MINERAL LEASE FUND REPORT

Utah Water Research Laboratory

Fiscal Year 2009

for

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

by

Mac McKee, Director

Utah Water Research Laboratory
Utah State University
Logan, UT 84322-8200

February 2010

Foreword

The Utah Water Research Laboratory (UWRL) at Utah State University (USU) receives 2-1/4% of all deposits made to the Mineral Lease Account, "to be used for activities carried out by the UWRL having as a purpose the development and exploitation of water resources in the State of Utah."

This report is submitted to the Legislature by the UWRL 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 2008.

2. Budgeted expenditures for FY 2009.

3. Planned expenditures for FY 2010.

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.

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

Mac McKee
UWRL Director

Table of Contents

INTRODUCTION

ADMINISTRATION

PROJECT SUMMARIES

Table of Contents

Table of Contents

Introduction

Role of the Utah Water Research Laboratory

Research programs of the Utah Water Research Laboratory (UWRL) directly address current and future water resources needs of the state but are also recognized throughout, the nation and the world. State appropriation funds (SAF) and mineral lease funds (MLF) are targeted on problems facing the State of Utah. In FY 2009, MLF of $4 million accounted for 34% of total UWRL expenditures with the balance coming from federal, private, and other state sources. Total UWRL expenditures for FY 2009 were almost $12 million. By using MLF funds as a required match for other federally-funded projects, the UWRL is able to leverage $2 for every $1 Million in external funding to solve important Utah water problems.

The UWRL's projects are organized into eight major research programs under the direction of engineers and scientists affiliated with the Environmental Division and the Water Division of the Civil and Environmental Engineering Department, and also the Departments of Electrical and Computer Engineering, Mechanical and Aerospace Engineering, and the Department of Bio-Engineering at Utah State University. Brief summaries of these major research programs under these three divisions are 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. Seventy-three graduate students were supported in FY 2009. Undergraduate student involvement in UWRL projects for the purpose of student education and training is also integrated into the basic and applied research programs. The UWRL employed approximately 62 undergraduate students in FY 2009. As students graduate and are hired by Utah employers, they become effective means of technology transfer from the UWRL to the Utah water and environmental. 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 users organizations.

History of 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. In addition to the physical facilities, the State of Utah provides state-appropriated funds (SAF) and mineral lease funds (MLF) for research support at the UWRL.

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. Total research funding through the UWRL was almost 12 million in FY 09, making it one of the largest institutes in the nation. It is also one of the most productive in terms of research publications and graduate student education.

There are 34 faculty and 31 support staff at the UWRL. During FY 2009, 40 master's students and 33 doctoral students received support from UWRL projects. An additional 62 undergraduate students assisted with UWRL research. UWRL faculty collaborate with colleagues from other USU departments, faculty from other institutions, professionals from the private sector, and government agencies in Utah, and elsewhere. Several of our faculty, 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 recognition, 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 $92k 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) large irrigation system management, with applications specifically aimed at the Sevier River Basin, (2) aquatic and riparian habitat management in the Virgin River Basin, and (3) aquatic management and endangered species recovery in the Provo River Basin. 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, tools development, and programs across the State of Utah.

Mineral Lease Fund Expenditures

The table at the end of this Introduction summarizes the actual, budgeted, and planned expenditures of MLF allocated to the UWRL for FY 2008, FY 2009, and FY 2010 in the eight 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 6% of total MLF budgeted and planned expenditures in FY 2009 and FY 2010.

Relevancy and Benefits of the Mineral Lease Fund

In more ways than one, Utah is the second direst 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 and 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 the citizens of Utah.

Research Program

The goal of the UWRL research programs are 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 effect 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. Participation in national and international professional water and environmental organizations help to bring recognition and external project funding to the state, as well as learning from other research and best practices worldwide.

In order to develop the research program and focus projects, UWRL engineers and scientists have worked with the following network of organizations over the past fiscal years.

Department of Natural Resources

- Division of Water Resources
- State Engineer – Division of Water Rights

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)

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)

Professional Organizations and Associations

- American Water Resources Association
- American Society of Civil Engineers
- American Water Works Association

The Utah Center for Water Resources Research (UCWRR) participated as an active member of the National Institutes for Water Resources (NIWR). As indicated above, 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 opportunities for the UWRL to respond to these needs. UWRL faculty were also active in state sections of professional organizations, and served on

state, local, and national committees. All these activities provided opportunities to identify current and future research needs that will affect our state and the nation. This also strengthens the UWRL research identification process to maintain 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 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

In addition, UWRL personnel are frequently invited to provide technical and informational presentations 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 by 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/.

Outreach and service provided by faculty of the UWRL also supports youth programs, such as the Girl Scouts of Utah, through math, science, and engineering experiences for ages 5-15.

On the international level, the UWRL hosts numerous delegations from other countries that have interest in the research conducted at the UWRL and in the capabilities that UWRL professionals can offer to the solution of their water problems. In the past year, these have included visits by delegations from Palestine, Pakistan, India, Spain, Iran, and Iraq.

Benefits to the State of Utah

Specific state benefits resulting from MLF research projects are summarized for each project in the following sections of this report. Projects conducted by the UWRL in the past year have produced benefits for every county of the state. The following summarizes the recent and current benefits produced by MLF funding in the UWRL's seven program areas.

Bioprocess, Bioremediation, and Biotechnology

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 biotransformations, and engineering bioprocess-optimization of wetlands.

Environmental Quality: Land, Water, and Air

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. In addition to the research on water and land processes, this area also includes work on air quality problems in the state.

Groundwater Quantity, Quality, and Aquifer Management

Current research in the groundwater area ranges from theoretical developments in the stochastic and numerical analysis of pollution transport in ground water modeling conventional and toxic contaminants in natural and engineered systems and the practical aspects of designing technologies to clean up and manage fuel-contaminated sites in Utah's aquifer systems.

Surface Water Quantity, Quality, and Watershed Management

This diverse program has strengths in both the theoretical and applied aspects of 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). The program is also developing engineering approaches for production of drinking water, treatment, reclamation, recycling, and reuse of municipal and industrial wastewater.

Water Conveyance and Control

This program utilizes UWRL's unique hydraulics laboratory for physical modeling of hydraulic structures, including evaluation of scour below spillways and other structures, testing and evaluation of hydraulic machinery and piping systems, flow meter calibration, and testing of erosion control systems for slopes and channels. Analytical aspects of the program include design of pipe networks for water supply, porous media flow, sediment transport, and open channel flow.

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 training modules or educational materials, sometimes to provide technical support to Utah state agencies on water-related

issues (such as the State Attorney General's Office in litigation involving liability assessment in hazardous waste problems), and development of curricular materials for use in K-12 education programs in the state

Water Resources Planning and Management

This program area addresses institutional and legal aspects of water 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, user-driven decision support systems for water planning, terminal lake water level management, and dam safety risk assessment.

Administration, Advisory Support, and Special Equipment

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

Project Name	FY 2009 Actual Expenditures	FY2010 Budgeted Expenditures	FY2011 Planned Expenditures
Business Office	$146,978.35	$151,387.70	$155,929.33
Laboratory Infrastructure Support, Travel and Special Request	$25,352.19	$27,000.00	$27,810.00
Project Management of USGS 104	$16,328.81	$16,818.67	$17,323.23
Publications Office	$52,146.92	$53,711.33	$55,322.67
UWRL Administration	$40,235.96	$41,443.04	$42,686.33
Total	**$281,042.23**	**$290,360.74**	**$299,071.56**

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 in 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 and, in collaboration with water managers and policy makers in state and local agencies to identify opportunities 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 funds that comes to the state. FY 2009 administrative costs represented only 0.2 percent of total UWRL MLF expenditures.

Outreach and Business Support

Overall, annual research expenditures for the UWRL are approximately 12 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 2009 on these support activities accounted for 0.6 percent of total MLF funding.

Advisory Support on Water Problems

The UWRL received many requests in FY 2009 for advice and collaborative help on various water problems in the state. In FY 2009, 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 on 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 and 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.

To support hydraulics research activities associated with releases from dams in Utah (and related hydraulic phenomena, such as venting), the UWRL just completed a new state-of-the-art hydraulics modeling and testing laboratory.

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:

Bioprocess, Bioremediation, and Biotechnology

Environmental Quality: Land, Water, and Air

Groundwater Quantity, Quality, and Aquifer

Surface Water Quantity, Quality, and Watershed Management

Water Conveyance and Control

Water Resources Planning and Management

Water Education and Technology Transfer

Bioprocess, Bioremediation, and Biotechnology

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Bioprocess, Bioremediation, and Biotechnology

Project Name	FY2009 Actual Expenditures	FY2010 Budgeted Expenditures	FY2011 Planned Expenditures
Algae Biotechnology for Nutrient Removal in Waterwater Treatment Lagoons	$92,177.21	$50,000.00	$14,000.00
Detection of Microbes that Biodegrade MTBE Contamination	$6,277.96	$0.00	$0.00
Laboratory-Scale Biological Phosphorus Removal	$56,583.87	$50,000.00	$0.00
Microbe-Based Processes for Producing Bioplastic Materials	$3,048.54	$3,000.00	$0.00
Phosphorus Control and Management Using Biological Processes	$9,001.74	$9,271.80	$0.00
Pilot-Scale Biological Phosphorus Removal from Lagoon Wastewater Treatment Systems	$56,583.87	$50,000.00	$0.00
Real Time Polymerase Chain Reactions (RT-PCR) Instrumentation	$4,125.47	$4,249.23	$4,376.71
Designated Projects		$172,496.00	$0.00
Undesignated research projects in program area		$26,000.00	$27,500.00
Total	**$227,798.66**	**$365,017.03**	**$45,876.71**

Algae Biotechnology for Nutrient Removal in Wastewater Treatment Lagoons

Principal Investigators:
Ronald C. Sims
Sridhar Viamajala
Charles Miler

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

Project Description

- **Need and Purpose**:

  The City of Logan Wastewater Treatment Lagoons will not meet future requirements for water quality under current design and operation conditions. Wastewater systems across the state of Utah that utilize lagoons also will not meet future standards. There is a need to understand current lagoon performance with regard to nutrient removal, primarily phosphorus and nitrogen, and what can be done to improve the quality of waters leaving lagoon systems**.** Improvements in the design and operation of existing lagoon systems for wastewater treatment my be possible based on an understanding of behavior and fate of nutrients with regard to algal growth and recycle within a lagoon system as affected by changes in temperature, nutrient composition, and pH (see Figure 1).

- **Benefits to State:**

  The ability to re-design lagoon systems and change operation parameters to improve treatment with regard to phosphorus and nitrogen through the application of algae biotechnology will enable other communities in Utah to utilize this technology for the treatment of waters and wastewaters at costs that are significantly lower than alternative technologies.

- **Geographic Areas:**

  Study Area(s): City of Logan Wastewater Reclamation Facility that treats the wastewater of six towns, including Logan, Hyde Park, Smithfield, North Logan, Nibley, and Hyrum.

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

- **Accomplishments**:

  Findings. The average percentage phosphorus removal is only 23% (from 5.2 to 4.0 mg/L) (Figure 2), and future standards will require 50% removal or more. Nitrogen removal is near 100% in the warmer weather, but poor in the colder weather, and nitrogen loss occurs by volatilization of ammonia as the pH is increased through growth of algae within the lagoon system.

  Results: The AggieAir autonomous, multispectral remote sensing platform, developed at the Utah Water Research Laboratory, was used to obtain data on algae distribution across the Logan Lagoon system (Figure 4). Results indicate non-uniform distribution and low concentrations of algae within ponds comprising the Lagoon system. The uneven distribution of algae is due to the lack of mixing within each pond. Engineered mixing is required in order to improve algae growth and distribution, and simultaneous phosphorus and nitrogen uptake.

Work Plan FY09/FY10

- Monitoring Lagoon System through seasonal changes.
- Evaluate changes in design and operation through raceway bioreactors at laboratory and pilot scales.

Informational Resources

Presentation: Sustainable Production of Biofuels from Algae. Institute of Biological Engineering 2009 Annual Conference, California (March). IBE wiki site: http://openwetware.org/wiki/Institute_of_Biological_Engineering

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

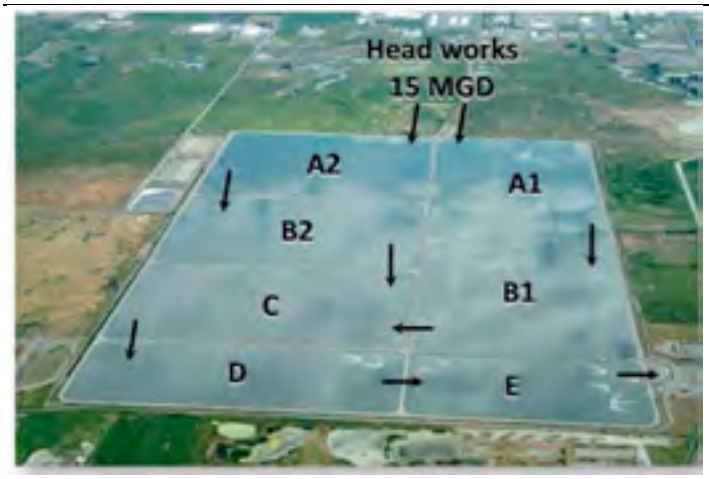


Figure 1. Logan Lagoon treatment system of seven ponds for a flow of 15 million gallons per day (MGD). Parallel ponds include A1/B1 and A2/B2 while ponds C, D, and E are sequential, and retention time is 60-90 days.

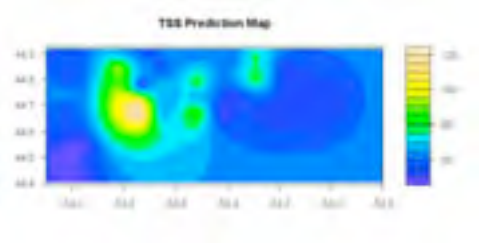


Figure 2. Phosphorus concentrations in the Logan Lagoon System

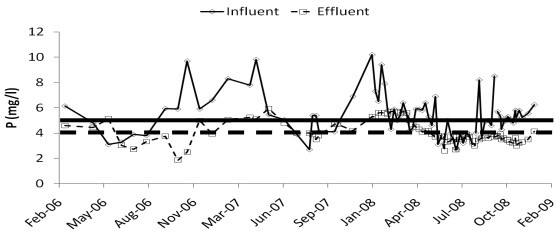


Figure 3. Nitrogen concentrations in the Logan Lagoon Systems.

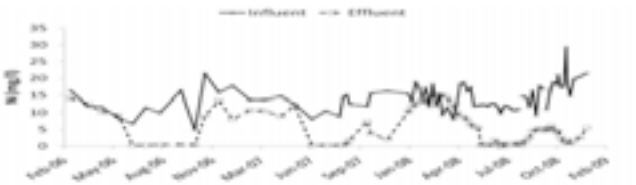


Figure 4. Algae (as total suspended solids or TSS).

Detection of Microbes that Biodegrade MTBE Contamination

Principal Investigators:
Ronald C. Sims
Charles Miler

Partners/Collaborators:
- ***State**: John Menatti, UDEQ*

Project Description

- **Need and Purpose**:

  Spilled gasoline contains methyl tertiarybuytl ether (MTBE). The DEQ's Division of Environmental Response and Remediation oversees remediation actions at a site contaminated by leaking underground fuel tanks (LUFTs), Figure 1. The Division needs procedures and tools to assist in site remediation. If microbes that can biodegrade MTBE are naturally present at a site, then the technology of Natural Attenuation (NA) can be used to remove MTBE from the site through the stimulation of the naturally occurring microbes. Sorption of MTBE to surrounding sediment would reduce the rate of movement of the MTBE in the ground water.

  Assistance to the UDEQ included development of an MTBE genetic probe for the detection of microbes that have the ability of degrade MTBE at a contaminated site and evaluation of sorption of MTBE in gasoline to underground sediments.

- **Benefits to State:**
  Bioremediation of MTBE could reduce or eliminate more costly methods of treatment that include pump and treat or sorption to activated carbon. The method to measure sorption of MTBE to underground sediments allow evaluation of the rate of migration of MTBE in ground water

- Geographic Area(s): including:

  Study Area: Abby's Corner and other underground contaminated sites containing MTBE.

  Areas Benefited: All areas of the state of Utah that have identified MTBE contamination of ground water.

- **Accomplishments**:

  Findings:

  1. A gene probe for MTBE was designed based on microbes that are known to produce enzymes to accomplish MTBE Biodegradation. The gene probe was tested on standard water and sediment samples.

  2. Sorption of MTBE was evaluated and is shown in Figure 2.

  Results: A genetic probe tool and a sorption isotherm method and results provide the DEQ with information and tools for evaluation and remediation of MTBE contaminated sites in Utah.

Informational Resources:

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

Figure 1. Aerial view of the Abby's Corner site in Salt Lake City.

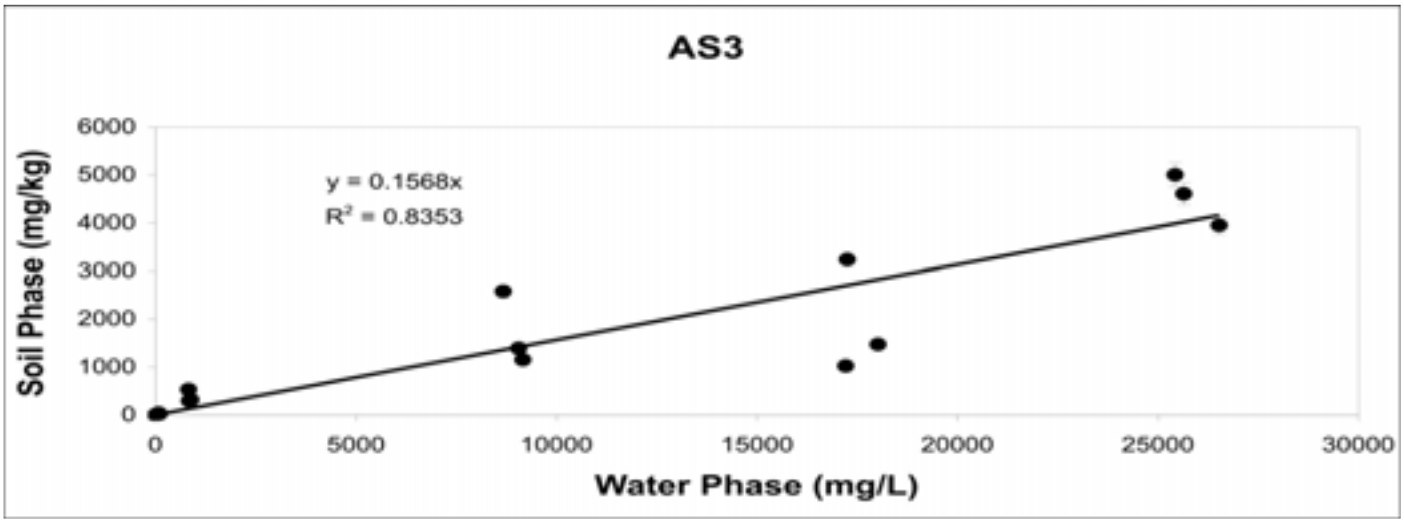


Figure 2. Sorption of MTBE between the water phase and the soil phase.

Laboratory-Scale Biological Phosphorus Removal

Principal Investigators:
Ronald C. Sims
Sridhar Viamajala
Charles Miler

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

Project Description

- **Need and Purpose**:

  A biological process for the removal of phosphorus from a Lagoon Wastewater Treatment System could save in excess of $100 Million compared with the installation of a chemical precipitation system. Laboratory-scale tests based on increasing indigenous algae growth over that observed in the current Lagoon System through engineered mixing are being evaluated for effectiveness of phosphorus uptake by the algae.

- **Benefits to State**

  Reduction in cost for wastewater treatment to remove chemical phosphorus will allow 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, and redirect the financial support to other important projects.

- **Geographic Area**:

  Study Areas: Northern Utah region that includes the cities of Logan, Hyde Park, Smithfield, North Logan, Nibley, and Hyrum.

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

- **Accomplishments**:

  Findings: Laboratory raceway-type reactors were constructed and operated to provide engineered mixing of wastewater and algae that resulted in the stimulation of algal growth with a simultaneous enhanced uptake of phosphorus.

  Results: The concentration of phosphorus in the wastewater was significantly reduced under engineered mixing conditions, even for the control bioreactors where no nutrient (nitrogen) was added. The results demonstrate that the algae that currently grow in the Logan Lagoons can be stimulated to increase in number and concentration, and thereby remove algae from the water.

Work Plan FY09/FY10

Develop scaled-up algae biotechnology systems for phosphorus removal.

Informational Resources

Presentation: Sustainable Production of Biofuels from Algae. Institute of Biological Engineering 2009 Annual Conference, California (March).

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

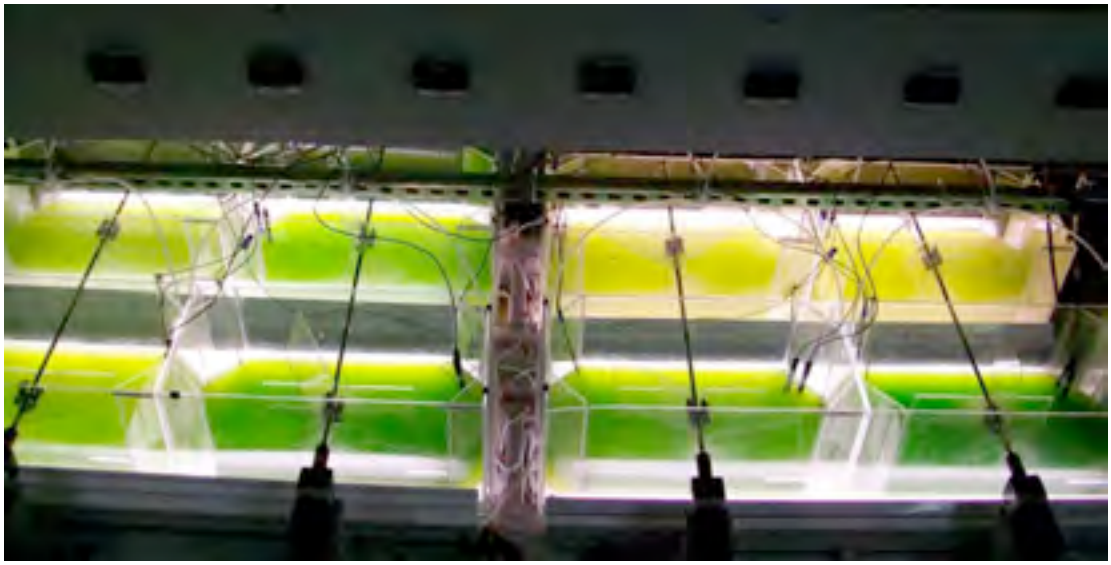


Figure 1. Laboratory raceway bioreactors designed and operated to improve algal growth and phosphorus uptake for treatment of the Logan Lagoon wastewater treatment system.

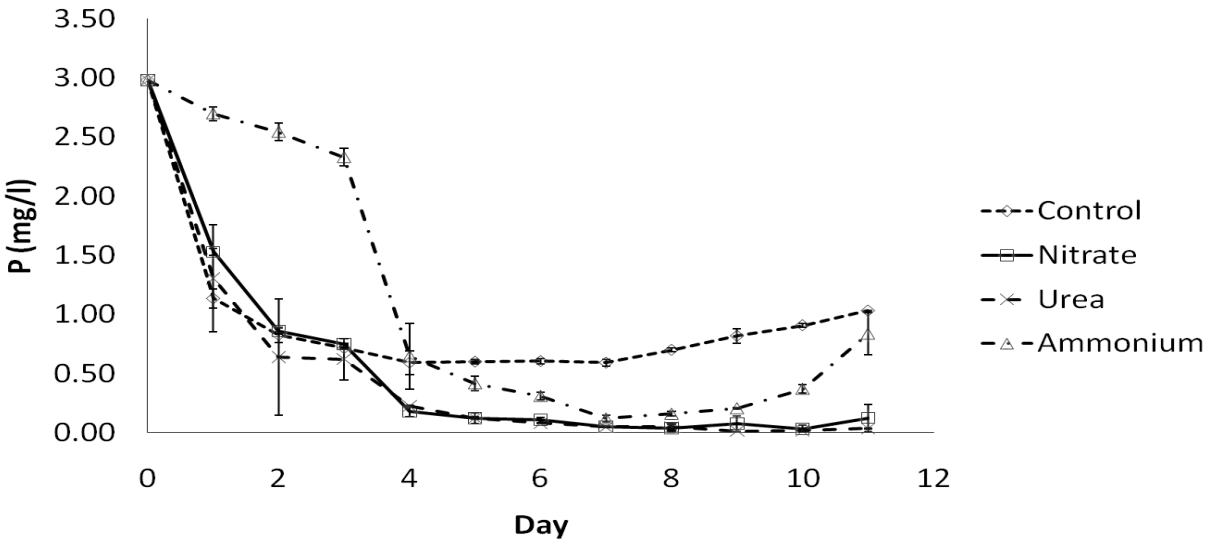


Figure 2. Results for phosphorus removal from Logan Lagoon wastewater by algae in laboratory raceway bioreactors supplemented with different forms of the nutrient nitrogen.

Microbe-Based Processes for Producing Bioplastic Materials

Principal Investigators:
Ronald C. Sims
Charles Miler

Partners/Collaborators:
- ***Local**: Issa Hamud, City of Logan*

Project Description

- **Need and Purpose**:

  This project developing microbe-based processes for the production of bioplastic materials as a substitute for petroleum-based plastics. The biological engineering processes and systems will create opportunities to use domestic feedstocks, including wastewater and waste chemicals, for the production of domestic sustainable plastics that can be used in the environmental, commercial, and medical industries.

- **Benefits to State:**

  Development of the know-how necessary to design, build, and implement large-scale industrial facilities that can produce plastic materials based on microbial systems and processes will generate new technologies, businesses, and products in Utah, as well as impact the entire nation. The biocompatibility and biodegradability of PHB make it a practical replacement for petroleum-based plastics. Applications range from commercial packaging to biomedical designs such as drug delivery systems, tissue engineering, and orthopedics. One of the most important aspects is sustainability.

- **Geographic Areas:**

  Study Areas: City of Logan Wastewater Reclamation Facility that treats the wastewater of six towns, including Logan, Hyde Park, Smithfield, North Logan, Nibley, and Hyrum.

  Areas Benefited: All areas of the state of Utah.

- **Accomplishments**:

  Findings: Microbes and feedstock chemicals are associated with municipal and other wastewaters. The monitoring of bioplastic production by microbes was accomplished by designing a bioplastic detection system using a genetic marker associated with light (fluorescence) production. The fermentor used for bioplastic production is shown in Figure 1.

  Results: This project demonstrated the possibility of using a genetic marker (green fluorescent protein) to indicate bioplastic expression in bacteria and the optimal time for harvesting bioplastic materials from the bacteria.

Work Plan FY09/FY10

Construct bacteria that are able to secrete bioplastic material through the cell membrane, thus decreasing the processing technologies which use toxic solvents, and separation and isolation steps for bioplastic recovery.

Informational Resources

This project was presented at the Massachusetts Institute of Technology as part of the 2008 International Genetically Engineered Machine (iGEM) competition and was awarded a Bronze Medal. Details of the project and the presentation can be viewed at the website address: http://2008.igem.org/Team:Utah_State/Project.

Contact: Dr. Ronald C. Sims, (435) 797-3156, E-mail: ronaldsims1@gmail.com.

Figure 1. Fermentor used for bioplastic production.

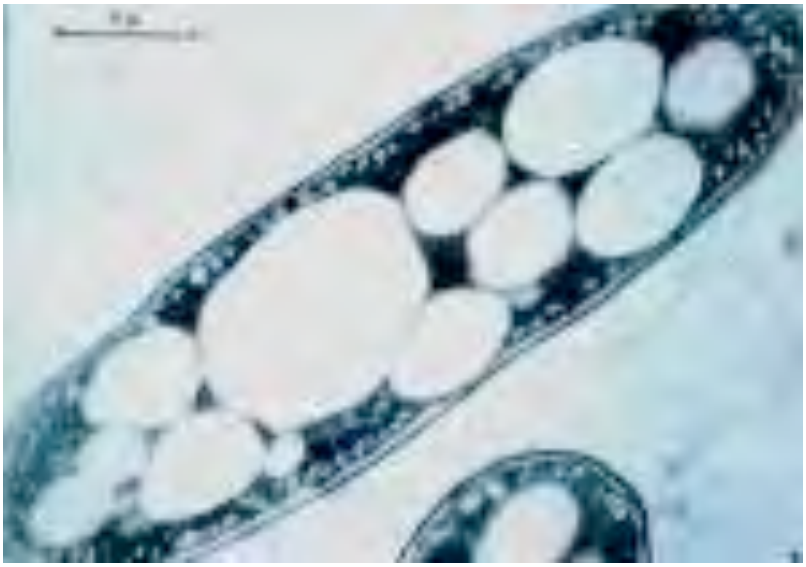


Figure 2. Bioplastic particles produced by bacteria.

Phosphorus Control and Management Using Biological Processes

Principal Investigators:
Ronald C. Sims
Sridhar Viamajala
Charles Miler

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

Project Description

- **Need and Purpose**:

  The City of Logan has been mandated to lower the concentration of the chemical phosphorus that leaves the Water Reclamation Facility and enters Cutler Reservoir. Phosphorus causes algae to grow resulting in a green appearance of the water and reducing the oxygen content of the water at night. This results in fish kills and deterioration of water quality.

  Current technology for reducing phosphorus concentration in water that has been estimated by the City of Logan to result in an increase of approximately $40 to $50 per month per household. This project is developing and testing inexpensive and natural biological processes that remove phosphorus through algae uptake at the Water Reclamation facility and then separation of the algae from the water before the water exists the facility and moves toward Cutler Reservoir.

- **Benefits to State:**

  Ability to reduce the pollutant phosphorus through the application of algae biotechnology will:

  1. Enable other cities, towns, and communities in Utah to utilize this technology for the treatment of waters and wastewaters to ensure environmental health and protection at costs that are significantly lower than conventional technologies.

  2. Enable to state of Utah Department of Environmental Quality to reduce the amount of loans and grants to community for upgrades to wastewater reclamation facilities, and redirect the financial support to other important projects.

- **Geographic Areas:**

  Study Areas: City of Logan Wastewater Reclamation Facility that treats the wastewater of six towns, including Logan, Hyde Park, Smithfield, North Logan, Nibley, and Hyrum.

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

- **Accomplishments:**

  Findings: A biotechnology process has been developed that reduces the phosphorus concentration levels below those mandated by the state of Utah and the U.S. Environmental Protection Agency. The process is applicable to other communities that utilize open ponds or lagoons for wastewater treatment.

  Results: Algae that grow and thrive in the Logan Lagoon system must be harvested before they die and release phosphorus back into the Lagoon water. As can be seen in the figure above, algae remove phosphorus from the water while they grow, and then release phosphorus back into the water (seen by the increase in concentration) when they die.

The Algae can be removed from the treated water using standard separation technology (Dissolved Air Flotation) so that the treated water leaving the system meets state and federal regulations for phosphorus concentration.

Work Plan FY09/FY10

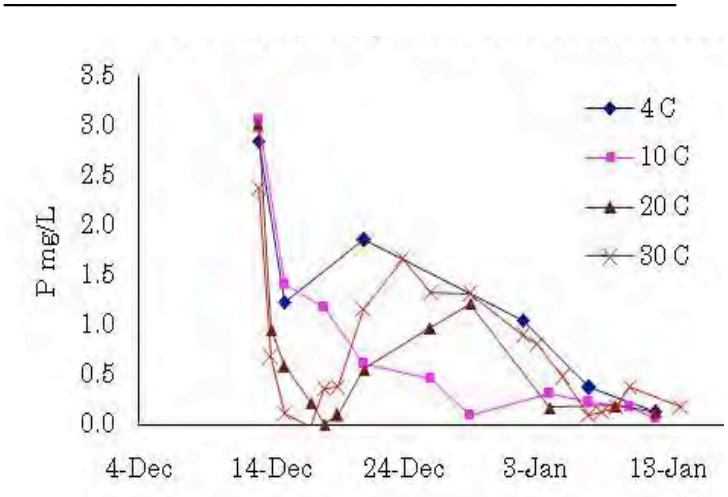
- Develop scaled-up algae biotechnology systems for phosphorus removal.
- Develop design criteria for separation of algae from water.

Informational Resources

Presentation: Sustainable Production of Biofuels from Algae. Institute of Biological Engineering 2009 Annual Conference, California (March). IBE wiki site:
http://openwetware.org/wiki/Institute_of_Biological_Engineering

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

Algae Bioreactor in the Laboratory



Effect of algae on phosphorus removal from Logan Lagoon water at temperatures representative of seasonal changes

Pilot-Scale Biological Phosphorus Removal from Lagoon Wastewater Treatment Systems

Principal Investigators:
Ronald C. Sims
Sridhar Viamajala
Charles Miler

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

Project Description

- **Need and Purpose**:

  A biological process for the removal of phosphorus from the Logan Lagoon Wastewater Treatment System could save in excess of $100 Million compared with the installation of a chemical precipitation system. Pilot-scale tests based on results of laboratory-scale tests for algae growth and phosphorus removal are being evaluated for effectiveness.

- **Benefits to State:**

  Ability to reduce the phosphorus pollution through the application of algae biotechnology will 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, and redirect the financial support to other important projects.

- **Geographic Areas:**

  Study Areas: Northern Utah region that includes the cities of Logan, Hyde Park, Smithfield, North Logan, Nibley, and Hyrum.

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

- **Accomplishments**:

  Findings: Outdoor Pilot-scale raceway-type bioreactors (8 feet long by 3 feet wide) were constructed and operated to provide engineered mixing of wastewater and algae that resulted in the stimulation of algal growth with a simultaneous enhanced uptake of phosphorus.

  Results: Results for growth of algae and phosphorus concentration reduction are shown in Figure 2. The concentration of algae in the pilot bioreactors (300 mg/L) were generally higher by a factor of five compared with the concentration of algae in the Logan Lagoons (60 mg/L). The concentration of phosphorus in the wastewater was significantly reduced as the concentration of algae increased under engineered mixing conditions. The results demonstrate that phosphorus removal and algae growth are inversely related, and that raceway bioreactors can accomplish reductions in phosphorus concentrations that meet state and federal standards.

Work Plan FY 09/FY10

Test the pilot scale reactors under seasonal changes in temperature.

Informational Resources

Presentation: Sustainable Production of Biofuels from Algae. Institute of Biological Engineering 2009 Annual Conference, California (March).

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

Figure 1 Pilot-scale raceway bioreactors designed and operated to improve algal growth and phosphorus uptake for treatment of the Logan Lagoon wastewater treatment system.

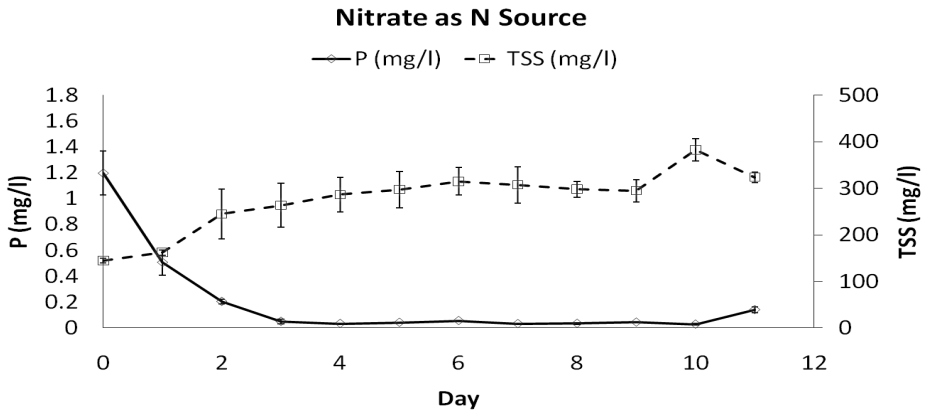


Figure 2. Results for algal growth (TSS = total suspended solids) and phosphorus removal from Logan Lagoon wastewater by algae in pilot-scale raceway bioreactors.

Real Time Polymerase Chain Reaction (RT-PCR) Instrumentation

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

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

Project Description

- **Need and Purpose**:

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

  The objective of this on-going project is to facilitate development of routine quantitative molecular biology capabilities within the EQL to support development of advanced molecular biology research.

  RT-PCR instrumentation made possible by this research funding has provided the EQL with quantitative molecular biology capabilities to generate quantitative 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 and their graduate students and technicians to carry out quantitative analysis of DNA from field generated soil, groundwater and reservoir samples, soil and water samples from pilot-scale laboratory columns, pure and mixed culture samples, and laboratory microcosm reactors to enhance our understanding of microbial community structure and interactions in natural and engineered contaminated environments. These RT-PCR tools are being used in conjunction with other microbial community analysis techniques, primarily ARISA analysis, to aid in exploring the make-up of impacted microbial communities of interest.

- **Benefits to the State:**

  Real-time PCR (RT-PCR) instrumentation provides quantitative capabilities for the low level detection of specific microorganisms and functional genes in environmental samples. The key aspect of this technology related to State of Utah problems is demonstrated in applications of RT-PCR techniques to:

  1. Provide quantitative analysis of specific organism numbers and/or gene copies 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 Utah reservoir microbial community composition to investigate microbial sources of taste and odor and eutrophication problems in them.

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

- **Geographic Areas**:

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

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

- **Accomplishments:**

  At least four separate studies are underway utilizing this equipment as a significant part of the analyses to support phytoremediation studies currently being conducted at Hill AFB. 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, and groundwater plumes adjacent to Hill AFB, and also to identify the sources of algal blooms and surface water impacts in Pineview Reservoir. Specific results generated from the use of this equipment are highlighted in the project summaries for these individual projects.

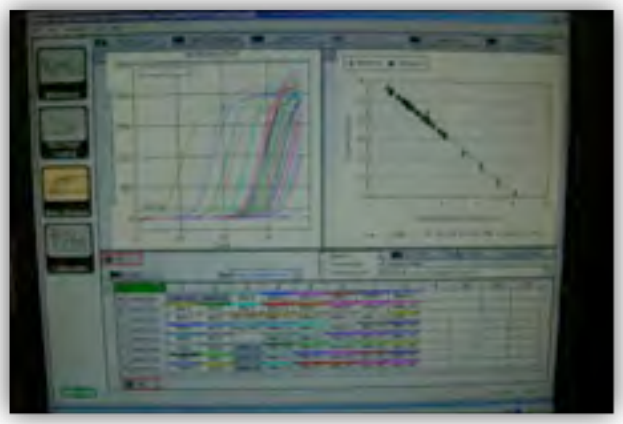
Work Plan FY 09/FY10

Continued further development of RT-PCR capabilities within the EQL is planned by supporting additional internal and external projects needing quantitative molecular biology support. This is being done through the application of RT-PCR to new molecular probes to broaden our range of experience in quantifying microbial DNA in phytoremediation areas, wastewater, natural reservoirs and landfills.

Informational Resources

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

Data processing and analysis of amplified products for sample quantitation



Screenshot of quantitative PCR amplification results for environmental samples

Environmental Quality: Land, Water, and Air

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Environmental Quality: Land, Water, and Air

Project Name	FY2009 Actual Expenditures	FY2010 Budgeted Expenditures	FY2011 Planned Expenditures
Advanced Instrumentation for Environmental Quality Analysis	$536,429.30	$50,000.00	$0.00
Analysis of Environmental Feasibilty for Proposed Green Waste Collection Program in Salt Lake County	$4,125.47	$4,249.23	$4,376.71
Analysis of Microbial Diversity and Dechlorinating Potential at Solvent Contaminated Sites throughout Utah	$23,717.41	$5,000.00	$0.00
Bioavailability of Nanoparticle Metals and Metal Ions to Microbes and Plants	$12,462.80	$12,836.68	$3,248.96
Cooperative Study of Cache Valley's Ambient Ammonia Distribution and Vertical Ozone Profiles	$91,474.81	$85,000.00	$87,550.00
Economic Worth of Data in Water Resources and Water Quality Analyses	$7,020.69	$0.00	$0.00
Evaluation of Deep Installations of Septic System Drainfields in Utah: Performance and Treament Effectiveness	$30,434.56	$31,347.60	$32,288.02
Evaluation of Duckweed as a Technology for Management of Nutrients and Emerging Contaminants in Municipal Wastewater Systems	$51,770.14	$60,000.00	$47,000.00
Evaluation of Water Supply and Wastewater Treatment/Reuse Options, Cedar City, Utah	$4,125.47	$4,249.23	$0.00
Identifying Sources of Indoor Air Contamination: 1, 2-Dichloroethane from Holiday Decorations	$21,647.06	$22,296.47	$0.00
"Lab-on-a-Chip" Miniaturized Salinity Sensor Arrays for Water Quality Monitoring	$74,222.83	$76,449.51	$58,720.00
Potential Impacts of Septic Systems on Ground Water in Castle Valley, Utah	$23,021.77	$23,712.42	$0.00
Raman Microscope System for Soil and Water Microorganism Analysis	$9,001.74	$0.00	$0.00
Release of Arsenic from Aquifer Solids in Northern Utah under Anaerobic Conditions: Exploring Relationships with Iron Mineral Reduction	$151,973.82	$156,533.05	$42,500.00
Sediment Management for Small Reservoirs: Logan First Dam Study	$9,203.67	$5,000.00	$5,150.00
Septage Treatment, Handling, and Disposal Practices in Utah	$16,524.77	$8,262.39	$8,510.26
Tree Core Sampling for Locating Potential Phytoremediation Sites	$19,140.80	$19,715.02	$0.00
Designated Projects		$966,005.00	$0.00
Undesignated Projects		$157,000.00	$237,000.00
Total	**$1,086,297.11**	**$1,687,656.60**	**$526,343.95**

Advanced Instrumentation for Environmental Quality Analysis

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

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

Project Description:

- **Need and Purpose**:

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

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

- **Benefits to the State:**

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

- **Geographic Areas**:

  Study Area: State of Utah

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

Informational Resources

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

Organic analysis- GC/MS

Inorganic analysis-ICP/MS

Biological analysis - PCR

Analysis of Environmental Feasibility for Proposed Green Waste Collection Program in Salt Lake County

Principal Investigator:
R. Ryan Dupont

Partners/Collaborators:
- ***Local**: Linda Hamilton, Public Works Director, Salt Lake County, Utah; Rick Graham, Public Works Director, Salt Lake City; John Ioannou, Manager, Salt Lake Valley Solid Waste Management Facility*

Project Description

- **Need and Purpose**:

  The purpose of this project was to evaluate the environmental impact of implementing a curbside green waste collection program in Salt Lake County, particularly with respect to changes in Green House Gas (GHG) emissions, and improving the overall carbon footprint of Salt Lake County.

  Various scenarios are presented within this study that assume different levels of public participation in a green waste recycling program, and comparisons are made to the current Base-Case situation in terms of changes in projected GHG emissions and energy requirements for green waste management. Also included is a scenario in which green waste recycling is eliminated at the Salt Lake Valley Solid Waste Management Facility including decisions regarding implementation of green waste collection and recycling County-wide to reduce the overall carbon emissions of the valley.

- **Benefits to the State:**

  Evaluating the environmental impact of solid waste management options can lead to reduced carbon emissions and energy use throughout Salt Lake County, and throughout the state since solid waste is collected, processed and disposed all over Utah. This solid waste management evaluation methodology can be used 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.

  2. Identifying options for solid waste management including source reduction, recycling, composting, and incineration, which can be used to modify these carbon and energy footprints and enhance the sustainability of solid waste management practices within the State.

  For Salt Lake County, this proposed County-wide green waste recycling program represents a significant investment in collection and green-waste processing costs. In addition, methane gas recovery for energy production takes place at the Salt Lake Valley Solid Waste Management Facility. Diverting green waste from the landfill for composting potentially diverts methane production potential from the gas recovery/energy generating facility, and the overall environmental benefits of making the switch to green waste diversion were quantified through this analysis.

- **Geographic Areas**:

  Study Area: Salt Lake 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 findings of this analysis were unexpected, and indicate that due to landfill gas collection and energy generation that takes place at the Salt Lake Valley Solid Waste Management Facility, the carbon sequestration provided through landfilling, and the energy requirements for composting, that the elimination of the green waste recycling program in Salt Lake County would result in the most significant reductions in GHG emissions and energy utilization of all of the options considered. Consistent with this observation is the fact that as more green waste diversion for composting takes place with increased public participation, GHG emissions and energy consumption required for the management of this diverted material significantly increase.

Results: Acknowledging the many benefits of a green waste diversion and composting program, including: revenue generation, landfill space preservation, valuable commodity (compost) production for soil conditioning and soil improvement, and public involvement in waste reduction and recycling, it appears most prudent for Salt Lake County to propose a voluntary green waste recycling program aimed at providing more efficient, commercial-scale collection of the currently recycled green waste stream, but not actively seek to increase the green waste recovery rate from the municipal waste stream. With substitution of commercial collection for the private vehicle collection/transport activities currently taking place, modest reductions in GHG emissions (544 $MTCO_2$/yr) and significant reductions in energy use (7,830 million BTUs) could be realized, while still providing the benefits of a community composting operation to the citizens of Salt Lake County.

Work Plan FY 09/FY10

- Disseminate through the end of December 2009 findings of this project to interested parties including:
  - Salt Lake Valley Solid Waste Management Council.
  - Salt Lake County Mayor.
  - Recycling Coordinators from city and county governments in the Salt Lake Valley.

Informational Resources

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

Website: http://homepage.mac.com/rdupo/SLCounty_Green_Waste_Study_Report_Files

Analysis of Microbial Diversity and Dechlorinating Potential at Solvent Contaminated Sites Throughout Utah

Principal Investigators:
R. Ryan Dupont
Darwin Sorenson
Joan McLean

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

Project Description

- **Need and Purpose**:

  The use of chlorinated solvents has been historically widespread throughout Utah resulting in a legacy of contaminated groundwater sites at both former and currently operating industrial facilities. Chlorinated solvent impacted groundwater poses a significant threat to public health and the environment when exposure pathways are completed, such as fruit trees and fruit growing above groundwater plumes. Results at phytoremediation sites suggest that significant differences in TCE transformation and metabolic products are occurring in trees, and may be due to differences in microbial communities within the trees themselves (endophyte community).

  The objective of this study was to determine if a correlation between TCE treatment and the endophytic community present in trees can be established in a controlled greenhouse environment, and further if the endophytes present in the tissues of these exposed trees originate either from the outside environment (i.e., soil, water, and air) or from the parent tree, and whether these endophytes play an active role in the bio/phytoremediation of TCE

- **Benefits to the State:**

  Determination of the significance of endophytic microbial communities on the transformation and fate of TCE in contaminated groundwater benefits the State in a number of ways including:

  3. Improving the understanding of the overall fate of TCE and its degradation products in contaminated environments located throughout the state.
  4. Improving the completeness of the quantitation of the fate of TCE and its degradation products as they move and are transformed within the environment at these contaminated sites.
  5. Identifying the potential and practicality of improving site remediation system effectiveness through the utilization of engineered endphytic communities to accelerate TCE transformation.

- **Geographic Areas**:

  Study Area: Hill AFB in Weber County.

  Areas Benefited: All locations in the state with TCE impacted groundwater sources would potentially benefit from the findings of this project in improving the understanding of the role of endophytic microbial communities in impacting TCE degradation for site remediation.

- **Accomplishments:**

  Findings: The endophytic microbial communities present in the hybrid poplar trees of this study were relatively high both in concentration and in diversity, both of which were affected by TCE treatment. It was observed that the community within these exposed poplars was able to adapt

to TCE addition. The microorganisms associated with plants should therefore always be included when phytoremediation is considered.

Results: Plant tissue chemical analyses indicated:

- All tissues of dosed trees were exposed to TCE as evidenced by measureable TCE concentrations in all root, stem and leaf samples analyzed in the study.
- Evidence of anaerobic microbial dechlorination was not seen, but metabolism of TCE to TCAA and TCEtOH in tree tissue was observed

Microbial community analyses indicated:

- Treatment of hybrid poplar trees with TCE had a significant effect on the microbial community. The quantity and diversity of bacteria and fungi were reduced in several cases with the addition of TCE.
- The diversity of the microbial community shifted due to TCE treatment based on multivariate statistical analysis.

Work Plan FY 09/FY10

Final analysis of all plants upon harvesting will be carried out during FY 10 to develop a comprehensive evaluation of TCE dose effects on hybrid poplar endophytic microbial communities in terms of quantity and diversity of eubacteria, fungi, and archea. In addition, comparisons will be made among original hybrid poplar cuttings, OU2 poplar cuttings, OU2 poplars grown in the greenhouse, and samples taken directly from OU2 trees at HAFB to more clearly determine the origin of endophytes present in these trees and their resultant response to naturally occurring and imposed green house TCE exposure scenarios.

Informational Resources

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

Website: http://homepage.mac.com/rdupo/MicrobialDiversity_Study_Report_Files

OU2 Plume Map

Hybrid Poplar Greenhouse Study

Bioavailability of Nanoparticle Metals and Metal Ions to Microbes and Plants

Principal Investigators:
Joan McLean

Partners/Collaborators
None

Project Description

- **Need and Purpose**:

  Metal oxide nanoparticle are being manufactured for use in a variety of applications in medicine, food safety, personal care products, agriculture and various other manufacturing operations and industries. Metal oxide nanoparticles also occur naturally in soil and water environments. We are investigating the bioavailability and toxicity of metal oxide nanoparticles of copper oxide and zinc oxide on a soil bacterium and on wheat. How metals affect beneficial soil bacteria survival has impacts on carbon and nutrient cycling and plant productivity.

- **Benefits to State:**

  Results will directly benefit the counties in Utah with current metal contamination from abandoned and active hardrock mining and counties planning to expand industrial development in the State of Utah. 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

- **Geographic Area**:

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

  Areas Benefited: All counties in Utah, by protecting environmental quality and human health from metal exposure.

- **Accomplishments**:

  Findings: Data are now being gathered and results analyzed.

  Results: We have shown that bacteria and plants (wheat) respond differently when exposed to metal ions and metals associated with nanoparticles. One question we are addressing is whether the biological response is due to only ions or are the nanoparticles directly bioavailable and toxic. We are developing analytical procedures to distinguish ions versus nanoparticles in bacteria and plant tissue.

Work Plan FY 09/FY10

The first year of this three-year project is completed. The main objective to be addressed this next year is how environmental variables affect plant-bacteria-metal interactions.

Informational Resources

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

Cooperative Study of Cache Valley's Ambient Ammonia Distribution and Vertical Ozone Profiles

Principal Investigator:
Randal S. Martin

Partners/Collaborators:
- ***Local:*** *Grant Koford, Bear River Health Department*
- ***State****: Utah DAQ (Air Monitoring Center)*

Project Description

- **Need and Purpose**:

  In December of 2008, the Cache Valley, as well as most of Utah's Wasatch Front, was officially declared non-attainment for the air pollutant $PM_{2.5}$ (particulate matter less than two and one-half microns in diameter) by the U.S. Environmental Protection Agency. Past research has found that in this region these wintertime pollutants are dominated by secondary (not directly emitted) compounds, primarily ammonium nitrate (NH_4NO_3). Further research has shown that the photochemical reactions necessary to form NH_4NO_3 are limited by the nitrate side of the compound, that is, the reactions to form atmospheric nitric acid (HNO_3) from precursor oxides of nitrogen emissions. Available ozone (O_3) plays a significant role in this series of atmospheric chemical reactions. Limited initial airplane studies on the vertical ozone found a strong positive O_3 gradient, with elevated values extending through the inversion layer, suggesting that at least some of the O_3 may be regionally, rather than locally derived. These findings could have significant implications on the effectiveness of any potential local remediation scenarios.

  Testing has been initiated to find light-weight, low cost methods of measuring vertical O_3 profiles via on-board measurement systems to be incorporated into tethered balloon packages or light-weight unmanned aerial vehicles (UAVs). Based on the successful past use of small, passive NH_3 samplers, one approach was to use similar O_3 samplers. Additionally, recent advancements in technology has made a smaller version of the standard O_3 boxes available to the scientific/regulatory community and one of these systems has been examined for possible use.

- **Benefits to State:**

  The Cache Valley air quality studies, cooperatively supported by local and state agencies, has led to the establishment of a viable and sustainable air quality research program with direct cooperation and coordination projects to understand air quality dynamics and inform better air quality management strategies.

- **Geographic Area**:

  Study Area: Cache Valley, Utah, including the entire, cross border airshed.

  Areas Benefited: Primarily, the Cache Valley, but findings and future work could logically be extended to the Wasatch Front, and perhaps the Uintah Basin (as air quality concerns there continue to grow).

- **Accomplishments**:

  Findings: The modification and application of light-weight air pollutant monitoring systems (in this case, O_3) seem promising. However, initial testing of passive O_3 badges to parallel studies seem less uncertain. Tests comparing the passive systems with collocated Federal Reference Method (FRM) monitors have shown significant differences, with the passive samplers severely under predicting O_3 concentrations in three of the four comparisons.

Results: In 2009, a portable, light-weight (< 2 kgs) O_3 monitor, which operates on the same principle of the much larger FRM monitors was acquired. The system was stripped down to further reduce the weight to enable it to be carried aboard a tethered balloon system or a small UAV. Characterization tests and reworking of the electronics for on-board battery operation were also accomplished.

The use of passive samplers has shown less promise. However, further laboratory tests are being conducted to verify the field comparisons.

Work Plan FY09/FY10

Work on developing protocols for economically and accurately measuring vertical ozone profiles will continue into FY10. Laboratory calibrations of the stripped-down light-weight, real-time O_3 monitor will be completed and it will be deployed, initially using a tethered balloon, then possibly on a UAV, to characterize the wintertime, vertical O_3 profile in the Cache Valley. Plans are to measure multiple profiles, under both inversion and non-inversion episodes.

Experiments are also underway to more fully characterize the passive O_3 monitors by generating known ozone concentrations and varying the exposure times. If successful, these systems may also be deployed on the aerial systems.

Informational Resources

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

Economic Worth of Data in Water Resources and Water Quality Analyses

Principal Investigator:
Jagath J. Kaluarachchi

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  Given that data gathering is always expensive in hydrologic and environmental studies, it is important to understand the value of data and to identify the optimal amount of data to be collected to address the goals and objectives so that there is a tradeoff between cost and worth of data. This study addressed this need by investigating the development of an appropriate methodology and demonstrating the applicability of this methodology in assessing the value of data compared to the intended objectives.

- **Benefits to State:**

  Collection of data for water resources planning and management and water quality assessment is a crucial step. Typically, such data gathering efforts are expensive and time consuming. Therefore, a sound scientific understanding of the value of data is important in resource allocation, especially in decision-making related to collection of additional data and information. In this work, a generic methodology that can be applied to many data gathering scenarios related to water quality management at the watershed scale was developed.

- **Geographic Areas**:

  Study Areas: Applicable areas across Utah where environmental quality data are gathered.

  Areas Benefited: Areas vulnerable for surface and groundwater contamination and where mitigation strategies need to be implemented.

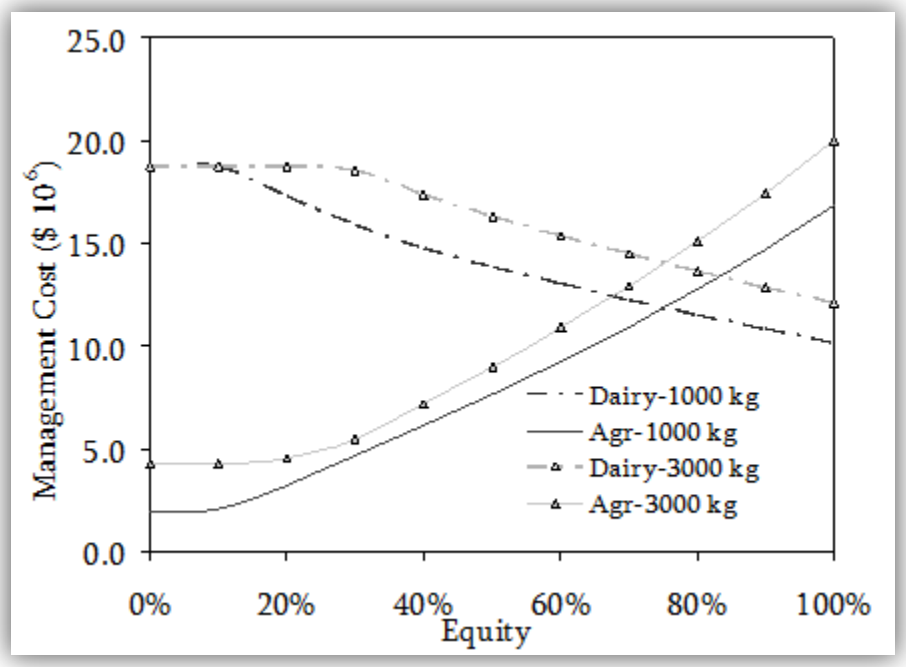
- **Accomplishments**:

  Findings: An appropriate methodology was developed and demonstrated to a variety of field scenarios.

  Results: Methodology developed to determine willingness-to-pay by stakeholders to collect environmental quality data to minimize health risks.

Work Plan FY 09/FY10

Project completed spring 2008



Informational Resources

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

Shaqadan, A. and J. J. Kaluarachchi (2008). Benefit-cost analysis for groundwater remediation considering socio-economic measures. Proceedings of the Annual Conference of Environmental and Water Resources Institute, Tampa, Florida, May.

Shaqadan, A. (2008). Decision analysis considering welfare impacts in water resources using the benefit transfer approach, PhD Dissertation, Utah State University, March.

Shaqadan, A. and J. Kaluarachchi (2006). Integration of socio-economic measures in benefit-cost analysis for groundwater remediation. Fall Meetings, American Geophysical Union, San Francisco, CA, December 11-15.

Evaluation of Deep Installations of Septic System Drainfields in Utah: Performance and Treatment Effectiveness

Principal Investigator:
Judith L. Sims

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

Project Description

- **Need and Purpose**:

  Common practice in the field of on-site wastewater treatment is that drain fields should be located at shallow depths in order to maximize aerobic decomposition of organic wastewater contaminants, and enhance evapotranspiration. This results in less transport of contaminants to ground water, and increased 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. This practice started many years ago in order to install the systems in soil materials that are more permeable than surface layers. The concern then was to dispose of the wastewater, with little attention given to the ability of the soil system to accomplish degradation of the wastewater contaminants. The practice of deep installation continues today – in some cases disposal is still emphasized instead of treatment-and also because the design process for deep systems results in much smaller systems.

  The concern is that treatment is not effective at the depths that septic systems are installed in Utah. Data will be developed to evaluate this issue.

- **Benefits to the State:**

  Utah's local health departments are presently permitting deep on-site systems without clear indication if these systems are adequately treating wastewater contaminants. Results of this research will provide information to the health departments on whether they can either continue permitting these types of systems with confidence or eliminate the use of the systems.

- **Geographic Area:**

  Study Area: Cache County.

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

- **Accomplishments**:

  Findings: With cooperation of the Bear River Health Department eight sites in Cache Valley were identified and sampling equipment installed in drain fields. Four of the sites utilize deep trenches for treatment of wastewater while four utilize shallow trenches. Sampling of the sites has begun and will continue through December of 2010. We have also worked with the owners of the sites to educate them on proper septic system use practices.

  Results: All analytical and sampling techniques have been developed and tested. Leachate samples from the drain fields are in the process of being analyzed for nitrate nitrogen, phosphorus, coliform bacteria, total suspended solids, and chemical oxygen demand to determine treatment effectiveness in both the shallow and deep trench systems.

Work Plan FY09/FY10

During FY09/10 we will continue sampling leachate produced within the eight study drain fields and will analyze the results of the contaminant measurements as we test the project hypothesis.

Informational Resources

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

Deep trench installation, Clarkston, November 2008

Deep trench system installation, Wellsville, November 2008

Site locations in Cache Valley

Installation of lysimeters using silica and bentonite. Access tubes extend to surface and are covered with a grate

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

Principal Investigator(s):
R. Ryan Dupont
Joan E. McLean

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 personal care products and pharmaceutical (PCPP) contaminants in municipal wastewater systems have become a growing concern to environmental regulatory agencies due to their effects on aquatic systems receiving these waste effluents. Conventional wastewater treatment systems are not effective in their removal. Current treatment alternatives are prohibitively expensive, particularly for small, rural communities.

  This study is to evaluate the effectiveness of duckweed (*Lemna minor*) for the uptake and transformation of phosphorous and PCPP contaminants from municipal wastewater especially in communities like Wellsville City and Logan City, which have lagoon wastewater treatment systems.

- **Benefits to the State:**

  Protection and enhancement of surface water quality, in terms of nutrient enrichment impacts, is of concern in many watersheds in the state. This project aims to develop an effective low-cost method for water quality improvements with a low or positive energy and environmental footprint.

- **Geographic Areas**:

  Study Area: Cache County.

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

- **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 phosphorous that accumulates in the duckweed biomass. The effectiveness of such a system is dependant, however, on the efficient and cost effective harvesting and stabilization/processing of this generated biomass.

  Results: Duckweed based nutrient removal has been found to be feasible based on:

  - Field scale growth of duckweed species at the Wellsville Lagoons range from 2,000 to 8,000 lb Dry Wt/Acre, with approximately 1 wt% phosphorous content.

- Phosphorous loading limitations to the Cutler Reservoir from Wellsville could be met through one to three duckweed harvests per year.

Duckweed biomass chemical analysis indicated:

- The duckweed has a high potential for methane production under anaerobic conditions based on the chemical composition of the harvested biomass.
- The duckweed has a high potential for ethanol production from harvested biomass fermentation.
- There is a high potential for the use of harvested duckweed biomass as an animal feed supplement based on its high complex protein content.

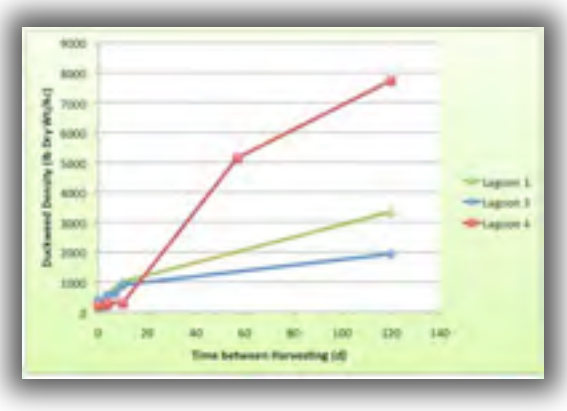
Work Plan FY 09/FY10

Laboratory studies of the growth and nutrient management potential of two aquatic plant species, Lemna minor and Wolffia globosa, that have been identified in Wellsville City wastewater lagoons will be carried out, along with anaerobic degradability, ethanol production, and animal feed digestability and nutrient potential studies. These later studies will be designed to evaluate the potential for the use of harvested biomass as a feedstock for methane and ethanol biofuel production, as well as for livestock feed potential. Finally, the produced plant biomass will also be utilized in additional laboratory flask studies to evaluate the potential for these species to bioconcentrate metals and hazardous organic compounds that occur in municipal wastewater.

Informational Resources

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

Website: http://homepage.mac.com/rdupo/Duckweed_Study_Report_Files



Duckweed Growth in the Wellsville Lagoons

Duckweed Cover on the Wellsville Lagoons

Evaluation of Water Supply and Wastewater Treatment/Reuse Options, Cedar City, Utah

Principal Investigator:
R. Ryan Dupont

Partners/Collaborators:
- ***Local**:* Gerald Sherrat, Mayor, Cedar City, Utah

Project Description

- **Need and Purpose**:

  This analysis was carried out at the request of Mayor Gerald Sherrat of Cedar City, Utah, (population 27,000) to evaluate proposed options for the exchange of water rights, treatment of municipal wastewater, and supply of treated wastewater effluent for irrigation use within the Cedar Valley. This study highlighted: current water supply and water use rates by the community of Cedar City; sustainable yield estimates for Cedar City's water supply; future supply development needs and reuse options; current wastewater treatment performance and nutrient management requirements; wastewater treatment options and estimated system costs; and recommendations for meeting future water supply and treatment demands to ensure a sustainable future for the growing Cedar City community.

- **Benefits to the State:**

  Evaluating the potential for effluent reuse and water rights exchange for Cedar City provides direct benefits to this community in terms of water quality and water resource planning for their future. This work has potential benefits to other communities within the state that may be faced with:

  6. Planning for growing community populations under conditions of dwindling water rights and water availability.

  7. Planning for sustainable growth and community development under pressure of carbon emission reductions, pollution prevention, and sustainable agricultural practices.

  8. For Cedar City, this proposed water exchange not only represents potential increases in water availability, but also marketable carbon credits and monetary benefits to local farmers by eliminating petroleum based fertilizers currently used in local agriculture with nutrient laden recycled wastewater. Fertilizer value and carbon credit enhancements could be realized throughout the state where safe and viable water reuse systems can be implemented.

- **Geographic Areas**: State of Utah.

  Study Area: Cedar City and Cedar Basin, Iron County.

  Areas Benefited: Irrigated agriculture and municipal wastewater treatment via Publically Owned Treatment Works occurs statewide, so all counties in the state would potentially benefit.

- **Accomplishments**

  Findings: Significant outdoor use of culinary water (52% of total municipal use) contributes to the high per capita water use rate in Cedar City (252 gal/cap/d), making it imperative that water conservation or water reuse options be seriously considered by the community in the near future. The high outdoor water use also appears to contribute to the higher than normal concentrations

of pollutants entering the community's wastewater collection system. Concerns regarding the protection of the Class 1A Pristine Aquifer in the Cedar Valley from excessive nutrient loading, suggests the use of alternative nutrient management options for Cedar City's wastewater.

Results: The current secondary wastewater treatment plant using nitrifying trickling filters provides up to 50% nitrogen removal, but this is not sufficient to ensure prevention of groundwater nitrate contamination below the effluent land disposal area. Improvements in the effluent disposal irrigation system, such as moving from flood irrigation to sprinkler irrigation, and controlling soil slope and grading are suggested. In addition, with effluent nitrate concentrations as high as 16 mg/L, some level of nutrient removal is necessary to ensure protection of the Cedar Valley aquifer from eventual nitrate contamination.

Four nutrient removal treatment train options compatible with the existing nitrifying trickling filter plant were evaluated in terms of nitrogen removal performance and capital and annual operating costs. These options included: Attached Growth Post-Denitrification, Attached Growth Pre-Denitrification, Suspended Growth Post-Denitrification, and Suspended Growth Pre-Denitrification. Based on nutrient removal efficiency and incremental cost above the existing treatment plant configuration, the Attached Growth Post-Denitrification and the Suspended Growth Pre-Denitrification processes should be considered for further analysis and detailed evaluation. Of particular interest are those options providing partial nitrogen removal which would allow for benefits to be accrued to parties participating in water rights exchanges with Cedar City as up to $40,500/yr in the form of crop nutrient value and potential salable carbon credits of $454,208 would exist in the reclaimed water.

Work Plan FY 09/FY10

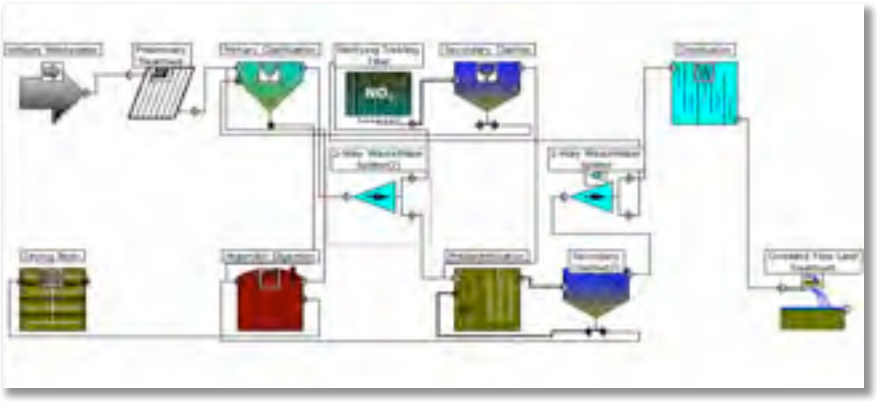
No additional work planned at this time.

Informational Resources

Contact:

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

Website: http://homepage.mac.com/rdupo/Cedar_City_Report_Files



Attached Growth Post-Denitrification Process Flowsheet

Identifying Sources of Indoor Air Contamination: 1,2-Dichloroethane from Holiday Decorations

Principal Investigator:
William J. Doucette

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

Project Description

- **Need and Purpose**:

  Groundwater contamination associated Hill AFB, Utah led to concerns about potential vapor intrusion into residences outside the facility boundary. Trichloroethylene (TCE) is the main contaminant of concern with 1,2-dichloroethane (1,2-DCA) present in some areas. An air-monitoring program implemented to detect vapor intrusion of these compounds found 1,2-DCA in homes outside areas of groundwater contamination, suggesting indoor sources in these cases. Investigative indoor air and product sampling were conducted to isolate consumer products emitting 1,2-DCA and to quantify the emission rates of identified products.

- **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. This study demonstrated that investigative indoor air sampling coupled with laboratory quantification of emission rates could be used to identify a specific indoor source of 1,2-DCA emissions (molded plastic holiday ornaments). Screening-level calculations also showed that the emission from these objects could lead to indoor air 1,2-DCA concentrations high enough to be of regulatory concern. The results were forward to the appropriate consumer protection agencies.

- **Geographic Areas**:

  Study Area: Residential areas located around Hill AFB, 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:**

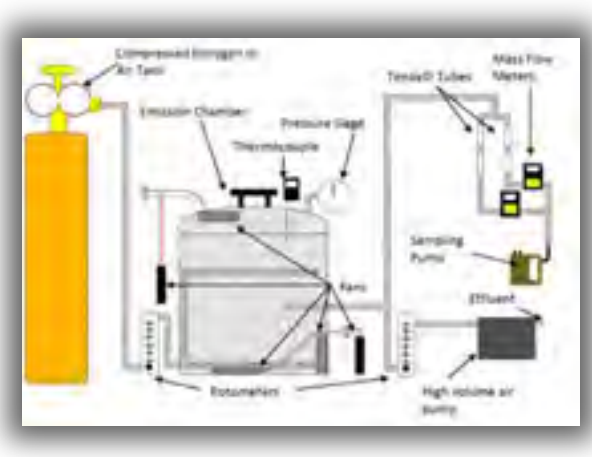
  Results: The combination of room-by-room air sampling and emission measurements was successfully used to identify molded plastic holiday ornaments, having measured emission rates as high as 0.3 μg 1,2-DCA/min. Subsequent testing of seven comparable retail items found similar 1,2-DCA emissions. Screening-level calculations show that the measured emission rates of 1,2-DCA from these items can lead to indoor concentrations high enough to be of regulatory concern (0.094 to 9.4 $\mu g/m^3$ based on 10^{-6} to 10^{-4} cancer risk levels).

Work Plan FY 09/FY10

Project completed.

Informational Resources

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



Schematic of the flow through emission chamber system.

Emission chamber containing ornament

Storage box sampling

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

Principal Investigator:
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. Most of the salt in the Colorado River 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 the majority of salinity ions (Cl^-, Na^+, SO_4^{2-}, Mg^{2+}, Ca^{2+}, and HCO_3^-) make the major contributions to Utah salinity problem. Benefits of this project are:

  9. Ion sensor arrays that can distinguish above individual ion concentrations and can be used for the measurement of salt loading in critical Utah rivers.

  10. A new portable detector integrated above ion probe arrays that is not currently available in market for measuring the most significant salinity ions that contribute salinity.

  11. Help farmers and Utah residents improve the timing and efficiency of water quality monitoring, and track the salinity sources in the water system.

  Utah Water Research Laboratory gathers water samples from different Utah sites having different salinity concentrations. The lab facilities (such as ion-exchange chromatograph) are used to validate our new detector device before it is used in field tests.

- **Geographic Areas**:

  Study Area: Price and San Rafael Rivers in Utah.

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

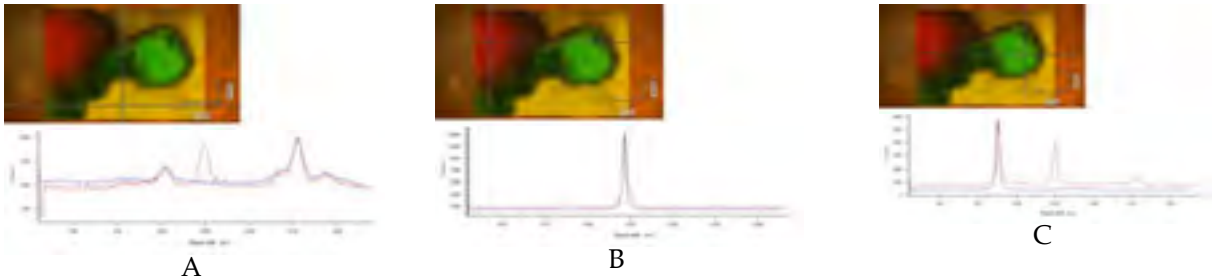
- **Accomplishments:**

  Findings: A new ionophore that can specifically and sensitively recognize SO_4^{2-} ion has been chemically synthesized and characterized. The resulting SO_4^{2-} ion probe sensor has been tested in standard sulfate water sample. A provisional patent application is being prepared by working with USU Technology Commercialization Office.

Results:

The main performance features of our newly developed ion probe sensor are:

1. A hydroxyl Schiff base molecule was synthesized from tetraethylenetetramine and 4-nitrosalicylaldehyde and explored.
2. The recognition site of synthesized ionophore to sulfate ion group is predicted by theoretical simulation.
3. E. coli has been identified as one of major biological contamination in drinking water system. In order to assess how the salinity ions could potentially impact on the microorganism in the water sample, we have applied Raman microscopy to image the ion distribution on the bacterial surface. This would provide the clue to genetically engineer microorganisms to bear the high salt concentrations and potentially clean up the heavy metal or salinity ion contamination.



A B C

Three colors indicate the different species: yellow (Mycobacteria JLS, A), red (NO_3^-, B), green (SO_4^{2-}, C).

This image result for the first time demonstrate the use of nano-sensor to probe ion distribution (NO_3^- and SO_4^{2-}) on single bacterial cell.

Patent activity:

1. Anhong Zhou, Amarchand Sathyapalan (2008). A Schiff hydroxamate molecule for sulfate ion selective electrodes", Provisional Patent application, Utah State University (Dec 2008, in preparation).
2. Anhong Zhou, Huifang Dou (2007). Electrochemical Chip with Miniaturized Sensor Array", U.S. Patent Application No. 11/761,916, filed by Utah State University (June 12, 2007).

Work Plan FY 09/FY10

- Recruit a research scientist or postdoc to join in this team in 2010 to synthesize new ion recognition candidate chemicals for detection at Utah sites.
- Pre-evaluation and test of these new synthetic recognition chemicals.
- Complete the provisional patent application for the new ion recognition chemicals.

Informational Resources

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

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

Potential Impacts of Septic Systems on Ground Water in Castle Valley, Utah

Principal Investigator:
Judith L. Sims

Partners/Collaborators:
- ***Local****:* Pam Hackley, Town of Castle Valley
- ***State:*** Mike Reichert, Division of Water Quality, Utah Department of Environmental Quality

Project Description

- **Need and Purpose**:

  This project addresses the protection of the groundwater quality in Castle Valley, Utah through the evaluation of potential impact from and management of on-site wastewater treatment systems in the Valley. Castle Valley is located in southeastern Utah approximately 17 miles east of Moab in Grand County, Utah. The Town of Castle Valley has 440 5-acre plots--each with their own well and septic system. Currently, the Town has approximately 270 approved water wells and 235 septic systems. Most of these wells and septic systems are situated on the unconsolidated deposits of the valley-fill, sole-source aquifer. The State of Utah Governor's Office of Planning and Budget estimates there will be almost 800 inhabitants in the Town by the year 2020, as Castle Valley is becoming increasingly popular as a site for vacation and retirement homes. The increase in development and its potential impact on the quality of groundwater resources is a cause of concern to the Town. All of the studies to date have stated that the single greatest potential source of contamination to the aquifer is septic systems**.** The overall goal of this project was to determine the threat of culinary water contamination and develop and implement a plan to protect the ground water in Castle Valley from contamination from septic systems. The project goal is to evaluate contaminant movement through drain field soils.

- **Benefits to the State:**

  Management of on-site wastewater disposal systems was identified as one of the nine priority non-point source pollution programs in the 2000 Utah Nonpoint Source Pollution Management Plan. This project addressed the protection of groundwater quality in Castle Valley, Utah through the evaluation of potential impact from and management of on-site wastewater treatment systems. Results of this study are being used in the development of a community outreach and communication program for on-site wastewater systems, including education in local geology, local water quality issues, and septic tanks and drain fields for the citizens of Castle Valley

- **Geographic Areas**:

  Study Area: Castle Valley, Utah in Grand County.

  Areas Benefited: Other communities in Utah may benefit from the community survey tool that was developed to assess community members' knowledge of septic system usage practices.

- **Accomplishments**

  Findings: The project involved sampling and analysis of leachate in four septic system drain fields throughout Castle Valley. Contaminants of concern included nitrate nitrogen, phosphorus, and coliform bacteria.

  Results: The study found that there is a slight to moderate risk to the aquifer from nitrate nitrogen in septic system effluent. The risk may be reduced by requiring new or replacement

septic systems to incorporate nitrogen-reducing technologies into design. There appeared to be an even less risk of movement of phosphorus and coliform bacteria through the drain field soils. The homeowners who participated in a survey of septic system usage practices showed an adequate knowledge of proper use of systems.

Work Plan FY 09/FY10

Project completed.

Informational Resources

Hirschi, Joshua (2009). Septic Systems in Castle Valley: Potential Impacts upon Groundwater and Possible Management and Mitigation Strategies. Draft M.S. Report, Department of Civil and Environmental Engineering, Utah State University, Logan, Utah.
Sims, Judith L. and Hirschi, Joshua (2009). Septic Systems in Castle Valley: Potential Impacts upon Groundwater and Possible Management and Mitigation Strategies. Report to Division of Water Quality, Utah Department of Environmental Quality, Logan, Utah.

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

Raman Microscope System for Soil and Water Microorganism Analysis

Principal Investigator:
Anhong Zhou

Partners/Collaborators:
None

Project Description

- **Need and Purpose**:

  This project to interface a Nanonics MV 1000 system to an existing Raman microscope system. This enhanced system would provide the multidimensional information for visualization and detection of single bacterial cells, e.g., E. coli, which are of great concern in water quality management.

- **Benefits to the State:**

  Ability to detect the broad spectrum of microorganisms in soil and water, specifically, with the acquisition of the Nanonics MV accessory will:

  12. Expand the capability of analysis of microorganisms in soil and water samples collected from Utah sites.

  13. Enable the single living cell analysis to quantify of most significant microorganisms that bioremedidate and biodegrade in contaminated soils, and on drinking and irrigation water in Utah.

- **Geographic Areas**:

  Study Area: This instrument will be primarily used in a research laboratory at USU, but contaminated soil or water can be analyzed from anywhere in Utah.

  Areas Benefited: Would benefit all sites in Utah

- **Accomplishments:**

  Findings: The installation of this new Nanonics MV module is underway, and some preliminary data for microorganisms is being collected. Mycobacteria JLS is a model microorganism used to demonstrate the capability of the bioremediation and biodegradation of PAH-contaminated soil.

  Results: The topography images and spectroscopy spectra of M. JLS are shown in Figure 1.

Work Plan FY 09/FY10

Instrument set up and testing will be completed.

Informational Resources

Contact: Dr. Anhong Zhou, Phone (435) 797 2863, E-mail: Anhong.Zhou@usu.edu

Website: Dr. Zhou at BIE Dept, USU: http://www.bie.usu.edu/

Data and images come from folder "**060209_2-day_old_JLS_on_AU_mica**"

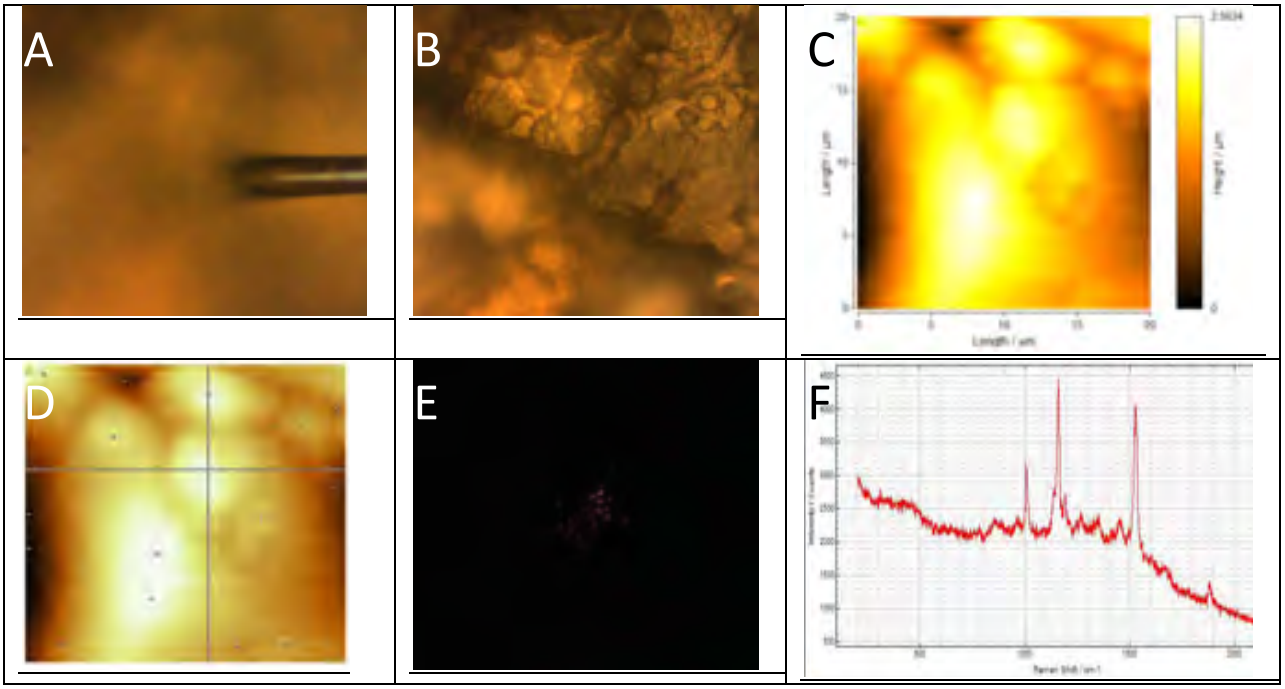
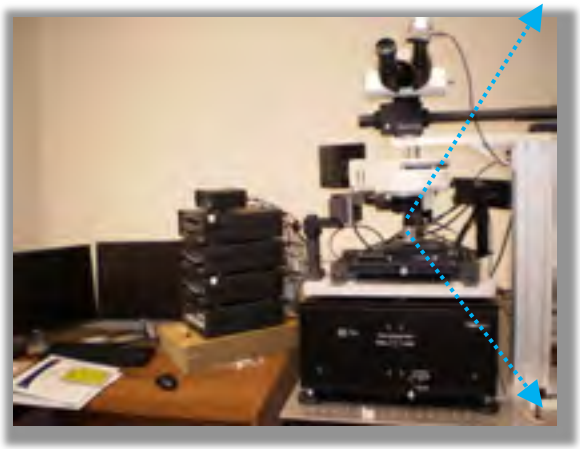
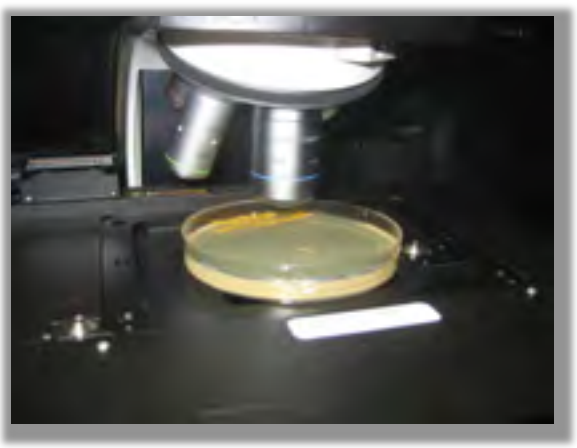


Figure 1. An example of the brightfield view of the AFM tip above a sample of JLS (A), the JLS sample in focus (B), AFM topography of JLS (C), AFM topography with Raman point overlay (D), laser focused on JLS for Raman acquisition (E), and Raman spectra of JLS (F).



Nanonics MV system (Partially supported from the matching funds under WR-1092 MLF)



Mycobacteria JLS under objective

Release of Arsenic from Aquifer Solids in Northern Utah Under Anaerobic Conditions: Exploring Relationships with Iron Mineral Reduction

Principal Investigator:
Joan E. McLean

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

Project Description

- **Need and Purpose**:

  Seventeen percent of the well water in Cache County tested as part of survey conducted by the USGS, contained levels of arsenic that exceeded the drinking water limit. Geologic formations throughout Utah contain arsenic. 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 around the City of Logan landfill.

- **Benefits to the State:**

  All counties in Utah will benefit from improved understanding of the biogeochemistry governing the behavior of arsenic in subsurface environments undergoing reducing conditions that may leading to groundwater contamination. Reducing conditions are imposed on subsurface systems as a remediation strategy for dechlorination of TCE and other chlorinated solvents. All counties have groundwater contaminated with TCE or PCE due to various industrial and dry cleaning operations. TCE and other chlorinated solvents are also common groundwater contaminants at military bases. Reducing conditions are also associated with municipal landfills where arsenic has been reported in monitoring wells. All counties have landfills with potential problems from arsenic. The counties most immediately benefiting from this research are Cache, Davis and Weber.

- **Geographic Areas**: State of Utah.

  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. Also, arsenic in groundwater is a worldwide problem.

- **Accomplishments**

  Findings: The arsenic in groundwater and subsurface sediments collected from locations around the City of Logan Landfill were from geologic sources, not contamination from improper disposal of arsenic containing waste at the landfill.

  Results: The concentrations of arsenic in groundwater at many locations throughout Cache Valley exceed the drinking water limit. The geologic material of Cache Valley contain arsenic minerals. Landfills are potential sources of arsenic. The highest concentrations of arsenic from wells around the City of Logan landfill are, however, located up-gradient of the landfill. Laboratory microcosm studies demonstrated that the subsurface sediments have the potential to

release arsenic to the groundwater. The extent of release was dependent on the sediment type and input of organic carbon.

Work Plan FY 09/FY10

Continue to investigate the biogeochemical factors that lead to the release of arsenic to groundwater from native geologic materials. This year will focus on the role of microorganisms in arsenic release.

Informational Resources

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

Sediment Management for Small Reservoirs: Logan First Dam Study

Principal Investigators:
Lizzette Oman
Mac McKee

Partners/Collaborators:
- ***Local**: Ben Barrett, Stan Kane, and Reid Olsen, Utah State Facilities*
- ***State**: Mike Rickert, 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 State**

  The state will benefit from the state guidelines 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 other water users. It will also allow water managers to extend the life of the run-of-river reservoirs in Utah.

- **Geographic Area:**

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

  Areas Benefited: Small run-of-river reservoirs are all over the state, so the potentially benefit is statewide.

- **Accomplishments**:

  Findings: Several things have been learned 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, periodically examine available river flow forecasts to better anticipate future flow conditions and regulate hydraulic operations at the dam.
- Monitor outflows from the hydraulic structures on the dam 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/year. 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.

Work Plan FY 09/FY10

Researchers at the UWRL will assist the operators of First Dam in conducting a sluicing event during spring runoff in 2010.

Informational Resources

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

Septage Treatment, Handling, and Disposal Practices in Utah

Principal Investigator:
Judith L. Sims

Partners/Collaborators:
- ***State**: Paul Krauth, Mark Schmitz, and David Snyder, Division of Water Quality, Utah Department of Environmental Quality*

Project Description

- **Need and Purpose**:

  Septic systems, frequently used in rural and suburban residential developments in Utah, can provide adequate water quality and environmental protection when properly designed, sited, constructed, maintained, and operated. However, septic systems do require maintenance, including periodic removal of scum, solids, and wastewater (referred to as septage) that accumulate in the primary treatment device, i.e., the septic tank.

  Septage has a high potential for adverse impacts on ground and surface waters if not handled, treated, and disposed of properly. When land applied, septage can create a potential threat to humans and become a source of non-point source contamination if the wastes are not disposed of according to the federal regulations for septage disposal (40 CFR Part 503). Septage can also adversely impact wastewater treatment facilities if not carefully added to the wastewater stream. There is a paucity of information on septage disposal in the State of Utah and serious potential for adverse impacts of improper septage disposal on human health and the quality of surface and ground waters. Hence, the overall goal of this project is to develop an understanding of the current status of septage management so that appropriate actions can be taken to ensure protection of public health and the environment.

- **Benefits to the State:**

  Information and training will be developed for Utah's septic tank pumpers and for local health department staff responsible for septage management programs. Areas of focus include state and federal regulations that govern septage disposal, as well as best management practices concerning septage disposal and treatment in Utah. The potential for contamination from improper septage disposal is high, but a proactive approach to septage management will ensure that treatment and disposal is accomplished in a manner that will be protective of public health and the environment.

- **Geographic Areas**: State of Utah.

  Study Area: All twenty-nine counties and the 12 local health departments.

  Areas Benefited: The entire State of Utah.

- **Accomplishments**

  Findings: During the past fiscal year, local health department staff and septic tank pumpers were surveyed. Pumpers were identified through health department records and through telephone and internet "yellow pages." In June 2009 about 300 surveys were sent to potential pumpers and to the twelve local health departments. Pumper regulations from other states were also investigated in order to start developing improved management guidelines for pumper operations.

Results: Surveys from about 35 pumpers were completed and from three-fourths of the health departments. Compilation and analysis of the survey results has began.

Work Plan FY 09/FY10

During the next fiscal year, the results from the pumper and health department surveys will be analyzed. Based on the findings pumper and health department education programs will be developed, and improvements to the present regulatory process for septage management in the State of Utah recommended.

Informational Resources

Sims, J.L. (2009). Survey forms for pumpers and for local health departments. Utah Water Research Laboratory, Utah State University, Logan, Utah.

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

Tree Core Sampling for Locating Potential Phytoremediation Sites

Principal Investigator:
William J. Doucette

Partners/Collaborators:
- ***Local:*** *Rob Wallace, Hill AFB, UT; Erik Dettenmaier, SES, Layton, UT*

Project Description

- **Need and Purpose**:

  Trichloroethylene (TCE) is one of the most frequently identified groundwater contaminants in the United States. TCE is also the most common contaminant found in the shallow groundwater aquifers in and around Hill Air Force Base (HAFB) in northern Utah. Volatilization of trichloroethylene (TCE) from trees (phytovolatilization) and directly from the soil surface can be a significant pathway in the removal of TCE from shallow groundwater plumes at some sites. The overall objective of this project was to quantify the amount of TCE removed from shallow contaminated aquifers at Hill AFB OU2 by volatilization through the leaves and trunks (phytovolatilization) of trees and directly from the soil surface. This information can be used to determine if natural attenuation/phytoremediation could be a viable remediation option at this and similar sites.

- **Benefits to the State:**

  Phytoremediation is a potentially cost-effective, sustainable approach for the remediation of shallow groundwater contaminated with chlorinated solvents like TCE. The demonstration of significant TCE removal by trees would help regulators determine if this approach is suitable for this site and others that have similar characteristics.

- **Geographic Areas**:

  Study Area: Residential areas located around Hill AFB, 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:**

  Results: Leaf phytovolatilization samples were obtained by sealing a glass chamber over a representative section of branch, purging the chamber with compressed breathing air, and collecting the transpired water and TCE on sorbent traps. The mass of water collected in the silica gel traps was determined gravimetrically and the amount of TCE collected on the Tenax© sorbent tubes was determined using thermal desorption gas chromatography/mass spectrometry (GC/MS). The amount of phytovolatilized TCE was expressed in terms of a transpiration stream concentration (TSC), μg TCE per liter of water transpired. Recirculating isolation flux chambers equipped with sorbent traps were used to collect TCE emitted from tree trunk and soil surfaces. The amount of TCE collected on the sorbent traps was determined using the same procedure as the leaf phytovolatilization samples. The measurements made on individual trees were appropriate scaled to estimate the total amount of TCE removed via phytovolatilization.

Work Plan FY 09/FY10

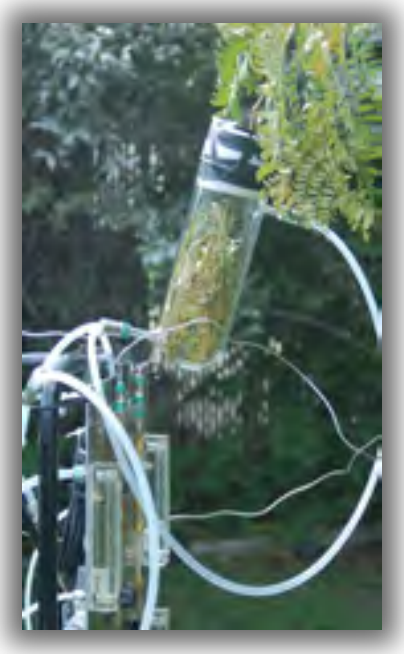
Project completed.

Informational Resources

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

Trunk flux measurements

Surface flux measurements



Leaf flux measurements

Groundwater Quantity, Quality, and Aquifer

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

Project Name	FY2009 Actual Expenditures	FY2010 Budgeted Expenditures	FY2011 Planned Expenditures
Components of the Alternative Electron Acceptor-Using Bacterial Community in TCE Contaminated Aquifers in Northern Utah	$89,660.99	$92,350.82	$0.00
Evaluation of Best Management Practices for Sustainable Groundwater Protection at Biosolids Land Application Sites	$40,946.63	$42,175.03	$0.00
Remediation of TCE Contaminated Soil and Groundwater at Hill Air Force Base (HAFB)	$18,531.97	$19,087.93	$0.00
Designated Projects		$127,961.00	$0.00
Undesignated Projects		$12,000.00	$86,000.00
Total	**$149,139.59**	**$293,574.78**	**$86,000.00**

Components of the Alternative Electron Acceptor–Using Bacterial Community in TCE-Contaminated Aquifers in Northern Utah

Principal Investigator:
Darwin L. Sorensen

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

Project Description

- **Need and Purpose**:

  Chlorinated solvents, especially TCE, have been widely used in industry. TCE is a suspected human carcinogen**.** Disposal practices used prior to the 1970s often involved landfill or soil trench disposal of spent solvents. This has resulted in frequent contamination of ground water. Cleanup 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.

  The project is directed at describing the microbial ecology of TCE contaminated aquifers at Hill AFB in terms that can be used in treatment system design. One objective has been to describe populations of bacteria within selected aquifers' microbial communities, and their biostimulated counterparts, which participate in or compete with dechlororespiration. Other anaerobic respiratory processes including iron reduction, sulfate reduction, and methanogenesis, have the potential of shunting energy (electron flow) away from dechlororespiration. There is evidence from microcosm studies that iron reduction may be a major sink of electrons in anaerobic respiration in some Hill AFB aquifer materials.

  An objective completed this year was to describe the distribution of chlorinated ethene solvent degrading bacteria and selected iron reducing bacteria in a contaminated aquifer plume west of HAFB. The distribution and population density of the 16S rRNA genes of *Bacteria, Dehalococcoides ethenogenes, Desulfuromonas michiganensis*, *Geobacter* spp. and *Rhodoferax ferrireducens*-like bacteria, as well as the functional genes trichloroethene reductive dehalogenase (*tce*A) and vinyl chloride reductase gene (*vcr*A) were determined. This study also evaluated the influence of the physical-chemical properties of the OU 5 aquifer material on the observed bacterial distribution.

- **Benefits to State:**

  Chlorinated solvents in ground water environments represent a threat to public health. Environmental regulations demand the cleanup of this kind of contamination. Evaluating the probability of success of cleanup technology represents an opportunity for improvement of the Utah environment and protection to 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 Air Force Base (HAFB) but will have application to trichloroethene (TCE), and other chlorinated ethene, contamination at several locations within Utah.

- **Geographic Areas**:

  Study Areas: 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 ground water contamination with chlorinated solvents has occurred.

- **Accomplishments**:

  Findings:

Aquifer material sampling in Clinton, Utah

Results: Twenty OU 5 soil cores were obtained from a 14-ha area that included a trichloroethene (TCE) plume. DNA was extracted from each core. Molecular analysis with qRT-PCR was used to quantify the densities of the 16S rRNA and functional genes. *Dehalococcoides* population density was low and its distribution was uneven with densities lower than $3.2x10^4$ copies/g (detection limit of $2.5x10^3$). *D. michiganensis* distribution was not uniform but was clustered near the TCE-source area with densities of $7.9x10^3$-$1x10^5$ copies/g (detection limit of $6.3x10^3$). *Geobacter* spp. distribution was uneven but broader, with densities of $4x10^3$-$1.6x10^6$ copies/g (detection limit of $3.2x10^3$). The *tce*A gene was measured in only two cores with densities close to detection limit of $1.6x10^3$ copies/g. The *vcr*A gene distribution was relatively uniform and broad and its densities were the lowest measured (detection limit of 63 copies/g). The distribution of this *Dehalococcoides*-associated gene indicates that reductive dechlorination capability exists in most, if not all, areas of the site.

Work Plan FY 09/FY10:

Future work will focus on detailed analysis of large flow-through aquifer material columns made using TCE contaminated aquifer material collected in Clinton, Utah. These columns have been operated for several years under the direction of Dr. R. Ryan Dupont and have, relatively recently, developed the ability to completely dechlorinate TCE. Work on this project will be a collaboration among similar projects under the direction of Professors Joan E. McLean and R. Ryan Dupont.

Informational Resources:

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

Yupanqui-Zaa, C.L., J.E. McLean, R.R. Dupont, J. Norton and D.L. Sorensen (2009). Dechlorinating and Iron Reducing Bacteria Distribution in a TCE Contaminated Aquifer. *Ground Water Monitoring and Remediation* (In Press).

Evaluation of Best Management Practices for Sustainable Groundwater Protection at Biosolids Land Application Sites

Principal Investigator:
Michael McFarland

Partners/Collaborators:
- ***Local:*** *Karthik Kumarsamy, Utah State University*
- ***State:*** *Mark Schmitz, Utah Division of Water Quality*
- ***Federal****: Robert Brobst, US EPA Region 8 Denver, CO*
- ***Business/Industry****: Alan Hais, Water Environment Research Foundation*

Project Description

- **Need and Purpose**:

  With the increasing demands for residential and commercial land use as well as the increasing costs associated with achieving new wastewater treatment standards, establishing scientifically defensible options for the beneficial use of biosolids generated within the state of Utah has become an urgent need for the Utah Department of Environmental Quality (UDEQ). In addition, the UDEQ as well as the Utah Department of Natural Resources and Utah Department of Agriculture and Food are considering best management practices aimed at restoring disturbed Utah landscapes. The objective of this study is to evaluate the effectiveness of currently implemented biosolids land application best management practices (BMPs) to mitigate the potential risk of groundwater contamination by both regulated and "emerging" contaminants.

- **Benefits to State:**

  The information generated from this project will be important to Utah land managers, biosolids producers as well as to Utah agricultural stakeholders in identifying sustainable methods for utilizing biosolids for animal feed production as well as to restore disturbed Utah landscapes. It is anticipated that the results of the research will lead to biosolids management practices that will help improve Utah landscapes as well as the agricultural economy while minimizing any adverse ecological and/or environmental impacts.

- **Geographic Areas**:

  Study Areas: The study area is national in scope, but the specific counties in Utah that have directly benefited from this research include Salt Lake County and Tooele County.

  Areas Benefited: The areas that most directly benefit from this effort include disturbed and/or marginal agricultural land located in Tooele counties where significant amounts of biosolids are being recycled.

- **Accomplishments**:

  Findings: The principle findings from this effort were that current best management practices established by the US Environmental Protection Agency for protection of groundwater quality at biosolids land application sites are sufficiently conservative to minimize the risk to public health from groundwater consumption. These findings were determined by the development of a risk characterization screening tool (RCST) that utilized the EPA's Multimedia, Multi-pathway, Multi-receptor Exposure and Risk Assessment (3MRA) technology as its computational framework. By application of the RCST to three case studies (biosolids land application sites located in the states of Virginia, Georgia and Washington), it was determined that BMPs associated with the depth to groundwater, regulated pollutant concentration and biosolids application rate reduce the risk of groundwater quality impairment to a level that is protective of human health.

Results: The primary result from this effort was the development of a risk characterization screening tool (RCST) that can be utilized by biosolids managers and other decision makers to support decisions on biosolids recycling practices. Execution of the RCST requires a minimum amount of site specific information from the user for a risk characterization scenario to be evaluated.

Work Plan FY 09/FY10:

To improve the RCST usability, there are a number of refinements that will be made in FY 09/10 including the following:

- Modify the RCST software to explicitly consider the impact of irrigation practices and other supplemental hydraulic loadings on the leachability of biosolids pollutants to groundwater.
- Modify the RCST software to alert the user when the biosolids land application rate is limited by the background soil nutrient levels.
- Modify the RCST software to characterize the potential human health risks associated with land applied biosolids microconstituents (e.g., pharmaceuticals, personal care products, detergents, fragrances, etc.) on groundwater quality.

Informational Resources

Contact: Dr. Michael J. McFarland, (435) 797-3196, E-mail: farlandm@msn.com.

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

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

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, has been unsuccessful due to the low population levels of native dechlorinating microorganisms, and the apparent competition for the added carbon by non-dechlorinating, iron reducing bacteria found in high concentrations in the formation at OU5. Laboratory scale studies have indicated the need for bioaugmentation, or the addition of dechlorinating bacteria, along with a source of carbon, for successful reductive dechlorination of TCE in OU5 aquifer material.

  The objective of this project is to move from the laboratory microcosm scale to large-scale flow through column scale in evaluating the limitations of biostimulation versus bioaugmentation under simulated field conditions. Developing molecular biology monitoring techniques for identifying principal microbial community members in the dechlorinating inocula and refining these methods for quantifying the viability and mobility of organisms in the simulated field environment is also being accomplished in this project.

- **Benefits to the State:**

  The small-scale soil and groundwater microcosm studies at the column flow-through scale provides specific design information for scale-up of the implementation of bioaugmentation at field sites that benefit the State in a number of ways including:

  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. Collection of treatment and design data for the control and production of degradation products at OU2 so that complete site remediation can be ensured.
  4. Cost-effective recovery of the impacted water resource at two specific Hill sites, and many more site across the state with similar contamination scenarios.

- **Geographic Areas**:

  Study Area: Hill AFB in Weber County.

  Areas Benefited: All locations in the state with TCE impacted groundwater sources would potentially benefit from the findings of this project in improving the predictability and reliability of bioaugmentation for contaminated site remediation.

- **Accomplishments:**

  Findings: The spatial distribution of substrate and microbial community have a significant impact on TCE transformation in OU5 soil. Unlike in the small microcosm studies, partial

dechlorination if TCE is observed 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 (iron & sulfate reduction, methanogenesis) of all donors evaluated, supporting and maintaining a microbial community with full functional gene capability for reductive dechlorination of TCE

Results: Bioaugmentation was found to accelerate TCE Transformation:

- No change was found in the extent of transformation, but the rate of transformation was found to increase with the addition of the BR Culture.
- Bioaugmentation decreased the time to the on set of TCE transformation by 7 to 16 months.
- Long-Term Transformation of TCE was supported using Emulsified Oil treatments.

Microbial community analysis indicated:

- A high diversity of organisms in the background soil.
- Carbon source is the determining factor in the microbial community that develops over time.
- The Community Extracted from the mobile groundwater is more indicative of TCE transformation potential than Community Composition determined from the soil phase.
- All carbon sources support reductive dechlorination in the presence of high sulfate conditions.

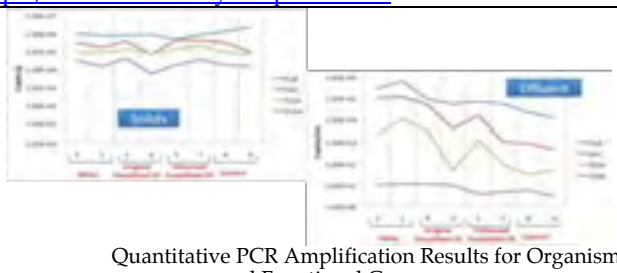
Work Plan FY 09/FY10

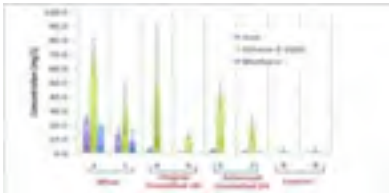
Influent and effluent monitoring of the columns is to continue through FY'10. In addition a fourth and final round (first round carried out in November 2006, second round in December 2007, third round in April 2009) of soil and water sampling for molecular biology, soil and water quality analyses is to be carried out in December 2009 to assess the persistence, growth, and continued distribution of the dechlorinating inocula and significance of sulfur metabolism throughout the pilot scale columns.

Informational Resources

Contact: Dr. R. Ryan Dupont, Phone (435) 797 3227, E-mail: ryan.dupont@usu.edu.
Website: http://homepage.mac.com/rdupo/HillAFB_Study_Report_Files

Flowthrough Columns


Quantitative PCR Amplification Results for Organisms and Functional Genes


Example Water Quality Results from Columns

Surface Water Quantity, Quality, and Watershed Management

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Surface Water Quantity, Quality, and Watershed Management

Project Name	FY2009 Actual Expenditures	FY2010 Budgeted Expenditures	FY2011 Planned Expenditures
A Three-Dimensional Hydrodynamic and Thermal Model of Cutler Reservoir	$1,073.00	$37,000.00	$0.00
Data Collection and Modeling Support for the Little Bear and Bear Rivers	$43,346.28	$25,000.00	$0.00
Development and Maintenance of the Bear River Watershed Information System	$10,037.04	$10,338.15	$2,300.00
Development of Technology for Streambed Thermal Property Instrument (SPI)	$60,960.21	$62,789.02	$0.00
Effect of Groundwater-Surface Water Interactions on Instream Temperatures	$70,512.43	$72,627.80	$73,000.00
Impacts of Climate Change and Land Use Changes on Water Resources	$8,594.89	$0.00	$0.00
Influence of an Automobile Causeway on Flow Patterns and Sediment Suspension in Utah Lake	$16,045.60	$2,000.00	$0.00
Instrumentation to Support a Center for Hydrologic Information Systems	$63,727.76	$30,000.00	$0.00
Monitoring Program to Assess Tributary Nutrient Loading into Cutler Reservoir for TMDL Support	$15,874.97	$16,351.22	$0.00
Pineview Reservoir Operations and Cyanobacterial Bloom Ecology	$158,917.47	$163,685.00	$158,600.00
Precipitation/Weather Monitoring in the Little Bear River	$8,352.86	$0.00	$0.00
Real Time Monitoring Internet Portal for the UWRL	$12,840.04	$13,225.24	$2,400.00
Technical Support for Bear River System Data Acquisition	$52,694.09	$54,274.91	$0.00
Temperature and Solute Model for the Virgin River	$32,290.35	$33,259.06	$0.00
The Fate of Pharmaceuticals and Personal Care Products Associated with Northern Utah Wastewater Treatment Effluents	$50,262.04	$25,000.00	$0.00
U.S. EPA Targeted Watersheds Grant	$18,286.27	$10,000.00	$10,300.00
Watershed Classificaiton Relevant to Bioassessment	$12,733.70	$13,115.71	$0.00
Weber Basin Decision Support System (DSS) Modernization	$15,181.41	$15,000.00	$0.00
Designated Projects		$472,756.00	$0.00
Undesignated Projects		$68,000.00	$110,000.00
Total	**$651,730.41**	**$1,124,422.11**	**$356,600.00**

A Three-Dimensional Hydrodynamic and Thermal Model of Cutler Reservoir

Principal Investigator:
Robert Spall

Partners/Collaborators:
None

Project Description

- **Need and Purpose**:

  Cutler Reservoir is located approximately 6 miles west of Logan, UT and is impacted by excessive nutrient loading. This contributes to the eutrophication of the reservoir and may result in the reservoir being classified as impaired. If so classified, the state must then establish a total maximum daily load for each contributing pollutant. Of particular concern in Cutler reservoir are levels of phosphorous and dissolved oxygen (DO) for which it has been declared impaired. The low levels of dissolved oxygen are problematic for the fish population of the reservoir. Although the reservoir is not impaired for temperature, levels above the maximum allowable of 27 degree C have been observed with some regularity during the summer months. In addition, high levels of suspended solids exist in the reservoir. To address these issues, it is beneficial to have a robust three-dimensional modeling procedure applicable to the reservoir.

- **Benefits to the State:**

  The results will determine the viability of three-dimensional thermal, hydraulic, and biogeochemical modeling of Cutler reservoir. If proven successful, the model will serve as a valuable tool in future management and restoration of Cutler reservoir and others of a similar nature within the State.

- **Geographic Area:**

  Study Area: Cache County.

  Areas Benefited: Cache County, and other counties with reservoirs throughout the state.

- **Accomplishments**:

  Findings: A numerical model is being constructed using the hydrodynamics code ELCOM to compute velocity and temperature distributions within Cutler Reservoir. Experimental temperature distributions, shown in Fig. 1, will be used to validate the model. The bathymetry has been obtained, and is plotted in Fig. 2. The bathymetry will be used in the ELCOM code to define the bottom boundary conditions.

  Results: The computational modeling is just beginning, so numerical results are not yet available.

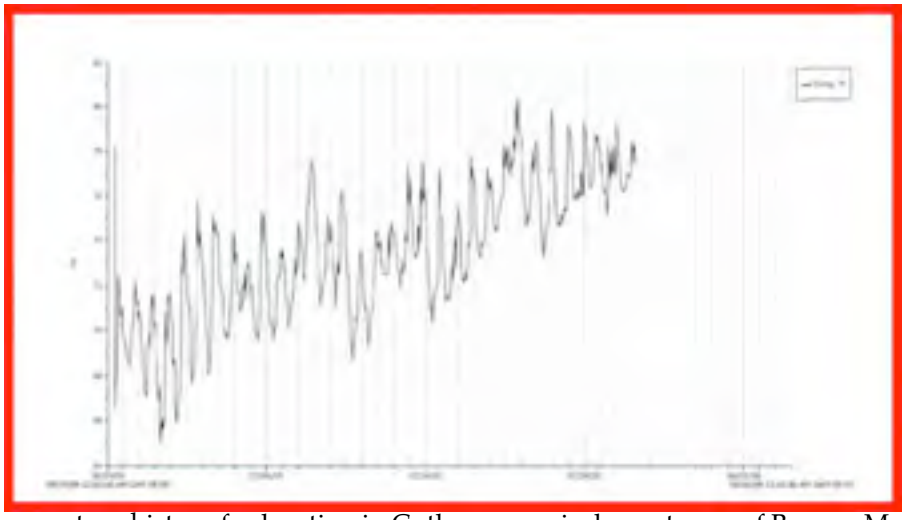


Figure 1. Temperature history for location in Cutler reservoir downstream of Benson Marina.

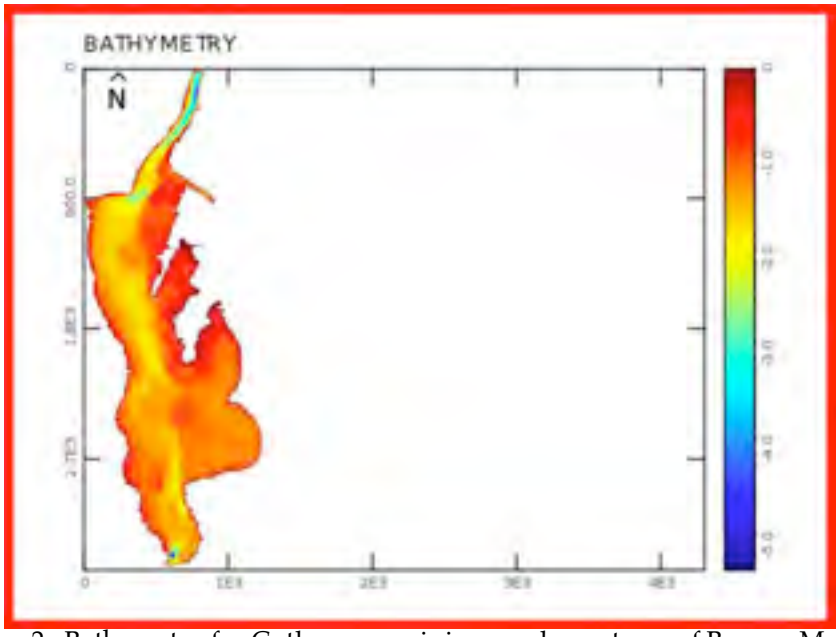


Figure 2. Bathymetry for Cutler reservoir in area downsteam of Benson Marina.

Work Plan FY 09/FY10:

The ELCOM hydrodynamic calculations will be completed. Additional temperature distributions within the reservoir will also be obtained for comparison with numerical results.

Informational Resources

Contact: Robert E. Spall, (435) 797-2878, E-mail: robert.spall@usu.edu.

Data Collection and Modeling Support for the Little Bear and Bear Rivers

Principal Investigator:
David K. Stevens

Partners/Collaborators:
- ***Local**: City of Logan*
- ***State**: Utah DWQ*
- ***Federal**: U.S. EPA/USDA*
- ***Business/Industry**: Twin Lakes Canal Co.*

Project Description

- **Need and Purpose**:

  The Bear River spans three states with numerous border crossings, ending its run at the Great Salt Lake in Northern Utah. Through external and internal funds, researchers at the UWRL have laid much of the groundwork for an integrated data collection and modeling system. A number of pieces remain to complete the picture.

  1. Expand monitoring to include six major and a number of lesser lakes and reservoirs along the river and tributary corridors, particularly to meet needs of the City of Logan and the Twin Lakes Canal Company.

  2. Continue to monitor water quality at seven sites in the Little Bear River.

  3. Reduce time to complete the simulation of complex river networks with human-caused changes in the flow patterns and water quality.

- **Benefits to the State:**

  Specific benefits to the State of Utah of the Bear River Decision Support project at the UWRL include:

  1. The ability to study nutrient sources in Cutler and Hyrum Reservoirs at several locations, the ability to measure dissolved oxygen, temperature, and other water quality constituents in those reservoirs, and the ability to deploy and retrieve thermistor chains to monitor the thermocline development and breakdown.

  2. The completion of a third water year of monitoring for nutrients in the Little Bear River.

  3. The development and application of modern parallel computing methods to the Little Bear and Bear River hydrologic, watershed, and river water quality models.

  4. The improved ability to provide resource managers, and other stakeholders tools for simulating the Bear River system in a timely way that could be used for decision support.

- **Geographic Areas**:

  Study Area: Logan, Benson, Richmond, Smithfield, Hyde Park, North Logan, Nibley, River Heights, Cache County.

  Areas Benefited: Cache County, other watersheds with similar water quality problems.

- **Accomplishments:**

  Findings: Data collected this past fiscal year using support of this project includes flow, water quality and temperature data, and sediment nutrient and oxygen dynamics for the Bear River, the Logan River, Spring Creek, Swift Slough, the Little Bear River, and Cutler Reservoir at several locations. Both field and laboratory measurements have been obtained and the data have been included in databases supporting the project. Appropriate quality assurance and quality control procedures have been followed.

  Results: Although data analysis is ongoing, preliminary results show that significant quantities of nutrients flow into Cutler Reservoir from the Bear River and other tributaries. Nutrient and oxygen dynamics in the Cutler sediments are typical of warm water, human impacted systems and reflect the proximity of nutrient loadings. The data are being incorporated into surface water quality models for use in load assessment.

Work Plan FY 09/FY10

The deliverables of the project will be considerable amounts of data collected in Cutler Reservoir using the boat, modernized software tools, calibrated and corroborated water quality models for the rivers and reservoirs in the Bear River basins in Utah, a completed Bear River Basin decision support system, final report, and software user's manual. The final version of the project software and report will be presented at the Utah Water Users', Utah AWWA and Utah Water Environment Association annual meetings.

Informational Resources

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

Website: http://www.bearriverinfo.org

Database: Cutler Reservoir Database (waterdata.uwrl.usu.edu)

Surface Water Quantity, Quality, and Watershed Management

Development and Maintenance of the Bear River Watershed Information System

Principal Investigator:
Jeffery S. Horsburgh

Partners/Collaborators:
- ***Local**: Jim Bowcutt, USU Extension*
- ***State**: Mike Allred, Utah DWQ; Lynn Van Every, Idaho DEQ, Don Newton, 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 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 is to provide ongoing support and development of the Bear River WIS. This project is being matched by funding from the three states. The WIS has proved to be a great benefit to water quality managers in all three states, and 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 will benefit several efforts ongoing in the State of Utah:

  1. The Water Quality Committee of the Bear River Commission is a tri-state committee that is focused on water quality issues in the Bear River Basin. The Bear River WIS supports the efforts of the Water Quality Committee (as well as many other water quality related organizations.
  2. The Bear River WIS has been an important outlet for water quality related outreach and education materials available for teachers, students, and researchers throughout the State of Utah.
  3. The Bear River WIS was the development ground for many of the tools that are supporting efforts to establish an environmental observatory in the Great Salt Lake Basin and that are the basis of national efforts to establish cyberinfrastructure for supporting environmental observatories and, more generally, hydrologic science.

- **Geographic Areas**:

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

  Areas Benefited: Primarily the Bear River Basin, although 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 water quality in the Bear River.
- 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 people, organizations, and projects in the watershed.
- A calendar of water quality related events and news.

Work Plan FY 09/FY10

In this next year, we will be working with our steering committee to maintain the current functionality of the Bear River WIS, add additional datasets as they become available, continue to componentize and generalize the functionality of the Bear River WIS so that it can be used to easily develop a watershed information system for any watershed.

Informational Resources

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

Website: http://www.bearriverinfo.org

The Bear River Watershed Information System.

Development of Technology for Streambed Thermal Property Instrument (SPI)

Principal Investigators:
Bethany T. Neilson
Heng Ban

Partners/Collaborators:
- ***State**: Dan Christensen, Utah Division of Wildlife Resources; Steve Meismer, Virgin River Program*

Project Description

- **Need and Purpose**:

  This project is developing a system to measure *in situ* streambed thermal properties (e.g., thermal diffusivity). The results will enable data gathering for more accurate predictions of stream temperature. Such a technology is not currently available in the market and can potentially result in intellectual property that can be applied in many similar applications.

- **Benefits to State**

  The State of Utah benefits from this project by having a more accurate means to predict instream temperatures and therefore, understand the effects of management strategies on aquatic species. This is particularly important in areas like the Virgin River where the state is continually attempting to find the delicate balance between water demands and the needs of two endangered species that are unique to the Virgin River (Virgin River Chub (*Gila seminuda*) and woundfin (*Plagopterus argentissimus*)). Both species suffer from instream temperature exceedances. Currently the TZTS is being used in the Virgin River for real-time stream modeling and forecasting to assist in stream temperature management. If proven successful and accurate in the Virgin River, this approach to management for instream habitat can be implemented in other river systems in Utah that have temperature impairments. Since the TZTS model was developed, applied, and tested within a number of diverse rivers within Utah, the model results will be a useful decision making tool within a large portion of the watersheds within the state. As new methods for estimating parameters associated with this model become available, accurate model predictions will become.

- **Geographic Area(s):**

  Study Areas: Curtis Creek, Cache County, near Hyrum, UT; Virgin River, Washington County, near Hurricane and St. George, UT.

  Areas Benefited: This project will provide thermal property estimates in any river or stream and therefore, all counties could potentially benefit.

- **Accomplishments**:

  Findings: The process for constructing the SPI probe was developed. Many challenges were overcome, including air-bubbles short-circuiting the probe. A calibration procedure and a peak performance power (meaning that based on each probe, there will be a current setting which minimizes error) was established. The probe response is a function of the medium's conductivity and the power input - thus a Levenberg-Marquardt method must be used to optimize the design.

  Results: We acquired the lab equipment to manufacture, calibrate and test different shapes and designs of probes. We have built and calibrated several probes, and have successfully developed

both small and large (in situ) versions. Code was developed in LabVIEW for quick data analysis. It was found that the code for large probes needs further development.

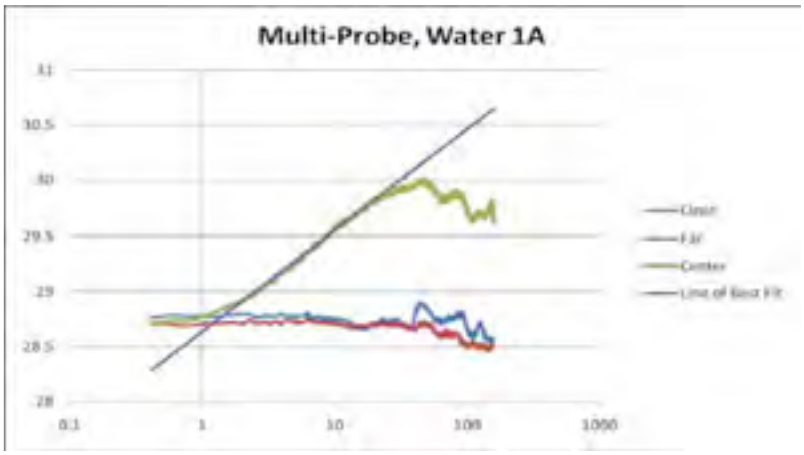


Figure 1 - Time response of multi-probe in water at 1A input. Off set probes receive no temperature increase due to convection off the center probe. Convection can be seen by the oscillating response over time.

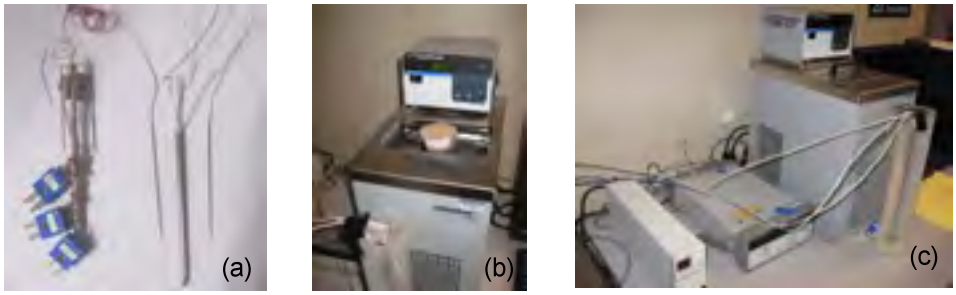


Figure 2 – (a) Evolution of multi-probe design. The Penta Probe (right) will be surrounded by four TCs to measure flow rate as well as diffusivity. (b) Large probe (SPI) in beaker of glycerol. Left to right: Power supply (set to 1A CC), DAQ system, Thermostatic Bath and the SPI Probe in glycerol solution. (c) A Virgin River sediment sample in the thermostatic bath for varied temperature testing.

Work Plan FY 09/FY10

The work scope for next year is to: (1) complete the probe development in the lab to produce a calibrated field probe, (2) conduct lab and field tests and measurements, and (3) complete theoretical modeling of the probe measurement.

Informational Resources

Contact: Dr. Bethany Neilson, (435) 797-7369, E-mail: bethany.neilson@usu.edu.
Dr. Heng Ban, (435)-797-2098, E-mail: heng.ban@usu.edu.

Effect of Groundwater-Surface Water Interactions on Instream Temperatures

Principal Investigator:
Bethany T. Neilson

Partners/Collaborators:
- ***State**: Dan Christensen/UDWR*

Project Description

- **Need and Purpose**:

  There are many physical processes that influence pollutant transport in a river or stream. One of the greatest challenges associated with predicting and modeling mass and energy movement accurately is quantifying each of these processes individually. A better understanding leads to appropriate management practices and protecting our source water.

  Curtis Creek, Utah was used in a case study for advancing the development of a data-centric modeling methodology over a broad range of conditions. The results can help to understand and quantify energy and mass fluxes in river systems. This study system was highly influenced by groundwater exchange. This required the estimation of a water balance in terms of gains and losses before a Two-Zone Temperature and Solute transport model could be used and tested.

- **Benefits to the State:**

  The State of Utah benefits from this project by having applications of the Two-Zone Temperature and Solute Transport model applied and tested within Utah. These modeling applications provide more accurate heat and solute predictions that can assist in more informed surface water management. Additionally, effects of management decisions involving channel alterations and beaver dam removal may be illustrated by past and future information provided by this study. This leads to better source water protection and reduction of management costs.

- **Geographic Areas:**

  Study Areas: Curtis Creek, Hardware Ranch, and Cache County, Utah.

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

- **Accomplishments:**

  Findings: Overall, the data collection efforts and newly developed strategies have yielded methods of determining effects gains and losses occurring within streams. Also, new methods to collect sediment temperature data representing the effects of bed conduction give reliable estimates of sediment thermal diffusivities using conduction models. These sediment temperature time-series are used to determine more accurate seepage rates.

  Results: Data collected from May to October 2008 showed that Curtis Creek has complex surface water-groundwater interactions (lengths ranging from 80 to 240 m). Gains and losses were quantified and shown to be significant in most of the sub-reaches (Figure 1).

  This research has also led to an Inland Northwest Research Alliance project using the methods developed in Curtis Creek in an Arctic stream.

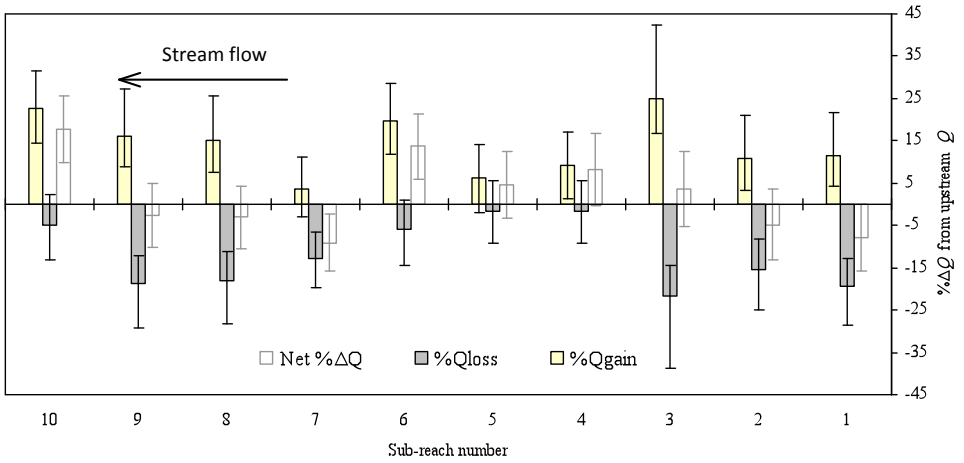


Figure 3. Gross gains and losses within each sub-reach. Net changes are also shown.

Work Plan FY 09/FY10

Research completed.

Informational Resources

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

Impacts of Climate Change and Land Use Changes on Water Resources

Principal Investigator:
Jagath J. Kaluarachchi

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  Given the expected changes in water resources due to climate change and land use changes associated with population changes, it is important identify the best water resources management scenarios in to the next half a century. This study proposes to develop suitable methodologies to predict the water resources available under climate change and land use changes in the next half a century.

- **Benefits to State:**

  The proposed methodology can be readily used by Division of Water Resources and other agencies to understand water resources in the coming decades under both climate change and land use scenarios.

- **Geographic Area(s):** including:

  Study Area(s): (Include: Cities, counties, regions of the state included in the project)
  State of Utah.

  Areas Benefited: Water Resources Planning and Management.

- **Accomplishments**:

  Findings: The conceptual framework for the proposed work was completed.

  Results:

Work Plan FY 09/FY10

Work completed in 2009.

Informational Resources

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

Influence of an Automobile Causeway on Flow Patterns and Sediment Suspension in Utah Lake

Principal Investigator:
Robert Spall

Partners/Collaborators:
None

Project Description

- **Need and Purpose**:

  Utah Lake is a shallow lake with a bottom consisting of very loose sediment. Surface generated waves developing over a relatively large fetch tend to "touch" the bottom, stirring up the sediment, resulting in its re-suspension. This re-suspended sediment limits light penetration into the depths, and consequently limits the process of photosynthesis. The State has previously considered the construction of an east-west running automobile causeway across the lake in the Pelican Point region (or perhaps slightly north). The influence of the causeway on sediment suspension is twofold: 1) decrease in the fetch available to build up surface waves, and 2) change the lake flow patterns which distribute the suspended sediment around the lake. Consequently, the purpose of this research is to determine the influence of a prototype causeway on flow patterns within the lake.

- **Benefits to the State:**

  The results will provide information regarding the influence of an automobile causeway on the flow patterns and temperature distributions on Utah Lake, which are of importance in the June Sucker restoration effort.

- **Geographic Area**:

  Study Area: Utah County.

  Areas Benefited: Utah County.

- **Accomplishments**:

  Findings: A numerical model was constructed using the hydrodynamics code ELCOM to compute velocity and temperature distributions within Utah Lake, and to model the influence of a prototype causeway on these flow variables. Additional field data were collected to supply needed information on lake bathymetry. The findings of this research indicate that a causeway is unlikely to have significant impact on flow patterns and temperature distributions within the lake.

  Results: Calculations were performed with a prototype causeway running east-west near the north end of the lake. The location of the causeway is shown in Fig. 1. The causeway is represented by a series of 200 m blockages running across the lake. That is, an alternating pattern of 200 m open water, 200 m blockage, 200 m opens water, etc. Smaller blockages are difficult to implement since the blockage cannot be smaller in size than the smallest grid cell. Cells that small would result in a model that was computationally intractable. The primary interest was whether or not significant temperature differences would develop across the causeway. The results as shown in Fig. 2 indicate that no noticeable temperature gradients across the causeway develop. In particular, the lines denoted north side and south side represent temperature histories at

locations near the middle of the lake, and just to the north and south sides of the causeway. These temperatures are nearly coincident. In fact, temperature profiles at other locations on the lake are also nearly indistinguishable from those obtained in the absence of a causeway. Since a 50% blockage likely represents an extreme upper level of blockage, it is unlikely that a causeway would cause significant influence on the lake temperature distributions. However, to confirm the influence of blockage percentage, additional blockages of 75% and 33% were also implemented. Again, no significant influence on the temperature distributions were found. In terms of velocity distributions, some disruption of the flow patterns near the causeway were observed, but these were not deemed large enough to significantly influence global sediment transport.

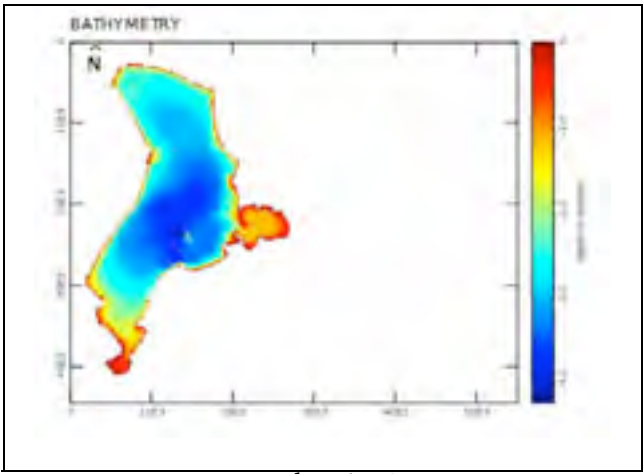


Figure 1. Utah Lake Causeway.

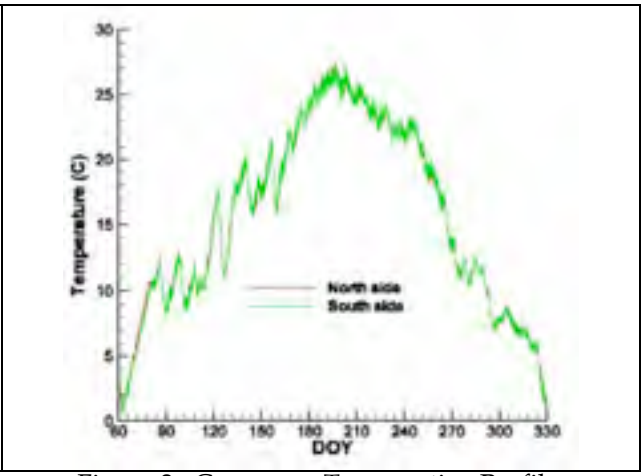


Figure 2. Causeway Temperative Profile.

Work Plan FY 09/FY10:

This work is completed.

Informational Resources:

Spall, R.E., Wilson, B., and Callister, E., "A Time-Dependent, Three-Dimensional Circulation Model of Utah Lake," HT-2009-88350, Proceedings of the ASME Heat Transfer Division Summer Conference, San Francisco, CA, July 19-23, 2009.

Contact: Robert E. Spall, (435) 797-2878, E-mail: robert.spall@usu.edu.

Instrumentation to Support a Center for Hydrologic Information Systems

Principal Investigator:
Jeffery S. Horsburgh

Partners/Collaborators:
None

Project Description

- **Need and Purpose**:

  Cyberinfrastructure is a new term that is being used for the computer hardware, software, and environmental sensor systems that are being developed to support data intensive science. With the huge growth of data collection over the past 10 years, particularly associated with high frequency data streams and high resolution spatial datasets, new infrastructure is needed to enable scientists and water resource managers to handle the ever growing volume of environmental data that are becoming available. The purpose of this project was to establish a state-of-the art research platform for developing cyberinfrastructure to support data-intensive research in the area of hydrology and water resources.

- **Benefits to the State:**

  The establishment of a state-of-the-art cyberinfrastructure research platform at the UWRL will have the following benefits to the state:

  1. Demonstrate how high-volume continuous datasets from environmental sensors can be managed using robust software and database tools that are generally available to state environmental managers.

  2. Demonstrate the value of high frequency, continuous datasets in hydrology and water resources management. Example applications include total maximum daily load (TMDL) water quality studies and canal/irrigation diversion management to state water quality and water resource managers).

  3. Develop methods for anomaly detection within continuous data streams, diagnosing environmental sensor malfunctions, and design of algorithms for remediating these problems with continuous data collection.

  4. Continue to host and develop watershed and hydrologic information systems in collaboration with state agencies, including the Bear River Watershed Information System (http://www.bearriverinfo.org) and the Great Salt Lake Information System (http://www.greatsaltlakeinfo.org).

- **Geographic Areas**:

  Study Area: All counties of the state of Utah, and data intensive science nationwide.

  Areas Benefited: All counties of the state of Utah, and data intensive science nationwide.

Surface Water Quantity, Quality, and Watershed Management

- **Accomplishments:**

  Findings: A new era of science is emerging in which new datasets with high spatial and temporal resolution are being collected to enable studies generating new hydrologic and watershed process understanding. In many cases, scientists are combining existing datasets in new ways using cyberinfrastructure to generate new knowledge. The research platform established by this project is being used to develop new cyberinfrastructure that supports research using new and existing datasets.

  Results: This project advanced or established the following capabilities available to the state.

  - A high-frequency, continuous monitoring research platform within the Little Bear River of Cache Valley. Continuous monitoring sites include stream hydrology and water quality as well as weather stations with soil moisture monitoring.
  - A robotic discrete analyzer for processing large volumes of water quality samples to support ongoing sampling and data collection efforts within the state of Utah.
  - A robust set of computer servers comprising an advanced data center with high capacity Internet capabilities for development of new cyberinfrastructure.

Work Plan FY 09/FY10

The purpose of this project was to establish the instrumentation capabilities described above. Although not directly supported by continuing funds from this project, it is anticipated that a variety of ongoing UWRL research projects focused within the state of Utah will be supported by the infrastructure that has been established.

Informational Resources

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

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

Principal Investigators:
David K. Stevens
R. Ryan Dupont
Darwin L. Sorensen
Joan E. McLean

Partners/Collaborators:
- ***Local**: Issa Hamud, City of Logan*

Project Description

- **Need and Purpose**:

  This project provides water quality monitoring in five rivers draining into Cutler Reservoir and at five locations in the reservoir itself. Measurement includes the loading of nutrients and suspended sediments, and general water quality as measured by temperature, dissolved oxygen, turbidity, and total dissolved solids. Additional data obtained sediment samples and the nutrient and oxygen fluxes from the sediments into the overlying water. These data are used to estimate the internal nutrient loading and corresponding oxygen demand under different other environmental conditions.

  Based on discussions with City of Logan Environmental Department personnel, the following sampling program will develop baseline information regarding nutrient loading and water quality in Cutler:

  1. Spring Creek (at Mendon Road).
  2. Logan River (near Mendon Road).
  3. Little Bear River (at Mendon Road) (monitoring using existing UWRL funds).
  4. Swift Slough near Cutler.
  5. Bear River into Cutler.
  6. Five locations within Cutler to include:

     Station 590098 (Non Impaired).

     Station 590099 (Temp & DO Impairment).

     Station 590100 (Temp & DO Impairment) (Benson Road).

     Station 490506 (Temp & DO Impairment).

     South of Valley View Highway (DO Impairment).

  These sampling locations have been sampled monthly beginning November 1, 2008 using grab sampling, vertical profiling, and manual field and laboratory analyses to aid in placement of continuous probe measurement stations. Flow estimates are also required to determine load. This means establishing a datum at each location and measuring the water surface elevation

relative to that datum using a staff gauge. Also, six rainfall events will be targeted for sampling over a 24-month period.

- **Benefits to the State:**

  The project benefits the state by providing a full accounting of total phosphorus loading into Cutler Reservoir and how conditions in the reservoir the respond to the total phosphorus loading. This supports State of Utah efforts to implement the total maximum daily load plan based on improvements to the City of Logan wastewater treatment plant to control phosphorus loads, and will help identify additional sources of phosphorus entering the reservoir.

- **Geographic Areas**:

  Study Area: Bear River Basin, Cache County.

  Areas Benefited: City of Logan/Cutler Reservoir.

- **Accomplishments:**

  We have installed three automated flow and water quality monitoring stations on the Logan River, Spring Creek, and the Bear River, in addition to an existing monitoring station on the Little Bear River. Monthly field sampling at each station is ongoing at these sites and at 5 locations in Cutler Reservoir for nutrients (total and dissolved nitrogen and phosphorus, total suspended solids, and Chlorophyll A (in the reservoir only). The data through October 2009 are available via a dedicated database housed at the UWRL.

  Results: The outcome of this project is a large and growing data set for public and research use. The data are currently accessible by contacting the PI. In the future, the data will be made available to the public via the Bear River Watershed Information System (http://bearriverinfo.org).

Work Plan FY 09/FY10

Data collection is ongoing. A first year report will be filed in January.

Informational Resources

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

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

Pineview Reservoir Operations and Cyanobacterial Bloom Ecology

Principal Investigator:
Darwin L. Sorensen

Partners/Collaborators:
- ***Local:*** *Scott Paxman and Brad Nelson, Weber Basin Water Conservancy District*
- ***State:*** *Kari Lundeen, Utah Division of Water Quality*
- ***Federal***: *Danny McBride and Cody Tusing, USDA, Natural Resource Conservation Service*

Project Description

- **Need and Purpose**:

  Cyanobacteria and algae blooms in water supply reservoirs often lead to taste and odor problems in finished drinking water. Recreational users are usually annoyed by the appearance associated with these blooms. Water users typically associate these blooms with pollution of some kind and often voice their concerns to reservoir managers and/or government water quality regulators. Algae and cyanobacteria blooms are generally believed to be due to high concentrations of the growth limiting nutrient. In most freshwater systems the practical limiting nutrient is phosphorus. Managing the watershed to reduce phosphorus loads can have socioeconomic consequences that are difficult for land users to accept. Nuisance blooms of algae and cyanobacteria occur annually in Pineview Reservoir. This study examines whether filling and drawing water from Pineview Reservoir contributes to conditions that trigger blooms. A more complete understanding of these conditions develop could inform decisions about reservoir operation so that blooms could be avoided.

  The major objective of this project is to describe the microbial and non-living components of Pineview Reservoir ecology and how the operation of the reservoir affects these components.

  The results of the project will provide scientific insight into the microbial ecology of reservoirs in the intermountain region. The complex interactions of microbial communities and their non-living environment are not well understood.

- **Benefits to the State:**

  Utah's growing population and water demand will probably lead to the use of Pineview Reservoir as a key water body in the storage and distribution of municipal water to the greater Ogden and, possibly, to the greater Salt Lake City area in the future. Knowing the microbial ecology of the reservoir and the phytoplankton response to nutrients and other physical and chemical conditions can inform reservoir and watershed manager's decisions so that the quality of the reservoir can be protected.

- **Geographic Areas:**

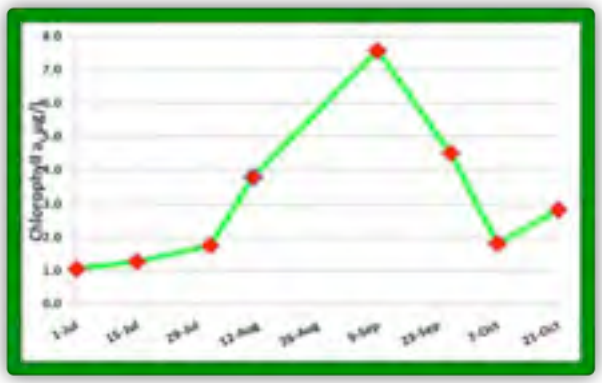
  Study Area(s): Ogden Valley including Huntsville town and the Eden and Liberty areas of Weber County.

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

- **Accomplishments**:

  Findings:

Sampling on Pineview Reservoir.



Pineview mid-reservoir surface chlorophyll *a* during the 2008 phytoplankton bloom period.

Results: The reservoir is thermally stratified to varying degrees, depending on geographic location, within the reservoir during the summer months. Surface water nutrient loading was relatively low and reservoir productivity and water quality were typical of oligotrophic-mesotrophic conditions much of the year. Diatom communities dominated throughout the reservoir until hypolimnion draw-down and wind conditions combined to mix anoxic, nutrient-rich hypolimnetic water into the water column triggering an *Aphanizomenon* and *Stephanodiscus* bloom in early September 2008. A dense bloom of the dinoflagellate *Peridiniopsis quadridens* in a shallow embayment that was receiving relatively high amounts of shallow ground water coincided with the bloom of *Aphanizomenon* elsewhere in the reservoir suggesting that ground water inflows may have provided available nitrogen and phosphorus. Iron oxide staining in seeps along the shore indicated that there were reducing conditions in the contributing aquifer. Nutrient loads contributing to primary production in the reservoir appear to be from multiple sources including irrigation return flows through anaerobic, shallow groundwater; internal cycling from iron-rich reservoir sediments; and tributary streams.

Work Plan FY 09/FY10

In-reservoir process monitoring will continue at a reduced level while efforts to describe and evaluate watershed processes that contribute phosphorus and nitrogen to the reservoir will be more intense. High frequency monitoring using turbidity, conductivity, temperature and stream depth (flow) instrumentation at four locations on the South Fork of the Ogden River will be evaluated as an index of nutrient, especially phosphorus, export from the land and loading to the reservoir. Weekly grab sampling on other major tributaries will also be conducted. Ground water quality near the reservoir will be monitored and ground water flow rates into the reservoir will be estimated.

Informational Resources

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

Precipitation/Weather Monitoring in the Little Bear River

Principal Investigator(s):
David K. Stevens
Bethany Neilson
Jeffery Horsburgh

Partners/Collaborators:
None

Project Description

- **Need and Purpose**:

  Non-point loadings in watersheds is related to watershed hydrology in terms of runoff and stream flow. The Bear River basin is critically lacking in hydrologic information systems, including stream flow, water quality, and basic climate data collection facilities. The lack of data collection facilities limits the capability to assess basic water and pollutant mass balances.

  Some observations in Cache Valley, and in other Utah watersheds, is that the precipitation is highly location-specific, particularly for single storms in which one subdrainage in a watershed receives heavy rainfall and an adjacent subdrainage receives next-to-none. Contaminant loading into water courses is even more site-specific because the impact that a particular storm event will have depends on whether the precipitation falls directly on or immediately upstream of a contaminant source. So a parcel of land on which there is an animal management operation that receives heavy precipitation may be adjacent to another pristine parcel that receives light precipitation, and contaminant loading will be over or under estimated.

- **Benefits to the State:**

  As part of several ongoing efforts, the equipment installed under this project will ultimately provide real time data for better management of the Bear River Basin Watershed and the Great Salt Lake.

  - The USU Water Initiative has invested in real time monitoring equipment for the Logan River as part of the Bear River Monitoring Network. This project will extend the capabilities of the Bear River Monitoring Network.
  - The EPA Targeted Watersheds grant is funding the development of an Internet Based Watershed Information System (WIS) for the Bear River Basin.
  - Equipment for two monitoring stations in the Little Bear River to collect continuous, real time measurements of streamflow and turbidity with telemetry equipment to connect these monitoring stations to the Bear River Monitoring Network. The downstream monitoring station will also support more accurate estimates of flow to Cutler Reservoir and will improve the overall water balance and management of this reservoir. Both of the proposed sampling locations in the Little Bear River coincide with Utah DWQ long-term monitoring stations and will provide important flow and water quality observations that will be of interest to DWQ.
  - Water management and research institutions are working to establish a CUAHSI Hydrologic Observatory in the Great Salt Lake Basin. This effort will leverage existing monitoring infrastructure in the Great Salt Lake Basin, of which the Bear River Basin is a major part.

- **Geographic Areas**:

  Study Area: Little Bear/Bear River Basin, Cache County.

  Areas Benefited: Watersheds statewide.

- **Accomplishments:**

  Findings: We have installed the two weather stations – one in the East Fork of the Little Bear River and one at the USU Experimental Farm in Wellsville, and telemetry networks are operational. The third and fourth will be used at the UWRL for testing purposes.

  Results: The outcome of this project is a large and growing weather data set for public and research used. The data are accessible via the Bear River Watershed Information System (http://bearriverinfo.org).

Work Plan FY 09/FY10

The work was completed in FY 09. Data collection using the instrumentation is ongoing.

Informational Resources

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

Website: http://www.bearriverinfo.org

Real Time Monitoring Internet Portal for the UWRL

Principal Investigator:
Jeffery S. Horsburgh

Partners/Collaborators:
None

Project Description

- **Need and Purpose**:

  There is a growing trend within hydrology and water quality management for collecting continuous, real-time streamflow, water quality, and climate data. Efforts at the UWRL include streamflow, water quality, soil moisture, and climate monitoring. The continuous data collection efforts generate large volumes of data that present challenges for data management, visualization, analysis, and publication. The purpose of this project is to create an Internet-based portal for real time monitoring data being collected by UWRL as a demonstration of innovative technologies for management of continuous, real time data from environmental sensors. The portal will integrate these efforts and provide access to the data to users over the Internet. All functionality will be server based and the only client software needed by users will be a web browser.

- **Benefits to the State:**

  A variety of projects are ongoing at the UWRL where real time or continuous data are being collected. Due to the volume of data generated by real time monitoring, computer infrastructure is needed to support real time data collection. Under this project we are developing tools and technologies that can be used to support management of continuous and real time data collection. River systems within the State of Utah that are benefiting from this work already include the Virgin River, the Little Bear River, the Bear River, Curtis Creek, the Cub River, and the Logan River. These data can be useful for individuals, classes, researchers, and managers for the research, management, or study of the systems that they represent. As part of this project we are also developing techniques and technologies that can be used to support watershed and hydrologic information systems. This project benefits the State of Utah not only by making these data available, but also by contributing technologies that are supporting watershed information systems for rivers within the state, including the Bear River Watershed Information System (http://www.bearrriverinfo.org) and the Great Salt Lake Information System (http://www.greatsaltlakeinfo.org) currently under development at the UWRL.

- **Geographic Areas**:

  Study Area: Generalized tools are being developed that could be applied to data collection efforts within all counties of the state of Utah.

  Areas Benefited: Specifically, the tools advanced by this project have benefitted data collection efforts throughout the state, including ongoing efforts within the Logan River, Bear River, Little Bear River, Curtis Creek, T.W. Daniels Experimental Forest, and soil moisture monitoring efforts near Delta.

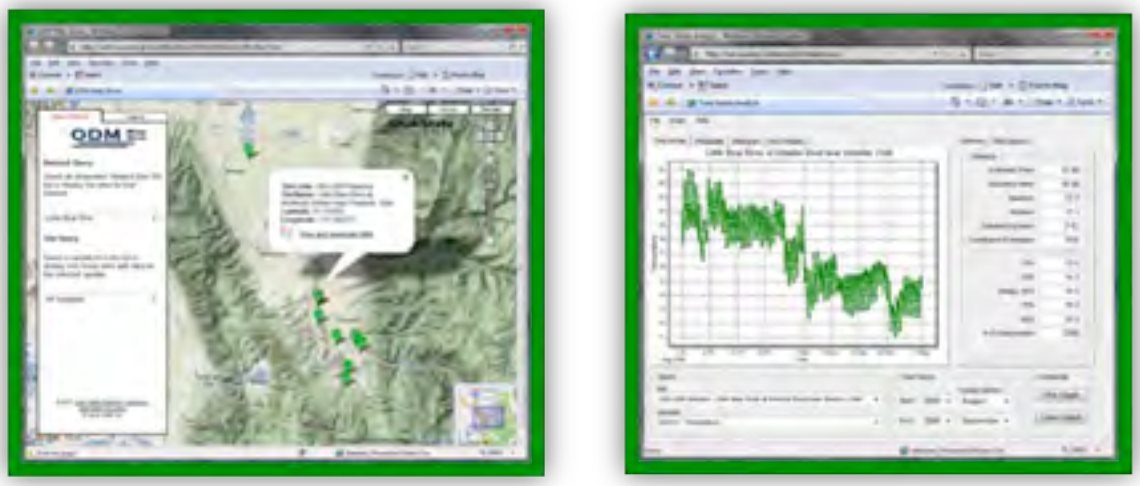
- **Accomplishments:**

  Findings: Continuous and real time datasets are incredibly useful for studying environmental processes, understanding the way watersheds function, and for informing water management decisions. Collection and management of these datasets, however, is difficult, and there are

relatively few freely available software tools for doing this. This project is advancing the development of a set of software tools for managing, visualizing, analyzing, and publishing continuous water quality related datasets.

Results: The software tools that have been advanced as part of this project include:

- A relational data model for storing environmental observations data.
- Tools for automatically loading streaming data from environmental sensors.
- A set of Internet applications for publishing and providing access to real time, continuous and streaming datasets, including:
  - A map server application based in Google Maps
  - A Time Series Analyst application for data visualization and analysis
  - Web services for publishing the data on the internet
  - Website and database technology for presenting



Internet applications for publishing, visualizing, and analzing continuous data streams from environmental sensors

Work Plan FY 09/FY10

Apply the tools that we have developed to other continuous and real time monitoring datasets within the state of Utah to increase their visibility, publication quality, and scientific use and reuse.

Informational Resources

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

Technical Support for Bear River System Data Acquisition

Principal Investigators:
David K Stevens
Bethany Neilson
Austin Jensen

Partners/Collaborators:
None

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 investigating two potential data acquisition systems 1) UAV aircraft to monitor sediment dynamics in lakes; and 2) fiber optic temperature data collection system for rivers and lakes.

- **Benefits to the State:**

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

  1. Improved understanding of the temperature dynamics in the Bear River basin.
  2. Innovative data acquisition systems for remote areas.
  3. Investigation of the influence of ground/surface water exchange for improved understanding of energy fluxes in mountain rivers that will improve prediction of water column temperatures.
  4. Beginning of a framework for understanding surface and groundwater temperature interactions and their impact on groundwater management.
  5. Data acquisition to assess dynamics of sediment transport in lakes.

- **Geographic Areas**:

  Study Area: Bear River Basin, Cache County.

  Areas Benefited: Watersheds statewide.

- **Accomplishments:**

  Findings: Fiber optic temperature measurements have been collected in Curtis Creek (Cache County) for analysis of local scale high spatial and temporal resolution temperature dynamics to incorporate into temperature models of the hyporheic and dead zones in river channels.

  An inexpensive unmanned aerial vehicle (UAV) has been deployed with the capability to carry and control various types of remote sensing equipment, and gather remotely sensed data which can then processed for distribution to researchers. 'Wet' sediment monitoring is being conducted for ground truthing of remotely sensed data.

Results: The UAV capabilities are:

- Programmable intelligence to fly a pre-determined flight path.
- Acquisition and storage of high-resolution images in the visual and near-infrared spectral bands.

The remote sensed image processing capabilities include:

- Location of images with respect to ground coordinates.
- Transformation of the resulting images into GIS-compatible formats.

The fiber optic temperature measurements include:

- Spatial resolution of 1-2 cm.
- Temporal resolution of < 2 seconds.

Work Plan FY 09/FY10

- Investigate ground truthing of remotely sensed data.
- Correlation of remotely sensed data with results from field campaigns.
- Integration of UAV-gathered data into sediment dynamic models in the Bear River Basin.
- Continued use of fiber optic temperature sensors in UT river basins to collect data for temperature model support.

Informational Resources

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

Website: http://www.bearriverinfo.org

Temperature and Solute Model for the Virgin River

Principal Investigator:
Bethany T. Neilson

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

Project Description

- **Need and Purpose**:

  Water shortages and drought result in low stream flows that are commonplace in Utah. In Washington County, rapid population increase and the associated water requirements are the drivers a number of water development projects (Sand Hollow Reservoir (2003) and the proposed Lake Powell pipeline). Although water quantity is usually the focus of efforts to cope with low flows, the effects on instream temperatures are also important because of endangered species that are unique to the Virgin River (Virgin River Chub (Gila seminuda) and woundfin (Plagopterus argentissimus). Under the Clean Water Act, states must establish water quality standards for temperature that meet the needs of sensitive species. Once these standards are set, states must understand when these limiting conditions occur, what caused the impairment, and which management options will remedy the impairment.

  In this project, a Two-Zone Temperature and Solute model is applied to the Virgin River for use as a management tool for the diverse stakeholders. Data representing specific processes have been collected to ensure appropriate representation of heat sources and sinks in the model. To assist in these efforts, further research has been conducted to determine data types that will provide for better model population and calibration in order to make more confident management decisions. This includes the use of pyranometers in the water column to quantify radiation behavior, remotely sensed thermal infrared and multispectral image data to assist in parameter estimation, dye tracer studies to test the conservativeness of RhWT, and the use of a variety of other data types for model calibration and corroboration.

- **Benefits to the State:**

  Utah has a number of temperature impaired streams. The ability to quantify the importance of different heat fluxes and model a broad range of heat transfer processes within natural systems will guide management and decision making processes throughout the state. The benefit of these capabilities is already being utilized in the Jordan River Temperature TMDL.

- **Geographic Areas**:

  Study Area: Washington County

  Areas Benefited: Primarily the Washington County, although the data collection and modeling capabilities can be implemented in any watershed in the state.

- **Accomplishments:**

Findings:

- The TZTS model has been successfully applied to the Virgin River during a number of time periods. It accurately reproduces mass balance and heat behavior in the main channel, dead zones, and even the subsurface conditions. These modeling results provide insight into thermal refugia for better river management for the engdangered fishes.

- The effects of turbidity on shortwave radiation reflection off the water surface and attenuation through the water column have been quantified for two different sediment types found in Washington County. The relationship for both reflection and attenuation is linear for certain ranges of turbidity. The results of this project will provide guidance about how to better manage sediment in the Virgin River.

Results:

- Three different applications of the TZTS model and real time modeling capabilities in the Virgin River.

- Estimates of thermal heterogeneity and its influence on thermal refugia for endangered species during low flows.

- Relationships to predict the amount of radiation penetrating the water column and how it behaves in the water column given a measure of instream turbidity.

Work Plan FY 09/FY10

Published information regarding the utility of thermal imagery in estimating model parameters is available. Final calculations and a report regarding the fate of radiation in a water column will be delivered to the Virgin River Program.

Informational Resources

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

Bingham, Q.G. (2009). "Data Collection and Analysis Methods for Two-Zone Temperature and Solute Model Parameter Estimation and Corroboration." Utah State University, Logan, UT.

Neilson, B.T. (2006). "Dynamic Stream Temperature Modeling: Understanding the Causes and Effects of Temperature Impairments and Uncertainty in Predictions." Dissertation, Utah State University, Logan, UT.

The Fate of Pharmaceuticals and Personal Care Products Associated with Northern Utah Wastewater Treatment Effluents

Principal Investigators:
William J. Doucette
Joe Stewart

Partners/Collaborators:
- ***Local**: Clint Rogers, Carollo Engineering and Michael Luers, Synderville Basin Water Reclamation District*

Project Description

- **Need and Purpose**:

  Pharmaceuticals and personal care products (PPCPs) are being increasingly identified in the environment. Concern over the potential ecological effects (i.e., hormone disruption, increased microbial resistance to antibiotics) attributed to some of these compounds, has lead to an increased interest in their distribution, environmental fate, and bioavailability. Many PPCPs enter the environment by passing untreated or partially treated through wastewater treatment plants (WWTPs). In addition, wastewater treatment plant biosolids containing PPCPs or their transformation products are often land applied and PPCPs may also enter surface or ground waters during runoff events. Once in the environment, PPCPs can be transformed or removed by various processes including: dilution, hydrolysis, photolysis, biodegradation, mineralization, and sorption however, the extent and rate of these processes depends on both the physical and chemical properties of the PPCP as well as the environment in which it is discharged. There is very little information regarding the identity, distribution and fate of PPCPs discharged from WWTPs in Utah. Nonylphenol, a endocrine disrupting metabolite of nonylphenol ethoxylate surfactants, was found in biosolids collected from a Northern Utah WWTP at concentrations as high as 1000 mg/kg on a dry weight basis during a recent project examining the environmental fate of nonylphenol. The focus of this proposed project is to conduct a preliminary survey of Northern Utah WWTP effluents and biosolids to determine the identity and concentrations of PPCPs.

- **Benefits to the State:**

  Results of this preliminary survey will help determine if PPCPs are being discharged into the environment from effluents and biosolids originating from Northern Utah municipal wastewater treatment plants. This information will be compared to similar observations in other areas of the US and used to determine the effectiveness of wastewater treatment facilities in removing PPCPs and assess the potential impact of these compounds on the surface and groundwaters within the State of Utah.

- **Geographic Areas**:

  Study Area: East Canyon Creek, including Morgan and Summit Counties.

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

- **Accomplishments:**

  Findings: Methods to collect and analyze water and solid samples for a variety of PCPPs are being developed including solid phase sorbent extraction of water samples, accelerated solvent extraction of fish samples and steam distillation extraction. These methods were used to analyze

water and fish samples collected from above and below the effluent discharge point of the Synderville WWTP treatment plant in East Canyon Creek, Utah.

Results: Preliminary results indicate that:

- Several PPCPs were tentatively identified in the Synderville WWTP effluent, East Canyon Creek water samples including: ibuprofen, carbamazepine, and progestrerone.
- Estimated concentrations were typically in the pg to ng/L range

Work Plan FY 09/FY10

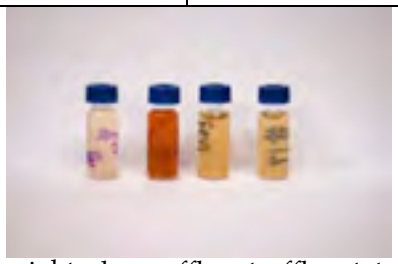
- Refine extraction and LC/MS analytical methods.
- Extract and analyze biosolids samples.
- Continue surveys of effluents .
- Collect and analyze aquatic plant samples collected above and below effluent discharge points to determine if plants can be used as active water samplers.

Informational Resources

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

Grinding fish samples

Stream sampling location



Water samples (from left to right: above effluent, effluent, two samples below effluent)

Surface Water Quantity, Quality, and Watershed Management

U.S. EPA Targeted Watersheds Grant

Principal Investigator(s):

David K. Stevens
Jeffery S. Horsburgh
Bethany T. Neilson
Nancy O. Mesner
Terry Glover
Arthur Kaplan

Partners/Collaborators:

- ***Local**: Jim Bowcutt (USU Extension)*
- ***State**: Mike Allred, Utah DWQ; Lynn Van Every, Idaho DEQ, Don Newton, Wyoming DEQ*
- ***Federal**: Jack Barnett, Bear River Commission*

Project Description

- **Need and Purpose**:

  The Targeted Watersheds Grant program was designed by the U.S. Environmental Protection Agency (EPA) to develop community-based approaches and management techniques to protect water quality. As part of this effort, the feasibility of water quality trading to assist in meeting instream water quality standards has been a topic of investigation. Water quality trading is a potential cost effective solution to mitigating key sources of pollution. Setting up a water quality trading program, however, requires the quantification of both point and nonpoint sources of pollution and an understanding of how pollutants behave in the system. As stated in guidance provided by the EPA, the steps required to complete a suitability analysis for trading a particular pollutant include the need to determine watershed loading profiles, understand the effect of load timing, and consider water quality equivalence when trading. To determine the feasibility of trading in the Bear River Basin, needs were identified and included: the ability to manage various data types from numerous agencies and resulted in the development of the Bear River Watershed Information System (WIS); and a scientifically sound method for estimating load profiles and delivery ratios and resulted in the development of an appropriate water quality modeling framework to provide farm/field loads over time.

- **Benefits to the State:**

  1. The Water Quality Committee of the Bear River Commission is a tri-state committee that is focused on water quality issues in the Bear River Basin. The Bear River WIS supports the efforts of the Water Quality Committee (as well as many other water quality related groups and organizations) in tracking and assessing the water quality of the Bear River basin.

  2. The water quality modeling framework developed for the Bear River basin can provide a scientifically sound mechanism to make a wide variety of watershed management decisions at various time and spatial scales. Additionally, the modeling approach developed can be applied to other watersheds in the state and provide the level of detail necessary to make decisions at a field scale.

- **Geographic Areas**:

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

  Areas Benefited: Primarily the Bear River Basin, although the WIS and modeling framework developed can be implemented for any watershed.

- **Accomplishments:**

  Findings: While the water quality trading in the Bear River Basin is a feasible management option, through many stakeholder meetings we found that more initiative to endorse or organize such activities from the different state governmental entities is necessary.

  Results: As part of this effort, USU developed an Internet Based Watershed Information System (WIS) for the Bear River (http://www.bearriverinfo.org). The 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. Additionally, a modeling framework was developed to determine seasonal farm/field total phosphorus loads, seasonal delivery ratios by sub-watershed, seasonal delivered loads to various receptor points, and the ability to calculate seasonal farm/field tradable loads from local knowledge of remediation potential. This information was then incorporated into a Water Quality Trading Calculator that was delivered to state TMDL and water coordinators to assist in numerous watershed management activities.

Work Plan FY 09/FY10

This project is now complete.

Informational Resources

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

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

Website: http://www.bearriverinfo.org

Watershed Classification Relevant to Bioassessment

Principal Investigators:
David G Tarboton
Charles P Hawkins

Partners/Collaborators:
None

Project Description

- **Need and Purpose**:

  The temporal pattern of streamflow influences biological diversity and stream ecosystem integrity. A quantitative understanding of how stream biota respond to variation in streamflow regimes is needed for developing strategies for effective assessment, conservation, and restoration of stream biota. Watershed classifications are needed to group streams that have similar flow regimes and to help predict streamflow regime class from watershed attributes so that relationships between streamflow regime and biological (macro-invertebrate) diversity can be used in watershed management.

- **Benefits to the State:**

  Many Utah streams are listed by the EPA as impaired due to point and non point sources of pollution and watershed alterations. This research will advance our understanding of the relationship between flow regime variables, watershed attributes and biological measures of stream ecosystem integrity in the Western U.S. This is important for the assessment of stream ecosystem functioning and impairment across the region and in Utah.

- **Geographic Area:**

  Study Area: The study area is the entire Western U.S., particularly Utah.

  Areas Benefited: Stream ecosystems throughout Utah are important, so all counties in the state would potentially benefit.

- **Accomplishments**:

  Findings: Geographic Information System methods to automatically extract watershed attributes have been developed. A set of variables that quantify aspects of the streamflow regime important for ecosystems, and methods to compute these from streamflow records have been developed. These variables have been used to formulate statistical models that predict taxa richness and composition, and thereby quantify the relationship between streamflow regime and biological diversity and stream ecosystem integrity.

  Results: The Geographic Information System software tools used to extract watershed attributes has been reported previously and is available the websites listed under informational resources below. Twelve ecologically important streamflow regime variables were identified and computed at 543 minimally impacted stream gage stations in thirteen Western US states. A principal component analysis was used to reduce these to 7 factors that characterized statistically independent aspects of streamflow. We then used K-means to classify streams into 4 to 8 hydrologically different groups based on these 7 factors. Figure 1 shows the K=4 classification that resulted.

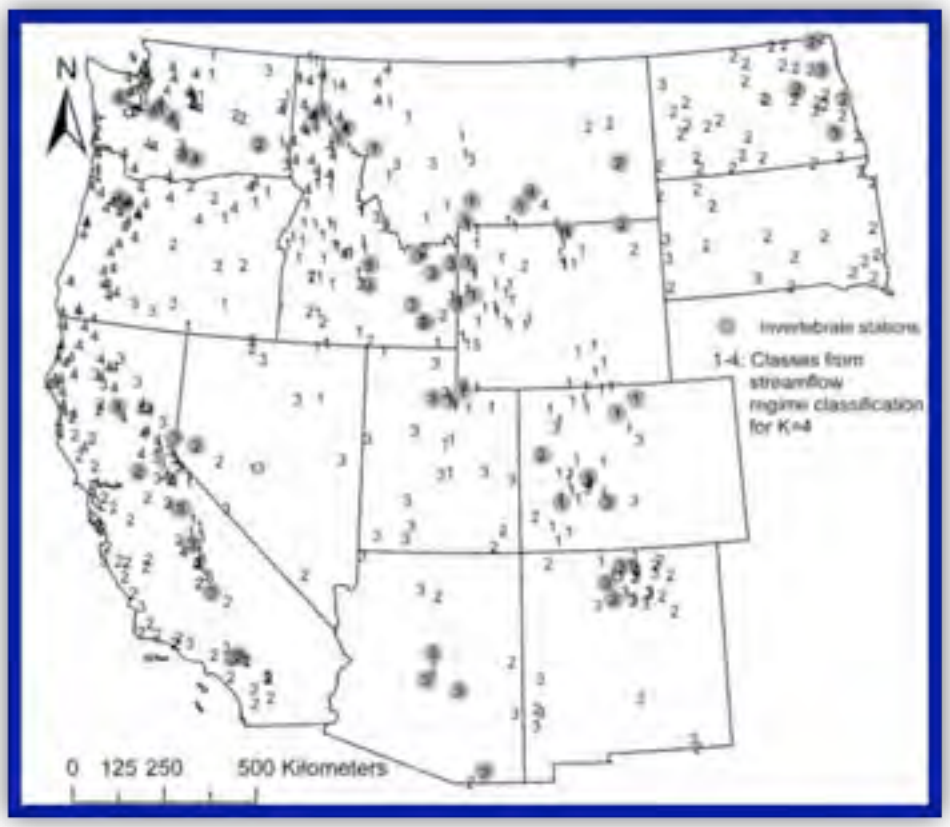


Figure 1. Location of 543 streamflow gauge sites used in this study. Numbers indicate regime class for K=4 classification. Sites with Invertebrate data are indicated.

Invertebrate data was used to develop Random Forests statistical models to predict taxonomic class membership from both streamflow and stream temperature variables. We found that models predicting composition performed best when both temperature and streamflow variables were used, although predictions based on streamflow variables alone were substantially better than null model predictions. Of the 7 factors of the streamflow regime we examined, variation in the factor describing baseflow appeared to be most directly associated with invertebrate assemblage structure.

Work Plan FY09/FY10:

The results above relate invertebrate assemblage structure to streamflow regime at gaged locations. We plan to complete development of the models to predict streamflow regime based on watershed attributes so that the methods can be applied at ungaged locations.

Informational Resources:

Contact: Dr. David G Tarboton, Phone (435) 797 3172, Email: david.tarboton@usu.edu.

Website for multi watershed delineation tool: http://hydrology.usu.edu/mwdtool
General website: http://www.engineering.usu.edu/dtarb.

Weber Basin Decision Support System (DSS) Modernization

Principal Investigator:
David K Stevens

Partners/Collaborators:
- ***Local**: Scott Paxman, Weber Basin Water Conservancy District*
- ***Federal**: Steve Noyes, USBR*
- ***Private**: Christina Bandaragoda, Sanjaya Bandaragoda*

Project Description

- **Need and Purpose**:

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

- **Benefits to the State:**

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

  Significant progress has been made to:

  1. Convert the model interface to Visual C#.Net 2005.
  2. Modify the Weber Basin mass balance model and database to include new flows into Park City from above Rockport.
  3. 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.

  Results:

  1. Working prototype of the modernized Weber Basin DSS.

2. Completed the distributed hydrology model.

Work Plan FY 09/FY10

Finish conversion of model interface to Visual C#.net 2005 and integrate the hydrology model and the water quality model.

Informational Resources

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

Water Conveyance and Control

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

Project Name	FY2009 Actual Expenditures	FY2010 Budgeted Expenditures	FY2011 Planned Expenditures
Accuracy of In-Service Water Meters at Low and High Flow Rates	$10,942.60	$10,000.00	$2,000.00
Acoustic Canal Flow Measurement	$18,428.00	$26,000.00	$0.00
Assessment of Commercially Available Flow Meters for Secondary Water Applications in Utah	$8,477.76	$0.00	$0.00
Determining Accuracy of Flow Measurements below USBR Dams and State of Utah Dams	$36,982.11	$38,091.57	$19,045.79
Hydraulic Structures for Flood Control and Flood Bypass	$17,601.22	$18,129.26	$0.00
Sediment Transport and Flood Control	$17,601.21	$18,129.25	$5,000.00
The Effects of Pipe Aging on Headloss	$16,592.07	$8,000.00	$0.00
Designated Projects		$156,792.00	$0.00
Undesignated Projects		$0.00	$50,000.00
Total	**$126,624.97**	**$275,142.08**	**$76,045.79**

Accuracy of In-Service Water Meters at Low and High Flow Rates

Principal Investigators:
Steven L. Barfuss
Michael C. Johnson

Partners/Collaborators:

- ***Local**: City of Logan Water and Wastewater Division*
- ***State**: Fourteen utilities within the U.S. are formally participating on this project, including four from the State of Utah: Salt Lake City Department of Public Utilities, City of Logan Water and Wastewater Division, Ogden City Corporation Public Utilities Division and City of Orem Department of Public Works*
- ***Business/Industry**: Water Research Foundation*

Project Description

- **Need and Purpose**:

  The objective of this project is to evaluate the accuracy of in-service flow meters (5/8- to 2-inch sizes) over a wider range of flow rates than is currently within AWWA standards. The project is also investigating the accuracy of "pulled" meters and the accuracy of water meters in systems where particulates in the water may become lodged in the meter or cause meter wear. Nearly 1000 distinctly different new and "pulled" meters of varying type and size will be accuracy-tested during the project period. In addition, both historical and current metering standards will be researched and documented.

- **Benefits to the State:**

  With knowledge of the accuracy of in-service flow meters, State utilities will better understand the capabilities of water meters currently being used in their systems. The data will also provide a foundation for meter change-out program for each utility thereby minimizing the cost of unmetered water and meter purchasing cost.

- **Geographic Areas**:

  Study Area: Residential water meters that are commonly used are included in this project. Also pulled water meters have been tested from utilities representing these Utah cities: Logan, Mendon, Ogden, Salt Lake City, Orem, and Draper.

  Areas Benefited: Information from this project will benefit all water utilities that use residential water meters, including many cities throughout the State of Utah.

- **Accomplishments**

  Findings: The results of this project are indicating that some meter types do not meet the AWWA standards as accurately as they claim. The data also show that some meter types are superior to others when measuring low flows. The test results clearly indicate that a higher than expected number of meters do not pass the AWWA low flow standard for accuracy in their new condition. In addition, only a small percentage of meters are able to accurately measure flows below the AWWA low flow standard. Test results are also indicating that some meter types are more susceptible than others to registry degradation with throughput for flows at and below the low AWWA flow rate.

  Preliminary results also indicate that a large percentage of the pulled meters that are being tested during this project are maintaining a similar level of registry accuracy as compared to new project meters subjected to endurance testing of the same type and size. Accordingly, more

pulled meters than were expected have been operating in the field below the AWWA standard. Early results from the particulate portion of the study indicate that most of these meters are maintaining better accuracies than expected, yet the effects of the particulates on specific meter types is apparent.

Results: Of all the sizes that have been tested in this project, the 5/8x3/4-inch meters are the most common and Table 1 shows how many meters met the AWWA accuracy standard.

Table 1. 5/8x3/4-inch meters meeting AWWA standard.

Meter Type	Number of meters meeting the standard in the new condition at specified flow			Number of meters meeting the standard after 2,000,000 gallons of throughput at the specified flow		
	0.25 gpm	1 or 2 gpm*	15 gpm	0.25 gpm	1 or 2 gpm*	15 gpm
Nutating Disc	30/30	27/30	30/30	28/30	25/30	19/30
Piston	37/48	43/48	48/48	27/48	42/48	43/48
Multi-jet	32/42	37/42	38/42	20/42	35/42	24/42
Single-jet	19/24	18/24	18/24	11/24	14/24	14/24
Fluidic Oscillator	6/6	6/6	6/6	6/6	6/6	6/6

*Multi-jet meters use the smaller flow rate.

Work Plan FY 09/FY10

- Finish meter testing by Feb 2010.
- Prepare final report due Oct 2010.
- Publish findings in journals and at appropriate conferences (ACE conference and others).

Informational Resources

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

WRF Project Website:
http://www.waterresearchfoundation.org/research/TopicsAndProjects/projectSnapshot.aspx?pn=4028

ACE Conference Paper: Flow Measurement Accuracies of New Residential Flow Meters.

Acoustic Canal Flow Measurement

Principal Investigators:
Todd Moon
Brent Carruth
Mac McKee

Partners/Collaborators:
None

Project Description

- **Need and Purpose**:

  Irrigation systems throughout the state of Utah, and indeed throughout the world, use open canals for irrigation. Measurement of water flow in canals is a critical need for canal companies and their customers. In addition, measurement of water flow rate, or gaging, in rivers and streams is a similarly critical need in water resource management. There is a similar need for measurement of flow rate in municipal sewer systems.

  Traditional methods for measurement of water flow rate in open channels include weirs and flumes which divert some or all of the water to pass over or through them. These methods have been used for centuries. To avoid costly construction, maintenance and calibration required by these methods, more technologically advanced methods use scientific instruments placed within the moving water itself to measure the flow rate, such as velocimeters with rotors and acoustic doppler velocimeters which have no moving components. While these methods are simpler to implement and less expensive, the instruments themselves suffer from the adverse effects of their harsh environment and require frequent cleaning, repair and/or replacement.

  Noncontact methods of water flow rate are thus needed and have been investigated by scientists over the past decade. While some good progress has been made implementing ultrasonic and electromagnetic sensing methods for water flow rate, much more remains to be done. The purpose of the present research is to investigate the use of ultrasound for noncontact measurement of water flow rate in open canal flows.

- **Benefits to the State:**

  Open channel irrigation systems would definitely benefit from an inexpensive noncontact method of water flow rate measurement. Presently, for most canals, water masters periodically measure the water level and determine the volumetric flow rate from empirical tables. These canals are aging. Some are over one hundred years old. Most canals are privately owned and operated and are cash poor. A simple, inexpensive noncontact water flow rate measurement system would be a valuable device for such companies.

  A manufacturing industry to construct these devices would bring in outside dollars to the state which would benefit both the local community which is home to the manufacturing plant and to the state through taxes.

- **Geographic Areas**:

  Study Area: The investigative research occurs at Utah State University

  Areas Benefited: Most counties in the state have open irrigation systems that would benefit.

- **Accomplishments:**

  Findings: Noncontact water flow measurement research has been investigated for less than a decade and additional research is much needed. A pulsed radar and ground penetrating radar combination was demonstrated to accurately measure the water flow rate of the Skagit River in Washington. This method could benefit from applying tomographic reconstructions of cross channel imaging, which this research has investigated.

  This use of pulsed radar relies on Bragg scattering to measure river surface velocity. Bragg scattering relies on surface roughness caused by turbulence, which is prominent on rivers. However, the surface is usually very smooth for small, slowly flowing canals typically observed in Cache County and this feature requires other means to measure surface velocity.

  In earlier experience measuring rocket propellant properties with ultrasound, it was observed that a surface wave propagated on the rubbery-type substance of the propellant. This research is examining if water might support just such a wave as well.

  A four-inch wide flume in the Experimental Fluid Dynamics Laboratory on the USU campus was used to make detailed measurements. A pair of 40KHz ultrasonic transducers powered by a stable sine wave oscillator from a spectrum analyzer and a digital storage oscilloscope were used to transmit and receive sound waves launched at a specific angle onto the flowing water in the flume. A preliminary assessment of the analysis of the recorded phase measurements indicates that water, too, transmits surface acoustic waves and that a relative phase change corresponds to the surface velocity of flowing water.

  Results: The measurement of water surface acoustic waves is believed to be new. Prior research on this subject has not been found. Obtaining surface velocity measurements using this phenomenon makes possible the design of an inexpensive, simple noncontact water flow measurement system. The other component to this system is to measure the channel cross section which has been investigated with short wavelength radio tomography.

Work Plan FY 09/FY10

- Continue measurements similar to those with the 40KHz transducers with a pair of 20KHz transducers and with a pair of 20KHz tweeter speakers for the purpose of lowering the component cost of the system.
- Design and test a radio tomography system to measure the channel cross section of a canal.

Informational Resources

Contact: Todd Moon, (435) 797-2970, E-mail: todd.moon@usu.edu.

Assessment of Commercially Available Flow Meters for Secondary Water Applications in Utah

Principal Investigator:
Steven L. Barfuss

Partners/Collaborators:
- ***State**: Nancy Hardman, Conservation Programs Coordinator for the Central Utah Water Conservancy District*

Project Description

- **Need and Purpose**:

  For many years, the State of Utah has been interested in metering secondary water systems to encourage water use accountability. Commonly, users of secondary water are charged flat rates with no restraint on volume of use. The State would like to find a low-cost, commercially available flow meter that is capable of accurately measuring secondary water flow rates, in order that consumer accountability is improved thereby reducing water consumption. To date, most small low-cost residential and commercial flow meters are mechanically operated, so that when debris-laden water is passed through the meter, meter parts can become damaged or stop working all together.

- **Benefits to State:**

  A final report has been submitted to the Central Utah Water Conservancy District (CUWCD). This report detailed the acceptability of potential culinary water meter designs in a harsh secondary water environment for meter accuracy and durability. Several water utilities in the State will use the report in decision processes regarding the metering of secondary water systems 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: Although residential meters (meters for culinary water connections) are much less expensive, secondary water environments often cause these meters to clog or fail. Two meter types, the fluidic oscillator and the single jet show promise in avoiding these problems thanks to their minimal number of moving parts. During this study, these two meter types were tested for accuracy and durability in alignment, mineral deposits, freezing, and dirty water.

  It appears that both of these meters would be appropriate choices for secondary water applications. Both of these meter types were found to accurately measure water within the flow range of a secondary system in their new condition, and when these meters were evaluated in the field, they generally showed no significant impact after two seasons of use.

  Most importantly, every utility is different. While the tests presented in this report cover several extreme conditions, more specific testing should be done on a per-utility basis. As evidenced, water quality and filtering play a role in meter accuracy. Management practices will also affect the efficiency of a secondary metering system.

Results: Utah State University report #1866 was prepared and submitted to the Central Utah Water Conservancy District in 2008. The title of the report was "Assessment of Commercially Available Meters for Secondary Water Applications in Utah."

Work Plan FY 09/FY10

Project completed

Informational Resources

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

Determining Accuracy of Flow Measurements Below USBR Dams and State of Utah Dams

Principal Investigator:
Steven L. Barfuss

Partners/Collaborators:
- ***State:*** *Matt Lindon, 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 dry and arid land requires irrigation to produce crops. As a result water suppliers have realized the importance of accurately measuring water used in their systems. Accurate information on the available methods and measurement devices and their specified accuracies is vital to ensuring the best achievable distribution and use of water.

  Initial investigations showed that a large number of flow measurement devices throughout the State of Utah were not measuring flow with the accuracy the manufacturer specifications claim. The purpose of this project is to determine major contributors to flow measurement errors and those devices that exhibit these errors. The study aims to provide direction for reducing the errors in water measurements.

- **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 will generate a data base of information that will be useful in determining 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: Seventy flow measurement devices have been assessed including fifty Parshall flumes, four ramp flumes, one cutthroat flume, four weirs, one rated section, five ultrasonic meters and five magnetic meters. Of the measurement devices assessed, 271 potential flow measurement issues were documented. Thirty three percent of the tested devices measured flow within manufacturer design specifications. The remaining sixty-seven percent exhibited flow measurement errors in excess of the design specifications. Of the devices with flow measurement errors sixty-three percent underestimate and thirty-seven percent overestimate the actual flow through the devices. This means that thirty-seven percent of the structures were releasing less water than their theoretical measurements calculate, preventing water users from receiving their true allocation of water (see Figure 1).

Results:

- A list of all sites visited, their locations, measurement device type, 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 FY 09/FY10

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

Informational Resources

Contact: Steven L. Barfuss, Phone (435) 797 3214, E-Mail: steve.barfuss@usu.edu.
Bryan J. Heiner (435) 797 3171, E-Mail: bryanheiner@gmail.com
Ryan P. Willeitner (435) 797 3231, E-Mail: r.w@aggiemail.usu.edu

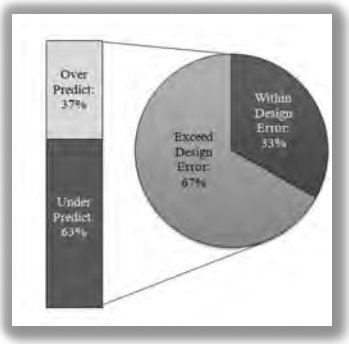


Figure 1. Errors in Flow Measurement for All Assessed Devices

Figure 2. Examples of Flow Measurement Devices Tested Throughout Utah.

Hydraulic Structures for Flood Control and Flood Bypass

Principal Investigator:
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**:

  There are several reasons why flood control has become even more of a critical issue for the State of Utah. One reason is the 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 was conducted on two 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 is an important issue. Such projects involve a 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 of the dams and spillway structures in the Western United States are located in the diversion channels that were used to construct the reservoirs and dams. It is too expensive to widen and excavate the channels to increase flow capacity so new ideas and designs for the spillway crest control sections are being researched.

- **Benefits to the State:**

  Direct benefits to the State of Utah will be from the knowledge and methodology gained from this research in the retrofit of dams and hydraulic structures. Almost all of the cities and counties of Utah should benefit directly from this research. Utah will better understand the need to retrofit or rehabilitate dams and hydraulic structures as well as costs and design parameters associated with the rehabilitation. Utah will be better suited to respond to issues of flood control, emergency response, and flood and storm water management. A better understanding 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**: All counties and cities in Utah.

  Study Area: Entire State of Utah.

  Areas Benefited: All counties and cities in Utah.

- **Accomplishments**

  Findings: Several concepts that were researched this year included the use of stair stepped spillways, side channel ogee crests, and control structures in high velocity approach channels. All of these concepts offer alternative solutions for flood control in Utah that will be more economical, sustainable, and have less environmental impact than the types of spillways currently used in Utah. Current studies utilize auxiliary spillways to increase the capacity of flood control structures. There are a number of possible applications of this type of auxiliary spillways that could be used in Utah.

  Results: Two papers were presented at the 2009 ASDSO Dam Safety in Hollywood Florida, September 2009.

- Eliminating Vortices at the Proposed Folsom Dam Auxiliary Spillway.
- Physical Modeling to Evaluate Spillway Performance for the Modern-Day PMF.

Participation in the Utah Floodplain and Storm Water Management Conference in St. George, Utah, November, 2008

Work Plan FY 09/FY10

Participate with the Utah Floodplain and Strom Water Management Association and the Utah Office of Homeland Security in developing a series of joint workshops on flooding and floodplain problems. Represent the UWRL on the board of directors of the Utah Floodplain and Strom Water Management Association. Flood routing, management, and planning. Retro-fit of dams for drought control and storage. Rehabilitation and retro-fit of spillway control structures.

Informational Resources

Contact: Dr. William J. Rahmeyer, Phone (435) 797 2938, E-mail: william.rahmeyer@usu.edu.

Sediment Transport and Flood Control

Principal Investigator:
William J. Rahmeyer

Partners/Collaborators:
- ***Local:*** *Salt Lake and Davis counties*
- ***Federal:*** *U.S. Army Corps of Engineers*

Project Description

- **Need and Purpose**:

  Utah streams and rivers formed under unique geologic and climatic conditions. Understanding sedimentation and erosion processes is important. How is sediment produced in our watersheds? How is it transported in the streams and rivers? What is the balance between erosion and deposition in our floodplains? The sedimentation process affects most man-made activities including agriculture, urbanization, reclamation, and mining. Short-term and long-term changes in climate and precipitation interact with the sedimentation process to cause flooding and debris flow problems in Utah. A major interest to the State of Utah and other Western States is the effect of the sedimentation process on the flooding and flood routing in floodplains.

  Knowledge of sediment transport have been developed for climates and geology different from those in Utah. Our research objectives are: 1) continue developing prediction methods and models of sedimentation and scour, 2) conduct basic and applied research to solve specific sediment problems that affect Utah, and 3) work with local and state agencies to provide education and support in the area of sedimentation.

- **Benefits to the State:**

  Direct benefits to the State of Utah will flow the knowledge and methodology gained from Utah specific research in sedimentation and erosion. Almost all areas of agriculture, mining, forestry, reclamation, and transportation should benefit directly from this research. The Division of Oil, Gas, and Mining; Division of Water Quality; Division of Water Resources; Utah Department of Transportation; and water conservancy districts will be informed of our results. A better understanding of this research and how it applies to Utah may positively impact federal guidelines and requirements of sedimentation and erosion control for Utah.

- **Geographic Areas**: All counties and cities in Utah.

  Areas Benefited: All counties and cities in Utah.

- **Accomplishments:**

  Findings: An understanding of the fundamental hydraulics of sedimentation and erosion for the semi-arid regions of Utah. The methods and equations for transporting sediment through culverts in the semi-arid regions of Utah..

  Results:

  Developed and fabricated the first of a kind circular water tunnel for studying sediment transport in a culvert. Tunnel included a 20 foot length of 12 inch diameter clear PVC pipe. Incipient motion, flow resistance, and sediment transport have been studied for several gravel and sand sizes. The formation and classification of bed forms in culverts has also been conducted.

Work Plan FY 09/FY10

- Fundamental hydraulics of sedimentation and erosion.
- Equations and methodologies to predict the sediment transport in steep mountain streams and closed conduits.
- Develop sediment transport equations and methods for UDOT.
- Study and develop methodology for the transport of sediment through culverts.
- Study and develop methodology for the flow resistance of sediment through culverts.
- Study and develop methodology for the incipient motion of sediment through culverts.
- An understanding of the effect of vegetation on the sediment transport in floodplains.
- Continue research and publishing journal articles on flood plain resistance and the effect of vegetation on flow resistance.
- The effect of the sedimentation process on erosion and deposition at culverts and road crossings.

Informational Resources

Contact: Dr. William J. Rahmeyer, Phone (435) 797 2938, E-mail: william.rahmeyer@usu.edu.

The Effects of Pipe Aging on Headloss

Principal Investigator:
Steven L. Barfuss

Partners/Collaborators:
None

Project Description

- **Need and Purpose**:

  Pipes are commonly used in a variety of engineering applications for the purpose of transporting fluids. For example, water distribution networks provide water for the majority of the people in Utah. In many cases, conditions within the pipes of water supply systems are favorable for corrosion, and other types of degradation. Furthermore, many aged pipes are in use, some of which were installed in the 19th century. As a result, many pipes in distribution networks are significantly affected by age related degradation. The buildup that can form as pipes age significantly impacts the flow dynamics of degraded pipes.

  Models are widely used to describe the hydraulics in a distribution system. Models have also been applied to degradation processes, such as chlorine decay. The overall goal of this project is to better understand the changes that take place in aging pipes in order to improve methods and minimize errors in pipe network modeling. This project gathered and tested aged pipes in a laboratory setting. Further testing consisted of application of the laboratory results to a pipe network along with the computational fluid dynamics modeling of two of the aged pipes.

- **Benefits to the State:**

  This project improves the understanding of how the degraded interior of aged pipes affects the modeling of conditions within the pipes. Improving the accuracy of network models will allow Utah's water system managers to better meet the present and future needs of water users.

- **Geographic Areas**:

  Study Area: Aged pipe sections from Centerville City, Kaysville City, and the Weber Basin Water Conservancy District (along with pipes from a few cities outside of Utah) have been studied during the course of this project. The specific results of each aged pipe section have been provided to the applicable city.

  Areas Benefited: All cities use pipes for the conveyance of potable water. The result of this testing can potentially improve the efficiency of distribution networks. In particular, cities with a significant portion of aged pipe have the most to gain from this research.

- **Accomplishments**

  Findings: Using the results of the laboratory and network testing, a method has been developed for correcting the diameters of aged pipes. Computational fluid dynamics (CFD) testing has also shown that Reynolds averaged Navier-Stokes (RANS) turbulence modeling and large eddy simulation are capable of providing highly descriptive flow data for small sections of aged pipes

  Results: Specific to the network modeling:

  - The method found for correcting pipe diameters is convenient to apply.
  - Not accounting for age related changes in pipe diameter was shown to result in errors of up to 10% in modeling the water age of a pipe with a Hazen-Williams C of 65.

- Because water age is an important factor in water quality, changes in pipe diameter are an important consideration in modeling water quality

Specific to CFD:

- Though difficult to apply CFD, provides a wealth of flow information.
- The k-ε-v^2-f model was found to give the best results of the turbulence models considered.
- Large eddy simulation is useful for resolving turbulence but does not give more accurate prediction of headloss than the RANS models.

Work Plan FY 09/FY10

- Complete the numerical modeling (the final stage of the project).
- A presentation with corresponding paper entitled "Improving Water Quality Modeling in Systems Containing Tuberculated Pipes" was presented at the AWWA annual conference and exposition in San Diego in June of 2009.
- Publish the project results.
  - Three journal papers are to be written, one each for the network modeling, RANS turbulence modeling, and large eddy simulation.

Informational Resources

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

Ryan Christensen, Phone (435)7973171, E-mail: ryan.christensen@aggiemail.edu.

Aging Pipes

Water Education and Technology Transfer

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

Project Name	FY2009 Actual Expenditures	FY2010 Budgeted Expenditures	FY2011 Planned Expenditures
Enhancement of On-Site Wastewater Treatment Field Training Site: Installation of Gray Water, Drip Irrigation, and Fixed Film Demonstration	$20,922.38	$21,550.05	$22,196.55
Intermountain Section American Water Works Association (IMS-AWWA) Scholarship and Student Outreach Committee	$2,068.86	$2,130.93	$0.00
Salt Lake Valley Solid Waste Management Council	$1,125.47	$1,159.23	$0.00
State of Utah Solid Waste Control Board	$1,125.47	$1,159.23	$0.00
Support for State Watershed Modeling and TMDL Plans	$14,888.50	$15,335.16	$2,500.00
Utah On-Site Wastewater Treatment Training Program	$15,490.47	$15,955.18	$16,433.85
Utah Water Quality Alliance (UWQA)	$18,619.70	$9,178.29	$2,000.00
Weber-Morgan Health Department Wastewater Advisory Committee	$2,500.00	$2,575.00	$0.00
Designated Projects		$47,729.00	$0.00
Undesignated Projects		$0.00	$18,000.00
Total	**$76,740.85**	**$116,772.07**	**$61,130.40**

Enhancement of On-Site Wastewater Treatment Field Training Site: Installation of Gray Water, Drip Irrigation, and Fixed Film Demonstration Systems

Principal Investigator:
Judith L. Sims

Partners/Collaborators:
- ***Local**: Twelve Utah Local Health Departments*
- ***State**: Division of Water Quality, Utah Department of Environmental Quality*
- ***Federal**: U.S. EPA Region 8*

Project Description

- **Need and Purpose**:

  On-site wastewater treatment systems, including septic tank soil-absorption systems, collect, treat, and dispose of wastewater generated by facilities such as homes, small businesses, and apartment buildings near the site of waste generation. The increasing use of on-site wastewater treatment systems and the impacts of failed systems on watersheds have been identified as concerns of high priority by the Utah Department of Environmental Quality (UDEQ).

  The lack of education, awareness, and installation and operation training contributes substantially to misuse and failures of on-site wastewater treatment systems. Therefore, there is a need for those involved in the development of new housing sites, including system designers, installers, regulators, and city and county planners to be trained in correct principles of planning, design, material and systems selection, and system installation for on-site wastewater treatment systems currently allowed under Utah regulations.

- **Benefits to the State:**

  Field demonstration models of various alternative on-site wastewater treatment technologies are installed at the Utah On-Site Wastewater Treatment Training Site and used to train Utah's designers, installers and others in the correct principles and practices for use of alternative systems in Utah. Training at the site serves to assure that all groups are receiving consistent and uniform training, understanding on-site wastewater treatment system code, and sound environmentally responsible principles.

  Utah local health department regulators are the information link between developers, designers, installers, community planners, and homeowners. They need to provide effective communications among these groups regarding alternative on-site wastewater systems and components. The on-site systems demonstration site assists regulators in understanding how these systems may prove useful in Utah in conjunction with conventional systems, if they are properly managed and operated after installation.

  Community planners at city and county levels in Utah are constantly faced with challenges to accommodate population growth of urban and rural areas. They must consider treatment and disposal of domestic wastewater as a factor in such planning. Pressures have increased for community growth into non-sewered areas that are unacceptable for conventional and the alternative on-site wastewater treatment systems currently allowed under Utah code. Through training at the demonstration site, community leaders can increase their understanding of these new technologies, which will enable them to make more informed decisions and investigations as they feel pressure from Utah citizenry to develop methods of wastewater treatment to accommodate growth.

- **Geographic Areas**:

  Study Area: The entire State of Utah. The Utah On-Site Wastewater Treatment Training Center is located on the campus of Utah State University in Logan, Utah.

  Areas Benefited: The entire State of Utah.

- **Accomplishments**

  Findings: Project activities included the design and installation of demonstration models of gray water, drip irrigation, and fixed film (packed bed) treatment systems that are used as field training aids. Workshop participants and other users of the demonstration site become aware of the relationship between potential pollution of ground and surface waters and soil in watersheds as well as public health protection as related to these alternative on-site wastewater treatment system components. Written and visual materials regarding the systems have also been developed and used in the training workshops.

  Results: A Utah guidance manual on the use of gray water was prepared according to Utah regulations. The Utah State University on-site training and demonstration site has installed a full-scale drip irrigation system that can be used for the disposal of either gray water or wastewater that has been treated in a fixed film system. A textile filter and a recirculating gravel filter, both of which are types of fixed film (packed bed media) were also installed. Educational materials were developed for each type of fixed film media systems describing their use as alternative wastewater treatment systems.

Work Plan FY 09/FY10

The project is completed.

Informational Resources

Sims, J.L. (2009). *Enhancement of On-Site Wastewater Treatment Field Training Site: Installation of Gray Water, Drip Irrigation, and Fixed Film Demonstration Systems.* Final Report to the Division of Water Quality, Utah Department of Environmental Quality, Utah Water Research Laboratory, Utah State University, Logan, Utah.

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

Figure 1: Installation of Drip Irrigation Systems.

Figure 2: Textile Filter at USU Demonstration Site

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

Principal Investigator:
Laurie 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 State:**

  This committee provides three scholarships to students who will benefit the field of water quality, supply, and treatment in the Intermountain West (Utah and southern Idaho). These 3 scholarships include: undergraduate ($1,000), graduate ($1,500), and diversity ($1,000). The committee is also working to integrate water topics into the Utah K-12 education curriculum.

- **Geographic Area:**

  Study Area: Statewide.

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

- **Accomplishments**:

  Results: Three students (two undergraduate and one graduate) were awarded scholarships for a total of $3,500 to study water quality and treatment at Utah State University during the Fall 2009 semester.

Work Plan FY 09/FY10

Continue to participate in IMS-AWWA meetings and activities. Three scholarships will be awarded in the Spring 2010 semester. Work will also begin on integrating water treatment topics into the State of Utah education curriculum, so ties will be investigated with the Utah Water Research Laboratory's International Office of Water Education.

Informational Resources

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

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

Salt Lake Valley Solid Waste Management Council

Principal Investigator:
R. Ryan Dupont

Partners/Collaborators:

- ***Local****: Linda Hamilton, Salt Lake County Public Works; Rick Graham, Salt Lake City Public Works; Brian Bennion, Salt Lake County Health Department; Russ Willardson, Council of Governments, Dwayne Wooley, Trans Jordan Landfill; Utah DEQ 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, business, 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 solid waste. The landfill facility operates a citizen unloading facility, provides recycling of 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 education of the public in areas related to waste reduction, recycling, and composting, and provides informational tours of the landfill facility and its operations.

  The SLVSWMF operates on the financial principle of an enterprise fund, and is supported by gate fees, rather than by tax funds. 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. An example of this special project request is detailed in a separate report related to investigating the impact of mandating green waste recycling on a County-wide basis on the carbon and energy footprint of the SLVSWMF's operation.

- **Geographic Areas**:

  Areas Benefited: Salt Lake City and Salt Lake County.

Work Plan FY 09/FY10

Continue involvement in decision making through attendance at monthly SLVSWMF Council meetings, and responding to special project requests at 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 Waste Control Board

Principal Investigator:
R. Ryan Dupont

Partners/Collaborators:
- ***Local**: Dennis Downs, Director, Division of Solid and Hazardous Waste*

Project Description

- **Need and Purpose**:

  Under the Utah Solid and Hazardous Waste Act, responsibility for overseeing solid and hazardous waste disposal rests with DEQ and the Utah Solid and Hazardous Waste Control Board (Waste Control Board). The Waste Control Board has the authority to issue orders implementing the provisions of the Act as well as to ensure compliance with the Act's provisions. Jurisdiction of the Waste Control 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 Act applies to all tanks covered by the Federal Resource Conservation and Recovery Act and specifically includes petroleum storage tanks. The Waste Control Board has the power to make rules regarding certification of tank installers, inspectors, testers, and removers as well as requiring the registration of underground tanks. Each owner or operator of an underground tank must register the tank with the Executive Secretary of the Waste Control Board.

- **Benefits to the State:**

  Membership on the Solid 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 at Waste Control Board meetings 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 waste management law.

- **Geographic Areas**:

  Areas Benefited: All affected parties state-wide.

Work Plan FY 09/FY10

Continue involvement in decision making through attendance at monthly Solid Waste Control Board meetings and associated facility tours, providing 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

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, 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 waterbodies. The requirements associated with the TMDL process include the quantification of loads from both point and nonpoint 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. This effort assists the DEQ and their consultants in the decision-making process and prioritization of investments.

- **Geographic Areas:**

  Study Areas: Salt Lake and Weber Counties.

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

- **Accomplishments**:

  Modeling is necessary to estimate pollution loads and understand how these translate into instream concentrations. In the case of the Jordan River, the state has requested that I complete a model of the instream water quality modeling. This requires reading documents, giving presentations, and in meetings to provide guidance as to how to best proceed in the TMDL process. I am also assisting Stantec as expert reviewer for the Watershed Model that is being developed for Salt Lake County. While the Jordan River TMDL and the Salt Lake County watershed modeling studies are independent efforts, the conclusions and resulting management decisions will need to be interrelated.

  Findings: After reviewing the Linkage Documentation for the Jordan River, I provided some insight into the linkage between dissolved oxygen and temperature at the Jordan River Linkage Symposium. Initial thoughts by the State and the hired consultants was that the temperature impairments in the Jordan River could be dealt with at a later time. For this presentation, I completed some calculations regarding the possible change in oxygen saturation and other coefficients (e.g., BOD decay coefficients and reaeration coefficients) given differences in temperature.

In the Salt Lake County watershed modeling effort, a model development plan has been reviewed and completed. Data to force and calibrate the model are still being gathered. The next steps will include the model setup and calibration.

Results: After the Linkage Symposium, temperature monitoring strategy to support model population and calibration was developed. Temperature is being considered with dissolved oxygen simultaneously.

Work Plan FY 09/FY10

Over the next year, I will continue to support both the Jordan River TMDL process and the Salt Lake Watershed Model development as part of the Jordan River TMDL Technical Advisory Committee and Salt Lake County Watershed Model Advisory Committee, respectively. I will also act as an independent model reviewer for both of these efforts.

Informational Resources

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

Utah On-Site Wastewater Treatment Training Program

Principal Investigator:
Judith L. Sims

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 depends on having 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 housing developments will continue to expand into current open space. Such development 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 with soils unsuitable for conventional systems. Training of those involved in the use of alternative systems will ensure that these types of systems will work correctly.

- **Benefits to the State:**

  As population growth and associated housing developments continue to threaten the preservation of agricultural lands in Utah, there is an increased need for accurate and thorough information on 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 use of conventional soil absorption systems due to high or fluctuating water tables, slowly permeable or highly permeable soil horizons, and extreme slopes. The On-Site Training Program provides the necessary education to utilize alternative systems in an effective manner that will protect both public health and the environment.

- **Geographic Area**:

  Study Area: Entire State of Utah.

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

- **Accomplishments**:

  Findings: A state legislative initiative was introduced and passed as House Bill 14s during the 2001 Legislative Session to develop 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 Department of Environmental Quality, 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:

  - Level 1: Soil Evaluation and Percolation Testing.
  - Level 2: Design, Inspection, and Maintenance of Conventional Systems.
  - Level 3: Design, Operation, and Maintenance of Alternative Systems.

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

  Results. During FY08/FY09, three Level 1 workshops, three Level 2 workshops, two Level 3 workshops were taught, as well as three Level 1 renewal workshops, three Level 2 renewal workshops, and two Level 3 renewal workshops.

Work Plan FY09/FY10

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

Informational Resources

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

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

Sims, J.L., Cashell, M., Cowan, B., and Jex, Richard (2009). *Course Manuals for Levels 1, 2, and 3 Certification*. Utah Water Research Laboratory, Utah State University, Logan, UT.

Utah Water Quality Alliance (UWQA)

Principal Investigator:
Laurie McNeill

Partners/Collaborators:
- ***State**: Utah Water Quality Alliance*

Project Description

- **Need and Purpose**:

  The Utah Water Quality Alliance (UWQA) meets regularly to discuss issues of importance to the Drinking Water Industry in Utah.

- **Benefits to State:**

  Representatives share information and resources related to the drinking water industry, including new technology, strategies to meet regulations, funding for research projects, etc.

- **Geographic Area:**

  Study Areas: The UWQA is comprised of representatives of the Metropolitan Water District of Salt Lake and Sandy, Jordan Valley Water Conservancy District, Central Utah Water Conservancy District, Weber Basin Water Conservancy District, and Salt Lake City Public Utilities.

  Areas Benefited: same as above

- **Accomplishments**:

  Results: Issues discussed included distribution system water quality and monitoring for pathogens.

Work Plan FY 09/FY10

Continue to attend UWQA meetings and consult with water utilities as appropriate.

Informational Resources

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

Weber-Morgan Health Department Wastewater Advisory Committee

Principal Investigator:
Darwin L. Sorensen

Partners/Collaborators:
- ***State:*** *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 their counsel to the Board of Health relative to the use of on-site (e.g., septic system) wastewater treatment and disposal. Staff 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 is composed of representatives from local government, land developers, consulting engineers, the Weber Basin Water Conservancy District, Central Weber Sewer Improvement District, the Utah Geological Survey and academia (Utah State University). The committee meets on an as-needed basis—approximately six times each year. 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.

- **Geographic Areas**:

  Study Areas: Weber and Morgan Counties.

  Areas Benefited: Weber and Morgan Counties.

Accomplishments:

Results: 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. 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 general, the committee considers the scientific and public health protection principles underlying the rule and seeks to find ways that land can 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 Weber River Canyon.

Work Plan FY 09/FY10

It is anticipated that Dr. Sorensen will continue to serve as member of the committee in FY09/FY10.

Informational Resources

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

Water Resources Planning and Management

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

Project Name	FY2009 Actual Expenditures	FY2010 Budgeted Expenditures	FY2011 Planned Expenditures
A Decision-Support System for Op imal Agricultural Water Management Under Water Deficit Conditions in Utah	$6,603.71	$0.00	$0.00
Advanced Statistical Learning Techniques for Predicting Water Levels in the Great Salt Lake	$23,005.69	$23,695.86	$0.00
Agricultural Water Resources Management Training	$18,390.48	$18,942.19	$19,510.46
Analysis of Water Supply and Demand of the Salt Lake Valley Considering Land Use Changes and Population Dynamics	$4,447.52	$0.00	$0.00
Conversion of Agricultural Water to Municipal and Industrial Use	$921.21	$25,000.00	$24,000.00
Cooperation of Multiple UAVs for High-Resolution Remote Sensing in Water Management	$39,986.38	$0.00	$0.00
Dam Failure Life-Loss Estimation	$9,947.20	$10,245.62	$10,552.98
Dam Safety Risk Analysis Computations	$9,947.20	$10,245.62	$10,552.98
Dam Safety Risk Management	$9,947.20	$10,245.62	$10,552.98
Decision Support System (DSS) for Virgin River Water Management	$725.23	$0.00	$0.00
Demonstration Application of UAV Architecture for Habitat Mapping of River Corridors - Phase I	$8,671.52	$0.00	$0.00
Demonstration Application of UAV Architecture for Habitat Mapping of River Corridors - Phase II	$16,472.92	$0.00	$0.00
Development of Flow Measurement Procedures for Pipe Installations with Non-Ideal Conditions	$5,000.00	$0.00	$0.00
Establishing Real-Time and Seasonal Crop Evapotranspiration of Large Irrigated Systems at Different Spatial Scales	$14,962.14	$15,411.00	$15,873.34
Evaluation of the Effects of Increased Stream Discharge and Non-Native Fish Removal on the Population Perfomance of the Colorado River Cutthroat Trout in the West and East Fork of Boulder Creek, UT	$21,678.99	$0.00	$0.00
Improved Dam-Breach Flood Plain Inundation Mapping	$17,927.44	$0.00	$0.00
Increasing Data Accuracy, Reliability, Accessibility, and Understanding to Improve Basin-Wide Water Resources Decisions	$20,551.14	$5,000.00	$0.00
Labyrinth Weir Research	$31,030.81	$31,961.73	$0.00
Lay-Flat Lateral Hydraulics for IDEal Drip Irrigation Systems	$7,254.81	$0.00	$0.00
Low-Level Outlet Air Vent Sizing for Small to Medium Sized Embankment Dams	$21,052.35	$5,000.00	$0.00
Metering of Secondary Irrigation Water Systems	$17,767.63	$4,000.00	$0.00
Multispectral Image Processing for Water Management and Other Agricultural Applications	$56,530.52	$28,265.26	$0.00
Multispectral UAV Collaborative Remote Sensing System for Irrgation Water Management and Ecological Assessment	$261,689.93	$269,540.63	$277,626.85
Optimal Agricultural Water Management under Water Deficit Conditions	$7,020.69	$0.00	$0.00
Optimal Merging of Dfferent Scale Soil Moisture Measurements into Land Surface Modeling Sytems	$38,249.76	$39,397.25	$0.00
Optimizing Water Management for Environmental Purposes	$66,892.93	$40,000.00	$11,000.00
Quantification and Management of Salt Production in the Desert Lake Watershed	$96,937.68	$85,000.00	$25,000.00
Raindrop Sizing	$1,876.68	$2,100.00	$0.00
Real-Time Management of Irrigation Systems in the Sevier River Basin	$137,027.86	$141,138.70	$0.00
Technical Solutions to Stormwater Issues in Cache Valley Irrigation Canals	$11,970.22	$0.00	$0.00
Treated Wastewater Use in Agricultural Irrigation	$19,642.54	$42,219.13	$0.00
UAV Remote Sensing Service Center	$183,151.96	$150,000.00	$42,000.00
Ultra Light, High Gain UAV Fish Tracking Antennas	$9,062.54	$0.00	$0.00
Water Conservation and Drought Planning and Reservoir Carryover Storage	$29,367.63	$30,248.66	$0.00
Water Resources Sensitivity to Changes in Vegetation	$12,733.70	$13,115.71	$7,200.00
Designated Projects		$849,387.00	$0.00
Undesignated Projects		$130,000.00	$201,000.00
Total	**$1,238,446.21**	**$1,980,159.98**	**$654,869.59**

A Decision-Support System for Optimal Agricultural Water Management Under Water Deficit Conditions in Utah

Principal Investigator:
Jagath J. Kaluarachchi

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  A methodology is needed to better allocate agricultural water especially in conditions of water deficits such that other water use sectors are not affected. This project aims to develop this methodology and develop an appropriate DSS.

- **Benefits to State:**

  The work will provide a mechanisms to help extension agents and farmers develop a water allocation and water use strategy especially in drought years.

- **Geographic Areas:**

  Study Area: Bear River Valley, Utah.

  Areas Benefited: Water resources planning and management.

- **Accomplishments**:

  Findings: A methodology was developed and demonstrated to bear River Valley region of Utah.

  Results:

  Aljuaidi A. (2009). *Water allocation for agricultural use considering treated wastewater, public health risk, and economic issues*. Phd Dissertation, Utah State University, Logan, UT.

Work Plan FY 09/FY10

Work completed in early 2009.

Informational Resources

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

Advanced Statistical Learning Techniques for Predicting Water Levels in the Great Salt Lake

Principal Investigator:
Gilberto E. Urroz

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

Project Description

- **Need and Purpose**:

  Accurate prediction of Great Salt Lake (GSL) levels would help GSL shareholders, such as the Utah Division of Water Resources, municipal and County governments in the counties of the Great Salt Lake Basin (Box Elder, Weber, Davies, Salt Lake, and Toele), as well as industries in the shoreline, in terms of planning, development, and emergency response.

- **Benefits to the State:**

  Accurate prediction of Great Salt Lake (GSL) levels would help GSL shareholders, such as the Utah Division of Water Resources, municipal and County governments in the counties of the Great Salt Lake Basin (Box Elder, Weber, Davies, Salt Lake, and Toele), as well as industries in the shoreline, in terms of planning, development, and emergency response.

- **Geographic Areas**:

  Study Area: Great Salt Lake Basin

  Areas Benefited: Great Salt Lake Basin, Box Elder, Weber, Davies, Salt Lake, and Toele Counties

- **Accomplishments:**

  Findings:

  - Statistical techniques were used to predict GSL levels by "training" computer programs using existing data provided by the Utah Division of Water Resources. Techniques used: Artificial Neural Networks (ANN), Support Vector Machines (SVM), and Relevance Vector Machines (RVM).

  - All statistical and simulation techniques produce good "training" GSL level trends, as illustrated in Figure 1.

  - All statistical and simulation techniques produced accurate predictions for the testing period 2000-2007, both in the testing phase (with feedback), and the blind iterative testing (new predictions). See Figures 2 and 3.

  Stand-alone application: A primitive tool for prediction is available at:

  http://www.neng.usu.edu/cee/faculty/gurro/GSL_w/stand%20alone%20application.htm

  Results:

  - Relevance Vector Machines (RVM) produced the best predictions from the point of view of statistical indicators of good data matching.

- Relevance Vector Machines (RVM) provide a wider range of parameter adjustments to improve predictions of GSL levels.

Work Plan FY 09/FY10

Continue refining statistical learning techniques for GSL level prediction focusing on Relevance Vector Machines (RVM) looking at the following improvements:

- Use of multi-dimensional approach to determine the parameters needed for accurate prediction of GSL levels.
- Maintaining and updating web site for practical applications

Informational Resources

Contact: Gilberto E. Urroz, Ph.D., P.E., Phone (435) 797 3379, E-mail: gilberto.urroz@usu.edu.

Website: http://www.neng.usu.edu/cee/faculty/gurro/GSL_w/index.htm

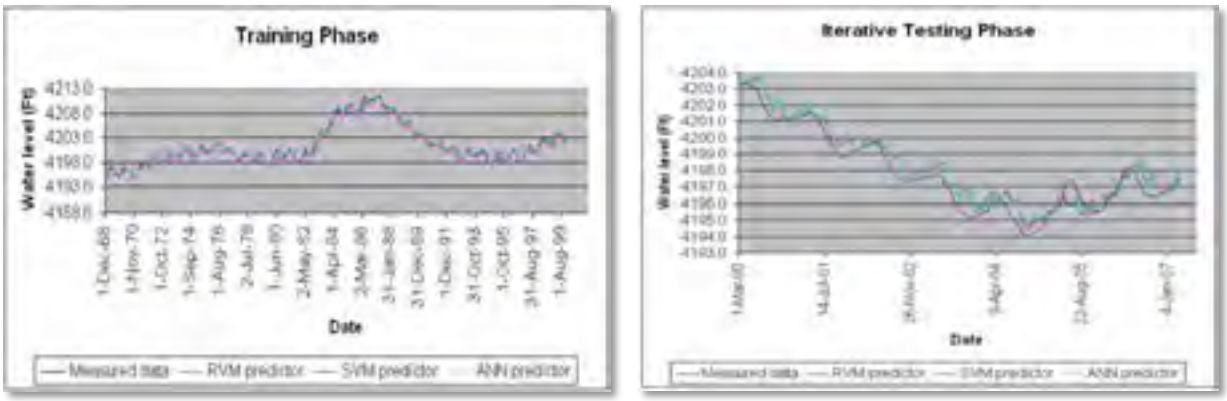


Figure 1. Statistical learning machines are trained using GSL elevation data from 1968 to 1999. The machines are then used to predict GSL levels for the period 2000 to 2007. A computer program is available online for GSL shareholders.

Agricultural Water Resources Management Training

Principal Investigators:
Gary Merkley
Mohamed Shaban

Partners/Collaborators:
None

Project Description

- **Need and Purpose**:

  As in many places in the USA and around the world, Utah has experienced water shortages that, in the long term, tend to become increasingly problematic. Water quality problems are also becoming more prominent with time. Much of the emphasis in dealing with water scarcity and quality problems has been directed to infrastructure and technological improvements. Very 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 irrigators, and the difficult operational decisions they face with respect to water management. In fact, many of the problems with water delivery (canal and or pipeline) design and operation for agricultural irrigation are due to a lack of understanding of agricultural irrigation by policy makers, administrators, and operational personnel.

  Through intelligent and heuristic simulation tools in the form of a game, the effect of decisions for a variety of situations can simulate field experience alone. 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 statewide, so all counties in the state would potentially benefit.

- **Accomplishments:**

  Findings: The study has not yet been completed and there are no findings to date.

  Results: The study has not yet been completed and there are no results to date.

Work Plan FY 09/FY10

This project will be completed in December 2011. The modeling work continues as the initial design is modified and developed in greater and greater detail. After and operational version of the model is completed, it will be tested in a workshop with various potential members of the target audiences, and from this feedback the model will be further modified and expanded.

Informational Resources

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

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

Analysis of Water Supply and Demand of the Salt Lake Valley Considering Land Use Changes and Population Dynamics

Principal Investigator:
Jagath J. Kaluarachchi

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  With urbanization, land use pattern changes in Utah and elsewhere. At the same time, climate change driven hydrology affect streamflow and groundwater resources. Therefore, it is important understand the dynamics between land use changes, climate change and water resources in rapidly changing and water deficit region such as Utah.

- **Benefits to State:**

  This work will develop the methodology to assess the changes to hydrology, impacts on water resources and potential economic damage due to climate change. This work can be readily applied to major basins of Utah that are vulnerable to climate change. The results of such an analysis can be readily incorporated in to future water resources planning to avoid severe economic and social impacts in the middle of the century.

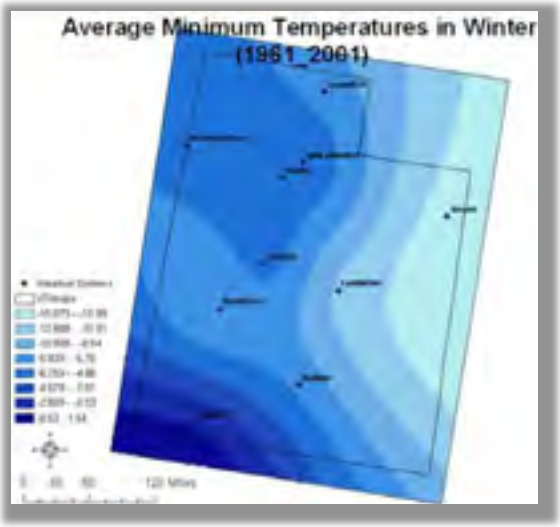
- **Geographic Areas**:

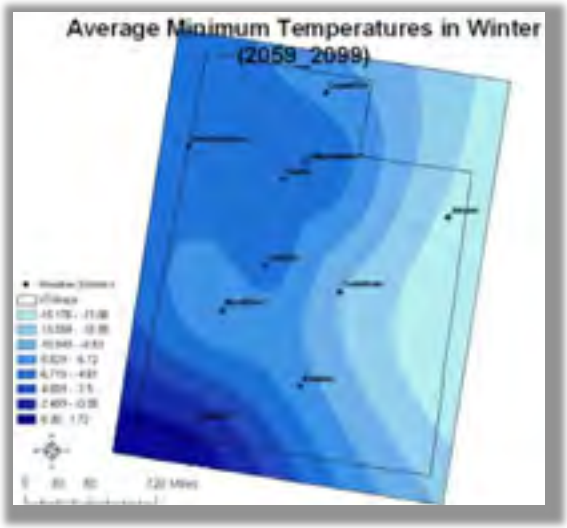
  Study Areas: Salt Lake Valley, Utah but applicable to any similar region in Utah or elsewhere.

  Areas Benefited: Water resources planning and management, watershed management.

- **Accomplishments**:

  Findings:





Results: A methodology to predict temperature of Salt Valley in the middle of the century under climate change was developed and applied.

Work Plan FY 09/FY10

Work will not continue further.

Informational Resources

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

Conversion of Agricultural Water to Municipal and Industrial Use

Principal Investigators:
Michael C. Johnson
Dallin Stephens

Partners/Collaborators:
- ***State**: Todd Adams, Eric Klotz, Water Resources*

Project Description

- **Need and Purpose:**

  The Division of Water Resources has three main strategies to manage the state's water. These areas are, first, reducing per capita water usage through water conservation, second, tracking the transfers of agricultural water to municipal and industrial (M&I) water uses, and third, developing large scale water projects, such as the Lake Powell Pipeline Project. This project addresses the second strategy of the Division of Water Resources tracking of information about the transfers of water rights from agricultural to M&I use by creating a flowchart proper accounting of water rights as they are transferred.

- **Benefits to State:**

  This project will benefit the state by providing a process to accurately track the transfer of water rights as agricultural land is developed for M&I uses. With a more complete understanding of where water rights now reside, better decisions can be made for water management.

- **Geographic Areas**:

  Study Areas: The study areas include between fifteen to twenty cities across the state that have developed agricultural land into M&I uses over the past ten years, including Logan and its suburbs, Layton, St. George and it suburbs, Tooele and its surrounding area. Other areas are the developing cities in the southwestern portion of the Salt Lake Valley, as well as the southern area of the Utah Valley. Other areas will also be investigated as needed as the project progresses.

  Areas Benefited: This project will benefit all cities in the state which are experiencing growth.

- **Accomplishments**:

  Findings: A search through the records contained in the Division of Water Rights' database has revealed the history of the transfer of water rights in the Logan area. These records show that there are a variety of cases in which the water rights ownership was not changed when the land it was used on was sold. There are also cases where the right did remain with the land when it was sold. An organization of this information into a concise and clear report is pending.

  Results: The key results of this project is to create a flowchart to follow in the transfer of water rights and testing it on the organization and analysis of the findings from the communities studied.

Work Plan FY 09/FY10

- Collect historical data on the transfer of water rights in specific, case study locations listed in the "Study Areas" section of this report.

- Organize this data in such a way that a general understanding of the current trends in water transfers can be summarized.
- Based on this understanding, prepare and modify the flowchart for best process under which to transfer water rights. This flowchart will then be used by the Division of Water Resources.

Informational Resources:

Contact: Dr. Michael C. Johnson, (435) 797-3176, E-mail: michael.johnson@usu.edu.

Dallin Stephens, (435) 797-3152, E-mail dallin.stephens@aggiemail.usu.edu.

Cooperation of Multiple UAVs for High-Resolution Remote Sensing in Water Management

Principal Investigator:
Wei Ren

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  An autonomous unmanned aerial vehicle (UAV) equipped with onboard sensors is expected to achieve high-resolution remote sensing for water management. However, greater efficiency and operational capability will be realized from a team of UAVs operating in a cooperative fashion. A team of low-cost UAVs flying in formation promises less expensive. More capable systems can accomplish objectives impossible for a single, expensive commercial aircraft. For example, multiple low-cost UAVs can be used as a reconfigurable sensor web for remote sensing. The advantages include increased feasibility, accuracy, robustness, flexibility, cost and energy efficiency, and probability of success.

- **Benefits to State:**

  It is expected that a team of UAVs can fly in a formation to achieve water management in a cooperative manner. The approaches developed in the project can also be applied to other application scenarios including cooperative air-quality mapping, cooperative environment monitoring, precision agriculture, and air traffic management.

  - **Geographic Areas**:

    Study Area: Sevier River Basin.

    Areas Benefited: All areas of the state.

- **Accomplishments**:

  Findings: A scalable software package for cooperation of a team of UAVs has been developed. Control algorithms for multi-UAV cooperation have also been developed.

  Results: A multi-UAV cooperative control algorithms and a software package for a multi-UAV platform to implement the algorithms was developed. A user-friendly graphical control console is developped to implement the algorithms. The software package is scalable with the capability to introduce more UAVs. The software package enables different algorithms and strategies for multiple UAVs to be tested in this platform. The software and algorithms were experimentally tested on a team of 2 UAVs flying in a formation.

Work Plan FY 09/FY10

Continue to explore distributed coordinated strategies for multi-UAVs.

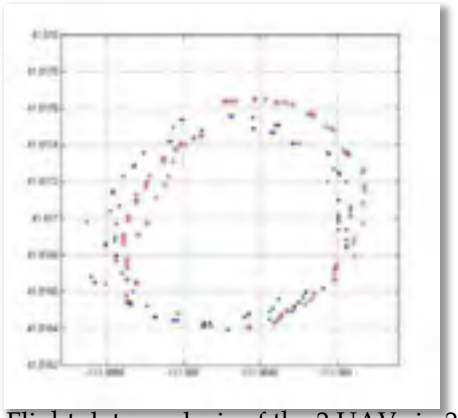
Informational Resources

Contact: Dr. Wei Ren, (435) 797-2831, E-mail: wei.ren@usu.edu.

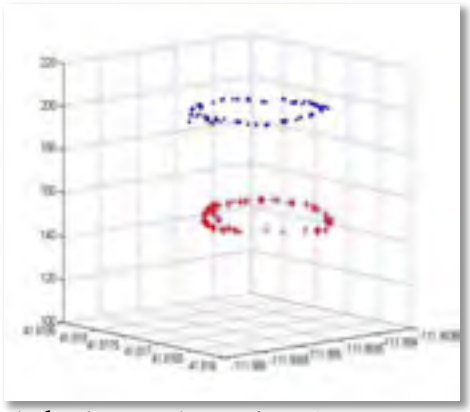
Website: http://www.neng.usu.edu/ece/faculty/wren/

Software architecture developed in the project

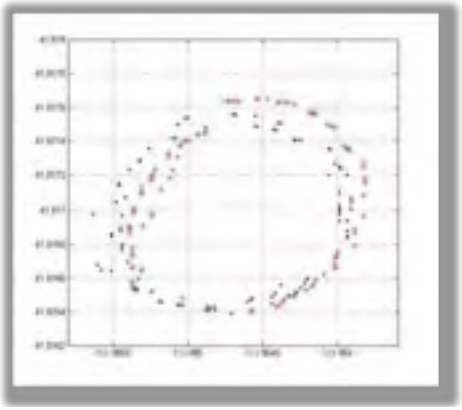
Experimental setup at Cache Junction farm



Flight data analysis of the 2 UAVs in 2D



Flight data analysis of 2 UAVs in 3D



Dam Failure Life-loss Estimation

Principal Investigator:
David S. Bowles

Partners/Collaborators:
- ***Federal:*** *USACE*

Project Description

- **Need and Purpose:**

  The objective of this project is to develop a practical approach to life-loss estimation and evacuation planning for natural and dam- and levee-failure floods, which overcome the limitations of the empirical approaches, while depending on readily available data sources and requiring only a reasonable level of effort to implement.

- **Benefits to State:**

  The approach to dam failure-life loss estimation, which is being improved under this project, is applicable to dams and levees in Utah. The use of dam safety risk assessment for dams in Utah can be expected to increase as a direct result of National Dam Safety Program initiatives in both risk ranking and potential failure modes analysis. Our research results are available for use by the Utah State Engineer's Office and practicing engineers in Utah and are being applied by federal dam safety agencies such as the US Army Corps of Engineers, the US Bureau of Reclamation, the Department of Homeland Security and the Federal Energy Regulatory Commission.

- **Geographic Area**:

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

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

- **Accomplishments**:

  Findings: LIFESim, a spatially-distributed dynamic simulation approach for estimating potential life loss for dam safety risk assessment has been developed. The LIFESim approach emphasized the important processes that have been found to affect the magnitude of life loss resulting from major floods, while depending on readily-available data sources and requiring only a reasonable level of effort for implementation. LIFESim comprises the following internal modules: 1) Loss of Shelter, including prediction of building performance; 2) Warning and Evacuation, including a dynamic transportation model component; and 3) Loss of Life, in which empirical fatality-rate probability distributions, developed by McClelland and Bowles (1999) in the first phase of this project, are applied to the number of people estimated by LIFESim to remain in one of three homogeneous flood-lethality zones at the time of arrival of the flood wave. Estimated flood dynamics are obtained from a dam break-flood inundation model such as DAMBRK or HEC RAS and input to the LIFESim model in GIS form.

  Results: The Deterministic or Uncertainty Modes of LIFESim have been demonstrated for two USACE dams under a wide range of warning times and conditions and for small and large downstream communities. Recently LIFESim was applied for the Interagency Performance Evaluation Team (IPET) to estimate pre- and post-Katrina potential life loss for area protected by the New Orleans Hurricane Protection System for Headquarters, US Army Corps of Engineers, Washington, D.C.

A simplified version of LIFESim has been developed by the US Army Corps of Engineers Hydrologic Engineering Center based on our a design. The approach has been added to HEC-FIA and is being used in practice by the Corps of Engineers.

The US Army Corps of Engineers Hydrologic Engineering Center is also developing a user-friendly version of the full LIFESim software and applying it to a major Corps of Engineers dam.

Work Plan FY 09/FY10

The FY/10 focus will be on developing guidance for the assignments of values to parameters in LIFESim and other guidelines for setting up LIFESim applications. In addition, cooperation with researchers in the US Army Corps of Engineers, The Netherlands, Canada and the UK will be pursued.

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.

Dam Safety Risk Analysis Computations

Principal Investigator:
David S. Bowles

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 these limitations, a generalized dam safety risk analysis model that will be widely available to perform dam safety risk analysis computations in a flexible and user-friendly way.

- **Benefits to State:**

  The approaches to dam safety risk analysis being developed under this project are applicable to dams in Utah. It is expected 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. Our research results are available for use by the Utah State Engineer's Office and practicing engineers in Utah and are being applied by federal dam safety agencies such as the US Army Corps of Engineers, the US Bureau of Reclamation, the Department of Homeland Security and the Federal Emergency Regulatory Commission. Benefits are expected to include improved understanding, prioritization, and justification of dam safety risk reduction measures.

- **Geographic Areas:**

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

  Areas Benefited: Any county with a dam or potentially impacted by dam failure is a potential 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 continued development takes place. DAMRAE is designed to overcome the limitations of existing business 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 USACE tolerable risk guidelines. A flexible capability exists for obtaining tabular and graphical presentations of estimated risks at different levels of detail.

  Results: A generic project framework provides functionality to analyze structural and non-structural risk reduction measures, considered as alternatives or staged measures, including obtaining 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 representing stage-discharge relationships.

The effects of changes in the event tree structure or changes to probability, state function relationships or consequences inputs on risk estimates and evaluations can be explored using a sensitivity analysis functionality incorporated in DAMRAE. In addition to applying DAMRAE to individual dams, it can serve as a core engine in a portfolio risk assessment and management system.

Work Plan FY09/FY10:

DAMRAE is undergoing continuous improvement of user interface features and computational and post-processing functionalities. FY09/FY10 improvements will focus on developing a database version of DAMRAE to facilitate an expansion of the functionality of DAMRAE in the following ways:

- Remove the current constraint on the dimension of an event tree (about 150,000 branches).
- Speed up computations.
- Check-in and check-out capability for DAMRAE input files and results.
- Link to a portfolio risk management system.
- Applications to long dams or levees.
- Uncertainty analysis.
- 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.

Dam Safety Risk Management

Principal Investigator:
David S. Bowles

Partners/Collaborators:
- ***Federal:*** *USACE, USBR, FERC*

Project Description

- **Need and Purpose:**

  The overall objective of this ongoing research is to improve the availability and capability of practical risk-informed approaches to dam safety risk management.

- **Benefits to State**

  The approaches to dam safety risk management being developed under this project are applicable to dams in Utah. It is expected 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 are available for use by the Utah State Engineer's Office and practicing engineers in Utah and are being applied by federal dam safety agencies such as the US Army Corps of Engineers, the US Bureau of Reclamation, the Department of Homeland Security and the Federal Emergency Regulatory Commission. Benefits include improved understanding, prioritization, and justification of dam safety risk reduction measures.

- **Geographic Areas:**

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

  Areas Benefited: Any county that is potentially impacted by dam or levee failure is a potential beneficiary of this project.

- **Accomplishments**:

  Findings: For more than two decades, Utah State University researchers have developed procedures that explicitly consider the risks associated with the performance of dams. They have also applied these procedures to about 750 dams in Utah, in other parts of the United States (including dams owned by the U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers and some regulated by the Federal Energy Regulatory Commission) and in Australia, Spain and England.

  Results: Information obtained from these applications has been used to support many decisions to improve the safety of existing dams. Applications have provided an opportunity to field-test procedures resulting from research and have lead to the identification of additional research needs. Training programs have been given on six continents, to the major dam safety professional organizations, and to major federal agencies with dam safety responsibilities. International guidelines have been contributed to and national, regulatory and federal agency guidelines have been reviewed.

Work Plan FY 09/FY10:

1. Portfolio Risk Assessment: Continued advances in portfolio risk assessment, including development of procedures for large portfolios in which screening is needed and for owners that have limited resources, such as those regulated by the states.

2. Tolerable Risk Evaluation: Further development of practical approaches to using information from tolerable risk evaluation for making dam safety decisions on individual dams and portfolio of dams. The investigation of the ALARP (as low as reasonably practicable) and disproportionality principles, setting guidelines for progressive risk reduction, establishing a basis for short-term risk reduction, and dam safety regulatory impact analysis.

3. Uncertainty Analysis: Dams exist in an environment of risk and uncertainty. This work is addressing the following areas:

    a. Characterization of uncertainties associated with the extreme floods and earthquakes.
    b. Practical approaches for uncertainties in dam safety risk analysis.
    c. Evaluation of the significance of uncertainties in risk analysis and risk evaluation results, and assessing their implications for dam safety decision-making.
    d. Guidance for decision makers with the interpretation of the uncertainties in risk assessment outcomes.

4. Guidance on Dam Safety Risk Management: Technical guidance is available through the Institute for Dam Safety Risk Management at USU.

5. Seminars and Workshops: Further development and presentation of briefings, seminars, and workshops to professional groups in the United States and overseas.

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.

Decision Support System (DSS) for Virgin River Water Management

Principal Investigator:
Thomas B. Hardy

Partners/Collaborators:
- ***State**: Ron Thompson, Washington County Water Conservancy District; Steve Meismer, Virgin River Program; Rick Freidell, Utah Division of Wildlife Resources*

Project Description

- **Need and Purpose:**

  This project supports the maintenance of a Decision Support System (DSS) for a real time water temperature forecasting model for the main stem Virgin River. The real time forecasting tool receives temperature and flow data every hour from an array of sampling stations within the Virgin River and then forecasts the expected hourly flow and temperature data over the next seven days. These results are then used by the Virgin River Program to alter the water allocation practices within the main stem Virgin River in order to ameliorate potential impact of high water temperatures on the endangered woundfin minnow and other aquatic resources.

  The maintenance of this system at the UWRL allows resource managers within the Virgin River Basin to effectively manage flows for the protection and survival of the endangered and threatened aquatic resources within the Virgin River. The forecasting ability of the system allows for tactical water allocations that can account for expected inflows, near term meteorological conditions, and existing reservoir storage and agricultural water deliveries downstream.

- **Benefits to State:**

  This work directly supports the recovery of endangered and threatened aquatic resources within the Virgin River.

- **Geographic Area:**

  Virgin River Basin, Washington County.

  Study Areas: Hurricane, LeVerkin, Washington, St. George, Bloomington, Washington County.

  Areas Benefited: Hurricane, LeVerkin, Washington, St. George, Bloomington, Washington County.

- **Accomplishments**:

  Findings: The real time monitoring and forecasting system for water temperatures in the main stem Virgin River provides reliable predictions of water temperatures over the seven day forecast period for critical reaches of the main stem Virgin River inhabited by the endangered and threatened aquatic resources that face thermally limiting conditions associated with low flows and high ambient air temperatures. Use of the DSS to schedule alternative release of water for downstream uses has been demonstrated to ameliorate deleterious thermal conditions.

  Results: The implementation of this module of the UWRL DSS was shown to be an effective tool to allow resource managers to optimize water delivery schedules to meet hydropower and agricultural demands while minimizing deleterious thermal conditions for the endangered and threatened aquatic resources within the main stem Virgin River.

Work Plan FY 09/FY10

This project was terminated by the Virgin River Program due to insufficient maintenance of the required real time water temperature-monitoring network within the basin.

Informational Resources

Contact: Dr. Thomas B. Hardy, (512) 245-6729, E-mail: Thom.Hardy@TXState.edu.

Demonstration Application of UAV Architecture for Habitat Mapping of River Corridors -- Phase I

Principal Investigator:
Thomas B. Hardy

Partners/Collaborators:
***State**: Ron Thompson, Washington County Water Conservancy District; Steve Meismer, Virgin River Program; Rick Freidell, Utah Division of Wildlife Resources*

Project Description

- **Need and Purpose:**

  Long term habitat monitoring of riparian and stream habitat conditions is required as part of the Virgin River Integrated Management Program. Also, the Utah Division of Wildlife Resources currently associates its fisheries full-pass monitoring activities to specific spatial locations of instream mesohabitats that are currently tied to dated aerial photography. The UAV based acquisition of high quality imagery that is more timely and cost effective than existing fixed wing aerial photography and has the potential to address both the long term monitoring needs of the Virgin Program as well as supporting their fish sampling efforts.

  This project pilot level project is collecting and analyzing UAV based imagery from the Santa Clara River for the purpose of monitoring riparian system and stream habitat conditions. The UAV will also be flown on the main stem Virgin River to acquire instream mesohabitat imagery for use by the Utah Division of Wildlife Resources. The imagery will be compared to three test sections where the UWRL has conducted change detection based on standard aerial photography techniques. This imagery on the Virgin River will be compared to two previously analyzed sites on the main stem and also will provide near real time data for use by the Utah Division of Wildlife Resources as part of their standardized monitoring activities.

- **Benefits to State:** Demonstration of this technology to meet near real-time data acquisition for mapping riparian and fisheries habitat at a fraction of the cost of existing remote sensing platforms will allow resource agencies to expand their access to high quality digital information necessary to support aquatic and terrestrial monitoring programs.

- **Geographic Area:** Virgin River Basin, Washington County.

  Study Areas: Hurricane, LeVerkin, Washington, St. George, Bloomington, Washington County.

  Areas Benefited: Hurricane, LeVerkin, Washington, St. George, Bloomington, Washington County.

- **Accomplishments**:

  Findings: The UAC system has been successfully deployed to collect and provide near real time high quality imagery of the riparian and aquatic habitats within the Virgin River over extended spatial scales at a fraction of the cost of conventional remote sensing platforms. Imagery obtained exceeded the spatial resolution needs identified by the resource agencies and was delivered the day after image acquisition rather than a several month delay associated with conventional aerial photography. Auto-mosaic of geo-referenced imagery was provided in a format downloadable to tablet PCs to directly support field surveys.

Results: The results of the pilot project have been highly successful and the application of the technology is being expanded to a wider range of river and riparian corridor systems not only in Utah by throughout the United States.

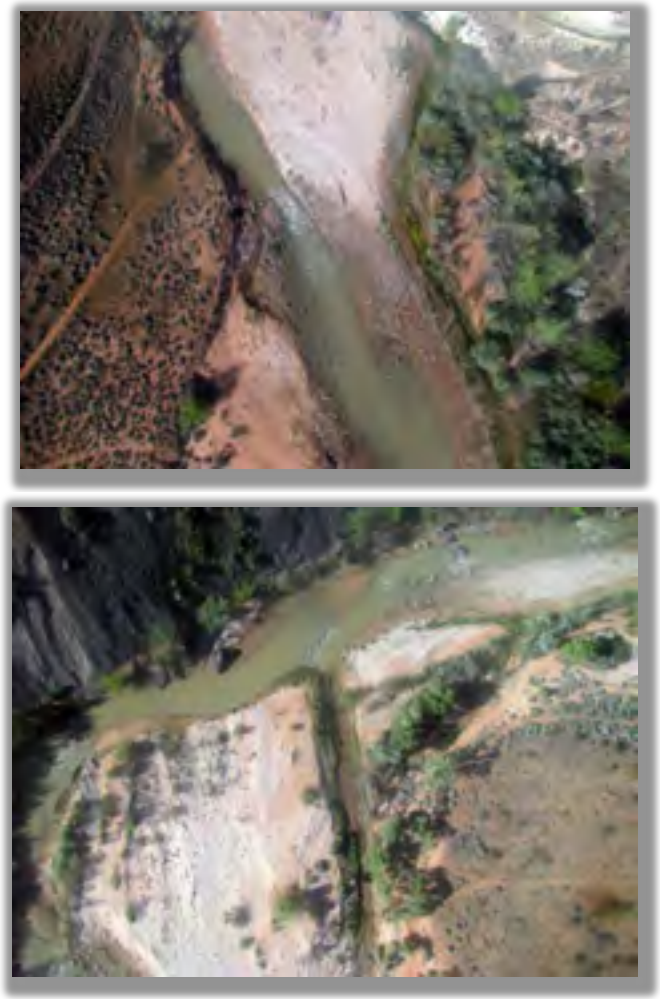
Work Plan FY 09/FY10

At present, the UAV pilot level program is being expanded to river systems in Nebraska and Texas including acquisition of imagery from several more river systems throughout Utah. A variety of work products from raw imagery to classified imagery for aquatic habitats and riparian habitats are being evaluated for a large range of system sizes and characteristics.

Informational Resources

Contact: Dr. Thomas B. Hardy, (512) 245-6729, E-mail: Thom.Hardy@TXState.edu.

Website: http://aggieair.usu.edu



Imagery Samples

Demonstration Application of UAV Architecture for Habitat Mapping of River Corridors – Phase II

Principal Investigator:
Thomas B. Hardy

Partners/Collaborators:
***State**: Ron Thompson, Washington County Water Conservancy District; Steve Meismer, Virgin River Program; Rick Freidell, Utah Division of Wildlife Resources*

Project Description

- **Need and Purpose:**

  This project will entail a pilot level project to collect and analyze UAV based imagery from the Virgin River for the purpose of monitoring riparian system and stream habitat conditions. The Utah Division of Wildlife Resources will also evaluate the imagery in terms of supporting near real time imagery needs for instream mesohabitat mapping.

  Long term habitat monitoring of riparian and stream habitat conditions is required as part of the Virgin River Integrated Management Program. Also, the Utah Division of Wildlife Resources currently associates its fisheries full-pass fisheries monitoring activities to specific spatial locations of instream mesohabitats that are currently tied to dated aerial photography. The UAV based acquisition of high quality imagery that is more timely and cost effective than existing fixed wing aerial photography has the potential to address both the long term monitoring needs of the Virgin Program as well as supporting their fish sampling efforts.

- **Benefits to State:**

  Demonstration of this technology to meet near real-time data acquisition for mapping riparian and fisheries habitat at a fraction of the cost of existing remote sensing platforms will allow resource agencies to expand their access to high quality digital information necessary to support aquatic and terrestrial monitoring programs.

- **Geographic Area:** Virgin River Basin, Washington County.

  Study Areas: Hurricane, LeVerkin, Washington, St. George, Bloomington, Washington County.

  Areas Benefited: Hurricane, LeVerkin, Washington, St. George, Bloomington, Washington County.

- **Accomplishments**:

  Findings: The UAC system has been successfully deployed to collect and provide near real time high quality imagery of the riparian and aquatic habitats within the Virgin River over extended spatial scales at a fraction of the cost of conventional remote sensing platforms. Imagery obtained exceeded the spatial resolution needs identified by the resource agencies and was delivered the day after image acquisition rather than a several month delay associated with conventional aerial photography. Auto-mosaic of geo-referenced imagery was provided in a format downloadable to tablet PCs to directly support field surveys.

  Results: The results of the pilot project have been highly successful and the application of the technology is being expanded to a wider range of river and riparian corridor systems not only in Utah by throughout the United States.

Work Plan FY 09/FY10

At present, the UAV pilot level program is being expanded to river systems in Nebraska and Texas including acquisition of imagery from several more river systems throughout Utah. A variety of work products from raw imagery to classified imagery for aquatic habitats and riparian habitats are being evaluated for a large range of system sizes and characteristics.

Informational Resources

Contact: Dr. Thomas B. Hardy, (512) 245-6729, E-mail: Thom.Hardy@TXState.edu.

Website: http://aggieair.usu.edu

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

Principal Investigator:
Steven L. Barfuss

Partners/Collaborators:
- ***Local:*** *Terry Henderson, FloSonics*
- ***State:*** *Utah Department of Natural Resources, Division of Water Rights*

Project Description

- **Need and Purpose:**

This project is developing procedures to measure flow when clamp-on ultrasonic flow meters are used 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 will also be of great benefit to them. A very small percentage of all field piping have adequate lengths of straight pipe between the metering location and disturbances caused by valves, pipe elbows, or pumps for accurate flow measurement. 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 indicated flow reading.

An example of poor approach conditions 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, as well as being extremely close to the pump intake.

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

- **Benefits to State:**

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

- **Geographic Areas:**

  Study Area: State of Utah

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

- **Accomplishments**:

  Findings: New project, with no reportable finding at this time.

  Results: New project, with no reportable finding at this time.

Work Plan FY 09/FY10

- Develop a working database of common flow meter installation requirements as published by flow meter manufacturers.
- With the help of interested entities, develop a list of common piping configurations which produce non-ideal flow conditions of interest to water users that make field flow measurements.
- Conduct field velocity profile measurements downstream of a selected number of vertical turbine pumps, elbows and valves to better understand the magnitude and the degree of disturbances associated with these setups.
- Conduct similar measurements in the laboratory in order to obtain an appropriate range of non-ideal flow conditions and to validate velocity profile measurements taken in the field.
- Develop CFD models using Fluent to simulate typical non-ideal velocity profiles and flow scenarios to better understand the nature of the flow disturbance.
- Compare physical data to CFD results for the same piping configurations.
- Using CFD and the known range of non-ideal flow conditions, generally apply other simulated non-ideal piping scenarios to the application of ultrasonic metering use.
- Develop procedures for installation or flow measurement correction.

Informational Resources

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

Establishing Real-Time and Seasonal Crop Evapotranspiration of Large Irrigation Systems at Different Spatial Scales

Principal Investigators:
Christopher M.U. Neale

Partners/Collaborators:
- ***Local**: Bear River Canal Company*

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 for water rights adjudication and control. Improved and timely estimates of irrigation water demand can help understand 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 estimates is needed.

- **Benefits to State:**

  Improved water management can lead to water savings and potentially 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:**

  Study Areas: Bear River Canal Company in Box Elder County and irrigated areas of Sevier County.

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

- **Accomplishments**:

  Findings: The SETMI model has been updated to estimate spatial ET from satellite and airborne remote sensing using both the energy balance approach (Two-source model and SEBAL) and the reflectance-based crop coefficient approach. The model is written in Visual Basic and operates within an ArcGIS environment for easy manipulation and display of spatial data.

  Results: Field level irrigation application evaluations were conducted on two different types of soils within a section of the Bear River Canal Company irrigated area during the summer of 2008. Results indicate that approximately 27% water could be saved if the irrigation application duration were decreased by one hour.

Work Plan FY 09/FY10

Based on the field evaluation results and findings, additional soils and fields in other parts of the Bear River Canal Company irrigated area will be selected and evaluated during the summer of

2009, in order to apply the water demand model to the entire irrigation system. Satellite imagery for 2008 and 2009 season will be obtained and used to run the SEBAL energy balance model for obtaining the spatial ET estimates throughout the system. The SETMI TSM model will also be applied to the entire area for comparison purposes.

Informational Resources

Lecina, S., C.M.U. Neale, G.P. Merkley, and C.A.C. dos Santos (2009). Increasing Field Work Productivity in Irrigation Evaluation Processes through the Use of Combined Irrigation Models. 2009. *ASCE World Environmental and Water Resources Congress 2009*: *Great Rivers*. Conf. Proc. 342, 428 (2009), DOI:10.1061/41036(342)428.

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

Evaluation of the Effects of Increased Stream Discharge and Non-Native Fish Removal on the Population Performance of the Colorado River Cutthroat Trout in the West and East Fork of Boulder Creek, UT

Principal Investigators:
Casey Williams
Thomas B. Hardy

Partners/Collaborators:
- ***State****: Mike Ottenbacher – Utah Division of Wildlife Resources*
- ***Federal****: Mike Golden – U.S. Forest Service*
- ***Business/Private:*** *Mike Avant – Garkane Energy*

Project Description

- **Need and Purpose:**

  This project is evaluating realistic quantifiable objectives for instream flow restoration associated with hydropower operations. Field monitoring of population response of the Colorado Cutthroat Trout within the main stem Boulder Creek as well as the East and West Forks of Boulder Creek is being conducted in order to assess the response of both non-native trout removal and restoration of bypass flows below the East Fork Diversion structure.

  Quantitative assessments of proposed mitigation actions associated with non-native fish removal and bypass flow releases will help resource managers and hydropower operators set realistic quantifiable objectives during FERC relicensing proceedings. Given the economic trade off between power production and bypass flows for fish populations, quantifiable objectives are needed for FERC relicensing proceedings.

- **Benefits to State:**

  This research will directly benefit the State by informing resource managers on the quantitative relationships between incremental flow releases in bypass reaches below hydropower facilities and expected population responses in salmonid populations. This will provide a more realistic assessment of expected environmental benefits in the cost-benefit analysis used by FERC when setting hydropower operating licenses.

- **Geographic Areas:** Boulder Creek Drainage, Garkane, County.

  Study Area: Garkane, County.

  Areas Benefited: Garkane, County and state-wide where FERC hydropower licensing exist.

- **Accomplishments**:

  Findings: The main stem of Boulder Creek and the affected areas of the East and West Forks of Boulder Creek have been surveyed for Colorado Cutthroat Trout population distribution and age structure. These data have been used to establish control sites and sampling sites throughout the system for use in long-term monitoring the associated populations. Fish barriers have been established and the initial eradication of non-native trout has been completed.

  Results: Annual population density, age structure, and distribution of the aquatic resources at all sampling locations has been completed and submitted to the appropriate state and federal resources agencies.

Work Plan FY 09/FY10

Additional monitoring of flow, temperature, macroinvertebrates, and fisheries resources will be undertaken throughout the spring, summer and fall of 2010. In addition, the UWRL personnel will participate in the fall 2010 non-native fish removal activities.

Informational Resources

Hardy, T.B., C.S. Williams, C.W. Thomas (2010). Trout population monitoring in Boulder Creek: 2009. Utah Water Research Laboratory, Utah State University, Logan, UT.

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

Improved Dam-Breach Flood Plain Inundation Mapping

Principal Investigators:
Sanjay S. Chauhan
David S. Bowles
Brian K. Stevens

Partners/Collaborators:
***State**: Utah Division of Water Rights*

Project Description

- **Need and Purpose:**

  Inundation maps are a useful decision-making tool for emergency management, flood warning, and evacuation. Unsteady flow models such as DAMBRK, FLDWAV, and HEC-RAS are available for dam breach analysis. Advanced GIS tools are also available for processing the terrain data and displaying the results of breach analysis to develop inundation maps. Despite these technological advancements, their application seems to lag in practice due to laborious and time consuming steps involved in their use. In this project we have developed an improved GIS-based inundation mapping system (UTIMS-Utah Inundation Mapping System) to automate the routine tasks for preparing HEC-RAS inputs and to efficiently transfer and display the dam-breach modeling results in GIS to develop inundation maps.

- **Benefits to the State:**

  The State of Utah will benefit from our work by having a tool to develop consistent and efficient GIS-based inundation maps for its dams. It will be of help to the State's overall emergency management preparedness.

- **Geographic Areas**:

  Study Areas: The Millsite Dam and Reservoir on Ferron Creek, near Price, Utah were used as case study areas.

  Areas Benefited: Various counties of the State would potentially benefit in their dam breach related emergency preparedness.

- **Accomplishments**:

  1. UTIMS Users manual.

  2. Graphic user interface of the inundation mapping tool (UTIMS-Utah Inundation Mapping System) and its iterative process diagram are displayed in Figures 1 and 2.

Work Plan FY09/FY10

A web page with a link to download UTIMS and its user manual is under development.

Informational Resources

Contact: Dr. Sanjay Chauhan, (435) 797-3202, E-mail: sanjay.chauhan@usu.edu.

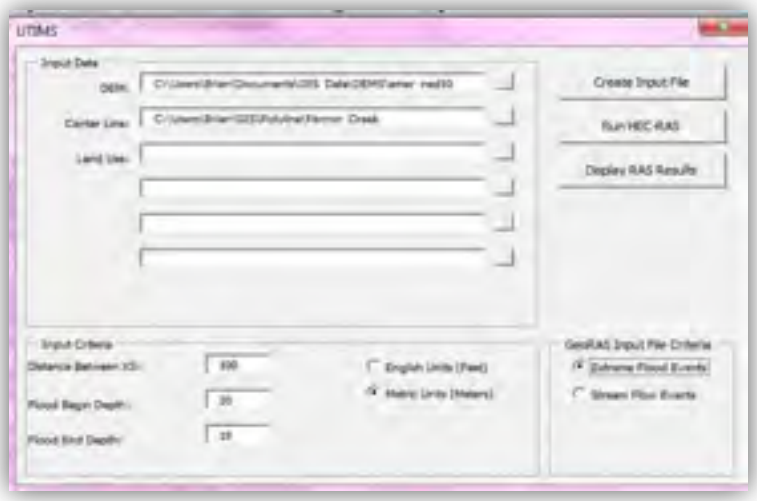


Figure 1

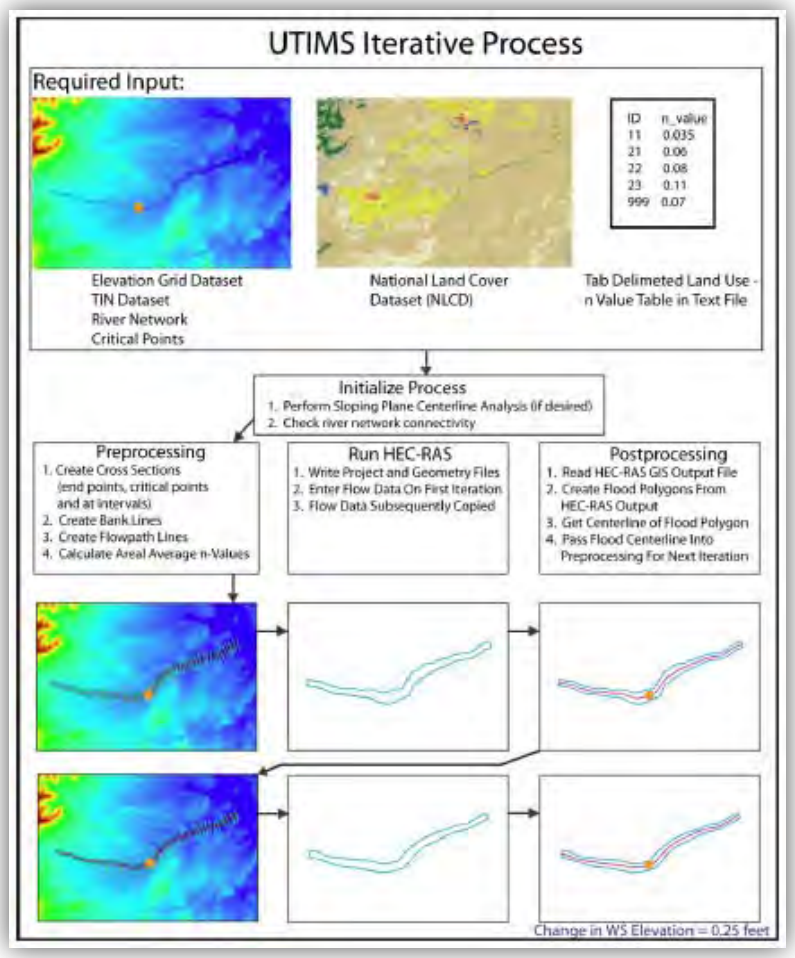


Figure 2.

Increasing Data Accuracy, Reliability, Accessibility, and Understanding to Improve Basin-Wide Water Resources Decisions

Principal Investigators:
Blake P. Tullis
Mac McKee

Partners/Collaborators:
***State**: Aaron Hunt, DNR-Water Rights; Matt Lindon, Deputy State Engineer*

Project Description

- **Need and Purpose**:

  Effective management of a water resource requires accurate, reliable, and accessible flow measurement data. Water Distribution Systems managers in Utah must make critical decisions regarding water diversions, exchanges, and ultimately delivery of the proper quantity to the end-user. Real-time, accurate, flow measurement data should help in making sound decisions in meeting water delivery obligations. Most Distribution Systems have some means of flow measurement (flumes, weirs, etc.). However, many of those structures are often constructed incorrectly (e.g., out-of-level, incorrect dimensions, and/or the staff gage is located incorrectly), suffer maintenance deficiencies with affect the calibration (e.g., excessive sediment build up in a flume or upstream of a weir), or a lack of communication between those develop the head-discharge relationship for the structure and those who apply it can result in flow measurement errors. The objective of the study is to, in cooperation with a water distribution system, inspect flow measurement structures, identify and correct where possible and deficiencies, check the structure calibration, and add automated data collection and telemetry system to make the data available real-time.

  Summit Creek in Smithfield, UT agreed to participate in this case study. Five flow measurement in this Northern Utah system were evaluated, calibrated, and automated. A list of corrective actions were recommended/ implemented for the flow measurement structures, along with a summary of the training provided to the Water Master (or other responsible parties) with respect to maintenance and/or operational deficiencies that impact flow measurement accuracy at specific structures.

- **Benefits to the State:**

  Improved (or verified) flow measurement accuracy raises the confidence in and effectiveness of the water distribution decision-making. Having the data available real-time via a telemetry system and website facilitate real-time decision making with respect to water allocation and management.

- **Geographic Areas**: State of Utah.

  Study Area: Smithfield, UT (Summit Creek Distribution System).

  Areas Benefited: Irrigation flow measurement is common throughout the State so all counties in the state could potentially benefit, either through increased awareness of the problem (current study results) or through participation in future studies.

- **Accomplishments**

  Findings: Five flow measurement structures were evaluated and calibrated. Common problems included structures being out of level, staff gages incorrectly referenced, and on structure

operated under a fully submerged condition due to a stream confluence and diversion structure located immediately downstream.

Results: New calibrations were provided appropriate for the flow measurement structures. Education regarding the importance of staff gage positioning and a solution was provided and implemented (by the River Commissioner) to overcome the submergence problem. In one case, a flow rate measurement error of ~80% was corrected. Telemetry systems were installed on four of the structures and the data are posted on a Division of Water Rights web page. (www.waterrights.utah.gov/distinfo/realtime_info.asp).

Work Plan FY 09/FY10

Flow measurement structures in the Upper Bear River Distribution System will be evaluated with the same objective as the current study.

Informational Resources

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

Website: http://www.neng.usu.edu/uwrl/www/faculty/btullis.html

Cipoletti Weir (Clearcreek, UT)

Submerged Parshall Flume (Smithfield, UT)

Parshall Flume (Smithfield, UT)

Labyrinth Weir Research

Principal Investigator:
Blake P. Tullis

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

Project Description

- **Need and Purpose**:

  With the revisions of probable maximum flood flows and greater emphasis on dam safety, many spillways are found to require rehabilitation or replacement. Labyrinth weirs are often a favorable design option, 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. Furthermore, current information and data available for labyrinth weir design and evaluation are incomplete.

  The study objectives include: improve the design and analyses of labyrinth weir spillways by consolidating available data sets and information, assimilating and expanding current design methodologies, and utilizing physical models to investigate areas in need of research.

- **Benefits to the State:**

  The results of this study may prove useful dam rehabilitation projects where the spillway capacity needs to be increased. 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.

- **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: Surface spill flow control structures are common to nearly all dams so the application of the study results could extend to all counties.

- **Accomplishments:**

  Findings: The primary accomplishment in 08-09 was an extensive literature review and the development of an extensive scope of work and experimental method. A significant amount of experimental data have been collected in 09-10 which will be presented in next year's report.

Work Plan FY 09/FY10

Approximately 10 different lab-scale labyrinth weir models (varying sidewall angles and crest shapes) will be fabricated and tested in the 4-ft flume at the UWRL. Half-cycle labyrinth weirs (triangular apexes) with varying sidewall angle and crest shape will be evaluated in a 2-ft flume at the UWRL in an effort to provide additional data regarding the hydraulics of oblique weir and also try to determine the influence of nappe interference on labyrinth weir hydraulics.

Informational Resources

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

Website: http://www.neng.usu.edu/uwrl/www/faculty/btullis.html

Labyrinth Model Study (UWRL)

Labyrinth Model Study (UWRL)

Prototype Labyrinth Weir (Waco, TX)

Lay-Flat Lateral Hydraulics for IDEal Drip Irrigation Systems

Principal Investigators:
Gary Merkley
Evan Thompson

Partners/Collaborators:
- ***Local**: Keller-Bliesner Engineering, LLC*
- ***International**: International Development Enterprises*

Project Description

- **Need and Purpose**:

  Scarce water resources and/or a lack of water resource technologies are common limitations facing a large majority of small farmers. Affordable irrigation technologies must be developed to help farmers by generating more income through increased agricultural productivity. International Development Enterprises (IDE) is an international non-profit organization that has been helping poor farmers escape poverty. IDE develops low-cost irrigation technologies and equips local small-scale enterprises to manufacture, distribute, install, and service the technologies at a fair market price.

  One technology that has been developed by IDE is the IDEal drip irrigation system. This system consists of very thin walled (150-250 micron) lay-flat laterals that operate at extremely low pressures. The system uses micro-tube emitters that are similar to "spaghetti"-type tubing, which is common in drip irrigation systems in the United States. These irrigation systems have only recently been implemented, and are only found in a few locations around the world. Little is known about the hydraulics of the system, and as a result, it is difficult to design systems. While some research has been done on low pressure, gravity-fed drip irrigation systems, no studies have been done on the hydraulics of IDEal drip tape. Determining the hydraulics of IDEal lay-flat laterals will provide designers with the necessary information to create effective irrigation systems.

- **Benefits to the State:**

  The main objective of this research is to further the understanding of low-cost solutions to irrigation. Development in these technologies will provide numerous non-government organizations with the information they need to help small farmers. This research forms a partnership with IDE to bring low-cost irrigation solutions to families in Utah and around the world.

- **Geographic Areas**:

  Study Areas: Logan, Utah, and Ethiopia.

  Areas Benefited: Irrigated agriculture is statewide, so all counties in the state would potentially benefit, but especially those with water shortage and small land plots.

- **Accomplishments:**

  Findings: The hydraulics of IDEal low-pressure drip irrigation system components were analyzed under controlled laboratory conditions and the results can be applied to the design of these systems. The hydraulic loss coefficient for the lateral-submain connector valves was determined based on laboratory measurements. Fieldwork in Ethiopia helped to provide practical information about the design and operation of these systems.

  Results: It was found that the hydraulic loss due to friction in the lay-flat laterals can be accurately estimated with standard friction loss equations using a smaller effective diameter

based on the wall thickness and inlet pressure head. The equivalent length barb loss, expressed as an equivalent length of lateral, was calculated for button emitters, as well as for micro-tubes inserted to lengths of 5 and 10 cm. The head-discharge relationship and coefficient of manufacturer's variation of pre-punched lateral holes (without emitters), button emitters, and micro-tubes were characterized. Engineers and technicians now have much more technical information to apply to the design of these low-head irrigation systems.

Work Plan FY 09/FY10

- This project was completed in May 2009.
- Follow-up work on the same irrigation systems will begin in mid-November 2009 and continue until November 2010. The follow-up work will focus more on system design aspects, as opposed to hydraulic characteristics, and will include work on mini-sprinklers, also of low pressure.

Informational Resources

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

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

Setting up the experiments

Lateral runway

Taking flow measurements

Low-Level Outlet Air Vent Sizing for Small to Medium Sized Embankment Dams

Principal Investigator(s):
Blake P. Tullis
Jason Larchar

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

Project Description

- **Need and Purpose**:

  State regulators who approve dam designs, report having little or no information regarding requirements for sizing air vents for low-level outlet works. Some work has been done by the US Army Corps of Engineers (USACE) on air vent sizing for vertical slide gates in outlet tunnels. Limited amounts of field data were used to validate the model. The gate/intake geometries for small to medium sized dam low-level outlet works typically do not feature a vertical slide gate but rather have slide gates mounted on the sloping upstream face of an earth fill dam, followed by a mitered elbow transition.

  This study is developing a better understanding of air demand in low-level outlet works verifying the accuracy of the USACE and providing improvements where possible. The work includes laboratory testing, CDF modeling, and a field data collection. The results of this study should be beneficial to all parties involved in dam safety (designers, regulators, and owners).

- **Benefits to the State:**

  Using the results of this study, the Utah Office of Dam Safety (DNR-Water Rights) will be able to specify air vent sizes associated with new dam construction and dam improvement projects. Adequate air vent capacity is critical to the safety and longevity of the low-level outlet, which facilitates reservoir releases once the reservoir level falls below the spillway elevation.

- **Geographic Areas**:

  Study Area: State wide.

  Areas Benefited: Reservoir use is common throughout the State (e.g., municipal and industrial, irrigation, and hydropower uses) so all counties in the state would potentially benefit.

- **Accomplishments:**

  Findings: An air vent sizing algorithm was developed using the data obtained in this study to allow designers/regulators to determine the appropriate air vent size for small to medium sized embankment dams, featuring either a round or rectangular control gate installed on the upstream face of the dam.

  The CFD modeling of the low-level outlet had limited success. The lab-scale low-level outlet works was evaluated using CFD software. Due to the added computational complexity/uncertainty associated with two-phase flow (air and water), the CFD model was first applied to a non-vented outlet flow condition (single phase flow). The CFD computed flow rates varied between ~5 and 17% low, relative to the flow rates measured in the laboratory at various reservoir depths and a gate opening (round gate) of 50%. The predictive accuracy decreased as the reservoir depth decreased. Potential limitations in the turbulence modeling algorithm are a potential cause and are being investigated. Until better correlation between the physical and numerical data can be achieved for the simplified case (no air), CFD modeling of the air-vented,

two-phase flow will not be productive. These results, however, do suggest that "out of the box" CFD modeling results are not always accurate, at least for this specific application, and should be verified with physical model or prototype data where possible.

Work Plan FY 09/FY10

Additional funding is anticipated through DNR-Water Rights to collect air vent flow rate data on various dams around the State during the 2010 irrigation season in an effort to verify the laboratory results.

Informational Resources

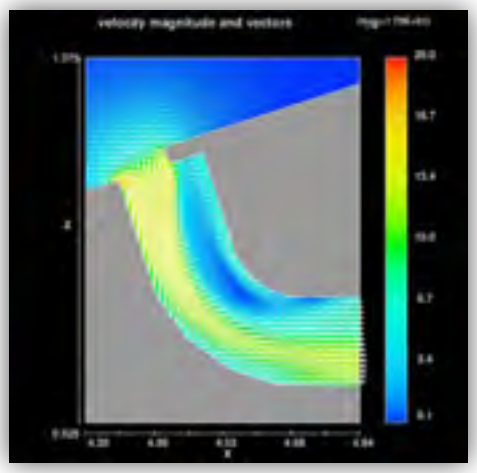
Contact: Dr. Blake P. Tullis, Phone (435) 797 3194, E-mail: blake.tullis@usu.edu.
Website: http://www.neng.usu.edu/uwrl/www/faculty/btullis.html

Slide gate (Uinta Mountains, UT)

Air vent intake & gate control (Woodruff, UT)

Lab-scale low-level outlet model

CFD flow domain



CFD model results (flow velocities)

Metering of Secondary Irrigation Water Systems

Principal Investigators:
Michael C. Johnson
Steven L. Barfuss
Gregory L. Richards

Partners/Collaborators:
- *State: Todd Adams, Water Resources, Eric Klotz, Water Resources*

Project Description

- **Need and Purpose:**

  Many cities and suppliers of water in the State of Utah are using secondary water for irrigation purposes. Because of its nature, secondary water contains debris that has made it impractical in the past to meter its use. Many secondary systems do not provide for metering so users often use more water than is needed and waste occurs. In order to provide user accountability, secondary providers need to accurately account for water use and bill accordingly. The purpose of this study is to identify possible technologies to accurately meter secondary water.

- **Benefits to State:**

  The state benefits by enabling water suppliers to understand what technologies are available to them to meter secondary water. High quality potable water is best used for indoor purposes while secondary water is well suited for irrigation. If feasible means are available for secondary water providers to monitor irrigation use and bill for that use, more potable water is made available for cities to grow and serve more residents without having to develop more sources or increase treatment costs on existing sources to meet the demand.

- **Geographic Area(s):** including:

  Study Area(s): Weber Basin, Spanish Fork, Grantsville, Draper.

  Areas Benefited: The information is applicable to any irrigated residential and commercial area in the State of Utah. The technology is applicable to all areas in the world that use secondary irrigation and need to measure use.

- **Accomplishments**:

  Findings: Several means for metering secondary irrigation water are available including centralized filtration, local filtration, and newly emerging metering technologies. The implementation of the technology to be used is system dependent.

  Results: Two papers have been published in the Journal AWWA which is a peer reviewed journal that benefits water users in the State of Utah as well as water users across the world.

Work Plan FY 09/FY10

The project was completed October 31, 2009.

Informational Resources

Richards, G.L., Johnson, M.C., and Barfuss, S.L. (2009). Revenue Losses Due to Water Meter Inaccuracies at Ultra-Low Flows. Accepted for publication *in Journal AWWA*.

Richards, G.L., Johnson, M.C., and Barfuss, S.L. (2009). Metering Residential Irrigation Water: Technological Approaches and Cost Estimation. *Journal AWWA*, 101(6):52-63.

Contact: Dr. Michael C. Johnson, (435) 797-3176, E-mail, michael.johnson@usu.edu.

Water Resources Planning and Management

Multispectral Image Processing for Water Management and Other Agricultural Applications

Principal Investigator:
Huifang Dou

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, the water shortage problem is getting worse. Monitoring evapotranspiration (ETa) and identifying soil moisture situations over large areas, helps 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 and practical temporal limits as well as weather related obstructions (like clouds), accurate forecast of daily agricultural water consumption using remote sensing is not a trivial problem. Therefore, effective algorithms must be explored 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 program will assist water resource managers to efficiently promote the orderly and timely planning, conservation, utilization and protection of Utah's water resources. Also, this research program will 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 Areas: Sevier and Millard Counties.

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

- **Accomplishments**:

  Findings: Two cameras can be successfully installed on one UAV and the images captured from the two cameras can be synchronized (a, b). NDVI images are able to effectively eliminate the noises from clouds, as shown in figure (c).

Results: During this year, we successfully installed two cameras, one for RGB and another for NIR. Also, a novel UAV based Multispectral imagery system called "GhostFoto" was developed. This system can control the two cameras synchronously capturing images and sending them real-time to the Ground Control Station. Furthermore, the software makes it possible for the two cameras working with the installed Inertial Measurement Unit (IMU) and Global Positioning System (GPS) to provide all necessary information about UAV status and geographical coordinates. With this information, each pixel on every captured image can be orthorectified. Flying tests, using a reflectance panel, provide multispectral images. Two methods of classification algorithms, extreme learning machine and Mittag-Leffler expansion, are under development. We are applying these two methods to achieve the best classification results based on our fly-testing images.

Work Plan FY 09/FY10

The Year-3 research effort includes the following: Based on remotely sensed multispectral images real-time acquired from Unmanned Autonomous Vehicles (UAV), develop and implement signal processing algorithms for crop and forage classifications, growth status estimation, as well as water management by monitoring, evaluating, and predicting ETa and soil moisture content at designated key areas in Utah. These activities will be coordinated in collaboration with on-going research at the Utah Water Research Laboratory. Attention will be given to testing of algorithms using actual field data.

Informational Resources

Contact: Dr. Huifang Dou, (435) 7972858, Email: douhf@engineering.usu.edu

Underneath the aircraft

White Panel Calibration

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

Principal Investigator:
YangQuan Chen

Partners/Collaborators:
- ***Local:*** *Jim Walker, 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 UAV technology and compact multispectral-imager are both becoming low cost and 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 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 highly detailed information to farmers about soil moisture conditions in individual fields enabling farmers to better manage scarce irrigation resources, and (2) manage their 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. 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 Areas: 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: An inexpensive unmanned aerial vehicle (UAV) has been developed with the capability to carry and control various types of remote sensing equipments, and gather remotely sensed data which can then processed for distribution to water managers and farmers.

  Results: Include 1) A team of 3 working fully open-source UAVs for various mission scenarios such as irrigation water management and ecological assessment. 2) Patent disclosures.

Work Plan FY 09/FY10:

- Explore the thermal infrared (TIR) capability on 72" platform.
- Improve and test flight controllers and patent our own flight control tuning methods.
- Improve on-board GPS and avionics measurements so that post-processing of aerial images is more accurate.
- Explore the use of local GPS reference station information for more accurate postprocessing of image georeferencing.
- Continue development of protocols for information sharing among multiple UAVs.
- 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: Dr. YangQuan Chen, Phone (435) 797-0148, E-mail: yangquan.chen@usu.edu

Website: http://yangquan.chen.googlepages.com/ 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.
Publication list 2008-2009: http://mechatronics.ece.usu.edu/yqchen/paper/08/ and http://mechatronics.ece.usu.edu/yqchen/paper/09/.
News paper story: http://yangquan.chen.googlepages.com/Scan08062009_160254.pdf.
News release: http://research.usu.edu/htm/news/articleID=5169.

Optimal Agricultural Water Management Under Water Deficit Conditions

Principal Investigator:
Jagath J. Kaluarachchi

Partners/Collaborators:
***State**: Division of Water Resources, Utah Department of Natural Resources*

Project Description

- **Need and Purpose:**

  In a water deficit region such as Utah, a methodology is needed to address how best to allocate water for irrigation such that agricultural production and benefits are not comprised while ensuring other water use sectors are not affected.

- **Benefits to State:**

  The rural parts of the State of Utah are still actively involved in agricultural activities, from crop cultivation to dairy farming and ranching. However, most parts of these agriculture-dominated regions of the state have moderate to severe water deficits that often hinder the full implementation of their desired agricultural goals. Due to uncertainty about water deficit conditions, farmers cannot plan for the optimal land area/crop cultivation in a given season to maximize their annual profits. Most Midwestern states have sophisticated analytical tools available to the farming community to address these concerns so that they can rotate their land use patterns every season based on the water deficit and local market conditions. This project developed a web-oriented agricultural water management system for the State of Utah such that the farming communities can use the system to determine the optimal land area/crop combinations in any given season knowing the water deficit and local market conditions to maximize agricultural profits.

- **Geographic Area(s):**:

  Study Area: Bear River Valley, Utah.

  Areas Benefited: The work is applicable in irrigated agriculture areas across the state.

- **Accomplishments**:

  Findings: The study found that under water deficit conditions in a given year, the farmer needs to identify the optimal mix of crop and land combination to maximize the profits rather than using the typical crop/land combinations. In doing so, the extension services can play a role in using the optimization analysis and tools developed here to educate the farmers to identify this optimal land are/crop mix in a given seasons.

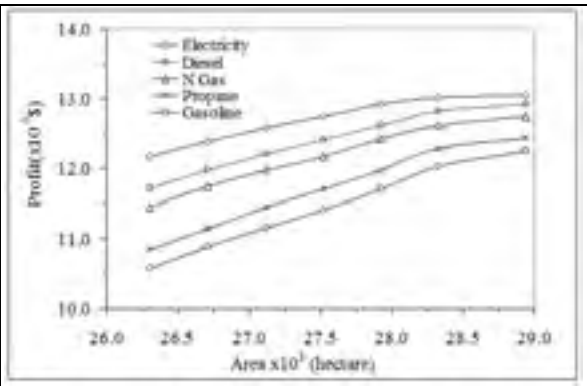
  Results: The farmers need to take the advantage of deficit irrigation in developing irrigation schedules in a water deficit year with the proposed land/crop combination to maximize profits.

Al-Juaidy, A. E., D. Rosenberg, and J. J. Kaluarachchi (2009). Economic evaluation of water management options in water deficit Gaza Strip, Palestine, *submitted*, Journal Water Resources Planning and Management, August.

Al-Juaidy, A. E., J. J. Kaluarachchi and U. Kim (2009). Treated wastewater use in water deficit regions for agriculture: economic, environmental, and public health issues, *in press*, Journal of American Water Resources Association, November.

Aljuaidi, A. E., D. E. Rosenberg, and J. J. Kaluarachchi (2009). Water management with reuse of treated wastewater, desalination, and conveyance in the Gaza Strip, Palestine, AWRA Annual Meetings, Anchorage, AK, December.

Aljuaidi A. 2009. Water allocation for agricultural use considering treated wastewater, public health risk, and economic issues. Phd Dissertation, Utah State University.

<table>
<tr><td>  </td><td> 
</td></tr>
<tr><td></td><td></td></tr>
</table>

Work Plan FY 09/FY10

Work completed spring 2009.

Informational Resources

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

Optimal Merging of Different Scale Soil Moisture Measurements into Land Surface Modeling Systems

Principal Investigator:
Luis A. Bastidas

Partners/Collaborators:
None

Project Description:

- **Need and Purpose:**

  The project examined an optimal way to assimilate three types of non-synchronous different scale observations.

  1. In situ measurements – discrete in space, continuous in time.

  2. Satellite remote sensing observations – discrete in time, continuous in space.

  3. Small aircraft remote sensing observations – discrete in time, "semi-continuous" in space, into a land surface modeling system.

- **Benefits to the State:**

  The focus of the study was on semi-arid environments, which are a significant part of the western United States and, in particular, of the State of Utah. The findings regarding the inferior performance of the models in semi-arid environments are of importance for improved simulations and forecasts of the turbulent heat and water fluxes.

  The theoretical foundations developed for the assimilation of the non-synchronous different scale observations will surely help in addressing the deficiencies found, and could improve land surface models used by a variety of state agencies.

- **Geographic Areas**:

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

  Areas Benefited: Entire State of Utah.

- **Accomplishments:**

  Findings: The main accomplishment of this theoretical study has been the development of an appropriate framework for the assimilation of non-synchronous different scale observations. Next is to further test the procedure and develop applications with real data.

  Simultaneously, a study about the effect of land surface model parameter uncertainty and its assessment has been carried out. The ability of the land surface models to properly simulate the moisture and temperature state variables in semi-arid areas was compared with tropical forest environments. The models tend to perform well in the latter, because they are designed with those environments in mind. Hence, models need to be designed specifically for semi-arid environments.

  Results: Important findings were that the models have serious problems representing the runoff generation in arid areas. Also, it has been found that an inclusion of the soil respiration process is needed for proper simulation of the carbon fluxes. The parameters are not easily transferred and

further classification of the semi-arid systems is required. As stated the study was a theoretical one and the main accomplishment has been the development of an appropriate framework for the assimilation of non-synchronous different scale observations. Thus the main purpose of the study has been achieved. A proposal for submission to a Federal Funding Agency has been developed to further test the procedure and develop applications with real data.

Work Plan FY 09/FY 10:

The main goal of the project has been achieved, and the project is complete.

Informational Resources

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

Optimizing Water Management for Environmental Purposes

Principal Investigators:
David E. Rosenberg
Omar Alminagorta

Partners/Collaborators:
- ***Federal**: Bob Barrett, Sharon Vaughn, and Briget Olsen, U.S. Fish and Wildlife Service*

Project Description

- **Need and Purpose:**

  Typically, scarce water in districts or river basins is allocated to maximize economic benefits of agriculture, municipal, or hydropower water uses or minimize capital and operational costs. These economic allocations are subject to existing physical, legal, and regulatory requirements such as to make allocations within existing infrastructure capacities, satisfy water rights, or meet in-stream flow requirements. Many optimization methods and software exist to identify efficient water infrastructure developments and operations for economic-, financial-, and engineering-based management. However, few efforts identify how limited, scarce water can be more efficiently applied to improve the environmental or ecological-performance of water systems.

  This project is developing optimization techniques to identify cost- and water-efficient infrastructure expansions and operations for improved environmental management. The first step is identifying a study site in Utah to demonstrate and apply these techniques.

- **Benefits to the State:**

  The project has served as a first-step towards developing optimization and analysis techniques that identify cost- and water-efficient management approaches for improved environmental performance. Application of these techniques and recommended approaches will reduce water-agency related management costs, improve the environmental and ecological health of Utah rivers and wetlands, and showcase Utah as a leader in the new field of environmental water-use efficiency.

  Water managers and stakeholder groups who work in Utah on the Bear, Weber, Green, and Provo Rivers (table, next page) expressed interest and described problems where system optimization modeling could improve water management for environmental purposes. The first study will focus on a wetland at the Bear River Migratory Bird Refuge (BRMBR) on the Bear River.

- **Geographic Areas:**

  Study Area: The Bear River Migratory River Refuge at the terminus of the Bear River in Box Elder County.

  Areas Benefited: Managed wetlands statewide, so all counties in Utah could potentially benefit.

- **Accomplishments:**

  Findings: Allocating scarce water to improve environmental services is a concern throughout Utah, including to:

  - Reduce excess phosphorus loading and identify potential groundwater sources in the middle Bear River (above Cutler Reservoir).

- React to limited available summer water in the lower Bear River (below Cutler Reservoir).
- Respond to phosphorus loading and eutrophication in some Weber Basin reservoirs.
- Time Flaming Gorge reservoir releases to promote recovery of endangered humpback chub, Colorado pikeminnow, razorback sucker, and bonytail fish in the Green River.
- Coordinate numerous carp removal, June sucker reintroduction, and spawning habitat improvement projects totaling more than $1-2 million/year on the Provo River.

Results: At the BRMBR, we have begun developing a conceptual systems optimization model that recommends allocations of limited Bear River water to different managed wetland units to improve wetlands performance. This development includes identifying:

- Indicators by which to quantify wetlands performance to achieve objectives, and
- Water management, vegetation, and predictor control actions available to managers.

Work Plan FY 09/FY10

- Finish developing the conceptual systems optimization model for the BRMBR through participatory modeling meetings with BRMBR managers.
- Identify and collect the data needed to populate the model.
- Use existing data already collected by BRMBR managers, values published in the literature, expert judgment, and/or conduct ecological experiments at the Refuge.
- Run the systems model. Report recommended water allocations and work collaboratively with BRMBR managers to verify that model recommendations are reasonable.
- Modify the base case model to include uncertainties in wetland ecological responses.

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.

Bob Fotheringham	Cache County	Bear
Tage Flint and Scott Paxman	Weber Basin Water Conservancy District	Weber
Bob Barrett, Bridget Olson, Shannon Vaughn	Bear River Migratory Bird Refuge, U.S. Fish and Wildlife Service	Bear
Joan Digorgio	The Nature Conservancy	Bear
Todd Adams, Todd Stonely	Utah Division of Water Resources	Statewide
Heather Patno	U.S. Bureau of Reclamation (USBR)	Green
Reed Harris	Utah Department of Natural Resources	Provo

Quantification and Management of Salt Production in the Desert Lake Watershed

Principal Investigator:
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 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 to the Colorado River.

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

- **Benefits to the State:**

  - Improves 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 that have a salt load from natural and agriculture areas of the state.

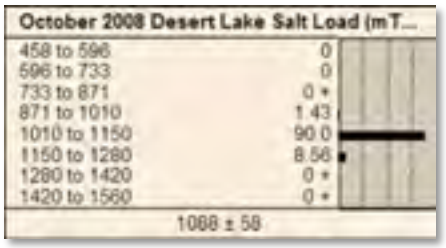
- **Accomplishments**:

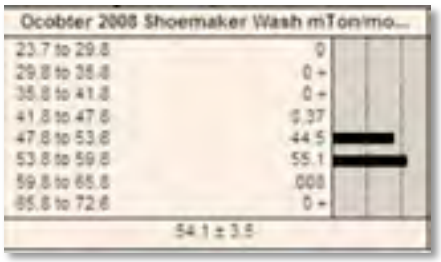
  Findings: The hourly, daily, and monthly Bayesian Belief Model produces good results when the real-time input data are reliable. The model shows that Shoemaker Wash produces the smallest amount of salt to the system through surface water, while Desert Lake Wash and Timothy Wash produce the majority of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

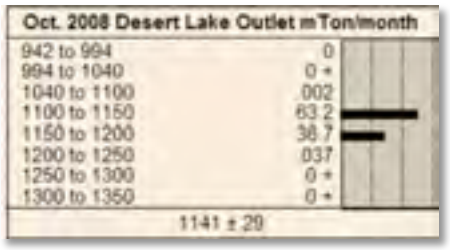
  There is a lag between irrigation and salt loading during the non-irrigation season. During winter, it is difficult to obtain a reliable estimate for salt loading because of freezing.

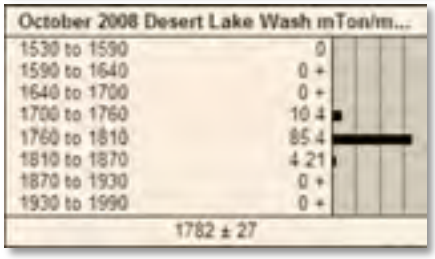
  A groundwater model built by the project shows good initial results in identifying different salt sources using ionic ratios, with a distinct difference identifiable between natural and agricultural sources.

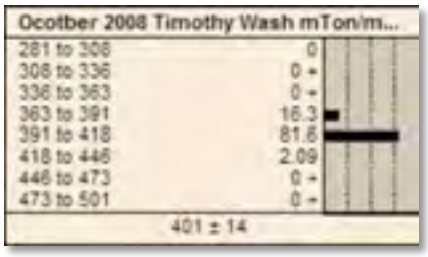
Results: The figures below show the monthly estimates of salt loading from the smallest and largest contributors among the several sites analyzed. These results show that Shoemaker Wash provides the smallest quantity of salt while Desert Lake Wash produces the majority of the salt load for the system.











Work Plan FY 09/FY10

- Improve flow loading of the model by capturing data on all water inputs to the Desert Lake system. Update relationships in the real-time model.
- Develop an evapotranspiration model with a better estimate of the different ground. This will involve using the UAVs from the UWRL.
- Improve the Groundwater Model:
  - Gather and process water data for different time frames of the year.
  - Develop a more regional model.

Informational Resources

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

Raindrop Sizing

Principal Investigators:
Blake P. Tullis
Barton Smith

Partners/Collaborators:
None

Project Description

- **Need and Purpose**:

  Erosion control products are commonly used with construction and reclamation projects to improve embankment stability and the water quality of discharges exiting the work site. Transportation projects funded by the Utah Department of Transportation include provisions for erosion control. Commercial erosion control products (blankets and hydraulically applied mulches) are tested per an ASTM standard (ASTM D6459) or similar standards, using rainfall simulators facilities at various laboratories around the country [included a facility at the Utah Water Research Laboratory (UWRL), Utah State University]. The amount of raindrop kinetic energy is proportional to the raindrop diameter cubed. Consequently, the actual raindrop size significantly impacts the performance of erosion control products tested. The ability to differential between high- and low-performance erosion control materials and ultimately the ability to specify the minimum product quality standard to achieved the desired level of erosion protection, boils down to the raindrop sized use in testing and the ability to quantify the raindrop size.

  D6459 recommends using a raindrop sizing method that utilizes a pie pan filled with sifted flour. A commercially available instrument, called a disdrometer, is designed to measure both raindrop size and velocity, using laser technology. In an effort to determine the raindrop sizing accuracy of the D6459 pie pan method and the disdrometer as well as the raindrop velocity (disdrometer only), a study was conducted using high-speed photography/laser system. The results of the study will provide reference information for future updates to the ASTM D6459 erosion control product-testing standard and, more importantly, improve the delineation of the erosion control product quality, which will result in improved erosion control.

- **Benefits to the State:**

  Evaluating the accuracy of the current raindrop sizing methods will help to improve the standards by which erosion control products are tested and categorized, and will ultimately lead to improved erosion control product specification by regulators and improved water quality. This will be benefit those in Utah and other states, who work in the environment (highway construction-UDOT) as well as those working to protect the environment.

- **Geographic Areas**: State of Utah.

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

  Areas Benefited: Environmental protection though limiting erosion associated with rainfall events is of concern statewide so the results of the study could extend to all counties

- **Accomplishments**

  Findings: Laboratory tests were conducted featuring a raindrop-generating device that produced uniformly sized raindrops. The high-speed photography system was used to

determine the raindrop size and velocity over a range of fall heights. Data were also collected using the disdrometer (raindrop diameter and velocity) and the pie-pan method (raindrop size). The disdrometer correctly identified the actual raindrop size as the predominant size statistically, however, it also reported a significant population of smaller raindrops sizes, despite the fact that all of the raindrops were essentially uniform in size. The disdrometer raindrop velocity data, in general, accurately characterized the overall raindrop velocity range. As with the raindrop sizing, however, there was a statistically significant quantity of low raindrop velocity data that did not correlate with the high-speed photography, which were likely an artifact of raindrops falling near the laser boundary.

Results: As anticipated, the pie-pan method produced irregularly shaped (non-spherical) as a result of impacting the flour. Consequently, when evaluating raindrop sized based in a standard sieve analysis, the irregular-shaped raindrops will result in an over-prediction of the actual raindrop size. The pie pan (or other container) method is a very low-cost method that gives reasonable but overestimated results. It has the distinct disadvantage of not being an automatable measurement method for remote sensing.

Work Plan FY 09/FY10

No additional funding has been provided for FY 09-10, however, we plan to submit a technical paper to the ASTM journal outlining the findings of the study.

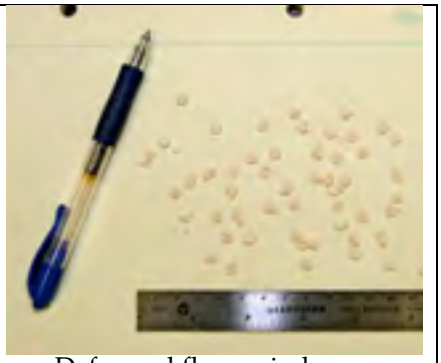
Informational Resources

Contact: Dr. Blake P. Tullis, Phone (435) 797 3194, E-mail: blake.tullis@usu.edu.
Website: http://www.neng.usu.edu/uwrl/www/faculty/btullis.html

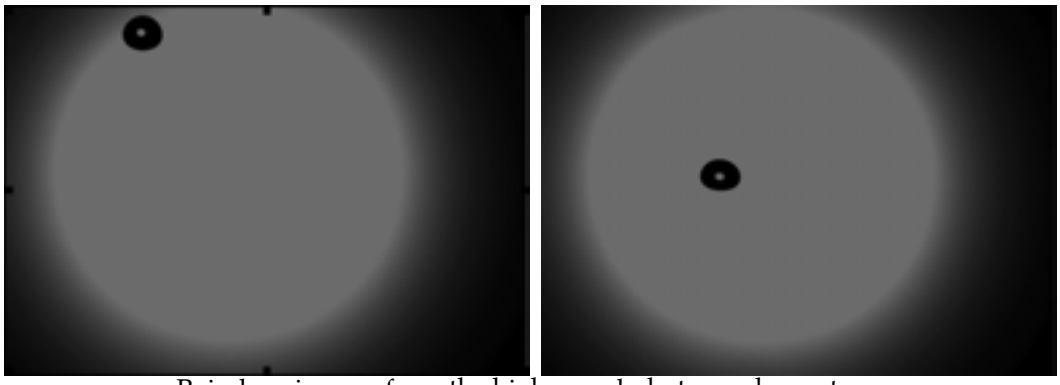
www.thiesclima.com/
disdrometer.html

Image of disdrometer.

Raindrops after impacting flour.



Deformed flour raindrops.



Raindrop images from the high-speed photography system.

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

Principal Investigators:
Mac McKee
Wynn Walker

Partners/Collaborators:
- ***Local**: Jim Walker, Sevier River Water Users Association (SRWUA)*
- ***Federal**: Roger Hansen, U.S. Bureau of Reclamation (USBR)*

Project Description

- **Need and Purpose**:

  As water demands increase in the western states and as concerns for endangered species and water quality begin to affect the allocation of water resources, greater emphasis will have to be placed on 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 already shown a dramatic increase in 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:

  o A real-time reservoir operations model for forecasting releases required to meet downstream water demands for Sevier Bridge and DMAD reservoirs.

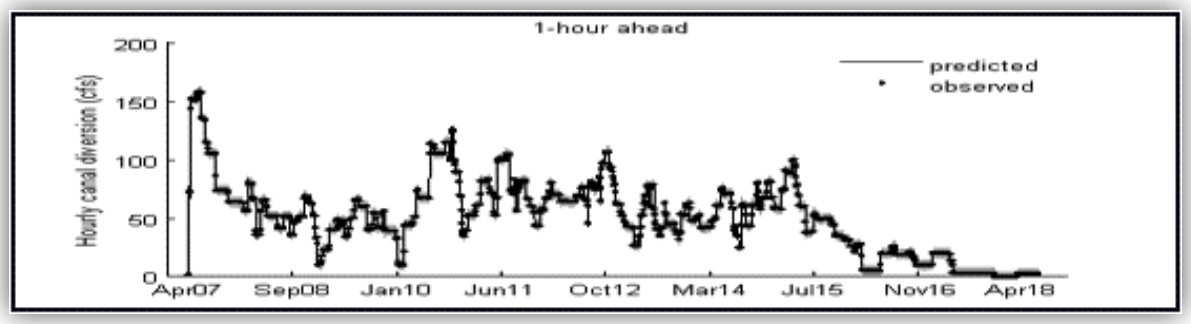
- A model to produce daily forecasts of flows into DMAD reservoir. This helps solve a critical management problem for releases from Sevier Bridge Reservoir that the river commissioner is responsible for.
- Hourly and daily operations models for the Leamington, Central Utah, and Vincent Canals.
- A model to provide real-time corrections in the operation of Canal B in the Delta, Utah area, in order to improve efficiency of water deliveries by several percent.
- A model to forecast evapotranspiration rates in the Delta, Utah area for up to seven days in advance.

Work Plan FY 09/FY10

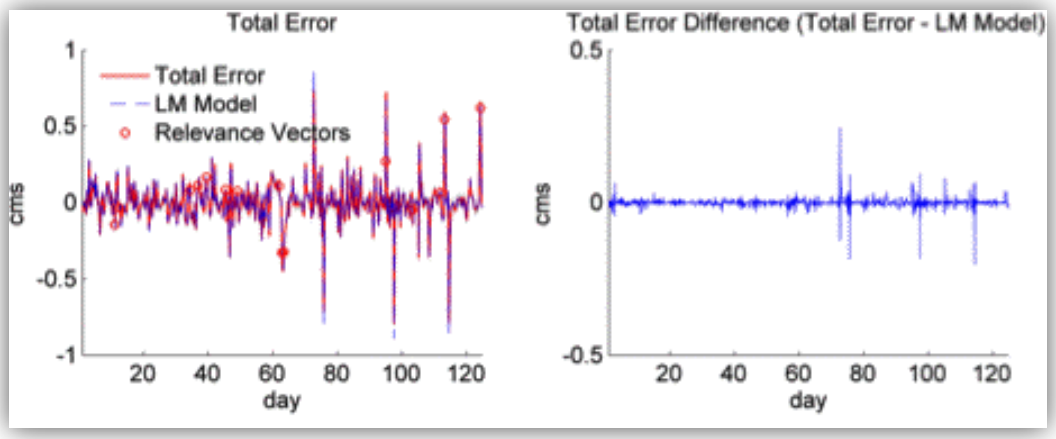
- Work with the US Bureau of Reclamation and the SRWUA to implement all operations models on the SRWUA web site.
- Continue development of short-term irrigation demand forecasts for the Canal B area in order to improve canal performance with respect to efficiency of water deliveries.
- Develop agent-based models of irrigator behavior for the Canal B area to test the importance of economic data in anticipating short-term irrigation demands.

Informational Resources

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



Hourly Forecasts of Irrigation Water Demand for the Central Utah Canal (2007)



Reduction in the Error of Canal B Flow Estimates Using Data-Driven Models

Technical Solutions to Stormwater Issues in Cache Valley Irrigation Canals

Principal Investigators:
Gary Merkley
Katerine Napan

Partners/Collaborators:
- ***Local****: Several canal companies*
- ***State****: Utah Division of Water Rights*

Project Description

- **Need and Purpose**:

  This project supported a number of concurrent activities to help ameliorate problems due to stormwater runoff entry into Cache Valley irrigation canals, including:

  1. Meetings with canal company officials and water users.
  2. Field measurements at flow measurement sites.
  3. Field measurements of seepage loss in irrigation canals.
  4. Design of new flow measurement structures.
  5. Installation of a repeater antenna on the USU Engineering building.
  6. Design and installation of several telemetry sites for flow measurement.
  7. Design and installation of a new BCW in the Bear River City irrigation canal.
  8. Design and installation of a new BCW and water-level recorder enclosure on the Southwest Field Canal in the Cache County Fairgrounds.

  These activities were performed in collaboration with several Cache Valley and Bear River City canal companies, municipalities, and the Utah Division of Water Rights. Many of the activities were performed upon request by canal company officials, and all were related to issues of stormwater runoff into the canals, especially from municipal and industrial areas.

- **Benefits to the State:**

  Utah's many irrigation systems and canals are impacted by urban encroachment on agricultural areas, resulting in stormwater runoff contributions to irrigation canals. This project is aimed at mitigating such problems in a large area of Cache Valley by implementing solutions, as well as lead directly to improvements in water management. The results can be applied to canal systems throughout the state.

- **Geographic Areas**:

  Study Area: Cache Valley, Utah.

  Areas Benefited: Cache Valley, Utah, and the entire state.

- **Accomplishments:**

  Findings: Researchers and local water masters have reported the existence of seepage problems in the Blacksmith Fork irrigation systems in Cache Valley, Utah, but there was very little knowledge of the amount of seepage, and of the spatial locations and temporal variation of these losses. This study provided a better understanding of the seepage behavior within and between these canals throughout the irrigation area. Spatial variation was observed along the canals whereby a descending trend of the mean seepage loss was found in the downstream direction. Spatial variation was also found among canals. Canals located on the eastern bench of Logan

City had higher seepage losses than those of the canal reaches in the western part of the city. Temporal analyses of the monthly seepage showed higher losses in late July and August.

Results: Extensive information was gathered about seepage losses in most of the Cache Valley irrigation canals. This information can be used to improve water management and identify target reaches for canal lining or other seepage reduction measures.

Work Plan FY 09/FY10

- This project was completed in December 2008.

Informational Resources

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

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

Testing the equipment

Map of the canals

Current metering in canal

Treated Wastewater Use in Agricultural Irrigation

Principal Investigators:
Gary Merkley
Leila Ahmadi

Partners/Collaborators:
- ***Local**: Cache Valley municipalities and 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. How to manage the increasing quantities of treated wastewater from M&I sources.

  The premise of this project is that 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 very well 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 augmented wastewater volumes from treatment plants. This can also lead to a win-win situation for two groups, which have increasingly competed for available water resources.

- **Geographic Areas**:

  Study Area: Cache Valley, Utah.

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

- **Accomplishments:**

  Findings: The study has not yet been completed and there are no findings to date.

  Results: The study has not yet been completed and there are no results to date.

Work Plan FY 09/FY10

- This project will be completed in the summer of 2010. The data collection is completed, and the modeling work continues. Various operating scenarios for treated wastewater usage in irrigated

agriculture will be developed and compared, and conclusions and recommendations will be made about the feasibility of each scenario.

Informational Resources

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

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

UAV Remote Sensing Service Center

Principal Investigator(s):
Thomas B. Hardy
Mac Mckee

Partners/Collaborators:
None

Project Description

- **Need and Purpose**:

  Many current sources of remote sensing (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 system (UAS) called AggieAir can fill this need by providing low-cost, multispectral aerial imagery quickly and frequently. In addition, AggieAir's independence on a runway for takeoff and landing enables it to be launched from almost anywhere. Examples of applications which could benefit from AggieAir include agriculture, riparian habitat mapping, road and highway surface monitoring, wetland mapping, fish and wildlife tracking.

  AggieAir has been developed over the last few years and has recently reached a stable and robust status. Therefore, it would be 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 continue AggieAir development and research. For this to happen, a service center will need to be created to handle the services so the research can keep running undeterred. The service center will also be 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 will have the potential to help Utah save water and maintain roads. The service center can help save water by offering farmers a low-cost solution to mapping the soil moisture of their crops to irrigate more efficiently. Furthermore, this data can also help canal operators manage water 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). Roads can also be surveyed before, during and after construction with the service center. Currently this is only done before construction.

  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 around AggieAir. The service center will allow us to test the waters as well as get some experience to learn what would be required to make this happen.

- **Accomplishments:**

  The funds from this project have started and fully equipped a new service center at the Utah Water Research Laboratory called AggieAir Flying Circus (AAFC). 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 for these applications.

  A new workshop was equipped with tools, workbenches, shelving, and enough materials to build nine aircraft. Of the nine aircraft, two have been built and are fully functional. Enough equipment, including a ground station, was also acquired to support three crews in the field.

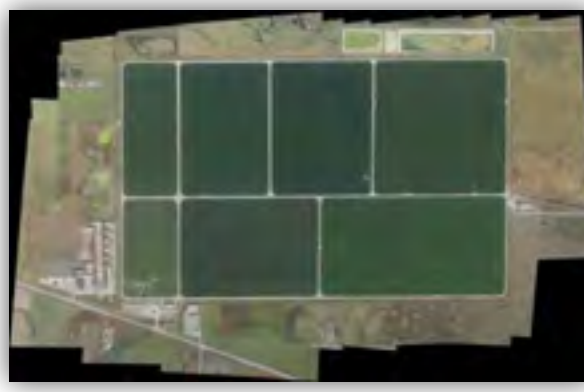
Work Plan FY 09/FY10

- Build training manuals.
- Hire and train more crew members to handle a larger workload.
- Build more aircraft for the additional crew members
- Obtain COA from FAA

Informational Resources

Contact: Austin Jensen, Phone (435) 797 3315, E-mail: austin.jensen@aggiemail.usu.edu

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



Map of Logan Lagoons

Map of a section of Mud Lake

AAFC Ground Station

Ultra Light, High Gain UAV Fish Tracking Antennas

Principal Investigators:
Reyhan Baktur
YangQuan Chen
Austin Jensen

Partners/Collaborators:
None

Project Description

- **Need and Purpose**:

  The study of fish habitats is very important to understand and prevent human activity having a significant effect on fish populations. This information is commonly used before building structures which could possibly affect the migration pattern of protected fish species.

  Current fish tracking systems require users to catch and plant the fish with transmitters, and to track them at a later date with a high gain directional antenna and receiver. Tracking the fish usually takes many hours of fieldwork using cars and boats. To make the tracking process less time consuming and more accurate, this project will focus on developing an antenna to be used on an unmanned aerial vehicle (UAV). The UAV would then be used to fly over habitat and track the fish autonomously.

- **Benefits to the State:**

  The ability to track the location of fish at a lower cost and with less man power will effectively advance the study of fish in Utah's rivers. The successful completion of this project will have far reaching impacts on aquatic resource studies, wildlife studies and agricultural sectors given the high demand for locating and tracking a variety of domestic and wildlife species across the state and region.

- **Geographic Areas**:

  Study Area: Bear River

  Area Benefited: Statewide.

- **Accomplishments:**

  Findings: Through some ground tests and comparisons with the current antennas used for fish tracking, it was shown that a light-weight antenna can be developed which is compatible with the UAV and is sensitive enough to hear the transmitter from the fish while flying at 200m above the ground.

  Results:

  - Antenna has been developed and tested on the ground with good results.
  - Development of a receiver has begun which will listen to the signals from the antenna and record the signal strength.

Work Plan FY 09/FY10

- Finish development of the receiver which will listen to the signal from the antenna and record signal strength along with GPS position.
- Fly antenna with receiver to prove the system works.
- Improve receiver so it also reads the coded number from the signal so each fish can also be identified.

Informational Resources

Contact: Austin Jensen, Phone (435) 797 3315, E-mail: austin.jensen@aggiemail.usu.edu

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

UAV with fish tracking antenna

Water Conservation and Drought Planning with Reservoir Carryover Storage

Principal Investigator:
David E. Rosenberg

Partners/Collaborators:
- ***Local**: Issa Hamud, Mark Neilson, City of Logan; Tage Flint, Weber Basin WCD; Scott Paxman, Weber Basin WCD; Nancy Hardman, Central Utah WCD*
- ***State**: Scott Adams, Scott Stonely, UDWR*
- ***Federal**: Fred Liljegren, USBR*
- ***Private**: Peter Mayer, Aquacraft, Inc.*

Project Description

- **Need and Purpose:**

  Water conservation is a cost-effective way to 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. And 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 reduced use and whether reductions can persist and grow over the next 15 years 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 water-wasting appliances are retrofitted, and determine what incentives (economic, informational, technology, community, etc.) can encourage and motivate customers to conserve water. Additionally, customers need more information to support their outdoor landscape choices as landscape irrigation is the largest component of municipal water use and an important area to target water conservation efforts.

  Utah's arid climate also makes water conservation an important part of strategies to cope with periodic droughts. Options can include a diverse array of conservation, surface water storage, groundwater extraction, cutbacks, trades, exchanges, etc. Here again, Utah water utilities can benefit from better tools to develop and plan portfolios of actions to respond to droughts.

- **Benefits to the State:**

  The 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). The value landscape engineering project has also made analysis tools and information available to home- and business owners to help them identify the lifecycle financial costs, labor requirements, water use, and energy use of their landscaping choices. This information can help owners select water and energy-efficient landscapes. The drought planning project will provide Utah water utilities with procedures and recommendations, including target surface water storage levels, to respond to droughts. Implementation will reduce utility's drought coping costs and increase the likelihoods that customers will not have to face costly cutbacks through droughts.

- **Geographic Areas:**

  Study Areas:

  - *Indexing water conservation* project: detailed end-use data was collected by Aquacraft, Inc. in Oakland, CA; Seattle, WA; and Tampa, FL. However, the approach and findings are

applicable in Utah. And, Aquacraft is completing an end-use study for Salt Lake City, UT which may be available for further study.
- *Intervening to encourage water conservation* project: currently with the City of Logan, Cache County. However, we expect to add one or two more cities along the Wasatch Front.
- *Value landscape engineering* project: Utah-statewide. Tool is generic and allows users across the state to modify inputs specific to their local growing conditions.
- *Drought planning* project: Weber Basin in Summit, Weber, Morgan, and Davis counties.

Areas Benefited:

Municipal water providers and landowners statewide, so all counties in Utah can and likely will benefit.

- **Accomplishments:**

Findings: All projects are still in progress, but several important preliminary findings are:

- Both the flush rate of an old toilet and the number of flushes per day are factors that contribute to the water saved when retrofitting an old toilet.
- Cache Valley and Wasatch Front water utilities and conservancy districts are interested in an intervention study to identify what can motivate people to conserve water.
- A landscape with warm season turf costs less and uses about 40% less water than a landscape with cool-season turf.

Results:

- Secured seed funding for the *Intervening to encourage water conservation* project.
- Developed a spreadsheet tool to make the value landscape engineering lifecycle analysis.
- Worked with Weber Basin as the case study location for the drought planning project with reservoir carryover storage based on interest by the Weber Basin WCD.

Work Plan FY 09/FY10

- Replicate technology and behavioral component analysis for toilets on washing machines, showers, dishwashers, and faucets.
- Complete focus groups and home-visits with residential, business, and institutional water users. Finalize experimental design for 5-year intervention study. Submit grant to NSF.
- Simulate reservoir storage policies in Weber Basin using the Weber Basin model. Identify costs for drought planning options and develop drought planning optimization model.
- Finalize *Value landscape engineering* spreadsheet tool and submit to project sponsor.

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

Water Resources Sensitivity to Changes in Vegetation

Principal Investigator:
David G. Tarboton

Partners/Collaborators:
None

Project Description

- **Need and Purpose**:

  Land cover and climate change with their associated impacts on hydrology are among the pressing areas of research within the western United States. The central theme of this work is examining how watershed management and land use or land cover along with climate change impact water production, through analysis of historical observations and statistical and physically based computer models. This study is investigating factors that may impact the production of runoff in the semi arid intermountain region in and around Utah. Specifically, we are interested in estimating the runoff from a watershed as driven by precipitation and snowmelt and how this runoff changes as land use, land cover or climate changes. We are also interested in predicting the Great Salt Lake (GSL) level under conditions of land cover and climate changes.

- **Benefits to the State:**

  Water is a critical resource in Utah and this project involves an effort to understand how land use and watershed management affects the amount of runoff produced from Utah Watersheds. The Great Salt Lake is a critical resource in Utah, whose level is affected by runoff from surrounding watersheds. This research aims to better quantify the impacts on the GSL of potential runoff changes due to climate and land use changes.

- **Geographic Area(s):**

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

  Areas Benefited: Runoff from 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 better understanding these impacts.

- **Accomplishments**:

  Findings: Trends in precipitation, streamflow, temperature and land use have been examined for a representative set of 39 watersheds across the state of Utah. A water balance approach was used to quantify the sensitivity of runoff production to changes in land cover based on differences in evapotranspiration from different land cover types.

  Results: The most consistent trend noted was in temperature, which is increasing for the majority of watersheds investigated. We did not note any significant trends in precipitation. Fourteen of the 39 watersheds examined had significant decreasing trends in streamflow and runoff ratio. We were unable to find definitive causes for these streamflow and runoff ratio trends, though we do have indications that some of them are associated with human development, storage in reservoirs and land cover and land use changes.

  Past watershed research, much of which is specifically oriented toward the West, has demonstrated that timber harvest, or vegetation removal, reduces net evapotranspiration (ET) and results in increased streamflow. We developed a water balance approach that quantifies sensitivity of runoff production to changes in land cover based on using coefficients that quantify differences in evapotranspiration from different land cover types. This water balance approach

provides predictions of how water production changes with land cover changes. By considering a range of water balance model parameters we provide water balance derived bounds on how streamflow could change given land cover changes. Figure 1 gives an example of the general finding that increasing coniferous forests decreases streamflow. Other land cover percentages adjust proportionately. The relative potential evapotranspiration coefficients are: Coniferous 0.9, Deciduous 0.8, Range/Shrub/Other 0.6, Barren 0.5 and Agriculture 1.0

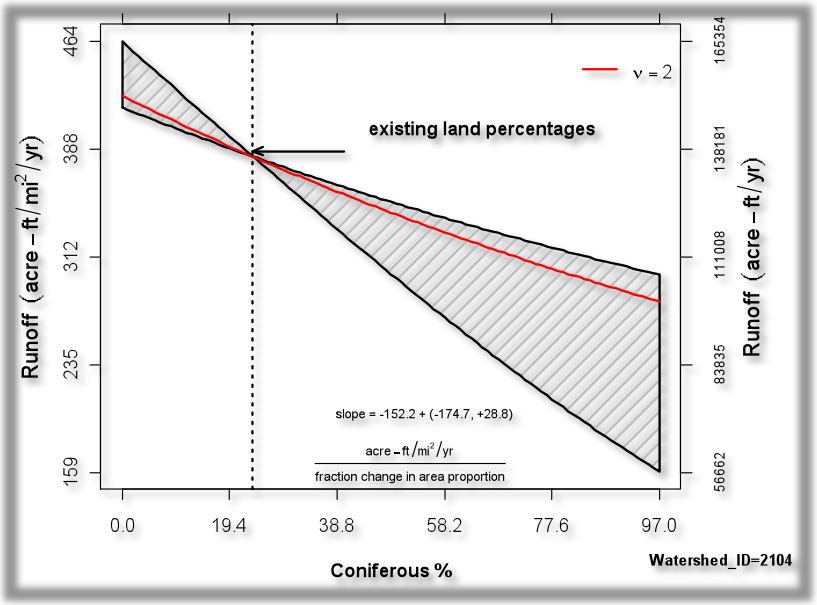


Figure 1. Runoff sensitivity to changes in coniferous land cover percentage in the Duchesne River near Tabiona Watershed.

Work Plan FY 09/FY10

The results noted depend directly on the assumed potential evapotranspiration coefficients which are difficult to quantify and depend on other factors such as topography, soils and climate. The relative potential evapotranspiration is not a single number based on type of vegetation. To better quantify these effects we are will use a spatially detailed physically based model to evaluate the system response. We propose to use the RHESSys model because it provides a detailed representation of snow, runoff, soil and vegetation processes important for addressing our questions.

Informational Resources

Contact: Dr. David G Tarboton, Phone (435) 797 3172, Email: david.tarboton@usu.edu

Website: http://www.engineering.usu.edu/dtarb.

Research Faculty, Professional, and Support Staff

Research Faculty, Professional and Support Staff

Utah Water Research Laboratory and Utah Center for Water Resources Research

Mac McKee, Director
William J. Doucette, Associate Director
Blake P. Tullis, Assistant Director
David K. Stevens, Head of Environmental Division
Gilberto E. Urroz, Head of Water Division
R. Ivonne Harris, Publications Specialist
Jan S. Urroz, Administrative Supervisor

Utah Water Research Laboratory Faculty

Mac McKee, PhD, Director UWRL/UCWRR, Professor, CEE/UWRL
Steven L. Barfuss, MS, Research Assistant Professor, CEE/UWRL
Luis Bastidas, PhD, Research Associate Professor, CEE/UWRL
A. Bruce Bishop, PhD, Professor, CEE/UWRL
David S. Bowles, PhD, Professor, CEE/UWRL
Sanjay S. Chauhan, PhD, Research Assistant Professor, CEE/UWRL
William J. Doucette, PhD, Associate Director, UWRL/UCWRR; Professor, CEE/UWRL
R. Ryan Dupont, PhD, Professor, CEE/UWRL
Thomas B. Hardy, PhD, Research Professor, CEE/UWRL
Jeffery S. Horsburgh, PhD, Research Assistant Professor, CEE/UWRL
Michael C. Johnson, PhD, Research Assistant Professor, CEE/UWRL
Jagath J. Kaluarachchi, PhD, Professor, Associate Dean, College of Engineering, CEE/UWRL
Randal S. Martin, PhD, Research Associate Professor, CEE/UWRL
Michael J. McFarland, PhD, Associate Professor, CEE/UWRL
Joan E. McLean, MS, Research Associate Professor, BIE/CEE/UWRL
Laurie S. McNeill, PhD, Associate Professor, CEE/UWRL
Bethany T. Neilson, PhD, Assistant Professor, CEE/UWRL
William J. Rahmeyer, PhD, Professor, CEE/UWRL; Department Head, CEE
David Rosenberg, Ph.D., Assistant Professor, CEE/UWRL
Judith L. Sims, MS, Research Associate Professor, BIE/UWRL
Ronald C. Sims, PhD, Professor, Department Head BIE
Darwin L. Sorensen, PhD, Research Professor, BIE/CEE/UWRL
David K. Stevens, PhD, Professor, Head of Environmental Division, CEE/UWRL
David G. Tarboton, PhD, Professor, CEE/UWRL
Blake P. Tullis, PhD, Assistant Director, UWRL/UCWRR; Associate Professor, CEE/UWRL
Gilberto E. Urroz, PhD, Associate Professor, Head of Water Division, CEE/UWRL

Research Faculty, Professional and Support Staff

Utah Water Research Laboratory Staff

Marianne Brown, Staff Assistant I
Tracy Brown, MS, Business Officer III
Andrea Carroll, Accounting Technician
Peg Cashell, MS, Soil Scientist
Shannon Clemens, BS, Research Engineer
Leslie Cole, Receptionist/Staff Assistant III
Maria Gates, BS, Accountant
Said Ghabayen, PhD, Research Engineer
Ian Gowin, BS, Research Engineer
Sandra Guerrero, BS, Research Assistant
R. Ivonne Harris, BA, Publications Specialist
Heather Hepworth, Library Assistant
Austin Jensen, MS, Research Engineer
Suba Muruganandam, PhD, Post Doc
Lizzette Oman, MS, Research Engineer
Tamara Peterson, BS, Business Manager
Ashley Pratt, Office Assistant/Runner
Carri Richards, BS, Public Relations Specialist
Ekaterina Saraeva, PhD, Post Doc
Zac Sharp, MS, Research Engineer
Joe Stewart, MS, Research Engineer I
Chad Taylor, Engineering Technician II
Chris Thomas, BS, Field Biologist
Jan Urroz, BS, Supervisor of Administrative Services and Infrastructure
Casey Williams, PhD, Post Doctoral Fellow
Mark Winkelaar, BS, Research Engineer

Adjunct Appointments and Emeriti Faculty

Lloyd Austin, MS, Adjunct Professor, CEE/UWRL/Utah Department of Natural Resources
Jay M. Bagley, PhD, Professor Emeritus, CEE/UWRL
Duane G. Chadwick, MS, Professor Emeritus, EE/UWRL
Calvin G. Clyde, PhD, Professor Emeritus, CEE/UWRL
William J. Grenney, PhD, Professor Emeritus, CEE/UWRL
Frank W. Haws, MS, Senior Research Engineer Emeritus, UWRL
Daniel H. Hoggan, PhD, Professor Emeritus, CEE/UWRL
Trevor C. Hughes, PhD, Professor Emeritus, CEE/UWRL
C. Earl Israelsen, PhD, Professor Emeritus, CEE/UWRL
Eugene K. Israelsen, MS, Senior Research Engineer Emeritus, UWRL
Roland W. Jeppson, PhD, Professor, CEE/UWRL
Upmanu Lall, PhD, Adjunct Professor, UWRL/CEE/Columbia University
Eva C. Nieminski, PhD, Adjunct Associate Professor, CEE/UWRL/Utah Department of Environmental Quality
J. Paul Riley, PhD, Professor Emeritus, CEE/UWRL
Norman E. Stauffer, PhD, Adjunct Professor, CEE/Utah Department of Natural Resources
J. Paul Tullis, PhD, Professor Emeritus, USU Foundation, CEE/UWRL