American Ecological Engineering Society

Sixth Annual Meeting:
Efficient Sustainability in a Dry Land

University of California, Berkeley
April 13-14, 2006

We extend a special “Thank You” to the following people:

Glenn Pillsbury for the California aqueduct cover photo;

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The 2006 AEES Conference Committee for their tireless devotion,
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Dr. Alex Horne
Dr. Maia Singer
Christina Toms
Nicole West

The American Ecological Engineering Society

Mission

The American Ecological Engineering Society (AEES) shall promote the development of sustainable ecosystems that integrate human society with its natural environment for the benefit of both by fostering education and outreach, extending professional development and associations, raising public awareness, and encouraging original research.

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American Ecological Engineering Society
2006 Conference Program

The University of California, Berkeley Faculty Club
Berkeley, CA 94720-6050

Wednesday, April 12th

8:30 a.m. Fieldtrip- Wetlands in Wine Country
7:00 p.m. Evening Mixer, Raleighs- 248 Telegraph Avenue, Berkeley

Thursday, April 13th

7:45-8:30	Continental Breakfast (Room 120C- Steele Room, Bechtel Engineering Center)
8:30-8:40	Welcome Dr. Alex Horne and Conference Committee Plenary Session: Ecological Engineering in Arid Climates
8:40-9:10	Dr. Daniel Kammen Renewable and Appropriate Energy Laboratory (RAEL) UC Berkeley
9:10-9:55	Dr. Denise Reed Department of Earth and Environmental Science, University of New Orleans
9:55-10:15	Dr. Steve McCutcheon, AEES President Driftmier Engineering Center, University of Georgia, Athens
10:15-10:45	Coffee Break (Room 120C- Steele Room, Bechtel Engineering Center)
10:45-11:15	Plenary Session (cont): Ecological Engineering in Arid Climates Dr. Alex Horne Professor Emeritus, Department of Environmental Engineering, UC Berkeley
11:15-12:00	Plenary Speaker Dr. G. Mathias Kondolf Department of Landscape Architecture and Environmental Planning, UC Berkeley
12:00-1:30	Lunch (on your own)
1:30-2:45	Session I: Ecological Approaches to Urban Development (Hynes Room, Faculty Club) Session II: Ecosystem Modeling and Analysis (Seaborg Room, Faculty Club)
2:45-3:15	Coffee Break and Posters (Howard Room, Faculty Club)
3:15-4:30	Session I: Ecological Approaches to Urban Development (cont) (Hynes Room, Faculty Club) Session II: Ecosystem Modeling and Analysis (cont) (Seaborg Room, Faculty Club)
4:30-5:45	Business Meeting (Hynes Room, Faculty Club)
6:00-9:00	Social at Dr. Horne's Home, with panoramic view of San Francisco Bay 875 Bates Ave, El Cerrito, Transportation Provided

Friday, April 14th

7:45-8:30	Continental Breakfast and Poster Session (Howard Room, Faculty Club)
8:30-9:45	Session III: River Restoration (Hynes Room, Faculty Club) Session IV: Engineering Sustainable Agriculture (Seaborg Room, Faculty Club)
9:45-10:15	Coffee Break and Posters (Howard Room, Faculty Club)
10:15-11:30	Session III: (cont) River Restoration (Hynes Room, Faculty Club) Session V: Ecological Engineering and Waste Management (Seaborg Room, Faculty Club)
11:30-12:45	Lunch (on your own)
12:45-2:00	Session VI: Monitoring Ecological Health (Hynes Room, Faculty Club)
12:45-2:20	Session VII: Ecological Engineering for Water Quality Management (Seaborg Room, Faculty Club)
2:00-3:15	Session VIII: Ecological Engineering in the Developing World (Hynes Room, Faculty Club)
3:15-3:45	Break (Seaborg Room, Faculty Club)
3:45-4:00	Student Design Competition Award Ceremony (Seaborg Room, Faculty Club)
4:00-6:00	Wrap-up Discussion (Seaborg Room, Faculty Club)

Saturday and Sunday, April 15th- April 16th

Fieldtrip- Treatment Wetlands at Lake Tahoe

Oral Session Schedule
AEES Conference 2006

Thursday, April 13th

Plenary Session: Ecological Engineering in Arid Climates
Chairs Alex Horne and Nicole West
Sibley Auditorium

8:30 a.m. Introduction

9:00 a.m. Daniel Kammen, University of California, Berkeley
Meeting the Need for Safe Drinking Water in Rural Mexico through Point-of-Use Treatment, page 1

9:30 a.m. Denise Reed, University of New Orleans
Floods, levees, and restoration: a comparative assessment of coastal Louisiana and the San Francisco estuary, page 2

10:45 a.m. Alex Horne. University of California, Berkeley
Efficient Sustainability in a Dry Land: Advantages and drawbacks of constructed treatment wetlands in arid climates, page 3

11:15 a.m. G. Mathias Kondolf, Plenary Speaker, University of California, Berkeley
Understanding watershed-scale and long-term changes in physical and ecological processes as a basis for sustainable ecosystem restoration, page 5

Session I: Ecological Approaches to Urban Development
Chairs Aaron Gabriel and Jeffrey Huber, University of Arkansas
Hynes Room

1:30 p.m. Roger Hilten, University of Georgia, Athens
Assessing the effectiveness of greenroofs to increase building efficiency and reduce buildings' effect of the environment, page 6

Friday, April 14th

Session III: River Restoration
Chair Marty Matlock, University of Arkansas
Hynes Room

Session IV: Engineering Sustainable Agriculture
Chair Stewart Diemont, The Ohio State University
Seaborg Room

8:30 a.m. Stewart Diemont, The Ohio State University
Plant community design and successional patterns in indigenous agroforestry systems of Chiapas, Mexico, page 33

8:55 a.m. Jay Martin, The Ohio State University
Designing agricultural systems for the prosperous way down: Guidance from Cuba, page 35

9:20 a.m. Philip Bachand, **Bachand & Associates**
Reducing Non-point DOC Exports from Rice Fields: A Pilot Study and Quantitative Survey to Determine the Effects of Different Hydrologic Management Practices, page 36

Session V: Ecological Engineering and Waste Management
Chair Stewart Diemont, The Ohio State University
Seaborg Room

10:15 a.m. Jennie Morgan, The Ohio State University
Removal of pathogenic and indicator bacteria from dairy wastewater using an ecological treatment system, page 37

10:40 a.m. Bailey Green, Lawrence Berkeley National Laboratory
Advanced Integrated Wastewater Pond Systems: Efficient Water Reclamation for Arid Environments, page 39

11:05 a.m. Khalid Kadir, University of California, Berkeley
Sunlight-Mediated Inactivation of *Enterococcus faecalis* in Pond Systems: The Importance of Indirect Photoinactivation and the Role of Reactive Oxygen Species, page 40

Session VI: Monitoring Ecological Health
Chair Noah Hume, Stillwater Sciences
Hynes Room

Session VII: Ecological Engineering for WQ Management
Chair Mark Beutel, Washington State University
Seaborg Room

Session VIII: Ecological Engineering in the Developing World
Chair Kara Nelson, University of California, Berkeley
Hynes Room

Poster Assignments
AEES Conference 2006

River Restoration and Management

1. **Mark McElroy, Malcolm Pirnie, Inc.**
   Watershed-scale analysis of channel stability using LIDAR data and low-level aerial photography, page 60
2. **Shannon McMorrow, University of Florida**
   Amphibian assemblages of headwater creeks in an urban landscape: implications for stream management, page 61
3. **Katherine Shurgar, University of Arkansas**
   Using the Natural Channel Design Process to Restore an Urban Stream in Rogers, Arkansas, page 63

Ecological Approaches to Urban Development

4. **Aaron Gabriel, University of Arkansas**
   Campus Hydroscapes: Watershed as a planning platform for campus improvements in the University of Arkansas Athletic Valley, page 64
5. **Jeffrey Huber, University of Arkansas**
   Habitat Trails: Habitat for Humanity, page 66
6. **Emily Ayers, University of Maryland**
   Raingarden ecosystems: what's happening belowground? page 69
7. **Laura Schumann, University of Maryland**
   Lightweight green roof technology for temperature control of existing sloped roof buildings, page 70
8. **Leslie Bartsch, University of Arkansas**
   Design of a Habitat for Humanity Neighborhood as a Low Impact Development, page 71
9. **R. Zeledon Kelly, University of Arkansas**
   Bio-swales and wet meadow design using PONDPACK 10.0, Habitat Trails, Rogers, Benton County, Arkansas, page 73

Natural and Constructed Wetlands

Ecological Engineering for Water and Wastewater Management

CE113N Class project:
Stormwater collection and treatment designs for the UC Berkeley campus

29. Patrick Ulrich, Melissa Asher, Samantha Engelage, Asahi Okada, and Larry Wong
30. Nick Cilic, Michael Hwang, Kelly Wong, Heena Patel, and Norman Wong
31. Eleanor Kane, Kevin Trott, Colin Dudley and Lindsay Soh
32. William Schilling, Erin Brosnan, Elizabeth Eagon, Irene Chu, and Michael Downey
33. Erik Meserve, Sarah Kloss, Christopher Portner, Katherine Ming, and Jia Liu
34. Christopher Sales, Mien Ling Chong, Zara Clayton-Niederman, William Man, and Monisha Brown

Meeting the Need for Safe Drinking Water in Rural Mexico through Point-of-Use Treatment

Micah Lang[1], Forest Kaser[1], Fermin Reygadas[1,4], Kara Nelson[2] & Daniel M. Kammen[1,3,4]

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[2] Department of Civil and Environmental Engineering
[3] Goldman School of Public Policy
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Millions of rural Mexicans risk contracting serious diseases every time they drink water. Building centralized treatment and distribution systems for every community is cost-prohibitive and time consuming. In contrast, inexpensive and rapidly deployable technologies designed to disinfect water at the point-of-use (POU) are now available. Unfortunately, Mexican water institutions have thus far not taken advantage of these technologies. The trend toward decentralization has shifted the responsibility for water provision to local authorities without providing the resources they need to achieve success. Several federal agencies, including the Secretary of Health (SSA) and the Secretary of Social Development (SEDESOL), have active outreach programs in local communities across the nation and could be highly effective at implementing POU technologies. In this paper we argue that POU technologies, implemented by federal agencies in cooperation with states and municipalities, have a crucial role to play in making safe drinking water available throughout rural Mexico.

Floods, levees and restoration: a comparative assessment of coastal Louisiana and the San Francisco estuary.

Reed, Denise J. Dept. Earth and Environmental Science, University of New Orleans, New Orleans LA 70148 (djreed@uno.edu 504-280-7395)

Scientists recognize floods and storm surges as natural disturbance factors in landscape dynamics, and their role in delivering sediment important for tidal wetland sustainability has been demonstrated in both coastal Louisiana and the San Francisco estuary. The risk these events present to the human environment results in the building of ever higher levees and the interruption of flood contributions to elevation maintenance. Preliminary evidence from Hurricane Katrina suggests that the interruption of sediment supply to Louisiana coastal wetlands makes them less resilient to the physical forces of hurricane storm surge. Those marshes which continue to receive sediment from coastal sources, however, are more resilient to storm-associated stresses. Restoration of coastal wetlands in both systems is frequently thought to be fundamentally limited by sediment supply, as upstream river management has dramatically reduced sediment loads in the late 20th century. Importantly, studies of marsh accretionary processes show that once substrate elevations are sufficiently high for plant colonization, vegetative contributions to soil development become increasingly important. Plans for flood management, navigation, and other land use development in both coastal Louisiana and the San Francisco estuary must be implemented with a full understanding of both the potential synergies and conflicts between these uses and the conditions necessary for a sustainable wetland landscape.

Efficient Sustainability in a Dry Land: Advantages and drawbacks of constructed treatment wetlands in arid climates.

Alex J. Horne. Ecological Engineering Group, Department of Civil & Environmental Engineering. University of California, Berkeley CA 94702-1710. anywaterss@comcast.net.

Desert wetlands are rare but are welcome oases. Because of their scarcity, constructed treatment wetlands in the arid southwest must treat waste as well as provide wildlife habitat and aesthetic beauty. These services balance their high evapotranspiration losses and need for space. The two main limiting factors in all treatment wetlands are low temperature and lack of labile organic carbon for bacterial waste processing. Desert wetlands are hot so have an advantage over those in cooler climates. Labile organic carbon in desert wetlands can be improved with the correct mosaic of plants. The largest inherent drawback of desert wetlands is an increase in total dissolved solids due to high evapotranspiration. Increasing wetland treatment efficiency to reduce size lowers evapotranspiration losses. Ten of the 16 SW desert wetlands surveyed were designed treat municipal or agricultural effluent for groundwater recharge that eventually became part of the potable water aquifers. All had nitrate removal as a priority. In contrast, the other 6 desert wetlands processed more concentrated wastes prior to discharge to surface waters or land disposal. Although detention times of 4-12 days were quite similar, size (typically 10-23 acres; range 10-500) and volume treated (< 1 to 60 mgd) were more variable. Spatial efficiency varied widely (2.5-18 mgd/acre) and most desert wetland removed 25-95% of typical pollutants ranging from nitrate and phosphate to heavy metals or pathogens. They were almost always considered a success. Winter performance was rarely considered but was < half the summer rate. Three wetlands reported mosquito problems, probably due to high ammonia in the inflow, which deters mosquito fish. Desert wetlands are popular with the public since most other water

features are restricted by law. For arid zone treatment wetlands waste must be fully oxidized before it reaches desert wetland to prevent mosquito problems and they must be space efficient to reduce TDS increases.

Notes

Understanding watershed-scale and long-term changes in physical and ecological processes as a basis for sustainable ecosystem restoration.

Dr. G. Mathias Kondolf
Department of Landscape Architecture and Environmental Planning
University of California, Berkeley

River restoration projects are most frequently undertaken on a reach scale, in response to local problems or opportunities (such as property ownership limits). Even if the objectives are restricted to solving a perceived local problem (e.g., channel instability), restoration efforts are more likely to be successful if undertaken in a larger, catchment context. Where possible, restoration of processes (geomorphic, hydrologic, and ecological) will be more sustainable than attempts to restore desired forms. Usually, these processes cannot be understood and addressed at the reach scale, but require a catchment-scale perspective. Rivers are largely products of their history, and we are easily misled in diagnosing the current state of a river channel if we think only in present-day terms. It is essential that we understand the history of the river and its catchment to understand its present state. This does not imply that we must set pre-disturbance conditions as the restoration goal, as sometime assumed, but we need to be clear-eyed about what processes and ecosystem services we can restore, and which alterations we must accept as constraints. The value of a catchment-scale and historical approach to river restoration is illustrated in case studies from North America and Europe.

Assessing the effectiveness of greenroofs to increase building efficiency and reduce buildings' effect on the environment.

Hilten, R. N., T. M. Lawrence, and E. W. Tollner. Dept. of Biological and Agricultural Engineering, University of Georgia, Athens, GA 30602.

With the rapid expansion of the "green" building industry, greenroofs can provide both a literal and figurative method to increase greenness. Greenroofs are widely touted to decrease both stormwater runoff quantity and building energy loads for heating and cooling, for which both reductions are essential to the green building industry. Quantitative accounts of the effectiveness of greenroofs to decrease runoff and energy loads are rather lacking for U.S. climates. Thus, a relatively simple method was devised to assess runoff and energy load effects of greenroofs using both a soil moisture transport simulation and a building energy simulation. Inputs for the simulations were derived during a study of a modular block greenroof installation sited in Athens, GA on the University of Georgia campus. With specific greenroof parameters such as soil density, thermal conductivity, porosity, and hydraulic conductivity, stormwater runoff and building energy loads can be predicted for buildings sited in any location where sufficient weather data is available. For seven evaluation cities chosen for the study, simulation results revealed that runoff was reduced by as much as 70 % and building energy loads were reduced by 5 – 10 %.

Monitoring urban campus swale to attract birds.

Chen, W. Walter & Limin Yang. Department of Civil Engineering, National Taipei University of Technology, 1, Sec. 3, Chung-Hsiao E. Rd, Taipei, Taiwan (**waltchen@ntut.edu.tw**, 886-2-27712171 ext. 2628)

The growing complexity of city infrastructures created complex ecosystems that are unique to the urban environment in Taiwan. As the population density in cities of Taiwan reaching as high as 41,791 persons/km (world number one), a more creative method was needed to address the problem of over population and habitat loss. One of the pioneer projects engaged by the Ministry of Education was to encourage urban schools to create small swales in their campuses to connect the otherwise isolated habitats (parks and other green spaces) to form continuous ecological corridors, but the effectiveness of these projects was never verified with scientific evidences. Therefore, this research used the swale at the National Taipei University of Technology as an example to study if the swale provided an important habitat for small animals, birds, and insects. Video cameras were installed to monitor the activities of the swale continuously to see if birds were attracted to the swale to feed. Then, using the analogy of the St. Basil's cake, a mathematical technique was used to compute the probability of migratory birds (or non-migratory birds) spotting the swale from the air. A video clip was also made to show a simulated aerial view of a bird's journey through the campus swale.

Notes

Campus Hydroscapes: Watershed As A Planning Platform For Campus Improvements In The University Of Arkansas Athletic Valley

Gabriel, Aaron (presenter) & Luoni, Stephen. University of Arkansas Community Design Center, School of Architecture, University of Arkansas (agabriel@uark.edu 479.575.5772)

> *"…the landscape itself is a medium through which all ecological transactions must pass, it is the infrastructure of the future."*
>
> Richard Weller "Landscape Architecture and the City Now"

Watershed Urbanism

Contemporary planners have never known what to do with water. Seen as an obstacle to development it is drained away or appropriated as a transport mechanism for goods and wastes. *Campus Hydroscapes* counters with a model for integrating riparian systems with urban systems. It is a watershed-based land-use proposal that incorporates ecological services into urban systems servicing mobility and transit, recreational program, housing, and campus aesthetics.

College Branch is a first order stream in the University of Arkansas "Athletic Valley" with headwaters along a ridge dividing the Illinois and White River Watershed. Chronically displaying dysfunctions associated with intense urbanization, it has been on the Arkansas Department of Environmental Quality (ADEQ) 303(d) impaired waters list since 1998. Remediation of two critical reaches of the stream present a demonstration project for campus revitalization based on watershed improvement that provides a statewide educational asset.

Campus Hydroscapes

A multidisciplinary design endeavor, *Campus Hydroscapes* incorporates Landscape Architecture, Architecture, Urban

Planning, and Biological and Ecological Engineering. It offers three scenarios for implementation as individual strategies, or a successive phasing of all three. HydrologyPixelation modestly decentralizes stormwater in vegetated swales with minimal alteration of existing land use. RiparianBands stratifies parking and other land uses along linear treatment and retention swales. TotalMarsh is a maximized approach, consolidating building program along edges of large constructed wetlands for floodplain and stormwater retention. These water management solutions offer self-correcting ecological services as a low maintenance alternative to expensive, monolithic command-and-control engineering solutions. They reinvigorate the potential of the campus as an integrated environment serving as a model for the city.

Impact of Residential and Commercial Development on Urban Streams in Fayetteville, Arkansas

Kyle Kruger[1], Dr. Marty Matlock[2]
[1]Graduate Research Assistant, [2]Associate Professor, Department of Biological and Agricultural Engineering, University of Arkansas, 203 Engineering Hall, Fayetteville, Arkansas, 72701 USA

Urban streams serve as valuable resources for their cities. These streams are important for controlling and transporting waters most often generated from storm events. Water management is not the only function of urban streams. Often these streams provide a suite of ecological services that are unrecognized by the community. The growth and development of a city often takes priority over stream preservation and enhancement. When new areas are developed near a steam ecosystem, any part of the ecosystem downstream from the site can be impacted by the development activity upstream. We measured changes in several stream ecosystems throughout the City of Fayetteville watershed. Sites were chosen in areas with recent and planned development. The results show that poorly managed development can severely impact stream quality and habitat. However, with appropriate management practices, the impacts of the development can be minimized and overall stream habitat and quality can be preserved.

Using Urban Stormwater Runoff as an Ecological Resource.

McGregor, F. Robert, AMEC Earth & Environmental, Inc., Lakewood Colorado 80226 (robert.mcgregor@amec.com 303-935-6505)

"The urbanization of open land produces extra stormwater runoff that can erode natural channels and pollute surface streams. There are ecological engineering methods that use this extra stormwater runoff as a valuable urban resource to create greenspace, improve aquatic habitat, improve wildlife habitat and provide urban recreation opportunities. This approach uses sound ecological engineering approaches to construct landscapes that reduce flood risks, control erosion and mitigate the adverse water quality impacts of the extra runoff. The constructed landscapes include vegetated swales, wetlands, grassy buffer areas and other features. If these features are well-integrated into an urban setting, they can pay additional dividends to homeowners in the form of higher real estate values. Attractive designs can build public support for ecological engineering practices that will prove to be more sustainable over the long run because of their positive economic benefits when compared to traditional regulatory approaches whose primary motivations for action are the avoidance of fines and penalties. These ecolo0ical engineering designs are sometimes referred to as Natural Urban Waterway (*NUW*) Designs. Five case studies for NUW Design projects constructed in Colorado and Utah confirm the advantages of this approach for building public support and providing effective water quality management, enhancement of urban wildlife habitat and special urban recreation opportunities."

Notes

Habitat Trails: Habitat for Humanity: From Infill House to Green Neighborhood Design

Huber, Jeffrey (presenter); Gabriel, Aaron & Luoni, Stephen. University of Arkansas Community Design Center, School of Architecture, University of Arkansas (jehuber@uark.edu 479.575.5772)

> "Research indicates that when impervious area in a watershed reaches 10 percent, stream ecosystems begin to show evidence of degradation, and coverage more than 30 percent is associated with severe, practically irreversible degradation."

Green Streets: Innovative Solutions for Stormwater and Stream Crossings

The large acreage devoted to human settlement makes the disposal of stormwater a problem during even modest events. Growth coupled with increased impervious areas has degraded ecological functioning and bio-diversity in our urban communities. "Pipe and pond" solutions transport runoff problems elsewhere and are prone to systematic failures, whereas ecologically based solutions, like "green streets" can treat runoff *in-situ* and improve regional groundwater quality. The integration of an ecological fabric in urban infrastructure offers solutions to achieve sustainability in the built environment and bypass the costly infrastructure associated with civil engineering solutions. Contrary to civil "pipe and pond" solutions, the "green street" becomes an integral landscape component in a larger watershed solution.

Parks, not Pipes: The Ecological in Infrastructure

Habitat Trails proposes an ecological approach to urban development, through a hydrological network that involves infiltration, recreation, conveyance, and higher water quality on and off site. Land is developed in accord with the site's existing

hydrological drainage, catchments, and recharge patterns. Stormwater runoff generated by the new development is retained and treated through a contiguous network of bioswales, infiltration trenches, stormwater gardens, sediment filter strips, and a constructed wet meadow. "Green street" solutions enhance water quality beyond the minimum detention requirements, dissipate peak flows to prevent flooding, and provide erosion and sediment control. Rather than costing $450/linear foot for a curb-gutter-pond solution, "green street" infrastructure costs $250/linear foot. The integration of a constructed treatment landscape with open space builds greater value and added collateral benefits, by pooling otherwise private resources to create a shared neighborhood landscape with enhanced neighborhood aesthetics and pedestrian-oriented environments, additional passive recreation assets, and provision of wildlife habitat.

Ecosystem Analysis: The Modeling Problem

David K. Gattie
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Ecosystems are intractable units of nature and as such must be abstracted for analysis and for developing insight into ecosystem function and properties. These abstractions are models developed from empirical data, and strongly biased by the perspective of the observer. The models are, to a great extent, comprised of mathematical functions and oftentimes subjected to statistical methods for assessing relationships between and among various compartments of interest. As such, the models reflect the observer's perception of the system, and serve the critical role as the initial condition for analysis and subsequent decision-making. Critical questions must then be asked about our current approach for model development particularly when these models are used in the design and management of ecological systems and other systems that impact ecological systems. This presentation addresses the need for assessing current methods for ecosystem model development and the need for developing fundamental principles for modeling ecological systems based on general systems science and network constructs. Concepts such as holism, emergent properties, self-design, patterns, indirect effects, and complexity are integrated into the presentation and discussed as to whether such properties can be quantitatively analyzed, qualitatively assessed, or if they are destined to become only clichés in the domain of ecosystem modeling and analysis.

Linkages between Stream Morphology and Aquatic Habitat Quality

Hession[1], W.C., C. Cianfrani[2], J. Clark[3] and A. Pearce[3]
[1] Biological Systems Engineering, Virginia Tech (chession@vt.edu)
[2] Natural Science, Hampshire College
[3] Civil & Environmental Engineering, University of Vermont

We have conducting studies on Pennsylvania and Vermont streams to better understand the linkages between stream morphology (physical condition) and aquatic habitat quality. Our studies include a combination of field-based morphologic and habitat measurements and hydraulic modeling. The hydraulic modeling has been done using both one-dimensional and two-dimensional hydraulic models. Determination of aquatic habitat quality has focused on various habitat indices and heterogeneity. Experimental and theoretical variograms were used to evaluate spatial variability of measured and modeled parameters (e.g. width, depth, velocity, and Froude number). We will present the results of our studies and compare/contrast the various habitat quality indices, as well as the use of one- and two-dimensional models and their applicability. Our results have implications for stream restoration and the plethora of management activities that rely on rapid geomorphic assessments.

Notes

Hydraulic, Water Quality and Social Assessment Of The Nzoia Basin, Kenya Fishery

E. W. Tollner*, M. Muchiri, G. Habron, and H. Ssegane
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Developing agriculture and industries are threatening the sustainability of the Lake Victoria fishery. The government of Kenya and Moi University are concerned with putting policies in place that will ensure that watersheds feeding Lake Victoria are developed in a sustainable manner. The aquaculture CRSP is embarking on a project to identify a test watershed and develop capacity at a regional university to enable future local efforts to protect national watersheds. The Nzoia basin was selected. One common theme in the watersheds visited to date was the lack of riparian buffers. A typical riparian buffer is shown in figure 1.

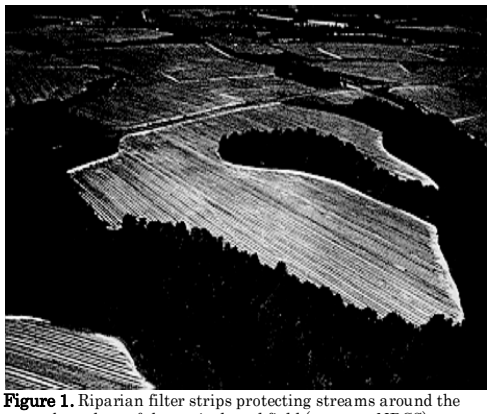
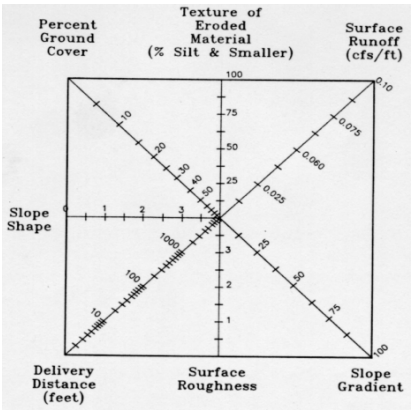


Figure 1. Riparian filter strips protecting streams around the boundary of the agricultural field (courtesy NRCS).

The Universal Soil Loss equation will be used to model soil detached in the field above the buffer. The USLE has been well documented in Wischmeier and Smith (1978).

The USEPA (1980) sediment delivery ratio will be used to model soil retention in riparian buffers. Although this model was originally developed for use in silvicultural applications, it has

promise in evaluating a wide variety of buffer types. The model evaluates the following parameters shown on figure 2.



Stiff diagram for determing relative contribution of the indicated factors to the reduction of sediment; 1 m=3.28 ft; 1 cfs/ft=0.093 m^3/s-m (from U.S. Forest Service, 1980).

The presentation will elaborate on each parameter and show how they are combined to provide an effectiveness factor for buffer strip evaluation.

Interdisciplinary modeling for aquatic ecosystems curriculum development workshop.

Mark E Grismer[1], Laurel Saito[2], Heather Segale[3]
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The science and management of aquatic ecosystems is inherently interdisciplinary, with issues associated with hydrology, atmospheric science, water quality, geochemistry, sociology, economics, environmental science, and ecology. This interdisciplinary nature, suggests that interdisciplinary approaches to addressing them should be productive, but truly interdisciplinary work is often difficult to implement. One of the ways to approach the diversity of needs in managing and understanding aquatic ecosystems is to employ mathematical modeling. Models based on available scientific knowledge and theories can be used to bridge the gap between the ability to scientifically predict with reasonable certainty, and the need to make decisions. Despite the strengths of interdisciplinary modeling approaches, there are several impediments to the implementation of successful interdisciplinary modeling of aquatic ecosystems (e.g., different spatial and temporal scales, different degrees of uncertainty of data and models, lack of awareness of what modeling options are available, difficulties in communication between disciplines, lack of education and training in interdisciplinary approaches, etc.). To address some of these impediments, a workshop was held in July 2005 in which educators and students from different disciplines interacted to develop a curriculum for a graduate-level course on interdisciplinary modeling for aquatic ecosystems. The overall

objective of the course was to *engage interdisciplinary discourse in modeling aquatic ecosystems*. The successful implementation of the curriculum will specifically address the impediments identified above by introducing students to models that are available in different disciplines and how such models might be applied together to address aquatic ecosystem issues, addressing issues of variability and uncertainty in implementing interdisciplinary approaches, and giving students experience in working in interdisciplinary teams to apply interdisciplinary modeling approaches to increase knowledge about aquatic ecosystems. This presentation will summarize the key observations of the workshop and information about the curriculum.

Environmental Accounting Using Emergy: engineering cost accounting for a prosperous way down.

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With declining availability of fossil fuels, increased demands for resources, and no foreseeable changes in human appetite for goods and services, a peaking and recession of technology and economy seem likely. The next decades may exhibit periods of material and energy shortages and contraction of technology. Loads on the environment may increase resulting in more demand for ecological engineering that can implement successful interfaces between human dominated systems and environments.

This talk provides a framework for engineering cost accounting that relies on Emergy Synthesis methods. Ecological engineering requires a cost accounting method that can capture and represent the true value of environmental services and natural capital. Several ecological engineering projects representing different scales and intensities are evaluated to demonstrate the methodology.

How riverbeds become structured under low-sediment supply conditions: Implications for restoring dam-impacted rivers.

M.A. Wydzga[1], J.G. Venditti[2], M.A. Hassan[3], T. Dunne[1]

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Coarse, degraded river reaches are commonly observed downstream of dams across the Western United States. In response to the cut-off in gravel supply that occurs following dam closure, the downstream riverbed typically becomes coarse and immobile. The immobile bed conditions lead to a significant degradation of both spawning and rearing salmonid habitat. We propose that in addition to the riverbed surface coarsening, the structure of the riverbed surface (i.e. the way the grains arrange themselves on the surface of the bed) is fundamentally different under post-dam closure conditions. This surface bed structure takes the form of both grain clusters and grains interlocking with one another. A series of physical modeling experiments are being undertaken to examine the following: 1) how a gravel riverbed becomes structured in response to a reduction in coarse sediment supply; 2) how a structured riverbed increases the beds resistance to erosion; and 3) how a coarse, structured riverbed interacts with pulses of injected gravel (i.e. gravel augmentation) that are intended to restore basic sediment transport processes by remobilizing the bed.

Notes

Restoration of potentially mercury-contaminated dredger tailings in the Western US: Case study of the Merced River Ranch.

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Historic dredger mining has impacted aquatic and riparian habitat throughout the Western U.S., via displacement of river channel and floodplain deposits and local and regional mercury contamination resulting from amalgamation practices. The Merced River Ranch, California, located within the Dredger Tailings Reach of the lower Merced River, experienced extensive dredger mining activity from the early to mid-1900s. To provide information in support of restoration design development at the Ranch, several years of studies have been carried out including geomorphic, biologic, and biogeochemical investigations of current conditions. This presentation addresses the question of how to use existing wetland habitat within the dredger tailings piles, focusing on the balance between the wetlands as a locally important avian habitat and a potential source of mercury methylation to the surrounding ecosystem. Particular baseline investigations leading up to the channel and floodplain restoration design will be described, including (1) a mercury assessment above, within, and below the Merced River Ranch, (2) a gravel processing experiment conducted to characterize the potential risks of mercury mobilization resulting from re-use and removal of the tailings and, (3) a survey of avian habitat use within the dredger tailings.

A Field-Calibrated Model of Pioneer Riparian Tree Recruitment for the San Joaquin Basin, CA.

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In the Central Valley of California, pioneer cottonwood and willow species dominate the near-river forests. Historically, seedling recruitment for these disturbance-adapted species coincided with spring floods. Changes in flow timing and magnitude due to river regulation have decreased the success of seedling cohorts and contributed to the decline of these riparian tree populations. In order to address gaps in our understanding of these species and potential restoration strategies, we field-calibrated a conceptual model of seedling recruitment for the dominant pioneer woody species, *Populus fremontii*, *Salix gooddingii*, and *Salix exigua*. We conducted experiments to identify seedling desiccation thresholds and seed longevity, used field studies to measure seedling competition and seasonal seed release patterns, and modeled interannual differences in dispersal timing using a degree-day model. These studies were integrated into a recruitment model that generates annual estimates of seedling density and bank elevation based on inputs of seasonal river discharge, seed dispersal timing, and seedling mortality from desiccation. The model predictions successfully captured interannual and species-level patterns in recruitment observed independently throughout a 20-km reach of

the lower Tuolumne River from 2002-04. The model correctly predicted that seedling densities were highest in 2004 and lowest in 2003, and that *Salix exigua* recruitment would be less extensive than for the two tree species. This work shows promise as both a quantitative approach linking hydrology, climate and plant community dynamics, and as a process-based framework for guiding flow releases and other management actions to restore riparian tree population along Central Valley rivers.

The Codornices Creek Restoration Project: Urban Stream Restoration for Steelhead Habitat in Albany/Berkeley, California

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Codornices Creek flows from the Berkeley Hills through the highly urbanized cities of Berkeley and Albany in the San Francisco Bay Area. The creek flows through over 25 culverts and has been straightened and channelized through much of its lower reaches. Codornices Creek has a potential anadromous salmon run from SF Bay which is an extremely valuable resource for endangered central coast steelhead. Beginning in about 1997, the Waterways Restoration Institute (WRI) started negotiating with UC Berkeley to include an expanded creek right of way in their new student housing development plans. The long and sometimes painful negotiations with UCB, the downstream railroad, adjacent property owners and local sports clubs culminated in a three phase project consisting of restoration plans for almost 3,000 feet of degraded creek.

Phase I construction of the project was completed in 2004 and finally planted in 2005. This reach contains the widest floodplain and potential habitat benefits for the project. This talk will describe the design process and initial monitoring results for the first phase of the project for physical, chemical and biological processes. Phase II is scheduled to begin construction in 2006. Timing on the construction for the final phase of the project is currently unknown and depends on the redevelopment plans of UCB.

Notes

Watershed-Scale Analysis of Channel Stability Using LIDAR Data and Low-Level Aerial Photography.

Mark McElroy and Bruce Schwenneker, Malcolm Pirnie, Inc., Newport News, Virginia 23606 (mmcelroy@pirnie.com 757-873-4418, bschwenneker@pirnie.com 757-873-4420).

The James River watershed covers approximately 22,000 sq. mi. in North and South Dakota. It also has the flattest gradient of any river in North America, dropping only 135 feet in the 474 river miles (0.000054 ft/ft) in South Dakota. Because of a history of flooding causing significant impacts, $217,952,000 between 1955 and 1997 (excluding agricultural losses), the James River Water Development District (JRWDD) and the Omaha District Army Corps of Engineers are conducting a Feasibility Study and Environment Impact Statement (FSR/EIS) for an Ecosystem Restoration and Flood Damage Reduction Feasibility Study for the James River. With resources such as LIDAR, high resolution aerial imagery, and low altitude helicopter fly-over video available to the project, a relatively complete analysis of the river's geomorphology was able to be conducted using ARC-GIS®. We estimated bankfull dimensions, floodprone width, meander width ratio, energy slope, valley slope, radius of curvature, valley length, and channel length. In addition, depositional features and riparian condition were inventoried using the low altitude helicopter fly-over video data. By conducting this analysis we have been able to selectively assess portions of a major river and develop data that will aid in determining how various alternatives will potentially affect the river and its ecology.

Development Of A Remotely Sensed Qualitative Habitat Evaluation Index (Rs-Qhei) Using Aerial Photograpy And Satellite Imagery As A Tool For River Restoration

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A Remotely Sensed Qualitative Habitat Evaluation Index (RS-QHEI) is derived and used to assess a restoration project on the Sandusky River, Ohio. The RS-QHEI used a digital aerial photograph and a satellite image to quantitatively define three of the six original metrics of the field based Qualitative Habitat Evaluation Index (QHEI). Values of channel morphology, riparian zone width/type, and gradient/ pool-riffle width were deduced from the digital images. Metrics were scored, summed, and compared to field based QHEI's calculated by the Ohio Department of Transportation (ODOT) for pre- and post-dam removal conditions at 9 different locations. Results of the study show no significant difference in the final QHEI score calculated by ODOT and the RS-QHEI, though the RS-QHEI scored lower than field based method. When compared graphically the procedures showed little correlation ($R^2 = 0.1425$). Therefore, the RS-QHEI can be viewed as complimentary to the field based QHEI. Both indices showed a clear recovery of the physical habitat one year after the dam removal. We suggest that the RS-QHEI is a more quantitative tool for evaluating larger scale attributes and could be used prior to a field based QHEI. The RS-QHEI provides a fast, cheap, and long term way to monitor restoration projects such that information collected over many years of monitoring could be used to determine if restoration projects, such as dam removals, are successful.

Plant community design and successional patterns in indigenous agroforestry systems of Chiapas, Mexico.

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The Lacandon Maya, an indigenous group who live in Chiapas, Mexico, practice a form of agroforestry that mimics the successional stages of the surrounding ecosystem. By following natural cycles, they are able to reap large benefits from their land without the use of agrochemicals. Each successional stage of their agroforestry system is used for consumption and raw material production. The successional stages include a field stage (*milpa*), four fallow forest stages, and primary forest. Plant community assessment and analyses of soil chemistry and biology were performed in each successional stage. Interviews with Lacandon farmers were conducted to determine dominant plant community that should be expected in each fallow stage. Over 35% of the plant species encountered in the second and third fallow stages were among the dominant species indicated by Lacandon during interviews prior to sampling. Furthermore, the first fallow stage, or early pioneer stage, of Lacandon successional management was dominated by later successional species, indicating management and planting of these species by the Lacandon. Total soil nematode concentrations were a function of traditional field stage ($P < 0.001$)

and was found to increase with time elapsed since the *milpa*, or first stage of succession ($P = 0.005$). These results lend credence to Lacandon traditional ecological knowledge and indicate that their knowledge system may be used to sustainably manage tropical rainforest ecosystems.

Notes

Designing Agricultural Systems for the Prosperous Way Down: Guidance from Cuba.

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In the coming decades agriculture will be forced to adapt to lower energy levels due to decreased petroleum production. For countries that rely heavily on industrialized agriculture, such as US, this will require substantial changes in the way food is produced and delivered. For instance, current methods of crop production, in which petroleum driven irrigation and fertilization account for more than 90% of the inputs, must become more reliant on renewable energies and ecological processes. Indigenous methods may offer alternatives, because they are more sustainable, and less reliant on petroleum-related inputs, than industrial methods. However, while indigenous systems may have less energy inputs, they typically have decreased production compared to industrial methods. This leads to an important challenge: How to maintain agricultural production levels with decreased petroleum inputs. Changes that have occurred in Cuban agriculture since 1991 may provide guidance. Following a severe reduction of petroleum imports, Cuban agriculture has been redesigned to switch from fossil fuel dependent to self-sufficient methods, while maintaining production levels.

Reducing Non-point DOC Exports from Rice Fields: A Pilot Study and Quantitative Survey to Determine the Effects of Different Hydrologic Management Practices

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S. Deverel, Hydrofocus, Inc.
J. Gallucci, D. Mourad and W. Horwath, UC Davis
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G. Green, Ducks Unlimited
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Funding by the State Water Resources Control Board as part of the Bay Delta Authority Drinking Water Program

Rice is a relatively new crop in the San Joaquin-Sacramento Delta and several factors suggest rice is an attractive crop alternative for the Delta: a profitable crop for farmers, may mitigate oxidative subsidence, and benefits to water birds. As pressure grows to expand rice through the Delta, there is a need to quantify surface and subsurface loads for dissolved organic carbon (DOC) and disinfection byproducts (DBP's); and to begin developing and understanding Best Management Practices (BMPs) available to reduce their export. Under this project, three 100-acre fields in the Delta were selected along a southeast-northwest gradient in the Delta and converted to rice production. Experimental plots were set up to test the effects of the different hydrologic BMPs on DOC and DBP loads from surface and subsurface flows. Median surface and subsurface DOC loads approximately ranged from 0 – 500 g/ac/d depending upon the season and management regimes. DOC and DPB loads were highly correlated with each other and with flows. Implemented surface and subsurface BMPs reduced both surface and subsurface DOC and DBPs loading. Surface and subsurface DOC and DBP exports from rice under different management regimes were compared to those from corn and effects of soils were investigated.

Removal of pathogenic and indicator bacteria from dairy wastewater using an ecological treatment system.

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In the quest to improve the sustainability of water treatment options, plant-based systems, such as wetlands and ecological treatment systems, have become a promising alternative. To date, most of the research on ecological treatment systems has focused on the ability of these systems to remove excessive nutrients, turbidity and biochemical oxygen demand from wastewater. However, another factor key to making these systems successful is ensuring their ability to remove pathogens present in wastewater. Wastewater is the primary source of fecal contamination in aquatic ecosystems, containing total and fecal coliforms on the order of 10^7-10^9 and 10^6-10^8 100 ml^{-1}, respectively. This study assessed the ability of an ecological treatment system to remove total coliforms, *E. coli* and *Salmonella* from dairy wastewater. Total coliform, *E. coli* and *Salmonella* data was collected from the ecological treatment system located on Waterman Farm (WETS) at The Ohio State University. A three phase dosing experiment was conducted during the summer and early fall of 2005 to assess the capacity of the WETS to remove pathogens from wastewater. Wastewater was diluted with wellwater at a ratio of 1:3 during the month of July, in August the ratio of wastewater increased to 1:1, and in September increased to 2:1. Regardless of wastewater concentration, total coliform and *E. coli* concentrations were consistently reduced by at least 96% from influent to effluent of the WETS and *Salmonella* was completely eliminated from the effluent. These results

indicate that ecological treatment systems have the potential to successfully remove pathogens from wastewater.

Notes

Advanced Integrated Wastewater Pond Systems: Energy-Efficient Water Reclamation for Arid Environments.

Green, F. Bailey. Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, One Cyclotron Road, MS 90-1050B, Berkeley, CA 94720 (fbgreen@lbl.gov 510-495 2612).

"Many of the problems and shortcomings associated with conventional wastewater treatment systems both mechanical and natural systems including waste stabilization ponds, aerated lagoons and constructed wetlands have informed and have been addressed by the development of the Advanced Integrated Wastewater Pond Systems® Technology. Pioneered at the University of California, Berkeley by the late Emeritus Professor William J. Oswald, the AIWPS® Technology utilizes and integrates a number of biological and physical-chemical processes to provide advanced wastewater treatment and water reclamation for safe irrigation reuse. Data collected at first and second generation municipal AIWPS® Wastewater Treatment Facilities in California will be used to illustrate the design and performance characteristics of this energy efficient and ecologically engineered wastewater treatment technology that is especially well suited for arid climates. The optimization of in-pond methane fermentation and the potential recovery of biogas; the minimization of wastewater treatment related greenhouse gas emissions; the avoidance of land and energy requirements for the disposal of residual biosolids; and other special characteristics of the AIWPS® Technology will be discussed. Energy use data will be presented to compare the energy intensities of various conventional and ecologically engineered wastewater treatment technologies and processes.

Sunlight-Mediated Inactivation of Enterococcus faecalis in Pond Systems: The Importance of Indirect Photoinactivation and the Role of Reactive Oxygen Species

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Waste stabilization ponds, a low-cost, low-maintenance option for treating wastewater, are particularly effective at pathogen removal. The pathogen removal processes can be divided into two groups: dark processes and light processes. This research is focused upon the light mediated processes.

Previous authors have hypothesized the different mechanisms of photoinactivation to include direct cellular absorption of UV-B light resulting in DNA damage, internally catalyzed photo-oxidation resulting in damage to internal cellular structures, and externally catalyzed photo-oxidation resulting in damage to external structures of microorganisms (Curtis, 1992; Davies-Colley et al., 2000). The last two mechanisms are catalyzed by endogenous and exogenous photo-sensitizers, respectively, and result in the production of reactive oxygen species that are the cause of the cellular damage that leads to inactivation.

The specific goal of this research is to better understand the mechanisms involved in the sunlight-mediated inactivation of *Enterococcus faecalis* and to identify the variables that influence the rate of inactivation. The roles of dissolved oxygen concentration and the production of reactive oxygen species (ROS) by different types of exogenous sensitizers are of particular interest. In these experiments waters from different sources are inoculated with high concentrations of pathogen-indicator

organisms and exposed to simulated sunlight. Variables including pH, dissolved oxygen concentration, temperature, and insolation are carefully controlled and monitored.

Experimental results have demonstrated direct photo-inactivation of *E. faecalis* due to sunlight UV-B as well as indirect photosensitized inactivation (Figure 1). This indirect mechanism occurs both endogenously, in solutions of buffered distilled water, as well as exogenously, in waste stabilization pond effluent (Figure 1). In reactors containing both filtered and unfiltered waste stabilization pond effluent, exogenous inactivation decreased as nominal filter pore size decreased (Figure 2). Synthetic humic acids (Aldrich) were also able to act as exogenous sensitizers (Figure 2). In addition, a correlation was observed between dissolved oxygen concentration and inactivation rate. In DI water DO levels from low to double air saturation resulted in increased inactivation, while in pond effluent DO levels below air saturation decreased inactivation while DO levels above air saturation had no effect (Figure 3).

Measurements of various reactive oxygen species ($^1O_2$, H_2O_2) have pointed to the importance of $^1O_2$ in the exogenous photoinactivation process. In pond water, $^1O_2$ levels increased from low DO to air saturation, but remained the same at double air saturation. This phenomenon could partially explain the lower inactivation rate of low oxygen reactors when compared to air saturation, and the lack of increased inactivation in double air saturated reactors. In addition, adding histidine, a known quencher of $^1O_2$, to the reactors decreased inactivation, confirming that this species plays a key role in the inactivation process. Finally, experiments undertaken with the addition Rose Bengal ($^1O_2$ is a known photo-product of solutions containing Rose Bengal) affirm the ability of $^1O_2$ to inactivate *E. faecalis*.

Both the addition of H_2O_2 to the reactors as well as quencher experiments using pyruvate (H_2O_2 quencher) have demonstrated the lack of importance of H_2O_2 in the photoinactivation process. Attempts to use formate ($OH^{\cdot}$ quencher) and superoxide dismutase (superoxide quencher) have been inconclusive as these interfered with the photochemical processes occurring in the reactors. Accurate measurements of $OH^{\cdot}$ and superoxide have not been possible with the available analytical tools.

Davies-Colley, R. J., Donnison, A. M. and Speed, D. J. (2000) Towards a mechanistic understanding of pond disinfection. *Water Science and Technology* **42**(10-11), 149-158.

Curtis, T. P., Mara, D. D. and Silva, S. A. (1992) Influence of pH, oxygen, and humic substances on ability of sunlight to damage fecal coliforms in waste stabilization pond water. *Applied and Environmental Microbiology* **58**(4), 1335-1343.

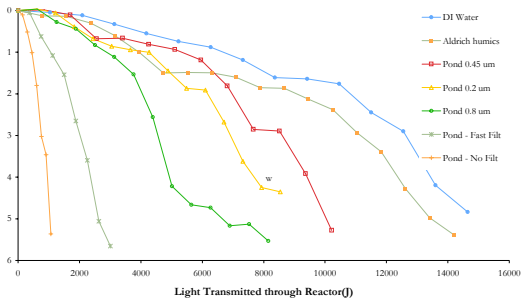

Fig 1: Inactivation of *E. faecalis* versus the amount of light transmitted through the reactor. Reactors contained DI water, pond water filtrates, or DI water with 5 mg/L of Aldrich humc acid and were exposed to simulated sunlight without UVB.

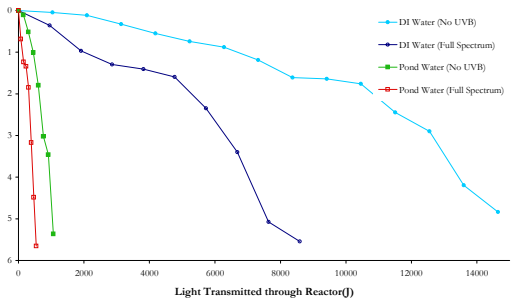

Fig 2: Inactivation of *E. faecalis* versus the amount of light transmitted through the reactor. Reactors contained DI water or pond water and were exposed to simulated full spectrum sunlight or simulated sunlight without UVB.

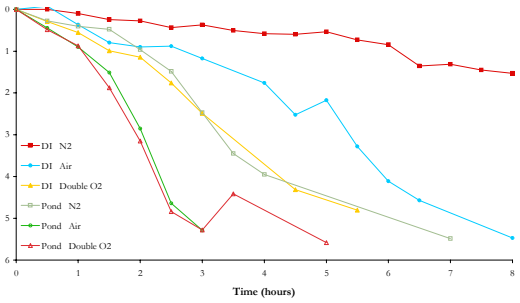

Fig 3: Inactivation of *E. faecalis* over time in DI water and pond water. Reactors were sparged with nitrogen, air, or double (42%) oxygen and exposed to simulated sunlight without UVB.

The National Wadeable Streams Assessment in Arkansas: An Overview

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In recent years attention has been drawn to the fact that data sets are not available that can be used to determine large scale water quality evaluations. In 2004 the U.S. EPA conducted the final field work on a project that is meant to begin a solution to this problem. The project is titled the Wadeable Streams Assessment and is meant to be "a national assessment of the condition of wadeable streams and rivers in the conterminous U.S". The Ecological Engineering Group at the University of Arkansas conducted the Arkansas portion of the field work. Sampling areas were divided by level II ecoregions, of which there are three in Arkansas: Southeastern USA Plains, Ozark, Ouachita-Appalachian Forest, and Mississippi Alluvial and Southeast USA Coastal Plains. The wide range of ecoregions in Arkansas, from plains to mountains, gave us an opportunity to see how the methods worked in a variety of settings. Sample procedures included geomorphology, habitat, benthic macroinvertebrate, and water chemistry. While the overall quality control certifications, training, and coordination between states and within the Arkansas team was successful, there were procedural difficulties associated with the challenges of sampling across ecoregions with a standardized methodology. The data has been analyzed using a multitude of statistical methods and presented to cooperating entities at regional meetings by the EPA.

Notes

Identification and evaluation of limiting factors on algal growth in headwater Ozark streams

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The goal of this project was to evaluate the limiting factors on periphytic algal growth in streams within the Beaver Lake Watershed through fieldwork and lab analyses over two sampling seasons. Five of ten study sites within the Beaver Lake Watershed showed phosphorus limitation using passive diffusion nutrient enrichment periphytometers. Five of the ten sites showed that nutrients were not limiting algal growth on the periphytometers and where at the maximum potential productivity. The results showed that the watershed may be sensitive to nutrient loading in streams where an increase of phosphorus and secondarily nitrogen may increase the periphytic biomass accumulation of algae. Light availability was characterized during the nutrient enrichment studies and may be identified as the limiting factor on periphytic growth in the presence of high ambient nutrient concentrations and low productivity. Relatively low algal production in the presence of moderately high nutrients at selected sites demonstrates the complexity of interactions between physical and chemical stream characteristics which may limit periphytic algal growth. Nutrient enrichment bioassays represent a useful tool for evaluating stream nutrient-trophic status relationships.

Trophic conditions and nutrient limitation at Beaver Lake, Arkansas

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Beaver Lake is a reservoir on the White River in Arkansas constructed for purposes of flood control, hydropower generation, and water supply. The primary inflows, creeks, and tributaries into Beaver Lake receive water with varying concentration of nutrient (nitrogen and phosphorus) which result in an increase of primary productivity (eutrophication). The objective of the project was to determine of Beaver Lake, and to measure the response of algae to nutrient enrichment. We used an algal bioassay to determine whether nitrogen or phosphorus limits algal growth, evaluating how algal growth responds over a gradient of nutrient conditions. Preliminary results show that concentrations of algae are higher in the Riverine Zone than in the Transitional Zone; therefore, it can implied that eutrophic conditions persist in the riverine zone and shift to mesotrophic conditions in the transition zone. The results also show that algal growth in this reservoir appears to be nitrogen limited, and algal biomass increases with the addition of increasing amounts of nitrogen (and phosphorus).

Organic carbon sources related to land use in Beaver Reservoir watershed, Northwest Arkansas

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The use of chlorine in drinking water disinfection is a common water treatment practice. When chlorine reacts with natural organic compounds, disinfection byproducts (DBP) are formed like trihalomethane (THM) or halogenated acetic acids (HAA). The U. S. Environmental Protection Agency (USEPA) has identified THM and HAA as a public health risk as these chemicals are potential carcinogens and toxic to digestive and urinary organs. Beaver Lake Reservoir is the source for Northwest Arkansas' drinking water, servicing approximately 350,000 people and industries. A monthly monitoring approach with supplemental storm chasing of Beaver Lake tributaries was used to identify carbon sources within the Beaver Lake watershed. Discrete samples for total organic carbon (TOC) and dissolved organic carbon (DOC) concentrations were collected at 20 sites. Percent land use in each sub-watershed was determined using the most current GIS data. Sites were selected incorporating urban, agriculture, and forest dominated land uses and different stream orders. Preliminary results at base flow indicated that watersheds dominated by urban land use displayed the greatest organic carbon concentrations. Forested

catchments had the least organic carbon concentrations, whereas streams draining agriculturally dominated catchments displayed intermediate concentrations. Additional study will incorporate riparian zone land use within the sub-watersheds, carbon isotope analysis, and the role of the physical channel and bed load characteristics in organic carbon concentrations and transport.

Notes

Methylmercury accumulation in fish tissue as a function of lake trophic status: A review.

Dent, Stephen, R. and Marc Beutel, Dept. Civil and Environmental Engineering, Washington State University 99163 (sdent@wsu.edu 509-339-3674).

Mercury contamination in lake biota is a rising concern as nearly one-third of all US lakes have mercury contaminated fish consumption advisories. Mercury can be converted into bioavailable methylmercury when dissolved oxygen becomes depleted at the sediment-water interface of lakes. Under anoxic conditions sulfur reducing bacteria produce methylmercury as a byproduct of their metabolism. Methylmercury readily bioaccumulates at the base of the food web (benthic oligochaetes and algae), concentrating in upper-level organisms (fish and birds) as they consume contaminated biota. In 2001 and 2002, the Washington State Department of Ecology conducted a study on 18 different lakes in Washington, measuring mercury concentrations in fish tissue and bottom sediments. This presentation presents the preliminary findings of a statistical evaluation to test the hypothesis that lake trophic status and a lake's tendency to exhibit anoxia in bottom waters is correlated with methylmercury in fish. The relationship between mercury levels and a number of trophic and morphometry parameters will be examined, including the anoxic factor. This parameter is equal to the number of days per year that a sediment area equal to the lake surface is anoxic, encapsulating both the spatial and temporal extent of hypolimnetic anoxia. Results from this study will aid in realizing our long-term goal to develop in-lake management techniques to reduce the formation of methylmercury and its subsequent bioaccumulation in lake biota.

Control of mercury release from profundal lake sediments using oxygenation

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Mercury contamination in aquatic ecosystems is a growing concern throughout the US. Mercury accumulates in upper-trophic-level organisms, thereby posing a health risk to people who consume contaminated wildlife. Methylmercury (MeHg), the form of mercury that accumulates in biota, is produced via the methylation of inorganic mercury by microorganisms, predominately sulfate reducing bacteria (SRB). Since SRB thrive under anaerobic conditions, methylation rates are generally higher under low-oxygen conditions. A number of studies have shown that hypolimnetic anoxia is a key pathway for the exposure of biota to MeHg in lakes. Anoxic bottom waters tend to accumulate MeHg during the summer and fall, and biota are exposed to the MeHg during fall mixing episodes. This study presents preliminary results of an experiment to test the hypothesis that increased dissolved oxygen levels at the sediment-water interface of profundal lake sediments will result in lower production and release of MeHg from lake sediments. Because source control of this highly dispersed pollutant is difficult, and mercury is already widely distributed in the environment, in-lake management strategies such lake oxygenation may be a key to controlling methylmercury contamination in lake biota.

The role of submerged and emergent macrophytes in mercury biogeochemistry: Implications for wetland restoration in San Francisco Bay

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Wetland restoration in the San Francisco Bay-Delta (SFB-D) provides an opportunity to reclaim critical habitat objectives for endangered wildlife and species of concern in the region. However, due to historic regional mercury (Hg) contamination, restoration efforts are complicated by concerns of exacerbating methylmercury (MeHg) production, a potent toxicant that accumulates in aquatic food webs and has been shown to be associated with wetland settings. Microbial Hg(II)-methylation is a function of 1) microbial activity (primarily sulfate reducing bacteria) and 2) the bioavailability of inorganic Hg(II) for methylation, both of which can be impacted by the interaction of vegetation with a number of above- and belowground biogoechemical cycles. We report pools and fluxes of total-Hg and reactive Hg(II) from vegetation of several habitats of the SFB-D, ranging from submerged aquatic vegetation (SAV) in the Delta

(e.g. *Egeria densa*) to halophytic emergent vegetation of high salt marsh plains (e.g. *Salicornia virginica*). These data suggest that detrital inputs may significantly increase the availability of reactive mercury in vegetated ecosystems. Comparisons of mercury methylation rates between vegetated and non-vegetated habitats also suggest that plants are capable of influencing Hg availability and microbial sulfate reduction rates, thereby influencing MeHg production either positively or negatively. Although experimental studies are needed to understand which plant characteristics promote or enhance Hg(II)-methylation, vegetated habitats (SAV, fresh and saltwater marshes) appear to be significantly greater producers of MeHg than neighboring non-vegetated habitats (sloughs, open water channels, mudflats). Therefore, understanding how plants influence Hg biogeochemistry may aid in reconstructed wetland designs, which maximize water quality and habitat objectives while simultaneously minimizing MeHg production.

Notes

Preliminary assessment of chromium partitioning in constructed wetlands treating tannery effluents.

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Constructed wetlands have been used for polishing tannery effluents, focusing mainly on their ability to further reduce organic loadings. The high costs associated with conventional treatment of tannery effluents are making constructed wetlands an interesting alternative, especially in developing countries. However, the fate of chromium contained in tanning wastewaters, a metal whose toxicity is much debated, has not been documented to date.

Nine experimental wetlands were built at the University of Memphis to determine the partitioning of chromium inside laboratory scale systems. A set of duplicate wetlands was assigned to each of the following three parameters: adsorption onto media, plant effects, and intermittent feed. An additional duplicate set acted as control. The experiment goals were to determine where the chromium accumulated in the wetland system, and if intermittent loading affected systems' performance.

Results show BOD and chromium reductions of 95-99% and 90-99%, respectively. Chromium removal performances were statistically different for all systems ($p<0.01$), except when comparing the control against the intermittent feed systems ($p>0.05$). Analysis of plant tissues revealed that total Cr accumulated represented less than 1% of the chromium removed, and this was in decreasing order: roots > shoots > roots' surface. Scanning electron microscope analysis confirmed minimal Cr on roots and the presence of Cr and biomass on the gravel surface.

Chemical speciation modeling supports a potential Cr removal through adsorption onto iron oxides from the systems. The hypothesized chromium removal through sedimentation and adsorption onto media and litter matter will be further evaluated through sequential extractions.

Notes

Low-cost water technologies for developing countries: the sustainability argument

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As universal access through piped and treated water appears infeasible for much of the rural and peri-urban poor, point-of-use and alternative water delivery and treatment mechanisms have grown in importance. Several factors are cited in their favor – cost effectiveness, community participation and ecological sustainability amongst them. This talk will provide an overview of empirical experiences with some of these technological options, and will draw some conclusions about the different ways in which sustainability can be assessed, enabled or hindered.

Gas Production and Water Quality Analysis of Agricultural Biodigesters in Costa Rica.

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Water pollution in rural areas negatively impacts human health and ecosystems throughout the developing world. Reducing these impacts depends in large measure on the development and dissemination of small-scale, economically feasible technologies for wastewater treatment. Biodigesters facilitate anaerobic digestion of biomass, resulting in energy production and wastewater treatment. In Costa Rica, over 500 biodigesters have been installed on farms to treat animal wastewater and meet farmers' energy needs for cooking. The efficiency of the low-tech biodigesters in Costa Rica has not been rigorously investigated. In this study, nine biodigesters on small-production farms in the Parismina Watershed of Costa Rica were investigated. Over 225 water samples were collected from these sites and analyzed for 11 different parameters, including biochemical oxygen demand (BOD), total suspended solids (TSS), total nitrogen (TN), and ammonia (NH_3). Biogas from all biodigesters was 60% to 75% methane. Average BOD concentrations were reduced from 525 mg/L in the raw wastewater to 88.2 mg/L in the biodigester effluent. Average TSS concentrations were reduced from 2132 mg/L to 455 mg/L, and TN was reduced 267 mg/L to 171 mg/L. Dissolved nutrients, such as NH_3, rose from 47.3 mg/L to 80.3 mg/L, thereby increasing the usefulness of the effluent as a fertilizer. It was determined that the biodigester effluent could be utilized as fertilizer or through aquaculture, but that unused biodigester effluent should undergo further treatment in a low-tech treatment alternative, such as a wetland or ecological treatment system before being discharged to the river.

Notes

Exploring the treatment potential of wastewater drainage ditches in the Andean Amazon of Peru: Project overview and preliminary findings.

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The widespread deficiency of sanitation services in developing countries poses increasingly grave threats to human and ecosystem health. The focus of this study is the treatment potential of wastewater drainage ditches in Oxapampa, Perú, a rural town of 14,000 residents in the Andean Amazon. These earthen and vegetated ditches route wastewater from approximately 5,000 residents through the town and into a third-order river, the Río Chorobamba.

This study is designed to achieve two primary objectives: (1) investigate the intrinsic attenuation of pollutants in sewage effluents in wastewater drainage ditches and (2) test the effect on water quality of various experimental modifications to the ditches that will inform how ditches may be designed and managed in order to amplify their treatment performance.

Findings related to the first study objective are presented. Wastewater effluents in three open vegetated ditches are compared to those in five closed underground conduits which acted as controls. The following water quality parameters were measured: NO3-N, NH4-N, PO4-P, TSS, BOD5, dissolved oxygen and fecal coliform bacteria. PO4-P and BOD5 values are significantly higher ($p<0.05$) in closed pipes than in ditches. Sediment physiochemical properties such as the phosphorus sorption index, equilibrium phosphorus concentration (EPCo) and exchangeable-P indicate that sorption to sediments is an important intrinsic P

retention mechanism in these ditches. Despite evidence for intrinsic treatment during transport in ditches, high pollutant loads tend to overwhelm the existing treatment capacity of these systems. Experimental modifications to the ditches will be performed to improve treatment before discharge to the river.

Watershed-Scale Analysis of Channel Stability Using LIDAR Data and Low-Level Aerial Photography.

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The James River watershed covers approximately 22,000 sq. mi. in North and South Dakota. It also has the flattest gradient of any river in North America, dropping only 135 feet in the 474 river miles (0.000054 ft/ft) in South Dakota. Because of a history of flooding causing significant impacts, $217,952,000 between 1955 and 1997 (excluding agricultural losses), the James River Water Development District (JRWDD) and the Omaha District Army Corps of Engineers are conducting a Feasibility Study and Environment Impact Statement (FSR/EIS) for an Ecosystem Restoration and Flood Damage Reduction Feasibility Study for the James River. With resources such as LIDAR, high resolution aerial imagery, and low altitude helicopter fly-over video available to the project, a relatively complete analysis of the river's geomorphology was able to be conducted using ARC-GIS®. We estimated bankfull dimensions, floodprone width, meander width ratio, energy slope, valley slope, radius of curvature, valley length, and channel length. In addition, depositional features and riparian condition were inventoried using the low altitude helicopter fly-over video data. By conducting this analysis we have been able to selectively assess portions of a major river and develop data that will aid in determining how various alternatives will potentially affect the river and its ecology.

Amphibian assemblages of headwater creeks in an urban landscape; implications for stream management

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Headwater streams are important habitat for aquatic breeding amphibians, but stream management plans usually focus on the riparian buffer zone along a stretch of stream rather than the importance of headwater type and in-stream habitat. The recent global decline of amphibians has been attributed to climate change, infectious disease, habitat fragmentation and environmental destruction. The present study examined the distribution of amphibians, in particular frogs and salamanders, in headwater creeks within the urban area of Gainesville, Florida, and related observed summer distributions to stream headwater type, in-stream habitat availability and the extent and quality of the riparian zone. Twenty urban creeks were sampled for larval amphibians via dipnetting and nocturnal frog call surveys. Three reference rural streams in conservation areas were sampled for comparison. Although historic herpetological surveys reported abundant salamanders in the streams sampled, no salamanders were encountered in the current study. Frogs, however, were common. The relative importance of headwater type, in-stream habitat and riparian zone quality and extent for observed distributions will be addressed. The relative importance of habitat fragmentation and regional climate change has not yet been addressed. Our preliminary data suggest that bridges alter in-stream habitat significantly in headwater streams and may be an important factor for amphibian distributions in urban areas.

Notes

Using the Natural Channel Design Process to Restore an Urban Stream in Rogers, Arkansas.

K. Shurgar and Marty Matlock

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The City of Rogers, Arkansas, is part of the sixth fastest growing region in the nation. As a result of the rapid land-use change from an agricultural to an urban landscape, in-stream processes and flow regimes for area streams have been dramatically altered. These impacts include decrease in sediment transport function, increase in incision and entrenchment, and overall reduction of in-stream biological processes. The goal of the project is to restore ecological services and sediment transport competency in a one-mile reach of Blossom Way Branch. In 2002, 1500 ft were restored using Natural Channel Design (NCD) principles. Phase II of the project includes restoration of the remaining 3500 ft. Channel dimension, profile, plan-form, and particle distribution were surveyed. Primary NCD techniques employed in this design included increase in stream length, belt-width, and sinuosity, and reconnection of the stream to a floodplain.

Campus hydroscapes: Watershed as a planning platform for campus improvements in the university of arkansas athletic valley

Gabriel, Aaron (presenter) & Luoni, Stephen. University of Arkansas Community Design Center, School of Architecture, University of Arkansas (agabriel@uark.edu 479.575.5772)

> *"…the landscape itself is a medium through which all ecological transactions must pass, it is the infrastructure of the future."*
>
> Richard Weller "Landscape Architecture and the City Now"

Watershed Urbanism

Contemporary planners have never known what to do with water. Seen as an obstacle to development it is drained away or appropriated as a transport mechanism for goods and wastes. *Campus Hydroscapes* counters with a model for integrating riparian systems with urban systems. It is a watershed-based land-use proposal that incorporates ecological services into urban systems servicing mobility and transit, recreational program, housing, and campus aesthetics.

College Branch is a first order stream in the University of Arkansas "Athletic Valley" with headwaters along a ridge dividing the Illinois and White River Watershed. Chronically displaying dysfunctions associated with intense urbanization, it has been on the Arkansas Department of Environmental Quality (ADEQ) 303(d) impaired waters list since 1998. Remediation of two critical reaches of the stream present a demonstration project for campus revitalization based on watershed improvement that provides a statewide educational asset.

Campus Hydroscapes

A multidisciplinary design endeavor, *Campus Hydroscapes* incorporates Landscape Architecture, Architecture, Urban

Planning, and Biological and Ecological Engineering. It offers three scenarios for implementation as individual strategies, or a successive phasing of all three. HydrologyPixelation modestly decentralizes stormwater in vegetated swales with minimal alteration of existing land use. RiparianBands stratifies parking and other land uses along linear treatment and retention swales. TotalMarsh is a maximized approach, consolidating building program along edges of large constructed wetlands for floodplain and stormwater retention. These water management solutions offer self-correcting ecological services as a low maintenance alternative to expensive, monolithic command-and-control engineering solutions. They reinvigorate the potential of the campus as an integrated environment serving as a model for the city.

Habitat Trails: Habitat for Humanity: From Infill House to Green Neighborhood Design

Huber, Jeffrey (presenter); Gabriel, Aaron & Luoni, Stephen. University of Arkansas Community Design Center, School of Architecture, University of Arkansas (jehuber@uark.edu 479.575.5772)

> "Research indicates that when impervious area in a watershed reaches 10 percent, stream ecosystems begin to show evidence of degradation, and coverage more than 30 percent is associated with severe, practically irreversible degradation."
>
> Green Streets: Innovative Solutions for Stormwater and Stream Crossings

The large acreage devoted to human settlement makes the disposal of stormwater a problem during even modest events. Growth coupled with increased impervious areas has degraded ecological functioning and bio-diversity in our urban communities. "Pipe and pond" solutions transport runoff problems elsewhere and are prone to systematic failures, whereas ecologically based solutions, like "green streets" can treat runoff *in-situ* and improve regional groundwater quality. The integration of an ecological fabric in urban infrastructure offers solutions to achieve sustainability in the built environment and bypass the costly infrastructure associated with civil engineering solutions. Contrary to civil "pipe and pond" solutions, the "green street" becomes an integral landscape component in a larger watershed solution.

Parks, not Pipes: The Ecological in Infrastructure

Habitat Trails proposes an ecological approach to urban development, through a hydrological network that involves infiltration, recreation, conveyance, and higher water quality on and off site. Land is developed in accord with the site's existing

hydrological drainage, catchments, and recharge patterns. Stormwater runoff generated by the new development is retained and treated through a contiguous network of bioswales, infiltration trenches, stormwater gardens, sediment filter strips, and a constructed wet meadow. "Green street" solutions enhance water quality beyond the minimum detention requirements, dissipate peak flows to prevent flooding, and provide erosion and sediment control. Rather than costing $450/linear foot for a curb-gutter-pond solution, "green street" infrastructure costs $250/linear foot. The integration of a constructed treatment landscape with open space builds greater value and added collateral benefits, by pooling otherwise private resources to create a shared neighborhood landscape with enhanced neighborhood aesthetics and pedestrian-oriented environments, additional passive recreation assets, and provision of wildlife habitat.

Notes

Raingarden Ecosystems: What's Happening Belowground?

Ayers, Emily Mitchell & Patrick Kangas. Department of Biological Resources Engineering, University of Maryland, College Park, MD (emayers@umd.edu, 718-556-5268) & Department of Biological Resources Engineering, University of Maryland, College Park, MD (pk31@umail.umd.edu, 301-405-1259).

Raingardens begin life as a planted sterile soil mix, but are rapidly colonized by soil animals. Within a few years, earthworms are already hard at work reorganizing the soil profile. The entire soil ecosystem participates in the process, breaking down surface litter and transporting the organic residue into the soil matrix. Root systems expand, further increasing soil organic matter, enhancing the soil habitat, and improving soil structure. Over the first decade, an organically-enriched layer forms just below the soil surface. Ten raingardens in the Washington D.C. metro area were surveyed. Their ages ranged from one to ten years. Earthworm abundance and diversity, root biomass, macroinvertebrate diversity and soil organic matter content were measured at each of the sites. The results form a chronosequence, illustrating the development of raingarden ecosystems over time.

Lightweight Green Roof Technology for Temperature Control of Existing Sloped Roof Buildings.

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The rising costs of nonrenewable energies and the uncertainty of their supply indicate that we must find ecologically sound energy saving devices for our buildings. In Europe's dense cities, green roofs have been used successfully to moderate temperature, impede storm water runoff, and create habitat. Although green roofs are becoming more popular in the United States, we believe their high installation costs, heavy load-bearing requirements, and difficult application on existing roof slopes limits their widespread use. We designed a novel retrofit green roof technology that uses fast-growing vine species and a trellis that suspends vegetation above a buildings' roof. The effect of green roofs on building temperature and humidity were determined by comparing time series data of control houses (no green roof) and houses with green roofs. We used scaled (1:12) houses with native vine species, Virginia creeper (*Parthenocissus quinquefolia)*, located in environmental growth chambers that simulated the climate of Maryland in July. Additionally, we report on the growth rate of several vine species. These initial experiments demonstrate that the new green roof technology could be a viable alternative to existing heavy green roof designs, which will help save energy in existing buildings.

Design of a Habitat for Humanity Neighborhood as a Low Impact Development

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Habitat Trails is a 5-acre green neighborhood development consisting of 17 dwelling units for Habitat for Humanity of Benton County, Inc. in Rogers, Arkansas. The project was a collaboration between University of Arkansas Community Design Center in the Department of Architecture, the Ecological Engineering Group in the Department of Biological and Agricultural Engineering, and the Department of Landscape Architecture. The University of Arkansas Ecological Engineering Group utilized low impact development practices to design an ecologically based stormwater management system. The system consists of bioswales that deliver on-site and off-site run-off to a 0.75 acre wet meadow retention basin. The bioswales and meadow were designed to control peak runoff flows and volumes to that of pre-development conditions by providing ample infiltration area, significant detention time, and vegetative evapotranspiration. The design process included use of PondPak and MicroStation software. The design optimizes ecological services by providing songbird habitat, pollutant removal, and human recreational space.

Notes

Bio-swales and wet meadow design using PONDPACK 10.0 Habitat Trails, Rogers, Benton County, Arkansas.

R. Zeledon Kelly[1], Marty Matlock[1], Aaron Gabriel[2], and Sammi May[3]

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The UA Ecological Engineering Group and the Community Design Center developed a model green community for Habitat for Humanity of Benton County, Arkansas. This subdivision in Rogers, Arkansas, named Habitat Trails, occupies 5.09 acres and features 12 homes (17 residences) integrated with a greenfield, a wet meadow, and bio-swales. The City of Rogers, Arkansas, Storm Management Practices require the post-developed runoff for the 2, 5, 10, 25, 50, and 100-year storm events to be limited to the peak runoff prior to development. Low Impact Development (LID) techniques such as bio-swales and wet meadow were integrated into the design plan with the aim of decreasing peak flow rates, delaying peak times and reducing sediment and nutrients transport. These LID features and outlet structures were designed using PondPack 10.0 (Haestead Methods/Bentley). The network design for hydrology consisted of five retention ponds, fourteen detention ponds and one wet meadow. The network runoff was calculated using the Unit Hydrograph Method. The wet meadow design additionally accounted for the runoff from 59 acres surrounding the property, which was calculated using the Rational Method. The model required multiple iterations with design and layout in order to optimize the design of each component. As a result the model demonstrated that the post-developed peak outflows were at or

below the pre-developed outflows, for 2, 5, 10, 25, 50 and 100-year Storm events.

Notes

How do marshes keep pace with relative sea-level rise: Interactions between flooding stress and root volume.

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Rapid rates of coastal wetland loss in Louisiana are widely recognized. Increasing concern has given rise to an array of research efforts hoping to explain the processes contributing to loss, thus allowing for the implementation of sustainable management practices and effective restoration. One factor contributing to wetland sustainability is that of how volumetric contributions of organic matter to wetland soils vary over time and space, under the influence of flooding stresses.

To date, organic contributions to wetland soil have largely been investigated on a mass basis. This approach assumes that the specific gravity of organic matter remains constant regardless of external factors, such as flooding regime and nutrient availability. This ignores the potential for variability in volumetric contributions from vegetation. Increased soil volume would contribute toward maintaining a marsh surface elevation that allows for vegetative proliferation. It is possible that increased flooding could stress a plant modifying the specific gravity of biomass through aerenchyma production. The resulting increased contributions to soil volume merits field investigation. This process most likely operates within a suite of physical boundaries, the violation of such constraints resulting in decreased productivity and increased susceptibility to factors contributing toward wetland loss.

This research investigates the relationships among the specific gravity of live roots, soil chemistry, and flooding regime for the plant *Spartina alterniflora* in a salt marsh field setting. Knowledge

concerning these relationships has substantial implications for wetland conservation and restoration strategies focusing on periodic flooding of marshes through river diversions.

Notes

Hydrologic evaluation for ecological engineering of phosphatic clay settling areas.

McLaughlin, Daniel, Sean King, Wes Ingwersen, and Mark Brown. Department of Environmental Engineering, University of Florida, 32611 (mclaugd@ufl.edu 352-392-2429)

Clay Settling Areas (CSAs) are dominant features of the post phosphate mining landscape that currently comprise 60,000 acres in Central Florida. Wetland creation on CSAs may be possible since surface water features naturally form as a result of their isolated watersheds and impermeable clays. Since hydrologic regimes dictate the type of species that survive and compete, it is imperative to understand the temporal and spatial characteristics of CSA hydrology when designing and engineering created wetlands. A temporal model was developed to predict CSA hydrology in terms of both stage and volume and was calibrated using continuous stage and climatic data. Various empirical models were compared and used to estimate the evapotranspiration component of the model. Preliminary results indicate CSAs tend to retain water longer with a less fluctuating hydrologic regime in comparison to other Florida wetland systems and that evapotranspiration is the major water loss. A GIS based model was developed using the results from the temporal model to predict the spatial extent and hydroperiods of wetlands occurring on CSAs. Hydroperiod maps of CSAs generated using the spatial model can be used to aid in the selection and location of species to be planted.

Acceleration of natural succession in the post-phosphate mining landscape.

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Acceleration of natural succession within constructed wetlands on clay settling areas of phosphate mine restoration sites presents challenges. Three categories of field trials will evaluate success of artificial seed sources to settling areas in arrested succession because of disjunct seed sources and disconnectivity with naturally vegetated areas. Different hydroperiods and shade and elevation gradients may affect growth and survival of planted plots. In the summer of 2005, clay settling area H-1 was cleared of *Typha* sp. and planted with broad-leaved marsh, grassy shallow marsh, graminoid, and bay swamp and shrub vegetation in order to examine growth affected by topographic position and wetland hydroperiod, species resistance to invasive species, and reestablishment of native *Typha* sp. populations. The percent species survival of these plantings was determined with plotted transects in the fall of 2005. Two additional marsh plantings are scheduled for spring of 2006. Understory plots will be planted in spring of 2006 on three, one-acre *Salix* sp. wetland sites to determine the success of stimulating diverse forested wetland growth and enhancing natural succession. Vegetated mats from deep water marsh areas on clay settling wetlands will be planted with bald cypress tuberlings and seeds, and monitored for successful establishment.

Design For An Iron Cycle Microcosm

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Aspects of the iron cycle were simulated and tested in the laboratory with a sequential microcosm system. In nature, dissolved iron cycles between two oxidation states as water flows across watersheds: the reduced ferrous form (+2) and the oxidized ferric form (+3). To simulate this cycle a microcosm system was designed that links different iron environments in a sequential pattern. An initial aquatic tank, filled with rusty scrap iron, was used to create a pulse of ferric iron. A wetland soil column with reducing conditions was connected to the initial rust tank in order to convert the iron to the ferrous form. A final aquatic tank, seeded with iron oxidizing bacteria, was connected to the wetland soil in order to convert the iron back to the ferric form. Tests were performed by passing tap water with low iron content through the system. Results demonstrated the expected transformations between the two oxidation states of dissolved iron over a three month period, along with other aspects of wetland soil biogeochemistry. Afterwards, the output of the flow through system was connected to the input to create a continuously cycling system for further studies of the iron cycle. Uses of the system for teaching wetland biogeochemistry are discussed and speculations for possible ecological engineering applications are suggested.

Co-treatability of 1,1,2,2-tetrachloroethane and trichloroethylene in engineered wetland soils.

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A study was carried out to evaluate the co - treatability of 1,1,2,2-tetrachloroethane (1,1,2,2-TeCA) and trichloroethylene (TCE) in a soil earmarked as a medium for an upflow engineered wetland system for treating chlorinated ethenes and ethanes. The study was a prelude to column studies. The two compounds were selected because they commonly occur together in groundwater. The engineered soil was a mixture of BionSoil/Latimer peat/Sand (37.5%/37.5%/25% w/w). All the treatments were inoculated with a culture known to degrade chlorinated ethenes to ethene. A killed control was included to discern abiotic and biotic contributions. Degradation rates of both compounds at low and high concentrations were examined. Overall, the co-treatability of 1,1,2,2-TeCA and TCE in the engineered wetland soil is feasible. 1,1,2,2-TeCA exhibited degradation rates of 0.0278 – 0.1845d^{-1} with the higher concentration treatments exhibiting higher degradation rates. The degradation rates of 1,1,2,2-TeCA in treatments containing 1,1,2,2-TeCA alone were only slightly higher than the ones in which 1,1,2,2-TeCA and TCE were co-treated. This suggests that co-treatment of 1,1,2,2-TeCA is as feasible as treatment of 1,1,2,2-TeCA alone. However, the concentrations of both compounds are an important design consideration. The main degradation mechanisms and pathways for 1,1,2,2-TeCA appear to have been dehydrochlorination of 1,1,2,2-TeCA to TCE followed by reductive dechlorination of TCE to *cis*-1,2-DCE, *cis*-1,2-DCE to vinyl chloride (VC) and VC to ethene. Ethene was later transformed into ethane. The fact that there was no accumulation of intermediate daughter products suggests that

their degradation rates were generally higher than those of the parent compounds.

Notes

Wetland trees revisited after twenty years on phosphatic clay settling areas.

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Clay settling areas (CSAs) occupy nearly half of the land area after mining for phosphate in central Florida. As of now the long-term viability of created wetlands on CSAs has not been demonstrated. Examination of wetland trees planted on CSAs twenty years ago offers the opportunity to determine if forested wetlands can be established where soil type is uncharacteristic and the wetland footprint is still changing due to clay consolidation. Trees planted twenty years ago on five CSAs representing three soil types (clay, sand-clay, and sand) were sampled to determine growth, survival, and seedling success. In addition to trees, soils and other vegetation were sampled and light penetration was measured in planted plots and non-planted areas of similar hydrology within sites to determine if trees play a role in enhancing ecosystem development. Of the three species planted, survival was highest on the sand-clay site but growth among survivors was similar to clay sites. Water level played a significant role in growth, survival and establishment of seedlings. In comparison with non-planted areas with similar hydrology, trees potentially enhance ecosystem development by contributing to organic matter build-up and altering light availability. In conclusion, forested wetland systems may be engineered on CSAs given an appropriate species complement and suitable hydrology.

Influence of Hydro-period on Production and Phosphorus Storage in Wetland and Forage Grass Species in the Lake Okeechobee Basin

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Nutrient export from agricultural activities in the Lake Okeechobee watershed have contributed to eutrophication of the Lake and regulatory implementation of a phosphorus (P) TMDL. Historically, anthropogenic manipulation of hydrology lowered the water table, creating improved conditions for upland forage grass production. This also increased runoff rates and phosphorus loading to the Lake. Hydrologic restoration of historically isolated wetlands within the watershed is a proposed BMP to increase P retention capacities of these wetland ecosystems, thus decreasing P loads entering the Lake. However, longer hydro-periods could potentially decrease pasture productivity, in turn, adversely affecting the economic viability of the cattle industry in the region. Previous studies have shown that soils under longer hydro-periods in the Okeechobee Basin have greater P storage potential than surrounding upland soils. This research focuses on P storage in vegetation under various hydro-periods in pasture wetlands and the efficacy of using an alternative forage species to maintain forage production after restoration.

For the purpose of this study, total P storage in wetlands (with a 50 m upland buffer) includes soil (10cm depth), above ground biomass (AGB), below ground biomass (BGB) and litter components. Soil is the primary P storage mechanism representing greater than 88% of the total P storage, while BGB, AGB and litter, represent 8%, 3%, and 1% respectively. Total biomass (AGB+BGB) production and P storage were inversely related to

hydro-period in wetlands of the more intensively managed pasture, while P storage was positively related to hydroperiod in wetlands of the less intensively managed pasture. Management intensity, which is a function of cattle density and pasture maintenance, may be influencing P storage capacities of vegetation and affecting the relationship between hydro-period and P storage.

In a separate mesocosm study in Gainesville, Florida, *Paspalum notatum* (Bahia) and *Hemarthria altissima* (Floralta, a wet-tolerant forage) were evaluated under five different hydrologic treatments. Water levels were stabilized at 10, 0, -10, and -15 cm relative to the soil surface, while the control only received rain water and was allowed to drain completely. Floralta had greater forage (AGB) production and P storage than Bahia in all treatments; however, Bahia had greater total biomass (AGB+BGB) production in all but the 10 cm inundated treatment. Bahia total P storage was only greater than Floralta in the -10 cm water level. This indicates that Floralta has a greater hydrologic tolerance than Bahia and similar P storage potential. Therefore, in order to maintain pasture carrying capacity and vegetative P storage during BMP implementation, Floralta may be a more suitable forage in restored pastures wetlands.

Response of algal productivity to flow regime turbulence in an algal turf scrubber.

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The role of bed turbulence was explored as a limiting factor to the productivity of attached filamentous algae in an algal turf scrubber (ATS) treating digested dairy manure. A series of experiments were performed on three laboratory scale (1 m^2) ATS units in which the bed turbulence was varied via two methods: (1) varying the volumetric flow rate (from 25 to 110 lpm) while the dump bucket tipping frequency was held constant; and (2) varying the tipping frequency (from 6 to 30 tips per minute) while the flow rate was held constant. Experiments were performed for a range (0.2-1.5 g TN/m^2/day) of nitrogen loading rates. Turbulence for each condition was measured on a relative scale by measuring the dissolution rate of plaster of paris clods. Results show that, at low N-loading rates, there was little or no response in productivity to increasing turbulence. In addition, there was no significant response of productivity to increasing flow rate (tipping frequency constant) for any N-loading rate. However, at higher N-loading rates there was a significant increase in productivity corresponding to increased turbulence created by a greater tipping frequency for a

set flow rate. This conforms to limiting factor theory, which states that, with all other factors in excess, bed turbulence set by the tipping frequency (rather than the flow rate) becomes the factor most limiting and that most directly controls the system productivity. These results have implications for the optimization of the bed turbulence regime and pump power requirements for the application of the ATS as a waste treatment technology.

Notes

Modeling Above-ground Biomass Production of Hybrid Poplar Tree (*Populus spp.*) Farm using Biosolids as a Remediation Tool.

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In response for a need to utilize large volumes of biosolids generated in the Washington, D.C. Metropolitan area, the University of Maryland Cooperative Extension, Washington Sanitary Suburban Commission and ERCO, Inc are coordinating a reclamation project in Prince George's County, Maryland demonstrating how deep row application of biosolids can be used to establish N-demanding hybrid poplar trees in a six year rotation. The project site is on an abandoned surface sand and gravel mine that, prior to reclamation as a tree farm, consisted of sand and gravel remnants underlain by a clay layer. As such, it was devoid of organic matter and subject to erosion. The biosolids serve as a long-term nutrient source for the fast-growing, nutrient-demanding poplar trees that in turn provide erosion control, wildlife habitat, and potentially become a marketable product. Trees are harvested in a seven year rotation that is followed by reapplication of deep-row biosolids and new plantings. Samples for stands planted in 1999, 2000, 2001, 2002 and 2003 were collected. Data on DBH, Height and dried weight will be used to develop allometric equations to estimate above-ground biomass growth for five year stands and results will be reported.

A Design For A Boat Washwater Treatment Ecosystem

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An unusual wastewater is produced in marinas where boats are lifted from the water and pressure-washed to remove attached organisms from the hulls. This wastewater contains elevated concentrations of certain heavy metals, such as copper, nickel and zinc, that are associated with the boat bottom paints and propeller assemblies. A design for a constructed ecosystem to treat this wastewater is described in this presentation. A living machine-type system was designed and tested at the bench-scale for treatment performance at a marina on Baltimore Harbor, Maryland. The system is a sequence of connected aquatic tanks including a recirculating peat filter, an oyster shell bar and a macrophyte tank. Heavy metals were effectively removed when the wastewater was run through the system at low loading rates (five percent turnover per day) but performance was reduced at high loading rates (20 percent turnover per day). Aspects of the design are described and plans for a full-scale system are presented.

An Investigation of Newly Developed Oxygenation Techniques in Shallow Streams and Shallow Anoxic Hypolimnetic Regions

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Streams receiving untreated wastewater and the hypolimnetic regions of drinking water reservoirs are two examples of environmental waters in which low dissolved oxygen concentration (DO) is commonly encountered. Aeration and oxygenation methods are frequently used to artificially raise the oxygen concentration in these waters. Methods for effluent receiving streams include: bubble aeration, overflow structures, surface agitation, and side stream oxygenation. Methods used for hypolimnetic regions in reservoirs include: artificial destratification, diffuse or plume bubble oxygenation, and submerged oxygen contact chambers. Each the aforementioned aeration and oxygenation methods suffer from cost inefficiencies due to low oxygen absorption efficiencies when used in relatively shallow streams or reservoirs. The low oxygen absorption efficiencies arise from oxygen losses to the atmosphere in shallow streams and to the epilimnion via disruption of the thermocline in shallow hypolimnions of reservoirs.

This study focused on testing the effectiveness of raising DO in shallow streams and shallow hypolimnions of reservoirs using the SDOX^{TM}, a developmental oxygenation technology capable of delivering water supersaturated with oxygen directly into a water system. The SDOX^{TM} is also able to attain higher oxygen absorption efficiencies than the aforementioned technologies. Utilizing the SDOX^{TM}, DO was injected into two shallow (less than 1 m depth) Northwest Arkansas streams at rates as high as 36 g/min over a period of several days. BOD, DO, and stream conditions (temperature, pH, conductivity, and flow rates) were

monitored at four sites located above and below the point of oxygen injection in order to test the effectiveness of the device and to determine the effects of the SDOX™ on the overall oxygen balances of the streams. Analysis of the oxygen balances showed increased DO up to 3 mg/L over 2000 ft reaches in both streams with minimal loss of oxygen to the atmosphere.

Hypolimnetic oxygenation studies were preformed on Lake Atalanta, a 35 acre, 12 m maximum depth lake in Northwest Arkansas. During two deployments the SDOX™ delivered DO at rates of 45 g/min, which effectively raised the average DO of an approximately 5,600 m^3 region of the 3 m deep hypoliminion by 1.1 mg/L. Temperature and oxygen balance analysis indicate no disruption of the thermocline or loss of DO to the epilimnion.

Notes

Coal mine carbon monoxide control using air biofilters: feasibility and design considerations

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In previous research we demonstrated that bench-scale compost-based air biofilters reduced carbon monoxide (CO) emitted at 1000 ppmv from a gasoline powered engine and bottled sources by as much as 45%. The compost media of air biofilters, like natural soil microbial communities, harbors beneficial bacteria and fungi that metabolize and co-metabolize CO, which actually serves as the second largest global sink for CO. Given that CO is a primary culprit in killing trapped coal miners, we explored the steps and feasibility of applying air biofilters as a CO control technology in underground coal mines. Based on personal experience with bench-scale biofilters and published data on pilot and full-scale biofilters, we evaluated the technical design issues (e.g., moisture, viability, power, and elimination rates) of implementing a system of underground mine biofilters. Implementation would reduce the human risk of coal mining and provide a 'leap forward' to society in demonstrating the utility of ecological engineering.

Effect of convection coefficient on predicted and measured SOD values in free flowing streams

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Benthic oxygen demand, also known as sediment oxygen demand (SOD), can greatly contribute to the oxygen demand in free-flowing streams. SOD has been reported to encompass as much as 90% of total river deoxygenation. Consequently, accurately quantifying SOD is of vital importance in water quality studies. The most commonly utilized technique for determining SOD is the use of a chamber placed directly over the sediment in the stream. Static chambers reduce the effective stream velocity over the sediment to zero. Since stream velocity directly correlates with the SOD the static chamber method may misrepresent actual SOD values. It is generally agreed upon that within critical velocity range increased velocity results in an increase in SOD. This occurs through the mechanism of increasing the stream convection coefficient, $h_{m,}$ and reducing the boundary layer thickness in the water overlaying the sediment. Osborn et. al have developed a measure-plus-calculate model that utilizes a combination of *in situ* and laboratory techniques for determining SOD values without the use of a chamber. However, the method poses a problem with properly comparing SOD values determined using the chamber based techniques with those obtained from the model because of the effect of the chamber on stream velocity. This problem causes difficulty for comparing chamber derived SOD measurements to model based measurements when validating the model. Mesocosms containing sediment were constructed so that the total oxygen budget of a test stream could be measured and SOD determined directly. The mesocosms were used to compare static chamber SOD measurements, determinations of SOD, and actual

values. Comparisons were made at three velocities: low, medium and high, within the range where velocity significantly affects convection coefficient. Data from these tests will be used to compare this model to chamber measurements and determine if the model can accurately convert static chamber measured SOD to free-stream (unobstructed) SOD by adjusting only the convection coefficient.

Molecular Characterization of Microbial Communities in the Pitting Corrosion Parts (FeS) and the Undersurface Soils of a Crude Oil Storage Tank.

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To protect metals from corroding, many researchers have studied microbially influenced corrosion (MIC) of metallic materials in recognition of the need for prevention of MIC failures. Culture-independent techniques, PCR detection and denaturing gradient gel electrophoresis analysis (DGGE) were used to determine the structures of microbial communities in pitting corrosion parts, soils around pitting corrosion, soils around non-pitting corrosion, and anaerobic culture of corrosion related bacteria. We detected specific-16S rDNA of acid producing bacteria (APB) such as Clostridium group III and IV, and *Lactobacillus* group, and sulfate producing bacteria (SRB) such as SRB group 6. From DGGE analysis, bacterial and archaeal communities are significantly similar in all samples. 16S rDNA of APB such as low G+C gram positive bacteria and SRB such as *Desulfovibrio*-like bacteria were detected. *Lactobacillus fermentum* was not previously reported to be associated with SRB found with MIC. The major 9 archaeal 16S rDNA sequences obtained in this study were related to acetotrophic methanogens (*Methanosarcinaceae amd Methanosarcinaceae*), and hydrogenotrophic methanogens (*Methanobacteriaceae* and *Methanomicrobiacea*). These results indicate that pitting corrosion was caused by both direct microbial influence corrosion and indirect microbial influence corrosion. Another important result is that whole bottom plate of the crude oil storage tank was exposed to similar microbial communities, and for that reason we could decide bottom plates of tank can be always attacked by indigenous soil bacteria. The finding from this

study could be used for designing suitable ecological engineering solutions to the problems as well as devising useful applications of the MIC phenomenon.

Notes

Ecological complexity, self-organization and complex systems design.

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Systems vary in size, organization and intricacy. The variation depends on several factors including the number of components, component connectedness, and the amount of functional and relational coupling of components within the system. Simple systems perform relatively few functions and have relatively few components connected in a manner that minimizes distributive function, information content, functional and relational coupling. Systems which are more intricate than simple systems may be described as complicated systems. Complicated systems may perform several functions and have a relatively large number components and information content. However, complicated systems are still relatively free of functional and relational coupling. Complex systems are highly intricate and range from relatively small numbers of connected components to large numbers of connected components that, in each case, tend toward high and increasing levels of information, distributed function, and functional and relational coupling. That is, complex systems are information rich systems that may efficiently perform several functions simultaneously. Toward this end, complex systems may distribute function and couple components physically, functionally, and relationally to encourage beneficial systemic emergent properties that are not evidenced from the parts. As complex systems, ecological systems are self-organizing, coupled, and information rich systems that are the result of energy gradients which have driven them far from thermodynamic equilibrium. As such, these systems have prolific and intertwined physical, functional and causal relationships that lead to emergent system properties. Further, the synthesis of function and relationship, the

scale, and the hierarchical nature of ecosystems tends to make the analysis of ecological systems intractably difficult to compute and to date unpredictable to design. Design implies organization and organization exists in various entities such as, institutions, electrical and mechanical products, ecosystems etc. Axiomatic Design Theory is an effort to formalize the design process into a science and searches for a unified design theory process. The axiomatic methodology began as comparisons of designs through relativistic measures of design effectiveness. Further, Axiomatic Design Theory and the axioms of independence and information seek to provide a scientific basis for the understanding of design organization through the structured mapping of uncoupled, coupled, and decoupled systems. However, this paper proposes that axiomatic design is limited to simple and complicated systems and that a new design theory and methodology is required to encompass the complexities associated with natural systems.

An ecological engineering approach to closed basin stormwater management in North Central Florida.

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Closed watershed basins, especially those draining to a central location surrounded by residential activities, present unique opportunities and constraints for ecological engineering of stormwater systems. In closed basins, stormwater must not only be conveyed, but it must also be stored so as to minimize unsightly, unhealthy, and potentially hazardous conditions. The 20.9 hectare Oak Hammock retirement community in Gainesville, Florida, is located within a 38.7 hectare closed watershed basin. The community was designed around a central stormwater basin (the lowest point on site), utilizing existing wetlands, a sink area of relatively permeable soils, and a lined, 0.5 hectare, constructed lake.

This study combines two phases: an integrated research and monitoring program (Phase 1) with a management and education program related to stormwater, wetlands, and the lake ecosystem at Oak Hammock (Phase 2). In Phase 1 we have monitored water quality and quantity throughout the site to construct water and nutrient budgets and found that increased hydroperiods and depths of inundation from increased impervious surfaces have resulted in the death of most of the predevelopment wetland vegetation. Additionally, overflow of stormwater from the wetland into the lake during large storm events has resulted in rapid nutrient enrichment of the lake. In Phase 2 we have made recommendations for replanting wetland vegetation based on new hydrologic characteristics, along with suggestions for ecological engineering treatments to remove lake nutrients. Overall we have established an adaptive management approach to ecologically

engineering the stormwater system at Oak Hammock and present our results here.

Notes

Determining Cost Efficient and Treatment Effective Soil and Plant Mixes in Bioretention Cells

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The Rockdale Career Academy, a non-traditional high school facility that provides technical instruction to students in Rockdale County, Georgia, began construction in January 2005. Twenty-three bioretention cells were incorporated into the storm water management design (developed by Breedlove Land Planning, Inc) to treat storm water quality and quantity. In order to provide a teaching and research tool for the high school, six of these cells were specifically designed for experimental purposes, namely to study the effectiveness of different soil mixes and plant mixes for treating storm water runoff. The swale areas surrounding the bioretention cells were set up to study the effects different soil media have on the treatment capacity of the sod.

Objectives of this study are to optimize cost and treatment effectiveness of the soil and plant mixes for the bioretention cells, to determine the most cost efficient and effective sod swale media, and to provide an educational model for students and faculty at the Rockdale Career Academy for learning and teaching purposes. To meet the objectives, a water quality sampling and testing schedule will be established. Of the six experimental bioretention cells, two are planted completely (with the exception of a few trees) with Bermuda sod over an organic, composted soil conditioner while the four remaining cells are comprised of swales of Bermuda sod planted over a clay base with several different soil and plant mixes. The different soil and plant mixes are as follows: two cells have a soil mix with 40% top soil, 10% organic, composted soil

conditioner, 10% expanded clay, and 40% coarse river sand (type B), while two cells have a soil mix with 40% top soil, 20% organic, composted soil conditioner, 20% expanded clay, and 20% coarse river sand (type A). Two wild flower mixes are planted in both soil types (A and B) in order to test each soil type with each plant mix. Water quality samples will be taken at the outlets of each bioretention cell and analyzed. Economic analysis will also be done to determine the soil/plant mix that is most effective at treating storm water quality while remaining cost efficient.

Notes

New Milton High School: Sustainable Storm Water Management for a Suburban High School Campus

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The new Milton High School is located in Alpharetta, Georgia. Construction of the new school was completed in the summer of 2005. The urban sprawl in the bustling Atlanta area has forced local school systems to move further into formerly rural areas where they can find tracts of land large enough to support the program of large high schools. This land is often in previously undisturbed and environmentally sensitive areas. Local school systems have struggled to provide adequate facilities for the growing population, while the development community has struggled to provide adequate storm water practices to protect the rivers, streams, and lakes from the pollutant laden runoff that accompanies urbanization and suburban sprawl.

The goal of the project is to provide a storm water model for suburban growth patterns in a progressive and sustainable manner that emulates the natural conditions and pre-development hydrology. The new Milton High School Site included four major basins, all of which contributed to a small creek. The seventy-four-acre site included twenty-nine acres of horse pasture with the remainder being wooded in pre-development conditions. The headwaters of a stream lie within the wooded area of this site with many springheads contributing to the nearly two thousand feet of creek bed. The design team laid out the master plan by situating the bulk of the development within the area that was previously pastureland. This helped to preserve the wooded riparian buffer that has protected the state waters in pre-development conditions.

The goal for new Milton High School was to spread the storm water out into as many areas as possible in order to increase the infiltration exposure and to treat the storm water as close to the source as possible. The result became a multilevel treatment system that included thirty-nine bio-retention cells and three sand filters. By handling the storm water in smaller increments and allowing the storm water to sheet flow and spread out over shallow, landscaped areas, many of the problems associated with storm water runoff were avoided.

GIS and Meta-analysis: Techniques for the Site Suitability Analysis of Agricultural Best Management Practices.

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The organophosphate pesticides chlorpyrifos and diazinon are used to maintain high levels of agricultural production in West Stanislaus County, California. Irrigation and storm water runoff carries some of the applied pesticides into surface waters, where water quality in the San Joaquin River and Delta can be impaired. Best Management Practices (BMPs) have demonstrated the ability to remediate agricultural runoff; the greatest net effect on watersheds will be achieved when BMPs are optimally sited to intercept non-point source pollution. The meta-analysis combined historic monitoring, pesticide application, agricultural land use, rainfall, and streamflow data to identify "hotspots" where BMPs could have the greatest impact on non-point source pollution.

An exhaustive search was made for data from samples analyzed for chlorpyrifos and diazinon collected in Stanislaus County, west of the San Joaquin River. Nearly 4000 individual chlorpyrifos and diazinon measurements were compiled from five sites on the San Joaquin River and six sites on tributary creeks. Previous studies were of short duration without sampling on consecutive days, focused largely on pesticide loads from dormant orchard spraying coupled with winter rain events. At Orestimba Creek at River Road, of the 191 samples which exceeded the California Department of Fish and Game Criterion Continuous Concentration (CCC) of 0.014 □g/L chlorpyrifos, 67% were in the dry summer season. Crops with summer chlorpyrifos applications were important toxicity sources in reaches with low dry-season flows. Incorporating these meta-analysis results, traditional cartographic

modeling techniques and GIS site suitability analysis were applied to identify sites most suited for new BMPs.

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