14^{th} Annual Meeting

American Ecological Engineering Society

2014

PROGRAM and ABSTRACTS

June 9 – 11, 2014

Charleston, South Carolina

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This Programs & Abstracts document was edited and compiled by Anand Jayakaran (Clemson University) using R and LaTeX code originally developed by Dr. Lara Lusa (Institute for Biostatistics and Medical Informatics, University of Ljubljana, Slovenia) lara.lusa@mf.uni-lj.si.

PROGRAM

		Colonial	Pinckney	Laurens	Calhoun
Monday	8:00AM – 9:00AM	Check-in and Continental Breakfast			
	9:00AM – 12:00PM	Plenary Session			
	12:00PM – 1:20PM	Lunch			
	1:20PM – 3:20PM		Concurrent Sessions -1, Track 1 (Streams)	Concurrent Sessions -1, Track 2 (Phytoremediation)	Concurrent Sessions -1, Track 3 (Bioretention)
	3.20PM – 3.30PM	Break			
	3:30PM – 5:10PM		Concurrent Sessions -2, Track 1 (Ecohydrology)	Concurrent Sessions -2, Track 2 (Ecosystem Disturbance)	Concurrent Sessions -2, Track 3 (Green Infrastructure)
	5:10PM – 7:00PM	Poster/Exhibitor Reception			
	7:00PM –	Dinner on your own			
Tuesday	7:30AM – 8:00AM	Check-in and Continental Breakfast			
	8:00AM – 12:00PM	Tours			
	12:00PM – 12:45PM	Lunch on your own or with tours			
	12:45PM – 2:45PM		Concurrent Sessions -3, Track 1 (Ecohydrology II)	Concurrent Sessions -3, Track 2 (Nutrient Dynamics)	Concurrent Sessions -3, Track 3 (Green Infrastructure II)
	2:45PM – 2:55PM	Break			
	2:55PM – 4:15PM		Concurrent Sessions -4a, Track 1 (Special Curriculum Session)	Concurrent Sessions -4a, Track 2 (Agroecosytems)	Concurrent Sessions -4a, Track 3 (Wetland Design)
	4:15PM – 4:25PM	Break			
	4:25PM – 5:25PM		Concurrent Sessions -4b, Track 1 (Special Curriculum Session II)		Concurrent Sessions -4b, Track 3 (Coastal Ecosystems)
	5:25PM – 7:00PM 7:00PM –	Student Design Spectacle in Marion Square Social in Southend Brewery & Smokehouse			
Wednesday	7:30AM – 8:00AM	Continental Breakfast			
	8:00AM – 9:10AM	Student Design Competition Presentations and Awards			
	9:10AM – 10:40AM	Special Session - In Plenary			
	10:40AM – 11:00AM	Break, hotel checkout			
	11:00AM – 12:00PM	AEES Business Meeting			
	12:00PM – 1:30PM	Lunch			
	1:30PM – 6:30PM 6:30PM –	Depart for kayaking trip Low country boil, Folly Beach			

8:00AM–9:00AM **Check-in and Continental Breakfast** (Colonial)

9:00AM–12:00PM **Plenary Session** (Colonial)

12:00PM–1:20PM **Lunch** (Colonial)

1:20PM–3:20PM **Concurrent Sessions -1, Track 1 (Streams)** (Pinckney) *Chair: D. Johnson*

1. **Developing a Full-Delivery Mitigation Solution – the Cannon Creek Stream Mitigation Site**
   Daniel H. Johnson and Will McGoldrick
2. **Concentration, Duration, and Frequency Relationships of Fine Sediment Transport on Biological Impairment**
   John S Schwartz and Robert Woockman
3. **Runoff Production for Undeveloped Headwater Streams in the Lower Coastal Plains of South Carolina**
   Thomas H. Epps, Daniel R. Hitchcock, Anand D. Jayakaran, Drake Loflin, Thomas M. Williams and Devendra M. Amatya
4. **On-site Stream Reconstruction on West Virginia Valley Fills**
   Leslie C. Hopkinson, J. D. Quranata and N. DePriest
5. **Quantifying Flood Flow Stage Reduction Benefit in Two-stage Ditches**
   Jessica L. D'Ambrosio, Andrew D. Ward and Jonathan D. Witter
6. **Development of Discharge-Frequency Relationships for Stream Geomorphological and Ecological Processes**
   Molly Moran, Andrew D. Ward, Jonathan D. Witter and Jessica L. D'Ambrosio

1:20PM–3:20PM **Concurrent Sessions -1, Track 2 (Phytoremediation)** (Laurens) *Chair: B. Winfrey*

1. **Mycelium in the Biofilter: Accessing Fungal Dynamics in Wood Chip Biofilters Treating Livestock Emissions**
   Jason P. Oliver, Kevin A. Janni and Jonathan S. Schilling
2. **Land Treatment of Food Processing Wastewaters: Reducing Metals and Nitrate Pollution Using Poplar Trees**
   Niroj Aryal and Dawn Reinhold

3. **Plant Ecology and Function in Stormwater Biofilters in Melbourne, AUS**
   Brandon K Winfrey, Andrew S. Mehring, Richard F. Ambrose, Lisa A. Levin and Belinda E.

4. **Phytoforensics: Techniques for Assessing Plant Contamination**
   Matt, A. Limmer and Joel G. Burken

5. **Performance of Large-Scale Algal Cultivation for Urban Water Quality Restoration in the Great Lakes**
   David M. Blersch

6. **Engineered Floating Vegetation Mats for the Passive Treatment of Acid Mine Drainage**
   William H Strosnider, Shannon Adams and Robert W. Nairn

1:20PM–3:20PM **Concurrent Sessions -1, Track 3 (Bioretention)** (Calhoun) *Chair: J. Robinson*

1. **Low impact development in the lowcountry landscape: Using hydrology as a design element**
   Joshua L. Robinson

2. **Evaluating the Performance and Long-Term Maintenance of a Failing Bioretention Cell in North Carolina**
   Jessica M Fears, William F. Hunt and Andrew R. Anderson

3. **Evaluation of The Performance of Five Low Impact Development Practices in Clay Soils**
   Fouad H. Jaber and Sandhya Mohan

4. **Does it Pay to Act Mature? Assessing Bioretention Cell Performance Seven Years Post-Construction**
   Lory L. Willard, Tess Thompson, Leigh-Anne Krometis, Greg Evanylo and Brian Badgley

5. **Removal Efficiencies of Bioretention Cells in Coastal South Carolina**
   Jessica A. Palazzolo, Anand D. Jayakaran and Daniel R. Hitchcock

6. **Enhancing Climate Resiliency through Green Infrastructure: the Minnehaha Creek Watershed Case Study**
   Trisha L.C. Moore, John Gulliver and John Nieber

3:20PM–3:30PM **Break**

3:30PM–5:10PM **Concurrent Sessions -2, Track 1 (Ecohydrology)** (Pinckney) *Chair: A. Ludwig*

1. **Measured Stormwater Runoff Seasonal Variation in a Small Traditional Suburban Development in East Tennessee**
   Andrea L. Ludwig and Wesley Wright

2. **Mitigating Stream Health and Conditions with Low Impact Development**
   Saed Shannak and Foud H. Jaber

3. **Watershed Characteristics and Conductivity in Five Central Appalachian Watersheds**
   Nicholas A. Cook and Leigh-Anne Krometis

4. **Eco-Morphological Stream Design and Assessment Tools for the Alabama Piedmont**
   Gregory D. Jennings, Eve Brantley, Brian Helms and Jason Zink

5. **Stormwater Mitigation Performance through Regenerative Stormwater Conveyance (RSC) in North Carolina**
   Adrienne R. Cizek, William F. Hunt and R. J. Winston

3:30PM–5:10PM **Concurrent Sessions -2, Track 2 (Ecosystem Disturbance)** (Laurens) *Chair: A. Jayakaran*

1. **Modeling an Urban Wetland's Methane Fluxes Using the Eddy Covariance Method**
   Timothy H. Morin, Gil Bohrer, Liel Naor-Azreli, Renato P. Frasson, Karina V. R. Schaefer and William J. Mitsch

2. **Strawberry Swamp - a Swamp on The Edge**
   Anand D. Jayakaran, William H. Conner, Daniel R. Hitchcock, Stephen Hutchinson, Alex T. Chow, Bo Song and Thomas M. Williams

3. **Defining C and LS Factors of the RUSLE to Model Soil Erosion in Urban Landscapes.**
   Dhanuska Wijesinghe, Charles A. Pellett, Holly Garret, David L. White and Dara M. Park

4. **Relating Emergy Intensity of Pollutants and Biological Indicators in Riverine Systems**
   Elliott T. Campbell and Brandon K. Winfrey

5. **Identifying Controls on Stormflow, Nutrient and Carbon Export From Urban Watersheds with Stormwater Control Measures.**
   Colin D Bell and Sara K. McMillan

3:30PM–5:10PM **Concurrent Sessions -2, Track 3 (Green Infrastructure)** (Calhoun) *Chair: D. Hitchcock*

1. **White Island: A Case Study in Implementing Living Shorelines in Urban Landscapes**
   Karah L. Conklin, Amanda Ludlow and Dennis Flynn

2. **Can Biomimicry Bring Ecological Engineering Out of the Woods?**
   Christopher A Streb

3. **Sustainable Stormwater on the Coast!**
   Greg P. Hoffmann, Blaik Keppler, Sadie Drescher and Katie Ellis

4. **Emerging Alternative Sources of Water Promoting Green Infrastructure in Urban Areas**
   Shashi Kant, Fouad H. Jaber and R. Karthikeyan

5. **The Role of Evapotranspirative Processes for Stormwater Management in Coastal South Carolina Watersheds with Shallow Groundwater**
   Daniel R. Hitchcock, Anand D. Jayakaran, Jessica A. Palazzolo and Thomas H. Epps

5:10PM–7:00PM **Poster/Exhibitor Reception** (Colonial)

7:00PM–11:50PM **Dinner on your own**

7:30AM–8:00AM **Check-in and Continental Breakfast** (Colonial)

8:00AM–12:00PM **Tours**

12:00PM–12:45PM **Lunch on your own or with tours**

12:45PM–2:45PM **Concurrent Sessions -3, Track 1 (Ecohydrology II)** (Pinckney) *Chair: J. D'Ambrosio*

1. **Stream Restoration, Floodplain Connectivity, and Nutrient Retention in 2nd order Appalachian Stream**
   Nathan C. Jones, C Guth, Durelle T. Scott, E. Hester and W. Cully Hession
2. **Analysis of Ferric and Ferrous Iron Concentrations in a Constructed Stream Restoration System**
   Peter I. May, Anita Alexander, Harrison Scherr, Shawn David, Derek Lam and Geoffrey Chan
3. **Tailoring Stream Restoration Design to Watershed Nutrient Reduction Goals**
   Angela Gardner Allen
4. **Stream Restoration Innovations Focused on Aquatic Habitat Enhancement**
   Gregory D. Jennings
5. **Rambunctious Floodplains for Urban Resilience, Health, and Biodiversity**
   Brian P. Bledsoe
6. **Eco-Hydrologic Indices of a Long-Term "Reference" Forested Watershed in Atlantic Coastal Plain**
   Devendra M Amatya and Carl Trettin

12:45PM–2:45PM **Concurrent Sessions -3, Track 2 (Nutrient Dynamics)** (Laurens) *Chair: M. Burchell*

1. **Impacts of Climate Change on Harmful Algal Blooms and Ecosystem Services of Lake Erie**
   Jay F. Martin, Yami Gebremariam Seyoum, Andreas Culbertson and Stuart A. Ludsin
2. **Redox Breakpoints: a Master Engineering Forcing Function for Water Quality Remediation of Impaired Basins**
   David C Austin

3. **Variation of Microcystin Levels in Fish Related to Algae Blooms in Lake Erie**
   David M Wituszynski, Chenlin Hu, Ruth Briland, Jay F. Martin, Stuart A. Ludsin and Jiyoung Lee

4. **Ecological Functioning of Coastal Stormwater Ponds and Their Impacts on Marine Receiving Waters.**
   Erik M. Smith

5. **Determining Ideal Nitrogen Loads for Restored Forested Wetlands Slated to Receive Agricultural Drainage Water**
   Michael R. Burchell, Tiffany L. Messer and Francois Birgand

6. **Tracking the Fate of NO_3^- through Restored Wetlands: A Mesocosm 15N Tracer Study**
   Tiffany L. Messer and Michael R. Burchell

12:45PM–2:45PM **Concurrent Sessions -3, Track 3 (Green Infrastructure II)** (Calhoun) *Chair: T. Moore*

1. **Performance of an Intensive Green Roof Using Native Plant Communities**
   Douglas J. Daley, Krystal A. White and Elliot Alexander

2. **A New Green Roof Media Utilizing Recycled Shredded Tires and Compost**
   Katherine H. Baker, Lauren K. Mehalik, Abigail S. Mickey and Shirley E. Clark

3. **Incubation of Innovative Methanogenic Communities to Seed Anaerobic Digesters**
   Freddy Witarsa, Stephanie Lansing, Stephanie Yarwood, Martina Mateu and Veronika Zhiteneva

4. **Emergy, People, and Saving the Rain: A Sustainability Analysis of Green Infrastructure in Syracuse, NY**
   Eugene P. Law, Stewart A.W. Diemont, Valerie Luzadis, Timothy Toland and Rian Croteau

5. **Varying Pretreatments and Retention Times in a Food Waste Anaerobic Digester**
   Andrew, P Bresee,, Grant Shriver and Stephanie Lansing

6. **Working with Nature to Restore Dunes, Prevent Erosion, Use Dredge Soils, and Establish Permanent Ecological Habitats**
   Rodney W. Tyler and Britt Faucette

2:45PM–2:55PM **Break**

2:55PM–4:15PM **Concurrent Sessions -4a, Track 1 (Special Curriculum Session)** (Pinckney) *Chair: D. Blersch*

1. **Facilitating Opportunities: Envisioning the Successful Conversion to Longleaf Pine with Graduate Students**
   Jon Calabria

2. **An Innovative University Course with a Focus on Real-World Problem Solving and Ecological Engineering**
   Andrew D. Ward, Jessica L. D'Ambrosio and Jonathan D. Witter

3. **Transforming Ecological Engineering Education Using a Hybrid Pedagogical Approach**
   Puneet Srivastava, O. O. Fasina, David M. Blersch, S. R. Chaudhury, P. K. Raju and Regina Halpin

4. **Entrepreneurship in Ecological Engineering Education**
   Patrick C. Kangas, Jamie Smith, Bryce Selby and Peter I. May

2:55PM–4:15PM **Concurrent Sessions -4a, Track 2 (Agroecosytems)** (Laurens) *Chair: J. Bevington*

1. **Assessment of Cattle Grazing Impacts on Integrated Crop-Livestock Systems**
   Tong Liu, Luis F. Rodríguez, Angela R. Green, Maria B. Villamil, Blake E. Lehman and Daniel W. Shike

2. **Influence of Carbon and Sediments on Transport of Nutrients from Pine and Switchgrass Ecosystems**
   Augustine Muwamba, Devendra M. Amatya, Herbert Ssegane, Tim Appleboom, E. W. Tollner, G. M. Chescheir, Jamie E. Nettles, M. A. Youssef, Francois Birgand and R. W. Skaggs

3. **Evaluating Nutrient Management Practices to Reduce Phosphorus Discharge from the Maumee River**
   Marie C. Gildow, Seyoum Y. Gebremariam, Jay F. Martin and Stuart A. Ludsin

4. **Identifying Suitable Conservation Strategies for an East-Central Illinois Agro-Ecosystem: a Coupled Human-Natural Systems Approach**
   Graham W Kent, Luis F. Rodríguez, Richard A. Cooke and George F. Czapar

2:55PM–4:15PM **Concurrent Sessions -4a, Track 3 (Wetland Design)** (Calhoun) *Chair: P. May*

1. **Evaporative Wetlands: Effect of Salinity on Evapotranspiration and Biomass Production of Four Macrophyte Species**
   Juliana Valencia and Juan Castańo

2. **Design Elements for Creating and Restoring Wetlands to Restore Ecosystem Functions**
   Changwoo Ahn, Kurt Moser, Kristin Wolf, Suzanne Dee, Rita Peralta, Alicia Korol, Greg Noe and Mary Voytek

3. **A Design and Research Case Study of a Large Constructed Stormwater Wetland in New Bern, NC**
   Laura S. Merriman, William F. Hunt and Kristopher L. Bass

4. **Assessing the Performance of Floating Wetland Islands for Nitrogen Management of Reclaimed Water**
   Rafael Vazquez-Burney, Jeffrey Harris, James Bays, Kerstin Kenty and Ryan Messer

4:15PM–4:25PM **Break**

4:25PM–5:25PM **Concurrent Sessions -4b, Track 1 (Special Curriculum Session II)** (Pinckney) *Chair: D. Blersch*

1. **Serious Learning Games for Ecological Design**
   David Tilley and Jose Luis Izurza

2. **Ecological Engineering as a Consulting Practice: What We Do and How Students Can Be Better Prepared**
   David C Austin and Jim Bays

3. **An Introduction to Geospatial Statistics: A Search for New Information from "Old" Data**
   James, L Bevington, Francesco Morari and George Vellidis

4:25PM–5:25PM **Track 2 -No Talks**

4:25PM–5:25PM **Concurrent Sessions -4b, Track 3 (Coastal Ecosystems)** (Calhoun) *Chair: C. Toms*

1. **Carbon Sequestration and Soil Carbon Accumulation in a 7-year-old Constructed Brackish Marsh in eastern NC**
   Yojin Shiau, Michael R. Burchell and Stephen Broome

2. **Sea Level Rise, Green Infrastructure And Resilience Along The Extant Brunswick-Altamaha Canal**
   Lisa E. Biddle, Jon Calabria and Jason Evans

3. **The Once and Future Lagoon: California Bar-Built Estuaries in the 21st Century**
   Christina Toms

5:25PM–7:00PM **Student Design Spectacle** (Marion Square)

7:00PM–11:30PM **Evening Social** (Southend Brewery)

WEDNESDAY, June 11, 2014

7:30AM–8:00AM **Continental Breakfast** (Colonial)

8:00AM–9:10AM **Student Design Competition Presentations and Awards** (Colonial)

9:10AM–10:40AM **Special Session - In Plenary** (Colonial)

10:40AM–11:00AM **Break, hotel checkout**

11:00AM–12:00PM **AEES Business Meeting** (Colonial)

12:00PM–1:30PM **Lunch** (Colonial)

1:30PM–6:00PM **Depart for kayaking trip** (Folly Beach)

6:00PM–11:30PM **Low Country Boil, Folly Beach** (Folly Beach)

ABSTRACTS OF ORAL PRESENTATIONS

Concurrent Sessions -1, Track 1 (Streams)

Developing a Full-Delivery Mitigation Solution – the Cannon Creek Stream Mitigation Site

Daniel H. Johnson[1] *and Will McGoldrick*[2]

[1]Wildlands Engineering, Inc., Mount Pleasant, SC, USA [2]SCDOT, Columbia, SC, USA
[1] djohnson@wildlandseng.com

In January, 2013 Berkeley County (County) issued a Request for Proposals (RFP) for coastal stream mitigation to support projects funded by the County's One Cent Local Option Sales Tax. The 'full-delivery mitigation' solicitation was only the second to be issued in the state of South Carolina. The RFP, which follows a similar approach to the NC Ecosystem Enhancement Program's full-delivery program, allows mitigation providers to submit mitigation projects that are appropriate to offset the projected impacts of specific Department of Transportation (DOT) or municipal projects and has allowed local municipalities and the S.C. DOT to contract for turn-key mitigation and transfer the development and risk of mitigation to the private mitigation sector. The submitted mitigation sites are evaluated based on technical merit, provider experience and expertise, and cost. The mitigation site that provides the most value is selected for contracting. Once contracted, the provider is responsible for funding and delivering mitigation. The Cannon Creek Mitigation Site was selected to provide stream mitigation credits to compensate for impacts to jurisdictional linear features associated with the widening of Henry Brown Boulevard and construction of the Jedburg Rd./I-26 and Sheeps Island Parkway/I-26 interchanges. The site is located within the Santee River Basin, Cooper River Watershed (Hydrologic Unit Code 03050201), and Middle Atlantic Coastal Plain Level III Ecoregion. Cannon Creek is a degraded and incised coastal plain stream system that confluences with the West Branch of the Cooper River, a 303d listed waterbody. The stream adjacent buffer is in poor condition and provides limited stormwater and nutrient filtering. Mitigation activities will entail Priority I and II restoration of approximately 4,500 linear feet of Cannon Creek and 300 linear feet of contributing tributaries and will generate approximately 16,100 credits. In addition, approximately 14 acres of wetlands will be perpetually protected via a conservation easement. This stream restoration project includes an existing condition assessment, detailed hydrologic and hydraulic assessment, mitigation plan development, landowner coordination, conservation easement acquisition, stream and wetland restoration, permitting, construction, and five years of post-construction monitoring. The project is anticipated to be constructed in November, 2014.

Concentration, Duration, and Frequency Relationships of Fine Sediment Transport on Biological Impairment

John S Schwartz and Robert Woockman

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Siltation, excessive suspended sediment in rivers and streams beyond some natural condition, is a major cause of water quality impairment in the United States. Total maximum daily loads (TMDLs) for sediment must be generated to meet state water quality criteria, but Tennessee, like most U.S. states, has no sediment standard that defines the levels that may cause impairment. Although 32 states have developed numeric criteria for turbidity or suspended sediment concentrations (SSC) or both, these criteria are typically written as a percent exceedance above background, and what constitutes background is not well defined. Defining a background level is problematic, considering SSC and related turbidity levels change with flow stage and season, and limited scientific data exist on relationships between sediment exposure and biotic response. This presentation summarizes two studies examining the impacts on aquatic biota from episodic fine sediment transport, one study in the Dakotas, and other in Tennessee. This Dakota study located in Northern Great Plains Ecoregion co-located 54 USGS gauging stations with flow and suspended sediment data, and fish data from federal and state agencies. Suspended-sediment yields were computed for each site, and yields were found to be significantly different between stable and unstable sites. Functional traits data was summarized by fish species found in this ecoregion, including attributes on mesohabitat preferences, water quality tolerance, trophic structure, and feeding, diet, and spawning behaviors. Using the species functional traits information and site fish presence/absence data, forming a matrix that included, per site, the number of occurrences a trait attribute occurred for fish species present. Ecological analysis found significant differences for several trait attributes between stable and unstable channels. Fish located at unstable sites tended to: 1) prefer open-water mesohabitat, 2) be dominated by herbivores with algae diet, and 3) exhibit non-guarding spawning behavior. The Tennessee study used continuously recorded sonde turbidity data, and using turbidity to estimate SCC. This study developed concentration, duration, frequency (CDF) curves to characterize the episodic behavior of fine sediment transport. CDF relationships were correlated at ten Tennessee Macroinvertebrate Index (TMI) sites, and it was found that basin size was a key variable to a stressor response. Use of functional traits data and CDF relationships examined in this study provide useful information supporting development of sediment TMDLs.

Runoff Production for Undeveloped Headwater Streams in the Lower Coastal Plains of South Carolina

Thomas H. Epps[1], *Daniel R. Hitchcock*[2], *Anand D. Jayakaran*[2], *Drake Loflin*[3], *Thomas M. Williams*[2] *and Devendra M. Amatya*[4]

[1]University of Tennessee, Knoxville, TN, USA [2]Clemson University, Georgetown, SC, USA
[3]SUNOCO, Darlington, SC, USA [4]USDA Forest Service, Cordesville, SC, USA
[1] thomasepps@gmail.com

Population growth has spurred on increased land development for the Lower Coastal Plain (LCP) region of South Carolina. Land cover change has been associated with declining water quality and stream conditions all over the world, often due to increased stormwater runoff generated by greater impervious areas that carries diverse pollutants from diffuse sources. Projections for the LCP show further population growth and land cover change for the next few decades that could have a negative impact on local water bodies. This can be abated through better development strategies that incorporate green infrastructure into stormwater management plans. Because of its coastal location and flat topography, the LCP experiences a seasonally shallow water table that makes the infiltrative practices common in green infrastructure design more difficult. Groundwater levels are variable due to seasonal evapotranspirative demand and the timing of replenishment by rainfall. The aim of this work was to build upon previous knowledge of local hydrology and to study the rainfall response in undeveloped headwater streams to establish a baseline for storm flow dynamics that will help predictions of runoff production that can be applied to improving stormwater management strategies. Two headwater streams in the LCP were monitored over a three year period for streamflow, water table level, and rainfall. Upper Debidue Creek is slated for development while Watershed 80 in the Santee Experimental Forest serves as a reference site due to federal protection. Storms greater than one inch of rainfall were selected over this period for comparison. Total storm response (all outflows) and the direct runoff (total minus baseflow; obtained from hydrograph separation) were used to assess runoff to rainfall ratios for larger storm events. Storm response ratios were compared to antecedent rainfall and groundwater levels to determine the best predictor for runoff production. While antecedent rainfall did not show a strong relationship with outflows, groundwater level just prior to a storm event did. Segmented regression results show strong evidence of a groundwater threshold level above which runoff production increases sharply. Runoff measurements from these storm events were used with rainfall to back-calculate Curve Numbers according to USDA methodology to determine whether locally accepted Curve Numbers used in stormwater management are good predictors of runoff. The range of Curve Numbers calculated from these storms was linked to the seasonally shallow groundwater levels.

On-site Stream Reconstruction on West Virginia Valley Fills

Leslie C. Hopkinson, J. D. Quranata and N. DePriest

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[1] Leslie.Hopkinson@mail.wvu.edu

Surface mining reclamation practices in West Virginia result in stable valley fills with planar shape profiles. Environmental concerns related to these engineered structures include the loss of headwater stream length, increased flooding risk, and elevated downstream conductivity and metal levels. One reclamation technique, geomorphic landform design, may offer opportunities to improve aspects of West Virginia valley fill design. The approach designs landforms in a steady-state, mature condition and considers long-term climatic conditions, soil types, slopes, and vegetation. This work will seek to answer the following question: Can stable, landforms be designed such that streams are mitigated or preserved on site, while maintaining the same overall footprint as conventional reclamation? A series of field work was completed to characterize mature landforms in southern WV. These characteristics were used to design landforms for three valley fills of varying size. Preliminary results indicate that the geomorphic landforms can account for 85-98% of the total fill volume of the traditional valley fill condition when streams are mitigated within the permit area. This value decreases by approximately one half when streams are preserved on site. Median slopes for the alternative designs were 10-20% compared to 40-50% of the pre-mined topography. Ultimately, the research will provide the coal industry and regulators with knowledge to advance reclamation.

Quantifying Flood Flow Stage Reduction Benefit in Two-stage Ditches

Jessica L. D'Ambrosio, Andrew D. Ward and Jonathan D. Witter

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Two-stage ditches have been used for more than a decade as an agricultural best management practice to return fluvial form and function to drainage ditches and to reduce nutrients such as nitrogen and phosphorus after they leave the farm field. This study addressed questions on drainage ditch management that include, but are not limited to: can alternative ditch geometries be used to manage flood flow; can we have confidence that an alternative ditch geometry will not increase downstream flooding and not exceed permissible velocities during flood events compared to a conventional trapezoidal ditch geometry; can a tool be developed to aid others in predicting and selecting appropriate places on the landscape to maximize flood storage volume. We addressed two objectives: 1. Create a series of hydrology scenarios at the cross-section scale based on measured discharge data that reflect conditions typical of agricultural ditches in the region over a range of drainage area sizes and landscape characteristics. 2. Determine how two-stage geometries affect flood flow attenuation and what the effect a two-stage geometry might be at a cross-section scale on storage volume, local flooding (stage), and permissible velocities. Based on an analysis of measured gage data from sites less than 26 km2, a stage reduction benefit can be achieved with implementation of a two-stage ditch resulting in less water in the agronomic field without exceeding permissible velocities. The hydrology response scenarios we developed were applicable for some modeled sites; however, in other modeled sites use of the USGS peak discharge equations provided better hydrology estimates. Combining the hydrology scenarios with site characteristics led to development of regression equations with easily obtainable parameters such as bed slope (i.e., 0.1%), drainage area (i.e., 10 km^2), and flooded width ratio (i.e., 3:1) to predict stage reductions. Equations were developed across a range simulated vegetation types using Manning's n as a roughness value. The equations can help agricultural resource personnel make better decisions about where a two-stage ditch would provide the most flood reduction benefit on the landscape. Our initial screening tool can be used to aid in predicting the probability of flooding in ditches at the farm scale, show the benefit of two-stage ditches on flood stage reduction, and selecting appropriate places on the landscape to implement two-stage ditches. Knowing how frequently discharges exceed bankfull and flood the benches can aid in determining the potential nitrogen reduction of the practice and where nutrient reductions can be targeted. Further study will allow us to make recommendations that can be used in future implementation of two-stage ditches across the Great Lakes region.

Development of Discharge-Frequency Relationships for Stream Geomorphological and Ecological Processes

Molly Moran, Andrew D. Ward, Jonathan D. Witter and Jessica L. D'Ambrosio

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The historical focus of stream/river discharge-frequency relationships has been on design for infrequent, extreme events. This relationship is commonly determined using instantaneous annual peak discharge data from United States Geological Survey (USGS) gaged sites. The use of annual peak series of data usually provides good estimates of extreme events and the frequency of these events is consistent with statistical concepts. An annual series of instantaneous values will, however, often provide misleading and incorrect estimates of the frequency and magnitude of discharges with recurrence intervals less than a few years. Many geomorphological and ecological processes function on these shorter timescales and are very dependent on the frequency of occurrence. Better understanding of frequency of these low flows is useful for quantification and comparison of water-quality benefits that arise from discharges that reach floodplain areas, as well as clarifying differing flows' contributions to sediment transport. An approach to finding more accurate frequencies for low flows was used with data from more than 150 USGS gaged sites in Michigan, Indiana, and Ohio that had drainage areas ranging from 100 to 2900 square kilometers and periods of record longer than 30 years. Across states and drainage areas, the expected statistical frequency of discharge events was seen to be inaccurate at more frequent recurrence intervals when considering how many times the discharge occurred or was exceeded in the gage's average daily discharge data series. As the recurrence intervals decreased, the difference between the statistically expected and actual number of occurrences was seen to have increased.

Concurrent Sessions -1, Track 2 (Phytoremediation)

Mycelium in the Biofilter: Accessing Fungal Dynamics in Wood Chip Biofilters Treating Livestock Emissions

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Biofilters used to capture and treat exhaust air emissions often experience highly dynamic shifts in moisture and temperature. Investigations of biofilter microbial community response to abiotic conditions and its feedback on capture and oxidization of emissions are limited, and have been focused primarily on bacterial oxidation. It has been suggested that increasing the portion of fungi in the biofilm might improve biofilm resilience and biofilter performance in such dynamic environments, but this is poorly documented beyond bench-scale. In this study, ergosterol and chloroform fumigation extraction (CFE) techniques were adapted to determine the ratio of fungi:total microbial biomass on and in wood media of a full-scale biofilter. This biofilter treats polluted air continuously vented from the deep pit manure storage below a swine nursery. Wood chip wafers were used as biofilm baits and pooling of surface scrapes and sample drill shavings facilitated assessment of microbial biomass dynamics in the biofilms and in the wood, respectively. A universal sample mass threshold was identified to make the protocol adaptable for other biofilms. In samples retrieved from various locations in the biofilter, there was no difference in fungal:total microbial biomass ratios inside the wood baits. In biofilm communities however, all microbial biomass increased near the biofilter inlet while the fungal:total microbial biomass ratio was significantly greater further from the inlet, coincident with a decrease in total microbial biomass and wood moisture content. In these drier wood samples, confocal microscopy showed fungal hyphae supporting biofilms and continuity between biofilm hyphae and their filamentous growth inside the wood chips. In addition to an adaptable sampling protocol, this work demonstrated the aptitude of fungi to resist desiccation stress. The ability of fungi to sheltering within porous media and expand biofilms upon rewetting may, in part, explain this resiliency.

Land Treatment of Food Processing Wastewaters: Reducing Metals and Nitrate Pollution Using Poplar Trees

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Land application of high-strength food processing wastewater can result in anoxic and anaerobic soil environments. Under these conditions, metals like manganese, iron, and arsenic can leach and pollute ground water, a major source of drinking water. On the other hand, nitrate pollution may occur under aerobic conditions due to nitrification of ammonium and organic nitrogen. Poplar plantations could reduce both metal and nitrate pollution while allowing increased loading rates of land application of food processing wastewater. Field and large column studies were conducted to identify underlying processes that contribute to the capability of poplar trees to reduce metal and nitrate leaching during land application of wastewaters, contributing to the field of ecological engineering by promoting development of sustainable ecosystems for the benefit of both humans and the environment. Initial small scale column studies indicated the capabilities of poplars to decrease metal mobilization through increasing evapotranspiration (crop factor of 3.86 ± 0.60), enhancing carbon treatment and metal uptake, and nitrate through denitrification and plant uptake. Results from large-scale columns and field studies are expected to confirm these observations under more realistic conditions. Analysis of research data from field and large-scale columns currently under progress are expected to indicate contribution of poplar trees to metal and nitrate mobilization by plant uptake, enhanced oxygenation and increasing soil redox potential, rhizostimulation of soil microorganisms, reduction of soil moisture, and increased carbon treatment.

Plant Ecology and Function in Stormwater Biofilters in Melbourne, AUS

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In the last two decades, water resource and stormwater management in SE Australia has led to extensive construction of stormwater biofilters. Their effectiveness and structure has been studied by the Facility for Advancing Water Biofiltration (FAWB) in Melbourne, VIC, AU. However, some systems receiving little maintenance may decrease in treatment effectiveness and infiltration capacity. Plant communities and hydraulic conductivity are being studied in Melbourne biofilters in collaboration with FAWB to evaluate the impact of management on biofilter function. Current plant community structure will be compared to seed bank analyses, planting plan during construction, and planting during maintenance. Current hydraulic conductivity will be compared to previous infiltration studies and level of plant and biofilter management. Results could be used to inform optimal long-term management plans for biofiltration systems in southern California.

Phytoforensics: Techniques for Assessing Plant Contamination

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Plants are solar powered groundwater pumps, often translocating contaminants above-ground, thereby providing an onsite source of information regarding site contamination. While plants have been widely used for remediation (i.e., phytoremediation), accessing this contaminant information has also allowed delineation of contaminated groundwater (i.e., phytoscreening). To screen the contaminants in tree tissues rapidly and cheaply, several novel analytical approaches will be briefly described. Such approaches include in vitro solid-phase microextraction (SPME) along with in planta SPME; the latter developed to repeatedly sample individual trees over long periods of time to assess seasonal trends in chlorinated solvent concentrations. Such sampling over four years has revealed that chlorinated solvent concentrations are highest in planta during periods of high transpiration. Passive sampling devices have been placed in trees to provide additional long-term monitoring without the need of SPME. Additionally, analyses have been performed on-site using in planta portable gas chromatography mass spectrometry (GC-MS) to provide real-time data. Collectively, these methods have been used to delineate contaminant plumes at numerous sites across North America and Europe. Of approximately 2,000 trees analyzed using these methods, chlorinated solvents were found in over 1,000 trees. These methods have also been used to demonstrate phytoremediation efficacy at field sites. When combined with estimates of transpiration, the measured contaminant concentrations have been used to estimate total contaminant mass removal at phytoremediation sites.

Performance of Large-Scale Algal Cultivation for Urban Water Quality Restoration in the Great Lakes

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Restoration of urban watersheds in the lower Great Lakes region must focus on low-cost remediation of continuing and legacy non-point inputs of contaminants from the aquatic environment. Controlled land-based cultivation of benthic filamentous algae offers a remediation strategy for aquatic environments that is potentially low-cost, can be easily implemented on land of marginal value, and can potentially produce multiple benefits from water quality improvements and biomass production. The results of research into the performance characteristics and economic viability of benthic algal cultivation for contaminant removal from a Great Lakes tributary waterway are presented. Two pilot-scale cultivator raceways were installed near the mouth of the Buffalo River in Buffalo, NY and operated from April to November of 2013. Water was continuously pumped from the river and passed over a cultivated bed of benthic algae in the raceway. Weekly-harvested algal biomass samples were analyzed for total productivity, ash content, nutrient content, and metals content, and inlet-outlet water quality was sample monitored throughout. Daily average productivity of recoverable biomass for the entire season was 14.1 g DW m^{-2} d^{-2}, with a maximum weekly average of 27.3 g DW m^{-2} d^{-2}. Recoverable biomass composition averaged 75.6% ash, 11.6% carbon, 1.3% nitrogen, and 0.14% phosphorus, and also included measurable quantities of heavy metals. In addition, increases in dissolved oxygen and pH were measured between the inlet and outlet. An economic model of large-scale algal cultivation for restoration of urban aquatic systems developed using these results suggests that the cost per unit recovery for any one elemental contaminant is high, but the combination of multiple remediation and restoration benefits from a single process mitigates the prohibitive cost.

Engineered Floating Vegetation Mats for the Passive Treatment of Acid Mine Drainage

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Engineered floating vegetation mats of emergent macrophytes are an emerging application of ecological engineering that have promising water quality improvement and habitat creation applications. However, relatively little research has been published regarding their design, construction, or effects on the underlying water column. The passive treatment of acid mine drainage often requires vertical flow bioreactors to render the water anaerobic, reduce metals (e.g., Fe^{3+}), and generate alkalinity via sulfate reduction. Engineered floating vegetation mats could improve performance of vertical flow bioreactors by providing for lower dissolved oxygen concentrations in the water column via inhibition of oxygen diffusion, a continual source of organic carbon for sulfate reduction and oxygen stripping via senescence, and dampened impacts on treatment performance from temperature swings via insulation of the water column. This study gives an overview of experiments used to explore the effects of floating vegetation mats on the underlying water column and details how they may be coupled with vertical flow bioreactors for higher performance sustainable acid mine drainage treatment.

Concurrent Sessions -1, Track 3 (Bioretention)

Low impact development in the lowcountry landscape: Using hydrology as a design element

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Over the next 20 years the population of the South Carolina coastal counties is expected to grow nearly 25%. Water quality, habitat degradation, sedimentation, and flooding have challenged Lowcountry residents for more than 300 years, and ongoing urbanization will further complicate these challenges. The economic prosperity of the region depends on the health of its water resources, and engineers must provide infrastructure for the growing human population while preserving and restoring vital ecosystem functions. Low Impact Development (LID) methods provide a conceptual framework for sustaining natural rainfall hydrology and managing urban runoff. However, concerns over the cost, complexity, and actual value of LID confound owners, design professionals, and regulators, thus limiting its implementation. The coastal landscape presents unique constraints to LID, but it also creates tremendous opportunity when coupled with sound land planning. Contrary to conventional "pipe-and-pond" stormwater conveyance infrastructure, LID seeks to maintain natural hydrology by using techniques that slow, spread, and soak stormwater runoff close to its source. In the Lowcountry, the land is flat, the soils are mostly sandy, and the water table is high. These specific attributes lend themselves to vegetated, open conveyance and seasonally-variable infiltration and evaporation cells that mimic the natural surface hydrology of the landscape. By treating stormwater as a resource within the context of a functional landscape, LID can yield healthy sites that harmonize human infrastructure and healthy ecology. This presentation will introduce and discuss the specific challenges and opportunities of LID along the South Carolina coast, citing project examples and recent research.

Evaluating the Performance and Long-Term Maintenance of a Failing Bioretention Cell in North Carolina

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Published data on stormwater runoff are relatively scarce from military installations, which are regulated under EPA's Energy Independence and Security Act of 2007 for hydrologic and water quality impacts. Bioretention is a stormwater control measure that intercepts stormwater runoff and reduces peak flows as well as certain pollutants. An existing bioretention cell on a military installation in North Carolina was chosen for study. This bioretention cell was installed prior to the publication of the latest state requirements for stormwater best management practices (BMPs). This provided an interesting opportunity to evaluate the current performance of a bioretention system that did not meet state standards, and to model various maintenance schemes required to restore hydrology in a failing system. The purpose of the study was to monitor the current performance of one of the bioretention cells to determine how well a clogged system can function from a water quality and hydrologic standpoint. This will help inform decisions about how to prioritize maintenance and retrofits of these systems. Flow-paced samples of copper, lead, zinc, nitrogen, phosphorus, and total suspended solids were collected at the influent, overflow, and underdrain of one bioretention cell for nine storm events in 2013. During six of the nine storm events, ponded water in the system was high enough to overtop the outlet structure, causing untreated overflow to exit the system. Excess ponding in the system is partially due to the low infiltration rate of the fill media. One-way ANOVA was used to compare means of mass loadings for each analyte between water entering the system as inflow and water exiting the system through the underdrain. Mass loadings of copper, zinc, Total Kjeldahl Nitrogen, ammonia, nitrate-nitrite, and total phosphorus were significantly different (α = 0.05) between the inflow and underdrain; however, loadings of lead, soluble reactive phosphorus, and total suspended solids were not significantly different (α = 0.05) between the inflow and underdrain. This indicates that the system is providing water quality benefits for some parameters but not others. Additionally, maintenance strategies (i.e. removing and/or replacing various depths of bioretention media) will be modeled using DrainMOD to determine the best way to restore hydrologic function to a clogged system.

Evaluation of The Performance of Five Low Impact Development Practices in Clay Soils

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Urbanization is altering the composition of landscapes nationwide, with urban areas characterized by a high proportion of impervious surfaces that adversely impact the water cycle of the region. The loss of infiltration of runoff into soil reduces ground water recharge. Increased surface runoff, velocity and pollution, all byproducts of rainfall on impervious surfaces, impede urban waterways tremendously. Increase in volume of runoff can lead to flooding, with receiving water bodies exhibiting stream bank erosion and channelization. Low impact development (LID) is considered to be a way to mitigate the adverse effects of increasing impervious cover, using decentralized measures to retain stormwater runoff on-site, and thereby seeking to mimic the natural pre-development hydrology of a site. Effectiveness of LID practices in various regions in the United States has been evaluated. However, modeling studies have suggested that the adaptability of LID designs to other regions is problematic, requiring modified solutions to be field tested in every location to confirm how they will perform. Therefore, there is still a great need to evaluate these practices in the field and to collect quantitative data on LID practices performance, especially in clay soils characterized by low infiltration. This project evaluates urban stormwater best management practices in a typical urban watershed in the Dallas Fort Worth area. The objectives were to design, construct and demonstrate the effectiveness of green building infrastructure at the Texas A&M AgriLife Research and Extension Center in Dallas. The five LID BMPs targeted in this project are permeable pavements, bio-retention area, rainwater harvesting, green roofs, and detention ponds. Reduction in both volumes and pollutants concentration were recorded for all BMPS.

Does it Pay to Act Mature? Assessing Bioretention Cell Performance Seven Years Post-Construction

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Bioretention cells (BRCs) are low-impact development stormwater management structures intended to integrate water quantity and quality management. By routing stormwater through a BRC with a specified media, vegetation, and mulch layer, nutrients, bacteria, total suspended solids (TSS), and heavy metals are removed. BRCs are also designed to reduce surface runoff volume and peak flow while encouraging groundwater recharge. Although guidelines estimate a BRC design life of about 25 years, most available data reflect the performance of cells less than two years old. The present effort is aimed at monitoring a BRC installed in 2007 to treat a 0.16 ha parking lot in Blacksburg, VA, USA to determine its performance seven years post-construction. Following construction, this BRC was monitored for five months to determine initial flow reduction and TSS, bacteria, and nutrient mass removal. By monitoring for the same parameters seven years later, changes in cell performance over time can be quantified. ISCO automated stormwater samplers are used to collected flow-weighted inflow and outflow samples, which are then analyzed for fecal indicator bacteria (FIB) (total coliforms, E. coli, and Enterococci), TSS, total nitrogen (TN), and total phosphorus (TP). To determine if denitrification is occurring within the BRC, media samples taken throughout the cell are also being analyzed via qPCR for a series of targets associated with common denitrifying bacteria (nirK, nirS, and nosZ). This analysis will help determine if denitrifying bacteria have colonized the cell, and if so, where within the cell they live. The bioretention media was also sampled to quantify changes in media nutrient content and particle size. Preliminary results indicate that the BRC remains effective at reducing peak flows and runoff, with only 5 of 12 storms producing outflow. Export of E. coli was observed following several storm events, indicating that some FIB may survive within the BRC between storms, only to be flushed out during larger subsequent events. Total coliforms and Enterococci were reduced by the BRC during all but one storm. Other anticipated results include positive mass removal of TN, TP, and TSS, although at a lower rate than when the BRC was first built. This reduced performance may be linked to a possible increase in TN and TP within the bioretention media. The median particle size within the top few centimeters of the bioretention media is expected to be smaller due to the inflow of fine sediment from storm runoff. If denitrifying bacteria are present in the BRC, they most likely live in the top layers of the cell, where there is a considerable carbon source. However, this will not aid in denitrification because the soil is rarely sufficiently saturated in the top layers to create anaerobic conditions. Results of this research will provide insight into nutrient and sediment accumulation in BRCs over time, allowing an estimate of the expected useful life of BRCs.

Removal Efficiencies of Bioretention Cells in Coastal South Carolina

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Flooding and stormwater control is an issue in coastal South Carolina because of shallow water tables, low gradients, and rapid urbanization in the region. A best management practice (BMP) using low impact design (LID) principles known as a bioretention cell (BRC) is gaining popularity for stormwater management. Five BRCs in four landscape positions (well-drained uplands, tidal-proximal, poorly-drained-uplands, and floodplain) were sampled during storm events along a primary stormwater path (inflow through the soil profile to the groundwater) and secondary path (inflow to the overflow/outlet where available) for water quality and instrumented for water table elevation and soil moisture. Samples were also collected during non-storm days to estimate ambient pollutant concentrations in the groundwater. Linear regressions were used to evaluate the removal (slope) and determine a calculated ambient concentration based on the y-intercept of the regression line. Pollutants tested were nitrate (NO_3^-), ammonia (NH_3), dissolved nitrogen (Diss N), non-purgeable organic carbon (NPOC), Phosphate (PO_4^{3-}), fecal coliform (FC), and E. coli (EC). The primary pathway within all the BRCs showed removal of 87 to 98% for NO_3^-, with the exception of the poorly drained uplands BRC (56-66%). The removal of NO_3^- - along the secondary pathway was 26-32%. The removal of NH_3 along the primary pathway within floodplain and tidal-proximal BRCs was 74-96%, while at the remaining two upland BRCs and along all the secondary stormwater pathways, NH_3 was being exported suggesting a short-circuiting along the secondary pathways. All the BRCs showed removal of Diss N (78-99%) along the primary stormwater path with the exception of the floodplain BRC that exported Diss N. The FC percent removal for all the BRCs was high (89-99%) with the exception of the tidal proximal and poorly drained upland BRCs along the primary stormwater path. All the sites had high removals of EC (93-97%) along the primary stormwater pathway. There was variability in pollutant removal rates that appeared to be linked to differences in landscape position, water table, and soil moisture - further analysis of removals in light of these variables will be presented. Calculated ambient concentrations (y-intercept of a linear regression) corresponded with observed ambient concentrations consistently at one of the well-drained uplands. Further analysis of the significance of measured ambient measurements in comparison to calculated values will also be presented.

Enhancing Climate Resiliency through Green Infrastructure: the Minnehaha Creek Watershed Case Study

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Green infrastructure, which refers to the network of soil-vegetation systems known to provide water quality and quantity benefits to urban and downstream ecosystems, may also increase the resiliency of urban areas to hydrologic extremes. Both the recent climate record and climate models suggest that such extremes, namely intense storms and drought periods, will occur with increasing frequency across many areas of the US, including the upper Midwest. The potential to enhance the adaptive capacity of communtities to climate extremes through green infrastructure was explored in two studies within the Minnehaha Creek watershed in SE Minnesota. In the first, the role of green infrastructure in dampening flood impacts associated with mid-21st century climate scenarios in urban and developing rural contexts was examined. In the second, the potential to augment stream baseflow during drought periods in an urban stream through stormwater infiltration within green infrastructure elements was quantified through complimentary field and modeling techniques. While it was found that hydrogeologic conditions in the study watershed were not ideal for sustaining stream baseflow in the case of drought, results of climate and landuse scenario modeling suggested the importance of preserving green infrastructure networks as communities develop to reduce flooding impacts associated with extreme rainfall events.

Concurrent Sessions -2, Track 1 (Ecohydrology)

Measured Stormwater Runoff Seasonal Variation in a Small Traditional Suburban Development in East Tennessee

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Urban stormwater runoff management is a keystone element to sustainable and low-impact urban development. In Tennessee, over 80 new municipal stormwater separate storm sewer discharge permits are approaching their renewal period, triggering an increased focus on runoff reduction methods and associated enforcement programs. Many of the tools that estimate runoff rely on the appropriate use and selection of runoff coefficients, which help to estimate the amount of runoff generated from precipitation as described by land permeability. In this study, stormwater runoff was measured for three years at two nested sampling locations within a suburban development (approximately 35 acres) with traditional stormwater drainage system (curb and gutter and large-storm detention) near Knoxville, Tennessee. A water balance approach was used to quantify runoff coefficients for each measured storm event and seasonal variation within the three-year data set was quantified. Results of this study will be presented along with a brief synopsis of lessons learned from a neighborhood-wide rain garden initiative.

Mitigating Stream Health and Conditions with Low Impact Development

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Urban growth contributed to increase stormwater runoff due to the increased in impervious surfaces. The increased of stormwater runoff has negative hydrological impacts on streams. Stormwater runoff contributes to impair stream water quality and results in problems such as loss of habitat, sedimentation, increased temperature, and loss of fish population. Traditionally stormwater control measures such as detention pond were designed and constructed to reduce and control peak flows. Nonpoint source pollutants were not addressed to be controlled using these measures. Therefore, Low Impact Development practices were developed to negate the negative impacts of urbanization on water resources by reducing the runoff volume and peak flows as well as improving outflow water quality. A sub-hourly time step of the Soil and Water Assessment Tool (SWAT) model was calibrated and validated to predict stream flows for the Blunn Creek Watershed for the time period 1987-2012. The results showed that the sub-hourly SWAT model provides reasonable estimates of stream flow for multiple storm events. Calibrated stream flows for a 2 year period using the 15- minute time step had an R2 of 0.78 and a Nash-Sutcliff coefficient (NS) of 0.78. The 2-year validation period had an R2 of 0.70 and a NS of 0.67. The calibrated SWAT model was used to estimate potential stream bank erosion in the Blunn Creek Watershed. Low Impact Development (LID) practices were incorporated in the SWAT model as an alternative stormwater control measures. The practices evaluated include: bioretention area or rain garden, permeable pavement, detention pond, and a combination of permeable pavement and bioretention area. The evaluation of stream bank erosion was based on the exceedance of shear stress. Results showed that the greatest reduction in runoff volumes, peak flows, and excess shear stress under both real and design storms was when combining both bioretention and permeable pavement. The evaluation of flooding in SWAT model was based on the percentage of flows that exceeded bank-full flows. Results showed that combining bioretention and permeable pavement had the greatest reduction in peak discharges for all recurrence intervals (2-year, 10-year, 25-year, and 100-year). SWAT output of stream flows along with a statistical model that was developed by City Of Austin which analyzes the relationship between hydrological measures and aquatic life were used in assessing the impact of LID practices on potential aquatic life communities. Reduction in peak flows and increasing both baseflows and Aquatic Life Potential (AQP) values were the factors used to assess flows coming out of LID practices. Results showed that a combination of permeable pavement and rain garden resulted with the highest percentage of increase in AQP values and baseflows and greatest reduction in peak flows.

Watershed Characteristics and Conductivity in Five Central Appalachian Watersheds

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Given the dramatic landscape changes associated with natural resource extraction in the Central Appalachian region, environmental repercussions related to water quality changes and aquatic biodiversity are of increasing concern. In addition to these large-scale anthropogenic activities, smaller, localized pollution sources such as inadequate sewerage may also affect nearby ecosystems. Generally accepted measures of aquatic biodiversity are family or genus-level classification indices calculated from benthic macro-invertebrate surveys, Such indices have been developed for use in assessment of surface waters in regards to the Clean Water Act's goal to maintain "biological integrity" of the nation' waters. Previous studies report negative impacts to in-stream macro-invertebrate communities related to salt toxicity and fine sediment deposition, particularly for sensitive benthic taxa such as Ephemeroptera (mayfly) Plecoptera (stonefly), and Trichoptera (caddisfly); measures of conductivity are therefore increasingly used as a proxy for potential impacts of some discharges on in-stream ecology. While several studies have linked conductivity and/or watershed characteristics to benthic community composition, very few have identified the specific constituents of conductivity responsible for losses in macro-invertebrate abundance and/or diversity. This work represents an analysis of data collected from 47 field sites in five Central Appalachian watersheds over two years. Here, we attempt to quantify conductivity characteristics in parallel with benthic macroinvertebrate community assessments relative to regional anthropogenic landuses including surface mining as well as insufficient sewage treatment.

Eco-Morphological Stream Design and Assessment Tools for the Alabama Piedmont

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A set of eco-morphological stream design and assessment tools for the Piedmont region of Alabama was developed to support effective stream mitigation. The tools include: (1) hydraulic geometry relationships (i.e. regional curves) for predicting stable stream morphology (dimension, pattern, and profile) related to channel-forming discharge and drainage area; (2) streambank erodibility relationships for Bank Erosion Hazard Index (BEHI); and (3) stream/floodplain eco-morphological relationships for predicting stream and riparian ecological functions related to morphological conditions. These tools will be used in site assessment, project selection, restoration design and implementation, and follow-up monitoring for evaluating the success of ecosystem restoration projects in Alabama. This presentation describes the data collection process, results, and applications for the relationships.

Stormwater Mitigation Performance through Regenerative Stormwater Conveyance (RSC) in North Carolina

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Regenerative stormwater conveyance (RSC) are open channel, sand filtering systems that utilize a series of shallow aquatic pools, riffle weirs, native vegetation, and underlying media beds to manage storm flow. Surface runoff entering the system is conveyed as non-erosive surface flow or subsurface seep through the media, and can leave the system as surface flow, seep out, or via exfiltration and evapotranspiration (ET). The sand media bed is composed of 80% sand and 20% woodchips – larger portion of organics than bioretention media. Although these systems are expected to perform similarly to other media-based low impact development (LID) stormwater control measures (SCMs), research is needed to quantify the ability of RSCs to reduce stormwater runoff and pollutants. Two RSCs were installed in North Carolina – the Coastal Plain (Brun) and the Piedmont (Alam). Brun receives water from a 12-ac, 10% impervious watershed with sandy soils. Alam receives water from a 3.5-ac, 80% impervious watershed with clay soils. Surface flow through each pool-riffle is monitored using weirs. Subsurface flow is monitored via sampling wells. A groundwater well is located next to Brun to measures groundwater interactions. At Alam, flow-based surface samples are taken and analyzed for N, P, and TSS . Data collection began in Oct 2012 (Brun) and July 2013 (Alam). Concomitantly, artificial storm simulations occurred at a field-scale RSC at NCSU's research site in Raleigh, NC. Along with surface grab samples, real time nitrate and TKN readings of subsurface samples in three sampling wells were collected. Nine storms were simulated between Jan – Feb 2014. Surface flow reductions through the RSC systems were 98% and 70%, for Brun and Alam, respectively. High groundwater levels at Brun required temperature mass balances to discern storm seepage and groundwater. The majority of surface flow entering the RSCs is released through seep out, with ET and exfiltration accounting for $<$15%. Water quality samples showed little reduction in nutrient concentrations throughout the RSC. Monitoring will continue through May 2014, with expected improvements in nutrient reductions as the system establishes. It is expected that nitrogen reductions will be observed throughout the length of the RSC system. The conversion of surface runoff to seep out has significant implications for stormwater mitigation. Seep out is released from the system and undergoes media filtration, similar to shallow interflow in predeveloped watersheds. Unlike traditional SCMs, surface reductions along RSCs alone may not accurately reflect the system's ability to mitigate stormwater. However, if seep out demonstrates significant pollutant reductions, RSCs will likely prove to be an additional tool for LID stormwater mitigation toolbox.

Concurrent Sessions -2, Track 2 (Ecosystem Disturbance)

Modeling an Urban Wetland's Methane Fluxes Using the Eddy Covariance Method

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Wetlands are the largest source of methane (CH4) worldwide but offer a wide variety of ecosystem services and are commonly constructed in the United States to mitigate wetland loss., particularly in and near urban areas. CH4 emissions were measured at the Olentangy River Wetland Research Park over three summers and three winters using an eddy flux covariance system. In this study, we used linear and neural network modeling to arrive at a general empirical model for methane emissions from the ORWRP. The variables selected by the criterion suggest that CH4 emissions are largely related to the volatization of water and also the activity of wetland vegetation.

Strawberry Swamp - a Swamp on The Edge

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Coastal forested wetland swamps are sentinel sites for salinity intrusions associated with large tidally-influenced or storm-driven incursions of estuarine waters that may also indicate rising sea levels associated with climate change. A coastal freshwater forested wetland in coastal South Carolina has experienced dieback of freshwater forested wetland trees associated due to increased salinity within the wetland. Vegetation in the wetland is transitioning from a closed canopy associated with common freshwater wetland trees such as bald cypress, water tupelo and swamp tupelo, to a more open canopy due to the establishment of salt tolerant grasses. The swamp is prime habitat for several species as evidenced by game cameras and amphibian recorders installed within the swamp. A team of researchers at the Baruch Institute examined a series of historical aerial images to track changes in vegetation through the years. Recently, several water level and conductivity sensors were installed along the salinity gradient to measure temporal variations in water level and salinity within the swamp. Details of the methods used to monitor water levels, salinity, changes in forest structure and preliminary results will be presented.

Defining C and LS Factors of the RUSLE to Model Soil Erosion in Urban Landscapes.

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The South Carolina Botanical Garden (SCBG) is one of the most important natural heritage sites in the state. Heavy rain events of July 2013 caused unprecedented damage to the SCBG, including the Natural Heritage Trail (NHT). Erosive storm runoff washed out many endemic species and structures in the garden including bridges. Soil deposition from upland areas to the valley of the NHT was appreciable but not uniform. Predicting soil erosion will assist in determining strategies to reduce potential erosion to occur from future storm events. The Revised Universal Soil Loss Equation (RUSLE) is an empirical equation used to estimate soil loss in agricultural fields. It consists of five factors: rainfall and runoff (R), soil erodibility (K), length slope (LS), crop management (C) and support practice (P). However, the application of RUSLE can be problematic in undulating landscapes with complex topography and a variety of land cover types. While R and K factors are relatively uniform throughout the SCBG, C and LS factors are more variable, with the LS factor as the most sensitive in soil loss prediction. Therefore, identification of the input parameters and appropriate use of the C and LS factors must be determined. Field assessment and ArcGIS software was used to estimate C and LS factor for each analysis unit at three different scales: subcatchment (large scale), land use area (medium scale) and raster cell of the Digital Elevation Model (small scale). The LS factor algorithm developed by Arnhold et al. (2014) was used by identifying all possible flow paths within each analysis unit and subsequently calculating the mean slope length and slope angle. Similarly, spatial statistics are used to estimate mean C values for each analysis unit. R programming language was used to compare the three soil loss estimation models. Model development and comparison in soil loss estimations will be presented.

Relating Emergy Intensity of Pollutants and Biological Indicators in Riverine Systems

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It has been theorized that the intensity of emergy, intensity defined as emergy per unit area or volume and emergy defined as the cumulative energy of all forms necessary to produce a component of an observed system, is predictive of the component's ability to do work or magnitude of influence on the system. In this work, we test this theory by the evaluating the relationship of concentration and emergy intensity of common wastewater pollutants in treated effluent (nitrogen, phosphorus, and suspended solids) to biochemical oxygen demand (BOD) and the Index of Biological Integrity (IBI) in receiving riverine systems. BOD and IBI will be used to indicate ecosystem health, with high BOD and low IBI indicating poor ecosystem health. We predict that higher emergy intensity of pollutants will correlate with high BOD and low IBI, with the composite measure of emergy intensity of pollutants having the highest correlation with the measured biological indicators. This result would support the theory that emergy intensity is indicative of influence in a studied system. From these results, we can develop the Emergy Intensity Index (EII), intended to predict pollutant impact on riverine ecosystems.

Identifying Controls on Stormflow, Nutrient and Carbon Export From Urban Watersheds with Stormwater Control Measures.

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Hydrologic and biogeochemical patterns are altered by urbanization as elevated concentrations of nutrients, sediment and dissolved organic carbon (DOC) have the potential to adversely affect receiving ecosystems. The goal of this research was to understand the timing and magnitude of water and solute export during storm events in two urban and two suburban watersheds with stormwater control measures (SCMs) in Charlotte, NC. We analyzed stream flow patterns for 109 rain storms from June 2010 – December 2011 to characterize hydrologic response, and a subset of 50 storms were sampled intensively to identify concentration patterns of four environmentally reactive solutes (nitrate, soluble reactive phosphorous (SRP), DOC, dissolved organic nitrogen (DON)). Sites varied with extent of urbanization and SCM type, and storms were sampled across a range of antecedent moisture conditions and precipitation event magnitudes. These aforementioned environmental factors were used to make comparisons of water and solute export between sites and to develop predictive relationships (namely linear models and regression trees) across sites. While event-scale runoff ratios did not differ significantly between sites, the total rainfall-runoff ratio was higher at the urban sites (between 47-49%) than the suburban (37-39%). Classification and Regression Tree analysis also showed land use as a primary control over the time lag between the centroid of precipitation depth and the centroid of stormflow volume, and that other environmental variables only led to deviations in this time lag at the least developed site. When comparing nutrient concentration magnitudes between sites, it was observed that both event mean and peak concentrations of nitrate were significantly higher at sites with wetland SCMs (0.706 and 0.448 mg-N/L, respectively) compared to those with wetpond SCMs (0.312 and 0.207 mg-N/L, respectively). However, SRP peak and event mean concentrations were controlled by land use, as the suburban sites (0.334 and 0.218 mg-P/L, respectively) were significantly higher than the urban sites (0.050 and 0.026 mg-P/L, respectively). Analyzing the nutrient data across sites revealed strong linear relationships between peak discharge and peak nitrate concentration, as well as seasonal controls on the variability of DOC export. Chemical flushing during events was fairly consistent across solutes and sites, as the pattern of cumulative solute mass exported mirrored that of cumulative stormflow volume. Results showed that for these sites land use is a primary control on stormflow export timing and magnitude. The magnitude of nutrient export can vary based on land use history (SRP), the type of SCM (nitrate) and season (DOC). The results have implications for design of SCMs in similar metropolitan areas.

Concurrent Sessions -2, Track 3 (Green Infrastructure)

White Island: A Case Study in Implementing Living Shorelines in Urban Landscapes

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Roux Associates designed the transformation of White Island, an 80-acre former municipal landfill, into rare maritime grassland habitat for the New York City Department of Parks & Recreation. The project served as mitigation for the loss of grassland habitat during construction of a nearby retail center. The ultimate goal of the restoration was to replace the existing degraded environment with a diverse maritime grassland habitat suitable for ground nesting shorebirds and other wildlife. To achieve this goal, the project included invasive species removal and control, grassland habitat creation and shoreline stabilization. This presentation will focus on the design and implementation of the shoreline stabilization activities as well as discuss the resiliency of the design following Hurricane Sandy. Prior to the project, the island exhibited severely eroded shorelines and exposed landfill debris. The first stage of the restoration effort involved stabilizing the island's shoreline to prevent waste from entering adjacent waterways. Living shoreline stabilization techniques (i.e., utilizing vegetation and bioengineering materials to provide natural erosion control) were selected to provide structural stability while also creating functional habitat. Three types of shoreline stabilization measures were utilized in the design including conventional armor stone as well as vegetated articulated concrete block and cellular confinement systems. Stabilization techniques were selected based on the slope, fetch and anticipated wave action for each section of the island's shoreline. Construction along the shoreline began in February 2012 and was completed in September 2012. In late October 2012, the island received a 15-foot storm surge during Hurricane Sandy, with no erosion or loss of vegetation, thus demonstrating the resiliency and superior performance of incorporating vegetation into stabilization practices. Results of this project have confirmed the success of living design elements to stabilize severely eroded shorelines.

Can Biomimicry Bring Ecological Engineering Out of the Woods?

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Biomimicry, or bio-inspired design, is best known and perhaps best employed in the world of industrial design, architecture and art. Without a doubt, technological innovations based on emulating nature's genius have led to advances in turbines, pumps, and even swim suits that increase efficiency and performance. But is there a role for biomimicry in the world of ecological restoration? The author explores this question through his experience using biomimicry as the design framework for a green bulkhead on the Cuyahoga River. The Cuyahoga River Navigation Channel has heavy barge traffic, frequent storm flows, and is lined by bulkheads for over 5 miles. The bulkhead design team is using a biomimicry process to design retrofits that will offer protection and forage for larval fish. Through this and other examples, we explain why biomimicry is more than just a meme. It has evolved into a formidable discipline that can be employed by ecological engineers as a tool for any design challenge. Moreover, it offers those practicing ecological restoration in ultra urban environments to expand their consideration to natural models outside of their system of reference, and perhaps achieve ecological functions more suited for the extreme novel ecosystems of our urban landscapes. We argue that ecological engineering, by incorporating elements of the the biomimicry design framework, may find a more succinct and evocative means of describing our discipline as we look to nature to better mimic ecosystem processes and services.

Sustainable Stormwater on the Coast!

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Development along South Carolina's coast is growing rapidly. Conventional development practices have been shown to increase stormwater runoff pollution significantly and alter coastal hydrology. These negative impacts from changes in stormwater runoff are well-documented. In coastal South Carolina, the impacts include decreased tidal creek and estuary health, reduced tourism and resource-related industries, increased flooding, and property damage. Often, low impact development (LID) practices are touted as a solution to these problems and an opportunity to create more sustainable, resilient environmental systems. However, progress on LID implementation in many coastal communities is hindered by a lack of engineering and planning guidance, among other barriers. During the past two years, the Center for Watershed Protection, Inc. has collaborated with the Coastal Training Programs (CTPs) at the Ashepoo-Combahee-Edisto (ACE) Basin and North Inlet-Winyah Bay National Estuarine Research Reserves (NERRs) to develop an LID Manual for Coastal South Carolina. There are two main goals for the manual. First, the manual will be a resource that meets the needs of engineers, landscape architects, planners, stormwater managers, and other coastal decision makers. In order to address these needs, the project team used surveys, informal discussions, and facilitated meetings with a diverse group of stakeholders to identify and understand barriers to LID implementation and present potential solutions. One of the biggest obstacles identified through the stakeholder interaction was that the different groups each require different types of information to overcome LID implementation barriers. Therefore, the LID Manual for Coastal South Carolina was divided into sections that targeted specific stakeholder groups, such as planning guidance and technical specifications. The second goal was to tailor content to the conditions in coastal South Carolina. To accomplish this, the project team facilitated a series of collaborative focus group meetings with applied science researchers and engineers. In these meetings the team learned about the unique challenges and opportunities for stormwater management in coastal South Carolina, including the potential impacts of climate change. Based on these interactions, the existing guidance, specifications, and design tools from other states and regions were modified, adjusted, or replaced so that the manual addressed the South Carolina coastal conditions. The resulting LID Manual for Coastal South Carolina will be an important tool to expedite the implementation of LID practices. Planners will now have the information they need to facilitate LID through ordinance and regulation changes; designers will have the design tools they need to develop effective practices; and regulators will have the specifications they need to ensure that LID efforts are implemented successfully and sustainably.

Emerging Alternative Sources of Water Promoting Green Infrastructure in Urban Areas

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Growing population with increased urbanization and concomitant rise in domestic water demand are posing serious challenges for future water supply. There is urgent need for addressing emerging alternative water resources especially for the regions with poor freshwater supply. The research aims at evaluation of emerging alternative water sources including of A/C condensate and greywater in urban area. The A/C condensate quantity and quality were evaluated for potential the water reuse. A computer simulation model based on psychometrics was developed to quantify the A/C condensate using relative humidity, dew point, and temperature of the outside and inside room conditions for unit mass of the dry air supply. The condensate quality was also analyzed for the parameters including the pH, EC, sulphate, nitrate, calcium, magnesium, chloride, and the heavy metals detection. The traces of the metals detected in the AC condensate include Zn and Cu. The research also emphasized on evaluation greywater for water-reuse in urban settings. Variability in greywater quality were considered and a portable in-house water treatment system was proposed. The decentralized unit considered was carbon-integrated membrane filtration system, which included pre-filtration with four serial filters of 50, 20, 10, and 5 micron followed by microfiltration (MF), granular activated carbon (GAC), ultrafiltration (UF), ultra violet (UV), and reverse osmosis (RO). Multi-grade effluent quality were analyzed at each stage of treatment for replicated samples of varying strength greywater from laundry, shower, and hand wash. The prioritized water quality parameters used for treatment evaluations included; BOD, N-NO3, P-PO4, Turbidity, TDS (Total Dissolved Solids), DO (Dissolved Oxygen), and TC (Total Coliform). High grade effluent were observed at UF, and RO units with consistent effluent flux. The multi-grade effluent obtained through portable greywater treatment unit together with high quality A/C condensate can be used for potable and no-potable water use. The quantitative and qualitative evaluations of the alternative sources depict their major potential in reducing municipal water-demand.

The Role of Evapotranspirative Processes for Stormwater Management in Coastal South Carolina Watersheds with Shallow Groundwater

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In the face of dual pressures in coastal South Carolina - residential and commercial development along with potential climate change impacts - water resource management becomes a formidable challenge. Hydrologic processes in coastal forested watersheds with shallow groundwater are typically driven seasonally by evapotranspiration. As a response to increasing urbanization, low impact development (LID) practices that are designed to decrease stormwater runoff and volumes by mimicking natural hydrology via infiltration and/or evapotranspiration are being investigated. This presentation focuses on ecohydrological criteria being developed for sustainable land and water resource guidance in coastal South Carolina, specifically in upland forested and freshwater wetland areas. Forest and wetland water budgets in watersheds with flat topography and shallow groundwater with the goal of defining pre-development conditions are being refined, including the seasonal influence of evapotranspiration on water table elevation as it drives highly variable watershed outflow and thus runoff throughout the year. Coastal vegetated stormwater control measures specifically engineered wetland and bioretention systems - are being investigated to determine hydraulic and water quality performance based on the influence of groundwater. An assessment of the evapotranspirative processes for both existing vegetation and installed practices (green infrastructure) - as well as their benefits via ecohydrological services at various scales - can provide useful guidance toward resource protection with the goal of creating resilient communities, whether via conservation or restoration efforts or better site design. These landscape elements are complex within and between these varying scales. Results have implications for watershed planning and site engineering, including stormwater management and design. These results also have implications for guidance toward the prioritization of conservation and restoration efforts. With accurate measures and predictions of evapotranspiration rates and the appropriate hydrological metrics, sustaining coastal water resources may be achieved to protect from flooding, water quality impairment, and degraded ecological health of downstream receiving waters.

Concurrent Sessions -3, Track 1 (Ecohydrology II)

Stream Restoration, Floodplain Connectivity, and Nutrient Retention in 2nd order Appalachian Stream

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Floodplain wetlands provide many valuable ecosystems services, and it is generally accepted that hydrologic connectivity between rivers and their floodplains can decrease the downstream flux of pollutants such as excess nitrogen (N) and phosphorus (P). This occurs because of the increased residence time of floodwaters and biogeochemical processing that takes place at the sediment-water interface when redox gradients form. However, in low-order streams where many restoration activities occur, the residence times experienced in the floodplain are relatively short, suggesting restricted biogeochemical processing. We conducted a year-long study within the floodplain of a recently restored 2nd order stream. Inundation experiments were conducted on a seasonal basis (e.g. spring, early summer, late summer, fall, and winter). During each experiment, stream water was pumped into a 450m2 floodplain slough for 3 hours. Flow was measured at the inlet and outlet of the slough, and stage was measured at three cross sections within the slough. For the first two hours of each experiment, water quality samples were taken at the three cross sections, and during the third hour, nitrogen uptake was measured using a TASCC injection. During each flood, a measurable "first flush" of soluble reactive phosphorus (SRP), dissolved organic carbon (DOC), and ammonium (NH4+) was observed. While particulate fractions were not measured, the floodplain was a source of SRP, a sink of total dissolved nitrogen, and variable source/sink of DOC during the five experiments. Nitrogen uptake was variable, but was an order of magnitude higher than typically seen within the stream channel. The results from the seasonal experiments were extrapolated to the entire floodplain of the associated restored reach using a simple inundation model. Because of the short periods of inundation, initial model results suggest limited water quality benefits (e.g. load reductions) are achieved from floodplain reconnection in low-order streams.

Analysis of Ferric and Ferrous Iron Concentrations in a Constructed Stream Restoration System

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Regenerative Stream Conveyance or RSC is an alternative headwater stream restoration technique that has recently been applied in Rock Creek Park, Washington, D.C. Techniques such as RSC are too often implemented without plans for post-construction assessment and monitoring. Here, we discuss water quality data from the repeated monitoring of a restoration site. The stream restoration unintentionally increased a naturally occurring condition whereby iron-oxidizing bacteria produced a rust-colored iron floc throughout certain sections of the site. The water quality parameters that were tested were ferric (3+) and ferrous iron (2+), dissolved oxygen concentration, dissolved oxygen percent saturation, pH, oxygen reduction potential, temperature, and turbidity. The focus of the study was on iron oxidation and reduction. The ability of saturated soils to oxidize the ferrous forms of iron, converting them to the insoluble ferric forms, was evaluated. A series of 23 consecutive pools were sampled from the restored stream system, and there were spikes of both forms of iron in the middle of the restored reach while lower levels of both iron forms were found in the upper and lower reaches of the stream. Implications for this type of stream restoration technique are discussed.

Tailoring Stream Restoration Design to Watershed Nutrient Reduction Goals

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As mitigation laws begin to solidify across the country, stream restoration has become an important tool in offsetting deleterious effects development has on lotic ecosystems. The recent final draft of "Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects" (Bergs et al. 2013) is an example of a quantitative tool that can be used in design and put back into a watershed model. Implementation of similar programs can be expected in the future as watershed planners broaden focus from Stormwater Control Measures (SCMs) to other engineered options for reducing pollutant loads to drinking water reservoirs and nutrient sensitive estuaries. Such tools and regulations should not be an afterthought or "bonus credit" of a design process, but should be the impetus for tailoring a stream design for the goal of nutrient reduction. This presentation reviews the literature to date on nitrogen specific removal rates for stream restoration projects and their components and provides research based design recommendations to maximize potential for nutrient removal. The discussion centers around the Chesapeake Bay rules and presents a design method for nutrient retention from the outside (upland and riparian corridor) to the inside (instream geomorphology and biogeochemistry) of a valley cross-section.

Stream Restoration Innovations Focused on Aquatic Habitat Enhancement

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Stream restoration projects attempt to improve natural stream functions related to hydrology, biogeochemistry, and ecology. Recent innovations in stream restoration technologies focused on aquatic habitat enhancement include toe-wood revetments, log-enhanced riffles, and log vanes. These structures used in combination with channel realignment, floodplain creation, bank grading, and native riparian planting, are intended to optimize stream habitat values. This presentation describes experiences in several watersheds with the design and implementation of restoration projects focused on aquatic habitats. Stream widths in these projects range from 5 to 100 ft, with the structures scaled to fit the channel size and expected stress conditions. Design and construction considerations for each structure will be presented, along with techniques for avoiding common problems such as dislodging and sedimentation.

Rambunctious Floodplains for Urban Resilience, Health, and Biodiversity

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Naturalization of stream and drainage system networks can be a driving force in water-centered urban planning that provides synergistic benefits on a variety of sustainability fronts. These fronts include the urban water cycle, mitigating temperature extremes and heat island effects on human health, and ultimately reducing vulnerability and improving robustness in the face of climate nonstationarity and extremes. An incentive is needed for decision-makers to proactively make significant investments in water-centered urban planning in an atmosphere of uncertainty. I explore a new suite of hydrologic techniques for risk, reliability, and uncertainty analysis as an impetus for improving the robustness of current floodplain management policies and making urban stream corridors more "rambunctious." Such a shift in the floodplain management paradigm can ultimately reduce vulnerability and renew opportunities for ecological engineering of novel socio-ecosystems and provision of ecosystem services. A case study on the Cache La Poudre River in Colorado is used to illustrate how the proposed risk analysis techniques can be integrated with floodplain management, stormwater, and riparian buffer initiatives to increase the footprint, connectivity, and societal benefits of urban stream corridors.

Eco-Hydrologic Indices of a Long-Term "Reference" Forested Watershed in Atlantic Coastal Plain

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Effects of land use change like conversion of forested lands for developments, particularly the increased urbanization near coastal waters in recent years, have heightened concerns on flooding, stormwater, rapid and increased freshwater and associated contaminant discharges to nearby water bodies and estuaries, and loss of ecosystem functions and habitats. In recent years, low impact development (LID) approach has been initiated by regulatory agencies to achieve a pre-development or a "reference" level hydrology and stormwater runoff from the developed or developing lands. In this presentation, we suggest that the long-term hydrology data and study results from an existing 1st order watershed acting as a control (with no disturbance for about last 80 years, except for one by Hurricane Hugo in 1989) within the USDA Forest Service Santee Experimental Forest located at the headwaters of the East Branch of Cooper River draining into the Charleston (South Carolina) harbor on the Atlantic Coastal Plain can be used as "reference" level eco-hydrologic information for "pre-development" scenario analysis in the LID and similar other design practices. We will present the data/information on water balance, water table dynamics, storm event hydrograph characteristics i.e. runoff coefficient, peak flow rate, time to peak, and event duration and their seasonal variability, as well as flood and low frequency curves. Analysis of these data from pre-Hugo period and 14 years after Hugo demonstrated the resiliency of this natural forest system to the hurricanes. Other characteristics such as surface depressional storage, runoff curve number (CN), forest potential evapotranspiration (PET) and actual ET for the same "reference" watershed useful for the LID and other best management practices, (storm)water management, and restoration works will also be highlighted. We hypothesize that these and similar other data/results from a network of similar long-term experimental sites in other eco-regions within the country, capturing spatial variability and year-to-year variability in climate, may provide the foundation as potential "reference" eco-hydrologic indices not only for pre-development planning and assessing the post-development impacts on surface and ground water in a region, but also provide a baseline for protection and restoration of watersheds and wetlands within urbanizing landscapes where LID and other best management practices are used to mimic the predevelopment levels.

Concurrent Sessions -3, Track 2 (Nutrient Dynamics)

Impacts of Climate Change on Harmful Algal Blooms and Ecosystem Services of Lake Erie

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Ecosystem services of Lake Erie include providing drinking water supply for over 11 million people, and sustaining an $11.5B tourism industry. However, many of the ecosystem services it provides are jeopardized by decreases in water quality, including harmful algae blooms (HABs) and hypoxia. While these declines have been hypothesized to worsen in the future due to climate change, this hypothesis has not been examined, and no quantitative predictions exist to guide management plans. To fill this knowledge gap and guide future management plans, we evaluated the impact of climate change on several of Lake Erie's ecosystem services using global climate models and IPCC scenarios as inputs to a Soil and Water Assessment Tool (SWAT) model of the Maumee watershed. Outputs from this model provided inputs to ecological models of HABs, hypoxia and fish abundance. Results include changes in Lake Erie water clarity, abundance and frequency of HABs and hypoxia from 2011 to 2099 for two IPCC scenarios (RCP2.6 and RCP8.5). While both scenarios predicted changes in precipitation and temperature, the RCP8.5 scenario predicted pronounced wet conditions in spring and warmer temperatures in winter and summer throughout the 21st century, leading to significant shifts in spring flow regimes accompanied by increased nutrient loads discharging to Lake Erie. HAB outbreaks during the years 2071-2099 will become more frequent and will cover up to seven times more lake area compared to HAB blooms observed in recent years. Similarly, water clarity will be significantly affected and hypoxia will become more frequent and spatially widespread in the lake during the last 30 years of the century. These results highlight the need to accelerate the adoption of management practices to mitigate further degradation of ecosystem services due to climate changes predicted for the end of the century.

Redox Breakpoints: a Master Engineering Forcing Function for Water Quality Remediation of Impaired Basins

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Nutrient flux from sediments is an important, sometimes predominant, forcing function setting trophic status and other state conditions of lakes, reservoirs, and estuaries. Authors commonly characterize the dynamics of these processes as bimodal phenomena: either aerobic or anoxic in character. In reality, the nature of these biogeochemical reactions is not so easily categorized. There are systems of redox reactions that lead to biogeochemical cascades on either side of critical state thresholds. Classic feedback phenomena sometimes characterize these processes. Wastewater and water engineers refer to these thresholds as redox breakpoints. For example, it is common practice to operate denitrifying reactors to nitrate breakpoints with inputs from redox probes. The numerical value of a given redox breakpoint will vary by the redox scale to which the probe is calibrated, by the manufacture of the probe itself, and by the relative concentrations and proportions of redox active solutes that can vary substantial between water and wastewater sources. The numeric value for a given breakpoint is operationally important at a given site, but has little theoretic meaning. Operationally, corroborating data empirically establish numeric values on the mV scale for a given reactor and desired breakpoint. Theoretically, what is important is that a redox breakpoint exists and can be determined. The proof of this concept is hundreds, if not thousands, of water and wastewater reactors that operate on redox breakpoints. A lake, reservoir, or tidal estuary is a biogeochemical reactor with identifiable redox breakpoints. Some common breakpoints govern flux of of iron, manganese, phosphate, ammonium, or methylmercury from sediments to the water column. There are opportunities for engineering interventions to manipulate these breakpoints to control these fluxes. The dissolved oxygen concentration may not adequately characterize these breakpoints and even may be irrelevant. Engineering manipulation of redox breakpoints can profoundly shift the trophic status of water bodies or suppress flux of methylmercury to the water column. This presentation will present data from projects that demonstrate controls on redox breakpoints in natural water bodies. Featured technologies are destratification, hypolimnetic oxygenation, and nitrate amendments in lakes, reservoirs, and a small tidal estuary. Manipulation of redox breakpoints is a powerful ecological engineering tool in practical and conceptual terms.

Variation of Microcystin Levels in Fish Related to Algae Blooms in Lake Erie

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Lake Erie is an important economic and cultural resource, but it is threatened by recurring blooms of toxin-producing cyanobacteria (blue-green algae). Lake Erie waters experiencing blooms have regularly been found to contain levels of microcystin, a potent liver toxin linked to human illnesses and animal deaths, much in excess of published World Health Organization limits. For this reason, concerns exist about the human health impacts of algae blooms on the lake, which remain largely unquantified. Further, changes in climate have and may continue to alter the bloom in size, duration, and intensity, possibly increasing the risk they pose to public health. It has been demonstrated that microcystin is transferred through food webs, and studies have found fish from Lake Erie containing various levels of microcystin, sometimes in excess of WHO guidelines for safe consumption. This is especially relevant to Lake Erie, as it supports the largest fishery of all the great lakes, accounting for billions of dollars of revenue as well as a distinct group of lifestyles. The discovery of microcystin in commercially and recreationally important fish species therefore has severe implications for the communities around the lake both economically and culturally, in addition to public health in general. Despite this, few studies have ana;yzed the variation of microcystin concentrations in fish within Lake Erie, and these past studies were all performed either on a single species, or on small samples of multiple species. Additionally, all were done within timeframes of one or two years. These studies derived conflicting results as to the danger of consuming fish from the lake, likely both because of the extremely variable nature of the algae blooms from year to year, and because of the different species which were studied. There is a need for studies that cover a wider range of species, and incorporate data from additional years. To help address this gap in knowledge, in the summer of 2013 we gathered large samples of three of the most commonly harvested fish in Lake Erie: Walleye (n>35), Yellow Perch (n>20), and White Perch (n>50). These fish were collected both before and after the peak bloom, and both inside and outside the extant bloom at the time of collection. By analyzing the toxin content of these fish, we are able to determine if fish size, species, location, and harvest time significantly affect the concentration of toxin in the edible part of the fish, and whether any of the fish harvested during this period exceed levels of microcystin established for safe consumption. Finally, a comparison with data reported in the literature allows us to estimate the effect of blooms on the toxin burden of the fish, leading in turn to an estimation of the public health threat posed by future expansion of the blooms. We will therefore have a better understanding of the system's resilience to safeguard public health under the stress of a changing climate.

Ecological Functioning of Coastal Stormwater Ponds and Their Impacts on Marine Receiving Waters.

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Stormwater ponds are the most common 'best management practice' for controlling stormwater runoff associated with development. They are particularly prevalent in the southeast coastal plain, due to the region's flat topography, shallow water table, and storm-driven precipitation patterns. A geospatial inventory based on 2006 aerial imagery documents over 14,000 ponds along the coast of South Carolina, representing a cumulative surface area in excess of 21,000 acres. Most of these ponds have direct discharge structures that ultimately drain to coastal waters. As such, understanding the water quality conditions in coastal ponds and assessing the potential impacts of their discharges on receiving waters is therefore essential for evaluating the effects of development on the ecological condition of the region's coastal zone. A systematic study of 26 residential ponds, located throughout the northern portion of SC's coastal zone, was conducted to address how these ponds function as ecological systems, how they respond to nutrient enrichment associated with development, and the effects their discharges have on ecosystem processes in marine receiving waters. Across all ponds, concentrations of total nitrogen (TN) were less variable than total phosphorus (TP), which varied by over two orders of magnitude and tended to increase with increasing residential development density. Total phytoplankton biomass was strongly related to TP concentrations, as were rates of net ecosystem metabolism (measured by the diurnal oxygen curve technique). The bulk of net organic production within ponds was in the dissolved form. While phosphorus appeared to be efficiently cycled within ponds, nitrogen inputs tended to be converted to and accumulate as dissolved organic nitrogen. Bioassay experiments revealed the dissolved organic matter discharged from these ponds did little to stimulate autotrophic primary production in tidal creek waters, but significantly increased the metabolic activity of heterotrophic microbial communities. Alteration of coastal hydrology due to proliferation of stormwater detention ponds, combined with excessive phosphorus loading associated with residential development, is thus promoting the creation of a new source of bioavailable organic input to the coastal zone; this input can significantly alter the net autotrophic/heterotrophic balance of receiving waters and likely contributes to the low dissolved oxygen conditions present in many of these waters.

Determining Ideal Nitrogen Loads for Restored Forested Wetlands Slated to Receive Agricultural Drainage Water

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Wetland restorations strategically designed to improve water quality should do so without negatively affecting surrounding ecosystems. Previous studies in the Albemarle-Pamlico peninsula, in North Carolina, have reported wetlands receiving agricultural drainage water to store water while reducing nutrients, sediment, and fecal bacteria. However, controlled experiments have been difficult to complete and wetland effectiveness is variable depending on such factors as soil type, loading rate, and wetland to watershed ratio. The primary goal of this study was to determine the amount of pumped agriculture drainage water that could be diverted from an estuary into wetland restoration sites without significant impact to downstream nitrogen limited receiving waters. A mesocosm experiment was designed to test wetlands constructed with two soil types from future coastal NC wetland restoration projects to develop a predictive model that would identify the optimum assimilation capacity within these systems. Six large wetland mesocosms were constructed and planted in 2011 with triplicate mesocosms for each soil type. Three smaller mesocosms served as controls for the experiment and contained only the simulated drainage water. Eleven studies were conducted from September 2012 to October 2013. Water was loaded into wetlands as batches, with NO3-N levels between 2.5 to 15 mg L^{-1}. Within the water column, dissolved oxygen, pH, water depth, nitrate-N, and ammonium-N were measured daily, nitrogen and dissolved organic carbon concentrations were measured hourly with the use of a UV spectrometer. Grab samples were taken from the water column on days 0, 5, and 10 to evaluate Total Kjeldahl Nitrogen, dissolved organic carbon, and chloride. Additionally, water temperature, soil redox, and nitrogen and carbon changes in plant and soil samples were measured to evaluate potential for denitrification and other biological uptake. Preliminary batch runs have exhibited NO3-N percent removals ranging between 41-100% dependent on soil type, temperature, antecedent moisture conditions, and nitrogen load. Multivariate statistical analyses were utilized to determine differences between nitrate-N reductions in the two wetland soil treatments and controls. Variables included carbon availability, temperature, antecedent moisture condition, N loading, and pH. Preliminary results indicate significant differences between seasons, residence time, and dissolved oxygen concentrations (α=0.05). A range of removal rate constants were determined from these wetland batch experiments to predict the assimilation capacity of the full scale wetland restoration areas during various times of the year and differing hydrologic and water quality conditions. Results from this project will determine the assimilation potential of these two wetland soils. Findings plan to be applied to sections of the full-scale forested wetland systems scheduled to come-on line in the next 2 yrs.

Tracking the Fate of NO_3^- through Restored Wetlands: A Mesocosm 15N Tracer Study

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Wetlands receiving agricultural drainage water have been found to effectively reduce nitrogen (N) loads entering adjacent estuaries in the Albemarle-Pamlico peninsula. However, whole system estimates of N transformations have been difficult to identify and quantify within these environments. Denitrification has been identified as the primary pathway for N removal within wetlands and provides complete removal of N from wetland systems. The second most important removal mechanism in wetlands is plant uptake, however as the plants die, mineralization of the tissues can re-introduce organic and inorganic sources of N to the wetland or downstream. Understanding the biogeochemical factors that affect N reduction in these systems could increase the potential for these wetlands to be designed for more efficient pollutant removal services. A mesocosm experiment was designed at North Carolina State University in 2011 to test wetlands constructed with two soil types for future coastal NC wetland restoration projects with the goal of developing a predictive model that would identify the optimum N load. However, the study could not confidently estimate the predominant removal mechanisms of nitrate-N. Therefore, a 15N isotope tracer study was completed to further improve our understanding of the fate of applied nitrate in these wetland systems. During August 2013, a 7 day 15N tracer study was completed. Simulated drainage water was enriched with 0.1% KNO3 -15N and loaded into the mesocosms. Sediment and biomass samples were taken at the beginning and end of the experiment to be analyzed for 15N/14N to assess the biomass and soil 15N and TN pools. Nitrate-15N, N2-15N, nitrate-N, nitrous oxide-N, ammonium-N, and Br- grab samples were taken on days 1, 2, 3, 5, and 7 of the batch run to determine nitrogen transformation pathways. NO3-N and dissolved organic carbon concentrations were measured hourly with a Spectro::Lyzer automatic field spectrophotometer probe. Additionally, grab samples were taken to access Total Kjeldahl Nitrogen and chloride. Dissolved oxygen, pH, water depth, and soil redox were evaluated throughout the experiment with specialized probes and a stage gage. Preliminary results showed significant reductions in nitrate-N ($\alpha = 0.05$) with 91% and 88% removal within 7 days in the wetland systems. Majority of the reduction is believed to be due to denitrification based on preliminary 15N evaluations. Results should quantify plant uptake and denitrification within these wetland systems during the end of the growing season and clarify the significance of total and temporary N removal. Findings will provide wetland designers a better understanding of N dynamics within these systems and could improved design methods for future restored wetlands.

Concurrent Sessions -3, Track 3 (Green Infrastructure II)

Performance of an Intensive Green Roof Using Native Plant Communities

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Green roofs are an accepted practice to reduce stormwater discharge and improve a building's energy performance. Rooftop environments present numerous challenges for designers due to extreme conditions of heat, insolation, wind, drought, freezing and nutrient stress. The SUNY College of Environmental Science and Forestry (Syracuse, NY) installed an intensive green roof on its new Gateway Center in 2012. Unlike sedum-based extensive designs, the Gateway green roof design is intended to replicate two protected native plant communities in New York. The eastern Lake Ontario dunes and the alvar pavement barren plant communities are adapted to environments analogous to rooftop settings. The publicly accessible rooftop design is intended to educate campus visitors, provide pollinator pathways through the urban Syracuse area, and incorporate rare or protected species that are not commonly accessed by the public. We will present lessons learned regarding roof design along with preliminary analyses from monitoring and modeling the heat and water fluxes in the system during the summer and fall of 2013. Hydraulic conductivity in native alvar soils is 2 to 3 orders of magnitude less than the soil medium specified for the roof, indicative that scientists and designers must have closer communication during the design phase. First year plant growth exceeded expectations; the extra soil depth provided an excess of moisture and nutrients compared with the analogous plant communities. Pore water samples indicate that the freshly applied soil matrix underwent a high degree of nutrient leaching during the first year; this nutrient leaching is a short-term, potentially adverse, effect. The green roof plants did not experience a dormant period during the driest part of the summer, which is common in the native communities. As expected, surface soil temperatures are directly affected by canopy cover, and the amplitude of diurnal variations in soil temperature decreases with depth. Reflected energy from adjacent walls have a noticeable effect on rooftop microclimate conditions, and we will explore how this affects plant selection design. Pollinator studies indicate that the flowering plants are successfully attracting pollinators.

A New Green Roof Media Utilizing Recycled Shredded Tires and Compost

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Green roofs are emerging worldwide as a low-impact development (LID) strategy. Artificial soils, more lightweight than natural soils, better accommodate the weight-bearing limit of buildings. A medium containing recycled crumb rubber supplemented with compost (RM) was compared to commercially available green roof media (CM). Leachate and solid samples were analyzed for culturable heterotrophs, coliforms and E. coli, bacterial DNA, nutrients, and community physiological diversity (Biolog) between the two media. Twice per week, 1.68 L pots filled with the appropriate medium were watered with synthetic rainwater. At the start of weeks 6 and 9, each pot was spiked with 20 mL of 104 CFU E. coli to simulate environmental contamination. Samples were assayed for heterotrophs and E. coli using Hach MPN and Millipore MF techniques. DNA was extracted using the MoBio PowerWater® and PowerSoil® protocols, amplified through PCR using 16S ribosomal and E. coli specific primers, and characterized through pyrosequencing. Biolog Ecoplates were used to assess the community physiological diversity present between the two media. Nutrient tests included ammonia, total nitrogen, nitrate, total phosphorus, and metals. Culturable heterotrophic microbial numbers were found to be higher in the RM compared to CM in both leachate and media samples. There was a transient increase in the number of coliforms after the E. coli spike. Coliform levels returned to acceptable EPA levels more quickly in CM than RM. In both leachate and media samples, microbial DNA concentrations were initially higher in the CM and continued to increase over time. As the study progressed, DNA concentrations in the RM increased to levels similar to the CM. E. coli was present in the final RM samples. Higher concentrations of nutrients were found in the CM leachate. Microbial community diversity appeared to be greater in RM samples. Overall, the RM showed no increase in the release of pathogenic microbes or nutrient loads and does not exceed regulatory standards. Although the microbial communities vary between the two media types, the RM has potential to be a good alternative to current green roof materials. This offers significant advantages both environmentally and societally and should be investigated further.

Incubation of Innovative Methanogenic Communities to Seed Anaerobic Digesters

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Anaerobic digestion (AD) is a microbial-based technology that can be used to convert manure into renewable energy in the form of methane (CH4)-enriched biogas. Since biogas production in unheated digesters decreases when temperature decreases in the winter, many systems are equipped with heating systems to maintain AD temperature, but the installation of these systems increase costs precluding small-scale farmers. There is a need to reduce the heating requirements of temperate small-scale AD systems. In this study, wetland sediment (WLS), landfill leachate (LF), and mesophilic digestate (MesoD) were used as different methanogenic sources to determine if they could increase CH4 production in digesters operating at 15, 25, and 35°C. The three inoculum sources were incubated (acclimated) and fed with autoclaved dairy manure for 90 and 196 days at the three temperatures, and then used as inoculum at different inoculum to substrate ratios (ISR) (50% (w/w), 35%, 20%, 0%) for two biochemical methane potential (BMP 1 with inoculum acclimated for 90 days, and BMP 2 with inoculum acclimated for 196 days) tests at the corresponding acclimation temperatures. In the BMP tests, serum bottles were filled with dairy manure and the designated inoculum source, capped to create anaerobic conditions, and biogas production monitored for 90 days. Quantitative polymerase chain reaction (q-PCR) was used to quantify the mcrA gene to determine changes in methanogenic concentration before and after inoculum incubation. Terminal restriction fragment length polymorphism (T-RFLP) was also used to determine changes in methanogenic community before and after inoculum incubation. At the end of BMP 1, the LF treatment incubated at 25°C, with 50% ISR, produced 194 $\pm$ 7 mL CH4/g VS, which was not significantly different from the volume produced by the MesoD treatment incubated at 35◦C and 50% ISR (202 $\pm$ 4 mL CH4/g VS), illustrating that the use of LF inoculum for digestion at 25şC could result in similar quantities of CH4 production as digestion carried out at 35°C using MesoD. There was an incubation effect at 35°C, with the highest CH4 producer in BMP 2 (incubated for 196 days) at 35◦C producing 1.2 times the amount produced by the highest CH4 producer at the same temperature in BMP 1 (incubated for 90 days); however, no significant difference was observed between the highest CH4 producers at 25°C in BMP 1 and 2. Overall, there was less difference between treatments that received 50% ISR and 35% ISR in BMP 2 than in BMP 1 at 25 and 35°C, illustrating that the effect of the ISR decreased as incubation period increased. The highest CH4 production observed at 15°C was at least 50-98% lower than values observed at 25 and 35°C. The correlation between CH4 production in the BMP tests and the inoculum methanogenic community composition will be presented.

Emergy, People, and Saving the Rain: A Sustainability Analysis of Green Infrastructure in Syracuse, NY

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The use of green infrastructure for stormwater management has been lauded for both cost savings and increased sustainability. In Onondaga County and the City of Syracuse, New York approximately $80 million has been spent on various green infrastructure projects over the past 16 years in an effort to reduce the impact of combined sewer overflows on the water quality of Onondaga Lake, one of the most polluted lakes in the United States. An emergy evaluation of 16 projects, four each for the four major green infrastructure types utilized (rain gardens/bioretention, tree plantings, green roofs, and porous pavements) was performed to compare the inputs and outputs of each system on a common basis. Construction, operation, and maintenance inputs were obtained from designers and contractors involved with each project. The results indicated that the dominant emergy inputs for many of these projects are soil and stone substrates and the labor and machinery used to install them, suggesting that making efforts to better utilize the existing sediments would considerably improve the sustainability of these systems. Porous pavement, which largely relies upon these inputs, had the lowest overall emergy sustainability index of the four green infrastructure types. Another trend that was noted was that positive economies of scale exist for green roof installations, but that the opposite is true of rain gardens and porous pavement projects. Sustainability evaluations such as this one could improve decision making related to the design and implementation of green infrastructure as a stormwater management alternative that improves city sustainability.

Varying Pretreatments and Retention Times in a Food Waste Anaerobic Digester

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Every year in America over 68 billion pounds of food goes to waste. Food waste is produced in high quantities across the United States, much of which originates in dining halls. In this case, food waste will be described as food that has been thrown away, and not composted or recovered. Landfills are anaerobic, so that food waste in them produces methane, which is a much more potent greenhouse gas than CO2. Instead of sending this food waste to landfills, efforts should be concentrated on diverting it to composting facilities or to anaerobic digestion facilities to produce usable energy. Anaerobic digesters are systems that create ideal conditions for methane production and then capture the methane for usable energy. Variations in pretreatment methods and retention times will be investigated to determine the optimal conditions for an anaerobic digester based on production of methane-enrich biogas. This research will be conducted as a prototype for a proposed large-scale anaerobic digester that will be used at the University of Maryland. In order to maximize methane production, and thus energy production, four iterations of influent characteristics will be investigated. Two differing pH values and temperatures influent values will be tested using two different retention times. The effectiveness of each pretreatment (pH and temperature) will be determined by the amount of methane-rich biogas produced by the digester. The two temperature ranges tested will be 35C and 25C at two pH levels of 7.5 and 6.5. These pH levels will be achieved using vinegar to lower the pH and lye to raise the pH. The four different influents characteristics would then be (35C, pH 7.5), (30C, pH 6.5), (25C, pH 7.5), and (25C, pH 6.5). These four different influent characteristics will then be exposed to two different detention times, five and ten days, resulting in a total of eight different test scenarios. Before and after the test, the digester will be washed thoroughly to ensure that pervious scenarios do not influence results. Inoculum will be used from an existing mesophilic digester to ensure methanogenic microorganisms are available. The tests will be conducted in 1 L reactors. Daily to tri-weekly tests will be conducted on the production of biogas and the percent methane of the biogas, as well as the volatile solids of the food waste before and after digestion to access degradation of the organic-rich substrate. It is expected that the food waste with 35C and a pH of 7.5 will produce the most methane, with levels 4 to 5 times the methane production averaged from dairy manure substrates. The results will be used in the design of the full-scale prototype anaerobic digestion design for the University of Maryland's dining hall food waste.

Working with Nature to Restore Dunes, Prevent Erosion, Use Dredge Soils, and Establish Permanent Ecological Habitats

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For over 15 years, observations of beach erosion and dune restoration have been logged by our team. Inventions of technologies for sediment control using Compost Filter Socks (mesh tubes filled with filter media) have become one of the leading tools used for effective sediment control in the construction industry. Changing the focus of this technology to beaches, inlets and marshe AND changing fill media to sand and dredge provides benefits that are economic and ecological. Combinations of SoilSoxx, gabions, vegetation, and proper designs can yield affordable, effective ecologically sensitive results. Focusing on rootzone benefits of organic matter, containment and vegetation allows for maximum dune success in shorter time. Relying on combined approaches of these sustainable technologies is a new management strategy to reducing bacteria in marshlands in coastal areas.

Concurrent Sessions -4a, Track 1 (Special Curriculum Session)

Facilitating Opportunities: Envisioning the Successful Conversion to Longleaf Pine with Graduate Students

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A service-learning project envisioned the conversion of a coastal area to a Longleaf-Pine/Wiregrass plant community. Graduate students worked collaboratively to document existing conditions, formulate a restoration trajectory and stipulate a transition strategy. Students communicated the results through a poster format and the site is now being considered for restoration as part of a mitigation plan. Service-learning pedagogy should not be overlooked for the development of professional students, particularly in landscape architecture. The interaction of the students, clients and faculty is beneficial. Students have the added pressure of working for a client, who becomes familiar with the design process and helps the faculty direct the intervention. This presentation outlines the process and reports on the students' reflections. Over the course of a long weekend, students visited the site, studied restoration and suggested a design in an intensive charrette format. Students indicated the focused effort on a real world experience was intensive. However, many reported that they enjoyed the challenge and look forward to the implementation of their design.

An Innovative University Course with a Focus on Real-World Problem Solving and Ecological Engineering

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Evidence of constructed canals and dams to support irrigated agricultural can be traced back thousands of years to the ancient civilization of Mesopotamia. In the United States, the first levee to prevent flooding along the Mississippi River was completed in 1727. However, it was during the 19th Century that river engineering really came to the fore in Europe, the United States and European Colonies. In contrast, to the growth of river engineering in the 19th Century the fields of fluvial geomorphology, ecological engineering, and stream restoration had not yet been established. It was the middle of the 20th Century before fluvial geomorphology became a recognized area of study at universities in the United States. The field of ecological engineering began to emerge in the second half of the 20th Century due to the work of Howard Odum (1924-2002) and in 1989 was formally established by Mitsch and Jorgensen. In the last few decades consideration of channel structural features such as pools, riffles and meander patterns has been ubiquitous but are often poorly understood. In stream engineering projects consideration of the ecology of the system is often inadequate. Much of the problem lies with our higher education system. Providing field experiences is complex, time consuming, expensive, and has liability considerations. Finding room in an engineering degree curriculum for science courses relating to stream ecology is a barrier. Perhaps, the main problem is a lack of academic instructors with the knowledge or interest in providing courses that transcend disciplinary boundaries. A common component of engineering accreditation requirements is meeting the following educational outcomes: (1) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability ; (2) an ability to function on multidisciplinary teams ; and (3) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. Real-world problem solving and team work is often the domain of one or two capstone design courses. This presentation will outline how a undergraduate/graduate upper level course on Stream Geomorphology and Watershed Hydrology has for more than a decade provided a consistent and reproducible learning experience that has led to many real-world solutions, incorporates each of the three educational outcome described earlier, and integrates hydrology, hydraulics, stream geomorphology, ecological engineering principles, and biological assessments. A foundational component of the course is learning to identify the problem, determine information needs, acquiring the needed information and data, and then using that knowledge to develop a solution that satisfies societal needs while also being an integrated self-sustaining solution.

Transforming Ecological Engineering Education Using a Hybrid Pedagogical Approach

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The traditional undergraduate engineering curriculum is based on a compartmentalized sequence of specialized courses that build upon the fundamental courses taken by the students in mathematics, chemistry, physics, and core engineering subjects (e.g. engineering mechanics and thermodynamics). The students are expected in the senior year capstone design experience to combine all of the learning in these compartmentalized fundamental and specialized courses into developing solutions to practical engineering problems. Unfortunately, several problems arise from this educational approach. First, students frequently lack motivation for learning fundamental material. Second, material is often presented one time and assumed to be mastered even though cognitive science reveals that repetition is central to effective learning. Consequently, students have difficulty retaining the concepts covered in the first three years and integrating them into a comprehensive capstone design experience in their senior year. The segmental learning approach results in a lack of student interest and ability to integrate material presented in different courses. Recently, we received funding from the USDA-Higher Education Challenge Grants program to address this issue in engineering curriculum. Our overarching goal is to enhance the quality of undergraduate instruction and curriculum in order to better meet projected workplace needs in environmental sciences. Since ecological engineering curriculum is relatively new, we plan to achieve these long-term goals by first developing and testing a pilot curriculum in ecological engineering. We propose to transform ecological engineering curriculum by introducing project-based "spiral curriculum" concepts, multimedia cases based on real-world problems, and hands-on investigations. By intertwining multimedia cases with a spiral curriculum approach that emphasizes hands-on laboratory exercises, we will create an innovative, hybrid pedagogical model. By instilling collaborative spirit in students through team study of multimedia cases, we plan to enhance their intellectual capabilities for working on complex interdisciplinary problems. As part of this project, we are collecting benchmark datasets on (a) the courses that needs to be included in a model ecological engineering curriculum and (b) the skill set the graduating students should have to be successful in the ecological engineering workplace. We plan to present the results obtained from the analysis of this benchmarking dataset in hopes of initiating a broader discussion on ecological engineering curriculum. We hope that our efforts would help the broader ecological engineering community to reach a consensus on a model ecological engineering curriculum that can be adopted throughout the nation in the near future. This would help make the ecological engineering curriculum attractive to a broader audience of students.

Entrepreneurship in Ecological Engineering Education

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Entrepreneurship by students emerges in certain disciplines such as computer science, in part because of the relative ease of programming software and because of the relatively high demand for useful applications. In other disciplines, such as ecological engineering and technology, this phenomenon is more limited with less student involvement. A qualitative model of entrepreneurship is presented and related to ecological engineering education. An analogy is offered between computer science and ecological engineering in terms of "programming" ecosystems to self-design applications to meet the demand of society in areas of water quantity and quality management, erosion control and biomass production. Possible positive and negative consequences of encouraging entrepreneurship by students are offered. A draft outline of a course in "Entrepreneurship in Ecological Engineering" is proposed. Experience from students, projects and curricula at the University of Maryland are used as context for the discussion.

Concurrent Sessions -4a, Track 2 (Agroecosytems)

Assessment of Cattle Grazing Impacts on Integrated Crop-Livestock Systems

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Livestock and crop production systems are often integrated to enhance productivity and land utilization in modern agriculture. Farmers in the Midwest are interested in grazing corn residue after harvest to reduce winter feed costs; however, the effects of cattle grazing on the performance of agroecosystems are poorly understood. Challenges in effectively managing these systems are potentially exacerbated by uneven grazing distributions, which could potentially cause negative impacts on soil properties and subsequent crop production, or represent missed opportunities for improving current management practices. We have developed a long-term approach to study grazing impacts on integrated corn-cattle production systems, and to develop decision support capabilities for sustainable management. Our central hypothesis is that uneven grazing distributions of cattle lead to a spatial heterogeneity of grazing impacts. Our rationale is that if we can better understand the key components and interactions in these systems, then best management practices can be developed to improve the system sustainability. Cattle locomotion data were collected via GPS collars through three fall grazing seasons in central Illinois. In addition, cattle performance, soil properties and crop yield data were collected in each grazing season. A set of analytical tools including data mining algorithms, statistical analysis and spatial analysis were used to study the spatial and temporal patterns of cattle movement during grazing. Based on the patterns identified from movement data, an agent-based model was developed to simulate the herd dynamics on corn stover. Movement of cattle was simulated by modeling the biological motivators (e.g. hydration and hunger) and external factors (e.g. forage, water, and darkness). The effects of two management practices (continuous grazing and strip grazing) on cattle performance and soil properties were also compared to an ungrazed control. The results show that cattle under strip grazing management had increased body weight gain compared to those in a continuous grazing system. Both grazing systems resulted in greater soil bulk densities and penetration resistance than the ungrazed control; however, their ranges are within optimal values for crop production. This study will improve the understanding of the spatial grazing patterns and impacts of cattle on agroecosystems, and provide the modeling capacities for studying different scenarios to identify best management practices for these integrated systems.

Influence of Carbon and Sediments on Transport of Nutrients from Pine and Switchgrass Ecosystems

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Nutrients attached to sediments are subject to export when runoff (includes drainage) occurs from coastal forest, agricultural, and urbanized lands to nearby estuaries. The carbon to nitrogen (C: N) and carbon to phosphorus (C: P) ratios are indicators of availability of nutrients. Switchgrass (Panicum virgatum L.) has been planted in rows between young loblolly pine (Pinus taeda L.) tree beds of a managed pine forest ecosystem in order to utilize that space and available resources within it, for potential production of cellulosic bioenergy crop. The objectives of the study were: (1) to assess effects of flow and water table elevation on total organic carbon (TOC) and total suspended sediments (TSS) and their interactions with the drainage water N and P and (2) to identify temporal changes of C: N and C: P ratios in water draining from watersheds with different forest and switchgrass management treatments. Four small watersheds of about 25 ha each located in Coastal North Carolina were used for the study: young pine (planted in early 2010) with natural understory (D0), young pine (planted in early 2010) with switchgrass in rows between pine beds (D1), mature pine (planted in early 1997) with natural understory (D2), and switchgrass only (D3). Switchgrass seeds were broadcasted in April 2012. Drainage flow, water table elevation, and drainage water quality parameters (TKN, NH4-N, NO3-N, phosphate, TOC, and TSS) were monitored from mid-November 2009 to early December 2013. Seasonal drainage water TSS and TOC loads increased with increase in drainage outflows and water table elevation. For all the sites, drainage water P concentration decreased with increases in TOC and TSS concentrations. However, N concentration increased with increases in TOC and TSS concentrations. The C: N ratios were low during the pine trees harvesting year (2009). During the first half of the year after planting pine trees on D0 and D1 and after planting switchgrass on D1 and D3, a decreasing C:N trend was observed and, thereafter, varied with variations in outflows. Based on the C: N ratio, we hypothesize that nitrogen in drainage water discharged downstream during the harvesting year and in the first year after planting switchgrass and pine will be more available for utilization in the downstream ecosystems. These results may be useful for planning of silivicultural management and management of drainage water quality downstream on coastal pine ecosystem.

Evaluating Nutrient Management Practices to Reduce Phosphorus Discharge from the Maumee River

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Recent studies indicate that increasing inputs of soluble reactive phosphorus (SRP) from agricultural watersheds is the leading cause of intensifying eutrophication and increasingly severe harmful algal blooms (HABs) in Lake Erie. This trend is particularly prevalent at the outlet of the agriculturally-dominated Maumee River. As the largest single source of SRP to Lake Erie, recent government publications have recommended the implementation of nutrient management plans to reduce SRP inputs from the Maumee by 41%. Although the recommendation is based on successful SRP reductions elsewhere within the United States, no quantitative analyses have yet verified the actual ability of these practices to reduce phosphorus discharge from the Maumee watershed. This quantification can be provided by using the Soil and Water Assessment Tool (SWAT) watershed modeling program to examine scenarios focused on the following three specific nutrient management plans: (1) fertilizer placement within the subsoil, (2) improved timing of fertilizer application to avoid heavy precipitation events, and (3) increasing adoption of spring-application of fertilizer with reduced autumn-application. Modeling these management practices both individually and in combination can predict potential SRP reductions. Analysis of these scenarios will provide further guidance on how to reduce SRP inputs to Lake Erie most effectively.

Identifying Suitable Conservation Strategies for an East-Central Illinois Agro-Ecosystem: a Coupled Human-Natural Systems Approach

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Nutrient losses from Midwestern agricultural production are contributing to the Hypoxic region in the Gulf of Mexico. To mitigate nutrient flows and address water quality issues in the Upper Mississippi River watershed, management must recognize diverse landscapes, land-use practices, and weather along with varied agricultural production, human priorities, values and institutions. There are well-established conservation strategies aimed at improving water quality, and public initiatives promoting their implementation. Identifying the suitable strategy for a particular producer in the appropriate area must reconcile economic, environmental and societal forces for effective watershed management. The aim of this study was to comprehensively model implementation of best management practices (BMPs) in the Upper Salt Fork River watershed in East-Central Illinois for environmental and economic outcomes. We implemented a natural systems model using the Soil and Water Assessment Tool (SWAT) and an agent-based (ABM) approach to model human systems outcomes. Three relevant conservation strategies for East-Central corn and soybean production (winter cover cropping, drainage water management, and seasonal nutrient application timing) were considered for economic outcomes (producer returns and yields, community budgets) and environmental outcomes (nitrogen and phosphorus transport). At the levels observed in the watershed, the implementation of these three best management practices is likely reducing nitrogen and phosphorus offsite transport by 8-10%, and increasing corn yields by 1.5%, at a cost of $3/acre. Winter cover cropping provided simultaneous environmental and economic gains to producers, when coupled with small fertilizer reductions ($<$5%). In general, larger fertilizer reductions ($>$10%) posed untenable economic losses independent of management decisions. Incentives for implementing BMPs were effective but expensive. Cost sharing was effective up to an adoption threshold, and enforcing taxes to induce adoption had the potential to become excessively punitive.

Concurrent Sessions -4a, Track 3 (Wetland Design)

Evaporative Wetlands: Effect of Salinity on Evapotranspiration and Biomass Production of Four Macrophyte Species

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According to Brix (2004), evaporative wetland systems are used as a zero wastewater discharge technology in which the water removal is reached through evapotranspiration. These system take advantage of the fact that the evapotranspiration in wetlands is larger than the reference potential evapotranspiration (Brix, 2004; Pauliukonis & Schneider ,2001). In addition, there are planting schemes that create oasis and "clothesline" effects that increases the evapotranspiration even more (Brix, 2004). Despite this advantage, evaporative constructed wetlands fed with wastewater, accumulate salts and nutrients within the system that may counteract the larger evapotranspiration rates (Macek et al., 2007, Ravindran, 2007). The aim of this study was to determine the salinity effects on evapotranspiration rates and biomass production of four wetland plants. Over 12 months, a lab scale pots planted with Typha latifolia sp, Phragmites australis sp, Juncus effusus sp, and Heliconia psittacorum sp. were placed in a greenhouse at Universidad Tecnológica de Pereira. Containers were randomly assigned at four salinity levels: 1%, 5%,10%15% NaCl concentration, and the pots were arranged randomly in a single rectangular block. Each container was flooded daily with salty water. Evapotranspiration were reported as the difference of weights between each feeding cycle (Howell, 1995). Unplanted pots were used as blanks. At the end of the experiment, the above and below ground biomass was calculated as recommended by Haddad et al (2006). Evapotranspiration rates were negatively affected by salinity. Data showed chronic salt stress for the pots fed with 15% NaCl. Juncus effusus sp and Heliconia psittacorum sp. showed early deterioration, while Phragmites australis sp and Typha latifolia sp were more resilient. Similarly, it was found that the biomass production is severely affected with the increase of salinity. Pots under high salinity levels showed a reduction on biomass production. Evapotranspiration was directly correlated to biomass production among salinity treatments ($r=0.915$, $p < 0.01$). ?

Design Elements for Creating and Restoring Wetlands to Restore Ecosystem Functions

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The practice of compensatory mitigation assumes that created and restored wetlands will replace losses in wetland structure and function within the 5 to 10 year monitoring period required by mitigation regulations. Numerous reviews of past permitted projects were highly critical indicating that few mitigation projects were deemed successfully constructed replacements. The goal of compensatory wetland mitigation is no-net-loss of functions, and services, not acreage. There is generally poor scientific understanding of how we can facilitate the development of ecosystem functions and services to meet functional mitigation. Still, there is no exemplary methodology and design elements that can guide wetland creation and restoration to guarantee or at least improve the development of ecosystem services. We studied the effects of design elements (i.e., microtopography-MT, hydrologic connectivity-HC, and planting diversity) that can be applied or managed in created and/or restored wetlands to facilitate the developments of soil properties and processes that support the development of ecosystem services of water and habitat quality. The goal of the study was to characterize HC, MT, and planting diversity in created mitigation wetlands and to investigate the effects of the key abovementioned variables on the development of ecosystem functions, including denitrification, soil carbon accumulation, and biomass production. The study results reveal how the design elements (i.e., MT, HC, and plant community diversity) interact or are interrelated, and how they influence wetland hydrology (e.g., water table depth-WTD), soil development, and plant community (diversity index, H') that drive and control most ecological functions to be developed in created wetlands. The understanding generated by this study will provide useful information that will improve the design protocols for created/restored mitigation wetlands. Wetland designers and engineers will be encouraged to develop creation or restoration plans that adopt the knowledge to be obtained from the proposed study in designing and monitoring mitigation wetlands.

A Design and Research Case Study of a Large Constructed Stormwater Wetland in New Bern, NC

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This project was a unique water quality partnership between the City of New Bern, North Carolina, The North Carolina Ecosystem Enhancement Program (EEP), and the North Carolina Clean Water Management Trust Fund. The project involved the construction of a stormwater wetland to capture and treat runoff from a 486-ha highly urbanized watershed in New Bern, NC. The wetland was proposed as an environmental initiative by the City, and as a part of the EEP Nutrient Offset Program. The project is unique in both its size and scope and is the largest stormwater retrofit built to date in North Carolina. The site location and contributing watershed represents a rare chance to intercept stormwater before it gets to the Neuse River, less than one-kilometer away, and coastal estuarine system. The project site is located on a 21-ha tract of land already owned by the City of New Bern. Prior to construction, the tract included approximately 6-ac of freshwater wetlands adjacent to Jack Smith Creek. The remaining 15-ac is open, cleared, and undeveloped. The size of the tract and its proximity to the creek created the potential to use it for stormwater treatment. The completed project now includes approximately 10-ha of planted stormwater wetland areas, 0.5-ha of wetland creation, 1.0-ha of wetland enhancement, 4-ha of wetland preservation, with all remaining disturbed areas planted in native grasses. The designed areas consist of 5 different cells with varying characteristics: i.e. no organic amendment vs. organic-rich soils, meandering streams connecting pools vs. a sheet flow design. The water from Jack Smith Creek is directed into the wetland using pumps operated by float switches. In addition, the site is currently being used by NC State University as a wetland research park to evaluate the ability of large-scale wetlands to improve water quality. Water quality and hydrology monitoring stations are spaced throughout the site to evaluate its performance. Vegetation surveys are also being conducted to compare species richness in organic-rich soil vs. organic-poor soil (sand). It is our hope that this project will set a new standard for treating stormwater at a watershed scale and is an education center for design and construction of stormwater control measures in a coastal environment. The research that results from this project will not only expand the knowledge base in stormwater treatment, but also provide guidance on how to develop water quality goals balanced with ecological services and surrounding environments.

Assessing the Performance of Floating Wetland Islands for Nitrogen Management of Reclaimed Water

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The Pasco County Master Reuse System (PCMRS), located in Florida, USA, is the sole method of wastewater effluent management for Pasco County. The PCMRS is a flexible system serving approximately 12,000 residential reclaimed water customers. As regulations evolve, Pasco County is committed to complete water reuse for beneficial purposes. The County's vision includes growth to over 25,000 residential reclaimed water customers. Consistent with the Total Maximum Daily Load (TMDL) for Tampa Bay, the PCMRS was given an allocation for total nitrogen (TN) to the Hillsborough Bay Drainage Basin (HBDB), which drains directly to Tampa Bay. This value is calculated based on an assumed TN attenuation rate for reclaimed water used for irrigation as it infiltrates through the soil and a representative concentration of TN in the PCMRS. To meet this allocation the County must lower TN concentrations in the reclaimed water applied in the HBDB. One strategy the County is pursuing is to passively use storage facilities to reduce TN. The County currently operates a 100 million gallon (MG) reclaimed water reservoir and a 500 MG reservoir is currently under construction. As a possible storage system enhancement, floating wetland islands (FWI) were studied. Passive reduction of TN by FWI on reclaimed water reservoirs could allow for the increased use of reclaimed water within the HBDB. To assess the efficacy of FWI to reduce TN in reclaimed water reservoirs, an 18-month controlled study was conducted. The study consisted of the installation of a total of 1,600 square feet of FWI within a four-acre test cell receiving reclaimed water at rates designed to mimic reclaimed water reservoirs. Monitoring was conducted of the hydrology, weather, water quality, and plant tissue content, as well as a tracer study, to assess treatment potential, and sizing criteria. Removal efficiency for TN was measured to be approximately 63% during the performance period after the FWI were established. Average TN concentrations were reduced on average from 6.4 mg/L to 2.4 mg/L. The results were compared to a 3-month control period after the FWIs were removed from the test cell. By evaluating the difference between the two periods, the rate at which the FWIs removed TN from the test cell was calculated to be 0.9 lbs/sq.ft of island per year. The results revealed that during the performance period, TN treatment was consistent with rates measured in treatment wetlands, and that TN treatment was superior with the presence of FWIs. In addition to treatment performance, observations were drawn related to habitat creation, species succession, and nuisance species control.

Concurrent Sessions -4b, Track 1 (Special Curriculum Session II)

Serious Learning Games for Ecological Design

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The introduction of serious learning games (SLG) into the ecological technology design curriculum was explored. Serious games are games designed with the purpose of teaching knowledge, developing skills and thinking in new ways. During the last decade it has received national and international attention as a unique method for improving individual learning. We first explored the utility of SLG in an urban ecohydrology design course where students develop original serious games based on course content. We learned that students appeared to relish their time in-class in general and especially loved time spent developing and playing their games. Specifically, we learned: 1) do not have students design games for lower-level audiences (e.g., high school, non-majors, general public) because it allowed the students to "dumb-down" the content; 2) do not allow students to use trivia cards as a main game mechanic because it only encourages memorization and does not force players to think more deeply about strategy or connections; and 3) some students were highly satisfied with the game design experience but others thought it was a waste of time. In our second effort students in energy & environment developed games called settlers of a land where they were supposed to use course content (systems diagramming, energy analysis, emergy accounting, etc) to design SLG that fellow students could play. We will report on the successes and failures of our fledgling efforts and review the theories behind the pedagogical benefits of SLG.

Ecological Engineering as a Consulting Practice: What We Do and How Students Can Be Better Prepared

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In the consulting industry, de-facto ecological engineering is a thriving, innovative practice area of great disciplinary diversity. The meta-definition of ecological engineering as the design of nature and society for the benefit of both provides a vital intellectual and ethical orientation to professional practice. A multitude of projects provides the details of its realization. What is much harder to do is provide theoretical frameworks for professional ecological engineering practice. We are too intensely engaged in demanding project work, however, to define what it is that we do. The market forces a certain ad-hoc structure to ecological engineering practice, but as projects accumulate, patterns of practice emerge along with design expertise. There is constant mingling of disciplinary boundaries. Unfortunately, the market rarely calls for "ecological engineering services" per se. Professional ecological engineering practice calls for ecologically literate and design-savvy application of foundational disciplines. A hard reality of consulting practice is that work gaps in any one discipline are inevitable. A multidisciplinary education is decisively beneficial for consistent, full-time work. The M.S. or Ph.D. student who 'gets' ecological engineering and has solid training in core disciplines is an excellent potential hire for professional practice. Undergraduate education my not offer sufficient preparation. As the field of ecological engineering progresses, some concepts from the 1990s may need reevaluation with regard to relevance to professional practice, e.g.: 1) Treatment wetland design fundamentally employs unit process methods. Thus, the classic assertion that ecological engineering does not use them needs substantial modification. Although many in industry once mastered Odum diagrams (or STELLA equivalent) in graduate school, they are rarely used or requested in professional practice. Life cycle analysis (LCA) - arguably a form of ecological engineering - is typically constrained to human-dominated processes and systems, and rarely incorporates emergy analysis as a standard practice. The point of these examples is not to criticize curricula; rather, we emphasize that market drivers now shape professional ecological engineering practice far more than early theory that gave birth to the discipline. How these drivers shape practice has practical implications for student preparation and should be intense interest to developers of ecological engineering curricula. This presentation will provide a project-based overview of professional ecological engineering practice from an environmental consulting perspective. The goal is to contribute this view to the overall discussion of curriculum development. An examination of our professional ecological engineering practice can be a useful guide toward extracting a basis for the structure of ecological engineering curricula and training.

An Introduction to Geospatial Statistics: A Search for New Information from "Old" Data

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Currently, researchers are facing challenges in regards to the sources, availability and reliability of funding. Whether or not this trend is to continue is uncertain but what is clear is the need to derive more value from every study. Another current trend is the adoption of gps and other georeferencing techniques even for studies whose primary objective is not spatially based. For example, many soil studies will georeference samples so that new samples can be taken from the same location at a later date yet, the primary use of the samples is to study something inherent to the soil such as the relationship between pH and organic matter or other soil attributes. However, it is not the samples, their intended use, or the data they yield that provides value. New knowledge is synthesized by the analysis portion of a study. Therefore, adding new analysis techniques can increase the knowledge and value derived from a study. Since many georeferenced datasets have not undergone a spatial analysis, there is an avenue to squeeze more value from already collected (and paid for) samples. In particular, factorial kriging analysis (FKA) is a well-studied yet underutilized technique. FKA is a multivariate spatial technique that is often describes as a spatial principal component analysis (PCA). Benefits include isolation of spatially dependent correlations, identification of underlying, sometimes causal processes, and characterization of the spatial scale of the phenomena under study. This talk will provide an overview of FKA, discussion of its benefits, and some examples.

Concurrent Sessions -4b, Track 3 (Coastal Ecosystems)

Carbon Sequestration and Soil Carbon Accumulation in a 7-year-old Constructed Brackish Marsh in eastern NC

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Carbon sequestration in wetlands through accumulated plant biomass can potentially make these ecosystems net carbon sinks. However, the dynamic of accumulated biomass (carbon input) and greenhouse gas (GHG) fluxes (carbon outputs) have not been well studied in brackish salt marshes with salinities $>$ 20 ppt. This research was conducted to provide a clearer understanding of whether carbon sequestration can be considered a significant ecosystem service provided by restored brackish salt marshes. Since March 2011, GHG samples were collected using a replicated static chamber method within three distinct plant zones (S. alterniflora, J. roemerianus and S. patens) at a 7-year-old restored tidal brackish marsh and a nearby natural marsh in Carteret County, North Carolina. In addition, two plant biomass harvests (aboveground and belowground) were conducted before the beginning and near the end of the 2013 growing season to estimate the primary productions from different vegetation types. Aboveground and belowground litter bags study were conducted to estimate the decomposition rates of different vegetation types in the marsh during 2013. Within a salinity range 20-30, fluxes of carbon dioxide (CO2) were 0.39-0.74 g C m^{-2} day^{-1}, methane (CH4) were -0.1-1.4 mg C m^{-2} day^{-1} and nitrous oxide (N_2O) were -0.04-0.09 mg N m^{-2} day^{-1} in the restored marsh. Average biomass accumulation rates were 6.83, 4.76 and 5.92 g C m-2 day-1 at the Low, Mid and High marshes, respectively. However, GHG emissions were lower in the natural marsh, where fluxes of CO2 was 0.22-0.40 g C m^{-2} day^{-1}, CH4 was 0.1-0.9 mg C m^{-2} day^{-1} and N2O was 0.02-0.05 mg N m^{-2} day^{-1}. Average biomass accumulation rates were also lower in the natural marsh, where the rates were 10.24, 3.40 and 4.99 g C m-2 day-1 at the Low, Mid and High marshes, respectively. We estimated overall net carbon storage rates were 5.29 and 6.49 g C m^{-2} day^{-1} at the restored and the natural marshes, respectively. The soil carbon content in the restored marsh was expected to increase annually by 0.97 %, 0.18 % and 0.53 % in the Low (S. alterniflora), Mid (J. roemerianus) and High (S. patens) marshes, respectively. Our results show restored brackish marshes served as effective carbon sinks and carbon sequestration should be considered as one of the important ecosystem services in wetlands.

Sea Level Rise, Green Infrastructure And Resilience Along The Extant Brunswick-Altamaha Canal

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Recent projections of sea level rise indicate that global mean sea levels could rise up to 2.0 meters (6.6 feet) by the end of this century. Coastal communities need to respond with innovative design strategies to adapt to uncertain changes in water levels and precipitation. Green infrastructure is an adaptable design strategy that could enhance the resilience of coastal communities to adapt to sea level rise and increased flooding risk. Green infrastructure is one method of utilizing the soft, absorptive powers of nature to manage water from both stormwater runoff and seawater. In this thesis, green infrastructure techniques are applied in a site design that specifically addresses sea level rise on the extant Brunswick-Altamaha Canal in Glynn County, GA. The historic Brunswick-Altamaha Canal is a 12-mile transportation canal built in the 1850s that has been unused for the past 150 years. The canal is a significant historic feature in the cultural landscape of Glynn County, although presently degraded and underutilized. Preliminary plans by Glynn County have identified the potential for reutilization of the canal into a recreational greenway and blueway trail. Because the canal's original lock structures are deteriorated, both the northern and southern ends are open to tidal influences, making the canal reutilization effort a case study in sea level rise design for coastal greenways and blueways. Recognizing this potential, this research-design thesis investigates the impacts of sea level rise both on the 12-mile canal corridor and a specific site along the corridor. Observations conducted during multiple site visits, GIS Lidar data, and online interactive maps were used to gather data on predicted sea level rise along the reaches of the canal. Based on the inventory and analysis, a design is proposed for a public park and trailhead for the greenway/blueway. The design aims to increase the ecological resilience of the site through the use of green infrastructure to enable a trajectory of ecological restoration back to a more natural state. Elevated, floating, and floodable infrastructures are design strategies that recognize the eventual impermanence of the park while providing for a vibrant public space for the community today. Bioswales help facilitate marsh migration by changing their function through time to act as stormwater conveyance today and tidal inlets with sea level rise. Visualization of ecological change is also an important element of the design process, and a series of graphic water markers create an artistic and dramatic visual element in the landscape that reveals the changing water levels. The design of the trailhead park and campground is one example of how creative design and the use of small, incremental green infrastructure practices can be applied to an inland coastal site to increase future resilience in our coastal communities.

The Once and Future Lagoon: California Bar-Built Estuaries in the 21st Century

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Many coastal lagoons in California have undergone tremendous changes since the mid-1800s due to anthropogenically-driven changes in watersheds, streams, and shorelines. These alterations have severely impacted estuarine and nearshore ecosystems and jeopardized the populations of species such as salmon that are critical to both natural food webs and human economies. Though efforts are now underway to attempt to undo this historic damage, these efforts face the added challenge of planning for climate change and ever-growing human populations. Rising sea levels, increased surface- and ground-water extractions, an increasingly arid coastal climate, and ecological invasions are among the processes that will impact lagoon resiliency in the future. This talk will describe ways in which these changes can be anticipated, avoided, or minimized through ecological engineering to help preserve lagoons in the 21st century.

ABSTRACTS OF POSTER PRESENTATIONS

Poster Session

A Case Study for Ecological Engineering Education: The 'AG' Heritage Park Stormwater Wetland Design at Auburn University

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In the pursuit of a model ecological engineering curriculum, the Department of Biosystems Engineering at Auburn University, funded by the USDA, is investigating the benefits of multimedia case studies in student learning and design practice in undergraduate ecological engineering curriculum. The template setting for this case study was selected to be the Agricultural 'Ag' Heritage Park (AHP), located south of Auburn University's campus. The objective of the case study development was to implement a design in an ecologically compromised watershed that is resilient enough to withstand high volumetric flows from storm events in an urbanized, campus environment. The AHP intercepts stormwater runoff from an ecologically degraded 93-acre watershed. Runoff is stored in a two-acre pond and subsequently discharged through about three acres of potential wetland area, which is the focus of this case study. A stormwater wetland providing runoff retention and the remediation of diffuse pollution for this watershed was selected as the central objective to the design. The design exercise required students to analyze and evaluate design components such as site hydrology, water balance, and hydraulic structures. Hydrologic and geospatial modeling software were used to model the hydrologic behavior of the watershed and the existing reservoir, employing the NRCS methods of peak discharge and curve number to determine peak runoff rates and total runoff volume for the 2, 5, 10, and 25-year, 24-hour duration storm events. The final design includes a proposed treatment wetland that focuses on target contaminants, flow rates, and economic considerations. The ultimate goal of this case study template is to integrate core ecological engineering curricula such as hydrology, wetland design, and hydraulic design with current engineering tools, including modeling software, geospatial mapping, and computer-aided drafting. These concepts and tools will give students the knowledge and experience needed to make not only sound engineering decisions, but it will equip them to design sustainable and resilient ecosystems in the context of a rapidly changing and growing human population. This case study will become the keystone element of a model ecological engineering curriculum that will give context to classroom exercises and assignments while bridging the gap between academia and industry.

A Vertical Algal Turf Scrubber Model for Green Bulkhead Design

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Algal turf scrubbers (ATS) use photosynthesis to remove nutrients from eutrophic or wastewater, while generating biomass that may be converted to useful byproducts, such as algal biofuels. ATS have been successfully adapted to clean dairy effluent, streams, and large aquaculture systems, among others, and scaled to dimensions as large as multiple hectares. Although ATS are highly efficient and relatively cost-effective algae producing systems, one drawback of their traditional design is the significant horizontal footprint required to remove nutrients from larger bodies of water, making this technology less practical in urban settings where space is at a premium. We examine a novel vertical application of the ATS model to the Baltimore (MD) Inner Harbor. Harbor water is rated consistently poorly on metrics of N and P concentrations and biological oxygen demand, and is the target of a multi-stakeholder campaign to substantially improve its quality by 2020. A University of Maryland study calculated that vertically oriented ATS could be affixed to up to 0.6 ha of available space on Harbor bulkheads. At scale, this approach has the potential to substantially ameliorate water quality while using the otherwise neglected resource of the bulkhead area. The vertical ATS prototype consists of a screen of plastic mesh attached to a simple PVC frame. Water is pumped from the Harbor and allowed to flow down the screen, where filamentous algae attach naturally and must be harvested on a regular basis. New challenges this vertical redesign must overcome include the Harbor's daily tidal flux and balancing the potential for significantly increased weight loads due to ice formation with bulkhead structural integrity. Algal production and N and P removal from a vertical ATS prototype are compared to that of an existing horizontal ATS in the Harbor.

Changes in Annual Degree Day Composition by Climate Region

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Heating and cooling degree days (HDD, CDD) are measurements shown to be highly correlated with space conditioning requirements. Looking at historical data representing annual degree days, we can gain an understanding of how heating and cooling requirements change over time. In the United States, the average individual spends 90% of their life indoors. These buildings they spend their time in are responsible for 68% of electricity consumption, 39% of energy use, and 38% of C02 generation in the United States. Improvements in the design of buildings themselves and a restructuring of how people interact with them has the potential for significant gains towards sustainable goals. Currently space heating represents 41.5% of energy consumption in the home, and air conditioning represents 6.2%. As climate change is predicted to cause warming in most areas, we are likely to see a change in the proportionate energy consumption related to space heating and cooling. Time series data representing 119 years (1895-2013) of annual heating and cooling degree days for the United States was obtained from NOAA. Linear regression was used as a primary means of analysis for states grouped by climate region. Of these only the Northeast, Northwest and Upper Midwest regions yielded statistically significant results for both HDD and CDD. All three regions saw an annual increase in CDD and decrease in HDD over the study period. Using energy conversion calculations put forth in a previous study, HDD and CDD were converted into a single number that is representative of total annual energy demand for heating and cooling. The net result is that these regions have been experiencing a slight annual decline in energy costs over the study period. The data was then separated into two time periods (1895-1970 and 1971-2013), and regression was run on these periods. In all regions the latter period saw a greater annual change in HDD and CDD that was not within the realm of standard error of the first period. Changing temperature will impact costs associated with space heating and cooling; large consumers of energy in both residential and commercial sites. Existing infrastructure designed for historical temperature conditions is vulnerable to these changes. Future infrastructural development planning needs to take into account the range of long term space conditioning requirements a region will experience. Infrastructure designed for increased thermal resilience will be most effective at minimizing space conditioning costs, and maintaining occupant satisfaction.

Characterizing Selenium Leaching from Southern West Virginia Valley Fills

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Selenium is found in southern West Virginia coal seams and overburden. Overburden is used for constructing mountaintop removal valley fills. This selenium is leached into watersheds and is toxic in excessive concentrations. The objective of this study was to characterize leaching of mobile selenium from two WV valley fills. Unsaturated column leaching tests were performed on coal overburden samples from two southern WV surface mines. Duplicate 15.2 cm diameter columns containing each soil were periodically leached with simulated rain water (1,010 mL) similar in pH (5.2) to southern WV rainfall. Leachate water was tested for dissolved Se, dissolved metals, pH, conductivity, sulfate, acidity, and alkalinity. Saturated jar tests were performed by filling a series of 3.8 L jars with each soil, saturating the jars, and collecting water samples after specified time intervals. The samples were tested for the same parameters as the unsaturated test. The desorption coefficient was calculated for each soil. Preliminary results indicate that conductivity ranges were 100-1132 μS/cm and 503-2940 μS/cm for the unsaturated and saturated tests, respectively. Maximum selenium concentrations occurred in the unsaturated tests during the first two pours (0.071-0.185 mg/L). The desorption coefficient varied by soil type but was consistent between replicated samples. Results from this work will be used in contaminant modeling.

Connections Between Hampshire College's Storm Water Drainage System and Stream Temperatures and Water Quality

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I measured stream temperature and conductivity on the Hampshire College campus in Amherst, MA to observe how storm water drainage systems and their effluents affect these water quality parameters. Twelve continuous temperature logging sensors and one conductivity probe were submerged throughout the network of small, forested streams (flows <1 ft^3/s) contained in the 62 ha watershed on the eastern half of the campus. During both base flow and storm flow conditions, I sampled water quality seven times at four sites for conductivity, temperature, dissolved oxygen, and total suspended solids. I found that loggers 30 and 25, which are located within 40 meters downstream of storm water outflow culverts, exhibited different behavior than other loggers in this small watershed. Upstream from a culvert connected to a 765 meter long drainage network, temperatures for logger 41 were seen to have an average daily variance of 5.9C. However, downstream of the culvert at logger 30, average daily variance decreased to 2.5C. Logger 25 is located in an area of the watershed with the highest impervious surfaces cover (47%) and longest network of pipes used to drain that area (totaling 1090 meters). This logger never experienced temperatures below 1.7C or daily averages below 4C during the ten month study period, even as cold winter weather drove stream temperatures elsewhere in the watershed to near 0C. Over the entire study period, this site also saw the highest conductivity value (964 μS/cm in February), which is nearly twice that of the second highest measurement (496 μS/cm) obtained during the study period. The cause of this was presumed to be the use of deicing salts applied to this highly impervious area during the winter months, which was later confirmed by ICP-AES analysis. During colder winter conditions, most loggers responded to rain storms with small and brief increases in temperature thought to result from warmer rain water mixing with the near freezing stream water. This does not hold true for loggers 30 and 25, which are directly associated with the longer networks of storm water drainage pipes. The patterns are in fact opposite, as small and brief decreases in water temperatures of about 3C are seen during the same rain storms. It is hypothesized that as new water enters these drainage systems, colder water that has been in these underground pipes for extended time quickly surges into the stream. Although the college is mindful of its environmental impacts, its storm water drainage systems were observed to alter water quality characteristics such as water temperature and conductivity. At such small scales the ecological implications may be minimal. However, these results demonstrate how drainage systems common in developed or urban areas influence stream temperature, which may contribute to the alteration of aquatic habitats.

Controlled Algae Growth for Water Quality Improvement at the Port of Baltimore, Maryland

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Water quality in the Chesapeake Bay has declined over the last century due to development of the watershed and the associated cultural eutrophication of the Bay. To reverse this trend, much research is being conducted on methods for removing nutrients from waters of the Bay and its tributaries. In this study research is reported on an experimental Algal Turf Scrubber® (the algal turf scrubber or ATS™ is trademarked to Hydromentia LLC of Ocala, Florida) that treated water at the Port of Baltimore, Maryland during the summer and fall of 2013. The ATS was 2 meters wide and 100 meters long with a 1% slope and it was constructed of a plastic landfill liner laid on top of a paved road bed. Algae were grown as periphyton on a plastic screen that was placed on the bottom of the ATS, with water pumped over the system from the Baltimore Harbor. Algal biomass production rates averaged 26.8 grams dry weight/m2-day over the study period and nutrient content of the algal biomass averaged 1.50% Nitrogen and 0.28% Phosphorus. Overall nutrient removal rates in the harvested algae were equivalent to 1085 kg Nitrogen/ha-year (966 lbs Nitrogen/acre-year) and 200 kg Phosphorus/ha-year (178 lbs Phosphorus/acre-year). Significant progress on the technique of harvesting algae was made in the study by incorporating methods used for cleaning urban storm drains. After draining the ATS, algae were harvested from the screen with a large vacuum truck. The algae and remaining water then were placed in a lined chamber where the material was dried by evaporation and weighed. The results of the research are discussed in terms of the potential sustainability of the ATS technology for large-scale water quality improvement.

Correlation of Productivity and Environmental Factors in Pilot-scale Algal Turf Scrubbing in the Great Lakes

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The use of algal turf scrubbing for water quality improvements through pollutant recovery is well known and has been employed in many environments. Most systems are operated through multiple seasons for benefits of long-term performance, and, typical for open algal cultivation systems of mixed communities, shifting characteristics of biomass productivity and quality has been observed in response to seasonally changing environmental parameters. Little work has been done, however, on quantifying the response of biomass quality and quantity to these parameters. This work presents the productivity and ash content of algal biomass produced in a fresh-water algal turf scrubber operating in Buffalo, NY, for three seasons as a function of seasonal temperature variation. Biomass was subsampled weekly from the upper, middle, and lower sections of a 40-foot ATS floway and analyzed for ash content and ash-free dry mass (AFDM). These numbers were then correlated with the mean weekly temperature under which the algae were grown. The results show strong direct correlation of AFDM with temperature in the middle and lower sections of the floway, where the AFDM was significantly highest as well. This correlation was not observed in the upper section of the floway, likely because of the influence of the high turbulence that contributes to scour. Ash percent was high ($>$70%) in all sections. In the middle and lower sections, ash percent showed an increasing then decreasing trend as a function of temperature, with a maximum at 21°C, although this trend was not observed in the upper section. These results indicate that temperature is a strong determinant of biomass growth rate and characteristics relating to types of algae that dominate seasonally, which has significant implications for expectations of seasonal yield of valuable biomass from algal turf scrubbers in temperate climates.

Daily Variation of Carbon Dioxide Flux in a Constructed Salt Marsh in Eastern NC

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Greenhouse gas emissions from wetland ecosystems have been studied for decades, but traditional sampling frequencies were limited to the availabilities of instruments and labor. With tidal fluctuations, the groundwater table depth may change in a short period which may stimulate daily carbon dioxide (CO2) flux variations in brackish tidal marshes. This study was designed to provide a clearer understanding of how daily CO2 flux varied diurnally in a restored salt marsh in eastern North Carolina. An infrared CO2 gas analyzer (IRGA) was used to measure short-term CO2 flux variations at a 7-year-old restored tidal marsh in Carteret County, North Carolina. The instrument was designed to measure CO2 flux at 5 minute intervals for 12-24 hrs at the S. patens dominated low marsh once in a month. In addition to the fixed location monitoring, soil CO2 fluxes were surveyed three times at 6 locations in 3 different marsh elevations (Low, Mid and High). Manual CO2 samples were also collected by applying a replicated static chamber method at the same frequency to compare the flux rates from the two different approaches. Results showed daytime CO2 fluxes were 0.5-1 μmol m-2 s-1 and 2-3 μmol $^{-2}$ s^{-1} in different months and decreased during precipitation events. In addition, the overnight CO2 flux fluctuated more rapidly (-0.5-2.0 μmol m^{-2} s^{-1} and 1-4 μmol $^{-2}$ s^{-1}) in different months and was affected by tidal movements and precipitation. From the soil CO2 flux survey, the lowest CO2 flux (1-2 μmol $^{-2}$ s^{-1}) was found in the J. roemerianus dominated Mid marsh and the highest CO2 flux (5-7 μmol $^{-2}$ s^{-1}) was found in the S. alterniflora dominated Low marsh. When comparing the traditional manual sampling method and continuous flux measurement, the traditional method only measured the CO2 flux at low tide during daytime while the IRGA method captured diurnally emission including night time and different tide conditions, so that static flux method may be underestimate fluxes. Our results indicate high frequent measurement of CO2 flux are ideal to capture daily variations to a more accurate estimation of carbon loss from tidal marshes, especially in the growing season when soil microbes are active.

Designing the Next Generation of Denitrifying Bioreactors: Coupled Biological and Physiochemical Processes to Remediate Nitrogen and Phosphorus

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In an effort to restore Stroubles Creek, a watershed affected by both urban and agricultural runoff and the resultant high nutrient levels, this project sought to design and monitor a denitrifying bioreactor (DNBR). Fundamentally, a DNBR is a repository of carbon based media strategically installed to intercept high nutrient concentration groundwater. Preliminary analysis of ground and surface water in the Stroubles Creek Watershed demonstrated the need for phosphorous (P) and nitrogen (N) removal to reduce eutrophication. Multiple DNBR media (with hypothesized activity on both N and P) were analyzed using a lab-scale treatment system designed in attempt to optimize denitrification efficiency. Additionally, effects of media bacterial pre-inoculation on treatment efficiency over time were examined in the small-scale DNBR system. The effectiveness of the carbon media were analyzed through nutrient mass balances and carbon loss. In order to determine best placement for a field scale DNBR, water samples were collected at 10 ponds (2 agricultural and 8 urban) as well as 6 springs in the New River Watershed. Studies demonstrated that for Stroubles Creek, a mixed urban and agricultural watershed, a soley woodchip DNBR performed most efficiently with inoculation. These data allowed for the recommendation of a full-scale field DNBR to be placed in a spring feeding Stroubles Creek. The appropriate DNBR was proven an effective best management practice in the watershed and likely in others of similar composition. In an effort to extend the impact of the project, Virginia Tech students and faculty will utilize the DNBR to study denitrification and water quality in upcoming years.

Developing an Online Environmental Landscape Certification Program for South Carolina

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Landscape maintenance is a large, rapidly growing, and unregulated small business sector SC. Landscape contractors have the opportunity to manage landscapes in a manner that can protect our natural resources and improve the quality of stormwater runoff. Beyond a pesticides applicators license, no experience or training is currently required to manage and maintain landscapes in SC. A Lever-Initiative grant was awarded to develop an online Environmental Landscape Certification Program to help landscape professionals meet client expectations and protect SC natural resources. A survey was conducted to identify stakeholder buy-in including content, cost, and preference on learning style. To increase adoption by contractors and technicians, specific strategic areas throughout SC were selected to spearhead the program. Stakeholder listening-sessions were conducted in March in Charleston, Florence and Greenville/Spartanburg to identify barriers to success, fine-tune logistics, and develop critical program content. Modules in development give detailed information on pertinent landscaping practices. This certification should help to increase the economic viability of the SC landscape industry while helping to protect natural resources.

Digital Elevation Model (DEM) Error Propagation in Watershed Delineation

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A typical watershed delineation workflow in GIS starts with a DEM grid and proceeds to fill any extraneous sinks and subsequently determine the flow direction and flow accumulation of each cell. Pour points are snapped to cells of high flow accumulation, and all cells which flow towards that pour point are included in the watershed. Where underground storm drains are present, either the DEM or the flow direction and flow accumulation derivatives should be modified accordingly. Even without underground storm drains, DEM error is propagated through the derivatives and can introduce uncertainty into the delineated watershed. DEM error varies according to the source of the elevation data. Furthermore, there is often spatial autocorrelation in the error. Slope is one spatial condition which increases DEM error. DEMs derived from contour maps may be affected by 'ghost contours,' a form of systematic error. Especially in the case of LiDAR derived DEMs, there is uncertainty as to the value being measured – ranging from the soil surface to plant canopy or rooftops. A Monte Carlo simulation of DEM iterations, conditioned for slope, and adjusted for underground storm drains, will be used to generate fuzzy watershed delineations. This output can be used to guide field observations for efficient verification.

Does Species Composition Affect Water Quality Improvement in Stormwater Biofilters?

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Studies have shown certain plant traits (i.e., total root length, longest root, rooting depth, percentage of fine roots, and growth rate) are correlated to high pollutant removal of nitrogen, phosphorus, and metals from stormwater runoff biofilters in a Mediterranean climate. Extensive species-specific studies of plants roles in stormwater biofilter treatment performance were used as the basis for a mesocosm study that investigates water quality improvement in monocultures, dicultures, and tricultures of Carex spissa, Juncus patens, and Baccharis salicifolia in southern California. These plants were selected for three primary reasons: 1) Species are suitable for use in stormwater biofilters in southern California due to drought- and flood-tolerance, native CA status, and inclusion in . 2) species are native California analogs to highly studied species in similar Australian research, and 3) species possess varied functional traits associated with high pollutant removal and maintenance of hydraulic conductivity. This study intends to examine the relationship of these varied functional traits with ecosystem function (i.e., water quality improvement and hydraulic conductivity). Large columns filled with layers of sandy loam, sand, and gravel were planted with combinations of these three plant species. Influent and effluent water quality is sampled following simulated storm events. Relative plant growth is estimated by measuring the tallest five stems of each species in each experimental unit monthly. Roots will be characterized after storm simulation trials end. Results for this experiment are pending. Water quality results are expected early-mid summer.

Double-Sided Modular Living Green Wall

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An innovative green wall design will be investigated to measure its effectiveness in keeping plants alive (as most green walls have a 10% die-off-rate), the Leaf Area Index (LAI), and the public interaction with the wall. The design will be implemented on a mount, independent of a single solid wall. Each module of the wall is diamond shaped with plants growing on either side. The modular aspect of this green wall allows for two modules in an irrigation series. The upper module will be aeroponic; the other below the first will be hydroponic. These module pairs will be situated on a swivel, which will allow them to be manually rotated to maximize sun exposure, exposing both sides of the module. We believe these more flexible aspects will give the wall more resiliency and encourage more public interaction than other current green wall designs. Due to different watering rates on the upper and lower modules, we will place different plant species on different modules, depending on their specific watering needs. The upper module will be watered more, so more water sensitive plants will be planted there. Over the course of two months, we will observe the plant die-off-rate. We will measure the Leaf Area Index weekly. After one month of growth we will place the wall in a public environment with instructions on how the modules should be oriented depending on the time of day. We hope that these instructions will encourage public interaction with the wall. After the first month of growth, we will observe the number of people that interact with the wall on a daily basis. This project is a multidisciplinary collaboration between undergraduates in the Environmental Science and Technology department, and graduate students with the Architecture department, and is ongoing. We have just finished the design and construction of the wall and will continuously monitor these data from when the plants are planted, within this week, until the end of May.

Effect of Water Content on Nutrient Removal and Drought Resilience in Stormwater Treatment Systems

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Constructed wetlands and bioretention systems are widely accepted as stormwater best management practices. These systems are designed to retain water and reduce the effects of nonpoint pollution through retention and remediation with infiltration, filtration, absorption, and biological activity. However the optimum water content for pollutant removal has yet to be identified in a quantifiable manner. Likewise, the resilience of these ecological systems to drought and their recovery time to maximum performance should be studied methodically. In controlled columns and in five field-scale systems, parallel systems of varying water content will be evaluated for stormwater treatment performance. The variance of nitrification and denitrification processes and ecological resilience will also be monitored. Once established, these trials will undergo a drought simulation and then a monitored recovery period until remediation performance is reestablished. Similar vegetation, soil composition, and pollutant loading will isolate the effect of saturation on system performance and contribute to knowledge of system design and management. Such qualitative and quantitative analysis is an important part of justifying and promoting use of wetlands and bioretention for stormwater best management.

Motivation of Students to Learning Activities Outside of a Classroom

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Student motivation is defined by the extent to which students show attention and effort in learning activities. Student performances are at their best when students' motivation is high. Past research has focused on evaluating and motivating students in classroom settings, however, the majority of learning by students occurs outside of the classroom. Even with careful planning, design and execution of a course, learning can be limited if students are not motivated enough to be responsible for outside of class activities, such as completing assignments, reading feedback, reviewing solutions, preparing for class, and otherwise actively studying. Therefore, this study aims to evaluate approaches to enhancing students' motivation for activities outside of the classroom. The study is timely as instructional techniques such as flipped, blended, and online classrooms, which place responsibility on students to learn outside of the classroom, gain popularity. Moreover, changing dynamics of pedagogy with the invention of new instruction tools, widespread use of social media, and developments in educational psychology demand innovative approaches to keep students engagement in learning. The study conducted surveys in three different core courses in Biosystems Engineering. Surveys, conducted at the beginning of the semester, evaluated student extrinsic and intrinsic motivation, learning preferences, and resource management strategies. After interventions in the form of teacher behavior, methodology or structure of course, additional surveys to understand the efficacy of the intervention will be conducted. Finally, students will be surveyed on motivation and perception of students to the approaches at the end of the spring semester. The results will elucidate motivation of students at a course level and between the courses. In addition, approaches to increasing student motivation will be evaluated.

Evaluating the Sustainability and Natural Subsidy of the Oyster Aquaculture Industry in Maryland

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Oyster aquaculture is largely believed to be a sustainable industry in the Chesapeake Bay because it benefits water quality while reducing pressure on wild stocks. Few, if any, studies have evaluated the sustainability of oyster aquaculture operations in the Chesapeake Bay. We used an emergy analysis and Life Cycle Assessment (LCA) to evaluate the sustainability of two rearing methods of American oysters (Crassostrea virginica) in the Chesapeake Bay; on-bottom cage culture and floating raft culture. Both methods use on-shore nursery systems and deploy adult oysters in open cages at designated Aquaculture Enterprise Zones (AEZ). Floating raft culture suspends mesh bags containing adult oysters at the water surface close to shore, whereas on-bottom culture holds oysters in cages on the sediment approximately 9.5 km from the aquaculture facility. To date, preliminary results for on-bottom culture are available. Our emergy analysis showed that emergy inputs are 2.13E+18 solar emjoules per joule (sej/J) in non-renewables (F) and 9.37E+14 sej/J in renewable resources (R). The largest non-renewable inputs were goods and services from the economy, and triploid oyster seed, produced in hatcheries. The greatest renewable emergy input was microalgae feed, produced and delivered to the AEZ by natural energies. This analysis did not account for additional yields of oyster aquaculture such as habitat provision, nutrient cycling, and water quality improvements. Further research will incorporate these factors into the analysis and will compare results to floating raft culture methods.

Evaluation of Green Infrastructure to Reduce Stormwater Discharge from an Urban Watershed

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Urban watersheds, specifically those with high percentages of impervious cover, create increased runoff volumes, flows, and energy that can result in downstream erosion and other water quality impacts. These highly impervious landscapes could benefit from the use of sustainable restoration strategies based on green infrastructure principles that mimic natural hydrological and ecological processes. Effective sustainable land use strategies for highly developed areas require an optimization at varying spatial and temporal scales: not only at the watershed level, but also at the scale of the urban centers and residential neighborhoods. This is especially the case with respect to selection and design criteria for stormwater control measures (SCMs) as related to their individual and collective performance within an urban watershed as well as to their integration into the existing landscape. In order to accurately conclude whether or not the SCMs are effective, both individually and collectively, a rainfall-runoff watershed model is needed. Geographic Information Systems (GIS) is being utilized to create a digital elevation model (DEM) and, stormwater systems map, and to perform spatial analyses on the Sand River watershed in Aiken, SC. Once stormwater system inputs are complete, ArcHydro will be used to create and analyze, among other applications, hydro networks, watershed delineation, flow direction, flow accumulation, and hydrographs for peak flow and runoff. Once this model is calibrated based on existing storm events, we can predict the effect of various storm events and ultimately determine what sub-watersheds would be best suited for future SCMs. This model is essential to the objective of understanding the current design and operation of the existing stormwater system. This presentation will focus on an ongoing urban retrofit project for stormwater management– the Aiken Green Infrastructure project – with the goal of downstream water quality improvement at the Sand River headwaters by reducing upstream stormwater volume and flows. Retrofitted SCMs include pervious paving materials, bioretention cells, and a cistern. The overall objective is to assess the effectiveness of the SCMs both at the individual practice scale and the larger watershed scale. This project is part of the statewide Intelligent River^{TM} monitoring and data visualization effort, which offers science-based knowledge to guide decision-making with respect to water resources management. Successes and challenges of the project will be discussed, and preliminary data will be presented.

Fate and Transport of Sediment-Associated Bacteria during Storm Events in an Urban Stream

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Storm runoff from urban and agricultural areas is linked to significantly increased microbial concentrations within receiving surfaces waters. Watershed-scale water quality models are often used to characterize stream systems in order to design total maximum daily load (TMDL) restoration plans and best management practices (BMP). While current models treat microbes as free-phase particles, previous evidence suggests that indicator bacteria associate with fine sediment, which can resuspend during severe weather. Furthermore, sediment-attached microbes tend to persist longer, potentially posing an increased threat to human health. The purpose of this study is to improve understanding of the transport of E. coli and enterococci in conjunction with streambed sediment resuspension during storm events. Concentrations of Escherichia coli (E. coli) and enterococci are generally used as indicators of human health risk and potential pathogen presence in keeping with state and federal water quality regulations. Water samples were collected at the Virginia Tech StREAM Lab under dry and storm conditions. During storms, an ISCO automatic sampler collected water samples at intervals of 15 or 30 minutes. Samples were tested for bacterial and suspended sediment concentrations. Anticipated results for this study include quantification of increased levels of E. coli and enterococci around peak flow. Data will also be presented correlating microbial concentrations with turbidity and flow rates over the course of the storm.

First Three Years of Vegetation Development as Affected by Initial Planting Richness in Created Mesocosm Wetlands

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Understanding the relationship between plant species richness and structural and functional developments of created wetlands can benefit future mitigation projects. A three year study of five species of wetland plants common to the Virginia piedmont, and often planted in created and restored wetlands in the region, were studied to determine the role of initial planting richness in vegetation community development using a set of 20 mesocosms. At the end of each growing season, all species present were identified. Plant community characteristics of percent coverages (e.g., total, planted, and volunteer species per mesocosms) were measured and species richness (S), Shannon's diversity index (H'), and prevalence index (PI) were calculated. Hydrology was initially provided by watering until the plants were established and thereafter maintained by precipitation equally for all mesocosms. Six mesocosms had leaking problems shortly after the experiment began, producing differences in average water depth, thereby creating two distinctively different hydrologic conditions for the experiment, designated as dry vs. wet condition, that were factored into the final data analysis. All plant attributes studied were significantly affected by IPR, except TPC. S and H' were both positively influenced by IPR mainly due to differences between monotypic mesocosms (IPR=1) and those with IPR=5, and the trend was fairly consistent throughout the three years of monitoring. Decreases in PI over the years indicated that the mesocosms were becoming typical of wetlands with more hydrophytic plant species over time. Differences in hydrologic conditions that had developed in six mesocosms due to the leaks in the beginning of the experiment significantly impacted some of the plant community attributes, including PI that was consistently lower in the "wet" mesocosms compared to "dry" ones. Development of several community characteristics in our experimental mesocosms mimicked those of young created mitigation wetlands in the Virginia piedmont, indicating that the mesocosm wetlands were following the same community trajectory as created wetlands. The study outcome showed positive effects of IPR on the early development of vegetation in created mesocosms wetlands. IPR should be considered when creating wetlands to help with the establishment and development of diverse plant communities.

Hydraulic Design of a Green Bulkhead System

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A green bulkhead is a special type of living shoreline best management practice for water quality improvement and beautification in urban harbors. We are developing a green bulkhead system for the harbor in Baltimore, Maryland as part of a long-term project. In our system wetland plants are grown in netting that is hung along the bulkhead for nutrient removal. In this presentation a design for the hydraulic system to support the wetland plants is described. Water is pumped from the harbor into a storage tank, which then is used to drip water across the netting that supports the plants. A bicycle-powered pump is employed to operate the system that involves volunteer participation by people visiting the harbor for recreation. Signage about the system is used to engage the people and to provide educational information about water quality issues in the harbor and the green bulkhead system. Preliminary results of the construction and implementation of a pilot trial of the system are described.

Hydraulic Efficiency of Bioretention Cells in Coastal South Carolina

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Flooding and stormwater control is a significant issue in coastal South Carolina because of prevalent shallow water table conditions, low gradients and rapid urbanization. A best management practice (BMP) using low impact design (LID) principles known as a bioretention cell (BRC) is gaining popularity for stormwater management. Five BRCs in four landscape positions (well drained uplands, tidal proximal, poorly drained uplands, and floodplain) were instrumented for microclimate, soil moisture and water table elevation to determine hydraulic efficiency. Three BRCs did not have an overflow outlets, one BRC (floodplain) employed an underdrain system, and one BRC (tidal proximal) had an overflow outlet. Temporal analysis of water table data showed that water table elevation exhibited seasonal fluctuations at all the sites. The well drained uplands and poorly drained uplands BRCs had a shallow water table during the growing season and a deep water table during the dormant season. Groundwater at the tidal proximal BRC reflected semidiurnal fluctuations in level but on a seasonal basis was relatively static compared to the seasonal variation of groundwater at other sites. In situ conductivity measurements of groundwater at the tidal proximal BRC, showed a spike in conductivity between October and December 2012 after the passage of Hurricane Sandy. The floodplain BRC water table was localized by a confining clay layer and showed little seasonal variation, much like the poorly drained uplands BRC. However, within storm groundwater variation at these two BRCs were large compared to the well-drained uplands and tidal proximal BRC. Small diurnal fluctuations in water table elevation occurred during dry days caused by potential evapotranspiration (PET). A linear regression analysis showed a significant relationship between each individual BRC's daily variation in soil moisture content (dry days only) and the daily PET. Soil moisture content was monitored in three zones (surface, shallow, and deep). Soil moisture content in the surface and shallow zones increased during the growing season and decreased during the dormant season within the well-drained upland BRCs. However, this trend was reversed within the poorly drained upland and floodplain BRCs. Seasonal trends in soil moisture within the tidal proximal BRC were not measured due to sensor malfunction. Infiltration rates measurements at every BRC exceeded published infiltration rates for the surrounding parent material. The highest infiltration rate was at the upland BRCs (93.7 cm/hr) where the media and parent material was predominantly sand. The lowest infiltration rate was found at the poorly drained upland BRC (19.9 cm/hr). There was a significant relationship by linear regression between the peak infiltration rate and peak rainfall intensity, while no significant relationships were found between the peak infiltration rate and soil moisture content or peak infiltration rate and water table elevation.

Hydrological Performance of a Great Lake Basin Alvar Plant Community and Intensive Green Roof System

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The intensive green roof on the Gateway Center of SUNY College of Environmental Science and Forestry (Syracuse, NY) is host to a rare native Great Lakes Basin plant community known as alvar pavement barrens. Alvars are floristically rich plant communities that survive in harsh conditions of high temperature and drought, conditions similar to a green roof ecosystem. Soil substrate and plant selection are important factors in stormwater and nutrient retention on a green roof. The goal of the study is to determine hydrological performance and the impacts on nutrient transport and retention in the native ecosystem and on the green roof. Methods include analyzing the soil nutrients, pH, depth, texture, hydraulic conductivity, moisture and pore water as well as runoff quality and quantity. The native alvar environment consists of thin soils on limestone bedrock; the intensive green roof provides deeper soil depth. Soil in the native alvar ecosystem is fine grained with a low hydraulic conductivity; it is alkaline and has high concentrations of magnesium, nitrogen and carbon. The soil moisture regime varies from hydric to severely desiccate. The green roof soil is coarse grained material with a high hydraulic conductivity; it is also alkaline and has high concentrations of phosphorous, potassium and calcium. The soil does not maintain saturated or desiccated conditions for long periods of time. Heavy storm events in the native alvar ecosystem create periods of flooding followed by sustained drought, the nutrient levels are relatively stable. Heavy storm events impact the green roof by leaching nutrients from the soil, this affects water quality of the runoff and reduces the nutrients available for plant uptake. This study will inform the green roof soil and flora management practices.

Impact of Stream Restoration on Riparian Soil and Stream Sediment Denitrification Potential in North Carolina

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Agricultural streams undergo considerable disturbance including channelization, erosion, and sedimentation. Additionally, fertilizer is often applied in excess of crop demand, and excess nitrogen (N) and phosphorus (P) can be transported to streams, particularly during storm events. When contaminated surface water reaches nutrient-sensitive aquatic areas, excess N and P causes eutrophication, resulting in algal blooms, depletion of oxygen in the water, and fish kills. Restoration practices such as natural channel design aim to restore the physical stream structure via installation of structures such as cross vanes, which create a riffle-pool sequence, simulating natural stream channel form. While in-stream and bank stabilization restoration approaches are generally not designed to improve water quality in terms of nutrient removal, they may have the benefit of improving water quality through N removal. Denitrification is a desirable removal process for N in aquatic ecosystems because it transforms a biologically active form of N (NO3) into gaseous forms (N2O and N2). This study quantifies the denitrification potential of riparian soil and stream sediment collected in various stream features (e.g., pools, riffles, runs, point bars and cross vanes). Study sites included four stream reaches (agricultural restored, agricultural unrestored with and without forested buffer, and forested reference) in the Piedmont region of North Carolina. Potential denitrification rates were measured using the acetylene block method, wherein stream and riparian sediments were amended with nitrate and carbon to derive potential N2O production over time. Potential denitrification rates in the forested site riparian zone were significantly lower than denitrification rates in agricultural site riparian areas ($p<0.01$). This could indicate NO3-rich runoff from agricultural fields leads to the presence of microbial communities responsible for denitrification. Across all sites, potential denitrification rates were significantly higher in riparian areas (mean: 245 $\pm$ 35 ng N/g dry soil/hour) than in stream features (mean: 30 $\pm$ 5 ng N/g dry soil/hour). In-stream denitrification potential rates at the restored site were significantly lower than at the unrestored sites (p¡0.01). Additionally, in-stream denitrification rates were highest in pools at all sites except the restored site, where pools were constructed below cross vanes. These results illustrate the importance of riparian areas in improving water quality and suggest in-stream geomorphology influences nitrogen transformations and has implications for future stream restoration design. We are currently investigating potential drivers of denitrification (e.g. organic content of soils, grain size distribution) to further inform future stream restoration design and nutrient management.

Learned Lessons from a Rural Integrated Small-Scale Self-Sustained Waste-to-Clean Energy Generation System.

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Located in the tropical country of Costa Rica, the project Improving Access to Clean Energy in Rural Central America Using On-site Solar-Biopower Generation aims to "develop and deploy an integrated small-scale self-sustained waste-to-clean energy generation system producing value-added by-products such as fertilizers for local farming applications and reclaiming water". The system is integrated by a flat panel solar collector unit, a thermophilic digester unit, a combined heat and power unit, and a post-treatment unit. The present work focuses in the learned lessons from the issues we have had to face to set up the post-treatment unit. In Alajuela, Costa Rica, four cells were designed and built to receive and treat the effluent coming from the thermophilic digester unit. All materials for construction were locally sourced. An intermittent sand filter (cell 1), a subsurface vertical flow constructed wetland (cell 2), and two free water surface constructed wetlands (cells 3 and 4) form a full-scale research site that will facilitate research on engineering design of this kind of green technology in rural Central America communities. Problems encountered and overcome at the site include leaking in cell 1 and 2, the appropriate selection of plants for cells 2, 3 and 4, control erosion problems surrounded the cells' area, suspended solids clogging the inlet area in cells 1 and 2, mat designs for cell 3, and harvest activities for cell 4. Herein we present our system design and lessons learned from the first year of operation. These learned lessons will serve to prepare a manual guide to develop Constructed Treatment Wetlands in places where supplies are limited, either limited budget or availability in rural Central America communities.

Life Cycle Assessment of Thin Extensive, Modular Green Roof Systems on A Sustainable Residential Home

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Urbanization of the environment, has led to increased urban heat island effect, more stormwater runoff, and declining air and water quality. Living technologies (i.e., green infrastructure) have been developed to mitigate many of these problems. Integration of green infrastructure can be seen in living systems such as the sustainable solar houses built for the U.S. Department of Energy Solar Decathlon competition. WaterShed is the winning house designed and built by researchers at the University of Maryland in 2011. Of the many living technologies integrated with its design, WaterShed features an extensive green roof system. However, despite the increasingly widespread use of green roofs, their benefits and overall efficiencies are poorly understood. Life Cycle Assessment (LCA) is a powerful tool used to assess environmental impacts associated with all the stages of a product's life. By evaluating energy and material inputs and outputs, LCA can be extended to systems like green roofs to understand potential environmental costs and benefits. Using WaterShed as a model, this study performs a cost-benefit analysis of the major inputs in the design of WaterSheds' green roof relative to its benefits. Existing data of green roof benefits, such as electricity savings, rainfall absorption, and habitat, were compiled and analyzed for WaterShed. This study has potential implications in enhancing design, management and industry practices associated with green roof construction.

Low Impact Development: a Strategy For Resilience Urban Design Against Climate Change

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LID holds the promise of mitigating the impact of flooding in urban areas, especially under climate change. For the high intensity-low duration storms, expected for the Northeastern USA, a portion of the infiltration-excess runoff from impermeable surfaces can be captured in LID structures to reduce local flooding. The efficacy of this approach for any given storm will depend on storm depth, intensity, land cover, LID scale and initial storage conditions. This study compares runoff calculations in EPA SWMM5.0 for an urban watershed in New York for different LID scales (5 to 20%), precipitation frequency (2 to 100 year) and precipitation durations (1 hour to 1 day). A cost/benefit analysis is performed on to compare the value of LID under each scenario.

Macroalgal Feeding Trials for Abalone Aquaculture Development

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Macroalgae (seaweeds) have been cultivated for thousands of years along coasts in China, Japan and other countries especially for food products. More recently, macroalgae are cultivated to manage nutrient pollution, since the algae take up nutrients during their growth and the nutrients are removed from the water when the algae are harvested. As part of a macroalgal cultivation project in the Chesapeake Bay, we are studying the use of harvested algae as a food source for abalone aquaculture. Abalones were raised in aquaria in a laboratory setting and they were fed pieces of a red alga (Gracilaria sp.) that was grown in the Bay. Preliminary results of the feeding experiments indicate that abalone can at least survive on Gracilaria as a food source. Based on projected scale-up of macroalgal culture in the Bay, estimates of abalone production are presented as a step towards a feasibility study for the development of abalone aquaculture.

Modeling the Creation of Dissolved Oxygen Refugia to Reduce Fish Kills in Baltimore Harbor

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The expansion of hypoxic and anoxic dead zones in waters of local and national significance underscores the importance of oxygen and its depletion in natural aquatic systems. The water quality in Baltimore Harbor is impaired by urban runoff, legacy industrial pollutants and sewage leaks and spills. Under certain conditions, the high nutrient loads from urban inflows have spurred rapid algal "blooms" that are ultimately consumed by bacteria. These blooms draw the dissolved oxygen concentrations down to levels that have contributed to unpredictable episodic fish kills. A recurring syndrome in the harbor, fish kills are a visible reminder of the need to improve water quality in an area that is visited by millions of tourists each year and serves as an important economic driver in the city. This study modeled the positive effects on dissolved oxygen of an algae-based water treatment system (Algal Turf Scrubber® or ATS™ trademarked to the Hydromentia Corporation, headquartered in Ocala, Florida) at multiple scales and locations distributed throughout Baltimore Harbor. The resulting plan for reducing fish kills in the harbor relies on a network of land-based ATS™ that add dissolved oxygen as a byproduct of photosynthesis and produce algal biomass for nutrient removal. The ATS™ can form different sized oxygen "refugia" for times when low DO events create dead zones, and they would ideally provide shelter to fish and invertebrates that would otherwise succumb to the event and add to the fish kill. Modeling of the dissolved oxygen plume created at the outfall of the algal treatment system was accomplished using the Delft3D Suite, a spatial modeling program for simulating transport processes that is especially apt for coastal or marine environments. A three-dimensional grid-based program represents the spatial mass flows and the movement of dissolved oxygen from a point source discharge to the harbor. The flow from the algal treatment system was scaled with data from the Baltimore Inner Harbor experimental ATS™ to allow imaging of the oxygen plume. For each simulation, the background dissolved oxygen concentration in the harbor is assumed to be mg/L and the concentration of the point source from the ATS is assumed to be 15 mg/L (a value that was routinely recorded through the operation of the pilot Harbor ATS™). The size of the oxygen refuge created increased with increasing ATS area as did the oxygen enrichment of the water, which reached over 3 mg/L, 4 mg/L and 5 mg/L from low oxygen water (2 mg/L). A number of potential sites for ATS exist around the Baltimore Harbor on known and unused properties. A total of 46 possible ATS sites (24.9 ha total) that are within 30 m of the harbor are identified. The properties range in size from 0.04 to 8.7 hectares . A subsample of these sites were used to model and graphically represent the anticipated size and oxygen concentrations of the refugia they could be used to create.

Occurrence, Transport, and Fate of Microplastics in the National Parks along Southeast coastline of the US

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Microplastic has become a worldwide pollution problem in the marine environment. Compared with common plastic debris, microplastic has a much smaller size which is usually identified as less than 1 mm. The ingestion of microplastic by marine biota such as zooplankton, mussels and worms has been reported recently. Due to its small particle size and recalcitrant property, microplastics can be transported to a long distance with ocean current. In the southeastern coastline of US, it is affected strongly by the warm current of Mexican Gulf. The high-dense population in the Gulf region could be a significant source of microplastics. In addition, discharge of the Mississippi River carries huge amount of agricultural pollutants such as herbicide and pesticide. These organic pollutants are generally hydrophobic with low solubility in water but they can be adsorbed by microplastics and make microplastics as a kind of pollutant carrier. All these pollutant-contained microplastics could be carried by the Gulf Current from Louisiana and Texas along the southeastern coastline and spread to the northern states such as North Carolina. There are 21 National Park sites along southeast costal line from Louisiana to North Carolina. Compared with other seashore sites, the ecological function and wildlife species in National Parks are protected well by law and regulation, and there is no direct terrestrial input of plastic debris or microplastic to the parks. Therefore, these National Parks provide good sites to investigate the occurrence, transport and fate of microplastics influenced by Gulf Current. The aims of the study emphasized on the quantity and types of microplastics in beach samples. Sand samples from thirteen National Parks along the southeast coastal line were collected to analyze the amount of microplastics. Results indicated that there are some significant differences of microplastic amount between the sites in North Carolina and Florida, suggesting that the Gulf Current plays a transport role on the distribution of microplastics. Furthermore, the characteristics of sand sample such as particle size, organic matter content, and moisture content; and the characteristics of surface ocean water such as salinity, turbidity, and temperature will be tested. These data will be further analyzed and the relation with the distribution of microplastics will be set up. Results of this study will be helpful to understand the current levels of microplastics in southeast coastal line and particularly the transport effect by Gulf Current. Further ecological risk evaluation of microplastics can be conducted with these results.

Opportunities and Value of Study Abroad Programs: A Firsthand Account

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Cultural exchanges and study abroad programs are a valuable education tool which is underutilized by most US curricula especially in STEM majors. One reason is a lack of awareness about the value of participation in an exchange. Often, the idea has never been suggested or realized as an option by the student. For those students who do consider a study abroad program, there are plenty of misconceptions about cost and about various barriers such as difficulty in transferring credits which deter further investigation. These problems can be easily solved by any program that plays an active role in educating, encouraging, and enabling students to study abroad. As far as value is concerned, there are many reasons to engage in a study abroad program. It is a well-accepted idea that spending time in a different culture can broaden a student's perspective particularly on social issues. Depending on the country and duration of stay, there is a potential to learn a new language through immersion. It may also be valuable to study technical topics in "expert" countries that are considered leaders in the field-for example, hydraulic engineering in the Netherlands or mechanical engineering in Germany. Though there are many more, the benefits outlined above coincidentally reflect many of the goals of a typical degree program. As we begin to update our educational system in response to the changing social climate, integration of study abroad programs should be considered. As a recent graduate of an exchange program, I will offer my personal experiences as evidence to support the values claimed above. I will outline my linguistic struggles, compare the cultures of my host and home country, and illustrate the technical insight gained while living in an "expert" area. Cumulatively, these stories should convey my personal growth as a student living near Venice, Italy as a member of TAPAC – the TransAtlantic Precision Agricultural Consortium exchange program.

Phytoremediation and Natural Treatment Systems: Science and Design

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A phytoremediation class targeted at upperclassmen and graduate students was developed in 2011 and has been taught annually since by the authors. The class is taught in a distance classroom allowing practitioners to join the class in addition to on-campus students. As with any interdisciplinary topic, the class enrolls a wide variety of students, requiring several weeks of background science to be covered. The class evolves to educate students about the removal mechanisms for a variety of contaminants. To include more practical information and hands-on experience, one or two visits to field sites are also included. Guest lectures are provided by experts either visiting campus or via Web-Ex in the distance classroom. Such guest lectures provide additional points of view for students and case studies. Collectively, the course has been well attended and well received by students.

Quantification of Hydrocarbons in Urban Stormwater: Comparison of Carbon Isotope Analysis with Current Methodologies

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The presence of carcinogenic and mutagenic hydrocarbons in storm water and receiving water bodies highlight the need to find effective methods to measure these pollutants in storm and surface water. Past studies tracking concentrations of hydrocarbons in water have been limited because conventional analytical methods of analysis for petroleum HCs (i.e., total petroleum hydrocarbons [TPH], or extractable petroleum hydrocarbons [EPH]) only track selected compounds present in storm water. Because of the ability to differentiate between 'new carbon' from contemporary sources and 'fossil carbon' from petroleum HCs, analysis of natural 14C and 13C can identify the contributions of all petroleum-derived HCs present in storm water. This research is significant because it is the first to compare subsets of total petroleum HCs, as tracked by conventional analyses, to more complete monitoring of hydrocarbons using stable isotopes. The two conventional methods chosen for this study are US EPA Method 1664 A: N-Hexane Extractable Material (hexane extraction, gravimetric analysis) and Massachusetts Department of Environmental Protection Method: Extractable Petroleum Hydrocarbons (methylene chloride extraction and GC-FID analysis). We will compare these results with a new method of hydrocarbon quantification in water and sediment with stable/radio carbon isotope analysis. Because the petroleum from which these chemicals originate has a carbon isotope signature distinct from plant and soil organic matter, the total mass of hydrocarbons in a sample can be determined. Comparing mass balances of petroleum hydrocarbons from each approach will offer important insights to best monitor petroleum hydrocarbons to protect the health of humans and ecosystems. Specifically, results will indicate if conventional methods of monitoring subsets of petroleum HCs in storm water are sufficient and can be used as proxies for total HCs, or if more extensive monitoring is warranted.

Rising Resistance: Exploration of Patterns of Antibiotic Resistance in Stroubles' Creek to Drive Further Research

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Antibiotic resistant genes (ARGs) from urban and agricultural sources that enter the natural environment are a significant public health concern. The dissemination of ARGs from these sources to water sources is not well understood. This study aims to characterize the dispersal of ARGs correlated to antibiotic resistance within the Stroubles' Creek Watershed. Stroubles' Creek is the site of the Virginia Tech StREAM Lab and is surrounded by crop fields that have been heavily supplemented with manure for decades. It is hypothesized that the concentration of ARGs from these manure-impacted sub-watersheds is greater than that from forested watersheds downstream. Using qPCR, the ARGs ermF and tetG were quantified in soil, stream bed and suspended sediment, water and manure samples, taken from both manure-impacted sub-watersheds and forested watersheds at seven points along Stroubles Creek. No significant differences in the concentration of ermF and tetG from manure-impacted sub-watersheds and forested watersheds have been observed. Given that the forested sub-watersheds are downstream, it is not surprising that they are less than pristine; these data also suggest that ARGs can travel significant distances in surface waters from their original points of origin. Further research is recommended using an alternative sampling site as control. To continue this study, an analysis will be performed using selective media infused with antibiotics to gain insight on expressed antibiotic resistance in bacteria throughout the watershed.

Self-optimization of Mixed Algal Communities via Automated Feedback Control of Light Input

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Ecosystems display characteristics of being moderated by internal feedback control, but there has been little study into the influence of external feedback pathways on the internal organization of those systems[1,2]. The objective of this proposed research is to investigate the metabolic self-optimization of an aquatic phototrophic microcosm that is subject to automated feedback control of light input. In this research, self-contained miniature phototrophic ecosystems will be prepared in sealed 250ml Erlenmeyer flasks, which will be kept in individual test chambers. Each chamber will be maintained at a constant temperature by forced airflow, with an internal light source sufficient for algal photosynthesis. In the experiment, replicate microcosms will be isolated from external light input, and connected to a continuous pH monitoring system that will toggle the activation of the light source based on high and low pH setpoints. Frequency and length of light and dark periods will be recorded, as well as temperature fluctuations, optical density, chlorophyll-a content, cell count, and dissolved oxygen concentrations over time. These community expressions of metabolic characteristics will be used to determine net auto- or heterotrophy, growth rates, and net primary productivity of the organisms present. It is expected that light and dark periods will stabilize in a sinusoidal oscillation about an optimal cycle length that maximizes the efficiency of growth and productivity with minimal light input. The data gathered from this experiment will be used to develop mathematical models for use in designing feedback control systems for mixed-community photobioreactors.

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Soil Temperature and Moisture Differentials from Concrete Sidewalks.

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Anecdotal observations suggest that impervious surfaces influence water content and temperature in adjacent soil and subsequently may affect plant quality. Soil moisture and temperature sensors are used to assist in irrigation management in greenhouse and nursery crop production, sports fields, golf courses, and residential landscapes. Previous research suggests that many plant species do not perform well close to concrete sidewalks. It is often assumed that heat from the sidewalk results in warmer and drier soil environments not optimal for plant growth. A study was conducted using GS3 soil sensors (Decagon Devices) in the Sustainable Demonstration Garden at Clemson University to measure the effect of sidewalks on soil water content and temperature. Soil sensors were installed in three replicate locations within the garden at 15, 30, 45 and 60 cm increments from sidewalks, at a depth of 10 cm into the soil on August 9, 2013, and moved in two-month intervals on October 17, 2013 and January 23, 2014, for a total of three timed intervals. Measurements are logged every 30 minutes using EM50G data loggers (Decagon Devices). Weather data was organized from the Clemson University Entomology Weather Station to determine the correlation between soil conditions and air conditions. Data analysis calculating the Local Correlation (LoCo) Score, reveal the correlation among the three replicates. Further analyses of data were performed using a one-way ANOVA. It is hypothesized that soil moisture and temperature near the sidewalk will fluctuate more than sensors placed at increasing distances. The findings from this study will help landscape contractors manage landscapes in a more sustainable manner by improving irrigation practices (sprinkler placement) and plant placement. Future research needs include: investigating greater distance distributions, varied impervious surfaces, the role of compaction, and identification of optimal plants. Results of the three monitoring periods will be presented at the conference.

Stormwater Runoff from a Sloped Greenroof Located in the Mid-Atlantic Region of North America

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Vegetated extensive greenroofs can reduce peak runoff rates during storm events. As the desire to install greenroofs expands beyond roofs with little slope to those with more steep slopes, like often found on residential homes, there is a need to understand how slope affects runoff. WaterShed, the University of Maryland's winning entry in the 2011 U.S. Department of Energy Solar Decathlon competition, integrated solar photovoltaics and energy efficient appliances with many living technologies into the design of the house to improve its environmental sustainability and energy consumption. The house, owned by a regional electric power utility, now serves as a showcase on how residential homes can positively influence their surroundings. The living technologies include vegetated green roofs, green walls, treatment wetlands, and bio-swales. The objective of our research was to compare the runoff between the sloped green roof and the adjacent sloped photovoltaic roof on WaterShed. This runoff will be measured by a custom designed flume that captures the runoff from each roof and return a flow rate. The design of this flume is new due to the low flow rate and application, while the design criteria for this flume was derived from traditional stream flow flume techniques. The resulting data will produce hydrographs which will allow us to compare flow rates and total runoff between the two sloped roofs for a given storm event. This data is critical to not only the runoff analysis between the two type of roofs, but also providing an input to an evapotranspiration (ET) model for the green roof. How these living technologies perform over time is crucial for both ensuring regulatory standards are met and providing feedback for future improvements to the design and technology itself.

Surface Water-Groundwater Interaction: A Study of Hydraulic Flow Paths and Nutrient Dynamics in a Floodplain Reach of a Restored Stream

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A common practice of stream restoration is to reconnect a stream with its natural floodplain. Floodplain re-connection is done to achieve such benefits as reduced flood stage, nutrient removal, sediment deposition, and protection of the natural stream channel topography. In order to measure nutrient removal and hydraulic storage in a reconnected floodplain, natural flood conditions can be simulated. An artificial flood was conducted over two consecutive days on a 50 meter reach of the Stroubles Creek floodplain, a 2nd-order stream near Blacksburg, VA. The first day consisted of a nutrient injection with sampling at regular intervals for multiple nutrient parameters at three cross-sections within the reach. The experiment also focused on modeling the exchange of groundwater and surface water by measuring water level, temperature, conductivity, and volumetric moisture content in soil on the surface and subsurface of the floodplain before, during, and after the flood experiment. The first day represented "dry" antecedent conditions and the second day represented "wet" antecedent conditions. This was the summer trial of the research project as we investigate seasonal variability in both nutrient transport and hydraulics. The results were analyzed as part of an ongoing investigation within the StREAM Lab at Virginia Tech.

The Use of Mesocosms Matched with Field Analogues in an Undergraduate Water Quality Class

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An undergraduate water quality class constructed four mesocosms that they manipulated and monitored for a semester while identifying local natural analogues for comparison. All systems were aquatic based and continuously recirculating with each system manipulated to express a differing water quality gradient. Data were collected on a peat bog, a subsurface flow wetland, a iron cycling seep, and an attached algae bed over the course of the class with comparisons made to their natural system counterparts. A discussion of the class and students input and approaches are detailed with a view toward creating alternative learning that stimulates interest in ecological engineering approaches.

Traditional Ecological Knowledge and Forest Restoration: Soil Quality Beneath Lacandon Maya Agroforestry System Trees

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The rainforests of Chiapas, Mexico, not unlike rainforests around the world, are rapidly being degraded by logging, cattle ranching, and farming operations. These changes in land management lead to deterioration of soil quality, which can hinder ecosystem restoration attempts. Restoration projects are further encumbered because of a lack of knowledge of native trees that are productive and facilitate succession. The swidden agroforestry system of the Lacandon Maya has allowed them to sustainably manage their land for hundreds of years without soil degradation. The Lacandon plant and care for a number of tree species during the fallow period of their multi-successional system to facilitate the restoration of soil fertility. Vegetation and soil samples were taken around six of these species (Poulsenia armata [Akun], Cedrela odorata [Ku'ch], Enterolobium cyclocarpum [Petzkin], Swietenia macrophylla [Puuna], Lonchocarpus guatemalensis [Yax-bache], and Heliocarpus appendiculatus [Jaror; to be confirmed]) to evaluate their effect on soil quality. Soil samples were analyzed for nutrient levels and nematode populations. Available phosphorous concentrations under the canopy of P. armata trees were 23.0% higher than those outside the canopy 79.5% higher than those under the canopies of other species. Soil organic matter near P. armata trees was 18.8% higher than that near other species. A greater effect was observed under larger, older trees and decreased with distance from the tree. It also appears that levels of soil organic matter (19.2% higher), total nitrogen (15.8% higher), and available phosphorous (35.4% higher) were highest in trees sampled in the kax, or forest, stage. These soil properties of the samples were also positively correlated with the time an area had to recover after the most recent milpa planting period, indicating that the analyzed trees helped restore soil quality after cultivation. Finally, populations of bacteriovorous nematodes were twice as high beneath H. appendiculaus trees, potentially increasing the populations of saprophytic bacteria, thereby hastening soil organic material and detritus decomposition, releasing nutrients. These results appear to validate the traditional ecological knowledge that the Lacandon Maya apply in their agroforestry system and demonstrate its potential to enhance soil quality and facilitate restoration of tropical forest landscapes.

Uptake and Phytometabolization of the Antimicrobial Triclocarban by the Jalapeno Pepper (Capsicum Annuum)

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Agricultural land application of wastewater residuals has been recently identified as a source of emerging contaminants such as personal care products (PCPs). These organic pollutants can accumulate in plants irrigated with reclaimed water, leading to concerns about human health risks from consumption of contaminated food crops. Our data, in a previous soil-based study, revealed that the antimicrobial triclocarban was translocated to pepper fruits (12.6 ng/g dw) after 60 d. Comparison between concentrations of unlableled triclocarban and 14C-labeled triclocarban indicated that a substantial portion of triclocarban in pepper was present in a metabolized form. However, the metabolic pathway of triclocarban following plant uptake is unknown. Therefore, the current study aims to investigate the potential plant uptake and phytometabolization of triclocarban by the jalapeno pepper (Capsicum annuum) in hydroponic culture, using 14C-labeled compound. The plants are allowed to reach maturity and bear fruit if applicable. Fruits are then harvested in time intervals to evaluate the triclocarban accumulation trend over times. At the conclusion of the experiments, both triclocarban and its phase II conjugates are expected to be detected in the plant tissues by liquid chromatography mass spectrometry.

Utilizing Ecohydrology in the Virginia State Water Plan

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The Office of Surface and Ground Water Supply Planning of the Virginia Department of Environmental Quality (DEQ) and The Center for Watershed Studies in the Biological Systems Engineering (BSE) Department at Virginia Tech are collaborating enhance the Virginia State Water Supply Plan through data analytics, unique visualization tools, and hydrologic modeling. Analysts are working to integrate all existing habitat models performed in Virginia streams into a modeling and decision support system for analyzing cumulative impacts from water supply activities. We are currently gathering Flow:Habitat tables from Instream Flow Incremental Methodology (IFIM) and other habitat mapping studies, and using them to simulate aquatic habitat distributions under current water supply demands and demands projected out to the year 2040. The results of these analyses will be used to determine habitat gains or losses due to projected water supply activities. We are also conducting an analysis of habitat peaks for the various species and guilds in the target studies, and comparing these peaks to a variety of Ecological Flow statistics (from the tool-kits such as HIT and IHA). By doing this comparison, we hope to determine if flow metrics that are believed to have ecological significance can be used to create a predictive relationship with observed habitat at the statewide level.

Valuation of Select Ecosystem Services in Regenerative Stormwater Conveyance (RSC)

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Regenerative stormwater conveyance (RSC) systems are open channel, sand filtering systems that utilize a series of shallow aquatic pools, riffle weir grade controls, native vegetation, and underlying sand channels to treat, safely attenuate, and convey storm flow. RSCs have demonstrated the ability to treat and manage stormwater runoff. Also, per their nature-based design, they have a high potential to offer additional ecosystem services, such as carbon sequestration, habitat provision, biodiversity, soil formation, and nutrient cycling. As RSCs are often located in close proximity to development areas, such ecosystem services can be directly realized by surrounding communities. Seven RSC sites aged between 1 and 14 years underwent ecosystem analysis during May 2012 and will undergo another analysis in early May 2014. Ecosystem analysis includes taking 20 cm soil cores for carbon analysis, habitat rating using an adapted from the NC DENR wetland wildlife rating rubric, plant enumeration for diversity index, earthworm counts, and 10 cm soil cores for microbial biomass analysis (an indicator of the degree of nutrient cycling). Ecosystem assessment also occurred at two natural ephemeral headwater reference sites and two conventional SCM conveyance systems. Based on the extent of each service provided over the chronosequence of RSCs, an estimated additional ecosystem value calculated in the form of net present value. Specific ecosystem function valuation for natural ecosystems is based on previous published literature. These values are applied to the valuation of services in RSCs to the fraction that the RSCs represent the service relative to their reference sites. Initial data show some progression in ecosystem function with age. Older systems show carbon content, microbial biomass, and habitat rating closer to or at measurements recorded at reference sites. Plant diversity appears to be consistent over the establishment of RSCs, and similar to reference sites. Earthworms are not present at very young sites, but present at older sites to a varying degree. Net present value of RSCs calculations will be conducted in May 2014, upon the completion of the final ecosystem assessment. It is estimated that RSCs will contribute between $25k and $50k per ha of RSC from the selected ecosystem services, in addition to stormwater mitigation values. This research has implications for sustainable (sub)urban development, where natural ecosystem have been converted to developed areas. Nature-based stormwater practices, such as RSCs, may compensate some of the loss through provision of additional ecosystem services. Also, cost evaluations often do not consider the benefits of nature-based systems over conventionally engineered systems.

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