MINERAL LEASE FUND REPORT

Utah Water Research Laboratory

Fiscal Year 2013

for

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

by

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Foreword

The Utah Water Research Laboratory (UWRL) located at Utah State University (USU) has been a leader in water and environmental research for over 50 years. The UWRL receives 2¼% of all deposits made to the Mineral Lease Account, "to be used for activities… having as a purpose the development and exploitation of water resources in the State of Utah."

This report is submitted to the Legislature in compliance with House Bill 103 passed during the 1993 General Session. This legislation requires the UWRL to "provide the Legislature, through the Office of the Legislative Fiscal Analyst, with a complete accounting of the use of that money (MLF) on an annual basis." Following the requirements of the legislation, this report presents the following accounting of those funds:

1. Actual expenditures for FY2013

2. Budgeted expenditures for FY2014

3. Planned expenditures for FY2015

As a general overview, the introduction to this report summarizes the role and history of the UWRL.

The activities of the UWRL are organized into research areas with specific projects that address a broad spectrum of high priority water resources needs and issues in the state. This report contains a summary of each project including a statement of the need and purpose, the specific benefits to the citizens of Utah, and areas benefited. The UWRL also seeks to leverage the accomplishments and expand the benefits of these projects through collaboration and partnership with local, state, and federal agencies. As today's water resources management problems become more complex, our internationally renowned faculty and their students are meeting current challenges and finding solutions to tomorrow's water and environmental problems now.

The Community and Economic Development Appropriation Subcommittee of the Legislature reviews this report as part of its normal budgetary process under Title 63, Chapter 38, Budgetary Procedures Act. The UWRL welcomes any comments or questions that result from this review.

Mac McKee
UWRL Director

Table of Contents

Table of Contents

INTRODUCTION

ADMINISTRATION

PROJECT SUMMARIES

Table of Contents

Table of Contents

Table of Contents

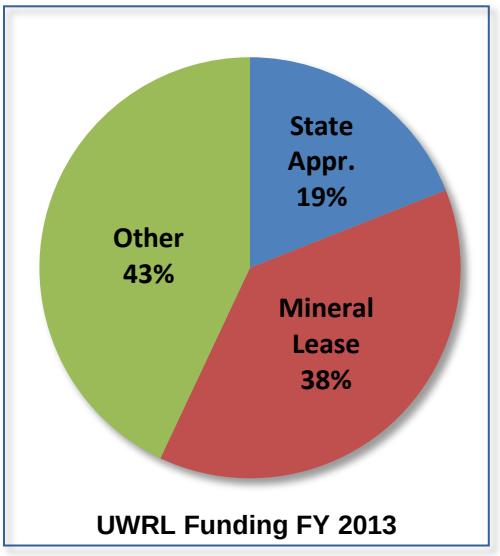
Introduction

Role of the Utah Water Research Laboratory

Research programs of the Utah Water Research Laboratory (UWRL) directly address current and future water resources needs of the state, and are also recognized throughout the nation and the world. The State of Utah provides state-appropriated funds (SAF) and mineral lease funds (MLF) for research support at the UWRL. These funding sources directly target problems facing the State of Utah. In FY 2013, MLF funding of over 3 million accounted for 44% 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 2013 were almost $8 million.

The UWRL's projects are organized into six major research programs:

Drinking Water and Wastewater Treatment
Environmental Quality Management and Remediation
Surface and Groundwater Quality and Quantity
Water Conveyance, Distribution and Control
Water Education and Technology Transfer
Water Resources Planning and Management



These programs are under the direction of engineers and scientists affiliated with the following departments within the College of Engineering:

Civil and Environmental Engineering
- (Environmental and Water Divisions)
Electrical and Computer Engineering
Mechanical and Aerospace Engineering
Biological Engineering
Computer Science

A brief summary of the ongoing work in each of the six research areas is presented at the end of this section.

The UWRL research program related to MLF is very diverse as indicated by the project summaries in this report. The overall research program, funded by both state funds and external contracts and grants, is even broader. We continue to be involved in many field-scale soil and water remediation research projects. At several experimental watersheds, we are investigating hydroclimatological 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 water and environmental managers and professionals in Utah. 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.

In addition to our research role, the UWRL is involved in university graduate and undergraduate education through hands-on projects, part-time employment, and research assistantships, as well as public and professional service, technology and information transfer, and public education. Almost all research and applied projects include graduate student involvements, and result in masters or doctoral

degrees. Undergraduate student involvement in UWRL projects for the purpose of student education and training is also integrated into the basic and applied research programs.

UWRL Student Involvement FY2013

Graduate Students Supported (FY13)	72
Undergraduate Students Supported (FY13)	102

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 is 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.

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. Construction was completed in December 1965, and included one of the best hydraulics laboratories in the United States and a unique erosion testing facility with a large rainfall simulator. Sixteen years later, an extensive remodeling project, including the addition of an environmental quality laboratory was completed. The UWRL completed a new hydraulics modeling and testing laboratory in 2009 to support hydraulics research activities associated with releases from dams in Utah (and related hydraulic phenomena, such as venting) and the design of hydraulic structures in Utah, such as the new irrigation lift stations on Utah Lake. In all, the UWRL has a total of more than 113,000 square feet of state-of-the-art laboratory, computer, and office space.

UWRL Financial/Academic Summary (FY 2013)

Research Products (FY12)	
Number of Active Projects	257
Dollar Value of Active Projects	7,030,792
Scholarly Publications in Peer-Reviewed Journals	93
Scholarly Presentations at Professional Conferences	152
Outreach Products (FY12)	
Short Courses and Field Training	16
Degrees Granted	
Ph.D.	7
MS	30
ME	14

In 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. With total research funding through the UWRL of nearly $8 million, it is one of the largest institutes in the nation. As shown in the table below, it is also highly productive in terms of research publications and graduate student education.

There are currently 30 faculty and 32 support staff at the UWRL. During FY 2013, 36 master's students, 36 doctoral students, and 6 hourly post-doctoral fellows received support from UWRL projects. An additional 73 undergraduate students assisted with UWRL research. UWRL faculty collaborate with colleagues from other USU departments, faculty from other institutions, professionals form the private sector, and government agencies in Utah and elsewhere. Several of our faculty members, including the 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 national and international engineering and science panels and committees.

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 is funded at an annual level of approximately $92,000 of federal funds through the U.S. Geological Survey (USGS). This year, the base grant in combination with MLF directly benefit the State of Utah in areas of (1) developing a capability to evaluate and implement drought indices on a spatial basis for inclusion in a National Integrated Drought Information System (NIDIS) pilot study creating a drought early warning system for the Upper Colorado River Basin; (2) establishing a classification system for low head dams based on the dangers created at various flow conditions and identifying a potential simple solution to eliminate the drowning hazards presented by such dams (3) developing a framework for estimating crop water use using remote sensing through a standardized approach, thus providing guidelines and specifications for applying certain evapotranspiration (ET) models and producing ET products that are acceptable to the USGS WaterSmart program and the scientific and user community; (4) Investigating the value of using AggieAir, a low-cost, high-resolution multispectral remote sensing platform, as a tool to provide accurate and quality spatial data for municipal applications to help manage water and environmental issues in wetland and riparian areas, landfills, and parks and recreation areas; and (5) Designing a public demonstration bioretention basin to increase public awareness and education of bioretention in Utah and to provide data for determining bioretention infiltration rates for semi-arid climates. In the future, the USGS 104 Program will continue to be used to support applied research tools and accomplish information and technology transfer to address Utah's water quantity and quality problems, other source water protection strategies, and development of tools and programs across the State of Utah.

Mineral Lease Fund Expenditures

The table at the beginning of the next section summarizes the actual, budgeted, and planned expenditures of MLF allocated to the UWRL for FY 2012 and FY 2013 in the six major research program areas. A breakdown of these expenditures by individual projects is contained in tables presented at the beginning

of each research program section of this report. UWRL administration and technology transfer expenditures accounts for approximately 7% of total MLF budgeted and planned expenditures in FY 2012 and FY 2013.

Relevancy and Benefits of the Mineral Lease Fund

In more ways than one, Utah is the second driest state in the union. It records only 13 inches of water a year, mostly in the form of winter snowfall, which must then sustain the social, economic, and environmental water needs throughout hot, dry summer periods. As has often been emphasized by our state leaders over the decades, water is indeed the key resource essential to Utah's quality of life and economic vitality. Therefore, it is critically important to protect, manage, and wisely use our precious water for the benefit of Utah's citizens.

Research Program

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

Utah Department of Natural Resources Division of Water Resources State Engineer – Division of Water Rights	**Utah Department of Environmental Quality** Drinking Water Water Quality Solid and Hazardous Waste
State Regulatory and Advisory Committees DEQ Water Quality Board Utah Solid and Hazardous Waste Control DEQ Drinking Water Board	**State Water Associations and Organizations** Utah Center for Water Resources Research (UCWRR) Utah Rural Water User's Association Water Environment Association of Utah Utah League of Cities and Towns Utah On-Site Wastewater Treatment Association (UOWA)
Professional Organizations and Associations American Water Resources Association American Society of Civil Engineers American Water Works Association	**Regional and National Research Alliances** Lake Powell Technical Advisory Committee Universities Council on Water resources (UCOWR) Inland Northwest Research Alliance (INRA) National Institutes for Water Resources (NIWR)

In order to focus research on problems and needs that are both relevant and current, the UWRL engineers and scientists work closely with state and local agencies and are actively involved with and serve on many state and local organizations, committees, and boards. The UWRL Director, Associate Director and most of the faculty meet frequently 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 worked with the following network of organizations over the past fiscal years.

The Utah Center for Water Resources Research (UCWRR) at the UWRL participated as an active member of the National Institutes for Water Resources (NIWR). UWRL faculty members were also active in state sections of professional organizations, and served on state, local, and national committees. Participation in national and international professional water and environmental organizations helps to bring recognition and external project funding to the state, provides opportunities to learn from other research and best practices worldwide, and helps to identify current and future research needs that will affect our state and the nation. This strengthens the UWRL research identification process to maintain the relevancy of our research programs to Utah.

Outreach

The mission of the UWRL includes outreach activities related to public service, information dissemination, technology transfer, and short courses. These activities are provided for the benefit of Utah state and local agencies, elected officials, Utah citizens, and the nation. Outreach is provided by faculty, staff, and students associated with the UWRL. Additional outreach is provided through our World Wide Web (WWW) site: http://uwrl.usu.edu.

Public Service

UWRL faculty members serve on state and local advisory panels to provide technical expertise, input, and review of water-related issues. Specific panels include:

- Drinking Water Board
- Water Treatment Operators Certification Commission
- Salt Lake County Solid Waste Management Council
- Utah State Solid and Hazardous Waste Control Board
- Cache County Solid Waste Advisory Board
- Jordan River Water Quality Technical Advisory Committee (Utah DEQ)
- Willard Spur Science Panel, a panel formed by the Utah Division of Water Quality
- Utah Division of Water Quality, Department of Environmental Quality, Task Force Member,
  R317-4 Onsite Wastewater Systems Stakeholders Workgroup
- Water Environment Association of Utah, Board of Directors and Biosolids Committee
- Logan City Air Quality Task Force
- Bear River Health Dept.'s Air Task Force
- Governor Herbert's Unmanned Aerial Systems Test Site Advisory Board

In addition, UWRL personnel are frequently invited to provide technical and informational presentation before state and national professional groups, such as the American Water Works Association, and

national and international organizations engaged in financing water developments, such as the World Bank.

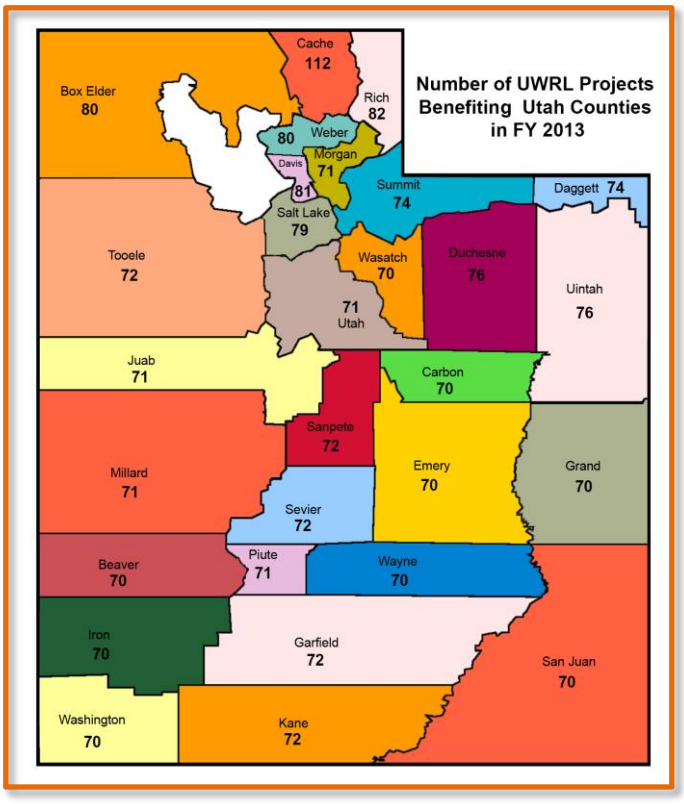
Information Dissemination and Technology Transfer

UWRL information dissemination, outreach, and technology transfer 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, 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 provides a feature article on different research projects, faculty, and students at the UWRL. The Utah On-Site Wastewater Treatment Training Program at the UWRL provides on-site wastewater training in support of the State of Utah certification program for on-site wastewater treatment professionals. Undergraduate and graduate students participate in projects that involve hands-on, real-world activities. Additional information can be found at: http://uwrl.usu.edu/partnerships/training/.

Benefits to the State of Utah

MLF funding is often used as leverage to acquire additional funding from other sources, which allows us to perform even more research in the State. As shown in the map, a significant number of total UWRL projects conducted during the past year that have benefited each of Utah's counties



The following summaries report some of the recent and current benefits produced by MLF funded projects in the UWRL's six program areas, and specific state benefits are detailed in each project summary in subsequent sections of this report.

Drinking Water and Wastewater Treatment

The program is developing engineering approaches for the treatment and production of drinking water and the treatment and reclamation of waste water for recycling and reuse of municipal and industrial wastewater, as well as evaluating the effectiveness of various septage treatment options in Utah environments. Research in this area is also creating new processes for the sustainable production of bioplastics from Utah wastewater.

Environmental Quality Management and Remediation

This program emphasizes an integrated engineering and science approach to environmental quality of land, water, and air. It includes characterization and remedial design approaches for contaminated subsurface environments at laboratory scale along with the largest field scale research of any similar academic program in the nation. Varied research in this area includes bioreactor processing of environmental materials, and engineering scale-up of biologically-based reactions are being developed in diverse areas of specialization including composting, waste reuse, biosolids processing, management of environmental biotransformation, and engineering bioprocess-optimization of wetlands. 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 winter inversions.

Surface and Groundwater Quality and Quantity

This diverse program has strengths in both the theoretical and the applied aspects of surface and groundwater. Surface water research includes modern surface water hydrology, including climate modeling, rainfall processes, snow hydrology, floods, droughts, terminal lake analyses, soil erosion, stream water quality modeling, water-quality management, assessment and control of nonpoint source pollution and storm water, characterization and control of dissolved and particulate natural organic matter (NOM). Current research in the groundwater area ranges from theoretical developments in the stochastic and numerical analysis of pollution transport in groundwater, conventional and toxic contaminants in natural and engineered systems, and the practical aspects of designing technologies to clean up and manage contaminated sites in Utah's aquifer systems. Work is also ongoing in the development of more accurate low-cost water quality sensors.

Water Conveyance, Distribution and Control

This program utilizes UWRL's unique hydraulics laboratories for physical modeling of hydraulic structures, including optimal design for weir structures, hydraulic structures for flood control and flood bypass, testing and evaluating hydraulic machinery and piping systems, and flow meter calibration. Analytical aspects of the program include pipe network designs for water supply, sediment transport, non-contact flow measurement, open channel flow, low-head dam effects, and dam safety risk analysis.

Water Education and Technology Transfer

Several projects conducted by the UWRL, including many that are 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, sometimes to provide technical support to Utah's state and local agencies on water-related issues.

Water Resources Planning and Management

This program area addresses various institutional and legal aspects of water, such as rights transfers, distributed water demand and supply modeling using geographical information systems, and cost

allocation and determination of user fees for multiple purpose water resources projects. Additional areas include reservoir operating policies, water conservation, river basin planning, habitat monitoring and restoration, user-driven decision support systems for water planning, and incorporation of remote sensing technology to improve water resources management.

Administration

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
UWRL Administration

Project Name	FY2013 Actual Expenditures	FY2014 Budgeted Expenditures	FY2015 Planned Expenditures
Business Office	$154,892.41	$159,539.18	$164,325.36
Laboratory Infrastructure Support, Travel and Special Request	$33,847.42	$27,000.00	$27,810.00
Project Management of USGS 104	$13,211.72	$13,608.07	$14,016.31
Publications Office	$58,842.97	$60,608.26	$62,426.51
UWRL Administration	$68,033.58	$70,074.59	$72,176.82
Total	**$328,828.10**	**$330,830.10**	**$340,755.00**

Administration, Advisory Support, and Special Equipment

The numerous projects conducted by faculty and students at the Utah Water Research Laboratory (UWRL) with financial support from the MLF program are administered by the officers of the UWRL. The Director and Associate Director of the UWRL also work to maintain liaison with water planning and management officials across the state. Frequently, faculty from the UWRL are requested for 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, MLF funds are sometimes used to cover expenses required to support these activities until other funding opportunities can be developed. Finally, when a number of Utah-based research needs arise that require specialized equipment that cannot be made available through other means, MLF resources are sometimes used to acquire these items.

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, consistent with the needs of evaluating the productivity of the research supported by MLF funds. Collaboration with water managers and policy makers in state and local agencies identifies where applied research can contribute toward the solution of important water resources problems. MLF money spent on administration at the UWRL provides minimal salary support for the UWRL Director and Associate Director and supports the administration of the USGS 104(b) program funding that comes to the state. FY 2013 administrative costs represented approximately 6% of total UWRL MLF expenditures.

Outreach and Business Support

Overall, annual research expenditures for the UWRL fluctuate between $ 8 and $ 12 million, and at any point in time there will be nearly 300 active research contracts administered at the UWRL. These projects require significant support from the UWRL Business Office in the form of accounting and financial oversight. Further, they benefit from assistance that comes from the UWRL Publications Office, which provides support for outreach activities (such as the production of presentations, maintenance of the UWRL and UCWRR web pages, etc.). MLF expenditures in FY 2013 on these support activities accounted for 1% of total MLF funding.

Advisory Support on Water Problems

The UWRL received many requests in FY 2013 for advice and collaborative help on various water problems in the state. In FY 2013, the UWRL provided support to defray travel costs from MLF sources so UWRL faculty could participate in meetings in the state to coordinate UWRL activities with ongoing water problems, to work to identify and seek funding for new applied research in the state, and to provide expert advice relative to current water management issues faced by various state and local agencies. These activities are enumerated in the project reports section of this document.

Special Equipment

Numerous communities in Utah face problems with the management of soils and aquifers that have been contaminated by hazardous materials. The UWRL is active in providing state-of-the-art scientific input to understand these problems. Similarly, the UWRL is engaged in applied research on the management of contaminants of concern for various municipalities that supply potable water to communities in the state, such as is the case for current research on metals and pharmaceuticals for Park City water supplies and wastewater. The UWRL also tries to maintain an active program of coordination with state agencies such as the Utah Division of Water Rights on problems associated with the operation of safety of dams. Investments in state-of-the-art equipment are sometimes made from MLF resources to support these activities and to provide long-term, sustainable capability to continue these efforts in the state. New equipment acquisition and their integration into research are described in specific project reports.

Research Project Summaries

Research Project Summaries

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:

Drinking Water and Wastewater Treatment

Environmental Quality Management and Remediation

Surface and Groundwater Quality and Quantity

Water Conveyance, Distribution and Control

Water Education and Technology Transfer

Water Resources Planning and Management

Drinking Water and Wastewater Treatment

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Drinking Water and Wastewater Treatment

Project Name	FY2013 Actual Expenditures	FY2014 Budgeted Expenditures	FY2015 Planned Expenditures
Advanced Instrumentation for Environmental Quality Analysis	$371,727.41	$0.00	$0.00
Biological Phosphorous Removal from Lagoon Wastewater: Pilot-Scale Rotating Algae Biofilm Bioreactor (RABR)	$103,582.48	$106,689.95	$87,300.00
Effectiveness of Utah's On-Site System Design: Depth Considerations and Removal of Emerging Contaminants of Concern	$34,685.53	$56,500.00	$55,000.00
Enhancing Methane Production at Water Reclamation Facilities in Utah	$73,987.25	$76,206.87	$0.00
Low Level Hexavalent Chromium (Cr-6) in Drinking Water	$54,014.47	$56,000.00	$0.00
Managing Drinking Water Quality in Park City	$97,792.37	$115,740.00	$0.00
Mitigation of Methane Emissions from septic Systems	$53,406.79	$70,000.00	$71,000.00
Producing Bioplastic Materials Using Microbe-Based Processes	$10,525.79	$37,500.00	$0.00
State of Utah Drinking Water Board	$1,000.00	$1,050.00	$1,100.00
Designated Projects		$227,740.00	$15,400.00
Undesignated research projects in program area		$63,000.00	$10,000.00
Total	**$800,722.09**	**$810,426.82**	**$239,800.00**

Advanced Instrumentation for Environmental Quality Analysis

Principal Investigators:
Craig D. Adams
William J. Doucette
R. Ryan Dupont
Randal Martin
Joan E. McLean
Laurie S. McNeill
Darwin L. Sorensen
David K. Stevens
Joe Stewart

Partners/Collaborators:
Local: *All UWRL Environmental Quality Projects*

Project Description

- **Need and Purpose:**

  The Environmental Quality Laboratory (EQL) of the Utah Water Research Laboratory (UWRL) is involved with the identification and quantification of inorganic and organic compounds and biological entities in environmental field samples or in samples derived from various laboratory and pilot scale experiments. Methods for the analysis of samples obtained from soil, water, air, biota and other environmental media are developed using a variety of state of the art instrumentation. The EQL also utilizes advanced equipment for the collection and processing of environmental samples prior to analysis. Major instrumentation and equipment available to researchers working at the EQL include:

  - High performance liquid chromatography/mass spectrometry (LC/MS).
  - High performance liquid chromatography (HPLC) with diode array and evaporative light scattering detectors.
  - Gas chromatography/mass spectrometry (GC/MS) with electron impact (EI) and chemical ionization (CI) ion sources and thermal desorption, SPME and headspace autosamplers.
  - Accelerated Solvent Extractor and solvent concentrator.
  - Inductively Coupled Plasma-Mass Spectrometer (ICP-MS).
  - Atomic Absorption Spectrometer, equipped with flame (FAA), Zeeman corrected graphite furnace (GFAA) and mercury/hydride atomizers (MHAA).
  - Ion chromatography with electrical conductivity detector and UV/Vis absorption detectors.
  - Automated Discrete Wet Chemistry Analyzer.
  - Anaerobic, hydrogen-free glove bags and incubation chambers.
  - Real Time and Standard PCR.
  - Microscopes with phase-contrast and epifluorescence capability.

- **Benefits to the State:**

  The analytical methods developed are used for the analysis of samples collected from various sites in Utah in support of projects involved with surface water, ground water, soil and air quality monitoring and remediation.

- **Geographic Areas:**

  Study Area: State of Utah.

  Areas Benefited: Projects needing analytical support are generated statewide, so all counties in the state would potentially benefit.

Informational Resources

Contact: Dr. Craig D. Adams, Phone (435) 797 9115, E-mail: craig.adams@usu.edu.

New Triple-Quad GC/MS for Organic Analysis

Biological Phosphorus Removal from Lagoon Wastewater: Pilot-Scale Rotating Algae Biofilm Bioreactor (RABR)

Principal Investigators:
Ronald C. Sims
Charles Miller
Terence Smith
Chad Nielson

Partners/Collaborators:
Local: *Issa Hamud, City of Logan*
State: *Ed Macauley, UDEQ*
Business/Industry: *WesTech, Inc.*

Project Description

- **Need and Purpose:**

  In order to meet total maximum daily load (TMDL) established by the State of Utah and to prevent pollution of Cutler Reservation, Logan City is required to remove phosphorus from wastewater leaving the Logan Lagoons treatment plant. In order to upgrade the current lagoons system, a biological-based engineering technology that accomplishes phosphorus removal to 1 mg/L or less could save in excess of $40 million compared with the installation of a mechanical plant. A new technology, which is based on the uptake of phosphorus by algae grown as a biofilm, is being tested to determine if the technology can meet the TMDL standard of 1 mg/L.

- **Benefits to the State:**

  New engineering jobs and services in Utah based on the biofilm technology will boost economic growth and allow other communities using lagoons to upgrade treatment to meet standards at low costs (fees) to the communities. The new technology will also enable the Utah Department of Environmental Quality to reduce the amount of support in the form of loans and grants to communities for upgrades to wastewater reclamation facilities utilizing lagoon treatment systems.

- **Geographic Areas:**

  Study Area: A Northern Utah region that includes the cities of Logan, Hyde Park, Smithfield, North Logan, River Heights, Providence, Nibley, and Utah State University.

  Areas Benefited: All areas of the state of Utah that utilize ponds or lagoons for the treatment of wastewater, which includes Northern, Central, and Southern Utah.

- **Accomplishments:**

  Findings: The Rotating Algae Biofilm Reactor (RABR) that was previously utilized and described in the 2012 report was redesigned to double the amount of surface area for algae growth per volume of wastewater treated in an effort to improve phosphorus removal from the wastewater. The enhanced RABR (Figure 1) successfully removed phosphorus to levels below 1 mg/L. The redesigned RABR also enhanced algae biomass growth, which can be used as feedstock for other biological processes to transform algae constituents into value bioproducts including bioplastics and biofuels.

  Results: A combination of algae uptake of phosphorus from the wastewater and an increase in wastewater pH due to algae growth resulted in a reduction in the phosphorus concentration in

the wastewater to levels below the TMDL standard of 1 mg/L. The enhanced RABR with additional surface area for algae growth and uptake of phosphorus into the algae biofilm and out of the wastewater is shown Figure 1. Algae growth was demonstrated in spring and summer seasons, and reflected sunlight of lower intensity on the inside of the RABRs resulted in growth equivalent to that observed on the outside that received direct sunlight.

A plastic cover was constructed over the enhanced RABR in order to reduce the high levels of toxic sunlight that impact the algae during the summer months, and also to provide a greenhouse effect that will increase the temperature of the biofilm and water during the winter months. The plastic cover reduced the light intensity impacting the algae biofilm surface by 30%. The effect of the cover on continued algae growth and wastewater treatment in winter months will be determined this coming winter.

Figure 1. Rotating Algae Biofilm Reactor (RABR) with increased surface area for algae growth and increased phosphorus removal from Logan City Wastewater Treatment Lagoons wastewater.

Work Plan FY13/FY14

Future research will include evaluating reactor performance in the winter season, and mathematical modeling of biofilm growth and performance.

Informational Resources

Contact: Mr. Issa Hamud, Director, Logan City Environmental Dept., Phone (435) 716-9752, E-mail: issa.hamud@loganutah.org.

Publications:

Smith, T., Y. Sobah, K. Sims, I. Hamud, R. Thompson, M. Kesaano, and R.C. Sims (2013). Sustainable Nutrient Management and Biogas Production from Domestic Wastewater with the Rotating Algal Biofilm Reactor. *International Biomass Conference and Expo*. April 7-10, Minneapolis, MN.

Effectiveness of Utah's On-Site System Design: Depth Considerations and Removal of Emerging Contaminants of Concern

Principal Investigators:
Judith L. Sims
James Beardall (Student)

Partners/Collaborators:
Local: *Richard Worley, Bear River Health Department*

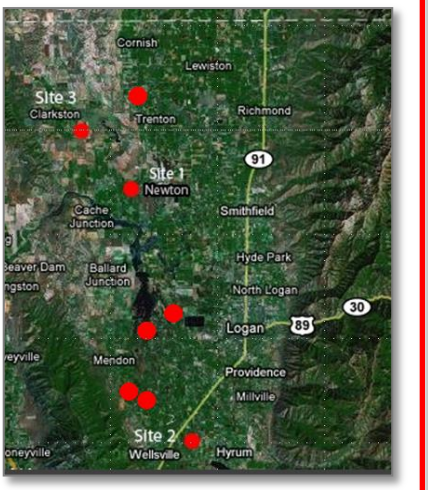
Project Description

- **Need and Purpose:**

  This study investigates the effectiveness of Utah's design procedures for on-site wastewater treatment systems (more commonly known as septic systems):

  Focus Area No. 1: Common practice for on-site wastewater treatment is to locate drain fields at shallow depths in order to maximize aerobic decomposition of organic contaminants, to enhance evapotranspiration in order to reduce transport of contaminants to ground water, and to increase removal of nutrients (nitrogen and phosphorus) through vegetative uptake. However, in Utah, drain fields have often been, and continue to be, installed at depths of 8 to 10 feet or even deeper in soil materials that are more permeable than surface layers. The concern is that treatment is not effective at these depths. We are studying how these deep systems perform with regards to treatment of contaminants.

  Focus Area No. 2: Proliferation of new pharmaceuticals and personal care products (PPCP) has resulted in an increased interest in the fate of these emerging contaminants in on-site wastewater treatment systems. This part of the study examined the fate of six selected emerging contaminants (i.e., acetaminophen, caffeine, sulfamethoxazole, fluoxetine, carbamazepine, and progesterone) in a controlled laboratory setting simulating a Utah conventional pipe and gravel on-site drain field and an engineered pipe and gravel drain field, with added absorptive media (peat and charred straw) below the gravel. In addition, laboratory batch studies were conducted to evaluate quantitatively the potential fate (biodegradation and sorption) of the selected contaminants in peat/soil and charred straw/soil environments.



Site locations in Cache Valley

- **Benefits to the State:**

  Focus Area No. 1: Utah's local health departments are presently permitting deep on-site systems without clear indication that these systems are adequately treating wastewater contaminants. Results of these investigations are providing information to the health departments on whether they can either continue permitting these types of systems with confidence or should eliminate the use of the systems.

  Focus Area No.2: State regulators, including staff at the Utah Division of Water Quality, are becoming more involved in setting requirements for the removal of emerging contaminants of concern from wastewater. Information on ways that on-site systems can be modified to improve removal will be of critical importance.

Deep trench system installation, Wellsville, November 2008

- **Geographic Areas:**

  Study Area: Cache County

  Areas Benefited: All areas of Utah where septic systems as well as deep systems are commonly used for on-site wastewater treatment.

- **Accomplishments:**

  Findings: Focus Area No. 1: With the cooperation of the Bear River Health Department, eight sites in Cache Valley were identified, and sampling equipment was installed in drain fields. Four of the sites utilized deep trenches for treatment of wastewater and four utilized shallow trenches. During FY 11- 12, we analyzed data collected from the site. We also worked with the owners of the sites to educate them on proper septic system use practices. Focus Area No. 2: Columns were constructed to simulate conventional pipe and gravel on-site wastewater drain fields as well as engineered drain fields containing absorptive materials (peat and charred straw) designed to enhance removal of PPCPs. Septic tank effluents spiked with each contaminant of concern were pumped into the columns, and samples were collected from the bottom of the columns and analyzed for the presence of each of the selected contaminants. Laboratory Batch Studies: The major mechanisms (adsorption, biodegradation, or volatilization/hydrolysis) for target PPCP reductions in a conventional drain field and in engineered drain fields were investigated by comparing concentrations of the selected PPCPs in PCCP-spiked wastewater reactors compared to PPCP-spiked wastewater reactors with inhibited microbial activity.

  Results: Focus Area No. 1: Leachate samples from the drain fields were analyzed for nitrate nitrogen, phosphorus, coliform bacteria, total suspended solids, and biological oxygen demand to determine treatment effectiveness in both the shallow and deep trench systems. Results indicate that satisfactory treatment of these wastewater contaminants is occurring in both shallow and deep systems. Focus Area No. 2: The column study experiments established that both the conventional and engineered on-site wastewater drain fields have the ability to reduce the concentrations of four of the six target PPCPs. The charred straw columns provided the best removals. Laboratory Batch Studies: Results from batch reactor experiments to determine removal mechanisms indicated that volatilization/hydrolysis was a minimal mechanism for target PPCP concentration reduction. Results also showed that adsorption was the main mechanism for PPCP concentration reduction with the exception of progesterone, where biodegradation played a significant role. Isotherm experiments showed that, overall, charred straw had greater PPCP adsorptive capacities than the peat and soil for most of the contaminants.

Work Plan FY13/FY14

For Focus Area No. 1, we will analyze leachate produced within the eight study drain fields and will continue to determine treatment effectiveness in shallow and deep drain fields. Focus Area No. 2 research has been completed, and publications concerning the results are being prepared.

Informational Resources

Contact: Ms. Judith L. Sims, (435) 797-3230, E-mail: judith.sims@usu.edu.

References: Beardall, James (2013). *The Fate of Pharmaceuticals and Personal Care Products in Conventional and Engineered On-Site Wastewater Drain Fields*. M.S. Thesis (Draft), Department of Civil and Environmental Engineering, Utah State University, Logan, UT.

Enhancing Methane Production at Water Reclamation Facilities in Utah

Principal Investigators:
Michael J. McFarland
Morris Demitry

Partners/Collaborators:
Local: *Lance Wood, Central Weber Sewer Improvement District*
State: *Mark Schmitz, Utah Division of Water Quality;*
Jeff Barrett, Utah Governor's Office – Renewable Energy Initiative

Project Description

- **Need and Purpose:**

Restaurant and industrial food service providers in Utah discharge significant amounts of fats, oils and grease (FOG) into local municipal wastewater collection systems (i.e., sewers). FOG from these sources includes waste cooking oil or ''yellow grease" and grease-trap and interceptor wastes or ''brown grease." FOG has historically created a severe problem in Utah sewers by restricting flow and resulting in sanitary sewer overflows.

In order to increase energy production and provide a beneficial reuse for FOG, together with other food processing wastes at wastewater reclamation facilities, several utilities in the United States have been evaluating the co-digestion of FOG with municipal sewage sludge to enhance methane production. Although the feasibility of increasing methane production through the co-digestion of food wastes with municipal sludge has been demonstrated in laboratory studies, the limited solubility of lipids, as well as long-chain fatty acids, has been cited as a major cause for digester failure.

The purpose of this research is to establish the technical feasibility of enhancing methane production at the Central Weber Sewer Improvement District Wastewater Treatment Plant (WWTP) using co-digestion with FOG and other food wastes. Central Weber Sewer Improvement District WWTP currently utilizes their methane gas in co-generation systems to produce electricity that is used to offset their power requirements. Figure 1 depicts the anaerobic digestion systems typically found at municipal wastewater treatment plants.

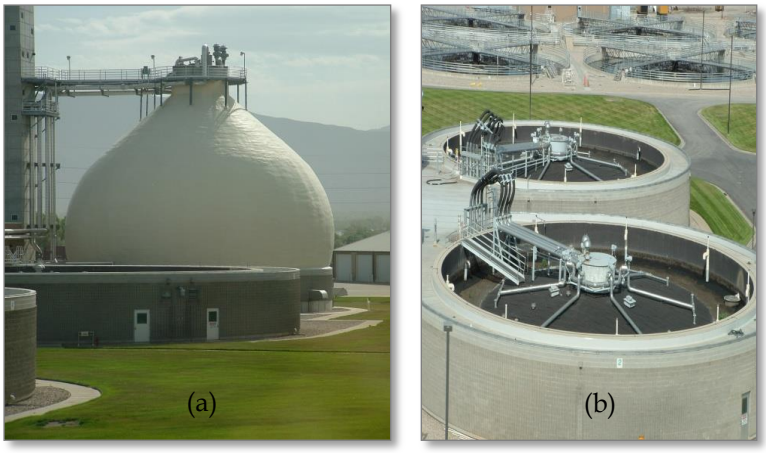


Figure 1 - Anaerobic Digestion Systems at the Central Weber Sewer Improvement District WWTP: (a) Egg-Shaped Digester; (b) Conventional Floating Roof Digesters

- **Benefits to the State:**

  Successful results from this graduate research activity will generate a number of benefits for the state of Utah including the following:
  - Generate new markets for FOG and food wastes
  - Expand the generation and use of renewable energy
  - Reduce organic waste generation through recycling activities
  - Develop new energy production for Utah water reclamation facilities
  - Improve wastewater conveyance system operations

- **Geographic Areas:**

  Study Area: Weber County, Utah.

  Areas Benefited: The entire state of Utah.

- **Accomplishments:**

  Findings/Results: Preliminary meetings between the principal investigators and the primary collaborating facility have been held. We discussed and coordinated the availability of FOG and food wastes from locations within the vicinity of the facility. The preliminary discussions were focused on the most effective approach to transport FOG and food wastes to the facility and whether or not there were any technical limitations in terms of what materials could represent challenges in enhancing energy production. The primary student working on this effort, Morris Demitry, has been working at the Central Weber Sewer Improvement District's WWTP to help them prepare for co-digestion of FOG and food wastes.

Work Plan FY13/FY14

The Utah State University team will work in close collaboration with the technical staff at the Central Weber Sewer Improvement District and the State Department of Water Quality in accomplishing this project. The technical focus for the next fiscal year will comprise the following five tasks:

- Estimate the theoretical production of methane from the co-digestion of FOG and Food waste in the facility.
- Find appropriate sources of FOG and food wastes from the Weber County area that are willing to participate in this study.
- Determine the increase in renewable energy production associated with FOG and waste food co-digestion.
- Develop best management practices for the collection, transport, and management of FOG by the facility.
- Determine the amount of supplemental organic matter needed to achieve energy neutrality at the Central Weber Sewer Improvement District's water reclamation facility.

Informational Resources

Contact: Dr. Michael J. McFarland (PE), Phone: (435) 994-0905, Email: farlandm@msn.com.

Low Level Hexavalent Chromium (Cr-6) in Drinking Water

Principal Investigators:
Laurie S. McNeill
Joan E. McLean
Christel Olsen (Graduate Student)
Rahel Beyene, Nathan Coonen, Josh Hortin (Undergraduate Students)

Partners/Collaborators:
***Local**: Salt Lake City Public Utilities, Logan City, Park City*

Project Description

- **Need and Purpose:**

  In December 2010, the Environmental Working Group (EWG) issued a public report about hexavalent chromium (Cr-6) occurrence at very low levels in US drinking water sources. In that report, Salt Lake City, UT, was targeted as a system of concern due to a detection of 0.3 parts per billion (ppb) of Cr-6, which was the 11th highest level of the 35 cities tested. SLC easily complies with the current Maximum Contaminant Level (MCL) for Total Cr, which includes both trivalent chromium-3 (Cr-3, a trace nutrient) and hexavalent chromium (Cr-6, a likely human carcinogen). Nevertheless, this report generated a lot of concern within the SLC Department of Public Utilities, other drinking water systems in Utah, and the public they serve. The US Environmental Protection Agency (USEPA) is currently reviewing toxicology data for Cr-6, and may establish a new MCL specifically for Cr-6. A new federal MCL for Cr-6 is likely to be substantially lower than the current MCL for Total Cr, which will have an enormous impact on drinking water systems across the US.

  In order for drinking water utilities to understand the chromium chemistry within their water and comply with a Cr-6 MCL, they must be able to measure Cr-6 at those low levels. A second issue is that, with these very low levels of Cr-6 being of concern, any Cr-6 that leaches from stainless steel components of pumps, pipes, wells, and other water plant infrastructure may now produce a significant level of contamination. If the new MCL for Cr-6 is set below 1 ppb (as some people have predicted), then utilities might exceed the MCL due to Cr-6 leaching into their water, even if there is no Cr-6 contamination in their source water. Any Cr-3 present can also be oxidized to Cr-6 by chemical disinfectants present in water distribution systems.

- **Benefits to the State:**

  If USEPA sets a MCL for Cr-6, every public water system in Utah must comply. This project will provide a thorough evaluation of preservation and analysis techniques for Cr-6, and various UT treatment plants will be sampled to determine sources of chromium to drinking water and possible treatment techniques for removing Cr-6. This will help water utilities understand sources and behavior of Cr-6 and evaluate the best way to comply with regulations related to chromium.

- **Geographic Areas:**

  Study Area: Salt Lake City (Salt Lake County), Logan (Cache County), Park City (Summit County).

  Areas Benefited: All drinking water treatment utilities in the State of Utah.

- **Accomplishments**:

  Findings/Results: Bench-scale testing was done to investigate mechanisms of chromium removal, and results were correlated with sampling that was conducted at additional full-scale treatment plants, including four in Utah. Cr-6 was detected at all plants, but concentrations were very small (< 2 ppb in the source water, and < 1 ppb in finished water), and well below the MCL of 100 ppb. Results indicate that including ferrous iron (Fe^{+2}) coagulant along with conventional ferric iron (Fe^{+3}) coagulants (called "reduction coupled coagulation") can remove significant amounts of Cr-6.

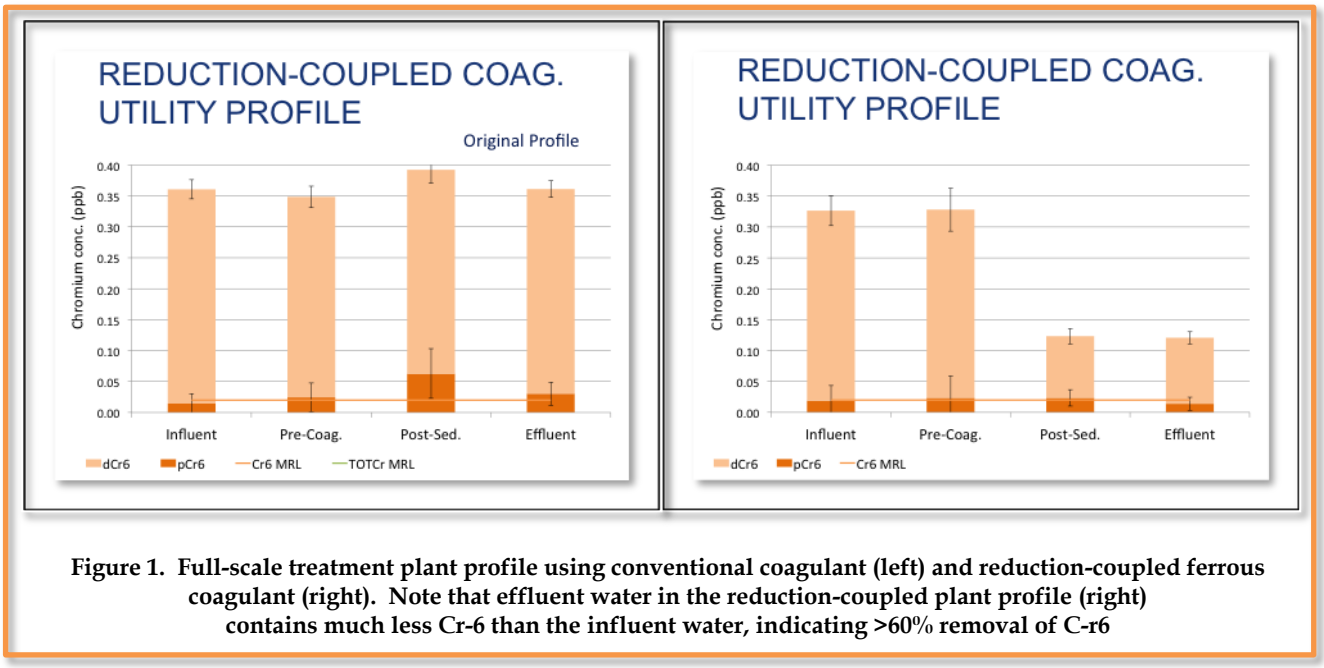


Figure 1. Full-scale treatment plant profile using conventional coagulant (left) and reduction-coupled ferrous coagulant (right). Note that effluent water in the reduction-coupled plant profile (right) contains much less Cr-6 than the influent water, indicating >60% removal of C-r6

Work Plan FY13/FY14

1. Collect additional samples from various water treatment plants across UT to look at sources and treatment of Cr-6.
2. Conduct laboratory experiments to investigate field speciation preservation methods for chromium.

Informational Resources

Contact: Dr. Laurie S. McNeill, (435) 797-1522, Email: Laurie.McNeill@usu.edu.
Ms. Joan E. McLean, (435) 797-3663, Email: Joan.McLean@usu.edu.

Publications:

Results from this project were presented in two conference presentations, one peer-reviewed report, and one peer-reviewed journal publication (McNeill et al, *Journal AWWA*, 104(7), July 2012, pp. E395-E405. (DOI: http://dx.doi.org/10.5942/jawwa.2012.104.0092).

Managing Drinking Water Quality in Park City

Principal Investigators:
Laurie S. McNeill
Joan E. McLean
David K. Stevens
William Kent, Tiana Hammer (Graduate Students)
Jason Blankenagel, Nate Rogers (Undergraduate Students)

Partners/Collaborators:
***Local**: Park City, UT*
***National**: Water Research Foundation*
***Business/Industry**: Confluence Engineering*

Project Description

- **Need and Purpose:**

  Park City is one of Utah's most famous cities due to its ski resorts and the Sundance Film Festival. It was named "The Best Town in America" by *Outside* magazine in 2013. However, Park City is also becoming infamous due to its drinking water quality. In 2007 and 2010, Park City experienced adverse water quality events with discolored water and high levels of arsenic, thallium, manganese, iron, and mercury in their water distribution system. Park City has an incredibly complex water system, with various sources (including groundwater, surface water, and water passing through old mine tunnels), several treatment plants, unique water demand patterns, and a complicated water distribution system with more than 50 pressure zones. The goal of this project is to assess the causes of these adverse water quality events, evaluate monitoring techniques that can be used to predict future events, and recommend strategies to prevent contaminant release. Tasks include the following:

  1. Evaluate historic water quality data as a preliminary assessment of causes of water quality events. Park City's current data management practices will also be assessed.

  2. Evaluate techniques to minimize deposition and/or subsequent release of corrosion scale, sediments, and biofilms in the distribution system. This will include sampling at water sources and in the distribution system, as well as bench-scale experiments.

  3. Develop a strategy for on-line, real-time monitoring of the Park City water system, along with tools to manage and interpret collected data. The ultimate goal is to produce a guidance document to help the water utility respond to changes in their distribution system and avoid adverse water quality events.

- **Benefits to the State:**

  This project will help Park City manage their complex water system to provide high quality water to their citizens and visitors. The understanding gained about chemical and biological processes in the water distribution system, as well as strategies developed for real-time monitoring and assessment of these systems, will be applicable to many other water utilities in Utah and across the US.

- **Geographic Areas:**

  Study Area: Park City (Summit County).

  Areas Benefited: All drinking water treatment utilities in the State of Utah.

- **Accomplishments**:

Findings/Results: Routine monthly monitoring at 14 different sites within the Park City water distribution system, as well as at eight water sources, began in November 2012 (Figure 1). Sites are monitored for field parameters (pH, EC, ORP, temperature, turbidity, and chlorine residual). Additional aliquots are filtered in the field and/or added to pre-preserved bottles, then returned to the Utah Water Research Laboratory (UWRL) and analyzed for total and dissolved metals, dissolved major cations and anions, alkalinity, organic carbon, and suspended solids. Data are being integrated into a UWRL-developed online database for easy access and analysis by the utility and project team.

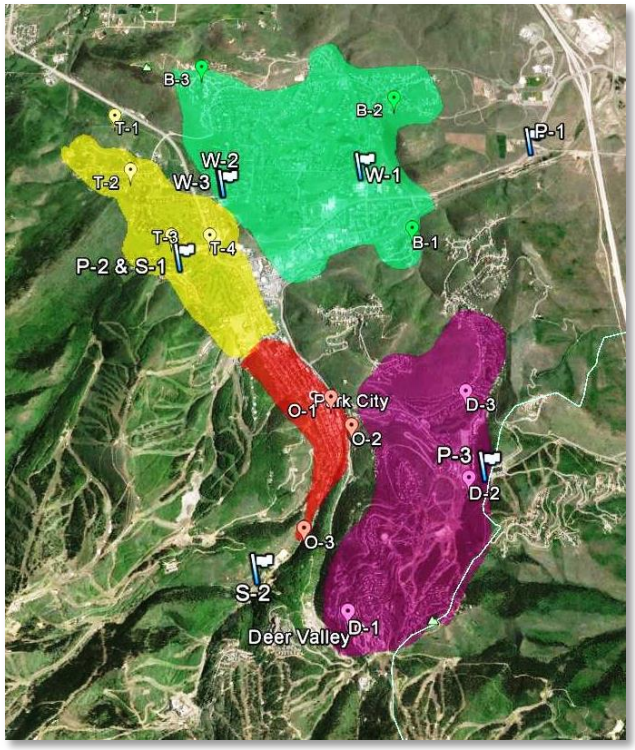


Figure 1. Sampling locations

These MLF funds were leveraged into a $495,000 project sponsored by the Water Research Foundation (project lead is Confluence Engineering). Preliminary results were presented at a workshop in June 2013 that was attended by nearly 60 representatives of water systems from throughout Utah.

Work Plan FY13/FY14

1. Continue to collect routine monitoring samples and analyze results.
2. Install on-line water quality monitoring panels and compare data to routine monitoring results.

Informational Resources

Contact: Dr. Laurie S. McNeill, (435) 797-1522, Email: Laurie.McNeill@usu.edu.
Ms. Joan E. McLean, (435) 797-3663, Email: Joan.McLean@usu.edu.
Dr. David K. Stevens, (435) 797-3229, Email: David.Stevens@usu.edu.

Mitigation of Methane Emissions from Septic Systems

Principal Investigators:
Judith L. Sims
Joshua Ellis (Student)

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  Concerns with climate change have led to efforts to reduce the emission of greenhouse gases (GHGs). Methane has been identified as a GHG that is over twenty times more effective at trapping heat in the atmosphere than carbon dioxide. Using assumptions developed by the Intergovernmental Panel on Climate Change (IPCC), the U.S. Environmental Protection Agency GHG inventory (2009) estimated that 76 percent of wastewater sector methane emissions in the United States are from onsite (septic) systems, due to the large number of individual septic systems in use and the anaerobic conditions present in septic tanks.

  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 the poor air quality that occurs in Cache Valley and in other areas of Utah during winter inversions.

  A project funded by the Water Environment Research Foundation (*Evaluation of Greenhouse Gas Emissions from Septic Systems*, 2010) concluded that study is needed to develop technologies for the control of GHG emissions from on-site wastewater systems. In this project we are investigating the potential effectiveness of mitigating the impacts of methane produced in septic tanks by collecting the methane and treating it in a compost system where the methane can be converted to carbon dioxide, which can then be used by plants growing on the compost (Figure 1).

- **Benefits to the State:**

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

- **Geographic Areas:**

  Study Area: Cache County.

  Areas Benefited: Areas of Utah where air quality problems exist and septic systems are commonly used for on-site wastewater treatment.

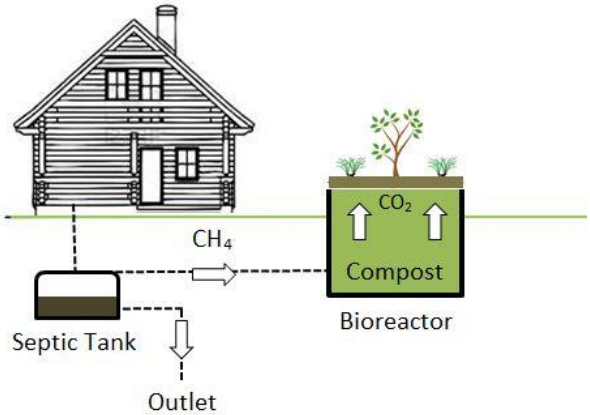


Figure 1. A schematic showing the process of mitigating methane at a local residence.

- **Accomplishments:**

Findings: The project tasks include the following:

1. Development of a technology to capture methane from the septic tank venting system.
2. Development of sampling and analysis techniques to measure methane in the septic tank gas stream and methane and carbon dioxide in the compost pile.
3. Investigation of the factors associated with composting that will affect and enhance the microbial conversion of methane to carbon dioxide, including, but not limited to, composition of the composting material, temperature and moisture effects, and sizing and depth of the compost pile.
4. Use of gene probes targeted to follow the dynamics of groups of microorganisms (i.e., the methanotrophs) involved in the methane to carbon dioxide conversion process.
5. Investigation of the type of plants that could be grown in the compost and their use of the produced carbon dioxide.

Results: During FY 12-13, we focused on Project Tasks 2, 3 and 4. We also developed analytical techniques to measure methane in environmental samples. We investigated several types of compost materials (manures, lawn clippings, and kitchen wastes) for their potential to develop populations of methanotrophs by probing the compost samples for soluble methane monooxygenase (sMMO) and particulate methane monooxygenase (pMMO) genes, which code for enzymes within methanotrophs that are responsible for methane oxidation. All of the compost materials appeared to contain methanotrophs. We also measured methane emissions from the various compost materials (Figure 2).

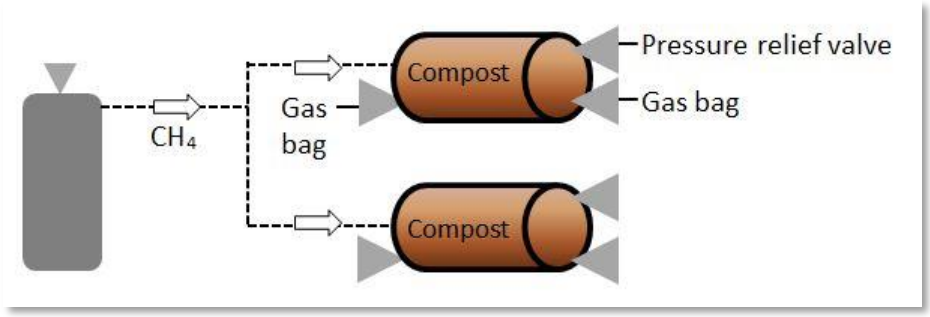


Figure 2. An illustration of a lab scale set-up for testing methane mitigation from multiple compost samples. Reactors are 6-inch pieces of 3-inch diameter PVC pipes capped off and fabricated to hold gas bags and a pressure relief valve.

Work Plan FY13/FY14

During FY13-14, we will utilize the expertise of a student in the mechanical engineering program to develop a technique to capture methane from a septic tank. We will also work to optimize our composting methodology to enhance methane conversion to carbon dioxide and will investigate the use of different types of plants that can grow in the compost.

Informational Resources

Contact: Ms. Judith L. Sims, (435) 797-3230, E-mail: judith.sims@usu.edu.

Producing Bioplastic Materials Using Microbe-Based Processes

Principal Investigators:
Ronald C. Sims
Charles Miller
Ashik Sathish (Research Engineer)
Asif Rahman (Student)
Brian Smith (Student)

Partners/Collaborators:
Local: *Issa Hamud, Logan City*
Business/Industry: *WesTech Inc., SLC*

Project Description

- **Need and Purpose:**

  Sustainable and environmentally benign methods and products are needed to reduce the costs of renewable bioplastic materials as substitutes for petroleum-based bioplastics. Locally produced bioplastic materials contribute to local economic development, national security, and sustainability.

- **Benefits to the State:**

  The production of bioplastic materials from microbes that use local organic feed sources will protect water and soil quality, and also generate new technologies, businesses, and products in Utah. Applications range from one-time use plastics, to commercial packaging, to biomedical designs such as drug delivery systems, tissue engineering, and orthopedics. Bioplastic materials are biodegradable and will reduce the need for petroleum-based plastic materials that accumulate in landfills in Utah communities.

- **Geographic Areas:**

  Study Area: Confined animal feeding operation (CAFO) areas in rural Utah, and the Logan Wastewater Reclamation facility treating wastes from seven communities in Northern Utah.

  Areas Benefited: All areas of the state of Utah, especially rural communities and cities where wastes will be utilized as sources of nutrients for microbes that transform wastes into bioplastic materials.

- **Accomplishments:**

  Findings: When wastewater-grown algae were used as a source of food for bacteria that were programmed using synthetic biological engineering principles and tools, bioplastic materials were produced by the bacteria (Table 1). The bioplastic produced has properties similar to polyproplyene and polyethylene, two petroleum-based plastics.

  Results: Algae that grows naturally in Logan City wastewater was demonstrated to be a good source of nutrients for bacteria that could utilize the nutrients and a biochemical pathway for bioplastic production. The results demonstrate that high value bioplastic materials can be produced using low value waste chemicals.

  We were also able to modify bacteria that manufactured the bioplastic material and demonstrate secretion of bioplastics (Figure 1). The images of the bacterium *E. coli* were taken using scanning electron microscopy instrumentation to illustrate the areas where the bacteria secreted bioplastic

material as shown by the fine hair-like structures on the outside of the cells. Secretion of bioplastic will result in decreased costs for separation, purification, and concentration of bioplastic materials that will enhance their economic competitiveness in comparison to petroleum-based bioplastic materials.

Table 1. Algae used as food source for microbial transformation to bioplastic materials (PHB)	
Food Source	Average PHB Yield: (% of cell dry mass)
Algae	31%* 34% 27%
Algae + Glucose	51%

Work Plan FY13/FY14

We will utilize a 100-Liter reactor for continued scale-up of bioplastic production and will utilize other feedstocks that are waste materials, including algae and cheese whey that are produced locally.

Informational Resources

Contact: Dr. Ronald C Sims, (435) 797-3156, E-mail: ron.sims@usu.edu.

Publications:

Rahman, A., J.T. Ellis, and C.F. Miller (2012). Bioremediation of domestic wastewater and production of bioproducts from microalgae using waste stabilization ponds. *J Bioremed Biodeg* 3:e113. doi:10.4172/2155-6199.1000e113.

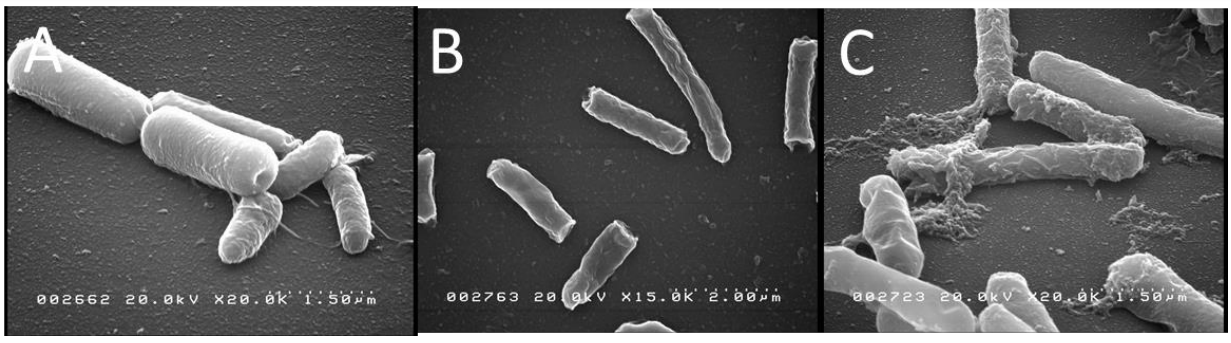


Figure 1. Scanning Electron Microscopy images of the modified bacterium E. coli: (A) and (B) are non-secreting bacteria and (C) are bacteria that have been modified to secrete bioplastic materials.

State of Utah Drinking Water Board

Principal Investigators:
David K. Stevens

Partners/Collaborators:
State: *Kenneth Bousfield, Director, Division of Drinking Water*

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.

- **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 and oversight of state and federal revolving loan funds for drinking water management to the Division of Drinking Water in their rulemaking, facility inspections and reviews, policy implementation, and conflict resolution. The PI attends ~monthly meetings of the Drinking Water Board held throughout the State and provides comments and input on drinking water treatment and distributions issues that arise during the course of the Division's implementation of Federal and State drinking water laws.

- **Geographic Areas:**

  Study Area: State of Utah.

  Areas Benefited: State of Utah.

- **Accomplishments:**

  Findings/Results: The PI attended all regularly scheduled Drinking Water Board meetings and facility tours from July 1, 2012 to June 30, 2013, and provided review and comment on all Board items relevant to his area of expertise.

Work Plan FY13/FY14

Continued involvement in the Board through 2015.

Informational Resources

Contact: Dr. David K Stevens, Phone (435) 797-3229, E-mail: david.stevens@usu.edu.

Website: http://www.drinkingwater.utah.gov/Board/board.html.

Environmental Quality Management and Remediation

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Environmental Quality Management and Remediation

Project Name	FY2013 Actual Expenditures	FY2014 Budgeted Expenditures	FY2015 Planned Expenditures
Alternative Electron Acceptor Biogeochemistry in TCE Contaminated Aquifers in Northern Utah	$77,934.15	$80,272.17	$0.00
Analyzing the Spread of Phragmites Australis over Short Time-Scales Using Spatial and Genetic Tools	$33,085.26	$32,808.65	
Environmental Impact of Expanded Recycling Programs in Salt Lake County	$10,000.00	$10,300.00	$10,609.00
Evaluation of Duckweed as a Technology for Management of Nutrients and Pharmaceutical Contaminants in Municipal Wastewater Systems	$34,693.00	$35,733.79	$0.00
Impact of Metals and Metal Ions on Soils and Plants	$25,000.00	$25,750.00	$33,792.91
Investigations into Elevated Wintertime Ozone in Utah's Uintah Basin	$37,938.90	$39,077.07	$40,249.38
Monitoring Organic Contaminants in Air Using Plants as Passive Samplers	$65,230.03	$67,186.93	$69,202.54
Phytoremediation Evaluation Site for Quantifying the Fate of Trichloroethylene (TCE)	$22,648.77	$23,328.23	$24,028.08
Real-Time Polymerase Chain Reaction (RT-PCR) Instrumentation	$5,000.00	$5,150.00	$0.00
Remediation of Chlorinated Solvent Contamination of Groundwater	$57,087.96	$58,800.60	$26,522.50
Remediation of TCE-Contaminated Soil and Groundwater at Hill Air Force Base (HAFB)	$5,000.00	$16,520.89	$4,741.70
Study of Cache Valley's Vertical Ozone Profiles and Application to the Uintah Basin	$44,746.81	$46,089.21	$47,471.89
Designated Projects		$266,817.91	$57,500.00
Undesignated Projects		$75,000.00	$12,000.00
Total	**$418,364.88**	**$782,835.45**	**$326,118.00**

Alternative Electron Acceptor Biogeochemistry in TCE Contaminated Aquifers in Northern Utah

Principal Investigators:
Joan E. McLean
R. Ryan Dupont
Darwin L. Sorensen
Babur Mirza (Post-Doctoral Fellow)
Suzy Smith (MS Student)

Partners/Collaborators:
Federal: *Kyle Gorder and Mark Roginske, Hill AFB*

Project Description

- **Need and Purpose:**

  The presence of trichloroethylene (TCE) in groundwater and surface waters is the result of the manufacture, use, and improper disposal of the chemical in prior decades. TCE has been widely used as an industrial solvent in military, commercial, and industrial applications. Due to its extensive use at military facilities, about 1,400 United States Department of Defense properties are contaminated with TCE. Considering the widespread contamination of groundwater environments and the nature of TCE's toxicity to human health, it was ranked as number 16 out of 275 substances on the 2005 Priority List of Hazardous Substances for the Comprehensive Environmental Response, Compensation, and Liability Act.

  Biostimulation with or without bioaugmentation has been used at various contaminated sites to promote the reductive dechlorination of TCE. At some sites these remediation strategies are successful yet at others full dechlorination to non-toxic ethene is not observed. We set-up large columns (6 feet in height) packed with TCE contaminated aquifer solids collected from Hill Air Force Base. The columns were fed with several carbon sources with and without addition of a dechlorinating culture. After seven years of operation only the whey treated columns produced biogeochemical conditions conducive to full dechlorination. An important area of research is why other carbon sources failed to promote the right conditions.

- **Benefits to the State:**

  All counties in Utah would benefit from improved understanding and the development of remediation strategies for dechlorination of TCE and other chlorinated solvents that are contaminating groundwater resources.

- **Geographic Areas:**

  Study Area: Hill Air Force Base, Davis County, and Weber County.

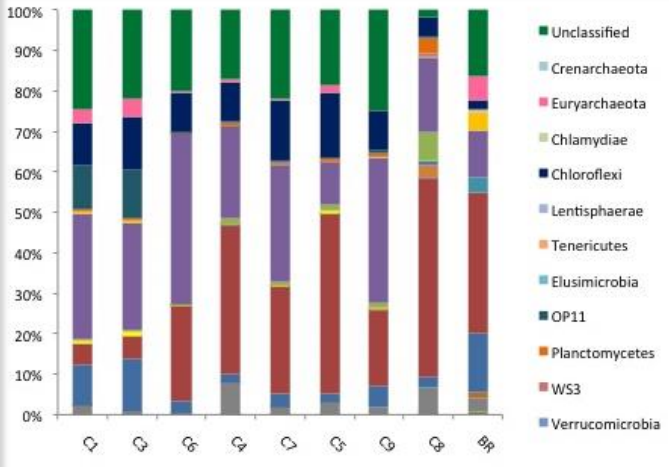


Figure 1. Distribution of the 16S rRNA gene sequences across bacterial phyla in columns amended with different carbon sources (C1 and 3 whey treated, C4, 5, 6, 7 treated with emulsified oil and C8, 9 no carbon addition)

Areas Benefited: In addition to the specific areas above, this project will contribute to groundwater protection throughout the state.

- **Accomplishments:**

Findings: Complete reductive dechlorination of TCE to innocuous breakdown products was observed in the column sample treated with the whey. We observed a clear shift in the microbial communities in response to the application of different carbon amendments, which influenced geochemical conditions. Reduced conditions in combination with the appropriate soil microbial communities resulted in complete reductive dechlorination. These findings are useful in the reclamation of field sites that have been heavily contaminated with the TCE.

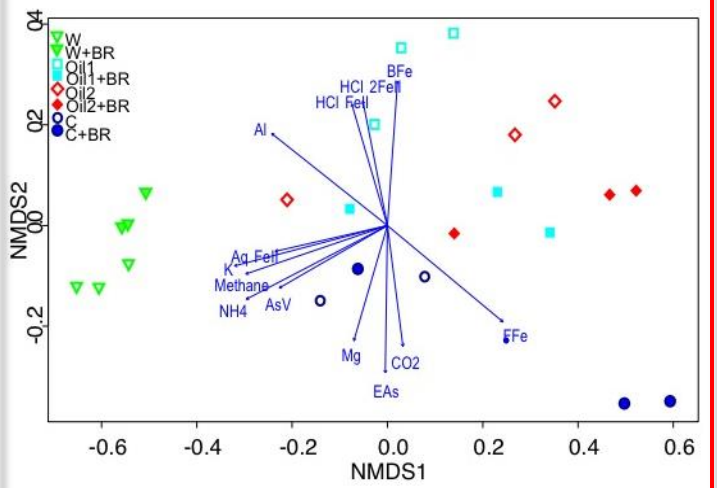


Figure 2. Association of the different soil physiochemical conditions with the column samples amended with different carbon sources

Results: Columns packed with aquifer solids from HAFB were leached with TCE containing groundwater and one of three carbon sources for over seven years. These columns were sampled in summer 2010 by collecting three cores from each 6-inch layer within the 6-foot column. The microbial communities that were established in the columns were treated with different carbon sources. Complete reductive dechlorination was observed in the columns treated with the whey. There was a significant shift in the microbial community composition (Figure 1). We observed changes in the soil geochemical conditions in association with these different treatments (Figure 2). NH_4 and methane were observed in the columns amended with the whey treatment, which suggests that these columns were under completely reduced conditions. In summary, our results suggest that, for the complete reductive dechlorination of TCE, the presence of the right microbial communities, along with completely reduced conditions, are necessary.

Work Plan FY13/FY14

A study with small sized columns will be carried out to identify the active microbial community involved in the reductive dechlorination through the sequencing of the rRNA rather than the DNA, and also identify the microorganisms responsible for carrying out the intermediates steps necessary for the complete TCE reduction (TCE to dichloroethene to vinyl chloride to ethene).

Informational Resources

Contact: Ms. Joan E. McLean, (435) 797 3199, E-mail: joan.mclean@usu.edu.

Analyzing the Spread of *Phragmites Australis* over Short Time-Scales Using Spatial and Genetic Tools

Principal Investigators:
Mac McKee
Austin Jensen
Bushra Zaman

Partners/Collaborators:
Local: *Bear River Migratory Bird Refuge*

Project Description

- **Need and Purpose:**

  Phragmites australis is an invasive grass species that is rapidly outcompeting native cattails, bulrushes, and other valuable species in US wetlands and is causing a substantial loss of quality wetland habitat, especially in areas heavily used by highly valued migratory birds. This threatens the ecological, social, and economic services that wetlands provide. To control the spread of this invasive grass, managers need efficient and accurate ways to monitor its spread, quantify the habitat it displaces, and evaluate the degree to which control measures are working.

  This project examined the use of AggieAir™ unmanned aerial vehicles (UAVs), developed and operated by the Utah Water Research Laboratory (UWRL) and the Center for Self-Organizing Intelligent Systems (CSOIS) at Utah State University, for acquiring remotely sensed imagery to quantify wetland plant coverage and monitor the spread of *Phragmites* in the Bear River Migratory Bird Refuge (BRMBR), a large wetland in northern Utah. A multiclass relevance vector machine (MCRVM) model, also developed at the UWRL, was trained with remotely sensed vegetation reflectance data and on-ground sampling and used to classify previously unseen data into vegetation types, especially *Phragmites*, and to quantify its rate of spread over the growing season. Ground surveys also provided DNA samples of *Phragmites* to determine the different mechanisms of *Phragmites* spread (rhizomes versus seeds) under flooded and unflooded conditions. The MCRVM classification software was also tested to determine whether it could successfully use AggieAir imagery to identify different *Phragmites* genotypes.

- **Benefits to the State:**

  - This project provides wetlands managers with new, inexpensive, and valuable methods to evaluate the rates of *Phragmites* spread over the course of the growing season and the efficacy of their attempts to control it, as well as new information on the water levels that both encourage and discourage *Phragmites* spread.

  - These technologies will help wetlands managers to allocate scarce water, personnel, and budget resources to achieve Utah's wetlands objectives and support the hunting, birding, and recreation that are vital to the Utah communities that border the Great Salt Lake.

- **Geographic Areas:**

  Study Area: The Bear River Migratory Bird Refuge, UT.

  Areas Benefited: Any of Utah's wetlands and the communities that surround them.

- **Accomplishments:**
  Findings: This project has:

  - Tested the capability of UAVs to acquire imagery that can be used to automatically assess the location, abundance, and rate of spread of *Phragmites australis* at the BRMBR using a multi-class relevance vector machine.
  - Developed software that can locate *Phragmites* at very high resolutions with an overall classification accuracy of 95% using unique spectral signatures (approximately 25 cm spatial resolution), and determine its spread.
  - Collaborated with Watershed Sciences Department at USU to assess the method of spread of *Phragmites*, whether by seed or clonally by rhizomes (underground stems) in order to guide the type and timing of *Phragmites* control efforts at the BRMBR.
  - Initiated investigation of whether data from the DNA findings can be correlated with information contained in the aerial imagery acquired with the AggieAir platform.

  Results: The AggieAir™ UAV platform has proven to be an inexpensive and highly effective tool to acquire useful multispectral data. The data acquired by this platform can be provided as input to a multivariate relevance vector classification machine to produce highly accurate quantitative descriptions of the types of land cover in the imagery. The combination of remote sensing UAVs and the MCRVM has the potential for broad application in agricultural and natural resource management. The preliminary results of the analysis of DNA data and the high-resolution aerial imagery indicate that individual genetic clonal types of *Phragmites* can be identified with high accuracy (more than 90% accuracy) from the AggieAir imagery.

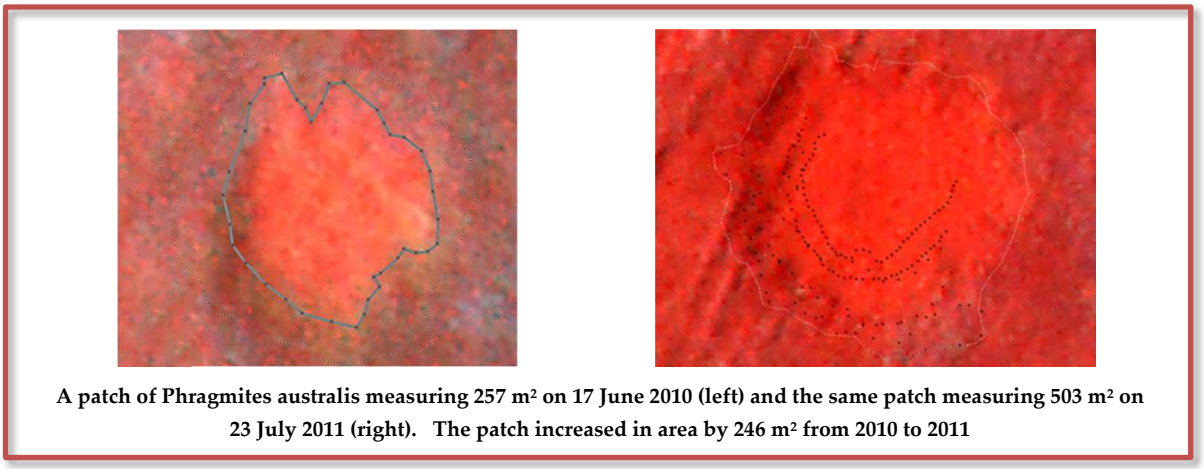
Work Plan FY13/FY14

This project is complete.

Informational Resources

Contact: Dr. Mac McKee, (435) 797-3188, E-mail: mac.mckee@usu.edu.

Website: http://aggieair.usu.edu.



A patch of Phragmites australis measuring 257 m² on 17 June 2010 (left) and the same patch measuring 503 m² on 23 July 2011 (right). The patch increased in area by 246 m² from 2010 to 2011

Environmental Impact of Expanded Recycling Programs in Salt Lake County

Principal Investigators:
R. Ryan Dupont

Partners/Collaborators:
Local: *Patrick Leary, Public Works Director, Salt Lake County; Rick Graham, Public Works Director, Salt Lake City; Russ Willardson, Public Works, West Valley City; John Loannou, Manager, Salt Lake Valley Solid Waste Management Facility*

Project Description

- **Need and Purpose:**

  This project has assisted solid waste managers in Salt Lake County, Salt Lake City, and West Valley City to evaluate the environmental impact of implementing an expanded curbside green waste collection program in Salt Lake County, expanding food waste composting in Salt Lake City, adding municipal solid waste (MSW) recycling options for the community of West Valley City, and improving the overall carbon footprint of Salt Lake County, including Green House Gas (GHG) emissions. The West Valley City project also included a cost evaluation for additional collection routes moving from bi-weekly to weekly recyclables collection.

  Various scenarios were presented that assume different levels of public participation in recycling programs, and comparisons were made to the current Base-Case situation and increased recycling efforts in terms of changes in projected GHG emissions, energy requirements, and costs.

- **Benefits to the State:**

  Evaluating the environmental impact and costs of solid waste management options can lead to reduced carbon emissions, reduced energy use, and more efficient and less costly solid waste management throughout Salt Lake County and throughout the State. Solid waste management evaluation methodology, based on the U.S. EPA's WAste Reduction Model (WARM), can be used to explore ways to reduce carbon emissions and improve energy utilization in all Utah communities and counties by (1) identifying the carbon and energy footprints of current solid waste management practices and (2) identifying options for solid waste management such as source reduction, recycling, composting, and incineration that can be used to modify carbon and energy footprints and enhance sustainability of solid waste management practices within Utah.

- **Geographic Areas:**

  Study Area: Salt Lake City, West Valley City and Salt Lake County.

  Areas Benefited: Solid Waste Management activities occur statewide so all counties in the state would potentially benefit from this project.

- **Accomplishments**:

  Findings: The benefits of green waste diversion and composting programs include revenue generation, landfill space preservation, and a salable commodity in compost. It appears prudent for Salt Lake County to pursue a voluntary green waste recycling program using commercial collection and to encourage food waste collection for composting by Salt Lake City.

An increase in food waste composting at the SLVSWMC by diverting only 3% of the food waste component (≈2,803 T/yr) yields a net reduction in the facility's carbon footprint by 715 metric T/yr and produces an annual energy savings of more than 2,000 million BTUs. Salt Lake County data indicate that weekly collection of recyclables would increase overall MSW diversion by only 3% at an additional cost of more than $1 million/yr. Even this small additional diversion rate could result in significant reductions in the carbon footprint (1,353 metric T/yr) and energy consumption (19,654 million BTU); however, the region and nation would realize these significant environmental benefits at a very high cost to West Valley City.

It is recommended that cities provide additional recycling containers to households desiring to increase recycling levels and continue the current bi-weekly collection, thereby encouraging additional MSW diversion with no significant increase in waste management costs.

Results: Findings and recommendations of this project were disseminated to SLVSWM Council, Salt Lake City, Salt Lake County, and West Valley City personnel for their consideration and implementation. Continued discussion with these entities involved the sensitivity of results in terms of waste composition assumptions, recycling and waste generation rates, etc.

Work Plan FY13/FY14

- Continue energy and environmental footprint analyses for Salt Lake County, Salt Lake City, and other communities in the Salt Lake Valley related to improving the efficiency of their MSW management programs.
- Re-evaluation of study results based on waste and recycling stream audits being conducted by Salt Lake City and Salt Lake County during spring and summer 2012.

Informational Resources:

Contact: Dr. R. Ryan Dupont, Phone (435) 797 3227, E-mail: ryan.dupont@usu.edu.

Evaluation of Duckweed as a Technology for Management of Nutrients and Pharmaceutical Contaminants in Municipal Wastewater Systems

Principal Investigators:
R. Ryan Dupont
Joan E. McLean
William J. Doucette
Naho Garvin (Student)
Leila Ahmadi (Post-Doc)

Partners/Collaborators:
Local: *Don Hartle, City Manager, Wellsville City;*
Issa Hamud, Director, Environmental Department, Logan City

Project Description

- **Need and Purpose:**

  Nutrients, particularly phosphorous, and other contaminants such as personal care products and pharmaceuticals (PCPP), in municipal wastewater systems are increasingly of concern due to their effect on aquatic ecosystems receiving wastewater treatment plant effluents. Conventional wastewater treatment systems are not effective in the removal of these contaminants, and chemical or advanced biological treatment alternatives that do provide contaminant removal are often prohibitively expensive to implement, particularly for small, rural communities.

  This study is evaluating the effectiveness of a duckweed-based system (*Lemna turionifera* and *Wolffia borealis*) for the uptake and transformation of nutrients and PCPP contaminants from municipal wastewater, especially in communities like Wellsville City and Logan City, that have lagoon wastewater treatment systems currently in place.

Figure 1. Fresh Duckweed Mat Harvested from the Wellsville Lagoons

- **Benefits to the State:**

  Protection of surface water quality from nutrient enrichment and PCPPs is a concern in many watersheds in the state. This project is developing an effective, low-cost treatment method for removing nutrients and PCPPs from wastewater with a net positive energy and environmental footprint.

- **Geographic Areas:**

  Study Area: Cache County, UT.

  Areas Benefited: All locations in the state with actual or potential nutrient and PCPP impacted surface water where low-cost, sustainable nutrient management systems are required for water quality improvements.

- **Accomplishments**:

  Findings: A duckweed-based wastewater treatment system can be feasibly implemented at the Wellsville lagoons based on significant duckweed growth rates, high concentrations of nutrients that accumulate in the duckweed biomass, and removal rates of PCPPs via duckweed comparable to more expensive mechanical treatment systems. The effectiveness of such a system is dependent, however, on the efficient and cost effective harvesting and stabilization/processing of the generated biomass. Mid-scale laboratory anaerobic digesters for harvested biomass

stabilization and methane generation have been operating on freshly grown duckweed and field-harvested biomass. Methane production capacity and reactor stability are being evaluated, as well as the fate of PCPPs associated with the harvested biomass within anaerobic digestion systems. The use of digester effluent for the growth of heterotrophic algae and the production and harvesting of potentially valuable biofuel materials is also under way.

Results: More than 250,000 lb of dried duckweed material could be harvested from the 56-acre Wellsville lagoons on an annual basis, amounting to approximately 2,500 lb of phosphorus being recovered in the harvested material. In addition, duckweed achieved removal of pharmaceutical compounds comparable to literature reported values (Acetaminophin 56-99%, Sulfamethxazole 45-86%, Fluoxetine 82-93%, Carbamazepine 0-38%, Progesterone 82-98%) for more expensive and complex physical/chemical treatment systems. Bi-weekly harvesting of duckweed biomass would provide sufficient P removal for Wellsville to meet its permit limits until approximately 2017. This technology clearly provides a low cost alternative to much more expensive advanced biological or chemical treatment processes, and produces a valuable end product in the form of harvested duckweed biomass.

Intermediate scale anaerobic digesters of 5 L volume were initially grown on calcium acetate substrate, and were subsequently fed increasingly higher loads of duckweed in an attempt to acclimate digesters to complete duckweed solids feedstock. Reactor pH and gas composition stability (≈75% to 80% methane) are indicated in Figures 2 and 3 as the digesters moved from pure substrate (calcium acetate) to increasing proportions of duckweed biomass. Digester acclimation in terms of total gas production continues as indicated in Figure 4, and is expected in early FY14. Heterotropic algae production to concentrations of 2 to 6 g/L has been achieved on glucose substrate, and testing of duckweed digester effluent as substrate for continued heterotropic algae production will commence in early FY14.

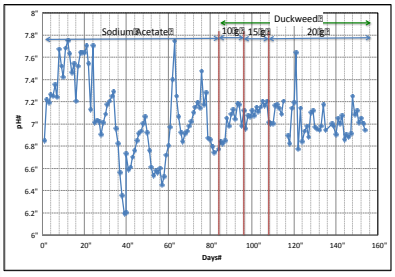


Figure 2. pH of Lab Scale Digester

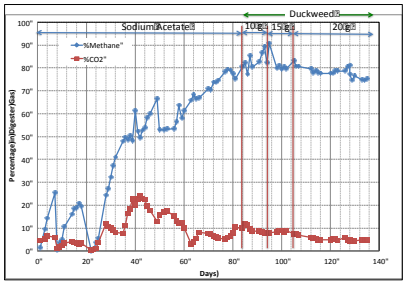


Figure 3. Methane Composition of Lab Scale Digester Gas

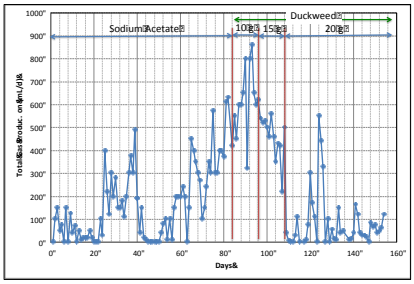


Figure 4. Gas Production from Lab Scale Digester

Work Plan FY13/FY14

The impact of PCPP bioconcentration in the harvested duckweed biomass on sludge stabilization and processing steps (anaerobic digestion, micro-algae production), and the transformation and fate of these PCPP compounds during anaerobic digestion and through the production of heterotropic algae is being carried out during FY14.

Informational Resources

Contact: Dr. R. Ryan Dupont, Phone (435) 797 3227, E-mail: ryan.dupont@usu.edu.
Website:
http://duckweedresearch.blogspot.com/2012/05/duckweed-research-presentations-and.html.

Impact of Metals and Metal Ions on Soils and Plants

Principal Investigators:
Joan E. McLean
Anne Anderson (Biology)
David Britt (Biological Engineering)
Christian Dimkpa (Biology)
John Cupp (Post-Doctoral Fellow)

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  Metal oxide nanoparticles (NPs) are manufactured for use in a variety of applications in medicine, food safety, personal care products, agriculture, and various other manufacturing operations and industries. Because of the ubiquitous use of metals in industrial and domestic products, metals are common pollutants in landfills and in wastewater treatment systems. Use of manufactured metal NPs in various industries and in agriculture may lead to adverse affects on plants and soil microbial ecosystems. This project is investigating the bioavailability and toxicity of metal oxide NPs of copper and zinc on a beneficial soil bacterium and on wheat in order to identify the ways metals affect beneficial soil bacteria survival, impact carbon and nutrient cycling, and ultimately, plant productivity.

- **Benefits to the State:**

  Results will directly benefit the counties in Utah with current metal contamination from abandoned and active hard rock mining and counties planning to expand industrial development by protecting environmental quality and human health as related to metal exposure.

- **Geographic Areas:**

  Study Area: Counties with abandoned and active mining operations and counties with industrial operation—all counties in Utah.

  Areas Benefited: All counties in Utah.

- **Accomplishments:**

  Findings: Copper oxide and zinc oxide NPs released to the environment could create persistent impacts on susceptible beneficial soil microbes and on plant productivity.

  Results: We are conducting laboratory research to study the complex interactions among metal oxide NP/metal ion geochemistry and biological factors that control the bioresponse of bacteria and wheat plants to nanoparticles (Figure 1). Metal oxide NPs, at sublethal concentrations, affect the metabolism of both wheat plants and their associated bacteria. Our recent work has shown that exposure of our test soil bacterium to the NPs increased production of the metal complexing agents, siderophores, and decreased indole acetic acid (growth hormone) and phenazine (antifungal agent) production (Figure 1 section A) (Fang et al. 2013). Metal complexes were shown to be as bioavailable to soil bacteria as free metal ions (Figure 1 section B) (McLean et al 2013). Exposure of wheat plants to CuO and ZnO NPs resulted in shorter roots than control plants. Use of X-ray absorption spectroscopy revealed that CuO was present in shoot tissue

whereas only Zn ions were detected in shoot tissue of exposed plants (Figure 1 section C) (Dimkpa et al 2012).

Work Plan FY13/FY14

We will continue to explore changes in the metabolism of bacteria and plants when challenged with NP metal oxides. The focus this year is on how NPs may alter bacterial-plant interactions affecting plant productivity. We are using molecular tools to observe altered gene expression of wheat plants with and without associated bacteria on exposure to ZnO and CuO NPs.

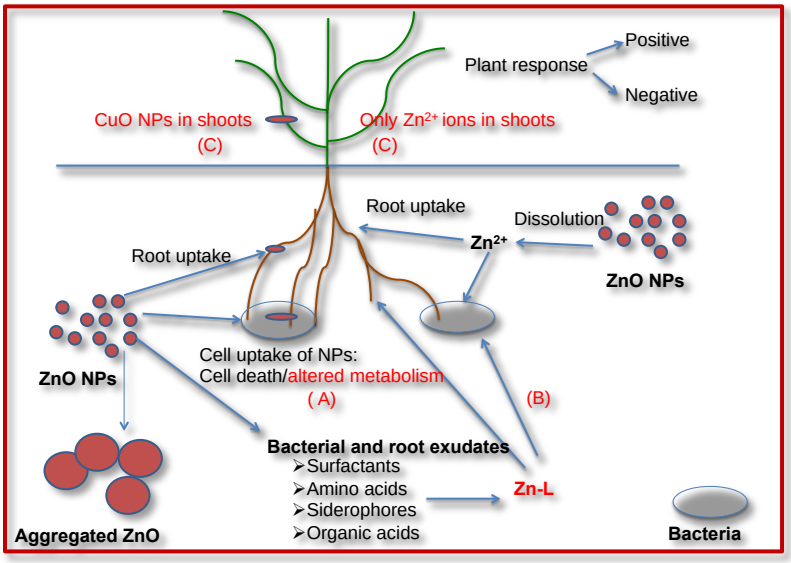


Figure 1. Schematic of the fate of metal oxide NPs in the soil environment with interactions among NPs, geochemistry, bacteria and plants. Processes that were studied this year are highlighted in red.

Informational Resources

Contact: Ms. Joan E. McLean, (435) 797-3199, E-mail: joan.mclean@usu.edu.

Publications:

McLean, J.E., M.W. Pabst, C.D. Miller, C.O. Dimkpa, and A.J. Anderson (2013). Effect of complexing ligands on the surface adsorption, internalization, and bioresponse of copper and cadmium in a soil bacterium. *Pseudomonas putida*. *Chemosphere*, 91:374-382.

Fang T., J.-L Watson, J. Goodman, C.O. Dimkpa, N. Martineau, S. Das, J.E. McLean, D.W. Britt and A.J. Anderson (2013). Does doping with aluminum alter the effects of ZnO nanoparticles on the metabolism of soil pseudomonads? *Microbiol. Res*. 168:91-98.

Dimkpa C.O., J.E. McLean, N. Martineau, D.W. Britt, R. Haverkamp, and A.J. Anderson (2013). Silver nanoparticles disrupt wheat (*Triticum aestivum* L.) growth in a sand matrix. *Environ. Sci. & Technol*. 47:1082-1090.

Dimkpa, C.O., J.E. McLean, D.W. Britt, and A.J. Anderson (2012). Bioactivity and biomodification of Ag, ZnO, and CuO nanoparticles with relevance to plant performance in agriculture. *Industrial Biotechnol*. 8:344-357.

Dimkpa, C.O., J.E. McLean, D.E. Latta , E. Manangón, D.W. Britt, W.P. Johnson, M.I. Boyanov, A.J. Anderson (2012) . CuO and ZnO nanoparticles: phytotoxicity, metal speciation and induction of oxidative stress in sand-grown wheat. *J. Nanopart. Res*. 14:1125-1140.

Environmental Quality Management and Remediation

Investigations into Elevated Wintertime Ozone in Utah's Uintah Basin

Principal Investigators:
Dr. Randal S. Martin
Wendy (Meiners) Merkley (MS Student)
Clay Woods (Ph.D. Student)

Partners/Collaborators:
Local: *Uintah Impact Mitigation Special Service District (UIMSDD)*
State: *Utah Division of Air Quality (UDAQ) & Air Monitoring (AMC), USURF's Energy Dynamic Laboratory – Logan and Vernal Branch, USU – Vernal campus Bingham Research Center*
Federal: *US Environmental Protection Agency (EPA), Bureau of Land Management (BLM), National Park Service (NPS), National Oceanic and Atmospheric Administration (NOAA)*

Project Description

- **Need and Purpose:**

  A typical elevated wintertime O_3 (ozone) in the generally rural Uintah Basin was recognized in early winter 2010. Subsequent studies found that winter meteorological conditions, especially snow cover and inversions, were extremely important; however, an extreme abundance of oil and production related volatile organic compounds (VOCs) and oxides of nitrogen (NO_x) were also observed. Elucidation of the source strengths and chemical formation mechanisms will be fundamental to any potential future remediation scenarios. As in previous years, a combination of efforts including MLF funding, as well as funding from several cooperating agencies and research partners, allowed more resources and personnel to contribute to the completion of the 2012/2013 study.

- **Benefits to the State:**

  Ultimately, accurately assessing the wintertime O_3 behavior in the Uintah Basin will quantify the extent of the potential problem, determine the contributing causes of the elevated pollution, and help to identify the most effective remediation scenarios.

- **Geographic Areas:**

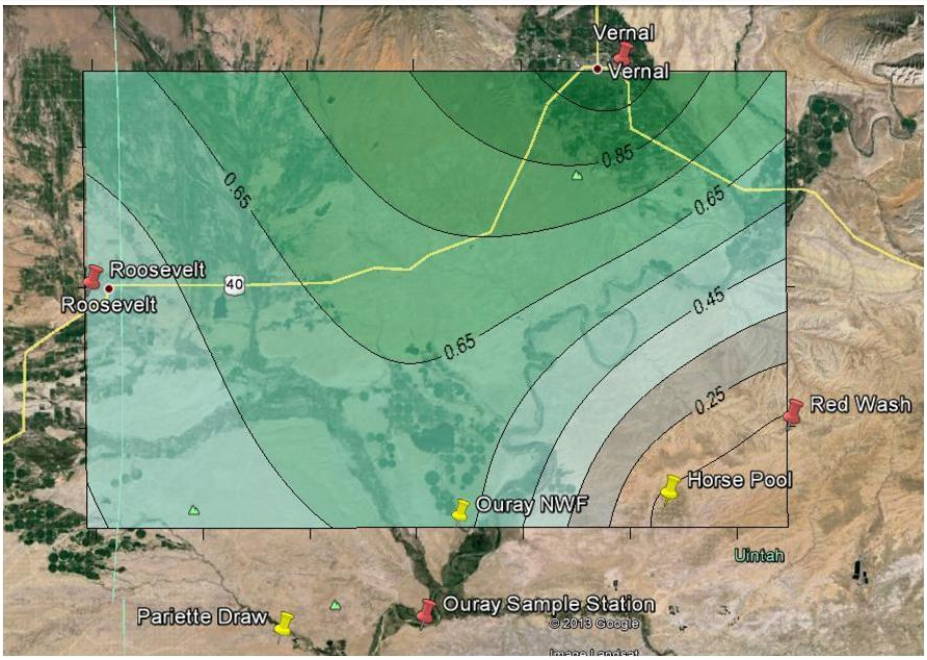
  Study Area: Utah's Uintah Basin (primarily Uintah and Duchesne counties). However, it should be noted that the Basin does include small portions of northwest Colorado (e.g. Dinosaur and Rangley).

  Areas Benefited: The population and industry of the Uintah Basin would be the direct beneficiaries of the described studies. Additionally, similar issues are currently under study by cooperating investigators in the Pinedale, Wyoming area, and it is expected the lessons learned from each area will be shared across the region and with other areas where similar issues could exists (e.g. Farmington, NM).

- **Accomplishments:**

  Findings: Unlike the previous winter (2011/12), when no inversions and, therefore, no O_3 exceedances were observed, the winter of 2012/13 saw multiple inversion/O_3 exceedance episodes. Key data collected under this project included spatial measurement of gas-phase ammonia to compliment NOAA-PMEL's particulate measurement and analysis and spatial &

diurnal measurements of reactive carbonyl compounds (formaldehyde, acetaldehyde, acetone, etc.) to assess Basin-wide photochemical potential in cooperation NOAA-CSD.
Results: The figure below shows the gas-phase ammonia (NH_3), in parts per billion, as measured Feb. 18-21, 2013 over the northeast section of the Uintah Basin. The values (< 1 ppb) are typical of most rural areas in the U.S. and in line with the particle-phase ammonium (NH_4) as measured by NOAA-PMEL. For comparison, NH_3 data as recorded for the same general time period by the National Atmospheric Deposition Program showed 38.2 ppb and 3.6 ppb for Cache Valley (concentrated agricultural industries) and Salt Lake City (highly urbanized), respectively.



Gas-phase ammonia (NH3) measured over the northeast section of the Uintah Basin February 18-21, 2013 (values are in parts per billion).

Work Plan FY12/FY13

The work accomplished in FY12/FY13 went a long way toward identifying key factors in the Uintah Basin's O_3 formation issues. However, many questions still remain, and the various investigators are in the planning stages for continued studies during the winter of 2013-14.

Informational Resources

A comprehensive report combining the information from all of the cooperating investigators is in the final preparation. Additionally, Dr. Martin and two investigators from NOAA submitted a proposal, which was for special sessions dealing with air quality issues associated with oil and gas development at the December 2013 meeting of the American Geophysical Union. With over 50 abstracts submitted, there will be three oral sessions and one poster session.

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Monitoring Organic Contaminants in Air Using Plants as Passive Samplers

Principal Investigators:
William J. Doucette
Todd Wetzel

Partners/Collaborators:
Local: *Erik Dettenmaier, Hill AFB, UT*

Project Description

- **Need and Purpose:**

  Volatile organic compounds (VOCs) including many with documented short- and long-term adverse health effects can enter indoor environments through internal (e.g. paints, paint strippers, fuels, cleaning supplies, building materials, adhesives) and external sources (e.g. vapor intrusion from contaminated groundwater). Indoor air concentrations of VOCs vary but are consistently higher indoors than outdoors. The use of ornamental plants has been suggested as a simple, unobtrusive, and cost effective method for sampling and purifying indoor air. The waxy surface of the leaves has the potential to provide a good surface for the passive capture of VOCs.

  The objectives of this study are to (1) determine if plants can be used as passive samplers to determine the concentrations of VOCs in air and (2) investigate the feasibility of using plants to remove or "filter" VOCs from indoor air. To accomplish the objectives, we will first evaluate the leaf-air concentration factor (LCF), which is the relationship between VOC concentrations in leaf and air as a function of VOC concentration, plant species and time. Three approaches will be used to quantify this relationship. In the first approach, we will use a static headspace method to generate LCFs as a function of plant species and compound concentration. In the second approach we will use a flow-through plant growth chamber constructed of glass and stainless steel to generate LCFs, establish leaf uptake and release kinetics, and determine if plants can be used as VOC "filters." In the third approach, we will conduct a full-scale house release study where common consumer products emitting VOCs will be introduced into a test home.

- **Benefits to the State:**

  Results from this study will contribute to our basic understanding of indoor air quality and the potential to use ornamental plants to monitor and improve indoor air quality. This project will have a direct and positive impact on citizens throughout the state of Utah because of the high percentage of time spent in indoor environments, especially by children and the elderly. An improved understanding of the fate of VOCs in indoor air by regulatory agencies such as the Utah DEQ will also enable the more efficient expenditure of public dollars based on risk management prioritization that will be made possible by this information.

- **Geographic Areas:**

  Study Area: State of Utah.

  Areas Benefited: Indoor air quality is a statewide issue, so all counties in the state would potentially benefit.

Plants sampled in house release

- **Accomplishments**:

  Findings/Results: Initial studies show good correlations between the leaf and air concentrations observed in the three different study types. Preliminary results also show that LCF values are related to the lipid content of the leaves and the octanol/air partition coefficient (K_{oa}) of the chemical. This suggests that plant leaves can be used to monitor indoor air concentrations of VOCs.

  Recent Findings/Results:

Table 1. Leaf concentration factors (LCF) determined using static headspace method

Compound	Log K_{oa}	Ficus [12.39% lipid] LCF (L/Kg)	Spider [9.3% lipid] LCF (L/Kg)	Pothos [6.67% lipid] LCF (L/Kg)	Cactus [3.82% lipid] LCF (L/Kg)
Benzene	2.78	23.86 ± 7.00	15.07 ± 11.41	12.20 ± 5.62	7.21 ± 3.59
Toluene	3.31	75.68 ± 19.90	63.80 ± 40.16	38.18 ± 15.64	19.23 ± 4.22
Xylene	3.78	187.68 ± 46.65	174.56 ± 143.01	481.03 ± 148.31	75.34 ± 24.65
1,2-DCA	2.78	36.56 ± 7.50	28.06 ± 10.95	25.17 ± 5.48	17.49 ± 4.55
TCE	2.99	36.7 ± 10.03	21.54 ± 13.30	12.29 ± 6.08	7.14 ± 3.22
PCE	3.48	89.72 ± 23.22	21.79 ± 9.63	19.11 ± 6.80	15.47 ± 3.53

[%] - Lipid % by dry weight, Values reported as average ± standard deviation

- LCFs determined during initial house release experiments are similar to those determined using the static headspace method.
  - Use of leaves as passive samplers is likely limited to situations where air concentrations are pbbv and above.
- Flow through chamber experiments.
  - Use to generate sorption/desorption kinetics.

Work Plan FY13/FY14

We will continue to examine sorption/desorption kinetics as a function of plant type. The house release experiment will be repeated with four or five plant species and with conventional passive samplers at several locations within the test house.

Informational Resources

Contact: Dr. William J. Doucette, Phone (435) 797-3178, E-mail: william.doucette@usu.edu.

Plant being introduced into chamber system

Headspace method for leaf air partitioning

Phytoremediation Evaluation Site for Quantifying the Fate of Trichloroethylene (TCE) Taken Up by Trees

Principal Investigators:
William J. Doucette
Oliver Diamond
Joe Stewart

Partners/Collaborators:
Local: *Kyle Gorder, Erik Dettenmaier, Hill AFB, UT*
Industry*: Ivan Ray, Weber Canal Company*

Project Description

- **Need and Purpose:**

  Chlorinated volatile organic compounds (CVOCs) are among the most common groundwater contaminants in the US and are found at many locations in the State of Utah, including many communities surrounding Hill Air Force Base. Phytoremediation using fast growing trees has been promoted as a low cost, sustainable remediation alternative for the clean-up of shallow groundwater contaminated with CVOCs like trichloroethylene (TCE). Phytovolatilization from leaves and stems is thought to be a significant loss mechanism for TCE and similar CVOCs. Once transferred into the atmosphere the reaction with hydroxyl radicals rapidly degrades the CVOCs. Plants also have the ability metabolize CVOCs into less persistent and toxic compounds.

  One of the main limitations preventing the implementation of phytoremediation at many sites is the lack of acceptance by the regulatory community. This is often due to a limited understanding of the removal mechanisms and the scarcity of quantitative data supporting the removal effectiveness.

  The goal of this study is to establish a small phytoremediation evaluation site just outside Hill Air Force Base Operable Unit 2 (OU2) that can be used to refine measurement and scaling approaches for estimating the total annual mass of TCE removed from shallow groundwater aquifers by volatilization and metabolism and further investigate the potential for CVOCs and/or their metabolites to contaminate edible fruits.

- **Benefits to the State:**

  Results from this study will contribute to our basic understanding of phytoremediation and the potential to use trees to monitor and improve groundwater quality. It will also provide important information regarding the potential of TCE and other CVOCs to contaminate edible fruits. An improved understanding of the phytoremediation removal mechanisms and kinetics will provide regulatory agencies such as Utah DEQ with the necessary information to determine the potential for using phytoremediation as an alternative to more costly remediation approaches. Information generated regarding the potential for fruit contamination will also enable regulators to better evaluate the risk associated with eating fruit from trees growing over contaminated groundwater.

- **Geographic Areas:**

  Study Area: Weber County.

Areas Benefited: Phytoremediation could be used statewide, so all counties in the state would potentially benefit.

- **Accomplishments**: Approximately 30 poplar whips were obtained from the Utah State University (USU) research farm and planted in a seep area between the Hill AFB boundary and the Weber Canal within OU2 during May 2013.

Work Plan FY13/FY14

Tree cores or xylem samples, leaves, fruit, and leaf, trunk, and soil volatilization flux samples will be collected at least once a month between July and October for a period of several years once the trees are established. Tree core or xylem samples will be analyzed for TCE and other CVOCs using a headspace GC/MS method. Leaf samples will be analyzed for TCE and metabolites of TCE by GC/MS after an appropriate extraction and derivitization procedure. Volatilization of TCE through leaf, trunk, and soil surfaces will be quantified using flow-through or recirculating sampling enclosures followed by GC/MS analysis. A Thiessen approach will be used extrapolate the individual sample or flux measurements to the entire site.

Informational Resources

Contact: Dr. William J. Doucette, Phone (435) 797-3178, E-mail: william.doucette@usu.edu.

Poplar pole being planted

Soil auger used to plant poplar poles

Poplar pole one month after planting

Real-Time Polymerase Chain Reaction (RT-PCR) Instrumentation

Principal Investigators:
R. Ryan Dupont
Joan E. McLean
Darwin L. Sorensen
Babur Mirza (Post-Doc Fellow)

Partners/Collaborators:
Local: *Issa Hamud, Logan City Environmental Department*
Federal: *Kyle Gorder, Mark Roginski, Environmental Management Directorate, Hill AFB*

Project Description

- **Need and Purpose:**

  The use of molecular biology tools in environmental engineering has been growing in importance over the past decade. Qualitative tools for determining the presence or absence of particular microorganisms or functional genes have been the predominant means of investigating contaminated sites and evaluating the performance of bioremediation systems. RT-PCR now provides a means for quantitatively describing microbial communities and function and has become a standard technique for engineering application of molecular biology concepts to bioremediation.

  The objective of this project is to facilitate development and implementation of routine quantitative molecular biology capabilities within the Utah Water Research Laboratory's Environmental Quality Lab (EQL) to support the development of advanced molecular biology research.

  RT-PCR instrumentation provides the EQL with quantitative molecular biology capabilities to generate information regarding the numbers of organisms and functional gene copies in a wide range of environmental soil and groundwater samples. This instrumentation is being utilized by a number of researchers to carry out quantitative analyses of DNA from field and laboratory generated soil, groundwater, plant, and reservoir samples; These RT-PCR tools are being used in conjunction with other microbial community analysis techniques, primarily pyrosequencing, to aid in exploring the make-up of impacted microbial communities and understanding interactions in natural and engineered contaminant environments.

- **Benefits to the State:**

  RT-PCR instrumentation provides quantitative capabilities for the low-level detection of specific microorganisms and functional genes in environmental samples. This technology relates to a number of projects that directly benefit the State of Utah as demonstrated in applications of RT-PCR techniques to:

  1. Provide quantitative analysis of specific organism numbers, gene copies, and/or gene expression using messenger RNA probes so that environmental responses to engineered perturbations (carbon donor addition, electron acceptor addition) can be quantitatively analyzed for improved contaminated site management throughout Utah.

  2. Provide quantitative analysis of microbial community composition in Utah reservoirs to investigate microbial sources of taste and odor and eutrophication problems.

3. Evaluate differences in microbial communities within impacted trees at Hill AFB, an innovative application of molecular biology tools to phytoremediation sites in order to investigate the role microbial communities internal to trees (endophytes) play on the overall fate of TCE at contaminated sites.

4. Evaluate the presence and abundance of arsenic reducing bacteria in soil and groundwater surrounding the Logan City Landfill to isolate the landfill's influence on groundwater quality impairment.

- **Geographic Areas:**

  Study Area: Various counties throughout Utah where soil, groundwater, reservoir, and plant samples have been collected for analysis, including Cache, Davis, Morgan, Salt Lake, Tooele, and Weber Counties.

  Areas Benefited: All counties in the state would potentially benefit from microbial community analysis using these molecular tools on samples from natural, contaminated, or engineered sites.

- **Accomplishments**:

  Findings: At least four separate studies are currently underway or have been recently completed utilizing this equipment as a significant part of the analyses to support system performance evaluation or remedial design. These quantitative molecular tools have been useful in tracking the progress of remediation and the growth and maintenance of remediation cultures applied at a chlorinated solvent site at Hill AFB; evaluating the molecular composition and diversity of groundwater plumes adjacent to Hill AFB; identifying the sources of algal blooms and surface water impacts in Pineview Reservoir; evaluating the presence and abundance of arsenic reducing species in soil and groundwater adjacent to the Logan City Landfill; assessing the composition and diversity of bacterial, archeal, and fungal communities associated with poplar plants in a phytoremediation study at Hill AFB; and evaluating the presence, abundance, and expression of functional genes associated with TCE transformation in large-scale flow through column studies related to OU5 at Hill AFB.

  Results: Specific results generated from the use of this equipment are highlighted in the project summaries for these individual projects.

Work Plan FY13/FY14

Efforts are underway to expand the range of organisms and functional genes that can be quantified using RT-PCR methods. Focused studies improving the recovery of DNA from complex environmental media, and lowering the detection limit of the method are also on-going. This instrumentation will also be utilized in a newly funded laboratory study to investigate at a very fine scale the rate and extent of reductive dechlorination of TCE in response to different carbon donor amendments, along with the release and transformation of arsenic in response to this biostimulation.

Informational Resources

Contact: Dr. R. Ryan Dupont, Phone (435) 797 3227, E-mail: ryan.dupont@usu.edu.

Remediation of Chlorinated Solvent Contamination of Groundwater

Principal Investigators:
Joan E. McLean
R. Ryan Dupont
Darwin L. Sorensen
Suzy Smith (MS student)

Partners/Collaborators:
Federal: *Kyle Gorder and Mark Roginske, Hill AFB*

Project Description

- **Need and Purpose:**

  All counties in Utah have groundwater contaminated with TCE or PCE due to various industrial and dry cleaning operations. TCE and other chlorinated solvents are also common groundwater contaminants at military bases. An improved understanding of the biogeochemistry that influences the dechlorination of solvents will aid in the development of methods for evaluating sites and in the selection of bioremediation options for the successful reclamation of contaminated groundwater.

  Biostimulation has been used at various contaminated sites to promote the reductive dechlorination of TCE, but the addition of a carbon donor also stimulates bacteria that use iron (III) and arsenic (V) as the terminal electron acceptor (TEA). Previous microcosm studies using TCE contaminated aquifer solids from Hill Air Force Base indicate that selection of a carbon donor for biostimulation in the remediation of chlorinated solvent–impacted aquifers may greatly influence the extent of the reductive dissolution of iron minerals and the release of arsenic.

Figure 1. Processing the six-foot columns packed with aquifer solids for Hill AFB. Groundwater with TCE plus various carbon sources has been passed through the columns for over seven years. The columns are now being sampled to investigate the bio-geochemical processes that are favorable to TCE degradation. But what happens to arsenic?

- **Benefits to the State:**

  All counties in Utah would benefit from improved understanding and thus development of remediation strategies for dechlorination of TCE and other chlorinated solvents that are contaminating groundwater resources.

- **Geographic Areas:**

  Study Area: Hill Air Force Base, Davis and Weber Counties.

  Areas Benefited: In addition to the specific areas above, this project will contribute to groundwater protection throughout the state.

- **Accomplishments:**

  Findings: Complete dechlorination of TCE to innocuous breakdown products will occur if the optimal biogeochemical conditions are promoted with the addition of a carbon source. Although carbon addition may be an effective remediation option, an unintended consequence may be the release of arsenic into groundwater.

Results: Columns packed with aquifer solids from HAFB were leached with TCE containing groundwater and one of three carbon sources for over seven-years. These columns were sampled by collecting three cores from each 6-inch layer within the column (Figure 1). Using selective chemical extraction procedures, the biogeochemistry of iron and arsenic, as affected by carbon source addition, was evaluated. Conditions conducive to dechlorination were also favorable for arsenic solubilization (Figure 2), with half of the original mass of arsenic leached out of the columns treated with whey. Whey treated columns showed complete dechlorination of TCE to non-toxic ethane, but arsenic was leached from iron minerals throughout the column (Figure 3). Remediation of TCE contaminated sites may be limited if arsenic is a natural component of the geologic material.

Work Plan FY13/FY14

Identify the microbial community structure, along with the biogeochemical conditions that support the optimal community structure, necessary for the complete dechlorination of TCE in groundwater systems and how these conditions also affects arsenic solubility and mobility.

Informational Resources

Contact: Ms. Joan E. McLean, (435) 797 3199, E-mail: joan.mclean@usu.edu.

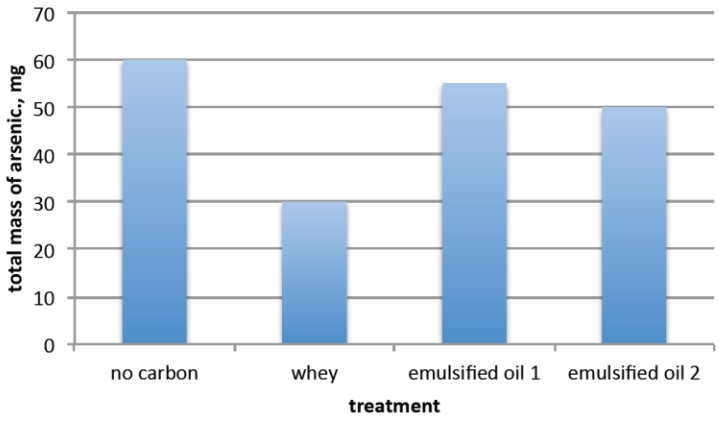
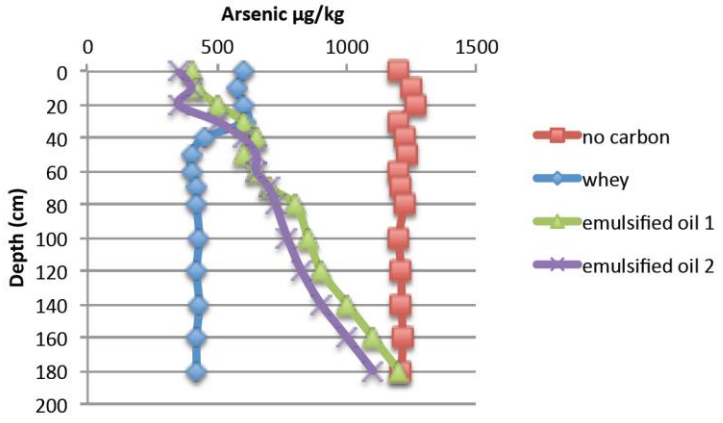


Figure 2. Total mass of arsenic in the columns after 7.5 years of treatment. Addition of any carbon source caused leaching of arsenic out of the column. Treatment with whey led to complete dechlorianation of TCE, but leaching of half of the mass of arsenic out of the column

Figure 3. Arsenic associated with iron oxides, as defined by selective chemical extractions. Arsenic in the surface profile is removed from host iron minerals with addition of any carbon source. The whey treatment produced conditions for arsenic solubilization throughout the profile



Remediation of TCE-Contaminated Soil and Groundwater at Hill Air Force Base (HAFB)

Principal Investigators:
R. Ryan Dupont
Joan E. McLean
Darwin L. Sorensen
Jenny Norton

Partners/Collaborators:
Federal: *Kyle Gorder, Environmental Management Directorate, Hill AFB*

Project Description

- **Need and Purpose:**

  Attempts to stimulate the bioremediation of TCE contaminated groundwater at Hill AFB, Operable Unit 5 (OU5) using relatively simple and inexpensive biostimulation technology were unsuccessful due to low population levels of native dechlorinating microorganisms and the apparent competition for added carbon by non-dechlorinating, iron-reducing bacteria found there in high concentrations. Laboratory scale studies indicated the need for bioaugmentation, along with a source of carbon, for successful reductive dechlorination of TCE in the OU5 aquifer.

  This project evaluates the limitations of biostimulation versus bioaugmentation under simulated field conditions from the laboratory microcosm scale to large-scale flow through column scale. It also develops molecular biology monitoring techniques to identify principal microbial community members in the dechlorinating inocula, and refines these methods to quantify the viability and mobility of organisms in the simulated field environment.

- **Benefits to the State:**

  This project benefits Utah in a number of ways including the following: (1) improving the reliability of source area treatment at OU5 so that TCE exposure and risk to adjacent property owners can be reduced over time in a cost-effective manner, (2) verifying molecular biology tools to provide Hill AFB and the Utah Department of Environmental Quality (DEQ) with cost-effective techniques to monitor the movement and viability of added microbes to ensure adequate control during site remediation, (3) collecting treatment and design data for the control and production of degradation products at OU2 so that complete site remediation can be ensured, and (4) providing cost-effective recovery of impacted water resources at two specific Hill AFB sites and many more sites across the state with similar contamination.

- **Geographic Areas:**

  Study Area: Hill AFB in Weber County.

  Areas Benefited: All locations in the state with TCE impacted groundwater sources as they improve the predictability and reliability of bioaugmentation for contaminated site remediation.

- **Accomplishments**:

  Findings: The spatial distribution of substrate and the microbial community have a significant impact on TCE transformation in OU5 soil. Unlike the small microcosm studies, partial dechlorination of TCE is observed in the flow-through columns with carbon donor addition

without bioaugmentation. The column study confirmed whey as the optimal carbon source in terms of both the rate and extent of TCE transformation. In addition, whey produced the greatest diversity of microbial metabolic pathways of all donors evaluated, supporting and maintaining a microbial community with full functional gene capability for reductive dechlorination of TCE over the cumulative 2,700 days of the study.

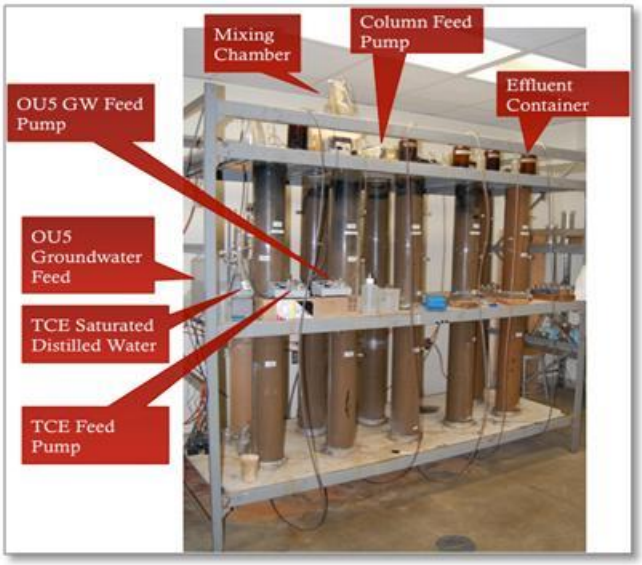
Results: Concentrations of 16S rRNA genes of *Dehalococcoides*, functional genes *tceA, vcrA,* and *bvcA* and quantities of *tceA* and *vcrA* transcripts were determined in the top 9 cm layer of each column using Quantitative PCR. QPCR analyses showed essentially equal concentrations of nearly all targets including *Dehalococcoides* (log 9.3/g), *tceA* (log 7.3/g), and *vcrA* (log 7.5/g) in both the augmented and non-augmented columns. The transcript numbers for *tceA* and *vcrA* genes was also similar in both augmented and non-augmented columns. However, the *bvcA* gene was only detected in the bioaugmented column. Pyrosequencing found *Dehalococcoides* with a frequency of 4.3 x 10^{-4} among 51,550 sequences from non-augmented column samples and 6.7 x 10^{-4} among 64,346 sequences from augmented samples; an enrichment factor of 1.6. Bioaugmentation accelerated TCE dehalogenation and enriched the population density of known dehalogenating bacteria for years following treatment.

Work Plan FY13/FY14

Analysis and data reduction of incrementally sampled soil within the columns continued in FY13 for molecular biology and soil geochemical characteristics.

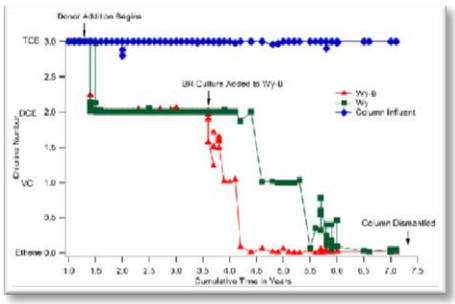
Informational Resources

Contact: Dr. R. Ryan Dupont, Phone (435) 797 3227, E-mail: ryan.dupont@usu.edu.



Flow through columns

Soil core sample collection from columns



Example of TCE transformation results in the form of Chlorine number from whey-amended columns

Study of Cache Valley's Vertical Ozone Profiles and Application to the Uintah Basin

Principal Investigators:
Dr. Randal S. Martin
Mr. Clay Woods (Ph.D. Student)

Partners/Collaborators:
Local: *Uintah Impact Mitigation Special Service District (UIMSDD)*
State: *Utah Division of Air Quality (UDAQ), Air Monitoring Center (AMC).*

Project Description:

- **Need and Purpose:**

  Cache Valley, as well as most of Utah's Wasatch front, is currently non-attainment for $PM_{2.5}$ (particulate matter less than 2 ½ μm in diameter). As of Oct. 1, 2012, Cache County and the Utah Division of Air Quality are in the final steps of developing the required State Implementation Plan (SIP), of which Dr. Martin has been a key participant. Past research has shown that the availability of oxidants, primarily ozone (O_3), is key to the $PM_{2.5}$ formation chemistry. This project is developing and testing a light vertical O_3 system and examining the vertical ozone structure in the wintertime air in Cache Valley using a package adaptable to different vertical platforms (e.g. tethered balloons and unmanned aerial vehicles (UAVs)). Additionally, the unexpected phenomenon of acceptable levels of wintertime O_3 in the Uintah Basin and the need to understand both temporal and spatial O_3 formation, transport, and transformation behaviors has provided an opportunity to apply techniques developed under this project and do comparison studies with external investigators. Over the past three winters of study, the Uintah Basin has exceeded the current ozone standards by significant margins in two of those three years.

- **Benefits to the State:**

  Research into effective methodologies for understanding the vertical behavior of locally generated and regionally transported O_3 will be of key importance when developing remediation strategies, and may be applicable to other air quality issues, as well. Additional air quality benefits may be achieved as differing instrumentation is adapted to the test platform (e.g. real-time, miniaturized methane or ammonia sensors).

- **Geographic Areas:**

  Study Areas: During the past study period, the areas within the study included the Uintah Basin air shed (Uintah and Duchesne Counties) and Cache Valley, UT (including the entire cross-border airshed).

  Areas Benefited: Most of the recent field work has been conducted in the Uintah Basin, in conjunction with a large study organized by the Utah Division of Air Quality but with many cooperating agencies and Universities, including USU-Vernal and the U of U. The Cache Valley airshed is also a direct beneficiary, as much of this work went into the recently submitted SIP.

- **Accomplishments:**

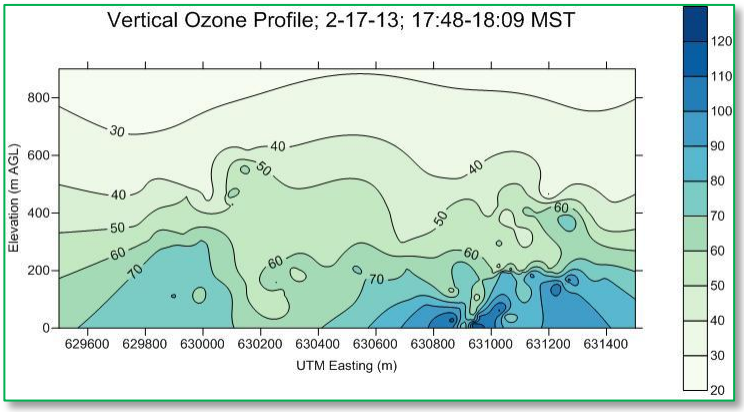
  Findings: In previous years, a 2B Technologies Model 202 Ozone monitor suspended under a tethered balloon package was modified to allow lightweight, stand-alone operation, and it was tested in various scenarios within Cache Valley and the Uintah Basin. This past year the O_3

package was further modified to fit within the payload bay of an autonomous unmanned aerial vehicle (UAV) platform. The airframe is part of the Utah Water Research Laboratory's (UWRL) AggieAir UAV program. The package made several spatial profiles near the location (Horse Pool) of other concentrated measurements in the Uintah Basin by other co-investigators. The figure below shows Austin Jensen (UWRL) and Jim Roberts (NOAA) launching the UAV in the Uintah Basin (Feb. 2013).

Results: The UAV/O_3 system was able to successfully capture the vertically and horizontally layered structure of O_3 with the boundary layers at the sampling location, and they compared very well with the static measurements of the other collocated investigators. The figure below shows a vertical "curtain" O_3 profile as measured in the oil and gas production area of the Uintah Basin. As shown in the figure, the O3 was concentrated near ground level, indicating local production, and the UAV system was able to clearly delineate the inversion layer (~400 m agl) and the variations in O_3 depleted areas (e.g. near 630200 UTM-E) near NO_x and VOC emission areas.

Work Plan FY13/FY14

Work on developing protocols for economically and accurately measuring vertical ozone profiles will continue into FY13-14. We also continue to pursue other funding opportunities to aid in the continued evolution of the system to the UAV-based instrument. It is further anticipated that the UAV will be deployed once again in 2013/2014 Uintah Basin wintertime O_3 studies and may include other small packages, potentially including IR cameras for VOC identification or methane sensors.



Informational Resources

Contact: Dr. Randal S. Martin, (435) 797 1585, E-mail: randy.martin@usu.edu.

Surface and Groundwater Quality and Quantity

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Surface and Groundwater Quality and Quantity

Project Name	FY2013 Actual Expenditures	FY2014 Budgeted Expenditures	FY2015 Planned Expenditures
A Methodology for Improved Groundwater Recharge Estimation in Semi-Arid Regions	$10,000.00	$10,300.00	$0.00
Evaluating the Effectiveness of Three Utah Wastewater Treatment Facilities in Removing Pharmaceuticals and Personal Care Products	$11,618.63	$40,000.00	$41,200.00
Incorporation of Heat into Solute Models	$167,693.40	$172,724.20	$0.00
Investigating Stream Dissolved Organic Matter Dynamics in the Little Bear River Using Continuous Monitoring	$27,624.44	$28,453.17	$29,306.77
Investigating Turbidity and Sediment Transport Dynamics in the Little Bear River Using Continuous Monitoring Data	$5,140.26	$5,294.47	$5,453.30
"Lab-on-a-Chip" Miniaturized Salinity Sensor Arrays for Water Quality Monitoring	$128,796.22	$132,660.11	$86,640.00
Model for Assessment of State of Utah 319 Projects for Controlling Non-point Source Water Pollution	$40,126.71	$41,330.51	$42,570.43
Monitoring Program to Assess Tributary Nutrient Loading into Cutler Reservoir for TMDL Support	$24,193.70	$24,919.51	$0.00
Optimizing Storm Water BMP Performance through Vegetation Selection and Harvesting Strategies	$116,535.94	$120,032.02	$123,632.98
Release of Arsenic from Aquifer Solids under Anaerobic Conditions	$92,196.06	$94,961.94	$97,810.80
Salinity Reduction Measures for the Upper Colorado River Basin	$27,652.45	$28,482.02	$29,336.48
Technical Support for Bear River System Data Acquisition	$29,681.62	$13,902.21	$14,319.28
Water Allocation and Salinity Issues of the Sevier River Basin	$25,862.27	$26,638.14	$27,437.28
Weber Basin Decision Support System (DSS) Modernization	$12,768.08	$13,151.12	$0.00
Designated Projects		$450,141.70	$56,700.00
Undesignated Projects		$141,010.00	$10,000.00
Total	**$719,889.78**	**$1,344,001.12**	**$564,407.32**

A Methodology for Improved Groundwater Recharge Estimation in Semi-Arid Regions

Principal Investigators:
Jagath J. Kaluarachchi
Fathi Anayah (Graduate Student)

Partners/Collaborators:
***Industry**: International Water Management Institute (IWMI)*

Project Description

- **Need and Purpose:**

  In agriculture dominated semi-arid river basins, more than 80% of the water use is for agriculture. In estimating water balance across a river basin, accurate estimates of evapotranspiration (ET), also known as crop water use, are needed. Classical methods of estimating ET use significant amounts of data related to land use and land cover combined with meteorological data that sometimes are not readily available. Given the time and cost of gathering such detailed data, estimation of water use and demand in river basins can lead to significant uncertainty. This project developed an improved approach, The Complementary Relationship Methodology, to estimate ET independent of land cover and land use that uses simple meteorological data as temperature, wind speed, relative humidity, and dew point. The key advantages of the method are the simplicity of the data, the ability to gather metrological data relatively easily, and the ability to predict regional ET estimates suitable for water resources planning and management. Since the methodology depends on simple meteorological data, the analysis can be combined with climate prediction models to predict regional ET and therefore water resources availability in the next few decades.

- **Benefits to the State:**

  Given the dominance of agriculture in Utah, especially in rural communities, accurate estimation of ET is important in water resources planning and management. The Complementary Relationship Methodology proposed here is capable of making accurate estimates of ET with minimal data. This allows the planner to allocate existing water effectively and to estimate potential future water demands under climate change.

- **Geographic Areas:**

  Study Area: For model development purposes, the study areas will include global sites including the US where data with contrasting climatic conditions, land use/class, and other physical conditions are available.

  Areas Benefited: Areas with limited water supply that have agricultural activities sustaining rural economies.

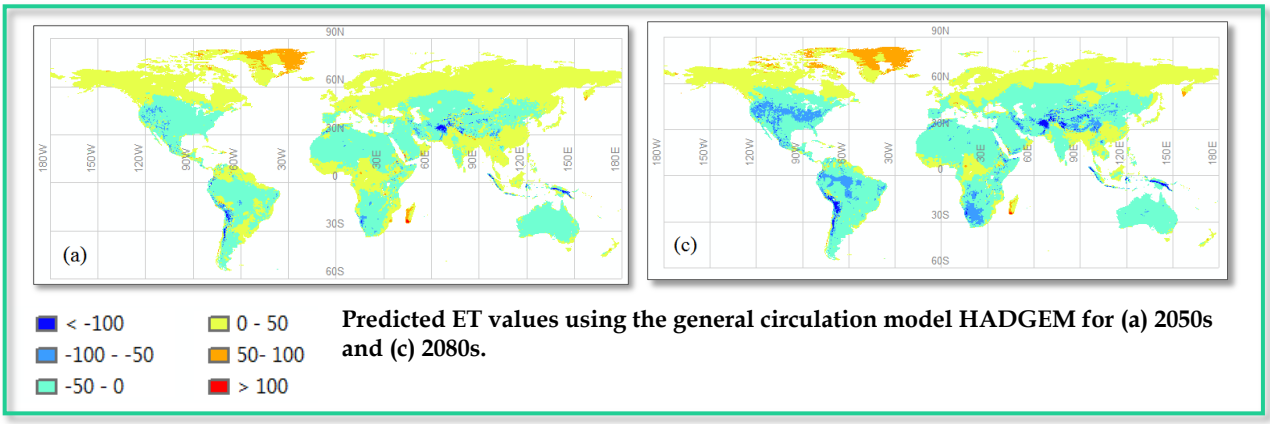
- **Accomplishments:**

  Findings: The work was divided into three major areas consisting of (a) model development, (b) model applications, and (c) global prediction of ET and water surplus under climate change. For model development purposes, data from 39 sites across the globe were selected using FLUXNET database, giving priority to contrasting land use/class, climatic conditions, and physical

conditions. Once the model was developed, the applicability was tested at country scale using Ghana as a test area. Ghana was selected because it was used previously by pioneering scientists, such as Penman, in early studies related to ET because of the strong arid to semi-arid conditions in the north and tropical humid conditions in the south. In the analysis related to climate change, a global study was conducted to assess ET and water surplus (precipitation minus ET) under current conditions and in the first and second halves of the next century.

Results: The results given below show the accuracy of the proposed method, GG18, compared to results of recent studies using performance indicators root mean square, bias, and correlation coefficient. The results indicate very good performance across all indicators for 34 FLUXNET sites across the world. The next two figures show the predicted ET across the globe using HADGEM model for the 2050s and 2080s.

Citation	Method	# of sites	RMSE (mm/month)			BIAS (mm/month)			R^2		
			min	max	mean	min	max	mean	min	max	mean
Present study	**GG18**	**34**	**10.3**	**59.9**	**20.6**	**0.5**	**58.1**	**10.6**	**0.01**	**0.94**	**0.64**
Suleiman and Crago [2004]	Radiometric surface temp. temperature	2	32.0	53.4					0.78	0.94	
Mu et al. [2007]	Revised remote sensing and Penman-Monteith	19	7.7	56.4	29.2	2.9	41.1	15.6	0.13	0.96	0.76
Szilagyi and Kovacs [2010]	CRAE method	3	2.6	39.7	15.3	0.0	21.0	8.4	0.79	0.95	0.85
Han et al. [2011]	Enhanced GG method	4	3.7	16.0	10.7				0.82	0.98	0.92
Huntington et al. [2011]	Modified AA method	5			11.0						0.71
Mu et al. [2011]	Modified remote sensing and Penman-Monteith	46	9.4	52.0	25.6	0.3	28.6	10.0	0.02	0.93	0.65
Thompson et al. [2011]	Penman-Monteith and soil moisture model	14	34.0	175.0	94.1						



Predicted ET values using the general circulation model HADGEM for (a) 2050s and (c) 2080s.

Work Plan FY13/FY14

The work on the project was completed in June 2013.

Informational Resources

Contact: Dr. Jagath J. Kaluarachchi, (435) 797-3918, E-Mail: jagath.kaluarachchi@usu.edu.

Evaluating the Effectiveness of Three Utah Wastewater Treatment Facilities in Removing Pharmaceuticals and Personal Care Products

Principal Investigators:
William J. Doucette
Joe Stewart
Oksana Roth

Partners/Collaborators:
***Local**: Waste water treatment facilities in Brigham City, Spanish Fork, and Hyrum City, Utah,*

Project Description

- **Need and Purpose:**

  Pharmaceuticals and Personal Care Products (PPCPs) in the environment have become a growing concern within the last decade due to the potential ecological effects (e.g., hormone disruption, increased microbial resistance to antibiotics) attributed to some of these compounds. Pharmaceuticals include prescription drugs, over-the-counter medications, and veterinary drugs. Personal care products include lotions, fragrances, and soaps. In addition to traditional personal care products, the term PPCPs has been adopted to represent a wide variety of chemicals used in consumer products including plasticizers and fire retardants. Most PPCPs enter the environment by passing untreated or partially treated through wastewater treatment plants (WWTPs) or septic systems and during the land application of WWTP biosolids containing PPCPs.

  The main objective of this project was to investigate the effectiveness of three Utah WWTPs, each using different treatment technologies, in removing PPCPs. Six PPCPs were selected for this study based on reports of their being found in WWTP effluent and biosolids (Table 1). Removal effectiveness was evaluated by measuring the concentrations of these PPCPs in wastewater influent, effluent, and biosolids samples collected several times during the year. The wastewater treatment technologies used by the three WWTPs were oxidation ditches, trickling filters, and membrane bioreactors (MBR) represented by Brigham City, Spanish Fork, and Hyrum City, Utah, respectively.

Table 1. Selected PPCPs and their uses

Compound	*Acronym*	*Classification*
Caffeine	CAF	Stimulant
Acetaminophen	ACM	Analgesic, antipyretic
Sulfamethoxazole	SMZ	Antibiotic
Tris(2-chleroethyl) phosphate	TCEP	Flame retardant
Carbamazepine	CBZ	Anticonvulsant
Bis(2-ethylhexyl) phthalate	DEHP	Plasticizer

- **Benefits to the State:**

  Results from this study contribute to our basic understanding of the fate of PPCPs in WWTPs and determine which treatment processes are more effective in removing PPCPs. Information on the PPCP concentrations in WWTP influents and biosolids also help facilitate modeling efforts to

protect surface water and groundwater resources from these compounds. An improved understanding of the fate of PPCPs in WWTP by regulatory agencies such as the Utah DEQ also enable the more efficient expenditure of public dollars based on risk management prioritization made possible by this information.

- **Geographic Areas:**

  Study Area: Brigham City (Box Elder county), Spanish Fork (Utah county), and Hyrum City (Cache County), Utah.

  Areas Benefited: Wastewater is generated statewide, so all counties in the state would potentially benefit.

- **Accomplishments:**

  Findings/Results: Caffeine (3.9 – 15.4 µg/L), acetaminophen (7.4 – 71.5 µg/L), and sulfamethoxazole (0.043 – 1.79 µg/L) were detected in the influents of all plants during all sampling events and removals calculated from differences between influent and effluent concentrations were >80%, >99%, >60%, respectively. In the effluents, only sulfamethoxazole (0.02 – 0.52 µg/L) and carbamazepine (0.01 – 0.05 µg/L) were detected in all plants during all sampling events. Tris(2-chloroethyl) phosphate (<LOQ – 0.35 µg/L), carbamazepine (<LOQ – 0.12 µg/L) and bis(2-ethylhexyl) phthalate (<LOQ – 43.7 µg/L) were also detected in several influent and effluent samples but not consistently. Effluent concentrations of the six PPCPs were below the levels of concern based on available toxicity data.

LC/MS system for analysis of PCPPs

Extraction of water samples for PCPPs

Table 1. Estimated percent removal of PPCPs by Brigham, Hyrum, and Spanish Fork WWTPs.

Month	May			July			August		
Technology	OD	MBR	TF	OD	MBR	TF	OD	MBR	TF
Compound	Brigham	Hyrum	Spanish Fork	Brigham	Hyrum	Spanish Fork	Brigham	Hyrum	Spanish Fork
CAF	> 98.8	94.1	87.7	> 98.6	> 98.3	83.9	> 99.4	> 99.1	80.5
ACM	> 99.9	99.9	99.9	> 99.8	> 99.7	> 99.8	> 99.9	> 99.9	>99.9
SMZ	90.9	59.3	94.2	74.9	(*)	88.8	83.2	75.3	90.4
TCEP	> 52.2	44.3	68.1	(*)	(*)	19.7	(*)	28.2	(*)
CBZ	20.8	(*)	64.9	(*)	(*)	(*)	(*)	39.4	(*)
DEHP	> 2.7	> 34.2	> 97.3	> 20.0	> 34.4	> 32.8	<LOQ	<LOQ	<LOQ

Note: (*) – Effluent concentration > influent concentration.

Work Plan FY13/FY14

This project ended FY13.

Informational Resources

Contact: Dr. William J. Doucette, Phone (435) 797 3178, E-mail: william.doucette@usu.edu.

Incorporation of Heat into Solute Models

Principal Investigators:
Bethany T. Neilson

Partners/Collaborators:
Local: *Corey Cram, Washington County Water Conservancy District*
State: *Brad Hunt/UDWR; Steve Meismer, Virgin River Program*
Federal: *Rick Friedell, US Fish and Wildlife Service*

Project Description

- **Need and Purpose:**

  In many watersheds, exchanges between surface water and groundwater play an important role in understanding solute transport and transformations. Quantifying the relative magnitude and direction of these exchanges is important for understanding both the energy and the mass balances within streams and rivers. A number of different methods have been developed to assist in quantifying these interactions, including data collection techniques that use a variety of sensors and sampling procedures and a combination of data collection and modeling techniques. There are questions, however, as to the appropriateness and accuracy of these methods for different systems. This project analyzes the data resulting from the combination of several different data collection techniques as multiple lines of evidence toward quantifying the magnitude and direction of fluxes between surface water and groundwater using various modeling approaches. Further, because conditions within Curtis Creek have changed significantly over the past few years due to beaver colonization, significant efforts have been focused on understanding the influence of beaver dam complexes on groundwater/surface water interactions and heat and solute transport.

- **Benefits to the State:**

  This area of research provides for a more complete understanding of the impacts of transient storage and surface water-groundwater interactions on streams in Utah and the Intermountain West. It also provides a platform to understand the influences of beaver dams on instream processes. As methods are developed to measure and predict the fate and transport of constituents in streams and rivers, while simultaneously considering the impacts of surface water-groundwater interactions, the state of Utah will have the tools and methods necessary to complete these types of studies and better manage limited water sources. This effort will also assist the state in understanding the implications of the recently passed State of Utah Beaver Management Plan.

- **Geographic Areas:**

  Study Area: Curtis Creek, Hardware Ranch, Cache County, Utah; Silver Creek, Summit County, Utah; and Virgin River, Washington County, Utah.

  Areas Benefited: The current applications of the modeling approach span desert and mountain watersheds. Therefore, the entire State of Utah could potentially benefit.

- **Accomplishments:**

  Findings: Data collection strategies and new approaches to model development have provided more accurate heat and solute fate and transport predictions through the main channel, dead zones, and the surface-groundwater interface of rivers and streams (referred to as two-zone

transport models). Analytical solutions have been developed to describe these transport processes better than more traditional methods using numerical solutions. Additionally, the introduction of heat into solute transport models allows for more cost-effective data collection and predictions that cover larger time periods that are often limited when using solute alone. New techniques have also been developed to account for spatial variability in system characteristics using information extracted from aerial high resolution multispectral and thermal infrared imagery gathered by AggieAir. The analytical solutions combined with a convolution approach provide methods to incorporate spatially variable parameters and investigate increased data resolution on solute transport predictions. Finally, we are quantifying the influences of beaver dam development (see illustration) over time on solute and heat transport.

Results: Analytical solutions of two-zone solute transport, as well as temporal moments, have been developed with the use of Laplace transforms and have been tested against observed solute data within various systems. These solutions allow parameters within the model to be treated as functions of space rather than having to transfer information from reach to reach. Imagery has been found to be critical in estimating parameters and in capturing the longitudinal and lateral spatial variability present within desert and mountain streams in Utah. Many conference presentations have been delivered and three journal articles recently published, with one in revision and two more nearly ready for submission.

Work Plan FY13/FY14

The two-zone solute analytical solutions and temporal moments are complete. We have tested these formulations on various data sets within rivers in Utah. The overall objective is to fully integrate heat into the solute model so accurate predictions of both heat and solute can be made. We continue to collect data in different study reaches to quantify the influences of beaver dams on heat and solute transport. A new modeling approach to quantify the changing heat fluxes on beaver ponds is also being developed.

Informational Resources

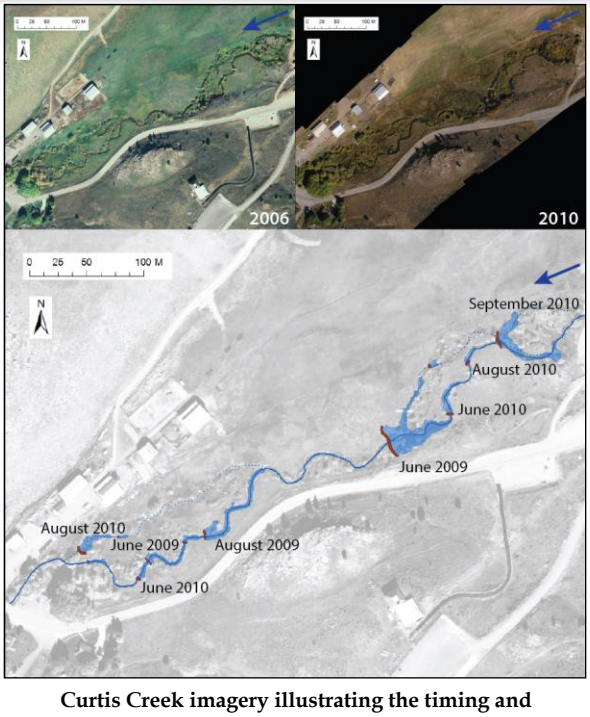
Contact: Dr. Bethany T. Neilson, (435) 797 7369,
E-mail: bethany.neilson@usu.edu.

Representative Publications:

Neilson, B.T. (2012) Determining key heat fluxes necessary for instream temperature predictions. *2012 Fall Meeting, American Geophysical Union*. Abstract H51M-02. San Francisco, CA. (INVITED). December 3-7.

Heavilin, J. and B.T. Neilson (2012). An analytical solution to main channel heat transport with surface heat flux. *Advances in Water Resources*, 47:67-75, doi: http://dx.doi.org/10.1016/j.advwatres. 2012.06. 006.

Schmadel*, N.M., B.T. Neilson, and T. Kasahara (2013). Deducing the spatial variability of exchange within a longitudinal channel water balance. *Hydrological Processes*, doi:10.1002/hyp.9854.



Curtis Creek imagery illustrating the timing and impact of beaver colonization

Investigating Stream Dissolved Organic Matter Dynamics in the Little Bear River Using Continuous Monitoring

Principal Investigators:
Jeffery S. Horsburgh
Amber Spackman Jones
Brant Whiting (Student)
Nate Mouzon (Student)

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  Dissolved organic matter (DOM) is ubiquitous in aquatic environments and plays a major role in the health of stream ecosystems. Riverine DOM is important in carbon dynamics and nutrient budgets because it participates in the complexation of trace metals and the mobilization of pollutants. It is also a key water quality constituent that affects the cost and efficacy of drinking water treatment as well as disinfection byproduct formation. Many processes from the local to regional scale, such as climate variability, artificial drainage, and land use change, are known to affect the flux and composition of riverine DOM. However, the usual, infrequent grab-sampling approaches have been inadequate to characterize the timing, magnitude, and composition of DOM transported within watersheds. Few studies have examined changes in DOM concentrations in streams over continuous time scales, and this has resulted in an incomplete understanding of the mechanisms affecting DOM dynamics. New optical sensors capable of measuring Chromophoric DOM (CDOM) as a surrogate for DOM concentrations with frequencies on the order of minutes are now becoming available for use in streams and rivers. This project is investigating the use of high frequency CDOM monitoring within the Little Bear River Watershed of northern Utah, coupled with grab sampling and laboratory measurements of DOM. The objective is to determine the mechanisms controlling DOM dynamics in western rivers like the Little Bear River.

- **Benefits to the State:**

  The hydrologic regimes of most of Utah's rivers are driven by spring snowmelt. Results from analyses of high frequency data collected in the Little Bear River indicate that approximately 50 – 60% of the annual sediment (and associated phosphorus) loading in the river occurs within a time period of about 2 – 3 weeks during the early spring snowmelt period. This short response period is poorly characterized by a few water quality grab samples, which provide no information at all about sources of phosphorus or sediment. While DOM may behave significantly different than phosphorus or sediment, we anticipate that it will exhibit behavior that is not well characterized by low frequency grab samples. The continuous monitoring techniques that we are developing will provide information about the timing, magnitude, and composition of the sources and flow paths of DOM. The research will aid the State of Utah Division of Water Quality, utilities providing drinking water to municipalities, and other water quality organizations in controlling the impact of DOM on water quality and aquatic environments.

- **Geographic Areas:**

  Study Area: Little Bear River in Cache County.

  Areas Benefited: The Little Bear River and other river systems state-wide.

- **Accomplishments:**

  Findings: Previous studies within the Little Bear River have shown that large percentages of the fluxes of some water quality constituents occur within a very short time window associated with spring snowmelt. To capture CDOM data during high flow events (such as snowmelt) we are working to overcome the challenges associated with deploying the CDOM sensors, which will be necessary to successfully collect data in the Little Bear River. We are examining different techniques for obtaining viable measurements that can be corrected for common interferences such as turbidity, which can be high during snowmelt periods. We are also designing and testing sensor housings appropriate for deploying CDOM sensors in high-flow scenarios.

  Results: We are working to (1) develop a demonstration of how new CDOM sensors can be deployed and used to make continuous estimates of DOM concentrations, (2) develop a demonstration of how continuous CDOM measurements can be integrated with existing monitoring and telemetry systems like the one in the Little Bear River, and (3) examine the timing and magnitude of DOM fluxes in the Little Bear River to examine potential sources and flow pathways. We continue to maintain seven continuous, aquatic monitoring sites in the Little Bear River at which CDOM sensors could be installed. We have already established the necessary database and data processing protocols that will enable us to integrate the new CDOM sensors with existing monitoring and telemetry equipment in the Little Bear.

Work Plan FY13/FY14

We will deploy and test new CDOM sensors and conduct high frequency monitoring in the Logan River at the UWRL as a controlled experiment to test the deployment techniques that we have been developing. We will then deploy these sensors at multiple sites within the Little Bear River, coupled with much lower frequency grab sampling and laboratory measurement of DOM to investigate the mechanisms controlling DOM dynamics.

Informational Resources

Contact: Dr. Jeffery S. Horsburgh, Phone (435) 797-2946, E-mail: jeff.horsburgh@usu.edu.

Website: http://littlebearriver.usu.edu.

Sensor fouling is one challenge we are working to overcome in making reliable CDOM measurements

A continuous monitoring site on the Little Bear River

Investigating Turbidity and Sediment Transport Dynamics in the Little Bear River Using Continuous Monitoring Data

Principal Investigators:
Jeffery S. Horsburgh
Amber Spackman Jones
Brant Whiting (Student)

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**
  In recent years, water managers have increasingly recognized the need to include sediment control strategies within watershed management plans. In many cases, suspended solids are regarded as a primary indicator of pollution. Information on the timing and sources of the sediment transported by a river is an important requirement for designing effective sediment control strategies. High concentrations of suspended sediment can limit light for aquatic vegetation growth, contribute to low dissolved oxygen levels, impact aquatic insects, damage fish gills, and impact fish spawning. Additionally, pollutants such as phosphorus are often associated with suspended sediment through complex binding effects. This can increase the time such pollutants are resident within a watershed because of repeated deposition with their sediment hosts. Turbidity, which is an optical measure of water clarity, is often used as a surrogate variable for suspended solids concentration because it is easy and inexpensive to measure. This project used high-frequency turbidity monitoring at several different sites within the Little Bear River Watershed of northern Utah, coupled with much lower-frequency grab sampling of sediment concentrations to investigate methods to better quantify the sources, timing, and magnitude of sediment fluxes.

- **Benefits to the State:**
  Because the analysis and monitoring techniques we developed provide information about the timing, magnitude, and the source of sediment loading, they are of interest to the State of Utah Division of Water Quality and other water quality organizations nationwide as a more effective way of quantifying TSS loading. Indeed, we have already begun coordinating with individuals within the Utah Division of Water Quality to share our experience and expertise.

- **Geographic Areas:**

  Study Area: Little Bear River in Cache County.

  Areas Benefited: The Little Bear River and other similar river systems state-wide.

- **Accomplishments:**

  Findings: Within the State of Utah, the hydrology of most rivers is driven by spring snowmelt. Results from analyses of data collected in the Little Bear River indicate that approximately 50-60% of the annual sediment (and associated phosphorus) loading within the Little Bear River occurs within a time period of about 2-3 weeks during the early spring snowmelt period. This short response period is poorly characterized by water quality grab sampling, which provides no information at all about sources of sediment. Relationships between turbidity and sediment concentrations are site-specific. This leads to the need to evaluate our approaches for estimating

continuous sediment concentrations using surrogates like turbidity, which can be measured in-situ with high frequency.

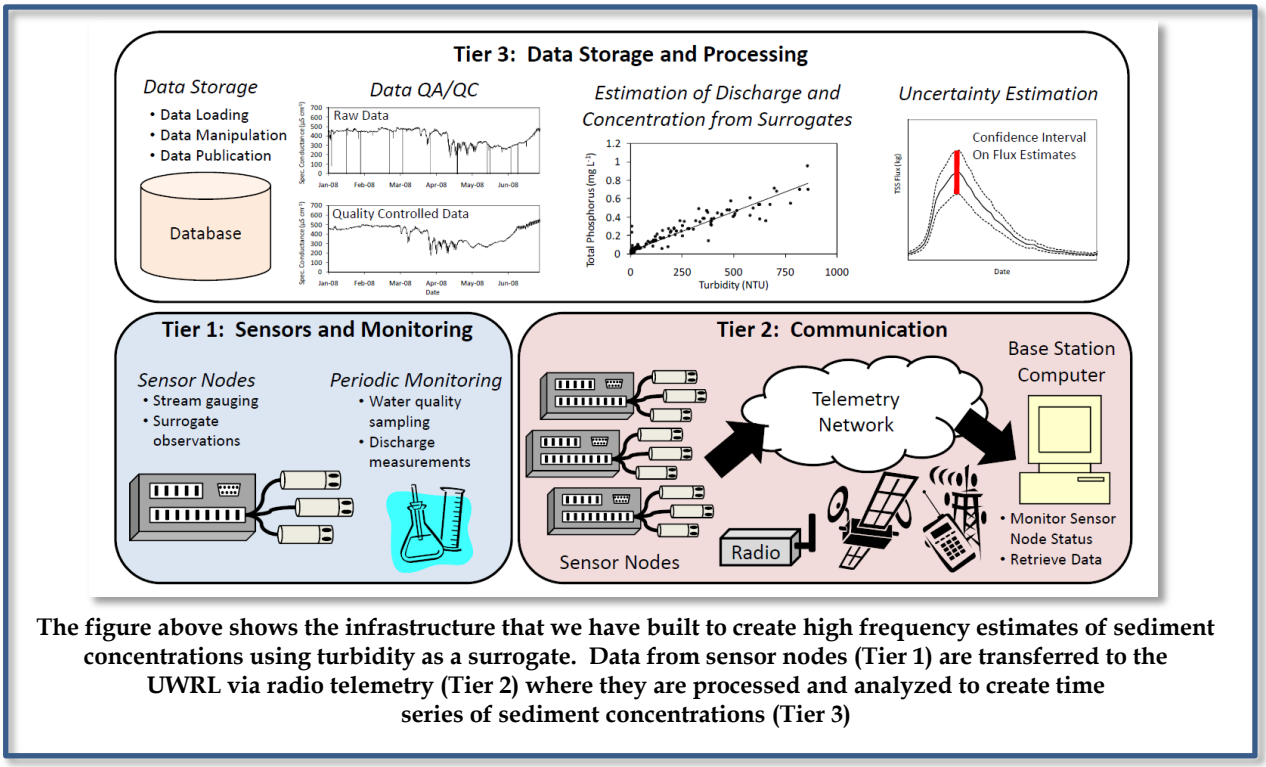
Results: We developed the monitoring infrastructure to create continuous turbidity measurements and made routine and event sampling visits to monitoring sites in the Little Bear to collect the data needed for this project. We investigated the generality of the surrogate monitoring approach, including examining the effects of point vs. width and depth integrated sampling on estimates of sediment loading. We also investigated the site specific nature of relationships between turbidity and sediment concentrations and developed robust methods for estimating suspended sediment concentrations and loads from continuous turbidity and streamflow data. Relationships between suspended sediment concentrations and turbidity were established at each of the monitoring sites and a suspended sediment loading profile was developed for the Little Bear River watershed. Finally, we examined new data characterizing the particle size distribution of sediment to examine the effects of particle size distribution on the relationship between suspended sediment and turbidity. Continuous data collection is ongoing at seven stream sites and four continuous weather stations.

Work Plan FY13/FY14

Work on this project is now complete. However, as part of related projects we will continue our work with ongoing data collection at several monitoring sites within the Little Bear River to assemble high frequency records of water quality. Results of this project are documented in the final thesis report of Master of Science student Brant Whiting.

Informational Resources

Contact: Dr. Jeffery S. Horsburgh, Phone (435) 797-2946, E-mail: jeff.horsburgh@usu.edu.
Website: http://littlebearriver.usu.edu.



The figure above shows the infrastructure that we have built to create high frequency estimates of sediment concentrations using turbidity as a surrogate. Data from sensor nodes (Tier 1) are transferred to the UWRL via radio telemetry (Tier 2) where they are processed and analyzed to create time series of sediment concentrations (Tier 3)

"Lab-on-a-Chip" Miniaturized Salinity Sensor Arrays for Water Quality Monitoring

Principal Investigators:
Anhong Zhou

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  Utah is one of seven western states in the United States (Arizona, New Mexico, California, Utah, Colorado, Wyoming, and Nevada) making up the Colorado River Basin Salinity Control Forum. The forum manages the problem of elevated salinity levels in the Colorado River. Salt in the Colorado River, aside from the natural sources, generally results from activities in support of irrigated agriculture in the Upper Colorado River, especially in drainages such as the Price and San Rafael Rivers in Utah. However, there is substantial uncertainty about the efficacy of salinity management in the basin due to the lack of a commercially available detection device to adequately measure salinity levels in the river. This project is aimed at developing a portable, reliable, affordable chemical sensor device capable of measuring the concentrations of individual salt ions in the field.

- **Benefits to the State:**

  The ability to detect a majority of salinity ions (Cl-, Na+, SO42-, Mg2+, Ca2+, and HCO3-) will help Utah to better manage and control contributions to the Colorado River salinity problem. Benefits of this project include (1) ion sensor arrays that can measure salt loading in critical Utah rivers, (2) a new portable detector not currently available for measuring the most significant salinity ions contributing to salinity from Utah and other states, and (3) help for farmers and Utah residents to improve the timing and efficiency of water quality monitoring and track the salinity sources in the water system.

- **Geographic Areas:**

  Study Area: Price and San Rafael Rivers, Cache County in Utah.

  Areas Benefited: Salinity concerns are statewide, so all counties in the state would potentially benefit from this project.

- **Accomplishments:**

  Findings: We are beginning to fabricate integrated sensor arrays for use as DNA biosensors for the detection of multiple genotypes of waterborne pathogens. These low cost sensor arrays can be easily adapted for multiple ion detection.

  Results:
  1. A project focus this past year was to work closely with USU Office of Commercial Enterprises to find an industry partner interested in licensing our patented sensor technology for water quality monitoring.
  2. As shown in the figures below, a cost-effective sensor arrays (much less expensive than the previously fabricated sensor) was fabricated. These sensor arrays are gapped-duplex label

free DNA biosensors to specifically detect the human genotype of *Cryptosporidium*. One invention disclosure was submitted to USU Office of Commercial Enterprises.

3. Work on fabrication of the integrated sensor array device is performed in the Cleanroom lab at the Physics Department at Utah State University (see photo below).

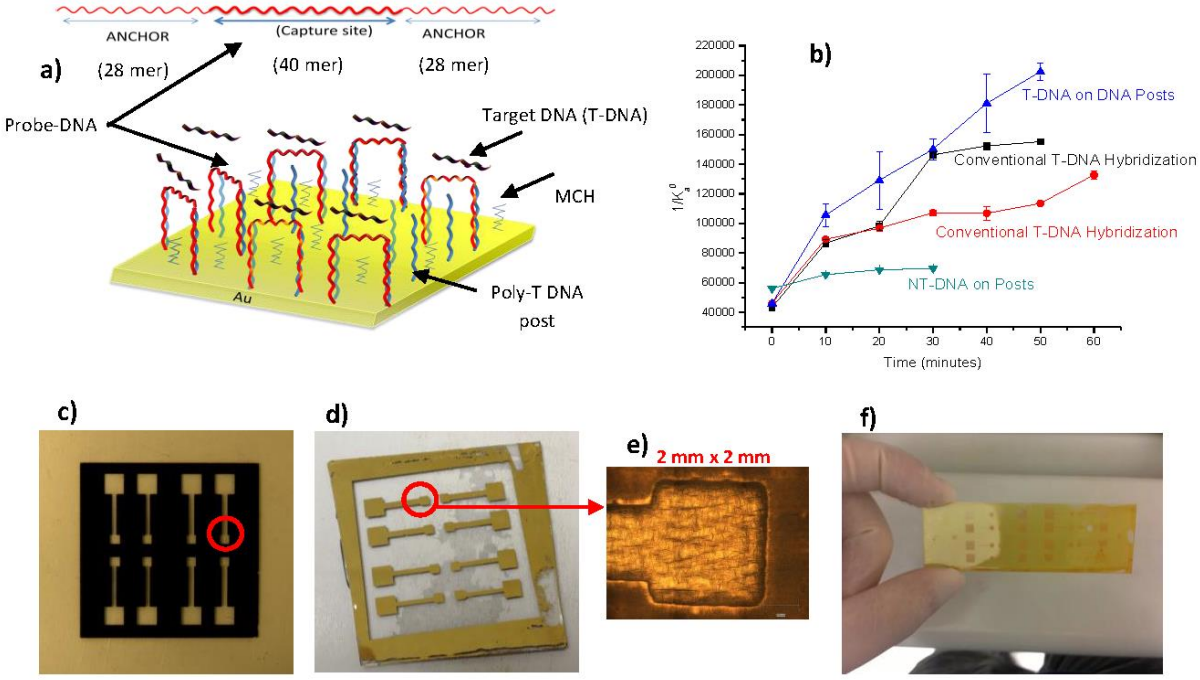


Figure 1. Gapped-duplex label-free DNA biosensor: (a) schematic of working principal, (b) preliminary electrochemical impedance data showing the specificity in detection of sequence specific target DNA, (c) mask of low cost sensor array,(d) sensor array fabricated on transparent sheet, (e) individual sensors (2 mmx2mm), (f) sensor array fabricated on a glass slide

Work Plan FY13/FY14

- Continue working with USU Office of Commercial Enterprises to commercialize our previously patented multiple-ion sensor detection technology.
- Optimize the design and fabrication of the prototyped sensor array device.
- Optimize the circuit design of minimalized potentiostat to adapt to a portal instrument for multiple ion detection in water.

Informational Resources

- R. Fernandez, S. Williams, R. Li, A. Zhou, Gapped-Duplex Structure to Label-Free Mismatch Detection of Pathogen DNA on Solid Substrate, *manuscript in preparation.*
- R. Fernandez, A. Zhou, Gapped duplex approach to label-free DNA mismatch detection, invention disclosure submitted to USU Intellectual Property Services (May 14, 2013).

Contact: Dr. Anhong Zhou, Phone (435) 797 2863, E-mail: Anhong.Zhou@usu.edu.
Website: Dr. Zhou at Dept of Biological Engineering, USU: http://www.be.usu.edu.

Salinity probe project at UWRL, USU:
http://uwrl.usu.edu/researchareas/surfacewaterquality/labonachip.html.

Model for Assessment of State of Utah 319 Projects for Controlling Non-Point Source Water Pollution

Principal Investigators:
David K. Stevens
Darwin L Sorensen
Nancy Mesner;
Lorien Belton; Douglas Jackson-Smith; Phaedra Budy
JInsu Choi; Nira Salant (Students)

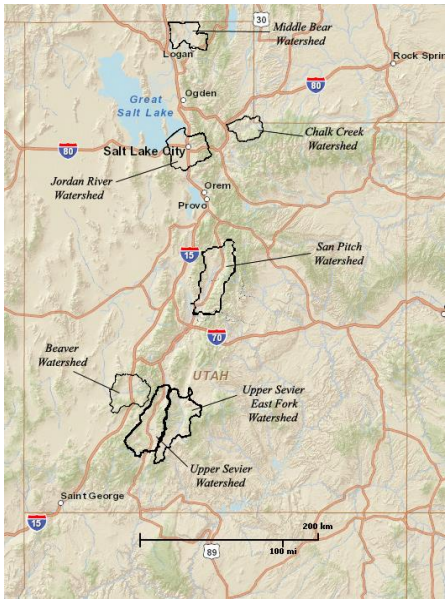
Partners/Collaborators:
***Local**: Bear River Canal Company*
***State**: Utah Department of Environmental Quality*

Project Description

- **Need and Purpose:**

  Nonpoint source (NPS) pollution remains a significant public policy concern in the State of Utah, and it makes addressing pollution problems a challenge because of the dispersed nature of NPS pollution and the large numbers of actors involved. Individual changes may not be significant enough to noticeably improve environmental conditions. Public programs can encourage voluntary changes in individual behavior thought to contribute to documented water quality problems.

  Public efforts to reduce NPS water pollution in Utah have met with some success. A comprehensive water quality monitoring program tracks current conditions and water quality trends for all 14,250 miles of rivers and streams, and nearly 3,000 lakes and reservoirs in Utah (UDEQ 2009). Nevertheless, a detailed assessment of the impact of public 319-funded projects on measured water quality has yet to be conducted in the state. This study assesses the efficacy of these projects.



Assessment locations for State of Utah 319 non-point source water pollution reduction projects

- **Benefits to the State:**

  Most of the agricultural watersheds in Utah have supported non-point source pollution mitigation projects under EPA's 319 program as well as other federal and state programs of the Dept of Interior, U.S. EPA, and USDA. More than half of the almost $30 million expended since 1990 has gone to watershed projects that typically involve cost-sharing, technical assistance, and educational programs to encourage landowners to implement appropriate best management practices (BMPs) to reduce pollution loadings to impaired waterways.

- **Geographic Areas:**

  Study Area: Beaver River, Chalk Creek, San Pitch River, Upper Sevier River, Middle Bear River. A map of the watershed is provided above.

Areas Benefited: Watersheds statewide.

- **Accomplishments:**

Findings/Results: Overall, our study found that most 319-funded projects are still in place, still functional, and appreciated by the landowner. Only a small minority of BMPs experienced implementation problems. Poor design was the most cited reason for difficulties in implementing animal waste BMPs, and helped explain the least successful rural stream BMP projects. Our qualitative assessment—based on interviews and field assessments—suggests that Roughly 60 percent of BMPs likely or definitely produced positive impacts on water quality. Another 15 percent were in situations where it was difficult to clearly evaluate the net water quality impacts. About a quarter of all BMPs in rural watersheds were considered unlikely to have improved water quality. The lack of impact usually related to the placement of the BMPs in areas that were far from the targeted water body and/or designed mostly to accommodate other goals (such as improving irrigation efficiency). From the landowner point of view, the water quality impacts from BMP use are less evident (or important) than the beneficial impacts on labor, farm productivity, or recreation activities from the projects.

The qualitative study indicated that most respondents had a good basic understanding of the state's NPS program goals and the state's most significant pollutant concerns. Respondents expressed several concerns about program efficacy, including concerns about allocation of 319 funding (e.g., too focused on staff support rather than actual implementation of projects); poor coordination between the state agencies for land management programs; poor contract management and poor record keeping on project outcomes and impacts; monitoring approaches that limited the ability to adequately document program impacts; and failure of the program to 'tell the 319 story' to Utah citizens and decision makers.

Evidence from watershed hydrologic models suggests that the full suite of 319-funded BMPs likely improved nutrient loadings and concentrations by very modest amounts (phosphorus dropped between 0.1% and 3%, while nitrogen declined 0.1-0.2%, over a 15 year period of simulations). The small changes in total nutrient loadings were associated with two factors: (a) the relatively small proportion of the watershed that was affected by 319 BMP implementations, and (b) the high background levels of nutrient flows in the affected waterways. Water quality improvements were more significant at the subbasin scale—particularly in the winter and spring when hydrologic conditions generated higher total nutrient loads.

Taken as a whole, assessment of BMP impacts was constrained by poor record keeping, a lack of pre-project data, and the absence of systematic and ongoing monitoring of BMPs and water quality conditions. Improved monitoring efforts and data management for future BMP projects will be necessary to ensure program evaluations can provide more detailed, project-specific information on key parameters for NPS source reduction. Several suggestions for improving the program's administration and implementation, partnerships, monitoring and reporting, and communications and outreach will be included in the final report.

Work Plan FY13/FY14

Completion of final report revisions.

Informational Resources

Contact: Dr. David K. Stevens, Phone (435) 797 3229, E-mail: david.stevens@usu.edu.

Monitoring Program to Assess Tributary Nutrient Loading into Cutler Reservoir for TMDL Support

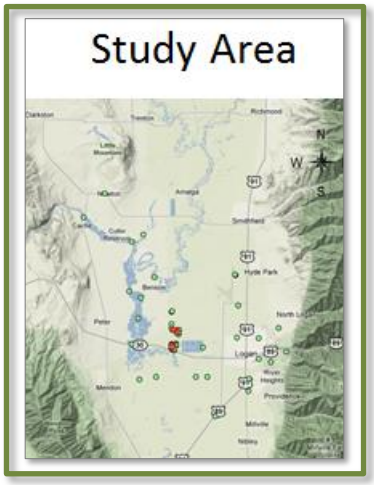
Principal Investigators:
David K. Stevens
R. Ryan Dupont
Darwin L. Sorensen
Joan E. McLean
Jeffery S. Horsburgh
James Milleson
Ana Ovalle and Ruba Mohamed (Students)

Partners/Collaborators:
Local: *Issa Hamud and Jim Harps City of Logan*
Wynn Cardon, land owner, producer
Jason Fuhriman, producer

Project Description

- **Need and Purpose:**

This project provides water quality monitoring in eight rivers draining into Cutler Reservoir, at five locations within the reservoir itself, at 15 waste water reuse sites, and at 15 waste water collection system sites. Measurements include loadings of nutrients and suspended sediments and general water quality as measured by temperature, dissolved oxygen, turbidity, and total dissolved solids, as well as heavy metals at the waste water reuse and collection system sites. We also obtained additional data related to sediment samples and the nutrient and oxygen fluxes from the sediments into the overlying water, in addition to primary production measurements in several of the tributaries. These data are used to estimate the internal nutrient loading and corresponding oxygen demand under different environmental conditions.



Based on discussions with City of Logan Environmental Department personnel, a sampling program was carried out in these locations to develop baseline information regarding nutrient loading and water quality in Cutler Reservoir:

- Spring Creek (at Mendon Road).
- Logan River (near Mendon Road) .
- Little Bear River (at Mendon Road) (monitoring using existing UWRL funds).
- Swift Slough near Cutler (2 sites).
- Clay Slough near Benson.
- Blue Springs near Benson Road.
- Bear River into Cutler.
- Cutler Reservoir (5 locations).
- Ground water monitoring wells (15 stations) and four nesting lysimeters at 12-, 24-, and 36-inch depths in two pastures irrigated with treated wastewater from the City of Logan WWTP.
- Fifteen waste water collection system sites in Smithfield, Hyde Park, North Logan, Logan, Nibley, Providence, and River Heights.

The river and reservoir sampling locations have been sampled monthly, beginning January 2009, using grab sampling, vertical profiling, and manual field and laboratory analyses to aid in placement of continuous probe measurement stations. Flow estimates to determine load were made by establishing a datum at each location and measuring the water surface elevation relative to that datum using a staff gauge. Rainfall events were targeted for sampling over a 24-month

period, as were in-reservoir diurnal monitoring. In addition, the well and lysimeter stations and the waste water collection system sites have been sampled since April 2010.

- **Benefits to the State:**

  The project benefits the state by estimating a full accounting of total phosphorus loading into Cutler Reservoir and the reservoir response to loading, supporting state TMDL plan implementation based on City of Logan improvements to control phosphorus loads at the WWTP, and by identifying additional phosphorus sources entering the reservoir.

- **Geographic Areas:**

  Study Area: Bear River Basin, Cache County.

  Areas Benefited: City of Logan/Cutler Reservoir.

- **Accomplishments**:

  Findings: Automated flow and water quality monitoring stations have been installed, and monthly field sampling is ongoing at project sites for nutrients and Chlorophyll A (in the reservoir only). Well and lysimeter sites have been monitored for nutrients, pH, dissolved oxygen, specific conductance, and turbidity since April 2010. Waste water collection system sites were sampled for BOD5, suspended solids, and nutrients, as well as pH, dissolved oxygen, temperature, turbidity, and specific conductance. Field sampling efforts were reduced during 2012/13 and integrated with parallel data collection efforts in the Cutler Reservoir contributing watershed.

  Results: The outcome of this project is a large and growing data set for public and research use. The data through June 2013 are currently accessible by contacting the PI. In the future, data will be accessible to the public at http://bearriverinfo.org (the Bear River Watershed Information System). The data and preliminary conclusions were presented at the Cache County Cutler Reservoir Management committee, the WEAU Spring Conference in St. George, and the USU Spring Runoff Conference. In addition two master's degrees have been awarded based on this project. One degree explored the sediment oxygen demand and nutrient release at several locations in Cutler Reservoir and the Bear River, and the second measured and provided model inputs for assessment of primary production in several tributaries to Cutler and predicted the diurnal variation of dissolved oxygen for the Little Bear River at Mendon Rd.

  These two projects also explored the effect of watershed land use on SOD and primary production and found that watersheds with higher percentages of agriculture had higher SOD and primary production than those from watersheds with land use dominated by forest and grazing lands.

Work Plan FY13/FY14

Data collection is ongoing. A draft final report for the related project with Logan City was filed in November 2011.

Informational Resources

Contact: Dr. David K Stevens, (435) 797 3229, E-mail: david.stevens@usu.edu.
Website: http://www.bearriverinfo.org.

Optimizing Storm Water BMP Performance through Vegetation Selection and Harvesting Strategies

Principal Investigators:
R. Ryan Dupont
Joan E. McLean
Malgorzata Rycewicz-Borecki (Ph.D. Student)
Jacob Richardson (MS Student)
Thomas Nyanda (Post-Doc)

Partners/Collaborators:
Local: *Bill Young, Logan City Public Works Department*
iUTAH Research Coalition. Cache County Storm Water Coalition

Project Description

- **Need and Purpose:**

  The Environmental Protection Agency (EPA) National Pollutant Discharge Elimination System (NPDES) water pollution control program mandates that municipalities across Utah install structural stormwater best management practices (BMP) as a means of reducing polluted runoff from major industrial facilities, city storm sewers, and construction sites that disturb five or more acres of land. Stormwater detention basins are often used in response to this federal mandate. This progressive program aims to minimize discharge volumes and pollutant loadings from urbanized areas entering receiving water bodies and to address the growing water quality problems and increased flooding from urban and rural non-point sources.

  Logan City and surrounding municipalities are beginning to address storm water quality and quantity issues. To do so, they need locally generated, quantitative research to accurately depict the effectiveness of vegetative species within storm water management facilities. This study measured biomass production and water quality improvement effectiveness in a controlled laboratory environment and is validating findings at a field demonstration study site. The laboratory scale study provided controlled, laboratory scale replicates of storm water retention basins to measure plant biomass production and total nutrient and metal removal. Water uptake for seven vegetative species was quantified in the laboratory under simulated (frequency and duration) rainfall events. The field demonstration site, an existing subdivision (Green Meadows) storm water detention area in Logan, Utah, is producing quantitative water quality improvement effectiveness data based on plant production and contaminant removal in response to periodic plant harvesting for three species, compared to naturally propagated weed species and non-vegetated control plots.

- **Benefits to the State:**

  This study is providing storm water nutrient and metal removal effectiveness of species found and planted locally that Utah municipalities can use to optimize storm water BMP systems. The data are specific to Utah's climate and geologic conditions. Logan City officials intend to utilize this information in the upcoming TMDL regulations that target reductions in the nutrient loading (particularly phosphorous) of discharges into Cutler Reservoir. Additionally, the quantitative results will prove critical to Utah's BMP designers and managers responsible for species selection under local/regional site conditions and nutrient and metal removal requirements.

- **Geographic Areas:**

  Study Area: Laboratory study at Utah State University Research Greenhouse, Field demonstration site: Green Meadows Subdivision detention basin, 600 S and 800 W, Logan, Utah.

Areas Benefited: All counties in Utah would potentially benefit from quantitative data that can be utilized within storm water management systems.

- **Accomplishments**:

Findings: Data analysis and reporting for nutrient and metal removal data from the lab greenhouse study are complete. Results indicated a strong correlation between nutrient and metal removal capacity within, and biomass harvested from, a BMP. Lab-scale evidence of species differences in nutrient and metal concentrations accumulated in the harvestable, above-ground biomass suggests that the common reed and sedges are optimal plants to improve water quality of stormwater in arid, northern Utah. Field-scale performance monitoring was carried out at the Green Meadows field demonstration site (Figure 1) during the summer/fall season, FY11, and spring/summer/fall seasons, FY12. The masses of both harvested above ground plant material and harvestable nutrients and metals from the treatment areas from mid- and end-season harvesting were documented under actual field climatic conditions. Long-term monitoring of FY11 and FY12 storm events indicates a significant storm water retention capacity within the collection system throughout the Green Meadows subdivision. Significant storm water infiltration was observed prior to entering the on-site storm water treatment area. Site evaluation (FY13 on) will document performance of the as-built storm water collection system and develop design guidelines for the implementation of an "infiltration" collection system at other sites throughout Utah.

Results: Plant biomass production (sedge, sunflower, cattail, naturally seeded plots), and nutrient and metal mass recovery from the treatment areas, as a function of seasonal harvesting (mid- and end-season versus only end-season), was evaluated for FY11 and FY12 through above-ground biomass harvesting from each of the field test plots. With no surface discharge from the planted areas, maximum nutrient and metal removal is possible in these systems. Figure 2 shows the significant increase in harvested biomass after plant establishment throughout the field plots. The naturally seeded, mixed plant community not only provides significantly higher biomass than other single test species, but generally yields higher nutrient and metals recovery as well. Twice a year harvesting produced significantly higher recovery for nitrogen and copper, and did not negatively impact the production of biomass or recovery of other contaminants of concern. Outreach activities included on-site tours of the facility by member of the Cache County Storm Water Coalition and participants in a state-wide water quality symposium held in Logan in 2012.

Work Plan FY13/FY14

Contaminant removal performance data will be collected at the field site during the summer and fall of 2013 and spring of 2014. Field plant harvesting and soil sampling from late fall 2013 will be added to the database of nutrient and metal uptake and harvesting performance. Runoff, storm water storage, and infiltration within the collection system will continue to be monitored, and tracer studies and storm water transport modeling will help to improve storm water collection and treatment system design in the state.

Informational Resources

Contact: Dr. R. Ryan Dupont, Phone: (435) 797 3227, E-mail: ryan.dupont@usu.edu.

Figure 1. Vigorous Plant Growth at Meadows Field Demonstration Site, Spring 2012

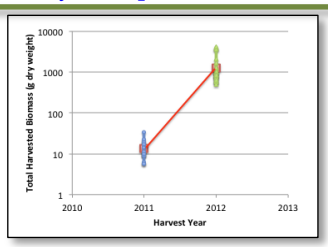


Figure 2. Harvestable Biomass over Time from the Green Meadows Field

Release of Arsenic from Aquifer Solids under Anaerobic Conditions

Principal Investigators:
Joan E. McLean
Darwin L. Sorensen
Babur Mirza (Post-Doctoral Fellow)
Xianyu Meng (Ph.D. Student)
Allia Abu-Ramaileh (MS Student))

Partners/Collaborators:
Local: *Issa Hamud, Director of Environmental Department, City of Logan*

Project Description

- **Need and Purpose:**

  Arsenic is one of the most frequently detected individual contaminants in domestic private wells used for household drinking water and public water supplies in the U.S. Of the domestic wells tested that had As in excess of the drinking water limit (10 µg/L), 10% were located in the basin-fill aquifers of California, Nevada, New Mexico, Arizona, and Utah. Seventeen percent of the well water in Cache County, as reported by the Utah Geological Survey, contained levels of arsenic that exceeded the drinking water limit. The USGS has also reported elevated concentrations of arsenic in well water in Salt Lake and Utah counties. Geologic formations throughout Utah contain arsenic; however, many of these formations are stable and pose no threat to humans or the environment. In other locations, changes in aquifer conditions, in particular with the introduction of organic matter, either intentionally for remediation purposes or unintentionally, may lead to the release of arsenic to ground water resources. The overall objective of this study is to investigate conditions that lead to arsenic release to groundwater at a sampling location in the Cache Valley Basin.

- **Benefits to the State:**

  All counties in Utah will benefit from an improved understanding of the biogeochemistry governing the behavior of arsenic in subsurface environments undergoing reducing conditions that may lead to groundwater contamination. The counties most immediately benefiting from this research are Cache, Davis, and Weber.

- **Geographic Areas:**

  Study Areas: City of Logan Landfill, Cache County; Hill AFB, Weber-Davis County.

  Areas Benefited: In addition to the specific areas above, this project will contribute to protection of groundwater resources throughout the state. Arsenic in groundwater is a worldwide problem.

- **Accomplishments:**

  Findings: The arsenic in basin-fill aquifers of the Southwest US is from natural sources, often associated with volcanic deposits. At our study site, arsenic occurs from the soil surface to depth of groundwater. We have demonstrated that arsenic release is associated with the zone where the groundwater table seasonally fluctuates causing cycling from oxidized to reduced condition. We are presently investigating the microbial community structure that is involved in iron and arsenic reduction.

Results: Samples were collected from the soil surface to depth of groundwater (Figure 1). Microcosms were constructed using select core material and incubated with and without an added carbon and energy source. Microcosms were sacrificed over time and analyzed for changes in chemical and microbiological properties that influence arsenic mobility. Unlike other regions of the world where arsenic mobility is related to iron reduction and the presence of identified arsenic reducing bacteria, at our study site arsenic mobility is initially independent of iron chemistry and there is a unique diversity of arsenic reducing bacteria that have developed in this semi-arid basin-fill carbonaceous aquifer (Figure 2).

Figure 1: Sediments sample collection and the initial processing at the field sites

Work Plan FY13/FY14

We will continue to investigate the biogeochemical factors that lead to the release of arsenic to groundwater from native geologic materials. We are developing more sensitive molecular tools to identify the microbial communities mainly responsible for arsenic mobilization in this region.

Informational Resources

Contact: Ms. Joan E. McLean, (435) 797-3199, E-Mail: joan.mclean@usu.edu.

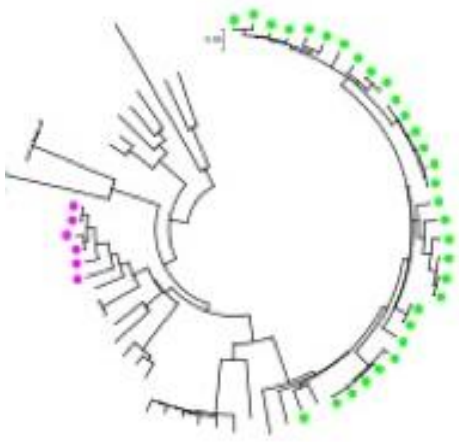


Figure 2: Unique sequences for the arsenate reductase gene (arrA) were detected in the samples collected from the Cache Valley Basin sites. Overall, arsenic reducing microbial community at these sites was distinctly different (as indicated by the green color circles) as compared to those of pure cultures (pink color) and uncultured bacterial sequences detected in the different regions of the world.

Salinity Reduction Measures for the Upper Colorado River Basin

Principal Investigators:
Jagath J. Kaluarachchi
Jongho Keum (Student)

Partners/Collaborators:
Federal: *US Geological Survey*

Project Description

- **Need and Purpose:**

  Salinity production in the upper Colorado River basin results from both natural and anthropogenic sources, and the economic damage caused to the lower Colorado River basin from salinity can be in excess of $300 million per year. Most anthropogenic sources are driven by individual land uses and practices. Compared to most agricultural pollutants that are sometimes known carcinogens, salinity risk is limited to economic losses in agricultural and urban land uses, and health risks are considered marginal. When salinity originates from alluvial (marine) deposits, however, the pollutants may pose a health risk, (e.g., selenium in the Colorado River basin). There is a need to investigate the estimated benefits of different levels of reduction in salt loadings in comparison to the corresponding economic damage or costs of salinity control and to distribute the economic impacts as equitably as possible among the different stakeholder groups to minimize conflicts. In a recent funding from the US Geological Survey, we investigated the existing modeling framework (through USGS SPARROW model) proposed for the Upper Colorado River Basin (UCRB) salinity prediction and the corresponding advantages and limitations of this approach. In this project, we will extend the previous work on salinity reduction by investigating optimal salinity reduction measures, considering cost and equity among different land users and strategies. The specific objectives proposed are to investigate the effectiveness of the existing USGS model, SPARROW, in predicting the salinity generation from the different watersheds of the upper basin; the adequacy of the existing monitoring network and the need to expand the network; and the cost-equity tradeoffs in salinity reduction measures in different watersheds.

- **Benefits to the State:**

  Since Utah is one of the states benefiting from Colorado River water, the quality of water used by local stakeholders is of great interest in order to maximize the beneficial use of water. With increasing salinity, the productivity of water in agriculture may be limited. In addition, any salinity generation inside Utah due to various land use practices can be costly in terms of salinity reduction requirements for local stakeholders. Therefore, a study dedicated to understand the salinity generation mechanisms, monitoring needs, and salinity reduction allocation tradeoffs are of great value to Utah decision-makers.

- **Geographic Areas:**

  Study Area: The study area consists of the Upper Colorado River Basin.

  Areas Benefited: Mostly areas occupied irrigators and other agricultural activities.

- **Accomplishments:**

Findings: USGS developed SPARROW91 (Kenney et al., 2007), which is a mass balance model for TDS using spatially referenced regression with 1991 data. The model is representative because it considers both deterministic and statistical properties, while accommodating physical properties related to water quality. Since the model is a regression model, the number of monitoring locations and the amount of data are important factors in determining the accuracy of the model (only experienced researchers should use this model). Also, the model cannot be applied to small basins with limited data such as the Lower Gunnison and Muddy Creek watersheds selected in the early part of this study.

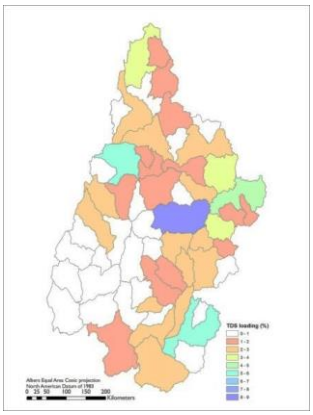


Figure 1. Percentage of the total TDS loading generated within each watershed

The SPARROW model for the UCRB was used in this study without significant revisions. Mass balance of SPARROW computes salt load leaving of the river, which includes the salt generated from the reach's watershed, plus the salt loads from the upstream reaches. Kenney et al. (2007) estimated the coefficients of model parameters of salinity load generated from each source. The first analysis will determine the amount of salts generated, and therefore, the amount that can be reduced if salinity control programs are installed in each watershed. Using the incremental salt loading from each watershed, management scenarios for salt reduction will be developed.

Results: Three watersheds among the 59 in the UCRB generate almost 20% of the total salt loadings (Figure 1). With an average of 3.7 stations per watershed, there are many monitoring stations where TDS yield is relatively low, and a few where salt yield is relatively high (see Table 1). The results of this analysis show that monitoring program needs to be updated based on the actual salt generating capacity of the watersheds. The methodology proposed here is capable of addressing the issues related to monitoring networks in the UCRB.

Table 1. Examples of poor distribution of monitoring stations in selected watersheds.

Salt Yield	Watershed	Area (mile^2)	Number of Monitoring Stations
High	HUC 14080101 Upper San Juan	3,431	8
	HUC 14060009 San Rafael	2,433	2
Low	HUC 14060004 Strawberry	1,164	7
	HUC 14010002 Blue	683	14
	HUC 14010003 Eagle	972	18

Work Plan FY13/FY14

The next task of this project is to assess the monitoring requirements to model salinity generation using SPARROW and identify redundancy in the network. This task is followed by the cost-equity tradeoff analysis to identify the optimal allocation of salinity reduction measures across the 59 different watersheds.

Informational Resources

Contact: Dr. Jagath J. Kaluarachchi, (435) 797-3918, E-Mail: jagath.kaluarachchi@usu.edu.

Technical Support for Bear River System Data Acquisition

Principal Investigators:
David K. Stevens
Bethany T. Neilson
Austin Jensen
Hussein Ali Batt (Student)

Partners/Collaborators:
***Federal**: Annette de Knijf, USFWS*
***Private/Business**: Bear Lake Watch*

Project Description

- **Need and Purpose:**

  This project provides high-level technical support for development of alternative data acquisition networks for large-scale remote data gathering stations in watersheds, on rivers, and in lakes. We are providing field and analytical support for the Middle Bear River, Little Bear River, Logan River, and Spring Creek water quality monitoring stations to complete a basin-wide network for assessment of nutrient loads and other water quality measures for Cutler Reservoir and the Cutler Reservoir TMDL implementation. We have also provided support for monitoring in Mud Lake (adjacent to Bear Lake) to explore statistical learning theory applications for sediment load estimation.

- **Benefits to the State:**

  Specific benefits of the modeling work ongoing at the UWRL to the State of Utah include the following:

  1. Improve understanding of the sediment and nutrient dynamics in the Bear River basin.
  2. Provide innovative data acquisition systems for remote areas.
  3. Establish relationships among regulated water quality variables at key monitoring locations to improve high-frequency load estimation for Cutler Reservoir.
  4. Build data-driven models of sediment-rich water systems to support estimation and management of sediment loads.
  5. Acquire data to assess dynamics of sediment transport in lakes.

- **Geographic Areas:**

  Study Area: Bear River Basin, Rich, Cache County.

  Areas Benefited: Watersheds statewide.

- **Accomplishments**:

  Findings: A large and growing database for the rivers in the Bear River Basin has allowed us to develop an unprecedented capability to assess long term relationships at key water quality monitoring points in Cache County for a variety of research and management purposes. These data are publically available and are served through the web-based Bear River Information System developed under previous projects.

The data collected through this project have been used by a variety of researchers and graduate students at USU and nationwide. Several papers and a book chapter have been published with data collected using the Bear River monitoring network, and large-scale new projects will use the data from the database system.

On the basis of field monitoring carried out during Summer 2011 in Mud Lake to assess the transport of sediment into and out of Bear Lake from the Bear River under this project, using Hydrolab measurements to characterize the general water quality, the graduate student involved in this project has published a successful dissertation, and two manuscripts have been submitted for publication, with a third nearing completion. The data collected were used in conjunction with a statistical learning model known as relevance vector machines (RVM) to predict the sediment behavior in this shallow, vegetated lake. This provides needed insight for sediment transport in the Bear River Basin, in other parts of Utah, and in the Intermountain West region.

The completed RVM modeling work showed that the RVM model effectively predicted water quality in Mud Lake and led to the identification of redundant water quality monitoring stations in the lake. This will be useful for future sediment monitoring network design to minimize monitoring costs without loss of information concerning sediment loads in similar systems.

Results:

- Remote data collection for water quality and hydrologic measurements in Bear River tributaries.
- Robust database system for research and public viewing and analysis of flow and water quality data.
- Statistical learning theory model of sediment and other water quality measures in Mud Lake.
- Journal manuscript accepted in Environmental Engineering Science. A second is in review and a third is nearing completion.

Work Plan FY13/FY14

- Complete publications for Mud Lake statistical learning theory model of sediment loading.
- Explore non-parametric statistical analysis of surrogate measures data (e.g., suspended solids or total phosphorus vs. turbidity at several sampling locations) for publication.
- Prepare proposals to continue funding the existing monitoring network and to extend the network for additional locations and sensors.

Informational Resources

Contact: Dr. David K. Stevens, (435) 797 3229, E-mail: david.stevens@usu.edu.

Website: http://www.bearriverinfo.org.

Water Allocation and Salinity Issues of the Sevier River Basin

Principal Investigators:
Jagath J. Kaluarachchi
Daeha Kim (Student)

Partners/Collaborators:
State: *Utah Department of Water Resources*

Project Description

- **Need and Purpose:**

  The Sevier River Basin is a closed basin located in south central Utah, covering approximately 10,575 square miles or 12.5% of Utah's land area. This basin provides water for nearly 23% of privately held land, as well as domestic and industrials uses. For water rights purposes, the basin is divided administratively into lower and upper basins, with much of the water in the upper basin produced from winter snowfall and spring runoff. The bulk of the spring runoff water produced upper basin's high elevations is stored in three major reservoirs: Otter Creek, Piute, and Sevier Bridge. In addition, Gunnison Bend, DMAD, and Fool Creek reservoirs have smaller storage capacity and help regulate flow during the peak growing season. Water for agriculture is typically allocated during early spring, mostly in March. This allocation is based on the available reservoir volumes from the prior year and anticipated runoff for the coming year, which will not occur until May or June. Since the expected spring runoff is unknown or best estimated using prior data, there is considerable uncertainty of water availability in any given growing season. Given this uncertainty, water allocation is a challenge to water managers in each year. The purpose of Phase 1 of this work is to develop a reliable hydrologic model that can predict water availability and expected reservoir volumes using prior year information and measured winter snowfall data. Another concern is salinity is the lower basin, which is generated from irrigation return flows during the growing season. Currently, ground water is used to reduce salinity in the Sevier River. In Phase 2 of this work, the cost effectiveness of this approach will be evaluated and suitable recommendations will be provided.

- **Benefits to the State:**

  Given the dominance of agriculture in Utah, especially in rural communities, accurate estimation of water availability based on snowfall measurements in the winter and prior year information is crucial to water managers. If this hydrologic model is successfully developed for the Sevier River Basin, which has managed flows from the multiple reservoirs, we believe the work can be extended to other basins in Utah, as well as to other places in the US.

- **Geographic Areas:**

  Study Area: The study area consists of the Sevier Basin, occupying approximately 12.5 percent of the land area of Utah.

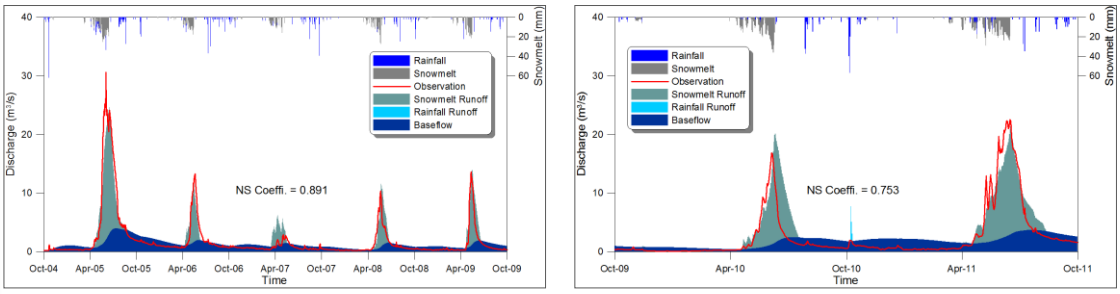
  Areas Benefited: Areas with limited water supply that have agricultural activities sustaining rural economies.

Station	NS Efficiency		RMSE (cm)	
	Calibration	Verification	Calibration	Verification
Mammoth Creek above West Hatch Ditch	0.891	0.753	1.294	2.272
Sevier River at Hatch	0.807	0.668	2.682	3.947
Clear Creek above Diversions	0.573	0.838	0.894	0.915
Salina Creek near Emery	0.64	0.822	0.312	0.287
Manti Creek below Dugway Creek	0.822	0.481	0.629	0.719

- **Accomplishments:**

Findings: Since some gauging stations in the main channel of Sevier River do not represent natural flow due to flow alterations and reservoir operations, it is difficult to calibrate a hydrologic model using altered streamflow data directly. Instead, if the natural flow is generated by parameters regionalized from several stations representing natural flow regime, the level of alteration and the water use can be computed by comparing generated natural flow with observed data. The proposed hydrologic model, a combination of the simplified SNOW 17 for snowmelt and a simplified tank model, is used for generation of natural flow. The upper soil zone of the tank model represents rainfall and snowmelt, and they are separated because of large differences of surface hydrologic response between them. Daily temperature and precipitation data at SNOTEL stations are used as input from the past 30 years of PRISM data. Five USGS stations not affected by river diversions are selected to calibrate for parameter for regionalization.

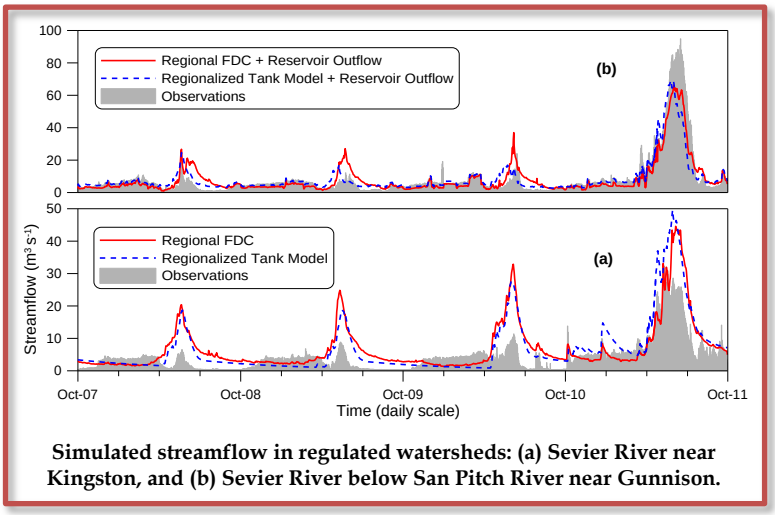
Results: Generally, results for statistical fitness of the proposed hydrologic model in each station show the model performance is acceptable. The model performs well in generating snowmelt runoff and base flow. Unfortunately, it is difficult to generate rainfall driven runoff accurately since this runoff is represented by daily streamflow data that are too small to be distinguished from base flow. In general, the proposed hydrologic model works satisfactorily for predicting streamflow from snowmelt, which is the dominant hydrologic process in the Sevier River Basin.



Generated and observed streamflow at Mammoth Creek above Diversion in the period of calibration (left) and verification (right)

Work Plan FY13/FY14

The next task of this project is to assess the salinity impacts of water on agriculture. At the present time, pumped groundwater is used in the Sevier River to reduce salinity effects to help improve agriculture productivity. The next task is to assess if such a measure is cost effective and help to mitigate the negative impacts of salinity. The work will extend to 2013-14 to complete the economic benefit analysis of this mitigation task.



Simulated streamflow in regulated watersheds: (a) Sevier River near Kingston, and (b) Sevier River below San Pitch River near Gunnison.

Informational Resources

Contact: Dr. Jagath J. Kaluarachchi, (435) 797-3918, E-Mail: jagath.kaluarachchi@usu.edu.

Weber Basin Decision Support System (DSS) Modernization

Principal Investigators:
David K. Stevens

Partners/Collaborators:
Local: *Scott Paxman, Weber Basin Water Conservancy District*
Private: *Christina Bandaragoda, Sanjaya Bandaragoda*

Project Description

- **Need and Purpose:**

  The Weber Basin DSS is a GIS-based modeling and data analysis platform in MapWindow. The DSS is modular in nature and accommodates a variety of additional functional units, in the form of plug-ins, which can be used with support from the GIS mapping. This project is redeveloping and modernizing the Weber Basin DSS to allow its continued viability into the future and to allow its extension to watersheds statewide.

- **Benefits to the State:**

  Specific benefits of the Weber Basin Decision Support project to the State of Utah are:

  1. Modern extensible tools for assessment of watershed/river system flow and water quality.
  2. Improved ability to market software tools for new projects, both in Utah and outside of Utah.
  3. Improved installation protocols so that the software will be updated automatically using modern internet protocols.
  4. Improved accessibility of data visualization tools via extension of internet-based Time Series Analyst

- **Geographic Areas:**

  Study Area: Weber River Basin; Summit, Morgan, Weber, and Davis Counties.

  Areas Benefited: Watersheds statewide.

- **Accomplishments**:

  Findings: The following elements have been completed:

  - Build a distributed hydrology and river flow model for the Weber Basin to provide an alternative set of inputs for the water quality portion of the model.
  - Convert the model interface to Visual C#.Net 2005.
  - Modify the Weber Basin mass balance model and database to include new flows into Park City from above Rockport.

Significant progress has been made to:

- Integrate the hydrology model and the water quality model into the Visual C# interface.
- Improve the existing internet-based Time Series Analyst tool to enable access for visualization of hydrology and water quality data and model results via the internet.

Results:

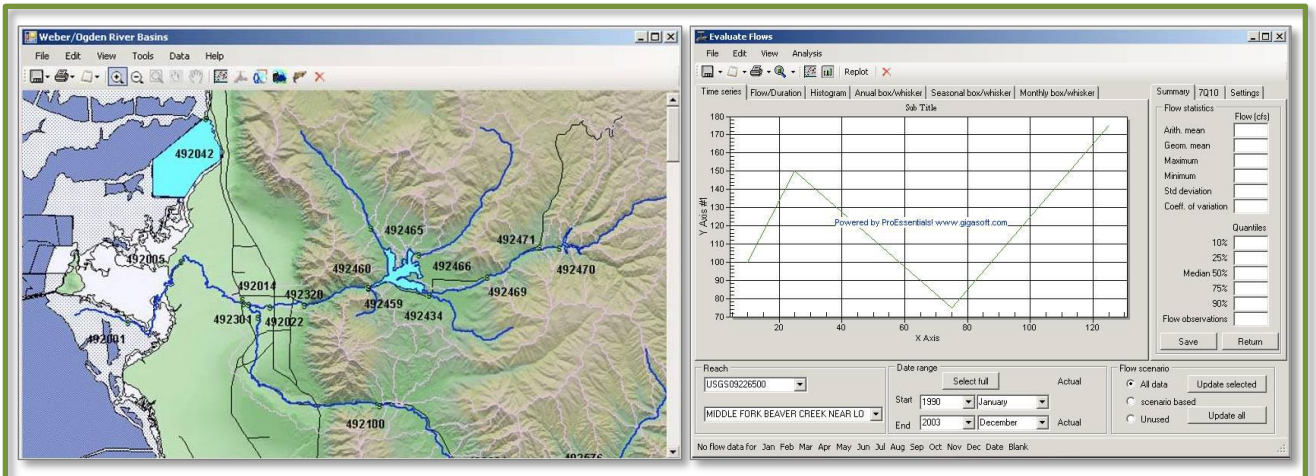
- A working prototype of the modernized Weber Basin DSS.
- A completed distributed hydrology model.
- Integration of the Weber Basin mass balance model and database into the Visual C# interface.
- Partial integration of the hydrology model and the water quality model into the Visual C# interface.
- A partially working prototype Time Series Analyst tool to enable access for visualization of hydrology and water quality data and model results via the internet.

Work Plan FY13/FY14

Complete the WBDSS integration and deploy the modernized WBDSS at the Weber Basin Water Conservancy District with staff training and complete the web-based time series analyst for data/model results visualization.

Informational Resources

Contact: Dr. David K Stevens, (435) 797-3229, E-mail: david.stevens@usu.edu.



Sample screen shots from Weber Basin DSS

Water Conveyance, Distribution, and Control

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Water Conveyance, Distribution, and Control

Project Name	FY2013 Actual Expenditures	FY2014 Budgeted Expenditures	FY2015 Planned Expenditures
Labyrinth Weir Research	$42,752.02	$44,034.58	$0.00
Low Head Dam Dangers	$18,836.05	$19,401.13	$0.00
Open Channel and Closed Conduit Field Flow Measurement, Maintenance and Upgrade for the State of Utah	$12,710.59	$13,091.91	$13,484.66
Designated Projects		$20,500.00	$10,000.00
Undesignated Projects		$0.00	$5,000.00
Total	**$74,298.66**	**$97,027.62**	**$28,484.66**

Labyrinth Weir Research

Principal Investigator:
Blake P. Tullis

Partners/Collaborators:
***Local**: Everett Taylor, DNR-Water Rights*

Project Description

- **Need and Purpose**:

  With the revisions of probable maximum flood flows and greater emphasis on dam safety, many spillways are found to require rehabilitation or replacement. Labyrinth weirs are often a favorable design option because these 'folded linear weirs' facilitate flood routing and increase base-flow reservoir storage capacity. However, the many geometric design parameters and the distinct hydraulic behaviors of these structures can make it difficult to engineer an optimal weir design.

  This study included two phases: arced labyrinth weirs and staged/notched labyrinth weirs. Arced labyrinth weirs represent a weir option that would be installed in a reservoir application followed by a discharge channel downstream. The arced layout allows the inclusion of more labyrinth weir cycles (more total weir length) for a given discharge channel width. Preliminary studies evaluated arced labyrinth weirs with 6^o and 12^o sidewall angles. This study evaluated 12^o and 20^o sidewall angles, with variation in cycle number. A staged labyrinth weir features segments where the crest is lower (a notched section or a complete cycle) which are used to concentrate base flows and/or modify downstream flood hydrographs.

- **Benefits to the State:**

  The results of this labyrinth weir study may provide a spillway upgrade alternative and may prove useful in increasing the sustainability of existing dam with undersized spillways. Labyrinth weirs are a commonly used alternative to a linear weir for increasing the spillway capacity without increasing the width of the spillway apron. Insufficient data are currently available for the range of labyrinth weir design alternatives. The Utah Division of Water Resources is currently designing an arced labyrinth weir for Millsite reservoir (UT) based on this research.

- **Geographic Areas**:

  Study Area: All work will be completed in the Hydraulics Lab at the Utah Water Research Laboratory (UWRL) at Utah State University.

  Areas Benefited: Spillway structures are common to nearly all dams, so the application of the study results could extend to all counties.

- **Accomplishments:**

  As part of this study, two separate labyrinth weir experimental studies were carried out in FY13. Study-1 looked at apex width influences on discharge efficiency, size-scale effects, and the influence of geometry variation on discharge efficiency relative to the standard labyrinth weir

design method (USU-MLF). This project will culminate in a MS thesis (Tyler Seamons), a peer-reviewed journal paper, and a conference paper.

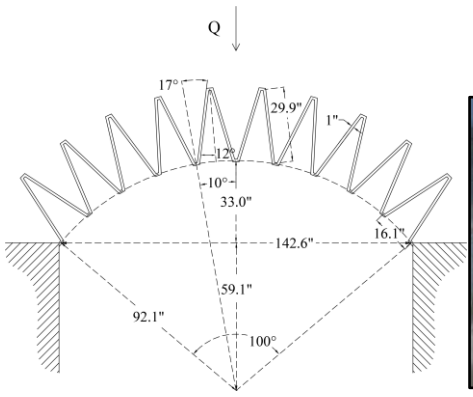
Study-2 was an investigation into weir nappe flow vibration. A test facility was built and significant exploratory efforts were made to help determine causes and methods for mitigation. This study is focusing on linear weir vibration, but it applies to labyrinth weirs; prototype labyrinth weir nappe vibration has been reported in practice. We are using particle image velocimetry (PIV) to evaluate flow conditions at the crest in an effort to identify potential causes of the vibration. This is a MS thesis study (Aaron Anderson). We are collaborating with Sebastien Erpicum (University of Liege, Belgium) who has also evaluated nappe vibration in his laboratory. This study will culminate in a minimum of 1 peer-reviewed journal paper and a conference paper.

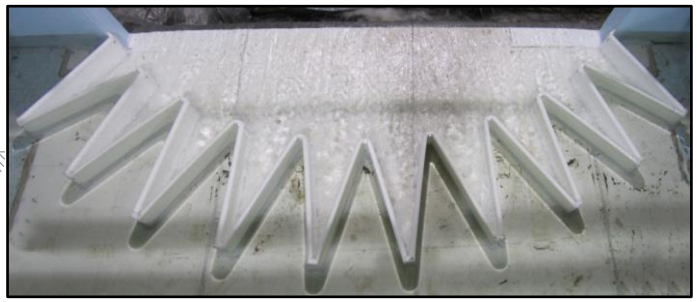
Work Plan FY13/FY14

In FY14, the current studies should be finished, the thesis written and defended, and the papers submitted for review. Additional nappe vibration data will be collected as we move into the quantitative data collection portion of the study (PIV, high-speed video, acoustic data).

Informational Resources

Contact: Dr. Blake P. Tullis, Phone (435) 797 3194, E-mail: blake.tullis@usu.edu.





Schematic and photograph of an arced labyrinth weir tested in this study (q = 10°, a = 12°, N = 10)

Low Head Dam Dangers

Principal Investigators:
Michael C. Johnson
Riley J. Olsen

Partners/Collaborators:
State: *Mike Suflita, Utah DWR; Utah Division of Parks and Recreation; Utah Division of Forestry and State Lands*
Local: *Salt Lake County Parks and Recreation; Murray City Fire Dept.*

Project Description

- **Need and Purpose:**

Low-head dams are small dams, usually no taller than 5 to 10 feet, found on rivers and canals throughout Utah and the United States. They run from bank to bank across a river with the purpose of impounding small volumes of water to be used for irrigation, municipalities, industry, and recreation. Many people drown at low-head dams each year due to a dangerous countercurrent known as a "hydraulic" that is created as water flows over the dam. In fact, two kayakers drowned at a low-head dam on the Jordan River in Murray, UT in August of 2010. Because of this deadly flow pattern, low-head dams have been nicknamed "drowning machines" by paddling enthusiasts as well as water safety experts. The purpose of this study is to identify a relationship between easily measureable parameters that can be used to classify the hazards at low-head dams at various flow conditions. Once this has been done, several possible remediation options will be tested that have been proposed as a way to eliminate the deadly current at low-head dams.

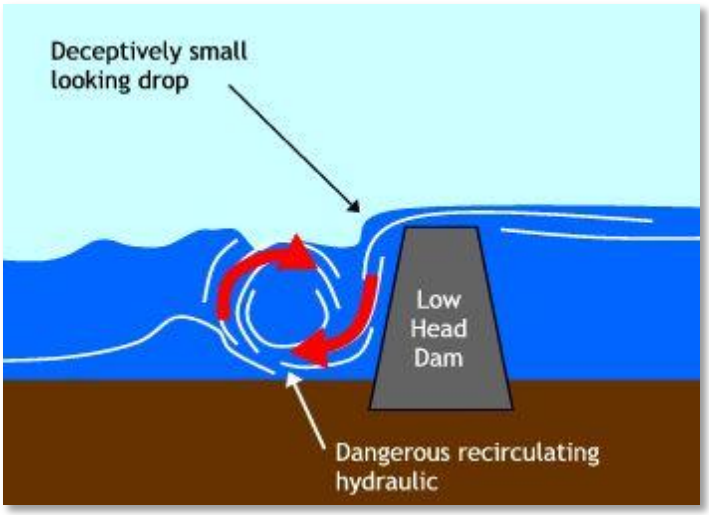


Figure 1: The countercurrent, or "hydraulic," created when water flows over a low-head dam

- **Benefits to the State:**

The intent of this project is to raise awareness of the potentially deadly flow conditions that can be found at low-head dams, and to identify possible solutions to make these structures safer. If the low-head dams can be made safer by altering the flow, a benefit would be a reduction in the

number of drowning incidents caused by low-head dams in the State of Utah and possibly world-wide. Informing the public of the dangers present at these structures, as well as possible remediation options that dam owners could implement, would make for safer water related recreation. Also, because many low-head dams are owned by the state of Utah, liability could be reduced at dams where a solution can be implemented.

- **Geographic Areas:**

  Study Area: The Winchester Crossing dam site on the Jordan River in Murray, UT is the main focus of this study.

  Areas Benefited: The results of this project should be applicable to dams similar in size and shape to those studied, including low-head dams throughout Utah, the United States, and even the World.

- **Accomplishments:**

  Findings: The hydraulic processes present at low-head dams have been studied in depth by hydraulic engineers for decades, but surprisingly, very few studies have been performed with the purpose of improving public safety at these structures. Some solutions have been found, such as the complete removal of the dam or the addition of steps to the downstream side of the dam that break up the countercurrent, but these solutions are often impractical because of the large costs associated with implementation. Also, if the dam still serves a purpose, complete removal of the structure is obviously not a possibility. Remediation options, including the use of deflectors, have been identified and function to prevent entrapment downstream of low head dams.

  Results: One combination of easily measured parameters has been identified that accurately depicts transition points between relatively safe states of flow at low-head dams and the more dangerous ones that feature a countercurrent. The use of this factor to warn recreational water users of the hazards present at a low-head dam under hazardous flow conditions could save lives. This finding has been published in the *Journal of Hydraulic Engineering*. Several options for remediation have been identified and two were found to be acceptable for preventing entrapment. The findings have been summarized and a technical paper has been submitted to the *Journal of Hydraulic Engineering*.

Work Plan FY13/FY14

- This project is complete.

Informational Resources

Contact: Dr. Michael C. Johnson, (435) 797-3176, E-mail: michael.johnson@usu.edu.
Mr. Riley J. Olsen, (435) 797-3152, E-mail: riley.j.olsen@gmail.com.

Open Channel and Closed Conduit Field Flow Measurement, Maintenance and Upgrade for the State of Utah

Principal Investigators:
Steven L. Barfuss
Jesse M. Pope
Michael Budge
Jordan Jarrett

Partners/Collaborators:
State: *James Greer and Gertrudys Adkins, Utah DWR*

Project Description

- **Need and Purpose:**

  Limited and depleted water resources have become an issue of increased concern, especially in Utah where the arid land requires irrigation to produce ample crops. As a result, water distribution system managers have realized the importance of accurately measuring water used in their systems. Understanding the available methods and measurement devices and their specified accuracies is vital to ensuring that the best achievable distribution and use of water is occurring.

  Initial investigations showed that a large number of flow measurement devices throughout the State of Utah were not measuring flow at the accuracy that design manufacturer specifications claim. The purpose of this project has been to determine major contributors to flow measurement errors and to assess the devices that exhibit these errors in an attempt to provide direction for reducing these measurement errors.

- **Benefits to the State:**

  Improved accuracy of flow measurements throughout the State of Utah will ultimately improve the allocation of water rights. Over time, small errors in flow measurement can add up to very large errors in the allocation of water rights. This project is generating a database of information to determine which flow measurement structures have the greatest need for remediation, repair, or recalibration.

- **Geographic Areas:**

  Study Area: Entire State of Utah.

  Areas Benefited: All irrigated areas of Utah.

- **Accomplishments**:

  Findings: As of August 9, 2013, 179 flow measurement devices have been assessed. These devices include 116 Parshall flumes, fifteen ramp flumes, one cutthroat flume, sixteen weirs, sixteen rated sections, three sluice gates, seven ultrasonic meters, and five magnetic meters. Only thirty-five percent of the tested devices measured flow within manufacturer design specifications. The remaining sixty-five percent exhibited flow measurement errors in excess of the design specifications. Some of the major contributing factors to inaccuracies were uneven

settlement, sediment and moss buildup in and around the structure, corrosion or damage to the device, and uneven flow where head measurements are taken. These factors create incorrect measurements that prevent water users from receiving their true water allocations.

Results:

- A list of all visited sites and their locations, measurement device types, accuracies, and problems were sent to the Utah Division of Water Rights.
- Verification certificates for each site visited were created and sent to the measurement device operator, the Utah Division of Water Rights, and any other interested party.

Work Plan FY13/FY14

- Continue to locate flow measurement devices throughout the State of Utah.
- Visit flow measurement device sites, perform verification tests to determine the accuracy of the flow measurement devices, and document concerns for the error associated with each structure.
- Continue to report findings to the Utah Division of Water Rights and encourage the improvement and maintenance of degraded or inaccurate flow measurement devices.

Informational Resources

Contact: Steven. L. Barfuss (435) 797 3214, Email: steve.barfuss@usu.edu.
Jesse M. Pope (435) 797 3231, Email: jesse.pope@aggiemail.usu.edu.
Michael Budge (435) 797 3231, Email: mike.budge@aggiemail.usu.edu.
Jordan Jarrett (435) 797 3231, Email: Jordan.c.jarrett@gmail.com.

Examples of Flow Measurement Devices Tested in Utah

Water Education and Technology Transfer

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Water Education and Technology Transfer

Project Name	FY2013 Actual Expenditures	FY2014 Budgeted Expenditures	FY2015 Planned Expenditures
Development and Maintenance of the Bear River Watershed Information System	$6,560.65	$6,757.47	$6,960.19
Education Program for Homeowners and Other Users of Septic Systems in Utah	$3,241.08	$3,338.31	$3,438.46
Enhancement of Septic System Educational Programs in Utah with Advanced Training	$6,916.22	$11,378.13	$11,719.47
Intermountain Section American Water Works Association (IMS-AWWA) Scholarship and Student Outreach Committee	$1,000.00	$1,030.00	$1,060.90
Salt Lake Valley Solid Waste Management Council	$1,000.00	$1,030.00	$1,060.90
State of Utah Solid and Hazardous Waste Control Board	$1,000.00	$1,030.00	$1,060.90
Statewide Nutrient Criteria Development: Core Advisory Team	$3,000.00	$3,090.00	$3,182.70
Support for State Watershed Modeling and TMDL Plans: Tools to Assist in Nutrient Criteria Development Using QUAL2Kw	$23,942.18	$24,660.45	$25,400.26
Utah Water Education Project	$65,726.22	$32,500.00	$0.00
Designated Projects		$25,420.87	$10,000.00
Undesignated Projects		$7,500.00	$0.00
Total	**$112,386.35**	**$117,735.23**	**$63,883.78**

Development and Maintenance of the Bear River Watershed Information System

Principal Investigators:
Jeffery S. Horsburgh
Hope Braithwaite (Student)

Partners/Collaborators:
State: *Mike Allred, Utah DWQ; Lynn Van Every, Idaho DEQ; David Waterstreet, Wyoming DEQ*
Federal: *Jack Barnett, Bear River Commission*

Project Description

- **Need and Purpose:**

  As part of a USEPA Targeted Watersheds Grant in the Bear River Basin (Utah, Idaho, Wyoming), USU developed an Internet Based Watershed Information System (WIS) for the Bear River (http://www.bearriverinfo.org). The Bear River WIS is a central location where users can get data and information related to water quality and other watershed related issues in the Bear River Basin. This project provides ongoing support to and development of the Bear River WIS and is being matched by funding from the states of Utah and Idaho. The WIS has proven to be a great benefit to water quality managers in three states, and has been used in water quality educational programs at various levels. This project is continuing to support the partnerships and collaborations that have resulted in the current WIS.

- **Benefits to the State:**

  Continued support of the Bear River WIS benefits several efforts ongoing in the State of Utah:

  1. The Water Quality Committee (WQC) of the Bear River Commission is a tri-state committee that focuses on water quality issues in the Bear River Basin. The Bear River WIS supports the efforts of the WQC and many other water quality related organizations.
  2. The Bear River WIS has been an important outlet for water quality related outreach and education materials to be made available to teachers, students, and researchers throughout the State of Utah.
  3. The Bear River WIS was the development platform for many of the tools that are supporting efforts to (1) establish an environmental observatory in the Great Salt Lake Basin, (2) establish a national cyber-infrastructure for environmental observatories, and (3) improve hydrologic science. A new information system for the Great Salt Lake (http://www.greatsaltlakeinfo.org) has been created based on the WIS.

- **Geographic Areas:**

  Study Area: Bear River Basin, including Cache, Rich, and Box Elder counties.

  Areas Benefited: Primarily the Bear River Basin; however, the WIS can be implemented for any watershed.

- **Accomplishments**:

  Findings: The Bear River WIS provides unprecedented access to data in the Bear River Basin. The combination of informational resources, data resources, data visualization and analysis tools, and outreach and educational components make the Bear River WIS a unique system for promoting water quality awareness and improvement in the Bear River Basin.

Results: The Bear River WIS is a fully functional watershed information system that includes the following components:

- Informational watershed descriptive profiles that detail the Bear River Basin.
- Support for outreach and educational opportunities related to Bear River water quality.
- A wealth of geographic information systems (GIS) datasets and water quality, hydrology, weather, and climate monitoring datasets for the Bear River Basin.
- A variety of tools for data visualization and analysis.
- A resource guide that details the people, organizations, and projects in the watershed.
- A calendar of water quality related events and news.

The source code from the Bear River WIS has been used to develop an information system for the Great Salt Lake under funding from the State of Utah Division of Forestry, Fire, and State Lands (http://www.greatsaltlakeinfo.org). The source code for the Bear River WIS has now been transferred into a content management system that can be accessed by a number of project partners and ensures that it remains an important resource for water quality related information in the Bear River Basin.

Work Plan FY13/FY14

Work related to the Bear River WIS on this project is now complete, and management of the Bear River WIS has been transferred to USU Water Quality Extension. This was made possible through migration of the WIS to a standardized content management system. This simplified its maintenance, ensured its sustainability, and opened up opportunities for collaborators and contributors outside of USU. We will continue to work with the Bear River WIS steering committee, which consists of members of the Bear River Commission's Water Quality Committee, to maintain the current functionality of the Bear River WIS. Through USU Water Quality Extension, we are continuing to evaluate and modify the content of the WIS to ensure that it remains up to date and relevant.

Informational Resources

Contact: Dr. Jeffery S. Horsburgh, Phone (435) 797-2946, E-mail: jeff.horsburgh@usu.edu.
Website: http://www.bearriverinfo.org.

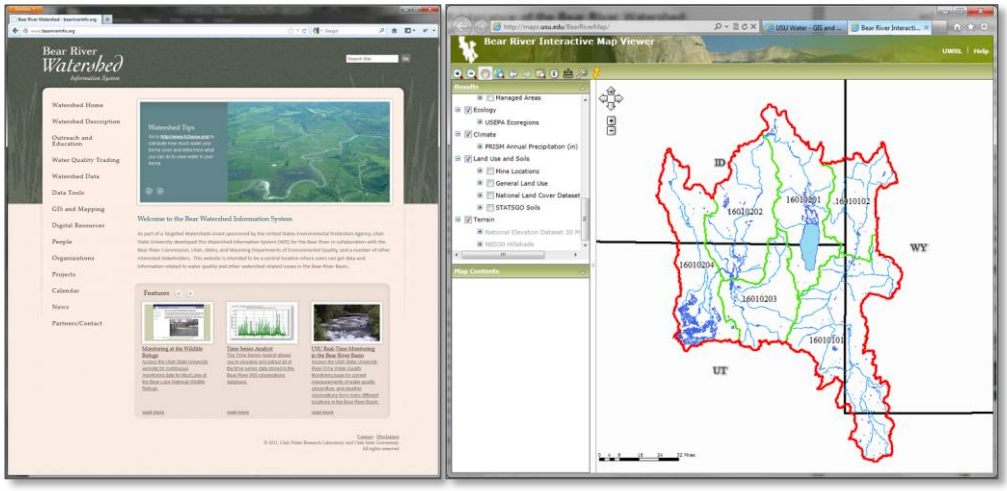


Figure 1. The Bear River Watershed Information System

Education Program for Homeowners and Other Users of Septic Systems in Utah

Principal Investigators:
Judith L. Sims

Partners/Collaborators:
Local: *All Utah Local Health Departments*
State: *Utah Division of Water Quality*

Project Description

- **Need and Purpose:**

  The goal of the project is to develop and deliver an educational approach to improve owner/user stewardship of on-site wastewater treatment systems. There are many brochures and flyers that list "dos and do nots" for the users of septic systems, but such simple guidelines can be easily forgotten and not incorporated into everyday personal habits. We propose that the effectiveness of educational tools for ensuring that septic systems are adequately operated and maintained would be greatly enhanced if the users better understood their role in the protection of public health and environment (i.e., if they better understood their role as environmental stewards). If septic system users had information focusing on understanding their responsibilities with respect to septic systems, and if they understood the options to fulfill their role as environmental stewards and operators of their "personal wastewater treatment plants," we predict that the effectiveness of homeowner on-site septic systems would be enhanced.

- **Benefits to the State:**

  Expected benefits to Utah watersheds include protection of water supplies from the harmful effects of excessive organic materials, nitrogen, phosphorus, suspended solids, and pathogens that may occur from runoff of wastewater from surfacing failing on-site systems. Subsurface transport of wastewater from overloaded systems may carry contaminants (especially pathogens and nitrogen) to ground water or through watershed base-flow to surface waters. Proper management of septic systems by homeowners or system users should reduce the flow of contaminants to water bodies from failing systems or improperly maintained systems.

- **Geographic Areas:**

  Study Area: Statewide.

  Areas Benefited: Presentation of educational workshops will be targeted for areas in Utah with impaired water bodies that may be affected adversely by septic systems or in areas were improperly managed septic systems could potentially impact water bodies or ground water. However, educational materials developed in this project will also be made available to all twelve Utah local health departments for dissemination to homeowners and other septic system users.

- **Accomplishments:**

  Findings: During the first year of the project, we investigated approaches to educational programs using social marketing techniques. Social marketing is the use of marketing principles to influence human behavior in order to improve health or benefit society. Social marketing includes: 1) focusing on a key issue; 2) developing a key objective to define the issue; and 3)

focusing on reaching the key audience with messages that work. We also developed and administered a survey to Utah on-site professionals to help us define topics that are essential for homeowners to know regarding the use (and abuse) and maintenance of their septic systems

Results: Based on our investigations, we have identified the following topics as essential for our educational program:

Ins and Outs of Septic Systems:

- What Type of System Do You Have?
- What Do You Need to Know About Your Septic System?
- Do You Know the Location of Your Septic System and Replacement Area?
- Is Your Septic System Working Okay?
- What Maintenance Has Been Done?
- What Maintenance Do You Need to Do?

Day-to-Day Management of Your Septic System:

- Don't Use Too Much Water.
- Don't Use Your Septic System as a Trash Can.
- Protect Your System from Physical Damage.
- Dispose of All Wastewater into Your Septic System.

Periodic Maintenance and Repair:

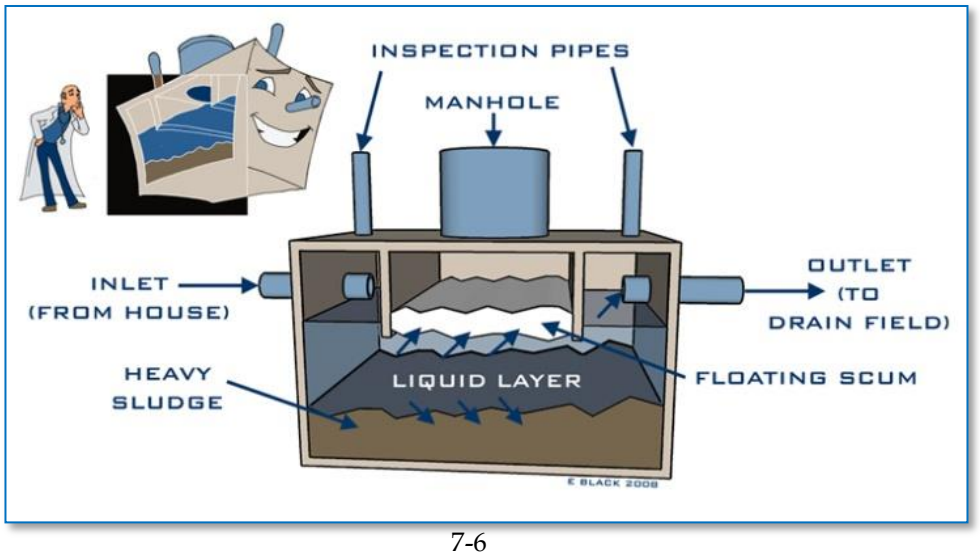
- Home and Yard, Including Drain Field.
- Septic Tank.
- Regulations.
- Signs of Septic System Problems.

Work Plan FY13/FY14

During FY 13-14, we will prepare the educational program materials, which will include homeowner/system user handouts and workshop presentations. We will begin to provide homeowner workshops at various locations around the state. We will also work with local health department staff who might want to present workshops themselves. We will also provide fact sheets to local health departments for distribution to homeowners and systems users and to real estate groups.

Informational Resources

Contact: Ms. Judith L. Sims, (435) 797-3230, Email: judith.sims@usu.edu.



Enhancement of Septic System Educational Programs in Utah with Advanced Training

Principal Investigators:
Judith L. Sims
Richard Jex
Margaret Cashell

Partners/Collaborators:
State: *David Snyder, Division of Water Quality, Utah Department of Environmental Quality*
Local: *Utah Health Departments*

Project Description

- **Need and Purpose:**

  The 2000 Utah Nonpoint Source Management Plan emphasized that education, awareness, and training are important tools in reducing nonpoint source (NPS) pollution of surface water, groundwater, and soils. The Plan also identified management of on-site wastewater disposal systems as one of Utah's nine priority non-point source pollution programs. The lack of education concerning appropriate siting of systems as well as operation and maintenance of systems contributes substantially to misuse and failure of on-site wastewater treatment systems.

  Since site and soil evaluations create the foundation for a working septic system, these evaluations should be correct and thorough, and potential limitations need to be properly assessed. For example, without training, soil textural differences may not be accurately distinguished, the hydraulic capacity of the soil may not be accurately determined or taken into account appropriately during the design phase, surface drainage may not be diverted as required from the drain field area, slope and landscape positions may be disregarded, or systems may be installed in saturated and/or poorly drained clay soils where conventional systems should not be constructed. It is also important that the gathered information accurately reflects the condition of the site and that the information is accurately recorded.

  Onsite professionals in Utah receive basic training in soils in the Level 1: Site and Soil Evaluation and Percolation Testing certification class. However, as regulations in Utah change such that soil and site properties will be utilized to a greater extent, advanced training that includes extensive field experiences is necessary.

  Utah Administrative Code R317-4, Onsite Wastewater Systems, mandates periodic inspections of alternative onsite wastewater treatment systems and R317-5, Large Underground Wastewater Disposal Systems, mandates periodic inspections of and the use of operating permits for larger onsite systems. There is also a requirement for periodic performance monitoring (sampling and analysis of effluent samples) for packed bed systems used in both large and small systems. In addition, there is a need to develop appropriate O&M procedures for systems that may accept wastewater that is different from typical residential wastewater, such as wastewater from restaurants. These systems have higher organic or hydraulic loadings that need to be addressed.

- **Benefits to the State:**

  Expected benefits to Utah watersheds include protection from the harmful effects of nitrogen, phosphorus, suspended solids, pathogens, and excessive organic loadings. Another benefit of the training programs will be an extension in the expected design lives of on-site wastewater treatment systems.

- **Geographic Areas:**

  Study Area: Workshops will be held in the Southwest Utah Department in Cedar City, the TriCounty Health Department in Vernal, and in the Weber-Morgan Health Department in Ogden during FY 2013-2014, after regulatory changes to Utah's on-site wastewater program have been adopted on September 30, 2013.

  Areas Benefited: All of Utah's 29 counties.

- **Accomplishments:**

  Findings: Information is not readily available in Utah at this time regarding advanced site evaluation techniques nor operation & maintenance of alternative, complex on-site wastewater treatment systems that address soil and site limitations.

  Results: Workshops have been developed that address advanced site evaluation techniques and operation & maintenance of alternative systems and incorporate changes to on-site regulations adopted in September 2013.

Work Plan FY13/FY14

During FY13/FY14, we will deliver the workshops at selected locations around the state.

Informational Resources

Contact: Ms. Judith L. Sims (435) 797 3230, E-mail: judith.sims@usu.edu.

Website: http://uwrl.usu.edu/partnerships/training/classes.html.

Workshop field and classroom training

Intermountain Section American Water Works Association (IMS-AWWA) Scholarship and Student Outreach Committee

Principal Investigators:
Laurie S. McNeill

Partners/Collaborators:
***State**: Intermountain Section American Water Works Association*

Project Description

- **Need and Purpose:**

  The drinking water industry is facing a wave of retirements and needs to recruit new engineers to join the field. This is particularly true in Utah.

- **Benefits to the State:**

  This committee provides scholarships to students who will benefit the field of water quality, supply, and treatment in the Intermountain West (Utah and southern Idaho). There are currently four scholarships: one undergraduate ($1,000), two graduate ($1,500 each), and one diversity ($1,000). The committee is also working to integrate water topics into the Utah K-12 education curriculum. A subcommittee also organized the first ever "Fresh Ideas Poster Contest" at the Intermountain Section's Annual Conference in September 2012.

- **Geographic Areas:**

  Study Area: Statewide.

  Areas Benefited: Statewide—students at any college or university in Utah or southern Idaho are eligible.

- **Accomplishments:**

  Findings/Results: Four students (one undergraduate and three graduate) were awarded scholarships totaling $5,000 to study water quality and treatment during the Fall 2012 semester. Two students are studying at Utah State University, one at BYU, and one at University of Utah. A total of 26 applications were received this year. The Fresh Ideas poster contest was also a great success. The winner received funding to present her poster at the national AWWA conference in Denver in June 2013.

Work Plan FY13/FY14

Participation in IMS-AWWA meetings and activities will continue. At least four scholarships will be awarded in Fall Semester 2013. Work will also begin on integrating water treatment topics into the State of Utah education curriculum; possible ties with the Utah Water Research Laboratory's International Office of Water Education will be considered.

Winning students at the Fresh Ideas Poster Contest:
Margie Borecki (3rd place), Christel Olsen (2nd place), Allia Abu-Ramaileh (1st place)

Informational Resources

Contact: Dr. Laurie S. McNeill, (435) 797-1522, E-mail: Laurie.McNeill@usu.edu.

Website: http://ims-awwa.site-ym.com/group/StudentPO.

Salt Lake Valley Solid Waste Management Council

Principal Investigators:
R. Ryan Dupont

Partners/Collaborators:
Local: *Patrick Leary, Russ Wall, Salt Lake County Public Works; Rick Graham, Salt Lake City Public Works; Brian Bennion, Salt Lake County Health Department; Russ Willardson, Council of Governments; Staff, Salt Lake County Solid Waste Management Facility; Dwayne Wooley, Trans Jordan Landfill*
State: *Scott T. Anderson, Director, Division of Solid and Hazardous Waste*

Project Description

- **Need and Purpose:**

  The goal of the Salt Lake Valley Solid Waste Management Facility (SLVSWMF) is to provide environmental stewardship, financial integrity, safety, recycling education, and quality service to benefit the environment, residents, businesses, and employees of Salt Lake County for the long term.

  The SLVSWMF operates a transfer station and landfill and is involved with the collection, transportation, and disposal of municipal and commercial solid waste within the Salt Lake City and Salt Lake County boundaries. The landfill facility operates a citizen's unloading facility, provides recycling for various commodities including household hazardous waste, collects landfill-generated methane for electricity production, runs a green waste compost production operation, and is involved in land reclamation. The facility is also proactively involved in educating the public in areas related to waste reduction, recycling, and composting and provides informational tours of the landfill and transfer station facility and their operations.

  The SLVSWMF operates on the financial principle of an enterprise fund, and is supported by gate fees, rather than by tax revenues. The SLVSWMF Council is tasked with oversight of operations at the facility, and makes recommendations to the owners of the facility (Salt Lake City and Salt Lake County) regarding operational issues and policies, the fee structure for services provided to the public, and other regulatory and management issues that arise during the course of running the enterprise.

- **Benefits to the State:**

  Membership on the SLVSWMF Council provides service to the citizens of Salt Lake City and Salt Lake County, the Utah DEQ, and the regulated community by providing technical overview and expertise in solid waste management to the operating staff of the facility. The PI attends monthly meetings of the SLVSWMF Council, provides comments and input on solid and hazardous waste issues that arise, and has responded to special requests from the Council or facility staff regarding technical issues affecting operation at the facility. Recent examples of this special project request include proposal preparation (FY 2013-2014) for a laboratory study investigating the impact of MSW shredding on solid waste degradability and methane production, and an effort detailed in a separate report related to investigating the impact on the SLVSWMF carbon and energy footprint of expanding green waste recycling on a County-wide basis and implementing food waste composting in Salt Lake City.

- **Geographic Areas:**

  Study Area: Salt Lake City, West Valley City, and Salt Lake County.

  Areas Benefited: Salt Lake City, West Valley City, and Salt Lake County.

- **Accomplishments:**

  Findings/Results: The PI attended all regularly scheduled SLVSWMF Council meetings throughout FY12/FY13 and provided review and comment on all Council items relevant to his area of expertise, being heavily involved in analysis and development of recommendations regarding implementation of mandatory green waste recycling, food waste recycling, and increased municipal solid waste recycling throughout Salt Lake City, West Valley City and Salt Lake County.

Work Plan FY13/FY14

Continue involvement in decision-making through attendance at monthly SLVSWMF Council meetings and responding to special project requests as they arise to support the SLVSWMF's mission and goals. Conduct a laboratory scale study evaluating the effect of MSW shredding on the rate and extent of waste decomposition and methane production to support the implementation of large-scale waste shredding at the facility.

Informational Resources

Contact: Dr. R. Ryan Dupont, Phone (435) 797 3227, E-mail: ryan.dupont@usu.edu.

Website: http://www.slvlandfill.slco.org.

State of Utah Solid and Hazardous Waste Control Board

Principal Investigators:
R. Ryan Dupont

Partners/Collaborators:
State: *Scott T. Anderson, Director, Division of Solid and Hazardous Waste*

Project Description

- **Need and Purpose:**

  Under the Utah Solid and Hazardous Waste Act (the Act), responsibility for overseeing solid and hazardous waste disposal rests with DEQ and the Utah Solid and Hazardous Waste Control 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 solid waste management units, hazardous waste storage, treatment and disposal facilities, including the various Federal chemical demilitarization facilities and private hazardous and low-level nuclear waste disposal facilities located in Utah's West Desert region.

  In addition, Utah has enacted the Underground Storage Tank Act to regulate underground storage tanks. The Underground Storage Tank Act applies to all tanks covered by the Federal Resource Conservation and Recovery Act and specifically includes petroleum storage tanks. The Board has the power to make rules regarding certification of tank installers, inspectors, testers, removers, and environmental consultants, as well as requiring the registration of underground tanks and management of the remediation of underground tank releases. Each owner or operator of an underground tank must register the tank with the Executive Secretary of the Solid and Hazardous Waste Control Board.

- **Benefits to the State:**

  Membership on the Solid and Hazardous Waste Control Board provides service to the citizens of the State of Utah, the Utah DEQ, and the regulated community by providing technical overview and expertise in solid and hazardous waste management to the Division of Solid and Hazardous Waste in their rulemaking, facility inspections and reviews, policy implementation, and conflict resolution. The PI attends monthly meetings of the Solid and Hazardous Waste Control Board held throughout the State, and provides comments and input on solid and hazardous waste issues that arise during the course of the Division's implementation of Federal and State solid and hazardous waste management laws.

- **Geographic Areas:**

  Study Area: State of Utah.

  Areas Benefited: State of Utah.

- **Accomplishments:**

  Findings/Results: The PI attended all regularly scheduled Waste Control Board meetings and facility tours from July 1, 2012 to March 1, 2013, and provided review and comment on all Board items relevant to his area of expertise.

Work Plan FY13/FY14

No further involvement in the Board occurred after his term expired in March 2013.

Informational Resources

Contact: Dr. R. Ryan Dupont, Phone (435) 797-3227, E-mail: ryan.dupont@usu.edu.

Website:
http://www.hazardouswaste.utah.gov/Board/UtahSolidandHazardousWasteControlBoard.htm.

Statewide Nutrient Criteria Development: Core Advisory Team

Principal Investigator:
Darwin L. Sorensen

Partners/Collaborators:
State: *Walter Baker, Director, Utah Division of Water Quality*

Project Description

- **Need and Purpose:**

  Utah, along with other states, is in the process of developing water quality criteria for the waters of the state (http://www.nutrients.utah.gov/index.htm). The policy development inherent with this process must be informed by the best available science because of the environmental, economic, and social impacts that the results will have on the communities and citizens of the state. The team advises the director and staff of the Utah Division of Water Quality. Members of the team include representatives from the Utah Department of Agriculture and Food, the Division of State Parks, the Division of Wildlife Resources, drinking water utilities, the US Environmental Protection Agency, environmental interests, the USDA Natural Resource Conservation Service, the Utah League of Cities and Towns, public owned wastewater treatment plant managers, storm water management, agricultural producers, scientific expertise, and ground water influences.

- **Benefits to the State:**

  Water quality nutrient standards formed by the Division of Water Quality will be applied throughout Utah. Dr. Sorensen is working with the other members of the team and the staff of the division to formulate general and site specific standards. Approaches for cost effective implementation of the standards and cost allocation for technology implementation are also being developed.

- **Geographic Areas:**

  Study Area: Statewide.

  Areas Benefited: Statewide.

- **Accomplishments:**

  Findings/Results: Various sectors represented on the team have presented their perspectives, and the approaches and standards used by other states are being considered. A technical subcommittee, of which Dr. Sorensen is a part, is focusing on the analysis of existing nutrient water quality data available in the state with the intent of recommending standards for various ecosystems of the state. Source waters, generally within National Forest boundaries, will have anti-degradation standards.

Work Plan FY13/FY14

The initial intention for the life of the team was two years, but they will continue to work for another year. It is anticipated that Dr. Sorensen will continue to serve as member of the team in FY14.

Informational Resources

Contact: Dr. Darwin L. Sorensen, (435) 797-3207, E-mail: darwin.sorensen@usu.edu.

Support for State Watershed Modeling and TMDL Plans: Tools to Assist in Nutrient Criteria Development Using QUAL2Kw

Principal Investigators:
Bethany T. Neilson

Partners/Collaborators:
Local: *Jenni Oman, Salt Lake County; Florence Reynolds, Salt Lake City*
State: *Nick vonStackelberg, Jeff Ostermiller, Hilary Arens, John Whitehead, UDEQ*
Business/Industry: *Theron Miller, Jordan River POTWs; Nick VonStackeberg, Stantec Consultants; Eric Duffin, Cirrus Consultants*

Project Description

- **Need and Purpose:**

  The Clean Water Act (CWA) requires total maximum daily load (TMDL) development for impaired water bodies. The requirements associated with the TMDL process include the quantification of loads from both point and nonpoint pollution sources, reallocation of these loads to meet instream water quality standards, and implementation plans. Additionally, there are new requirements regarding the development of numeric nutrient criteria. In order to meet these requirements, some sort of watershed and/or instream water quality model is necessary.

- **Benefits to the State:**

  States are tasked with developing TMDL plans and, more recently, statewide nutrient criteria, but those who must make the decisions often lack the expertise necessary to conduct the modeling studies and the understanding necessary to design the monitoring studies to support the modeling efforts. I have worked to provide guidance to the Utah Division of Water Quality (DWQ) and their consultants in making decisions and prioritizing investments.

- **Geographic Areas:**

  Study Area: Salt Lake and Weber Counties, State of Utah.

  Areas Benefited: Jordan River Basin, Great Salt Lake, Salt Lake County Drainages, State of Utah.

- **Accomplishments:**

  Findings:

  Jordan River TMDL Modeling Review: On the basis of work over the last number of years with Utah DWQ, a conference presentation and paper were developed to communicate effective methods of model calibration for use within the TMDL program. The paper was published in the Journal of Water Resources Management and Planning in 2013.

  Jordan River Temperature Modeling: Work was completed with the Utah DWQ and South Valley Water Reclamation Facility to complete the instream temperature modeling, which will assist in determining whether a site specific temperature standard is necessary for the upper portion of the Jordan River.

Statewide Wasteload Allocation Study: Efforts have been completed under a contract with Utah DWQ to complete the QUAL2Kw modeling portion of a larger project that is (1) investigating the need for numeric nutrient criteria and (2) providing guidance regarding data collection to develop site specific nutrient criteria. We will continue to work with DWQ to apply the model findings to development of nutrient criteria. Based on this work, a paper is in review that provides guidance regarding data collection to support QUAL2Kw modeling.

Numeric Nutrient Criteria Tools: Under a contract with Utah DWQ we developed tools to interface with QUAL2KW to assist in determining phosphorus and nitrogen thresholds that result in instream water quality standard violations. A paper that documents the utility of these tools is nearly ready for submission.

Results:

Jordan River Temperature Modeling /Statewide Wasteload Allocation/Numeric Nutrient Criteria Studies: We have completed data collection and the associated instream water quality modeling for nine streams below various wastewater treatment plants throughout the state. The models have been used to assist in determining their utility in developing nutrient criteria. They have also been used in the development of waste load allocations for water reclamation facilities. Many conference presentations, a master's student thesis, and three papers have resulted from these projects.

Work Plan FY13/FY14

Over the next year, I will continue technical support to the State of Utah through the numeric nutrient criteria development.

Informational Resources

Contact: Dr. Bethany T. Neilson, (435) 797-7369, E-mail: bethany.neilson@usu.edu.

Representative Publications/Presentations:

Jordan River TMDL Model Review

von Stackelberg, N.O., B.T. Neilson, H.N. Arens (2010). Collaborative calibration of a water quality model of an urbanized river. ASABE *TMDL 2010: Watershed Management to Improve Water Quality Conference*. Baltimore, MD, November.

von Stackelberg, N.O. and B.T. Neilson (2012). A collaborative approach to calibration of a riverine water quality model. *Journal of Water Resources Planning and Management*, doi: 10.1061/(ASCE)WR.1943-5452.0000332. Accepted. Posted online 17 Nov 2012.

Jordan River Temperature Modeling and Statewide Wasteload Allocation Study

Hobson*, A.J., B.T. Neilson, N. von Stackelberg, M. Shupryt, J. Ostermiller, G. Pelletier, and S.C. Chapra (In review). A data collection and calibration strategy for QUAL2Kw. *Journal of Water Resources Management and Planning*.

Hobson*, A.J., B.T. Neilson, and N. von Stackelberg (2013). QUAL2Kw as a decision support tool: considerations for data collection, calibration, and numeric nutrient criteria. *Water Environment Association of Utah Annual Conference 2013*. St. George, UT, May.

Utah Water Education Project

Principal Investigators:
Steven L. Barfuss
Michael Budge
Jesse Pope

Partners/Collaborators:
State: *Division of Water Resources*

Project Description

- **Need and Purpose:**

  Utah is one of the fastest growing states in the nation. As the population increases, the demand on water resources will also increase. Because Utah is the second driest state in the country, its limited water supply will always be a top priority.

  In a focused effort to educate the public about the state's water supply, as well as how to conserve its water supply and what is required to provide water to its citizens, a digital photograph computer screensaver is being prepared. Upon project completion, this computer screen saver is intended to be widely distributed to school districts, colleges and universities, and government agencies, as well as made available to the general public. The screensaver will include over 1000 carefully selected Utah water-related photos, and each photo will include a brief descriptive and educational caption. The captions will provide snippets of information and instruction about Utah's water resources and the proper use of the resources without burdening the reader with large amounts of text.

  The purpose of the project is to incrementally educate a diverse public about ways Utah's water is used, specifics regarding water conservation, and information about the State's streams, rivers, and lakes and the animals and people that rely on this resource. The selected photographs will be high quality, interesting, and beautiful so that the reader will be naturally encouraged to read the captions. Each photograph will include some aspect of Utah's water resources, water infrastructure, or water use, and photos will be strategically selected so that all 26 counties within the State of Utah will be represented in the screensaver.

- **Benefits to the State:**

  Utah is second only to Nevada in gallons of water used per person. Few Utahans would argue against the need to conserve water; however, most people will not change water-use behaviors unless they understand the importance of conservation and the need to be stewards of the resource. The intent of this screen saver project is to encourage viewers of the photos to naturally change personal behaviors in water use through incremental education. The end benefit to the State of Utah, of course, will be a reduction in per capita water use and preservation of the State's water resources.

- **Geographic Areas:**

  Study Area: Entire State of Utah.

  Areas Benefited: Entire State of Utah.

Figure 1. An example of the many photos included in the project.

- **Accomplishments:**

  Findings: The main portion of this project was completed in April 2013 and presented to the Division of Water Resources. A small amount of additional funding was recently provided to the project to maintain and to transition the use of the photos from the UWRL to the Division of Water Resources.

  Results: Upon completion in April 2013, the project had over 900 photos in use, each with its own caption and location. Three hundred pre-1940 historical photos were included in the collection as well. A public website hosted by the Utah Water Research Lab servers has been created and is designed to be the access point for the public. From there, users can download the photos as an installable screensaver for PC & Mac, or view them individually in an online gallery. The product was presented to the Utah Division of Water Resources in April 2013 for collaboration, distribution and publicity. Efforts to maintain, update, distribute, and publicize the project are ongoing.

Work Plan FY13/FY14

- Determine the most appropriate means for distributing the screen saver to the citizens of Utah. Specific target groups will be schools and public offices and places.
- Develop the most effective means for distributing the work through State agencies.
- Continue to work closely with the Division of Water Resources to gather input and collaborate.
- Maintain the photos through updates of the programs and website.

Informational Resources

Contact: Mr. Steven L. Barfuss (435) 797-3214, E-mail: steve.barfuss@usu.edu.

Water Resources Planning and Management

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Water Resource Planning and Management

Project Name	FY2013 Actual Expenditures	FY2014 Budgeted Expenditures	FY2015 Planned Expenditures
Allocating Scarce Water for Utah Wetlands with Ecological Uncertainties	$29,021.39	$35,100.00	$36,153.00
ASR Optimization Protocol and Decision Support	$16,081.72	$4,012.92	$0.00
Capturing Aerial Imagery on the San Rafael River, Utah, Using an Unmanned Aerial Vehicle (UAV) to Monitor and Assist in Evaluating Restoration Efforts	$14,629.20	$15,068.08	$0.00
Flood Potential Due to 100-Year Storm Events for Small Utah Cities	$16,693.44	$17,000.00	$0.00
Improving Hydrologic Model Predictions for the Effects of Land Use and Climate Change	$28,928.57	$29,796.43	$29,796.43
Integrating High Frequency Monitoring with High Resolution Modeling in the Little Bear River	$15,295.04	$15,753.89	$16,226.51
Irrigation System Water Use Efficiency Using Field Evaluations and Remotely Sensed Evapotranspiration Estimates	$20,800.40	$21,424.41	$0.00
iUTAH – Innovative Urban Transitions and Arid Region Hydro-Sustainability	$65,343.48	$67,303.78	$18,909.18
Low Cost Vertical Take Off and Landing Remote Sensing Systems for Water Engineering	$84,146.93	$98,570.00	$0.00
Multispectral UAV Collaborative Remote Sensing System for Irrigation Water Management and Ecological Assessment	$181,604.20	$152,500.00	$33,475.00
Pineview Reservoir Operations and Algae/Cyanobacterial Bloom Ecology	$101,564.69	$20,000.00	$0.00
Quantifying the Flow Field in Baffled Fish Culverts	$39,388.31	$0.00	$0.00
Real-Time Management of Irrigation Systems in the Sevier River Basin	$242,548.36	$249,824.81	$138,000.00
UAV Monitoring and Assessment Applications in Municipal Water and Environmental Management	$2,760.87	$2,843.70	$0.00
UAV Remote Sensing Service Center	$61,239.94	$125,000.00	$130,000.00
Water Conservation and Managing Water Shortages	$8,063.98	$20,000.00	$20,000.00
Water Resources Modeling for Utah's Cache Valley	$25,395.06	$26,156.91	$0.00
Designated Projects		$582,600.00	$51,537.12
Undesignated Projects		$137,500.00	$0.00
Total	**$953,505.58**	**$1,620,454.93**	**$474,097.24**

Allocating Scarce Water for Utah Wetlands with Ecological Uncertainties

Principal Investigators:
David E. Rosenberg
Karin M. Kettenring
Christopher M.U. Neale
Omar Alminagorta, Ayman AlAfifi, Melina Santos Vanderlinder, Liisa Piiparinen, Russell Babb, Sarah Stander, Michael Adamson, Erika Tillman, Sean Bedingfield (Students)

Partners/Collaborators:
Local: *Al Trout, Friends of Bear River Refuge; Joan Degiorgio, The Nature Conservancy; Bryan Dixon, Bear River Land Conservancy; Bob Fotheringham, Cache County*
State: *Toby Hooker, Utah Geologic Survey; Pam Kramer, Division of Wildlife Resources*
Federal: *Bob Barrett, Sharon Vaughn, Howard Browers, Karl Fleming, U.S. Fish and Wildlife Service*
Business/Commercial: *Eve Davies, PacifiCorp*

Project Description

- **Need and Purpose:**

  Wetlands, particularly along the Great Salt Lake, provide critical wildlife habitat, resting grounds for migratory birds, and social and economic services including water purification, storm water retention, and recreation for hunters. Wetlands need water, but in Utah and the western U.S., water is often scarce and not available to flood and maintain wetland habitats and functions. Scarce water challenges wetland managers on how to best allocate limited water to and within wetlands to improve ecosystem functions and services. Water allocation decisions are further complicated because responses by bird populations and native plant species are often uncertain.

  This project extends systems modeling underway at and for the Bear River Migratory Bird Refuge, Utah (the Refuge). Part I is building a wetland systems (optimization) model to identify water and vegetation management actions Refuge mangers can take to improve wetland performance under existing water, vegetation response, budget, staff time, and other constraints. Part II is quantifying the response over time of *Phragmites australis* (hereafter *Phragmites*), a non-native, invasive grass, to changing water levels. Part III is a federally-funded National Science Foundation effort to extend the model and identify the numerous near-optimal water allocation strategies for improving wetland and riparian performance in the lower Bear River Basin.

- **Benefits to the State:**

  The project benefits Utah in several direct and indirect ways. First, the project is helping Utah wetland managers to better manage and allocate their scarce water, personnel, and budget resources to achieve their wetland objectives. The project is also contributing new information on water levels that both encourage and discourage *Phragmites* spread. The project is demonstrating how to use this information and the uncertainties contained within it to manage water to reduce *Phragmites* spread. The project is also helping Utah environmental managers allocate scarce water to environmentally important areas across a watershed. These benefits will help Utah water managers better manage wetlands and riparian areas to support hunting, birding, and recreation that are vital to the Utah communities that border the Great Salt Lake and the state's rivers. Finally, the project is integrating systems modeling, ecology, invasion ecology, and remote sensing and showcases Utah as taking a new approach to environmental management.

- **Geographic Areas:**

  Study Area: Bear River Migratory Bird Refuge, north shore of the Great Salt Lake, Box Elder County, Utah; Bear River, Cache, and Box Elder Counties, Utah.
  Areas Benefited: Wetlands and riparian areas throughout the state of Utah.

- **Accomplishments:**

Findings and Results:

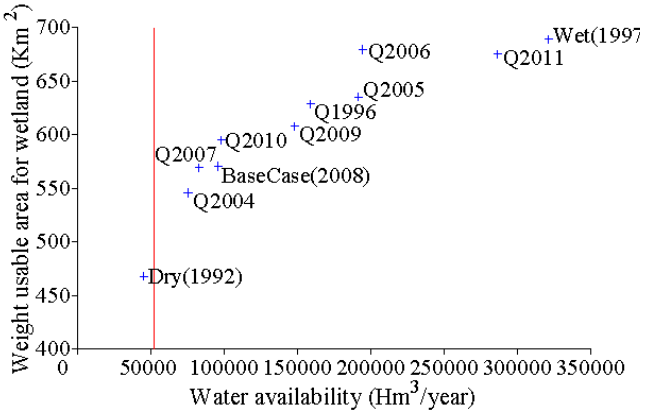


Figure 1. Relationship between water availability and wetland performance (measured as weight usable area for wetlands). Blue crosses represent water availability scenarios associated with the listed year. The red vertical line shows the Refuge's annual water right. Wetland performance falls drastically as water availability drops towards the Refuge water right.

  - Found that managing Refuge water levels more dynamically can increase wetland performance, and that wetland performance falls drastically as water availability approaches the Refuge water right (Figure 1).
  - Traveled 55 miles of the Bear River above Cutler Reservoir and set up two water flow and environmental monitoring sites.
  - Identified performance metrics for modeling riparian areas.
  - Submitted article titled "Systems Modeling to Improve the Hydro-Ecological Performance of Diked Wetlands" to the peer-reviewed journal *Water Resources Research*.
  - Submitted article titled "Use of remote sensing to assess changes in wetland plant communities in response to large-scale disturbance and management–a case study from the Bear River Migratory Bird Refuge, Great Salt Lake, UT" to the peer-reviewed journal *Western North American Naturalist*. Article accepted pending minor revisions.
  - Developed near-optimal water management algorithms for linear and integer problems.
  - Presented near-optimal , Refuge, and Bear River environmental work at the (i) International Congress on Environmental Modelling and Software: Managing Resources of a Limited Planet, Sixth Biennial Meeting International Environmental Modelling and Software Society (iEMSs), Leipzig, Germany, July 1-5, 2012, (ii) American Geophysical Union Annual Fall Conference in San Francisco, CA: Dec 3-7, 2012, and (iii) Environmental Water Resources Institute of the American Society of Civil Engineers in Cincinnati, OH: May 19 - 23, 2013.

Work Plan FY 13-14

- Quantify *Phragmites* response to changing water levels, embed this hydro-ecological relationship in the wetland systems model, and develop a user-friendly version of the model.
- Continue monitoring on the Bear River; set up third field site; start building models for lower Bear River that uses the identified performance metrics for wetlands and riparian areas.
- Develop near-optimal algorithms for convex, non-linear problems.

Informational Resources

Contact: Dr. David E. Rosenberg, Phone (435) 797 8689, E-mail: david.rosenberg@usu.edu.

Website: http://www.engr.usu.edu/cee/faculty/derosenberg/projects.htm.
Website: http://dx.doi.org/10.1061/41114(371)264.
Website: http://www.iemss.org/sites/iemss2012//proceedings/A2_0656_Rosenberg.pdf.

ASR Optimization Protocol and Decision Support

Principal Investigators:
Richard C. Peralta
Ali Forghani

Partners/Collaborators:
Local: *Richard Bay, Jordan Valley Water Conservancy District*

Project Description

- **Need and Purpose:**

  The Jordan Valley Water Conservancy District (JVWCD) began operating a full-scale Aquifer Storage and Recovery (ASR) system in 2002. Currently the system has 18 extraction/injection wells. The JVWCD wishes to optimize management of the ASR system. This includes considering economics and the amount of credit received from the State Engineer for the water that the JVWCD injects (injectate). The State Engineer allows multiple-year carryover credit of injectate, subject to the condition that 10% of the injectate is lost per year of carryover storage after the first 12 months from injection. This loss assumedly represents the escape of groundwater that has flowed laterally rather than directly toward extracting ASR wells. JVWCD managers believe they are physically able to recover more injectate than they receive credit for, and wish to know more accurately how much injectate they can physically recover. They want to know how best to inject and extract with time. Fully addressing the problem involves more accurately quantifying the amount of injectate that is recovered, and optimizing the timing of injections and extractions, subject to projected temporally varying water availability, water need, and cost. Software to facilitate use of the ASR optimization protocol is also desirable.

- **Benefits to the State:**

  To best integrate use of available water resources, Utah water managers increasingly consider applying aquifer recharge (AR) and aquifer storage and recovery (ASR) techniques. Usually, river water is treated and used to recharge (injected into) aquifers in the spring season. Groundwater is extracted (pumped out) later in the year when surface flow is low. ASR should be optimized with respect to cost, reliability, and other related issues. Considerations are (1) the amount of injectate the recharging organization can physically recover, (2) the amount of credit the State Engineer might give to the recharging organization and (3) the cost (considering energy use and well clogging) and timing of water need and availability. Although optimal ASR strategies are site- and management-specific, the procedure for developing them is transferable to other situations. This project will enhance the ability of the JVWCD to use Provo River water. As water manager confidence increases in their ability to recover more water and receive credit for it, the procedure will encourage ASR use by other organizations.

- **Geographic Areas:**

  Study Area: The new methodology will be developed and tested for the Jordan River Valley within Salt Lake County.

  Areas Benefited: This project will benefit all water providers that wish to intentionally recharge their aquifers thru wells and later extract the water for use. It will be applicable for sites worldwide. It is especially appropriate where the timing of surface water availability does not coincide with water need.

- **Accomplishments:**

  Findings:
  - Obtained and became familiar with Groundwater Vistas software, the graphical user's interface for the groundwater flow and transport simulation models used by CH2MHILL for the study area.
  - Reviewed SOMOS (Simulation/Optimization Modeling System) simulation-optimization (S-O) model capabilities for optimizing water injection to and extraction from ASR wells.
  - Modified a heuristic optimization algorithm to correctly compute multi-period ASR wells situations.
  - Prepared software to accept multi-period input and produce informative output.
  - Optimized multi-period ASR injection and extraction pumping strategies and obtained results consistent with expected physical system responses.
  - Partially developed an alternative optimization approach using equilibrium modeling.

  Results:
  - A new methodology prevents the awkward situation reported in 2012, in which extracted tracer mass sometimes exceeded injected tracer mass. This transport-model related situation no longer occurs.
  - With revised constraint formulation, heuristic optimization algorithms employed by SOMOS can successfully develop multi-period ASR pumping strategies.
  - The enhanced heuristic optimization algorithm can be used with the CH2MHILL groundwater flow model to compute optimal strategies for JVWCD 's ASR wells.

Work Plan FY13/FY14

- Perform baseline simulations to demonstrate how the JVWCD groundwater system currently responds to management.
- In consultation with JVWCD, select optimizations to be performed for their system.
- Perform selected optimizations for existing ASR system.
- Determine whether and how to further modify the model.
- Report results to Jordan Valley Conservancy District.

Informational Resources

Contact: Dr. Richard C. Peralta, (435) 797-2786, E-mail: peralta.rc@gmail.com.

Capturing Aerial Imagery on the San Rafael River, Utah, Using an Unmanned Aerial Vehicle (UAV) to Monitor and Assist in Evaluating Restoration Efforts

Principal Investigators:
Mac McKee
Bethany T. Neilson
Ian Gowing

Partners/Collaborators:
***State**: Dan Keller – Utah Division of Wildlife*
***Federal**: Justin Jimenez – Bureau of Land Management*
***State**: Paul Birdsey – Utah Division of Wildlife*

Project Description

- **Need and Purpose:**

  The AggieAir Flying Circus (AAFC), a service center at the Utah Water Research Water Laboratory that provides high resolution multispectral aerial imagery using a UAV, was contracted in 2011 by the Utah Division of Wildlife Resources to fly the lower 50 miles of the San Rafael River to provide high resolution aerial imagery after a high river flow event. As a result of this project, the San Rafael Restoration Committee wants to integrate the high resolution imagery that the AAFC can provide, along with the analysis of the data contained in the imagery, as an integral component in the San Rafael restoration effort. It is expected that the data and analyses will significantly improve the information content of the entire data collection effort of the San Rafael restoration process, and that significant research questions on the effects of tamarisk control on river morphology will be made easier to answer.

  The project will also yield significant research results on the accuracy and limitations of the use of inexpensive UAV platforms to provide data, such as digital elevation and terrain models, in place of more conventional--and much more expensive--approaches, such as LiDAR. Additionally temperature sensors will be positioned within the entire 50 mile study reach to help calibrate thermal imagery captured by AggieAir to address the issue of thermal regime within the San Rafael River.

- **Benefits to the State:**

  The San Rafael River is recognized as being in a severely degraded state and listed on the 303D list of degraded waters in the state of Utah. With the implementation of this River restoration scheme we anticipate to restoring the river to a more ecologically acceptable state, providing more comprehensive complex habitat to the native fish, encouraging change in channel morphology through removal of Tamarisk, planting more native riparian species along the river corridor, and removing man- made barriers to enhance fish movement/passage throughout the entire drainage.

- **Geographic Areas:** San Rafael River, Emery County, Utah.

  Study Area: Emery County.

  Areas Benefited: Emery County and state-wide, wherever river restoration projects are being implemented.

- **Accomplishments**:

  Findings: Due to the severe low flow nature of the San Rafael River (< 2 cubic feet per second for several months this summer), all UAV flights were postponed until next year when it is anticipated the river levels will return to a semi-normal state.

  Results: No UAV flights were conducted this year due to the severe low flow nature of the river.

Work Plan FY13/FY14

It is anticipated that UAV flights will commence during the summer of 2014 to begin monitoring and assisting river restoration actions currently being implemented both within and along the San Rafael River.

Informational Resources

Contact: Ian Gowing, (435) 797-3159, E-mail: ian.gowing@usu.edu.

The San Rafael River, summer 2013 during a period of extreme low flow

Flood Potential Due to 100-Year Storm Events for Small Utah Cities

Principal Investigators:
Michael C. Johnson
Marshall W. Saunders

Partners/Collaborators:
***State**: Todd Adams, Water Resources*
***Business/Private:** Matt Stayner, Bowen Collins*
***Federal:** Edward Clark, CBRFC*
***USU Staff:** Mark Winkelaar*

Project Description

- **Need and Purpose:**

  With the population growth in Utah, many cities are expanding their borders into the mountain range benches. Consequently, these homes are in the path of potential floods. In the event of a severe thunderstorm, a river or small stream can expand far beyond its banks. Even areas that do not normally have streams can accumulate enough rain water to create a flash flood. Since peak flood runoff information in these mountain ranges does not currently exist, cities are left without this critical potential flood information when considering city planning or flood prevention.

- **Benefits to the State:**

  By determining peak flood runoff in these mountain ranges, a city can better plan around potential flood areas and implement flood prevention methods. Many cities in the State of Utah cannot afford to hire an engineering firm to perform a detailed study of the mountain areas. The results of this study will provide Utah cities with detailed information about the amount of flood water coming out of the basins and will guide future growth and implementation of flood water structures for homes that are already in place. The project results could potentially save the state considerable money by avoiding the need for disaster clean up if and when floods occur.

- **Geographic Areas:**

  Study Area: The study area includes all basins in the state of Utah that are near or in a city and are considered to have the possibility of significant flood water damage. The following list indicates the number of currently identified study sites in each county: Box Elder, 5; Cache County, 12; Carbon County, 9; Davis County, 19; Juab County, 2; Millard, 1; Morgan County, 11; Salt Lake County, 18; Sanpete County, 6; Summit County, 6; Tooele County, 1; Utah County, 31; Weber County, 10; Wasatch County, 2; and Washington County 5.

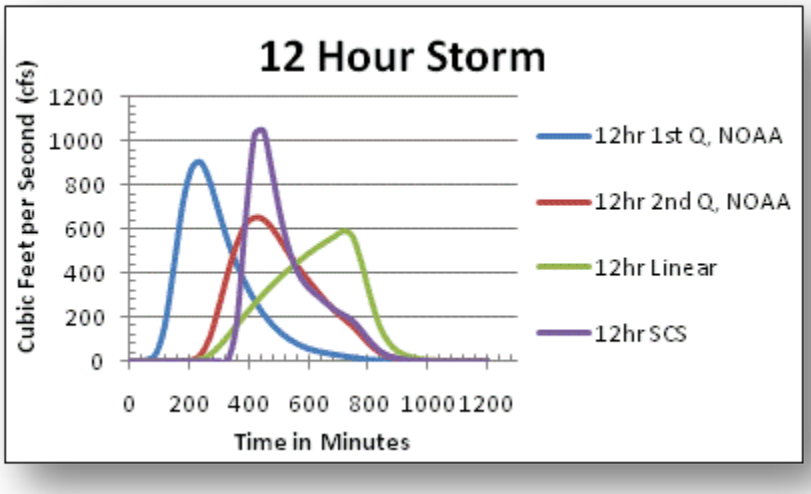
  Areas Benefited: This project will benefit all cities in the state that are experiencing growth and need data relative to planning for potential flood issues.

- **Accomplishments:**

  Of the 138 currently identified study areas, 138 studies have been completed or are in the final stages.

  Findings: The hydrograph figure below is an example of peak runoff flood water from one study out of the 138 identified study sites. This hydrograph represents Hyde Park Canyon for a 12-hour storm. Similar hydrographs are being completed for the other 137 study sites for 1-, 2-, 3-, 6-, 12-, and 24-hour storms. The different lines represent different ways to distribute rainfall

during the length of the storm. Each line has a different peak value, but the volume of runoff is the same for a given timeframe. For example, the 12-hour linear distribution that was used as a lower bound has a peak of about 600 cubic feet per second at about 720 minutes after the storm has started.



Results: The results indicate a high probability of flooding in areas of sub basins that do not contain a natural stream; consequently, this condition presents a potential hazard for the citizens and property in the path of the flood waters. This study also recognized that the State of Utah has very limited rainfall curve information, and that some curves differ widely.

Recommendations: Rainfall curve distributions should be made specific to Utah's storms and mountain regions. In many parts of Utah, rainfall gauge data is either lacking or insufficient in period of time or coverage. Since current soil and vegetation data combine valley and mountain areas, soil and vegetation data need to be specific to mountain regions only, which would improve the input data.

Work Plan FY13/FY14

- Distribute the report to cities/counties across the state to assist them in guiding Utah's future development and promote an awareness of the possible flooding hazards along the various basins in Utah.

Informational Resources

Contact: Dr. Michael C. Johnson, (435) 797-3176, E-mail: michael.johnson@usu.edu.
Mr. Marshall W. Saunders, (435) 797-3152, E-mail: marshallsaunders@aggiemail.usu.edu.

Improving Hydrologic Model Predictions for the Effects of Land Use and Climate Change

Principal Investigators:
David G. Tarboton
Ibrahim Mohammed (Former student)
Vinod Mahat (Former student)
Ahmet Yildirim (Student)

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  Hydrologic models are needed to predict the availability of water from watersheds within the Western US, including semi-arid regions of Utah where water is scarce. As land cover and land use change due to agriculture, urbanization, forestation, and as climate changes, the runoff changes. There is a need for detailed hydrologic models that use physical understanding of the hydrologic processes involved to model the hydrologic response and sensitivity of watersheds to these changes. This work involved hydrologic modeling that addresses the runoff produced from watersheds. It includes improvements in the capability to model snowmelt in vegetated areas and to simulate watershed responses to land use changes. It also includes improvements in the computational tools that support these hydrologic models so as to take advantage of parallel computing capability to simulate larger areas in greater detail.

- **Benefits to the State:**

  Water is a critical resource in Utah, and this project will provide a better understanding and an improved ability to predict water availability in the future as a result of land use and climate changes. Planning for development and growth in the state requires information on water availability as well as on the impacts of growth on water resources. This work is improving our capability to model snowmelt, which is a major source of water in the state. It is also improving our ability to simulate watershed responses to land cover changes using process based models that represent the land cover in better detail.

- **Geographic Areas:**

  Study Area: The study area is the semi-arid Western U.S., particularly Utah.

  Areas Benefited: Water Resources in watersheds throughout Utah may be subject to impacts from changes in land use and climate, so all counties in the state would potentially benefit from a better understanding of these impacts.

- **Accomplishments:**

  Findings: This work has focused on (1) improvement of the Utah Energy Balance Snowmelt model—specifically in the way it represents vegetation and is able to quantify the sensitivity of snowmelt to variability in vegetation density and leaf area index, (2) detailed simulation of watershed responses to land cover changes to evaluate the impact of transitions in forest canopy type and changes from forest to rangeland or other land cover, and (3) the development of a virtual tile approach to large digital elevation model computations to improve the capacity for hydrologic modeling taking advantage of parallel computing technology.

Results: The energy balance that drives snowmelt is affected by the way wind that drives turbulent energy exchanges interacts with the canopy. Improvements to the Utah Energy Balance Snowmelt model representation of these processes were evaluated using data collected at the Utah State University TW Daniels Experimental Forest and at the Niwot Ridge long-term ecological research station in Colorado. The results, reported in Mahat et al. (2013), demonstrate improvements in the ability to predict snowmelt from forested areas using practically available information.

The results in Mohammed and Tarboton (2013) quantify the sensitivity of Utah watersheds, such as the Weber River near Oakley where the simulation was run, to vegetation changes. The runoff sensitivity results suggest that during winter, reduced leaf area index (LAI) decreases canopy interception, resulting in increased snow accumulation and hence more snow available for runoff during the early spring melt season. Increased LAI during the spring melt season tends to delay the snow melting process. These simulations help quantify the sensitivity of water yield to vegetation change.

The work on parallel computational methods for hydrologic modeling has resulted in a new method for processing digital elevation model data that uses a virtual tile approach to manage computer memory (Yildirim et al., 2013). This method is able to process digital elevation model grids that are significantly larger than could otherwise be processed and improves our ability to represent detail in hydrologic models.

Work Plan FY13/FY14

In the current year we are focusing on integrated modeling of hydrologic and water management processes and developing the capability for broader application of process based models to address water resource questions. This work is in conjunction with our CI-WATER (http://ci-water.org) project, the goal of which is to Enhance Access to Data- and Computationally-Intensive Modeling. The user level virtual memory approach already taken was a first step. This year we anticipate developing a parallel version of the Utah Energy Balance snowmelt model and developing the capability to apply a watershed simulation model that includes water use and management processes over large areas using high performance computers.

Informational Resources

Contact: Dr. David G. Tarboton, (435) 797-3172, Email: dtarb@usu.edu.

Publications:

Mahat, V., D.G. Tarboton and N.P. Molotch (2013). Testing above and below canopy representations of turbulent fluxes in an energy balance snowmelt model. *Water Resources Research*, 49(2): 1107-1122, http://dx.doi.org/10.1002/wrcr.20073.

Mohammed, I.N. and D.G. Tarboton (2013). Simulated watershed responses to land cover changes using the Regional Hydro-Ecological Simulation System (RHESSYS). *Hydrological Processes*, (Early view online), http://dx.doi.org/10.1002/hyp.9963.

Yildirim, A.A., D. Watson, D. Tarboton and R.M. Wallace (2013). A Virtual tile approach to raster-based calculations in large digital elevation models. *IEEE Transactions on Parallel and Distributed Systems*. Submitted.

Integrating High Frequency Monitoring with High Resolution Modeling in the Little Bear River

Principal Investigators:
Jeffery S. Horsburgh
Amber Spackman Jones
Brant Whiting (Student)
Nate Mouzon (Student)

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  The future of water science will inevitably be more data intensive. These new data collection efforts are focused on precisely representing hydrologic environments and advancing our understanding of the functional behavior of watersheds (both natural and built) in efforts to "get the right answers for the right reasons." As conditions shift beyond our range of prior experience, improving our predictions for operational and management purposes depends on our understanding of hydrologic processes.

  Advancing understanding of the functional behavior of watersheds and encoding it within the next generation of predictive models requires synthesis of measurements at multiple scales and from multiple sources. This is a problem of data fusion, where the manner in which data are organized, encoded, and described can enable or inhibit scientific analysis. Additionally, as the amount and complexity of data grows, it becomes increasingly difficult for data analysts to find, interpret, and analyze data using existing query and reporting tools.

  In this project, we evaluate current and emerging water observing systems and the role of cyberinfrastructure in supporting day-to-day data collection, management, and sharing to support the next generation of environmental models. We also examine how the feedback between data collection and modeling can be better supported through cyberinfrastructure. The context of the project is the Little Bear River Experimental Watershed, which already has significant observational infrastructure installed that can serve as the basis for these studies.

- **Benefits to the State:**

  Providing accurate predictions of water availability and quality is essential to the state of Utah and the United States as our water resources are stressed by changes in population, land use, and climate. Predicting hydrologic and water quality responses within arid catchments undergoing these changes continues to be particularly difficult given the high uncertainty of precipitation, snow distribution, soil moisture, and human-impacts on these systems. Creating more accurate model representations that are supported by state-of-the-art data collection activities is one way to provide better information to inform the management of these systems. The monitoring and modeling techniques being investigated will provide better information about the timing, magnitude, sources, and flow paths of water. This will benefit the State of Utah Division of Water Quality, utilities providing drinking water from stream and reservoir sources to municipalities, and other water users throughout the state. The rich datasets that we continue to collect in the Little Bear River provide a unique location in which to do this research.

- **Geographic Areas:**

Study Area: Little Bear River in Cache County.
Areas Benefited: The Little Bear River and other river systems state-wide.

- **Accomplishments:**

Findings: Our work over the past year has illustrated that current watershed hydrology models generally lack mechanisms for accurately representing water management (irrigation diversions, irrigation, conveyance systems, etc.). Accounting for these aspects is critical to understanding and predicting hydrology and water quality within these systems. An additional limitation is that representation of snowmelt within most existing models is inadequate to match the types of responses that we are measuring using high-frequency in-situ monitoring.

Results: We have developed a model of the Little Bear River watershed using the Soil Water Assessment Tool (SWAT). SWAT contains some of the best representations of biogeochemical processes associated with human impacted and agricultural landscapes. We have worked to incorporate many important process representations into the SWAT model but have also identified significant limitations (such as those described above). We are now working to advance this SWAT model with an alternative snowmelt component.

Work Plan FY13/FY14

We are continuing to monitor streamflow and water quality at seven sites within the Little Bear River, including all associated field work. We are also refining the existing SWAT model by altering its initialization and by incorporating process representations that are more appropriate for western water systems like the Little Bear River. One example is the alternative representation of snowmelt processes, which is critical for the Little Bear but is currently poorly represented in SWAT. We are also working on development of other models for the Little Bear River, including an initialization of the Pennsylvania Integrated Hydrologic Model (PIHM).

Informational Resources

Contact: Dr. Jeffery S. Horsburgh, Phone (435) 797-2946, E-mail: jeff.horsburgh@usu.edu.
Website: http://littlebearriver.usu.edu.

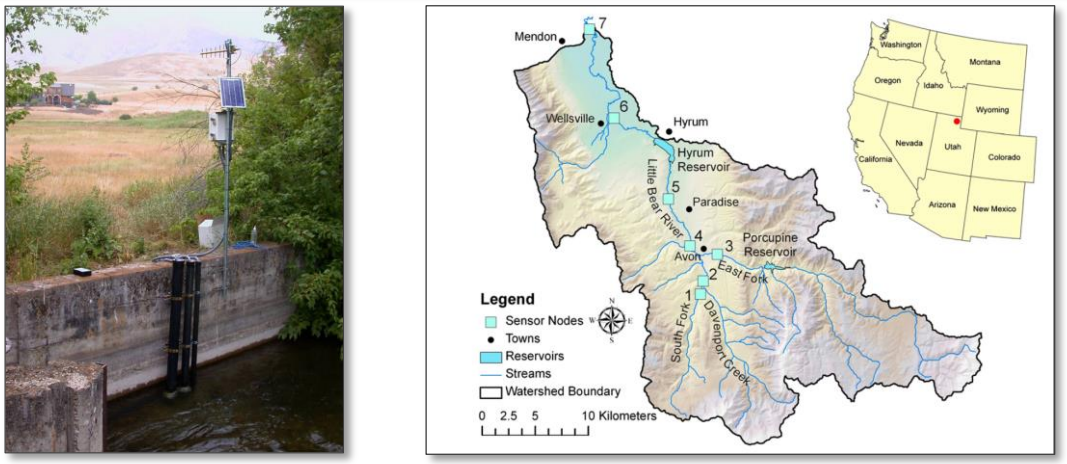


Figure 1. Continuous data collected at monitoring sites in the Little Bear River provide high frequency observations that are challenging the assumptions and process representations in our current suite of hydrologic models

Irrigation System Water Use Efficiency Using Field Evaluations and Remotely Sensed Evapotranspiration Estimates

Principal Investigators:
Christopher M.U. Neale
Hatim Geli (Post-Doc)
Jonna Van Opstal (Graduate student)

Partners/Collaborators:
Local: *Bear River Canal Company*
State: *Utah Agricultural Experiment Station*
Federal: *USDA-NRCS*

Project Description

- **Need and Purpose:**

  The growing demand for fresh water for municipal use in urban areas along the Wasatch front and in Cache Valley has led to water quality and quantity pressures on the exiting water resources. The Bear River basin is one of the few systems in the US West that still has unallocated water. Additional dams will likely be built within the system in the future to tap these water resources, even as the system is adjusting to a changing runoff hydrograph due to expected climate change. Solutions for improved management of the water resources in the Bear River basin must involve multiple stakeholders and possible include policy adjustments to the existing water laws. Improving the water management in large surface irrigated areas will be one of the important elements of the solution due to the high consumptive use of these systems and large diversions from the river. This study is providing the necessary information that system managers need in order to make future operational management decisions in adapting to changing conditions. The results will be relevant and applicable to other similar systems in Utah.

- **Benefits to the State:**

  Improved water management can lead to water savings and, potentially, to improved water quality. Decreases in diversions for irrigation can be stored for future use during drought years and guarantee minimum flows for the health of rivers systems and for other uses. The methodology being developed can be used in other irrigated areas of the state.

- **Geographic Areas:**

  Study Area: Bear River Canal Company in Box Elder County and irrigated areas of Weber and Sevier County

  Areas Benefited: Irrigated agricultural areas and systems in all 29 Utah counties

- **Accomplishments:**

  Findings: Spatial evapotranspiration estimated from a series of satellite imagery acquired over a growing season was used to establish seasonal crop water use in large irrigated systems and to establish the water balance and efficiency of the system at different levels. Both the Two Source Model (TSM) and the SEBAL energy balance models can provide accurate spatial evapotranspiration over large irrigated areas.

Results: The Spatial EvapoTranspiration Modeling Interface (SETMI) model was applied with multi-temporal satellite and/or airborne multispectral and thermal infrared imagery using TSM and SEBAL models to estimate the energy balance components from remote sensing and obtain spatial evapotranspiration of irrigated crops as well as riparian vegetated areas. Due to the failure of Landsat TM5 instrument in 2012, imagery from the MODIS sensor was used to estimate the seasonal ET from the Bear River Canal Company irrigated area complemented with airborne high resolution imagery from the USU LASSI/multispectral imaging system. The total volume of water used by ET was compared to the measured diversions into the main canal to establish a water balance and overall system efficiency. Eddy covariance flux towers were installed in alfalfa and corn fields, the two main crops within the area, to measure the evapotranspiration for comparison with the remote sensing methods. Water quality samples were collected and analyzed for different months during the season at the main inlets and outlets of the irrigated area and for a smaller lateral canal command area to examine the phosphorous and nitrogen balance. Irrigation field evaluation data collected over 5 different soils within the irrigated area were analyzed using the SIRMOD III model to obtain the infiltration parameters needed for modeling field surface irrigation application rates using the ADOR model.

Work Plan FY13/FY14

Conduct additional ET measurements with flux towers and apply the SETMI model to times series of satellite imagery (Landsat TM and MODIS) for modeling previous dry, normal, and wet years.

Informational Resources

Contact: Dr. Christopher Neale, (435) 797-3689, E-mail: christopher.neale@usu.edu.

Publications:

Van Opstal, J.D. and C.M.U. Neale (2013). Potential savings of water and nutrients for the Bear River Canal Company. *USCID Conference Proceedings, 7th International Conference on Irrigation and Drainage*, Phoenix, AZ.

Van Opstal, J.D. and C.M.U. Neale (2013). Energy and water balance of an irrigated agricultural area in Northern Utah. *Presented at the ACS meetings*, Cincinnati, OH.

Van Opstal and C.M.U. Neale (2013). Estimating irrigation performance for the Bear River Canal Company using spatial analysis tools. *Poster paper presented at the 2013 Spring Runoff Conference*, Utah State University, April.

iUTAH – Innovative Urban Transitions and Arid Region Hydro-Sustainability

Principal Investigators:
Jeffery S. Horsburgh
Bethany T. Neilson
David E. Rosenberg

Partners/Collaborators:
State: *Utah State EPSCoR Office, University of Utah, Brigham Young University*

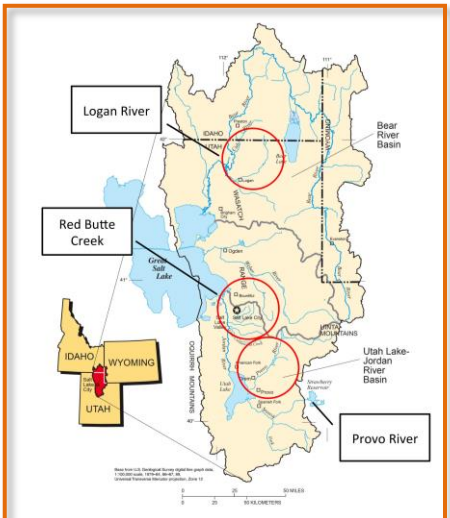
Project Description

- **Need and Purpose:**

  Water is critical to sustainable economic development in Utah and to the sustainability of our urban and natural ecosystems. Freshwater resources are facing immediate and long-term challenges due to population pressure and predicted changes in the amount and timing of precipitation. Utah's population will at least double in the next two decades, with most of this growth occurring along the narrow Wasatch Range Metropolitan Area (WRMA). Growth is expected to generate a significant increase in water demand that will need to be addressed through water transfers, infrastructure investments, and efficiency programs. The overarching goal for the iUTAH project is to enhance Utah's research competitiveness and sustainable water decision-making through strategic investments in the state's physical, human, and cyberscience infrastructure. Transdisciplinary teams of natural and social scientists have been formed to carry out hypothesis-driven research on hydroclimatic sustainability in the WRMA, a coupled human-natural system that is changing as a consequence of climate change and rapid urbanization.

- **Benefits to the State:**

  The innovative and transformational activities in this project include (1) the development of fully integrated hydrologic and social sciences observatories that encompass whole watersheds along an urbanizing land use gradient; (2) strategic activities designed to build a community of scholars across the state of Utah capable of addressing hydro-sustainability as a coupled human-natural system; and (3) integrated education and outreach activities, such as participatory and collaborative modeling efforts, to ensure our research directly addresses societal needs and will translate and communicate our scientific findings to stakeholders, policy makers, and the general public. An improved understanding of this complex system and the development and implementation of innovative solutions require better integration of social, hydroclimate, ecological, and engineering knowledge, and closer links between the academic community and local water management institutions. The theme of the iUTAH EPSCoR project is directly aligned with our state Science & Technology plan. It builds on our considerable existing strengths in water, urban and ecological sciences while expanding relevant expertise in the social sciences needed to understand complex, human-dominated systems. Our infrastructure investments will provide a common research platform and facilitate statewide science collaboration to enhance our ability to compete for major new interdisciplinary funding opportunities.

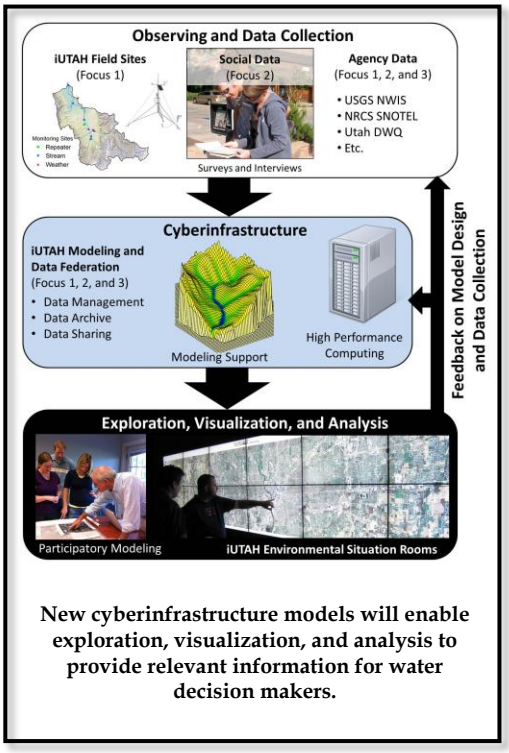


The iUTAH EPSCoR project is building new observing and data collection capabilities along a gradient of urbanization in three northern Utah watersheds

- **Geographic Areas:**

  Study Area: Logan River, Red Butte Creek, Provo River, WRMA, other urbanizing areas statewide.

  Areas Benefited: Logan River, Red Butte Creek, Provo River, WRMA, other urbanizing areas statewide.



New cyberinfrastructure models will enable exploration, visualization, and analysis to provide relevant information for water decision makers.

- **Accomplishments:**

  Findings: While many hydrologic and water management models currently exist, no single model provides adequate representation of all of the human mediated processes that shape the hydrology of western water systems such as those found in northern Utah, including diversions, transfers, return flows, and water use behaviors. Additionally, currently available hydrologic and water quality monitoring data are inadequate to characterize the highly modified hydrology and water quality of systems like the Logan River, Red Butte Creek, and the Provo River. Similarly, our understanding of human water use behavior at both the individual and organizational scale is incomplete, making it difficult for us to generate future water availability scenarios for important Utah water systems.

  Results: In the first year of this project we have participated in the design of hydrologic observatories in the Logan River, Red Butte Creek, and the Provo River aimed at furthering our understanding of the human mediated hydrologic systems within northern Utah along a gradient of urbanization. We have worked to develop the hardware and software cyberinfrastructure required to facilitate data collection within each of these observatories, including development of innovative new data management software. We are also participating in the design and development of social science observatories for these same systems, as well as integration of these primary data collection activities into coupled interdisciplinary models that better represent the human mediated hydrology of western water systems and provide more information directly relevant to future water availability scenarios and decision making.

Work Plan FY13/FY14

Year 2 will include continued work on the cyberinfrastructure aspects of the iUTAH project, and focus on the software systems required to enable iUTAH scientists and partners to share and collaborate around data and models of the state's hydrologic systems. Primary research using the data collected within the watershed observatories, and the development of the next generation of interdisciplinary coupled models will also be undertaken.

Informational Resources

Contact: Dr. Jeffery S. Horsburgh, Phone (435) 797-2946, E-mail: jeff.horsburgh@usu.edu.

Websites: http://www.iutahepscor.org, http://data.iutahepscor.org.

Low Cost Vertical Take Off and Landing Remote Sensing Systems for Water Engineering

Principal Investigators:
Austin Jensen
Mac McKee
Cal Coopmans (Ph.D. Student)

Partners/Collaborators:
Federal: *Roger Hansen, USBR*

Project Description

- **Need and Purpose:**

  To better manage water and other natural resources such as wetlands and floodplains, the Utah Water Research Laboratory (UWRL) has been actively developing a small UAV platform known as AggieAir that assists in water resources by capturing high resolution aerial imagery at a lower cost than conventional platforms (e.g. manned aircraft and satellite). AggieAir's fixed wing platform has been used successfully for many applications. However there is also a need for a rotary wing aircraft with the ability to take off and land vertically and to hover. This type of platform could launch and land in constrained areas, make close "point measurements" for applications such as vegetation mapping, and generate more detailed maps of small features such as dams. The goal of this project is to develop a rotary wing aircraft, referred to as the vertical takeoff and landing (VTOL) platform, as part of the AggieAir system. This will compliment the current fixed wing aircraft for applications in water related scenarios.

- **Benefits to the State:**

  AggieAir's fixed-wing UAVs have proven to be very useful for managing natural resources in the State of Utah. For example, the ability to acquire decision-relevant data on soil moisture and evapotranspiration in a timely fashion and at a low cost gives canal companies and irrigation districts in the state the ability to (1) provide farmers with highly detailed information about soil moisture conditions in individual fields, enabling them to better manage scarce irrigation resources; and (2) manage complex irrigation delivery systems more efficiently, thereby saving water that could be used to increase agricultural output or allocating it to other users whose demands are continually growing. The water savings could be as much as 5 or 10 percent of current deliveries.

  AggieAir's VTOL platform will complement the fixed wing platform and will benefit the State of Utah in many similar ways. The VTOL platform will also enable many new emerging applications.

- **Geographic Areas:**

  Study Area: Most of the test flights will take place at our test site near Cache Junction, UT. We have official approval from the FAA to conduct flights here (FAA Form 7711-1 2013-WSA-63).

  Areas Benefited: All counties in the state could benefit.

- **Accomplishments**:

Findings: An inexpensive VTOL unmanned aerial vehicle (UAV) has been further developed and is being made robust and capable of carrying and controlling various types of remote sensing equipment to gather aerial imagery. Improvements over the last year include a more stable/robust platform, a platform capable of flying over 30 min, and a modular frame.

Results: 1) Low-cost AggieVTOL prototyping approach using open source Paparazzi architecture; 2) demonstration of fully autonomous way point navigation; 3) grants obtained from NASA (2011-2014) despite fierce competition; 4) student competition at 2013 AUVSI SUAS with good teaming building progress; 5) focus on fault tolerance features; (6) invitation to give tutorial lectures at ICUAS13.

Work Plan FY13/FY14

- Finish development of hexarotor.
- Start using platform for routine data acquisition.
- Develop training and build manuals.

Informational Resources

Contact: Austin Jensen, (801) 633-0426, E-mail: austin.jensen@usu.edu.

Website: http://aggieair.usu.edu/.
AggieVTOL bookchapter: http://www.igi-global.com/bookstore/titledetails.aspx?TitleId=58292.

Figure 1: Hexarotor in flight

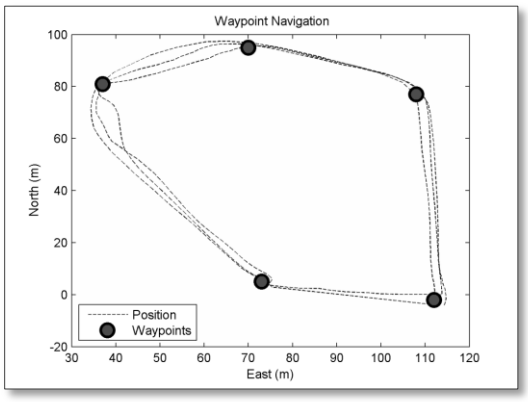


Figure 2: Recorded tracks of an AggieVTOL flight

Figure 3: View from AggieVTOL camera

Multispectral UAV Collaborative Remote Sensing System for Irrigation Water Management and Ecological Assessment

Principal Investigators:
Austin Jensen
Mac McKee
Calvin Coopmans (Ph.D. Student)

Partners/Collaborators:
Federal: *Roger Hansen, USBR*

Project Description

- **Need and Purpose:**

  Efficiency in agricultural water usage can be improved by offering low-cost, high-resolution (both spatial and temporal), multispectral remote sensing capabilities for irrigation scheduling and real-time water management. Autonomous unmanned aerial vehicle (UAV) technology and compact multispectral-imaging are both becoming lower cost and more affordable. Irrigated agriculture uses a large fraction of the fresh water resources around the world. In Utah, diversions for irrigated agriculture represent approximately 85 percent of the state's water use. Typically, water use in agriculture is very inefficient, and small improvements in efficiency would save significant quantities of water that could potentially be used to irrigate more land or be diverted to other, higher valued uses, such as municipal supply. This project focuses on development of a fixed wing UAV aircraft known as AggieAir and the payloads AggieAir will use to capture multispectral aerial imagery.

- **Benefits to the State:**

  The ability to acquire decision-relevant data on soil moisture and evapotranspiration in a timely fashion and at a low cost will enable canal companies and irrigation districts in the state to (1) provide farmers with highly detailed information about soil moisture conditions in individual fields, enabling them to better manage scarce irrigation resources, and (2) manage complex irrigation delivery systems more efficiently, thereby saving water that could be used to increase agricultural output or allocate to other users whose demands are continually growing. These advances will result in more water available for application in agriculture and less loss from system inefficiencies. The water savings could be as much as 5 or 10 percent of current deliveries.

- **Geographic Areas:**

  Study Area: Most of the test flights will take place at our test site near Cache Junction, UT. We have official approval from the FAA to conduct flights here (FAA Form 7711-1 2013-WSA-63).

  Areas Benefited: All counties in the state could benefit.

- **Accomplishments:**

  Findings: A new fixed wing version of AggieAir has been developed to replace the flying wing. The AggieAir – Minion is a conventional-style aircraft with more payload capacity and more flight time than its flying wing predecessor. In addition, flight is more stable and productive. A thermal camera has also been added to the list of payloads.

Results: Multiple successful missions have been conducted with the Minion platform and with the thermal camera. Grants were received (NASA, 2011-2014). Launcher design was not very useful in application so a redesign is needed.

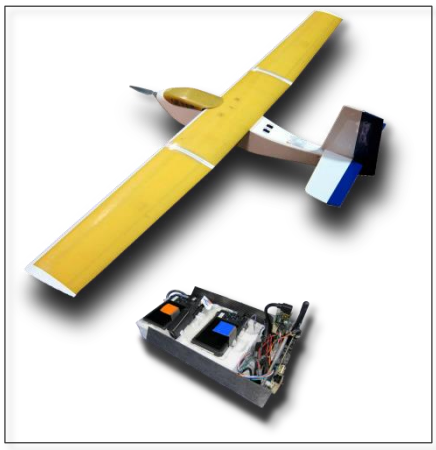
Work Plan FY13/FY14

- Develop a larger platform (called Titan).
- Improve launcher design.
- Research into improving thermal data is needed.

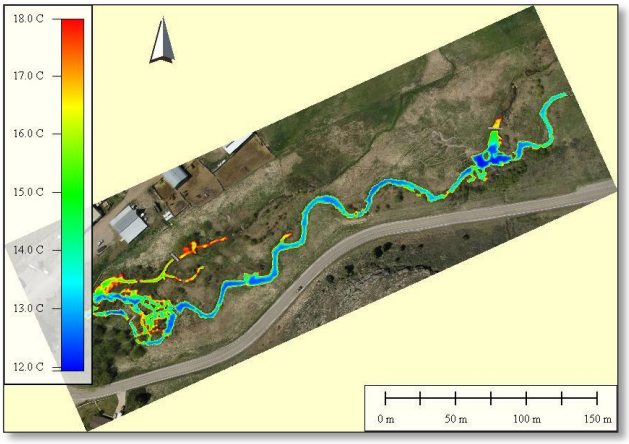
Informational Resources

Contact: Austin Jensen, (801) 633-0426, E-mail: austin.jensen@usu.edu.

Website: http://aggieair.usu.edu.



The AggieAir-Minion platform with its camera payload



A map of stream temperature collected from the AggieAir thermal camera

Pineview Reservoir Operations and Algae/Cyanobacterial Bloom Ecology

Principal Investigators:
Darwin L. Sorensen
Thomas Reuben (Student)
Christine Rumsey (Student)

Partners/Collaborators:
Local: *Scott Paxman and Brad Nelson, Weber Basin Water Conservancy District*
State: *Kari Lundeen, Utah Division of Water Quality*

Project Description

- **Need and Purpose:**

  Nuisance blooms of algae and cyanobacteria occur annually in Pineview Reservoir, Weber County, Utah. Previous water quality studies of the reservoir have identified both phosphorus and nitrogen as the nutrients limiting algae and cyanobacterial growth and have called for management action in the watershed to limit the loads of these nutrients to the reservoir. The socioeconomic costs of these actions are likely to be substantial. The present study, conducted in collaboration with the Weber Basin Water Conservancy District, seeks to provide empirical information for managers so that Pineview Reservoir water quality can be preserved or improved in the most cost-effective way.

- **Benefits to the State:**

  Utah's growing population and water demand will likely lead to the use of Pineview Reservoir as a key water body for the storage and distribution of municipal water to the greater Ogden and possibly the greater Salt Lake City areas in the future. Learning the factors that control phytoplankton productivity in the reservoir and the source and transport of nutrients will allow effective control methods to be selected. The approach and results of the study are likely to be applicable to other water bodies in Utah and the surrounding region.

- **Geographic Areas:**

  Study Area: Ogden Valley including Huntsville Town, Eden, and Liberty in Weber County.

- **Areas Benefited:** Ogden Valley, the greater Ogden area, and potentially, similar watersheds and reservoirs in Utah and the Intermountain West.

- **Accomplishments:**

  Results: Pineview Reservoir phytoplankton productivity and water quality was typical of mesotrophic conditions. The reservoir is thermally stratified during summer months and phosphorus accumulates in the bottom (hypolimnion) layer of the reservoir as summer progresses. A significant fraction of this phosphorus is removed from the reservoir as water is withdrawn for irrigation. Annual surface water nutrient loading has been lower than estimated in earlier studies, but loads associated with snow-melt runoff contribute the largest fraction of the total. Short but intense snow-melt events in the late winter and early spring on the valley floor may contribute substantial, "first flush," phosphorus loads. Ground water also contributes less nitrogen and phosphorus than estimated in earlier studies, but certain shoreline sectors near

Huntsville contribute more nitrogen and phosphorus than other sectors. Nitrogen cycling and nitrate transport modeling in the Huntsville area suggested that lawns may contribute a disproportionately high fraction of the nitrate leaching into ground water. Relatively steady concentrations of mobile phosphorus in groundwater at selected sites in and near Huntsville suggest equilibrium between phosphorus on the soil and that in solution. However, laboratory studies indicate that more phosphorus will associate with the soil if phosphorus concentrations increase. Dissolved organic matter does not influence phosphorus sorption.

Work Plan FY13/FY14

Ground water flow into Pineview Reservoir from the unconfined aquifer nearest the reservoir is small relative to surface water flows but the concentration of phosphorus in this water at certain locations far exceeds those anticipated. The project will close at the end of the 2013 calendar year.

Informational Resources

Contact: Dr. Darwin L. Sorensen, (435) 797-3207, E-mail: darwin.sorensen@usu.edu.

Publications:

Carrigan, L.D. and D.L. Sorensen (2012). Nonpoint source nutrient export from the Pineview Reservoir watershed to streams. Utah Water Research Laboratory, Utah State University, Logan, UT.

Reuben, T.N. (2013). *Nutrient contribution of the shallow unconfined aquifer to Pineview Reservoir*. PhD, Civil and Environmental Engineering, Utah State University, Logan, UT.

Reuben, T.N., B.K. Worwood, L.D. Carrigan, and D.L. Sorensen (2011). Pineview Reservoir nutrient loading, unloading, and the role of groundwater in the estimates. *Transactions of the ASABE*, 54(6):2219-2225.

Worwood, B.K. and D.L. Sorensen (2012). *Pineview Reservoir phosphorus and mineral nitrogen processes*. Utah State University, Utah Water Research Laboratory, Logan, UT.

Figure 1. Light measurement through the ice on Pineview Reservoir

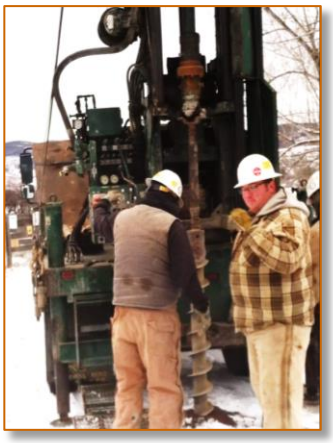


Figure 2. Drilling for water table aquifer cores

Quantifying the Flow Field in Baffled Fish Culverts

Principal Investigators:
Blake P. Tullis

Partners/Collaborators:
Local: *Tim Ularich, UDOT-Maintenance*

Project Description

- **Need and Purpose:**

  Many culverts are approaching or are past their original design lives and need to be repaired, rehabilitated, or replaced. Due to the expense and impact of traffic disruption associated with culvert replacement, alternate measures to extend the culvert project life are growing increasingly popular. One such method is slip lining, where a 'sleeve' is installed within an existing culvert barrel and stabilized. Plastic pipe sleeves are very popular for slip lining, but the reduced flow resistance, relative to corrugated pipe, can result in increased flow velocities and reduced flow depths in the culvert, creating a potential fish barrier. Hence, mitigation of the increased velocities should go hand-in-hand with slip-lined projects where fish passage (present or future) is to be considered. There has been very limited experience in providing for fish passage through slip-lined culverts.

  Baffles installed in culvert liners have been recommended as a possible solution for culvert relining when fish passage is a concern, but very limited data are available in the literature regarding baffle performance in circular culverts in relation to fish passage, as well as discharge capacity. Consequently, the evaluation the flow dynamics (turbulence) and the corresponding swimming behavior of fish to that flow environment will be evaluated in this study. As the single largest owner of culverts in the State of Utah, the Utah Department of Transportation (UDOT) has a keen interest in fish passage through rehabilitated culverts. As such, UDOT provided the initial funding for this study and MLF funds have been used to expand the research and contribution. The objective of the currently proposed study is to incorporate a flow dynamics component by determining mean flow velocities and flow depths and, perhaps more importantly, fluid acceleration data for turbulence quantification. Flow dynamics will be compared with fish behavioral results from the UDOT-funded study in an effort to better predict the likelihood of successful fish passage in baffled culvert designs not included in this study (i.e., improve the general applicability of the fish passage data).

  The scope of work for the project is summarized as follows:

  - Develop a technique for evaluating the 3-dimensional flow field in the free-surface flow, baffled culvert using a particle image velocimeter. Some complications may include the presence of entrained air bubbles and equipment access to the pipe (light sheet generating laser and imaging camera).
  - Collect high-frequency, 3-dimensional velocity data for a range of discharges and culvert slopes using the PIV system and an acoustic doppler velocimeter system for comparison.
  - Process the velocity data to calculate local flow accelerations and representative turbulence parameters.
  - Correlate the turbulence values with the fish behavior, relative to their ability to negotiate the baffled culvert.

- Use computational fluid dynamics (CFD) to further analyze the flow field and calibrate using the PIV velocity data.
- Determine hydraulic roughness coefficient data for baffled culvert using laboratory and CFD data.
- Write a peer-reviewed journal article summarizing the result of the study.

- **Benefits to the State:**

  UDOT does not currently have a design standard for baffled slip-lined culverts. The results of this study will be used to aid UDOT in developing a baffled culvert protocol for rehabilitated culverts where fish passage is a concern. The results of the study should have nation-wide application and perhaps even international application.

- **Geographic Areas:**

  Study Area: All work will be completed in the Hydraulics Lab at the Utah Water Research Laboratory (UWRL) at Utah State University.

  Areas Benefited: Culvert rehabilitation projects statewide and nationwide where fish passage issues may be of concern.

A brown trout navigating the baffled culvert during testing

- **Accomplishments:**

  Findings: This project began half way through FY11 and continued through FY13. The hydrodynamics of flow through baffled culverts was evaluated using computational fluid dynamics (CFD) numerical modeling. The CFD results will be compared with the PIV velocity profile previously collected to help calibrate and/or determine if CFD represents a reliable tool for baffled culvert flow analysis.

  Results: A peer-reviewed journal paper was submitted to the Journal of Hydraulic Engineering on fish passage through baffled culvert (an extension of the previous work and publication).

Work Plan FY13/FY14

In FY14, the analysis comparing the PIV and CFD data will be completed. The turbulent nature of the baffled culvert flows will also be correlated with fish passage behaviors in an effort to better understand when fish (brown trout) can and cannot successfully pass. The plan is to finish research on this topic in FY14 and submit two additional peer-reviewed journal papers with his results.

Informational Resources

Contact: Dr. Blake P. Tullis, Phone (435) 797 3194, E-mail: blake.tullis@usu.edu.

Real-Time Management of Irrigation Systems in the Sevier River Basin

Principal Investigators:
Mac McKee
Wynn Walker
Alfonso Torres
Andres M. Ticlavilca

Partners/Collaborators:
Local: *Jim Walker, Sevier River Water Users Association (SRWUA)*

Project Description

- **Need and Purpose:**

  As water demands increase in the western states, concerns for endangered species and water quality will have a greater impact on the allocation of water resources. Emphasis will have to be placed on more efficient water management if existing water rights are to continue to be met. Improvements in efficiency of water management require a low-cost mechanism for obtaining and distributing information about the state of the water supply system. This project is developing and adding significant data analysis functionality to the existing Sevier River Water Users Association (SRWUA) website to support real-time and long-term water management information needs.

- **Benefits to the State:**

  Application of this and related technologies in the Sevier River Basin in the past several years have shown an improvement in the decision-relevant information available to system managers in their efforts to increase the efficiency of basin-wide water management. Similar results could be achieved in virtually every river basin in Utah, especially those with substantial irrigated agriculture. The forecasting techniques developed by this project could potentially provide valuable information for better long-term decisions by farmers and ranchers for investments in crops and livestock, especially in years where drought might be likely. Similarly, the short-term forecasting methods developed by this project can provide system managers with information necessary to more precisely control the operation of large irrigation systems, such as those found in the Sevier Basin, thereby saving water and increasing the overall productivity of the system.

- **Geographic Areas:**

  Study Area: Sevier River Basin, including Sevier and Millard Counties.

  Areas Benefited: Irrigated agriculture is statewide, so all counties in the state would potentially benefit.

- **Accomplishments**:

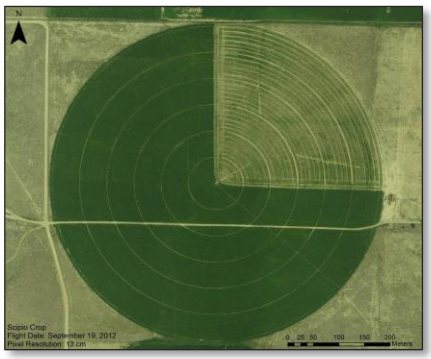
  Findings: Real-time reservoir, canal, and on-farm operations can be improved in the Sevier River Basin by several percent with the use of remote sensing tools and data-driven models such as those developed by this project.

  Results: Products generated by the project this year include:

- Software has been developed for the Canal B area near Delta, Utah that automatically downloads Landsat imagery and processes it to produce field-by-field and canal command area measurements of irrigation water use. This can be extended to any irrigated area in the State.
- Short-term forecasts of reference evapotranspiration rates in the Delta, Utah, area that are spatially distributed on irrigated fields. Forecasts are daily for a period of up to 16 days into the future.
- Models that distribute these short-term forecasts geographically are now available to describe field-by-field ET rates for up to 16 days into the future.
- A real-time reservoir operations model for forecasting releases required to meet downstream water demands for Sevier Bridge and DMAD reservoirs. This model has been programmed to run on SRWUA computers and is being implemented to support the operations decisions of Sevier Bridge and DMAD reservoirs.
- A model to produce daily forecasts of flows into DMAD reservoir. This helps solve a critical management problem for releases from Sevier Bridge Reservoir for which the river commissioner is responsible. This model is being programmed for distribution on the SRWUA computers.
- Flights of the UWRL autonomous aerial vehicles (UAVs) have been conducted by the AggieAir™ Flying Circus housed at the UWRL (see http://aggieair.usu.edu) for fields near Scipio, Utah. The AggieAir imagery has been used to provide high-resolution maps of plant tissue nitrogen and chlorophyll and spatial ET measurements. Models to estimate soil moisture in irrigated areas using these remote sensing techniques, as well as models to forecast changes in root zone soil moisture, are under development and show excellent promise.
- Several agent-based models of individual farmer irrigation decision behavior were built and tested to evaluate their ability to predict irrigation decisions. This might result in new tools to anticipate overall short-term irrigation water demands in the Canal B command area near Delta.

Work Plan FY12/FY13

- Continue to work with the US Bureau of Reclamation and the SRWUA to implement all operations models on the SRWUA website.
- Continue development of short-term irrigation demand forecasts for the Canal B area in order to improve canal performance with respect to efficiency of water deliveries. This work will place greater emphasis on the use of remotely sensed data acquired from Landsat.
- Develop remote sensing tools for estimating water requirements, evapotranspiration rates, and present and future soil moisture levels in the Scipio area for better management of center pivot irrigation systems.



Aerial imagery of the center pivot system in Scipio obtained from UAV flights used to estimate soil moisture, evapotranspiration rates, and plant nitrogen content.

Informational Resources

Contact: Dr. Mac McKee, Phone (435) 797 3188, E-mail: mac.mckee@usu.edu.

UAV Monitoring and Assessment Applications in Municipal Water and Environmental Management

Principal Investigators:
Austin Jensen
Mac McKee

Partners/Collaborators:
Local: Issa Hamud, Will Lusk, Logan City

Project Description

- **Need and Purpose:**

  For water and environmental management applications, remote sensing gives managers accurate spatial data to use in making management decisions. Even through research has shown that remote sensing can be a very useful tool, many water resources managers do not use it due to high cost, long processing time, and inflexibility. Free GIS state services or applications like Google Earth could be used for aerial imagery instead of purchasing the data. However, the imagery from these sources can be out-of-date, may have poor resolution, and rarely include all spectral information needed to use modern classification software or other advanced analytic techniques. To deal with some of these problems a new remote sensing platform, called AggieAir, has been developed at Utah State University. AggieAir is a small, autonomous aircraft with multiple on-board cameras to capture aerial imagery during flight. AggieAir is capable of capturing visual (red, green, and blue) imagery, near-infrared (NIR) imagery, and thermal imagery. For this project, we will investigate the value to cities such as Logan, Utah, of using AggieAir to help them manage their environment by capturing aerial imagery over areas of interest. The types of areas of interest include wetland and riparian areas, landfills, and parks and recreation areas such as golf courses.

- **Benefits to the State:**

  The objective of this project is to investigate the use of AggieAir in municipal water and environmental management problems. If AggieAir proves useful and is able to save Logan City water, money, and time, these techniques could be applied to other cities in Utah. Therefore, all areas of the state could benefit by saving more water, money and time while effectively managing the environment.

- **Geographic Areas:**

  Study Area: The Logan River, the Logan Golf Course, and a wetland mitigation site were selected as study areas. Precautions were taken to make sure the UAV does not fly over highly populated areas.

  Areas Benefited: Logan City and potentially many other cities in Utah.

- **Accomplishments**:

  Results: Imagery was acquired over the Logan River, the Logan Golf Course, and a wetland mitigation area. Multiple sets of images were acquired over the golf course and the wetland. The wetland and golf course imagery turned out to be in good quality so mosaics have been made; however, further processing is yet to done. The Logan River imagery was not useable due to a bug in the payload system at the time. There are plans to re-fly the Logan River.

Work Plan FY13/FY14

- Process the imagery that has been acquired.
- Re-fly the Logan River.
- Look at the effectiveness of calculating water stress over the golf course.
- Map native and non-native vegetation in the wetland mitigation area.

Informational Resources

Contact: Mr. Austin Jensen, (801) 633-0426, E-mail: austin.jensen@usu.edu.

Website: http://aggieair.usu.edu/.

Figure 1: Golf Course Visual and NIR mosaics

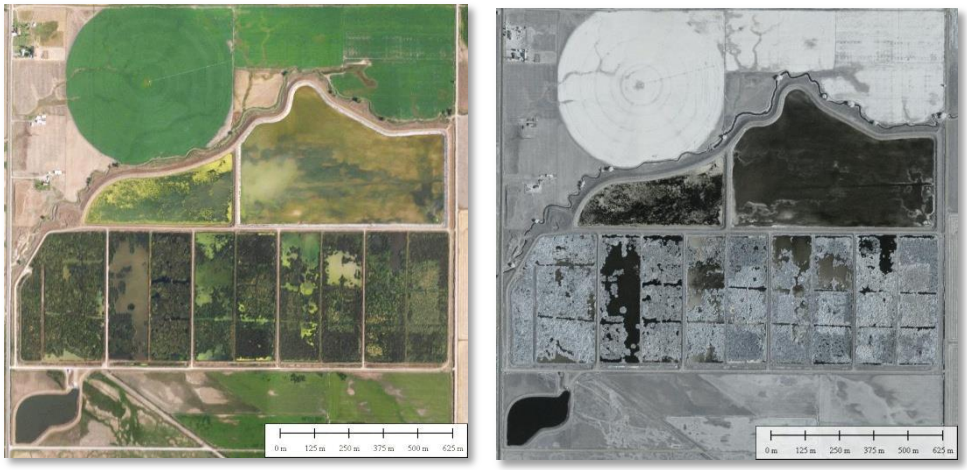


Figure 2: Wetland Mitigation Visual and NIR mosaics

UAV Remote Sensing Service Center

Principal Investigators:
Austin Jensen
Mac McKee

Partners/Collaborators:
Various end-users in Utah

Project Description

- **Need and Purpose:**

  Many current sources of remote sensing data (e.g. manned aircraft and satellite platforms) are too expensive, have low spatial resolution, or don't update frequently enough to be practical for many applications. A low-cost, small unmanned aerial vehicle (UAV) called AggieAir™ can fill this need by providing inexpensive, multispectral aerial imagery quickly and frequently. In addition, AggieAir's independence from a runway for takeoff and landing enables it to be launched from almost anywhere. AggieAir can benefit applications such as agriculture, riparian habitat mapping, road and highway surface monitoring, wetland mapping, fish and wildlife tracking, and many others.

  AggieAir has been developed over the last few years and has now reached a stable and robust status. Therefore, it is beneficial to start using AggieAir on a regular basis to provide aerial images for applications that could benefit from remote sensing data. In addition, the money made from these applications could be used to help fund continued AggieAir development and research. To facilitate this, a service center has been established to handle the operational and maintenance needs so the research can continue to progress undeterred. The service center is also a good source of feedback to help steer AggieAir research and development in the right direction.

- **Benefits to the State:**

  The data provided from the service center has the potential to help Utah save water and manage environmental resources more efficiently. The service center can help save water by offering farmers a low-cost solution for mapping the soil moisture of their crops in order to irrigate more efficiently. Furthermore, this data can also help canal operators and individual irrigators manage water diversions more effectively. The service center can also map roads and highways to monitor the quality of the asphalt and to update the road inventory (e.g. number of lanes, signs, culvert crossings, etc.). Roads can also be surveyed before, during, and after construction by the service center UAVs. Currently this is only done before construction. Wetlands managers can now obtain current data on the distribution of plant species and monitor the success of management practices to control invasive plants. Resources managers who are worried about monitoring and managing water quality can now obtain accurate, high resolution thermal images showing temperature distributions all along a stream or river.

  The service center will also indirectly provide new jobs and economic growth to the state of Utah. The long term goal is to use the service center as the first step toward starting a business that will be based around the AggieAir UAV platform. The service center will allow us to test the waters, as well as gain experience to learn what would be required to make this happen.

- **Geographic Areas:**

  Study Area: State-wide.

  Areas Benefited: State-wide.

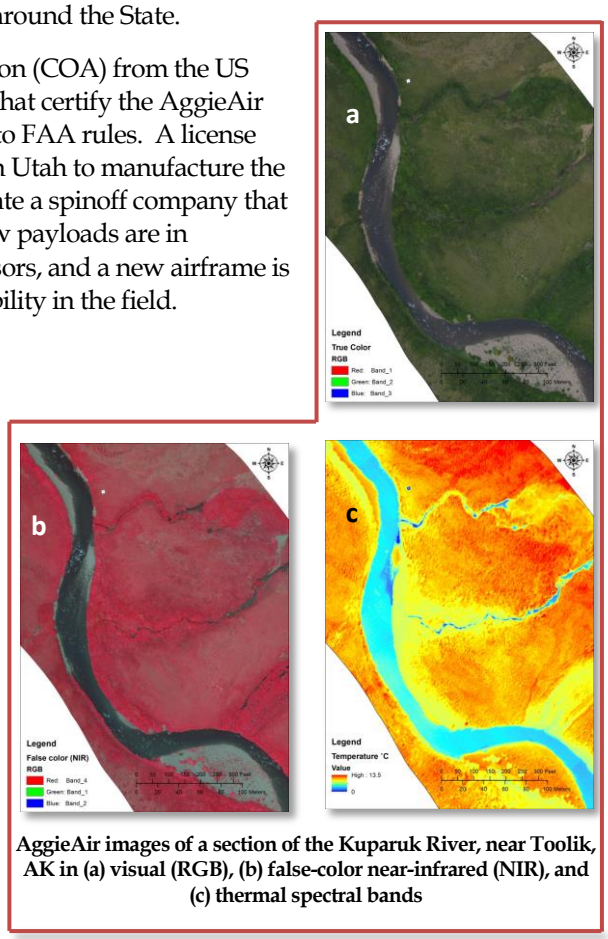
- **Accomplishments:**

Findings/Results: The funds from this project have developed and fully equipped a new service center at the Utah Water Research Laboratory called AggieAir Flying Circus (AAFC) (see http://AggieAir.usu.edu). As planned, the AAFC uses AggieAir on a regular basis to provide aerial images for applications that benefit from remote sensing data. The images below display some of the maps generated by the AAFC and the analysis of the imagery to address water management problems in a variety of applications.

Manuals have been completed so that the AggieAir service center can offer training services to customers who have purchased the UAVs from USU. Sales of aircraft have been made to organizations that wish to use AggieAir for their own remote sensing purposes and licensing agreements are in place with private companies in Utah to manufacture AggieAir aircraft and avionics. Additional field crews have been trained to fly the UAVs and process the imagery they collect.

In the past year, the AggieAir Flying Circus has provided support to research contracts in several states, with a very large number of flights conducted on a wide array of resources management problems in Utah. The AAFC is currently engaged by research projects on improving irrigation and nutrient management for center pivot irrigators in Scipio, on the quantification of salt that flows into the Green River from the Price River Basin, and on a large number of other similar projects. The AAFC is also been engaged in projects in water and natural resources management in Cache Valley for the City of Logan and in numerous other applications around the State.

The AAFC obtained two Certificates of Authorization (COA) from the US Federal Aviation Authority (FAA) in the past year that certify the AggieAir platform is airworthy and authorize its use subject to FAA rules. A license was signed between USU and a private company in Utah to manufacture the aircraft, and negotiations are now underway to create a spinoff company that will market AggieAir equipment and services. New payloads are in development that will include a wider array of sensors, and a new airframe is being designed that will provide much better capability in the field.



AggieAir images of a section of the Kuparuk River, near Toolik, AK in (a) visual (RGB), (b) false-color near-infrared (NIR), and (c) thermal spectral bands

Work Plan FY13/FY14

Expand the AAFC business base through acquisition of more research contracts, develop and license a spinoff company to market AggieAir technology (both aircraft and downstream services), and complete the development and deployment of new aircraft and payloads.

Informational Resources

Contact: Austin Jensen, Phone (435) 797 3315, E-mail: austin.jensen@aggiemail.usu.edu.
Website: http://aggieair.usu.edu/.

Water Conservation and Managing Water Shortages

Principal Investigators:
David E. Rosenberg
Adel Abdallah (Student)
Bereket Tesfatsion (Former student)
Francisco Suero (Former student)

Partners/Collaborators:
Local: *Issa Hamud, Mark Neilson, City of Logan; Tage Flint, Scott Paxman, Weber Basin WCD; Stephanie Duer, Salt Lake City*
State: *Scott Adams, David Cole, UDWR*
Federal: *None*
Business/Industry: *Peter Mayer, Aquacraft, Inc.*

Project Description:

- **Need and Purpose:**

  Water conservation can cost-effectively extend limited existing surface and groundwater supplies to accommodate rapid future population growth. The state legislature and governor have recognized the importance of water conservation and set ambitious targets to reduce average per-capita water use by 25% by 2025. Initial education and awareness efforts such as "Slow the Flow" have stagnated or reduced per-capita water use over the last decade, yet it is still unclear what exactly caused the reduced use and whether reductions can persist to achieve state-mandated goals. Utah water utilities need more and better tools to identify customers with high potential to conserve water, determine how technology and behavioral factors contribute to water savings when a water-wasting appliance is retrofitted, understand what incentives (economic, informational, technological, community, etc.) encourage and motivate customers to conserve, and identify linkages between energy and water use, and how to leverage those linkages to promote conservation. Additionally, customers need more information to support their outdoor landscape choices and actions because landscape irrigation is the largest component of municipal water use. Utah's arid climate also makes water conservation an important part of drought planning strategies, and there is a need to coordinate a diverse range of management actions such as groundwater extraction, trades, exchanges, and surface water storage. Here again, Utah water utilities can benefit from better tools to simulate water availability, plan for droughts, and respond to water shortages.

- **Benefits to the State:**

  Active water conservation projects are helping Utah water providers achieve the state goal of 25% reduction in per-capita water use while maximizing the effectiveness of utility conservation programs (increasing water volume saved while reducing program costs and staff time). Water conservation research projects are making analysis tools and information available to home owners and utility operators to help them select and implement water- and energy- efficient activities. The reservoir carryover storage project is providing Utah water utilities and the Utah Division of Water Resources with new tools to better model and proscribe reservoir operations. This work will allow a range of further studies that can connect reservoir operations to water conservation, infrastructure expansions, demand cutbacks, and runoff predictions. These tools will help in better planning drought responses and estimating runoff and flows to the Great Salt Lake, as well as flows required for environmental purposes. Using and extending these tools can reduce drought costs, decrease the likelihoods that customers will face costly cutbacks through droughts, and show ways to more cost-effectively operate structural and non-structural components of the water system.

- **Geographic Areas:**

  Study Areas: Integrated energy and water savings project: Metropolitan Water District of Salt Lake and Sandy in Salt Lake County; Drought planning project: Weber Basin in Summit, Weber, Morgan, and Davis counties.

  Areas Benefited: Municipal water providers and landowners statewide in all counties.

- **Accomplishments:**

  Findings:

  - It is cheaper to achieve percentage energy reduction targets than water reduction targets.
  - Conversation programs targeted to households that will save the most water and energy cost much less than blanket (non-targeted) programs.

  Results:

  - A water-energy systems model for Salt Lake City was built to identify the cost-effective conservation actions to meet water and/or energy conservation targets.
  - A journal article titled "Heterogeneous Residential Water and Energy Linkages and Implications for Conservation and Management" was accepted for publication in the *ASCE-Journal of Water Resources Planning and Management*. doi: 10.1061/(ASCE)WR.1943-5452.0000340.
  - The chapter titled "Evaluating storage carryover in the Weber River Basin using the Water Evaluation and Planning (WEAP) System" was published by the American Society of Civil Engineers in the book "Water Resources Systems Analysis through Case Studies: Data and Models for Decision Making." Watkins, David W, Jr. (ed). pp. 102-113. doi:10.1061/9780784412879.ch09.
  - A 2012 journal article titled "Estimating and Verifying United States Households' Potential to Conserve Water" (*ASCE-Journal of Water Resources Planning and Management*, 138(3), pp. 209-306. http://dx.doi.org/10.1061/(ASCE)WR.1943-5452.0000182) was awarded the Quentin Martin Best Research-Oriented Paper for the year. This award offers national recognition for water conservation research conducted at the Utah Water Research Laboratory.
  - Results on water-energy conservation for a water utility were presented at the Environmental Water Resources Institute of the American Society of Civil Engineers in Cincinnati, OH: May 19 - 23, 2013.

Work Plan FY13/FY14

- Apply utility-scale water-energy model to Salt Lake City water system.
- Consider additional water and energy conservation actions and perform sensitivity analysis on embedded energy intensity.
- Submit utility-scale water-energy work for publication.

Informational Resources

Contact: Dr. David E. Rosenberg, Phone (435) 797 8689, E-mail: david.rosenberg@usu.edu.

Website: http://www.engr.usu.edu/cee/faculty/derosenberg/projects.htm.
Website: http://ascelibrary.org/doi/abs/10.1061/9780784412879.ch09.

Water Resources Modeling for Utah's Cache Valley

Principal Investigators:
David E. Rosenberg
Leah Meeks (Student)

Partners/Collaborators:
Local: *Bob Fotheringham, Cache County;*
Bracken Henderson, UACD
State: *Gertrudys Adkins, Lee Sim, James Greer, Matt Lindon, and Boyd Clayton, Utah Division of Water Rights;*
David Cole, Utah Division of Water Resources
Business/Industry: *Joan Degiorgio, The Nature Conservancy*

Project Description:

- **Need and Purpose:**

  Management of water resources is becoming more important as water demands continue to increase and water supplies decrease, especially considering global warming model predictions. As a semi-arid state, Utah has a growing need for improved water management. Various state and federal agencies and others have modeled certain hydrologic and legal aspects for specific geographic regions in Utah. For example, the Utah Division of Water Rights is currently using MODSIM for the Green River and ArcView GIS to generate maps of some of the State's water resources. Cache Valley is a unique area because it has many of the water ailments that are becoming more prominent in Utah and the western United States: drought, flooding, water quality, full water allotment, increasing demand, and transitioning agricultural to urban land uses. Managers require systems modeling tools and capabilities that can integrate the hydrologic, legal, and management aspects of the water system to inform management.

- **Benefits to the State:**

  Because of its unique geographic and demographic location, Cache Valley is on the forefront of many water resources issues that are currently affecting many locations throughout Utah. Once created, network analysis tools can identify promising water system locations to source water for agricultural to urban water transfers, build or remove dams, protect ecosystem services, implement conservation measures, or diversify water supplies. A systems model can be used as an example and framework for modeling other areas of Utah and can help local and state agencies manage Utah's water resources by providing a practical tool for planning purposes. This use will help Utah's water resource agencies make better and more informed planning decisions and recommendations.

- **Geographic Areas:**

  Study Area: Lower Bear River, Cache, and Box Elder Counties, Utah.

  Areas Benefited: Municipal water providers and landowners statewide in all counties.

- **Accomplishments:**

  Findings:

  - Network analysis shows that the New Box Elder County Irrigation and South County Irrigation service areas are stable nodes in the water system. Removing or altering these

locations would affect other locations very little. Thus, these sites are promising candidates for agricultural to urban water transfers. Further, the Cache Valley Irrigation service area is highly redundant with another service area and is also a promising source for an agricultural to urban water transfer.

- If built, the proposed Washakie, Mainstem, and Millcreek dams have high topological significance. Their removal would affect many other locations in the system. Thus, these locations are promising sites to build dams.
- Water flows to the Weber Basin, Wasatch Front, and Idaho service areas are heavily affected by other locations in the water system. Thus, these sites are promising areas to implement conservation actions and/or diversify water supplies.
- Most junctions along the mainstem of the Bear River are topologically significant. Removing or altering these sites would affect many other locations in the system. Thus, these junctions are promising locations to protect environmental and ecosystem functions.

Results:

- Developed a tool to analyze water resources networks and identify the stable, topologically significant, and redundant nodes that are promising locations for agricultural to urban water transfers, building or removing dams, protecting ecosystems, or implementing conservation measures.
- Used the tool on the lower Bear River water system
- Submitted results of the network analysis for publication in the peer-reviewed *ASCE Journal of Water Resources Planning and Management*.
- Presented results of the network analysis as oral presentations and as conference proceeding papers at the (i) Seventh International Conference on Irrigation and Drainage, U.S. Society for Irrigation and Drainage Professionals, Phoenix, AZ: April 16-19, 2013, and (ii) Environmental Water Resources Institute of the American Society of Civil Engineers in Cincinnati, OH: May 19 - 23, 2013
- Advised Cache County on its water master plan over the year, participated in four steering committee meetings as part of the planning process, and attended a summary presentation to the Cache County council.

Work Plan FY13/FY14

- Revise and resubmit the results for publication in a peer-reviewed *ASCE-Journal of Water Resources Planning and Management*.
- Since May, 2013, Leah Meeks has been on a leave-of-absence and the project has been on hold. If Ms. Meeks returns in fall 2013, we will continue to integrate data held in a water rights database maintained by the Utah Division of Water Rights into a water resources management model for the lower Bear River.

Informational Resources

Contact: Dr. David E. Rosenberg, Phone (435) 797 8689, E-mail: david.rosenberg@usu.edu.

Website: http://www.engr.usu.edu/cee/faculty/drosenberg/projects.htm.

Conference Paper: http://ascelibrary.org/doi/abs/10.1061/9780784412947.227.

Research Faculty, Professional, and Support Staff

Research Faculty, Professional, and Support Staff

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David S. Bowles, PhD, Professor Emeritus, CEE/UWRL
William J. Doucette, PhD, Associate Director, UWRL/UCWRR; Professor, CEE/UWRL
R. Ryan Dupont, PhD, Professor, CEE/UWRL
William J. Grenney, PhD, Professor Emeritus, CEE/UWRL
Thomas B. Hardy, PhD, Research Professor, CEE/UWRL
Jeffery S. Horsburgh, PhD, Assistant Professor, CEE/UWRL
Michael C. Johnson, PhD, Research Assistant Professor, CEE/UWRL
Jagath J. Kaluarachchi, PhD, Professor, CEE/UWRL; Associate Dean, College of Engineering
Randal S. Martin, PhD, Research Associate Professor, CEE/UWRL
Michael J. McFarland, PhD, Associate Professor, CEE/UWRL
Joan E. McLean, MS, Research Associate Professor, CEE/UWRL
Laurie S. McNeill, PhD, Associate Professor, CEE/UWRL
Christopher Neale, PhD, Professor, CEE/UWRL
Bethany T. Neilson, PhD, Assistant Professor, CEE/UWRL
Richard C. Peralta, PhD, Professor, CEE/UWRL
William J. Rahmeyer, PhD, Professor, CEE/UWRL; Department Head, CEE
David E. Rosenberg, Ph.D., Assistant Professor, CEE/UWRL
Judith L. Sims, MS, Research Associate Professor, BE/UWRL
Ronald C. Sims, PhD, Professor, Department Head, BE
Darwin L. Sorensen, PhD, Professor Emeritus, BE/CEE/UWRL
David K. Stevens, PhD, Professor, Head of Environmental Division, CEE/UWRL
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Wynn Walker, PhD, Professor Emeritus, CEE/UWRL
Anhong Zhou, PhD, Associate Professor, BE/UWRL

Research Faculty, Professional, and Support Staff

Utah Water Research Laboratory Staff

Marianne Brown, Staff Assistant I
Tracy Brown, MS, Business Officer III
Mark Cannon, BS, Research Engineer
Andrea Carroll, Accounting Technician
Peg Cashell, MS, Soil Scientist
John Cupp, PhD, Post-Doctoral Fellow
Pabitra Dash, PhD, Programmer/Analyst
Maria Gates, BS, Business Officer III
Ian Gowing, BS, Research Engineer
Jessica Griffiths, BS, Staff Assistant I
Tessa Guy, BS, Research Assistant I
R. Ivonne Harris, MS, Publications Specialist
Austin Jensen, MS, Research Engineer
Richard Jex, Research Assistant
Amber Jones , MS, Research Engineer
Andrew Lee, Engineering Technician II
Babur Mirza, PhD, Post-Doctoral Fellow
Tamara Peterson, BS, Business Manager
Stephanie Reeder, BS, Programmer/Analyst
Carri Richards, BS, Public Relations Specialist
Zac Sharp, MS, Research Engineer
Joe Stewart, MS, Research Engineer I
Shannon Syrstad, MS, Research Engineer
Chad Taylor, Engineering Technician II
Andres Ticlavilca, PhD, Research Engineer
Alfonso Torres, PhD, Research Engineer
Jan Urroz, BS, Supervisor of Administrative Services and Infrastructure
NeCole Walton, BS, Accountant
Mindy Whiteley, Staff Assistant/Receptionist
Mark Winkelaar, BS, Research Engineer

Adjunct Appointments and Emeriti Faculty

Lloyd Austin, MS, Adjunct Professor, CEE/UWRL/Utah Department of Natural Resources
Jay M. Bagley, PhD, Professor Emeritus, CEE/UWRL
Duane G. Chadwick, MS, Professor Emeritus, EE/UWRL
Daniel H. Hoggan, PhD, Professor Emeritus, CEE/UWRL
Trevor C. Hughes, PhD, Professor Emeritus, CEE/UWRL
Eugene K. Israelsen, MS, Senior Research Engineer Emeritus, UWRL
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Upmanu Lall, PhD, Adjunct Professor, UWRL/CEE/Columbia University
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