests from RESAB regarding technical issues related to alternative renewable energy sources. He is a member of the Community Solar subcommittee of RECAB that is evaluating program options for increasing participation in the existing Logan City solar farm and considering options for expansion of the current program and facilities to include a commercial customer base. The Sustainability name change occurred in February 2021 to reflect the expanded membership and mission of the Board regarding climate change concerns, the City's greenhouse gas emission inventory, and steps necessary for greenhouse gas emission reductions to address climate change.

Principal Investigators:

R. Ryan Dupont (PI)

Partners/Collaborators:

Local: Emily Malik, Logan City Environmental Department

Amy Anderson, Holly Daines, Tom Jensen, Logan City Council

Geographic Areas:

Study Areas: Logan City and Cache County

Areas Benefited: Logan City and Cache County

Contacts:

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Websites:

https://www.loganutah.org/government/departments/light_and_power/energy_conservation_solar/recab.php

Findings/Results

Dupont attended all regularly scheduled remote RESAB meetings throughout FY20–21 and provided review and comment on all RESAB items relevant to his area of expertise. Topics included the following: (1) analysis of current and future resource mix to meet a 50% renewables component in Logan City's power portfolio by 2030, (2) input on the long-term renewable energy Road Map and 50% renewable resolution for Logan City that was passed by the Logan City Council in 2018, (3) participation on the Community Solar program analysis RECAB subcommittee, and (4) input on greenhouse gas emission reduction strategies, as well as programs and policies to support climate action.

Work Plan FY 21–22

The PI will continue his Involvement with the Logan RESAB, as well as his response to special project requests, as they arise, to support Logan City RESAB's mission and goals.

Figure 1: *Community solar array installed adjacent to the Logan City Wastewater Treatment Lagoons.*

Make Water Research Results More Reproducible

Project Description:

Need and Purpose

Few published science and engineering results are reproducible, despite broad interest in making such results reproducible. This contradiction exists because of several perceived and real challenges. (1) Reproducing article figures, tables, and other results requires more author effort to prepare and share their data, models, code, and directions. (2) Authors must learn new skills to organize and share materials online. (3) Authors may not share proprietary or sensitive materials. (4) Some workflows use stochastic, high-performance computing, big data, or methods with long run times that are too big to share or reproduce bit for bit. (5) Reproducing others' results takes time and expertise. (6) Funders, universities, and institutions value publication of novel, peer-reviewed journal articles rather than datasets, documentation, or reproduction of others' efforts. (7) Promoting and rewarding reproducibility may unintentionally encourage researchers to pursue easily reproduced methods rather than complex methods that offer bigger contributions yet cannot be reproduced with today's tools. The authors, journals, funders, and institutions that produce, publish, and support research must better coordinate to overcome these challenges (Figure 1). Here we share community practices that can make research data, models, code, and directions more available and results more reproducible.

Benefits to the State

Making research results more reproducible will allow more Utahns to access research. Improved access will also allow Utah researchers and businesses to use and extend research produced in Utah, the U.S., and the world. Making research results more reproducible will also improve public trust in research, data, and models and help organize materials in perpetuity for future users. Making research results more reproducible will also help narrow the gap between academics and professionals in practice.

Findings/Results

- A new result reproducibility policy was implemented for the Journal of Water Resources Planning and Management published by the American Society of Civil Engineers (ASCE) (Rosenberg et al., 2021). The policy set up a new process to verify the availability of data, models, and code used in manuscripts and the reproducibility of the results in tables, figures, and text. The policy offers authors of manuscripts that have verified reproducible results the financial incentive of free open access publishing. The policy will award the

Principal Investigators:

David E. Rosenberg (PI)

Partners/Collaborators:

Business/Industry: Dave Watkins, Michigan Tech University

Dana Compton, American Society of Civil Engineers

Brian Parsons, Environmental Water Resources Institute

David Mellon, Center for Open Science

Geographic Areas:

Study Areas: No specific study area exists for this project. Reproducibility work is conducted across Utah, as well as nationally and internationally.

Areas Benefited: Areas throughout Utah

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Publications:

Rosenberg, D. E., Jones, A. S., Filion, Y., Teasley, R., Sandoval-Solis, S., Stagge, J. H., Abdallah, A., Castronova, A., Ostfeld, A., and Watkins, D. 2021. *Reproducible Results Policy.* Journal of Water Resources Planning and Management, 147(2), 01620001. https://ascelibrary.org/doi/full/10.1061/%28ASCE%29WR.1943-5452.0001368

authors of the article with outstanding effort to reproduce results and reviewers who makes outstanding effort to reproduce results.

- The first paper with verified reproducible results is nearing publication.
- The PI was an invited speaker at the European Geophysical Union conference: "Can we make our science more reproducible?" April 26, 2021.

Work Plan FY 21–22

- Develop short videos to guide authors through the submission process for papers with reproducible results.
- Secure final financial commitments to fund free open access for manuscripts with verified reproducible results.
- Make first awards to authors and a reviewer for outstanding effort to make results reproducible and reproduce results

Figure 1: *Multiple entities can partner to make results more reproducible.*

Development of an On-Site Demonstration Site at the Ash Creek Special Service District

Project Description:

Need and Purpose

The Huntsman On-Site Wastewater Treatment Training and Demonstration Site on the campus on Utah State University (USU) in northern Utah is used for State of Utah certification workshops for on-site wastewater professionals as well as occasional tours for outside groups and for university classes. The site is an integral part of the USU On-Site Wastewater Treatment Training Program (https://uwrl.usu.edu/research/owt). However, because the USU demonstration site is located in northern Utah, the need exists for a similar demonstration site in the southern part of the state to serve on-site professionals in that area. Therefore, a second demonstration site is being constructed at the Ash Creek Special Service District (Ash Creek) site in Hurricane, Utah. Ash Creek also has classroom facilities for on-site certification workshops that will utilize the demonstration site. This southern demonstration site at Ash Creek will facilitate participation of instructors and regulatory staff from the area in the certification training program and in providing tours and other educational activities concerning septic systems and non-point source pollution (NPS) to their clients and the public.

Benefits to the State

Continued population growth and associated housing developments create an increased need for accurate and thorough information regarding on-site wastewater treatment technologies. Enhanced educational opportunities available at the Ash Creek demonstration site will benefit the on-site professionals active in the oversight of septic system siting, design, inspection, monitoring, and maintenance, especially professionals located in central and southern Utah.

Findings/Results

The approach to the development of the project is design/build. Demonstration displays will include displays related to: (a) septic tanks; (b) distribution devices for septic tank effluents in absorption systems; (c) in-ground absorption systems: standard trenches (pipe and gravel, chambers, bundled synthetic aggregates), deep wall trenches, pressurized drain fields, and absorption beds; (d) alternative systems: at-grade systems, mound systems, packed bed systems (intermittent sand filter, recirculating sand and gravel filters, textile system, peat system, and synthetic polystyrene media filter), and sand-lined trenches; (e) pump systems, tanks, and vaults; (f) control panels; (g) effluent filters for septic tanks; (h) valves for alternating drain fields; (i) dosing tanks; and (j) drip irrigation systems.

Principal Investigators:

Judith L. Sims (PI)
Brian Cowan
Richard Jex

Students:

Jeff Crandall (MS)
Nathan Guymon (MS)
Zachary McClellan

Partners/Collaborators:

Local: Mike Chandler, Ash Creek Special Service District

Utah's 13 Local Health Departments

State: Division of Water Quality, Utah Department of Environmental Quality)

Utah On-Site Wastewater Association (UOWA)

Geographic Areas:

Study Areas: Entire State of Utah

Areas Benefited: The development of the on-site wastewater demonstration site at Ash Creek will be especially beneficial to persons in southern and central Utah, but use of the site will be open to all on-site professionals and other interested parties from all parts of Utah.

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Websites:

https://uwrl.usu.edu/research/owt/

During FY20–21 we continued to design and build various demonstration displays. We revised the wording for signs and edited videos illustrating percolation testing, soil texturing procedures, field soil pit evaluation techniques, conventional on-site wastewater treatment system design, and operation and maintenance (O&M) procedures for alternative on-site wastewater treatment systems. Because of the continuing COVID pandemic, we have not yet completed installation of the displays as Ash Creek Special Service District. The project was extended one more year to complete the demonstration site.

Work Plan FY 21–22

We will finalize procurement of materials and demonstration materials, complete displays, and finish installation of the educational models at the Ash Creek demonstration site.

Figure 1: *The new demonstration site will be located at the Ash Creek Special Service District in Hurricane, Utah.*

Utah Onsite Wastewater Treatment Training Program

Project Description:

Need and Purpose

The Utah On-Site Wastewater Treatment Training Program was established in January 1998 in cooperation with the Utah Department of Environmental Quality (DEQ) and the thirteen Utah local health departments. It provides classroom and field (hands-on) training to Utah homeowners, regulators, designers, installers, pumpers, and other stakeholders in on-site wastewater treatment systems.

Adequately protecting environmental health and enhancing user satisfaction are achieved through knowledgeable selection, competent design, correct installation, and proper operation of on-site systems. Applying the right technology in the right location requires accurate information and up-to-date training. Landowners, homeowners, developers, lenders, installers, regulators, planners, municipal authorities, and elected authorities are all stakeholders in Utah on-site issues and must have current information and training to address these matters responsibly.

Utah will continue to grow, and as housing developments continue to expand into current open space, such developments may include areas of groundwater recharge, shallow soils, or shallow ground water. Current Utah rules allow the use of conventional septic tank systems, as well as eight alternative treatment systems that may be installed in areas where soils are unsuitable for conventional systems. Training those involved in the use of both conventional and alternative systems will ensure that these systems will work correctly.

Benefits to the State

The Utah On-Site Wastewater Treatment Training Program addresses the challenges associated with continued growth and associated housing developments along with the need for accurate and thorough information about on-site wastewater treatment technologies through workshops and participation in educational conferences. Many Utah soils are marginal or unacceptable for the use of conventional soil absorption systems due to high or fluctuating water tables, slowly permeable or highly permeable soil horizons, and extreme slopes, thus requiring the use of more advanced alternative systems. The Program provides the necessary education to utilize conventional and alternative systems in ways that will protect both public health and the environment.

Findings/Results

A 2001 state legislative initiative (House Bill 14s) mandated a certification program for persons involved in siting, designing, operating,

Principal Investigators:

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Brian Cowan
Richard Jex

Students:

Jeff Crandall (MS)
Nathan Guymon (MS)
Zachary McClellan

Partners/Collaborators:

Local: Utah's 13 Local Health Departments

Utah On-Site Wastewater Association (UOWA)

State: Division of Water Quality, Utah Department of Environmental Quality

Council of Local Environmental Health Directors (CLEHA)

Geographic Areas:

Study Areas: Entire State of Utah

Areas Benefited: The entire state (29 counties and 13 local health departments)

Contacts:

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Publications:

Sims, J.L., Cashell, M., Cowan, B., and Jex, R. 2020, 2021. *Course Manuals for Levels 1, 2, and 3 Original Certification and Recertification Workshops*. Utah Water Research Laboratory, Utah State University, Logan, UT

Workshops:

- Level 1: 3 workshops broadcast to 15 Utah and 3 Idaho locations—77 total participants
- Level 2: 3 workshops broadcast to 10 Utah locations—50 total participants.
- Level 3: 2 workshops broadcast to 5 Utah locations—25 total participants
- Level 1 & 2 Renewal: 3 workshops broadcast to 18 Utah Locations—126 total participants
- Level 3 Renewal: 3 workshops broadcast to 14 Utah locations—65 participants

Total Number of workshop participants, FY 20–21: 343

Test-out option for Level 1 & 2 certification renewal: 2 testing dates at 7 Utah locations—6 total participants

Websites:

https://uwrl.usu.edu/research/owt/

and maintaining both conventional and alternative on-site systems. The certification program, administered by the Division of Water Quality in the Utah DEQ, involves mandatory training provided by the Utah On-Site Wastewater Treatment Training Program. The certification program includes three levels, each of which requires workshops and testing provided through the Utah Training Program: (1) Level 1: Soil Evaluation and Percolation Testing; (2) Level 2: Design, Inspection, and Maintenance of Conventional Systems; and (3) Level 3: Design, Operation, and Maintenance of Alternative Systems. Because Level 1, Level 2, and Level 3 certifications expire after 3 years, workshops are also provided for certification renewal.

Due to the COVID-19 pandemic, all Spring FY 19–20 workshops were postponed until Fall FY 20–21. Fourteen workshops were held during FY 20–21 through video broadcasting to various locations in Utah and Idaho.

Licensed engineers, environmental scientists, and licensed contractors, based on experience and/or education, can elect to test for certification and waive attendance at the workshops. During FY 20–21, 2 Utah participants and 1 Wyoming participant elected this option.

Work Plan FY 21–22

We will continue to provide workshops in support of the mandatory State of Utah certification program for on-site wastewater professionals (through FY 2025). In-person workshops will resume in fall 2021 and depending on health concerns, continue in person in spring 2022.

Figure 1: *Workshop participants in field and classroom training.*

State of Utah Operators Certification Commission

Project Description:

Need and Purpose

Under the Utah Drinking Water Act (the Act), responsibility for overseeing drinking water treatment and distribution rests with DEQ and the Utah Drinking Water Board (the Board). The Board has the authority to issue orders implementing the Act and to ensure compliance with the Act's provisions. Jurisdiction of the Board covers public and private community drinking water systems, including the various Federal facilities. The Board created the Water Treatment Operators Certification Commission in 1984 and Stevens has been a member of that commission since 1987.

Benefits to the State

Membership on the Operators Certification Commission provides service to the citizens of the State of Utah, the Utah DEQ, and the regulated community by managing training for water treatment plant operators. This includes setting policy, administering examinations, and making decisions on appeals. Stevens attends yearly meetings of the Commission held in Salt Lake City and provides comments and inputs policies and procedures regarding the certification of water treatment and distribution system operators in accordance with Federal and State drinking water laws.

Figure 1: *Little Cottonwood treatment plant ponds.*

Principal Investigators:

David K. Stevens (PI)

Partners/Collaborators:

State: Marie Owens, Director, Division of Drinking Water

Tim Davis, Director, Division of Drinking Water

Michael Grange, Operator Certification Commission Secretary, at Division of Drinking Water

Geographic Areas:

Study Areas: State of Utah

Areas Benefited: State of Utah

Contacts:

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Websites:

https://deq.utah.gov/drinking-water/operator-certification

Findings/Results

The PI attended all scheduled Operators Certification Commission meetings July 1, 2020 to June 30, 2021, and provided review and comment on all Commission items relevant to his area of expertise.

Work Plan FY 21–22

Involvement on the Board will continue through 2022.

Center of Excellence for Water

Project Description:

Need and Purpose

Egypt has a critical need to improve its ability to meet current and projected water demands. The goal of this project is to catalyze long-term improvement in Egyptian water resources management by improving its innovative applied research and education enterprise through the creation of the Alexandria Water Resilience Center of Excellence (AWR-COE). The AWR-COE will serve the needs of the Egyptian people and economy, including industry, and support the government to face water challenges, develop policy, and prepare a next generation of graduates and entrepreneurs to be agents of change that stimulate economic growth. Inclusion of women, disabled persons, and talented yet financially needy faculty and students, is central to all aspects of our design and implementation.

Based on our theory of change, we hypothesize that, if research needs are identified for the private and public sectors and the required profile for graduates is drawn based on labor market's need, and if the expertise of the US partners is transferred such that it builds on the capacity of Egypt's higher education institutions through their faculty, students, and research administrators by providing the right infrastructure and environment, then the AWR-COE will be a sustainable model to generate innovative, modern, and competitive solutions to develop the Egyptian economy, strengthen government policy, and equip future graduates to be change agents, thus achieving Egypt 2030 goals and contributing to global Sustainable Development Goals.

Benefits to the State

The project will provide opportunities for faculty and students at USU to exchange ideas with our Egyptian partners, travel to Egypt for collaboration in water related research, study at Egyptian Universities, and have Egyptian partners travel to USU for the same purpose. This will result in a deeper understanding of water management in arid lands that will benefit Utah directly and provide opportunities for future collaboration internationally.

Findings/Results

This is an international collaborative project funded by USAID using partnerships between five US universities (Utah State, Washington State, Univ. of California-Santa Cruz, Temple University, and the American University of Cairo (Egypt), five Egyptian Partner Universities (EPUs, Alexandria University, Ain Shams University, Zagazig University, Beni Suef University, and Aswan University), and a number of agency, public, and industrial

Principal Investigators:

David Stevens (PI)
Ryan Dupont (Co-PI)
Kurt Becker (Co-PI)

Students:

Mohammad Al Mestiraihi (PhD)

Partners/Collaborators:

National: UD AID

Geographic Areas:

Study Areas: Logan, UT

Areas Benefited: Statewide

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partners in Egypt. FY 20–21 was the project's second year. The Covid-19 pandemic, which affected both the US and Egypt, disrupted plans for FY 20–21 due to travel and other restrictions. The USU team had scheduled a Logan workshop that had to be postponed due to travel restrictions. When it became clear that the restrictions would continue through the fiscal year, the workshop was modified to provide nine Egyptian participants via Zoom with training in the use of modern, innovative teaching strategies in water engineering and science over an eight-week period from January–March 2021. We also coordinated, reviewed, and assigned development teams for 17 new courses for Egyptian Universities with teams composed of US faculty members and two or more Egyptian partners. The USU team presented two webinars during FY 2020-21: Innovative Teaching Strategies and The Importance of the Syllabus in Course Development. The USU team also ran monthly Zoom meetings for the Pillar II committee consisting of both the US and Egyptian partners on the committee. Finally, some work was done to extend the overall project through 2027 with a small increase in budget due to delays and increased costs due to the pandemic. A proposal and budget were developed, and the process is being negotiated with USAID and the Egyptian Ministry for Water Resources.

Work Plan FY 21–22

This project will continue through 2026 and, in the coming fiscal year, we will complete the development of the 17 undergraduate courses, issue a call for proposals for and development of 23 graduate level courses in water resources sustainability for implementation at the five EPUs, hold Phase IV of the Learning Management Systems workshop and Phase III of the Innovative Teaching Strategies workshop in Cairo in October 2021, present a workshop on State-of-the-Art Water Curriculum to 30 Egyptian participants in Egypt in two phases: the first in October and the second sometime in spring 2022. We will also attend the Cairo Water Week conference in Cairo October 24–29 where the project will hold a full day dedicated session and at which we will present work related to the Needs Assessment report from FY 19–20 and overall progress of our portion of the project. This is in addition to individual faculty efforts in the course development portion of the project.

Figure 1: *UWRL researchers are helping to find solutions to the challenges Egypt faces related to sources of water, wastewater services, and irrigation and are designing new courses and degrees for Egyptian universities in fields related to water issues.*

Publications:

- Dupont, R.R., K. Becker, D. Stevens M. Al Mestiraihi. 2020. *Needs Assessment Report*. Center of Excellence for Water, Cairo, Egypt
- Al Mestiraihi, M., & Becker, K. H., & Dupont, R. R., & Stevens, D. K. 2021, July. *Developing Undergraduate Water Program Courses: Meeting the Needs of the Egyptian Workforce.* Paper presented at 2021 ASEE Virtual Annual Conference Content Access, Virtual Conference. https://peer.asee.org/developing-undergraduate-water-program-courses-meeting-the-needs-of-the-egyptian-workforce
- Al Mestiraihi, M., & Becker, K. H., & Dupont, R. R., & Stevens, D. K. 2021, June. *Skill Requirements for New Water Professionals Graduates in Egypt: Industry and Public Sector Perspective*. Paper presented at the 2021 UCOWR/NIWR Annual Water Resources Virtual Conference

Websites:

https://www.usaid.gov/egypt/higher-education/center-excellence-water

State of Utah Drinking Water Board

Project Description:

Need and Purpose

Under the Utah Drinking Water Act (the Act), responsibility for overseeing drinking water treatment and distribution rests with DEQ and the Utah Drinking Water Board (the Board).

The Board has the authority to issue orders implementing the Act and to ensure compliance with the Act's provisions. Jurisdiction of the Board covers public and private community drinking water systems, including the various federal facilities. Utah Water Research Laboratory faculty member Blake Tullis has served on the State of Utah Drinking Water Board from FY 2020 to the present.

Benefits to the State

Membership on the Drinking Water Board provides service to the citizens of the State of Utah, the Utah DEQ, and the regulated community by providing technical overview and expertise for drinking water management, as well as oversight of state and federal revolving loan funds, to the Division of Drinking Water in their rulemaking, facility inspections and reviews, policy implementation, and conflict resolution. Tullis attends approximately quarterly meetings of the Drinking Water Board held throughout the State or virtually and provides comments and input on drinking water treatment and distribution issues that arise during the course of the Division's implementation of federal and state drinking water laws.

Principal Investigators:

Blake Tullis (PI)

Partners/Collaborators:

State: Marie Owens, Director, Division of Drinking Water

Geographic Areas:

Study Areas: State of Utah

Areas Benefited: State of Utah

Contacts:

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blake.tullis@usu.edu

Websites:

https://deq.utah.gov/boards/utah-drinking-water-board

Findings/Results

Tullis attended all regularly scheduled Drinking Water Board meetings and facility tours from July 1, 2020, to June 30, 2021, with the exception of one due to a conflict in schedule, and provided review and comment on all Board items relevant to his area of expertise.

Work Plan FY 21–22

The PI will continue this board service through 2023.

Water Resources

Actual, Budgeted and Planned Expenditures of Mineral Lease Funds

Water Resources: PI	Project Name	Actual FY2021	Budgeted FY2022	Planned FY2023
Lane, B.	Characterizing streamflow and temperature patterns to assess impacts of summer depletion on the Blacksmith Fork River	$13,481		
Lane, B.	RAPID: Monitoring and modeling watershed-scale post-wildfire streamflow response through space and time	$13,105	$13,498	$13,903
Neilson, B.	Logan River Watershed LiDAR	$61,756	$63,609	$65,517
Neilson, B.	Logan River Observatory	$28,292	$29,141	$30,015
Neilson, B.	Quantification of Groundwater Influences in High Gradient Utah Streams and Rivers	$29,292	$30,171	$31,076
Neilson, B.	Logan City Stormwater Monitoring	$28,292	$29,141	$30,015
Rosenberg, D.	Adapt Lake Powell and Lake Mead Releases to Inflow to Give Managers more Flexibility to slow Draw Down	$23,616	$24,325	$25,055
Rosenberg, D.	Targeted Water Conservation using nonparametric ranking and behavioral psychology	$23,616	$24,325	$25,055
Tarboton, D.	The Future Hydrology of The Colorado River Basin	$77,378	$79,699	$82,090
Tarboton, D.	Evaluating National Water Model Snow Components	$75,205	$77,462	$79,785
Torres, A.	Water Use Assessment in Urban Open Areas	$4,767	$4,911	$5,058
Torres, A.	Active Transportation Facilities in Canal Corridors	$4,767	$4,911	$5,058
	Designated projects		*$34,461*	*$53,677*
	Undesignated research projects in program area		*$55,146*	*$29,440*
	TOTALS	**$383,567**	**$470,800**	**$475,744**

Characterizing Streamflow and Temperature Patterns to Assess Impacts of Summer Depletion on the Blacksmith Fork River

Project Description:

Need and Purpose

As one of the driest and fastest growing states, Utah faces a critical challenge in identifying how limited and increasingly uncertain water resources can be more efficiently allocated to meet human and environmental water needs. In dry summers in northern Utah, irrigation diversions dewater lowland river reaches, affecting native trout populations, which then take years to recover. Understanding how stream temperature and flow are altered by distributed irrigation diversions and seepage return flows is fundamental to predicting temperature changes under different water management practices and the ecological consequences of these changes.

Benefits to the State

The focus of this project is to improve integrated freshwater management in Utah, particularly in lowland agricultural regions downstream from mountain canyons. We are monitoring trends in streamflow, groundwater exchange, and stream temperature over three summers to improve understanding of the combined roles of climate and irrigation activities in stream temperature trends. This in turn will allow us to assess tradeoffs between

Figure 1: *High inter-annual climate variability can lead to depleted to fully dewatered valley streams in dry years, when remaining streamflow is diverted for irrigation. Improved monitoring of hydrologic fluxes including return flows and irrigation seepage will help better manage these streams for humans and river ecosystems.*

Principal Investigators:

Belize Lane (PI)
Bethany Neilson (Co-PI)

Partners/Collaborators:

Local: Nibley City, UT

State/National: Trout Unlimited

Geographic Areas:

Study Areas: Lower Blacksmith Fork River, Nibley, UT

Areas Benefited: This research directly benefits Nibley, and the information gained and methods developed should be applicable the all lowland irrigated streams and rivers in Utah

Contacts:

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Publications:

Alger, S. M., Lane, B., Neilson, B. T. 2021, June. Combined *influences of irrigation diversions and associated subsurface return flows on river temperature in a semi-arid region*. Hydrologic Processes. 35(8), e14283. https://doi.org/10.1002/hyp.14283

water uses and propose solutions that support both irrigators and fisheries and provide a detailed monitoring dataset to inform early water banking efforts following passage of the Utah Water Banking legislation this year.

Findings/Results

Four years of hydrologic monitoring have helped determine how river flow and temperature vary in the summer due to major diversions below the canyon mouth in a typical intermountain irrigated river valley. Results indicate that, during dry water years when flows are very low, small inflows such as springs and irrigation seepage have a large impact on the amount of water in the channel and the temperature of that water. These return flows can cool the stream and help fish survive in otherwise excessively warm low flow conditions, particularly when riparian shading is limited.

Work Plan FY 21–22

This project is complete.

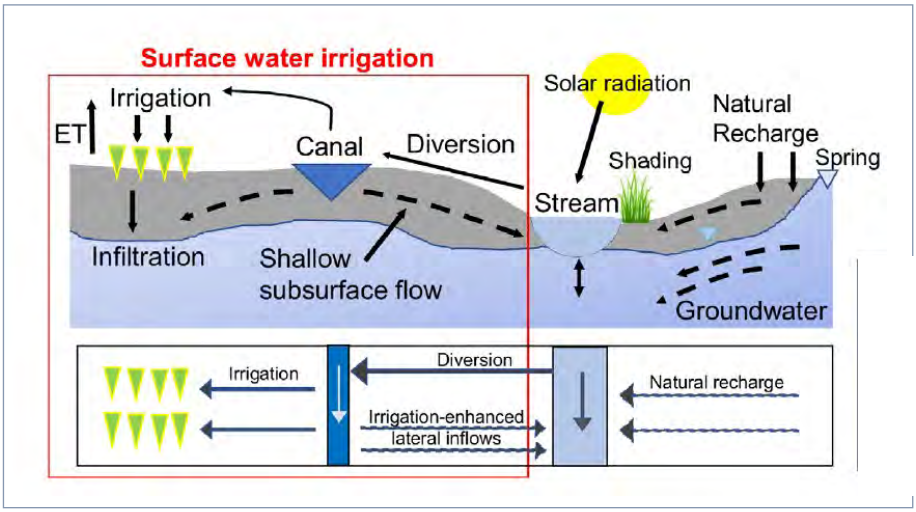

Figure 2: *Summer stream temperature under depleted flow conditions depends on the timing and rate of water diversions and both natural and irrigation-enhanced (red box) lateral inflows, as well as time-varying streamflow, weather and shading.*

RAPID: Monitoring and Modeling Watershed-Scale Post-Wildfire Streamflow Response through Space and Time

Project Description:

Need and Purpose

Wildfires alter rainfall-runoff processes, accelerating erosional processes and increasing sediment transport rates by orders of magnitude. In the western U.S, these changes pose considerable risks to downstream infrastructure and ecosystems, and natural resource managers urgently need practical and reliable predictive tools to support post-wildfire management. Traditional empirical scaling models can result in significant under-prediction of downstream impacts, while the high data requirements of mechanistic hydrologic models preclude their application at larger scales. To fill this gap and improve our understanding of post-wildfire hydrologic response across a western watershed requires rapid mobilization to capture the initial response in a recently burned watershed with long-term streamflow records and variable watershed and burn characteristics. The active Grizzly Creek wildfire in Glenwood Canyon, CO, presents a unique, time-sensitive opportunity to collect necessary field data to monitor these processes and develop transferable analytical tools.

Benefits to the State

An improved understanding of flooding, sediment transport, and debris flow risks and variability following wildfire and downstream impacts support better management and mitigation strategies across the western US, including Utah.

Figure 1: *Lane's team is monitoring post-wildfire hydrologic response to track changes in streamflow and sediment dynamics in the Grizzly Creek Fire burn scar.*

Principal Investigators:

Belize Lane (PI)
Brendan Murphy (Co-PI)

Students:

Haley Canham (MS)

Partners/Collaborators:

Local: Glenwood Springs, CO

State/National: National Science Foundation

Geographic Areas:

Study Areas: Glenwood Canyon, CO

Areas Benefited: Western US, particularly steep forested hillslopes adjacent to state and national assets including highways, railroad, reservoirs

Contacts:

Belize Lane
435.797.4145
belize.lane@usu.edu

Findings/Results

This data will directly support and inform post-wildfire mitigation which costs tens of millions of dollars across the western U.S. each year and help agencies move towards pre-wildfire proactive management.

Work Plan FY 21–22

Continued field data collection and analysis are planned.

Figure 2: *Lane's team is monitoring post-wildfire hydrologic response to track changes in streamflow and sediment dynamics in the Grizzly Creek Fire burn scar.*

Logan River Watershed LiDAR

Project Description:

Need and Purpose

Snow recharged karst aquifers (a topography formed by the dissolution of soluble rocks such as limestone) are the primary source of municipal and agricultural water supply in many mountainous areas including Northern Utah. Logan City relies on karst springs for drinking water, and groundwater discharge to the Logan River is the primary water source for irrigation. Projected variability in climate may result in shifting patterns of snow and rain, thus creating uncertainty regarding the sustainability of this water resource. Effective water resource management and planning must be informed by an assessment of climate change implications for karst mountain watersheds. Thus, a clear need exists for better data regarding snow distributions and support of predictive tools that provide insight regarding watershed response to shifting patterns of temperature and precipitation.

Benefits to the State

As part of Logan River Observatory (LRO), the Logan River watershed has been instrumented with flow gaging stations, multi-probe water quality sondes, and weather stations along a path from mountain unimpacted areas to urban areas. Highly accurate topography data (0.5-m resolution) (Figure 1) was recently collected using LiDAR (a method using airborne lasers) to complement the climatic, hydrologic, and chemical data from preceding and ongoing efforts. The resulting detailed topography and land cover information provided by LiDAR (Figure 2) is supporting detailed hydrologic studies associated with a current NSF funded grant. These data are currently being used to (1) identify sink holes and closed basins that drive hydrologic responses as part of a PhD student's research at Arizona State University; (2) support analyses using additional LiDAR data collected during periods of snow cover as part of a PhD student's research at University of Utah; and (3) assist in determining channel development patterns as part of an MS student's research at USU. Together with other ongoing research in the Logan River watershed, these data will inform efforts to assess the resiliency of water resources in northern Utah and other snow-recharged karst mountainous regions.

Findings/Results

LRO faculty, staff, and students worked with University of Utah collaborators to identify, install, and survey control points that would align the bare earth LiDAR data and the snow-on LiDAR data collected in early 2021. Newly completed research by Brophy

Principal Investigators:

Bethany T. Neilson (PI)
Patrick Strong (Co-PI)

Partners/Collaborators:

Local: Logan City, Cache Water District

State: Utah Division of Water Resources, Utah Division of Water Quality

Federal: USGS Utah Water Science Center

Geographic Areas:

Study Areas: Logan River watershed

Areas Benefited: Utah's most populated areas that depend on mountain precipitation as their primary water source. The information gained and methods developed will also be applicable to the entire state of Utah.

Contacts:

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bethany.neilson@usu.edu

Publications:

Brophy, D.P. 2021. *Testing Methods of Surficial Sinkhole Identification Using Remotely Sensed Data*. All Graduate Plan B and other Reports. 1526. https://digitalcommons.usu.edu/gradreports/1526

(2021) clearly illustrated the need for high-resolution LiDAR data in identifying key areas of recharge in the Logan River basin.

Work Plan FY 21–22

During the coming year, we will support an additional snow-on LiDAR data collection.

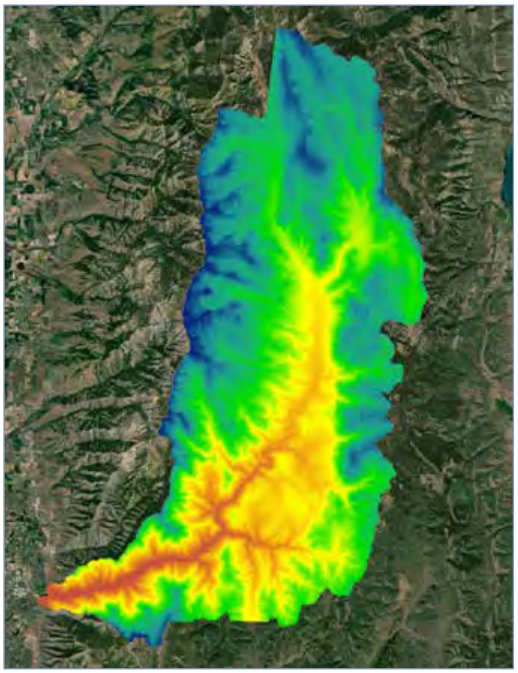

Figure 1: *High-resolution digital elevation model from the Logan Canyon LiDAR flight.*

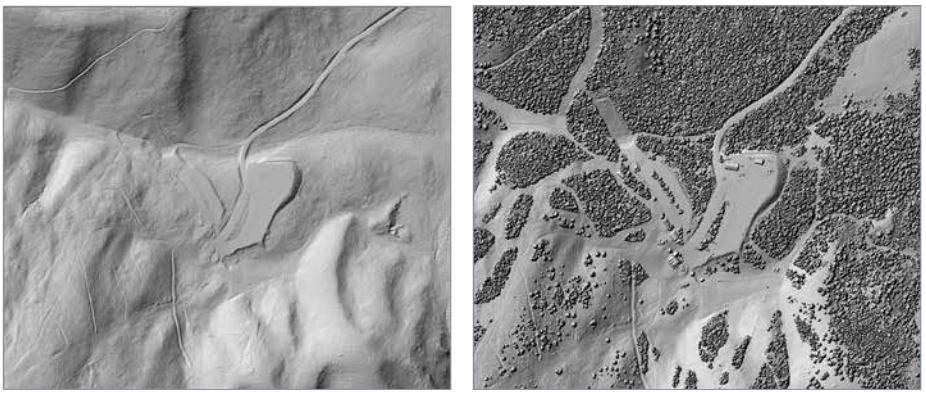

Figure 2: *Bare earth digital elevation model (DEM) (top) and DEM with digital terrain model (bottom) near Beaver Mountain.*

Logan River Observatory

Project Description:

Need and Purpose

In 2012, the National Science Foundation (NSF) awarded $20 million to Utah State University and other Utah universities in an infrastructure grant that established a monitoring network in the Logan River and two other watersheds in Utah. Ongoing NSF support for maintenance and operations of these stations was discontinued when the state of Utah became ineligible for NSF's EPSCoR funding. At that point, the Logan River Observatory (LRO) was established, and the Logan River monitoring network was expanded to include 21 river flow, 8 real-time water quality, and 6 weather stations, making it one of the most highly instrumented watersheds in the U.S. This infrastructure and the associated data position Utah to lead the country in water related research and development of innovative water management approaches in water scarce regions. Through integration of research and teaching and involvement of community members and local and state government entities, this infrastructure can support the critical water management decision making that is now necessary across Utah.

Benefits to the State

Ongoing operation and maintenance of these stations and the data that they provide are critical to water supply and water quality monitoring in northern Utah. The Logan River watershed spans wilderness areas, Forest Service land, and urban and agricultural areas, so the lessons learned and the methods developed for integrating efforts by various levels of government, citizen led organizations, and management entities are highly transferrable to watersheds spanning pristine to rural to urban areas throughout Utah and the western U.S.

The Utah Division of Water Resources plans to use LRO flow and water quality data for water management and potential water development projects within the Logan River basin. These data are also critical for quantifying the water entering the Bear River and eventually the Great Salt Lake. The Utah Division of Water Quality plans to use the data to assess compliance with state water quality standards, determine funding needs for additional stream restoration projects, and identify and address other water quality related problems. The Cache County Water Conservancy District and Logan City are using LRO data to gather information about drinking water source status and protection. The data also inform Logan City's stormwater management efforts. LRO data help the Cache County Water Conservancy District to meet their mission of protecting and managing water resources in Cache County.

Utah State University installed and operates these stations and uses them for teaching, research, and K–12 outreach. The data gathered in the Logan River Observatory are available free to the public online (http://lrodata.usu.edu/).

Principal Investigators:

Bethany T. Neilson (PI)
Tianfang Xu (Co-PI)
Belize Lane (Co-PI)

Students:

Dane Brophy (MS)
Hyrum Tennant (MS)

Partners/Collaborators:

Local: Logan City, Cache Water District

State: Utah Division of Water Resources, Utah Division of Water Quality

Federal: USGS Utah Water Science Center

Geographic Areas:

Study Areas: Logan River watershed

Areas Benefited: Utah's most populated areas that depend on mountain precipitation as their primary water source. Information gained and methods developed are applicable to all of Utah.

Contacts:

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435.797.7369
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Jeffery S. Horsburgh
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jeff.horsburgh@usu.edu

Websites:

https://uwrl.usu.edu/lro/

Publications:

- Neilson, B.T., Strong, P., and Horsburgh, J.S. 2021. *State of the Logan River Watershed*. Report. UWRL, USU, Logan, Utah, USA. https://bit.ly/lro-21
- Neilson, B.T., J.S. Horsburgh, P.A. Strong, H. Tennant, A.S. Jones. 2021. *Logan River Observatory: karst mountainous pristine to valley human impacted.* Spring 2021. Research and Observatory Catchments: The Legacy and the Future Seminar Series. https://bit.ly/karst-bn
- Alger, S.M., Lane, B., Neilson, B.T. 2021. *Combined influences of irrigation diversions and associated subsurface return flows on river temperature in a semi-arid region.* Hydrologic Processes. 35(8), e14283. https://doi.org/10.1002/hyp.14283
- Neilson, B. T., Tennant, H., Strong, P.A., Horsburgh, J.S. 2021. Detailed streamflow data for understanding hydrologic responses in the Logan River Observatory. Hydrologic Processes. 35(8), e14268. https://doi.org/10.1002/hyp.14268
- Tennant, H., B.T. Neilson, M.P. Miller, T. Xu. 2021. *Ungaged inflow and loss patterns in urban and agricultural sub-reaches of the Logan River Observatory.* Hydrological Processes. 35 (e14097). https://doi.org/10.1002/hyp.14097
- Murray, D., B.T. Neilson, J. Brahney. 2021. *Source or Sink? Quantifying beaver pond influence on non-point source pollutant transport in the Intermountain West.* Journal of Environmental Management. 285(12127). https://doi.org/10.1016/j.jenvman.2021.112127

Long-term funding from the Utah Legislature and additional funds from Logan City and the Cache County Water Conservancy District have allowed the LRO to establish strong relationships with many local entities and organizations and created new opportunities to work with local entities, including (1) Cache County Water Conservancy District working with three CEE Senior Design groups to determine the feasibility of future water development projects and alternative diversion structure strategies; (2) Logan City to as they anticipate water availability changes in the Logan River from changing snow patterns (related NSF research grant); (3) Logan River Task Force to determine methods for invasive tree removal along the lower Logan River (Figure 1); (4) various Logan River stakeholders to determine appropriate minimum instream flowrates to maintain instream temperatures when redesigning a primary diversion structure; and (5) canal companies to provide flow rates throughout canal systems and the Logan River.

Findings/Results

We have improved, maintained, and relocated LRO sites to continue informing various ongoing management and research projects. The 0.5-m-resolution LiDAR data finished this year is supporting various ongoing research projects including a snow-on LiDAR project (1 PhD at U of U), a sinkhole and recharge location identification project (1 MS at USU, 1 PhD at ASU), and a channel development project (1 MS at USU). We have also maintained and updated the Logan River Observatory website (http://lro.usu.edu) to ensure we meet end user needs, refined quality control procedures to decrease lag time, and have provided real time flow data online (http://lrodata.usu.edu/). Many faculty, staff and students continue to be involved in the LRO. We are building a growing network of collaborators and encourage faculty to use LRO data in their research and teaching. This past year, 1 NSF proposal was funded that depends significantly on LRO data and infrastructure. An additional NSF proposal is being revised and 4 other USGS proposals have been funded. Two MS theses were published, and other publications are in process.

Work Plan FY 21–22

During the coming year, we will continue data collection to support ongoing research, including refining methods of data collection and dissemination. We will also continue to support new proposals being developed that will focus research efforts on the Logan River watershed and will utilize Logan River Observatory data.

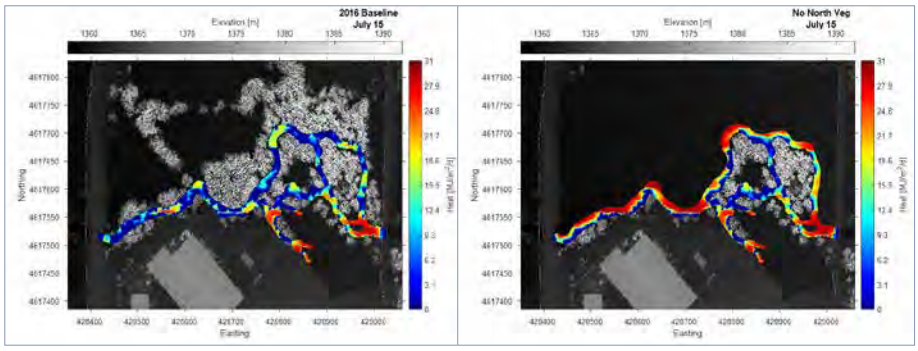

Figure 1: *Analysis of increased solar heating on a section of the Logan River associated with proposed tree removal along the north bank.*

Quantification of Groundwater Influences in High Gradient Utah Streams and Rivers

Project Description:

Need and Purpose

Characterizing groundwater gains and losses in stream and river systems is critical because of their effect on in-stream water quantity and quality. Some modeling approaches indirectly estimate the influence of groundwater sources and sinks on heat and solute transport in rivers. A wide range of data-centric methods are also used to estimate groundwater exchanges. Recent groundwater exchange studies in northern Utah have focused efforts on smaller scale reaches using a wide variety of data types, but a need also exists for a broader, variable scale investigation of groundwater gains and losses along fast flowing high-gradient streams and river systems.

Benefits to the State

This research has an overall focus on analyzing existing flow and chemical data collected throughout northern Utah streams. The study aims to quantify groundwater influences in pristine mountainous and human impacted urban portions of each watershed. Detailed flow, temperature, and chemistry data have been gathered in the Logan River starting in 2014 and in the Blacksmith Fork starting in 2018 over various spatial scales and flow conditions. These data are available along the main-stem as well as tributary inflows and diversions. In the Logan River, many sampling efforts collected both chemical and flow data to combine flow and chemical mass balances and estimate groundwater contributions to surface water. Time series data from a subset of locations in each watershed also provide fundamental information regarding temporal variability of exchanges. The results of this research will contribute to better management of local water quantity and quality.

Findings/Results

Previous research used flow and mass balances to quantify karst and matrix groundwater in gaining, losing, and simultaneously gaining/losing reaches within the upper portion of the Logan River watershed (see Neilson et al. 2018 for details). Building on these methods and recent data collection (flow, chemistry and temperature), Tennant (2021) and Tennant et al. (2021) established new methods for determining surface and groundwater flow sources and quantities contributing to the urban and agricultural portions of the Logan River during summer, low flow conditions. Efforts to further our understanding of karst mountain recharge and discharge continue as we investigate the variability in precipitation and snow accumulation throughout the Logan River watershed and the relationship to flow in the Logan River each year (Xu et al., in revision).

Principal Investigators:

Bethany T. Neilson (PI)
Tianfang Xu (Co-PI)
Belize Lane (Co-PI)

Students:

Hyrum Tennant (MS)
Timothy Clark (MS)

Partners/Collaborators:

Local: Logan River Observatory, Cache Water District, Logan City

State: USGS Utah Water Science Center, Utah Division of Water Resources

Federal: National Science Foundation, USGS

Geographic Areas:

Study Areas: Logan River, Logan, UT and Blacksmith Fork, UT

Areas Benefited: This research will directly benefit the most populated portions of Utah, but the information gained and methods developed should be applicable to the entire state.

Contacts:

Bethany T. Neilson
435.797.7369
bethany.neilson@usu.edu

We are using a combination of different process-based models, machine learning approaches, and field sampling methods to understand linkages between snow and river baseflow. An NSF proposal was funded in March 2021 and 5 new graduate students are starting on this research.
In the Blacksmith Fork, we continued to collect flow and temperature data to determine how irrigation canals influence groundwater recharge to dewatered sections of rivers below diversions. We have found that groundwater seeps linked to adjacent canal systems that recharge shallow groundwater are critical to maintaining temperatures in river sections below irrigation diversions (Alger et al. 2021). An additional NSF proposal is being revised to fund future efforts along these lines, and work has begun with various stakeholders to investigate methods for improving instream flow, water temperatures, and fish passage.

These unique approaches and data sets provide multiple methods for understanding complicated groundwater interactions in karst mountain watersheds, complex urban area influences on rivers, and rivers dewatered by irrigation diversions. Many conference and seminar presentations about these findings have been given over the years. Over the last year 3 PhD and 5 MS students have been working on various aspects of these projects.

Work Plan FY 21–22

Many conference presentations and journal articles are in progress based on these efforts. Four MS students have recently completed their research and degrees focused on this area. One student is finalizing his MS work focused on analyzing the hydrologic responses to changes in precipitation and snow patterns in the Logan and Blacksmith Fork rivers. Five new students at three different universities are now starting their research associated with the Logan River surface and groundwater connectivity.

Work requested by the Logan River Task Force and local canal companies is also ongoing to support decision making and understand diversions and water movement throughout the urban and agricultural portion of the Logan River.

Figure 1: *Hyrum Tennant and Daniel Thurber sampling a spring in Franklin Basin along the Logan River.*

Publications:

- Neilson, B.T., J.S. Horsburgh, P.A. Strong, H. Tennant, A.S. Jones 2021. *Logan River Observatory: karst mountainous pristine to valley human impacted*. Spring 2021. Research and Observatory Catchments: The Legacy and the Future Seminar Series. https://bit.ly/karst-bn
- Alger, S. M., Lane, B., Neilson, B. T. 2021. *Combined influences of irrigation diversions and associated subsurface return flows on river temperature in a semi-arid region*. Hydrologic Processes. 35(8), e14283. https://doi.org/10.1002/hyp.14283
- Neilson, B.T., Tennant, H., Strong, P.A., Horsburgh, J.S. 2021. *Detailed streamflow data for understanding hydrologic responses in the Logan River Observatory*. Hydrologic Processes. 35(8), e14268. https://doi.org/10.1002/hyp.14268
- Tennant, H., B.T. Neilson, M.P. Miller, T. Xu. 2021. *Ungaged inflow and loss patterns in urban and agricultural sub-reaches of the Logan River Observatory*. Hydrological Processes. 35 (e14097). https://doi.org/10.1002/hyp.14097
- Two graduate students published theses: Hyrum Tennant (2021), and Timothy Clark (2020); and other papers are in process.

Logan City Stormwater Monitoring

Project Description:

Need and Purpose

As part of Logan City's regular stormwater sampling program and USU's ongoing water quality research in urban stormwater systems within Logan City, USU is assisting Logan City in collecting and interpreting flow and water quality monitoring data within the Logan River and related stormwater conveyances. Because of the historical role of agriculture in this area and the availability of agricultural water conveyances within the city, Logan City's stormwater collection system was designed to collect stormwater within irrigation canals throughout Logan City, which then convey stormwater downstream to Cutler Reservoir. This combined use system is relatively common in the State of Utah and the intermountain west and requires monitoring of combined irrigation and stormwater to assess the impacts that stormwater may have on the quality of delivered irrigation water and downstream waterbodies.

Benefits to the State

This project provides continued expansion of Logan River Observatory monitoring efforts into urban and agricultural environments. It provides a demonstration of how continuous monitoring and stormwater sampling data can provide increased understanding of the functioning of combined urban/agricultural water systems. The cyberinfrastructure and data dissemination protocols we have developed can be adapted as needed to ensure these approaches can be transferred to other small cities across Utah.

Findings/Results

In prior years we assisted Logan City in the design, purchase, and installation of continuous flow and water quality monitoring stations in the Northwest Field and South Benson canals. We coordinated with Logan City's flow structure installation at these locations and have installed continuous monitoring equipment and telemetry. We have also installed storm monitoring equipment at these locations and at the Utah Water Research Laboratory (UWRL) Logan River Observatory station. This year, we moved a sampling location upstream to South Benson Canal along 600 West to avoid issues encountered at the original sampling location.

In 2020–2021, we collected continuous sensor data and discrete water quality samples (baseline and storm event sampling) during the irrigation season (Table 1). Grab samples from these storm events show varied responses, with the highest concentrations of biochemical oxygen demand (BOD), total phosphorus, and E. coli often occurring at the Northwest Field

Principal Investigators:

Bethany T. Neilson (PI)
Jeffery S. Horsburgh (Co-PI)

Partners/Collaborators:

Local: Logan City, Paul Lindhart, Bill Young

Geographic Areas:

Study Areas: Canals within Logan City

Areas Benefited: Logan City, Cache County, and other areas of the state with similar stormwater systems

Contacts:

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Jeff Horsburgh
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Datasets:

Data are available for this work at the following links:

- Logan River at UWRL, http://lrodata.usu.edu/site/LR_WaterLab_AA
- Northwest Field Canal, http://lrodata.usu.edu/site/NWF_1600N_CNL
- South Benson Canal, http://lrodata.usu.edu/site/SLB_600W_CNL

(NWF) Canal site. BOD at the UWRL is typically below the detection limit, and can be below detection limit at the other sampling locations. BOD samples above the detection limit in the canals ranged from 6 to 41 mg/L at the NWF canal and 5 to 18 mg/L at the South Logan Benson Canal near the pumping station. Total phosphorus concentrations ranged from non-detect to 0.05 mg/L at the UWRL, from 0.01 to 0.31 mg/L at the NWF Canal, and from 0.04 to 0.16 mg/L at South Logan Benson near the pumping station. E. coli ranged from 1 to 240 org/100 mL at the UWRL and from 96 to >2400 org/100mL at both canal sites.

Table 1: *Summary sample event timing, precipitation totals, background flows at the UWRL, and flows at the Northwest Field Canal sampling location.*

Sampling Date	Sampling Begin Time	Sample Duration	Total Precip* (cm)	Pre-event UWRL Flow (cms)	Peak-event UWRL Flow (cms)	Pre-event NWF Flow (cms)	Peak-event NWF Flow (cms)
7/28/202	16:30	6:00	0.2	2.92	3.23	0.71	1.45
8/26/2020	0:00	5:00	0.37	2.48	2.56	0.78	1.76
9/19/2020	8:00	10:45	0.5	2.41	2.5	0.07	1.05
10/11/2020	0:00	9:30	0.71	2.49	2.92	0.43	1.32
5/22/21	22:30	23:15	0.3	5.3	5.5	0.44	0.72

** Totals are based on data collected at the Logan River Observatory Climate Station at Logan River Golf Course (http://lrodata.usu.edu/site/LR_GC_C).*

We continue to work with Logan City to analyze monitoring results and determine future monitoring efforts that will develop advanced understanding of hydrologic and water quality processes within Logan City and assist Logan City with their stormwater management efforts.

Work Plan FY 21–22

We plan to continue work with Logan City to develop routine monitoring protocols, operate existing flow and water quality monitoring sites and equipment, interpret data, and establish new monitoring sites as needed.

Adapt Lake Powell and Lake Mead Releases to Inflow to Give Managers More Flexibility to Slow Draw Down

Project Description:

Need and Purpose

As a 20-year Colorado River drought continues, Lake Powell and Lake Mead continue to draw down (Figure 1, left). How will reservoir inflows, releases, and additional water conservation efforts beyond mandatory targets speed or slow reservoir draw down, stabilization, and recovery? How do managers adapt releases to inflow?

Benefits to the State

This work seeks to provoke thought and discussion about negotiations of new operations for a combined Lake Powell-Lake Mead system: more specifically, how to convert a shrinking pie (lose-lose) water conflict—the Colorado River basin becoming more arid—into more positive processes for people and endangered fish? Key benefits for combined management include the following:

- Gives each party more flexibility to make their individual water consumption, conservation, and reservoir storage decisions independent of other parties
- Adapts reservoir releases to inflow to give parties more flexibility to conserve water, slow draw down to protection volumes, and reduce sudden, unanticipated draw down
- Allows parties to manage all available water not just prior conserved water
- Allows parties to access stored water and have more flexibility to protect temperature needs of endangered Grand Canyon fish (Figure 2).

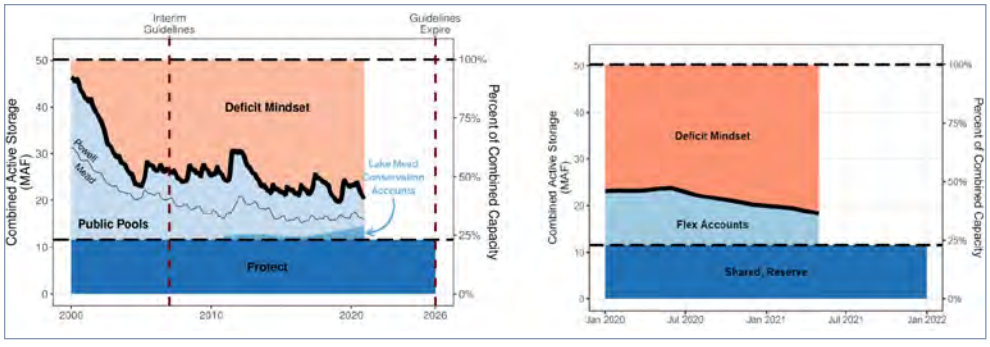

Figure 1: *Combined Lake Powell-Lake Mead storage. Convert reservoir conservation accounts and public pools (left, current operations) into individual flex accounts that give parties more flexibility to conserve and consume independent of other parties (right).*

Principal Investigators:

David E. Rosenberg (PI)

Students:

Jian Wang (postdoc)
Mozzam Rind (MS)

Partners/Collaborators:

Federal: Clayton Palmer, Brent Oseik, Western Area Power Administration

Theodore Kennedy, U.S. Geological Survey

Federal/State/Local: 16 managers and experts from across the basin

Business/Industry: Kevin Wheeler, Water Balance Consulting

Geographic Areas:

Study Areas: Portions of Daggett, Duchesne, Uintah, Carbon, Emery, Grand, Wayne, Garfield, Kane, and San Juan counties, Utah within the Colorado River basin. Also portions of Wyoming, Colorado, New Mexico, Arizona, California, Nevada, and northern Mexico

Areas Benefited: Municipal and agricultural water provides throughout Utah

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Publications:

- Wang, J., and Rosenberg, D. E. 2021. *Living within our Means: Adapting Colorado River Basin depletions to available water.* Submitted to Journal of Water Resources Planning and Management. https://digitalcommons.usu.edu/water_pubs/171/ and https://doi.org/10.5281/zenodo.5502196
- Rosenberg, D. E. 2021. Adapt *Lake Mead releases to inflow to give managers more flexibility to slow reservoir draw down.* Utah State University, Logan, Utah. https://digitalcommons.usu.edu/water_pubs/170/
- Rosenberg, D. E. 2021. *Invest in Farm Water Conservation to Curtail Buy and Dry.* 169, Utah State University, Logan, Utah. https://digitalcommons.usu.edu/water_pubs/169/

Datasets:

Rosenberg, D. E. 2021. *Colorado River Coding.* https://doi.org/10.5281/zenodo.5522835

Findings/Results

- Adapting basin wide depletions to inflows can lower Lake Powell release temperatures and provide more certainty for endangered fish of the Grand Canyon (Figure 2).
- Triggering the new adaptive rule at Lake Mead elevation of 1,060 feet can sustain both reservoirs above their critical levels for longer than current operations.
- When triggering, Lower and Upper Basin users conserve from 0.5 maf per year less to 1.0 maf per year more water than the largest mandatory cutback of 1.375 maf per year.
- Open source interactive and simulation models allow parties to explore adaptive strategies under different basin flows.

Work Plan FY 21–22

- Continue to solicit manager feedback for combined Lake Powell-Lake Mead system operations and update the interactive model.
- Finalize work to quantify tradeoffs between Glen Canyon Dam releases for hydropower and aquatic invertebrates of the Grand Canyon.
- Seek funding for further work.

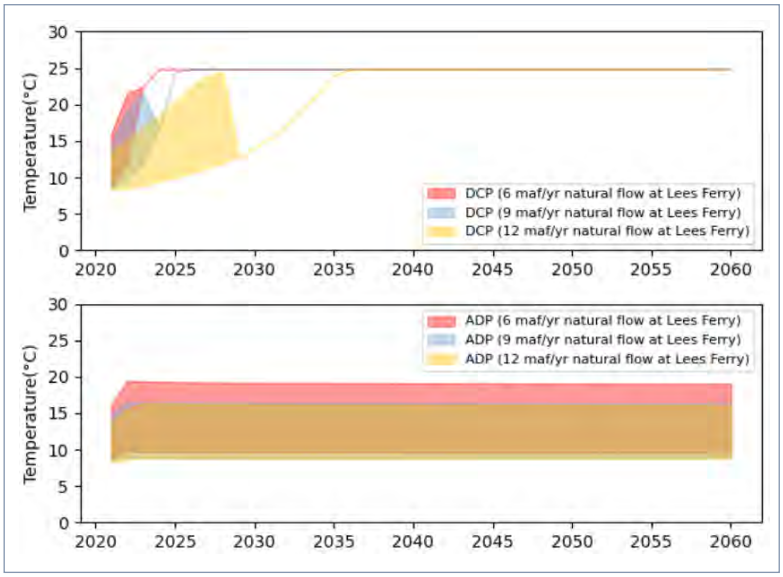

Figure 2: *Adapt basin depletions to inflows (bottom) to lower Glen Canyon Dam release water temperatures and provide more certainty for Grand Canyon endangered fish compared to current operations (top).*

Targeted Water Conservation using Nonparametric Ranking and Behavioral Psychology

Project Description:

Need and Purpose

Water conservation can help extend limited existing surface and groundwater supplies to accommodate future population growth or carry a utility through a drought. Utah's legislature and governor have recognized the importance of water conservation and have set targets to reduce average per-capita water use by 25% by 2025. Initial education and awareness efforts such as "Slow the Flow" have reduced per-capita water use over the past decade, yet questions remain regarding what exactly caused the reduced use, whether reductions can persist, which users to target to save the most water, and how to reach users so they will act. Targeting exploits differences (heterogeneities) among users and should consider a user's overall water use (rank), behaviors (such as duration of showers or landscape irrigation), installed technologies (such as flow or flush rates of showers and toilets), and opportunities to conserve. Utah water utilities can benefit from better tools to help them group, target, and communicate with customers to reduce use.

Benefits to the State

Research to target customers with the most potential to conserve can increase water volume saved while reducing water utility program costs and staff time. Households must have a positive attitude, support from peers, and opportunities to conserve water. Tools to target users with the most potential to conserve can help utilities plan for droughts or future growth. Using and extending tools to target users can reduce drought costs and decrease the likelihood that customers will face costly cutbacks through droughts.

Findings/Results

- Using the Residential End Uses of Water national data set (DeOreo et al, 2016), we ranked households by their ability to save water through appliance retrofits and behavior changes (Figure 1). Twenty-five percent of the population can save ~13,000 gallons per day or half the maximum daily volume if all households conserve. Retrofitting toilets is a prime action.
- We developed customized messages to encourage households to adopt conservation actions (Figure 2). The message identifies end uses of water where the household does well and opportunities for improvement. These messages help users compare their use to other households (peer-pressure), show where the household is doing better than other households (perceived control), and provide household specific messages (social marketing).

Principal Investigators:

David E. Rosenberg (PI)

Students:

Mahmuder Aveek (??)
Ryan James (??)

Geographic Areas:

Study Areas: Cache County, Utah, and counties throughout Utah

Areas Benefited: Municipal water providers and residential users statewide in all counties

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Publications:

Ryan James's thesis was submitted for publication in the journal Earth's Future and another paper based on his work was submitted for publication.

Work Plan FY 21–22

We will complete the analysis for outdoor water use, modify messages to include feedback from colleagues, and complete the study.

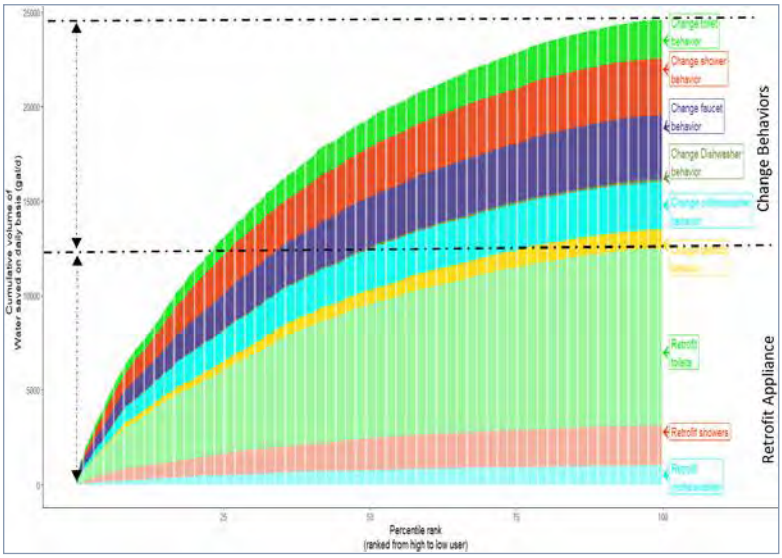

Figure 1: *Cumulative conservation potential of the REU-2016 households by changing behavior (dark fill) or by changing existing inefficient appliances (light fill).*

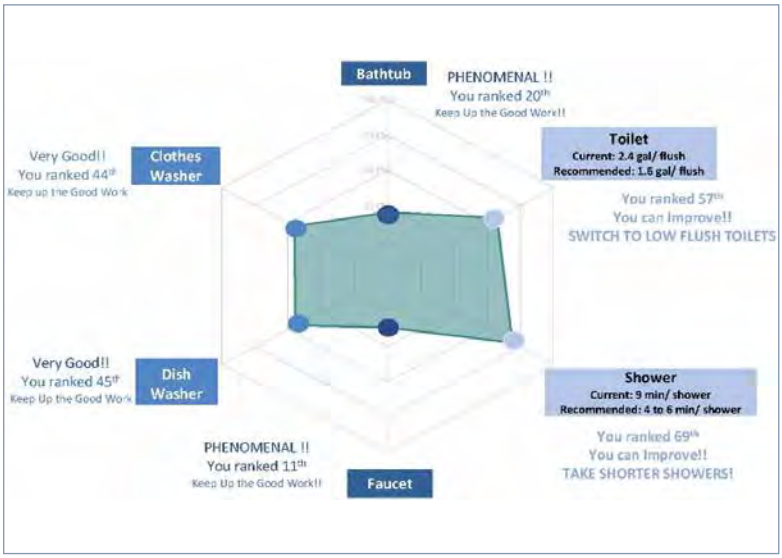

Figure 2: *Part of a communication to customers that shows water use for 6 appliances and suggestions to improve.*

The Future Hydrology of the Colorado River Basin

Project Description:

Need and Purpose

Long-range planning of the Colorado River water supply requires assessments of the impact from continuation of the current drought that began in 2000, the impact of potentially extreme future droughts, and the long-term and progressive decline in watershed runoff caused by a warming climate. This study is quantitatively deriving a set of drought scenarios that characterize plausible future Colorado River droughts to be considered in planning for the future.

Benefits to the State

The Colorado River Basin drains much of Utah, and under the Colorado River Compact and other elements of the Law of the Colorado River, Utah is one of the upper basin states apportioned a fraction of the Colorado River water. This water is used in the Wasatch front via the Central Utah Project, and elsewhere. Secure water supply planning for Utah requires an understanding of the availability and variability of future streamflow in the Colorado River.

Findings/Results

To evaluate the severity of sustained droughts, we advanced a new methodology based on calculating sequence-average and cumulative depletions relative to the natural flow mean. We identified the most severe droughts of the past 600 years from observed and tree-ring reconstructed streamflow at Lees Ferry, the Colorado River stream gaging site just below Lake Powell, which is used for Colorado River planning and management. Three past droughts stand out in the record of prior flows. The millennium drought from 2000–2018 (and ongoing), is characterized by a water year average flow of 12.44 maf/yr, significantly below the 1906–2018 mean of 14.76 maf/yr. This leads to a 19-year cumulative deficit of 44 maf, close to the total storage in the Colorado system. The mid-20th century drought from 1953–1977 has a water year average flow of 12.89 maf/yr. Both of these droughts from the historical record have potential for recurrence and should be planned for. Tree-ring reconstructions of streamflow serve to extend the observable record and provide evidence of multiple severe sustained droughts in the past. The paleo tree-ring drought from 1576–1600 had an average flow of 11.76 maf/yr, notably lower than the historical droughts, and is representative of extreme droughts that occur naturally within the Colorado River Basin.

We developed and implemented a way to incorporate these estimates of future drought at Lees Ferry into the Colorado River Simulation System (CRSS). This required development of a disaggregation method to estimate conditions at every input node of CRSS, and the results provide a quantitatively derived set of drought scenario inputs that can be used by any stakeholder proficient

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David Rosenberg (PI)
Jack Schmidt (PI - Center for Colorado River Studies and Watershed Sciences, Utah State University)

Students:

Homa Salehabadi (PhD)
Sara Goeking (PhD, Watershed Sciences)

Partners/Collaborators:

Local: Eric Kuhn (retired general manager of the Colorado River Water Conservation District)

Academic: Brad Udall (Colorado State University)

Business/Industry: Kevin Wheeler (Water Balance Consulting)

Geographic Areas:

Study Areas: The Colorado River Basin, which overlaps into Daggett, Duchesne, Uintah, Carbon, Emery, Grand, Wayne, Garfield, Kane and San Juan counties in Utah as well as portions of the nearby states of Wyoming, Colorado, New Mexico, Arizona, California and Nevada

Areas Benefited: Agricultural and Municipal water users and providers throughout Utah

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Publications:

Salehabadi, H., D. Tarboton, E. Kuhn, B. Udall, K. Wheeler, D. Rosenberg, S. Goeking and J. C. Schmidt, (2020), *The Future Hydrology of the Colorado River Basin, Center for Colorado River Studies, White Paper 4,* Utah State University, https://qcnr.usu.edu/coloradoriver/news/WP4_Announce

Websites:

Center for Colorado River Studies, Future of the Colorado River Project, Publications: https://qcnr.usu.edu/coloradoriver/futures

Datasets:

Salehabadi, H. and D. Tarboton, (2020), *Data Collection to Supplement the Future Hydrology of the Colorado River Basin Study*, HydroShare, http://www.hydroshare.org/resource/6d351874f16947609eab585a81c3c60d

in CRSS, or any other model of the Colorado system, to analyze current risks or alternative management paradigms that might be useful in confronting future drought. We also provided one example of the stresses that a severe sustained drought would place on the Colorado River system by using the CRSS model and our estimates of future droughts to evaluate the frequency of Lake Powell elevations declining below a critical threshold if "business as usual" water management were pursued during a severe drought. The scenarios we developed indicated that, during long periods, Lake Powell pool elevations would fall below the level required to produce hydropower. Thus, new strategies and plans will be necessary to confront the challenge of severe future droughts.

Work Plan FY 21–22

Analysis of the three drought scenarios identified is complete. However, the approach used and drought scenarios developed are one set among many being developed and advanced by researchers working on Colorado River planning. The US Bureau of Reclamation, primarily responsible for Colorado River operation has identified a need to establish metrics to categorize the many hydrology scenarios advanced for use in Colorado River basin planning applications. A collaborative project with Reclamation will analyze the various current hydrology scenarios and generate additional scenarios for different planning time horizons that support drought response and climate change preparedness. To address these needs, we will develop (1) an analytical framework for characterizing hydrology scenarios, (2) a rigorous process for establishing suitability of scenarios to meet specific planning needs, (3) new scenarios to meet planning needs, and (4) innovative analyses for exploring system risks.

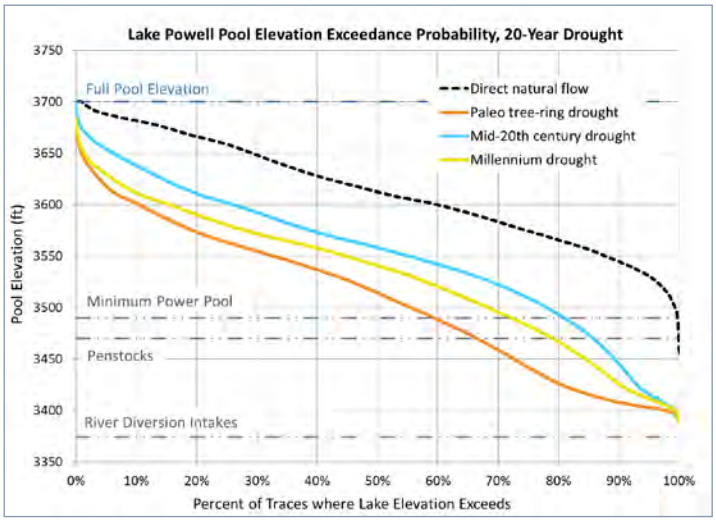

Figure 1: *Distributions of Lake Powell pool elevation modeled in CRSS using the drought scenarios developed. These simulations start from current reservoir levels and assume current "business as usual" Law of the River system operation, showing a considerable probability for periods with Lake Powell at a level below its hydropower penstocks. These results indicate the need for rethinking the management paradigms for operation of these reservoirs in the face of future droughts.*

Evaluating National Water Model Snow Components

Project Description:

Need and Purpose

In many parts of the world, including Utah, snow is a significant component of water resources. The National Oceanic and Atmospheric Administration's (NOAA) National Water Model (NWM) simulates storages and fluxes of the land and atmosphere system across the United States and provides forecasts up to one month ahead. However, the current representation of snowmelt processes in the NWM may be responsible for inaccurate estimation of snow water equivalent in some mountainous regions. This study is evaluating the strengths and limitations of the NWM snow representation by comparing its output to observations made at Snow Telemetry (SNOTEL) sites and satellite measurements of snow cover to identify causes for discrepancies and to research approaches to improve the simulation of snow processes within the NWM.

Benefits to the State

Snowmelt is a dominant source of runoff and water supply in Utah. Water resources decision making relies on water supply forecasts, such as those from National Weather Service River Forecast Centers and, increasingly, the National Water Model, operated by the National Water Center. However, questions have arisen as to the accuracy of output from the NWM and whether its accuracy can be improved and bias reduced. Water supply forecasts are used for irrigation and water resources planning. This work addresses improving our capability to model snowmelt, the major source of water in the state, which then can improve the simulation of streamflow for flood forecasting, water supply, and stream ecosystems. Better streamflow forecasts also advance our understanding of the impacts of water resources development activities, such as around the Great Salt Lake. Planning for potential growth and development in the state requires information on water availability, as well as on the effects of growth on our water resources.

Findings/Results

This study compared the U.S. National Water Model (NWM) reanalysis snow outputs to observed snow water equivalent and snow-covered area fraction (SCAF) at SNOTEL sites across the western U.S. Snow water equivalent (SWE) is the amount of water in the snowpack, quantified as the depth of water that would result if the snowpack were to melt. SWE was obtained from SNOTEL sites, while SCAF was obtained from MODIS satellite observations. We compared results for SNOTEL sites to gridded NWM and MODIS outputs for the grid cells encompassing each SNOTEL site. Differences between modeled and observed SWE were attributed to both model errors

Principal Investigators:

David Tarboton (PI)

Students:

Irene Garousi-Nejad (PhD)

Partners/Collaborators:

National: David Gochis, National Center for Atmospheric Research

Geographic Areas:

Study Areas: The study area is the semi-arid western US, which includes all of Utah.

Areas Benefited: Streamflow and snowpack in watersheds throughout Utah are forecast by the NWM, and water suppliers and users will benefit from improved forecasts due to improvements in NWM snow process representations.

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and errors in inputs, notably precipitation and temperature. The NWM generally under-predicted SWE, partly due to precipitation input differences, and also showed a slight general bias for model input temperature to be cooler than observed, counter to the direction expected to result in under-modeling of SWE. Under-modeling of SWE was also noted in a subset of sites where precipitation inputs were good. Furthermore, the NWM generally tends to melt snow early. The results showed considerable variability between modeled and observed snow-covered area, such that the comparison of snow cover presence or absence hampered useful interpretation of snow-covered area comparisons. These findings identify some challenges in the current snow model and open some new questions for future research. First, they emphasize the importance of more accurate precipitation and air temperature inputs for the NWM. Second, they suggest opportunities for research directed towards improvements in some of the model process representations.

Work Plan FY 21–22

This work is the ongoing dissertation research of Irene Garousi-Nejad. She plans to complete her dissertation during the current year. A paper describing this work is under review for a special issue of the journal Hydrological Processes focusing on the NWM retrospective analysis data comparison. Based on the insights gained in this analysis, ongoing research is evaluating enhancements to the snow processes parameterization in the NWM. Specifically, we are investigating alternative ways to more accurately partition precipitation between rain and snow, which was identified as an area for model improvement.

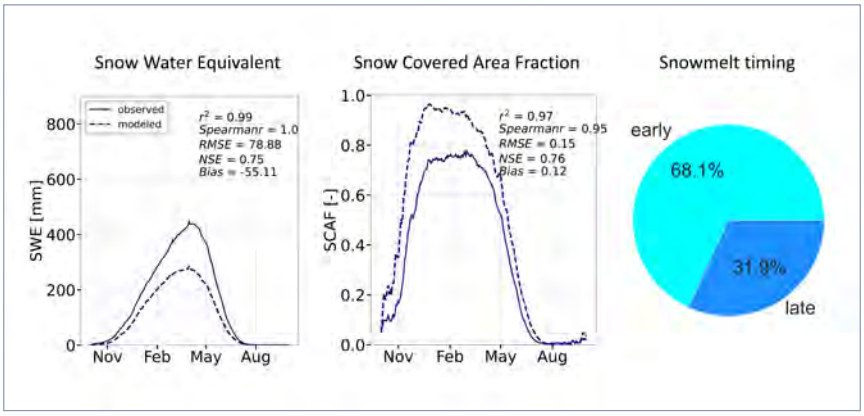

Figure 1: *Observed and modeled snow water equivalent, snow covered area and time when half the peak snow is melted averaged across 734 SNOTEL sites in the western US for the years between 2008 and 2018 with data available. This shows the general tendency of the National Water Model to under predict snow water equivalent and snow-covered area, and to predict earlier than observed snowmelt.*

Publications:

Garousi-Nejad, I. and D. Tarboton, (2021), *A Comparison of National Water Model Retrospective Analysis Snow Outputs at SNOTEL Sites Across the Western U.S.*, Authorea. Submitted to Hydrological Processes, http://doi.org/10.22541/au.161656955.51617798/v1

Datasets:

- Data and codes developed for this research are shared and publicly available as a collection on HydroShare
- Garousi-Nejad, I., & Tarboton, D. (2021a). *Data for a Comparison of National Water Model Retrospective Analysis Snow Outputs at SNOTEL Sites across the Western U.S.* HydroShare. https://www.hydroshare.org/resource/7a51f56c2cf24ae78012ac6a6d4815a6/

Water Use Assessment in Urban Open Areas

Project Description:

Need and Purpose

Urban open areas provide multiple benefits to urban dwellers that range from emotional and physical wellbeing; urban, residential, and cultural/touristic planning; and environmental and hydrological services to the city (e.g., drainage and cooling effects). Challenges related to water scarcity (droughts), elevated summer temperatures (increased irrigation water need), and the increased value of outdoor activities in recent years have emphasized the need for improvements to science and tools beyond existing methodologies and recommendations for water use in urban areas. This work is an initial effort to advance agricultural water use estimation using ground technology (eddy covariance), and remote sensing information (drones and satellites). The project started in 2021 at the Eagles Lake Golf Course, located in Roy, Utah, with the goal of adequately validating and quantifying water use in open areas (dominated by turfgrass and trees) that are prevalent in Utah and in other western US cities.

Benefits to the State

This project will enhance current knowledge on water use in urban green areas as well as explore the use of remote sensing technologies for continuous monitoring. In addition, these efforts support water management education for several Utah State University graduate students to enhance their professional experience upon graduation.

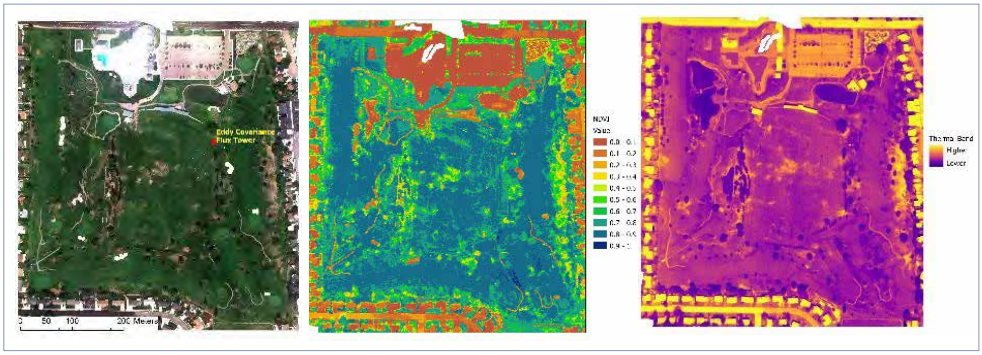

Figure 1: *RGB, NDVI, and thermal band for UAV images on September 3, 2021.*

Principal Investigators:

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Lawrence Hipps (PI)

Students:

Karem Meza (PhD)
Rui Gao (PhD)
Laura Christiansen (MS)
Oliver Hargreaves (MS)

Partners/Collaborators:

Local: Eagles Lake Golf course, Roy, UT

State/National: USDA Agricultural Research Service

Geographic Areas:

Study Areas: Roy, UT

Areas Benefited: Urban green areas and golf courses in Utah and the western US

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Findings/Results

Installation of eddy covariance equipment was completed, and the drone flight was performed. Eddy covariance information is being processed.

Work Plan FY 21–22

The project will continue data collection and analysis, along with preparation of academic manuscripts.

Figure 2: *Flux tower (top) located at Eagles Lake Golf Course (bottom).*

Active Transportation Facilities in Canal Corridors

Project Description:

Need and Purpose

In past years, local governments have been largely unsuccessful at formalizing trails along canal corridors. A variety of challenges have historically impeded these trails, including concerns of liability from the canal company, safety of the trail users, or loss of privacy from adjacent landowners. The informal and often times illegal use of canal corridors for public recreation is widespread in Utah. Some residents incorrectly assume that maintenance roads alongside canals are open to the public. This is made worse by the fact that online map servers such as Google show trails along canals that are actually closed to public access. As development has increased around these canals, unauthorized use has also increased. Most canal companies do not have the manpower or financial means to regularly police their canal corridor which has led to the misconception that public access is permitted. This unmanaged recreational use of the canal corridors has become a real concern for canal companies and local governments alike.

Formalizing the use of canal corridors as public trails is something local governments have been planning to do for decades. The majority of urban cities or counties that utilize larger canals have included canal trails as part of their transportation master plans. These trails are also an essential part of completing the planned trail network. As a result, establishing trails on many of Utah's canal corridors is already anticipated and planned.

Benefits to the State

The state of Utah has an increasing need for active transportation infrastructure, especially in rapidly developing areas across the Wasatch Front. Canal corridors offer ideal locations for siting shared-use paths because they are linear, flat, and have an interlaced presence within communities. The purpose of this study is to summarize the challenges of establishing canal trails and provide valuable insights and tools that can be used to resolve those challenges. In this work, and a report sponsored by the Utah Department of Transportation, reviewed various case studies of past canal trail projects across the state of Utah, interviewed stakeholders for future projects, and synthesized the information into a guide.

Findings/Results

The results of the study (a paper and a UDOT report in preparation) underline the complex nature of establishing trails in canal corridors. The projects are

Principal Investigators:

Patrick Singleton (PI)
Alfonso Torres-Rua (PI)

Students:

Matthew Crump (MS)
Adam Pack (MS)

Partners/Collaborators:

Local: Utah Canal Water Companies (interviewed for this study)

State/National: Utah Department of Transportation

US Department of Transportation Federal Highway Administration

Geographic Areas:

Study Areas: Urban areas of the state, including Cache, Weber, Davis, Salt Lake, and Utah counties, with additional interviews from some rural areas. Canal trails generally have the most impact in developed areas where establishing off-street pathways is more difficult.

Areas Benefited: Most of the Intermountain West region of the United States where canals are a vital part of many communities. Canal trails and the challenges associated with establishing them may vary by state, but many of the tools from the study are beneficial to all.

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Publications:

- *Active Transportation Routes using Canal Corridors: Decision Tools in Creating Successful Canal Trail Project* (under review by American Society of Civil Engineers - Urban Planning Journal, expected date of publication December 2021)
- *Active Transportation Facilities in Canal Corridors*, prepared for the Utah Department of Transportation Research and Innovation Division (in preparation, expected date of publication, December 2021)
- Crump, MS, 2021. *Active Transportation routes using Canal Corridors: Decision tools in Creating Successful Canal Trail Projects*. All Graduate Theses and Dissertations, 8247. https://digitalcommons.usu.edu/etd/8247

typically started by local governments like cities, but in some cases, larger-scale planning and more political capital is needed from counties or MPOs. In other instances, canal companies would be willing to accept a trail if offered assistance with maintenance or infrastructure improvements. The study found that land ownership, maintenance, safety, liability, funding, and privacy are the main stakeholder concerns. Landownership and liability related to canal trails can be complex, with different attorneys having varying opinions on the same issue. Each of these concerns is discussed in detail in the report, including common solutions to overcome them. The main tools used in successful projects in Utah, as reported from interviews, include long-term planning, stakeholder collaboration, iterative design, and active public involvement.

Work Plan FY 21–22

The report and peer-reviewed paper will be delivered to the Utah Department of Transportation.

Figure 1: *Canal trail in Saratoga Springs, UT.*

Section 4

Research Faculty, Professional and Support Staff

Utah Water Research Laboratory and Utah Center for Water Resources Research

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Jeffery S. Horsburgh, Associate Director
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Michael J. McFarland, PhD, Associate Professor, CEE/UWRL
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