

California Water Resources Center



Annual Report 2002 – 2003

July 1, 2002 – June 20, 2003

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UC Center for Water Resources

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FROM THE DIRECTOR



Dr. John Letey

The University of California Center for Water Resources (CWR) is composed of various programs which were initially established as separate programs. Each was established on a different date for different purposes.

The Water Resources Center (WRC) is a multicampus research unit in the University's Division of Agriculture and Natural Resources and is charged with stimulating and coordinating research and information dissemination on water. The Center was first funded in 1957 by the California legislature as a University-wide organized research unit. Over the years, its mission has expanded from an early focus on the State Water Project to one that encompasses virtually all water and water-related issues.

The Federal Water Resources Research Act of 1964 specified that each state have a water resources institute as part of the network of National Institutes of Water Resources (NIWR).

The University of California WRC was selected to be California's Institute. As a member of NIWR, the Center receives a base budget (\$84,234 during 2002-2003) and the opportunity to submit proposals to the National Competitive Grants Program and also receive USGS funding for specific research projects. The University of California received two of the six projects funded nationally from the Competitive Grants Program. These projects were "Dynamics of Point and Non-Point Source Fecal Pollution from an Urban Watershed in Southern California" with Dr. Stanley B. Grant from the University of California, Irvine as principle investigator (\$159,045) and "Distribution and Toxicity of Sediment-Associated Pesticides in the Sacramento River" with Dr. Donald Weston from the University of Berkeley as the principle investigator (\$199,927).

Through the Center, a USGS grant of \$20,000 was awarded to Dr. Graham Fogg at UC Davis for the project "Develop Random-Walk Solution Package for the U.S. Geological Survey's MODFLOW-2000 Ground-Water Transport Package" and \$792,000 to Dr. Joel Michaelsen at UC Santa Barbara for the project "Spatially Explicit Modeling and Monitoring of Hydroclimatic Extremes: Reducing the Threat to Food Security in the Developing World".

The Coordinating Board, comprised of academic senate members from the U.C. campuses, serves as the governing body of the WRC. The Advisory Council participates with the Coordinating Board members in reviewing research proposals to be funded from WRC and NIWR moneys and discussing business matters at joint meetings.

The largest proportion of the WRC budget goes to supporting research projects on a broad range of water-related issues. The annual progress reports on these projects are included within this publication. The projects serve the dual role of developing knowledge and training students.

The WRC provides the major support budget for the Water Resources Center Archives, located on the Berkeley campus. However, the financial and other support services by various donors and the Advisory Board to the Water Resources Center Archives are acknowledged and greatly appreciated. A more detailed report on the Archives is presented on page 11 of this annual report.

Salinity/Drainage Program

The Salinity/Drainage Program (S/D) was developed in 1985 to promote research in the area of critical agricultural and environmental problems on the west side of the San Joaquin Valley. The program was established after the discovery of selenium toxicosis of waterfowl at the Kesterson Reservoir, which then served as a collection site for farm subsurface drainage water.

The Prosser Trust Fund is administered through the Salinity/Drainage Program. Joseph G. Prosser and his son developed the tensiometer as a soil water-sensing device. Subsequent relationships he developed with scientists at the Citrus Experiment Station in Riverside, led to his providing the University of California an endowment to support the development of efficient irrigation activities. The annual income from this trust fund is distributed for research and extension activities pursuant to the terms of the trust.

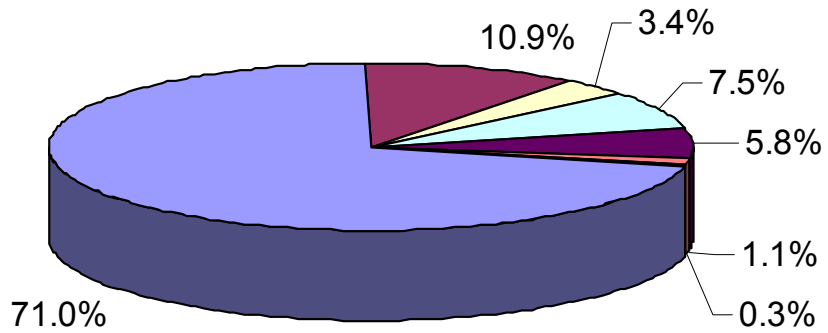
The Salinity/Drainage and Prosser Trust funds were designated for mission oriented research and, therefore, the call and review of proposals for these programs is separate from the WRC and NIWR funded projects. The annual research progress reports from these projects are published separately.

The following summarizes the budget distribution from the various sources of funding to the U.C. Center for Water Resources.

2002-2003 BUDGET DISTRIBUTION

		AMOUNT	%
<u>RESEARCH PROJECTS</u>		\$1,255,139	71%
WRC Grants	\$663,480		
S/D Grants	\$455,885		
NIWR Grants	\$ 79,234		
Prosser Grants	\$ 56,540		
<u>ARCHIVES (WRC)</u>		\$192,050	10.9%
Staff	\$172,050		
Operation	\$ 20,000		
<u>OUTREACH (WRC AND S/D)</u>		\$ 60,677	3.4%
Newsletter and Annual Reports	\$ 32,512		
Conferences and meetings	\$ 8,165		
Oral History	\$ 20,000		
<u>DIRECTOR & ASSOCIATE DIRECTOR (WRC & S/D)</u>		\$133,300	7.5%
<u>STAFF (WRC AND S/D)</u>		\$101,824	5.8%
<u>OFFICE EXPENSES (WRC AND S/D)</u>		\$ 18,674	1.1%
<u>NIWR ADMINISTRATION (NIWR)</u>		\$ 5,000	0.3%

The Center for Water Resources 2002-2003 Budget Distribution



- Research Projects
- Archives (WRC)
- Outreach (WRC and S/D)
- Director and Associate Director (WRC and S/D)
- Staff (WRC and S/D)
- Office Expenses (WRC and S/D)
- NIWR Administration (NIWR)



THE COORDINATING BOARD

The Coordinating Board establishes policy for the Center and makes final decisions regarding the allocation of available funds. It is chaired by the Vice President of Agriculture and Natural Resources, through whom it reports directly to the President of the University. The Board, appointed by the President of the University, is composed of at least 13 faculty members from diverse disciplines and various administrative, teaching and research responsibilities. All members

have a strong interest in water-related research. Eight of the nine campuses of the University are represented on the Board. The Board normally meets yearly. Members serve as liaisons or as contacts on their own campuses, as well as to agencies, citizens, faculty, and students in water-related research. These liaison interactions contribute valuable insights in establishing policy for the Water Resources Center. Members of the Coordinating Board during 2002-2003 were:

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THE ADVISORY COUNCIL

The Advisory Council shall include representatives from the State Water Resources Control Board, Department of Water Resources, California Department of Fish and Game, and the U.S. Geological Survey who are selected by the appropriate administrator for each agency. Additionally, experts from a broad spectrum of water interests are appointed to the Advisory Council.

The Council members serve a very effective liasion function between the Water Resources Center and the public and private organizations that are involved in the management, development, control and use of water resources.

The Advisory Council meets jointly with the Coordinating Board to evaluate and rank research proposals based on scientific merit and relevancy.

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RESEARCH ACTIVITY BY CAMPUS

LOCATION	2002 – 2003		
	PROJECTS FUNDED	GRADUATE STUDENTS SUPPORTED	UNDERGRADUATE STUDENTS SUPPORTED
UC Berkeley	6	11	1
UC Davis	9	10	6
UC Irvine	0	0	0
UC Los Angeles	1	1	0
UC Riverside	9	9	6
UC San Diego	0	0	0
UC Santa Barbara	1	1	1
UC Santa Cruz	2	2	2
TOTAL	28	34	16



INFORMATION PROGRAM ACTIVITIES

THE WATER RESOURCES CENTER ARCHIVES

Mission and Scope

The mission of the Water Resources Center Archives (WRCA) is to develop and maintain a collection of water-related materials to meet the research needs of the University of California's system-wide instructional, research, and service programs. Established in 1957, the collection is relied upon by the University community as well as government agencies, corporate professionals, and the public.

WRCA is a research library with more than 148,000 cataloged items. The scope of the collection includes fresh water supply and quality, groundwater, municipal and industrial water uses, flood control, water reuse, wastewater treatment, river mechanics, coastal engineering, estuaries, water pollution, and water law. WRCA collects a variety of types of materials including printed reports, government documents, books, manuscripts, maps, videos, photographs, and electronic resources. The collection concentrates on materials relating to California and the West, although there are national and international materials in the collection as well.

Access to the Collection

WRCA is a member of the Online Computer Library Center (OCLC), an international database that currently contains more than 50 million records in

the Library of Congress' Machine Readable Catalog (MARC) format. The system indicates which member library holds a given title, and is both a shared cataloging resource and interlibrary borrowing mechanism. Since 1983, all new WRCA material has been cataloged onto the OCLC database.

OCLC regularly uploads all of the recent cataloging records from all nine UC campuses. This cumulative tape is then uploaded to the Melvyl® Catalog, the University of California's online catalog database. Melvyl® is searchable on the World Wide Web (<http://melvyl.cdlib.org/>). This makes WRCA's collection available nationally and internationally.

In October 1998, WRCA became a participant in the California Digital Library's Online Archive of California (OAC), a union database of encoded archival finding aids. Finding aids provide detailed descriptions and outlines of archival collections and are essential tools for understanding the true content of a particular collection. The OAC is searchable at the collection, repository, and institutional levels, or the entire database can be searched for documents or photographs on particular subjects. Currently the Water Resources Center Archives has over 120 finding aids on the OAC, which expands use of the archival collections. WRCA's collections can be

found at
findaid.oac.cdlib.org/institutions/ark:/13030/tf009nb42r/.

Use of the Collection

Use of the collection in 2002-2003 included transactions (titles used on the premises and borrowed). Users, by category, were as follows: graduate students -31%, undergraduate students - 9%, faculty and staff - 6%, interlibrary loans - 8%, general public -46 %.

Staff Changes

In July 2002, Paul Atwood assumed his duties as the Technical Services Librarian. Paul received his MLIS from San Jose State University in 2002. He has archival management skills, extensive web experience as well as cataloging expertise.

Nancy Novitski was hired last fall as the Public Services Library Assistant and Trina Pundurs was hired as the Technical Services Library Assistant.

California Colloquium on Water

This popular lecture series continued in fall 2002 and spring 2003. This series is now in its third year and was co-sponsored by WRCA in conjunction with the UCB Center for California Studies. Financial support was provided by the Deans of the Colleges of Engineering, Environmental Design, Letters & Science, Natural Resources, and the Boalt Hall School of Law. Additional support was provided by the Metropolitan Water District of Southern California.

The *California Colloquium on Water* series hosts four lectures each semester on the second Tuesday of the month. Distinguished speakers from the fields of natural sciences, engineering, social sciences, humanities and law are invited to speak to students, faculty and the general public about water resources in order to contribute to informed decision making. All lectures are free and open to

the campus community as well as the community at large. For several semesters the lectures have been videotaped and cataloged and are available for loan from WRCA.

Speakers and topics presented in the fall and spring series were as follows:

Fall 2002

September

Philip Pister, Executive Secretary, Desert Fishes Council, Desert Fishes: "Reflections on Reality, Desirability, and Conscience"

October

Ron Robie, Director, Associate Justice, Court of Appeal, Third Appellate District "California's Water: Perspectives from the Bench"

November

J. David Rogers, Karl F. Hasselmann Missouri Chair in Geological Engineering at the University of Missouri-Rolla "Dams and Disasters: A brief Overview of Dam Building in California"

December

Tom Graff, California Regional Director, Environmental Defense "Environmental Advocacy: A Practitioner's Historical Perspective"

Spring 2003

February

Scott Stine, Professor of Geography & Environmental Studies, California State University, Hayward "Drought's and Deluges of California's Past Millennium"

March

James Westcoat, Jr., Professor of Landscape Architecture, University of Illinois at Urbana-Champaign "Water in Landscape Heritage Conservation & Design: Lessons from the Taj Mahal"

April

James Morgan, Goldberger Professor of Environmental Engineering Science, Emeritus, California Institute of Technology
"The Water Matrix: A Quantity to Quality Transition in the New Century"

May

William Preston, Professor of Geography, California Polytechnic State University, San Luis Obispo
"The Environmental History of Tulare Lake"

Publications

WRCA produces two publications - *Selected Recent Accessions* list, a bi-monthly list of new publications, and *WRCA News*, a newsletter that is published three times per year. These publications have become electronic only publications in order to reduce costs. An email list with a link to the PDF file is sent out to subscribers when a new publication is available. They are also available on the WRCA Web site (<http://www.lib.berkeley.edu/WRCA/>).

The Water Resources Center Archives and the Harmer E. Davis Transportation Library collaborated on the publication of a calendar for 2003 that featured historic photographs of ferryboats in the San Francisco-Oakland Bay Area. All of the photographs in *Before the Bridges* are courtesy of the National Maritime Historical Park in San Francisco. The calendar was published with generous sponsorship from Moffatt & Nichol Engineers and the ROMA Design Group. Thirteen hundred calendars were distributed to donors of the two libraries and sold in local bookstores, or via mail order.

The two libraries have recently completed compiling a calendar for 2004 featuring historic and contemporary images of two San Francisco Bay Area bridges. The calendar will feature photographs of the

eastern span of the San Francisco-Oakland Bay Bridge and the Carquinez Bridge. The images are from the pictorial collections of the Water Resources Center Archives and the California Department of Transportation (Caltrans) library. Publication of the 2004 calendar will be sponsored by HBG Flatiron, Inc., Moffatt & Nichol Engineers, ROMA Design Group, and T. Y. Lin International.

Web Site and Online Resources

The Water Resources Center Archives continues to develop and expand its Web site. The Web site includes an introduction to the library's print and electronic resources, lists of archival and video collections, specialized research guides, and all library publications. It also provides links to the California Digital Library (which includes Melvyl® and the Online Archive of California), electronic reference resources, article indexes, electronic journals, and other online resources.

The online resources provided by the Water Resources Center Archives help researchers get up-to-date information. Different systems provide information in bibliographic, full-text, or data forms. *Water Resources Abstracts* contains bibliographic citations to journals, books, documents, and reports on hydrology and other areas of water-related research. This system is now accessible to UC Berkeley students, faculty, and staff via the WRCA web site. WRCA also maintains subscriptions to two key CD-ROM databases: *U.S.G.S. Peak Values* and *U.S.G.S. Daily Values*, both published by Hydrosphere, Inc. WRCA staff members are experts at locating and retrieving data and information from all of these electronic resources.

Fundraising and Fee-For-Service

WRCA continues its fundraising activities. The Advisory Board to the Water Resources Center Archives continues to

meet semiannually and to assist with outreach and fundraising strategies.

WRCA continues to expand the use of the collection and increase outside revenues by providing fee-based document delivery services to non-UC requestors. Requests are received via OCLC, telephone, fax, or e-mail.

Special Projects & Events

WRCA would like to announce the *Catalog of Coastal Aerial Photograph*, a fully searchable Web database. The collection contains over 45,000 black and white photographs taken by the U.S. Navy and the U.S. Marine Corps from the mid-1940's into the 1950's. Collection emphasis is on U.S. coastal areas with a strong focus on California, Oregon, Washington, Guam and Hawaii. Maria Escobar, a graduate student interested in coastal studies, completed the original data set. This data was then converted and made accessible by the UC Berkeley's Digital Publishing Group. The catalog is searchable by state, country, and keyword. You can search the catalog at www.lib.berkeley.edu/WRCA/coastal-intro.html.

WRCA co-hosted a workshop entitled "Covering California's Water Story" with the Berkeley Graduate School of Journalism's Program in Environmental Journalism. On March 15, 2003, over 50 reporters and producers from the Bay Area attended a one-day workshop to improve their understanding and coverage of California water issues. Professor Matt Kondolf opened the day with an overview of the transport of water in California. A panel discussion followed on the issues facing farmers, cities and the environment. Rita Schmidt Sudman, Executive Director of the Water Education Foundation, moderated the panel, which included Randy Kanouse, Special Assistant for Internal Government Affairs at East Bay

Municipal Utility District; Barry Nelson, Senior Policy Analyst for Natural Resources Defense Council; and Dan Nelson, Executive Director of San Luis & Delta –Mendota Water Authority. In the afternoon session, Berkeley Professor John Dracup presented the history of Colorado River use, and UC Santa Cruz Professor Brent Haddad addressed current issues. The workshop was co-sponsored by the Society of Professional Journalists and the Society of Professional Journalists and was underwritten by the William and Flora Hewitt Foundation.

Grants

In May 2002, WRCA was awarded a follow-up grant by the San Francisco Foundation for \$8,000 to continue to add newly funded projects to the Information Center for the Environment web system. The grant also provided funds for temporary staff, Terry Richards and Xiaojun Peng, to upgrade WRCA's Bay Fund web site to include projects that were funded in 2002. The SF Bay Fund Inventory website hosted by WRCA has been vastly improved to include a project description, photographs, volunteer opportunities, documents, if available, and a link to each organization's web site. Please review the Bay Fund Inventory at www.lib.berkeley.edu/WRCA/bayfund/.

The Information Center for the Environment's (ICE) web-based system is located at UC Davis (<http://ice.ucdavis.edu/>). ICE hosts a variety of inventories offering information about restoration, mitigation and conservation projects in, or bordering, California. The inventory is a file in the Natural Resource Projects Inventory (NRPI). An important component of the grant is the design and implementation of a community outreach effort to contact schools, libraries, local organizations and businesses to increase awareness of the inventory and encourage its use.

Research Category I

Hydrology Climatology and Hydraulics

This category encompasses the physical processes that lead to water availability for human use on land, in lakes, streams and aquifers. Examples of investigations that logically fall in this category include studies of precipitation and stream-flow relationships, weather forecasting, climate modification, micrometeorological processes linking atmospheric water, solar energy, water use by plants (both commercial and native), and available soil moisture, hydrologic and hydraulic modeling and processes, and the development of databases.





Predicting Flow and Sediment Transport in Steep Channels: Field Study and Flume Experiments to Develop and Test Models

William E. Dietrich
Earth and Planetary Science
UC Berkeley

Project Summary

The majority of the total channel length in mountainous watersheds occurs in steep rough channels. Sediment mobilized on hillslopes must first pass through these channels before reaching lower-gradient reaches that bear fish. Although they are the dominant source of sediment to downstream channels, we currently lack the ability to model flow and sediment through high gradient streams.

Conventional transport equations, developed for lower-gradient reaches, typically over-predict sediment flux in these streams by several orders of magnitude. Therefore, we cannot determine the timing and magnitude of the response of the entire channel network to changes in sediment loads.

We have developed a model that uses field measurements in steep, rough channels to predict the transport rate of sediment. We hypothesize that current transport equations do not apply in steep, rough channels because 1) they do not account for the stress borne by large, relatively immobile grains, 2) they do not differentiate between seasonally and rarely mobile sediment and 3) they assume an unlimited sediment supply. The immobile grains reduce the stress

The majority of the total channel length in mountainous watersheds occurs in steep rough channels. We have developed a model that uses field measurements in steep, rough channels to predict the transport rate of sediment. Our modified transport equation significantly improved the prediction of sediment flux in simplified flume experiments.

available to transport the mobile sediment. We partition the total shear stress between the stress borne by the exposed immobile grains, and the stress borne by the finer, more mobile bed. We then modify a traditional bedload transport equation to use only the stress on the mobile fraction, rather than the total stress. To account for the limited supply of mobile sediment we scale the predicted transport rate by the proportion of the bed occupied by the mobile fraction (mobile sediment coverage). Our model requires six parameters (width, water discharge, channel slope and immobile grain spacing, protrusion and diameter) and two coefficients.

We tested this theory by simulating a high-gradient, rough stream in a small, steep flume. The experiments consisted of

feeding 3.7 mm gravel at a constant rate through fields of regularly spaced immobile spheres (30 mm in diameter).

Between experiments, we varied the supply of gravel and/or spacing between spheres. During each experiment we measured the proportion of the bed covered by mobile sediment and protrusion of spheres above the sediment deposit. We then predicted the transport rate for each run using the measured six parameters in our model. Sediment transport rates predicted by our modified bedload equation were generally within an order of magnitude of the measured values.

To further test and develop our model, we documented 15 flow events in a small, steep tributary of the South Fork Eel River during the winter of 2002-2003. Prior to the winter, we installed tracer particles and sediment traps in the streambed. We also measured the mobile sediment size, the channel slope, channel cross-sections and the immobile grain spacing, protrusion and diameter. During each event, we measured the flow depth and velocity, water slope, distance traveled by tracer particles, and collected the transported sediment. Traditional bedload transport equations over predicted the observed sediment fluxes by orders of magnitude. Preliminary calculations with our modified transport equation improved the prediction but still did not match the magnitude of the measured bedload flux.

Our modified transport equation significantly improved the prediction of sediment flux in simplified flume experiments. This suggests that coverage by mobile sediment and drag due to immobile particles are necessary

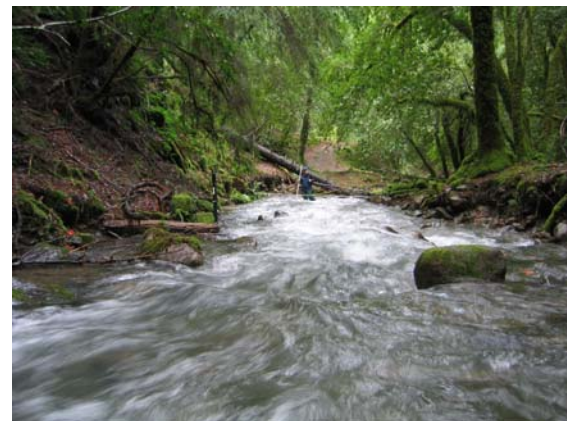
components of transport equations for steep, rough streams. To improve our predictions in streams, further work is needed to incorporate the spatial variability of natural streambeds. Once complete, our transport equation will be incorporated into a network-scale model to propagate sediment through a river system. Such a model could determine how a change in management practices that alter sediment supply affect the grain size and therefore aquatic habitat throughout the channel network.

Professional Presentations

Yager, E., J.W. Kirchner, W.E. Dietrich, and D.J. Furbish, Prediction of sediment transport in steep boulder-bed channels, *Eos, Transactions, American Geophysical Union*, 83(47), Fall Meeting Supplement, San Francisco, CA, Abstract H21G-03, 2002.

Student Training

Elowyn Yager, graduate, Ph.D.; Earth and Planetary Science, UC Berkeley



Photograph of the Fox Creek field site in Northern California. Person in photo is measuring the flow velocity.



Application of a New Model for Groundwater Age Distributions: Modeling and Isotopic Analysis of Artificial Recharge in the Rialto-Colton Basin, California

Timothy R. Ginn
Civil and Environmental Engineering
UC Davis

Project Summary

In California, water is a scarce resource. The "banking" of water in aquifers is a strategy for controlling water reserves. The ability of any given aquifer to serve as reservoir and filter for such waters (in particular, "reused" treated wastewater) is indicated by the groundwater residence time, or age. Banking is being considered at the Rialto-Colton basin aquifer, via infiltration through the Linden ponds (figure 1). Age serves as a useful indicator of ground water renewability and the feasibility of using aquifers for water storage, and equally importantly, it is approximately measurable. Carbon-14 (C^{14}) isotope is normally used as a tracer to compute the ground water ages. The primary focus of this project was to study groundwater age in the Rialto-Colton basin aquifer in Southern California using one-dimensional geochemical modeling along four flow paths, and to quantify their effect on C^{14} data by simulating reactive transport in the aquifer over several thousand years.

Before describing the details of the reactive transport modeling, we summarize the groundwater age distribution found for this aquifer system. The aquifer geology indicates three dominant zones, the upper,

The groundwater age in the lower aquifer zone is greater than 3000 years, in the middle zone is from 1000 to 2500 years, and in the upper zone is several hundred years. These ages are well beyond the characteristic storage time for water banking so this aquifer may serve for water banking purposes.

middle, and lower units. The results of the chemical analysis indicates that the groundwater ages differ significantly in each zone, with ages in the lower unit ranging above 3000 years, ages in the middle unit ranging from 1000-2500 years, and ages in the upper unit nearer to several hundred years. Ages all generally increase in the downstream direction but with some reversal of age in the upper and middle units due to local recharge. These ages are well beyond the characteristic storage time for water banking so this aquifer may serve well for water banking purposes. Pumping costs may be higher than expected for retrieval depending on the long-term effects of artificial recharge on groundwater pressures.

One-dimensional mass-transport modeling was used to determine a set of reactions that control the C^{14} content in ground water

in the Rialto-Colton basin. The effects of the set of reactions on C^{14} content were quantified by developing a comprehensive two-dimensional mass transport model using HGBC123D. The reactive-transport model simulates two-dimensional cross-sectional reactive transport in the middle and lower water-bearing units in the corridor between the unnamed fault and the San Jacinto Fault (Block A). The velocity field for the reactive-transport model was obtained from a four-layer MODFLOW model for the Rialto-Colton Basin. In order to obtain a two-dimensional representation of the velocity field, velocities were averaged across the aquifer between the unnamed fault and the San Jacinto Fault for each unit. Reactions included in the model are mineral (anorthite, K-feldspar, and quartz) dissolution and clay (kaolinite) precipitation/dissolution. A first step to modeling reactive transport is to determine equilibrium and kinetic reaction rates. Equilibrium constants are well established for all the mineral phases we used in the model. The kinetic reaction rates were obtained through model calibration by adjusting selected kinetic rates so that simulated concentrations of dissolved constituents match measured constituents. Initial conditions for the model were the temporally averaged dissolved constituents for each water-bearing unit. After calibration, the model was run to simulate concentrations of the dissolved constituents considered (total calcium, alkalinity, total sodium, total potassium, and total silica, as well as pH) and mineral phases at wells within the A block for 10 years (figure 1). Breakthrough curves for the constituents considered indicate that the concentrations initially increased or decreased then, within about four years, reached a relatively constant concentration for all wells. Breakthrough curves for the mineral phases are increasing (indicating dissolution) for anorthite, k-feldspar, and quartz, and decreasing (indicating precipitation) for kaolinite over the ten-year simulation period; however, the changes from year to year are very small. Although the reactive-transport

simulation should be temporally extended to several thousand years, these preliminary results, along with results from the Phreeqc analysis and analysis of the raw data, indicate that the reactions that might dilute the C^{14} content in the ground-water flow system are minimal. Therefore, a particle-tracking model, which keeps track of the travel time of an imaginary particle of water as it moves through the ground-water flow system, may be used to obtain ground-water ages that can be compared to simulated ground-water age simulated by solving the age equation of Ginn.

The reactive-transport model included a simplified four-layer velocity field. Because transport is controlled by aquifer heterogeneity, significant effort has been devoted to developing a texture model to incorporate into the ground-water flow model, and thus, produce a more complex velocity field. The computer code TproGS was used to produce stochastic simulations of equally probable distributions of aquifer texture. Input for the texture model was derived from borehole geophysical and lithologic logs from 18 wells. Two textures were used in the simulations, fine-grained and coarse-grained. Different aquifer parameters (horizontal and vertical hydraulic conductivity, horizontal and vertical anisotropy, and specific yield and storage coefficient) were assigned to each texture. The flow model contains 150 layers with an aquifer thickness of about three to four feet per layer. The velocity fields generated including the texture model will be used with future ground-water age modeling in the Rialto-Colton Basin.

Publications

Woolfenden, Linda R, Uma Seeboonruang, and Timothy R. Ginn, Modeling and Isotopic Analysis to Assess Artificial Recharge in the Rialto-Colton Basin, San Bernardino County, California, *Proceedings of the Geological Society of America Annual Meeting*, Abstracts with Programs, October 27-30, 2002.

Professional Presentations

Linda R. Woolfenden, Modeling and Isotopic Analysis to Assess Artificial Recharge in the Rialto-Colton Basin, San Bernardino County, California, Geological Society of America Annual Meeting, Denver Colorado, October 30, 2002.

T. R. Ginn, Geochemical heterogeneity in reactive transport; review and lagrangean upscaling, 7th SIAM Conference on Mathematical and Computational Issues in the Geosciences, Invited plenary talk, Austin, Texas, March 17-20, 2003.

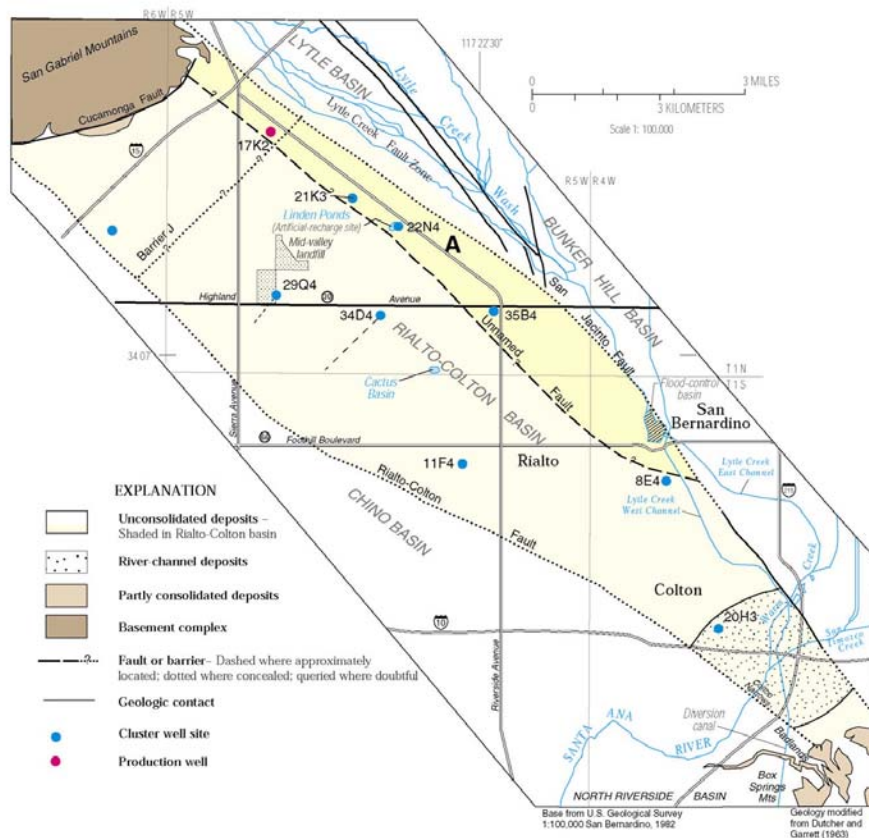
Student Training

Uma Seeboonruang, graduate; Civil and Environmental Engineering, UC Davis
Esther Chung, graduate; Civil and Environmental Engineering, UC Davis

Collaborative Efforts

John Izbicki, USGS, has signed on as advisor to the project and is collaborating in the interpretation of equilibrium chemistry signatures of water samples from the aquifer.

Figure 1





Emplacement and Release of Brines from the Subsurface

James R. Hunt
Civil and Environmental Engineering
UC Berkeley

Project Summary

Groundwater contamination resulting from the creation and release of dense brines is a common occurrence, but is rarely acknowledged. Brines can be generally defined as aqueous solutions with a total dissolved solids (TDS) concentration in excess of 10,000 mg L⁻¹. In addition to increased TDS, brines have a greater density and viscosity than that of freshwater. The most widespread and widely recognized occurrence of brine-induced groundwater contamination is seawater intrusion into coastal aquifers. Seawater has a TDS concentration of about 30,000 mg L⁻¹ and a density and viscosity only slightly greater than that of freshwater, making it relatively innocuous as a brine. Other examples of groundwater contamination resulting from brine releases are ammonium perchlorate spills, acid mine drainage, landfill leachate plumes, and unintentional releases from nuclear waste processing facilities. TDS concentrations of these highly concentrated brines can be in excess of 500,000 mg L⁻¹ with densities and viscosities much greater than that of freshwater. It is hypothesized that these physical properties will affect the subsurface fate of these highly concentrated brines.

Groundwater contamination resulting from the creation and release of dense brines is a common occurrence, but is rarely acknowledged. The ultimate objective of this research was to increase the understanding of brine fate by developing a comprehensive model describing the mixing behavior at stable and unstable brine/freshwater interfaces.

Little is currently understood about the transport of brines in water saturated porous media. The ultimate objective of this research was to increase the understanding of brine fate by developing a comprehensive model describing the mixing behavior at stable and unstable brine/freshwater interfaces. In order to specifically address these issues a laboratory-scale experimental program was designed and implemented. During the experimental realizations, the mixing zone was measured as brine displaced freshwater and as freshwater displaced brine. The dependence of mixing zone size as a function of brine physical parameters, i.e. density and viscosity, and experimental parameters, i.e. displacement rate, column permeability, and column diameter, was determined. Experimental data indicates that as brine displaces freshwater, the flow will be gravitationally unstable, but will be

stabilized by the viscosity difference. As flow rate decreases, gravitational instabilities tend to dominate over the viscous stabilization and overall mixing is enhanced. Conversely, as freshwater displaces brine, the flow will be gravitationally stable, but will be destabilized by the viscosity difference. As flow rate decreases, the gravitational stabilization tends to dominate over the viscous destabilization and overall mixing is suppressed.

Publications

Flowers, T. C. and J. R. Hunt, The influence of Density and Viscosity on Transport and Mixing in the Subsurface: Implications for In-Situ Remediation Technologies, Proceedings of the Second International Conference on Oxidation and Reduction Technologies for In-Situ Treatment of Soil and Groundwater (ORTs-2) (*In Press*).

Professional Presentations

Flowers, T. C. and J. R. Hunt, The influence of Density and Viscosity on Transport and Mixing in the Subsurface: Implications for In-Situ Remediation Technologies. Oral Presentation at the Second International Conference on Oxidation and Reduction Techniques for In-Situ Treatment of Soil and Groundwater, Toronto, Ontario, Canada, November 17-21, 2002.

Student Training

Tracey Flowers, Graduate, Civil and Environmental Engineering, UC Berkeley.



The Effect of Soil Water Content on Organic Chemical Sorption During Transport Through Unsaturated Soil

William A. Jury
Environmental Sciences
UC Riverside

Project Summary

Chemical transport through unsaturated soil has taken on heightened interest in recent years, due to ground water contamination from agricultural or industrial products such as Dibromochloropropane (DBCP) in numerous aquifers around the US. An important aspect of the characterization of the causes of ground water contamination and its remediation is an assessment of the travel time of a chemical from the surface to the water table. This assessment has become a critical factor in determining legal responsibility for ground water contamination, and it also is prominent in the design of best management practices for agricultural chemical usage. Many of the important chemicals of concern in ground water contamination are attracted to stationary organic and mineral surfaces in unsaturated soil, thereby rendering them less mobile than dissolved compounds with no affinity for the solid phase. Sorption characterization is therefore a critical part of the estimation of travel times to ground water.

For reasons largely arising from expense and experimental difficulty, almost no direct observation has been made of

An important aspect of the characterization of the causes of ground water contamination and its remediation is an assessment of the travel time of a chemical from the surface to the water table. Model calculations demonstrated that even mild sorption in low organic carbon regions can have a significant effect on mobility in soils of low water content, and will also reduce spatial variability of solute velocity. Thus, assessments that completely neglect sorption below the crop root zone will predict travel times to groundwater much shorter than predictions made that include sorption.

chemical movement and fate in the lower vadose zone. As a consequence, modeling has been used almost exclusively to make assessments of transport through this region. The difficulty in making measurements of soil properties in subsurface soils has resulted in modeling efforts that use relatively little data and a considerable amount of guesswork or extrapolation to characterize this zone. Because of the importance of travel-time estimates in litigation and management, it is essential to examine in detail the appropriateness of assumptions

made by some authors in neglecting sorption in soils low in organic matter. An important aspect of this examination is the study of transport in soils at low water content. In sandy soils such as those found in the Eastern San Joaquin Valley, it is common to assume that sorption is negligible below the root zone. However, according to theory, retardation caused by sorption should increase significantly as water content decreases unless the organic carbon content is negligible. This study was conducted to determine experimentally the significance of sorption as a function of water content in two soils of contrasting organic carbon level, and to explore through modeling the implications of neglecting sorption when making assessments of travel time through the vadose zone.

The effect of water content on pesticide sorption during transport through soils with different organic carbon contents was investigated in soil taken from two depths of a Delhi loamy sand. Chemical transport experiments were conducted in packed soil columns under three different water contents. Both soil regions had immobile water fractions between 20-30% of saturation, even in the saturated flow studies. The mobile region dispersion coefficient D_m was linearly related to velocity, as was the mass transfer coefficient α . Retardation factors increased as water content decreased, and column retardation factors were somewhat higher than those determined

from batch studies. Model calculations demonstrated that even mild sorption in low organic carbon regions can have a significant effect on mobility in soils of low water content, and will also reduce spatial variability of solute velocity. Neglecting sorption under conditions of low water content and low organic matter can cause serious error estimating travel time to groundwater, even if the compound is only mildly sorbed. Thus, assessments that completely neglect sorption below the crop root zone will predict travel times to groundwater much shorter than predictions made that include sorption.

Professional Presentations

W. Jury, Western Regional Research W-188 Meeting, Las Vegas, Nevada, Jan. 2003.

Student Training

Han Song On, graduate student, Univ. of Korea, Seoul (1 year study leave in US)
Atac Tuli, postdoctoral researcher, Dept. of Environmental Sciences, UC Riverside

Collaborative Efforts

Collaboration with Prof. Dong-Ju Kim Univ. of Korea, Seoul. Dr. Kim spent a sabbatical leave with me assisting on the problem of pesticide transport in soil. We are continuing to collaborate on this subject as I jointly supervise Dr. Kim's graduate student, Han-song On.



Sediment Storage and Routing in the Matilija Creek Basin, Ventura County

G. Mathias Kondolf
Dept of Landscape Architecture &
Environmental Planning
UC Berkeley

Project Summary

The Ventura River in Southern California historically supported one of California's southern-most runs of endangered anadromous steelhead trout, *Oncorhynchus mykiss*. Much of the former steelhead habitat was cut off in 1948 by construction of the Matilija Dam on Matilija Creek (55 mi²), one of the river's two principal forks. The Ventura River basin is underlain by highly erodible Tertiary marine sediments, is tectonically active, and has very high sediment yields. Matilija Dam is nearly full of sediment and is structurally unsafe. To address the dam-related issues, US Geological Survey and Bureau of Reclamation are conducting a feasibility study to remove the dam, which would re-open Matilija Creek to steelhead trout. Excessive levels of fine sediment have been documented to negatively affect spawning by salmon and trout, raising questions about how steelhead trout have historically prospered in drainages with high sediment yields such as Matilija Creek, and whether steelhead can successfully reestablish there. To understand the relationship among sediment supply, transport, in-channel storage, and fish habitat, we investigated the processes and timing of

Aquatic habitat in pools was not strongly affected by sediment movement during this study, but habitat was affected by hydrologic interactions, depending on whether the pools were located in bedrock canyon or alluvial reaches. Alluvial reaches lost surface flow and became warm, while canyon pools continued to provide excellent steelhead habitat with perennial surface flow, shade and cooler water temperatures.

sediment delivery to the streams that constitute potential habitat for steelhead trout.

We conducted field work from July 2001 to February 2003, a study period encompassing a drought year and an average rainfall year. Our methods included longitudinal profile surveys, pool surveys, sediment scour rods, gravel tracers, bulk dry-sieving and lithologic composition analysis and in-channel sediment storage inventories. After each storm, we resurveyed the stream to determine what changes had occurred. We also documented downstream diminution in grain size from the breakdown of shale fragments.

The Matilija Creek watershed contains a high percentage of fine sediment which could be expected to constrain steelhead trout reproduction. However, the fine sediment delivery to the stream depended on the storm sequence during the year as well as the proximity of potential habitat to sources of sediment (usually hillslopes or tributaries). Aquatic habitat in pools was not strongly affected by sediment movement during this study, but habitat was affected by hydrologic interactions, depending on whether the pools were located in bedrock canyon or alluvial reaches. Alluvial reaches lost surface flow and became warm, while canyon pools continued to provide excellent steelhead habitat with perennial surface flow, shade and cooler water temperatures. Habitat in most was influenced by factors not previously reported in the literature: accumulation of alder leaves (nearly filling the bottoms of some pools and presumably using dissolved oxygen), tufa cementation of gravels, and alder root growth in the streambed.

High sediment yields are natural in the Matilija Creek catchment, so there is little that can be done to manage the sediment yield or the timing of its delivery. However, as sediment yields increase after fires, so fire management may influence sediment effects on steelhead habitat. The effect of leaf accumulations in pools, extensive tufa cementation of gravels, and root growth in the bed on steelhead trout habitat, factors not previously documented in the literature, deserve further study.

Publications

Minear, J. Toby, Sediment dynamics and Southern Steelhead (*Oncorhynchus mykiss*) habitat on Matilija Creek, California, *Master's thesis in Landscape Architecture and Environmental Planning*, UC Berkeley, 2002.

Professional Presentations

Minear, J. Toby, Sediment dynamics and Southern Steelhead (*Oncorhynchus mykiss*) habitat on Matilija Creek, Southern California, College of Environmental Design Thesis Presentations, UC Berkeley, May 7, 2003.

Minear, J. Toby, Sediment dynamics in Matilija Creek, Southern California, Water in Mediterranean Climates Conference, UC Berkeley, April 17-18, 2003.

Student Training

J. Toby Minear, graduate, Masters, Environmental Planning, UC Berkeley
Kumkum Bhattacharyya, post-doctoral, Environmental Planning, UC Berkeley
Sarah Minick, graduate, Masters, Environmental Planning and City Planning, UC Berkeley
Tanya Patsouras, graduate, Masters, Landscape Architecture, UC Berkeley

Additional Funding

Council for International Exchange of Scholars - \$18,600 grant – used to support travel costs for collaboration with colleagues at the University of Lyon 3.

Collaborative Efforts

Ned Andrews, US Geological Survey, Boulder, served as an advisor to this study, third reader on Toby Minear's thesis, and provided linkages with USGS studies on the channel below Matilija Dam. Hervé Piégay and his doctoral student Frederic Liébault, University of Lyon 3, France, have contributed to this study through field work and analyses, drawing comparisons with basins in southeastern France under similar climatic conditions.

Ramon Batalla, University of Lleida, Spain, also participated in the project, drawing parallels to processes in basins in Catalonia.



Mount Shasta's Glaciers: An Endangered Resource?

Slawek Tulaczyk
Earth Sciences
UC Santa Cruz

Project Summary

The objective of this study is to assess the current stability of Mt. Shasta's glacier system through temporal analysis of ice volume and modeling of the possible near-future response to climate warming. Seasonal melt of Mt. Shasta's glaciers represents a significant water source to north central California, particularly during the annual dry season and in drought periods. Deterioration of these glaciers could have a significant practical impact on the water supply for the region. The health of the Mt. Shasta glacier system could be endangered when faced with decadal-scale climate warming trends. The latest climate models predict that northern California will warm by several degrees Celsius over the next century. If this prediction holds true, it is feasible that we may see a significant shrinkage or even a complete extinction of this glacier system in the next several decades.

The first year of this two year investigation focused on: (1) examining the photogrammetric record of fluctuations in the size of Mount Shasta's glaciers and, (2) field observations of glacier mass balance aimed at supporting energy balance parameterizations in future modeling. Our photogrammetric analysis of 5 glaciers since 1951 revealed that each of the glaciers increased in area throughout the time period, excluding a brief contraction in the late 1980's. The

The Whitney Glacier, North America's most southerly valley glacier, advanced 850m, or ~30% of its length, since 1951 and continues to expand. Such trend is significant because it presents a scenario in which climate warming may result in increased spring snow accumulation at high elevations and, consequently, in glacier growth.

Whitney Glacier, North America's most southerly valley glacier, advanced 850m, or ~30% of its length, since 1951 and continues to expand. Comparison with available meteorological data over the past century suggests that this expansion is linked to an increase in winter precipitation accompanied by a decrease in summer temperatures, resulting in an increased annual snow balance. While there has also been an increase in winter temperatures, resulting in a thinner spring snow pack at low elevations, the high elevations of the glaciers are insensitive to this warming, remaining below the freezing level for most of the winter. Such trend is significant because it presents a scenario in which climate warming may result in increased spring snow accumulation at high elevations and, consequently, in glacier growth. This would have far reaching implications for the assessment of the impact of climate change on California's snow reservoir.

During the summer of 2002, a series of ablation stakes and temperature sensors were deployed on the Hotlum and the Whitney glaciers, including a logging echo sounder system, to provide time series of surface melt and temperatures.

Correlation of these time series will help constrain model parameterizations of the glacier surface energy balance. For 2002, both of the monitored glaciers lost mass. However, the total loss was small considering that the winter of 2002 produced 54% of normal snowfall and was one of the warmest summers on record. This suggests that Mt. Shasta's glaciers may be relatively insensitive to climate change.

The second year of this study will supplement the energy balance information with observations of glacier dynamics in preparation for model construction. A global positioning system network will be deployed to obtain a time series of ice velocity to aid flow model parameterization. We will also be conducting radar surveys to determine ice thickness and bed topography.

Professional Presentations

Howat, I.M., Mount Shasta's Glacier System, Northwest Glaciological Society, Vancouver, B.C., Canada, October 18-19, 2002

Student Training

Ian Howat, graduate, Ph.D., Earth Sciences, UC Santa Cruz

Mike Ward, undergraduate, Earth Sciences, UC Santa Cruz

Nate Casebeer, undergraduate, Earth Sciences, UC Santa Cruz

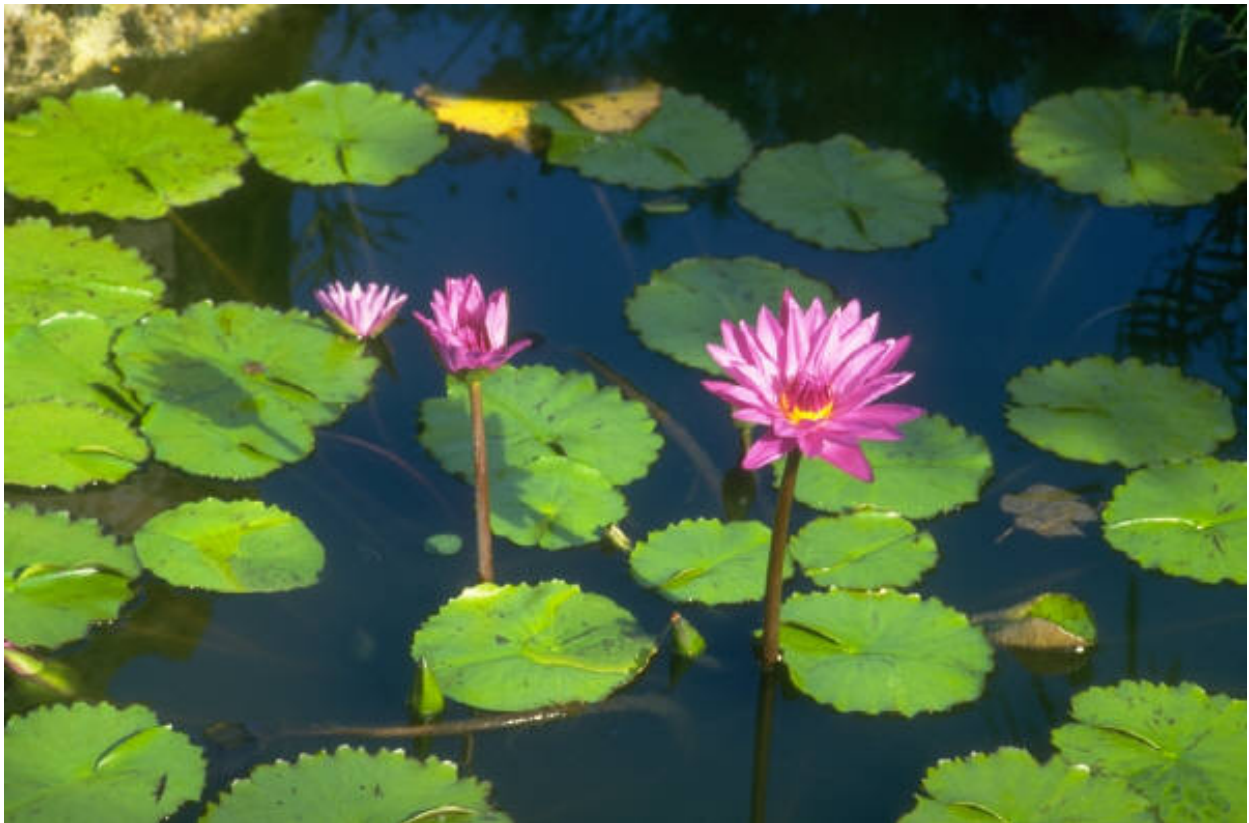


Field work on the Hotlum Glacier, showing echo sounder equipment and GPS position recording.

Research Category II

Aquatic Ecosystems

This category encompasses basic observational, analytical and theoretical knowledge about aquatic environments and ecosystems. Research areas of interest include biological, chemical and physical mechanisms that govern the behavior of aquatic ecosystems including work on the classification, transport and impact of contaminants and pollutants. Also included in this category are studies of the use of artificial ecosystems for water reclamation, fundamental investigations related to wetland management, studies of the impact of land use practices on aquatic habitats and reconstruction ecology.





Influence of Nutrient Loading on the Invasion of an Alien Plant Species, Giant Reed (*Arundo Donax*), in Southern California Riparian Ecosystems

Richard F. Ambrose
Environmental Science & Engineering Program
UC Los Angeles

Project Summary

The non-native giant reed (*Arundo donax*) is rapidly invading riparian ecosystems along rivers in mediterranean-type climates, including California. Invasion of Southern California riparian habitats has resulted in extensive monocultures of giant reed in some places, causing serious physical and biological problems. Giant reed increases risks of flooding, creates a fire hazard, out competes native species for scarce water resources, and reduces the value of riparian habitat for wildlife. Natural and human disturbance have played a large role in its successful invasion. However, natural disturbance along rivers in California is not a new phenomena and most physical human disturbance dates back much earlier than the onset of the massive giant reed invasion in California. Thus, other factors must contribute to the success of this plant's invasion. One of the main human alterations along rivers in California is the delivery of nutrients from adjacent land uses to river systems within a watershed. Since soils of mediterranean-type climates have much lower soil nutrient concentrations than other areas in the world, recent nutrient loading of rivers is hypothesized to be one of the main factors contributing to giant reed's invasion in California.

Invasion of Southern California riparian habitats has resulted in extensive monocultures of giant reed in some places, causing serious physical and biological problems. Since soils of Mediterranean-type climates have much lower soil nutrient concentrations than other areas in the world, recent nutrient loading of rivers is hypothesized to be one of the main factors contributing to giant reed's invasion in California.

This study investigates the role of nutrient loading on the invasion of giant reed in riparian ecosystems of Southern California. It addresses three critical water resource problems in California: (1) threats to river ecosystems by one of the most invasive alien plant species, (2) the impacts of land use type on river systems, and (3) the impact of increased nutrient loading in rivers on natural riparian ecosystem functioning. This research employs a watershed-scale approach to these critical water problems. Nutrient concentrations of soil and shallow groundwater surrounding patches of giant reed and native riparian vegetation are currently being analyzed throughout three watersheds of Southern California with predominately different land use types, the

Santa Clara River, Calleguas Creek and Topanga Canyon watersheds. Field sampling is stratified by land use types: agricultural, residential and natural/open space. In addition, plant material from each sampling site is being collected and analyzed for nutrient concentrations. Anticipated completion of sampling and corresponding analyses is October 2003. These data will provide information on the main sources of nutrients contributing to giant reed growth, problematic invasion of giant reed populations in these watersheds, and nutrient uptake by native riparian plants versus the alien giant reed.

Although nutrient availability and abundance may be critically important to the success of giant reed, little is known about this relationship. When completed, this research will provide fundamental information about the process of alien plant species invasion and essential information for the control of giant reed. Results of this study should be useful to watershed planners in determining the contribution of different land uses to giant reed invasion. Water quality agencies,



such as the Regional Water Quality Control Boards, need to know whether impacts to giant reed populations must be considered when regulating nutrient inputs to watersheds. Agencies responsible for riparian restoration need to know whether nutrient loads must be considered when planning giant reed control projects. By helping to elucidate the relationship between nutrient loads and giant reed abundance, the proposed research will provide important insight into management options for protecting the valuable riparian resources in Southern California.

Professional Presentations

Gretchen C. Coffman (presenter) and Richard F. Ambrose, Influence of nutrient loading on the invasion of an alien plant species, giant reed (*Arundo donax*), in Southern California riparian ecosystems, Cal-EPPC Symposium 2003 (California Exotic Pest Plant Council), Kings Beach, CA. October 2-4, 2003.

Student Training

Gretchen C. Coffman, graduate, Ph.D., Environmental Health Sciences, UC Los Angeles

Additional Funding

California State Coastal Conservancy (SCC) - \$14,000.

Friends of the Santa Clara River (FSCR) – \$5,000 in labor.

Collaborative Efforts

Dr. Thomas Dudley, Researcher, University of Reno, Nevada – collaborated on field experiments funded by the California State Coastal Conservancy, which are related to this Center for Water Resources Study.

Fruitgrowers Laboratory, Santa Paula, CA and DANR Laboratory, UC Davis – conducted chemical analyses.



Structure and Seasonal Changes of Nematode Communities From Vernal Pools (Santa Rosa Plateau)

Paul De Ley
Dept of Nematology
UC Riverside

Project Summary

Nematodes are diverse and abundant in soils and sediments, occupying a wide range of ecological roles that reflects the overall condition of the microbiological ecosystem. Our project constitutes the first study of nematode communities from vernal pools. It aims to provide the first ecological and taxonomic data from this fragile and biologically important habitat, through a combined morphological and molecular survey of two pools in the Santa Rosa Plateau Ecological Reserve (SRPER). These data will be analysed for the purposes of ecosystem health monitoring, and for possible occurrence of nematodes parasitizing the locally occurring endangered species of plants and fairy shrimp.

During the first year of this project, our activities consisted mainly of the training of undergraduate student helpers, and of the preparation and processing of the permits required for sampling in the SRPER. State permits were approved by October 2002, but unfortunately the federal permit took until May 16 to arrive, due to a personnel change in the permit section of the US Fish and Wildlife Service, and to the strict requirements for obtaining the appropriate type of permit. In order to maintain a two-year timetable with eight sampling series,

we requested and were approved for a no-cost extension from UC-WRC until March 31, 2005.

This project constitutes the first study of nematode communities from vernal pools. The findings will be useful for ecosystems health monitoring and the possibilities of nematodes parasitizing endangered species of plants and fairy shrimp. Initiation of the project was delayed several months during which required permits were received from US Fish and Wildlife Services.

Our first set of four samples (each consisting of five subsamples) was collected on June 12th, 2003 and is currently being processed for nematode counts and for mounting in permanent microscopy slides. Forty-eight individual nematodes were video captured and processed for molecular analysis. Fresh extracts contained an abundance of nematodes, with immediately noticeable differences in species composition of samples taken at the periphery of each pool versus those taken within the area of submergence, especially plant parasites. During sample extraction, between 0 and 4 fairy shrimp cysts were recovered per sample and returned to the sampling sites along with all remaining soil and organic

debris (as stipulated in the federal permit). No evidence of cyst parasitism or predation by nematodes was as yet detected in this small number of cysts, although large stylet-bearing predatory species were found that could conceivably puncture cyst walls.

Student Training

Sheila Esfahani, undergraduate, Dept of Biology, UC Riverside
Melissa Yoder, undergraduate, Dept of Biology, UC Riverside

Additional Funding

Student training was partly supported by small grants for student research from UC Riverside's instructional improvement program (\$250 awarded to Mrs. Esfahani for 1 quarter, \$500 awarded to Mrs. Yoder for two quarters). In a wider context, the vernal pool project also ties in with my award as Co-PI of \$600,000 from NSF's "Assembling the Tree of Life" program, to investigate molecular phylogeny of nematodes.





Pyrethroid Insecticides in Nursery Runoff: Transport and Impact on Aquatic Invertebrates

Jay Gan
Environmental Sciences
UC Riverside

Project Summary

The project evaluates ecotoxicological impact of synthetic pyrethroids in nursery runoff on aquatic organisms. Synthetic pyrethroids are insecticides that have acute toxicity to most aquatic organisms including invertebrates. However, synthetic pyrethroids are also strongly adsorbing to sediment and soil particles, and in surface water systems. This particular phase distribution makes interpretation of ecotoxicological effects using detected concentrations difficult. We determined the phase distribution of synthetic pyrethroids bifenthrin and permethrin in runoff water, adsorption to sediments, and inhibition of suspended solids on the toxicity of pyrethroids in water. The most significant finding so far is that in runoff or surface water, presence of small amounts of suspended solids can lead to great reductions in freely-dissolved pesticide concentration, which appears to correlate with reduced toxicity for organisms such as *Ceriodaphnia dubia*. This finding is important not only for assessing the actual ecotoxicological effects of synthetic pyrethroids in surface water, but also for developing environment-relevant sampling and analytical procedures.

In runoff or surface water, presence of small amounts of suspended solids can lead to great reductions in freely-dissolved pesticide concentration, which appears to correlate with reduced toxicity for organisms such as *Ceriodaphnia dubia*.

Professional Presentations

Gan, J., S.J. Lee, I. Werner, and J.N. Kabashima, Pyrethroids in nursery runoff: Phase distribution and toxicity, 23rd Society of Environmental Toxicology & Chemistry (SETAC) Annual Meeting in North America, Salt Lake City, UT; November 16-20, 2002.

Lee, S.J., J.S. Kim, J. Gan, W.P. Liu, and D. Crowley. Biodegradation of pyrethroids in sediments, 23rd Society of Environmental Toxicology & Chemistry (SETAC) Annual Meeting in North America, Salt Lake City, UT; November 16-20, 2002.

Student Training

Qin, Su-jie, graduate, Ph.D.,
Environmental Science, UC Riverside.

Collaborative Efforts

Extensive collaboration with Dr. Inge Werner, Aquatic Toxicology Laboratory at UC Davis.



Linking Upland Landcover Change With Wetland Structure in Elkhorn Slough, CA

Nina Maggi Kelly
Environmental Sciences
UC Berkeley

Project Summary

Elkhorn Slough supports one of the largest coastal marshes in California. While Elkhorn Slough contains a State ecological preserve and a NOAA research reserve, agriculture, specifically strawberry farming, in the watershed has increased dramatically since 1970, especially on steep slopes adjacent to pickleweed (*Salicornia virginica*) dominated salt marshes. This land use change has greatly increased sedimentation along the margin of the slough, where several sediment fans have formed that have filled marshes, mudflats, and channels, and altered the wetland plant community by changing environmental conditions in the marsh. The objective of this research is to use remote sensing to find the relationship between land use change and the alteration of wetland plant communities, to determine which environmental conditions are driving plant community change, and to develop strategies to monitor and manage this problem in the future.

The main question addressed by this research is: In sub-catchments of Elkhorn Slough where sediment fans have developed, has there been a successional change in coastal salt marsh vegetation that can be linked to increased or mismanaged agriculture in the watershed? Supplemental questions are: 1) Does plant community change correlate with changes

While Elkhorn Slough contains a State ecological preserve and a NOAA research reserve, agriculture, specifically strawberry farming, in the watershed has increased dramatically since 1970. Indications are that between 1980 and 2001, a significant loss (approximately 50%) in pickleweed salt marsh has occurred where sediment fans have formed. In its place pockets of freshwater marsh and riparian forest have developed.

in environmental variables induced by deposition of upland sand and sediment?
2) Does restoration or improved management of catchments lead to less sedimentation and more stability and recovery in wetland plant communities?

After interviewing local experts and surveying by foot the perimeter of the slough, 15 sediment fans formed in salt marshes were chosen as study sites. Ten are located in sub-catchments with active agriculture, three are located downstream of a cattle ranch, and two sites are located in sub-catchments that were restored five years ago.

Initial remote sensing change detection work has indicated that between 1980 and 2001, a significant loss (approximately 50%) in pickleweed salt marsh has occurred where sediment fans have

formed. In its place pockets of freshwater marsh and riparian forest have developed. With the use of historical aerial photos from 1971, 1980, 1992, and 2001 at the Elkhorn Slough National Estuarine Research Reserve (ESNERR), we will create a decadal record of wetland vegetation change on sediment fans. To determine what environmental conditions have driven this shift in vegetation, we are sampling the sediment fans and control areas for salinity, soil texture, nitrogen, and elevation. Early results show that there is a significant drop in salinity on the sediment fans that correlates with the shift in vegetation from pickleweed to freshwater marsh. This is possibly due to freshwater inputs from upland farm runoff. The final step will be to determine a relationship between the extent of wetland vegetation change between 1970 and the present, and the area of uplands converted to agriculture and meeting an erosional disturbance criterion. Using multiple regression methods, it may be possible to predict how wetland vegetation will respond to changes in upland land use/land cover. The erosional disturbance criteria will be based on an index of upland disturbance, defined by the area of bare soil during winter months, lack of Best Management Practices, presence of gullies and other features in the uplands.

This study will guide management and restoration of wetlands in Elkhorn Slough and other highly impacted coastal watersheds. The groups working in Elkhorn Slough that would benefit most from this research are the Natural Resource Conservation Service (NRCS), ESNERR, and the Elkhorn Slough Foundation. NRCS is actively working with farmers in the watershed to reduce erosion and off-farm sediment and improve wetland habitat. The Elkhorn Slough Foundation is involved with several wetland monitoring and restoration projects, and is currently purchasing new land parcels for conservation purposes. Elkhorn Slough had lost almost half of its

wetland habitat area between 1931 and 1981 as a result of diking and draining for agricultural use. In California, coastal watersheds are undergoing extensive development, and the impact of changing watershed land use on coastal wetlands has not been well documented. Knowledge of these processes will support cumulative effects analyses that address landscape degradation and controls on wetland development, useful in future wetland management and restoration planning.

Professional Presentations

Kristin Byrd and N. Kelly, Development of a classification system for linking watershed land-use change and wetland vegetation response in the Elkhorn Slough Watershed, Monterey County, California, NOAA Coastal Geotools '03, Charleston, South Carolina, January 9, 2003.

Student Training

Kristin Byrd, graduate, Ph.D., Department Of Environmental Science, Policy, and Management, UC Berkeley

Collaborative Efforts

We would like to thank staff at the Elkhorn Slough National Estuarine Research Reserve and The Elkhorn Slough Foundation for their input, especially Dr. Kerstin Wasson, Research Coordinator and Mr. Eric Van Dyke, GIS Coordinator.



PhD student Kristin Byrd at Elkhorn Slough



Restoring Alpine Lake Ecosystems Through Control of Trout Spawning

Peter B. Moyle
Wildlife, Fish and Conservation Biology
UC Davis

Project Summary

Trout are often stocked into alpine lakes based on the assumption that resident trout populations are not self-sustaining and would go extinct without regular stocking. However, this assumption has not been rigorously tested. The objectives of our study were to (1) estimate the proportion of currently-stocked alpine lakes in the Sierra Nevada that contain self-sustaining trout populations, (2) identify the characteristics of lakes associated with self-sustainability, and (3) quantify the effects of stocking termination on trout density and individual growth rates in self-sustaining populations. We surveyed trout populations in 95 John Muir Wilderness (JMW) lakes before and after a 4-8 year stocking halt and 111 Sequoia/Kings Canyon National Park (SEKI) lakes after a ≥ 20 year stocking hiatus. Seventy-two percent of JMW study lakes and 66% of SEKI study lakes contained self-sustaining trout populations based on evidence of successful recruitment during the no-stocking period. Regression analysis identified spawning habitat area and lake elevation as significant factors influencing trout population persistence. Trout populations in lakes with $>2.1 \text{ m}^2$ of spawning habitat and located at elevations $<3520 \text{ m}$ were nearly always self-sustaining. For self-sustaining populations, the termination of

stocking did not result in significant changes in population density or individual growth rates. We conclude that most trout stocking in Sierra Nevada alpine lakes could be permanently halted without negatively impacting these fisheries.

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Professional Presentations

Trip Armstrong, Assessing self-sustainability of trout populations in Sierra Nevada Alpine lakes using an experimental halt to stocking, 2003 Annual meeting Western Division of the American Fisheries Society, San Diego, California, April 17, 2003.

Student Training

Trip Armstrong, graduate, Ph.D., Graduate Group in Ecology, UC Davis
Shasta Ferranto, undergraduate, Wildlife, Fish and Conservation Biology, UC Davis

Additional Funding

California Department of Fish and Game,
\$25,000

Collaborative Efforts

Collaborated with Dr. Roland Knapp,
Research Associate at Sierra Nevada
Aquatic Research Laboratory, UC Santa
Barbara.





Upstream and Upslope Translocation of River-Borne Materials by Aquatic and Riparian Organisms: Contrasts in Spatial Fluxes Along Mainstems and at Tributary Confluences

Mary Power
Integrative Biology
UC Berkeley

Project Summary

Nutrients and contaminants exported from watersheds to rivers can be incorporated back into terrestrial food webs via aquatic insect emergence. Emerging insects from contaminated areas deliver contaminants to terrestrial insectivores, which may be disproportionately concentrated in riparian habitats. Contaminants derived from mainstem rivers may penetrate further upslope along tributary confluences, but the impacts of tributaries on the abundances, activities, and landscape movements predators of aquatic emergence are poorly known, as are river-to-watershed fluxes in general. To evaluate backflows of contaminants across the landscape, we must evaluate how aquatic and riparian organisms move and interact across landscape boundaries in river networks.

We examined these river-to-watershed fluxes by sampling organisms and surveying their stable carbon and nitrogen isotopic composition in an impacted river (the Truckee River north of Lake Tahoe). Studies in a relatively unimpacted river (the South Fork Eel River in Mendocino Co.) are ongoing this summer (2003). Preliminary data from both watersheds

Nutrients and contaminants exported from watersheds to rivers can be incorporated back into terrestrial food webs via aquatic insect emergence. Our analyses will reveal the spatial scales of movements of nutrients and other substances from rivers back into watersheds, and evaluate the effect on these fluxes of tributaries.

indicated that carbon and nitrogen originating in mainstem, tributary, and adjacent terrestrial habitats are isotopically distinct, so mixing models could be used to assess upslope and upstream backflows mediated by insect emergence and its consumption by riparian predators.

In the Truckee River system, isotopically heavy nitrogen indexed nutritional backflows from the Truckee River that are likely to correlate with transport of mercury to the high desert food web in the surrounding watershed. Mercury analyses are ongoing, but the nitrogen evidence shows an exponential decline away from the river in ^{15}N enrichment in riparian birds, lizards, and spiders. Dramatic enrichment (and presumably contamination) occurs just downstream from Steamboat Creek near Highway 395,

where present organic and historical mine deposit inputs into the Truckee River may increase the likelihood of transfer of bioavailable mercury into the channel food web. Our analyses will reveal the spatial scales of movements of nutrients and other substances from rivers back into watersheds, and evaluate the effect on these fluxes of tributaries. This information will allow us to evaluate positive benefits of these fluxes (e.g. nutritional subsidies from mainstem rivers to riparian consumers we value, such as bats or song birds) as well as the spatial extent of adverse effects (contaminant transport into upland areas) that arise where rivers have been polluted.

Professional Presentations

Mary Power, Food webs in River Networks, given at Arizona State University (Dept Biology departmental seminar), University of California Berkeley (Integrative Biology departmental seminar), September 26, 2003.

Rivard, A. Cabana, G., Rainey, W., and M.E. Power, Tracing fluxes of aquatic production into desert terrestrial food webs, Annual GRIL (Inter-university Limnology Group), St-Hippolyte, Québec, Canada, March 2003.

Student Training

Alexandre Rivard, Graduate Student, MS, Univ. du Quebec a Trois Rivieres
Gregory Bulté, Undergraduate, Univ. du Quebec a Trois Rivieres
Jesse Walker, Undergraduate, Integrative Biology, UC Berkeley
Rebecca Doubledee, Graduate Student, Ph.D. candidate, Integrative Biology, UC Berkeley
Mike Limm, Graduate Student, Integrative Biology, Ph.D. candidate, UC Berkeley

Additional Funding

Cabana, Gilbert, 2003, NSERC of Canada (National Science and Engineering Research Council): Using contaminants and stable isotopes from rivers to dissect the structure of terrestrial flood plain food webs, \$40,000

Power, Mary, 2002, National Center for Earth Surface Dynamics, NSF Science and Technology Center subcontract as co-PI, \$130,000 per year for 5 years.

Collaborative Efforts

Ongoing collaborations with Gilbert Cabana, a former postdoc in the Power lab and now a professor at the Université de Québec a Trois Rivieres have led us into investigations of the role of river-to-watershed trophic export as a potential pathway for contaminant transport from rivers into terrestrial ecosystems. Cabana's student Alexander Rivard is preparing a Master's thesis from this work. Analyses of mercury are ongoing in their laboratory.



Research Category III

Water Quality

Research in this category encompasses all factors and processes affecting the quality of the sources of surface and groundwater regardless of the use, and the quality and treatment of water in the transportation and distribution systems. Topics that fall within this category include studies of the sources and the nature of contaminants including those emanating from agricultural and industrial processes, effects of contamination on human health, plant and wildlife, wastewater treatment and reclamation processes, and retrospective evaluations of the effectiveness and impacts of different strategies utilized in California for improving water quality and for preventing water quality degradation.





Development of a Liquid Membrane Technique to Measure the Temporal Variation in “Bioavailable” Copper and Nickel in the South San Francisco Bay

Kenneth Bruland
Ocean Sciences
UC Santa Cruz

Project Summary

The aim of project W-958 is to measure the concentration of "bioavailable" copper and nickel in South San Francisco Bay. The bioavailability of trace metals to phytoplankton (with respect to both toxicity and biolimitation) is generally correlated to the free or inorganic metal ion concentrations rather, than the total metal concentration. South San Francisco Bay has been designated as an impaired water body under the clean water act because the “total concentration” of dissolved copper and nickel often exceeds the water quality objectives. However, there is strong evidence to suggest that most of this nickel and some of the copper is complexed to anionic hydrophilic ligands such as ethylenediamine tetraacetic acid (EDTA) that are not directly assimilated by microorganisms. Copper is also strongly bound to natural organic ligands in a form that is not directly available to the plankton community.

In order to determine the free or labile fraction of copper or nickel, the total dissolved concentration of these metals has to be determined first. The high concentration of alkali and alkaline earth ions in seawater and the high content of dissolved organic matter (DOM) in estuarine

waters make direct determination of these trace metals very difficult.

South San Francisco Bay has been designated as an impaired water body under the clean water act because the “total concentration” of dissolved copper and nickel often exceeds the water quality objectives. We found that between 90-95% of the total dissolved copper was bound by organic ligands, and therefore not “bioavailable” to phytoplankton.

We developed an automated flow injection method for determination of total copper and other trace metal concentration. We also developed a supported liquid membrane (SLM) technique for the determination of free and labile copper concentration.

The complete automated on-line flow system consisting of a peristaltic pump, electrically actuated valves and a membrane holder unit is computer controlled via a digital I/O card to switch valves and start or stop the peristaltic pump. The sample solution, containing copper species was pumped through the donor channel of the membrane containing the copper complexing ligand which selectively extracts inorganic and labile organic copper

species. After the extraction, the selectively enriched analyte in the stagnant acceptor solution is pumped into a vial in a fraction collector for off-line analysis by GFAAS.

We analysed water samples collected from two stations, in South San Francisco Bay. The samples were collected from Dumbarton Bridge and San Bruno Shoals stations, in January and March 2003 respectively and kept frozen till analysis. They were then extracted by SLM and the copper concentration in the extracts determined by GFAAS.

We found that between 90-95% of the total dissolved copper was bound by organic ligands, and therefore not "bioavailable" to phytoplankton. Thus only about 5-10% of the total dissolved copper exists as inorganic and/or labile organic copper species. These measurements are consistent with earlier copper speciation measurements that we have made in South San Francisco Bay using electrochemical methods.

Publications

Kuria Ndung'u, Robert P. Franks, Kenneth W. Bruland and A. Russell Flegal, Organic complexation and total dissolved trace metal analysis in estuarine waters: comparison of solvent-extraction graphite furnace atomic absorption spectrometric and chelating resin flow injection inductively coupled plasma-mass spectrometric analysis. *Analytica Chimica Acta* 2003 481: 127-138

Professional Presentations

Kuria Ndung'u, Robert P. Franks, Kenneth W. Bruland, A. Russell Flegal, Trace metal preconcentration using chelating resin flow injection: Role of organic complexation Southern and Eastern Africa Network of Analytical Chemists (SEANAC), Inaugural Conference, Gaborone, Botswana, July 7-10, 2003.

Kuria Ndung'u, Kenneth W. Bruland, A. Russell Flegal, Analytical application of supported liquid membranes in trace metal extraction and speciation, PERMEA 2003, Membrane science and technology conference, Tatranské Matliare, Slovakia September 7-11, 2003

Student Training

Kuria Ndung'u, Post graduate, UC Santa Cruz, Institute of Marine Sciences



Experimental Determinations of Henry's Law Constants of Polybrominated Diphenyl Ether (PBDEs) to Evaluate Exposure to Aquatic Biota

M. Judith Charles
Department of Environmental Toxicology
UC Davis

Project Summary

Polybrominated diphenyl ethers (PBDEs) flame retardants, are a class of persistent organic pollutants (POP's) that are structurally similar to polychlorinated biphenyls (PCBs). Concentrations of PBDE in fish and human milk have increased over the past decade due to their widespread use as flame retardants in commercial products. If current trends continue, environmental concentrations of PBDEs will double every 5 years. In California, the highest human levels of PBDEs reported to date were measured in Californian women, and increasing concentrations of PBDEs were reported in harbor seals (*Phoca vitulina richardsii*) residing in the San Francisco Bay, over the past decade. The finding of PBDEs in Arctic air and fish indicate global transport of PBDEs.

The environmental fate and transport of a chemical depends on its physical-chemical properties. Henry's law constant is one key property that governs air-water exchange or partitioning. Whether a pollutant is volatilized from waters, or is deposited into waters from the atmosphere impacts the transport of pollutants to remote sites and the bioavailability of pollutants in waters. To understand whether volatilization is an important fate

Knowledge of Henry's Law Constant is important to assess the distribution of PBDEs (flame retardant chemicals) in the aquatic and atmospheric environments. The first known experimental measurements of the constant for these chemicals were accomplished.

process for PBDEs, the Henry's law constants (K_H , $\text{Pa m}^3 \text{mol}^{-1}$) must be known. Knowledge of such constants will also assist in evaluating exposure of PBDEs to aquatic organisms; and atmospheric losses and inputs that affect global transport and deposition of PBDEs to aquatic systems. The objective of this project is to experimentally determine the K_H of select PBDE congeners. In the first year of the project, difficulties were encountered which are being addressed. Despite these difficulties, the K_H of six PBDE were measured. These measurements are the first experimental measurements of Henry's law constants for these chemicals. Preliminary interpretation of the data indicate that in certain cases, volatilization of PBDEs from waters can be an important fate process. Due to uncertainties associated with the measurements, the results will be validated in the second year, and the experimental measurements of the K_H will

be expanded. The data will be used to shed light on the fate of PBDEs in aquatic systems.

Professional Presentations

Lau, Fiona, Destailats, Hugo, Charles, M. Judith, Experimentally Determined Henry's Law Constants for Six Brominated Diphenyl Ether Congeners, 23rd International Symposium on Halogenated Environmental Organic Pollutants and POPs, Boston, MA, August 24-29, 2003.

Student Training

Fiona Lau, Chemistry graduate, Department of Environmental Toxicology, UC Davis.



Nature of Flow and Gas Dynamics Below Spreading Ponds

Jordan Clark
Department of Geological Sciences
UC Santa Barbara

Project Summary

During the last 50 years, the soaring demand for freshwater has placed unprecedented stress upon many aquifers in California and elsewhere. One recent development in groundwater/surface water management aimed at augmenting water supplies has been artificial recharge. This practice consists of recharging recycled or surplus surface water into permeable aquifers and extracting this recharged water at some later date. A common method for recharging surplus surface water relies upon percolation from spreading basins. Spreading basins are typically shallow sandy bottom basins from which water can rapidly infiltrate into the ground. It is unclear whether the bulk of the flow beneath these basins occurs primarily in saturated portions of the Vadose zone or if unsaturated flow dominates. The type of flow has important implications for the kinds of *in situ* biogeochemical reactions that can occur and the behavior of dissolved gases. The latter is critical when trying to design and interpret the behavior of gas tracers such as sulfur hexafluoride (SF_6) and noble gas isotopes. Experiments using these gas tracers have become acceptable methods for evaluating travel times from recharge locations to wells, important criteria used during the permitting processes of artificial recharge operations in the State of California.

Artificially recharging aquifers with recycled or surplus surface waters is one approach to augment future water supplies. Whether the water flows from the spreading basins to the aquifer is in the saturated or unsaturated state has implications for the kinds of *in situ* biogeochemical reactions that can occur. Internal results suggest the flow was in the saturated state.

A dual gas tracer experiment was initiated during September, 2002 at the El Rio spreading grounds, Ventura County, CA to examine the nature of flow beneath spreading basins. Prior to the experiment, little or no recharge was taking place in these basins (daily infiltration rate $< 0.2 \text{ m}^3/\text{s}$). Thus, the experiment was begun during the initial wetting after a "dry" period. SF_6 and an isotope of He gas, ^3He , were chosen as tracers because they are transferred across the air-water interface at different rates. Hence, by examining changes in their ratio, gas exchange rates can be quantified independent of mixing that will cause changes in their absolute concentrations. We hypothesized that if flow occurs primarily in saturated portions of the Vadose zone, then there will be little gas exchange and the $^3\text{He}/\text{SF}_6$ ratio in the

groundwater will be approximately equal to the ratio in the spreading basin.

The gas tracers were injected into El Rio pond #2 (surface area = ~3.8 ha) for one week beginning on September 27. Prior to the tracer injection, the pond had been actively recharging for ten days. During the injection period, the percolation rate averaged approximately 2.3 m³/s, hence about 1,100 ac-ft of water was tagged with the gas tracers. Groundwater samples have been collected from eight nearby production wells (travel distances from the spreading basin range between 10 m and 950 m). Initially, samples were collected every few days and presently they are collected every six weeks. During the last sampling campaign (6/13/03), tracer was detected at four wells. SF₆ arrived within five days at the closest well, El Rio #6, which lies about 10 m from the pond and is screened between 50 m and 92 m below ground surface. The maximum concentration at this well was observed after 21 days and was approximately 25% of the mean concentration in the portion of the basin closest to the well. The rapid transport and the relatively high concentration of SF₆ observed at El Rio #6 suggests that very little gas was lost during transit and, thus, the flow must have been through saturated portions of the Vadose zone. This result will be confirmed later this summer when the ³He samples are analyzed in the laboratory of Dr. G. Bryant Hudson (Lawrence Livermore National Laboratory). Furthermore, laboratory column experiments will be conducted to examine the behavior of dissolved gases during unsaturated flow. Dr. Arturo Keller (UC Santa Barbara) will collaborate with this work.

Publications

Clark, J. F. (2003), Application of Geochemical techniques for flow characterization near artificial recharge operations, *Proceedings of the 11th Biennial Symposium on Groundwater Recharge*, in -press.

Avisar, D. and J. F. Clark (2003), A gas tracer study in the El Rio spreading ponds, Ventura County, California, *Proceedings of the 11th Biennial Symposium on Groundwater Recharge*, in -press.

Professional Presentations

Clark, J. F. "Application of Geochemical Techniques for Determining Groundwater Travel Times near Artificial Recharge Sites," 11th Biennial Symposium on Groundwater Recharge, Tempe, Arizona, June 2003

Avisar, D and J. F. Clark, "A Gas Tracer Study in the El – Rio Spreading Pond: Ventura County, California," 11th Biennial Symposium on Groundwater Recharge, Tempe, Arizona, June 2003

Student Training

Dror Avisar, post-doctoral researcher, Institute of Crustal Studies, UC Santa Barbara

Margo Ragland, undergraduate, Hydrological Sciences, UC Santa Barbara

Collaborative Efforts

Collaborative work has begun with Dr. Arturo Keller (UC Santa Barbara) and Dr. G. Bryant Hudson (Lawrence Livermore National Laboratory) on this research project.



Cryptosporidium in Bivalves as Indicators of Fecal Pollution in the California Coastal Ecosystem

Patricia Conrad
Dept of Pathology, Microbiology, and Immunology
UC Davis

Project Summary

The objective is to obtain critical data on the epidemiology of *Cryptosporidium* in freshwater, estuarine, and nearshore marine ecosystems along the California coast in order to better understand fecal pathogen contamination. We hypothesize

1) that *Cryptosporidium* parasites are present in bivalve shellfish collected at sites exposed to fecal contamination, including sites near human sewage outfalls and livestock runoff, and 2) that *Cryptosporidium* genotypes will differ significantly in bivalves collected at sites exposed to human fecal contamination (e.g. near sewage discharge sites) compared with bivalves collected at sites contaminated with livestock feces (e.g. downstream from agricultural runoff). If our hypotheses are correct, bivalves may be sensitive and practical water quality monitoring tools.

In the first year of the project, we have performed tank exposure experiments showing that *Cryptosporidium* oocysts are detectable in freshwater clams at a variety of environmentally plausible doses and water temperatures. We have also been collecting clams and mussels from freshwater, estuarine, and marine sites along the California coast considered 'high risk' or 'low risk' based on their proximity to sewage outfalls and livestock runoff.

Our data support the fact that bivalve shellfish may be useful bioindicators of fecal contamination in aquatic environments, and that the sources of fecal contamination may include domestic animals, livestock, wildlife, and humans.

We have detected *Cryptosporidium* in mussels collected at high risk fecal exposure sites but not in mussels collected from low risk sites. Several genotypes of *Cryptosporidium* have been detected, including *C. parvum*, *C. felis*, and *C. andersoni*. Our data support the fact that bivalve shellfish may be useful bioindicators of fecal contamination in aquatic environments, and that the sources of fecal contamination may include domestic animals, livestock, wildlife, and humans.

Publications

Conrad P.A., M. Miller, A.J. Kjemtrup, W. Smith and I.A. Gardner, The human-wildlife-domestic animal interface provides exciting research opportunities for parasitologists, *Journal of Parasitology* 89: 527-536, 2003.

Professional Presentations

Conrad, P.A., M. Miller, A. Kjemtrup, W. Smith and I.A. Gardner, Protozoal problems emerging at the human-wildlife-

domestic animal interface, Wildlife Disease Association Annual Meeting, Humboldt, CA, July, 2002, and International Congress of Parasitology, Vancouver, CA, Aug, 2002.

Conrad, P.A., M. Miller, A.M. Kjemtrup, W.A. Smith and I.A. Gardner, Exciting protozoological discoveries at the human-wildlife-domestic animal interface, Society for Tropical Veterinary Medicine, Iguassu Falls, Brazil, June, 2003, and American Veterinary Medical Association, Denver, CO, July, 2003.

Smith, W.A., M.A. Miller, I.A. Gardner, E.R. Atwill, S. Jang, D. Jessup, C. Leutenegger, A. Melli, P.A. Conrad, Shellfish as indicators of fecal borne protozoa and bacteria in the California marine ecosystem, Wildlife Disease Association Annual Meeting, Humboldt, CA, July, 2002.

Smith, W.A., E.R. Atwill, I.A. Gardner, M.A. Miller, J. Ames, S. Jang, A. Melli, D. Jessup, P.A. Conrad, Sea otters, shellfish, and fecal pathogens: can we connect the dots?, Defenders of Wildlife Carnivore Conference, Monterey, CA, November, 2002.



Melissa Miller and Woutrina Miller out planning mussels near moss Landing, California

Smith, W.A., H.M. Fritz, E.R. Atwill, I.A. Gardner, R.P. Hedrick, K.D. Arkush, A.C. Melli, P.A. Conrad, Detecting environmental levels of *Cryptosporidium* parasites in clams (*Corbicula fluminea*), International Association for Aquatic Animal Medicine, Kona, HI, May, 2003.

Student Training

Woutrina Smith-Miller, graduate, DVM, MPVM, PhD, Comparative Pathology, UC Davis.

Collaborative Efforts

California Department of Fish & Game, California State Mussel Watch Program, Central Coast Regional Water Quality Control Board, UC Extension.



Nicki Barnes collecting mussels near Bodega Bay, California



Fate of Viruses, Endocrine Disruptors, and Nitrogen in Non-Conventional Onsite Wastewater Treatment Processes: A Technical and Economic Analysis

Jeanine L. Darby
Civil and Environmental Engineering
UC Davis

Project Summary

Onsite small wastewater treatment systems have been constructed and are currently in operation at the UC Davis wastewater treatment facility for investigation of the fate of indigenous coliphage, nitrogen, and endocrine disruptors in these systems. The treatment systems that have been selected for evaluation are unique because of their high efficiency and role in the future of onsite wastewater treatment. The treatment systems that are in operation encompass several state-of-the-art technologies, including (a) three high porosity, high surface area multi-pass biofilm reactors (see Fig. 1), (b) two submerged aerated biofilm reactors; one to be inoculated with specific bacteria (i.e., bioaugmentation) for enhanced performance (see Fig. 2), and (c) a traditional septic tank followed by single-pass sand filters. In addition, soil lysimeters (see Fig. 3) have been assembled to further evaluate the effect of upstream processing on the performance of soil adsorption systems (i.e., standard leach field).

The treatment systems are typically used for the treatment (or pre-treatment) of wastewater from individual or clustered

Onsite small wastewater treatment systems have been constructed and are currently in operation at the UC Davis wastewater treatment facility for investigation of the fate of indigenous coliphage, nitrogen, and endocrine disruptors in these systems. Due to the nature of the treatment systems, it will be possible to evaluate the removal and transformation of wastewater constituents under a range of conditions.

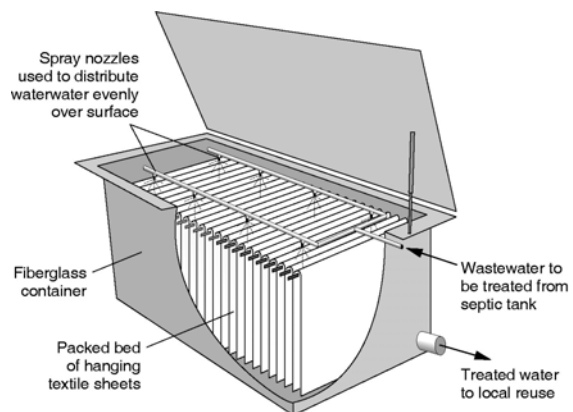


Figure 1
Diagram of high efficiency biofilm reactor used for wastewater treatment, currently under evaluation at UC Davis.

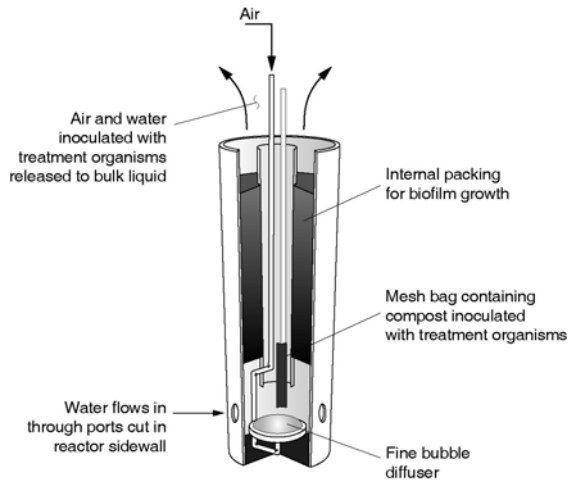


Figure 2

Diagram of submerged aerated biofilm reactor used to facilitate bioaugmentation processes in wastewater treatment, currently under evaluation at UC Davis.

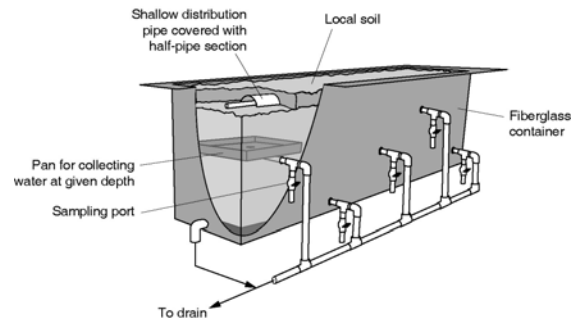


Figure 3

Diagram of soil lysimeter used for assessing performance of onsite wastewater treatment processes.

buildings or small communities before discharge to the soil environment. After discharge to the soil, the partially treated wastewater undergoes additional treatment by soil microorganisms, followed by evaporation or infiltration to the local groundwater. Constituents that are typically present in wastewater include dissolved and particulate organic materials, nutrients, pathogenic and non-pathogenic microorganisms, and chemicals resulting from human activities (e.g., hormones, pharmaceuticals). These constituents are removed to varying degrees depending on the nature of the treatment process used. The purpose of the present research is to determine the fate of these constituents when treated in conventional and non-conventional treatment systems and after discharge to the soil.

Due to the nature of the treatment systems, it will be possible to evaluate the removal and transformation of wastewater constituents under a range of conditions. For example, based on preliminary research, the biofilm reactors are able to provide nearly complete BOD and TSS removal, complete nitrification, and 30 to

70 percent total nitrogen removal (through anoxic denitrification) depending on the mode of operation. In contrast, the submerged aeration systems function similar to conventional nitrifying activated sludge systems when operated without bioaugmentation. However, when bioaugmentation is initiated before nitrification develops, BOD is removed and the nitrification reaction is inhibited, thus producing an effluent low in biodegradable organic substrate yet high in ammonia. Alternately, if a nitrifying culture is established before bioaugmentation, there is evidence that aerobic denitrification processes will occur, resulting in an effluent low in BOD and inorganic nitrogen. Similar transformation and removal dynamics are expected for other wastewater constituents.

The application of these effluents to soil lysimeters will improve our understanding of the fate of wastewater constituents under different treatment scenarios and in the soil. The results will be useful for decision makers contemplating the appropriate use of onsite wastewater treatment systems for protection of public and environmental health.

Publications

Leverenz H., G. Tchobanoglous, and J. Darby, Review of Technologies for the Onsite Treatment of Wastewater in California, *Center for Water Resources Engineering*, University of California Davis, No. 2002-2, 2002.

Leverenz H., L. Ruppe, G.Tchobanoglous, and J. Darby, Evaluation of High Porosity Media for the Treatment of Onsite Treatment of Wastewater, (peer reviewed) *Small Flows Journal*, Vol. 2, No. 2, 2001.

Professional Presentations

Leverenz, H.L., The use of pretreatment technologies for the removal of wastewater constituents, National Symposium on Individual and Small Community Sewage Systems (ASAE), Sacramento, CA, March 21-24, 2004.

Student Training

Gina Choi, undergraduate, Civil and Environmental Engineering, UC Davis
Ian Maki, undergraduate, Civil and Environmental Engineering, UC Davis

Erin Onieda, undergraduate, Civil and Environmental Engineering, UC Davis
Olivia Virgadamo, graduate, M.S., Civil and Environmental Engineering, UC Davis

HsinYing Liu, graduate, Ph.D., Civil and Environmental Engineering, UC Davis
Harold Leverenz, graduate, Ph.D., Civil and Environmental Engineering, UC Davis

Additional Funding

The following equipment has been donated (values estimated) for the purpose of conducting the research:

- Delta Precast & Jenson Precast - Four septic tanks, \$5,000
- Orenco Systems, Inc. - Three biofilm reactors, \$6,000
- Priana Inc. - Two aeration systems, \$4,000
- Orenco Systems, Inc. - Six soil lysimeters basins, \$3,000
- Infiltrator Systems, Inc., Orenco Systems, Inc. & Pirana Inc. - Miscellaneous pumps, basins, control systems, supplies \$10,000

Collaborative Efforts

Bioaugmentation processes will be monitored and characterized through interdepartmental collaboration with Dr. Stefan Wuertz. The collaborative work will include sequencing of bacterial DNA needed to construct molecular probes to be used for identification of relevant treatment organisms.



Development of an Autonomous O₂ Delivery System for In-Situ Aerobic Bioremediation

Marc Deshusses
Chemical and Environmental Engineering
UC Riverside

Project Summary

This project deals with treatment of groundwater contaminated with organic compounds such as gasoline. In many cases, the tendency has been to allow for natural attenuation of the contaminants because of the lower treatment costs. However, natural attenuation can be slow, and oxygen depletion resulting in anaerobic aquifers is the rule rather than the exception. Anaerobic conditions result in expanding plume sizes and slow remediation. In many instances, a corrective action has to be taken and oxygen has to be supplied to the aquifer. This is usually done by sparging the aquifer with air or with pure oxygen, or by injection of liquid or solid peroxide which will slowly release oxygen in-situ. Delivering oxygen to a contaminated aquifer is expensive.

In the present project, we are developing a new and autonomous system for the delivery of oxygen to contaminated aquifers. The principle of this new system is still confidential in order to avoid compromising patent application. The research has progressed well. After one year of research, the basic proof of concept has been demonstrated, hence a UC disclosure of invention is being written. As individual parts of the system were

We are developing a new and autonomous system for the delivery of oxygen to contaminated aquifers. The basic proof of concept has been demonstrated. If the project is successful, it could have a significant impact on the way active in-situ bioremediation is conducted.

tested, new issues not initially considered to be critical have arisen. These required modification of the initial design of the proposed system. One issue of particular importance is the long term stability and decreasing yield of the energy generation system over time. We will be working towards resolving this issue in the second year. As the basic proof of concept has now been demonstrated, the focus will be shifted towards the integration of the different parts of the system into a functional autonomous O₂ delivery system. This will be followed by detailed evaluation and testing of the prototype. Optimization of the system will be conducted before field testing, hopefully towards the end of the second year of the project. At the same time, the initial cost estimation of the system will be refined. If the project is successful, it could have a significant impact on the way active in-situ bioremediation is conducted.

Student Training

Anthony M. Avila, graduate student,
Department of Chemical and
Environmental Engineering, UC
Riverside.

Collaborative Efforts

This project is a collaborative effort of
Dr. Deshusses (bioremediation
expertise) and Dr. Yan (energy
systems), both in the Department of
Chemical and Environmental
Engineering at UC Riverside.



The Catalysis of Perchlorate Ion Electroreduction at Transition Metal Electrodes

W. Ronald Fawcett
Chemistry
UC Davis

Project Summary

Perchlorate salts are used in rocket fuel, which was produced in Nevada and parts of California. Because of poor handling procedures, these chemicals entered the ground water system and can now be found at the ppb level in major water sources such as the Colorado River. Perchlorate is very stable in water and difficult to remove. It represents a major health threat because of its interference with thyroid function. We have been investigating electrochemical methods for destroying perchlorate in situ by reducing it to the harmless chloride ion.

We first tested a cell using pure nickel foil as a cathode and a platinum counter electrode as anode. The experiments demonstrated that significant reduction of perchlorate can be obtained

Our initial results indicate that electrochemical destruction of perchlorate may provide an effective means of removing this contaminant.

electrochemically; but for various technical reasons, this particular system would not be a practical solution. Part of the problem was the dissolution of nickel. We next tested Raney nickel which is 50% nickel and 50% aluminum. This research is in progress but our initial results indicate that electrochemical destruction of perchlorate may provide an effective means of removing this contaminant.

Student Training

Maria Rusanova, post-doctoral fellow,
Chemistry Dept., UC Davis



Perchlorate Removal in Groundwater by Perchlorate Reductases from the Perchlorate Respiring Bacterium, Perc1ace

William T. Frankenberger
Environmental Sciences
UC Riverside

Project Summary

Perchlorate (ClO_4^-) is an important energetic component of solid rocket fuel. The major source of ClO_4^- pollution is the military, space program and supporting industries. Wastewater generated from the manufacturing, maintenance, and testing of solid rocket propellants can contain NH_4 perchlorate in the grams per liter concentration range. ClO_4^- is recalcitrant in the environment and is potentially toxic. The California Department of Health Services adopted an action level of 4 ppb for perchlorate in potable water. Physicochemical water treatment technologies (e.g. membrane and ion-exchange systems) have been considered for ClO_4^- remediation, but they are expensive and not practical for ClO_4^- perchlorate removal from ground water. Moreover, these processes produce high salt waste streams contaminated with perchlorate and require further treatment to remove residual ClO_4^- . Microbial reduction of ClO_4^- to environmentally-acceptable innocuous end products is currently an area of intense interest. Microorganisms that reduce ClO_4^- to chloride and molecular oxygen have been isolated. For designing an efficient biological-based ground water ClO_4^- remediation strategy, but the biochemical

and molecular data on the enzymatic reduction of ClO_4^- are needed.

The California Department of Health Services adopted an action level of 4 ppb for perchlorate in potable water. Microorganisms that reduce ClO_4^- to chloride and molecular oxygen have been isolated. For designing an efficient biological-based ground water ClO_4^- remediation strategy, but the biochemical and molecular data on the enzymatic reduction of ClO_4^- are needed. Treatment systems designed to employ cell-free enzymes catalyze the ClO_4^- reduction reaction without the production of biomass wastes.

The ClO_4^- respiring organism, perc1ace when grown using either ClO_4^- or NO_3^- as a terminal electron acceptor produced ClO_4^- reductase to a significant extent. The ClO_4^- reductase activity appeared to be within the periplasmic space, with activities as high as $14,000 \text{ nmol min}^{-1} \text{ mg protein}^{-1}$, indicating that it is a soluble enzyme. A ClO_4^- reductase from cell-free extracts of perc1ace was purified 10-fold by ion-exchange and molecular exclusion fast protein liquid chromatography (FPLC). The ClO_4^- reductase catalyzed the reduction of ClO_4^- at a V_{max} and K_m of 4.8 Units mg

protein⁻¹ and 34.5 μM, respectively. Maximal activity was recorded at 25-30°C and pH 7.5 – 8.0. Perc1ace ClO₄⁻ reductase is a dimer with molecular masses of 35.07 kDa and 75.1 kDa determined by SDS-PAGE. Matrix-Assisted Laser Desorption Ionization-Time of Flight/Mass Spectrometry (MALDI-TOF/MS) analysis of the 35 kDa protein revealed several tryptic peptides. To study the genetic determinants of ClO₄⁻ reductase, the amino terminal sequences of 22 tryptic peptides of the approximately 35 kDa ClO₄⁻ reductase subunit were obtained by electrospray mass spectrometry. GenBank Blast analysis of the amino acid sequences revealed similarity to reductases, dehydrogenases and heme proteins. In batch studies of *in vitro* reduction of perchlorate, perc1ace ClO₄⁻ reductase reduced perchlorate in water with either NADH or methyl viologen as an electron donor. Less enzyme activity was observed with methanol and ethanol. Addition of perc1ace ClO₄⁻ reductase to ion-exchange (IEX) brine impacted with ClO₄⁻ substantially enhanced ClO₄⁻ removal by salt tolerant bacteria. Experiments showed that ClO₄⁻ reductase immobilized to Ca alginate reduced ClO₄⁻. Additional studies are focusing on: optimization of reaction conditions for perchlorate reduction by immobilized perchlorate reductases, molecular characterization of the overall genetic determinants of ClO₄⁻ bioreduction by perc1ace by cloning the genes using degenerate primers designed from the amino acid sequences of ClO₄⁻ reductase tryptic peptides and over-expression of recombinant ClO₄⁻ reductase. Such a recombinant enzyme available in large quantities can be immobilized and safely used for the treatment of perchlorate contaminated ground water on site. Treatment systems designed to employ cell-free enzymes catalyze the ClO₄⁻ reduction reaction

without the production of biomass wastes. Moreover, the spent enzymes can be regenerated and reused, substantially reducing cost. Cell free perchlorate reductase immobilized on calcium alginate displayed ClO₄⁻ reductase activity.

Publications

Okeke, B.C., T. Giblin, and W.T. Frankenberger Jr., Perchlorate and nitrate by salt tolerant bacteria. *Environmental Pollution*, 118, 357-363, 2002.

Giblin, T. and W.T. Frankenberger Jr., Perchlorate and nitrate reductase activity in the perchlorate respiring bacterium perc1ace. *Microbiological Research*, 156, 311-315, 2002.

Losi, M.E., T. Giblin, V. Hosangadi, and W.T. Frankenberger, Bioremediation of perchlorate-contaminated groundwater using a packed bed biological reactor. *Bioremediation Journal*, 6, 97-104, 2002. Giblin, T., M.E. Losi, V. Hosangadi, and W.T. Frankenberger, Bacterial perchlorate reduction in simulated reverse osmosis rejectate. *Bioremediation Journal*, 6, 105-111, 2002.

Okeke, B.C. and W.T. Frankenberger Jr., Molecular analysis of a perchlorate reductase from a novel perchlorate respiring bacterium, perc1ace. In preparation.

Student training

The project provided practical training for over 30 students of Environmental Science 155 through several hours of laboratory classes on "Bioremediation of perchlorate in ground water" organized by our laboratory. The project also supported in part, a post-doctoral fellow (Benedict C. Okeke) to carry out the study.



Abiotic Nitrogen Removal Mechanisms in Rapid Infiltration Wastewater Treatment Systems

Mark R. Matsumoto
Chemical and Environmental Engineering
UC Riverside

Project Summary

Nitrogen management is an important element of a water reuse plan, especially where groundwater recharge using reclaimed wastewater is being practiced. In these situations, land based municipal wastewater treatment systems such as rapid infiltration (RI) treatment are desirable because of the direct recharge associated with the system and for their lower costs. In RI systems, biological nitrification-denitrification is considered to be the primary nitrogen removal mechanism. However, depending on the soil characteristics of the RI systems, other mechanisms such as adsorption within the soil matrix may also provide significant nitrogen removal. Ongoing monitoring at a 150,000 m³/d (40 MGD) RI facility in southern California (Rapid Infiltration and Extraction (RIX) Facility, City of San Bernardino) suggested that nitrogen removal efficiency is a function of the fraction of ammonium nitrogen in the influent. As the percentage of ammonium nitrogen in the influent increased, the apparent nitrogen removal efficiency improved. It was hypothesized that this phenomenon is related to the high mica content the soils found at this RI facility, and that the major nitrogen removal mechanism may be ammonium adsorption rather than biological nitrification-denitrification.

While it is apparent that nitrification-denitrification does indeed occur, the source of energy for the denitrification portion is still unknown. Based on previous studies of biological denitrification, there should not be sufficient organic carbon in the wastewater to achieve the level of nitrogen removal experienced at RIX.

During the first year of study soil samples from various depths and locations within multiple infiltration basins at the RIX facility were collected. Experiments were performed to determine the ability of the samples to remove ammonium and/or nitrate via adsorption. To separate nitrogen removal via adsorption versus that from biological activity, tests were performed with both sterilized and non-sterilized soil and wastewater samples. It was determined that little or no ammonium adsorption occurred with the first 10 feet of soil depth and only limited adsorption occurred at lower depths. Therefore, if the ammonium adsorption did indeed occur at the RIX facility, the adsorption capacity in the upper 10 feet of soil has been exhausted.

Results from laboratory testing, however, show that biological nitrogen removal reactions are significant. These results were also supported from analyses of

samples collected from subsurface samplers (lysimeters), which were installed at the RIX facility by the plant personnel. An interesting observation has been that a relatively large amount of nitrogen is removed biologically with a small amount of organic content in the wastewater. Generally, much higher amounts of biodegradable organic matter is needed to achieve the amount of nitrogen removal experienced at the RIX facility. In addition, the denitrification process occurs at depths (greater than 2 feet) that are not typically reported for RI systems.

During the past year we developed an alternative experimental plan to study the biological nitrogen removal processes at RIX. A series of soil columns varying in depth from 2 to 20 feet were built to study the nitrogen removal process as a function of depth and to study the impact of various operating changes, such as length of application and drying period between applications, on nitrogen removal. These studies are still ongoing. While it is apparent that nitrification-denitrification does indeed occur, the source of energy for the denitrification portion is still unknown. Based on previous studies of biological denitrification, there should not be sufficient organic carbon in the wastewater to achieve the level of nitrogen

removal experienced at RIX. Thus, the question remains as to the source of organic carbon or energy for the denitrification process.

Student Training

Kevin Bell, graduate, M.S., Chemical and Environmental Engineering, UC Riverside

Desirea Quam, graduate, M.S., Chemical and Environmental Engineering, UC Riverside

Araceli Arellano, undergraduate, Chemical Engineering, UC Riverside

Tuong-Phu Ngo, undergraduate, Environmental Engineering, UC Riverside

Lena Downar Herron, undergraduate, Undeclared, Life Sciences, UC Riverside

Additional Funding

City of San Bernardino has provided personnel assistance in setting up pilot systems.

Collaborative Efforts

Valerie Housel, City of San Bernardino
Chris Amrhein, UC Riverside



Core drilling



Soil column experiment



DNA Aptamers-Based Detection of Atrazine in Water

Ashok Mulchandani
Chemical and Environmental Engineering
Bourns College of Engineering
UC Riverside

Project Summary

Agricultural producers across the country rely on atrazine as the foundation of their weed control programs. Many crops, commodities and services in the U.S. could not be supplied in an economic fashion without the use of these herbicides. However, the economic benefits from herbicide usage are not achieved without potential risks to human health and the environmental due to the toxicity and potency of these herbicides. Extensive pollution of the environment by atrazine is of major concern as an increasing number of studies reveal contamination of rivers and groundwaters by these herbicides. Because of their toxicity, EPA has set the maximum contaminant level (MCL) for these herbicides at 3 parts per billion (ppb). A survey by the Cal/EPA's Department of Pesticide Regulation (DPR) on water samples taken from 3,564 wells in 48 of California's 58 counties revealed the detection of atrazine above regulatory limits in areas where the soil conditions favor movement of pesticides to-ground water.

The objective of the research is to develop novel biological receptors, ssDNA (single-stranded deoxyribonucleic acid) aptamers, for the selective and cost-effective bioremediation and selective, sensitive, rapid and low-cost detection of atrazine in drinking water supplies.

The research is developing novel biological receptors (ssDNA aptamers) for cost-effective bioremediation and rapid low-cost detection of atrazine in drinking water supplies. After four rounds of SELEX, four ssDNA aptamers were selected for further investigation.

The work to-date has focussed on the screening of a random DNA for the selection of aptamers with affinity for atrazine using systematic evolution of ligands by exponential enrichment (SELEX) as shown in Figure 1. After four rounds of SELEX, four ssDNA aptamers were selected for further investigations. The selected ssDNA aptamers were sequenced and evaluated for the binding affinity to atrazine.

Student Training

Mr. Pablo Sanchez, graduate, Ph.D.,
Microbiology, UC Riverside.

Additional Funding

This funding was helpful in securing the funding from UC BioStar program to develop an aptamer-based bioassay for lipoprotein profile.



Use of Bioassays to Assess the Water Quality of Wastewater Treatment Plants for the Occurrence of Estrogens and Androgens

Daniel Schlenk
Dept of Environmental Sciences
UC Riverside

Project Summary

Water reclamation is a mechanism employed by several water districts in arid climates to maintain sufficient quantities of potable water. However, recent findings of pharmaceuticals and personal care products in tertiary treated wastewater as well as other surface water have called into question whether reclaimed water is safe for human consumption. The specific aims of this project were to determine whether estrogenic and anti-estrogenic (androgenic) compounds are adequately removed by standard water treatment processes. Waste water from 2 different treatment plants (Tertiary treatment; and Wetlands treatment) have been evaluated for estrogenic activity using 2 biological methods that evaluate direct acting estrogens and indirectly acting estrogens. The treatment plant receives non-disinfected secondary treated water from the Orange County Sanitation District, and provides flocculation, dual-media filtration, and chlorine disinfection prior to distribution. Evaluation of this wastewater using an estrogen receptor cell-line indicated the presence of direct acting estrogens (likely natural human-derived estrogens or synthetic pharmaceutically-derived compounds) in the concentrations of 1-5 ng/L. Evaluation of direct and indirect estrogens using whole animal fish assays

Wastewater from a treatment plant was found to have estrogen concentrations of near 100 ng/L depending on method of detection. No measurable estrogenic activity was found by either procedure following wetland treatment.

indicated concentrations near 100 ng/L. Evaluation of wetlands using both assays pre and post treatment indicated no measurable estrogenic activity. Studies in the United Kingdom have indicated that concentrations of 1-5 ng/L are likely responsible for feminization of feral fish populations observed in receiving streams. However, it is still unclear what effect these concentrations may have on humans or wildlife populations in the United States.

Professional Presentations

Lingtian Xie, Yelena Sapozhnikova, Ola Bawardi, Greg Woodside and Daniel Schlenk, Evaluation of Estrogenicity in Tertiary Treated Wastewater Effluent Reused at Landscape Irrigation and Industrial Sites, Orange County, CA, 2003 and at the National Society of Environmental Toxicology and Chemistry Meeting in Austin TX, November 9-13, 2003

CWEA Specialty Topics Conference on Emerging Pollutants, Endocrine Disrupting

Chemicals/Pharmaceuticals, El Camino
Country Club, Oceanside, CA, March 2003

Southern California Association of POTWs,
Emerging Pollutants, OCSD, Fountain
Valley, CA, February 2003

Student Training

Ola Bawardi, Undergraduate and Graduate,
Environmental Science, UC Riverside

Additional Funding

\$ 439,044 Water Environment Research
Foundation (2003-2005)

Collaborative Efforts

Greg Woodside, Orange County Water
District



The Speciation and Reactivity of Wastewater-Derived Organic Nitrogen

David Sedlak
Civil and Environmental Engineering
UC Berkeley

Project Summary

Pollution of surface waters with dissolved nitrogen compounds can result in excessive growth of algae. Most regulations and nutrient control programs assume that all forms of nitrogen have an equal tendency to stimulate algal growth. However, nitrogen present in organic compounds (i.e., dissolved organic nitrogen) may not cause as much algal growth as inorganic forms of nitrogen, such as nitrate and ammonia. If dissolved organic nitrogen species are not as bioavailable as inorganic species, it may be appropriate to focus more attention to the control of non-point sources of nitrogen (e.g., stormwater runoff) as opposed to organic nitrogen-rich sources, such as denitrified wastewater effluent. During the first year of this project, algal growth bioassays were conducted on denitrified wastewater effluent samples, in the presence and absence of bacteria isolated from an effluent-receiving water. Bioassay results indicated that wastewater-derived organic nitrogen is not

Most regulations and nutrient control programs assume that all forms of nitrogen have an equal tendency to stimulate algal growth. Our results suggest that while it is inappropriate to assume wastewater-derived organic nitrogen can not cause algal growth, it will not cause as much growth as inorganic nitrogen.

available to the algae *Selenastrum Capricornutum* in the absence of bacteria. However, approximately half of the wastewater-derived organic nitrogen was available to algae in the presence of bacteria during a two-week incubation. Our results suggest that while it is inappropriate to assume wastewater-derived organic nitrogen can not cause algal growth, it will not cause as much growth as inorganic nitrogen.

Student Training

Elif Pehlivanoglu, Doctoral Student,
Graduate Level, Civil and Environmental
Engineering, UC Berkeley



Evaluating the Effectiveness of Vegetated Buffers to Remove Nutrients, Pathogens, and Sediment Transported in Runoff From Grazed, Irrigated Pastures

Kenneth Tate
Agronomy and Range Science
UC Davis

Project Summary

Irrigated pastures serve a critical role in the economic stability of California's livestock industry by providing low cost, high quality summer forage. Surface water runoff from irrigated pastures can transport pollutants to nearby waterbodies. There is limited information on the pollutant trapping efficiency or nutrient holding capacity of vegetated buffers within these systems, making it difficult to make informed recommendations for size and long-term management of buffers. Buffer recommendations should be based upon an understanding of the relationships between grazing management, irrigation management, short-term buffer trapping efficiency, and long-term buffer capacity for the suite of pollutants common to pastures.

Our preliminary analysis indicates that the buffers were slightly to moderately effective at trapping pollutants during the 6 trials in 2002. For example, reduced levels of nitrogen occurred from plots with short and long buffer treatments relative to the non-buffered control plots. Maximum vegetation uptake occurs within the first 4 m of the buffer, and within the first 10 days of application, despite continued

The preliminary results indicate that the improvement of pasture runoff is dependent upon the integrated application of buffers and improvements in irrigation and grazing management.

movement of ^{15}N down-slope from the application zone through the buffer soil's A horizon (0-7cm) with repeated irrigations.

Overall the trapping efficiency of these buffers is much less than we expected. Buffer treatments had little effect in reducing the volume of runoff from each plot, indicating that the hydrologic transport potential is roughly the same regardless of treatment. Buffer effectiveness is dependent upon reduction in total runoff via increased infiltration, allowing filtration and attenuation of pollutants within the soil profile. Irrigation water application rate during these trials was set to mimic the rates commonly applied in this landscape, rates which lead to 40 to 60% of applied irrigation water being realized as pasture runoff. It is very likely that the infiltration capacity of the buffers is being overwhelmed by the excessive irrigation application rates, allowing pollutants to be flushed from the



buffers. Other findings were that as runoff rate increases, so does pollutant transport. Also pollutant transport increases as the level of fresh cattle fecal load prior to irrigation increases. The effects of runoff rate and fecal load greatly out-weighed the buffer treatment for both generic *E. coli* and fecal coliform.

The preliminary results indicate that the improvement of pasture runoff is dependent upon the integrated application of buffers and improvements in irrigation and grazing management.

Professional Presentations

Tate, K.W., Project Update, USDA NRCS Continuing Education Field Day, SFREC, Browns Valley, CA, March 2003.

Tate, K.W., A. Bedard-Haughn, and E.R. Atwill, Project Update, SFREC Annual Field Day. SFREC, Browns Valley, CA, April 2003.

Tate, K.W. and A. Bedard-Haughn. Project Update, CA Society for Range Management and UC Rangeland Watershed Workgroup Annual Meeting, SFREC, Browns Valley, CA, May 2003.

Student Training

Angela Bedard-Haughn, Ph.D., Soil Science, UC Davis

Leslie Roche, undergraduate, Agricultural Systems and the Environment, UC Davis

Lisa Fung, undergraduate, Biotechnology, UC Davis

Collaborative Efforts

We are currently working with the Instituto Nacional de Investigación Agropecuario (INIA) of Chile to arrange a 3 day tour and short course on buffer design and management to be held at SFREC.



Research Category IV

Water Development and Management Alternatives

This category encompasses methods and techniques for formulating and evaluating water resources planning, development and management alternatives. Topics that logically fall in this category include policies and planning and operating water supply systems, conjunctive use of surface and subsurface storage, alternative uses for reclaimed and low quality water markets and water pricing and development and improved criteria for water project planning.



**NO FUNDED PROJECTS
IN CATEGORY IV**

Research Category V

Water Law, Institutions and Policy

This category encompasses all institutional arrangements (including laws and regulations) that are available or potentially available for developing and managing water resources. Topics which logically fall in this category include institutional arrangements for managing water scarcity, institutional arrangements for managing groundwater (both quantitatively and qualitatively), potential institutional conflicts associated with specific water development and management alternatives and the evolution of water management institutions in California. There is an especially compelling need for policy studies which involve analytical investigations of alternative polities for dealing with all aspects of California's water situation.





Economic Incentive and Policies to Improve Water Quality in a Binational Watershed

Linda Fernandez
Environmental Sciences
UC Riverside

Project Summary

The project has generated information to determine whether it is feasible to clean up the Tijuana binational watershed through enhanced fiscal resources by passing on costs to the larger public served by the watershed. The watershed is 1731 square miles along the Baja California-California border. Water flows from south to north, out of Tijuana, Mexico into San Diego, California coastal area used for recreation and habitat. This coastal area is referred to as the Tijuana Estuary and contains approximately half of the most valued salt marsh wetlands habitat remaining in Southern California. The Tijuana Estuary is designated as a National Estuarine Research Reserve and a National Wildlife Refuge for a diverse array of terrestrial and aquatic species including six different endangered species.

The project has produced realistic estimates of monetary value of improving the water quality for recreational (swimming) and aesthetic viewing of wildlife in the downstream Tijuana River National Estuarine Research Reserve. These estimated benefits from improved water quality outweigh the costs of improvement. The initial focus on costs has been on wastewater treatment.

By connecting the industrial, commercial and residential activity linked to Tijuana's economy and NAFTA consumers, it is possible to explore binational policies for financing environmental quality in the binational watershed.

The current focus of the project is on the more complex routes of generating finance to cover costs related to other than wastewater treatment to improve the binational watershed. Data collection efforts have been focused on the Tijuana River National Estuarine Research Reserve to obtain cost and restoration information for Mexico. Canon de los Laureles (Goat Canyon) is a 4.6 square mile area in Mexico where sedimentation control, pollution prevention of runoff from urban sprawl and riparian habitat restoration are underway in addition to the model restoration marsh downstream in the U.S. part of the Estuary. The successful Ecoparque treats wastewater through filtration and constructed wetlands for water reuse in one of Tijuana's nonsewered areas, and has involved local and binational financing through public and NAFTA trade funds. It is included in the analysis of multiple efforts to handle the water pollution problems in addition to conventional wastewater

treatment plant that has not been completely effective in coping with the volume and nature of the more diffuse water pollution in this binational watershed.

Additionally, the municipal level financial information from Tijuana and San Diego has been compiled to enable a complete assessment financing for binational watershed management. By connecting the

industrial, commercial and residential activity linked to Tijuana's economy and NAFTA consumers, it is possible to explore binational policies for financing environmental quality in the binational watershed.

Student Training

Monica Das, graduate student, Economics Dept., UC Riverside



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