MINERAL LEASE FUND REPORT

Utah Water Research Laboratory

Fiscal Year 2012

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 FY 2012

2. Budgeted expenditures for FY 2013

3. Planned expenditures for FY 2014

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

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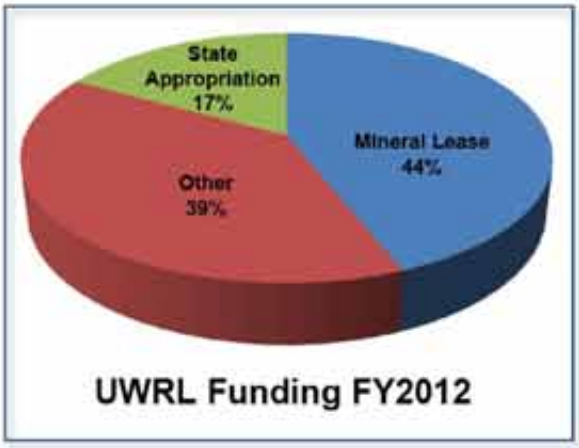
Introduction

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 2012, 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 2012 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



UWRL Funding FY2012

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

A brief summary of the ongoing work in each of the six research areas is presented at the end of this Introduction 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 Lab 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 are also integrated into the basic and applied research programs.

UWRL Student Involvement FY2012

Graduate Students Supported (FY12)	64
Undergraduate Students Supported (FY12)	68

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.

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.

UWRL Financial/Academic Summary (FY 2012)

Research Products (FY12)	
Number of Active Projects	269
Dollar Value of Active Projects	7,652,675
Scholarly Publications in Peer-Reviewed Journals	65
Scholarly Presentations at Professional Conferences	87
Outreach Products (FY12)	
Short Courses and Field Training	22
Degrees Granted	
Ph.D.	13
MS	24
ME	5

There are currently 35 faculty and 35 support staff at the UWRL. During FY 2012, 31 master's students and 33 doctoral students received support from UWRL projects. An additional 68 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) 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; (3) assessing changes in wetland vegetation over time using high resolution imagery in several spectral bands obtained by application of low-cost unmanned aerial vehicles, as well as genetic sampling, to determine the relative contribution of seeds vs. rhizomes in the spread of invasive Phragmites patches in a Utah wetland over one year under flooded vs. unflooded conditions; and (4) 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. In the future, the USGS 104 Program will 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.

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.

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)

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:

Utah Water Quality Board
Utah Solid and Hazardous Waste Control Board
Lake Powell Technical Advisory Committee
Salt Lake county solid Waste Management Council
State of Utah Wastewater Treatment Plant Operator Certification committee
Utah Drinking Water Board
Weber-Morgan Health Department Wastewater Advisory Committee

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.

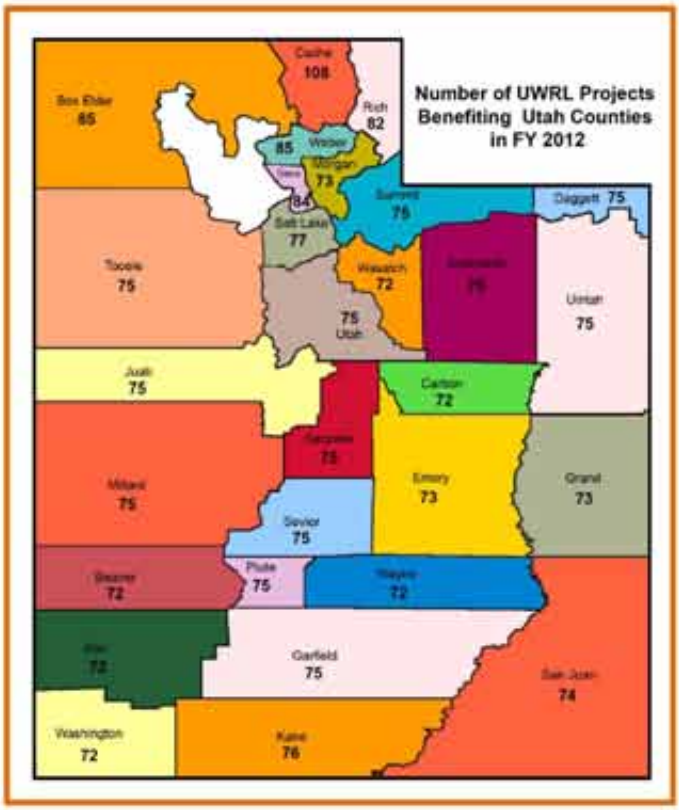
Information Dissemination and Technology Transfer

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, 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

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	FY2012 Actual Expenditures	FY2013 Budgeted Expenditures	FY2014 Planned Expenditures
Business Office	$140,623.80	$144,842.51	$149,187.79
Laboratory Infrastructure Support, Travel and Special Request	$10,445.92	$27,000.00	$27,810.00
Project Management cf USGS 104	$14,315.99	$14,745.47	$15,187.83
Publications Office	$57,151.40	$58,865.94	$60,631.92
UWRL Administration	$68,162.94	$70,207.83	$72,314.06
Total	**$290,700.05**	**$315,661.75**	**$325,131.60**

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 2012 administrative costs represented approximately 6% of total UWRL MLF expenditures.

Outreach and Business Support

Overall, annual research expenditures for the UWRL are almost $ 8 million, and at any point in time there will be approximately 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 2012 on these support activities accounted for 1% of total MLF funding.

Advisory Support on Water Problems

The UWRL received many requests in FY 2012 for advice and collaborative help on various water problems in the state. In FY 2012, 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 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 also made from MLF resources. 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	FY2012 Actual Expenditures	FY2013 Budgeted Expenditures	FY2014 Planned Expenditures
Biological Phosphorous Removal from Lagoon Wastewater: Pilot Scale Rotating Algae Biofilm Bioreactor (RABR)	$108,230.00	$100,000.00	$0.00
Effectiveness of Utah's On-Site System Design: Depth Considerations and Removal of Emerging Contaminants of Concern	$66,043.93	$65,000.00	$0.00
Enhancing Methane Production at Water Reclamation Facilities in Utah	$5,983.66	$6,163.17	$0.00
Producing Bioplastic Materials Using Microbe-Based Processes	$10,206.15	$136,034.39	$145,000.00
Designated Projects		$127,740.00	$10,500.00
Undesignated research projects in program area		$62,980.00	$7,000.00
Total	**$136,463.74**	**$497,963.06**	**$162,500.00**

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

Principal Investigators:
Ronald C. Sims
Charles Miller
Terence Smith

Partners/Collaborators:

- ***Local:*** *Issa Hamud, City of Logan*
- ***State:*** *Ed Macauley, UDEQ*
- ***Federal:*** *U.S. Department of Energy*
- ***Business/Industry:*** *WesTech, Inc.*

Project Description

- **Need and Purpose:**
  Logan City is required to remove phosphorus from wastewater leaving the treatment plant to prevent the pollution of Cutler Reservoir. A biological-based engineering technology that accomplishes this requirement could save in excess of $100 million compared with the installation of a mechanical plant. A new technology has been developed and is being evaluated for meeting the requirement for treatment of the wastewater to a level of 1.0 mg/L phosphorus.

- **Benefits to the State:**
  Development of an economical biotechnology process to upgrade municipal wastewater treatment will provide new engineering jobs and services in Utah. 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: 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: Three pilot-scale bioreactors were successfully constructed and operated (Figure 1) for nutrient removal. The reactors enhanced algae growth, which simultaneously enhanced phosphorus uptake into the algae and removal from the water.

  Results: As algae grow, they take up phosphorus and remove it from the wastewater, Phosphorus uptake into the RABR algae is the result of enhanced algae growth on the biofilm reactor. The uptake of phosphorus into the algae biofilm and out of

Figure 1. Three Rotating Algae Biofilm Reactors Treatment Wastewater for Phosphorus Removal

the wastewater is shown Figure 2. Algae growth was demonstrated in spring, summer, and fall 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.

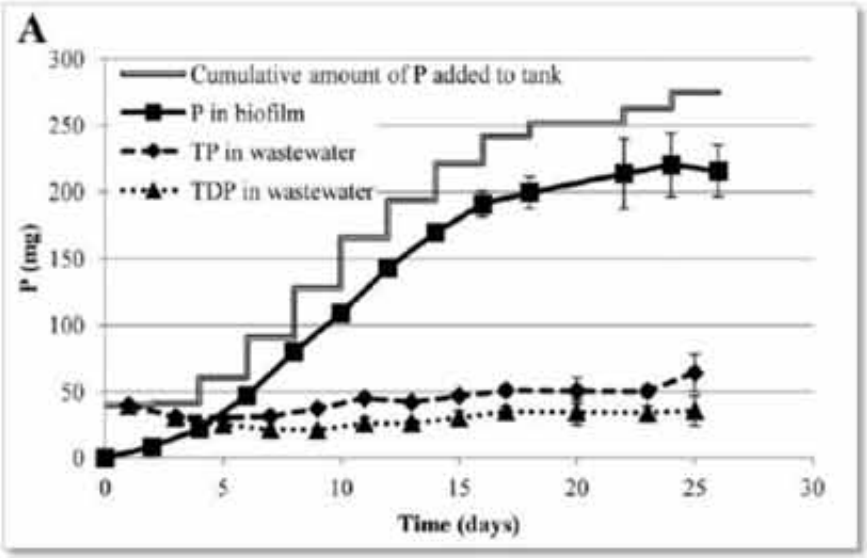


Figure 2. Phosphorus Uptake into Algae Growing on RABR surface.
(P=Phosphorus, TP = Total Phosphorus, TDP = Total Dissolved Phosphorus.)

Work Plan FY12/FY13

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.

References

Christenson, L.B. and Sims, R.C. (2012). Rotating algal biofilm reactor and spool harvester for wastewater treatment with biofuels by-products. *Biotechnology and Bioengineering,* 109:1674–1684.

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 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 the depths that septic systems are installed in Utah. 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 examines the fate of six selected emerging contaminants 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. The laboratory columns have been set up and are presently being monitored. In addition, laboratory batch studies are being 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 is 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.

- **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.

Deep trench system installation, Wellsville, UT, November 2008

Deep trench installation, Clarkston, UT, November 2008

- **Accomplishments:**

  Findings: 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 utilize deep trenches for treatment of wastewater and four utilize shallow trenches. During FY 11- 12, we analyzed data collected from the site and began preparing publications. We have worked with the owners of the sites to educate them on proper septic system use practices.

  Results: Leachate samples from the drain fields have been 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 wastewater contaminants is occurring in both shallow and deep systems. These results include removal of total of suspended solids, phosphorus, and coliform bacteria, decrease in biological oxygen demand, and conversion of ammonia nitrogen to nitrate nitrogen that indirectly indicates the presence of oxygen, which can be used in degradation processes by microorganisms.

Work Plan FY12/FY13

During FY12-13 we will resume sampling and analyzing leachate produced within the eight study drain fields and will continue to determine treatment effectiveness in shallow and deep drain fields.

We will complete the laboratory scale column experiments and the batch scale laboratory studies to investigate possible means of removing pharmaceuticals and other emerging chemicals of concern in wastewater applied to septic system drain fields using peat and burnt straw ashes as drain field amendments.

Informational Resources

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

References

Beardall, J. and J.L. Sims (2012). Examining the Fate of Emerging Contaminants in an Engineered On-site Wastewater Drain Field. *Utah On-Site Wastewater Association (UOWA) Annual Conference*, Davis Applied Technology College, Kaysville, UT, February 8-9.

Enhancing Methane Production at Water Reclamation Facilities in Utah

Principal Investigators:
Michael J. McFarland

Partners/Collaborators:
- ***Local:*** *Thomas A. Holstrom, Central Valley Water Reclamation Plant*
- ***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, oil 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 Valley WWTP using co-digestion with FOG and other food wastes. Central Valley WWTP currently utilize their methane gas in co-generation systems to produce electricity that is used to off-set their power requirements. Figure 1 depicts the anaerobic digestion systems at each of the three facilities to be evaluated in the current study.

Figure 1 - Anaerobic Digestion Systems at the Central Valley 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:

  - 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: Salt Lake County area, 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.

Work Plan FY12/FY13

The technical focus for the next fiscal year will comprise the following three tasks. The Utah State University team will work in close collaboration with the technical staff at the Central Valley WWTP and the State Department of Water Quality in accomplishing these efforts.

- Estimate the theoretical production of methane from the co-digestion of FOG and Food waste in the facility.
- 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.

Informational Resources

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

Producing Bioplastic Materials Using Microbe-Based Processes

Principal Investigators:
Ronald C. Sims
Charles Miller
Asif Rahman (student)

Partners/Collaborators:
- ***Local:*** *Issa Hamud, Logan City*
- ***Business/Industry:*** *WesTech_Inc, SLC*

Project Description

- **Need and Purpose:**

  New methods are needed to reduce the costs of renewable bioplastic materials in order to complete with 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 domestic feed sources will generate new technologies, businesses, and products in Utah. Applications range from commercial packaging to biomedical designs such as drug delivery systems, tissue engineering, and orthopedics. The bioplastic materials are biodegradable and will reduce petroleum-based plastic materials that accumulate in landfills in Utah communities.

- **Geographic Areas:**

  Study Area: Confined animal feeding operations (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.

- **Accomplishments:**

  Findings: Synthetic biological engineering principles and tools were used to program common bacteria to produce bioplastic material from simple substrates (Figure 1). The bioplastic produced has properties similar to polyproplyene and polyethylene, two petroleum-based plastics. The bacteria were also engineered to secrete the bioplastic material without disrupting the cell (Figure 2).

  Results: The engineering of the secretion process is a biotechnology breakthrough that will significantly reduce the cost of bioplastic production and processing. In addition, the use of inexpensive feedstocks that come from wastes, such as algae grown on wastewater, has been tested and preliminary results show that bioplastic materials can be produced using waste chemicals.

Figure 1. Bioplastic material produced using common bacteria.

Work Plan FY12/FY13

Future research will involve continued scale-up to production levels of pounds, and will also involve using 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.

References

Linton, E., Rahman, A., Viamajala, S., Sims, R.C. and Miller, C.D. (2012). Polyhydroxyalkanoate quantification in organic wastes and pure cultures using a single-step extraction and 1H NMR analysis. *Water Science and Technology*. Accepted Manuscript.

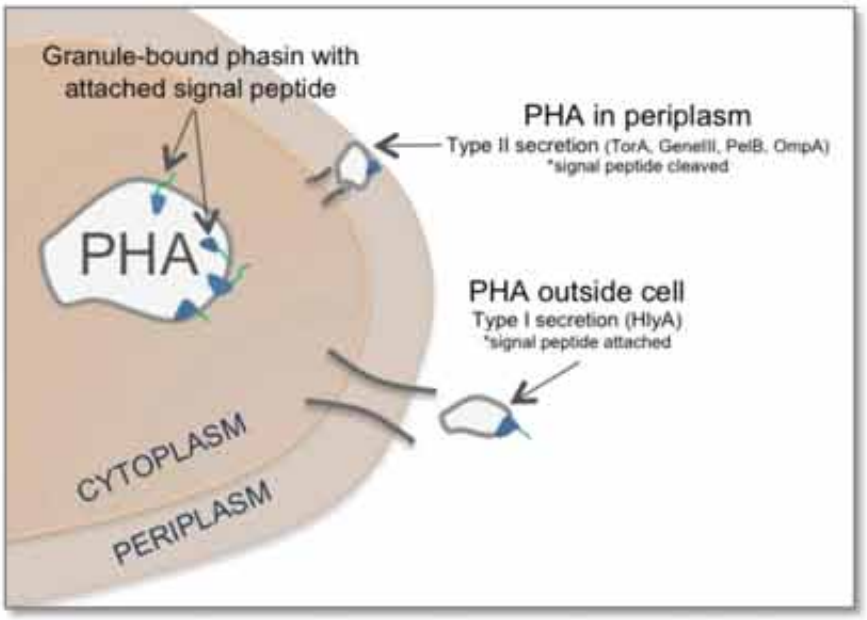


Figure 2. Bioplastic material is secreted by common bacteria, which reduces further processing. (PHA=polyhydroxyalkanoate bioplastic).

Environmental Quality Management and Remediation

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

Project Name	FY2012 Actual Expenditures	FY2013 Budgeted Expenditures	FY2014 Planned Expenditures
Analyzing the Spread of *Phragmites Australis* Over Short Time-Scales Using Spatial and Genetic Tools	$37,352.82	$38,472.39	$0.00
Assessing Phosphorus-Transport from Biosolids Land Application Sites in Utah	$26,614.83	$27,413.33	$28,235.73
ATK Static Test Environmental Assessment	$21,120.00	$21,753.60	$0.00
Conditions Affecting the Clean-Up of TCE- Contaminated Aquifers in Northern Utah	$63,020.94	$70,000.00	$0.00
Evaluation of Duckweed as a Technology for Management of Nutrients and Emerging Contaminants in Municipal Wastewater Systems	$43,749.95	$50,212.45	$0.00
Environmental Impact of Expanded Recycling Programs in Salt Lake County	$1,000.00	$16,520.83	$0.00
Impact of Metals and Metal Ions on Soils and Plants	$22,204.03	$35,000.00	$0.00
Investigations into Elevated Wintertime Ozone in Utah's Uinta Basin	$31,358.06	$32,308.65	$33,792.91
Low Level Hexavalent Chromium (Cr-6) in Drinking Water	$62,969.63	$125,000.00	$123,750.00
Monitoring Organic Contaminants in Air Using Plants as Passive Samplers	$27,209.23	$23,025.56	$23,866.33
Real-Time Polymerase Chain Reaction (RT-PCR) Instrumentation	$7,246.83	$7,464.29	$0.00
Remediation of Chlorinated Solvent Contamination of Groundwater	$64,256.22	$70,000.00	$75,000.00
Remediation of TCE-Contaminated Soil and Groundwater at Hill Air Force Base (HAFB)	$7,246.83	$7,464.29	$0.00
Risk Characterization Using Modified 3MRA at Biosolids Land Application Sites	$31,066.77	$31,998.77	$32,958.74
Study of Cache Valley's Ambient Vertical Ozone Profiles and Applioation to the Uintah Basin	$32,565.95	$33,542.93	$34,549.22
Uptake of Organic Contaminants from Groandwater and Transfer into Edible Plants: Species Differences	$29,633.05	$30,522.04	$31,437.70
Volatile Organic Compounds in Indocr Air: Source Identification, Emission Flux Determinations and Model Development	$25,360.79	$26,121.61	$26,905.25
Designated Projects		$531,014.65	$14,306.00
Undesignated Projects		$137,560.00	$12,000.00
Total	**$539,470.58**	**$1,370,895.94**	**$446,801.88**

Environmental Quality Management and Remediation

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 native 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 work.

  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 *Pragmites*, 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.

- 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 and salinity 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:

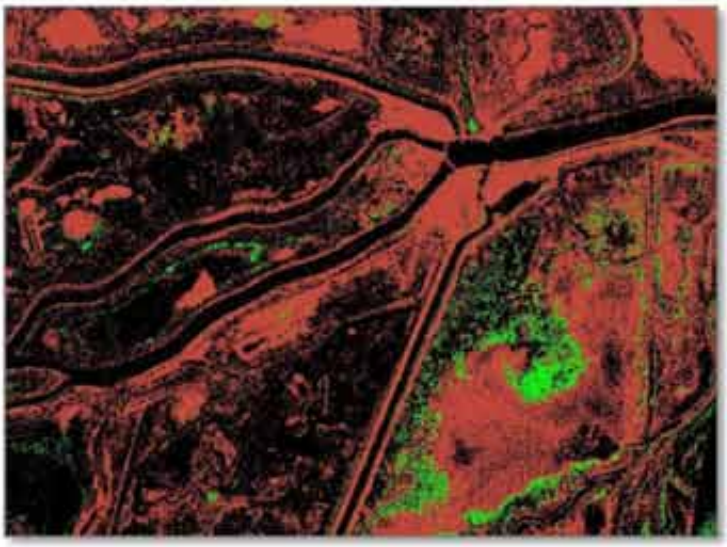
  Study Area: The Bear River Migratory Bird Refuge, UT.

  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.



Additional area occupied by *Phragmites* (shown in green) in the BRMBR between June and September, 2010

- 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 from the AggieAir imagery.

Work Plan FY12/FY13

Future research will focus on final confirmation of the accuracy in successfully identifying different clonal genotypes of *Phragmite* using AggieAir imagery.

Informational Resources

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

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

Environmental Quality Management and Remediation

Assessing Phosphorus-Transport from Biosolids Land Application Sites in Utah

Principal Investigators:
Michael J. McFarland, PE, BCEE
Mohan Kumar (Graduate Student)

Partners/Collaborators:

- ***Local:*** *Central Davis Sewer District, Kaysville, UT*

Project Description

- Need and Purpose:

  Phosphorus Site Index (PSI) is a phosphorus transport assessment tool that can be used to estimate the risk of phosphorus (P) transport from soils. This study has considered two biosolids land application sites in Utah, both of which have received biosolids amendments over time, to develop a specialized PSI for the State of Utah. Total P was correlated with the PSI estimation in one site, while P measured at a nearest water source was used as an indicator of risk at the other site.

  While national water quality regulations mandate certain application practices, a more accurate tool is necessary to estimate P losses from biosolids land application sites. The Phosphorus Site Index for two biosolids land application sites in Utah was calculated and its validity established. Erosion-Productivity Impact Calculator (EPIC) model was also used to simulate P transport over these sites to further determine the accuracy of PSI. A PSI worksheet was developed in an easy to use form, covering recommended best management practices and methods of preventing P transport from soils.

- Benefits to the State:

  The information generated from this project was implemented in a PSI worksheet software that will be of benefit to Utah land managers, municipal wastewater treatment plants, biosolids generators, biosolids land appliers, and Utah agricultural producers in identifying sustainable methods for biosolids land application for agricultural use. The PSI worksheet can be used as a simplified estimator of phosphorus losses from biosolids land application sites in Utah.

- Geographic Areas:

  Study Area: Ensign Ranch biosolids land application site, Tooele County, Utah; Central Davis Sewer District biosolids land application site, Davis District, Utah.

  Areas Benefited: The above study areas where biosolids are land applied, as well as any future sites where biosolids maybe land applied for agricultural use in Utah.

- Accomplishments:

  Findings: Current guidelines set by the 590 Nutrient Management Standard for the state of Utah severely restrict continued land application of biosolids over a given site. Results have demonstrated that multiple applications of biosolids on a site increases soil test P above 100 ppm, and application is not recommended. This restriction can be overcome by a better model that is able to assess the risk of P losses from the site.

Results: Results from this effort have led to better calibration of PSI models that predict phosphorus mobility on biosolids land application sites in the state of Utah. Model improvements are summarized in a completed master's thesis from this study entitled: "Phosphorus Mobility at Biosolids Land Application Sites in Utah" by Mohan Kumar (2012).

Work Plan FY12/FY13

This project is now complete. No additional funding is being requested in support of this effort.

Informational Resources

Contact: Dr. Michael J. McFarland, 435.797.3196, E-mail: farlandm@msn.com.

ATK Static Test Environmental Assessment

Principal Investigators:
William J. Doucette
Laurie McNeill
Scout Mendenhall (MS student)
Danny Ryan (undergraduate)

Partners/Collaborators:
- ***Business/Industry:*** *ATK*

Project Description

- Need and Purpose:

  Tests of horizontally restrained rocket motors at the ATK facility in Promontory UT, USA result in the deposition of an estimated 1.5 million kg of entrained soil and combustion products (largely aluminum oxide, gaseous hydrogen chloride and water) over areas as large as 80-130 km^2 and at distances up to 16-20 km from the test site. As the cloud cools, the deposition material, referred to as Test Fire Soil (TFS), drops on the surrounding area. Local residents and farmers observing TFS deposited on their gardens, fields, and crops have expressed concerns regarding the potential impact of this material. To address these concerns, we conducted greenhouse studies with corn and alfalfa exposed to TFS, collected during an August 2010 test, through various soil and foliar applications. The impact of the TFS was evaluated by comparing the growth and tissue composition (i.e. nutrient content, metals, anions) of controls relative to the treatments.

- Benefits to the State:

  This research will help ATK (a leading employer in the State of Utah) to better understand the environmental effects of their static motor tests. Results will also help to address the concerns of local residents about the effects of material deposited during the static tests.

- Geographic Areas:

  Study Area: ATK Promontory facility in Box Elder County.

  Areas Benefited: Box Elder County, including Thatcher, Tremonton, Corrine, and Penrose.

- Accomplishments:

  Findings/Results: Exposure to TFS, containing elevated levels of chloride, aluminum and pH (likely due to the high temperature conversion of calcium carbonates to calcium oxide) relative to native soils, affected the germination, growth, and tissue concentrations of various elements, depending on the type and level of exposure. Germination was inhibited by high concentrations of TFS in soil but the impact was minimized if the TFS was pre-leached with water. Corn and alfalfa biomass production was reduced in the 10% TFS/soil mixture relative to controls and corn grown in soils treated with TFS did not develop kernels. Tissue concentration differences between controls and TFS exposed plants were observed for some elements. Foliar applications of TFS had no significant impact on biomass production but did show some difference in the elemental composition of leaves relative to controls. Washing the TFS off the leaves after 7 days lessened the impact. Results to date indicate that the TFS deposition could have an effect depending on the amount and growth stage of the crops but the impact could be mitigated with application of additional irrigation water. The high level of chloride associated with the TFS is likely the main cause of the observed impacts.

Environmental Quality Management and Remediation

Work Plan FY12/FY13

Project completed.

Informational Resources

Contact: Dr. William J. Doucette, Phone: (435) 797 3178, E-mail: william.doucette@usu.edu.
Dr. Laurie McNeill, Phone: (435) 797-1522, Email: laurie.mcneill@usu.edu.

Cloud formed after static test

Greenhouse columns growing corn and alfalfa

Close up of column watering

Corn leaves after TFS application in greenhouse

Environmental Quality Management and Remediation

Conditions Affecting the Clean-Up of TCE-Contaminated Aquifers in Northern Utah

Principal Investigators:
Darwin L. Sorensen
Subathra Muruganandam (Post Doctoral Associate)

Partners/Collaborators:
- ***Federal:*** *Mark Roginske, Hill AFB*

Project Description

- **Need and Purpose:**

  Chlorinated solvents, especially trichloroethene (TCE), have been widely used in industry. TCE is a suspected human carcinogen; however, cleanup related to improper disposal of these slow-to-degrade solvents has proven difficult and expensive. Methods that rely on in-place degradation of the solvents by microbial activity provide hope for effective cleanup at relatively low cost. Early laboratory experiments have indicated that biostimulation for dechlorination of solvents in some aquifer materials at a site near Hill Air Force Base (AFB), Utah may be delayed or may not become established. Investigations into the cause for this potential treatment failure are being conducted.

  Laboratory-scale experiments using flow-through columns can control several environmental factors while maintaining much of the complexity of the microbial community and physical/chemical environment. Experiments have been conducted in columns to determine the physical and biological conditions influencing the onset of dechlorination.

- Benefits to the State:

  Chlorinated solvents in ground water environments represent a threat to public health, and environmental regulations demand the cleanup of this kind of contamination. Evaluating the probability of success for a cleanup technology represents an opportunity to improve the Utah environment and protect the health of the citizens of the State. Avoiding the misuse of technology can hasten cleanup and avoid the wasteful expenditure of limited cleanup funds. The project has been focused on Hill AFB but will have application to TCE and other chlorinated ethene contamination at several locations within Utah.

- **Geographic Areas:**

  Study Area: The cities of Sunset and Clinton in Davis County along with Hill Air Force Base.

  Areas Benefited: Communities surrounding Hill Air Force Base, in Davis and Weber Counties, and several other industrialized areas in the state where groundwater has been contaminated with chlorinated solvents.

- Accomplishments:

  Findings/Results: Work this year has focused principally on completing analyses and analyzing data from the analysis of large flow-through aquifer material columns made using TCE contaminated aquifer material collected in Clinton, Utah, and operated in a 15° C (59° F) laboratory for 7.5 years. Experiments to enhance solvent dechlorination involved adding whey or emulsified vegetable oil with lactic acid solutions to the top of the columns. Samples of bacterial DNA from the surface layer of each column was

sequenced using high-throughput techniques (pyrosequencing) to reveal the diversity of bacteria associated with each treatment and the associated dechlorination capability.

Conclusions based on data analysis results from the extensive chemical and biological analyses of multiple layers from each of the seven columns include the following:

- Biostimulation with whey resulted in complete TCE degradation within the first sampling layer (3.5 in; 9 cm; 1 day flow) compared to partial and no TCE degradation in emulsified oil and non-biostimulated control columns, respectively.
- Augmentation of one of the whey-treated columns with a TCE dehalogenating bacterial culture accelerated complete dehalogenation by more than 1.25 years.
- Quantitative, real-time polymerase chain reaction (qPCR) analysis of the whey column samples revealed an increase in TCE reductase gene (tceA gene) copy numbers (log 7.5/g) compared to emulsified oil (log 7.0/g) and no carbon treatments (log 4.5/g).
- Geochemical evidence of long-term, highly reducing conditions corresponded to complete dechlorination in whey-treated columns.

Work Plan FY12/FY13

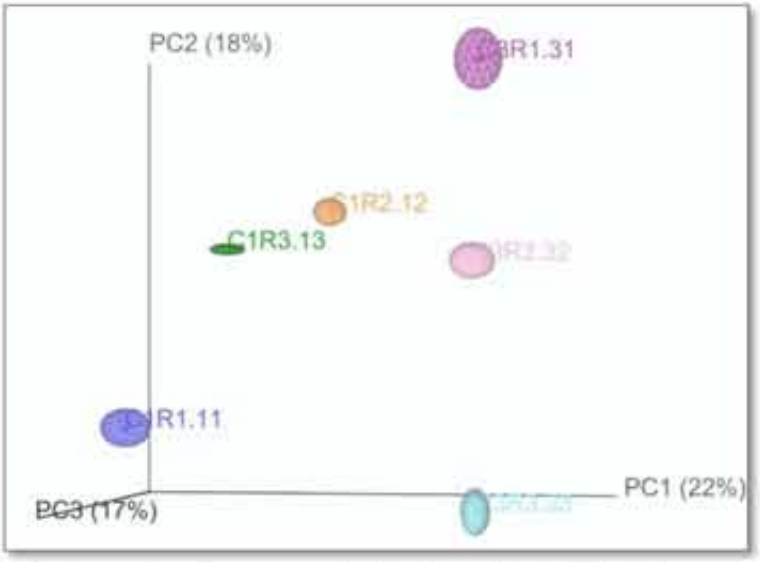
Data reduction and publication of results from this and existing data is our goal.

Informational Resources

Contact: Dr. Darwin L. Sorensen, (435) 797-3207, Email: darwin.sorenson@usu.edu

References:

Zaa, C.L.Y., J.E. McLean, R.R. Dupont, J.M. Norton and D.L. Sorensen (2010). Dechlorinating and iron reducing bacteria distribution in a TCE-contaminated aquifer. *Ground Water Monitoring and Remediation,* 30(1):46-57.



Principal coordinate analysis of pyrosequencing data showed that the bacterial communities of the surface soil replicate samples in column 1 (C1R1, C1R2, C1R3) and column 3 (C3R1, C3R2, C3R3) were significantly different more than 3.5 years following inoculation of column 3.

Environmental Quality Management and Remediation

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

Principal Investigators:
R. Ryan Dupont
Joan E. McLean
William J. Doucette
Jon Farrell (student)

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 a growing concern due to their effect on aquatic systems receiving wastewater treatment plant effluents. Conventional wastewater treatment systems are not effective in their removal. Current chemical or advanced biological treatment alternatives 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.

- **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 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.

Duckweed Mat Harvested from the Wellsville Lagoons (≈ 3 in thick)

- **Accomplishments:**

  Findings: Duckweed-based nutrient removal systems can be feasibly implemented at the Wellsville lagoons based on significant duckweed growth rates and high concentrations of nutrients that accumulate in the duckweed biomass. The effectiveness of such a system is dependent, however, on the efficient and cost effective harvesting and stabilization/processing of the generated biomass. Field studies were completed to develop long-term growth and harvesting performance data to further define the sustainability of duckweed-based treatment, and provide input data for a growth/harvesting and nutrient removal/water quality improvement model. In addition,

laboratory flask studies to evaluate the potential for duckweed species to bioconcentrate nutrients and bioconcentrate and metabolized hazardous PCPP contaminants (acetaminophen (ACT), sulfamethoxazole (SLF), fluoxetine (FLX), carbamazepine (CRB), and progesterone (PRG)) in municipal wastewater were completed.

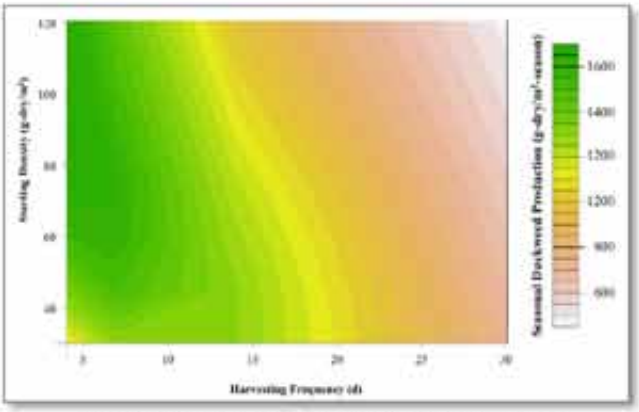
Results: The duckweed species found in the Wellsville lagoons completely cover these 56-acre lagoons for 5 to 6 months of the year in this temperate climate zone. More than 250,000 lbs. of dried duckweed material could be harvested from the Wellsville lagoons on an annual basis. This amounts to approximately 2,500 lbs. of phosphorus being recovered in the harvested material. Evaluation of optimal harvesting schemes via modeling (see figure below) showed that a single harvest of these lagoons can produce 0.5 kg-dry duckweed/m^2 per 90-day harvesting season (30% removal of annual P load). Bi-weekly harvesting can produce 1.5 kg-dry duckweed/m^2, which accounts for 90% removal of the annual phosphorus loading from Wellsville City. In addition, duckweed achieved pharmaceutical removals via plant uptake and sorption comparable to literature reported removals (ACT 56-99%, SLF 45-86%, FLX 82-93%, CRB 0-38%, PRG 82-98%) that use much more expensive and complex membrane bio-reactors and powdered activated carbon systems.

These results indicate that the growth and bi-weekly harvesting of duckweed biomass on would provide sufficient P removal for Wellsville to meet its permit limits until influent wastewater flows reach 0.66 MGD at approximately 2017. Beyond that period, additional P removal via land application or chemical treatment would be required in addition to duckweed harvesting. This technology clearly provides a low cost alternative to much more expensive advanced biological or chemical treatment processes, which cost approximately $150/lb. N or P removed and without the production of a valuable end product as generated by the duckweed system.

Results from the PCPP removal studies demonstrated enhanced removal of the test compounds via plant uptake and adsorption by duckweed systems. The fate of these PCPP compounds subsequent to the biomass uptake step is the subject of on-going studies.

Work Plan FY12/FY13

The impact of PCPP bioconcentration in the harvested duckweed biomass on subsequent sludge stabilization and processing steps (animal feed, anaerobic digestion), and the transformation and fate of these PCPP compounds during processing is being considered in laboratory scale reactors.



Modeled Duckweed Biomass Production over a Growing Season from the Wellsville Lagoons

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.

Environmental Quality Management and Remediation

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 Ioannou, 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 FY12/FY13

- 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.

Impact of Metals and Metal Ions on Soils and Plants

Principal Investigators:
Joan E. McLean
Anne Anderson (Biology)
David Britt (Biological Engineering, USDA Project PI)
Christian Dimkpa (Biology)

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  Metal oxide nanoparticle and silver nanoparticles 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 nanoparticles 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 nanoparticles of copper oxide and zinc oxide and silver nanoparticles 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: Silver, copper oxide, and zinc oxide nanoparticles released to the environment could create persistent impacts on susceptible beneficial soil microbes and on plant productivity.

  Results: Wheat roots are impacted by contact with CuO and ZnO nanoparticles as is evident from stunted root growth and discoloration of roots compared with the control (Fig 1). **At** a biochemical level, the presence of ZnO nanoparticles reduced the synthesis of phenazines by a beneficial soil bacterium (Fig 2). Phenazines, a bacterial secondary metabolite, are important for growth of biofilms, and are some of the agents that provide antagonism to soil fungi, protecting the bacteria and its host plant.

Work Plan FY12/FY13

We will continue to explore changes in the metabolism of bacteria and plants when challenged with **N**P metal. These changes may be beneficial in production of metabolites of commercial value.

Informational Resources

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

References:

Calder, A.J., C.O. Dimkpa, J.E. McLean, D.W. Britt, W.P. Johnson and A.J. Anderson (2012). Soil components mitigate the antimicrobial effect of silver nanoparticles towards a beneficial soil bacterium, *Pseudomonas chlororaphis* O6. *Sci. Total Environ.*, 429: 215-222.

Dimkpa, C.O., J. Zeng, J.E. McLean, D.W. Britt, J.Zhan, and A.J. Anderson (2012). Production of indole-3-acetic acid via the indole-3-acetamide pathway in the plant-beneficial bacterium *Pseudomonas chlororaphis* O6 is inhibited by ZnO nanoparticles but enhanced by CuO nanoparticles. *Appl. Environ. Microbiol.*, 78: 1404-1410.

Dimkpa, C.O., J.E. McLean, D.W. Britt, W.P. Johnson, B. Arey, A.S. Lea and A.J. Anderson (2012). Nanospecific inhibition of *pyoverdine siderophore* production in *Pseudomonas chlororaphis* O6 by CuO nanoparticles. *Chem. Res. Toxicol.*, 25: 1066-1074.

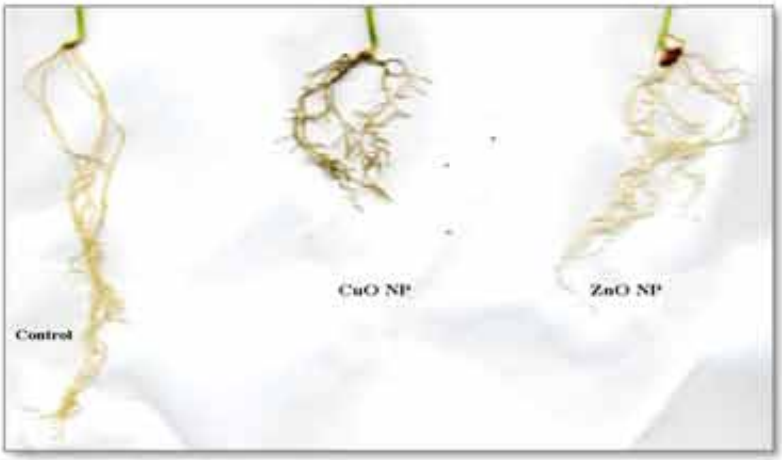


Figure 1. Effects of nanoparticles on root elongation and proliferation in wheat. CuO and ZnO nanoparticles have a negative impact of root growth.

Figure 2. Impact of ZnO nanoparticles on the production of phenazines. The microbe produces an orange colored phenazine (control). With increasing concentrations of the nanoparticles, the production of these phenazines decreases. Phenazines provide protection to the bacteria and to its host plant.

Environmental Quality Management and Remediation

Investigations into Elevated Wintertime Ozone in Utah's Uintah Basin

Principal Investigators:
Randal S. Martin
Wendy (Meiners) Merkley (MS student)
Clay Woods (PhD student)
Kori Moore (PhD student/EDL fellow)

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:

  Initial measurements of wintertime ozone (O_3) at a few locations in northeastern Utah's Uintah Basin during the winter of 2009/2010, followed by a much more intensive campaign in the winter of 2010/2011, found unacceptably high levels of ambient ozone spread throughout the region. The second (2010/2011) study found O_3 levels very similar to the earlier winter, with some of areas exceeding the National Ambient Air Quality Standards as many as 25 times during the examined three-month period. In late 2011 the initial investigators, along with several outside agencies and research groups, came together and developed a more comprehensive research plan for the winter of 2011/2012 to identify the region's important parameters relative to the Basin's photochemically- and meteorologically-dependent elevated O_3 levels. 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 be contributed to the completion of the 2011/2012 study.

- Benefits to the State:

  Ultimately, accurately assessing the wintertime O_3 issues 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).

  Areas Benefited: The population and industry of the Uintah Basin, including areas which extend into Colorado, 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.

- Accomplishments:

  Findings: Unlike the previous two winters, no extended inversion episodes were observed during the winter of 2011/2012. Although no O_3 exceedances were observed anywhere within the Basin during the recent study period, important baseline speciated air pollutant concentrations and meteorology data were still collected, both by the USU/UWRL team and the cooperating investigators. In addition to the Basin-wide distributed O_3 measurements, intensive data were collected during the winter season at two "supersites: Horsepool, an oil/gas production area and Roosevelt, a population center. As an example, similar to indications from 2010/2011 study results, atmospheric methane (CH_4) was measured at

concentrations well above accepted tropospheric background concentrations (1.7-1.8 ppm). Figure 1 shows the range of CH_4 measured at various locations around the Basin during late February 2012. Although not shown here, the total non-methane hydrocarbons (TNMHCs) were likewise found to be elevated beyond typical rural values.

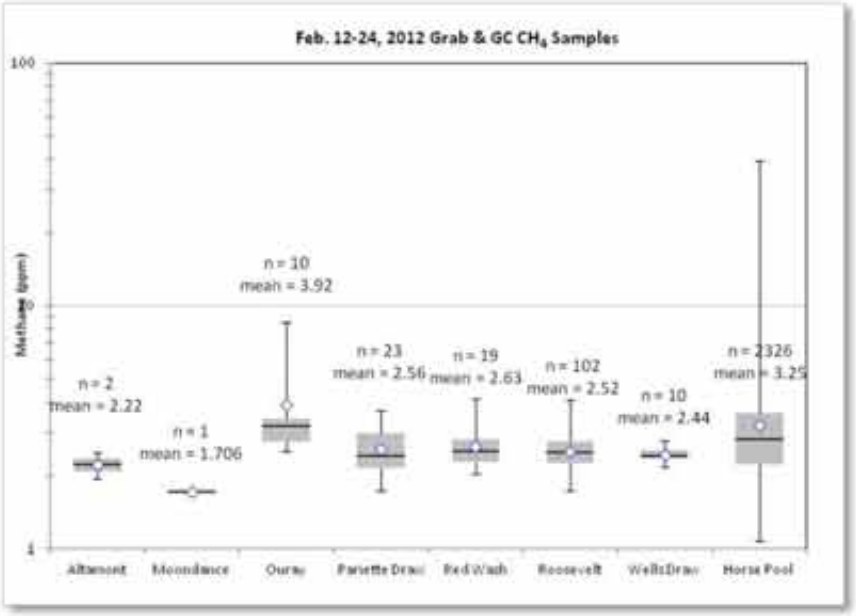


Figure 1. Ambient methane in the Uintah Basin (Feb. 12-24, 2012)

Results: The combined results from the 2009/2010 and 2010/2011 studies and the high concentrations of likely O_3 precursor species, oxides of nitrogen (NO_x) and volatile organic compounds (VOCs), are indicative of a potentially serious violation of current O_3 standards, as was observed during the previous two years. Additionally, spatial measurements of these compounds suggest they are more abundant in the oil and gas production and exploration areas.

Work Plan FY12/FY13

Owing to the lack of cooperating meteorology, specific answers to the regions ozone formation chemistry were not able to be answered during the 2011/2012 campaign. Consequently, plans are being developed with the cooperation of this past year's investigating team to repeat some segments of the study during the coming winter season.

Informational Resources

As of Oct. 1, 2012, a single final report combining the information from all of the cooperating investigators is in the final preparation. Additionally, the multi-group/agency research team formed for the 2011/2012 study submitted a proposal, which was subsequently accepted, for a special session dealing with air quality issues associated with oil and gas development at the December 2012 meeting of the American Geophysical Union.

Contact: Dr. Randal S. Martin, (435) 797-1858, E-mail: randy.martin@usu.edu.

Environmental Quality Management and Remediation

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

Principal Investigators:
Laurie S. McNeill
Joan E. McLean
Christel Olsen (graduate student)
Suzy Smith (undergraduate student)
Rahel Beyene (undergraduate student)

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 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: An extensive matrix of experiments was conducted to evaluate the various buffers available for chromium speciation. The USEPA-recommended ammonium buffer was found to be most effective in a variety of water qualities. Samples were collected at 11 different treatment plants, including five in Utah, to investigate chromium behavior through the plants. Cr-6 was detected at all plants, but concentrations were very small (< 2 ppb in the source water, and < 0.6 ppb in finished water), and well below the MCL of 100 ppb. Results indicate that treatment chemicals such as lime and ferric coagulant may contribute low levels of hexavalent chromium (~1 ppb) to water, but most of this added chromium is removed through the treatment process (Figure 1). Preliminary results also show that snow samples contain up to 2 ppb of total chromium, likely due to air deposition. It is unknown how this will affect chromium concentrations in the influent water to treatment plants, but it could play a significant role.

  Results from this project were presented in 2 conference presentations, one conference poster, one webinar, and one peer-reviewed journal publication (McLean et al, *Journal AWWA*, 104(6), June 2012).

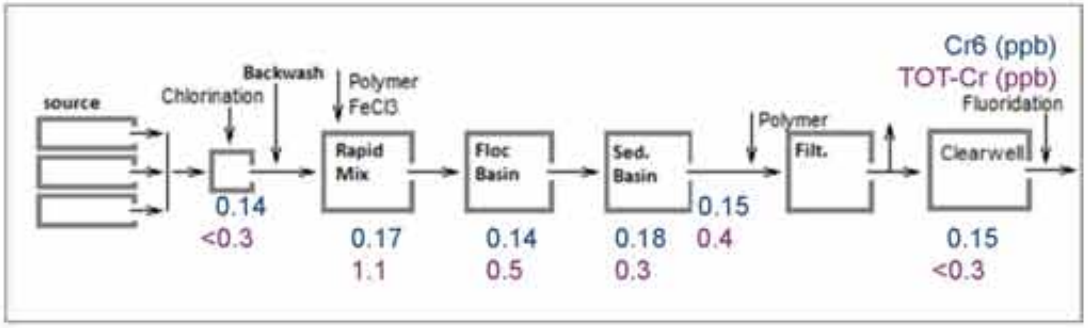


Figure 1: Chromium concentrations measured throughout a Utah water treatment plant

Work Plan FY12/FY13

1. Continue laboratory experiments related to preservation and analysis of Cr-6.
2. Collect additional samples from various water treatment plants across UT to look at sources and treatment of Cr-6.
3. Collect additional snow samples to investigate the potential contribution to chromium levels in drinking water plant influent water.

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.

Environmental Quality Management and Remediation

Monitoring Organic Contaminants in Air Using Plants as Passive Samplers

Principal Investigators:
Dr. William J. Doucette
Todd Wetzel

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

Project Description

- Need and Purpose:

  Concerns about the potential build up of volatile organic compounds (VOCs) in indoor air have increased as energy conservation methods minimized the introduction of outdoor air. VOCs, including many with documented short- and long-term adverse health effects, can enter indoor environments through internal (i.e. paints, paint strippers, fuels, cleaning supplies, pesticides, building materials, adhesives) and external sources (i.e. vapor intrusion from contaminated groundwater). Indoor air concentrations of VOCs vary widely, but concentrations of most VOCs are consistently higher indoors than outdoors. Typical approaches used to sample indoor air include evacuated canisters and sorbent tubes. The use of ornamental plants has been suggested as a simple, unobtrusive, aesthetically pleasing, 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. However, the efficiency and kinetics of capture has not been well characterized. To investigate the potential use of plants as indoor air VOC samplers, three types of studies are being performed. The first consists of monitoring air and plant concentrations over time after a controlled release of several VOCs into a residential building containing several plant species. The second study uses a flow-through glass and stainless plant growth chamber to evaluate the relationship between air and plant leaf VOC concentrations. The third study uses a headspace approach to measure equilibrium leaf-air partition coefficients.

- 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.

- Accomplishments:

  Findings/Results: Initial studies show good correlations between the leaf and air concentrations observed in the three different studies. This suggests that plant leaves can be used to monitor indoor air concentrations of VOCs.

Environmental Quality Management and Remediation

Work Plan FY12/FY13

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.

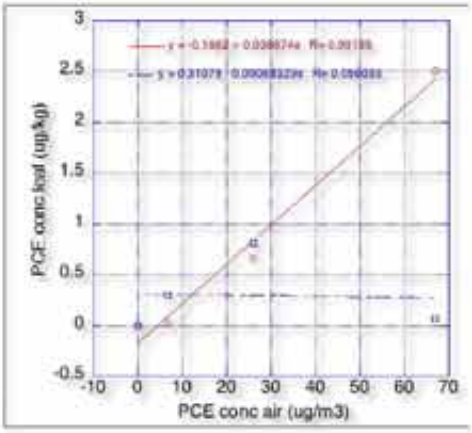
Informational Resources

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

Plants sampled in house release



Relationship between leaf and air concentrations

Environmental Quality Management and Remediation

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

Principal Investigators:
R. Ryan Dupont
Joan E. McLean
Darwin L. Sorensen
Subathra Muruganandam

Partners/Collaborators:

- **Local:** *Issa Hamud, Logan City Environmental Department*
- **Federal:** *Kyle Gorder and 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 functions and has become a standard technique for engineering application of molecular biology concepts to bioremediation.

  The objective of this project is to facilitate development 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 ARISA analysis, and 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 FY12/FY13

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.

Informational Resources

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

Environmental Quality Management and Remediation

Remediation of Chlorinated Solvent Contamination of Groundwater

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

Partners/Collaborators:

- ***Federal:*** *Kyle Gorder and Mark Roginski, Environmental Management Directorate, Hill AFB*

Project Description

- **Need and Purpose:**

  All counties in Utah have ground water 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 ground water.

  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) as the terminal electron acceptor (TEA) in potential competition with dechlorination processes. 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 in direct competition with dechlorination processes.

- **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 affective remediation option, an unintended consequence may be the release of arsenic into ground water.

  Results: Columns packed with aquifer solids from HAFB were leached with TCE containing ground water 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 column. We determined that conditions necessary for full dechlorination were depletion of Fe(III) minerals and sulfate reduction, both conditions indicative of highly reducing environments, and the presence of active dechlorinating bacteria, as determined

through RNA analysis. Conditions conducive to dechlorination, however, were also favorable for arsenic solubilization. Elevated concentrations of arsenic were found in the pore water of all carbon treated columns and the arsenic had been transported throughout the column (Figure 1). The total mass of arsenic draining out of the six foot columns over the 7.5 years of operations is illustrated in Figure 2, with the whey treatment promoting release of over 35 mg of arsenic. We evaluated which mineral forms of arsenic were being dissolved within the treated columns using chemical extractions. The addition of carbon led to the dissolution of even relatively stable arsenic associated minerals. Figure 3 shows that the addition of whey to the columns caused the dissolution of iron oxides releasing associated arsenic.

Work Plan FY12/FY13

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.

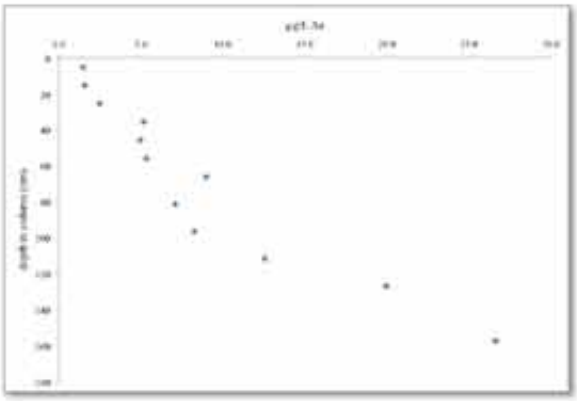


Figure 1. Arsenic concentration increased in the pore water down the column profile with the addition of carbon. The intent of biostimulation is the dechlorination of TCE to nontoxic by-products, but the reducing conditions imposed caused the solubilization and transport of arsenic

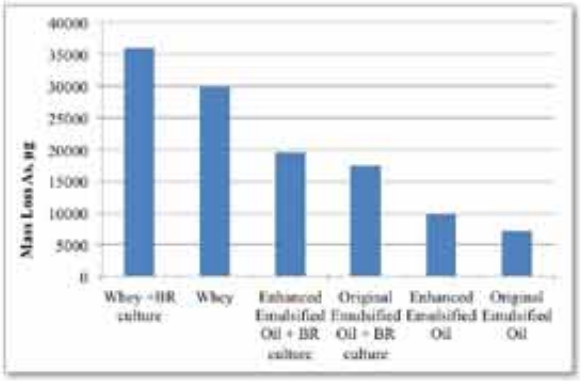


Figure 2. Total mass of arsenic removed from the columns over 7.5 years. The whey treatments caused the largest dissolution and loss of arsenic in the columns, with arsenic being removed along with the microbial dissolution of iron oxide minerals (Figure 3)

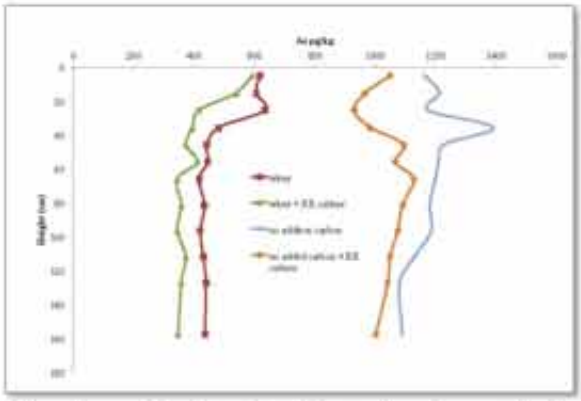


Figure 3. Arsenic was released from iron oxide minerals as these minerals were dissolved through microbial activity promoted by the addition of whey and whey + a microbial culture

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

Principal Investigators:
R. Ryan Dupont
Joan E. McLean
Darwin L. Sorenson
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.

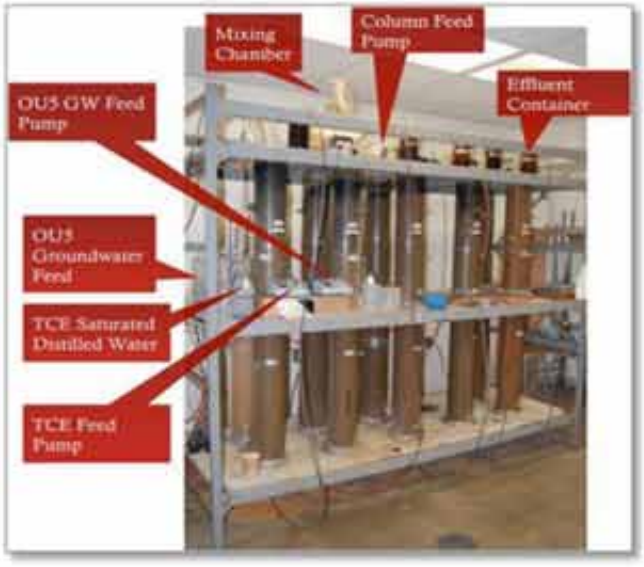
Results: Concentrations of 16S rRNA genes of *Dehalococcoides*, functional genes *tceA*, *vcrA*, and *bvcA* and quantities of *tceA* and *vcrA* transcripts were determined in the top 9 cm layer of each column using Quantitative PCR. QPCR analyses showed essentially equal concentrations of nearly all 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 4.3×10^{-5} among 51,550 sequences from non-augmented column samples and 6.7×10^{-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 FY 12-13:

Analysis and data reduction of incrementally sampled soil within the columns continued in FY12 for molecular biology and soil geochemical characteristics.

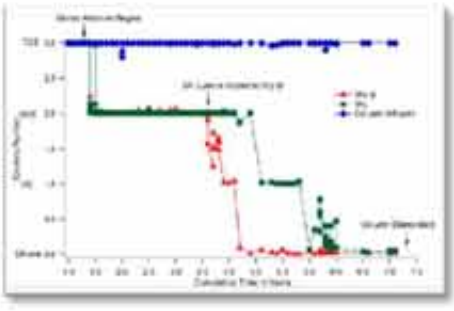
Informational Resources

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

Risk Characterization Using Modified 3MRA at Biosolids Land Application

Principal Investigators:
Dr. Michael J. McFarland, PE, BCEE
Karthik Kumarsamy (graduate student)

Partners/Collaborators:

- ***State:*** *Utah Division of Water Quality*
- ***Federal:*** *US Environmental Protection Agency*
- ***Industry:*** *Water Environment Research Foundation*

Project Description

- **Need and Purpose:**

  Compliance with water quality standards and the increases in biosolids production has pushed the industry towards considering a more sustainable solution, such as biosolids land application. Earlier risk assessments were used to establish current national regulations. However, improvements to risk assessment methodology have led regulators, as well as public health advocacy groups, to reassess current national rules to ensure that they are sufficiently protective of public health and the environment.

- **Benefits to the State:**

  Biosolids land application practice is not only a sound economic solution, but it is an approach that takes advantage of the nutrients present in the material. This risk assessment can aid in better managing this fertilizer resource and in strengthening the beneficial use practice.

- **Geographic Areas:**

  Study Area: Although the study areas are located in WA and UT, two counties in UT were considered for this study. The biosolids land application sites of Ensign Ranch in Skull valley and Central Davis Sewer District farm were included in the risk assessment. A detailed study was performed at the Yakima County site in WA. Figure 1 shows the conceptual layout of the site in Yakima County, WA.

Figure 1. Conceptual layout of site

Areas Benefited: Two areas that directly benefited from this effort include disturbed and/or marginal agricultural land located in Tooele county where significant amounts of biosolids are being recycled. The other area was the farm land located around Central Davis Sewer District. Since extensive contaminant monitoring data is available at only few locations in the nation, and because access to data was provided for the WA site, the WA site was used to test the model.

- **Accomplishments:**

A method has been developed to increase the understanding of biosolids land application practices using computer based modeling. In order to fully characterize a site using the original modeling platform, over 900 variables are required. This study developed an approach that can characterize the site using less than 50 variables to estimate a screening level risk assessment. This technique has the potential to allow screening level site specific characterization of risk.

Findings: The original modeling platform did not allow for easy characterization of a site. The Multimedia, Multi-pathway, Multi-receptor Exposure and Risk Assessment (3MRA) platform is based on extensively validated models; however, its use in biosolids management has been absent due to the poor user interface and the software's limitation in adapting to other applications. This study demonstrated the software's use for simulation biosolids land application practice.

Results: Findings indicate federal regulations are fully protective of biosolids land application practice and that certain sites have the potential for higher application rates.

Work Plan FY12/FY13

This project is now complete. No additional funding is being requested in support of this effort.

Informational Resources

Contact: Dr. Michael J. McFarland, Phone 435-797-3196, E-mail: farlandm@msncom.

As a result of this MLF funded research, two peer reviewed research papers have been accepted for publication:

1. McFarland, M.J., K. Kumarsamy, R.B. Brobst, A. Hais and M.D. Schmitz (2012). Groundwater Quality Protection at Biosolids Land Application Sites. Accepted to the *Journal of Water Research*.

2. McFarland, M.J., K. Kumarsamy, R.B. Brobst, A. Hais and M.D. Schmitz (2012). Protecting Groundwater Resources at Biosolids Recycling Sites. Accepted to the *Journal of Groundwater*.

The principal investigator was also invited to give a technical presentation of the major results at an international water research symposium:

McFarland, M.J., K. Kumarsamy, R.B. Brobst, A. Hais and M.D. Schmitz (2012). Characterizing the Risk to Groundwater Quality from Biosolids Beneficial Use Activities. Presented at the *Water Environment Federation Specialty Conference on Residuals and Biosolids*, March 2012, Raleigh, NC.

Environmental Quality Management and Remediation

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

Principal Investigators:
Dr. Randal S. Martin
Ms. Crystal (Viator) Woods (MS student)

Partners/Collaborators:
- ***Local:*** *Bear River Health Department*
- ***State:*** *Utah Division of Air Quality (UDAQ) & Air Monitoring Center (AMC)*

Project Description:

- **Need and Purpose:**

  The 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, the 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. Additionally, O_3 is a federally-regulated pollutant on its own. The goal of this project is to develop and test a light vertical O_3 system and examine the vertical ozone structure in the wintertime air in the Cache Valley. 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 a secondary opportunity to apply techniques developed under this project over the last two 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.

- **Geographic Areas:**

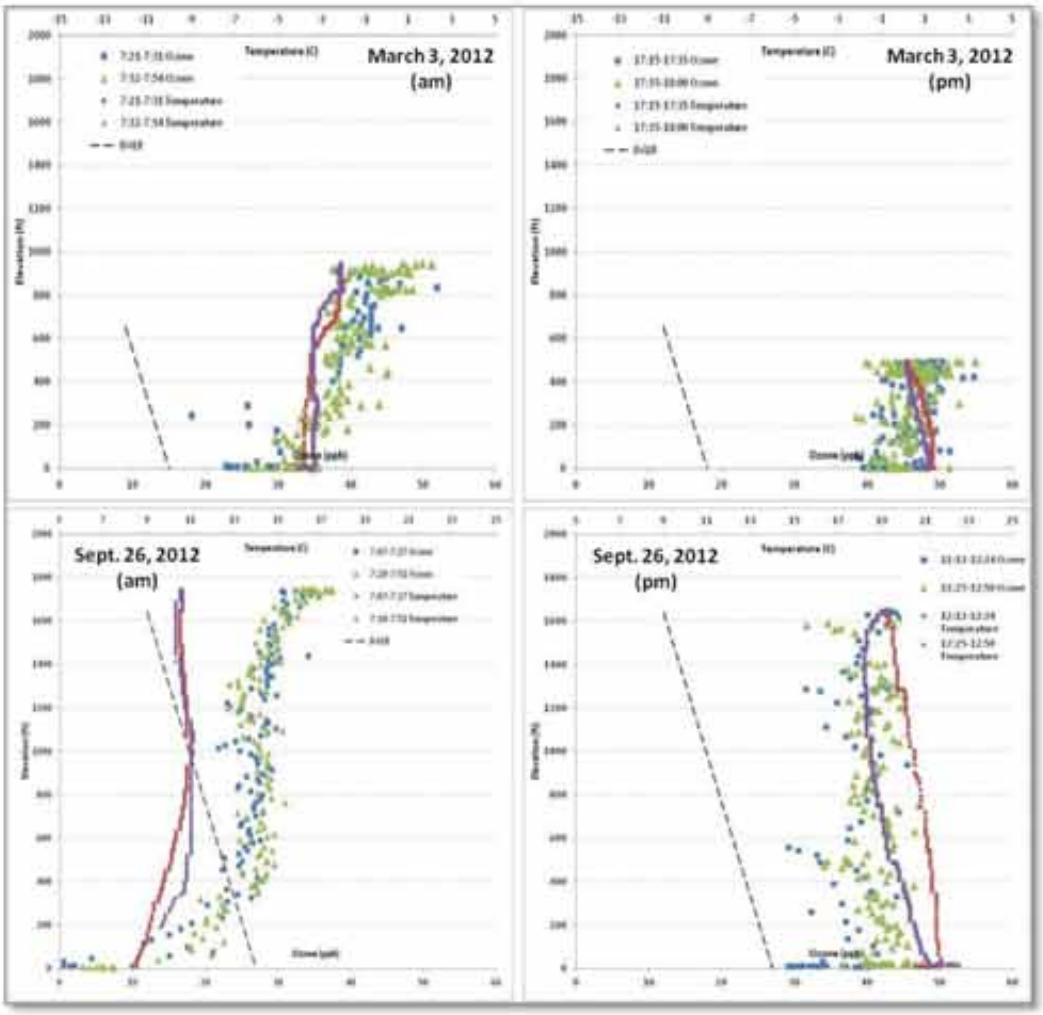
  Study Areas: Cache Valley, UT (including the entire cross-border airshed) and multiple areas within the Uintah Basin (Uintah and Duchesne counties).

  Areas Benefited: The Cache Valley airshed is the direct beneficiary, but findings and future work could logically be extended to the Wasatch Front and other non-attainment areas. The preliminary results from the Uintah Basin examination have demonstrated the likelihood of local, ground level wintertime O_3 formation and will be instrumental in understanding the area's unique air quality issues.

- **Accomplishments:**

  Findings: A finalized version of a portable 2B Technologies Model 202 Ozone monitor was fully assembled, tested, and characterized in the laboratory under conditions expected for ambient wintertime conditions. The system was used on several days, over two years to examine the vertical O_3 profile in Cache Valley. Additionally, the system was used in Utah's Uintah Basin during two winter campaigns. With funding from both projects, the research team was able to upgrade to a larger balloon with more lift that has allowed higher and concurrent, vertical measurement of meteorological parameters, as well as O_3.

Results: The improved vertical O_3 system used with a tethered balloon system was successfully able to capture the vertical structure of O3 with the boundary (inversion and non-inversion) layers in the Cache Valley, as well as some measurements in the 2011/2012 Uintah Basin campaign. The figure below shows a comparison of Cache Valley O_3 profiles for a winter and a fall day. As can be seen for these days, the O_3 profiles were similar; however, we are able to obtain much higher elevations since the new balloon became available.



Work Plan FY12/FY13

Work on developing protocols for economically and accurately measuring vertical ozone profiles will continue into FY12-13. We also continue to pursue other funding opportunities to aid in the evolution of the system to a UAV-based instrument (e.g. UWRL's AggieAir). It is further anticipated that the tethered balloon system will also be deployed to 2012/2013 Uintah Basin wintertime O_3 studies.

Informational Resources

Contact: Dr. Randal S. Martin, (435) 797 1858, E-mail: randy.martin@usu.edu.

Environmental Quality Management and Remediation

Uptake of Organic Contaminants from Groundwater and Transfer into Edible Plants: Species Differences

Principal Investigators:
William J. Doucette
Naho Orita (MS Student)

Partners/Collaborators:
- **Local**: *Kyle Gorder and Erik Dettenmaier, Hill AFB, UT*

Project Description

- Need and Purpose:

  Chlorinated solvents, fuel related compounds, explosives, pharmaceuticals and personal care products (PPCPs), and other organic chemicals have contaminated surface and groundwater at many locations in the State of Utah, including many communities surrounding Hill Air Force Base. Quantitative information regarding the uptake of organic contaminates by plants is needed for risk assessment, groundwater plume delineation, and phytoremediation applications. Unfortunately, relatively little experimental data is available due to the difficulty and expense involved with the generation of such data. The literature also suggests that species differences can have a significant influence on the uptake and transport of organic pollutants, especially for the plant family Curcurbitaceae. For example, studies have reported a nearly 10-fold difference between zucchini and cucumber. Determining the potential significance of species on the uptake of organic chemicals is critical, especially in risk assessment. However, because standard methods for quantifying the plant uptake of organic chemicals are not available, direct comparison of results from different studies is difficult and the reported differences may be associated more with experimental protocol than actual species differences. This study uses a pressure chamber technique to examine the uptake of organic contaminates in the Curcurbitaceae family and seeks to determine whether the reported species variability is real or an artifact of the experimental methods used.

- Benefits to the State:

  The potential uptake and transfer of organic chemicals into fruits and vegetables is a critical concern for residents living near Hill Air Force Base and other areas where groundwater is contaminated by organic chemicals. Results obtained from this study will benefit the State of Utah by providing baseline information that can be used in screening-level risk assessments.

- Geographic Areas: State of Utah.

  Study Area: Residential areas located around Hill AFB, UT and other areas where contaminated groundwater exists.

  Areas Benefited: Residential areas located around Hill AFB, UT and other residential areas within State of Utah located above shallow groundwater contaminated with organic chemicals.

- Accomplishments:

  Findings/Results: Transpiration Stream Concentration Factors (TSCF) for 14C-caffeine (log Kow = -0.07), 14C-triclocarban (log Kow = 4.9) and 14C-endosulfan (log Kow = 3.8), relative to titrated water, were determined using a pressure chamber method for soybean (glycine max L.), zucchini (cucurbita pepo ssp pepo), and squash (cucurbita pepo ssp ovifera). TSCF values for caffeine (TSCF = 0.8), endosulfan (TSCF = 0.2) and triclorcarban (TSCF = 0.05) were statistically equivalent for squash and soybean. For zucchini, the

TSCF for caffeine was the same as for squash and soybean. However, for the more hydrophobic endosulfan and trichlorcarban, the TSCF values were 0.6 and 0.4, or about 3 and 10 times greater, respectively, than the soybean and squash. The greater difference in TSCF with increasing log Kow suggested a solubility enhancement in the zucchini xylem sap. To test this hypothesis, the solubilities of caffeine, endosulfan and triclocarban in soybean and zucchini xylem sap were determined and compared to deionized water using a modified shake flask method. Caffeine solubility in the xylem saps of soybean and zucchini was equal to deionized water (22000 mg/L). Endosulfan and triclocarban solubilities in the zucchini xylem sap were significantly greater (0.43 and 20.6 mg/L, respectively) than that of the soybean xylem sap (0.31 and 10.6 mg/L, respectively) and deionized water (0.34 and 11.2 mg/L, respectively). This suggests that the enhanced root to shoot transfer of hydrophobic organics reported for zucchini may be partly due to increased solubility in the xylem sap. Further xylem sap characterization is needed to determine the mechanism of solubility enhancement.

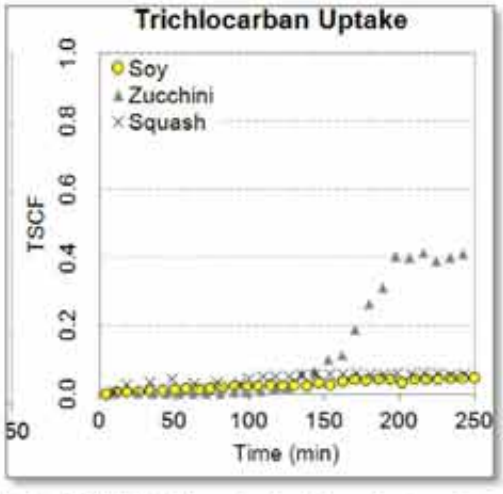
Work Plan FY12/FY13

Project completed.

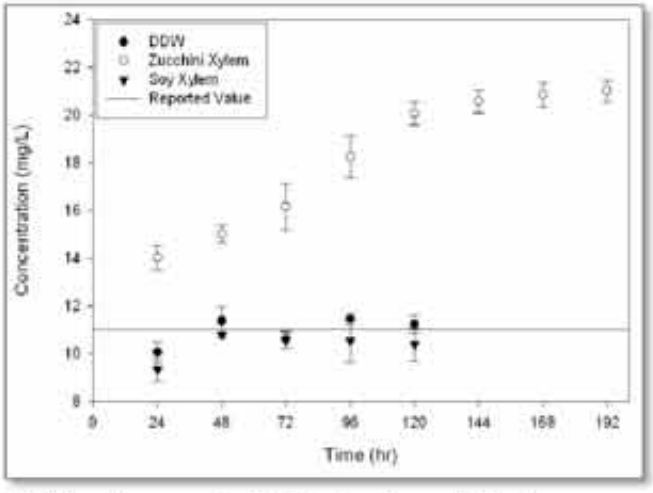
Informational Resources

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

Zucchini plant used in pressure chamber



Uptake (TSCF) of triclocarban by three plant species



Solubility enhancement of triclocarban in zucchini xylem sap

Environmental Quality Management and Remediation

Volatile Organic Compounds in Indoor Air: Source Identification, Emission Flux Determinations, and Model Development

Principal Investigators:
William J. Doucette
Dave Firmage (MS student)

Partners/Collaborators:
- **Local:** *Kyle Gorder and Erik Dettenmaier, Hill AFB, UT*

Project Description

- Need and Purpose:

  Many consumer products contain chlorinated volatile organic compounds (cVOCs) that are also the focus of CERCLA (Superfund) soil and groundwater cleanups in the USA. The emissions of these VOCs from consumer products into indoor environments can lead to false assumptions during vapor intrusion (VI) investigations. The focus of this study was to determine the relationship between the emission rates of cVOCs from common household products and their concentrations in indoor air.

- Benefits to the State:

  Distinguishing between external and internal sources of chlorinated solvents is critical in determining the most appropriate, cost effective remedial approach for residences located over shallow contaminated groundwater. The goal is to demonstrate that the laboratory-measured emission rates of chlorinated solvents from consumer products can be used to predict indoor air concentrations and thus help to distinguish between internal and external sources of chlorinated solvents in residential homes.

- Geographic Areas:

  Study Area: Residential areas located around Hill Air Force Base, UT.

  Areas Benefited: Residential areas located around Hill AFB, UT and other residential areas within State of Utah located above shallow groundwater contaminated with chlorinated solvents.

- Accomplishments:

  Findings: Emissions rates of volatile chlorinated solvents from an adhesive (PCE), a cleaning solvent (PCE and TCE), and a plastic holiday ornament (1,2-DCA) were measured in the laboratory using a flow through chamber approach. Screening-level calculations indicated that the measured emission rates of these items could lead to indoor concentrations high enough to be of regulatory concern. A follow up indoor air monitoring study was performed to test the screening-level calculations. The three objects were placed in a single room on the second floor of a two-story residence with finished basement. Indoor air concentrations were measured using sorbent tubes/thermal desorption GC/MS and an onsite GC/MS over a three-day period, which was followed by an additional two-day period after source removal. After 24 hours, measured concentrations of PCE and TCE were as high as 100 $\mu g/m^3$ within the source room on the second floor and 10 $\mu g/m^3$ in rooms on the first floor. After 36 hours, PCE and TCE were also found within the basement at concentrations about 3 $\mu g/m^3$.

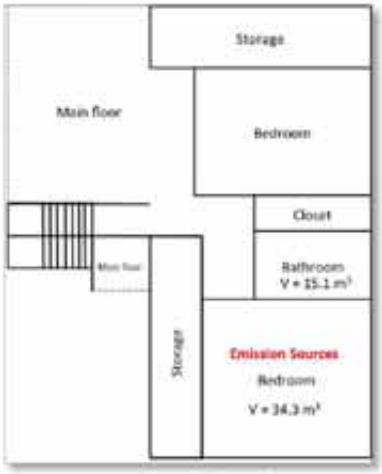
Environmental Quality Management and Remediation

Work Plan FY12/FY13

Project completed in 2012.

Informational Resources

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



Test home floor plan

Consumer products in house

Air monitoring in home

Location	PCE (ug/m3) HVAC off	PCE (ug/m3) HVAC on	TCE (ug/m3) HVAC off	TCE (ug/m3) HVAC on
Top floor	10	12	0.3	0.3
Middle floor	5	10	ND	0.3
Bottom floor	3	11	ND	0.3

House air concentrations

Surface and Groundwater Quality and Quantity

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

Project Name	FY2012 Actual Expenditures	FY2013 Budgeted Expenditures	FY2014 Planned Expenditures
A Methodology for Improved Groundwater Recharge Estimation in Semi-Arid Regions	$29,290.16	$30,168.86	$31,073.93
Evaluating the Effectiveness of Three Utah Wastewater Treatment Facilities in Removing Pharmaceuticals and Personal Care Products	$40,292.44	$40,000.00	$41,200.00
Incorporation of Heat into Solute Models	$113,334.41	$116,734.44	$120,236.48
Investigating Stream Dissolved Organic Matter Dynamics in the Little Bear River using Continuous Monitoring Data	$80,890.29	$83,317.00	$85,816.51
Investigating Turbidity and Sediment Transport Dynamics in the Little Bear River Using Continuous Monitoring Data	$18,923.21	$19,490.91	$0.90
"Lab-on-a-Chip" – Miniaturized Salinity Sensor Arrays for Water Quality Monitoring	$129,820.07	$13,902.21	$14,319.27
Monitoring Program to Assess Tributary Nutrient Loading into Cutler Reservoir for TMDL Support	$33,885.68	$34,902.23	$0.00
Optimizing Stormwater BMP Performance through Vegetation Selection and Harvesting Strategies	$105,961.83	$109,140.68	$112,414.91
Quantification and Management of Salt Production in the Desert Lake Watershed	$13,984.93	$0.00	$0.00
Release of Arsenic from Aquifer Solids Under Anaerobic Conditions	$139,552.95	$80,000.00	$0.00
Technical Support for Bear River System Data Acquisition	$32,237.54	$33,204.67	$34,200.81
Water Allocation and Salinity Issues of the Sevier River Basin	$28,773.17	$29,636.37	$30,525.46
Weber Basin Decision Support System (DSS) Modernization	$20,392.29	$21,004.06	$0.00
Designated Projects		$450,141.70	$23,155.00
Undesignated Projects		$141,010.00	$0.00
Total	**$786,438.95**	**$1,182,653.13**	**$492,942.37**

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

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

Partners/Collaborators:
None

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 western USA and other parts of the world where data with contrasting climatic conditions, land use/class, and other physical conditions are available. Additional work will be conducted in the western USA including Utah for projection of water surplus in the next century under climate change scenarios.

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

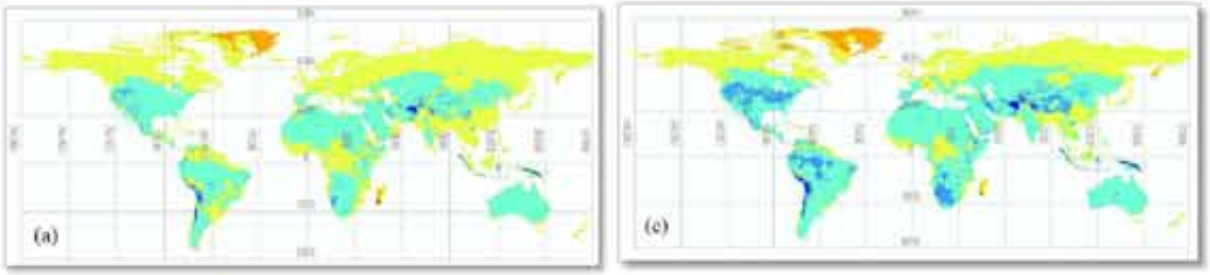
- **Accomplishments:**

  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 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 FY12/FY13

The work on the project completed June of 2012.

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:**

The occurrence of Pharmaceuticals and Personal Care Products (PPCPs) in the environment has become a growing concern within the last decade due to the potential ecological effects (i.e., 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 is to investigate the effectiveness of three Utah WWTPs, each using different treatment technologies, in removing PPCPs. Ten specific PPCPs were selected for this study based on their wide range of chemical properties and reports of their being found in WWTP effluent and biosolids (Table 1). Removal effectiveness will be 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 are 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	Abbreviation	Use
Caffeine	CAF	Stimulant
Acetaminophen	ACM	Analgesic and antipyretic
Sulfamethoxazole	SMZ	Antibiotic
Tris(2-chloroethyl) phosphate	TCEP	Flame retardant
Carbamazepine	CBZ	Anticonvulsant and mood stabilizer
Estrone	EST	Reproductive hormone
Progesterone	PRG	Reproductive hormone
Gemfibrozil	GEM	Antihyperlipidemic
4-n-nonylphenol	4-NP	Detergent metabolite
Bis(2-ethylhexyl) phthalate	DEHP	Plasticizer

- **Benefits to the State:**

Results from this study will 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 will 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 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: 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: Influent, effluent, and biosolids samples were collected in May, July, and August of 2011. The highest influent concentrations were measured for caffeine (3.9 – 15.4 µg/L) and acetaminophen (7.4 – 71.5 µg/L). Sulfamethoxazole, tris(2-chloroethyl) phosphate, and carbamazepine were measured in the effluent of all three WWTPs. Removal efficiencies (Table 1) calculated from differences between influent and effluent concentrations were caffeine (>80%), acetaminophen (>99%), and sulfamethoxazole (>60%). Tris(2-chloroethyl) phosphate, carbamazepine, and bis(2-ethylhexyl) phthalate were not consistently found above the method limits of quantitation (LOQs). The effluent concentrations of the measured PPCPs were below the levels of concern suggested by available toxicity data.

Table 2. Estimated percent removal of PPCPs by Brigham, Hyrum, and Spanish Fork WWTPs

Note: (*) – Effluent concentration > influent concentration

Informational Resources

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

LC/MS system for analysis of PCPPs

Extraction of water samples for PCPPs

Incorporation of Heat into Solute Models

Principal Investigators:
Bethany T. Neilson

Partners/Collaborators:
- ***Local:*** *Corey Cram, Washington County Water Conservancy District*
- ***State:*** *Dan Christensen/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.

- **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. As methods are developed to measure and predict the fate and transport of constituents in stream 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.

- **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 (Figure 1) 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.

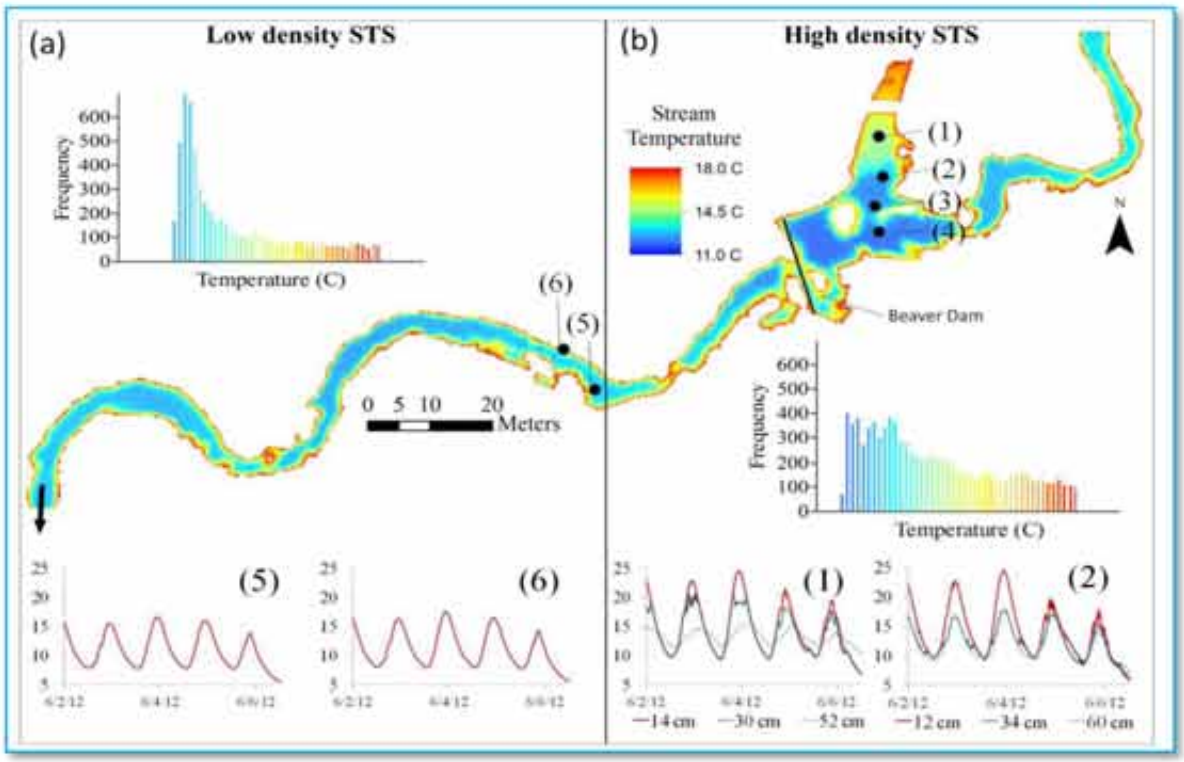


Figure 1. Thermal imagery of Curtis Creek, UT at 1 pm in mid May 2012. (a) represents a low density surface transient storage (STS) reach and (b) a high density reach. Frequency distributions show the shift in temperature distributions from (a) to (b) due to increased STS areas created by beaver dams. Time series plots are temperature data vertically within the water column at numbered sites on thermal imagery. Legend values for time series data signify the depth of sensor within water column.

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 (similar to that shown in Figure 1) has been found critical in estimating parameters and in capturing the longitudinal and lateral spatial variability present within desert and mountain streams in Utah. Additionally, three local conference presentations have been delivered and two peer reviewed journal articles are nearly ready for submission.

Work Plan FY12/FY13

The two-zone solute analytical solutions and temporal moments are complete and the heat transport equations have been partially solved analytically. 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.

Informational Resources

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

Investigating Stream Dissolved Organic Matter 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:**

  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, thus leading to 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 our rivers in Utah are driven by spring snowmelt. Many of our rivers are used as drinking water sources. 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 sediment and phosphorus 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. We are currently examining different techniques for obtaining viable measurements that can be corrected for common interferences such as turbidity. We are also designing and testing sensor housings that will be appropriate for deploying CDOM sensors in high-flow scenarios. Overcoming these challenges will be necessary before we are able to successfully collect data in the Little Bear River.

  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 the existing Little Bear River monitoring and telemetry system, and 3) examine the timing and magnitude of DOM fluxes in the Little Bear to examine potential sources and flow pathways.

Work Plan FY12/FY13

We will purchase 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 three different 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. We will integrate the new CDOM sensors with existing monitoring and telemetry equipment in the Little Bear and establish the necessary database and data processing protocols.

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 will use 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 are developing provide information about the timing, magnitude, and the source of sediment loading, they will be 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 have developed the monitoring infrastructure to create continuous turbidity measurements and have made routine and event sampling visits to monitoring sites in the Little Bear to collect the data needed for this project. We have investigated the generality of the surrogate monitoring approach, including examining point vs. width and depth integrated sampling. We have also investigated the site specific nature of relationships between turbidity and sediment concentrations and have developed robust methods for estimating suspended sediment concentrations and loads from continuous turbidity and streamflow data. Relationships between suspended sediment concentrations and turbidity have been established at each of the monitoring sites and a suspended sediment loading profile has been developed for the Little Bear River watershed. Continuous data collection is ongoing at 7 stream sites and 4 continuous weather stations.

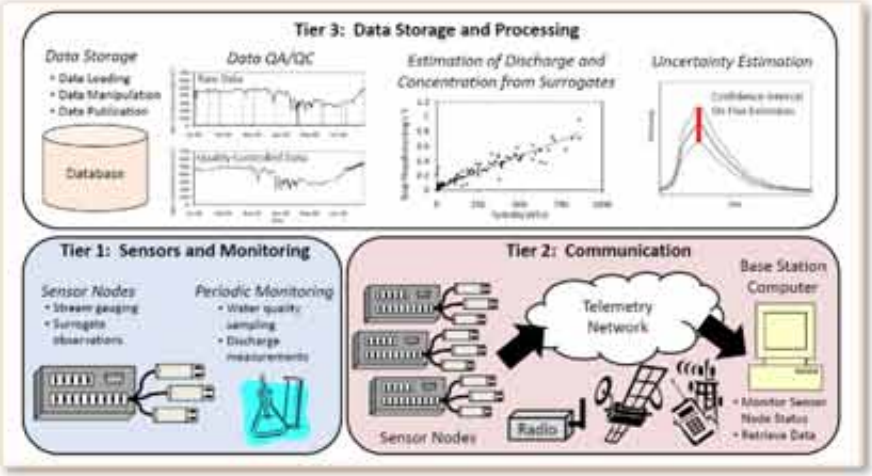
Work Plan FY12/FY13

We will continue our work with ongoing data collection at several monitoring sites within the Little Bear River to assemble high frequency turbidity data as a surrogate for suspended sediment. We will refine our preliminary relationships between suspended sediment and turbidity, our high-frequency estimates of suspended sediment concentrations and streamflow at monitoring sites in the Little Bear and use the data to examine spatial and temporal patterns in sediment loading. We will examine new data characterizing the particle size distribution of sediment at different times of the year to provide more information about sources of suspended sediment and to examine the effects of particle size distribution on the relationship between suspended sediment and turbidity. Additionally, we will examine new data from weather stations within the watershed for potential relationships between the timing of snowmelt and soil moisture dynamics and the timing of suspended sediment loads within the Little Bear. Finally, we will continue to examine the utility of this combination of datasets for better quantifying the sources, timing, and magnitude of sediment fluxes in the Little Bear River.

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.

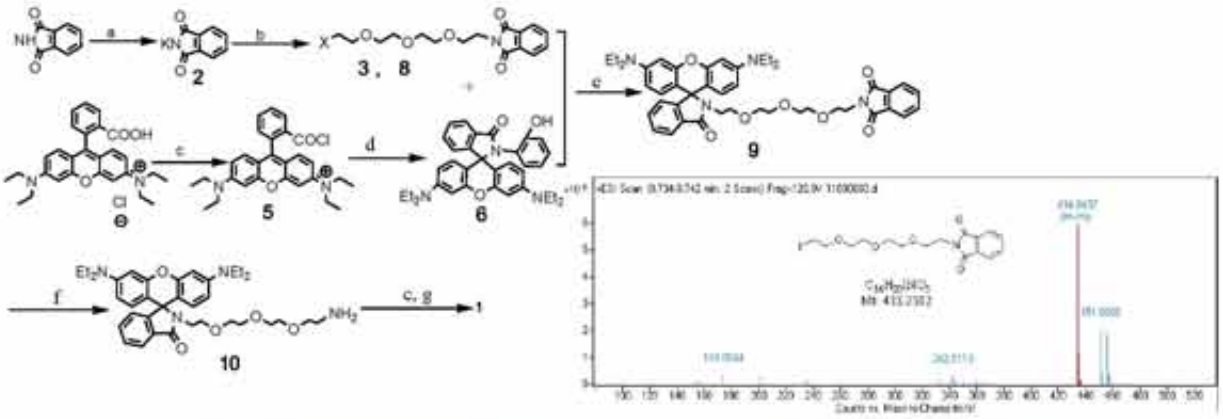
- Accomplishments:

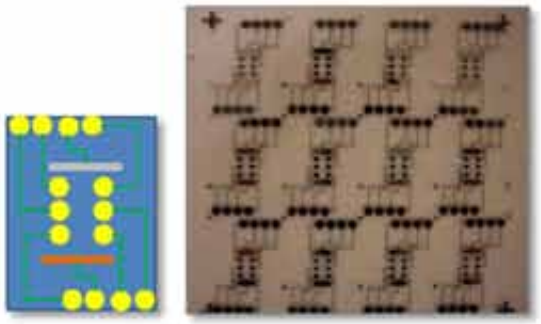
  Findings: We have continued to synthesize new ionophores that have the potential to be used as recognition compounds to bind with target ions. Several synthesis schemes have been proposed, and the corresponding intermediates in these proposed schemes have been synthesized and characterized using Mass Spectroscopy. We have started to fabricate integrated sensor arrays, which could be used as DNA biosensors for the detection of multiple genotypes of waterborne pathogens.

  Results:

  1. Five synthesis schemes have been proposed, and each of synthesis routes has been tried. The chemical structures of the intermediates in these synthesis routes have been identified by using the facilities (Mass Spectroscopy and NMR) from the Utah Water Research Laboratory and the USU Chemistry Department.

2. As an example of proposed synthesis approaches in this past year, the reaction route shown below illustrates the novel idea of synthesis of new compounds (i.e., Rhodamine B) that can recognize ionophore molecules by monitoring the fluorescence changes before and after binding.
3. Graduate student Neil Draper and Han Zhang started fabrication of the integrated sensor array device in the Nanofab lab in University of Utah (see photo below).





Sensor design (left) and prototype of fabricated sensor array (right)

Graduate student Neil Draper (left) and undergrad Spencer Williams (right) in Nanofab lab, University of Utah (summer, 2012)

Work Plan FY12/FY13

- Optimization of the design, fabrication, and initial evaluation of a lab-on-a-chip device that has potential detection of multiple ions simultaneously.
- Design and fabrication of a microfluidic device that functions as the chamber for the dilution or mixture of multiple ions or DNA sequences.
- Bio-functionalization of the sensors with species-specific DNA to form multiple sensor arrays for detection of multiple species of waterborne pathogen DNA.
- Work with USU Intellectual Property Services Office for any potential patent application.

Informational Resources

Zhang, H., H. Chen, T. Gilbertson, A. Zhou (2012). Microfluidic System to Study Fatty Acid Induced Intracellular Calcium Influx in Immortalized Taste Bud Cells, *Lab-on-a-Chip World Congress*, September 25-26, 2012, San Diego, U.S.A.

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/waterquality/labonachip.html.

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
Ana Ovalle (student)
Ruba Mohamed (student)
James Milleson

Partners/Collaborators:
- ***Local:***
  Issa Hamud, City of Logan
  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 the loading 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. Additional data related to sediment samples and the nutrient and oxygen fluxes from the sediments into the overlying water was also obtained, 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 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:**

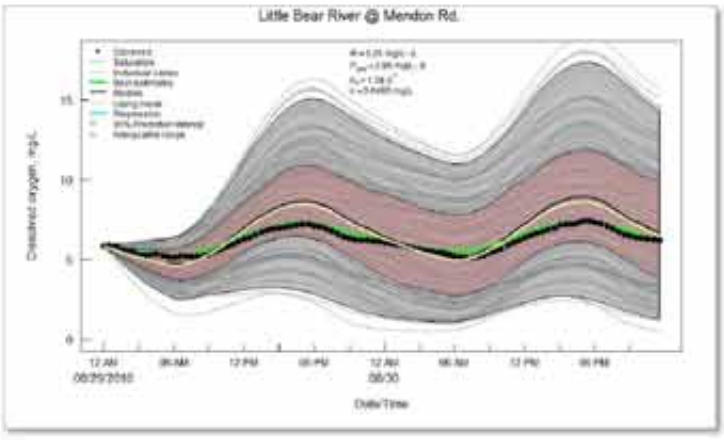
  Findings: Automated flow and water quality monitoring stations have been installed and monthly field sampling is ongoing at project sites for nutrients and Chlorophyll A (in the reservoir only). Well and lysimeter sites have been monitored for nutrients, pH, dissolved oxygen, specific conductance, and turbidity since April 2010. Waste water collection system sites were sample for BOD5, suspended solids, and nutrients, as well as pH, dissolved oxygen, temperature, turbidity, and specific conductance.

  Results: The outcome of this project is a large and growing data set for public and research use. The data through June 2011 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). A presentation of the data and preliminary conclusions was given the Cache County Cutler Reservoir Management committee and two masters 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, as shown below for the Little Bear River at Mendon Rd.

  These two projects also explore 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 FY12/FY13

Data collection is complete. A draft final report was filed in November 2011 and comments are pending.



Informational Resources

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

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

Optimizing Stormwater BMP Performance Through Vegetation Selection and Harvesting Strategies

Principal Investigators:
R. Ryan Dupont
Joan E. McLean
Malgorzata Rycewicz-Borecki (student)
Amanda Goodwin (student)

Partners/Collaborators:
- **Local:** *Bill Young, Logan City Public Works Department*

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 5 or more acres of land. Stormwater detention basins are often used in response to this federal mandate. This progressive program aims to minimize pollutants and discharge volumes from urbanized areas entering receiving water bodies and to address the growing problems of impacted water quality and increased flooding from urban and rural non-point sources.

  Logan City and its surrounding municipalities are beginning to address stormwater quality issues as well as quantity. To do so they need locally generated, quantitative research to accurately depict the effectiveness of vegetative species within stormwater management facilities. This study measures biomass production and water quality improvement effectiveness in a controlled laboratory environment and in a field demonstration site study. The laboratory scale study provides controlled, laboratory scale replicates of stormwater retention basins for measuring biomass production and total nutrient and metal removal. Water uptake will be quantified for seven individual vegetative species under simulated (frequency and duration) rainfall events. The field demonstration site, an existing subdivision stormwater detention area in Logan, Utah, will produce quantitative water quality improvement effectiveness data based on plant production and contaminant removal in response to periodic plant harvesting for three species as compared to voluntary weed species and non-vegetated control plots.

- Benefits to the State:

  This study will provide Utah municipalities with the stormwater nutrient and metal removal effectiveness of species found and planted locally. 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: Logan, Utah. Laboratory study at Utah State University Research Greenhouse, Field demonstration study: Green Meadows Subdivision detention basin, 600 S and 800 W.

  Areas Benefited: All counties in the state would potentially benefit from quantitative data that could be utilized within their stormwater management systems.

- Accomplishments:

Typical plant crop harvested from laboratory greenhouse BMP

Findings: Data analysis and reporting for nutrient and metal removal data from the lab greenhouse study were on-going during FY12. Greenhouse study results indicated a strong correlation between nutrient and metal removal capacity within a BMP and biomass harvested from the BMP. There was evidence at the lab-scale of species differences in concentrations of nutrients and metals accumulated in the harvestable, above-ground biomass, that suggest that the common reed and sedges are optimal plants for use for water quality improvement of stormwater in an arid, northern Utah climate.

Performance monitoring at the field-scale was carried out at the Green Meadows field demonstration site during the summer/fall season of FY11 and spring/summer season of FY12 through the quantification of the mass of harvested above ground plant material. The analysis of nutrient and metal species in the harvested biomass and surface soil for each of the plant species was evaluated under actual field climatic conditions.

Vigorous Plant Growth at Green Meadows Field Demonstration Site, Spring 2012

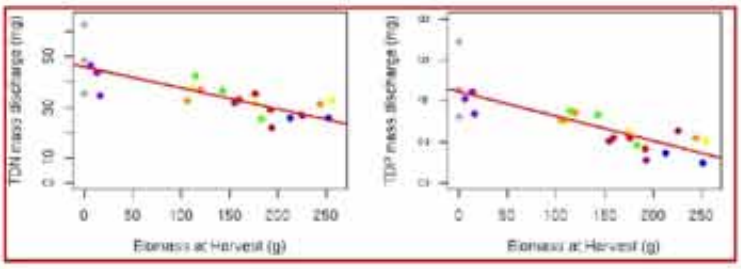
Results: Test plant species (sedge, sunflower, cattail) were successfully propagated and were vigorously growing at the Green Meadows demonstration site in the spring/summer of FY12. Stormwater event influent concentrations were monitored. Plant biomass production, as a function of seasonal harvesting (mid- and end-season versus only end-season), is being evaluated with early summer FY12 above ground biomass harvesting from each of the field test plots. Complete containment of all stormwater in the spring/summer FY12 period occurred within the field demonstration test plots. With no surface discharge from the planted areas, maximum nutrient and metal removal is possible in these systems. Based on preliminary greenhouse and field data, this represents approximately 10 to 15 kg of nutrient removal through plant uptake in a typical BMP, or approximately $2,000 of avoided annual nutrient removal costs/BMP. With potentially a thousand such BMPs throughout an area the size of Cache Valley, this represents a potential avoided annual cost for nutrient control of over $2,000,000.

Work Plan FY12/FY13

Operation of the field demonstration site will continue through FY13 to capture runoff input, biomass production as a function of harvesting frequency, and contaminant removal performance data during the summer and fall of 2012. Field plant harvesting and soil sampling will be carried out at the end of the growing season in late fall 2012 to develop background data on nutrient and metal uptake and partitioning in the four plant species and invasive plants grown during the first complete year of operation of the demonstration site. Reporting of nutrient and metal uptake potential in these systems will be carried out during the latter half of FY13.

Informational Resources

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



Total Dissolved N and P Released from Greenhouse BMPs as a function of Harvested Biomass

Quantification and Management of Salt Production in the Desert Lake Watershed

Principal Investigators:
Lizzette Oman
Said Ghabayen
Mac McKee

Partners/Collaborators:
- **Local:** *Emery Water Conservancy District*
- **Federal:** *Nick Williams, Steve Noyes, Bureau of Reclamation; Colorado River Salinity Science Team*

Project Description

- Need and Purpose:

  Salt in the Colorado River has economic and environmental effects on the whole Colorado River Basin. As the water of the Colorado becomes more saline, upstream water users will come under greater scrutiny for methods to control salt in the river. To respond to this problem, Utah must have better estimates of salt loading to its tributaries into the Colorado River.

  Currently salt loading in Utah's streams is estimated from monthly water and stream flow samples averaged over time. This project is employing real-time monitoring information for both flow and water quality to estimate salt loading from runoff at Desert Lake in Emery County and is developing tools to identify the different sources of salt in the Desert Lake drainage, which will lead to better control of the salt produced by agriculture, as well as natural sources.

- Benefits to the State:

  - Improved estimates of salt loading for the Desert Lake system.
  - Identification of individual contributions of salt to the Desert Lake system.
  - Evaluation of monitoring measures to improve the salt source and load estimation and reduce the uncertainty in the estimates.

- Geographic Areas:

  Study Area: Desert Lake Waterfowl Management Area and drainage basin. The system drains into the Price River, which flows to the Green River.

  Areas Benefited: Upper Colorado River basin and irrigated agriculture statewide. Potentially all areas of the State that have a salt load from natural and agricultural sources will benefit.

- Accomplishments:

  Findings: The hourly, daily, and monthly Bayesian Belief Model produces good results when the real-time input data are reliable. The model shows that Shoemaker Wash produces the smallest amount of salt to the system through surface water, while Desert Lake Wash and Timothy Wash produce the majority of the loading.

There is a lag between irrigation and salt loading during the non-irrigation season. During winter, it is difficult to obtain a reliable estimate for salt loading because of freezing and the problems this poses for the real-time sensors that monitor salt concentrations and stream flow.

The groundwater model built during the project shows good results in identifying different salt sources using ionic ratios and shows a distinct, identifiable difference between natural and agricultural sources. The value of this work has been increased through the use of the data collected this year on boron and other isotopes in the surface and ground water.

Aerial imagery obtained through use of the unmanned aerial vehicles (UAVs) developed by the UWRL and deployed by the AggieAir™ Flying Circus (http://aggieair.usu.edu) has been used to demonstrate their application in estimation of evapotranspiration rates at Desert Lake as a part of the overall water balance calculations.

Results: Work using the isotopic data has shown that estimates of salt loading from the Desert Lake watershed can be refined to confidently distinguish between the salt that results from irrigated agriculture and other agriculturally related activity and the salt that comes from natural sources in the watershed. This will help to target salinity management operations in the area more precisely.

Informational Resources

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

Aerial Imagery Obtained by Use of UAVs, Used to Estimate Evapotranspiration in the Desert Lake Area

Release of Arsenic from Aquifer Solids under Anaerobic Conditions

Principal Investigators:
Joan E. McLean
Xianyu Meng (PhD student)
Allie Abu-Ramaileh
Suzy Smith (Undergraduate)
Lindsey Stevens (Undergraduate)

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 Geologic 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 sampling locations near the City of Logan landfill.

- **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 throughout the state. Arsenic in groundwater is a worldwide problem.

- **Accomplishments:**

  Findings: Arsenic in groundwater comes from geologic sources. Arsenic occurs from the soil surface to depth of groundwater. Arsenic release is associated with the transition zone where the fluctuating ground water table causes cycling from oxidized to reduced conditions.

  Results: Samples were collected from the soil surface to depth of groundwater (Fig 1). The sediments were divided into layers based on color and texture, indicative of changes in mineralogy and redox conditions that may influence arsenic solubility. Arsenic in the pore water exceeds the drinking water standard of 10 µg/L (Fig 2A), with the highest concentration in the zone of changing redox conditions due

to seasonal fluctuation in the ground water. Arsenic is associated with various minerals down the profile (Fig 2B). These various associations affect the solubility of arsenic. Arsenic association with various mineral phases was confirmed using advance x-ray spectroscopy methods at Argonne National Laboratory (Fig 3). Arsenic is associated with iron, calcium, and manganese minerals.

Figure 1. Sampling and sample processing in the field

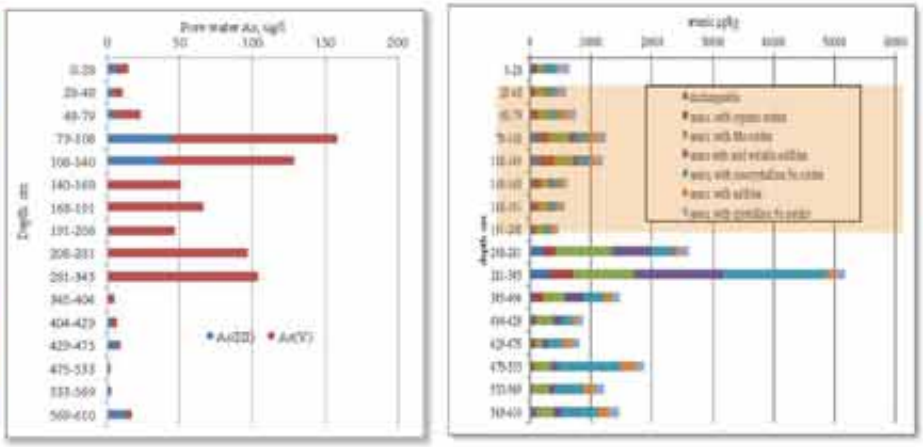


Figure 2. Arsenic concentration in the pore water (A) and arsenic association with the solid phase as defined by chemical extractions (B)

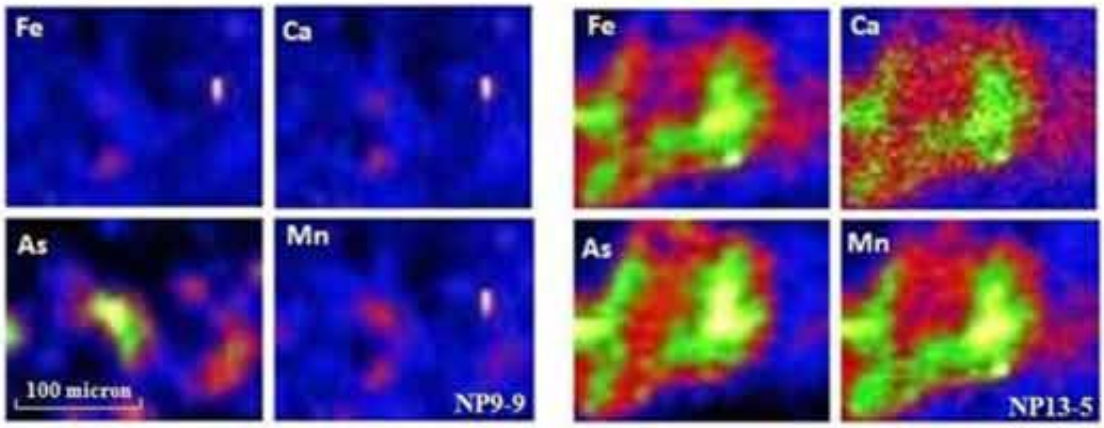


Figure 3. Imaging techniques utilizing Argonne National Laboratory Synchrotron base X-ray spectroscopy.

Work Plan FY 12/FY13

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 techniques for identifying bacteria that are responsible for arsenic mobilization. With use of synchrotron advance x-ray absorption spectroscopy, we can directly examine how arsenic is associated with minerals.

Informational Resources

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

Technical Support for Bear River System Data Acquisition

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

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

Project Description

- Need and Purpose:

  The focus of the project is to provide 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, the 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.

- Benefits to the State:

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

  1. Improving understanding of the sediment and nutrient dynamics in the Bear River basin.
  2. Providing innovative data acquisition systems for remote areas.
  3. Establishing relationships among regulated water quality variables at key monitoring locations to improve high-frequency load estimation for Cutler Reservoir.
  4. Building data-driven models of sediment-rich water systems to support estimation and management of sediment loads.
  5. Acquiring 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.

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 has resulted in the successful dissertation defense of the graduate student involved, 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.

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.

Work Plan FY12/FY13

- Continue support of monitoring network.
- Complete publications for Mud Lake statistical learning theory model of sediment.
- 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 for continued funding of existing monitoring network and to extend 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:
None

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 the land area of Utah. This basin provides water for nearly 23% of land that is privately held and for domestic and industrials uses. The basin is divided administratively for water rights purposes: lower and upper basins, with much of the water produced in the upper basin from winter snowfall and spring runoff. The high elevations in the upper basin produce runoff during spring, and the bulk of this water 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. Therefore, water allocation is a challenge to water managers in each year, given this uncertainty. 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 snowfall data in the winter. 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 the second phase 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 that 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.

- **Accomplishments:**

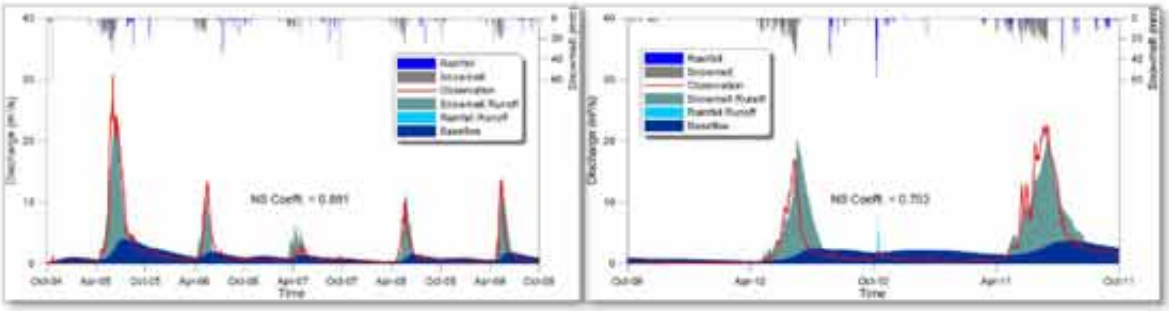
  Findings: Since some gauging stations in the main channel of Sevier River do not represent natural flow due to flow alterations and reservoir operations, it is difficult to calibrate a hydrologic model using altered streamflow data directly. Instead, if the natural flow is generated by parameters regionalized 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.

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	0.640	0.822	0.312	0.287
Manti Creek below Dugway Creek	0.822	0.481	0.629	0.719



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

Work Plan FY12/FY13

The work will extend to 2012-13 to complete the hydrologic model to predict natural flow in the basin. This model will be used to predict water availability in the late spring and summer such that appropriate water allocation can be made by water managers towards the end of winter.

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 and 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.

- 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 (completed).
  - Convert the model interface to Visual C#.Net 2005. (Completed).
  - Modify the Weber Basin mass balance model and database to include new flows into Park City from above Rockport. (Completed).

Significant progress has been made to:

- Integrate the hydrology model and the water quality model into the Visual C# interface (progress).

Results:

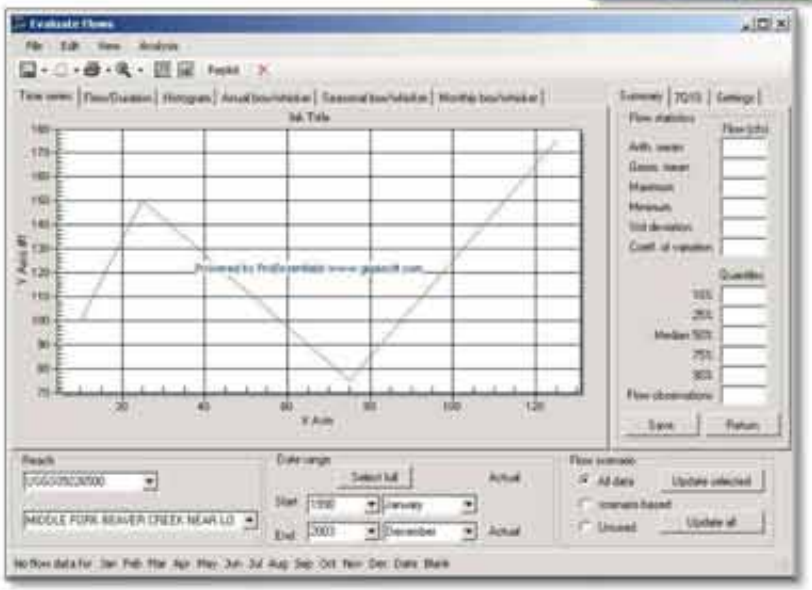
- A working prototype of the modernized Weber Basin DSS.
- A completed distributed hydrology model.
- Integration of the Weber Basin mass balance model and database into the Visual C# interface.
- Partial integration of the hydrology model and the water quality model into the Visual C# interface.

Work Plan FY12/FY13

Complete integration of the hydrology model and the water quality model into the Visual C# interface, complete assessment of Rockport diversion flows, testing of the integrated system, and deployment of the modernized WBDSS at the Weber Basin Water Conservancy District with staff training.

Informational Resources

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



Water Conveyance, Distribution, and Control

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

Project Name	FY2012 Actual Expenditures	FY2013 Budgeted Expenditures	FY2014 Planned Expenditures
Dam Safety Risk Analysis Computations	$23,733.71	$24,497.22	$0.00
Development of Flow Measurement Procedures for Pipe Installations with Non-Ideal Conditions	$17,456.35	$17,930.56	$0.00
Hydraulic Structures for Flood Control and Flood Bypass	$17,367.97	$57,373.00	$0.00
Impact of Distributed Flow Measurement Using S&M Flumes on Irrigation System Water Management	$19,362.61	$0.00	$0.00
Labyrinth Weir Research	$56,832.35	$53,537.34	$60,293.97
Low Head Dam Dangers	$11,800.06	$10,000.00	$0.00
Open-Channel Unified Flume Calibrations	$16,463.93	$17,000.00	$0.00
Remote Control for the Crockett Canal Head Gates	$5,235.09	$0.00	$0.00
Sediment Management for Small Reservoirs: Logan First Dam Study	$2,029.17	$5,000.00	$5,150.00
Open Channel and Closed Conduit Field Flow Measurement, Maintenance, and Upgrade for the State of Utah	$23,146.13	$23,640.56	$21,972.00
Designated Projects		$137,277.69	$37,737.79
Undesignated Projects		$178,950.00	$10,000.00
Total	**$193,528.42**	**$580,456.87**	**$135,153.75**

Dam Safety Risk Analysis Computations

Principal Investigators:
David S. Bowles
Anurag Srivastava (Student)

Partners/Collaborators:
- ***State:*** *Matt Lindon, State Engineer's Office*
- ***Federal:*** *USACE*

Project Description

- Need and Purpose:

  The overall objective of this ongoing research is to provide an efficient computational tool for performing dam safety risk analysis computations.

  Proprietary software developed for business risk analysis applications is ill-suited for use in dam safety risk assessment. In response to this need, a generalized dam safety risk analysis model has been developed and is being improved. The eventual goal is to make the model widely available to dam safety professionals to perform dam safety risk analysis computations in a flexible and user-friendly way.

- Benefits to the State:

  The approaches to dam safety risk analysis being developed under this project are applicable to dams in Utah. It is expected that their use for dams in Utah will increase as a direct result of National Dam Safety Program initiatives in both risk ranking and potential failure modes analysis. The research results from this project are available for use by the Utah State Engineer's Office and practicing engineers in Utah. They are being applied by federal dam safety agencies such as the US Army Corps of Engineers (USACE) and the US Bureau of Reclamation. Benefits are expected to include improved understanding, prioritization, and justification of dam safety risk reduction measures.

- Geographic Areas:

  Study Area: Utah Water Research Laboratory/Utah State University.

  Areas Benefited: Any county with a dam or potentially impacted by dam, levee, or canal failure is a beneficiary of this project.

- Accomplishments:

  Findings: Software for efficient, flexible, and generalized event tree analysis called DAMRAE (DAM safety Risk Analysis Engine) has been developed. DAMRAE is now being used by the USACE while development continues. DAMRAE is designed to overcome the limitations of existing business-oriented risk analysis software.

  DAMRAE includes a graphical user interface (GUI) for developing and populating event tree inputs and a generalized algorithm for calculating and post-processing results. It provides estimates of the probabilities of various failure modes and their associated consequences for an existing dam. The post-processing step allows the user to combine results for various loading types (e.g. flood and earthquake) and to make comparisons against tolerable risk guidelines. A flexible capability exists for obtaining tabular and graphical presentations of estimated risks at different levels of detail.

A generic dam project framework provides the functionality to analyze structural and non-structural risk reduction measures, considered as alternatives or staged measures, to obtain estimates of the risk reduction and the cost effectiveness of risk reduction. Applications made for a dam in a specific safety state can be readily updated by modifying the event tree structure and revising inputs for loading or system response probabilities (SRPs), dam failure consequences, risk reduction cost estimates, and other inputs such as state functions for stage-discharge relationships to represent changes to spillways.

The effects of changes in the event tree structure or changes to probability, state function relationships, or risk estimates consequences can be explored using sensitivity analysis incorporated in DAMRAE. In addition to individual dam applications, DAMRAE can serve as a core engine in a portfolio risk assessment and management system through a linked database. The capability to include the increased probability of failure for a long dam has been included in a special modification of DAMRAE.

Results: Recent work has lead to improvements in user interface features and computational and post-processing functions. Development and verification of the database capabilities of DAMRAE facilitate an expansion of functionality in the following ways:

- Continues to increase the maximum dimension of event tree that can be analyzed to account for a wider range of failure modes, complex loading cases, and a wider range of exposure and consequences scenarios.
- Further increases the computation rates.
- Links to a portfolio risk management system.
- Generalizes the applicability to long dams, levees, or canal embankments.
- Provides uncertainty analysis.
- Automates verification of software changes.

Work Plan FY12/FY13

DAMRAE is undergoing continuous improvement of user interface features and computational and post-processing functions. Proposed improvements in the next fiscal year will focus on completing an uncertainty analysis capability and developing a capability for automated verification of software changes.

Informational Resources

Contact: Dr. David S. Bowles, (435) 797-4010, E-mail: david.bowles@usu.edu.

Website: http://uwrl.usu.edu/people/faculty/bowles.html.

Development of Flow Measurement Procedures for Pipe Installations with Non-Ideal Conditions

Principal Investigators:
Steven L. Barfuss
Devin Stoker

Partners/Collaborators:

- ***State:*** *Utah Department of Natural Resources – Division of Water Rights*
- ***Business/Industry:*** *Terry Henderson – FloSonics*

Project Description

- **Need and Purpose:**

  This project has developed procedures to improve flow measurements where clamp-on ultrasonic flow meters are used to measure flow in non-ideal piping configurations. The State of Utah promotes the proper allocation of water rights and is interested in information that improves the accuracy of flow measurements.

  Field technicians who make a career of measuring flow rates for irrigation companies, power companies, and municipalities have indicated that this type of research has great value to them. Only a very small percentage of all field piping has adequate lengths of straight pipe between the metering location and disturbance sources such as valves, pipe elbows, or pumps to accurately measure flow. Because flow meter manufacturers do not have procedures for non-ideal applications, the field technicians are left to their own expertise to "tweak" or "estimate" the flow rate from the flow indicated by reading the meter.

  An example of a poor approach condition is shown in Figure 1, a photograph of a pump on the Lower Bear River, located in Northern Utah. As seen in the photograph, the ultrasonic meter was placed just inches downstream from a 90-degree bend and is extremely close to the pump intake.

Figure 1: Bullen Farms Pump #43 (courtesy: Utah Division of Water Rights)

- **Benefits to the State:**

  The improved accuracy of flow measurements resulting from this study will ultimately improve water rights allocation, system management, and water conservation in the State of Utah.

- **Geographic Areas:**

  Study Area: State of Utah.

  Areas Benefited: State of Utah, with application to all states in the U.S.

- **Accomplishments:**

  Findings: Laboratory experiments and numerical CFD simulations confirmed that the distorted velocity profiles downstream of a single 90-degree elbow adversely affect ultrasonic flow measurement accuracy. The numerical models were verified to match the physical measurements to a reasonable level of confidence. The trends observed in the measured velocity profiles and in the CFD simulations coincide with the recommendations of straight pipe lengths and installation instructions given by ultrasonic flow meter manufacturers.

  Results: The results of the physical scenario studied show that the ultrasonic flow meter always under-predicted the true flow rate when installed in non-ideal piping. By integrating the velocity profile of the fluid across the ultrasonic signal path and comparing the resulting total velocity to the same velocity for a fully-developed and symmetric velocity profile, the numerical models that were solved can potentially be used as a tool to apply corrections to ultrasonic flow meter measurements. For the physical scenario of a single 90-degree elbow, flow measurement error was reduced by nearly 90% by applying a developed correction equation.

Work Plan FY12/FY13

- Academic Journal paper to the Journal of Irrigation and Drainage (ASCE). Paper was accepted for publication in April 2012, to be published in FY12/FY13.

- This project is completed.

Informational Resources

Contact: Mr. Steven L. Barfuss (435) 797 3214, Email: steve.barfuss@usu.edu.
Mr. Devin M. Stoker (435) 797 3231, Email: devin.stoker@aggiemail.usu.edu.

Hydraulic Structures for Flood Control and Flood Bypass

Principal Investigators:
William J. Rahmeyer

Partners/Collaborators:
- ***Local:*** *Utah County and cities*
- ***Federal:*** *U.S. Army Corps of Engineers, U.S. Bureau of Reclamation*

Project Description

- **Need and Purpose:**

  Flood control has become even more of a critical issue for the State of Utah for several reasons, one of which is development along and within floodplains. Urban growth not only contributes to larger floods, but also reduces the size and ability of our flood ways and channels to convey major flows. Research for this project was conducted on three new and innovative concepts in hydraulic structures that will have a direct impact and benefit for Utah communities.

  The retrofit of dams and reservoirs for increased storage involves the unique design of a spillway and control structure that can both raise the pool elevation of the reservoir and also increase the outflow capacity of the spillway. Many dams and spillway structures in the Western United States are located in diversion channels that were used to construct the reservoirs and dams. Widening and excavating the channels to increase flow capacity is too expensive, so new ideas and designs for the spillway crest control sections are being researched. The effects of road crossings and bridges also have a significant effect on flood control and flood bypass.

- **Benefits to the State:**

  The knowledge and methodology gained from this research in the retrofit of dams, hydraulic structures, and road crossings will directly benefit almost all of the cities and counties in the State of Utah by providing a better understanding of the need to retrofit or rehabilitate dams and hydraulic structures, as well as the costs and design parameters associated with the rehabilitation. Utah will be better prepared to respond to issues of flood control, emergency response, and flood and storm water management. The understanding gained from this research and how it applies to Utah will positively impact federal guidelines and requirements of flood and storm water control for Utah.

- **Geographic Areas:**

  Study Area: Entire State of Utah.

  Areas Benefited: All counties and cities in Utah.

- **Accomplishments:**

  Findings: The concepts researched this year focused on the remediation of a dam and spillway for both an increase in reservoir capacity and an increase in the outflow hydrograph of different storm events (i.e. 100-yr, 500-yr, and **PMF**). The use of standard ogee crests and broad crested weirs were investigated with different lengths, rotations, and the addition of notched weirs. However, the most significant accomplishment of this year's work was conducting the study by incorporating both numerical (CFD) modeling and physical modeling. **A** paper was presented that discussed the new application of combining physical and numerical models into a composite model. This paper was based on the ogee and broad crested weirs from this year's studies.

A second area of study focused on the transport of bedload sediment in culverts. Culvert bedload transport is a significant cause of culvert and road crossing failures in Utah. A laboratory experiment was conducted on sediment transport in culverts, and a paper and a conference presentation were then made at the 34th IAHR World Conference. A third area of study focused on the problem of adding bridge columns in a waterway for the widening of a bridge. For a bridge crossing in Idaho, it was found that increasing the length of the column rows could cause flow oscillation and waves in the waterway. The types of wave oscillations were highly erosive and damaging to both bridge abutments and channel banks and levees. A conference presentation was made on this work.

Results: Work was completed and information prepared on:

- Eliminating Wave Oscillations for the I-84 Bridge Crossing of the New York Canal, Boise, ID.
- Physical Modeling and Numerical Modeling of the Success Dam.
- Impact of culvert design on flood control and bypass, since sediment deposits in culverts limit the flow capacity of the culverts and the road crossings that incorporate them.
- Use of UAV's for floodplain assessment and culvert sedimentation impact on floodplains.

Work Plan FY12/FY13

- Initiate the Hydro Composite Modeling Laboratory to develop combined physical and numerical modeling expertise at the UWRL. A Webpage will be developed to promote and establish the national/international recognition of the UWRL as the leader in composite modeling.
- The first project for the HCML laboratory and the UWRL is the 2012 Folsom Dam Auxiliary Spillway Physical Hydraulic Model, CESPK-ED-HD Contract W91238-10-D-0001, Project 103923. The project is being coordinated with McMillen LLD of Boise Idaho who will conduct the numerical modeling efforts. The project will be finished in 2013.
- Participate with the Utah Floodplain and Storm Water Management Assn. and the Utah Office of Homeland Security to develop a series of joint workshops on flooding and floodplain problems.
- Continue research related to flood routing, management, and planning; retro-fitting dams for drought control and storage; rehabilitation and retro-fitting of spillway control structures; and eliminating wave oscillation from bridge columns.

Informational Resources

Contact: Dr. William J. Rahmeyer, Phone (435) 797 3180, E-mail: william.rahmeyer@usu.edu.
Website: http://hcml.usu.edu.

Publications/Awards:

Rahmeyer, W., S. Barfuss, and B. Savage (2012). Improving the Design of Hydraulic Structures with the Application of Composite Modeling. Paper submitted to the *2012 Int'l Conf. on Computational Fluid Dynamics, 7th Annual Conf. and Proceedings.*

Rahmeyer, W. and Clegg (2012). Canal Wave Oscillations from the I-84 Bridge Expansion in Boise, ID. Paper accepted for the *TRBd 91st Annual Meeting, Washington, DC.* January 2012.

Rahmeyer, W. and Goodridge (2012). Sediment Transport of Gravel in Circular Culverts. Paper reviewed and accepted for the *TRB 91st Annual Meeting*, Washington, DC. January 22-26.

Rahmeyer, W., S. Barfuss, and B. Savage (2011). Composite Modeling of Hydraulic Structures. *Dam Safety 2011 ASDSO Annual Conf.*, Nat'l Harbor, MD, Refereed Paper and Conf. Presentation.

William Rahmeyer received the Idaho Transportation Department 2012 Excellence in Transportation Award and 2011 ACEC of Idaho Engineering Excellence Grand Award for the I-84 New York Canal Modeling and Modification, along with an honorable mention at the 2012 National AECE award ceremonies for his work with the I-84 New York Canal.

Impact of Distributed Flow Measurement using S&M Flumes on Irrigation System Water Management

Principal Investigators:
Blake P. Tullis

Partners/Collaborators:
- ***Local:*** *Hyde Park Irrigation Company*
- ***State:*** *Lee Sims, State of Utah Division of Water Rights*

Project Description

- Need and Purpose:

  Accurate flow measurement in water distribution systems is essential for developing and monitoring best water management practices. Many water distribution system in the State of Utah have a very limited number of flow measurement structures, if any, and in many cases, the accuracy of the data is suspect. One of the primary reasons for the limited number of flow measurement structures is the cost associated with such structures as most water distribution systems have limited operating capital.

  The S-M flume, however, represents a relatively low-cost alternative for open channel flow measurement. The S-M flume consists of a rectangular channel section (inserts can be fabricated for installation in natural, trapezoidal, or other channel shapes) and vertical half cylinders installed on the sidewalls opposite one another. The half cylinders consist of PVC pipe cut in half longitudinally. The half cylinders create a local flow acceleration region where a critical section can occur, creating a control point and a unique head-discharge relationship. The upstream water depth is typically measured inside the PVC pipe, with a hole drilled through the sidewall of the pipe to create a hydraulic connection. In some cases, these flumes can be designed as semi-portable (i.e., the insert-type would be portable; however, the flume would likely need to have additional upstream guide walls installed to transition the flow into the measurement flume.

  Some research has already been conducted on S-M flumes. The objective of this study has been to design ~two S-M flumes for installation in the water distribution system of the Hyde Park Irrigation Company, verify the head-discharge relationship of the flumes at the Utah Water Research Laboratory, install the flumes in Hyde Park and evaluate the durability, longevity, and long-term accuracy of the flumes, and to evaluate the impact of the flow measurement data on the water resources management program of the Irrigation Company. Observations regarding ease of installation, public perception, and maintenance issues will also be provided.

  The scope of work associated with this project is summarized as follows:
  - Coordinate activities with the Hyde Park Irrigation Company.
  - Identify approximately two different canal locations in the water distribution system where flow measurement structures are needed.
  - Design an S-M flume for each location based on flow requirements and canal size using published data in the literature.
  - Construct and test a lab-scale version of each S-M flume (if the prototype scale is too large) at the UWRL.
  - Construct and install prototype S-M flumes in the field and perform a field calibration for verification.
  - Develop a discharge monitoring system, collect discharge data, and determine how the data should be used to benefit the water management practices of the Irrigation Company.

- **Benefits to the State:**

  Quantifying irrigation water flow rates is important to the Division of Water Resources because they are ultimately responsible for issuing, managing, and reallocating water rights and usage in the State of Utah. State distribution systems and local irrigation water companies have the responsibility to ensure that the appropriate water quantities are provided to the individual water users. This project, which will essentially be a case- or pilot-study, will help to determine the practicality and potential usefulness of employing the relatively inexpensive S-M flumes as open channel flow measurement devices in Utah. As more flow data become available, the ability to manage the water resources in the State of Utah will improve. Aaron Hunt and Lee Sim (Utah Division of Water Resources) are key supporters of this study.

- **Geographic Areas:**

  Study Area: All work was completed in the Hydraulics Lab at the Utah Water Research Laboratory (UWRL) at Utah State University and in the Hyde Park irrigation canal system.

  Areas Benefited: Irrigation systems statewide.

- **Accomplishments:**

  Findings/Results: Three S&M flumes were fabricated (8-ft, 1-ft, and 1-ft) and installed at different locations in the canal system supplying water to Hyde Park distribution system and at local diversion points in the Hyde Park distribution system. Significant trouble-shooting was required to solve problems associated with installing a flow measurement structure in a channel with an earthen invert (scour issues primarily). Flow measurement data were collected with the various S&M flumes and correlated with less precise flow measurement methods such as specified gate openings. The results of this study will be presented in a Master's thesis (Travis Hollingshead).

Work Plan FY12/FY13

No additional work is planned on this topic. The project will be completed during FY13.

Informational Resources

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

Website: http://uwrl.usu.edu/people/faculty/tullisb.html.

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 may need rehabilitation or replacement. Labyrinth weirs are often a favorable design option, as 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 6º and 12º sidewall angles. This study evaluated 12º and 20º sidewall angles, with variation in cycle number. A stage labyrinth weir features segments were 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:**

  As a spillway upgrade alternative, the results of this labyrinth weir study may prove useful in increasing the sustainability of existing dam with undersized spillways. Labyrinth weirs are a commonly used alternative for increasing the spillway capacity over a linear weir 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 FY12, one dealing with arced labyrinth weirs for in-reservoir applications and staged/notched labyrinth weirs. Effort continues on producing peer-reviewed journal publications on the topic of oblique weirs.

  Findings: Nine different laboratory-scale arced and non-arced labyrinth weir geometries (sidewall angle, arc angle, number of cycles) were evaluated for discharge coefficients, nappe stability and aeration characteristics, and local submergence effects. The study found that, in general, the discharge efficiency, as quantified by the discharge coefficient, was higher for the larger sidewall

angle and larger arc angle geometries for low upstream heads. As the upstream head increased the discharge efficiency of the arced labyrinth weir decreased relative to the smaller sidewall angles tested. The data presented in this study will be helpful to design engineers interested in high-efficiency spillway control structures in reservoirs.

The staged/notched labyrinth weir concept is potentially useful when trying to contain base flows to a reduced spillway area (notched in downstream apexes) or when downstream flood routing hydrograph restrictions limit peek spillway discharges (staged weir). A staged weir is one where a part of a cycle, an entire cycle, or multiple labyrinth weir cycles feature a lower crest elevation than the rest of the weir. This maintains the reservoir at a lower level (increased flood storage) and the leading edge of the outflow hydrograph is restricted to the staged section. As the reservoir level increases, the rest of the weir engages in flood routing. To date, there has been no design data available to aid in notched/staged labyrinth weir design. The only method available is a super position method where each segment is treated individually and the sum of the parts assumed representative of performance. This study found that errors as high as 20% existed between the actual weir performance and the superposition approach.

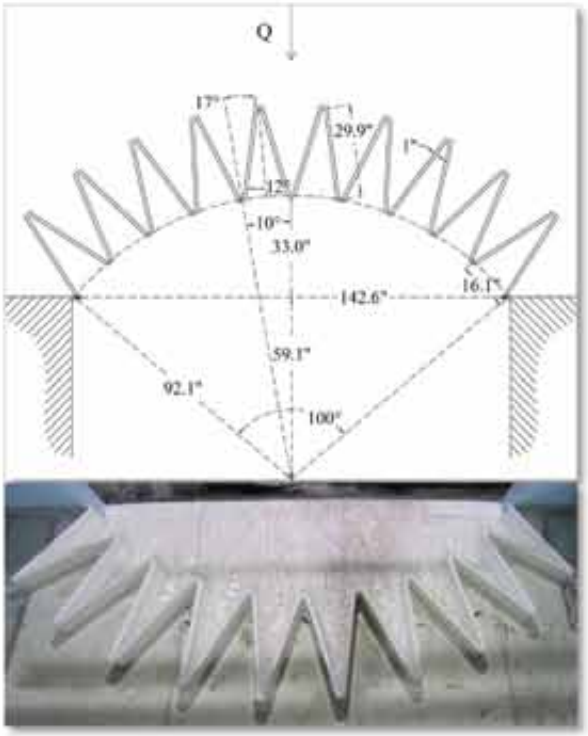
Draft versions of two oblique weir papers have been prepared and will be submitted to peer-reviewed journals following final review and revision.

Work Plan FY12/FY13

In FY12-13, the project will evaluate (1) apex width impacts on labyrinth weir discharge efficiency and (2) nappe vibration causes and remedies. Multiple peer-reviewed journal submissions related to this work are anticipated.

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 ($\theta = 10°$, $\alpha = 12°$, $N = 10$)

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, that can be 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.

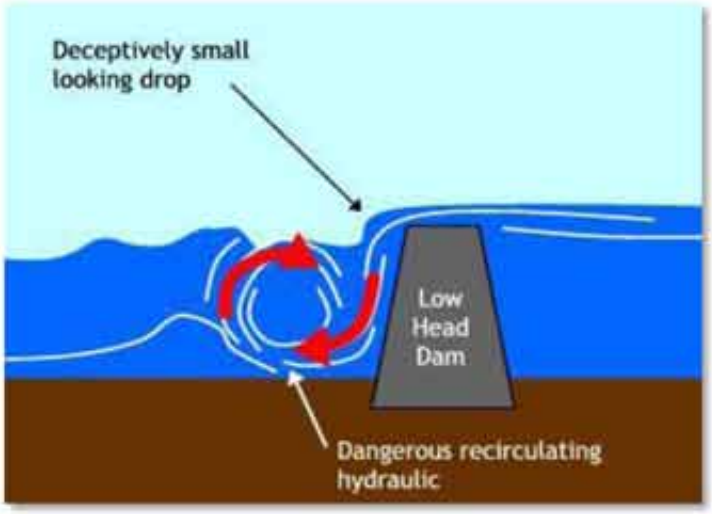


Figure 1: The countercurrent, or "hydraulic," created when water flows over a low-head dam

- **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.

  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. Because this project is still underway, no results have been published as of yet. Upon completion, the results of this study will help to identify means to enhance public safety at low head dams. The results could also be published in the Journal of Hydraulic Engineering.

Work Plan FY12/FY13

- Continue testing possible remediation options to determine if such options effectively eliminate the dangerous countercurrent known as a "hydraulic". This will be done using the computational fluid dynamics software Flow-3D ™, as well as physical modeling.

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 Unified Flume Calibrations

Principal Investigators:
Gary P. Merkley
Sathaporn Temeepattanapongsa (Student)

Partners/Collaborators:
- *None*

Project Description

- Need and Purpose:

  Over the long term, water shortages and water quality issues in Utah will continue to increase problematic become more severe in the future. Good water management requires the ability to measure flow rates, yet the capacity to measure discharges in canals is very limited in most open-channel conveyance and distribution systems in Utah. For example, free-flow calibrations are often used when flumes operate under submerged-flow conditions, which results in large measurement errors due to a lack of understanding of the flow regimes in flumes. Laboratory experiments showed that there is no single value of transition submergence for each flume size, even though this has been the assumption and practice for several decades.

  Previous work using UWRL experimental data showed how a single equation could be used for a 3-ft Cutthroat flume. Since Cutthroat, Parshall, and many other flume geometries use the same calibration equations, the findings can logically be extended to those flume types.

  This project will generate calibration data over a range of submergences, and analyze those results to come up with unified (free and submerged) calibration equations for each standard flume size, and for all Cutthroat flume sizes (standard or not), if possible. The results will be verified using existing experimental data, especially for free-flow conditions. Finally, the results will be applied to flumes in irrigation canals in Utah and elsewhere, eliminating the confusion and errors associated with distinctions between free and submerged flow, and will improve calibrations by eliminating the need to determine transition submergence.

- Benefits to the State:

  The State of Utah will benefit through an improved ability to calibrate Cutthroat flumes in irrigation and other canals. The new calibrations will combine free and submerged flow regimes into a single equation, thereby improving the ability to correctly measure discharges in irrigation and other canals for purposes of water management, water rights, and water quality analyses.

- Geographic Areas:

  Study Area: Cache Valley, Utah.

  Areas Benefited: Most of the State of Utah.

- Accomplishments:

  Findings: Several hundred 3-D hydraulic simulations have been completed and the results have been compared with laboratory and field data. It has been found that mathematical relationships can be defined for free flow conditions in all sizes of Cutthroat flumes.

Results: Standardized relationships have been developed for free-flow and unified (free and submerged flow) conditions for any size of Cutthroat flume, including intermediate sizes.

Work Plan FY12/FY13

The project was completed in May 2012.

Informational Resources

Publications:

One refereed technical manuscript was prepared and submitted in January 2012, and is currently under final review. A second manuscript was under preparation in July 2012.

Contact: Gary P. Merkley, Phone: 435-797-1139, E-mail: gary.merkley@usu.edu.

Website: http://www.engineering.usu.edu/htm/faculty-expertise/memberID=8850.

Remote Control for the Crockett Canal Head Gates

Principal Investigators:
Gary P. Merkley
Tyler Richards (Student)

Partners/Collaborators:
- **Local:** *Logan canal companies and City of Logan*

Project Description

- Need and Purpose:

  The objective of this project was to provide design and installation services to the affected canal companies for remote control of the Crockett Canal head gates, thereby permitting faster closing of the gates when rain begins to fall during the irrigation season. When a sudden rain occurs, it is imperative that the gates be closed as quickly as possible to discontinue Logan River water from entering the canal, thereby increasing the capacity to accept storm-water runoff and avoiding canal overtopping and subsequent water damage to adjacent properties. But this is difficult to do when the water masters or other canal company personnel are far from the head gates. For years, the canal companies have asked for assistance with the design and installation of a remote-control system for these gates, facilitating their timely closing at the onset of a precipitation event during the irrigation season (April to October each year).

- Benefits to the State:

  The proposed work has directly led to improved water management in several of the most important Cache Valley, Utah, irrigation canals and will greatly help alleviate storm-water runoff issues on properties near the canals. This benefits all of the canal water users, as well as the City of Logan and other neighboring cities through improved capability to deal with storm water runoff.

- Geographic Areas:

  Study Area: Cache Valley, Utah.

  Areas Benefited: Cache Valley, Utah.

- Accomplishments:

  Findings: Project work involved extensive collaboration with Logan canal company representatives, including many site visits. Findings include alternative head gate designs and budgets. The canal companies have approved a recommended design, and will purchase the equipment with their own funds.

  Results: The systems have been designed for gate automation and remote control and monitoring. Currently, Logan City approval of the designs was obtained, and the Crocket Canal Company began procurement and installation of the equipment.

Work Plan FY12/FY13

The project was completed on December 31, 2011, and a report was prepared about the project accomplishments.

Informational Resources

Contact: Gary P. Merkley, 435.797.1139, E-mail: gary.merkley@usu.edu.

Website: http://www.engineering.usu.edu/htm/faculty-expertise/memberID=8850.

Sediment Management for Small Reservoirs: Logan First Dam Study

Principal Investigators:
Amber S. Jones
Mac McKee

Partners/Collaborators:
- ***Local:*** *Ben Barrett, Stan Kane, and Reid Olsen, Utah State University Facilities*
- ***State:*** *Jeff Ostergaard, Utah Department of Environmental Quality*

Project Description

- Need and Purpose:

  Sediment eventually fills reservoirs, quickly in some cases, but usually not for many years. In percentage terms, the highest rates for loss of storage are found in the smallest reservoirs, while the lowest rates are in the largest reservoirs. The life span of a reservoir is determined by the rate at which sediments reduce the storage capacity. One way to preserve reservoir storage is to flush or sluice sediments through outlet works within the dam. When this is done, however, severe damage can be done to valuable downstream fisheries and fish habitat.

  Research on sediment management methods has focused almost exclusively on maintaining reservoir capacity and extending the economic lifespan of the dam. Little work has been done to understand the downstream consequences that flushing or sluicing might have on biotic resources. This project is creating a set of guidelines intended to help develop sediment management plans for small run-of-river reservoirs in Utah. The objective of such plans is to minimize the negative consequences of sediment flushing or sluicing on downstream aquatic resources and water quality.

- Benefits to the State:

  The state will benefit from the guidelines that will be made available for all managers of run-of-river reservoirs in Utah. Properly applied, the guidelines will help reservoir operators minimize the negative consequence of sediment flushing or sluicing on downstream aquatic resources, water quality, and water users. It will also allow water managers to extend the life of the run-of-river reservoirs in Utah.

- Geographic Areas:

  Study Area: First Dam on the Logan River and the Logan River Basin above First Dam.

  Areas Benefited: Small run-of-river reservoirs throughout the State.

- Accomplishments:

  Findings: We have learned several things from the flushing experiments conducted on First Dam:

  - Monitoring must happen during flushing/sluicing events in order to evaluate the performance of the event and to control the flushing/sluicing procedures during the event.

  - River flow is the main factor in terms of planning for a flushing experiment.

- During a flushing event, close attention must be given to flow data from real-time sites in order to verify that the hydraulic conditions required by the reservoir outlets are being met by the prevailing flow levels into the reservoir.
- For the several days that a flushing/sluicing event is conducted, available river flow forecasts must be periodically examined to better anticipate future flow conditions and regulate hydraulic operations at the dam.
- Outflows from the hydraulic structures on the dam must be monitored during flushing/sluicing events to ensure that the required hydraulic conditions are being met and maintained.
- During a flushing/sluicing event, estimates of the load entering and leaving the reservoir should be made in order to evaluate the performance of the procedures that were followed during the event.

Results: Mean annual sedimentation rates at First Dam have been quantified to be about 0.5 acft/yr. Sluicing during high runoff periods in the spring has been shown to reduce the amount of sediment that stays in the reservoir and the amount of fine sediment that is deposited against the dam and in the area near the outlet works. Most importantly, the project has shown that, when properly monitored, sediment sluicing at First Dam can be conducted without jeopardizing downstream aquatic resources.

Sediment management guidelines for small reservoirs have been provided to the Utah Department of Environmental Quality for application in the state, and a sediment management plan has been developed for use by the managers of First Dam.

Work Plan FY12/FY13

Researchers at the UWRL will assist the operators of First Dam in conducting a sluicing event during spring runoff in 2013 and in providing records of these activities to the Utah Department of Environmental Quality. UWRL researchers will also work with UDEQ personnel to distribute the Sediment Management Guidelines more broadly across the state and to examine water quality policies to identify better regulatory approaches to sediment management.

Informational Resources

Contact: Dr. Mac McKee, (435) 797-3157, E-mail: mac.mckee@usu.edu.

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

Principal Investigators:
Steven L. Barfuss
Devan Shields
Jesse Pope

Partners/Collaborators:
- ***State:*** *James Greer, Utah DWR*
  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: 168 flow measurement device assessments have been performed as of July 29, 2012. These devices include 110 Parshall flumes, fifteen ramp flumes, one cutthroat flume, thirteen weirs, sixteen rated sections, three sluice gates, seven ultrasonic meters and five magnetic meters. Only thirty-two percent of the tested devices measured flow within manufacturer design specifications. The remaining sixty-eight 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 FY12/FY13

- 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: Mr. Steven. L. Barfuss (435) 797 3214, Email: steve.barfuss@usu.edu.
Mr. Devan J. Shields (435) 797 3231, Email: dev.j.shields@aggiemail.usu.edu.
Jesse Pope (435) 797 3231, Email: jesse.pope@aggiemail.usu.edu.

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	FY2012 Actual Expenditures	FY2013 Budgeted Expenditures	FY2014 Planned Expenditures
Agricultural Water Resources Management Training	$20,917.45	$21,544.97	$0.00
Development and Maintenance of the Bear River Watershed Information System	$8,952.36	$9,220.93	$0.00
Enhancement of Septic System Educational Programs in Utah with Advanced Training	$5,380.59	$5,542.01	$5,708.27
Intermountain Section American Water Works Association (IMS-AWWA) Scholarship and Student Outreach Committee	$1,000.00	$11,376.13	$0.00
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	$7,246.63	$7,464.29	$7,688.21
Statewide Nutrient Criteria Development: Core Advisory Team	$1,000.00		
Support for State Watershed Modeling and TMDL Plans	$25,741.33	$26,513.57	$27,308.93
UAV Development UDOT Applications	$51,620.40	$53,177.25	$0.00
Utah On-Site Wastewater Treatment Training Program	$30,000.00	$5,000.00	$6,000.00
Utah Water Education Project	$23,751.03	$24,463.61	$0.00
Weber-Morgan Health Department Wastewater Advisory Committee	$1,000.00	$0.00	$0.00
Designated Projects		$25,420.37	$10,000.00
Undesignated Projects		$7,500.00	$0.00
Total	**$177,618.09**	**$198,265.66**	**$67,766.66**

Agricultural Water Resources Management Training

Principal Investigators:
Gary Merkley
Mohammed Shaban

Partners/Collaborators:
- **Local:** *Utah farmers and irrigators*

Project Description

- Need and Purpose:

  Utah has experienced water shortages that, in the long term, tend to become increasingly problematic. Water quality problems are also becoming more prominent. Much of the emphasis in dealing with water scarcity and quality problems has been directed toward infrastructure and technological improvements. Little has been done with regard to improved training tools that can be used to promote more complete understanding of the problems faced by farmers and the difficult operational decisions they face with respect to water management. In fact, many of the problems related to water delivery design and operation for agricultural irrigation are due to a lack of understanding of agricultural irrigation by policy makers, administrators, and others.

  Intelligent and heuristic simulation tools in the form of a game can simulate field experience and show the effects of decisions for a variety of situations. This understanding can lead directly to improvements in delivery system operation, design of delivery systems, and on-farm water management.

- Benefits to the State:

  The State of Utah will benefit through an improved capability to deliver effective training in the form of short-term workshops and seminars. The attendees will receive an in-depth understanding of the problems and decisions faced by irrigators and farmers. This improved understanding is expected to lead to improvements in the management of water for agricultural irrigation.

- Geographic Areas:

  Study Area: Cache Valley, Utah.

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

- Accomplishments:

  Findings: The model has shown an ability to determine the best irrigation management for a simulated growing season and work continues at present.

  Results: A publication on the model design from 2010, and a PhD dissertation that was approved in May 2012.

Work Plan FY12/FY13

The study has been completed. A manuscript has been drafted and is undergoing editing in July 2012.

Informational Resources

References:

Shaban, M.Z. and G.P. Merkley (2010). Training tool for on-farm water management using heuristic simulation software. *Paper presented at the USCID*, Ft. Collins, CO., Sept 28-Oct 1.

Marjang, N., G.P. Merkley, and M. Shaban. (2011). Center-Pivot Uniformity Analysis with Variable Container Spacing. *Irrig. Sci.* (published on-line March 3, 2011). DOI 10.1007/s00271-011-0272-6.

Contact: Gary Merkley, 435.797-1139, E-mail: gary.merkley@usu.edu.

Website: http://www.neng.usu.edu/bie/faculty/merkley/.

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 a new 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). We have recently transitioned the source code for the Bear River WIS 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 FY12/FY13

In the coming year, 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. We will add additional information and datasets as they become available. We have completed the migration of the WIS to a standardized content management system to simplify its maintenance, to ensure its sustainability, and to open up opportunities for collaborators and contributors outside of USU. 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

Enhancement of Septic System Educational Programs in Utah with Advanced Training

Principal Investigators:
Judith L. Sims
Brian Cowan
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, ground water, 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 that have higher organic or hydraulic loadings 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 2012-2013, after regulatory changes to Utah's on-site wastewater program have been adopted in early 2013.

  Areas Benefited: all 29 counties.

- **Accomplishments:**

  Findings: Information is not at this time readily available in Utah 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 addressing advanced site evaluation techniques and operation & maintenance of alternative systems.

Work Plan FY12/FY13

During FY12-13, 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). Currently there are four scholarships: undergraduate ($1,000), 2 graduate ($1,500 each), and diversity ($1,000). The committee is also working to integrate water topics into the Utah K-12 education curriculum.

- **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 2011 semester. These students are all from Utah State University. The committee developed significant outreach and fund-raising plans. A total of 29 applications were received this year, which was more than a 50% increase from 19 applicants in 2010-2011. One additional scholarship was endowed this year, increasing the number from 3 to 4 scholarships.

Work Plan FY12/FY13

Participation in IMS-AWWA meetings and activities will continue. At least four scholarships will be awarded in Fall Semester 2012. 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.

Informational Resources

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

Website: http://www.ims-awwa.org/scholarships/Scholarship_Win.html.

Salt Lake Valley Solid Waste Management Council

Principal Investigators:
R. Ryan Dupont

Partners/Collaborators:
- ***Local:*** *Patrick Leary, 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. A recent example of this special project request is 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 FY11-12 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 FY12/FY13

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.

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 throughout FY11-12 and provided review and comment on all Board items relevant to his area of expertise.

Work Plan FY12/FY13

Continue involvement in decision-making through attendance at monthly Solid and Hazardous Waste Control Board meetings and associated facility tours, and provide technical input and program review for relevant State Solid and Hazardous Waste programs.

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 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 statistical analysis of existing nutrient water quality data available in the state with the intent of recommending standards for various ecosystems of the state.

Work Plan FY12/FY13

It is anticipated that Dr. Sorensen will continue to serve as member of the team in FY12/FY13.

Informational Resources

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

Support for State Watershed Modeling and TMDL Plans

Principal Investigators:
Bethany T. Neilson

Partners/Collaborators:
- ***Local:*** *Jenni Oman, Salt Lake County*
  Florence Reynolds, Salt Lake City
- ***State:*** *Hilary Arens and 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. Many local governments also create watershed management plans. In order to complete these steps, some sort of watershed and/or instream water quality model is necessary.

- **Benefits to the State:**

  States are tasked with developing the TMDL plans, but often lack the expertise necessary to conduct the modeling studies. Additionally, they may lack the understanding necessary to design the monitoring studies to support the modeling efforts. These efforts provide guidance to DEQ 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, and State of Utah.

- **Accomplishments:**

  Findings:

  Jordan River TMDL Modeling Review: Based on 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. Additionally, a journal article was submitted based on this work and is currently under revision.

  Jordan River Temperature Modeling: Work has been nearly 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.

Results:

Jordan River Temperature Modeling and Statewide Wasteload Allocation Study: We have completed data collection and the associated instream water quality modeling for 9 streams below various wastewater treatment plants throughout the state. These models will be used by the DWQ within the context of developing nutrient criteria for the state of Utah and are currently being used in development of waste load allocations for various water reclamation facilities. Two conference presentations have resulted from a master's student and the thesis work along these lines is nearly complete.

Work Plan FY12/FY13

Over the next year, I will continue technical support to the State of Utah through the Jordan River Temperature Modeling and Statewide Wasteload Allocation studies.

Informational Resources

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

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 (Under revision). A Collaborative Approach to Calibration of a Riverine Water Quality Model. *Journal of Water Resources Planning and Management*.

Jordan River Temperature Modeling and Statewide Wasteload Allocation Study

Hobson*, A.J. and B.T. Neilson (2011). Investigating the effects of data resolution on QUAL2K predictions. *Utah State University Spring Runoff Conference 2011*. Logan, UT, March.

Hobson*, A.J., B.T. Neilson, and N. von Stackelberg (2012). Can consistent data collection and modeling strategies provide the information necessary to address instream water quality impairments? *Utah State University Spring Runoff Conference 2012*. Logan, UT, March.

UAV Development for UDOT Applications

Principal Investigators:
Steven L. Barfuss
Austin Jensen

Partners/Collaborators:
- ***State:*** *Utah Department of Transportation*

Project Description

- Need and Purpose:

  The purpose of this project is to further develop existing Unmanned Aerial Vehicle (UAV) technologies as they apply to State Departments of Transportation. Specifically, the research objective focuses on critical State highway and road issues where high resolution imagery from UAV systems is most appropriate. The project focuses have included:

  1. Monitoring wetland areas and regions of invasive plant species that are located along known DOT corridors.
  2. Photographing highway construction projects before, during, and after for safety, design, and decision-making purposes.
  3. Locating highway structures required for UDOT inventories.

- Benefits to the State:

  This project is providing UDOT with additional tools for inventorying, evaluating, and monitoring highway corridor wetlands, construction, and associated roadway structures. The project provides UDOT with high resolution images from the UAV that can be imported to UDOT GIS databases, avoiding the long intervals associated with standard aerial imagery updates. Using USU-developed software, the high resolution images can specifically be used to determine the extent of different wetland species within UDOT highway corridors so that much more economical wetland mitigation decisions can be made. The high resolution images also allow new highway construction areas to be viewed before construction begins, during the construction, and then again when it is completed. This process of acquiring multiple images at different times during construction projects allows UDOT officials to monitor construction projects for efficiency and safety, while also producing a historical record of the project.

- Geographic Areas:

  Study Area: Southern Parkway Freeway construction project (located south of St. George, Utah) and the proposed Vineyard highway alignment (located between I-15 and Utah Lake).

  Areas Benefited: State of Utah, with application to all states in the U.S.

- Accomplishments:

  Findings: As expected, the new construction phase of this project was extremely successful. The full length of the Southern Parkway was flown prior to construction, in the middle of construction, and then again after the construction of the freeway segment was completed. The Southern Parkway, located near St. George, Utah starts at the I-15 interchange and ends at the new St. George airport. For each flight, the set of images was stitched together in a single geo-referenced image that could be placed in Google earth or used as a UDOT GIS overlay.

The flights for the proposed Vineyard highway alignment near Utah Lake were performed for the purpose of classifying wetland plant species in UDOT's wetland mitigation bank near Utah Lake. The research showed that determining the difference between closely related wetland plant species by taking aerial photos is difficult especially when the plants are integrated together and not in a homogenous area. Several different analysis methods were used with varied results.

Results: The Southern Parkway images allowed researchers to visualize the highway construction progress, construction staging areas, and cut and fill regions. The high-resolution imagery allows for immediate updating of UDOT GIS databases, documentation and inventorying of roadway signage and other highway structures, and a historical record of the construction. It is apparent that he UAV can become not only a tool to learn from the past, but a real-time tool for use in the construction process. It is expected that if an UAV were allowed in the future to traverse a construction zone at regular intervals during the construction process, additional benefits such as determining the best methods for passing traffic safely through the construction zone could be realized.

During the Utah Lake wetlands mitigation bank phase of the project, it was determined that *Agrostis*, Baltic rush, *Phragmites* new, *Phragmites* old, and saltgrass were the most accurately classified plant species, while beaked sedge and narrowleaf/broadleaf cattail had the lowest classification accuracy. The accuracy errors seen during the classification process may have resulted from several possible causes: insufficient number of ground samples, insufficient number of ground control points, need for greater overlap in the aerial images, too coarse of GPS ground sample data in relation to image pixel size, possibility of multiple plant species in many of the ground-truthing polygons, accuracy of the seeding tool that was used, potential misalignment of the NIR to the RGB images, and time of the season in which the images were taken.

Figure 1. Supervised classification results of the Utah Lake Wetlands Mitigation Bank

Work Plan FY12/FY13

- The project was completed on June 30, 2012.
- The project has been submitted, reviewed, accepted and published online at UDOT.

Informational Resources

Contact: Mr. Steven. L. Barfuss (435) 797 3214, Email: steve.barfuss@usu.edu.
Mr. Austin Jensen (435) 797 3315, Email: Austin.Jensen@aggiemail.usu.edu.

Utah On-Site Wastewater Treatment Training Program

Principal Investigators:
Judith L. Sims
Margaret Cashell
Brian Cowan
Richard Jex

Partners/Collaborators:

- ***Local:*** *Utah's 12 Local Health Departments*
  Utah On-Site Wastewater Association (UOWA)
- ***State:*** *Division of Water Quality, Utah Department of Environmental Quality*
  Council of Local Environmental Health Directors (CLEHA)

Project Description

- **Need and Purpose:**

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

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

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

- **Benefits to the State:**

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

- **Geographic Areas:**

  Study Area: Entire State of Utah.

  Areas Benefited: The entire state (29 counties and 12 local health departments).

- **Accomplishments:**

Findings: A state legislative initiative introduced and passed as House Bill 14s during the 2001 Legislative Session mandated a certification program for persons involved in siting, designing, operating, and maintaining both conventional and alternative on-site systems. The certification program, administered by the Division of Water Quality in the Utah DEQ, involves mandatory training provided by the Utah On-Site Wastewater Treatment Training Program.

The certification program includes three levels, each of which requires workshops and testing provided through the Utah Training Program: (1) Level 1: Soil Evaluation and Percolation Testing, (2) Level 2: Design, Inspection, and Maintenance of Conventional Systems, and (3) Level 3: Design, Operation, and Maintenance of Alternative Systems.

Workshops are also provided for renewal of certification, as Level 1 and Level 2 certifications expire after 5 years and Level 3 certification expires after two years.

Results: During FY 2011-2012, two Level 1 workshops, two Level 2 workshops, and two Level 3 workshops were taught at various locations around the State of Utah, as well as five Level 1 renewal workshops, five Level 2 renewal workshops, and two Level 3 renewal workshops.

In cooperation with the Utah On-Site Wastewater Association, we co-sponsored a conference on Utah on-site wastewater treatment issues at the Davis Applied Technology College February 8-9, 2012 in Kaysville, Utah. Topics included nutrient impacts from septic systems, gray water reuse systems, proposed Utah on-site program regulatory changes, health department on-site program updates, and drinking water source protection issues.

Work Plan FY12/FY13

We will continue to provide workshops in support of the mandatory State of Utah certification program for on-site wastewater professionals.

Informational Resources

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

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

References:

Sims, J.L., M. Cashell, B. Cowan, and R. Jex (2011, 2012). Course Manuals for Levels 1, 2, and 3 Certification. Utah Water Research Laboratory, Utah State University, Logan, UT.

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.

- **Accomplishments:**

  Findings: The project has been underway for 14 months.

  Results: Over 800 photos have been selected for use in the project to date, with nearly 600 of those currently paired with written captions. Two hundred pre-1940 historical photos have been obtained to provide broader understanding of water use in Utah. University students are continuing to perform significant research to insure that short photo captions are accurate as well as educational. Preliminary website design for the project has begun and methods of distribution for the screensaver have been discussed. The photograph above is one example of the photos that will be used in the screen saver.

Work Plan FY12/FY13

- Continue literature reviews to research water-use patterns and water resources in each county.
- Continue to collect water-related photos that meet the project criteria to help educate people about water in Utah. Photos are either donated or provided through freelance photographers.
- 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 displaying the photos on individual computers.

Informational Resources

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

Weber-Morgan Health Department Wastewater Advisory Committee

Principal Investigators:
Darwin L. Sorensen

Partners/Collaborators:
- ***Local:*** *Brian Cowan, Weber-Morgan Health Department*

Project Description

- **Need and Purpose:**

  The committee's purpose is to provide scientific, technical, and socioeconomic information to the Health Department staff that will inform their decisions and counsel to the Board of Health relative to the use of on-site (e.g., septic system) wastewater treatment and disposal. Staff members of the Weber-Morgan Health Department who deal with on-site wastewater issues bring technical and technically-related policy issues to the wastewater advisory committee for advice. The committee comprises representatives from local government, land developers, consulting engineers, the Central Weber Sewer Improvement District, the Utah Geological Survey, and academia (Utah State University). The committee meets on an as-needed basis. Resolving conflicts between environmental protection policies, technical practice, and/or costs and benefits in the face of scientific uncertainty can be challenging for decision makers. A multidisciplinary evaluation of the issues and possible solutions, as is possible with the committee, can inform decisions about site specific applications of policy and technology.

- **Benefits to the State:**

  The Weber-Morgan Health Department serves all of Weber and Morgan Counties. The wastewater advisory committee was formed to provide technical advice to the staff of the Department and to the Board of Health. Some actions of the committee may provide guidance to other local health departments.

- **Geographic Areas:**

  Study Area: Weber and Morgan Counties.

  Areas Benefited: Weber and Morgan Counties.

- **Accomplishments:**

  Findings/Results: Historically, most issues addressed by the committee have been related to variance requests by citizens seeking to develop privately owned land that is not suitable for development under current Health Department rules. In these cases, the committee considers the scientific and public health protection principles underlying the rule and seeks to find ways for the land to be used without jeopardizing public health and environmental quality. This is possible in some situations when more detailed site information is made available and appropriate treatment technologies can be employed. In other situations, the committee advises against allowing a variance. Over its history the committee has considered a broad range of water quality protection issues including septic system densities in western Weber County and the development or redevelopment of relatively small plots in the environmentally sensitive Ogden and Weber River Canyons.

Work Plan FY12/FY13

It is anticipated that Dr. Sorensen will continue to serve as member of the committee in FY 12-13.

Informational Resources

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

Water Resources Planning and Management

Actual, Budgetee, and Planned Expenditures of Mineral Lease Funds
Water Reseurces Planning and Management

Projeet Neme	FY2012 Actual Expenditures	FY2013 Budgeted Expenditures	FY2014 Planned Expenditures
Advanced Statistical Learning Techniques for Predicting Water Levels in the Great Salt Lake (Extended to Include Utah Climatic Analysis Using Atmospheric-Oceanic Oscillations)	$19,510.89	$3,500.00	$0.00
Allocating Scarce Water for Utah Wetlands with Ecological Uncertainties	$26,499.79	$20,000.00	$0.00
ASR Optimization Protocol and Decision Support	$20,636.77	$40,000.00	$40,000.00
Effects of Rotenone Treatment for Removal of Non-Native Fish on the Macroinvertebrate Assemblage of Boulder Creek, Utah	$22,133.13	$0.00	$0.00
Estimating Real-Time and Seasonal Crop Evapotranspiration of Large Irrigated Systems at Different Spatial Scales	$4,012.92	$4,012.92	$0.00
Finding Appropriate Complexity for Distributed Hydrologic Model	$43,105.46	$44,396.62	$0.00
Flood Potential Due to 100-Year Storm Events for Small Utah Cities	$9,426.93	$9,709.74	$0.00
Improving Hydrologic Model Prediotions for the Effects of Land Use and Climate Change	$25,129.91	$25,000.00	$0.00
Integrating High Frequency Monitoring with High Resolution Modeling in the Little Bear River	$32,724.14	$5,201.91	$0.00
Interstate Movement of Bonneville Cutthroat Trout	$20,714.35	$5,000.00	$0.00
Irrigation System Water Use Efficiency Using Field Evaluations and Remotely Sensed Evapotranspiration Estimates	$20,046.97	$20,000.00	$20,000.00
Lake Fork / Uintah River System Optimization Review	$600.00	$92.03	$0.00
Low Oost Vertioal Take Off and Landing Remote Sensing Systems for Water Engineering	$57,949.53	$59,636.02	$13,909.18
Multispectral Image Processing for Water Management and Other Agricultural Applications	$7,199.16	$7,199.16	$0.00
Multispectral UAV Collaborative Remote Sensing System for Irrigation Water Management and Ecological Assessment	$133,149.61	$137,144.30	$70,000.00
Pineview Reservoir Operations and Algae/Cyanobacterial Bloom Ecology	$157,736.65	$20,000.00	$0.00
Quantifying the Flow Field in Baffled Fish Culverts	$28,005.61	$194.79	$0.00
Real-Time Management of Irrigation Systems in the Sevier River Basin	$143,833.99	$160,000.00	$150,000.00
Restoration of Interstate Migration Routes for Bonneville Cutthroat Trout	$2,360.67	$2,431.70	$0.00
Treated Wastewater Use in Agricultural Irrigation	$92.03	$94.79	$0.00
UAV Remote Sensing Service Center	$346,430.35	$150,000.00	$150,000.00
iUTAH - Innovative Urban Transitions and Aridregion Hydro-Sustainability	$2,000.00	$10,000.00	$15,000.00
Water Conservation and Managing Water Shortages	$13,315.16	$13,714.61	$0.00
Water Resources Modeling for Utah's Cache Valley	$32,401.62	$33,373.87	$33,373.87
Dedignated Projects		$576,774.16	$51,537.12
Undesignated Projects		$156,700.00	$0.00
Total	**$1,169,266.24**	**$1,504,220.62**	**$548,820.17**

Advanced Statistical Learning Techniques for Predicting Water Levels in the Great Salt Lake (Extended to Include Utah Climatic Analysis Using Atmospheric-Oceanic Oscillations)

Principal Investigators:
Gilberto E. Urroz
Niroj K. Shrestha (Student)

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

Project Description

- Need and Purpose:

  Accurate prediction of Great Salt Lake (GSL) levels may improve water resources management in the GSL basin. Statistical Learning Techniques utilize computer models for predicting GSL water levels, and their applications have been extended to the study of the relative influence of oceanic-atmospheric oscillations in Utah climate as reflected in streamflow in selected Utah rivers.

- Benefits to the State:

  Accurate prediction of Great Salt Lake (GSL) levels would help GSL shareholders, such as the Utah Division of Water Resources and the municipal and county governments in the counties of the Great Salt Lake, as well as industries in the shoreline in terms of planning, development, and emergency response. The analysis of Utah's climate improves understand of climatic patterns in the state of Utah in relation to water flows in major rivers in the state. This information is useful for river basin stakeholders, and for a better understanding of general climatic patterns in the state.

- Geographic Areas:

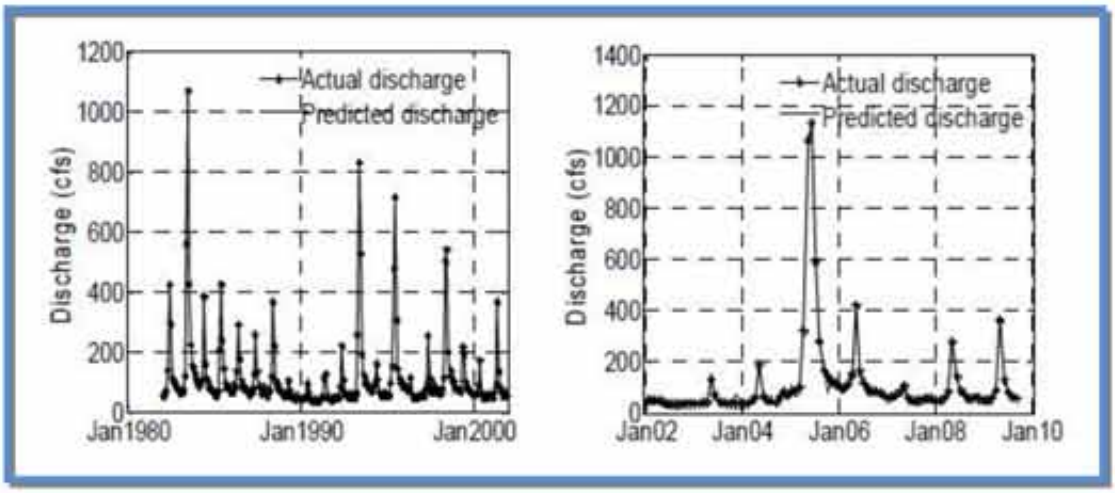
  Study Area: Great Salt Lake, Weber River, Sevier River, and Western Colorado River basins.

  Areas Benefited: Great Salt Lake basin, Box Elder, Weber, Davis, Salt Lake, and Tooele counties, along with counties in the Weber River, Sevier River, and Western Colorado River basins.

- Accomplishments:

  Findings: Statistical techniques were used to predict (1) GSL levels, (2) six-month lead-time predictions of streamflow, and (3) long-term predictions of streamflow in selected streams in Utah. This was accomplished by "training" computer programs using existing GSL water level data provided by the Utah Division of Water Resources, and streamflow and climatic data from other sources for the state of Utah. The FY 11-12 work for this project focused mainly in applying Multivariate Relevance Vector Machines (MVRVM) to the prediction of the quantities indicated above.

  Results: The following graphs illustrate the results of MVRVM applications for predicting flow rates on the Sevier River at the Hatch gage station using a six-month lead time for two different time periods: Jan 1980 – Jan 2000 and Jan 2002 – Jan 2010.



Both graphs show that the predictions follow the general trend of the observed discharges, thus indicating that Statistical Learning Techniques such as MVRVM can be used for predicting six-month-lead discharges with a high level of confidence. Similar results were obtained for the long-term lead in predicting discharges, as well as in applications related to predicting the levels of the Great Salt Lake.

Work Plan FY12/FY13

This project is complete. Other than producing publications, no additional work is expected for FY12/FY13.

Informational Resources

Contact: Dr. Gilberto E. Urroz, (435) 797-3379, E-mail: gilberto.urroz@usu.edu.

References:

Shrestha, N.K. (2012). *Identification of Influential Climate Indicators, Prediction of Long-term Streamflow and Great Salt Lake Elevation Using Learning Machine Approach*. Ph.D. Dissertation, Utah State University, Logan, UT.

Shrestha, N.K. and G.E. Urroz (submitted January 2012, pending revision). Machine Learning Regression Approach for Prediction of Great Salt Lake Water Surface Elevation. *Journal of Hydrology*, Elsevier.

Shrestha, N.K., M. McKee, and G.E. Urroz (In preparation). Bayesian Machine Learning Regression Approach for Identification of Influential Sea Surface Temperature Locations and Prediction of Streamflow for the Next Six Months in Utah. To be submitted to *Water Resources Research*.

Shrestha, N.K., M. McKee, and G.E. Urroz (In preparation). Long Lead-Time Streamflow Forecasting and Identification of Relative Influence of Oceanic-Atmospheric Oscillation Modes in Utah Using Bayesian Machine-Learning Regression. To be submitted to *Water Resources Research*.

Allocating Scarce Water for Utah Wetlands with Ecological Uncertainties

Principal Investigators:
David E. Rosenberg
Karin M. Kettenring,
Christopher M.U. Neale
Omar Alminagorta (Student)
Melina Santos Vanderlinder (Student)

Partners/Collaborators:

- **Local:** *Al Trout, Friends of Bear River Refuge; Joan Degiorgio, The Nature Conservancy; Bryan Dixon, Bear River Land Conservancy*
- **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 the western U.S. and Utah, water is typically scarce and not sufficiently available to flood and maintain habitats that can support wetland 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 the response of bird populations or the area covered by native plant species to water allocations are often uncertain.

  This project is extending systems modeling and ecological experiments 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 that 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* (common reed, hereafter *Phragmites*), a non-native, invasive grass, to changing water levels. We are using 1992 and recent 2010 aerial photographs and satellite images to inventory *Phragmites* coverage at the Refuge and relate changes to historical Refuge water level readings.

- **Benefits to the State:**

  The project is benefiting 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 the 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. Ultimately, this understanding will help Utah wetland managers to better manage wetlands to support the hunting, birding, and recreation that are vital to the Utah communities that border the Great Salt Lake. Finally, the project is integrating systems modeling, ecology, invasion ecology, and remote sensing and showcases Utah as taking a new approach to natural resource management.

- **Geographic Areas:**

  Study Area: Bear River Migratory Bird Refuge, north shore of the Great Salt Lake, Box Elder County, Utah.

  Areas Benefited: Wetlands through the state of Utah.

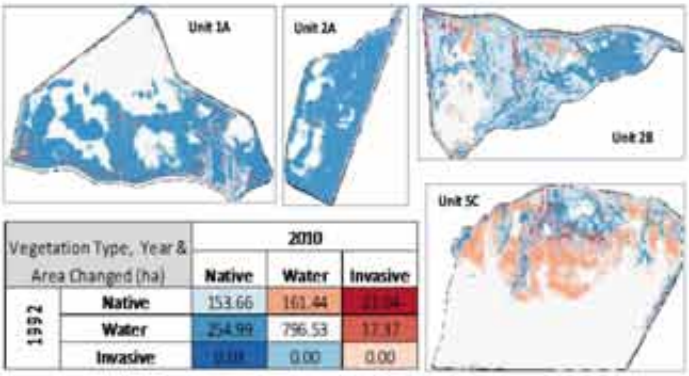
- **Accomplishments:**

  Findings and Results:

  - There are opportunities to improve water management and substantially increase wetland performance measured as the weighted usable area for wetlands (Table 1).
  - Water availability and vegetation response factors influence wetland performance more than the budget available for management (Table 1).
  - Invasive vegetation like *Phragmites* (Figure 2, dark red) is replacing native species in and around water delivery canals.
  - Preliminary results were presented to Refuge managers and their feedback was solicited and incorporated.

Table 1. Refuge systems model results when perturbing water availability and financial budget inputs

	Scenario	Inputs: Water Availability (year)	Inputs: Budget ($1000/year)	Result: Weighted Usable Area (km²/year)
	Base case	2008	180	564
1	Simulation	2008	180	288
2	Dry conditions	1992	180	463
3	Wet conditions	1997	180	697
4	Increase budget by 50%	2008	270	586
5	Decrease budget by 50%	2008	90	553
6	Increase vegetation response 15% per year	2008	180	452
7	Increase vegetation response 50% per year	2008	180	322



Vegetation Type, Year & Area Changed (ha)		2010 Native	2010 Water	2010 Invasive
1992	Native	153.66	161.44	21.94
	Water	254.99	796.53	17.97
	Invasive	0.00	0.00	0.00

Figure 2. Vegetation changes in 4 Refuge wetland management units from 1992 to 2010.

  - We re-submitted a $1,500,000 proposal to National Science Foundation (NSF) Dynamics of Coupled Natural and Human Systems (CNH) program to extend work to ecological uncertainties.
  - Dr. Rosenberg was awarded a $410,000 NSF CAREER grant for follow-up work on near-optimal management for environmental purposes in the lower Bear River basin.
  - Near-optimal algorithms were developed for linear and integer problems.

Work Plan FY12/FY13

- Submit for publication three peer-reviewed journal articles on systems modeling, vegetation change, and near-optimal solution algorithms to improve management.
- Quantify *Phragmites* response to changing water levels and embed this hydro-ecological relationship in the wetland systems model.
- Finish developing near-optimal algorithms for convex, non-linear problems; develop ecological performance indicators for riparian areas; measure performance indicators during Bear River trip with incoming freshmen; convene technical advisory committee to review near-optimal and performance indicator work.

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.

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 thinks they are physically able to recover more injectate than they receive credit for, and wishes 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 (inject 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) how much injectate the recharging organization can physically recover, and how much credit the State Engineer might give to the recharging organization and (2) 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:**

  - Obtained a 1998 report from JVWCD, prepared by CH2MHILL, concerning head contours resulting from assumed pumping strategy of ASR wells.
  - Reviewed 1998 CH2MHILL report on ASR wells.
  - Submitted questions to Bowen-Collins and USGS concerning calibrated flow models used for Salt Lake Valley and area near the ASR system.
  - Acquired from the USGS 1995 calibrated groundwater flow, 1995 particle tracking, and 1996 transport simulation reports and models used for Salt Lake Valley and area near ASR system
  - Acquired 1996 CH2MHILL report and groundwater flow model that has a finer mesh but otherwise uses the same data as the USGS Modflow model
  - Reviewed the reports and models of USGS and CH2MHILL by running the models and verifying the consistency between reported and simulated results
  - Selected the CH2MHILL flow model of 1996 to be used for this project
  - From JVWCD, acquired construction and pumping information about ASR system
  - For hypothetical ASR wells and injection/extraction strategies, evaluated the effect of alternative aquifer parameters on the percentage of recovered injected water. Presented results in April 2012 at Utah State University's Spring Runoff Conference.
  - Reviewed optimization methods applicable to the project.
  - Obtained and became familiar with Groundwater Vistas software, the graphical user's interface for groundwater flow and transport simulation, used by CH2MHILL for above projects.

Findings and Results:

  - Obtained unusual transport model results for hypothetical ASR confined and unconfined situations. (When using an assumed tracer concentration in injected water, the subsequently extracted tracer mass might exceed the injected tracer mass). Reported this to code developer.
  - Performed extensive simulations to identify situations under which the mass anomaly occurs.
  - Determined that some JVWCD ASR wells exist in situations where computed mass anomaly is likely to occur.

Work Plan FY12/FY13

- Determine how to address the mass computation situation.
- Perform baseline simulations to demonstrate how the system currently responds to management.
- Based upon JVWCD comments, organize optimization model to be able to perform specific optimizations.
- 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: richard.peralta@usu.edu.

Effects of Rotenone Treatment for Removal of Non-Native Fish on the Macroinvertebrate Assemblage of Boulder Creek, Utah

Principal Investigators:
Chris Thomas

Partners/Collaborators:
- ***State:*** *Utah Division of Natural Resources*
- ***Business/Private:*** *Garkane Power*

Project Description

- Need and Purpose:

  In 2009, the East Fork of Boulder Creek was treated with Rotenone to remove the Brook Trout population that was present. The purpose of the project was to compare the aquatic macroinvertebrate assemblages before and after treatment to determine the impacts on the food sources needed by the native Colorado Cutthroat trout populations in Utah.

  The research focused on aquatic macroinvertebrate density and distribution in the East Fork of Boulder Creek in southern Utah. Macroinvertebrates are the main food source of cutthroat and other salmonid fishes. By examining the current density and distribution of macroinvertebrates, possible changes in the macroinvertebrate assemblage can be predicted in the presence of the Rotenone treatment as a means to protect wild fish populations from invasive species of planted fish. This information will allow prediction of possible effects on Colorado cutthroat trout populations due to changes in macroinvertebrate assemblage.

- Benefits to the State:

  This research benefits the state of Utah by providing information about the impacts of Rotenone treatment on macroinvertebrates that are the critical food base for endangered Colorado cutthroat trout.

- Geographic Areas:

  Study Area: East Boulder Creek Watershed, Garfield County, Utah.

  Areas Benefited: State-wide where cutthroat trout populations exist and Rotenone treatment is used to control invasive fish species.

- Accomplishments:

  Findings: All macroinvertebrates in the samples have been identified, and we are compiling results of the population assemblages to determine the complete effects.

- Results: Complete results and a report are forthcoming. At this point it appears that Rotenone has the most effects on Plecoptera, commonly known as stoneflies, and to the order Ephemeroptera, commonly known as mayflies.

Work Plan FY12/FY13

- Determine whether Rotenone affected macroinvertebrate populations in Boulder Creek.
- Include information with the final report to Garkane Power and the Utah Division of Natural Resources.

Informational Resources

Contact: Mr. Chris Thomas, (435) 797-1184, E-mail: chris.thomas@usu.edu.

Boulder Creek, Utah

Estimating Real-Time and Seasonal Crop Evapotranspiration of Large Irrigated Systems at Different Spatial Scales

Principal Investigators:
Christopher M. U. Neale
Hatim Geli (Post-doc)

Partners/Collaborators:
- ***Local:*** *Bear River Canal Company*
- ***State:*** *Utah Agricultural Experiment Station*
- ***Federal:*** *USDA-NRCS*
- ***Business/Industry:*** *Palo Verde Irrigation District*

Project Description

- Need and Purpose:

  Reliable estimates of crop evapotranspiration (ET) are needed for improved water management of large irrigation projects, irrigation scheduling, integrated water demand estimates at different canal command levels, and water rights adjudication and control. Improved and timely estimates of irrigation water demand can increase understanding of the water pathways within the irrigation system and identify water management and application efficiency improvements. For large canal-supplied irrigation systems in Utah, satellite imagery from sensors such as the Thematic Mapper on the Landsat satellite has the appropriate scale and is cost effective. The satellite imagery can be supplemented with airborne imagery for critical periods of crop growth if imagery is unavailable due to the presence of clouds. A modeling environment that can use multi-temporal and multi-sensor remotely sensed imagery for estimating spatial ET is needed.

- Benefits to the State:

  Improved water management can lead to water savings and potentially to improved water quality, as 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:

  Northern and central Utah and southern California.

  Study Area: Bear River Canal Company in Box Elder County and irrigated areas of Sevier County. Palo Verde Irrigation District in Southern California.

  Areas Benefited: All counties in Utah with irrigated agricultural areas and systems.

- Accomplishments:

  Findings: Spatial evapotranspiration estimated from a series of satellite imagery acquired over a growing season can be used to establish seasonal crop water use in large irrigated systems and 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 SETMI model was refined to use multi-temporal satellite and/or airborne multispectral and thermal infrared imagery. Both the TSM and SEBAL were programmed in this environment to estimate the

energy balance components from remote sensing and obtain spatial evapotranspiration of irrigated crops as well as riparian vegetated areas. A new method of processing and correcting measured scintillometer data for estimating sensible heat fluxes and deriving ET was applied to data collected in a Tamarisk dominated riparian forest at the Cibola Refuge, CA and in Richmond, UT. Remotely sensed evapotranspiration using satellite imagery was incorporated into a model to evaluate the water balance of the Palo Verde Irrigation District and the Bear River Canal Company.

Work Plan FY12/FY13

The project has ended but we will continue to publish results from the data collection effort and modeling in the refereed literature.

Informational Resources

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

References:

Taghvaeian, S. (2011). *Water and Energy Balance of a Riparian and Agricultural Ecosystem Along the Lower Colorado River.* Ph.D. Dissertation. Dept. of Civil and Environmental Engineering, Utah State University, Logan, UT 84322-4110.

Lecina, S., C.M.U. Neale, G.P. Merkley, and C.A.C. Dos Santos (2011). *Irrigation evaluation based on performance analysis and water accounting at the Bear River Irrigation Project (U.S.A.). Agricultural Water Management*, 98: 1349-1363

Hatim M., E. Geli, C.M.U. Neale, D. Watts, J. Osterberg, H.A.R. de Bruin, W. Kohsiek, R.T. Pack, and L.E. Hipps (In press). Improved Scintillometer-Based Estimates of Sensible Heat Flux using LiDAR-Derived Surface Roughness. *Journal of Hydrometeorology*.

Taghvaeian, S., and C.M.U. Neale (2011). Water balance of irrigated areas: a remote sensing approach. *Hydrological Processes*, 25(26) (Special Issue: SI):4132-4141.

Geli, H. and C.M.U. Neale (2012). Spatial EvapoTranspiration Modelling Interface (SETMI). Remote Sensing and Hydrology. *Proceedings of a symposium* held at Jackson Hole, Wyoming, USA, September 2010) (*IAHS Publ.*, 352:171-174.

Finding Appropriate Complexity for Distributed Hydrologic Models

Principal Investigators:
Luis Bastidas
Saket Pande, Technical University of Delft, Netherlands

Partners/Collaborators:
- ***Federal:*** *National Weather Service, Colorado Basin River Forecast Center*

Project Description

- **Need and Purpose:**

  This project explored the use of Statistical Learning Theory as a way to determine the optimal modeling framework in terms of the appropriate levels of detail, while at the same time producing good and robust simulations of runoff and soil moisture from fields. To achieve this, we developed a way to measure the complexity of the models, and at the same time, incorporate different scale observations such as point in situ measurements, small aircraft remote sensing observations, and satellite observations.

  The project aimed to reconcile two constraints in hydrologic modeling: 1) increases in the resolution of the terrain representations and 2) limitations in the number of parameters that can be properly identified at fine resolutions due to lack of information and huge computational requirements.

  The study was carried out using a simple hydrologic model for the development of the measure. An application of the simplified models to water resources in arid regions was also tested. Another application involved the use of the distributed Research Development Hydrologic Model (RDHM) from the National Weather Service with the help of the Colorado Basin River Forecast Center, located in Salt Lake City. These agencies have provided high resolution spatial data and have helped to implement the model in our Linux based computers.

- **Benefits to the State:**

  The study focused on semiarid regions and on mountainous areas with snow cover, which includes a significant part of the western United States and, in particular, the State of Utah. In the future the developed procedures can be applied to areas within the State. This will allow for better hydrological simulations, which in turn will mean better estimation of the water resources available.

- **Geographic Areas:**

  Study Area: Due to some limitations with the extent of radar coverage over the Utah area, and as a first approximation, we tested the procedures with data from the Durango River Basin, which is mostly located in Colorado but has similar hydrologic conditions to those observed in Utah.

  Areas Benefited: All areas in Utah and throughout the Intermountain West.

- **Accomplishments:**

  Findings/Results: We have developed a theoretical approach to quantitatively measure the complexity of simple models and have implemented a procedure to numerically evaluate the measure for more complicated physical representations (more complex models). This latter procedure is currently being tested. The results related to the complexity measure have been finalized and accepted for publication.

We have also implemented several patterns based similarity measures to evaluate the performance of distributed models. These measures are beyond the commonly used mean error functions. They are inherently multi-dimensional and multi-objective and are based on the mathematics of set theory and the so called Earth's Movers Distance. We have concurrently evaluated the discharge at various points, together with the snow water equivalent and snow cover values derived from satellite and gage observations. All the computer simulations have been finished. Currently, we are post-processing the results.

A paper and a book chapter on the application of parsimonious models to water resources have been published. A paper on the theoretical development of the complexity measure with simple hydrologic and water resource models is in press.

Work Plan FY12/FY13

Project completed.

Informational Resources

Contact: Dr. Luis Bastidas, (435) 797-8228, E-mail: luis.bastidas@usu.edu.

References:

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Pande, S., L.A. Bastidas, H.H.G. Savenije and A. K. Gosain (2011). A parsimonious hydrological model for a data scarce dryland region. *Water Resources Management*, Doi: 10.1007/s11269-011-9816-z.

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Bastidas, L.A., S. Pande, G. Schoups, and N. van de Giesen (2010). Hydrological model output space and prediction uncertainty. *AGU Fall Meeting*, San Francisco, CA, December.

Kim, J., L.A. Bastidas, and E.P. Clark (2010). Uncertainty evaluation and appropriate distribution of the RDHM in the Rockies. *AGU Fall Meeting*, San Francisco, CA, December 12-17.

Kim, J. and L.A. Bastidas (2011). A Comparative Distributed Evaluation of the NWS-RDHM using Shape Matching and Traditional Measures with In Situ and Remotely Sensed Information. *AGU Fall Meeting*, San Francisco, CA, December 5-9.

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 don't 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.

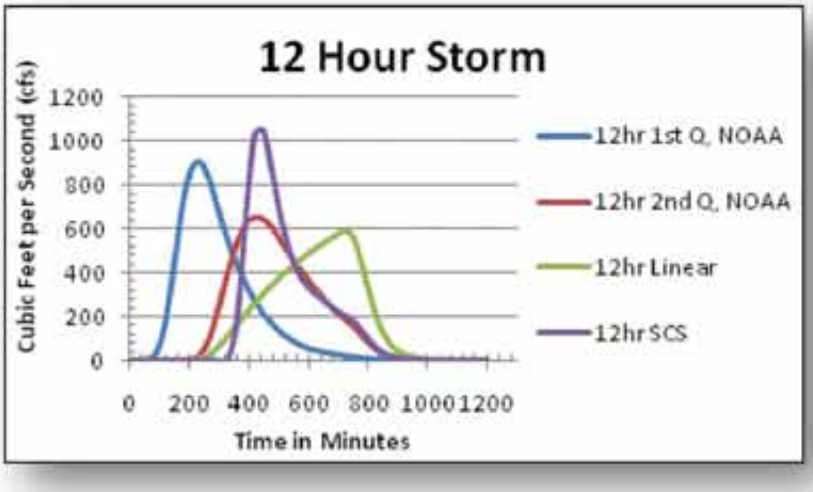
  Areas Benefited: This project will benefit all cities in the state that are experiencing growth and need data relative to planning for potential flood issues.

- **Accomplishments:**

  Studies Done: Currently, of the 138 identified study areas, 110 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 combines valley and mountain areas, soil and vegetation data needs to be specific to mountain regions only, which would improve the input data.

Work Plan FY12/FY13

- Complete the study area identification and perform a 100-year storm event analysis for each additional study area.
- Complete assembly of the data into a report, organized by county and city; distribute the report to the Utah Division of Water Resources and to cities 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:

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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 (Student)
Vinod Mahat (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. In the past statistical models have usually been used as a basis for predictions based on measurements of precipitation and snow. However, as conditions (land use and climate) change, the statistical basis for such predictions becomes diminished and there is a need for physically based 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 modeling that addresses the runoff produced from watersheds. It includes improvements in the capability to model snowmelt in vegetated areas as well as model the downstream impacts of this runoff on water resources and receiving water bodies such as the Great Salt Lake (GSL).

- **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. The Great Salt Lake is a critical resource in Utah, and its level is affected by runoff from surrounding watersheds. This project also addresses improving understanding of the dynamics of the Great Salt Lake.

- **Geographic Areas:**

  Study Area: The study area is the semi-arid Western U.S., particularly Utah, with a focus on watersheds draining into the Great Salt Lake.

  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) Improving the Utah Energy Balance Snowmelt model - specifically the way it represents vegetation and is able to quantify the sensitivity of snowmelt to variability in vegetation density and leaf area index, and 2) Understanding the dynamics of the Great Salt Lake. We address each of these in the results below.

Results: The energy balance that drives snowmelt is affected by the way solar and longwave radiation penetrate and interact with the vegetation canopy and 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 and Tarboton (2012) and Mahat (2011), demonstrate that the UEB model can correctly quantify the sensitivity of beneath canopy snowmelt to vegetation class consistent with observations and achieve satisfactory predictions of snowmelt from forested areas from practically available information. With respect to understanding the dynamics of the Great Salt Lake we have used historical data to examine the sensitivity of lake volume changes to precipitation, streamflow and evaporation and tie interactions among these involving lake area, volume and salinity. A mass balance model was developed to generate representative realizations of future lake level from climate and streamflow inputs simulated using the k-nearest neighbor method. Climate and salinity are used to estimate evaporation from the lake using a Penman model adjusted for the salinity dependent saturation vapor pressure. The results, reported in Mohammed (2012), show that fluctuation in streamflow is the dominant factor in lake level fluctuations, but that fluctuations in lake area, which modulates evaporation and precipitation directly on the lake, are also important. The results quantify the sensitivity of lake level to changes in streamflow and air temperature inputs, predicting, for example, that a 25% decrease in streamflow would reduce lake level by about 66 cm (2.2 ft), while a +4 °C air temperature increase would reduce lake level by about 34 cm (1.1 ft) on average. This sensitivity is important in evaluating the impacts of climate change or streamflow change due, for example, to increased consumptive water use on the level of the lake.

Work Plan FY12/FY13

In the current year we are moving from specific model aspects that predict effects of land use and climate change to more integrated modeling of the processes involved 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 whose goal is to Enhance Access to Data- and Computationally-Intensive Modeling. A first step in the work this year will include improvements in the parallel computation capabilities of terrain analysis preprocessing functions to support the configuration of integrated hydrologic models.

Informational Resources

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

References:

Mahat, V. (2011). *Effect of Vegetation on the Accumulation and Melting of Snow at the TW Daniels Experimental Forest.* Ph.D. Thesis, Civil and Environmental Engineering, Utah State University, Logan, UT. http://digitalcommons.usu.edu/etd/1078, 181 pp.

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Mohammed, I. (2012). *Relationships between Runoff, Land Cover and Climate in the Semi-Arid Intermountain Region of the Western U.S.A.* Ph.D. Thesis, Civil and Environmental Engineering, Utah State University, http://digitalcommons.usu.edu/etd/1158/, 307 pp.

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

Principal Investigators:
Jeffery S. Horsburgh
Amber Spackman Jones
Brant Whiting (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 are evaluating 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 seek to 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, where significant observational infrastructure has already been installed and 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 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. 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 in understanding and predicting hydrology and water quality within these systems.

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.

Work Plan FY12/FY13

We are continuing to refine 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 an alternative representation of snowmelt processes, which is critical for the Little Bear, but 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.

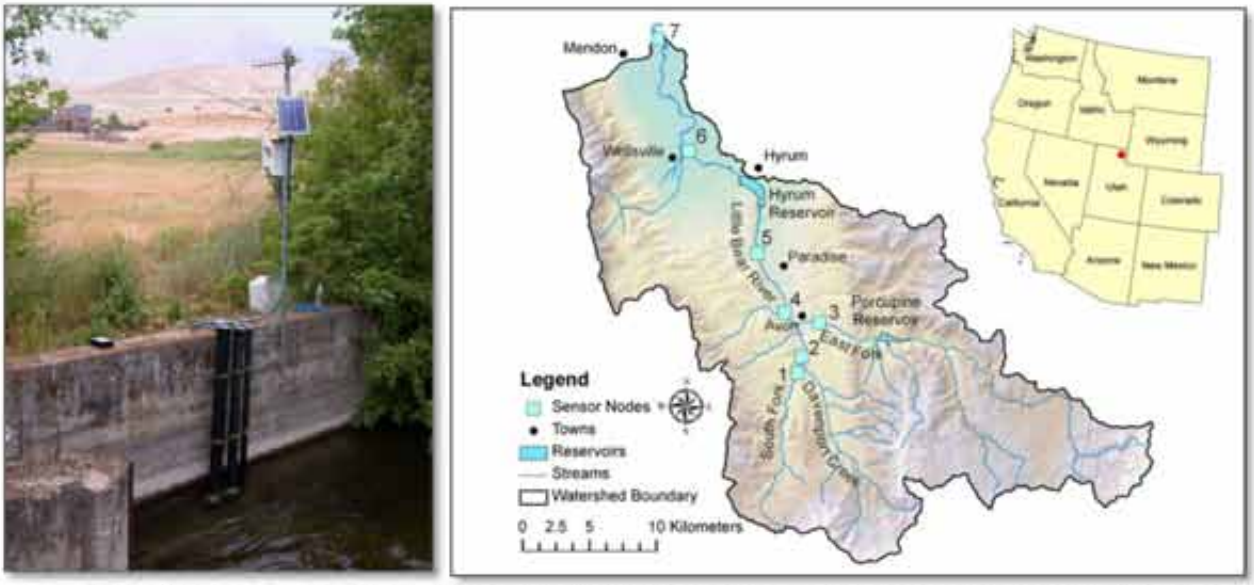


Figure 1. Continuous data collected at monitoring sites in the Little Bear River provide high frequency observations that are challenging the assumptions and process representations in our current suite of hydrologic models.

Interstate Movement of Bonneville Cutthroat Trout

Principal Investigators:
Casey Williams
Thomas B. Hardy

Partners/Collaborators:
- ***State**: Reed Harris – Utah Division of Natural Resources*
- ***Business/Private:** Warren Colyer and Kirk Dahle – Trout Unlimited*

Project Description

- Need and Purpose:

  Proposed construction of the Bear River Narrows Hydroelectric Project in southeastern Idaho has the potential to impact Bear River migration routes and Bonneville cutthroat trout distribution across the Utah/Idaho border, thereby impacting cutthroat trout populations in Utah. The proposed dam would inundate approximately 5 miles of the Bear River Narrows, much of which includes possible spawning and nursery grounds that support cutthroat trout populations in the Bear River. However, impacts to cutthroat trout in Utah related to dam construction are difficult to predict due to a lack of information pertaining to habitat availability and cutthroat trout distribution and migration patterns in the Bear River in both Utah and Idaho.

  This work focused on habitat delineation, cutthroat trout migration patterns and potential effects of impacts on the existing cutthroat population in the Bear River above and below the Utah/Idaho state line. Detailed habitat delineation, including mesohabitat measurements and hydraulic modeling, was conducted throughout the study area. In addition, a survey of current fish assemblage structure and Bonneville cutthroat trout distribution and migration patterns were conducted using accepted methods of fish collection and biotelemetry.

- Benefits to the State:

  This work will benefit the State of Utah by providing information to be used as a basis for conservation efforts of Bonneville cutthroat trout throughout its range. Specifically, information provided will help the state to meet the objectives of the Range Wide Conservation Agreement and Strategy for Bonneville cutthroat trout, Utah's Endangered Species Mitigation Program, and conservation efforts of Trout Unlimited. This study provided explicit information concerning migration and conservation of genetic diversity of interconnected local cutthroat trout populations within the metapopulation of the Bear River Geographic Management Unit.

- Geographic Areas: Bear and Cub Rivers, Cache County, Utah.

  Study Area: Cache County, Utah.

  Areas Benefited: Cache County and state-wide where Bonneville cutthroat trout populations exist.

- Accomplishments:

  Findings: Seasonal fish, habitat, and temperature surveys were conducted at five broad reaches of the Bear River in Idaho and Utah. During two years, thirty-three Bonneville cutthroat trout were implanted with telemetry tags and tracked throughout the year. Fish survey data and habitat analysis (including

temperature) indicate that the Bear River habitat within Utah is not capable of supporting Bonneville cutthroat for extended periods of time; however, the Bear River may act as a migration corridor among populations in the drainage.

Results: Fish surveys indicated a small population of Bonneville cutthroat trout exists in the Bear River upstream of the Utah/Idaho border, and another population is known to exist in the Cub River, which is a tributary to the Bear River. The telemetry study verified interstate migration of Bonneville cutthroat trout along the Bear River and suggests an intact genetic connection with cutthroat trout in the Cub River. Thus, the Bear River may be a vital factor in maintaining the current Bear River metapopulation of Bonneville cutthroat trout. Potential impacts of the proposed Bear River Narrows Hydroelectric Project to the Bear River in Utah are negligible and will most likely not affect available habitat resources.

Work Plan FY12/FY13

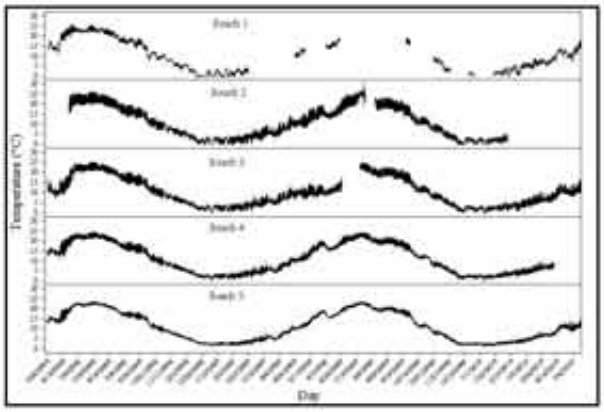
This project is completed.

Informational Resources

Contact: Mr. Chris Thomas, (435) 797-1184, E-mail: chris.thomas@usu.edu.

Electrofishing the Bear River

Bear River Bonneville cutthroat trout



Temperature data for the Bear River, Idaho and Utah

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

Principal Investigators:
Christopher M. U. Neale
Jonna van Opstal (Student)

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

Project Description

- Need and Purpose:

  There is a growing demand for fresh water for municipal use along the Wasatch front and in Cache Valley. The increase in urban areas has led to water quality and quantity pressures on the existing water resources. The Bear River basin is one of the few systems in the western US that still has unallocated water. It is only a matter of time before additional dams will have to be built within the system to tap these water resources, while adjusting to a changing runoff hydrograph due to expected climate change. Solutions for improved management of the water resources in the Bear River basin will require involvement of multiple stakeholders and possible 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 provides the necessary information for making system operation management decisions in the future to adapt to changing conditions. In addition, water quality at the tail-end of the Bear River is impacted by other irrigated areas and cities and towns upstream. Comprehensive research is needed to address the impacts of water quality on irrigated areas and vice-versa. The results will be relevant and applicable to other similar irrigated areas in the state of Utah.

- Benefits to the State:

  Improved water management can lead to water savings and potentially to improved water quality as 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:** Includes northern and central Utah.

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

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

- Accomplishments:

  Findings: Preliminary analysis of water quality samples collected at different locations of the Bear River Canal company irrigation canal and drainage system indicate significant increases of nitrogen and changes in phosphorous content as irrigation water flows through the system. During the summer of 2012, additional water quality sampling was conducted on parts of the system to further investigate the water/nutrient pathways. In addition, crop evapotranspiration was measured in corn and alfalfa using two

eddy covariance flux towers located in fields within the system. These data will be used to verify the airborne and satellite remote sensing based energy balance models for estimating crop evapotranspiration, in order to obtain a more precise water balance for the entire system.

Results: The SETMI model that estimates evapotranspiration from remotely sensed imagery has been re-coded in Visual Studio.Net and will be used to process airborne and satellite imagery obtained over the 2012 growing season with the goal of closing the water balance.

Work Plan FY12/FY13

Analyze the flux data acquired during the 2012 growing season and compare it to remote sensing model results. Close the water balance at the BRCC and plan a comprehensive water quality and flow measurement campaign for the summer of 2013

Informational Resources

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

Lake Fork/Uintah River System Optimization Review

Principal Investigators:
Mac McKee
Andres Ticlavilca
Alfonso Torres

Partners/Collaborators:
- ***State:*** *Dex Winterton, Duchesne Water Conservancy District*
- ***Federal:*** *Roger Hansen, US Bureau of Reclamation*

Project Description

- **Need and Purpose:**

  Advances in data-driven modeling techniques applied to the management of water resources systems have been pioneered at the Utah Water Research Laboratory in recent years. These are being applied to the operation of several of the large irrigation systems in the Sevier River Basin, contributing to the achievement of greater efficiency in the delivery and use of large quantities of irrigation water. The purpose of this project is to extend the application of data-driven modeling approaches for better forecasting of canal and stream flows in a new area of the State, the Lake Fork Irrigation System in Duchesne County.

- **Benefits to the State:**

  Application of data-driven modeling techniques in the Sevier River Basin in the past several years have produced tools that provide valuable additional information for reservoir and canal operators, enabling them to improve the efficiency of basin-wide water management. Similar results are expected for the Lake Fork System and potentially for every river basin in Utah, especially those with substantial irrigated agriculture. The short-term forecasting methods developed by this project can provide system managers with information necessary to more precisely control the operation of large and complicated irrigation systems such as those found in the Lake Fork System, thereby saving water and increasing the overall productivity of the system.

- **Geographic Areas:**

  Study Area: Lake Fork Irrigation System, Duchesne, UT.

  Areas Benefited: The Lake Fork System will have a direct benefit from our research, but the applications of our findings could benefit anyone working in agricultural or natural resource management settings who might use this remote sensing technology.

- **Accomplishments:**

  Findings: Preliminary findings indicate that real-time operations of portions of the Lake Fork System, especially the Sand Wash reservoir, can be substantially improved by subjecting the available operations data to analysis with data-driven methods. We expect that these findings could be extended to the entire system if sufficient process-based model results can be coupled with data-driven modeling techniques. Development of long-term water availability forecasts for the Lake Fort drainage using machine learning tools has shown preliminary successes.

Results: Analyses conducted to date indicate that the Sand Wash reservoir releases can be operated in real time so as to achieve stable downstream water levels in critical system, reservoir, and canal components.

Work Plan FY12/FY13

Work in the coming year will focus on extending the data-driven analyses to improve the reliability of long-term water availability forecasts and extend them further into the future. We will also make system-wide corrections in real time on the outputs of the River Ware model, which is now under development by others who are working for the Duchesne Water Conservancy District.

Informational Resources

Contact: Dr. Mac McKee, 435-797-3157, E-mail: mac.mckee@.usu.edu.

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

Principal Investigators:
YangQuan Chen
Brandon Stark (Ph.D. student)

Partners/Collaborators:
- ***Local:*** *Jim Walder, SRWUA*
- ***Federal:*** *Roger Hansen, USBR*
- ***Local:*** *Austin Jensen, USU UWRL*

Project Description

- Need and Purpose:

  To better manage water and other natural resources such as wetlands and floodplains, the Utah Water Research Laboratory (UWRL) and the Center for Self-Organizing and Intelligent Systems (CSOIS) have been actively developing UAV-based PRS (Personal Remote Sensing) systems using fixed-wing UAV platforms known as AggieAir. In many applications, it is highly desirable for UAVs to take off and land vertically in a constrained area or to make close "point measurement" such as for wetland invasive species characterizations. The goal of this project is a mature Vertical Take-Off and Landing (VTOL) platform to compliment AggieAir for personal remote sensing application in water related scenarios.

- Benefits to the State:

  AggieAir fixed-wing UAVs have proven to be very useful for managing natural resources in the State of Utah and other places across the country. 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 allocated to other users whose demands are continually growing. The water savings could be as much as 5 or 10 percent of current deliveries.

  AggieVTOL UAVs complement the AggieAir UAVs and will benefit the State of Utah in many similar ways, enabling many new emerging applications.

- Geographic Areas:

  Study Area: In collaboration with UWRL field engineers, Cache Junction and Bear River will be used as a test and demonstration site, including Bear River Migratory Bird Refugee (BRMBR).

  Areas Benefited: Wetland management in the BRMBR. All counties in the state could benefit.

- Accomplishments:

  Findings: An inexpensive unmanned aerial vehicle (UAV) known as AggieVTOL that can take-off and land vertically has been developed and is being made robust and capable of carrying and controlling various types of remote sensing equipment and gathering remotely sensed data, which can then be processed for distribution to water managers and farmers. AggieVTOL is a modular multi-rotor rotorcraft UAV prototype platform. Performance results demonstrate the effectiveness of the platform.

Results: 1) Low-cost AggieVTOL prototyping approach using open source Paparazzi architecture, 2) A book chapter (35 pages) published with IGI Global after rigorous peer review; 3) Demonstration of fully autonomous way point navigation; 4) Grants obtained from NSF (2011-2012) and NASA (2011-2014) despite fierce competition; 5) Student competition at 2012 AUVSI SUAS with good teaming building progress; 6) Focus on fault tolerance features; (7) Invitation to give tutorial lectures at ICUAS12 and ACC12.

Work Plan FY12/FY13

- AggieVTOL under OSAM (open source autonomous miniature) will target robustness issues.
- Optimize quadrotor VTOL UAV to have 20 min. autonomous flight time with one camera.
- Target two cameras (RGB and NIR) for octorotor VTOL UAV.
- Continue design iterations and a manufacturability study toward a salable product design.

Informational Resources

Contact: Dr. YangQuan Chen, (435) 797-0148, E-mail: yangquan.chen@.usu.edu.
Websites: http://mechatronics.ece.usu.edu/yqchen/ and http://aggieair.usu.edu/.
Team Wiki: http://www.engr.usu.edu/wiki/index.php/.
OSAM_UAVYoutube Channel: http://www.youtube.com/user/.
USUOSAMICUAS2011 Tutorial: http://uasconferences.com/ICUAS%2711_Tutorial.pdf.
News paper story: "USU Still Flying High" http://www.usu.edu/ust/index.cfm?article=50035 and http://www.auvsi.org/news/#SUAS2011.
AggieVTOL bookchapter: http://www.igi-global.com/bookstore/titledetails.aspx?TitleId=58292.

Figure 1: Two iterations of AggieVTOL

Figure 2: AggieVTOL in flight

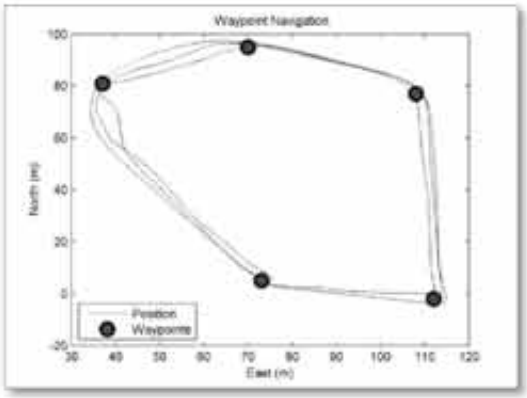


Figure 3: Recorded tracks of an AggieVTOL flight

Figure 4: View from AggieVTOL camera

Multispectral Image Processing for Water Management and Other Agricultural Applications

Principal Investigators:
Huifang Dou
Swathi Gorthi (Student)

Partners/Collaborators:
None

Project Description

- Need and Purpose:

  Water management is an important problem not only in the state of Utah, but also in many parts of the United States, and beyond. With the population increasing in most parts of the world, water shortages are getting worse. Identifying soil moisture conditions over large areas can help reduce water consumption in irrigation systems while increasing crop and forage productivity. Multispectral images, remotely sensed from satellites or aircrafts, provide an effective way for the analysis of water content over large crop fields and rangelands. However, due to low spatial resolutions of images, as well as weather related obstructions (like clouds), accurate prediction of daily agricultural water consumption using remote sensing is not a trivial problem. Therefore, effective algorithms are needed in order to accurately determine water content from remote sensing data. With the use of smart sensors and algorithms, we will be able to accurately determine soil moisture content, vegetation type, land usage and cropping and other needed information.

- Benefits to the State:

  Utah agriculture generates more than $1 billion in income for our farmers and ranchers while helping to fuel the state's rural economy. This research will assist water resource managers to efficiently promote the orderly and timely planning, conservation, utilization and protection of Utah's water resources. The research will also benefit Utah's farmers and ranchers by providing them with information and guidance about crop and forage growth status and soil moisture conditions.

- Geographic Areas:

  Study Area: Sevier and Millard Counties.

  Areas Benefited: all counties in the state would benefit from this research.

- Accomplishments:

  Findings: Based on remotely sensed multispectral images real-time acquired from SMEX02 and models for estimating soil moisture, a software package was developed and integrated with the UAV system to provide a friendly platform that farmers, ranchers, and water managers monitor, evaluate, and predict soil moisture content in designated key areas in Utah. The software runs on MATLAB platform. All programs were tested and verified against soil moisture estimations.

  Results: In this study, data collected in SMEX02 were used to test the models and verify the software. The software package includes 6 tools. They were written for different algorithms to build an appropriate soil moisture model. The inputs of models are vegetation indices, obtained from remotely sensed images; soil temperature, air temperature, and precipitation. The output is surface soil moisture

content (0-6cm). The differences of the prediction data and real data are evaluated based on Mean Absoluter Error (MAE) and Root Mean Square Error (RMSE) for different models. Table 1 and Table 2 summarize the results and the corresponding software tools. These tools are easily applied to predict soil moisture contents. With the help of a friendly graphical user interface, the system is a useful platform for remote sensing based water management and agricultural applications.

Table 1: Summary of Results

#	Models	MAE	RMSE
1	Support Vector Machines (SVM)	0.0499	0.0546
2	Relevance Vector Machines (RVM)	0.0279	0.0323
3	Multivariate Adaptive Regression	0.0279	0.0484
4	Model Trees Using M5 Algorithm	0.0411	0.0536
5	Adaptive Basis Function Construction	0.0389	0.0453
6	Multilayer Perceptron Networks	0.0677	0.0856
7	Ensemble Adaptive Basis Function Construction	0.0376	0.0431
8	Bagging RVM	0.0935	0.1034
9	Variance Optimized Bagging RVM	0.1115	0.1217
10	Boosting RVM	0.0205	0.0264

Table 2: Models and Software Tools

#	Models	Software Tools
1	Support Vector Machines (SVM)	SVR
2	Relevance Vector Machines (RVM)	Sparsebayes
3	Multivariate Adaptive Regression	ARESLab
4	Model Trees Using M5 Algorithm	M5primelab
5	Adaptive Basis Function Construction	ABFC
6	Multilayer Perceptron Networks	NNSYSID
7	Bagging RVM	B-Sparsebayes
8	Variance Optimized Bagging RVM	VOBSparsebayes
9	Boosting RVM	Boosting Sparsebayes

Work Plan FY12/FY13

The research effort for the next year includes the following: Integrating the current developed software tools for building the soil moisture models with the control platform of Unmanned Autonomous Vehicles (UAV), which are being commercialized by Utah Water Research Laboratory. The algorithms will be further test and verified with new field data at designated key areas in Utah. These activities will be coordinated in collaboration with on-going research at the Utah Water Research Laboratory.

Informational Resources

Contact: Dr. Huifang Dou, Email: huifang.dou@usu.edu.

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

Principal Investigators:
YangQuan Chen
Calvin Coopmans (Student)

Partners/Collaborators:
- **Local:** *Jim Walder, SRWUA*
- **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.

- 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. In the Sevier River Basin, 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: Sevier River Basin, including Sevier and Millard Counties.

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

- Accomplishments:

  Findings: An inexpensive unmanned aerial vehicle (UAV) has been developed and made robust with the capability to carry and control various types of remote sensing equipment, and gather remotely sensed data, which can be processed for distribution to water managers and farmers.

  Results: Enhanced airworthiness of a team of several working, fully open-source UAVs has been tested for various mission scenarios such as irrigation water management and ecological assessment, and patent disclosures have been filed. A full-day tutorial workshop on UAV-based "Personal Remote Sensing for TIR" at ICUAS2012 was offered (Philadelphia, May 12, 2012), and teaching modules are standardized for training natural resource managers in the State of Utah. Grants were received from NSF (2011-2012) and NASA (2011-2014). Launcher design was a good success!

Work Plan FY12/FY13

- Continue to explore and mature the Minion/Titan platforms.
- Continue to make the launcher commercially available.
- Develop SWIR payload module for Paparazzi architecture.
- Integrate RGB/NIR/TIR/SWIR payload capability (plug-n-play).
- Provide technical support and R&D center for the UAV service center under UWRL.
- Perform field test flights.
- Gather, calibrate, and process remotely sensed data.
- Plan and develop an interface to supply data to water system managers and possibly to farmers.

Informational Resources

Contact: YangQuan Chen, (435) 797-0148, E-mail: yangquan.chen@usu.edu.

Websites: http://mechatronics.ece.usu.edu/yqchen/ and http://aggieair.usu.edu/.
Team Wiki: http://www.engr.usu.edu/wiki/index.php/OSAM_UAV.
Youtube Channel: http://www.youtube.com/user/USUOSAM.
ICUAS2011 Tutorial: http://uasconferences.com/ICUAS%2711_Tutorial.pdf.
News paper story: "USU Still Flying High" http://www.usu.edu/ust/index.cfm?article=50035 and http://www.auvsi.org/news/#SUAS2011.

The two Minions (August 2012) – in a mission in New Zealand (NSF RAPID). (photo taken in NZ by the OSAM team)

Modular design (easy for shipping as normal luggage in international travel as tested and verified in a real mission to New Zealand, 8/7 to 8/18/2012)

Pineview Reservoir Operations and Algae/Cyanobacterial Bloom Ecology

Principal Investigators:
Darwin L. Sorensen
Lindsey D. Carrigan (Student)
Prajith Dev (Student)
Thomas Reuben (Student)
Brady Worwood (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 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. Diatom communities dominated the reservoir throughout the year, including during bloom periods. 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 and other uses. Annual surface water nutrient loading has been lower than estimated in earlier studies (e.g., the Total Maximum Daily Load study), 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.

Work Plan FY12/FY13

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 chemical characteristics and possible sources of this soluble phosphorus will be sought. Ground water quality monitoring near the reservoir will be emphasized to facilitate this search.

Informational Resources

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

References:

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. (2011). *Analysis of the import, export, and bioavailability of nitrogen and phosphorus within Pineview Reservoir, Utah, USA*. MS Thesis, Utah State University, Logan, UT.

Worwood, B.K. and D.L. Sorensen (2012). *Pineview Reservoir phosphorus and mineral nitrogen processes*. Utah State University, Utah Water Research Laboratory, Logan, UT, 75 p.

Figure 1. Flow measurement

Figure 2. Light measurement through the ice on Pineview Reservoir

Quantifying the Flow Field in Baffled Fish Culverts

Principal Investigators:
Blake P. Tullis

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

Project Description

- **Need and Purpose:**

Many culverts are approaching or are past their original design lives. These aging culverts will need to be repaired, rehabilitated, or replaced. Because complete replacement is expensive and intrusive, alternate measures to extend the culvert project life are becoming increasingly popular. One such method is slip lining, where a 'sleeve' is installed within an existing culvert barrel and stabilized. Plastic pipe sleeves are popular for slip lining, but the reduced friction within the barrel can create a barrier to fish due to increased water velocities. 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.

Baffled Culvert (UWRL)

Baffles installed in culvert liners have been recommended as a possible solution for culvert relining when fish passage is a concern; however, very limited data are available in the literature regarding baffle performance to aid fish passage in circular culverts. This study evaluates the flow dynamics (turbulence) and the corresponding swimming behavior of fish to that flow environment. 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 rehabilitate culverts. As such, UDOT is currently funding the fish behavior component of this study at the Utah Water Research Laboratory. The objective of the current 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. The flow dynamics will be compared with the fish behavioral results (UDOT study) in an effort to better predict the likelihood of successful fish passage in other baffled culvert designs.

The scope of work associated with this 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.
- Write a peer-reviewed journal article summarizing the results 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 aid UDOT in developing a baffled culvert protocol for rehabilitated culverts where fish passage is a concern. The results of the study should have nationwide 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 where fish passage issues may be of concern.

Baffled Culvert (UWRL)

- **Accomplishments:**

  Findings/Results: In FY12, The process for quantifying velocity flow fields using the PIV system were improved, and velocity data corresponding to fish passage studies conducted previously were quantified. A permit from the State of Utah (Certificate of Registration) was obtained to allow for the collection and keeping of live fish (brown trout). Fish were brought in to the lab and their behavior while passing through the baffled culvert observed. A paper was presented and submitted for publication in the proceedings of the 4th International Junior Researcher and Engineer Workshop on Hydraulic Structures (IJREWHS).

Work Plan FY12/FY13

In FY13, Additional PIV data and fish passage observational data will be collected in an effort to better characterize the correlation between shear stresses and fish passage through baffled culverts. This study will be one of the focuses of a Ph.D. dissertation (Mohanad Khodier).

Informational Resources

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

Baffled Culvert Test Set Up

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

Principal Investigators:
Mac McKee
Wynn Walker
Alfonso Torres
Andres 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) web site 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 and canal operations can be improved in the Sevier River Basin by several percent with the use of data-driven models such as those developed by this project.

  Results: Products generated by the project this year include:

  - 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) were conducted by the AggieAir™ Flying Circus housed at the UWRL (see http://aggieair.usu.edu) and experiments are on-going to use this imagery to provide estimates of soil moisture in irrigated areas near Scipio, Utah.
- 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 web site.
- 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 with UAVs and the use of data available from Landsat.
- Develop remote sensing tools for estimating water requirements, evapotranspiration rates, and nutrient levels in crop tissues and apply these in the Scipio area for better management of center pivot irrigation systems.

Informational Resources

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

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

Restoration of Interstate Migration Routes for Bonneville Cutthroat Trout

Principal Investigators:

Casey Williams

Partners/Collaborators:

- **State**: *Roger Wilson – Utah Division of Wildlife Resources*
- **Business/Private**: *Kirk Dahle, Paul Mason – Trout Unlimited*

Project Description

- Need and Purpose:

  Range-wide declines in Bonneville cutthroat trout populations are often associated with habitat loss and/or fragmentation of migratory pathways. Much of the current range of Bonneville cutthroat trout includes fragmented habitat that has resulted in limited movement, formation of sink populations, and extirpation of cutthroat trout from historic ranges. One of the primary goals of successful conservation efforts is re-establishment of population connectivity. However, success or failure of such reconnection efforts often goes unmeasured.

  This research has helped to describe the migratory patterns and increased range of Bonneville cutthroat trout in a recently reconnected stream system. Specifically, downstream migration distances, migration timing, spawning area, and seasonal habitat use of the Cub River Bonneville cutthroat trout population was investigated.

- Benefits to **the** State:

  This research provided information useful for conservation efforts and reconnection of Bonneville cutthroat trout habitat throughout its current range, which could help the state of Utah to meet the objectives of the Range-Wide Conservation Agreement and Strategy for Bonneville cutthroat trout, Utah's Endangered Species Mitigation Program, and the conservation efforts of Trout Unlimited. This study provided information concerning migrations of interconnected cutthroat trout populations within a large region, namely that of the Bear River Geographic Management Unit.

- Geographic Areas: Bear and Cub Rivers, Cache County, Utah.

  Study Area: Cache County, Utah.

  Areas Benefited: Cache County and state-wide where Bonneville and Colorado River cutthroat trout restoration is being conducted

- Accomplishments:

  Findings: Initial tagging efforts were conducted and biotelemetry tags were surgically implanted into 17 Bonneville cutthroat trout. Fall tagging efforts put tags in 17 more fish below the diversion dam. Tracking occurred in springtime by plan; however, no cutthroats were found in the Utah section of the Cub River.

  Results: Winter 2010 and spring 2011 tracking efforts helped to identify spawning areas of migratory Bonneville cutthroat trout in the Cub River above the diversion barrier. Downstream migration during the winter was tracked by plane, and no tagged Cutthroat trout were shown to be migrating into Utah.

The Cub river drainage has significant habitat within Utah; however, radio tracking results can be difficult to obtain with such cover. One tagged fish was shown to move up above the diversion dam again this spring to spawn, but high water has hampered the fish ladder operation. Other tagged fish could have moved over or above the ladder because high flows topped the ladder, causing it to be uncontrolled. At this point in time, we feel additional efforts would not result in BCT tagged in the Cub River being found in Utah.

Work Plan FY12/FY13

No further work is planned for this project.

Informational Resources

Contact: Dr. Casey Williams, (435) 797-1184, E-mail: casey.s.williams@aggiemail.usu.edu.

Bonneville cutthroat trout immediately after tagging

The same Bonneville cutthroat trout upon recapture

Treated Wastewater Use in Agricultural Irrigation

Principal Investigators:
Gary Merkley
Leila Ahmadi (Student)

Partners/Collaborators:
- ***Local:*** *Cache Valley municipalities*
- ***Industry:*** *Cache Valley farmers*

Project Description

- Need and Purpose:

  As in many places in the USA and around the world, Utah is experiencing a continuing trend to incrementally transfer water from agricultural applications to municipal and industrial (M&I) uses. As this occurs, two principal problems are emerging:

  1. The water supply for agricultural irrigation is diminishing, threatening sustainable agricultural productivity.
  2. Ways must be found to manage the increasing quantities of treated wastewater from M&I sources.

  The solution to the first principal problem can, to a significant extent, entail the solution to the second problem. That is, a transfer of water from agricultural to M&I users involves a significant wastewater return flow component which must be disposed of and which could compensate for the "loss" of water to agricultural users. The feasibility of such a complementary solution must be analyzed to determine the implications of using treated wastewater for agricultural irrigation.

- Benefits to the State:

  Understanding of the technical issues regarding the use of treated M&I wastewater for agricultural irrigation in Utah can potentially lead to a lessening of the impacts of water transfers on sustainable agricultural production, and provide an economically- and environmentally-beneficial destination for wastewater from treatment plants. This can also lead to a win-win situation for two groups that have increasingly competed for available water resources.

- Geographic Areas:

  Study Area: Cache Valley, Utah.

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

- Accomplishments:

  Findings: All of the data have been collected and the model is running. Most of the report has already been drafted.

  Results: Preliminary modeling results show that alternative treated wastewater management scenarios for agricultural irrigation can be evaluated and compared in terms of water supply, water quality, and economics.

Work Plan FY12/FY13

The student working on this project defended the PhD dissertation in October 2011 and completed the study.

Informational Resources

References:

Ahmadi, L. and G.P. Merkley (2009). Planning and Management Modeling for Treated Wastewater Usage.. *Irrig. and Drain. Sys.*, Springer. 23(2-3): 97-107.

Contact: Dr. Gary Merkley, 435.797.1139, E-mail: gary.merkley@usu.edu.

Website: http://www.engineering.usu.edu/htm/faculty-expertise/memberID=8850.

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 either 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 keep progressing 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 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 in control of invasive plants.

  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.

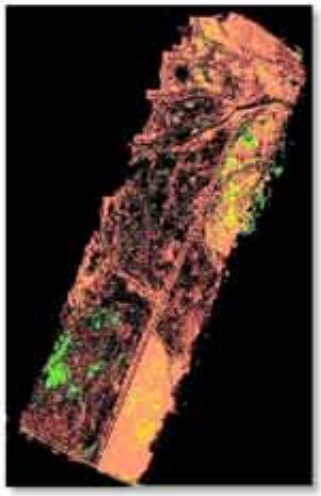
- Geographic Areas:

  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 in the past year to two organizations that wish to use AggieAir for their own remote sensing purposes. Additional field crews have been trained to fly the UAVs and process the imagery they collect.



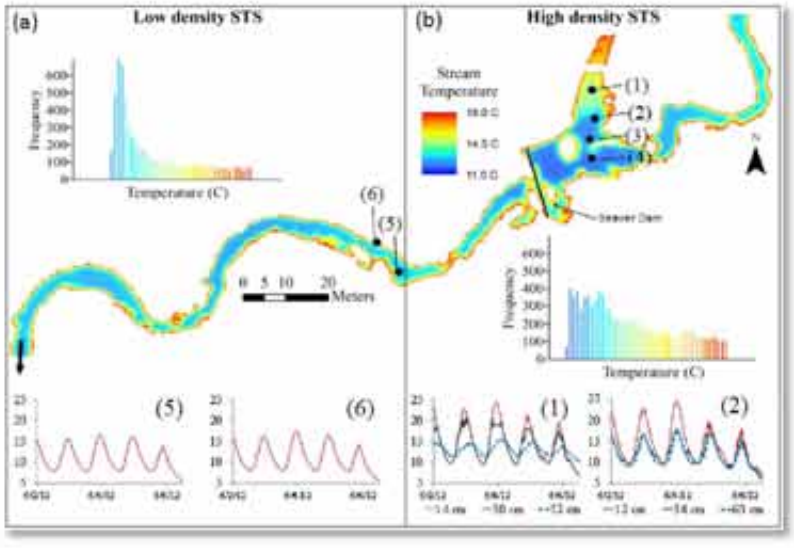
Detection of new *Phragmites* growth in the Bear River Migratory Bird Refuge in a three-month period (new Phragmites is shown in green; 25 cm resolution)

In the past year, the AggieAir Flying Circus has provided support to research contracts in three 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 the spread and control of the invasive and highly destructive species *Phragmites australis* in the Bear River Migratory Bird Refuge, on the management of wetlands by the Utah Department of Transportation, on the removal of nutrients and production of energy at the Logan City Sewage Lagoons, on the operation and maintenance of irrigation canals in the state, 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 has also been engaged in projects in water and natural resources management in Cache Valley for the City of Logan, in precision agriculture in Scipio, 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.

Work Plan FY12/FY13

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,
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austin.jensen@aggiemail.usu.edu.

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

iUTAH – Innovative Urban Transitions and Aridregion Hydro-Sustainability

Principal Investigators:
Jeffery S. Horsburgh
Bethany T. Neilson
David Rosenberg
Amber Spackman Jones

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  Water is critical to sustainable economic development in Utah and to sustainable 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 met through water transfers, infrastructure investments, and efficiency programs. The overarching goal for UT EPSCoR is to enhance Utah's research capability in sustainable water decision-making through strategic investments in the state's physical, human and cyberscience infrastructure. We are forming transdisciplinary teams of natural and social scientists to carry out research on hydroclimatic sustainability in the WRMA. An improved understanding of this complex human and natural system coupled with the development and implementation of innovative solutions requires better integration of social, hydroclimate, ecological, and engineering knowledge. The theme of Utah EPSCoR is directly aligned with Utah's Science and 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 are creating a common research platform and facilitating statewide science collaboration to enhance our ability to compete for interdisciplinary funding opportunities from sources like the National Science Foundation.

- **Benefits to the State:**

  The innovative and transformational activities in this project include: the development of fully integrated hydrologic and social sciences observatories that encompass whole watersheds, strategic activities designed to build a community of scholars across the state capable of addressing hydro-sustainability as a coupled human-natural system, and integrated education and outreach activities. This ensures that our research directly addresses societal needs and communicates our scientific findings to stakeholders, policy makers, and the general public.

- **Geographic Areas:**

  Study Area: Wasatch Range Metropolitan Area (WRMA), Provo Watershed, Red Butte Watershed, Bear River Watershed.

  Areas Benefited: Organizations and institutions statewide.

- **Accomplishments:**

  Findings: This project is just beginning. We have proposed three interdisciplinary focus areas to advance the infrastructure, research, and human capital capacity of the Utah science community. Activities in all focus areas will be synthesized through a central cyberinfrastructure (CI) that provides an integrated data system for storing, sharing, and publishing observations and outcomes. The coordinated CI system provides direct linkages between research, education, outreach, and application.

  Results: Expected results for iUTAH include enhancement of the STEM Workforce Development in Utah through formal science education activities that span the entire range of the STEM education. Research and education activities are planned for state-wide K-12 students and teachers; for undergraduates and faculty at community colleges and at primarily undergraduate institutions (PUIs); and for undergraduates, graduate students, postdoctoral fellows, early career faculty, and faculty at Utah's main research universities. Three, instrumented watersheds will serve as 'living labs' that involve statewide iUTAH partners in place-based research, and provide data for interdisciplinary modeling and urban scenario planning. iUTAH funds will support research fellowships for faculty at PUIs; research grants for middle school and high school teachers; collaborative research opportunities for undergraduate and graduate students; interdisciplinary postdoctoral fellowships; and summer research institutes for teams of K-12 students and teachers, undergraduate and graduate students, and science educators to get experience doing research and developing innovative new curricula.

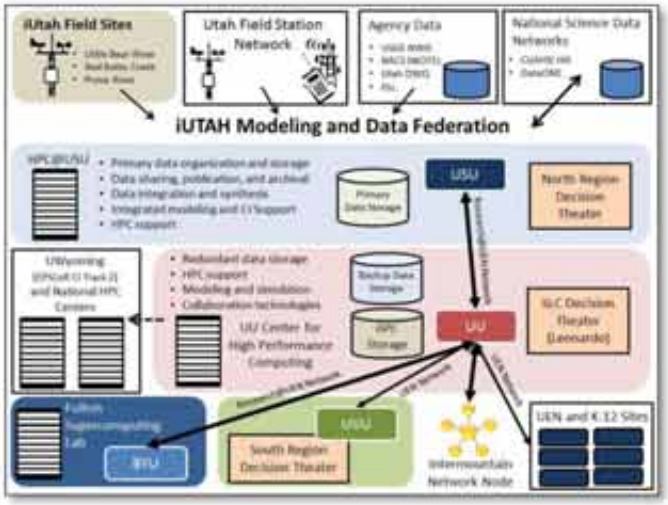
Work Plan FY12/FY13

This project will support the design, development, and deployment of the cyberinfrastructure facilities that will support the greater iUTAH cooperative agreement with the National Science Foundation. During this year, we will focus on creating the human and machine resources needed to support integrated data collection and management within the iUTAH observatory study areas.

Informational Resources

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

Website: http://iutahepscor.org.



iUTAH's infrastructure investments are creating a common research platform and facilitating statewide science collaboration to enhance Utah's ability to compete for interdisciplinary funding opportunities from sources like the National Science Foundation. For example, the iUTAH Modeling and Data Federation (depicted at left) will provide a cyberinfrastructure that enables interdisciplinary data sharing, integrated modeling, and unprecedented opportunities for collaboration among Utah's educational institutions.

Water Conservation and Managing Water Shortages

Principal Investigators:
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Partners/Collaborators:

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  Tage Flint and Scott Paxman, Weber Basin WCD
  Stephanie Duer, Salt Lake City
  Bart Forsyth and Courtney Brown, Jordan Valley WCD
- **State:** *Scott Adams and David Cole, UDWR*
- **Federal:** *Fred Liljegren, USBR*
- **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 those linkages can be leveraged to promote conservation. Additionally, customers need more information to support their outdoor landscape choices and actions as 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 will provide Utah water utilities and the UDWR with new tools to better model and proscribe reservoir operations and 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 how to more cost-effectively operate structural and non-structural components of the water system.

- **Geographic Areas:**

Study Areas:

- Intervening to encourage water conservation projects: Cities of Logan and North Salt Lake in Cache and Davis counties; Jordan Valley WCD in Salt Lake County.
- 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:

- Urban households exhibit large variability in their characteristics, knowledge, preferences, abilities and constraints to conserve water. Consequently, water providers should offer their customers a wide variety of water conservation programs and choices.
- Dishwashers use the most energy per gallon of water followed by showers and faucets, clothes-washers, and toilets. Water heater dispense temperature has the highest influence on overall household water-related energy-use and consequently to save energy, utilities should ask households to turn down their water heaters to 120 °F.

Results:

- Developed a new method to estimate and forecast heterogeneous indoor household water and energy-uses and show linkages among the uses.
- Secured approximately $15,000 in funding from the Western Water Alliance and followed-up prior interdisciplinary water conservation research work.
- Submitted two Master's theses: one on water-energy linkages (Abdallah) and a second on managing water shortages using the Water Evaluation and Planning model (Tesfatsion).
- Chapter on the Weber Basin model tutorial titled "Evaluating storage carryover in the Weber River Basin using the Water Evaluation and Planning (WEAP) System" accepted for publication in the upcoming book by the American Society of Civil Engineers titled "Case Studies in Environmental and Water Resources Systems Analysis."
- Article titled "Estimating and Verifying United States Households' Potential to Conserve Water" published in *ASCE-Journal of Water Resources Planning and Management*, 138(3), pp. 209-306. http://dx.doi.org/10.1061/(ASCE)WR.1943-5452.0000182.
- Presented water-energy conservation results at the American Geophysical Union Annual Fall Conference in San Francisco, CA, December 5-9, 2011.

Work Plan FY12/FY13

- Re-submit interdisciplinary water conservation proposal for multi-year study to National Science Foundation's Decision, Risk, and Management Sciences program.
- Build a water-energy systems model for Salt Lake City to identify the cost-effective conservation actions to meet specific water and/or energy conservation targets.

Informational Resources

Contact: Dr. David E. Rosenberg, Phone (435) 797 8689, E-mail: david.rosenberg@usu.edu.
Websites: http://www.engr.usu.edu/cee/faculty/derosenberg/projects.htm.
http://digitalcommons.usu.edu/etd/1087/.

Water Resources Modeling for Utah's Cache Valley

Principal Investigators:
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Gary Merkley
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 as water supply tends to 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. The 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: draught, 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, the Cache Valley is on the forefront of many water resources issues that are currently affecting many locations throughout Utah. Once created, 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 resources agencies make better and more informed planning decisions and recommendations.

- **Geographic Areas:**

  Study Area: Cache Valley, Cache County, Utah.

  Areas Benefited: Municipal water providers and landowners statewide in all counties.

- **Accomplishments:**

  - Since the project started in January, 2011, we have secured the participation of and had multiple phone calls and in-person meetings with Division of Water Rights and Resources staff to discuss how to incorporate Utah water rights into a water management model for the valley.

  - We are nearly finished developing a pre-processing engine that identifies and quantifies the extent that critical reservoir, diversion, demand, and other locations within a water resources network are:

- Redundant – operate similar to other nodes within the network.
- Vulnerable – influenced when other nodes are removed from the network.
- Topologically significant – non-redundant nodes that cause other nodes to be vulnerable.

Work Plan FY12/FY13

- Complete the network analysis and submit results for publication in a peer-reviewed scientific journal.
- Review the Utah Division of Water Resources model for the Lower Bear River.
- Integrate data held in a water rights database maintained by the Utah Division of Water Rights into the water resources management model.
- Advise Cache County in developing the Cache County water master planning effort.

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.

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Research Faculty, Professional, and Support Staff

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