Applicability, Demonstration and Research on the Use of Treatment Wetlands in Region 8

Priority Areas:
a) Wetland Program Planning: Core Element C
b) Regulation: approaches 4 and 5
c) Monitoring and Assessment: extent and effects of pollution and development of monitoring surveys
Regional: Montana Strategic Direction 4, 5, and 7

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Missouri River Basin (HUC Code 100200 -- Missouri Headwaters)

Total Project Cost (including matching) $298,152
Federal (EPA) cost $198,152 (66%)

Abstract:
Treatment wetlands (TWs) are ecologically-based "green" water treatment systems offering many ecological services to a watershed. Though thousands of TWs are presently treating contaminated water worldwide, rapid advancements of this relatively new technology have rendered the majority of these systems obsolete and effluent water quality from the newest generation approaches the quality of the most advanced municipal treatment systems at a fraction of the cost. Nonetheless gaps in current knowledge, and more importantly popular and regulatory perception, impede use of this technology in cold-climate areas such as EPA Region 8. We propose to construct a state-of-the-art research and demonstration TW system, develop and implement a monitoring plan to determine both its treatment and ecological efficacy, and disseminate the resulting information through formalized channels. The system will be monitored for performance criteria over a minimum two full years of operation to characterize system start-up and seasonal variation effects. Additional monitoring will focus on the ecological services by applying and verifying use of accepted ecological assessment tools to treatment wetlands. Thus, outputs include development of pilot treatment wetland to demonstrate feasibility of TW systems in the region, monitoring of performance data, verification of the applicability of existing ecological assessment methods to TWs, and development of information that will contribute to a broader understanding of wetland resources across a state or tribal nation. Long term outcomes include development of design guidelines leading to improved decision-making by state and local officials, facilitation of the TW permitting by regulatory agencies in the region, and providing a learning center through which the general public can witness the benefits of wetlands.

DESCRIPTION OF PROJECT

The acceptance and use of treatment wetland (TW) systems as a water quality remediation technology has undergone rapid expansion over the last two decades. Relatively low capital costs, very low operating costs, documented performance expectations in line with more traditional systems (Kadlec and Wallace, 2009), and the ecological benefits associated with increasing wetland acreage make this a highly attractive water treatment technology. In Europe, these systems have become the preferred alternative for towns and villages less than 2000 people (Brix and Arias, 2005; Molle et al., 2005). Recent year-round tests of pilot and full-scale TWs in cold regions have convincingly demonstrated their feasibility (Mander and Jenssen, 2003), and performance of most TWs shows a surprising insensitivity to cold-temperatures (Kadlec and Reddy, 2001). Research conducted at Montana State University (MSU) on the influence of temperature, plant growth, and other factors that vary seasonally indicates that plant species selection plays an important role in cold temperature performance and that use of novel (for TW applications) native plant species improves performance (Allen et al., 2001, Stein and Hook, 2005, Taylor et al., 2008). Nonetheless, the rapid improvements in the design and performance expectations over the last decade, combined with lingering public and regulatory misconceptions of TW applications, have impeded acceptance and use in the United States (Wallace and Knight, 2006), especially in cold-climate regions. However, conditions are ripe to convincingly demonstrate that, with refinement of proper sizing criteria, TWs can achieve a superior effluent quality year-round for a fraction of the cost compared to almost all alternatives, even in the seasonally cold-climate areas of EPA Region 8.

We propose to construct a state-of-the-art research and demonstration treatment wetland (TW) system at the existing Bozeman, MT Water Reclamation Facility (BWRF), implement a

monitoring plan to determine both treatment performance and ecological benefit expectations, and disseminate the resulting information to a wide audience, specifically targeting municipalities, tribes, and state regulatory agencies. In addition to being a demonstration of TW applications in the region, this system will be a unique research facility containing replications of different wetland types and hydraulic configurations. The BWRF is an activated sludge plant offering a unique opportunity to characterize TW treatment efficacy for input wastewater types ranging from raw to post-secondary. Because final effluent can be returned to the permitted BWRF, we will have the capacity to systematically optimize performance without risk of pollutant discharges. Therefore all activities of this project are developmental and wetland program building, and are outside the scope of existing regulatory requirements. Planned long-term monitoring and assessment of water quality will foster development of improved design criteria for a variety of potential TW applications for climatic conditions typical to Region 8.

A design based on a preliminary cost estimate features eight vertical flow (VF) wetland units followed by four horizontal subsurface flow (HSSF) wetlands, modeled after the newest generation of TW systems in Europe (Molle et al., 2008). Each VF wetland unit consists of three 10x10 ft cells, while the HSSF wetlands will be approximately 20x30 ft (exact size depends on hydraulic conductivity characteristics of the specific gravel used). The system will be plumbed so that each VF unit can be operated independently (eight replications) or two in series (effluent from one enters the second, four replications). Effluent from each stage of purification will be mixed and redistributed into the next (VF1 to VF2 to HSSF). This allows for maximum flexibility to measure performance as a function of hydraulic configuration and carbon and nitrogen hydraulic loading rates under identical seasonally-varying climatic conditions. The resulting performance data will be combined with existing knowledge to develop design criteria

for year-round operation over a broad range of applications including new domestic wastewater systems, retrofitting and/or expansion of existing systems, or polishing effluent of poorly performing existing systems.

We anticipate construction of this research and demonstration wetland will lead to a long term education, training and monitoring program funded from a variety of sources. As part of this grant, funds are requested for construction, to develop baseline data and characterize system start-up and seasonal variation effects over a two year minimum duration after construction. In addition to performance criteria, baseline monitoring related to wetland ecological functions and condition will be conducted. Results will lead to full-scale design criteria and standard operating procedures enabling the state of Montana to provide direct guidance to municipal engineers and operators to construct and operate these treatment systems in a consistent manner across the region.

PROJECT TASKS

The first task will be to finalize the design and construct the demonstration wetland system. Dr. Stein and Mr. LaVigne will work with an engineering consulting company to finalize a system design within the proposed budget, develop construction-grade plans and put construction out for bid. Actual construction will be performed by a licensed contractor. Based on our previous results (Stein et al., 2002; Taylor et al., 2008) we plan to use bulrush (*Schoenoplectus acutus*) in the VF units and sedges (*Carex utriculata* and *C. nebrascensis*) in the HSSF units.

It is important to note that since the system will utilize a small fraction of the BWRF flow as influent and return the TW effluent to it, the TW system size and design flow rate (one variable in the experimental design) is somewhat arbitrary. However, using the most

conservative European design standards (Arias and Brix, 2005), the proposed system will treat 4600 gal/d or the expected flow rate generated by approximately 50 people (Wallace and Knight, 2006). Current research (Molle et al., 2008) suggests this design standard could be conservative by a factor of 5, indicating that the same-sized system might successfully treat the flow rate generated by as many as 250 people, or approximately 80 households. Though the proposed design optimizes the research potential, the system could be scaled up or down to meet potential budgetary restraints without compromise of function as a demonstration wetland.

The second task is to characterize start-up and seasonal performance variation and develop and conduct a series of experiments designed to optimize the overall treatment efficacy as a function of flow rate, hydraulic configuration and possibly plant species selection. Dr. Stein will oversee an engineering graduate student who will be responsible for water quality measurements and analyses. We anticipate running the system as four identical replicates initially (VF1 to VF2 to HSSF stages) using screened raw wastewater as the input (Molle et al., 2008), but using the more conservative European flow rates (Arias and Brix, 2005). This configuration will bracket all possible applications; the first VF unit treating primary wastewater, the second secondary wastewater, and the HSSF serving as nutrient removal and polishing units. After system stabilization (defined as all replicates performing similarly, but not necessarily time invariant) two different flow rates (and thus pollutant loading rates) will be applied simultaneously to two of the two-stage VF units (2 replicates of 2 flow rates). These flow rates will be systematically increased (or decreased) with consideration of season and the resulting performance data will be used to develop regionally applicable design criteria. Several alternative operational schemes are possible increasing experimental design flexibility; post-primary (after solids removal) could be diverted from the existing plant and the VF wetlands

could be run as eight single-stage VF units followed by the HSSF units, thereby maximizing variation in flow rates and waste concentrations for system optimization. Funding from other sources will be pursued to expand the experimental options and monitor the system over a much longer time frame.

The third task, lead by Dr. Patten, will be to assess the ecological integrity of the TW. There are two ways to address this, one relates to wetland condition and the other to wetland function though these are not entirely inseparable (Fennessy et al., 2004). Ecological functions we will assess include biogeochemical cycling (e.g., nitrogen cycling and/or removal), hydrology (e.g., hydrological connectivity), and biological diversity (e.g., vegetation diversity represented by appropriate wetland species and habitat for animal species such as birds and amphibians). Of these functions, water quality will be assessed relative to inputs and outflows and hydrological function will be controlled by inputs. Biological diversity will be assessed using several wetland condition assessment methodologies. Although wetland functions are probably the most critical in determining the quality of a wetland, it is possible to find that wetlands "score" high for select functions, such as nitrogen removal or water quality, without scoring high in condition. Consequently, we will use accepted methods of determining wetland condition to allow comparison to more natural wetlands in the area.

There are several methods for assessing wetland conditions in Montana, most having similar or overlapping metrics or indicators. These methods range from broad landscape level assessments and mapping, to rapid field assessments, to intensive field assessments. We will initially adopt the rapid assessment method used by the Montana Department of Environmental Quality (MDEQ) recognizing that this method includes many parameters that might be inappropriate for assessment of a TW. However, focusing on parameters appropriate to a TW

application will allow for comparison of general on-site wetland condition relative to other wetlands that have been assessed by the technique.

We will also quantitatively assess those ecological factors that define wetlands, that is, hydrology, vegetation, soils and water quality. Of these factors, vegetation development and cover will be the primary factor (USEPA, 2002). Although vegetation composition and other wetland factors will be controlled in construction or functioning of the TW system, we will quantify their status during the duration of the study. This will include assessing plant species composition to determine whether other wetland species have colonized the TW. In addition to vegetation indicators, we will determine through qualitative observation use of the wetland by avian and amphibian species as well as other transient wildlife species. Comparisons of these uses in the TW will be made with data generated through observations and limited sampling at "natural" wetlands located less than a mile away from the TW site.

The fourth task will be to disseminate information to a wide audience via site tours, student education, technical publications, scientific conference presentations, and short courses targeting regulatory agencies and consulting engineers. The site will be available for visitation and we anticipate that regulators, engineers and students will be interested in a first-hand look at this breakthrough TW system. We will construct a kiosk showing the "invisible" parts that makes these multiple-stage TWs effective. Graduate and undergraduate students will play an important role in development of design criteria and will conduct the majority of water quality and ecological monitoring. A mixture of students and professionals associated with the project will attend and present results at annual scientific meetings. In addition, Drs. Patten and Stein will make presentations of the applicability and design of TWs to appropriate state, tribal and

local regulators and to the consulting engineering community ultimately promoting the technology to potential clients.

MILESTONE SCEHDULE

Task 1 will begin as soon as funds are available. Finalization of design and letting of construction bids will be completed within three months. Construction should be completed within the following 9-12 months subject to the timing of the award, season and weather conditions. Tasks 2 and 3 would commence immediately upon completion of construction and continue for a minimum of two full years of operation. Note that we anticipate additional funding from other sources (e.g. NSF, USDA) to implement a long term monitoring plan. Aspects of Task 4 would commence immediately after construction (site visits) and anticipate two people attending national meetings during years 2 thru 4. One short course per year will be conducted in years 2 thru 4 by Drs. Patten and Stein.

PROJECT NEED

Scientific understanding of the water purification processes occurring within TWs has expanded dramatically since their general acceptance in the late 1980's (Faulwetter et al., 2009). Concurrent experimentation and design innovations have moved the technology from isolated, and/or experimental applications to mainstream systems with performance expectations superior to all "extensive" (low energy input) systems (lagoons, and land treatment) with effluent water quality approaching that of the most advanced high energy systems such as activated sludge (Molle, et al., 2008; Kadlec and Wallace, 2009). However, these advancements have occurred primarily beyond the borders of the United States so that most operational US TWs, our design guidelines (e.g. USEPA, 2000), and our general perceptions of both function and performance are woefully obsolete. The documented effluent quality from the newest design generation

suggests that further advancements will be one of refinement for climatic conditions, rather than rapid changes in basic design and operation and, as in Europe, these systems could become the preferred alternative for most small municipalities in Region 8 and a viable alternative for even the largest cities in Montana, the Dakotas and Wyoming.

The need for low cost, high quality treatment systems in Montana and the region is acute. The State of Montana is well along in the process of implementing numeric nutrient criteria for wadeable streams. The proposed in-stream target values are extremely low (at or below technological treatment limits) in relation to effluent nutrient values at existing municipal wastewater treatment facilities. These values are reflective of other states in the region as well. The generally accepted treatment methodologies for achieving limits of technology with respect to nitrogen and phosphorous are not only extremely expensive, they require very experienced operators to optimize the treatment capabilities of these facilities. Therefore, there is an acute need for inexpensive and simple, yet very effective and consistent, technologies to address nutrient removal in small communities and developments, not only in Montana but across the Rocky Mountain and Northern Plains states. Treatment wetland construction costs are typically a fraction of conventional (e.g. activated sludge) systems. Operational cost savings are generally even greater; typically one tenth of the next cheapest system and one hundredth of activated sludge (Kadlec and Wallace, 2009). For example, our TW system will require no energy whatsoever except for minor pumping of water from and to the existing plant compared to $30,000 per month electrical costs alone at the BWRF.

Though the Army Corps of Engineers does not consider TWs as mitigation wetlands, the ability of TWs to provide some level of ecological service is well documented (see Kadlec and Wallace (2009) for many citations). Beyond the obvious water quality service, TWs provide

critical wetland bird habitat, and potentially mammal and amphibian habitat. Therefore even moderate adoption of TW technology within Region 8 will contribute to a net gain of wetland ecological services. This project will simultaneously address both treatment efficacy concerns in cold climates and document the potential ecological service of these wetlands in our Region.

NATIONAL AND/OR REGIONAL PRIORITY AREAS

This project will 1) demonstrate the feasibility of treatment wetland technology in the region, 2) conduct research investigations and experiments to optimize their water pollution elimination efficacy and 3) develop baseline information on the additional ecological services of this type of wetland, leading to greater adoption of this technology and providing another mechanism for net wetland area gain. Thus, it is directly relevant to the Healthy Communities and Ecosystems goal of the EPA 2006-2011 Strategic Plan, while addressing several National Priority Areas topics.

Our results will have a direct effect on the ***Regulatory Strategy core element of the Wetland Program Plan*** National Priority Area. The State of Montana is very interested in developing a design guideline outlining potential uses, design considerations, and ecological services of treatment wetlands that can be used by consulting engineers and others professionals and should be transferable to all state, tribal and local entities in the region. Our project will directly address this goal. It will also directly relate to approaches 4 and 5 of the ***Regulation*** National Priority Area. A major goal is to develop a municipal TW permitting program for Montana that could also be adopted into local ordinances for use by county health officials for use of TWs as individual household on-site treatment systems. Our education and outreach component will demonstrate how these wetlands can fit into broader watershed management and aquatic ecosystem protection goals and our research will refine information regarding the

function of these valuable resources. Our project also focuses on the ***Monitoring and Assessment*** National Priority Area. We will directly monitor the efficacy of a modern TW system under the relatively extreme climatic conditions of Region 8 and also apply and verify the applicability of existing ecological services assessments to this specific type of wetland. Ultimately, these activities could lead to ecological performance standards for TW sites.

In addition, the project will address three directions identified in Montana's wetland strategic plan (MDEQ, 2008). We will directly apply and verify assessment tools for evaluation of longer-term success and ecological effectiveness of created wetlands in Montana to a TW system. We will work directly with a local municipality (City of Bozeman) to develop a wetland system and determine the ecological effectiveness of such systems in Montana and Region 8. Data will be available to all jurisdictions within the region. Our results will have a direct effect on public policy through TW guideline development, but will also educate regulators, elected officials and general populace on the benefits of wetlands in the environment.

PROJECT GOAL AND OBJECTIVES

The overarching project goal is to increase the acceptance and use of treatment wetlands in cold regions, specifically the Rocky Mountains and northern Great Plains encompassing Region 8, and to assess the habitat and watershed-level ecological function of wetlands designed primarily for water treatment. Our four tasks serve as specific objectives. We anticipate that our results will convincingly demonstrate the effectiveness of TWs in Montana and EPA Region 8 and should allow for greater acceptance of these systems for water quality remediation, therefore directly leading to more wetland acreage as outlined in the EPA strategic plan.

The project will lead to several measureable outputs as identified in the RFP. These include; development of pilot treatment wetland to demonstrate its water quality amelioration and ecological effectiveness, verification of existing assessment methods applicability to TWs, and development of information that will contribute to a broader understanding of wetland resources across a state or tribal nation. Methods and progress timelines are described in previous sections.

Several measureable outcomes will be realized by completion of this project. The development of design guidelines will provide state and local officials working in regulatory environments, i.e. MDEQ and county heath departments, with increased knowledge of TW water quality and environmental efficacy potential, leading to improved decision-making. We anticipate that longer term monitoring results will facilitate the permitting of TWs in Montana, and potentially other states and tribes in the region. The demonstration wetland will be a learning center through which the general public can see first-hand the benefits of wetlands for water quality amelioration.

RESTORATION PROJECT INFORMATION

No wetlands currently exist at the proposed demonstration and research TW site. The site was graded in the 1970's as a rapid infiltration bed system for nutrient removal but has never been used as such. The current condition is essentially a mowed field. The monitoring program and experimental design were previously described. We are requesting EPA funding in support of a graduate student who will perform the baseline water quality monitoring for a two-year period immediately after construction. The MSU wetland research group has an established successful grant record for research into TW purification processes with funding from multiple federal, state and private entities including the National Science Foundation, USDA and ARCO-

BP. We anticipate that an EPA-funded research TW facility will greatly increase the potential for success in our future grants focusing on long term monitoring and assessment.

STAFFING INFORMATION AND APPLICANT EXPERIENCE

Annotated resumes are provided for the principal investigators, Drs. Otto Stein and Duncan Patten and Mr. Paul Lavigne, PE. Dr. Stein's research has focused on treatment wetlands for over a dozen years and is currently the North American coordinator for the IWA Constructed Wetlands Specialist Group. He is author or co-author on over 25 technical papers supervised many graduate students and made over 30 presentations on TWs, teaches a course on Natural Treatment Systems and is internationally recognized as an expert on treatment wetland systems. Dr. Patten has over 40 years experience as a wetland and riparian scientist and is a former President of the Society of Wetland Scientists, an international organization of wetland and riparian scientists. He is author or co-author on over 60 peer reviewed papers, has supervised over 45 graduate students and, with colleagues, made over 100 presentations on his ecological research, many of them about riparian and wetland systems. Mr. LaVigne is the WPCSRF Manager of Technical and Financial Assistance Bureau of MDEQ, responsible for technical review and assistance in the planning, design, construction and operation of municipal wastewater treatment plants in Montana. He is also responsible for the development and implementation of engineering design standards for municipal wastewater collection and treatment. He has been with MDEQ for 18 years.

PARTNERSHIP INFORMATION

The project is a partnership between two Montana state agencies (MSU, MDEQ), and the City of Bozeman. MSU will take the lead for project budgeting, all monitoring aspects and the dissemination of resulting information while MDEQ will be responsible for the contracting

aspects of the TW design and construction and is providing $50,000 toward construction. Bozeman will donate the land for the construction of the facility, pay the minimal electrical cost for pumping between the existing plant and the TW system and perform some water quality analyses in the treatment plant lab. This in-kind contribution is estimated at $50,000. Principal investigators will coordinate with Bozeman's municipal engineering department and wastewater treatment staff to insure seamless integration of the demonstration wetland with the normal operation of existing treatment plant. MDEQ will provide additional matching funds for the development of the demonstration project and MDEQ staff will be integrated into the development of TW design guidelines. Additionally, several private firms have expressed interest in donating time and/or materials to the demonstration project but no formal arrangements have been made.

TRANSFER OF RESULTS AND OUTREACH

Outreach is one of our four major tasks. Drs. Patten and Stein will make presentations of the applicability and design of TWs to appropriate state, tribal and local regulators and to the consulting engineering community. Key personnel associated with the project will be expected to attend and report results through traditional venues such as annual meetings sponsored by the Society of Wetland Scientists, International Water Association Constructed Wetlands group, Water Environment Research Foundation and the American Ecological Society. The project will also generate written scientific reports through graduate students theses and writing of scientific journal papers. Site visits to the demonstration wetland will offer a unique opportunity to educate the general public on the important role wetlands play in the removal of pollutants and general importance of wetlands on the landscape. We anticipate the wetland will be visited by MSU and K-12 science classes and could be an important component in attracting a major

national/international wetland conference to Montana. The development of TW design guidelines and permit requirements will promote the technology in Montana and could be an important guiding document to be emulated by other states and tribal entities catalyzing wetland creation throughout the region.

QA/QC AND INVASIVE SPECIES CONTROL

MSU and the City of Bozeman maintain state-of-the-art water quality laboratories and most anticipated water quality indices we will measure are routinely conducted. As suggested in the RFP, we will request EPA's assistance to determine the appropriate QA/QC practices for this project. If our environmental assessment procedures detect colonization of the TW system by invasive species we will control them in an appropriate manner as approved by the EPA Program Manager.

BUDGET NARRATIVE

Total project costs are estimated at $298,152. Funding is requested to finalize the design and to construct the demonstration treatment wetland (estimated cost $100,000/50,000 total/Federal). The MDEQ will provide an $50,000 toward construction and the City of Bozeman will donate use of approximately 1 acre of land and other services (estimated in-kind value $50,000) thereby more than satisfying the non-federal matching component. Federal funds will be used for all other budget items. Personnel costs are estimated at $59,600 including one month per year for project oversight by Dr. Stein, a 24-month graduate student stipend who will be responsible for wetland monitoring, and 300 hours of undergraduate labor associated with monitoring the wetland system. Travel funds will allow two people to attend a national wetland conference in years 2-4 to present findings. Water quality monitoring supplies are conservatively estimated at $5,000 over the four year project. "Other" category costs are for

tuition and fees for the graduate student. Indirect costs are calculated on the MSU standard federal negotiated rate of 42.5% TDC minus construction costs and graduate tuition and fees.

PAST PERFORMANCE

Drs. Stein and Patten have many years of experience managing research projects from a variety of federal and non-federal sources. In the past 5 years Dr. Stein has been a Principal Investigator on a total of seven grants worth just over 1 million dollars, including two currently active grants (from USDA-CSRS-NRI, $425,000; and South Dakota Dept. of Transportation, $120,000). Other funding sources include Montana Dept. of Transportation (MDT), NSF, Conoco Inc. and ARCO-BP. Inc. In all cases, reporting requirements, which vary by agency and specific grant, have been met in a timely manner. For example, the USDA award requires annual progress reports and MDT required quarterly progress reports and a final technical report. In most cases a major expectation was dissemination of results through journal articles, conference proceeding oral presentations and technical meetings and Dr. Stein has developed a reputation as an international expert on treatment wetland systems through these venues.

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OTTO R STEIN

A) Education

Pennsylvania State University	Environmental Resource Management	BS,	1980,
With Distinction			
Purdue University	Agronomy (Soil Science)	MS	1983
Colorado State University	Civil Engineering	PhD	1990

B) Professional Experience

Professor, Department of Civil Engineering, Montana State University, 2006-Present
Associate Professor, Department of Civil Engineering, Montana State University, 1996-2006
Visiting Scientist, National Institute for Water and Atmospheric Research LTD, New Zealand, 2001-2002
Assistant Professor, Department of Civil Engineering, Montana State University, 1990-1996

C) Ten Relevant Publications

Faulwetter, J.L., V. Gagnon, C. Sundberg, F. Chazarenc, M.D. Burr, J. Brisson, and O.R. Stein. 2009. Microbial Processes Influencing Performance of Treatment Wetlands: A Review. Ecological Engineering. 35(6):987-1004.

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D) Synergistic Activities

For approximately the last dozen years my research and teaching has focused on the optimization of constructed (treatment) wetlands and I have managed several research projects and graduate students on the topic. My next goal is to move my groups' research from controlled laboratory and greenhouse studies to studying of field scale operational treatment wetlands. My work on constructed wetlands has always had a strong interdisciplinary nature with engineering and plant science students working together as a team to focus on plant and seasonal effects on treatment efficacy. My current project with USDA also includes a microbiology student as a third leg of the interdisciplinary team.

I have held several leadership positions in various professional organizations including president of the Pacific Northwest Region of the American Society of Agricultural Engineers (1993-1996), Associate Editor for the ASCE Journal of Hydraulic Engineering (2002-2006), and am currently the North American Coordinator for Constructed Wetlands Specialist Group of the International Water Association (2006-present). I have also been on the scientific committee for several international conferences on water quality issues.

I led a group of faculty that developed the Bio-Resources option of Civil Engineering at MSU, the first curriculum accepting senior-level natural resources courses as engineering professional electives. I continue to support better integration of engineering and science education at both the undergraduate and graduate level.

I have advised a multitude of undergraduates (mostly, but exclusively engineers) in research projects through formal programs such as Research Experience for Undergraduates (REU), the MSU Undergraduate Scholars Program or for independent study credit, and informally by hiring for pay. Well over 50% of these students were women and approximately half (including most women) have gone to graduate school either with me or at other institutions.

Honors and Awards

College of Engineering Outstanding Research Award 2005
Bio-Resources Engineering Professor of the Year, 1992, 1993, 1995
College of Engineering Outstanding Instructor Award, 1991
Gamma Sigma Delta Honor Society

E) Collaborators

Ed Adams	Carlos Alonso	Jim Bauder	Jarett Barber
Sean Bennett	Matt Blank	Bob Boik	Bob Bramblett
Jacques Brisson	Mark Burr	Joel Cahoon	Anne Camper
Florent Chazarenc	Al Cunningham	Rick Engel	Wayne Gipp
Paul Hook	Warren Jones	Pierre Julien	Steven Kalinowski
Terry Logan	Clayton Marlow	Brian McGlynn	Tom McMahon
Bill Moldenhauer	Cindy Morris	Warren Neibling	Steve Perkins
John Priscu	Anne Rasmur-Raven	Charles Roth	Diederik Rousseau
Rebecca Seal	Brad Shepard	Xianming Shi	Paul Sturman
Mark Taper	Jan Vymazal	Cathy Zabinski	

Thesis Advisor Last Five Years.

R.L. Schultz, K.C. Rowbury, S.M. Anderson, D.G. Baune, D.J. Borden-Stewart, J.L. Kowles-Grove, K.A. Riley, J.R. Sturm

Total Number of Graduate Students Advised: 28 (9 women + 1 Native American)

DUNCAN T. PATTEN

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Research Professor, Department of Land Resources and Environmental Sciences, Montana State University, Bozeman, MT

Prof. Emeritus of Plant Biology, Dept. of Plant Biology, Arizona State University, Tempe, AZ

DEGREES

A.B., Biology-Chemistry, Amherst College, 1956
M.S., Botany, University of Massachusetts, 1959
Ph.D., Botany-Ecology, Duke University, 1962

ACADEMIC EXPERIENCE

Assistant Professor 1962-65, Virginia Polytechnic Institute
Assistant to Full Professor 1965-95, Arizona State University
Professor Emeritus 1995-, Arizona State University
Research Professor 1999-, Montana State University

ADDITIONAL EXPERIENCE OR HONORS

Senior Scientist, Department of the Interior, Glen Canyon Envir. Studies (1989-1996)
Bureau of Reclamation, Citizens Award. 1996.
Ecological Society of America, Distinguished Service Award. 1994.
Chair, Dept. of Botany/Microbiology, Arizona State University (1976-1980)
Director, Center for Environmental Studies, Arizona State University (1980-1995)
Business Manager, Ecological Society of America (1979-1995)
President, Society of Wetland Scientists (1996-1997)
President, Arizona Riparian Council (1985-1989)
Member and/or Chair. Several NAS/National Research Council committees.
Member NAS/NRC Board on Environmental Studies and Toxicology (1987-90) and the Commission on Geoscience, Environment and Resources (1990-93).
Chair, Technical Advisory Committee, National Institute for Global Environmental Change, 1994-96; member, 1990-96.
Member, EPA Science Advisory Board (2008-)
Fellow, American Association for the Advancement of Science (1979-)

RESEARCH GRANTS AND CONTRACTS SUPPORT

Research support, alone and with co-investigators, for projects ranging from riparian functions to integration of Glen Canyon Environmental Studies data for the period 1992-2008 totaled more than $5 million.

RESEARCH INTERESTS

Dynamics and restoration of riparian and wetland ecosystems. Desert and Rocky Mountain communities and ecosystems. Human impacts on ecosystems.

GRADUATE STUDENT PROGRAM

29 Masters students completed, 1 in progress. 15 Ph.D. students completed, 1 in progress.

RECENT and/or RELEVANT PUBLICATIONS

1991 Patten, D. T. Human impacts in the greater Yellowstone ecosystem: evaluating sustainability goals and eco-redevelopment. Conservation Biology 5 (3): 405-411.

1991 Patten, D. T. Defining the greater Yellowstone ecosystem. Pp. 19-26 in R. B. Keiter and M. K. Boyce (eds.), The greater Yellowstone ecosystem, Yale University Press.

1992 Stromberg, J.C. and D.T. Patten. Mortality and age of black cottonwood stands along diverted and undiverted streams in the eastern Sierra Nevada, California. Madrono 39:205-223.

1992 Stromberg, J.C. and D.T. Patten. Response of Salix lasiolepis to augmented stream flows in the upper Owens River. Madrono 39:224-235.
1993 Patten, D.T. Herbivore optimization and overcompensation, does response of western rangelands to native herbivory support these theories? Ecological Applications 3:35-36.
1993 Stromberg, J.C., B.D. Richter, D.T. Patten, and L.G. Wolden. Response of a Sonoran riparian forest to a 10-year return flood. Great Basin Naturalist 53(2):118-130.
1993 Wiens, J.A., D.T. Patten, D.B. Botkin. Assessing ecological impact assessment: lessons from Mono Lake, California. Ecological Applications 3:595-609.
1996 Stromberg, J.C., and D.T. Patten. Instream flow and cottonwood growth in the Eastern Sierra Nevada of California, USA. Regulated Rivers: Research and Management 12:1-12.
1997 Stromberg, J.C., J. Fry, and D.T. Patten. Marsh development after large floods in an alluvial, arid-land river. Wetlands 17:292-300.
1998 Shaftroth, P.B., G.T. Auble, J.C. Stromberg, and D.T. Patten. Establishment of woody riparian vegetation in relation to annual patterns of streamflow, Bill Williams River, Arizona. Wetlands 18:577-590.
1998 Patten, D.T. Riparian ecosystems of semi-arid North America: diversity and human impacts. Wetlands 18:498-512.
1999 Springer, A.E., J.M. Wright, P.B. Shafroth, J.C. Stromberg, and D.T. Patten. Coupling groundwater and riparian vegetation models to assess effects of reservoir releases. Water Resources Research 35:3621-3630.
2000 Shafroth, P.B., J.C. Stromberg, and D.T. Patten. Woody riparian vegetation response to different alluvial water table regimes. Western North American Naturalist 60:66-76.
2001 Patten, D.T., D.A. Harpman, M.I. Voita, and T.J. Randle. A managed flood on the Colorado River: background, objectives, design, and implementation. Ecological Applications 11:635-643.
2001 Marler, R.J., J.C. Stromberg, and D.T. Patten. Growth response of Populus fremontii, Salix gooddingii, and Tamarix ramosissima seedlings under different nitrogen and phosphorus concentrations. Journal of Arid Environments 49:133-146.
2002 Shafroth, P.B., J.C. Stromberg, and D.T. Patten. Riparian vegetation response to altered disturbance and stress regimes. Ecological Applications. 12:107-123.
2006 Baker, C, R.L. Lawrence, C. Montagne and D. Patten. Mapping wetlands and riparian areas using Landsat ETM+ imagery and decision-tree-based models. Wetlands 26:465-474.
2006 Patten, D.T. Restoration of Wetland and Riparian Systems: The Role of Science, Adaptive Management, History, and Values. Journal of Contemporary Water Research and Education 134:9-18.
2007 Baker, C., R.L. Lawrence, C. Montagne and D. Patten. Change detection of wetland ecosystems using Landsat imagery and change vector analysis. Wetlands 27:610-619.
2008 Patten, D.T., L. Rouse, and J.C. Stromberg. Isolated spring wetlands in the Great Basin and Mojave Deserts, U.S.A.: Potential response of vegetation to groundwater withdrawal. Environmental Management 41(3): 398-413.

Paul R. LaVigne

Professional Objective	Protection and improvement of water quality through engineering and science.

Education

1990-91	Montana State University, Bozeman, Montana Graduate studies in environmental engineering Dow Fellow, NSF Center for Biofilm Engineering
1985-89	University of New Mexico, Albuquerque, New Mexico Degree: B.S. Civil Engineering in May, 1989 - emphasis in hydrology. Graduated "Summa Cum Laude with distinction"
Honors and Awards	Outstanding Junior Civil Engineering Student, by faculty nomination, University of New Mexico Recipient of various scholarships 1986 - 1989.

Professional Experience

2004 – present	Manager, Montana Water Pollution State Revolving Fund Program, Department of Environmental Quality, Helena, Montana. Manage staff of 7 individuals, including five environmental engineers, an operations specialist and an administrative support staff. Responsible for a $700,000 per year operations budget and a $10 to 30 million per year revolving loan fund budget for planning, design and construction of water pollution control projects. Responsible for a technical assistance program for water pollution control facility operators, consulting engineers, public officials and the general public. Collaborated with Dr. Mike Suplee on the development of affordability and technical limitation waiver process with regard to Montana's numeric nutrient standards (on-going). Responsible for development and implementation of technical design standards for water pollution control facilities in Montana.
1991 - 2004	Environmental Engineer, Montana Department of Environmental Quality, Helena, Montana. Responsibilities include: managing wastewater treatment construction projects to ensure compliance with state and federal laws and regulations; independent engineering analysis of requests for deviations from state water and wastewater design standards; state's biosolids coordinator involved assisting the regulated community in the practical interpretation of the Federal 503 Biosolids regulations; reviewing wastewater plans and specifications for complex wastewater

	treatment proposals; training water and wastewater operators and engineers; conducting operation and maintenance inspections and comprehensive performance evaluations of municipal wastewater treatment facilities; assisting in the coordination, development and implementation of the Drinking Water State Revolving Fund program, including development of enabling legislation. Responsible for development of design standards for constructed wetlands for wastewater treatment.
1989-90	Civil engineer with Boyle Engineering Corporation, Albuquerque, New Mexico. Responsibilities included: designing and modeling of hydraulic structures; hydrologic modeling using various computer models; surveying for topographic information and horizontal and vertical control.
Summer 1987	Civil Engineer Technician with Jacobs Engineering Group, Albuquerque, New Mexico. Responsibilities included hydrologic modeling of "most probable maximum floods" for uranium mill tailing containment sites.

Extracurricular Activities

Chairman, Montana Water Environment Assoc. Biosolids Committee, 1992
President, Montana Water Environment Association, 2008-2009