MINERAL LEASE FUND REPORT
Utah Water Research Laboratory

Fiscal Year 2003

for

Office of the Legislative Fiscal Analyst
Room 425
State Capitol
Salt Lake City, UT 84114

by

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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 being submitted to the Legislature by the UWRL in compliance with House Bill 103 which was 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 includes the following:

1) Actual expenditures for FY 2003
2) Budgeted expenditures for FY 2004
3) Planned expenditures for FY 2005

The report is divided into an introduction and the summaries of each MLF research project. The introduction describes the role of the UWRL, summarizes the requested MLF expenditure information, describes the history of the UWRL, and discusses how the UWRL maintains the relevancy of its research programs to Utah water problems. Project summary reports are grouped into nine program areas. A table summarizing actual, budgeted, and planned expenditures for FY 2003, FY 2004, and FY 2005, respectively, is presented at the beginning of each program area section.

Each project summary report begins with a project description that includes a statement of the problem addressed and research objectives. Accomplishments for FY 2003 are then described. A synopsis of the FY 2004 and FY 2005 work plans is included for projects that will be on going during those fiscal years. A statement of the benefits to the State of Utah is also provided.

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

Mac McKee
UWRL Director

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Introduction

Role of the Utah Water Research Laboratory

Research programs at the Utah Water Research Laboratory (UWRL) directly address current and future needs of the state, the nation, and the world. State appropriation funds (SAF) and mineral lease funds (MLF) are used to address problems facing the State of Utah. In FY 2003, SAF and MLF accounted for 24% of total UWRL expenditures with the balance coming from federal, private, and other state sources. MLF funds are presently used to match externally funded projects, thereby leveraging significant additional funding for solving important Utah water problems. Total UWRL expenditures for FY 2003 were $9.4 million.

The UWRL is organized into nine major research programs supported by the Environmental Division, the Water Division, and the International Office for Water and Science Education (IOWSE). 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. This year, the UWRL has continued to focus on two priority areas identified by State of Utah agencies: (1) assisting the Drinking Water Division, Utah Department of Environmental Quality, with regard to source water protection plans, and (2) assisting the Water Quality Division, Utah Department of Environmental Quality, and the Utah health departments with regard to on-site wastewater treatment issues. Water quality and quantity issues are especially critical at this time of drought conditions in Utah.

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 our 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, we continue to be involved in university graduate and undergraduate education through hands-on projects, part-time employment, and research assistantships. We are also involved in public and professional service, technology and information transfer, and public education. Almost all research and applied projects include student involvement, and result in masters or doctoral degrees. Seventy graduate students were supported in FY 2003. Undergraduate student involvement in UWRL projects is significant, as student education and training are integrated with our basic and applied research programs. The UWRL employed approximately 126 undergraduate students in FY 2003 through leveraging of MLF and SAF support to build the larger total UWRL program. As they are hired by Utah employers, our students become effective means of technology transfer from the UWRL to the Utah water and environmental communities to assist with wise water use within drought conditions. Technology and information transfer are focused on public education, and on working with the Utah Department of Natural Resources, Water Resources Division, the Utah Department of Environmental Quality, and the twelve Utah local health departments.

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 a part of the national network of water research institutes. Total research funding through the UWRL was almost $9.4 million in FY 03, 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 22 faculty and 51 support staff at the UWRL. During FY 2003, 45 master's students and 25 doctoral students received support from UWRL projects. An additional 80 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 US and an allotment program for providing funds to 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 $84,000 of federal funds. This year, we used the base grant from the U.S. Geological Survey (USGS) in combination with MLF support as match for the development of information and technology transfer to assist the State of Utah with the conceptualization, design, development, and execution of Source Water Protection Plans. This year we continued collaborating with the Division of Drinking Water and the Division of Water Quality within the Utah Department of Environmental Quality (DEQ) on this project.

The joint committee was set up last year, comprised of Utah State University faculty and students in several colleges, as well as staff of the Utah DEQ, to address source water protection issues in Utah, and has resulted in a coordinated development of source water protection plans for the State of Utah. A major river basin within Utah has been selected for assistance, and information generation has been initiated. Included in the results are the on-site (septic tank/soil absorption bed) wastewater surveys, since on-site systems represent a non-point source of contamination to source water areas. The systems that have presented major problems as identified by the Utah Water Quality Board have been summarized in a database and incorporated as part of the source water protection information development.

A national peer review of all water centers administered by the USGS under the Section 104 Program was conducted during FY 99. The review panel was chaired by Dr. Henry J. Vaux, Jr., Associate Vice-President for Agriculture and Natural resources, University of California. The panel's recommendation is quoted as follows in this year's MLF report to highlight the important role of the UCWRR in addressing State of Utah water problems: The UCWRR "is one of the top Centers nationally with a very strong research, education, information transfer, and collaboration (intrastate) program. Extramural, state, and university discretionary support is very strong and commendable. The collaboration of the Center with state agencies and the role that the Center plays in water resource planning in the state exemplifies the kinds of arrangements, which the authors of the Water Resources Act of 1964 envisioned. This is an exemplary Center in nearly every respect."

We will continue to use the USGS 104 Program support to develop applied research information and to accomplish technology transfer for source water protection strategies, tools development, and programs across the State of Utah.

This year we are continuing to use the USGS 104 Program support to directly benefit the State of Utah in areas of: (1) source water protection, (2) on-site wastewater treatment training and certification, (3) management strategies for small dams in Utah for mitigation of fish damage and related issues, as described above, and (4) development of user-friendly decision support systems for management of large watershed areas in Utah. A statement prepared by the USGS review panel regarding benefits to the State of Utah is cited above. The state thus benefits directly with regard to water-related public health and environmental protection as well as with regard to water sustainability issues in both urban and rural areas of Utah.

Mineral Lease Fund Expenditures

The table at the beginning of this Introduction section summarizes the actual, budgeted, and planned expenditures of MLF allocated to the UWRL for FY 2003, FY 2004, and FY 2005 by the nine major research program areas. A breakdown of these expenditures by individual projects is contained in tables presented at the beginning of each research program area section of this report. UWRL administration and technology transfer expenditures accounted for approximately 16% of total MLF, budgeted and planned expenditures in FY 2003.

Relevancy and Benefits of the Mineral Lease Fund

Research Identification

In FY 2003, UWRL faculty kept current on state and national water research needs through professional and service activities and through research on improving efficiency during drought conditions. The Utah Center for Water Resources Research (UCWRR) participated as an active member of the National Institutes for Water Resources (NIWR). In addition, UWRL faculty participated as a member of the Lake Powell Technical Advisory Committee activities to identify research needs and arrange collaborative research efforts. The current Director represented the UWRL to the Universities Council on Water Resources (UCOWR). The UWRL also participated in the U.S. DOE-sponsored Inland Northwest Research Alliance (INRA), and the former Director (now the Interim Associate Director) served as the University Programs Coordinator (UPC) for INRA. The UWRL Director, Associate Director, and many faculty met 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, such as the American Water Resources Association, the American Society of Civil Engineers, the American Water Works Association, 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.

We continually seek to strengthen the UWRL research identification process to maintain Utah relevancy of our research programs. We are doing this through participation on state committees. The former UWRL Director serves on the DEQ Water Quality Board, UWRL Faculty member Dr. William J. Doucette serves on the Board of the Division of Hazardous Wastes, and Dr. Laurie McNeill serves on the DEQ Drinking Water Board. Dr. Darwin L. Sorensen is a member of the Lake Powell Technical Advisory Committee. The UWRL also encourages faculty participation in meetings attended by the Utah water community, such as the Utah Water User's Association Annual Meeting, the Utah Rural Water User's Association, the Water Environment Association of Utah, the Annual Uinta Basin Water Conference, the Utah Annual Water Summit, the Utah League of Cities and Towns, and the recently formed Utah On-Site Wastewater Treatment Association (UOWA).

Introduction

Technology Transfer

Besides working on research that is relevant to Utah, we seek to effectively communicate our basic and applied research results to all those who can benefit from them. We are continually assessing ways to make our research findings more accessible at the local, state, and national levels.

Our information transfer activities include our World Wide Web (WWW) site, conferences, workshops, training for State of Utah, U.S., and international professionals, publications' production support and sales, general education, and brochures. The UWRL World Wide Web address for UWRL publications is http://www.engineering.usu.edu/uwrl/www/uw_pub.html. Faculty share their expertise with state water resources and environmental agency personnel through ongoing presentations, meetings, and seminars offered in Salt Lake City and other venues in Utah.

The mission of the UWRL includes outreach activities related to technology transfer for the benefit of State of Utah agencies, Utah citizens, and the nation. Our outreach activities with regard to information dissemination include the following Internet sites: Utah On-Site Wastewater Treatment Training Center [http://www.engineering.usu.edu/uwrl/training], our World Wide Web (WWW) site: [http://www.engineering.usu.edu/uwrl], Utah Water Atlas [http://www.engineering.usu.edu/uwrl/atlas], and Utah Water Journal [http://www.engineering.usu.edu/uwrl/uwj].

Our ongoing interactions with state agencies at the faculty level and state agency staff level on a variety of issues will continue to operate as the core of our approach to focusing UWRL activities so that we can achieve maximum impact from our current budget. In addition, the UWRL Director, Associate Director, and faculty will continue to work with UDEQ, UDNR, the State Engineer's Office, and other state agency administrative and management personnel to provide guidance and priority to state needs and issues.

Examples

Specific state benefits resulting from MLF research projects are listed at the end of each project summary in the following sections of this report. Projects conducted by the UWRL in the past year have produced activities in every county of the state. (Refer to Figure 1 for a tally of UWRL projects by county). A few examples of current, past, and expected future benefits of MLF funding are listed below:

- The UWRL is has worked for the past three years with the UDEQ, Drinking Water Division, to address national regulations and requirements regarding Source Water Protection Plans in Utah. The assistance includes the development of new tools and methods for source water assessment of the risk of contamination of surface water supplies in Utah. This is especially important under drought conditions that have been recently experienced in Utah. A source water protection assessment tool (SWPAT) is under development for the Ogden River Watershed as a technology transfer product of this research.

- On-site wastewater treatment training and technology transfer for State of Utah personnel in the Utah Department of Environmental Quality (UDEQ) and local health departments continued in FY 2003. Current activities are described in this report. Undergraduate and graduate students participate through projects that involve hands-on, real-world activities. Utah health department staff and other Utah On-Site Wastewater Treatment professionals were trained in site characterization, treatment, and monitoring on-site systems and source water protection aspects of on-site systems. Additional information can be found at the UWRL web site: http://www.engineering.usu.edu/uwrl/training.

- UWRL faculty and staff taught on-site wastewater treatment workshops throughout the State of Utah over the past 12 months to local health department personnel and contractors that included: (1) Soil Evaluation and Percolation Testing, (2) Design, Inspection, and Maintenance, and (3) Design, Inspection, and Maintenance of Alternative Systems.

- The Utah On-Site Wastewater Association (UOWA) provides a major technology transfer service regarding site selection, installation, maintenance, and monitoring for Utah local health departments, UDEQ, and other on-site professionals.

- UWRL faculty are currently assisting UDEQ personnel in the evaluation of state needs regarding Total Maximum Daily Loads (TMDLs) for Utah's lakes, rivers, and streams, and the impacts of proposed land use changes on water quality. Personnel from the UWRL have provided direct technical assistance in 2003 for the preparation of TMDLs in Cache County and in the Sevier River Basin.

- Results of our laboratory investigations continue to provide cost-saving methods for improving the performance and safety of dams and of dam spillways in Utah, and can be expected to play an important role in future dam safety rehabilitation in the state. In addition, UWRL faculty and staff continue to develop procedures that consider risks associated with the performance of dams.

- In FY 2003 through FY 2007, the UWRL has been requested to assist the State of Utah to develop a plan and methods of management to minimize sediment release from dams during drawdown events. The UWRL has received U.S. EPA funding to assist the state in this effort.

- UWRL faculty serve on state and local advisory panels as part of our outreach and service activities, including the Utah Drinking Water Board (Dr. Laurie McNeill), Utah Water Quality Board (Dr. Ronald C. Sims), the Utah Solid and Hazardous Waste Board (Dr. William J. Doucette), Lake Powell Technical Advisory Committee (Dr. Darwin L. Sorensen), Salt Lake County Solid Waste Management Council (Dr. R. Ryan Dupont), and the Utah On-Site Wastewater Association (UOWA) (Dr. Ronald C. Sims, Ms. Judith L. Sims, and Dr. Darwin L. Sorensen).

- A geographic information system (GIS) approach has been developed by UWRL faculty and students to improve statewide water use estimations to forecast future water needs. UWRL faculty will work with personnel in the Department of Natural Resources, Division of Water Resources, to implement this tool into their river basin planning efforts. This work was partially supported by funds received from the US Geological Survey.

- Real-time management of irrigation systems in the Sevier River Basin is being implemented using computer (artificial neural network) models to increase the efficiency of basin-wide water management. This is especially useful when the total quantity of water decreases as in the recent drought conditions in Utah. Construction of similar models will continue in FY 2004 for implementation in Emery County for purposes of salinity management.

- Computer models for managing the quality of streamflows and improving the operational efficiency of Weber Basin water treatment plants continue to be developed and are expected to be transferable to other river systems in Utah.

- UWRL faculty are currently involved in improving drinking water treatment and plant performance in Utah with regard to coagulation and arsenic removal processes. We are also working closely with the Utah Water Quality Alliance through Dr. Laurie McNeill.

- Monitoring of fish populations within the Sevier River drainage is a cooperative project with the State of Utah Division of Wildlife Resources and the Sevier River Bridge Canal Company to guide decisions about long-term water allocation and enhancement of native fish in the Sevier River Basin. Similar assistance is being provided for the Virgin River Basin.

- The UWRL obtained land from USU and worked with Utah health departments and DEQ to establish the Utah On-Site Wastewater Treatment Physical Demonstration Facility in FY 2001, and the site became operational in FY 2002. In 2002 and 2003, the site was used extensively for training provided to a variety of participants from all around the state. Support was provided by the U.S. EPA and private industry through the submission of proposals.

- The use of vegetation for reclaiming mining areas is being investigated through the development of phytoremediation techniques at the UWRL to assist Utah and other intermountain areas with metal-contaminated soil and ground water.

- UWRL faculty continued to provide technical support to the Virgin River Resource Management and Recovery Program in FY 2003. The program considers actions that will promote protection of species and meet water allocation needs. UWRL faculty have participated in this important program for nearly two decades.

- UWRL personnel provided research support on a more realistic approach to assessing the impacts of altered flow regimes on drifting feeding fish species (i.e., trout). This will provide resource managers with a tool to make better decisions on protecting Utah fisheries resources.

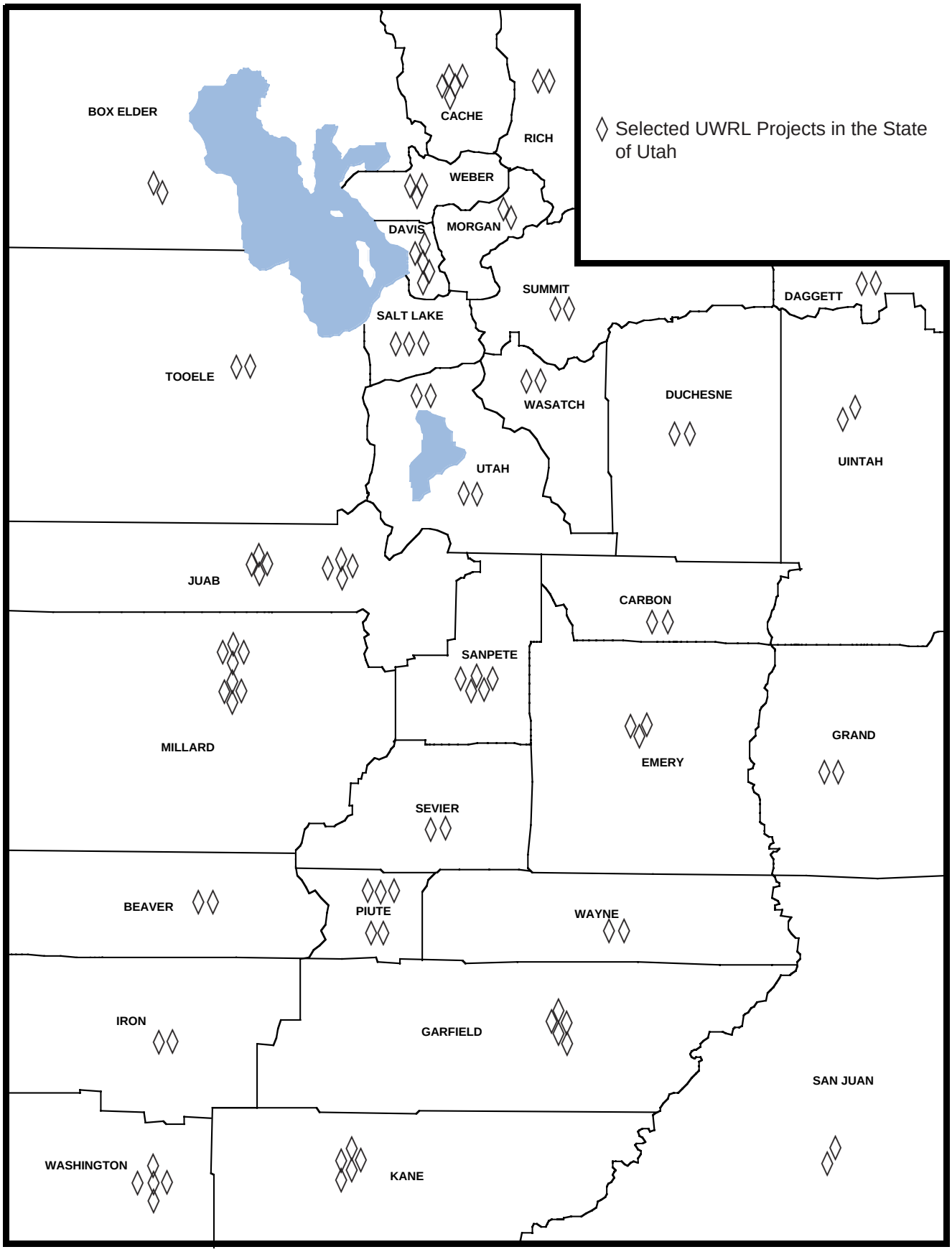

Figure 1. Projects conducted by the UWRL in the State of Utah.

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Summary by Research Projects

Total Projects	FY 2003 Actual Expenditures	FY 2004 Budgeted Expenditures	FY 2004 Planned Expenditures
Administration	$147,385.92	$150,333.64	$129,833.27
Bioprocess Engineering	$55,963.90	$73,931.49	$49,200.00
Hazardous and Toxic Waste Management	$128,983.97	$173,556.35	$105,508.68
Water Quality Engineering	$135,443.60	$128,488.85	$113,100.00
Water Education and Technology Transfer	$42,197.45	$45,433.03	$22,015.24
Fluid Mechanics and Hydraulics	$55,927.46	$76,260.38	$77,205.59
Ground Water	$32,309.13	$57,050.52	$57,050.52
Hydrology	$59,685.19	$67,663.12	$15,000.00
Water Resources Planning and Management	$161,528.32	$248,389.89	$198,738.71
Totals	**$819,424.94**	**$1,021,107.27**	**$767,652.01**

Summaries of Major UWRL Research Programs

Bioprocess Engineering

Bioreactor processing of environmental materials and engineering scale-up of biologically-based environmental reactions are being explored. Areas of specialization include: composting, waste reuse, biosolids processing, management of environmental biotransformations, and engineering optimization of wetlands.

Hazardous and Toxic Waste Management

This program emphasizes an integrated engineering and science approach for characterization and remedial design approaches for contaminated subsurface environments. In addition to laboratory scale work, the program has the largest field scale research dimension of any similar academic program in the nation.

Natural Systems Engineering

Impacts of engineered systems on habitat in aquatic ecosystems are evaluated through the development and application of assessment methods using computer simulation data analysis, and remote sensing. This program addresses threatened and endangered species, habitat enhancement, instream flow assessments, remote sensing of fish habitat, and videography-based prediction of stream sediment and meso-scale hydraulic features.

Water Quality Engineering

The program focuses on the development of engineering approaches for production of drinking water; treatment, reclamation, recycling, and reuse of municipal and industrial wastewater; and modeling of water quality. Areas of specialization include: low technology and advanced treatment processes for potable water treatment, characterization and control of dissolved and particulate natural organic matter (NOM), modeling conventional and toxic contaminants in natural and engineered systems, water reuse engineering, water-quality management, and assessment and control of nonpoint source pollution and storm water.

Water Education and Technology Transfer

Several projects conducted by the Utah Water Research Laboratory, 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.

Fluid Mechanics and Hydraulics

This program utilizes the UWRL 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.

Ground Water

Current research activities cover topics from theoretical developments in the stochastic and numerical analysis of transport in groundwater to practical aspects of the design of clean-up technologies for fuel-contaminated sites and management of Utah aquifer systems.

Hydrology

This diverse program has strengths in both the theoretical and applied aspects of modern hydrology, including climate modeling, rainfall processes, snow hydrology, floods, droughts, terminal lake analyses, soil erosion, and stream water quality modeling.

Water Resources Planning and Management

This program 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.

Bioprocess Engineering

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Bioprocess Engineering

Project Name	FY 2003 Actual Expenditures	FY 2004 Budgeted Expenditures	FY 2005 Planned Expenditures
Biotransformation Products of PAH Metabolism	$13,731.49	$23,731.49	$24,100.00
Identifying and Overcoming Impediments to Expanding the Beneficial Use of Biosolids	$42,232.41	$50,200.00	$25,100.00
Designated Amount for FY 04/FY 05 Research Projects		$0.00	$0.00
Undesignated research projects in program area		$0.00	$0.00
Total	**$55,963.90**	**$73,931.49**	**$49,200.00**

Biotransformation Products of PAH Metabolism

Principal Investigator(s):

Ronald C. Sims
Charles Miller
J. Karl Nieman
Frank Olson

Project Description:

The class of environmental carcinogenic chemicals referred to as polycyclic aromatic hydrocarbons (PAHs) tend to persist in the environment and contaminate surface and groundwater, air, and soil resources when left untreated. The State of Utah has PAH-contaminated environments typically where wood preservatives are or have been used, and includes U.S. Forest Service sites, industrial sites, oil-shale sites, and fire training sites.

Accomplishments (FY 2003):

This year we evaluated microbial agents (mycobacteria) that we isolated from a contaminated soil and as a result added three new microorganisms with biodegradation ability to the knowledge base for naturally occurring beneficial microorganisms that can be used for bioremediation of sites contaminated with PAH. The newly characterized microorganisms, mycobacteria JLS, KMS, and MCS, are described in the international publication "Journal of Microbial Ecology." The title of the article is *Isolation and Characterization of Polycylic Aromatic Hydrocarbon-Degrading Mycobacterium Isolates from Soil*, and the article appears in the January, 2004, issue of the Journal. These microorganisms have been demonstrated to both biodegrade PAHs as well as to bind these chemicals to soil in a manner that prevents downward migration both to groundwater resources and to surface water through lateral movement as runoff. The information obtained on these microorganisms provides valuable input into the development of bioprocess engineering systems, referred to as land treatment systems, for the protection of human health and the environment.

We are also evaluating the new Mutatox assay to decrease the mutagenic potential of soils and compost systems for treating hazardous and nonhazardous wastes on land treatment systems. We have evaluated the Hyrum City Municipal Wastewater Treatment plant and also the Brigham City Wastewater system with regard to biosolids produced and compost. Land treatment and compost treatment, both bioprocess engineering systems, were shown to achieve a reduction in toxicity as indicated by the assay used. The assay used and the bioprocess systems evaluated indicate successful treatments at the Brigham City and Hyrum City plants.

Work Plan (FY 2004 and FY 2005):

We will continue research on the development of bioprocess engineering systems to manage these newly characterized and naturally occurring microorganisms to accomplish rapid and significant destruction of PAHs in contaminated soil environments. We will continue to evaluate the binding mechanisms that immobilize PAHs in soil systems and prevent PAHs from entering groundwater. We will also continue to use the Mutatox assay and also the Microtox Toxicity Assay to test biosolids and residuals from wastewater treatment plants to assess the effectiveness of land treatment and composting systems to ensure protection of public health in Utah.

Benefits to the State:

Results of this research are directly applicable to the sustainable restoration of soil resources using economical engineering technologies at U.S. Forest Service sites and at other sites in Utah impacted by wood preserving contaminants as well as other industrial organic chemicals. Results of this study and the methods developed are providing an improved understanding of the binding and biodegradation of other toxic chemicals in soil environments. Also this research in bioprocess engineering provides the information necessary to design and manage treatment systems to ensure protection of public health and environmental resources including surface and groundwater, air, and soil. The overall goal is developing bioprocess engineering technologies for sustainable development and simultaneous protection of the environment in Utah.

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Identifying and Overcoming Impediments to Expanding the Beneficial Use of Biosolids

Principal Investigator(s):
Michael J. McFarland
George Onyullo

Project Description:

The State of Utah desires to significantly expand the beneficial use of biosolids (appropriately treated wastewater treatment sludge) rather than having them landfilled or incinerated. The beneficial use of biosolids involves the land application of biosolids as supplemental nutrients and/or soil conditioner for agriculture production, land reclamation, timber production, and home gardening.

Accomplishments (FY 2003):

The presence of heavy metals in biosolids is a significant problem because the known toxicities of these trace elements continue to raise important environmental questions with serious implications for public health risk concerns. In particular, the presence of heavy metals in biosolids, a derivative product of sewage sludge with beneficial agricultural value, has been cited as an example in many technical (Ciba et al., 1999; Carbonell-Barrachina et al., 2000; Obrador et al., 2001; McFarland, 2001) and non-technical publications (Bastian, 1997). As a result of the evaluation of the Central Davis Wastewater Treatment Plant data, it was determined that the management of the conditioning/dewatering process was critical in the final partitioning of heavy metals and ultimate toxicity of land applied biosolids. As a result of this analysis, a Ph.D. proposal was developed that focused on elucidating those factors that impact the fate of heavy metals within the dewatering process.

Beyond the human health and ecological impacts of heavy metals in sewage sludge, management of nutrients from biosolids at land application sites has now become an important environmental concern for Cache Valley, Utah. The State Department of Natural Resources (DNR) has proposed more stringent nutrient standards for direct and indirect discharges of phosphorus into surface waters in Cache Valley, UT. The establishment of programs to manage non-point source pollution of phosphorus from biosolids beneficial use sites has so far been ignored by publicly-owned treatment works (POTWs), however, the wastewater treatment plants in Cache Valley have been informed of the pending changes in their discharge permits that include, among other things, a significant reduction in phosphorus concentration in the effluent discharge. Moreover, POTWs will have to apply best management practices (BMPs) to reduce the non-point discharge of phosphorus from their land application sites. This requires that POTWs be technically skilled in establishing the appropriate agronomic rates and, at a minimum, develop appropriate programs to ensure that nutrient mobility does not become problematic.

With respect to phosphorus management at biosolids land application sites, a Ph.D. has been completed at the E.A. Millers Meat Packing plant in which an innovative phosphorus removal system to pretreat wastewater prior to biosolids processing was evaluated. The phosphorus removal system involves the use of a mineral adsorbent, called UteliteTM, which has been specifically designed to immobilize phosphorus. Results from the laboratory testing of the material with wastewater from

E.A. Miller demonstrated that that phosphorus levels could be consistently reduced from approximately 10 ppm to 0.5 ppm within one hour of treatment. A preliminary draft of a peer review publication on this work has just been completed and will be submitted for review in several weeks.

Work Plan (FY 2004 and FY 2005):

In a continuing effort to develop a nationally recognized biosolids research program, the phosphorus removal work at the E.A. Miller Meat Packing facility will be completed in the next few months. This activity will be complemented with new work that is currently being proposed for field research to be conducted at the Hyrum City Wastewater Treatment plant. The new proposal describes an eighteen-month two (2)-phase study in which the Utah Water Research laboratory (UWRL) in partnership with the Hyrum City Wastewater Treatment plant plans to conduct a comprehensive technical evaluation of the new Hyrum City Wastewater Treatment Plant biological phosphorus removal system. The overarching goal of this new effort is to generate high quality data that will enable Hyrum City to reliably and consistently meet the new phosphorus discharge limits.

Finally, a new proposal has been submitted to the Utah Department of Environmental Quality (UDEQ) to evaluate the value of land applying lime stabilized biosolids to alkaline rangelands. Restoration of degraded alkaline rangelands to reduce soil erosion and to improve forage productivity remains an ecological and environmental priority for the State of Utah. Biosolids land application represents a potentially cost effective remediation approach for improving the ecological health and productivity of affected alkaline rangelands.

Benefits to the State:

The information generated from these projects will be critical for the State of Utah in identifying potential problems and opportunities associated with the beneficial use of biosolids. The 40 CFR Part 503 Rule was a risk-based regulation that was supposed to ensure reasonable protection of public health and the environment. However, identification of unanticipated adverse effects resulting from the practice of land application of biosolids may require the State of Utah to impose management standards that are more stringent than the ones currently found in the 40 CFR Part 503 Rule. It is anticipated that the results of the research will lead to management practices that will result in minimizing the indirect discharges of phosphorus as well as other pollutants from biosolids land application sites in the State of Utah.

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Hazardous and Toxic Waste Management

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Hazardous and Toxic Waste Management

Project Name	FY 2003 Actual Expenditures	FY 2004 Budgeted Expenditures	FY 2005 Planned Expenditures
Analysis of Environmental Organic Contaminants	$10,693.03	$20,693.03	$20,693.03
Defining the Bioavailability of Toxic Trace Elements Using Microbial Biosensors	$18,602.74	$23,602.74	$20,400.00
Determination of Atmospheric Ammonia and Ambient Particulate Behavior in Cache Valley, Utah	$36,434.04	$46,434.04	$0.00
Evaluating the Uptake of Nonylphenol and Nonylphenol Ethoxylates by Crested Wheatgrass	$18,031.30	$28,031.30	$14,015.65
Field Scale Bioremediation: Relationship of Parent Compound Disappearance to Humification, Mineralization, Leaching, and Volatilization of Transformation Intermediates	$13,731.49	$15,000.00	$20,100.00
Health Risk-Based Economic Framework to Assess Pesticide Management	$5,752.71	$10,752.71	$0.00
Human Health Risk-Based Decision-Analysis at Hazardous Waste Contaminated Sites	$6,903.25	$0.00	$0.00
Remediation of TCE-Contaminated Groundwater at Hill AFB	$7,392.88	$7,600.00	$0.00
Uptake of TCE by Apple and Peach Trees and their Fruit Near Hill Air Force Base	$11,442.53	$21,442.53	$20,300.00
Designated Amount for FY04/FY05 Research Projects		$0.00	$0.00
Undesignated research projects in program area		$0.00	$10,000.00
Total	**$128,983.97**	**$173,556.35**	**$105,508.68**

Analysis of Environmental Organic Contaminants

Principal Investigator(s):
William J. Doucette
Coreen Crouch
Heidi Fabrizius
Mike Petersen
Terry Carlsen

Project Description:

The Organic Analysis Section of the Environmental Quality Laboratory of the Utah Water Research Laboratory (UWRL) is involved with the identification and quantification of organic compounds in Utah environmental field samples, or in samples derived from laboratory experiments. Methods for the analysis of environmental organic contaminants in a variety of environmental matrices including soil, water, air and biota are developed using techniques such as: supercritical fluid extraction, purge and trap extraction/concentration, headspace extraction, solid phase extraction, high performance liquid chromatography (HPLC), gas chromatography (GC), and gas chromatography/mass spectrometry (GC/MS).

Accomplishments (FY 2003):

Analytical methods utilizing HPLC, GC, and GC/MS have been developed for a wide variety of organic compounds and samples in support of laboratory and field scale studies including trichloroethylene (TCE), methyl tertiary butyl ether (MTBE), and pharmaceutical chemicals such as estradiol that affect water quality in Utah.

Work Plan (FY 2004 and FY 2005):

Method development will continue with a focus on headspace/GC/MS methods for the determination of metabolites of TCE, PAH, and MTBE in soil and plant tissue samples and solid phase extraction/HPLC methods for pharmaceutical chemicals in drinking water.

Benefits to the State:

The analytical methods developed by the Organic Analysis Section are used for the analysis of samples collected from various sites in Utah, such as Hill Air Force Base, in support of projects involved with soil and ground water monitoring and remediation.

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Defining the Bioavailability of Toxic Trace Elements Using Microbial Biosensors

Principal Investigator(s):
Joan E. McLean

Project Description:

Utah regulations on the concentration of toxic heavy metals in water and soils are based on total contaminant concentration. This assessment does not provide information on potential bioavailability of the metal. The bioavailability of a metal is related to the association of the metal with solution and solid phase components, not necessarily the total concentration.

In solution, metals will associate with various inorganic and organic anions, forming soluble complexes. The complexed metal, in theory, is not bioavailable. Chemical procedures used to determine metal concentration in solution only measure the total concentration of the metal, not the specific metal-anion associations. A direct measurement of the bioavailability of a metal would be more useful for the assessment of metal risk to the Utah environment than chemically determined total concentration.

To test metal bioavailability, we have developed metal detecting bioluminescent methods using a root-colonizing bacterium *Pseudomonas putida*. The bacterium produces light until there is oxidative stress in the cell on exposure to bioavailable metals. The relationship between total concentration and environmental risk may not be direct.

Accomplishments (FY 2003):

Over the last year, the sensitivity of the biosensor to copper has been improved and the response of the biosensors to copper free-ion activity and copper associated with various ligands has been examined. Common inorganic ligands (hydroxide, carbonate, and phosphate) and an organic ligand, citrate (a dicarboxylic acid present in root exudates and which plays a vital role in bioremediation of metal contaminated soils) were utilized to complex the copper in these bioassays.

The *P. putida* biosensor indicated that Cu-carbonate, Cu-phosphate, and Cu-citrate complexes are not bioavailable. Copper complexes with hydroxide, however, show a biological response, and therefore is bioavailable.

This biosensor, although proving useful in examining biological/chemical processes contributing to copper bioavailability in laboratory prepared copper solutions, lacks the selectivity necessary to be useful in soil and water samples that contain copper plus other heavy metals. The EPA STAR program awarded funding to further develop these biosensors. This funding is focused on identifying the genes involved in specific metal responses so that selective biosensors can be developed.

Work Plan (FY 2004 and FY 2005):

To understand how these newly developed biosensors respond to various metals, we will start with well-defined laboratory prepared solutions of single metal-ligand pairs. Complexity of these solutions will be increased, as we develop the biosensor model. Studies will also be conducted in the presence of particulate matter and colloidal material (natural clay, oxides and suspended organic matter). There is a continued debate on whether water samples should be filtered and if so through what size filter. What is important is whether the organisms take up the metal associated with solid phases. The biosensor will allow us to sample the bioavailability of particulate associated metals.

Benefits to the State:

Present methods to evaluate risks associated with metal contaminated soil or water are not cost effective. These chemical methods are time consuming and do not measure bioavailability. This project will develop accurate information regarding bioavailability. It will eliminate many costly and unnecessary procedures that are currently in use, and provide reliable information that can be used in an effective risk characterization of contaminated water in Utah.

These results will be used to develop technical management strategies with regard to risks for soil, sediment, and surface and ground water contamination, and to develop approaches to reduce risk to ground water and surface water posed by metal contaminated soils in Utah. Results will directly impact the counties in Utah with current metal contamination from abandoned hardrock mining and counties planning to expand industries and development in the State of Utah. Results will be useful to the Utah Department of Environmental Quality, various municipalities in the State of Utah, the State of Utah Division of Oil, Gas, and Mining, and county agencies for developing effective water quality management programs for heavy metal contaminated sites.

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Determination of Atmospheric Ammonia and Ambient Particulate Behavior in Cache Valley, Utah

Principal Investigator(s):
Randal S. Martin
Philip Silva
Dongzi (Davis) Zhu

Project Description:

The levels of particulate matter less than 2.5 microns (PM2.5) in Cache Valley's ambient air has exceed the soon-to-be-regulated National Ambient Air Quality Standard (65 $\mu g/m^3$) in each of the past two winters. The Logan site measured the highest concentrations in the state in both 2001 and 2002 (88 and 138 $\mu g/m^3$, respectively). A third year would cause the area to be classified as a non-attainment area and federal sanctions could be applied.

The determination of the sources/causes of these elevated levels is, therefore, of great interest to local and regional regulators and scientists. The goal of this project, therefore, is to determine the composition and valley-wide behavior of the PM2.5 particulate matter and, thereby, estimate the various source strengths. This would, in turn, allow elected officials and regulators to identify and implement the most efficient and effective remediation strategies.

Work conducted during the winters of 2000/2001 and 2001/2002 by Dr. Martin and colleagues with Utah's Division of Air Quality (DAQ) has found that the chemical composition of the PM2.5 can be broken down into five broad classes: light absorbing carbon (3-6%), organic carbon (16-19%), soils/metals (1-2%), sulfates (9-21%), and nitrates (43-59%). The sulfates and nitrates are typically associated with combustion, the latter especially associated with vehicular emissions. Chemically, sulfates and nitrates actually exist in the particulate phase as their ammonium salts. It is equally important to understand the atmospheric ammonia budget of Cache Valley to determine whether the basic component (NH_3) or the acidic components (NO_3 and SO_4) are the formation limiting species. Given the agricultural nature of Cache Valley, there could be an abundance of atmospheric ammonia.

Accomplishments (FY 2003):

Using MLF funds supplied via the Utah Water Research Laboratory (UWRL), several subprojects were initiated. The operation of a PM10 and PM2.5 sampling station established in Smithfield, UT, approximately 10 miles north of the DAQ Logan City sampling location, was continued. This site has shown that the particulate problems are not centered in Logan, but are a homogeneous problem throughout the Valley. This is especially true during the high-concentration periods associated with January and February inversion episodes. Related to this study, a more valley-wide particulate study was initiated in the Fall of 2002 and continued through the Winter months of 2003. Five portable AirMetric PM10 samplers on loan from the DAQ were deployed at additional sampling locations throughout Cache Valley, including the Utah State University (USU) campus, the American West Heritage Center (AWHC), Evan's Farm (Nibley), the Cache Valley Hunter Education Center, and Newton. The data showed that, within a 95% confidence interval, the winter-long PM10 concentrations were equivalent throughout the valley. The two exceptions were the AWHC site and the Smithfield site, which showed slightly higher and slightly lower concentrations, respectively.

Indicating that the Cache Valley particulate problem is most likely indeed a valley-wide problem a more exhaustive PM2.5 study was initiated in the Fall of 2003. Approximately 20 portable PM2.5 and PM10 samplers, as well as some additional funding support, were obtained from the DAQ and the samplers were deployed beginning in November 2003.

The operation of the atmospheric ammonia sampling system established October 2002 at the DAQ's Logan City sampling site was continued throughout 2003. To date, the sampling and analysis have shown the highest ambient NH_3 concentrations on the order of 20 ppb, occurring during the periods of elevated PM2.5 concentrations. The lower concentrations, which occurred during the summer months, were on the order of 5 ppb. It should be noted that even the lower values are equivalent to concentrations reported by other investigators for highly agricultural areas. An Environmental Engineering M.S. student (Dongzi Zhu), brought into the project in the Fall of 2002, has continually progressed with the research project and his other degree requirements.

Another project initiated in 2003 was the establishment of a vertical temperature network for Cache Valley. As noted previously, the frequent inversions within the Valley are significant contributors to the area's wintertime particulate problems. An inversion is physically defined as a positive change in temperature with altitude and it is the vertical location of this temperature shift which determines the height of a particular inversion and thereby the volume in which pollutants can be trapped. The elevation, frequency, and persistency of inversions are keys to understanding the local pollutant concentrations. With the aid of undergraduate researchers, a series of temperature loggers were deployed from the Valley floor up along the vertically steep Dry Canyon/Logan Canyon. Semi-monthly collection of the recorded data was initiated in March of 2003 and has shown clear evidence of the timing and elevation of several inversions.

Work Plan (FY 2004 and FY 2005):

Particulate sampling will continue at the Smithfield site on the current 1-in-6 day schedule. The Cache Valley PM2.5 and PM10 saturation (AirMetircs) study will continue through the "high" particle season, generally through the end of February. The ammonia sampling will continue on the same schedule as the Smithfield samples. Additionally, the vertical temperature profile compilation and analysis will continue.

Benefits to the State:

A more complete understanding of the sources and behaviors of Cache Valley ambient particles will directly benefit the State of Utah by providing detailed information to the relevant authorities in order for them to make the best possible decisions regarding future remediation schemes. USU would benefit not only through the establishment of a successful research program (especially beneficial if the cooperative proposal is funded), but also through the support of both graduate and undergraduate students. Utah State University has reaped indirect benefits associated with this project via contacts established with Utah's Division of Air Quality in the form of donated research and teaching equipment, contacts for future employment of students, and presentations of graduate seminars by state personnel. Furthermore, Kori Moore, an undergraduate research student working on the vertical temperature profile studies will present some of the data at the "Poster On The Hill" presentations at the State Capitol in January of 2004, and will likely present the final results at a national convention in June of 2004.

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Evaluating the Uptake of Nonylphenol and Nonylphenol Ethoxylates by Crested Wheatgrass

Principal Investigator(s):
William J. Doucette
Bryan Wheeler
Julie Chard
Ronald C. Sims
Bruce Bugbee

Project Description:

Nonylphenol ethoxylates (NPEs) are widely used surfactants that are commonly disposed of in wastewater collection systems in Utah. NPEs are subject to biological treatment within wastewater treatment facilities, but measurable amounts of untreated NPE and biodegradation intermediates such as nonylphenol (NP) have been identified in digested sewage biosolids. These biosolids are often applied to agricultural soils for their nutrient value. Further biodegradation of NPE and NP within the soil/biosolids system has been observed, but little is known about the potential of plants to take up these compounds or their metabolites.

Accomplishments (FY 2003):

Hydroponic experiments were conducted to examine the uptake and translocation of NP, NPE_4, and NPE_9 by crested wheatgrass (*Agropyron cristatum*). The uptake of phenol was also evaluated for comparison. Plants were exposed to NP, NPE_4, NPE_9, or phenol (^{14}C and unlabeled) for 11-14 weeks. Plant tissue was analyzed for ^{14}C and for the parent compounds. Rhizosphere mineralization was quantified via $^{14}CO_2$ production. The majority of the plant-associated ^{14}C was in the roots (NP = 98%, NPE_4 = 92% and NPE_9 = 81%). Carbon-14 concentrations in the foliar tissue ranged from $2.0x10^{-6}$ to $4.5x10^{-5}$ mg-equivalent per g (dry weight) but no parent compounds were detected, implying that the ^{14}C was transformed or unextractable. Little mineralization was observed for NP, NPE_4, and NPE_9; however, for phenol 11-21% of the added ^{14}C was mineralized. Experiments also showed that root desorption was restricted, either kinetically or by increased binding. The results demonstrate that root-to-shoot transfer of these contaminants is small and the association with roots may reduce the mobility of these contaminants in the presence of plants.

Work Plan (FY 2004 and FY 2005):

The fate of NP, NPE_4, NPE_9, and phenol within a plant/biosolid/soil system will be investigated using a series of greenhouse microcosm experiments. Microcosms containing a mixture of biosolids and soil will be spiked with ^{14}C-labeled NP, NPE_4, NPE_9, and phenol. Concentrations of ^{14}C and parent compound will be monitored over time to determine the extent and rate of degradation within the microcosms. Planted, unplanted and unplanted poisoned microcosms will be used to evaluate the impact of plants on the degradation of NP, NPE_4, NPE_9, and phenol. Plant tissue samples will also be collected and analyzed to determine if there is any significant uptake of the contaminants.

Benefits to the State:

Quantitative information regarding potential plant uptake and transfer of NP and other surfactant-related compounds into plant foliar tissue is needed by the State of Utah to determine appropriate loading rates for the land application of municipal sewage sludge (biosolids). The Utah Water Research Laboratory is collaborating with the Utah Department of Environmental Quality (UDEQ), Division of Water Quality, to identify land application sites for sampling and analysis. The information developed in this project will be provided to the UDEQ.

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Field Scale Bioremediation: Relationship of Parent Compound Disappearance to Humification, Mineralization, Leaching, and Volatilization of Transformation Intermediates

Principal Investigator(s):

Ronald C. Sims
Darwin L. Sorensen
Joan E. McLean
Judith L. Sims
J. Karl Nieman
Yanna Liang
Kevin Hall

Project Description:

This year we completed Phase II of the project to design and develop a gene probe that can be used for soil bioremediation in Utah. The gene probe can be used for: (1) determining the presence of polycyclic aromatic hydrocarbons (PAH) degrading microorganisms at a site, (2) monitoring the rate and extent of bioremediation at a site, and (3) determining the effect of nutrients and other management tools for increasing the presence of PAH-degrading microorganisms at a site. Last year we initiated this project with the goal of developing a genetic probe. There is also a potential problem of intermediate chemicals produced when parent chemicals are degraded through microbial processes. The identification and characterization of intermediates is important to determine whether one or more present a problem with regard to soil, air, or water (surface and ground water) contamination.

Accomplishments (FY 2003):

The gene probe has been developed and we are in the process of discussion with environmental consulting forms to use the gene probe in site evaluations.

We have identified several intermediates produced in the metabolism of carcinogenic polycyclic aromatic hydrocarbons (PAHs) by the newly characterized mycobacteria JLS, KMS, and MCS. The intermediates identified are more water soluble and appear to be more degradable than the parent model compound (pyrene). However, a newly identified intermediate (a quinone of pyrene) may be more persistent in the environment, and we are currently assessing the degradability of the quinone form and its distribution between water and soil solid phases to determine its fate in the environment.

We have discovered that, although a compound can disappear from the water phase, the compound or intermediate may become adsorbed to the soil solids and have a positive response on an indicator toxicity test. The solid phase toxicity was tested using the Finland Flash Assay. It was found that toxic forms in the water can become associated with the soil solids, and that treatment using microorganisms to biodegrade the adsorbed chemicals may reduce the toxicity.

Previous toxicity testing at regional and national scales was directed at the water (leachate and ground water) fraction, and did not include the soil solid particles that can be exposed to people and the environment as windborne dust. Results this year indicated that the solid particles of soil were detoxified by the prepared bed bioremediation system. The Finland Flash test is rapid and relatively inexpensive and shows great potential for application to Utah sites.

Work Plan (FY 2004 and FY 2005):

We plan to: (1) identify biomarkers, or intermediates, produced in PAH biodegradation that can be used for field confirmation of biodegradation as well as production of a potentially persistent compound that requires additional management; (2) evaluate the soil solid phase Finland Flask test for additional soil samples from other sites to determine the rate and extent of treatment of hazardous chemicals associated with the soil solid particles; (3) evaluate composting and land application for effects on intermediates and soil solids treatment. This may also apply to wastes classified as "nonhazardous," and includes municipal biosolids, manures, and industrial sludges.

Benefits to the State:

Results of these applied research investigations are directed at faster, better, and less costly monitoring methods for ensuring protection of public health and the environment. Our information also will provide Utah engineers, managers, and regulators involved with soil bioremediation technologies with tools for more rapid and less costly treatment using soil prepared bed systems, biopiles, and compost systems. The ultimate goal for benefit to the state is to provide more cost-effective and efficient tools for managing industrial residues within a sustainable context.

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Health Risk-Based Economic Framework to Assess Pesticide Management

Principal Investigator(s):
Jagath J. Kaluarachchi
Aklilu Tesfamichael

Project Description:

Pesticides are important to increase crop productivity and provide economic benefits to the agricultural community. Pesticides are also harmful to human health over long-term exposure through direct contact to farm workers and indirect exposure to the general public through the food chain. There is debate between environmentalists and the farming community to assess the need to use certain pesticides due to their inherent toxicity to human health and risk versus economic benefits to society. Banning highly toxic pesticides may reduce health risks to society, however, such banning may affect local economies that have limited alternatives for economic survival.

The goal of this work is to develop a detailed health risk-based economic decision analysis framework that can be used to evaluate the cost and benefits of banning a given pesticide and the corresponding pros and cons of introducing another pesticide with less toxicity to replace the initial pesticide.

Accomplishments (FY 2003):

A methodology to assess the uncertainty of pesticide residue data in drinking water risk assessment was completed and a manuscript is in progress. The results of this work were presented in the Annual American Water Resources Association (AWRA) conference in San Diego, CA in November 2003.

Work Plan (FY 2004 and FY 2005):

A regression methodology to determine the pesticide residue of substitute pesticides is currently being developed. This methodology can be used to estimate the probable residue of alternate pesticides that farmers may use in the case of banning atrazine from the market. We also propose to develop an economic analysis to determine the probable economic cost to society especially to the agricultural sector due to the potential banning of atrazine.

Benefits to the State:

Utah is a state that depends heavily on agricultural activities. The use of pesticides is common and also the corresponding health risks are always present due to the application of pesticides. The results will benefit the agricultural community. The community will be made aware of costs, risks, and benefits of using pesticides both on short-term and long-term time scales. Results of this study will be presented to the Utah Department of Agriculture.

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Human Health Risk-Based Decision-Analysis at Hazardous Waste Contaminated Sites

Principal Investigator(s):
Jagath J. Kaluarachchi
Ibrahim Khadam

Project Description:

Previous research work conducted by the Utah Water Research Laboratory (UWRL) has found that variability of population characteristics and uncertainty of hydrogeologic properties can affect risk assessment results and corresponding cleanup strategies. Although this work developed a probabilistic approach to incorporate population characteristics and uncertainty of hydrogeologic properties, the framework does not address the true economic cost of a contamination event to the society. In real-world economic analysis, economic costs and benefits due to a contamination event and associated cleanup should be considered while ensuring the public health of the exposed community. Such a task can only be accomplished through a rigorous decision-analysis framework incorporating costs, benefits, and health risks to the community.

The aim of this research project is to develop a comprehensive decision-analysis framework incorporating costs due to a potential health risk to the exposed community, cleanup costs, and social benefits.

Accomplishments (FY 2003):

A comprehensive risk-based decision analysis framework was developed to illustrate the importance of addressing the economic cost and public health in decision-making related to hazardous waste contaminated sites. The results of this research was published in two journal manuscripts recently, and also presented in two scientific conferences.

A MS thesis from this work was completed.

Work Plan (FY 2004 and FY 2005):

No work is planned for the next year.

Benefits to the State:

Utah has many contaminated ground water sites that need immediate attention for cleanup. As cleanup of contaminated ground water can be costly and time-consuming, it is important to develop cleanup strategies that consider the true economic costs to society while preserving public health. Although risk assessment and developing cleanup strategies based on health risks are superior to the MCL-based approach, the true economic impact to society is not considered in this approach. A

decision-analysis framework such as the one proposed from this study provides a broad view of the problem to environmental managers such that more effective economic decisions can be made. We believe that the results from this study can be directly used at different contaminated sites in Utah for developing improved decisions related to cleanup, especially in the current economic downturn in Utah.

Remediation of TCE-Contaminated Groundwater at Hill AFB

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

Project Description:

This project evaluated several different methods for degrading trichloroethylene (TCE), a commonly-used solvent and a human carcinogen. Dr. Laurie McNeill's involvement included using several analytical techniques to characterize the zero-valent iron used to degrade the TCE in-situ into harmless byproducts.

Accomplishments (FY 2003):

The project was completed in FY 2003, and the final report was submitted to the funding agency.

Work Plan (FY 2004 and FY 2005):

Report completed.

Benefits to the State:

There are many contamination plumes at Hill Air Force Base, including some with trichloroethylene (TCE). This project evaluated changes in the morphology and composition of zero-valent iron (ZVI) that had been used to degrade TCE. The results will help Hill Air Force Base evaluate how the ZVI that is installed in an underground permeable reactive barrier may change in volume and reactivity, which will impact the useful treatment life of the installed barrier.

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Uptake of TCE by Apple and Peach Trees and their Fruit Near Hill Air Force Base

Principal Investigator(s):
William J. Doucette
Bruce Bugbee
Coreen Crouch
Mike Petersen

Project Description:

Trichloroethylene (TCE) contaminated groundwater originating from Hill Air Force Base (HAFB) in northern Utah has migrated into surrounding communities. Concern among base officials and local residents regarding the potential for TCE uptake and translocation into edible fruits prompted an initial field survey in Fall 2001 where approximately 200 samples were collected (including replicates) from fruit trees and other vegetation above historical plume boundaries. Using headspace gas chromatography with electron capture detection (GC/ECD), TCE was detected in several fruit and tree core samples. The identity of TCE was confirmed on a subset of samples using headspace gas chromatography/mass spectrometry (GC/MS) operated in selected ion monitoring (SIM) mode. A more rigorous follow-up study was conducted in Fall 2002 to determine if the TCE identified in trees and fruit during the previous year was representative of a continuing problem or was a one-time occurrence.

Accomplishments (FY 2003):

Prior to the 2002 follow-up study, the headspace GC/MS method was validated specifically for apples, peaches, tomatoes and carrots. In Fall 2002, over 400 samples were collected (including replicates) from six communities surrounding HAFB. No TCE was found in any of the fruit or vegetable samples above the method detection limit (approximately 0.1 mg/kg fresh weight, depending on sample size) but TCE was again detected in several fruit tree core samples. The apparent difference between the 2001 and 2002 results may be from an improvement in data quality or from changes in the environmental conditions associated with transfer of TCE into fruit. Continued monitoring is planned for Fall 2003 in addition to a greenhouse uptake study using [^{14}C]TCE.

Work Plan (FY 2004 and FY 2005):

Continued monitoring is planned for Fall 2003 in addition to a greenhouse uptake study using [^{14}C]TCE to better understand the mechanisms of TCE accumulation in edible fruit.

Benefits to the State:

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

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Water Quality Engineering

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Water Quality Engineering

Project Name	FY 2003 Actual Expenditures	FY 2004 Budgeted Expenditures	FY 2005 Planned Expenditures
A Field Measurement Test for Arsenic in Drinking Water	$23,284.85	$5,821.21	$0.00
Assessment of the Treatment of Landfill Leachate and Lagoon Effluent in Constructed Wetlands Systems	$4,396.88	$5,000.00	$5,100.00
Development of Sediment Management Protocols for Small Diversion Reservoirs in Utah	$597.29	$25,000.00	$30,000.00
Parameter Uncertainty in Modeling Pesticide Runoff from Small Watersheds	$3,451.62	$0.00	$0.00
Partnership with the Utah Water Quality Alliance	$1,736.56	$11,736.56	$0.00
Source Water Protection Tools Development	$47,599.22	$35,699.42	$0.00
Uinta River Basin Water Management Study	$1,390.00	$231.67	$0.00
Utah On-Site Wastewater Treatment Training Program	$38,822.57	$45,000.00	$55,000.00
Weber/Ogden Basin Water Quality Study	$14,164.61	$0.00	$0.00
Designated Amount for FY04/FY05 Research Projects		$0.00	$10,000.00
Undesignated research projects in program area		$0.00	$13,000.00
Total	**$135,443.60**	**$128,488.85**	**$113,100.00**

A Field Measurement Test for Arsenic in Drinking Water

Principal Investigator(s):
Laurie McNeill

Project Description:

Due to increasing concern about the adverse health effects from exposure to low levels of arsenic in drinking water, the United States Environmental Protection Agency (USEPA) has lowered the Maximum Contaminant Level (MCL) for arsenic from 50 ppb down to 10 ppb. Utilities trying to meet the new MCL must be able to accurately measure arsenic concentrations in their raw and treated water. Although there are well-established laboratory methods for quantifying arsenic at concentrations less than 1 ppb, they require instrumentation that is expensive, complicated and not available at the typical utility. In fact, most water treatment utilities, especially the smaller utilities that will be most affected by the new arsenic MCL, must send samples off-site to a contract or state laboratory for arsenic analysis. This is not only expensive, but can also make it difficult for a utility to optimize arsenic removal due to the time lag between collecting a sample and receiving the analytical results. The goal of this project is to develop a fast, safe, easy-to-use and relatively inexpensive field test that can quantify arsenic at the low ppb level. The methods being investigated are based on standard hydride generation followed by arsine detection with a portable gas monitor.

Accomplishments (FY 2003):

The laboratory work and field testing for this project were completed in FY 2003. Results from the project were presented at the AWWA Water Quality Technology Conference in November 2002. The M.S. student working on the project completed his thesis and is now employed.

Work Plan (FY 2004 and FY 2005):

The final report will be submitted to the funding agency, and a manuscript is in preparation for publication in a peer-reviewed journal.

Benefits to the State:

The State of Utah will be particularly hard hit by the new arsenic regulation, with an estimated 50 water systems impacted by the new MCL. The estimated cost of compliance with the new rule for the State of Utah is $63 million. The vast majority of the impacted utilities are small groundwater systems that have little or no treatment in place, so meeting the new MCL may be very complicated and expensive. Four Utah water utilities (Metropolitan Water District of Salt Lake and Sandy, Taylorsville-Bennion Improvement District, Eagle Mountain Water System, and City of Delta) were among the eleven utilities who tested the field detection method at their plant. This testing provided method validation for the project and also provided the utilities with free, instantaneous arsenic analysis in their water. Dr. McNeill will work with the Utah Division of Drinking Water, the Utah Rural Water Association, and the Utah Water Quality Alliance to offer this developed field method for Utah water utilities wishing to use it.

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Assessment of the Treatment of Landfill Leachate and Lagoon Effluent in Constructed Wetlands Systems

Principal Investigator(s):

R. Ryan Dupont
Joan E. McLean
Matthew Perry
Ashraf Shaqadan

Project Description:

This project was initiated to assist the City of Logan in evaluating constructed wetland treatment systems for both leachate from the City's 85 acre Subtitle D landfill, and for polishing and as an alternative to chlorination for the effluent from the City's wastewater treatment lagoons. Leachate from the City's landfill is currently being transported via tanker truck to its wastewater treatment lagoons, a practice that is both expensive and potentially the cause of future discharge violations from the lagoons. Constructed wetland treatment systems have been used in municipal wastewater treatment applications, but few have been designed and operated in the Intermountain West, including Utah, and fewer still have been designed for the treatment of sanitary landfill leachate treatment. Logan City is also concerned with nutrient effluent violations from the current wastewater treatment lagoons, and with the future prospect of dechlorination of its lagoon effluent following disinfection to meet stream aquatic life protection standards.

This project was designed to provide the City of Logan with information for the application of constructed wetlands for the treatment of metals, nutrients, and dissolved organics within the landfill leachate, and for the removal of residual organic contamination, nutrients, solids, metals, and coliform bacteria in unchlorinated, secondary effluent from the Logan lagoons. In addition, an assessment was made of the removal mechanism(s) taking place for these contaminants of interest through the pilot wetland systems using analyses of water, soil, and plant samples to carry out mass balance calculations.

Accomplishments (FY 2003):

Based on the success of both leachate and lagoon effluent by laboratory scale constructed wetland treatment systems operated at the Utah Water Research Laboratory (UWRL), Logan City implemented the design and construction for both systems. As part of the design and construction permitting process for the landfill leachate wetland treatment system, the UWRL generated a Quality Assurance Project Plan (QAPP) for use in the sampling and monitoring of the performance of the constructed wetland in treating Logan landfill leachate. This QAPP detailed sampling and analysis methods for both conventional physical/chemical measurements, as well as biological measurements that are to be made to detail the biological diversity and functionality of the wetland treatment unit. The wetland treatment system for Logan landfill leachate was still under construction at the end of FY 2003, but is scheduled to begin leachate treatment in the winter of 2003-2004.

A Sampling and Analysis Plan (SAP) for the chemical and biological monitoring of the large wetland treatment system Logan City has constructed for its wastewater lagoon effluent was submitted to the City for consideration early in FY 2000, but due to budget constraints in Logan City, this SAP has not been funded.

Work Plan (FY 2004 and FY 2005):

Future support of the City of Logan's efforts in the monitoring and optimization of these wetland treatment systems is anticipated, but no projects or proposals with the City are current. It is hoped that the UWRL can provide technical assistance in some form to the City of Logan so that comprehensive, full-scale wetland treatment system performance for wastewater polishing in the Northern Utah climate can be clearly documented over multiple growing seasons. Discussions will continue with the City of Logan, and alternative funding opportunities will be pursued with them during FY 2004.

Benefits to the State:

The findings of a previous UWRL study led to a decision by the City of Logan to implement wetland treatment for both the Logan lagoon effluent as well as the landfill leachate. Design of both systems was made possible from the data collected in this UWRL study, and construction of the both treatment systems which are to be both fully operational early FY 2004, are a direct result of UWRL research. The City of Logan has realized a significant savings ($30+ million in capital cost, $1+ million in annual O&M costs) in the application of a wetland polishing system for both lagoon effluent and landfill leachate treatment compared to mechanical treatment system options.

The findings of the previous UWRL study and the effectiveness of the performance of these systems for the City of Logan are relevant to many other communities within the State of Utah that either require landfill leachate treatment or, more commonly, must provide polishing and disinfection of their wastewater effluent. With land still relatively inexpensive in the state, and with preliminary results showing that significant treatment efficiency can be provided using wetland systems for a wide range of organic and inorganic contaminants as well as bacteria, wetland treatment could represent a significant cost savings to communities across Utah, providing effective protection of public health and environmental quality without the use of expensive and hazardous disinfection chemicals and with minimal energy inputs compared with energy requirements of most mechanical treatment plants.

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Development of Sediment Management Protocols for Small Diversion Reservoirs in Utah

Principal Investigator(s):
Mac McKee
Blake Tullis
Ronald C. Sims
Thirumurugan Bose

Project Description:

Uncontrolled sediment releases from small reservoirs have been shown to produce deleterious impacts on downstream fish populations and their habitat. This is a significant non-point source water quality problem in Utah and around the west. The purpose of this project is to develop and disseminate management guidelines for the flushing of sediments from small reservoirs to minimize environmental impacts on water quality and aquatic resources, with emphasis on reservoirs located in regions with arid climates, such as Utah. These guidelines will be based on hydrology and geology of the watershed within which the reservoir is located, and on the hydraulic characteristics of the reservoir itself. The project will use First Dam, a small dam owned by Utah State University on the Logan River at the mouth of Logan Canyon, as a case study.

Accomplishments (FY 2003):

The project began in late FY 2003. It has focused thus far on an extensive literature review of reservoir flushing and sluicing approaches and on available models for evaluating sediment mobilization needs and methods in reservoirs.

Work Plan (FY 2004 and FY 2005):

Work in FY 2004 will focus on the development of an interim sediment management plan for First Dam. This will include the design and implementation of a water quality and stream flow monitoring program. The plan will be tested through controlled releases of sediment during spring runoff, and the effectiveness of these controls will be evaluated from monitoring data. The experience gained from sediment management experiments on First Dam will be used to develop guidelines for management of sediment in small diversion reservoirs in Utah.

Benefits to the State:

The knowledge gained from experimentation at First Dam will be used to prepare general guidelines appropriate for sediment management on the approximately 200 small reservoirs in Utah. These guidelines will address such factors as:

- Implications of watershed geology for water chemistry and sediment toxicity.
- Implications of watershed hydrology for sediment loading rates.
- Recommendations for most effective and/or least costly sediment control methodologies, based upon reservoir size, geomorphology, and bathymetry.
- Recommendations for flushing procedures, based on active reservoir volume, current morphologic characteristics of sediment deposits, inflow rates and discharge capacities, hydraulic limitations on control of outlet works, potential toxicity of bottom sediments, and downstream water quality regulations that must be met.

Dissemination in electronic and hard copy form of the general guidelines to Utah water resources agencies, river commissioners, water conservation districts, and dam owners and operators.

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Parameter Uncertainty in Modeling Pesticide Runoff from Small Watersheds

Principal Investigator(s):
Jagath J. Kaluarachchi
Soomodh Abraham

Project Description:

Pesticides are essential for optimal crop growth and to increase crop yield. However, most pesticides are harmful to human health and can produce transient or cumulative health effects. In order to develop sound pesticide management strategies, the fate and transport of pesticides in surface and ground water need to be understood and the influence of uncertainty of key parameters should be studied.

The aim of this research project is to assess the uncertainty of key physical, chemical, and biological parameters on predicting pesticides in runoff in small watersheds and the associated economic cost due to pesticide application. The uncertainty will be evaluated using a Bayesian network that integrates pesticide application with eventual contamination of surface water.

Accomplishments (FY 2003):

Uncertainty of model parameters in predicting the pesticide residue in runoff from agricultural watersheds was evaluated. The results showed some hydraulic parameters and chemical parameters can substantially affect the pesticide mass in surface runoff.

The research produced a MS thesis.

Work Plan (FY 2004 and FY 2005):

No work is proposed for next year.

Benefits to the State:

The State of Utah depends heavily on the income and contribution from an agricultural-based economy. Optimal pesticide usage is always recommended to preserve public health as well as to minimize economic losses due to excessive pesticide application. The methodology and the results derived from the demonstration examples of this work will provide useful information to agricultural extension specialists on the importance of optimal application of pesticides and the field variables controlling pesticide uptake and losses. The proposed methodology can be used by other researchers to address the economic costs due to various pesticides and crop combinations that are applicable to different areas and field conditions of Utah, and the results can be used in future agricultural practices.

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Partnership with the Utah Water Quality Alliance

Principal Investigator(s):
Laurie McNeill

Project Description:

Dr. Laurie McNeill has been working regularly with the Utah Water Quality Alliance, a coalition of the five large water districts in Utah, the Department of Environmental Quality (DEQ), and the Utah State Laboratory.

Accomplishments (FY 2003):

Through this partnership, ties have been established between the Alliance and Utah State University (USU). USU is now collaborating with several Alliance member utilities on research projects. Four students participated in the Alliance Annual Retreat in May 2003.

Work Plan (FY 2004 and FY 2005):

This is intended to be an ongoing partnership. Dr. McNeill will attend monthly meetings and will participate in other Alliance activities. USU students are also encouraged to participate.

Benefits to the State:

This partnership provides USU's technical expertise to the Utah Water Quality Alliance, and allows collaboration on relevant research projects that may benefit not only Alliance member utilities, but also all Utah water utilities. USU students are exposed to the "real world" of the drinking water industry, which improves their education and will eventually provide more qualified engineers to work for or with these Utah utilities.

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Source Water Protection Tools Development

Principal Investigator(s):
Darwin L. Sorensen
David G. Tarboton
Mariush W. Kemblowski
Saraubh Gogate
Qiang Shu
Eric Wahlstrom
David K. Stevens
Nancy Mesner
R. Ryan Dupont
Gilberto E. Urroz
Ronald C. Sims
Donald T. Jensen

Project Description:

The drinking water industry uses a multi-barrier approach to protecting the safety of drinking water that is distributed to the public. Assuring a safe source of untreated water is the first barrier. Drinking water utilities in Utah have finished the source water assessments required under the Safe Drinking Water Act Amendments of 1996. They now face the challenge of planning and implementing procedures for protecting and improving the safety of their source waters. Protective measures may be expensive and land use restrictions to protect water quality can decrease the potential for development. It is very important that source water assessments correctly identify potential risks and present a scientifically credible evaluation of the magnitude of the risk so that the monetary and social costs of protective management can be minimized. Simultaneously, management activities must effectively protect public health. It is vital that sound scientific principles are used to direct the assessment approach and that arbitrariness is avoided. We are developing a computer modeling-based source water protection assessment and planning tool that will help watershed managers appropriately apply the scientific principles of pollutant transport while maximizing the use of available information.

The tool includes a simplified exploratory hydrologic and pollutant transport model that retains indispensable mechanisms to provide managers with an assessment system with low data requirements. The model output is a first approximation of contaminant concentration at the drinking water treatment source point of diversion (POD). The model results may prompt questions about pollutant transport that can lead to an enhanced understanding of human activities and natural systems that influence unacceptable contamination risks. Major advantages of this modeling approach are that fundamental elements of watershed hydrology are included and arbitrary management boundaries are not used.

The development of geographic information systems (GIS) and digital elevation models (DEMs) has provided an unprecedented opportunity to describe the pathways of water movement in a watershed. Tarboton (1997) developed a procedure for the representation of flow direction and calculation of upslope areas using rectangular grid DEMs. This procedure has been included in the Terrain Analysis using Digital Elevation Models (TauDEM) software (Tarboton 2000; Tarboton 2003) that is used as a basis for the Surface Water Protection Assessment Tool (SWPAT) that is being developed. Overland flow and the transport of contaminants simulated in the assessment tool are routed using the surface flow model.

Visualization of the locations of potential contaminant sources relative to stream locations and topography within a watershed along with the possible route or routes of pollutant transport provides watershed managers with insight that can help in the risk ranking process and in selecting or designing pollution control mechanisms. GISs provide an elegant mechanism for displaying this kind of information as well as facilitating models for routing water and associated pollutants through the watershed to the drinking water treatment plant.

The tool assists the user in inventorying potential pollution sources within the watershed. We have essentially completed the development of the surface water transport portion of the model and have been focusing on groundwater transport processes.

Accomplishments (FY 2003):

The USGS ground water model, MODFLOW, and the companion ground water quality model MT3D have been interfaced with the graphical user interface of the computer program. This will allow users to evaluate the potential for contamination of well water used for drinking water. It will also allow them to consider the potential for contaminated ground water to degrade the quality of water in streams and reservoirs that may be diverted for drinking water treatment. This modeling capability will be compatible with the surface water program that was described by Moncur (2002). A detailed description of the tool was presented at the American Water Works Association Source Water Protection Symposium in January 2003.

A septic system inventory database was made functional and has been demonstrated for local health departments. The septic system database was developed in collaboration with the Tricounty Health Department headquartered in Roosevelt, Utah, and the Wasatch County Heath Department headquartered in Heber City, Utah.

Work Plan (FY 2004 and FY 2005):

A modeling component that simulates the transport of pollutants from surface water and from ground water through reservoirs is being developed and will be completed in the coming year. This model will simulate dispersion and dilution of dissolved and suspended pollutants and the potential for loss of suspended pollutants into reservoir sediments. It will also be capable of simulating degradation of pollutants within the reservoir and volatilization of pollutants from the surface.

Benefits to the State:

Utah drinking water systems and watershed managers may choose to use the tool to inform their decisions in the watershed protection planning process. As new industries or other developments are considered for drinking water source watersheds, this tool may be used to help assess the potential contamination resulting from these developments. Utah's steep, mountainous terrain and high intensity rainfall and snowmelt potential create a risk of rapid movement of water and pollutants through a watershed to a drinking water system. Management of this risk requires the use of a scientific, topography- and hydrology-dependent pollution potential assessment tool for drinking water sources. The septic system database will enable individual local health departments to computerize on-site wastewater treatment information access. It will enhance their ability to properly inventory and safely expand the use of on-site wastewater treatment systems within their jurisdictions.

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Uinta River Basin Water Management Study

Principal Investigator(s):
Trevor C. Hughes
David K. Stevens
Lloyd Austin, Utah Division of Water Resources
David Cole, Utah Division of Water Resources
Steve Noyes, U.S. Bureau of Reclamation
Jeff Horsburgh

Project Description:

Increased pressures are developing for uses of the finite water supply in the Uinta Basin in Northeastern Utah which require improving levels of water quality. Our objective is to develop a two-phase approach to water management, data analysis, and water quality modeling for the Uinta River Basin, described below. Our work will be integrated with the efforts of other study team members by the U.S. Bureau of Reclamation (USBR) and cooperating local, state, and federal agencies and will build naturally upon similar efforts for water management improvement in the Uinta Basin.

Utah State University's (USU) role, in conjunction with the U.S. Bureau of Reclamation, Uinta Basin Water Conservancy District, and the State of Utah Departments of Environmental Quality and Division of Wildlife Resources, is to provide expertise in development of computer-based decision support tools, data storage and analysis techniques, and models for water quality prediction and improvement in the Uinta River.

Phase I - Data Collection and Analysis and Work Plan Development.

Phase I provided an overview of historical and existing data sources of water quality, flows, reservoir and diversion operations, and previous modeling efforts within the project area. The review and synthesis of these data is intended to provide a framework under which specific modeling objectives can be formulated that match the anticipated needs of the participating agencies with existing or obtainable data requirements. We have assumed that USBR, UDWR, and UDWQ will participate in project data compilation. The Utah Water Research Laboratory (UWRL) will integrate the data sources into a comprehensive database for use by participating agencies and by the decision-support system. The product database will be upgradeable by all parties as new data become available through sampling and analysis.

The end product of Phase I entails the development of a specific study plan that clearly articulates the flow and water quality models for target reservoirs and stream reaches, modeled water quality constituents, and the time periods and time steps to be utilized. The study plan highlighted the specific approaches to be taken under Phase II which involves model integration, calibration, and verification procedures. The study plan also identified several different levels of modeling effort based on target objectives and the requirements for additional data collection efforts.

Phase II - Development of Water Quality Modeling Framework and Detail.

Based on the completion of Phase I, model identification, calibration, and verification was undertaken. A modeling framework, data analysis, and decision-support system was developed by the USBR, UDWR, and UDWQ, and UWRL for integrating water balance and stream and reservoir water quality models in the Ashley/Brush drainage. The State of Utah Department of Water Resources water balance model for the Uinta River system was incorporated as required. Stream and reservoir and quality models was integrated into the decision-support system.

Phase II involves the following tasks:

1. Incorporation of the State of Utah Department of Water Resources water balance model for the Uinta Basin.
2. Detailed study of the physical features of the stream reaches and reservoirs to build the geometric and hydraulic descriptions of these water bodies.
3. Collection of environmental data that drive the temperature regimes in each of the water bodies.
4. Collection of water quality data related metrics to be used as inputs to the stream and reservoir models.
5. Development of utility programs that extract information from one set of simulations for input into the next set for downstream reaches.
6. Development of the decision-support database and data analysis packages to include all stream reaches, lakes, and reservoirs.
7. Development of management assessment plans for Phase III.

Phase III - Evaluation of Alternative Operating and Management Plans.

Phase III will involve the evaluation of alternative operational and management strategies which specifically have the potential for increased protection or enhancement of water quality limited conditions within the basin. This effort will draw upon the results from both Phase I and Phase II which identify specific water quality problems and their mechanisms or sources. Evaluation of alternative scenarios will be constrained by both water delivery obligations under existing water rights any operational limitations imposed by existing facilities within the basin. Studies performed under Phase III will require participation and review by all team members. Study procedures, results, and conclusions will be presented in our contribution to the final study report, which is due to draft form by October 2000. Specific recommendations will also be provided on maintenance and/or enhancement opportunities within the basin.

Accomplishments (FY 2003):

Phase II of this project, data collection, assessment, and integration, was completed in FY 99. Phase III, model development, verification, and testing, was completed in FY 2001, under an extension to the original work plan to complete aquatic resource modeling efforts. In this phase, the decision-support system will be completed, scenario evaluation will be completed, and the final project report will be submitted at the end of Phase III in January 2003, during FY 2003.

Work Plan (FY 2004 and FY 2005):

Project completed.

Benefits to the State:

This project is being carried out in conjunction with the State of Utah, Divisions of Water Quality and Wildlife Resources, in addition to the U.S. Bureau of Reclamation. The results of this work will be a set of computer-based decision-support tools and models to aid the state and the entities in the Uinta Basin in managing basin stream flows to help maintain water quality, primarily for improving the operations and efficiency of irrigation systems using Uinta River water. The tools are being developed with an eye toward use of the system to other basins in Utah, such as the Provo, Sevier, and Price Basins in future studies.

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Utah On-Site Wastewater Treatment Training Program

Principal Investigator(s):
Judith L. Sims
Ronald C. Sims
Margaret M. Cashell
Richard Jex
Darwin L. Sorensen
Blake Tullis

Project Description:

In this project, statewide training addressing state-mandated certification of persons associated with and responsible for wastewater treatment for on-site (septic) systems is conducted and coordinated. Personnel who have been trained include local health department personnel, on-site system site evaluators, designers, and installers, and the general public with an interest in on-site wastewater treatment. In addition, the Director of the Utah Water Research Laboratory (UWRL), Dr. Ronald Sims, has provided assistance to the State of Utah with regard to on-site wastewater treatment issues as a member of the Utah Water Quality Board. Dr. Darwin Sorensen serves on the Weber-Morgan Health Department On-Site Wastewater Advisory Committee and is past chairman of the Utah On-Site Wastewater Association (UOWA). Ms. Judith Sims is presently serving as the chairman of the UOWA.

Conventional on-site wastewater treatment, consisting of a septic tank and a soil absorption field serving a single residence or business, accounts for about twelve percent of Utah's wastewater treatment systems. In six of the twelve Utah local health departments, this percentage is as high as 30 to 60 percent. About 2,000 new systems are added annually to the already 70,000 on-site systems operating in Utah.

Considering the high cost of centralized wastewater treatment, some experts have suggested that more should be done to encourage well-managed and effective on-site wastewater treatment. The U.S. Environmental Protection Agency (U.S.EPA) has also shown support for the long-term use of decentralized (on-site) wastewater treatment systems. Adequately protecting environmental health and enhancing homeowner 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.

Properly selected, designed, installed, and operated on-site wastewater treatment systems provide high levels of protection of human health and environmental quality. However, some systems do fail, with most of the documented failures of these systems occurring by discharge of effluent into saturated soils, backup into the house, or wastewater ponding on the soil surface. Systems are also considered to be failing if wastewater effluents high in nitrogen, phosphates, or pathogenic microorganisms reach surface or groundwater resources. Training of all those involved in wastewater treatment and disposal, i.e., those who evaluate a site to see if it is suitable for an on-site system, those who design and install the system, regulators who oversee the system, and homeowners who operate the system, will aid in the prevention of such failures.

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 groundwater. Current Utah rules allow the use of conventional septic tank systems as well as three 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, which require more management, will operate effectively.

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 to provide classroom and field (hands-on) training to Utah homeowners, regulators, designers, installers, pumpers, and other stakeholders in on-site wastewater treatment systems.

Accomplishments (FY 2003):

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 training provided by the Utah On-Site Wastewater Treatment Training Program. The certification program is funded through a $25.00 fee on each septic system permit issued in the State of Utah.

The certification program includes three levels:

Level I: Soil Evaluation and Percolation Testing

Level II: Design, Inspection, and Maintenance of Conventional Systems

Level III: Design, Operation, and Maintenance of Alternative Systems

During FY 2003, the following workshops in support of the certification program were held:

Level I: Heber, September, 2002; Richfield, October, 2002; Logan, April, 2003; and Cedar City, April, 2003

Level II: Heber, September, 2002; Richfield, October, 2002; Logan, April, 2003; and Cedar City, April, 2003

Level III: Logan, November, 2002 and May, 2003

During FY 2003, training program staff continued to participate in the establishment of an on-site wastewater treatment professional association (Utah On-Site Wastewater Association (UOWA)) to promote, facilitate, and elevate the professional development of individuals in the on-site industry and also to increase public awareness and education concerning on-site wastewater treatment issues. The third annual technical conference of the UOWA, with 85 participants, was held January 15-16, 2003 in Park City. A fall educational meeting of the UOWA was held in Springdale in October 2002 for 40 participants – this meeting was held in conjunction with the annual water quality symposium sponsored by the Utah League of Cities and Towns and the Utah Division of Water Quality. Both meetings were organized by staff of the Training Program. Judith Sims is serving as the 2003 chairman of the UOWA, Dr. Ron Sims is the past treasurer of the UOWA, and Dr. Darwin Sorensen is the past chairman-elect.

Grants from the Huntsman Environmental Research Center, the U.S Environmental Protection Agency 319 program, and Utah Kennecott Copper were used to continue construction of a physical demonstration site on the USU campus, where hands-on training with conventional and alternative on-site treatment systems can be provided. Training areas were developed for septic tanks, conventional systems, alternative systems, and site/soil evaluation techniques.

Work Plan (FY 2004 and FY 2005):

During FY 2004 and FY 2005, workshops will be presented as needed for the state certification program. Required workshops include: (1) Level I: Basic Site Evaluation Techniques and Percolation Testing for On-Site Wastewater Treatment, (2) Level II: Fundamentals of Conventional On-Site Wastewater Treatment Systems, and (3) Level III: Fundamentals of Alternative On-Site Wastewater Treatment Systems. Level I and Level II workshops will be held at various locations around the state so that conditions specific to different areas can be addressed during the workshops. Level III workshops are held at the physical demonstration site on the campus of Utah State University. In addition, Level III certification expires after two years, so Level III recertification workshops will also be conducted for those who need recertification.

During FY 2004 and FY 2005, training program activities will also focus on the development of educational brochures for homeowners, system designers and installers, and other decision-makers involved in on-site wastewater treatment. In cooperation with the U.S. Environmental Protection Agency and the Utah DEQ, the Program will also develop educational materials for students and teachers in Grades K-12 as well as for municipal officials. Training program staff members are also developing guidance for local boards of health, as they oversee on-site wastewater programs for local health departments.

In addition, during FY 2004 and FY 2005, training program staff will continue to participate in the development of the Utah On-Site Wastewater Association (UOWA). A spring educational conference will be held in Logan to demonstrate possible new technologies. The fourth annual technical conference of the UOWA will be held February 11-12, 2004 in Provo, UT.

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 training program will address these challenges through such means as workshops, newsletters, and educational brochures as well as developing educational tools for students and teachers.

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. Experience with and knowledge of alternative systems that can be utilized on such sites with unsuitable conditions is generally low in Utah. The Utah On-Site Wastewater Treatment Training Program will provide the necessary education to utilize alternative systems in an effective manner that will protect both public health and the environment.

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Weber/Ogden Basin Water Quality Study

Principal Investigator(s):
David K. Stevens
Thomas B. Hardy
Tao Hua
Rajan Phadnis
Yin Tong

Project Description:

One of the pressing issues in the Weber Basin in Utah is lake eutrophication from increased phosphorus and nitrogen from point and non-point sources. Population density and resultant sewage disposal is also causing increase in biological contamination in the surface and groundwater associated with numerous reservoirs.

The purpose of this study is to assist the State of Utah, local governments, and water districts in monitoring and understanding water quality in the Weber Basin. Specific water quality problems and their causes will be identified, and specific measures which should be implemented to preserve or enhance water quality will be determined. The study will result in a report documenting specific water quality problems and their causes and the procedures for implementing nonstructural or minimally structural solutions for preserving or improving water quality. Utah State University's (USU) role, in conjunction with the U.S. Bureau of Reclamation (USBR), Weber Basin Water Conservancy District (WBWCD), and the State of Utah Department of Environmental Quality (UDEQ), is to provide expertise in development of computer based decision support tools and models for water quality prediction and improvement in the Weber Basin.

Accomplishments (FY 2003):

In FY 01, Phase II of the new study was completed and Phase III was begun. Phase III encompassed the development of the water quality models and decision support tools outlined under Phase I. The theoretical basis, calibration, and any validation of the models developed under this phase were completed.

In FY 03, Phase III was completed. Phase IIl encompassed the development of the water quality models and decision support tools outlined under Phases I and II. The theoretical basis, calibration, and any validation of the models developed under this phase were completed and Phase III, investigation of the scenarios were also completed, culminating in a final project report at beginning of February 2004.

In FY 03, a request was made by the USBR to investigate modifications to the model and decision support package to allow for simultaneous partial releases from reservoirs that would more closely track the day-to-day operation of the Weber Basin system. After considerable effort, it was found that fundamental limitations in the water balance model preclude these modifications within the existing scope of work. Estimates are underway to determine the level of effort required to modify the water balance model for this purpose. Additional requests were made by the Weber Basin Water Conservancy District to modify the Decision Support software to allow for direct modification of flows

and water quality as model inputs at control points that were previously estimated from the database and upstream model simulations. A prototype of this modification has been completed and is in review by USBR and WBWCD. An outline of the final report has also been submitted for USBR review.

Work Plan (FY 2004 and FY 2005):

Work will be carried out by project PIs under a no-cost project extension to complete model modifications and final reporting.

Benefits to the State:

This project is being carried out in conjunction with the State of Utah, Division of Water Quality, Division of Fish and Wildlife, Weber Basin Water Conservancy District, in addition to the U.S. Bureau of Reclamation. The results of this work will be a set of computer-based decision support tools and models to aid the state and the entities in the Weber Basin in managing basin stream flows to help maintain water quality, primarily for improving the operations and efficiency of water treatment plants using Weber Basin water.

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Water Education and Technology Transfer

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

Project Name	FY 2003 Actual Expenditures	FY 2004 Budgeted Expenditures	FY 2005 Planned Expenditures
Development of Training Modules for the Utah On-Site Wastewater Treatment Demonstration Site	$25,099.31	$30,000.00	$0.00
Selection of Industrial Coatings Based on Environmental and Societal Impact Characteristics	$11,142.41	$10,150.00	$5,176.50
Statewide Nonpoint Source Pollution Education Related to On-Site Wastewater Treatment Systems	$4,610.32	$4,610.32	$1,152.58
Technical Support to Utah Attorney General's Office Related to DERR UST Site Litigation	$1,345.41	$672.71	$686.16
Designated Amount for FY04/FY05 Research Projects	$0.00	$0.00	$0.00
Undesignated research projects in program area	$0.00	$0.00	$15,000.00
Total	**$42,197.45**	**$45,433.03**	**$22,015.24**

Development of Training Modules for the Utah On-Site Wastewater Treatment Demonstration Site

Principal Investigator(s):
Judith L. Sims
Margaret M. Cashell
Richard Jex
Todd Wright
Blake Tullis
Darwin L. Sorensen

Project Description:

Centralized public wastewater treatment is often not an economical option in rural and remote areas. These areas must therefore use an on-site system to treat and dispose of their wastewater. In Utah, more than 70,000 on-site systems exist, serving about 12% of all households (about 300,000 people), and nearly 3500 systems are added annually. With Utah ranking among the top five states in population growth, on-site wastewater treatment is a growing concern and the need for professional training in sound wastewater treatment is a critical necessity.

These statewide challenges regarding the growth of small communities, sustainable development, and problems associated with existing on-site wastewater treatment systems led to the establishment of the Utah On-Site Wastewater Treatment Training Program in January 1998. The Utah Department of Environmental Quality (UDEQ) provided startup for funding of the Program. Additional matching funding was provided by the Utah Water Research Laboratory (UWRL) at Utah State University (USU). These funds were used to conduct workshops on the fundamentals of on-site wastewater treatment and disposal and site evaluation techniques, publish an educational newsletter, and prepare educational brochures.

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 training provided by the Utah On-Site Wastewater Treatment Training Program. The certification program is funded through a $25 fee on each septic system permit issued in the State of Utah. The certification program includes three levels: Level I: Soil Evaluation and Percolation Testing, Level II: Design, Inspection, and Maintenance of Conventional Systems, and Level III: Design, Operation, and Maintenance of Alternative Systems.

In this project, in support of the DEQ-sponsored certification program, the Utah On-Site Wastewater Treatment Training Program is developing a physical demonstration and training site at a 2-acre field site located near the Utah Water Research Laboratory on the campus of Utah State University. This site is used for training in the correct design, siting, installation, operation, maintenance, and troubleshooting of on-site wastewater treatment systems. Users of the site include on-site system installers, designers, regulators, students, land developers, and homeowners. Additional audiences may include equipment vendors, real estate agents, municipal authorities, elected officials, landscape architects, and septic tank manufacturers.

An initial grant from the Huntsman Environmental Research Center was used to prepare the site and install several educational modules. During this first phase of construction, we installed modules on 1) water conservation, 2) septic tanks, 3) conventional distribution systems, 4) trench and bed construction, and 5) pumping and electrical control systems. Other partners who supported the Phase I effort include Utah septic tank manufacturers and national vendors of on-site equipment, with donations of equipment and materials valued at $15,000.

In this project, we are continuing to construct Phase II of the physical demonstration and training site. Phase II consists of developing and installing the following educational modules:

1. Troubleshooting techniques.
2. Demonstration of appropriate construction techniques for Utah systems.
3. Installation of three advanced technology systems:
   - Sand filter system
   - Subsurface drip system
   - Peat filter system

Additional supplemental funding from the U.S. EPA 319 Non-Point Source Pollution Training and Demonstration Program is also being used in coordination with funds associated with this project to aid in the construction of the sand filter treatment system.

Accomplishments (FY 2003):

During FY 2003, we continued to install the troubleshooting educational module at the Demonstration and Training Site. On-site treatment and disposal systems often fail prematurely, and most individuals are not trained to adequately troubleshoot a system to determine its reason for failure. Specific troubleshooting problems addressed included hydraulic loading of an on-site system, wastewater distribution methods in the drain field, and leaky septic tanks.

In addition, during FY 2003, we continued to install the construction techniques educational module at the Demonstration and Training Site. The success of any on-site wastewater treatment system is dependent on appropriate construction techniques. We are demonstrating the effects of driving heavy equipment over a soil absorption area or installing a system when the soil is too wet, which results in compaction and smearing of the soil surface. We are also demonstrating how the soil surface can be regenerated by raking the surface and the importance of completing installation in a short period of time to reduce weather-related impact. Gravel size and cleanliness was also demonstrated.

Utah health departments have the opportunity to incorporate three alternative systems into their on-site programs. During FY 2003 we continued to incorporate construction techniques for these systems at the Site, with emphasis on preparing the soil surface under a mound system, vegetating a mound system, choosing adequate fill for both the mound system and the earth-fill systems, proper installation of chamber systems, finishing an at-grade system, and other concerns.

Work Plan (FY 2004 and FY 2005):

The project will be completed during FY 2004.

Three advanced technology systems will be installed at the Demonstration and Training Site during FY 2004. These systems, sand filter, subsurface drip, and peat filter systems, have been shown nationally to efficiently and economically produce high quality effluent. Although these systems are currently not allowed for use in Utah, training program staff in conjunction with representatives from local health departments have chosen these systems to demonstrate three of the many advanced technology systems that could be effective in Utah's arid and steep environments. These systems can be used on sites and soils that do not meet the criteria for conventional systems, including sites with high water tables, slowly permeable soils, and steep slopes. In addition, research has shown that both of these systems operate well in both hot and cold climates. These systems will be used not only for demonstration purposes, but will also be evaluated as to their usefulness in Utah.

Benefits to the State:

As population growth and associated housing developments continue to threaten the preservation of agricultural lands, 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 the continued development of the demonstration and training site on the campus of Utah State University, where education will be enhanced by "seeing and doing."

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Selection of Industrial Coatings Based on Environmental and Societal Impact Characteristics

Principal Investigator(s):
John Gershensen, Michigan Tech
R. Ryan Dupont
Richard Ratliff
Yu Ming
Revathi Pepalla

Project Description:

In this research project, a method is being developed for quickly comparing different industrial coating choices based on their environmental and societal impacts, and their performance in a given application. The method will expedite the selection of industrial coatings during conceptual design by developing a set of expressions that relate coating key performance criteria (abrasion resistance, hardness, corrosion resistance, chemical resistance, *etc.*) to environmental and societal impacts (human health effects, resource depletion, energy utilization, *etc*.). These performance-based relationships provide a common ground for choosing among similarly functioning alternatives and provide insight for minimizing the environmental burdens these coating alternatives represent. Final coating selections can then be made based upon their cost and their ability to minimize the magnitude of their environmental and societal impacts. These impact characteristics are chosen, not only for their importance in determining the environmental burden of the coating selection, but also for their auditability. The impact characteristic must be reliably quantifiable to insure the development of stable and meaningful relationships.

Design and manufacturing engineers need tools to allow them to weigh the environmental and societal impacts along with the cost of their component and process selection decisions early in the design process when information is scarce. While the proposed method is applicable to a wide range of manufacturing processes and products, industrial coatings were selected as the initial application for the development of the methodology due to the size of the coatings industry, the wide range of industries utilizing product and special purpose coatings, the wide range and large quantity of raw materials used in the production of commercial coatings, and the large variety of alternative coating methods that are available for analysis and alternative coating selection.

The selection process provides a rapid, quantitative methodology for identifying the most environmentally benign candidate for a given coating application, which minimizes energy and resource utilization, without conducting exhaustive analyses of the systems. The method is used during conceptual design and it is understood that traditional optimization of specifications should be used during embodiment design.

Accomplishments (FY 2003):

The technical focus of the second year of the project was in three areas: narrowing down the coating performance selection taxonomy from its complete structure of 2×10^9 elements to a much smaller subset of performance slices from which to select coatings to generate impact data; compilation of industrial coating information for coatings meeting the performance taxonomy requirements; and generating coating impact data from which to generate impact index values for the final coating selection process.

Coating Alternatives Taxonomy Refinement. As mentioned earlier, the final revision of the Coating Alternatives Taxonomy has 1.9×10^9 elements containing every possible combination of taxons linked together. However, not all of these taxon combinations are feasible. Therefore, many were "pruned" from the Coating Alternatives Taxonomy during FY 2003 based upon their infeasibility. Since the goal of the project is not to produce a comprehensively validated taxonomy but to demonstrate a method for relating performance variables to environmental impacts, this "pruned" taxonomy was used to generate a number of industrial "slices" of the complete Coating Alternatives Taxonomy for further validation purposes. Slices were generated for the basic coating performance criteria of: abrasion resistance, impact resistance, scrub resistance, heat resistance, and the water vapor transmission index. From these slices, a list of 90 coatings meeting the performance criteria were generated, and these lists of coatings (acrylics, epoxies, polyurethanes and urethanes) were used to generate environmental impact index values associated with each feasible coating.

Compilation of Industrial Coating Information. Once the coatings were identified, manufacturer's data regarding coating specifications, application recommendations, performance characteristics, etc., were compiled. Much of these data are available on-line from the major coating manufacturers, however, much is not, and students and faculty associated with the project contacted manufacturers directly to collect all necessary data for the impact calculation step. In addition, material safety data sheets (MSDSs) were compiled for coating components, and the USEPA, chemical property estimation software EPI Suite™ was used to estimate a chemical's physical, chemical, or toxicological properties if not available in the literature. All in all, chemical property and health and environmental risk data have been compiled or estimated for 130 compounds that represent the major hazardous components of the 90 test coatings.

Environmental Impact Calculations. Environmental impact index values have been generated for each coating from the Abrasion Resistance performance taxonomy based on life-cycle impact estimates that include: coating manufacturing, surface preparation, coating application, and coating removal. Coating use is normalized to a 1,000 ft^2 *functional unit* so that all coatings are compared on an equivalent basis. Environmental impacts at the global (ozone depletion potential, global warming potential, resource depletion), regional (acid precipitation, photochemical oxidant production) and local (human health toxicity, terrestrial toxicity, aquatic toxicity, land use) levels are estimated using index scores associated with a coating component's reactivity, toxicity, or resource demand, and these index scores are then normalized to allow valid comparison and selection of a coating generated from a given performance slice based on the minimal life-cycle environmental foot print.

Work Plan (FY 2004 and FY 2005):

Environmental impact indexes will be calculated for all coatings generated from the balance of the selected performance variable slices during FY 2004, and these results will be used to generate, in conjunction with the research team at Michigan Tech University, performance variable and coating specific performance versus environmental impact relationships. These performance versus environmental impact relationships are of interest in an effort to develop a predictive approach for estimating environmental impact for general classes of coatings. Both the performance taxonomy as well as the environmental impact taxonomy and database of impact values are being incorporated into a computerized expert system that will be completed during FY 2004.

Benefits to the State:

This project is intended to improve the selection of industrial coatings by design and manufacturing engineers by reducing the overall environmental, energy, and resource-use impact, their decision ultimately have. The product of this research will benefit the numerous users of industrial coatings in the public and private sector in the state, it can benefit manufacturers of coatings (e.g., Huntsman Chemical) by facilitating their evaluation of a coating's environmental impact during coating initial conceptual and final process design, and will benefit citizens within the entire state through improving environmental quality by facilitating the selection and use of coatings that minimize local and regional environmental impacts.

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Statewide Nonpoint Source Pollution Education Related to On-Site Wastewater Treatment Systems

Principal Investigator(s):
Darwin L. Sorensen
Judith L. Sims
Margaret M. Cashell

Project Description:

Local government officials, health department officials, and homeowners living in rural areas must respond to many technical and economic issues related to groundwater quality protection while providing for domestic wastewater treatment and disposal. It is very important that people in each of these groups are aware of the need to properly locate, install, and operate on-site wastewater treatment systems. This project is developing and implementing an information and education program that will provide elected officials, students, and the general public with on-site wastewater management information related to the prevention of non-point source pollution. The program is developing guidance, training tools, and a training course for planning and implementing on-site wastewater treatment so that nonpoint source pollution can be prevented. These materials are being developed for local government officials, homeowners, landowners and developers, and elementary school students.

Accomplishments (FY 2003):

Elementary school educators, especially fourth grade teachers, will be offered lesson plan materials about on-site wastewater treatment that can be integrated with the Utah core curriculum focus on Utah's natural history, the water cycle and soils. On-site wastewater treatment and nonpoint source pollution vignettes will be integrated into teacher inservice and professional development courses, including on-line access, offered through the International Office of Water Education (IOWE) at Utah State University (USU). Similar but more in-depth training will be offered for substitute teachers. Training for homeowners in the form of a "user's manual" for septic system owners is in the final stages of preparation. The National Association of Local Boards of Health has funded the preparation of a guide and video tape intended for training members of local boards of health on on-site wastewater treatment. These materials will be useful in finalizing the training materials for government personnel. Training for local officials will be offered through the Utah League of Cities and Towns.

Work Plan (FY 2004 and FY 2005):

Teacher training lessons and vignettes will be finalized and delivered to teachers. Short "presentations" or "courses" will be offered to city and county elected officials and their staff.

Benefits to the State:

When groundwater, and the surface water with which it interacts, becomes contaminated with pathogens, nitrate, and other pollutants from on-site wastewater disposal the environment is degraded and people's health and well-being is at risk. Elected officials in Utah's cities and counties are responsible for development planning and infrastructure management that can influence the proper location, design, installation and management of on-site wastewater treatment systems. Informed officials can make decisions about residential and business development patterns that will foster the protection of water quality. When more citizens of Utah understand the need for safe wastewater treatment and the risks to health and the environment of improper wastewater management they are more likely to choose to act in ways that will protect the quality of water resources and the health of the people of Utah.

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Technical Support to Utah Attorney General's Office Related to DERR UST Site Litigation

Principal Investigator(s):
R. Ryan Dupont

Project Description:

This project was initiated to provide technical assistance, site data analysis, file review, and expert witness support for state-initiated litigation to recover costs of site investigation and remediation at a free product release site in Milford, Utah. A technical opinion was requested regarding the nature and extent of soil and groundwater contamination and possible release history for free product at this Milford site. These technical opinions were provided based on a review of technical documents and chemical and pump test data available from the site.

Accomplishments (FY 2003):

A technical opinion was provided to the Attorney General's Office in support of cost recovery litigation that office was pursuing. Technical data review indicated that on-going releases appear to be occurring at the Milford site. A Work Plan and Budget was generated in response to a Work Assignment issued for chemical analysis of various free product samples collected from throughout the site to provide DEQ-expert opinion regarding the relationship, if any among these product samples collected from throughout the site. The pending litigation was settled and additional information regarding liability at the site was therefore no longer required.

Work Plan (FY 2004 and FY 2005):

This project was completed in FY 2003 and did not extend into FY 2004.

Benefits to the State:

Support to the State Attorney General's Office in pursuing cost recovery for site investigation and remediation activities throughout the State of Utah provided the office with improved estimates of liability and cost-recovery apportionment, and aided in the settlement of cost-recovery claims with reduced litigation costs. Owner liability was technically documented at this site through expert opinion where relative liability was in question, in direct support of the mission of the Utah Department of Environmental Quality (DEQ) and the State Attorney General's Office. Resolution of these liability questions also expedited remediation decisions, expediting the removal and control of contamination for the protection of public health and the environment throughout the State of Utah, particularly in the Milford area.

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Fluid Mechanics and Hydraulics

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Fluid Mechanics & Hydraulics

Project Name	FY 2003 Actual Expenditures	FY 2004 Budgeted Expenditures	FY 2005 Planned Expenditures
Hydraulic Design Data for Environmentally Sensitive Culvert Installations	$14,333.54	$14,500.00	$14,500.00
Hydraulic Performance of Labyrinth Weirs with Half-Round Crest for Unsubmerged and Submerged Conditions	$14,333.54	$14,500.00	$14,500.00
Hydraulic Structures for Flood Control and Flood Bypass	$14,554.27	$24,554.27	$25,045.36
Sedimentation, Erosion, and Flood Control	$12,706.11	$22,706.11	$23,160.23
Designated Amount for FY04/FY05 Research Projects			
Undesignated research projects in program area		$0.00	$0.00
Total	**$55,927.46**	**$76,260.38**	**$77,205.59**

Hydraulic Design Data for Environmentally Sensitive Culvert Installations

Principal Investigator(s):
Blake Tullis

Project Description:

Currently, very little design information is available for culvert designs for environmentally sensitive areas. It is becoming more common to design culverts, not based on the smallest diameter required to pass a design flow rate, but rather limit the maximum design velocity to facilitate fish and debris passage. The missing design information includes inlet and outlet loss coefficients for outlet-controlled flow and design flow curves for inlet-control. Commonly, these culverts have buried inverts or are bottomless. With this type of configuration, the determination of a representative Manning's n value (hydraulic roughness) becomes much more complicated as the channel walls and floor are made of different materials.

Accomplishments (FY 2003):

Conducted a thorough literature review to determine standard practices for environmentally-sensitive culvert installations and identify design data currently available.

Work Plan (FY 2004 and FY 2005):

We will focus on the following objectives:

- Evaluate the existence of size-scale effects with lab-scale culvert testing.
- Evaluate inlet loss coefficients and inlet control curves for buried invert culverts (fish passage culverts).
- Evaluate the performance of multi-barrel culverts to determine the appropriateness of superposition design methods.
- Evaluate predictive methods for composite roughness in rectangular channels and in circular culverts with buried inverts, with the goal of identifying a method that can be applied to fish passage culverts.

Benefits to the State:

Although Utah does not have a significant migratory fish population, fish habitat can be significantly reduced by a culvert, which inhibits fish passage. The need to facilitate natural debris passage may also become more important in the State of Utah as the need to maintain natural systems grows. In general, a design manual, which will function as supplement to the Federal Highways Administration's Hydraulic Design Study #5 (HDS-5), will be the final product of this study. It should prove a valuable resource for Utah Department of Transportation projects. Several Master's students are participating in this project.

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Hydraulic Performance of Labyrinth Weirs with Half-Round Crest for Unsubmerged and Submerged Conditions

Principal Investigator(s):
Blake Tullis

Project Description:

A significant amount of data has been collected at the Utah Water Research Laboratory (UWRL) and published regarding the hydraulic performance of labyrinth weirs with quarter-round (rounded on the upstream corner of the crest), but nothing has been published to date on half-round crests (rounded on both the upstream and downstream edges of the crest). At low water levels upstream of the labyrinth weir, the half-round crest is more efficient than the quarter-round due to the elimination of the sharp corner and subsequent flow separation. For many applications, maximized discharge capacity at low heads is a very important design parameter.

One concern about labyrinth weirs is that how sensitive their performance is to high tail water conditions (submergence). Submergence data for linear weirs has been published, but little information on labyrinth weir submergence.

Accomplishments (FY 2003):

A significant laboratory test program was carried out in FY 2003 at the Utah Water Research Laboratory using a 4-foot wide by 3-foot deep by 24-foot long experimental flume. Six different labyrinth weir designs were tested featuring side wall angles of 8, 10, 12, 15, 20, and 35 degrees. Each weir included two cycles. Rating curves were generated for each weir design for non-aerated, aerated, and vented nappe conditions. Submergence data were also collected for the 8 and 20 degree weirs. A masters student has also been working on this project.

Work Plan (FY 2004 and FY 2005):

We are currently working on a publication to be submitted to a professional journal. We are planning to collect some additional data to add to the publication, including a 7 degree weir, an 8 degree weir with a quasi-ogee crest profile, and the effects on the discharge capacity by decreasing the effective weir height through sediment deposition. Once the above referenced data have been collected and the paper has been accepted, the project will be complete.

Benefits to the State:

Labyrinth spillways are becoming more and more common with dam/spillway rehabilitation. This information will provide valuable data for engineers designing labyrinth spillways. This study also has wide value beyond the State of Utah.

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Hydraulic Structures for Flood Control and Flood Bypass

Principal Investigator(s):
William J. Rahmeyer

Project Description:

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 our 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 fusegate control structure was investigated as an alternative design to the more traditional and costly control structures such as radial gates. Fusegates are also a very attractive alternative for restoration of Utah's older and under-designed flood-control structures. The use of fusegates has been limited to applications in Europe and Asia. Only one application of fusegates has been used for flood control in Santa Fe, New Mexico. The year 2004 will see the first major application of a fusegate structure at Terminus Dam in California. Terminus Dam is almost complete and will be dedicated in March 2004. A second study of fusegate design was studied at the Utah Water Research Laboratory (UWRL) in 2003.

Another concept that was researched this year was the concept that utilizes bypass conduits to route excess flows around a section of channel or river. The bypass conduits utilize large control weirs that control the flood hydrographs and manage the sediment transport. There are a number of issues related to the bypass concept that have prohibited the use of bypass structures in Utah. A current study is focusing on the effects of bridge pier columns on flow diversion in flood channels. The construction of the bypass culverts for the Guadalupe River in downtown San Jose, CA are partially finished and should be complete in early 2004.

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. A unique design of a curved ogee crest utilizing an under-designed crest was modeled in 2003. It was found that the design increased pool elevation and increased flow capacity without the need to widen the diversion channels.

Accomplishments (FY 2003):

The fusegates were successfully tested, redesigned, retested, and evaluated for application in Utah and the United States. An international presentation was made last year that focused on flood control practices in Utah and the application of fusegates. Fusegates offer Utah a much more versatile and cost-effective design that allows increased flood control and flood storage with minimal environmental impact.

Detail data and laboratory measurements were made of the side channel lateral weirs used for bypass control. The weirs were analyzed for both flood control and for the effect of sediment diversion. A very unique design was created that allowed flood diversion and negated the effects of sediment deposition at the bypass structure. A student thesis was published based on this concept.

Another study was the effect of bridge or highway columns on flooding in floodplains and flood ways. The study included column geometry, the effect of debris trapped by the columns, and the effect of the columns on sediment transport and deposition. The results of this study have importance to Utah because of the need to add additional bridge columns or piers to existing stream crossings to accommodate the widening of Utah roads and highways.

A curved ogee crest was studied for the Success Dam near Porterville California. Several different designs and crest shapes were evaluated. An important concept that was investigated was the effect of reducing the peak outflow hydrograph of the reservoir by improving the efficiency of the crest at lower flowrates and reservoir levels.

Work Plan (FY 2004 and FY 2005):

Some of the largest physical models ever tested at the Utah Water Research Laboratory has been recently studied. The models have included fusegates, curved ogee crests, and river bypass culverts.

U.S. Army Corps of Engineers engineering manuals are planned on the use of lateral weirs and the use of curved ogee crests for flood and sediment control. Case studies will be submitted to the "Journal of Hydraulics" on the applications of lateral weirs for sediment control and the application of curved ogee crests for reducing peak outflows.

Benefits to the State:

The benefits to the state are identified in the Project Description Section. The fusegate structures and curved ogee crest spillways are of great interest to the Utah State Office of Dam Safety and to almost every county and water conservation district. The concept of flood bypass will have direct benefits to Utah communities for future impacts such as urban growth and new road or highway crossings.

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Sedimentation, Erosion, and Flood Control

Principal Investigator(s):
William J. Rahmeyer

Project Description:

Since 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.

Present knowledge and methodologies were 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.

Accomplishments (FY 2003):

Individual studies were conducted in the basic and fundamental hydraulics of sedimentation and erosion. Equations and methodologies were developed to predict the sediment transport in steep mountain streams and closed conduits. Work has been accomplished on the effect of vegetation in floodplains. A presentation at the Annual Utah Flood Plain Management Association (UFPMA) conference in St. George, Utah was made on the effect of the sedimentation process on erosion and deposition at culverts and road crossings. Dr. William Rahmeyer also made a presentation on measuring storm water in culverts per Phase II of EPA. A previous presentation on the effect of bridge crossing on floodplains was made at the UFPMA conference in Moab, Utah. Dr. Rahmeyer has been reelected to serve on the board of directors for the Utah Flood Plain Management Association.

Work Plan (FY 2004 and FY 2005):

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. A related subject is the effect of storm water release and management on floodplains. Papers and research initiation are planned in these areas.

Sediment transport equations and methods for the Utah Wasatch Mountain streams will continue to be developed. Additional work is planned for publications of the methods to predict the effects of vegetation resistance on floodplains.

Benefits to the State:

Direct benefits to the State of Utah will be from the knowledge and methodology gained from this 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.

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Ground Water

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Ground Water

Project Name	FY 2003 Actual Expenditures	FY 2004 Budgeted Expenditures	FY 2005 Planned Expenditures
Decision Support System Groundwater Quantity	$9,328.15	$19,328.15	$19,328.15
Fine-Scale Groundwater Modeling with the Hypercomputer	$6,622.37	$11,622.37	$11,622.37
Hydrologic Predictions with Support Vector Machines for Groundwater Monitoring	$9,455.36	$26,100.00	$26,100.00
Predicting Stream-Aquifer Interaction Using Artificial Neural Networks	$6,903.25	$0.00	$0.00
Designated Amount for FY04/FY05 Research Projects		$0.00	$0.00
Undesignated research projects in program area		$0.00	$0.00
Total	**$32,309.13**	**$57,050.52**	**$57,050.52**

Decision Support System Groundwater Quantity

Principal Investigator(s):
Mariush W. Kemblowski
Tirusew Asefa
Qiang Shu
Kashif Gill

Project Description:

For the last two years, we have been developing watershed management decision-support software (DSS) for self-sustained watershed management. This effort involves a large inter-disciplinary research group at the Utah Water Research Laboratory (UWRL). From the groundwater management viewpoint, the effects of the following management options are the DSS foci:

- Changing withdrawals from a surface water source to a groundwater source.
- Changing the distance (location) of a groundwater withdrawal from a stream (e.g., moving a well further away from the stream).
- Changing the amounts or timing of withdrawals from surface and groundwater sources.
- Development of additional groundwater recovery.
- Change of land use and cover.
- Potential to augment surface water low flow using regional ASR.
- Surface water infiltration management.

The software is currently being implemented in a pilot research project to develop optimal water management strategies for managing aquifer and stream-aquifer systems in the State of Washington. This effort is supported by a number of local governments in Washington State, and is a part of our long-term national research program concerned with self-sustained watershed management.

Accomplishments (FY 2003):

The basic architecture of the decision support system has been designed and is being tested. The emphasis is on the interconnectivity and mutual feedback among various DSS components, such as surface water quantity and quality, groundwater quantity and quality, and instream flow requirements. For example, the groundwater quantity (GWQn) module feeds to the surface water quantity (SWQn) module the current base flow and groundwater table conditions in a watershed. Based on that, the latter estimates effective recharge and "makes" decisions regarding surface and water use allocations. This information is in turn fed back to the GWQn module to simulate the groundwater regime for the next time step. Thus, the modules interact in an iterative, nonlinear manner.

At the implementation portion of the project, we have defined the aquifer system in Whatcom County, WA. A database with aquifer properties, well locations, and water rights, has been developed. The GWQn module has also been calibrated for steady state conditions.

Work Plan (FY 2004 and FY 2005):

In the next year, we will finalize the development of DSS and evaluate watershed development scenarios. We will also extend this approach to dealing with source water protection issues.

Benefits to the State:

We are in a very fortunate position, since the development of our watershed DSS is primarily supported by out-of-state funding. Also, in the ongoing process of initial testing and implementation, we are weeding out any software and scientific misrepresentations. Thus, by the end of FY 2003, we will be ready to efficiently implement these tools to the watersheds in the State of Utah, in collaboration with appropriate state agencies.

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Fine-Scale Groundwater Modeling with the Hypercomputer

Principal Investigator(s):
Gilberto E. Urroz

Project Description:

Development of a fine-scale flow and transport groundwater model using a new generation of fast, paralellized computers known as *hypercomputers*. The hypercomputer has been developed by *Starbridge Systems Inc.*, a Sandy, Utah-based company interested in collaborating with Utah universities to develop hypercomputer applications. The objective of this project is to develop an application aimed at the modeling of the fine structure of groundwater flow taking advantage of the extensive memory capacity and extremely fast computational speed of the hypercomputer. The model will be utilized to model flow and transport of a Utah aquifer--the Hill Air Force Base aquifer, in Davis County, Utah, being the best candidate.

Accomplishments (FY 2003):

Initiated contacts with *Starbridge Systems Inc.* to produce collaboration with researches at Utah State University (USU). Acquired hypercomputer software for future model development.

Work Plan (FY 2004 and FY 2005):

Will receive training in the use of the *Viva* hypercomputer software for programming purposes and model development, will identify a specific contaminant transport site for modeling, and will develop fine-scale groundwater flow and transport model for the hypercomputer.

Benefits to the State:

1. Better understanding and characterization of groundwater contamination problems utilizing a fine-scale model. The model can be applied to contaminated sites in Utah.

2. Collaboration between Utah State University and a Utah-based company to strengthen the knowledge and economic base of the State of Utah.

3. Development of funded research programs for the Utah Water Research Laboratory and Utah State University.

4. Increase number of graduate students at the Utah Water Research Laboratory and Utah State University to work in projects related to the hydraulic testing described above.

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Hydrologic Predictions with Support Vector Machines for Groundwater Monitoring

Principal Investigator(s):
Mariush W. Kemblowski
Tirusew Asefa

Project Description:

In watershed management, we are frequently faced with the problem of predicting mid-range term (6-12 months) hydrologic conditions. One typical example of it, which is of great importance in Utah, is the prediction of runoff volume for a given stream/river prior to the beginning of the irrigation season. Such prediction can then be sued by the farmers to make crop type decisions, and by the irrigation companies to manage their water reservoirs.

The physical processes involved in this problem are quite complex, and the data for running the associated models is typically not available. Due to these problems, in the past statistical time-series models have been utilized for predictions. However, their performance is not satisfactory, to say the least. In the last decade there has been a concerted effort made to develop new predictive tools, based on Statistical Learning Theory and the Tikhonov regularization approach. As a result, a new, powerful methodology emerged, called Support Vector Machines (SVMs).

A SVM uses the input and output observations to build an efficient, stable, and statistically robust predictive model. We have extended and applied this methodology to groundwater and surface water hydrology problems.

Accomplishments (FY 2003):

Our first implementation of SVMs was to groundwater contamination monitoring problem. The objective was to develop a method that would assist us in the design of efficient groundwater monitoring well networks. A paper on this subject, titled *Support Vector Machines in Groundwater Contamination Detection Monitoring Network Design*, was presented at the Fall 2002 American Geophysical Union meeting.

Currently we are implementing the same methodology to predict spring runoff in the Sevier Basin. In FY 2002, we have developed an SVM to predict spring runoff at the Hatch gauge using local snow monitoring station data as the input.

The Sevier River Basin of south central Utah is used as a case study and experimental site. It has been chosen because of its significant size, its importance in the agricultural sector of the state, its fairly well-developed database on historic hydro-meteorological conditions, and the willingness of local water resources managers to cooperate with the research and make use of the outputs of the project. The project will focus on development of approaches to forecast future spring runoff based on available snow cover and depth data, both at the local (Snowtel stations) and global (satellite data) level.

We have also applied the SVMs to designing efficient environmental monitoring networks. A paper on this subject was presented at the annual Conference on Geosciences organized by INRA (2003).

Work Plan (FY 2004 and FY 2005):

In the next year, we will extend the methodology to other areas in the Sevier Basin, and analyze the effects of Pacific Sea Surface Temperatures (SSTs) on spring runoff. In the following years, the monitoring network design toolbox (i.e., this methodology plus many others) will be utilized to create management-objective, oriented monitoring network in Cache Valley for bio-hydro-chemical processes.

Benefits to the State:

The SVM, tested and implemented at the Sevier River Basin, will be readily transferable to other basins in the State of Utah, and can be used for a variety of predictive problems.

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Predicting Stream-Aquifer Interaction Using Artificial Neural Networks

Principal Investigator(s):
Jagath J. Kaluarachchi
Mohammad Almasri

Project Description:

In areas of shallow groundwater tables in Utah, water exchange between surface water bodies such as streams, rivers, and creeks, and the adjacent aquifer can be significant. The direction and quantity of flow will be dependent on the individual water elevations in the aquifer and the surface water pathway. During high flow seasons, the aquifer can gain water from the stream (or the stream will lose water) and vice versa during low flow periods. This stream-aquifer interaction can play an important role in water resource planning and management at the watershed-scale.

Previous research related to large-scale simulations involving predicting one or more variables, knowing the historical relationships between input-output combinations, showed that artificial neural networks (ANN) are reliable and fairly accurate. The aim of this research project is to develop an ANN-based methodology to predict stream-aquifer interaction and demonstrate the applicability using available field data from the literature.

Accomplishments (FY 2003):

A detailed literature review of existing ANN applications in hydrology was investigated. Using the information, analytical models describing stream-aquifer interaction were found. The applicability of ANN to predict stream-aquifer interaction was investigated, and the development of a methodology is in progress. An artificial neural network-based model was developed to predict stream-aquifer interaction and verified using an analytical model. Results of this work showed that neural nets can be used to predict the stream-aquifer interaction.

Work Plan (FY 2004 and FY 2005):

No work is planned for next year.

Benefits to the State:

Utah has many watersheds that exhibit substantial surface water and groundwater interaction during both low and high seasons. For example, Cache Valley is a region where new groundwater withdrawal permits are withheld due to potential impacts on downstream water users of the Bear River. Due to the mathematical complexity of the physical problem describing surface and ground water interaction, detailed modeling at every stream reach is not possible. However, the use of an ANN-based predictor using historically observed stream stage and water table elevation data is relatively simple and straightforward. Therefore, we anticipate that this ANN methodology will be of great use to planners and managers of state and local water agencies to quantify stream-aquifer interaction on a seasonal basis.

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Hydrology

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Hydrology

Project Name	FY 2003 Actual Expenditures	FY 2004 Budgeted Expenditures	FY 2005 Planned Expenditures
GIS-Based Methods for Distributed Hydrologic Modeling	$12,370.47	$22,370.47	$0.00
Rainfall Runoff Processes - Online Module	$2,205.90	$183.83	$0.00
Terrain Stability Mapping	$12,090.02	$12,090.02	$0.00
Variable Resolution Scheme for Land Surface Modeling in Semi-Arid Areas	$33,018.80	$33,018.80	$0.00
Designated Amount for FY04/FY05 Research Projects		$0.00	$0.00
Undesignated research projects in program area		$0.00	$15,000.00
Total	**$59,685.19**	**$67,663.12**	**$15,000.00**

GIS-Based Methods for Distributed Hydrologic Modeling

Principal Investigator(s):
David G. Tarboton
Christina Bandaragoda

Project Description:

The objective of this project is to develop methods for the use of geographic information system (GIS) data and technology in hydrologic modeling. Geographic information systems provide the capability to efficiently gather and organize much of the geospatial data that is required as input to hydrologic models. Much hydrologic research and practice involves the use of distributed hydrologic models and the goal of this project is to improve this modeling methodology through the use of GIS technology that will be made available to water managers and planners in Utah.

Accomplishments (FY 2003):

Work this year has involved further development of the distributed hydrologic model TOPNET based on digital elevation model (DEM) and GIS information. This model was used in a National Weather Service Distributed Model Intercomparison Project (DMIP) in which the academic community and other researchers were invited to participate in a comparison of distributed models applied to test data sets. Our results were submitted to the National Weather Service and evaluated at a DMIP workshop in which we participated. Our results are also reported in a paper submitted to the "Journal of Hydrology" (Bandaragoda et al., 2003). Based upon the results obtained we were encouraged by the relatively good performance of the model, especially in comparison to streamflow from smaller interior watersheds not used in calibration and simulated as ungaged basins. We also identified some limitations in the ability to match hydrograph recessions and low flows due to the single exponential storage-discharge relationship that is due to the exponential decrease in hydraulic conductivity assumption in TOPMODEL. Future work will address this problem. The limited resources used to achieve these results show some of the potential for distributed models to be useful operationally. This participation in the DMIP project has lead to improvements in the model and procedures to take advantage of increasingly available geographic information such as national soils, vegetation, and terrain information in the model.

Work Plan (FY 2004 and FY 2005):

Our plans for FY 2004 include coupling the model with the Utah Energy Balance snowmelt model (Tarboton et al., 1995; Tarboton and Luce, 1996) that we have developed to extend our ability to simulate streamflow in regions with snowmelt and to evaluate the model in the Bear River Basin which is being targeted at a Laboratory Watershed by the Utah State University Water Initiative (Utah State University Water Initiative Task Force, 2003).

Benefits to the State:

Overall this study has led to improved hydrologic modeling capability in the area of streamflow modeling. This is of value to hydrologists, water resource planners and water managers.

References and Related Publications

Bandaragoda, C., D.G. Tarboton, and R. Woods (2003). Application of Topnet in the Distributed Model Intercomparison Project. Submitted to the *Journal of Hydrology*. DMIP Special Issue.

Tarboton, D.G., T.G. Chowdhury, and T.H. Jackson (1995). *A Spatially Distributed Energy Balance Snowmelt Model*. In: K.A. Tonnessen, M.W. Williams, and M. Tranter (Eds.). Proceedings of a Boulder Symposium, July 3-14, IAHS Publ. no. 228, p.141-155.

Tarboton, D.G. and C.H. Luce (1996). *Utah Energy Balance Snow Accumulation and Melt Model (Ueb)*. Computer model technical description and users guide, Utah Water Research Laboratory and USDA Forest Service Intermountain Research Station (http://www.engineering.usu.edu/dtarb/).

Utah State University Water Initiative Task Force (2003). *Integrated Water Planning ... At a University ... In a State ... In the Future*. Utah State University, Logan, UT, p.83.

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Rainfall Runoff Processes - Online Module

Principal Investigator(s):
David G. Tarboton
Christina Bandaragoda
Yasir Kaheil

Project Description:

The objective of this project was to develop an online module on Rainfall Runoff Processes. This was a collaborative project in partnership with the Colorado Basin River Forecast Center of the National Weather Service based in Salt Lake City, UT. The module is designed to provide a comprehensive and quantitative understanding of infiltration and runoff generation processes. The module is targeted at students with a scientific or engineering background and professionals with a college degree in science or engineering and is intended for use in the National Weather Service in house training programs for hydrologists as well as upper and graduate level courses at Utah State University (USU).

Accomplishments (FY 2003):

The module developed includes:

- A complete workbook (159 pages) on Rainfall Runoff Processes serving as the textbook for the module. This is available online in PDF format.
- Streaming video and slide presentations.
- Visualizations and computer animations to convey key concepts.
- Powerpoint presentations.
- Online quizzes serving as exercises where the user needs to respond to multiple choice questions or enter numeric answers to problems.
- An online final test.

The module has been delivered to the National Weather Service and has been used in Hydrology courses at Utah State University. The module is available at the following URL: http://www.engineering.usu.edu/dtarb/rrp.html.

Work Plan (FY 2004 and FY 2005):

The project is complete and no work is planned for FY 2004.

Benefits to the State:

This module provides an effective way for hydrologists in Utah and elsewhere to learn the science of rainfall runoff processes involved in streamflow and water supply forecasting. The Salt Lake City based Colorado Basin River forecast center that participated in the development of this module is responsible for river forecasts for the protection of life and property as well as for water resources. It is important in making these forecasts to have staff that are well trained and knowledgeable in the underlying science and this module facilitates this.

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Terrain Stability Mapping

Principal Investigator(s):
David G. Tarboton
Robert T. Pack
Kiran Chinnayakanahalli

Project Description:

Terrain Stability Models endeavor to capture the topographic and hydrologic susceptibility of a location to triggering of a landslide and to map locations of potential instability. The sudden failure and high speed of shallow landslides that mobilize as debris flows make them destructive of downstream resources, from both public safety and water quality perspectives where sediment inputs to streams from landslides are a water quality concern. The objective of this research is to improve methods for terrain stability mapping so as to be able to improve the assessment of risk from hydrologically triggered shallow landslides to both property and water quality.

Accomplishments (FY 2003):

Previous work has involved the development of the SINMAP method for Terrain Stability Mapping (Pack et al., 1998b; Pack et al., 1998a; Pack et al., 2001). This is one of a number of process based models used for terrain stability mapping. Other such models include SHALSTAB (Montgomery and Dietrich, 1994; Dietrich et al., 2001) and Quasi-Dynamic approaches (Borga et al., 2002). These models quantify terrain instability using different stability indices making direct comparison between them difficult.

We have developed a new method for the evaluation of terrain stability maps based on the locations of observed landslides. The new method uses a statistic based on the cumulative fraction of the stability index at locations of observed landslides, relative to the cumulative fraction of the stability index over the terrain. This statistic quantifies the discriminatory capability of a stability map in terms of the degree to which a terrain stability map is successful in "capturing" observed landslides in areas mapped as unstable while minimizing the extent of these areas. This statistic provides a way to compare models that use different stability indices and is a quantity that can be used for the calibration or optimization of model parameters using observed landslide initiation locations. This is useful when physical data necessary to estimate model parameters is limited. This work was reported in presentations (Chinnayakanahalli et al., 2003a; 2003b) and a MS thesis in preparation (Chinnayakanahalli, 2004, in preparation). In this work the performance of these models that use different indices are compared using data from the Chetwynd area in east central British Columbia where 696 landslide initiation locations were mapped. We found that in this particular region slope was the dominant variable that discriminated terrain instability. The optimally calibrated SHALSTAB and SINMAP models that also use drainage area as a predictor offered improved discriminatory capability over slope alone. The additional flexibility of the probability framework used by SINMAP gave it a slight advantage over SHALSTAB in discriminating unstable terrain.

Work Plan (FY 2004 and FY 2005):

We plan to complete the development and evaluation of this new method for quantifying the discriminatory capability of terrain stability maps. We then plan to incorporate this method in a future release of SINMAP so as to provide capability for the optimization of SINMAP parameters and quantification of uncertainty associated with SINMAP terrain stability risk assessments.

Benefits to the State:

Shallow landslides are a significant environmental and safety concern in much of the Western US, including Utah. Sediment from hydrologically triggered shallow landslides has an impact on stream habitat and water quality. This work is improving our capability to assess risks due to hydrologically triggered shallow landslides and appropriately manage terrain subject to these risks.

References and Related Publications

Borga, M., G.D. Fontana, and F. Cazorzi (2002). Analysis of Topographic Control on Shallow Landsliding Using a Quasi-Dynamic Wetness Index. *Journal of Hydrology*, 268(1-4):56-71.

Chinnayakanahalli, K., (2004, in preparation). *An Objective Method for the Intercomparison of Terrain Stability Models and Incorporation of Parameter Uncertainty*. MS Thesis, Civil and Environmental Engineering, Utah State University, Logan, UT.

Chinnayakanahalli, K., D.G. Tarboton, and R.T. Pack (2003a). An Objective Method for the Intercomparison of Terrain Stability Models. *Eos Trans. AGU*, 84(47): Fall Meet. Suppl., Abstract H31C-0480.

Chinnayakanahalli, K., D.G. Tarboton, and R.T. Pack (2003b). *An Objective Method for the Intercomparison of Terrain Stability Models and Incorporation of Parameter Uncertainty*. 23rd Hydrology Days, Fort Collins, CO.

Dietrich, W.E., D. Bellugi, and R.R. de Asua (2001). Validation of the Shallow Landslide Model, Shalstab, for Forest Management. In: M.S. Wigmosta and S.J. Burges (Eds.). *Land Use and Watersheds: Human Influence on Hydrology and Geomorphology in Urban and Forest Areas*. Water Science and Application 2, Amer. Geoph. Union, p.195-227.

Montgomery, D.R. and W.E. Dietrich (1994). A Physically Based Model for the Topographic Control on Shallow Landsliding. *Water Resources Research*, 30(4):1153-1171.

Pack, R.T., D.G. Tarboton, and C.N. Goodwin (1998a). *The Sinmap Approach to Terrain Stability Mapping*. 8th Congress of the International Association of Engineering Geology, Vancouver, British Columbia, Canada 21-25 September 1998.

Pack, R.T., D.G. Tarboton, and C.N. Goodwin (1998b). *Terrain Stability Mapping with Sinmap, Technical Description and Users Guide for Version 1.00*. Report Number 4114-0, Terratech Consulting Ltd., Salmon Arm, B.C., Canada. (Report and software available from http://www.engineering.usu. edu/dtarb/).

Pack, R.T., D.G. Tarboton, and C.N. Goodwin (2001). *Assessing Terrain Stability in a Gis Using Sinmap*. 15th annual GIS conference, GIS 2001, Vancouver, British Columbia, February 19-22.

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Variable Resolution Scheme for Land Surface Modeling in Semi-Arid Areas

Principal Investigator(s):

Luis A. Bastidas
Norman L. Miller, Lawrence Berkeley National Laboratory
Shujun Li

Project Description:

The evolution of coupled Atmospheric Model-Land Surface Model (AM-LSM) development has taken into account more detailed physical processes (e.g. biogeochemistry, streamflow), but so far has been oriented towards a single column (over a grid cell) conceptual representation of the processes. Data availability has become a limiting factor, especially as the model resolution is increased (50-200m) to account for detailed fine-scale watershed processes. These models, which are computationally intensive, may lack sufficient input forcing for realistic solutions. Medium-scale (1-12 km) models, on the other hand, may avoid this limitation at a loss of information. Based on earlier work carried out by Miller (1995) as a bridge between these two approaches, we are developing a nonuniform grid system that provides fine-scale structure at regions of high land surface sensitivity and medium-scale for regions of low sensitivity or problem-defined homogeneity. Such an approach will reduce computational demand, the number of parameters, preserve the spatial representation of information, and provide a framework for evaluating medium- and fine-scale models, as well as testing process sensitivities at a range of spatial scales.

This proposal is developed around the following hypothesis:

> *Vegetation, topographic, and hydrologic characteristics of the semi-arid Southwestern U.S. suggest that, for those environments, it will be more meaningful to link the inherent heterogeneity and scale of the terrain properties and hydrological processes with the grid cell size of the numerical representation in land surface models, rather than pursue the traditional mosaic-type or effective aggregation approach currently used by state of the art land surface models.*

Accomplishments (FY 2003):

We have developed and implemented a procedure that extends and improves the hTest procedure of Miller (1995) to take into account not only the terrain aspect but also the terrain elevation and aspect, soil and vegetation characteristics, and the topology of the river network. The procedure has been initially implemented over the San Pedro River Basin in Arizona, because of the richness of available data and the possibility of model intercomparison. The optimal parameter sets for the National Centers for Environmental Prediction (NCEP) Noah model have been obtained for five different semi-arid biome types. The initial results have been presented at the American Geophysical Union (AGU) Fall meeting (Bastidas et al., 2003).

Work Plan (FY 2004 and FY 2005):

We plan to perform a thorough test of the procedures developed using forcing fields from the NASA/NOAA Land Information System, the University of Washington retrospective data set, and outputs from the MM5 mesoscale model. Simultaneously we will develop a model evaluation and comparison procedure based on similarity and set to set distance measures.

Benefits to the State:

Semi-arid environments are a significant part of the western United States and in particular of the State of Utah. The development of a state-of-the-art modeling system specifically tailored to semi-arid environments will improve the forecast skills of the weather and climate models with obvious benefits to Utah in terms of better prediction of flash flooding and long-term vegetation dynamics and environment change.

References and Related Publications

Miller, N.L. (1995). Sensitivity of Surface Heat and Moisture Fluxes Due to Topographic Slope and Azimuth. *J. Geophys. Res*., 100(D9):18669-18685.

Bastidas, L.A., S. Li, N.L. Miller (2003). *A Scheme for Application of Non-Uniform Grids for Land Surface Modeling*. AGU Fall Meeting, San Francisco, CA, December 8-12.

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Water Resources Planning and Management

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

Project Name	FY 2003 Actual Expenditures	FY 2004 Budgeted Expenditures	FY 2005 Planned Expenditures
A GIS-Based Approach for Better Statewide Water Use Estimation	$1,791.88	$9,290.00	$15,000.00
Annual Population Monitoring in the Sevier River Drainage	$4,567.43	$14,567.43	$0.00
Computer-Based Intelligent Technology Research	$18,432.53	$38,969.77	$0.00
Culvert Hydraulic Analysis and Design for Rural Roads	$26,181.76	$36,181.76	$42,762.10
Dam Safety Risk Management	$24,404.54	$34,404.54	$35,361.40
Development of Real-Time Flood Forecasting System for Terrorist Inflicted and Other Dam Breach Incidents	$17,421.76	$17,500.00	$0.00
Quantification and Management of Uncertainty in Salt Loading from the San Rafael Irrigation System	$21,626.72	$19,919.98	$0.00
Real-Time Management of Irrigation Systems in the Sevier River Basin	$18,129.73	$18,129.73	$0.00
Technical Support for the Virgin River Resource Management and Recovery Program	$4,567.43	$21,926.68	$37,365.21
Uncertainty Analysis for Dam Safety Risk Assessment	$24,404.54	$37,500.00	$43,250.00
Designated Amount for FY04/FY05 Research Projects		$0.00	$10,000.00
Undesignated research projects in program area		$0.00	$15,000.00
Total	**$161,528.32**	**$248,389.89**	**$198,738.71**

A GIS-Based Approach for Better Statewide Water Use Estimation

Principal Investigator(s):
Mac McKee
David G. Tarboton
Lloyd Austin, Utah Division of Water Resources
Craig Miller, Utah Division of Water Resources
Larry Spangler, US Geological Survey
Shujun Li
Paul Harms

Project Description:

At five-year intervals, the U.S. Geological Survey (USGS) is required by Federal mandate to estimate and report on water use for each state in the nation. While the periodic USGS estimates of statewide water use are valuable for planning and management, many states--Utah included--have recognized a need to generate water use estimates on an annual basis, which would be more valuable in identifying and analyzing water use trends and forecasting future water use. This implies a need to provide better methods of data collection and analysis to improve the efficiency and accuracy of generating water use estimates.

Advances in data collection, analysis, and display technology show great promise in addressing the above needs. The proposed project will exploit electronically available data, GIS technology, and attendant analytic methods to develop a methodology for more efficiently generating statewide water use estimates. The objectives of the project are to: (1) formulate the conceptual design of a statewide water use model; (2) develop and implement approaches for estimating individual water use components consistent with the USGS water use categories; (3) estimate trends in water use in Utah in order to facilitate water use estimation for any given year; and (4) develop a methodology to forecast future water use. These activities have been conducted in coordination with the Division of Water Resources within the Utah Department of Natural Resources and with the Utah district office of the USGS.

Collaborators from the Utah Division of Water Resources included Lloyd Austin and Craig Miller. Collaborators from the Utah District office of the United States Geological Survey (USGS) included Heidi Hadley and Larry Spangler.

Accomplishments (FY 2003):

Non-state funding was successfully obtained to support most of the effort for this project. Utah State University (USU) faculty and students have worked closely with several individuals from the Utah Division of Water Resources and the USGS to develop GIS-based methodologies for estimating irrigation, domestic, and municipal water use.

Work Plan (FY 2004 and FY 2005):

In FY 2004, work will involve the deployment on the Internet of a GIS-based model for estimating water use in irrigated agriculture. This will include a users manual and example data sets and model output.

Benefits to the State:

The proposed research will benefit the water sector by developing and testing a GIS-based methodology to efficiently estimate water use in the categories of municipal supply and irrigation, with extensions to estimation of reservoir evaporation and evaporation from wetlands and other open-water bodies. The methodology will take advantage of readily available, dynamic databases and forecasts. The procedures, software, and documentation developed by the project will be provided to the Utah Division of Water Resources for use in the state and to the USGS for export and application in other states.

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Annual Population Monitoring in the Sevier River Drainage

Principal Investigator(s):
Thomas B. Hardy
Matt Combes

Project Description:

This project entails annual monitoring fish populations at standardized locations within the Sevier River Drainage. These efforts are intended to establish trends in fish abundance and community composition in light of inter-annual variations. The results of these studies will guide water resource allocation decisions and provide critical data in the protection of native species in the system.

Accomplishments (FY 2003):

Standardized monitoring of the fish populations were undertaken and the annual population monitoring reports were prepared for the Sevier River Bridge Canal Company and the Utah Division of Wildlife Resources.

Work Plan (FY 2004 and FY 2005):

Utah State University (USU) will continue to provide technical support through this period.

Benefits to the State:

This project is being carried out in conjunction with the State of Utah Division of Wildlife Resources and the Sevier River Bridge Canal Company. The results of this work will guide long-term water allocation strategies and ultimately the successful protection and enhancement of native species of fish within the Sevier River Basin.

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Computer-Based Intelligent Technology Research

Principal Investigator(s):
William J. Grenney
Anisha Arora
Parimala Pakalapati
Ashwin Chandra Sullia

Project Description:

This research examines cutting edge technology that may be applied for assisting in the decision-making process. As an example, many municipal, county, and state agencies use computer tools for managing their infrastructure. Engineers in the operating divisions at the lower end of the organizational hierarchy desire to choose a variety of computer-based tools for tactical planning and operational purposes. Managers at the top of the hierarchy desire a uniform "enterprise" database system that provides them direct access to agency-wide data for strategic management purposes. Frequently, these two different approaches at different levels cause inefficiencies within an agency.

The objectives of this research were to evaluate methodologies for multi-tier data management systems, and to develop a prototype for a practical agency system with particular interest in providing systems that are applicable for small and medium size communities.

Accomplishments (FY 2003):

The Utah State Department of Transportation (UDOT) provided some funding and a considerable amount of data to extend the results from FY 2002 project which focused on scaling down the database of over 65,000 roadway culverts to reside on a field laptop.

The application was extended to meet the needs of an extensive field investigation being conducted by an independent contractor under separate contract with UDOT. The contractor required immediate access to the characteristics of over 65,000 culverts located in Utah. In addition the contractor required a new database interface to record new data being collected in the field. The following modules were developed, tested, and provided to the contractor:

1. A completely revised schema was implemented to store inventory data in 26 tables containing over 200 parameter fields.

2. An event-driven interface was designed and implemented for inputting data and for sorting, selecting, and outputting stored data.

3. A complementary set of 26 database tables containing 102 fields was designed and implemented to store culvert field inspection data.

4. A complementary event-driven interface was developed for inputting data and for sorting, selecting and outputting stored data from the extended database.

5. The binary I/O files that had been an integral part of the previous system were replaced with conventional database tables.

Work Plan (FY 2004 and FY 2005):

During the implementation of the decision-support system for culvert condition inspection, it became apparent that one to the least accurate design parameters is the Intensity - Duration - Frequency (IDF) data available to designers in rural areas. This research will investigate sources for IDF data and will facilitate accessibility to the information for rural practitioners.

Benefits to the State:

A variety of computer tools are being used within municipal, county, and state agencies to serve diverse maintenance management needs. Many of the tools are individually tailored for a specific purpose and lack the functionality to share data with other applications. This has resulted in the establishment of numerous databases which are unavailable for more comprehensive management needs. This phase of the research resulted in a methodology that permits diversity at the operating level while maintaining data compatibility for aggregation and analysis at higher levels in the organization.

Figure 1 shows one of the eight computer interfaces developed for the application.

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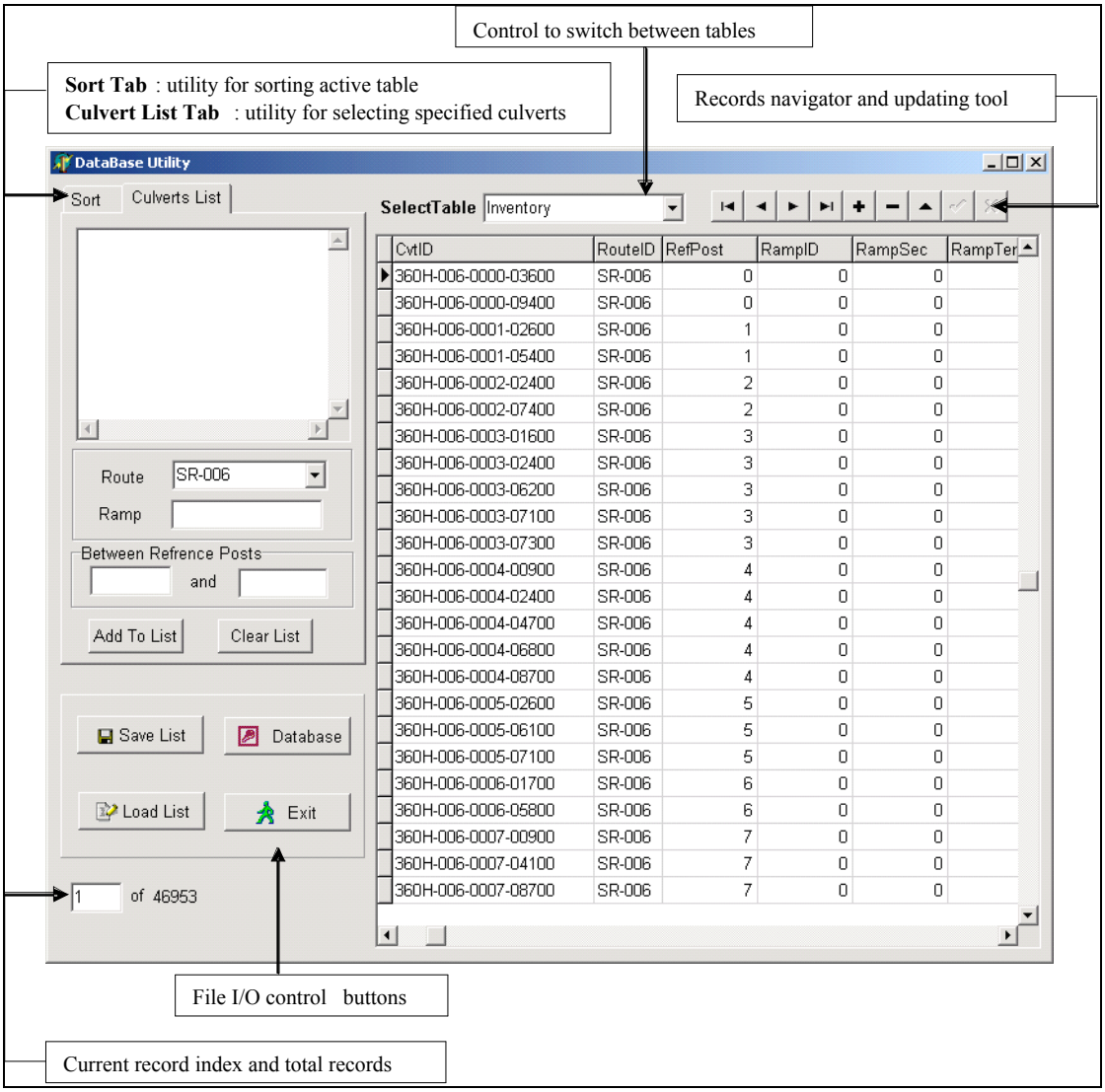

Figure 1. Event-Driven Interface for the Inventory Tables.

Culvert Hydraulic Analysis and Design for Rural Roads

Principal Investigator(s):
William J. Grenney
Thirumurugan Bose
Ramya Cuduvalli Nataraj
Sunil Kongara

Project Description:

Effective transportation within and among communities in Utah is essential for sustaining economic development and maintaining quality of life. Over 80% of Utah roads and highways are low volume rural roads. Because of the great distances between communities and the dispersed population, budgets for construction and maintenance are severely stressed. Often drainage and environmental considerations are important transportation issues having direct impact on communities. There is a continuing need for training, education, and research to implement modern methods in order to obtain the greatest effectiveness from limited dollars. Although much effort has gone into the development of systems for large departments of transportation, this research focuses on the needs of small and medium sized communities.

Accomplishments (FY 2003):

The main objective of this phase of the study was to compute reliable estimates of 25-, 50-, and 100-year peak discharge values for unregulated Utah Watersheds to provide the necessary input to the culvert design process. Detailed flood-frequency analyses were done for stream flow gaging stations in the Utah Virgin River Basin. The boundary of the flood region and data sets were refined during the course of analysis in order to improve flood frequency analyses based on a revised regional skew coefficient. Flood frequency prediction equations for selected recurrence intervals were developed using the regression model with selected basin characteristics as explanatory variables, and the results were incorporated in a Geographical Information System representation of the Utah portion of the Virgin River Basin (Figure 1).

Work Plan (FY 2004 and FY 2005):

The continuing requirements to examine the effects of existing culverts on aquatic habitat has generated a need to analyze the hydraulics of culverts that are partially buried in the streambed. This condition produces a non-standard irregular cross section and current design tools for this condition are complex and awkward to use. This research will provide a simpler tool for the analysis of such conditions.

Benefits to the State:

This research will result in a methodology and a computer tool for small and medium sized rural communities to more effectively plan, design, and maintain culverts for unique situations as well as for most standard installations.

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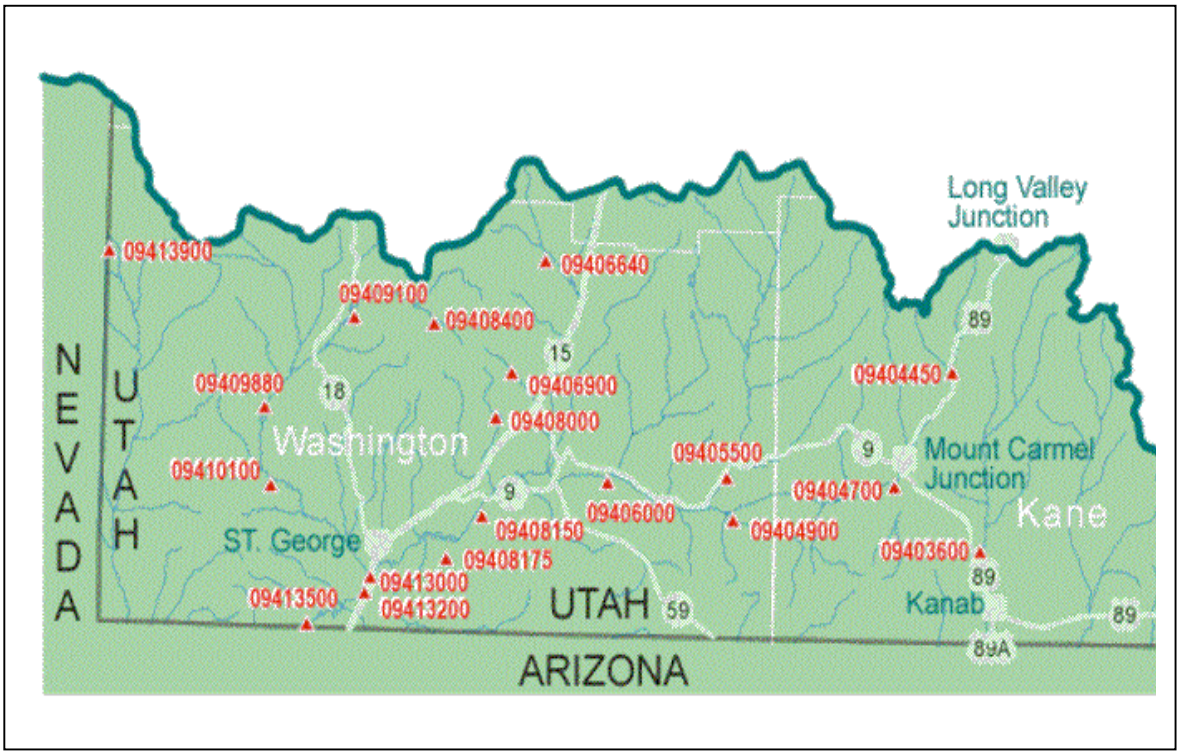

Figure 1. The Utah Virgin River Study Area.

Dam Safety Risk Management

Principal Investigator(s):
David S. Bowles
Loren R. Anderson
Terry F. Glover
Sanjay S. Chauhan
Anthony Chen
Duane McClelland
Wang Zhengang
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Sirisak Kongsomsaksakul

Project Description:

Dam safety management is intrinsically risk management. A team of Utah State University (USU) researchers has been developing and applying approaches to dam safety risk management for about two decades. We are now recognized internationally as leaders in this field. We have assisted the Utah State Engineer in evaluating dam safety risks at dams throughout Utah. We have also assisted the U.S. Bureau of Reclamation to develop and implement risk assessment in their dam safety program. We are currently assisting the U.S. Army Corps of Engineers implement approaches for individual and portfolio risk assessment. The USU team is now becoming involved in several other countries and with various international efforts to develop guidelines for this powerful emerging field.

The overall objective of this ongoing research is:

To improve the availability and capability of practical risk-enhanced approaches to dam safety risk management.

Specific areas of research are summarized under "Accomplishments" and "Work Plan" sections of this report.

Accomplishments (FY 2003):

Accomplishments in the past year have included the following:

- Advances in the portfolio approach to evaluation of the risks associated with a group of dams and prioritization of risk reduction measures. Many dam owners have now implemented these procedures with significant improvements in the rate of risk reduction. We are currently developing portfolio risk assessment (PRA) procedures for the U.S. Army Corps of Engineers and other dam owners.

- Development of practical approaches to using information from tolerable risk evaluation criteria or guidelines for making dam safety decisions on individual dams and portfolios of dams. A half-day interaction was held with the UK Health and Safety Executive (HSE) in London, England. The HSE is recognized as a world leader in risk-based safety regulation, including practical approaches to the Tolerability of Risk. This year, this work has lead to

papers by Bowles (2003b and 2003d), Bowles and Anderson (2003b), and Bowles et al (2003). It has also contributed significantly to revised sections of the draft ICOLD (McDonald, et al., 2003) Bulletin, *Risk Assessment in Dam Safety Management – A Reconnaissance of the Benefits, Methods and Current Applications*.

- Continuation of work to develop an improved practical life-loss estimation modeling system for use in dam safety risk assessment. Progress in the past year has been in two major areas: expansion of capability and demonstration of the Deterministic Mode of the model; and development and demonstration of a preliminary version of the Uncertainty Mode. The modeling system is described in Aboelata et al. (2002). The Deterministic Mode provides estimates of life loss from "best estimate" inputs. The simulation modeling system comprises the following internal modules: 1) Loss of Shelter, including prediction of building performance, 2) Warning and Evacuation, and 3) Loss of Life, based on empirical relationships developed in our earlier work (McClelland and Bowles 1999, and 2000; and McClelland and Bowles 2003a] from a wide range of case histories. Estimated flooding conditions are obtained from an external dam break and flood routing model. Other inputs include a digital elevation model, road layout, and data on populations at risk from readily available GIS sources. Application of the Deterministic Mode has been demonstrated for several different size communities under flood-induced and sunny-day dam failures of a large embankment dam (Aboelata et al 2003a). Application of the Uncertainty Mode has been demonstrated for sudden and delayed earthquake-induced failures of a large embankment dam (Aboelata et al 2003b). An invited demonstration was given as part of the Innovation and Technology Showcase at the FEMA FY 2003 Risk Management in a Multi-Hazard World Workshop.

- Continuation of a cooperative project with the City of Logan, Utah, the use of GIS information for improving the effectiveness of evacuation in the event of dam failure floods with some funding form FEMA. The effort includes links to a dynamic transportation model (Karre, 2002). It also includes a comparison of one- and two-dimensional flood inundation models for a Master's thesis being finalized by Zhu (2004).

- Development of guidelines for dam safety risk analysis and risk assessment. Dr. David S. Bowles is also one of five co-authors worldwide for the International Commission on Large Dams (ICOLD) bulletin on dam safety risk assessment (McDonald et al 2003).

  · Dr. Bowles represented the United States at the Committee on Dam Safety (COD) at the ICOLD Congress held in Montreal, Canada, and served as Acting Vice-Chairman of the COD.

- Dr. Bowles is serving as a member of the Advisory Team for the FERC Office of Energy Division of Dam Safety and Inspections for their development of guidelines for Performance Monitoring Program (Bowles 2003a).

  · An approach to representing spillway gate reliability considerations has been developed and tested on several dams (Lewin et al 2003). The approach places spillway gate reliability in the context of overall dam failure risk.

  · Dr. Bowles has reviewed a Draft Corps of Engineers Engineering and Design Guideline on Risk Analysis for Dam Safety Assurance.

- Dr. Bowles served as Chair of the U.S. Society on Dams (USSD) Working Group for preparation of an Emerging Issues White Paper (Bowles et al., 2003) on *Dam Safety Risk Assessment: What is it? Who's using it and why? Where should we be going with it?* The final white paper was published by the USSD and released at its April 2003 Annual Meeting (Bowles 2003c).

- All activities are being coordinated through the Institute for Dam Safety Risk Management at the Utah Water Research Laboratory and in association with the Department of Civil and Environmental Engineering. The Institute is gaining recognition in the field.

Work Plan (FY 2004 and FY 2005):

Efforts in the next two years will focus on several areas, including the following:

- Continued advances in portfolio risk assessment, including development of procedures for large portfolios in which screening will be incorporated and for owners, which have limited resources, such as those regulated by the states and for prioritizing investigations. Improved approaches for integration of individual and portfolio risk assessment outcomes into all aspects of dam safety programs (e.g., monitoring and surveillance programs and emergency management) and various business processes.

- Further development of practical approaches to using information from tolerable risk evaluation for making dam safety decisions on individual dams and portfolio of dams.

- Continued work developing the Simplified Mode OF THE Life Loss Estimation Model and work to improve the Deterministic and Uncertainty Modes of the model. The Uncertainty Mode will be used to generate a synthetic database for a range of Failure Event - Population Exposure settings. This database will be used to develop an "empirical" technique for life-loss estimation, referred to as the Simplified Mode. For settings that are adequately represented, the Simplified Mode will provide life-loss estimates for a lower level of effort, although with greater uncertainties, than the full modeling system. However, provided that GIS data are readily available, the level of effort needed for implementing the full modeling system is considered to be reasonable. In addition to model development and testing, the model will be further demonstrated for two Corps dams.

- A dynamic transpiration modeling approach will be explored for inclusion in the evacuation component of the Life Loss Estimation model.

- Improvement in the bases for estimating system response probabilities for dam safety risk analyses.

- Development of guidelines for dam safety risk analysis and risk assessment. Dr. Bowles will continue to serve as a reviewer for the ASCE, FERC, ICODS and UK guidelines.

- Further development and presentation of briefings, seminars, and workshops to professional groups in the United States and overseas.

- Dr. Bowles will continue to serve as Member of the US Society on Dams Committee on Dam Safety and the USSD Board of Directors.

Benefits to the State:

The improved approaches to dam safety risk management, which are being developed under this project, will be applicable to dams in Utah. It is expected that they will increase the value of the risk-enhanced approach for gaining insights, exploring risk reduction options, and justifying safety improvements at existing dams.

References and Related Publications

Aboelata, M. and D.S. Bowles (2003a). *Evacuation and Life Loss Estimation Model for Natural and Dam-Break Floods*. Invited demonstration and poster presentation. Innovation and Technology Showcase, FEMA FY 2003 Risk Management in a Multi-Hazard World Workshop, Emergency Management Institute, Emmitsburg, Maryland. Poster published on FEMA website. June.

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Aboelata, M., D.S. Bowles, and D.M. McClelland (2003b). *A Model for Estimating Dam Failure Life Loss*. Invited Paper in Proceedings of the Australian Committee on Large Dams Risk Workshop, Launceston, Tasmania, Australia. October.

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Lewin, J., G. Ballard, and D.S. Bowles (2003). *Spillway Gate Reliability in the Context of Overall Dam Failure Risk*. Presented at the 2003 USSD Annual Lecture, Charleston, South Carolina. April.

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McClelland, D.M. and D. S. Bowles (2000). *Life-loss Estimation: What Can We Learn from Case Histories?* Proceedings of the 2000 USCOLD Annual Lecture, Seattle, Washington. July 2000.

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Development of Real-Time Flood Forecasting System for Terrorist Inflicted and Other Dam Breach Incidents

Principal Investigator(s):
Daniel H. Hoggan

Project Description:

Since the terrorist attack on the New York City Twin Towers on September 11, 2001, local, state, and national officials have been focused more than ever on homeland security. There is considerable interest in protecting citizens from a wide range of potential terrorist attacks within the United States. The potential catastrophic flooding consequences from the breaching of one or more of our major dams is one of the homeland security scenarios that must be considered. An effective flood forecasting and warning system for populated areas downstream from a major dam and reservoir has the potential of saving many lives. Such a system would enable emergency management and law enforcement to act quickly and efficiently in the evacuation of citizens in harm's way. The flood forecasting system would provide real time information on impending flood levels, timing, and areal extent from a breach of any size and shape. The system would be triggered immediately upon an unexpected release from a dam, and through the use of remote sensing (gaging) stations and computer simulation models of the river and watershed downstream from the dam, critical information regarding the event would be generated and transmitted to appropriate agencies. This system would provide valuable real time information including graphical displays of the depth and extent of catastrophic flooding currently unavailable in existing flood warning systems. Existing systems do not have the capacity to handle flood flows of this extreme magnitude and severity. The scope of this project is to develop the concept of this new system including identifying all of the software and hardware needed, linking the various components in a workable system, and testing the integrated computer models using actual data (dam dimensions, watershed characteristics, stream flow parameters, etc.) for a selected location.

Accomplishments (FY 2003):

A formal proposal was prepared and submitted to the National Institute for Water Resources in its annual competitive grants competition for FY 2003-2004. The proposal addressed the issues identified in the "Project Description" above.

Work Plan (FY 2004 and FY 2005):

Additional funding agencies are being identified for proposal submission.

Benefits to the State:

There are several major dams located in the State of Utah, some of which pose a major hazard to downstream populations. The real-time flood forecasting and warning system of this proposal would provide substantial security to such populations.

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Quantification and Management of Uncertainty in Salt Loading from the San Rafael Irrigation System

Principal Investigator(s):
Mac McKee
Lizette Oman
Abedalrazq Khalil
Saket Pande

Project Description:

Irrigation in the valleys of the San Rafael River Basin in Emery County contributes substantial amounts of salt each year to the waters of the Green River. However, there is considerable uncertainty in how much salt flows out of these valleys, how much of the salt load is due to anthropogenic sources, including irrigation, and how salt management projects will affect total salt loads from the basin. This project will employ modern methods of data analysis to provide better estimates of salt loading from the basin and describe the amount of uncertainty those estimates contain. The project will also seek to identify data collection methods to reduce the uncertainty in estimates of salt loading.

Accomplishments (FY 2003):

Work in FY 2003 focused on statistical analysis of data available from historic stream flow and salt concentration measurements, including the real-time data provided in the on-line database operated by the Emery Water Conservancy District (EWCD) (see http://www.ewcd.org/). Work has focused thus far on analysis of salt loading from the San Rafael into the Green River. This will be extended further upstream as data and resources allow. In particular, statistical relationships between stage and discharge, and between conductivity and salt concentration have been developed. This has been done so as to provide the basis for a Bayesian belief network (BBN) model that will be used to quantify the uncertainty in the estimate of salt loading from the basin.

Work Plan (FY 2004 and FY 2005):

In FY 2004, linear and non-linear analyses of data using mass balance constraints on water and salt will be extended to refine the basis for the BBN model. Available data will be used to populate the Bayesian network, and the resulting model will be made available to the EWCD for generating salt loading estimates and for inclusion on their web site.

Benefits to the State:

Control and management of salt in the tributaries of the Colorado River is a difficult problem that is fraught with uncertainty. Application of methods that are specifically tailored to quantify and manage uncertainty and that can exploit the wealth of data that is becoming available from basin-wide real-time monitoring systems, such as the one operated by the EWCD, can potentially provide efficient and cost-effective ways of quantifying these salt loads and evaluating alternatives for reducing them. This is what will be demonstrated by the use of BBNs in this project.

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

Principal Investigator(s):
Mac McKee
Abedalrazq Khalil
Saket Pande
Rajaa Hassan

Project Description:

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. The object of this project is to develop significant data analysis functionality to the existing Sevier River Water Users (SRWU) web site to support real-time and long-term water management information needs.

Accomplishments (FY 2003):

In FY 2002 and FY 2003, real-time operations models have been developed using methods from statistical learning theory. These include artificial neural network (ANN) models, support vector machine (SVM) models, and "lazy learner" (LL) models. These models have been constructed to help provide real-time management information for determining releases from Piute Reservoir and diversions into the Sevier Valley/Piute Canal. The models have been made operational on the SRWU web site for use by reservoir and canal operators. Comparisons of model predictions versus actual canal operations are given in Figure 1.

Short-term predictive models were also built using artificial neural network approaches to forecast diurnal flows from Clear Creek into the Sevier River. An example of these forecasts, made hourly for a period 24 hours in advance, is given in Figure 2.

Long-term predictive models were constructed in FY 2003 to forecast stream flows at the Hatch gage in the Upper Sevier River Basin. These predictions come from an artificial neural network model that uses historical stream flow data, Snotel data, and sea surface temperature anomaly data from the Pacific and Atlantic Oceans. A comparison of the forecasts obtained from the ANN model versus historically measured flows is shown in Figure 3.

Work Plan (FY 2004 and FY 2005):

In FY 2004, work will extend the predictive capability of the models and identify impediments to model implementation and use. Emphasis will be placed on refinements that will allow hourly model updates. All models will be made available to the SRWU, and assistance will be given to implement the models on the SRWU web site (http://www.sevierriver.org/).

Benefits to the State:

Application of this and related technologies in the Sevier River Basin in the past four 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. These forecasting techniques 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 could supply system managers with information necessary to more precisely control the operation of large irrigation systems, thereby saving water and increasing the overall productivity of the system.

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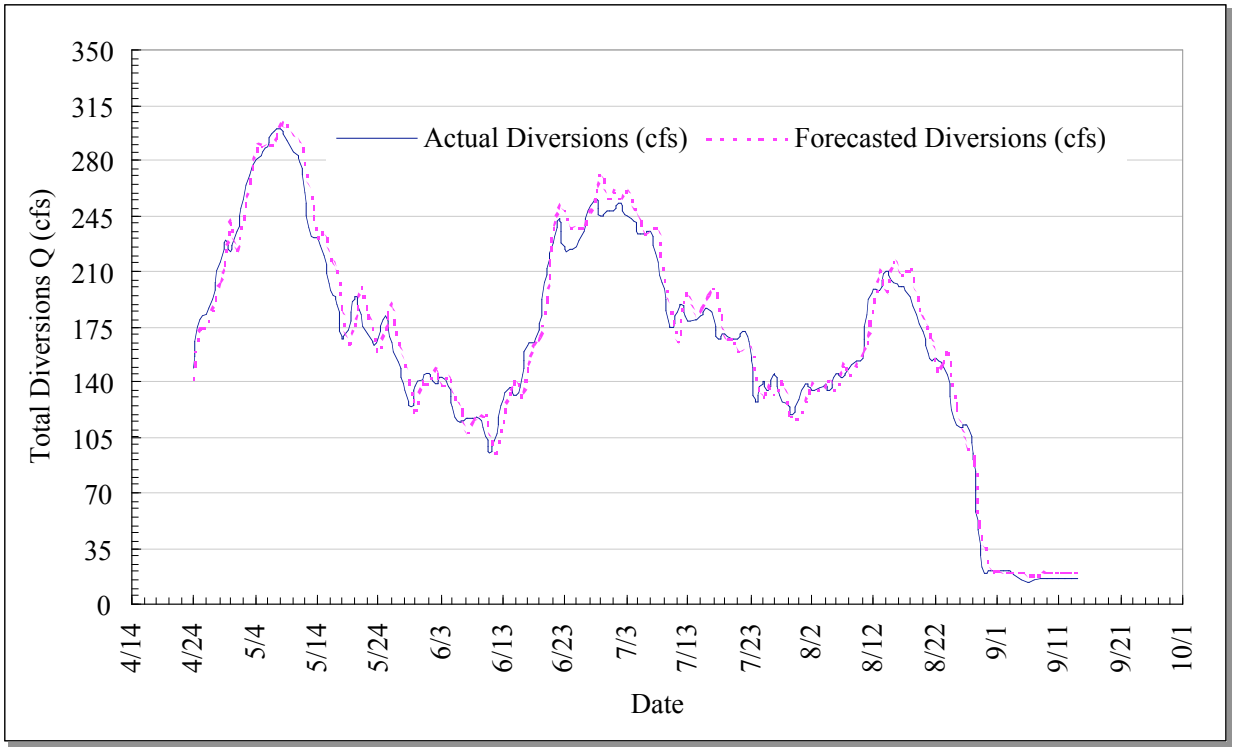

Figure 1. Comparison of Actual Sevier Valley/Piute Canal Diversions in 2002 with ANN Model Forecasted Diversions

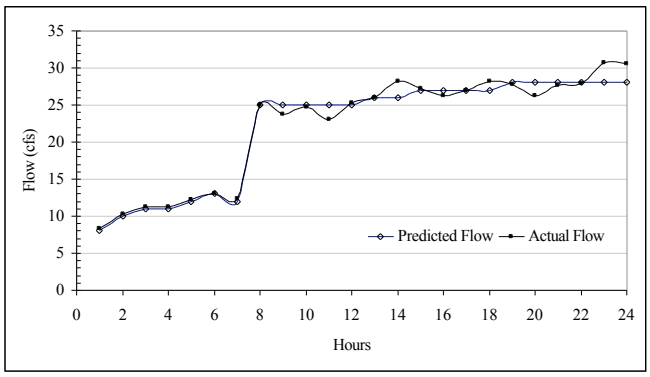

Figure 2. Predicted Versus Actual Diurnal Fluctuation of Flows in Clear Creek on 4/4/2001.

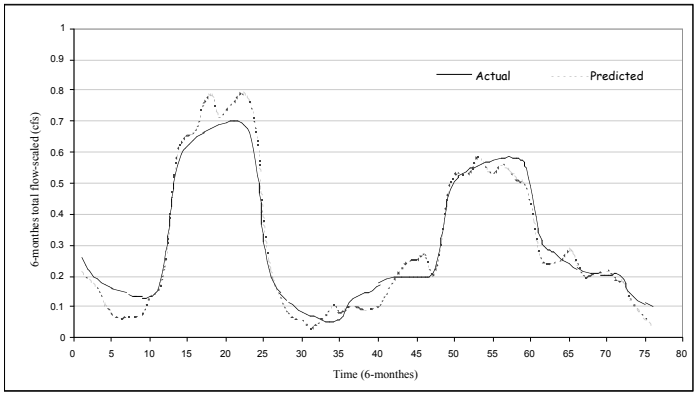

Figure 3. Time-Series Performance of the ANN Model in Predicting Seasonal Flows at Hatch.

Technical Support for the Virgin River Resource Management and Recovery Program

Principal Investigator(s):
Thomas B. Hardy
R. Craig Addley

Project Description:

The Virgin River Resource Management and Recovery Program represents a collaborative effort by local, county, state, and federal resource agencies to manage future water development in the Virgin River Basin while meeting recovery goals for listed species. The Program involves stakeholders and managers within the Virgin Basin through Technical Teams that identify research and management actions that will promote the protection and recovery of species while providing a framework to meet water allocation needs within the basin.

The purpose of this work is to provide technical support to the Program through participation on the Technical Committee. Utah State University (USU) has worked on the endangered fish species and related water resource problems in the Virgin Basin intensively since 1982. This institutional knowledge base and extensive research experience is invaluable to the Program as complex water allocation strategies and recovery actions are being considered.

Accomplishments (FY 2003):

Utah State University personnel have actively participated in monthly Technical Team meetings, conducted specific analyses for proposed water resource actions, and proposed recovery actions for the Program. This work also included development and review of technical scopes of work and review of study results by participating investigators.

Work Plan (FY 2004 and FY 2005):

USU will continue to provide technical support through this period.

Benefits to the State:

This project is being carried out in conjunction with the State of Utah Division of Wildlife Resources, U.S. Fish and Wildlife Service, National Park Service, Bureau of Land Management, and the Washington County Water Conservancy District. The results of this work will guide long-term water allocation strategies and ultimately the successful recovery of the endangered species of fish within the Virgin River Basin.

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Uncertainty Analysis for Dam Safety Risk Assessment

Principal Investigator(s):
David S. Bowles
Loren R. Anderson
Terry F. Glover
Sanjay S. Chauhan
Wang Zhengang
Maged Aboelata

Project Description:

Dams exist in an environment of risk and uncertainty. For the past two decades, Utah State University (USU) researchers have worked to developed procedures that explicitly consider the risks associated with the performance of dams. They have also applied these procedures to more than 400 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, in Australia, and in England. Information obtained from these applications has provided valuable bases for many decisions to improve the safety of existing dams.

As with traditional approaches to dam safety evaluation, the risk enhanced approach must address the existence of uncertainties. The overall objectives of this project are as follows:

1. *To characterize uncertainties associated with the inputs to dam safety risk assessment (e.g., extreme flood frequencies, earthquake hazard relationships, system response relationships, and consequences relationships).*

2. *To develop and evaluate alternative approaches to the propagation of input uncertainties in a dam safety risk analysis model to estimate the resulting uncertainties associated with output variables.*

3. *To evaluate the significance of uncertainties on output variables and the implications for dam safety decision-making.*

4. *To develop guidance for decision makers for the interpretation of the uncertainties associated with risk assessment outcomes.*

Accomplishments (FY 2003):

Accomplishments in the past year have included the following:

- An uncertainty analysis was completed for a risk assessment of a US Army Corps of Engineers dam (Chauhan and Bowles 2003). This work provided a demonstration of a framework for uncertainty analysis in dam safety risk assessment, including an approach to incorporating input uncertainties into the risk analysis model. It proposed some useful formats for representing uncertainties in risk analysis results, such as expressing risk evaluation outcomes in terms of the confidence associated with meeting tolerable risk guidelines. This is very important additional information for decision makers compared with deterministic analyses, using only best estimate inputs, or sensitivity analyses. Best estimate inputs, even though

they represent the best judgment of experienced dam engineering professionals, provide just a single point on the spectrum of estimated risks and will not in general correspond to the best estimate of the output variables. Sensitivity analysis takes a further step by providing the range around the best estimate results, but it has a severe limitation in that it does not provide an estimate of the confidence in results obtained from best estimate inputs.

- The deterministic preliminary life-loss estimation modeling system was extended to incorporate a preliminary version of an uncertainty mode (see also "Dam Safety Risk Management" project).

- A Ph.D. dissertation is underway by Wang Zhengang to develop an approach for considering the effects of the breaching of embankment dams in dam safety risk assessment. The approach is considering the potential for breaches to initiate at multiple locations, non-level dam crests, and wind effects in an uncertainty framework.

Work Plan (FY 2004 and FY 2005):

Over the next two years, efforts will be focused on the following areas:

1. Completion of uncertainty analysis for embankment dams.

2. Extension of the deterministic preliminary life-loss estimation modeling system (see also "Dam Safety Risk Management" project described in this section) to an uncertainty framework.

3. Improved uncertainty modeling of dam safety risk assessment calculations to include common cause failure model considerations. We are planning to explore the contributions of uncertainty in different inputs to the uncertainty in various types of outputs using multiple regression analysis and correlation procedures. There is a need for additional research to provide guidance on the appropriate application of uncertainty analysis before it can be widely used. In addition, the consideration of model or epistemic uncertainty is a challenge for which practical approaches are needed.

Results will be presented at professional meetings.

Benefits to the State:

The improved procedures for uncertainty analysis in dam safety risk assessment, which are being developed under this project, will be applicable to dams in Utah. It is expected that they will increase the value of the risk-enhanced approach for gaining insights, exploring risk reduction options, and justifying safety improvements at existing dams.

References and Related Publications

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Mariush W. Kemblowski, PhD, Professor, CEE/UWRL
Randal Martin, PhD, Associate Professor, CEE/UWRL
Michael J. McFarland, PhD, Associate Professor, CEE/UWRL
Joan E. McLean, MS, Research Associate Professor, CEE/UWRL
Laurie McNeill, PhD, Assistant Professor, CEE/UWRL
William J. Rahmeyer, PhD, Professor, CEE/UWRL
Judith L. Sims, MS, Research Associate Professor, CEE/UWRL
Ronald C. Sims, PhD, Interim Associate Director, UWRL; Professor, CEE/UWRL
Darwin L. Sorensen, PhD, Research Professor, CEE/UWRL
David K. Stevens, PhD, Professor, CEE/UWRL
David G. Tarboton, PhD, Professor, CEE/UWRL
Blake Tullis, PhD, Assistant Professor, CEE/UWRL
Gilberto E. Urroz, PhD, Associate Professor, CEE/UWRL

Research Faculty, Professional and Support Staff

Utah Water Research Laboratory Staff

R. Craig Addley, MS, Associate Director of INSE, Senior Research Engineer
Steven L. Barfuss, MS, Research Engineer
Leon Basdeskas, BS, Research Engineer
William Bradford, BS, Research Associate
Marianne Brown, Staff Assistant I
Carmell Burns, Staff Assistant III
Terry Carlsen, BS, Research Technician
Peg Cashell, MS, Soil Scientist
Shannon Clemens, BS, Research Engineer
Matt Combes, BS, Research Engineer
Coreen Crouch, BS, Research Technician IV
Diane Ditlevsen, Staff Assistant
Jennifer Downs, Staff Assistant
Andrae Ferguson, BS, Publications Specialist
Ian Gowing, BS, Research Scientist
Barbara Haines, BS, Education/Travel Coordinator
Betty J. Hansen, Staff Assistant II
R. Ivonne Harris, BA, Information Dissemination Coordinator
Cindy Henderson, Runner
Jeffery Horsburgh, MS, Research Engineer
Richard Jex, MS, On-Site Wastewater Engineer
Danielle Jorgensen, Library Assistant
Tami Kadis, Receptionist
Max Longhurst, MEd, Professional Development Specialist
Jennifer Ludlow, MS, Research Engineer
Debra Lundgreen, BS, Marketing Coordinator
Sharon Melton, Accounting Technician
Bethany Neilsen, MS, Research Engineer
Michael Petersen, PhD, Research Scientist
Tamara Peterson, BS, Business Manager
ValaRee Reese, Staff Assistant
Carri Richards, Business Assistant
Megan Richards, Coordinator
Susan Robison, BS, Research Technician IV
Christopher Schofield, Chief Distribution Engineer
James Shoemaker, MS, Research Engineer
Geoffrey G. Smith, MS & MBA, Director IOWSE
Blaine Sorenson, MS, District Training Coordinator
Alan Taylor, Shop Foreman
Chris Thomas, BS, Accountant III
Zachary Tippetts, MS, Web Designer
Cynthia Tyler, BS, Research Engineer
Jan Urroz, BS, Supervisor of Administrative Services and Infrastructure
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
Frank W. Haws, MS, Senior Research Engineer Emeritus, 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