2016 SC Water Resources Conference

South Carolina Water Resources at a Crossroads:
Response, Readiness and Recovery

PROGRAM

October 12-13, 2016

Columbia Metropolitan Convention Center

Columbia, SC

SPONSORED AND ORGANIZED BY

Clemson University Public Service and Agriculture

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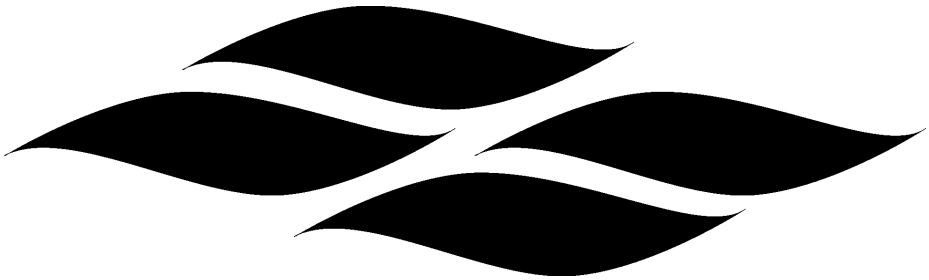

South Carolina Water Resources Conference

South Carolina Water Resources at a Crossroads:
RESPONSE, READINESS AND RECOVERY

2016 Program

October 12-13, 2016

www.scwaterconference.org

Conference Chair

Jeffery S. Allen, PhD

Clemson University South Carolina Water Resources Center

Conference Coordinator

Dawn Anticole White, MMC

Clemson University South Carolina Water Resources Center

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Cover Photo: Folly River - Courtesy of Kim Counts Morganello, Clemson University Water Resources Agent

DAY 1 • Morning • Wed, 10/12

2016 SC Water Resources Conference Schedule

7:30 AM	**Registration Opens**						
8:30-10 AM	Ballroom A **Opening Remarks** | *Jeffery Allen, Executive Director - Clemson University SC Water Resources Center* **South Carolina's Water Resources - Our Opportunity is Now** | *George Askew, Vice President - Clemson University Public Service and Agriculture (PSA)* **Morning Plenary Session: The October 2015 Flood in South Carolina: Federal and State Perspectives** *John Shelton, Assistant Director for Data - US Geological Survey; Jill Stewart, Director of Dam Safety and Stormwater Permitting Division, SC DNR;* *Maria Lamm, State Coordinator of Flood Mitigation Programs - SC DNR*						
10-10:30 AM	**Morning Break (Lower Level)**						
SESSION 1 10:30-NOON	**TRACK 1** **Water Policy and Planning** Lexington Room A	**TRACK 2** **Surface Water and Groundwater Systems** Lexington Room B	**TRACK 3A** **Stormwater** Richland Room A	**TRACK 4A** **Hydrologic Monitoring and Modeling** Richland Room B	**TRACK 4B** **Hydrologic Monitoring and Modeling** Richland Room C	**TRACK 3B** **Stormwater** Congaree A	**TRACK 5** **Climate, Floods and Drought** Ballroom A
SESSION TITLE MODERATOR	**Water Resource Planning I** Lori Dickes Clemson University	**Groundwater** Eric Strom US Geological Survey	**Monitoring** Cal Sawyer Clemson University	**Data Mining I** Tim Callahan College of Charleston	**October 2015 Extreme Event** Colt Bowles USACE	**Stormwater Pond Initiative** April Turner SC Sea Grant Consortium	**Flood of 2015 I** Noel Hurley US Geological Survey
PRESENTER 1 10:35-11	Scott Harder SCDNR South Carolina State Water Plan Update	Bruce Campbell US Geological Survey Development & Application of a Groundwater-Flow Model of the Atlantic Coastal Plain Aquifers, Aiken County to Support Water Resource Decisions	Andrew Stroud City of Columbia The City of Columbia Stormwater Management Program & Integrating Water Quality Community Outreach & Education with a Volunteer Adopt-a-Stream Program	Matt Neet University of South Carolina Employing Virtual Beach Software, Historic in Situ, Remotely Sensed & Coastal Observation System Data for Bacteria Forecast Water Quality Modeling in Sarasota, FL	David Shelley Congaree National Park Reconstructing the October 2015 Flood on Cedar Creek at Congaree National Park, SC	Erik Smith USC / North Inlet-Winyah Bay NERR SC Stormwater Ponds Research & Management Collaborative: Developing an Integrated & Sustainable Economic & Natural Resource Strategy for Construction, Use & Maintenance	Toby Feaster US Geological Survey The Flood of October 2015 and Other Major Floods in South Carolina
PRESENTER 2 11:05-11:30	Robert Osborne Black & Veatch Incorporating Resilience into Water Resource Planning	James Landmeyer US Geological Survey Assessment of Groundwater Quality of Atlantic Coastal Plain Aquifers, Aiken County, SC	Erika Hollis Upstate Forever Using Volunteer Monitoring to Improve Water Quality in Upstate South Carolina	Oscar Flite III Phinizy Center for Water Sciences Results of a Continuous Lagrangian River Cruise on the Savannah River to Determine Overall Metabolic Activity of this Ecosystem	Maggie Emmons University of South Carolina Assessing the Effects of Sanitary Sewage Overflows from the 1000-year Rain Event on Metal Cycling in the Congaree Watershed	Andrew Tweel SCDNR Stormwater Pond Inventory for the Eight Coastal Counties of SC	Peng Gao Carolinas Integrated Sciences and Assessments How Extreme was the October 2015 Precipitation Event in South Carolina?
PRESENTER 3 11:35-12	Nina Caraway CDM Smith Using South Carolina's New South Water Quantity Models to Support Regional Water Planning	Alexander Butler SCDNR Development of a Groundwater Recharge Model for South Carolina Using the USGS SWB Method	Susan Libes Coastal Carolina University Rapid Reporting in Long-term Monitoring Programs for Detection of Illicit Discharges by NPDES SMS4 Communities	Frances Ellerbe Woolpert The Rapid and Comprehensive Analysis of Storm Events from Continuous Water Quality Monitoring Datasets	Devendra Amatya USDA Forest Service Rainfall and Hydrograph Reponse from Watersheds for the October 2015 Extreme Precipitation Event on the Santee Experimental Forest	Katie Buckley Clemson University Healthy Landscapes, Healthy Ponds: Developing an Outreach Strategy for Pond, Community and Ecosystem Well-Being	Hope Mizzell SC Climatology Office Online Interactive Journal Outlines 2015 South Carolina Historic Rain and Flooding

DAY 1 • Afternoon • Wed, 10/12 2016 SC Water Resources Conference Schedule

12-1:30 PM LUNCH	**Ballroom B/C Lunch Plenary Session - Sponsored by Duke Energy** **The October 2015 Flood in South Carolina: Local Perspective** *Clint Shealy, Water Works Superintendent, City of Columbia*					
SESSION 2 1:45-3:15	**TRACK 1** **Water Policy and Planning** Lexington Room A	**TRACK 2** **Surface Water and Groundwater Systems** Lexington Room B	**TRACK 3A** **Stormwater** Richland Room A	**TRACK 4** **Hydrologic Monitoring and Modeling** Richland Room C	**TRACK 3B** **Stormwater** Congaree A	**TRACK 5** **Climate, Floods and Drought** Ballroom A
SESSION TITLE **MODERATOR**	**Water Energy Nexus** Rob Carey Clemson University	**Assessment and Allocation** David Graves SCDHEC	**Research Management BMPs** Heather Preston SCDHEC	**Data Mining II** Noel Hurley US Geological Survey	**Stormwater Pond Initiative** April Turner SC Sea Grant Consortium	**Flood of 2015 II** Gwen Geidel University of South Carolina
PRESENTER 1 **1:50-2:15**	David Ladner Clemson University Integrated Energy-Water Planning in the Eastern Interconnection	William Wenerick SCDHEC Stream Assessment Tools for Compensatory Mitigation	Joshua Robinson Robinson Design Engineers An Engineering Methodology to Quanitfy the Hydraulic and Hydrologic Performance of Green Roofs	Toby Feaster US Geological Survey Low-flow Statistics Updates in South Carolina	Lori Dickes Clemson University A Policy Overview of Stormwater Pond Management in South Carolina's Eight Coastal Counties	Maria Lamm SCDNR October 2015 Flooding Impacts on Floodplain Management at the State and Local Level
PRESENTER 2 **2:20-2:45**	Jerry Wylie SynTerra Corporation Coal Combustion Residuals: Environmental Risk and Remedy	Celeste Journey US Geological Survey Assessment of Stream Quality in the Piedmont and Appalachian Mountain Area of the Southeastern United States	Betsy Kaemmerlen Fuss and O'Neill An Innovative Approach to Storm Drainage: The Shandon Green Infrastructure Project	James Riddle Woolpert Spartanburg County Continuous Water Quality Monitoring Program Partnering for Results	Dianne Greenfield University of South Carolina SCDNR Updating the State-of-the-Knowledge: Ecological Function of Stormwater Detention Ponds Within the Coastal Landscape	Brian Bates Woolpert The 1000-year Flood from 10,000 feet
PRESENTER 3 **2:50-3:15**	Jay Weist WorleyParsons Case Study Electric Utility Compliance - New EPA Effluent Limitations Guidelines	Eleanor Jenkins Clemson University Using Simulation-Based Optimization to Guide Allocations of Surface and Ground Water Resources for Agricultural Water Use	Daniel Hitchcock Clemson University, Baruch Institute Stormwater Decision-Making in Coastal South Carolina: Is Science Informing Regulations?	Lynn Torak US Geological Survey Integrating Irrigation Metering and Imagery Acquired from Unmanned Aircraft Systems with Geostatistical Analyses to Enhance Agricultural Production & Conserve Energy and Water Resources in South Carolina	Geoff Scott University of South Carolina An Assessment of NPS Runoff Pollution in Coastal Stormwater Ponds of SC & the Potential for Development of Antibiotic Resistant Microbes	Edward Dickson AECOM October 2015 Dam Inundation: How the Flood Changed the Conversation Around Dam Inundation Mapping
3:15-3:45	**Afternoon Break (Lower Level)**					

DAY 1 • Afternoon • Wed, 10/12 2016 SC Water Resources Conference Schedule

SESSION 3 3:45-5:15	TRACK 1 **Water Policy and Planning** Lexington Room A	TRACK 2 **Surface Water and Groundwater Systems** Lexington Room B	TRACK 3A **Stormwater** Richland Room A	TRACK 4 **Hydrologic Monitoring and Modeling** Richland Room C	TRACK 3B **Stormwater** Congaree A	TRACK 5 **Climate, Floods and Drought** Ballroom A
SESSION TITLE **MODERATOR**	**HydroGeography** Lori Dickes Clemson University	**Groundwater Contamination** Eric Strom US Geological Survey	**Management & Applications/Outreach** Cal Sawyer Clemson University	**Hydrology/Water Quality Monitoring I** Devendra Amatya USDA Forest Service	**Stormwater Pond Initiative** April Turner SC Sea Grant Consortium	**Water Quality Changes as a Result of Flooding** David Graves SCDHEC
PRESENTER 1 **3:50-4:15**	Brian Bates Woolpert WOTUS - "If it doesn't result in a map, the definition is flawed"	James Landmeyer US Geological Survey Occurrence of Elevated Bromoforms in Drinking Water Produced from Deep Public-Supply Wells in Williamsburg County, SC	Kimberly Morganello Clemson University Rainwater Harvesting: Program Evaluation to Understand Real World Attitudes, Perceptions, and User Application of the Practice	Caitlyn Mayer College of Charleston Field Spectroscopy as a Tool for Enhancing Water Quality Monitoring in Coastal Watersheds: ACE Basin, South Carolina	Vijay Vulava College of Charleston Sources, Fate, and Transport of Contaminants in Engineered Stormwater Structures: A Coastal SC Perspective	William Davis & Jack Beers CDM Smith Utilizing GIS to Help Manage a Major Disaster Program: Case Study - The October Flood in SC and FEMA Substantial Damage Inspections
PRESENTER 2 **4:20-4:45**	Matthew Neet University of South Carolina Environmental Justice Guideline Comparisons with Coincident Fish Consumption Advisory Waterbodies in South Carolina	Francis Chapelle US Geological Survey The Removal Kinetics of Dissolved Organic Matter and the Optical Clarity of Groundwater	Guinn Wallover Clemson University Master Pond Manager: A Model Approach for Better Pond Management Outreach	Carson Pruitt Phinizy Center for Water Sciences Modeling an Urban Stream's Response to Precipitation, a Case Study in Augusta, Georgia	Christopher Mothorpe College of Charleston South Carolina Pond Management Approaches and Costs: An Economic State-of-Knowledge Review & Synthesis	Edward Rabon SCDHEC Monitoring the Effects of the South Carolina Flood Events in Charleston Harbor in October 2015
PRESENTER 3 **4:50-5:15**	Ronnie Martin SCDHEC Clean Water Act Implementation Assessment: How are States Implementing and are there Opportunities to Improve Efficiency?	Kevin Finneran Clemson University Combined Biological & Chemical Approaches in Groundwater Remediation	Chris Starker Upstate Forever Diving into Development Standards to Find Stormwater Remedies that Save Money and Improve Safety	S. Samadi University of South Carolina Embracing Uncertainty: A Case Study Examining Bayesian Algorithm to Conceptual and Distributed Hydrology Models over a Complex Environmental System	PANEL DISCUSSION WITH ALL PRESENTERS	Stephen Arnott SCDNR Effects of the Hurricane Joaquin Extreme Flooding Event in the Estuaries and Coastal Waters of South Carolina
5:30-7:00	**Reception, Poster Session and Judging for Student Poster Competition (Lower Level) / Sponsored by Santee Cooper**					

DAY 2 • Morning • Thurs, 10/13 2016 SC Water Resources Conference Schedule

7:30 AM	**Registration Opens**					
8:30-10 AM	Ballroom A **Welcome and Conference Remarks** | *Jeffery Allen, Executive Director - Clemson University SC Water Resources Center* **Morning Plenary Session: Legislative Panel, South Carolina Flooding Events and State Water Planning** *Moderator: Senator Paul Campbell, Ag & Natural Resources Committee* *Panel Participants: Senator Danny Verdin (Ag & Natural Resources Committee); Senator Vincent Sheheen (Ag & Natural Resources Committee); Rep Roger Kirby (Ag, Natural Resources & Environmental Affairs Committee); Rep Russell Ott (Ag, Natural Resources & Environmental Affairs Committee)*					
10-10:30 AM	**Morning Break (Lower Level)**					
SESSION 4 10:30-NOON	**TRACK 1** **Water Policy and Planning** Lexington Room A	**TRACK 7** **Coastal and Estuarine Systems** Lexington Room B	**TRACK 3** **Stormwater** Richland Room A	**TRACK 4** **Hydrologic Monitoring and Modeling** Richland Room B	**TRACK 5** **Climate, Floods and Drought** Richland Room C	**TRACK 6** **Infrastructure** Congaree A
SESSION TITLE **MODERATOR**	**Understanding and Communicating Risk** Rob Carey Clemson University	**Land Use and Urbanization** Anne Blair NOAA Hollings Marine Laboratory	**Research: Pond Management** Heather Preston SCDHEC	**Hydrology/Water Quality Monitoring II** Colt Bowles USACE	**Climate Change and Water Resources in the Carolinas** Katie Buckley Clemson University	**Infrastructure Water Use** Robert Osborne Black & Veatch
PRESENTER 1 10:35-11	Mike Caston SJWD Water District WHAT IF...? Using Dendroclimatology for Water Resource Planning	William Vesely College of Charleston Using Dissolved Organic Carbon Concentration and Character Data to Assess Land Use Change Effects on Coastal Waters	Austin Waldorf Coastal Carolina University Determining the Hydraulic Efficiency of Stormwater Detention Ponds in South Carolina through the Quantification of Hydrolic Budgets	Patrick McMahon S&ME Application of Various 1-D and 2-D Hydraulic Modeling Software for Stream Restoration Design	Kirsten Lackstrom Carolinas Integated Sciences and Assessments Climate and Water Resources in the Carolinas: Approaches to Applying Global Climate Change Information to Local & Regional Questions	David Ladner Clemson University Mapping South Carolina Drinking Water Quality for Alignment with Health-Record Databases in Epidemiological Studies
PRESENTER 2 11:05-11:30	Chris Mack AECOM Effective Strategies for Communicating Risk	Kimberly Sitta College of Charleston Top-down and Bottom-up Controls of Phytoplankton Assemblages in Two South Carolina Estuaries	Erik Smith University of South Carolina North Inlet-Winyah Bay NERR Pollutant Removal Performance in Stormwater Detention Ponds Typical of Coastal South Carolina	John Durkee Water Environment Consultants Using Models to Improve Your NPDES Limits	Michael Childress Clemson University Using the Coastal Salinity Index and Predicted Streamflow to Forecast SC Blue Crab Landings	Hope Walker Black & Veatch What Happens When the Dam Breaks? SJWD's Emergency Action Plan Program
PRESENTER 3 11:35-12	Sayward Harrison University of South Carolina Building Disaster-Resilient Communities: Stakeholder Perspectives on Risk, Response, and Recovery Following the 2015 SC Floods	Kathryn Ellis College of Charleston Hydrological Assessments of Tidal Creeks to Inform Nutrient Management Recommendations	Kimberly Jones Town of Bluffton Management Decision Implications Resulting from Analysis of Stormwater Best Management Practice Efficacy Across Temporal and Varying Spatial Scales	Shane Boring Kleinschmidt Associates Development of Habitat-based Minimum Flows for South Carolina Reservoirs: Options for Site-specific Data	Aashka Patel University of South Carolina A Bottom-up Approach for Assessing the Long-term Reliability of Water Supply in a Changing Climate	Jonathan Williams, HDR Fred Castles, Catawba-Wateree Water Management Group Raw Water Intake Contingency Planning for Resilient Water Supply - CWWMG

DAY 2 • Afternoon • Thurs, 10/13 2016 SC Water Resources Conference Schedule

12-1:30 PM LUNCH	Ballroom B/C **Lunch Plenary Session: Update on the South Carolina Surface Water Availability Assessment** **Opening Remarks:** *Colonel Alvin Taylor, SC DNR; Catherine Heigel, SCDHEC* **Project Partner Leads:** *Ken Rentiers, SC DNR; David Baize, SCDHEC; John Boyer, CDM Smith; Jeffery Allen, Clemson University*					
SESSION 5 1:45-3:15	**TRACK 1** **Water Policy and Planning** Lexington Room A	**TRACK 7** **Coastal and Estuarine Systems** Lexington Room B	**TRACK 3** **Stormwater** Richland Room A	**TRACK 4** **Hydrologic Monitoring and Modeling** Richland Room B	**TRACK 5A** **Climate, Floods and Drought** Richland Room C	**TRACK 5B** **Climate, Floods and Drought** Congaree A
SESSION TITLE **MODERATOR**	**Water Planning Tools and Techniques** Shawn Nanney Clemson University	**Monitoring** Rheta Geddings DiNovo SCDHEC	**Case Studies** Cal Sawyer Clemson University	**Emerging Contaminants** Gwen Geidel University of South Carolina	**Impact of Climate Change on Streamflow** Robert Osborne Black & Veatch	**Development of a Drought Early Warning System for the Carolinas** Jane Byrne Charleston Water System
PRESENTER 1 **1:50-2:15**	Anne Marie Johnson SCDHEC Utilization of the SC Watershed Atlas for Water Resource Planning and Management	Benjamin Theaput US Geological Survey Streamgaging Toward the Future: Continuous Nitrate Monitoring, Waccamaw River Watershed, SC	Debabrata Sahoo Woolpert Unraveling the Dissolved Oxygen TMDL Truth Using Continuous Water Quality Monitoring in South Carolina	Sarah Au Clemson University Bioavailability of Fluoranthene Adsorbed to Microplastics	Anoop Valiya Veettil Clemson University Water Resources in Savannah River Basin: Historical Assessment and Projected Climate Change Scenarios Analysis	Kirsten Lackstrom Carolinas Integrated Sciences and Assessments Development of a Drought Early Warning System for the Coastal Carolinas: Session Introduction
PRESENTER 2 **2:20-2:45**	Bruce Campbell US Geological Survey South Carolina Atlantic Coastal Plain Groundwater Availability Model	Barbara Beckingham College of Charleston Transport of Carbonaceous Materials and PAHs in a Tidal Creek-Bull Creek, Charleston, SC	Kendall Flint Holbrook Woolpert Regulations of Stormwater in South Carolina, History and Development over 45 Years	Paul Bradley US Geological Survey Bioactive and Biocidal Contaminants in Water, Sediment, and Tissue at Congaree National Park	David Werth Savannah River National Laboratory Quantifying the Effect of Compromised Water Resources on Operations at the Department of Energy's Savannah River Site	Greg Carbone University of South Carolina A Hydroclimate Extremes Atlas for the Carolinas Paul Conrads US Geological Survey Hydrologic Record Extension of Salinity Data to Evaluate Long-Term Coastal Drought Conditions
PRESENTER 3 **2:50-3:15**	Andrea Sassard SC Sea Grant Consortium Creation of a Visualization and Access Portal for Coastal South Carolina Water Monitoring and Sampling Locations	Brooke Czwartacki SCDNR Monitoring Saltwater Intrusion along the Coast of South Carolina	William Lamb Amec Foster Wheeler Kinley Creek Watershed Study: Solving Difficult Flooding Problems in an Urban Watershed	Paul Bradley US Geological Survey Microcystins Occurrence in Wadeable Streams in the Southeastern United States	Kirk Westphal CDM Smith Reducing the Risks of Climate Uncertainty on Water	Amanda Farris Carolinas Integrated Sciences and Assessments What Can Citizen Scientists Tell Us About Drought? Using the Community Collaborative Rain, Hail & Snow Network to Improve the Monitoring and Reporting of Drought Impacts in the Carolinas
3:15-3:45	**Afternoon Break (Lower Level)**					

DAY 2 • Afternoon • Thurs, 10/13 2016 SC Water Resources Conference Schedule

SESSION 6 3:45-5:15	TRACK 1 **Water Policy and Planning** Lexington Room A	TRACK 7 **Coastal and Estuarine Systems** Lexington Room B	TRACK 3 **Stormwater** Richland Room A	TRACK 4 **Hydrologic Monitoring and Modeling** Richland Room B	TRACK 6 **Infrastructure** Richland Room C
SESSION TITLE MODERATOR	**Water Resource Planning II** Mike Harrelson Santee Cooper	**Resource Management & Loss** Tim Callahan College of Charleston	**Implications of Hydraulic Design** Anne Blair NOAA Hollings Marine Laboratory	**Biological Communities** Katie Buckley Clemson University	**Nutrients and Water** Jane Byrne Charleston Water System
PRESENTER 1 3:50-4:15	Rebecca Berzinis Atkins Long-term and Two-period Analysis of Hydrologic Conditions of the South Edisto River	Jeremy Pike Clemson University Developing Sediment Management Guidelines for the Broad River Basin	Tangina Afrin Clemson University Discharge Characteristics of Perforated Pipe Underdrain-Aggregate System	Kevin Conlon US Geological Survey Determination of Changes in Water Quality, Streambed Sediment, & Benthic Macroinvertebrates as a Result of Stormwater Runoff from Selected Bridges in South Carolina	Chad Wagner US Geological Survey Effects of Land-Applied Biosolids on Surface-Water Loads and Groundwater Quality in the Jordan Lake Watershed, NC
PRESENTER 2 4:20-4:45	Angela Vandelay&Kelli Garcia Amec Foster Wheeler Development of Watershed Plans	Daniel Calhoun US Geological Survey Spatial and Temporal Assessment of Back-Barrier Erosion on Cumberland Island National Seashore	Katherine Johnson Phinizy Center for Water Sciences Stormwater Infrastructure and Channel Integrity: How to Assess Tributaries in the Watershed of Augusta-Richmond County and Other Urban Areas	Damon Mullis Phinizy Center for Water Sciences Thermal Regime below Thurmond Dam and its Relationship to the Longitudinal Organization of Macroinvertebrate Assemblages	Matt Huddleston SynTerra Corporation Adaptive Water Resource Management for Problem Algae
PRESENTER 3 4:50-5:15	Melanie Ruhlman Save Our Saluda Safe Yield and Minimum Flow Determinations in the Upper Saluda River Watershed	Jared Porter Kleinschmidt Associates Influence of Environmental Variable on Passage of American Shad at the Columbia Diversion Dam, Broad River, SC	Will Martin Clemson University Impact of Climate Change on Site Rainfall-Runoff Characteristics	Kelsey Laymon Phinizy Center for Water Sciences Comparison of Benthic Macroinvertebrates Colonizing Three Types of Passive Samplers for Non-Wadeable Streams	Shawn Rosenquist Phinizy Center for Water Sciences A Historical Perspective of Nutrient Levels, Sources and Processing in the Savannah River Basin
5:15	**Conference Closes**				

UNDERWRITER

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TITLE CONTRIBUTORS

*Santee Cooper
*Duke Energy

BENEFACTORS

Anderson Regional Joint Water System
*Charleston Water System
Greenville Water
*South Carolina Department of Health and Environmental Control
South Carolina Department of Natural Resources
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Startex-Jackson-Wellford-Duncan Water District
University of South Carolina School of the Earth, Ocean and Environment;
Department of Environmental Health Sciences
Woolpert

** Five-Time Contributor*

Letter from the Conference Chair

Welcome to the fifth biennial South Carolina Water Resources Conference (SCWRC). This year marks nearly a decade of planning and hosting these water meetings, which are critical information sharing venues for water scientists, planners, managers and decision makers from across South Carolina. This year's conference theme, "*South Carolina Water Resources at a Crossroads: Response, Readiness and Recovery"*, represents the work of numerous individuals and groups involved in research, management and on-the-ground response to extreme weather and other events impacting our water resources. The opening keynote and lunch plenaries on the first day will provide conference attendees an in-depth look at the October 2015 flood from the viewpoint of state and federal agencies, and one of the hardest hit municipalities, Columbia. The second day plenaries include a panel of state legislative leaders who will comment on the flood and pertinent efforts in state water planning, and an update on the South Carolina Surface Water Availability Assessment project (www.scwatermodels.com).

This year's conference will feature 109 oral and 46 poster presentations. The abstracts for these presentations have been actively solicited from colleges and universities; state and federal agencies; municipal water authorities and entities; environmental engineering, consulting and law firms; utility companies, nonprofit organizations; land trusts and economic development associations. The presentations over these two days represent countless hours spent researching, gaining understanding of and managing South Carolina's precious natural resources. Attendees will be able to choose from individual presentations in concurrent sessions among seven tracks, including Water Policy and Planning; Surface Water and Groundwater Systems; Stormwater; Hydrologic Monitoring and Modeling; Coastal and Estuarine Systems; Infrastructure; and Climate, Floods and Drought.

As in the past four conferences, the 2016 event has brought together over 300 participants to engage in learning about our natural resource and water issues through research in a wide variety of disciplines including engineering, agriculture, environmental conservation and water policy. This gathering will provide opportunities to understand water crises and challenges of the past and plan for resilient management of our water resources for the future. The conference has been sponsored by Clemson University Public Service and Agriculture since its inception in 2008. It is organized by the South Carolina Water Resources Center as a collaborative effort with a planning committee made up of statewide water resources professionals representing many of the major state universities and agencies, utilities, non-profits and private sector groups.

On behalf of all of the members of the conference planning committee, we thank you for your support of and involvement in this year's conference.

Jeffery S. Allen, Ph.D.
South Carolina Water Resources Conference Chair
Clemson University South Carolina Water Resources Center Executive Director

CONFERENCE DATES AND PROCEEDINGS

Allen, Jeffery S. and Dawn A. White (ed.), Proceedings of the 2016 South Carolina Water Resources Conference,
ISBN: 978-0-692-79009-0, 76 pages, October 12-13, 2016

Exhibitors

Exhibits open Wednesday morning and end Thursday evening. Exhibits are located on both the Upper Level outside the ballrooms and on the Lower Level outside the session breakout rooms (Lexington and Richland meeting rooms).

LOWER LEVEL

See diagram on facing page for exhibitor space assignments on the lower level.

Amec Foster Wheeler
Carolina Clear
Coastal Carolina University's Waccamaw Watershed Academy
College of Charleston Graduate Program in Environmental Studies
Duke Energy
Greenville Water
Normandeau Associates, Inc.
OTT Hyrdromet
South Carolina Department of Health and Environmental Control
South Carolina Department of Natural Resources
South Carolina Mitigation Association
S&ME
Santee Cooper
SynTerra
US Geological Survey
University of South Carolina School of the Earth, Ocean and Environment; Department of Environmental Health Sciences
Water Missions International (Hosted by Charleston Water System)
Wildlands Engineering, Inc.
YSI

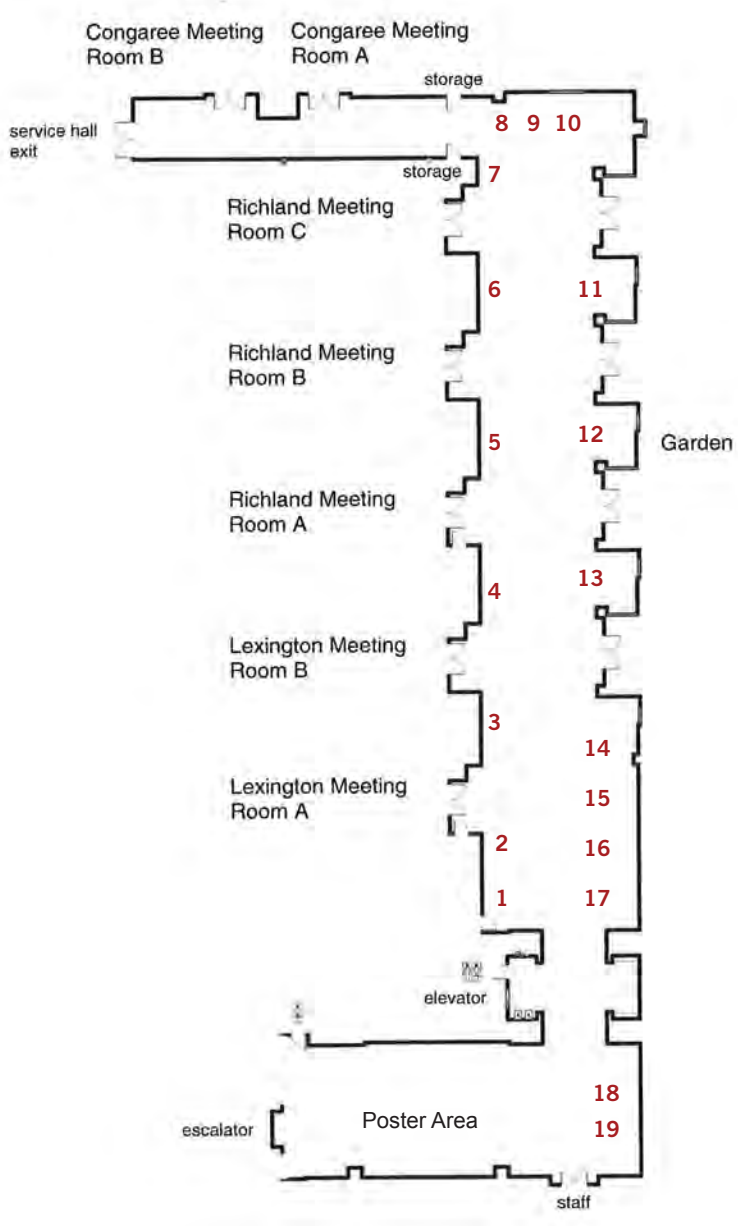
UPPER LEVEL

Exhibitors on the upper level are located near the registration desk, across from the ballrooms.

Carolinas Integrated Sciences and Assessments (CISA)
Clemson University Public Service and Agriculture / South Carolina Water Resources Center
Clemson University Center for Watershed Excellence
McCormick Taylor

Exhibit Locations - Lower Level

1. YSI
2. Greenville Water
3. Duke Energy
4. SC DNR
5. SC DHEC
6. Carolina Clear
7. OTT Hyrdromet
8. Wildlands Engineering
9. SC Mitigation Association
10. Normandeau Associates
11. Coastal Carolina University
12. University of South Carolina
13. Santee Cooper
14. Amec Foster Wheeler
15. College of Charleston
16. SynTerra
17. Water Missions International
    (*hosted by Charleston Water System*)
18. US Geological Survey
19. S&ME



Plenary Sessions

Wednesday 8:30 a.m.

Opening Remarks
Jeffery Allen - SCWRC Chair and Executive Director, Clemson University SC Water Resources Center

South Carolina's Water Resources - Our Time is Now
George Askew - Vice President for Clemson University Public Service and Agriculture and Dean, College of Agriculture, Forestry, and Life Sciences

The October 2015 Flood in South Carolina: Federal and State Perspectives
John Shelton - Assistant Director for Data, US Geological Survey
Maria Cox Lamm - State Flood Mitigation Director, SC Department of Natural Resources
Jill Stewart - Dam Safety and Stormwater Permitting Division Director, SC Department of Health and Environmental Control

Wednesday 12:00 p.m.

Session Sponsored by Duke Energy

The October 2015 Flood in South Carolina: A Local Perspective, City of Columbia Water Works
Clint Shealy - Water Works Superintendent, City of Columbia

Thursday 8:30 a.m.

Legislative Panel: October 2015 Flood and State Water Planning

Moderator: Senator Paul G. Campbell, Jr. - Senate Agriculture and Natural Resources Committee Member

Panel Members:
Senator Daniel Verdin - Senate Agriculture and Natural Resources Committee Chairman
Senator Vincent Sheheen - Senate Agriculture and Natural Resources Committee
Representative Robert Kirby - House Agriculture, Natural Resources and Environmental Affairs Committee
Representative Russell Ott - House Agriculture, Natural Resources and Environmental Affairs Committee

Thursday 12:00 p.m.

Update on the South Carolina Surface Water Availability Assessment

Opening Remarks:
Colonel Alvin Taylor - Director, SC Department of Natural Resources (SC DNR)
Catherine Heigel - Director, SC Department of Health and Environmental Control (SCDHEC)

Project Partner Leads:
Ken Rentiers - Land, Water and Conservation Division Deputy Director, SC DNR
David Baize - Chief, SCDHEC Bureau of Water
John Boyer - Senior Water Resources Engineer, CDM Smith
Jeffery Allen - Executive Director, Clemson University SC Water Resources Center

Poster Presentations

Poster Session and Student Poster Competition sponsored by Santee Cooper.

The Poster Session is Wednesday, October 12 from 5:30 p.m. to 7:00 p.m. on the Lower Level. Posters will be displayed in assigned order as numbered below. *Special Clean WateR3 Series featured in spaces 22-28.*

** Student posters*

1. ***Allen, Joshua,** Meghan E. Franco, Amy A. Cuthbertson, Susana Kimura-Hara, Susan D. Richardson
   University of South Carolina
   Is There a Disinfection By-Product Problem in Flint?

2. ***Alnahit, Ali,** Abdul Khan, Tom Owino
   Clemson University
   Impacts of Interpolation Schemes on Critical Source Areas Identification for Non-Point Source Pollution Control Based on SWAT Model

3. **Arrington, Tanner,** Jennifer Simmons, Hope Mizzell, Wes Tyler
   SC Department of Natural Resources
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4. ***Barnum, Drew,** Rachel L. Fein, Vijay M. Vulava
   College of Charleston
   Geochemical Fate of Three Antidepressant Chemicals in Natural Soils

5. ***Bowden, Shelby, Anton** Dumars, Timothy Callahan
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6. ***Cochran, Kristin,** Jorge Casado, Danilo Russo, Danilo Spasiano, Marianna Vaccaro, Roberto Andreozzi, Raffaele Marotta, Nuno M. Reis, Gianluca Li Puma, Dionysios Dionysiou, Daniel Schlenk, Susan Richardson
   University of South Carolina
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7. ***Conley, Kenda,** Barbara Beckingham, Jestine Deepe, Allan Clum
   College of Charleston
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8. **Conrads, Paul,** Daniel Tufford, Lisa Darby,
   US Geological Survey
   Critical Aspects of the Coastal Drought Index: Length of Salinity Data Record and Ecological Response Data

9. **Conrads, Paul,** Bryan McCloskey
   US Geological Survey
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10. ***Dearth, Nicole,** Joe Jones, Rebecca Mortensen, Cameron Doll, Dianne I. Greenfield
    University of South Carolina
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Clemson University
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Phinizy Center for Water Sciences
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University of South Carolina
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University of Charleston
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College of Charleston
Geochemical Fate and Transport of Diphenhydramine in Natural Soils

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Clemson University
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45. **Amatya, D.M.,** A. Muwamba, T. Callahan, S. Harder, A. Pellett, E.W. Tollner
USDA Forest Service
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Clemson University
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Clean WateR^3: An Undergraduate Experience

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Clemson University
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Clemson University
Development of Online Tools for Ornamental Container Nursery Water Conservation, Remediation, and Reuse

26. **Majsztrik, John,** Daniel Hitchcock, David Sample, Saurav Kumar, Sarah White
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Water Treatment Technologies for Specialty Crops

27. ***Moriarty, Clare,** Josh Short, William Strosnider, Sarah White, Daniel Hitchcock
Clemson University
Floating Treatment Wetlands: Effects of Varying Coverage on Eutrophic Pond Mesocosms

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Clemson University
Clean WateR^3: Integrating Extension and Research to Help Specialty Crop Growers Reduce, Remediate, and Recycle Water

Abstracts

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***Afrin, Tanjina**[1], Nigel Kaye[1], Abdul Khan[1], Firat Testik[2]

[1]Clemson University, [2]University of Texas at San Antonio

DISCHARGE CHARACTERISTICS OF PERFORATED PIPE UNDERDRAIN-AGGREGATE SYSTEM (T3,S6)

Perforated pipe underdrain-aggregate systems are becoming popular for managing excess stormwater runoff. Available literature and state design manuals for stormwater runoff management do not provide any guidance on optimum sizing of perforated pipes (length and diameter); effect of several geometric parameters on system discharge characteristics are unavailable also. For addressing these issues, a detailed computational parametric study of a perforated pipe underdrain-aggregate system with free overfall has been conducted. Several controlling trench geometric parameters (i.e., trench width, head, and aggregate depth over the pipe) and pipe geometric parameters (i.e., pipe wall perforation area per unit length of pipe, and the area of individual perforations) were varied to quantify the effect of these parameters' variation on system discharge characteristics. Results portray that, for each combination of these parameters, there is a finite pipe length after which system's discharge becomes independent of pipe length (defined as "critical length"). A functional form of the system discharge coefficient has been developed based on simulated results and the developed equation can be used for sizing underdrains in Low Impact Development (LID)/ Best Management Practice (BMP) stormwater systems. Variability in the modeled discharge coefficient using the developed equation is similar to the variability that can be found from full-scale installations. It was found that the effective pipe system discharge coefficient is a function of the pipe geometry and insensitive to trench geometry for the range of parameters tested. These results have practical applications in quantifying the peak outflow from the underdrain when a system is flooded.

***Allen, Joshua,** Meghan E. Franco, Amy A. Cuthbertson, Susana Kimura-Hara, Susan D. Richardson

University of South Carolina

+IS THERE A DISINFECTION BY-PRODUCT PROBLEM IN FLINT?

Last year, the presence of lead in tap water in Flint, Michigan brought increased attention to residents concerning the quality of their water. Although lead levels are back to normal, recent reports of skin rashes and respiratory issues have sparked questions surrounding tap water in these homes. This study aims to investigate the presence of contaminants, including disinfection byproducts (DBPs), in the hot water used for showering and bathing in the homes of residents in Flint. DBPs are formed when natural organic matter (NOM) reacts with disinfectants as well as bromide and iodide present in source water, and some are known to cause respiratory issues. Tap waters (both hot and cold) were sampled from homes where issues have been reported for analysis. Comparatively, tap water samples were also collected from Detroit, Michigan that uses the same source water (Lake Huron) and residences in Lyons, GA and Grovetown, GA. Quantitative analysis was performed for 57 priority unregulated DBPs, including iodo-acetic acids, halonitromethanes, iodo-trihalomethanes (THMs), haloketones, haloamides, haloacetaldehydes, haloacetonitriles, and nitrosamines, using gas chromatography-mass spectromety (GC-MS). Additionally, 100 volatile organic compounds (VOCs) were quantified using EPA method 8260B, and the VOC data revealed the presence of three THM DBPs, which were either at or below the regulatory limit of 80 µg/L for total THMs. Comprehensive, broadscreen analysis of the water samples via XAD resin extraction was carried out to identify possible unknown DBPs and other organic contaminants. These extracts were analyzed using GC-high resolution-MS at 25,000 resolution with a LECO time-of-flight mass spectrometer as well as an Agilent GC-MS. This work will shine light on possible harmful contaminants present in Flint tap water and give direction on what changes could be made for improved water quality.

***Alnahit, Ali,** Abdul Khan, Tom Owino

Clemson University

+EFFECT OF SPATIAL DISTRIBUTION OF PRECIPITATION ON TEMPORAL AND SPATIAL UNCERTAINTY OF SWAT OUTPUT

The Critical Source Areas (CSAs) have been widely recognized as priority locations for the control of NPS pollution and implementation of best management practices (BNPs). In previous studies, CSAs were identified based on factors such as pollutant concentration, load, and yield at the levels of subwatered and/or hydrologic response unit (HRU); however, the previous studies did not consider the impact of the temporal and spatial uncertainties of rainfall data, which is the driven force of NPS pollution. The objectives of this study were to (1) assess the impact of using different interpolation schemes on identifying CSAs and (2) assess seasonal and spatial uncertainty of different rain gauge density on both model parameters and predictive uncertainty. The study used five different methods; Thiessen polygons, statistical, geostatistical approaches to incorporate spatially variable of rainfall into the Soil and Water Assessment Tool (SWAT). The study also identified the impacts of five different gauge-density scenarios. The scenarios were evaluated by finding the best performing parameter set and their associated uncertainty ranges using the Sequential Uncertainty Fitting Procedure. By applying different interpolation schemes in SWAT model, the maps of CSAs at the subwatered level for controlling total nitrogen (TN) and total phosphorus (TP) were produced. The CSAs identified using different interpolation methods were the same, while some CSAs were different. This study concludes that using different interpolation methods will affect the location of some CSAs and further investigation on using the interpolation methods is needed.

Amatya, D. M.[1], A. Muwamba[2], T. Callahan[3], S. Harder[4], A. Pellett[4], E. W. Tollner[2]
[1]USDA Forest Service, Center for Forested Wetland Research, [2]University of Georgia, [3]College of Charleston, [4]South Carolina Department of Natural Resources

+ESTIMATION OF POTENTIAL EVAPOTRANSPIRATION USING THREE DIFFERENT METHODS FOR SPATIALLY DISTRIBUTED WEATHER STATIONS ACROSS THE STATE OF SOUTH CAROLINA, USA

Evapotranspiration (ET) is a major component of the water budget and hence reliable estimates of ET and potential evapotranspiration (PET) are needed for sustainable water resource management and planning, irrigation scheduling and crop water management. The objective of this study is to estimate spatially and temporally PET for the state of South Carolina using three methods for a standard grass reference and a 20-year (1996-2015) data set. Data will be collected from National Weather Service Cooperative Network weather stations distributed across the blue ridge, piedmont, and coastal regions of South Carolina. Depending on the availability of data, the three methods that will be used are: the full process-based Penman-Monteith (also referred to as REF-ET), the net radiation-based Priestley-Taylor, and the temperature-based Hargreaves-Samani method. The full process-based REF-ET method involves net radiation, air temperature, relative humidity, wind speed, and canopy resistance (which is a function of stomata conductance and leaf area index); because not all parameters may be available at all field stations the multiple methods will be compared only at a subset of stations in each of the three regions. The expected outcomes of the study include; (1) tabular summary statistics showing spatial and temporal distribution of the daily, monthly/seasonal, and annual PET from 1996-2015 for the three methods, (2) GIS-based interpolated contour maps showing mean monthly/seasonal and annual PET estimates with their standard deviations, and (3) estimates of lake water evaporation using the best available data. Compilation of these weather data and multi-method PET estimates will be used by the State to improve surface and groundwater assessments being developed as part of a multi-year project to update the State Water Plan.

Amatya, Devendra, C. A. Harrison, C. C. Trettin
USDA Forest Service

RAINFALL AND HYDROGRAPH RESPONSE FROM WATERSHEDS FOR THE OCTOBER 2015 EXTREME PRECIPITATION EVENT ON THE SANTEE EXPERIMENTAL FOREST (T4B,S1)

The extreme precipitation event on October 3-4, 2015, reported to be associated with a persistent deep easterly flow and the circulation of Hurricane Joaquin in the Atlantic Coast (*http://cms.met.psu.edu/sref/severe/2015/04Oct2015.pdf*) resulted in widespread flooding in many parts of South Carolina. To assess the resulting storm hydrograph response, we present an analysis of the precipitation amount and intensities measured in four gauges during the extreme event followed by their impacts on stream runoff and flooding using the measured data on groundwater wells and streamflow gauging stations at the USDA Forest Service Santee Experimental Forest (SEF) located 60 km north-west of Charleston, South Carolin. We compared a long-term rainfall intensity-duration-frequency (IDF) curve derived for various return periods of interest using daily (24-hour duration) data from 1951 through 2015 at the SEF with the established IDF curve for Charleston, South Carolina. The rainfall amounts measured at all four SEF rain gauges during the October 2015 extreme event exceeded those established for Charleston for all durations (3-, 6-, 12-, 24- and 48-hour), except for the 1-hour period. The peak stage heights recorded on October 04, 2015, at all the SEF watershed gauging stations of varying scales (1st order - WS 80 and WS 77, 2nd order - WS79, and the 3rd order - WS 78) were substantially higher than the previously recorded stages for the extreme event of October 24, 2008, exceeding the design capacity of the WS 77 watershed outlet. The stormflow hydrograph started with a very low flow at the onset of the rain event (September 28) with a gradual increase during the ensuing 5-day (September 28- October 2) period which received approximately 145 mm or more rainfall bringing the soils under saturation and/or ponding based on recorded well water tables. Subsequently, the October 3-4 rainfall on the SEF varied from 471 mm to 497 mm, generating dramatic runoff response from all the 1st, 2nd, and 3rd order watersheds that are being characterized to quantify the flow and its routing dynamics in the context of observed rainfall, stage, ground water table, and high flood marks across these watersheds. Initial analysis on WS 80 watershed indicates an exponential increase in streamflow after surface ponding exceeding 6 cm on one of its ground water wells. Correspondingly, peak discharges were estimated as 17.4 m^3 s-1 (10.9 m^3 s-1 km-2), 33.9 m^3 s-1 (6.8 m^3 s-1 km-2), and about 70 m^3 s-1 (1.35 m^3 s-1 km-2) for the 1st (WS 80), 2nd (WS 79), and 3rd (WS 78) order watersheds, respectively. A survey of high-water flood marks along forest roads and bridges shows large areas of the watersheds being inundated, consistent with the recorded gauging heights and water levels in all ground water wells. Additional analyses being conducted for these forested watersheds will provide insights into the effects of the extreme events on the existing IDF curve as well as controlling mechanisms affecting storm runoff generation and routing dynamics that may serve as a reference for this rapidly urbanizing low-gradient coastal landscape.

Arnott, Stephen A., Andrew W. Tweel, Joseph C. Ballenger, Amy E. Fowler, Dianne I. Greenfield, Peter R. Kingsley-Smith, Denise M. Sanger
SC Department of Natural Resources

EFFECTS OF THE HURRICANE JOAQUIN EXTREME FLOODING EVENT IN THE ESTUARIES AND COASTAL WATERS OF SOUTH CAROLINA (T5,S3)

In October 2015, extreme rainfall associated with Hurricane Joaquin resulted in historic flooding in South Carolina. The floodwaters flowed into estuaries along the state's coastline, causing dramatic shifts in coastal conditions. The Marine Resources Division of the South Carolina Department of Natural Resources responded to the event by mobilizing a coordinated monitoring effort

with the goal of recording water quality and biological information in estuaries and nearshore areas. In order to integrate data originating from disparate sections across the division, a cloud-based database and mapping system was built that allowed multiple data sources to be rapidly integrated and graphically displayed. Between October and December 2015, over 7,000 water quality measurements (mostly salinity, conductivity, temperature and dissolved oxygen) were recorded from over 700 stations along the coastline. These data were then compared against numerous long-term datasets of estuarine and coastal conditions compiled by the Division over the last several decades. In the initial days following the flood, estuaries along the entire coast of South Carolina showed very rapid declines in salinity, reductions in water temperature, dissolved oxygen and chlorophyll, and increases in waterborne bacteria. Transects taken off Charleston Harbor, the Santee River and Winyah Bay confirmed that a large freshwater plume extended well offshore, as also visible by satellite imagery. Near hypoxic conditions (< 3 mg l-1) occurred in numerous locations up to a month after the flood, and were most noticeable in the vicinity of the Winyah Bay estuarine system. Several biological monitoring programs found that the abundance of some estuarine-dependent species changed, although other species showed no detectable response. Catch rates of spotted seatrout (*Cynoscion nebulosus*), black drum (*Pogonias cromis*), blue crab (*Callinectes sapidus*) and white shrimp (*Litopenaeus setiferus*) all increased in lower estuarine habitats during the months immediately after the flood, while some freshwater species of fish were caught in areas where they had not previously been found. The increased catch rates of all these organisms were likely driven by downstream movements in response to the flood, causing them to aggregate in lower estuarine habitats where monitoring took place. In contrast, oyster (*Crassostrea virginica*) mortality occurred in some of the flood-impacted areas because they were unable to tolerate large shifts in salinity. Future data from the biological monitoring programs will be used to test whether longer term population processes, such as recruitment dynamics, were affected. The flood response information we gathered will be archived and made available as a reference dataset for comparison with future flood events.

Arrington, Tanner, Jennifer Simmons, Hope Mizzell, Wes Tyler
SC Department of Natural Resources

+CARTOGRAPHY AND THE FLOOD: A MAP OF SOUTH CAROLINA'S HISTORIC RAINFALL EVENT

The historic rainfall event in October of 2015 was widespread. Record rainfall totals occurred across much of the state, with rates exceeding 1000-year average recurrence intervals (ARI). This poster presents a unique cartographic method that shows ARI together with rainfall totals, revealing patterns and relationships between the two measurements.

***Au, Sarah**, Stephen J. Klaine
Clemson University

BIOAVAILABILITY OF FLUORANTHENE ADSORBED TO MICROPLASTICS (T4,S5)

Microplastics (MPs) are widespread and ubiquitous contaminants in aquatic ecosystems. MPs are in the same size fraction as most sediment particles and microorganisms, allowing them to be easily ingested by a variety of organisms. The ingestion of MPs can result in digestive tract blockage and MP translocation into the circulatory system, potentially indirectly reducing growth, reproduction, and ingestion rates of natural food items. However MP toxicity seems to largely depend on MP characteristics, and be species-specific. Further, should ingested MPs have adsorbed organic contaminants, MPs may potentially act as a source of environmental contaminants. The potential for MPs to alter the bioavailability of contaminants has been studied in very few organisms. Polycyclic aromatic hydrocarbons (PAH) are a class of persistent organic pollutants that are ubiquitous in aquatic ecosystems. Fluoranthene (FLU) is one of the US EPA's 16 priority PAHs, and its hydrophobic nature allows it to sorb easily to sediment and organic matter; this parameter suggests FLU will sorb to the hydrophobic surfaces of most MPs. The goal of this research was to characterize the bioavailability of MP-adsorbed FLU. The bioavailability of FLU adsorbed to polyethylene MPs to *Pimephales promelas* was characterized during standard 4-day bioassays. Fathead minnows exposed to FLU-saturated MPs resulted in higher FLU body burdens than waterborne FLU exposures without MPs. The ingestion of amphipods that were previously exposed to FLU-saturated MPs by fathead minnows also resulted in the presence of FLU in the bile of exposed fathead minnows. The results suggest that both the direct and indirect (via trophic transfer) ingestion of FLU-contaminated MPs may be uptake pathways of both MPs and adsorbed contaminants.

***Barnum, Drew,** Rachel L. Fein, Vijay M. Vulava
College of Charleston

+GEOCHEMICAL FATE OF THREE ANTIDEPRESSANT CHEMICALS IN NATURAL SOILS

The use of prescription antidepressant medications has increased significantly around the world and is becoming a more common pollutant in surface water and drinking water. In this study we investigated three of the most commonly prescribed antidepressant chemicals - bupropion (BUP), fluoxetine (FLX), and sertraline (SER). The main objective of our research was to measure competitive sorption and transport behaviors of these chemicals in natural soils. BUP is a unicylcic, aminoketone antidepressant with a water solubility of 312 mg/mL and pKa value of 7.9. FLX is a cyclic compound with a water solubility of 50 mg/mL and a pKa value of 9.8. SER is a tametraline compound with a water solubility of 3.5 mg/mL and a pKa value of 9.85. These properties indicate that each of these pharmaceutical chemicals can infiltrate ground water through the soil and enter our drinking water. In our previous studies we investigated sorption and transport behavior of each of these compounds individually in soils. In this study we investigated if these compounds

would compete with each other when sorbing to soil minerals. To study this competitive transport behavior, we injected solution containing all pharmaceutical chemicals through glass chromatography columns packed with soils from both the A and B soil horizons. Effluent solutions were analyzed using a high-pressure liquid chromatograph (HPLC) equipped with UV detector. Column breakthrough curves that showed each of the studied pharmaceutical chemical's transport behavior were plotted. Batch reactor sorption experiments were also conducted using the same two different soil horizons with various concentrations of solution containing all three pharmaceutical chemicals. Of the three antidepressant compounds, BUP was found to sorb the least, followed by FLX, while SER sorbed the strongest in both types of soils as indicated in the batch isotherm and column transport experiments. Both experiments show that FLX and SER sorb stronger to clay-rich soils than to organic-rich soils while BUP sorbed more strongly to organic-rich soils. The relative sorption characteristics between the three chemicals remained consistent in all batch reactor and column transport experiments. These findings indicate that BUP is the most likely to contaminate water resources while SER is the least to be sequestered in soil minerals.

Barry, William, Patrick McMahon, Matt Marquis
S&ME, Inc.

APPLICATION OF VARIOUS 1-D AND 2-D HYDRAULIC MODELING SOFTWARE FOR STREAM RESTORATION DESIGN (T4,S4)

The US Army Corps of Engineers Hydrologic Engineering Center, River Analysis System (HEC-RAS) software is a widely accepted tool for one-dimensional hydraulic modeling in support of stream restoration. Since the early 2000s, two-dimensional analyses has also been available using River2D or other two-dimensional analysis software. River2D is a depth averaged finite element hydrodynamic model that was originally developed for the purpose of evaluating fish habitat at the University of Alberta, Canada. With the release of HEC-RAS V5, 2D modeling may become more widely applied in stream restoration design. The new V5 incorporates an implicit finite volume hydrodynamic solver that may be linked to one-dimensional elements. This presentation will provide a comparative analysis of results from the application of HEC-RAS V4 one-dimensional modeling, River2D, and HEC-RAS V5 two-dimensional modeling when applied to the proposed design of the same stream restoration project. The results of each of these analyses will also be compared against observations of damage to the constructed stream restoration design that occurred during a major storm event. In addition to a comparison of the results, the implications of the differing calculation approaches and the differences in the results for stream restoration design will be addressed.

Bates, Brian, Daniel Whittington
Woolpert

WOTUS - "IF IT DOESN'T RESULT IN A MAP, THE DEFINITION IS FLAWED" (T1,S3)

The definition of "Waters of the United States" (WOTUS) has been ambiguous since its inception. Decades of pressure from various interest groups, increasing demand among competing entities, a lack of mapped extents, and numerous legal challenges and interpretations have done little to clarify the issue. So it is not particularly surprising that proposed changes to the Definition in 2015 have also been met with significant controversy. In an attempt to determine the regulatory consequences of the new definition, the South Carolina Department of Transportation conducted a pilot project to produce the best possible WOTUS maps of selected watersheds using nationally accepted and freely-available GIS data. This methodology for creating such a map should be reproducible using the same data sets for most areas of the country. This presentation will highlight the mapping assumptions that have to be made for each of the major components of the Definition and how they ultimately affect the extents of the Waters. Additional discussion will cover the magnitude of additional regulatory burdens and costs local governments will face associated with MS4 permit compliance as a result of the new WOTUS Definition.

Bates, Brian
Woolpert

THE 1,000-YEAR FLOOD FROM 10,000 FEET (T5,S2)

Last October a thousand-year rain event hit South Carolina, creating widespread flooding throughout much of the state. In an effort to address the immediate needs of those affected by this disaster, aerial imagery of one of the hardest hit areas was captured as soon as the clouds cleared. In coordination with the South Carolina Emergency Management Division (SCEMD), the flight area was delineated and flown, and the imagery was processed in less than 36-hours. In order to make the information available for wide spread use, an app was designed and built and made available through many websites including SCEMD and Richland County. The app showed vivid before-and-after images of the event using 2014 orthos provided by Richland County, South Carolina and Google, and was used immediately in the field by local and state recovery efforts including SCEMD, the South Carolina Department of Health and Environmental Control (SCDHEC), the South Carolina Army National Guard (SCARNG), Fort Jackson, the South Carolina Department of Transportation (SCDOT), Richland and Lexington Counties, and the City of Columbia. It continues to be used for the recovery and rebuilding efforts. Specifically, the aerial imagery and app helped local governments respond to road and dam failures, assisted in briefing ranking officials on the situation, and provided valuable information to the public via the SCEMD website and local newscasts. In addition to the imagery effort, staff members had the unique opportunity to assist state and local governments responding to the challenges related to dam assessment, State Guard troop deployment, and flood level evaluations.

Beckingham, Barbara, Michael Shahin, Kathryn Ellis, Timothy Callahan
College of Charleston
TRANSPORT OF CARBONACEOUS MATERIALS AND PAHS IN A TIDAL CREEK - BULL CREEK, CHARLESTON, SC (T2,S5)
Streams transport both dissolved and particulate organic carbon materials. It is important to understand these materials in tidal creek water because it provides insights as to their origins, capacity for supporting the base of the food web and even carrying organic pollutants in water. Surface water samples were collected from Bull Creek, Charleston, South Carolina over several hours on over 5 sampling dates from Fall 2015 to Summer 2016 and filtered to measure total suspended solids (TSS), dissolved organic carbon (DOC), and SUVA-254 (specific absorbance as an indicator of aromaticity of DOC). Water concentrations of polycyclic aromatic hydrocarbons (PAHs), a ubiquitous class of hydrophobic organic contaminants originating from both natural and anthropogenic sources such as forest fires or burning of fossil fuels, were also determined. Sampling was performed in concert with measurements of discharge attained by an acoustic doppler current profiler. Turbidity is based on the amount of light scattered by particles in the water column. The more particles that are present, the more light that will be scattered. Correlation between TSS and turbidity in the current study is compared to a freshwater system in SW Germany and other tidal systems in the USA and is seen to be off-set. The difference in y-intercept indicates that some fraction of the material measured as TSS in our samples scatters light differently (e.g. at 0 turbidity there is still some solid mass in water). A marginal difference of SUVA was measured within sampling events and indicates that a single measurement on a given day would be representative. However, SUVA varies between sampling events, especially following the historic high precipitation event in October 2015. DOC may be diluted during flood tides when the discharge values are higher, but is otherwise relatively constant over the sampling duration for these events. More data is needed to investigate this behavior. Further analyses will aim to understand the seasonality of the relationship between TSS and turbidity, whether this system is a net importer or exporter and whether the turbidity may serve as an indicator of the transport of organic contaminants in tidal creeks.

***Bell, Natasha,** Dan Hitchcock, Sarah White
Clemson University
+PLANT SELECTIONS FOR VEGETATIVE CHANNELS: EVALUATION OF SEVEN AQUATIC PLANT SPECIES FOR SUSCEPTIBILITY TO FIVE SPECIES OF PHYTOPHTHORA
Increased competition for freshwater resources, negative environmental impacts associated with non-treated agricultural and specialty crop production runoff, and potential for more restrictive regulations concerning water use and disposal have provided growers with significant incentives to develop on-site water treatment to enable water reuse. Effective and low-cost water remediation technologies are necessary to ensure that irrigation wastewater contaminants (e.g. phytopathogens, pesticides, or mineral nutrients) are not reintroduced to crops irrigated with recycled water. Vegetative channels effectively remediate pesticides and mineral nutrients, but their capacity to remediate phytopathogens has not been characterized. One such phytopathogen, Phytophthora, causes root, crown, and fruit rot in crops and causes hundreds of millions of dollars in crop losses each year in the US alone. The major objectives of this research project are: 1) to assess the potential susceptibility of seven wetland plant species (*Agrostis alba, Carex stricta, Iris ensata, Panicum virgatum, Pontederia cordata, Typha latifolia, and Sagittaria latifolia)* to infection by five species of Phytophthora (*P. cinnamomi, P. citrophthora, P. cryptogea, P. nicotianae*, and *P. palmivora*) commonly found at plant nurseries in the southeastern United States; and 2) to determine the pathogenicity of each of the five Phytophthora species on these wetland plant species.
A series of trials were conducted in a greenhouse in Pendleton, South Carolina. Plants were floated in 2-liter plastic pots filled with Milli-Q (EMD Millipore, Corporation, Billerica, MA) water amended with 10 mg/L of nitrogen from a 24-8-16 (N-P-K) water-soluble fertilizer during the late Spring and Summer of 2016. A randomized complete block design was used with six pathogen treatments replicated in six blocks. Plants were exposed to inoculum from each of the five species of Phytophthora or not exposed to pathogen inoculum (non-inoculated control). Five additional pots were used in each block with inoculum from one species of Phytophthora in each pot and no plant, in order to monitor inoculum production in the absence of plant roots over time. Plants were exposed to inoculum for two weeks. After two weeks, plants were rinsed, swished in a surfactant solution, then rinsed again before being placed in new 2-liter aquatic pots containing a solution of Milli-Q water amended with fertilizer solution and no inoculum for an additional two weeks. A baiting bioassay was used to monitor zoospore activity in each pot over the entirety of the experiment. At the conclusion of the experiment, roots were excised and embedded into PARPH-V8 selective medium, held at 20 °C in the dark for 7 days, and monitored daily to determine if mycelium of Phytophthora spp. developed. If mycelium developed, the roots were designated as infected. Preliminary data suggest that all seven plant species are not susceptible to the five species of Phytophthora tested, as no roots were infected. Plant species that do not serve as hosts to Phytophthora species in greenhouse trials are candidates for use in outdoor experimental vegetative channels. Experimental vegetative channels will be constructed in order to determine effects of inoculum loading, planting density, hydraulic retention time, and nutrient concentration on Phytophthora remediation.

Berzinis, Rebecca
Atkins
LONG-TERM AND TWO-PERIOD ANALYSIS OF HYDROLOGIC CONDITIONS OF THE SOUTH EDISTO RIVER (T1,S6)
The Edisto River is one of the longest free flowing blackwater river systems in the United States. This river, combined with the Ashepoo and Combahee, is referred to as the "ACE" basin and in the late 1990's was considered

as one of the most pristine coastal plain watersheds in the southeastern United States. However, in 2014, American Rivers included the South Fork Edisto River on its annual Most Endangered Rivers list. In 2015, this listing was extended to the entire Edisto River. American Rivers identified excessive water withdrawals as the main threat to fish and wildlife habitat, recreation, and water quality. Anecdotal accounts from recreational users of the South Edisto have suggested that over their lifetimes, the once completely fishable, swimmable, and navigable river is now characterized by greatly diminished recreational opportunities for boating, fishing and swimming. The USGS long-term daily streamflow record at station 02173000 (South Fork Edisto River at the Highway 321 bridge near Denmark, South Carolina) spans from 1932 to 2015 (minus data from 1972-1980) and was used to evaluate flow alterations associated with human perturbations such as water withdrawals or global climate change. The Nature Conservancy's Indicators of Hydrologic Alteration (IHA) software was used to analyze the entire record of hydrologic data into ecologically relevant parameters and to categorize flows as large floods, small floods, high flow pulses, low flows, or extreme low flows. According to IHA recommendation [based on Richter et al. (1997)], at least twenty years of daily records should be used to analyze hydrologic alteration for each period of interest. In the past thirty years, population and number of hectares under irrigation in the southeast has grown considerably (Mullen 2009). Therefore, a two-period analysis was completed to evaluate whether flow data from 1986-2015 (period two) is significantly different from 1932-1985 (period one). An extreme low flow was defined as an initial low flow below 10% of daily flows for the period. Over the entire 76-year period of record, 51 years had at least one occurrence of extreme low flows. A median of 4 days per year had occurrences of extreme flow flows in contrast to a median of 60 days per year during period two. Mean annual flow for period one was 782 cfs compared to 624 cfs for period two (median). A comparison of median monthly flows also differs greatly between time periods. For example, the median monthly flow for August was 356 cfs in period two compared to 478 cfs in period one. One of the IHA's statistics for hydrological parameters is a significance count, which can be interpreted similarly to a p-value in parametric statistics. The significance count for the median monthly flow for August was 0.06 (minimum value is 0, significantly different; maximum value is 1, little difference), indicating a highly significant difference between periods. Annual minima and annual maxima 1-day and 30-day means were calculated for period one and period two and were found to have highly significant significance counts (0.00 to 0.0001). This research is intended to be part one of a two-part study on documentation of current conditions of the South Edisto and an investigation of causes of conditions. Future research will evaluate climate data, water withdrawal information, and flow data for a similar river system to explore causes for the departure from historic flows in the South Edisto River.

Boring, Shane, Brandon H. Kulick
Kleinschmidt Associates

DEVELOPMENT OF HABITAT-BASED MINIMUM FLOWS FOR SOUTH CAROLINA RESERVOIRS: OPTIONS FOR SITE-SPECIFIC DATA (T4,S4)

The South Carolina State Water Plan (SWP) and supporting studies provide policy guidelines for determining appropriate minimum flows for protection of aquatic resources in dam-regulated river reaches (Badr et al. 2004, Bulak and Jobsis 1989). The South Carolina policy states that, in the absence of site-specific data, the recommended flow should be a seasonally-varying fraction of the river's mean annual flow (e.g., 20%, 30% or 40% of mean annual flow, varying according to season, in the Piedmont ecoregion). However, recent basin-specific modeling conducted in support of an ongoing update to the SWP suggests that water resources in some of South Carolina's river basins may be over-allocated, emphasizing the importance of site-specific instream flow recommendations that meet the habitat needs of key management and conservation species while preserving excess water for other designated uses, such as drinking water and hydropower. This paper presents a range of quantitative and qualitative methods for developing cost-effective, scientifically sound instream flow recommendations that are appropriate for the target species and stream segments under consideration. Methods presented will range from a simple wetted-perimeter approach appropriate for sessile organisms in small or backwatered streams, to widely-used one-dimensional (1-D) Physical Habitat Simulation (PHABSIM) models that allow for modeling of habitat suitability across a wide range of flows, to two-dimensional (2-D) hydrodynamic models appropriate for complex, braided river reaches. Finally, this paper will present two case studies from South Carolina: the Parr Hydroelectric Project IFIM Study on the Broad River, an example of a large, complex river reach requiring a combination of qualitative, 1-D and 2-D models and 2) the Lake Blalock IFIM Study, an example of a limited-scope study aimed at evaluating habitat suitability for a limited number of target species on the Pacolet River.

Boring, Shane, Katheryn Langley, Jared Porter, Jordan Johnnson
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INFLUENCE OF ENVIRONMENTAL VARIABLE ON PASSAGE OF AMERICAN SHAD AT THE COLUMBIA DIVERSION DAM, BROAD RIVER, SC (T7,S6)

Historically, many rivers in the Santee River basin, including the Broad River, supported populations of diadromous (migratory) fish species, including American shad (*Alosa sapidissima*), blueback herring (*Alosa aestivalis*), hickory shad (*Alosa mediocris*), striped bass (*Morone saxatilis*), American eel (*Anguilla rostrata*), Atlantic sturgeon (*Acipenser oxyrhinchus*), and shortnose sturgeon (*Acipenser brevirostrum*). Although some of those species may have been abundant historically, current populations have been reported in very low numbers in the Broad River downstream of the Columbia Diversion Dam, the most downstream of seven hydropower dams on the mainstem of the river. The long-term effects of

habitat fragmentation due to construction of dams and overfishing during the nineteenth century have drastically reduced populations of migratory diadromous fish species in the Broad River basin and all the river basins along the Atlantic Coast (McDonald 1887). In 2001, The US Fish and Wildlife Service (USFWS), South Carolina Department of Natural Resources (SCDNR), and National Oceanic and Atmospheric Administration Fisheries (NOAA Fisheries) published the Santee Cooper Basin Diadromous Fish Passage Restoration Plan, which set goals for reopening the spawning areas of Broad River upstream of the Columbia Diversion Dam to increase the reproduction of American shad, blueback herring, and other diadromous species. South Carolina Electric & Gas Company (SCE&G) subsequently constructed the Columbia Fishway at the Columbia Hydroelectric Project (FERC No. 1895) in 2006 according to the terms of an agreement to transfer ownership of the project to the city of Columbia and as a requirement of the Section 18 Fishway Prescription included in the project's Federal Energy Regulatory Commission (FERC) operating license. To date, American shad is the only target migratory species that has been documented at the Columbia Fishway. The numbers of American shad passing upstream have been monitored annually during the spring migration, with passage numbers generally increasing each year since completion of the fishway in 2007. The 899 American shad observed in 2015 was highest total passage observed at the Columbia Fishway since it began operation in 2007 and represented a more than three-fold increase over the previous maximum of 240 observed in 2012. Although number of fish passed has been monitored annually since 2007, no comprehensive analysis of the influence of environmental factors has been undertaken. This paper will examine relationships between timing and number of American shad passed at the fishway and important environmental factors such as streamflow, water temperature and turbidity. This paper will also examine relationship between the timing and number of fish passed at Columbia and the timing and magnitude of passage at the downstream St. Stephens Fish Lift on the Santee River and the Pinopolis Lock and Dam on the Cooper River.

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+ASSESSING THE HYDRAULICS OF A TIDAL CREEK ADJACENT TO BRIDGE CONSTRUCTION

Stringer Creek is a second-order tidal creek that has a confluence with Folly River near Folly Beach, South Carolina. This creek drains a salt marsh of approximately 0.2 km^2. In 2013 construction on a new bridge on South Carolina Highway 171 (Folly Road) over the Folly River involved the installation of temporary bridging materials and footings. As of late 2014, a new support piling on the completed bridge was located at the mouth of Stringer Creek. Pre- and post-construction stream flow data were collected during a two-week campaign each year in the late February - early April time frame using a Son Tek current profiler placed in the channel's thalweg. Cross sectional profiles were collected using a rotary laser unit and stadia rod referenced to a local benchmark. Results indicate that the cross sectional area for flow decreased from a pre-bridge construction condition of 27.7 m^2 in 2012 to 24.2 m^2 in 2015 (13%), and the area then increased after removal of the construction platform to 27.2 m^2 in 2016, which is about 0.5 m^2 less than the original 2012 area. The net stream flow volume during flood tides (as measured from the overbank elevation position) decreased at an average rate of 3,500 m^3/yr from 2012-2014, and increased 380 m^3/yr from 2014-2016 after removal of the construction platform. The creek's width remained constant throughout the study period while cross sectional area changed, indicating that the stream bed elevation in the channel was undergoing siltation (likely due to the decreased flow rate). Recent data has shown an increased cross sectional area, net volume, and flow rate following removal of the construction platform in 2014. These values are still not equivalent to the 2012 pre-construction measurements, suggesting that a new equilibrium has not yet been reached. This project is part of a larger effort by the SC Department of Natural Resources, who are studying the creek ecology in order to monitor changes in aquatic habitat. We will continue to collect data on stream flow and cross-sectional area for at least one more monitoring campaign in 2017.

Bradley, Paul[1], Bill A. Battaglin[1], Luke Iwanowicz[1], Frank Henning[2], Celeste A. Journey[1], Dana W. Kolpin[1], David Shelley[2]
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BIOACTIVE AND BIOCIDAL CONTAMINANTS IN WATER, SEDIMENT AND TISSUE AT CONGAREE NATIONAL PARK (T4,S5)

The US National Park Service (USNPS) is tasked with protecting Park lands to "…leave them unimpaired for the enjoyment of future generations." Contaminants of emerging concern (CEC), in general, and endocrine disrupting chemicals (EDC), in particular, have been identified as USNPS environmental priorities. EDC threaten the reproductive success and long-term survival of sensitive aquatic populations. For example, environmental release of EDC can induce male vitellogenin (egg yolk protein) expression, skewed sex ratios and intersex characteristics, degraded predator avoidance behavior, as well as reproductive failure and population collapse in sensitive fish species at concentrations that have previously been documented in wastewater effluent and effluent-impacted surface water systems. The USGS Toxic Substances Hydrology Program's Emerging Contaminants Project is working with the USNPS to assess EDC risk in individual Parks and in Park Monitoring Networks. Congaree National Park (*http://www.nps.gov/cong/index.htm*) was designated the nation's 57th National Park in 2003 and is part of the International Biosphere Reserve network. CONG protects nearly 10,900 ha of forested floodplain, including the largest contiguous tract of old-growth bottomland forest remaining in North America. CONG is composed almost entirely of floodplain and aquatic environments (greater than 90 percent riparian wetlands coverage) and is located downstream of several major metropolitan areas and associated wastewater treatment plants. Wastewater

EDC pose particular threats to aquatic ecosystems due to widespread releases of treated wastewater to surface water either directly or indirectly via bank filtration systems and episodic releases of untreated wastewater via surface runoff or combined sewer overflows. USGS-USNPS reconnaissance sampling conducted in 2010, documented the presence of wastewater compounds in primary surface-water sources to CONG, indicating that wastewater contaminant compounds are reaching Park aquatic habitats from external sources. In 2013, water and sediment samples were collected from 15 sites throughout the Park. Water samples were analyzed for total estrogenic activity (BLYES), 19 hormones, 110 pharmaceutical compounds, and 69 wastewater indicator compounds. Sediment samples were analyzed for 19 hormones and 57 wastewater indicator compounds. Preliminary results indicate a wide range of CEC, including EDC, are present in water and sediment in high visitation, front country locations as well as in remote locations in the Park, suggesting multiple contaminant sources.

Bradley, Paul, Keith A. Loftin, Jimmy M. Clark, Celeste A. Journey, Dana W. Kolpin, Daren M. Carlisle, Peter C. Van Metre
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MICROCYSTINS OCCURRENCE IN WADEABLE STREAMS IN THE SOUTHEASTERN UNITED STATES (T4,S5)

The presence of potential toxin-producing cyanobacteria has been documented in multiple stream assessments conducted by the USGS throughout the Southeastern US during 1993-2011. However, fluvial cyanotoxin occurrence has not been assessed systematically in the region. To begin to address this gap, the USGS Toxic Substances Hydrology and National Water Quality Assessment Programs conducted a spatial reconnaissance of fluvial microcystin concentrations in 75 wadeable streams during June 2014. Microcystins were detected (ELISA; MDL = 0.10 µg/L) throughout the region. The persistence and temporal variability of microcystins were assessed monthly through October 2014 in five of the streams where microcystins were observed in June and in one reference location. Microcystins were repeatedly detected in all but the reference stream. The widespread occurrence of microcystins observed in this reconnaissance demonstrates the need for further investigation throughout the Southeastern US and in fluvial systems, in general.

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HEALTHY LANDSCAPES, HEALTHY PONDS: DEVELOPING AN OUTREACH STRATEGY FOR POND, COMMUNITY, AND ECOSYSTEM WELL-BEING (T3B,S1)

Stormwater ponds are commonly used to address stormwater runoff in South Carolina. While primarily intended to treat volume and minimize flood risk, stormwater ponds have the added benefit of treating water quality. Despite being highly visible in many communities across South Carolina, residents who live on or near a stormwater pond are often unaware of its purposes, ownership, and best practices for long-term performance. Thus, maintenance efforts can be complicated by lack of awareness and knowledge on the part of adjacent landowners and community residents. This study used interviews, surveys, and focus groups to gauge awareness of stormwater pond maintenance needs, and to identify opportunities for instruction and awareness-building efforts. Our findings suggest that an outreach campaign designed to improve stormwater pond quality should consider the following recommendations: 1.) Provide Homeowners Associations with a comprehensive set of instructions for stormwater pond maintenance to share with residents. 2.) Address maintenance concerns of city and county public works departments by highlighting behaviors that prevent debris from clogging infrastructure, slow erosion, and limit the growth of problem plants. 3.) Provide educational resources on the benefits, cost, purpose, and maintenance of vegetated shoreline buffers. 4.) Appeal to the concerns of residents about the health of people, wildlife, and the overall ecosystem connected to a stormwater pond, and their preference for water-based recreational activities. 5.) Include positive images of a healthy pond to best capture the attention of homeowners to affect behavior changes that would lead to improved water quality protection. Target audiences and outreach messages differ across the life of the stormwater pond. During pre-construction and construction, messages should focus on design specifications, construction per the approved plans, and proper installation of sediment and erosion control best management practices. Once the pond is completed and ownership is transferred from the developer to the neighborhood association or property manager, messages should focus on actions all residents can take to maintain pond stability, function, and quality. Self-efficacy is a high priority for residents in making decisions about stormwater pond maintenance. Outreach messages addressing stormwater pond health and maintenance should be specific, instructive, and connect all community residents' actions and influence to the health of the pond. The results of this work include short and long-term communication and outreach strategies, with recommendations including updated tools and resources from trusted entities, motivating messages, draft illustrations, priorities for implementation, and more.

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DEVELOPMENT OF A GROUNDWATER RECHARGE MODEL FOR SOUTH CAROLINA USING THE USGS SWB METHOD (T2,S1)

Understanding groundwater recharge in essential to understanding the groundwater system as a whole. Much time has been given to understanding outputs and storage factors of the groundwater systems while relatively little is known about the distribution of recharge. Utilizing the Soil Water Balance (SWB) available from United States Geological Survey (USGS), the South Carolina Department of Natural Resources (SCDNR) is attempting to fill in the gap in knowledge about our water resources. The SWB code uses readily available data to generate estimates of the spatial and temporal distribution of recharge. Utilizing a modified Thornthwaite-Mather soil water accounting

method the SWB model calculates recharge in a gridded area using climate data and landscape characteristics. Recharge is calculated for each cell by the model as equal to sources minus sinks minus the change in soil moisture. The sources are precipitation, snowmelt, and inflow; sinks are interception, outflow and evapotranspiration. Data required to execute the SWB Model are temperature and precipitation, land use classification, hydrologic soil group and soil water capacity. Modules within the SWB code are used to calculate the water-budget components based on user inputs. For the South Carolina Model, inputs were derived from elevation, land use and soil maps from the Natural Resources Conservation Service (NRCS) and Climatic Data from the Daymet dataset available from Oakridge National Laboratory. Inputs are in the form of GIS datasets that were preprocessed utilizing ArcMap and Python scripting. The benefits of developing the SWB models for South Carolina include an ability to visualize and map areas that are important to recharge of the groundwater systems. The outputs from the SWB models will be used as inputs for groundwater flow models of the South Carolina Coastal Plain currently in development by the USGS and DNR. Utilizing historical and predicted land use and land cover patterns the SWB model can also be used to demonstrate how human influence on the landscape has impacted, or has the potential to impact, South Carolina's groundwater system.

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US Geological Survey

SPATIAL AND TEMPORAL ASSESSMENT OF BACK-BARRIER EROSION ON CUMBERLAND ISLAND NATIONAL SEASHORE (T7,S6)

Much research has been conducted to better understand erosion and accretion processes for the seaward zones of coastal barrier islands. However, on Cumberland Island National Seashore the greater management concern is the effect that erosion is having on the resources of the island's western shoreline, or the back barrier. Catastrophic slumping and regular rates of erosion as high as one meter annually threaten important habitat, historic and pre-historic resources, and modern infrastructure on the island. Prior research has helped the Park identify the most severe and vulnerable areas, but in order to develop effective management actions information is needed on what forces and under what conditions erosion is occurring. In February 2012, we constructed monitoring stations at four locations identified as erosional hotspots and, through the use of innovative techniques, investigated through May 2013 under what conditions erosion occurred. Further, we quantified the magnitude of erosion at each location to elucidate the relative influence of causative agents. Results indicate that erosion is, in general, highly variable within and among these locations. Observed erosion ranged from a maximum of 3 m of bluff line retreat to some areas that exhibited no net erosion. Three of the four sites displayed punctuated, mass wasting events that were coincident with above average high tides and storm events and were responsible for the majority of change noted. The last site exhibited steady, low magnitude retreat throughout the study period. Boating activity was acoustically detected at all sites during the study and occasionally occurred prior to measured erosion, however ascribing a degree of causation was not possible. While it is difficult to precisely subscribe certain amounts of erosion to specific agents, this study provides insight into the mode of erosion among sites and the interaction among factors that are leading to erosion events. Estimates of sea level rise were incorporated into the results to forecast conditions predicted to be in place by the end of the 21st century.

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DEVELOPMENT AND APPLICATION OF A GROUNDWATER-FLOW MODEL OF THE ATLANTIC COASTAL PLAIN AQUIFERS, AIKEN COUNTY, SOUTH CAROLINA TO SUPPORT WATER RESOURCE DECISIONS (T2,S1)

Aiken County is located in South Carolina along the Fall Line and is bordered by the Savannah River on the west, Edgefield and Saluda Counties on the north, Barnwell and Orangeburg Counties on the southeast and by Lexington County on the east. The 2014 population was estimated to be about 165,000 persons living in the County, an increase of about 14 percent from 2000. Aiken County is the fourth largest South Carolina county by land area, about 1,073 square miles. The primary objective of the assessment of the groundwater availability for Aiken County is to develop a detailed groundwater-flow model that can be used by Aiken County water utilities and state environmental and natural resource agencies to manage current and projected reported and unreported demands on groundwater resources and to ensure the highest quality of groundwater. This objective can be divided into 4 tasks, listed here in order of implementation 1.) develop a state-of-the science groundwater-flow and management model; 2.) calculate the water budget for the Aiken County area; 3.) document the general water-quality characteristics for public-supply wells across Aiken County; and 4.) assess the occurrence of any chemical contamination in selected public-supply wells. The grid spacing of the model is expected to be 300 by 300 feet, which will allow a detailed simulation of groundwater and surface water interactions. Most of the potable water produced in Aiken County, with the exception of North Augusta, is supplied by groundwater produced from the various Atlantic Coastal Plain (ACP) aquifers underlying the county. The ACP aquifers underlying Aiken County are very productive and generally contain high-quality groundwater that requires little treatment prior to use. The reliance on groundwater by Aiken County has increased steadily since the 1950's, but it is unknown if these withdrawals will affect the current or future availability or quality of groundwater in Aiken County. Irrigated agriculture acreage is expanding rapidly in Aiken County resulting in an increased demand on groundwater resources. In 2004 and 2010, the reported groundwater use for potable supply in Aiken County was about 12 million gallons per day. However, with the drilling of at least 9 high capacity (1,000 to 2,000 gallons per minute, each) irrigation wells in the south central part of

Aiken County, overall groundwater use is expected to be substantially larger in the coming years. These unmanaged irrigation withdrawals (with the prospect of additional large-scale withdrawals in years to come) have raised serious concerns among the existing groundwater-source water districts. A group of these water districts has requested a regulatory designation from the state environmental regulatory agency to more closely manage Aiken County's groundwater resources.

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SOUTH CAROLINA ATLANTIC COASTAL PLAIN GROUNDWATER AVAILABILITY MODEL (T1,S5)

The Atlantic Coastal Plain aquifers and confining units of South Carolina are composed of crystalline carbonate rocks, sand, clay, silt, and gravel and contain large volumes of high-quality groundwater. The aquifers have a long history of use dating back to the earliest days of European settlement in the late 1600s. Although extensive areas of some of the aquifers have or currently (2016) are experiencing groundwater level declines from large-scale, concentrated pumping centers, large areas of the South Carolina (SC) Atlantic Coastal Plain contain substantial quantities of high-quality groundwater that currently are unused. Groundwater use from the Atlantic Coastal Plain aquifers in South Carolina has increased during the past 70 years as the population has increased along with demands for municipal, industrial, and agricultural water needs. While South Carolina works to increase development of water supplies in response to the rapid population growth, the State is facing a number of unanswered questions regarding availability of groundwater supplies and the best methods to manage these important supplies. Overall, groundwater use in the SC Coastal Plain from 2004-2013 has increased slightly from about 202 million gallons per day (Mgal/d) in 2004 to an average of 209 Mgal/d from 2005 to 2013. There has been a significant increase in irrigated agriculture in South Carolina, with much of this new water demand met by groundwater use. In South Carolina this trend is likely to continue. Potential adverse effects of the continued increase in groundwater withdrawals include groundwater level declines and reduced baseflow to streams and other surface-water bodies. The SC Agriculture Commission is actively recruiting industrial-scale farms to locate in the Coastal Plain counties of South Carolina. These new farms will most likely use groundwater for their primary source of irrigation water and are likely to be clustered in areas with suitable soils, transportation, and labor. The South Carolina Water Plan, 2nd Edition states: "A comprehensive groundwater flow model of the Coastal Plain should be developed and used to predict the effects of future pumping and to determine optimal well spacings." The update to the existing SC Coastal Plain groundwater-flow model will provide the model described in the SC Water Plan. An updated groundwater flow model of the South Carolina Coastal Plain will benefit the State by providing a tool that can be used by water-resource managers to estimate current available water resources and to assess the effects of future water-use development and climate variability on available water resources. The USGS is working cooperatively with the SC Department of Natural Resources, SC Department of Health and Environmental Control, and SC Department of Agriculture to develop an updated groundwater-flow model of the South Carolina Coastal Plain.

Caraway, Nina, John Boyer, Kirk Westphal
CDM Smith

USING SOUTH CAROLINA'S NEW SOUTH WATER QUANTITY MODELS TO SUPPORT REGIONAL WATER PLANNING (T1,S1)

South Carolina's Surface Water Availability Assessment, now in its second year, has focused on the creation of a comprehensive surface water database; the development of unimpaired (i.e., naturalized) flows for each of the state's eight river basins; and the development of surface water quantity models. As the last of the eight models are being completed, we can begin to examine how the models can be used to support surface water planning and management in South Carolina and to support basin advisory groups during development of regional water plans. The models are intended to help answer a variety of questions regarding the availability and sustainability of the state's surface water resources, some of which include:

- Is their sufficient surface water in a basin to support the projected 50-year demands in a basin, while satisfying instream flow, recreational, energy and other flow needs? Where are their gaps?
- How can the basin's consumptive and non-consumptive water needs be managed conjunctively to satisfy demands into the future?
- How effective are the current actions specified in drought management plans and low inflow protocols? Will they be effective under projected 50-year demands?

This presentation will provide examples of how the models can be used to answer these, and similar questions. Examples will be presented from other states, where similar models were used to compare available water resource capacities and future needs, and support development of regional and statewide water plans.

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A HYDROCLIMATE EXTREMES ATLAS FOR THE CAROLINAS (T5B,S5)

This paper describes a digital atlas of hydroclimate extremes in the Carolinas. The atlas complements existing information sources on extreme precipitation (e.g. NOAA's Atlas 14) and drought (e.g. products from the National Drought Mitigation Center). It includes maps and figures characterizing time series of various measures of precipitation, drought, and the water balance. Some of the drought indices are those used operationally by resource managers, others are new, or offer spatial or temporal resolution not readily available from other sources. In its digital format, the atlas allows users to explore probability

distributions and recurrence intervals for a large number of stations across the Carolinas by season. It facilitates the integration of station and regional products, and photographs, videos, and narratives associated with drought and heavy precipitation events.

Caston, Mike, Billy Cothran
SJWD Water District
WHAT IF...? USING DENDROCLIMATOLOGY FOR WATER RESOURCE PLANNING (T1,S4)
"Drought is the most economically expensive recurring natural disaster to strike North America in modern time" (Celine Herweijer, 2007). Weather is usually that topic we bring up when we don't know what to say or have run out of things to talk about. This past year residents of Columbia, South Carolina had a lot to say about the weather. One thing the past 30 years has shown us is that weather is very dependable…you never know what it is going to do. Pick your crisis: drought or flood. We have had them both. I want to focus on drought. Not because I like drought, but because I think about it more. In recent years we have heard much discussion relative to climate change. The authors do not intend to argue for or against man-made climate change or global warming. The intent is to provoke thought and discussion on the need to take a much longer historical view of droughts for future water resource planning. I fear we tend to focus on the "crisis-de jour" and not learn enough from the past. While we cannot state with certainty when the next drought or flood will come, we can state with certainty that climate has changed repeatedly over time and that global climate is very complex. I was born in Chester, South Carolina on Christmas day in 1955. My dad told me it was in the 80s that day. I really don't remember, but he said it was hot for Christmas in Chester. It was also the year of the drought of record. Since the mid-1980s we have had multiple droughts, each seemingly worse than the previous one. The previous drought of record, the 1955 drought, is no longer the drought of record. How do we know what the drought of record is? Who keeps the record and how far back did someone keep it? There are records of stream flows and rainfalls that precede me, but how far back do they go? What sort of drought should we plan for? "The scientific discipline called dendrochronology is the study of tree rings and of environmental conditions and events of the past that tree growth can reflect. The beginning of scientific study of tree rings is generally ascribed to an astronomer named Andrew Ellicott Douglass, who in the early 1900s noticed not only variation in tree-ring width but also that this variability was similar between multiple trees. Dendrochronology subsequently expanded worldwide, and now over 3000 of the 12,000+ publications on dendrochronology can be classified as dendroclimatology" (Sheppard, 2010). The authors will look at a hypothetical occurrence of a drought over the past 1000 years, rather than droughts of record over the past 100 years that seem to be the prevailing thought in South Carolina and throughout the United States. We will attempt to provoke thought relative to: What if our region experienced a drought similar to that of the 16th century megadrought over North America? The focus will be more on the dendrochronology of our region, but will also recognize that paleoclimatology is much more than just the study of tree-rings. The interaction of the atmosphere, cryosphere, hydrosphere, lithosphere, biosphere and solar radiation is extremely complex and research by Dr. Dave W. Stahle, Connie Woodhouse, Martin Stute and others will be referenced.

Chapelle, Francis, Yuan Shen, Eric Strom, Ronald Benner
US Geological Survey
THE REMOVAL KINETICS OF DISSOLVED ORGANIC MATTER AND THE OPTICAL CLARITY OF GROUNDWATER (T2,S3)
Concentrations of dissolved organic matter (DOM) and ultraviolet/visible light absorbance decrease systematically as groundwater moves through the unsaturated zones overlying aquifers and along flowpaths within aquifers. These changes occur over distances of tens of meters (m) implying rapid removal kinetics of the chromophoric DOM that imparts color to groundwater. A one-compartment input-output model was used to derive a differential equation describing the removal of DOM from the dissolved phase due to the combined effects of biodegradation and sorption. The general solution to the equation was parameterized using a two-year record of dissolved organic carbon (DOC) concentration changes in groundwater at a long-term observation well in South Carolina. Estimated rates of DOC loss were rapid and ranged from 0.093 to 0.21 micromoles per liter per day (μM d-1), and rate constants for DOC removal ranged from 0.0021 to 0.011 per day (d-1). Applying these removal rate constants to an advective-dispersion model illustrates substantial depletion of DOC over flow-path distances of 200 m or less and in timeframes of two years or less. These results explain the low to moderate DOC concentrations (20–75 μM; 0.26–1 mg/L) and ultraviolet absorption coefficient values (a254 <5 m-1) observed in groundwater produced from 59 wells tapping eight different aquifer systems of the United States. The nearly uniform optical clarity of groundwater, therefore, results from similarly rapid DOM-removal kinetics exhibited by geologically and hydrologically dissimilar aquifers.

Childress, Michael[1], Dan Tufford[2], Junyu Lu[2], Greg Carbone[2], Paul Conrads[3]
[1]Clemson University, [2]Baruch Institute, University of South Carolina, [3]USGS South Atlantic Water Science Center
USING THE COASTAL SALINITY INDEX AND PREDICTED STREAMFLOW TO FORECAST SC BLUE CRAB LANDINGS (T5,S4)
Blue crabs are one of the most important commercial fisheries in the southeastern US and landings have shown steep declines during periods of prolonged drought. During droughts freshwater flow to the saltmarsh is reduced and blue crabs experience higher disease mortality and travel further inland seeking freshwater. As a result, commercial landings two years later are significantly negatively correlated with seasonal averages of a regional Coastal Salinity Index. To forecast blue crab landings further into the future, we used streamflow projections from an

OpenNSPECT hydrological model given different climate scenarios as input to an individual-based population model (SCBCRABS) to integrate the non-linear effects of flow and salinity variation on blue crab population structure and commercial landings. The OpenNSPECT model of the Edisto River watershed predicts that streamflow should continue increasing for the next 20 years, but observed streamflow has been decreasing suggesting surface and groundwater withdraws may be offsetting gains from increases in precipitation. By inclusion of both flow gains due to increased precipitation and flow losses due to withdraws, we can better forecast future blue crab commercial landings and response to drought.

***Cochran, Kristin[1],** Jorge Casado[2], Danilo Russo[3], Danilo Spasiano[3], Marianna Vaccaro[3], Roberto Andreozzi[3], Raffaele Marotta[3], Nuno M. Reis[4], Gianluca Li Puma[4], Dionysios Dionysiou1[5], Daniel Schlenk[6], Susan Richardson[1]
[1]University of South Carolina, [2]Universal Diagnostics SL, [3]University of Naples Federico II, [4]Loughborough University, [5]University of Cincinnati, [6]University of California-Riverside

+REMOVAL AND TRANSFORMATION OF PERSISTENT PRIORITY EMERGING CONTAMINANTS VIA ADVANCED OXIDATION TECHNIQUES AND TRANSFORMATION PRODUCT IDENTIFICATION USING MASS SPECTROMETRY

Conventional wastewater treatment does not fully remove many contaminants; as a result, they can be discharged from wastewater effluent into rivers and drinking water reservoirs and can adversely impact aquatic ecosystems and human health. These adverse effects also raise concerns about potable reuse of wastewater. In 2013, two Science Advisory panels determined which emerging contaminants (ECs) should be included on priority lists for monitoring in aquatic ecosystems and human potable water reuse, based on toxicity, persistence through wastewater treatment, and environmental water concentrations. These lists include pharmaceuticals, pesticides, hormones, and disinfection by-products (DBPs). Our project is investigating the removal and/or transformation of these ECs through advanced oxidation techniques, such as UV-C/H2O2, and microfiltration and reserve osmosis. These methods are being examined together, separately, and against conventional drinking water chlorine treatments. Transformation products (TPs) and DBPs are being identified via gas chromatography (GC)/high resolution accurate mass time-of-flight (TOF)-mass spectrometry (MS) and liquid chromatography (LC)/high resolution tandem mass spectrometry (LC-MS/MS) using an Orbitrap mass spectrometer. Extensive TP data has been obtained for benzoylecgonine degradation, the primary urinary metabolite of cocaine, using UV-C/H2O2. Several TPs have been identified using LC-Orbitrap-MS/MS, including meta-, para-, and ortho-hydroxybenzoylecgonine. Controlled laboratory chlorination/bromination reactions have been performed on other ECs and many TPs were identified, including chlorine- and bromine-containing by-products.

***Conley, Kenda[1],** Barbara Beckingham[1], Jestine Deepe[2], Allan Clum[3]
[1]College of Charleston, [2]Mount Pleasant Waterworks, [3]Charleston Water System

+REMOVAL OF MICROPLASTICS BY WASTEWATER TREATMENT PLANTS IN CHARLESTON, SOUTH CAROLINA

Microplastics are tiny plastics (<5 mm in size) that can take many forms - from spheres to fragments or fibers - but are all comprised of synthetic organic polymers of varying chemical composition. Microplastics have been found in water, sediments, and biota in both freshwater and marine systems all over the world. Consequences of microplastic pollution are not yet fully understood; however, potential effects are diverse. It is important to identify sources of microplastics into the environment in order to create effective solutions and limit these threats. Wastewater treatment plants (WWTPs) serve to collect and treat wastes that are known to include microplastic particles, fibers and microbeads. WWTPs are often cited as a suspected as a source of microplastics into the marine environment, yet few studies have quantified this route to the environment. This study aims to analyze the loading, removal efficiency and type of microplastic through three conventional WWTPs in Charleston that vary in treatment process, size, and service composition. We hypothesize that removal efficiency will be explained by treatment operations, and will be higher for the WWTP that utilizes skimmers to remove floatable debris. Influent, effluent and sludge samples from each WWTP will be analyzed using 1) physical separation, 2) chemical digestion in the sample matrix, and 3) counting and characterization of polymer type. Preliminary results from Summer 2015 at one of the WWTP indicated 92% removal of microplastic in treated effluents discharged to Charleston Harbor. This current work updates this estimate to a sampling event in Summer 2016 and expands it to 2 other WWTPs to enable comparison and estimation of the total load of microplastic to Charleston Harbor from WWTPs.

Conlon, Kevin, Celeste Journey, Andy Caldwell, Fred Falls
US Geological Survey

DETERMINATION OF CHANGES IN WATER QUALITY, STREAMBED SEDIMENT, AND BENTHIC MACROINVERTEBRATES AS A RESULT OF STORMWATER RUNOFF FROM SELECTED BRIDGES IN SOUTH CAROLINA (T4,S6)

Stormwater runoff from highways may be treated by structural or non-structural systems before discharging to receiving waters. In South Carolina, the majority of stormwater enters receiving waters without treatment through evenly distributed bridge deck openings (for example, scuppers). Even though numerous studies have been conducted to analyze stormwater quality from highways and, to a lesser extent, bridges to receiving waters, no specific studies have been conducted in South Carolina. However, the potential exists for the quality of the stormwater from bridge decks to be affected by many factors, including bridge deck area, daily traffic volume, and atmospheric deposition. In June 2013, the US Geological Survey, in cooperation with the South

Carolina Department of Transportation, began a multi-year investigation to quantify the downstream changes in receiving water-quality conditions during periods of observable stormwater runoff from 6 selected bridge deck locations in South Carolina. In 2014, 2 of the 6 bridges were selected and representative upstream (not bridge affected) and downstream (bridge affected) locations were identified. The receiving water at the bridge deck sites was sampled and analyzed for nutrient, metal, polycyclic aromatic hydrocarbon, and fecal indicator bacteria concentrations. Water-quality samples were collected during 14 non-storm (upstream location only) and 6 storm sampling events (upstream and downstream locations), by using a Lagrangian equal-width-increment sampling protocol. Additionally, comparison of sediment-quality conditions and benthic macro-invertebrate community structure at upstream and downstream locations from selected bridge decks were used to assess cumulative effects of stormwater runoff on receiving water. Preliminary findings will be presented.

Conrads, Paul[1], Bryan McCloskey[2]
[1]*US Geological Survey, South Atlantic Water Science Center,* [2]*Cherokee Nation Technologies*

+APPLICATION OF THE COASTAL SALINITY INDEX TO SITES IN FLORIDA BAY AND THE GULF OF MEXICO

Coastal droughts have a different dynamic from upland droughts, which are typically characterized by agricultural, hydrologic, meteorological, and (or) socioeconomic impacts. The location of the freshwater-saltwater interface in surface-water bodies is an important factor in the ecological and socioeconomic dynamics of coastal communities. Because of the uniqueness of drought impacts on coastal ecosystems, a Coastal Salinity Index (CSI) was developed by using an approach similar to the Standardized Precipitation Index (SPI). Instead of using precipitation data, as with the SPI, the CSI utilizes salinity data. The CSI is a standardized probability index with zero indicating historical median salinity amount, and positive and negative values representing increasingly fresh and saline conditions, respectively. The CSI is computed for various time scales to capture short- and long-term conditions. Evaluation of the CSI indicates that the index can be used for different estuary types (for example: brackish, oligohaline, or mesohaline), for regional comparison between estuaries, and as an index for wet conditions (high freshwater inflow) in addition to drought (saline) conditions. The CSI characterizing 1- to 24-month duration salinity conditions was computed for five tributary sites in Florida Bay and for nine tributary sites in the Gulf of Mexico. Comparison of the CSIs using the same time intervals shows how the intensity of drought and freshwater conditions varies along the southwest Florida coast. Time-series plots showing the CSI index for all the computed time scales show how sites vary in response to short- and long-term conditions. To evaluate the effectiveness of the CSI as a prediction and adaptive management tool, there is a need to develop linkages between the CSI and coastal drought response variables. However, identifying potential coastal drought response datasets is challenging. Coastal drought is a relatively new concept and existing datasets may not have been collected or understood as "drought response" datasets. Potential coastal drought response datasets include tree growth and liter fall, harmful algal bloom frequency, Vibrio infection occurrence, sportfish populations, and shellfish harvesting data. The CSI computed for Florida Bay shows a strong visual correlation with the occurrence of harmful algal blooms along the coast. The presentation will describe the application of the CSI to sites along the Gulf of Mexico and Florida Bay.

Conrads, Paul[1], Daniel Tufford[2], Lisa Darby[3]
[1]*US Geological Survey,* [2]*University of South Carolina,* [3]*National Oceanic and Atmospheric Administration*

+CRITICAL ASPECTS OF THE COASTAL DROUGHT INDEX: LENGTH OF SALINITY DATA RECORD AND ECOLOGICAL RESPONSE DATA

Coastal droughts have a different dynamic from upland droughts that are typically characterized by agricultural, hydrologic, meteorological, or socio-economic drought. The location of the freshwater-saltwater interface in surface-water bodies is an important factor in the ecological and socio-economic dynamics of coastal communities. Because of the uniqueness of drought impacts on coastal ecosystems, a coastal drought index (CDI) that uses existing real-time and historical salinity datasets for sites in South Carolina, Georgia, and Florida, USA was developed by using an approach similar to the Standardized Precipitation Index (SPI). CDIs characterizing the 1- to 24-month salinity conditions were developed and the evaluation of the CDI indicates that the index can be used for different estuary types (for example, brackish, olioghaline, or mesohaline estuaries), for regional comparison between estuaries, and as an index for wet conditions (high freshwater inflow) in addition to drought conditions. Unlike the SPI where long-term precipitation datasets of 50 to 100 years are available for computing the index, there are a limited number of salinity data sets of greater than 10 or 15 years for computing the CDI. To evaluate the length of salinity record necessary to compute the CDI, a 29-year dataset was resampled in 5-, 10-, 15-, and 20-year interval datasets. Comparison of the CDI for the different periods of record show that range of salinity conditions in the 10-, 15-, and 20-year datasets were similar and results were a close approximation to the CDI computed using the full period of record. The CDI computed with the 5-year dataset, with a smaller range of salinity conditions, had the largest differences with the CDI computed with the 29-year dataset but did provide useful information on coastal drought and freshwater conditions. It is essential that a CDI be correlated to coastal drought response parameters to show the importance of a unique coastal drought index. However, identifying potential coastal drought response datasets is challenging. Coastal drought is a relatively new concept and existing datasets may not have been collected or understood as "drought response" datasets. Some potential drought response datasets include tree growth and liter fall in tidal marshes, harmful algal blooms occurrence, Vibrio infection occurrence, shellfish harvesting data, and shark attacks. An ongoing National Integrated Drought Information System (NIDIS) drought early warning project in the Carolinas is

developing ecological linkages to the CDI and evaluating the effectiveness of the CDI as a prediction tool for adaptation planning for future drought.

Conrads, Paul
US Geological Survey
HYDROLOGIC RECORD EXTENSION OF SALINITY DATA TO EVALUATE LONG-TERM COASTAL DROUGHT CONDITIONS (T5B,S5)
Changes in the salinity of coastal waters during extreme meteorological conditions (droughts and floods) can result in substantial environmental response. The location of the freshwater-saltwater interface is an important factor in the ecological and socio-economic dynamics of coastal communities: It influences composition of freshwater and saltwater ecosystems, determines fisheries spawning habitat, and controls freshwater availability for municipal and industrial water intakes. Salinity is a critical response variable that integrates hydrologic and coastal dynamics including streamflow, precipitation, sea level, tidal cycles, winds, and tropical storms. Unlike other hydrologic variables, such as precipitation or streamflow, there are a limited number of long-term (> 50 year) salinity data sets. To recreate a > 90 year salinity history of the Waccamaw River for evaluating interannual-to-decadal variability of estuarine habitat, an empirical model was developed to extend (hindcast) monthly salinity values back to 1929. The model uses inputs of 1) 28 years of daily salinity data, 2) long-term daily streamflow data, and 3) daily tide records. The 90-year salinity record was used to compute a Coastal Salinity Index (CSI) for the site. The CSI is computationally similar to the Standardized Precipitation Index (SPI) and can be used for different estuary types (for example, brackish, oligohaline, or mesohaline estuaries), for regional comparison between estuaries, and as an index for wet conditions (high freshwater inflow). A correlation analysis was done with baldcypress (Taxodium distichum) tree-ring data from a tidal swamp along the Waccamaw River to evaluate whether the 90-year salinity record and the corresponding CSI could be used as an explanatory factor for tree-growth response to various levels of salinity exposure. There are many factors affecting baldcypress tree growth including precipitation, cloudiness, temperature (heat stress), and pore-water quality. Preliminary results indicate that the highest correlation (Pearson coefficient [r] = 0.38) was with the 24-month CSI and a 2-year time lag on the tree-ring growth rate index. Although the correlation is not strong, it is an accounting of one factor affecting tree growth. The CSI time interval and time lag indicates that baldcypress trees on the Waccamaw River may be affected by extended saline or “fresh” conditions of approximately 2 years. The presentation will describe the technique used for extending salinity records, comparison of the CSI with other climate indices (the SPI and Palmer Hydrologic Drought Index), and implications of anthropogenic basin alterations to hydrologic record extension.

Czwartacki, Brooke, Joesph Gellici
South Carolina Department of Natural Resources
MONITORING SALTWATER INTRUSION ALONG THE COAST OF SOUTH CAROLINA (T7,S5)
Fresh groundwater is one of the most important resources in the United States. In South Carolina, approximately 25% of the population live in coastal shoreline counties that depend on fresh groundwater supplies for domestic, municipal, industrial or agricultural purposes. The demand for groundwater continues to grow, and over-pumping has progressively developed cones of depression and intercepted natural flow; as a result, saltwater intrusion has become both a common and persistent problem for coastal communities dependent on groundwater. Along the coast, a dynamic equilibrium exists between fresh and saline groundwater with mixing occurring at a transition zone or interface. This zone is characterized by increasing concentrations of total dissolved solids ranging from <1000 mg/L (freshwater) to 35,000 mg/L (seawater). The seaward limit of freshwater in an aquifer is controlled by numerous factors including hydrogeologic setting, the amount freshwater flowing through the aquifer, proximity to tidally influenced saline water bodies, and relative densities between fresh and saltwater. Vertical movement of water across leaky confining layers, lateral movement, or upconing of dense saltwater can lead to saltwater intrusion. Intrusion into the Upper Floridan aquifer near the southern coast of South Carolina is well documented. Less, however, is known about the current extent and degree of salinity intrusion within other aquifers, particularly those along the central and northern coastline of South Carolina. In order to address this issue, a subset of wells from the existing South Carolina groundwater monitoring network was selected for the purpose of monitoring saltwater intrusion. For this phase of the project, the water-table aquifer and the shallow confined aquifers were targeted for monitoring. Wells range in depth from 40 to 600 feet and include wells open to limestone beds of the Middle Floridan aquifer (middle Eocene) in Beaufort County, open-hole wells completed in sandy limestone beds of the Gordon aquifer (late Paleocene to early Eocene) in Colleton and Charleston Counties, and wells screened in sandy beds of the Crouch Branch aquifer (late Cretaceous) in Georgetown and Horry Counties. All wells are instrumented with data loggers that continuously measure and record water level, temperature and conductivity. Data are verified with field measurements on a bimonthly basis. A second phase of the project will include monitoring deeper aquifers and adding additional wells that parallel the first, but that are located farther inland. Using specific conductance as a surrogate for chloride concentration, data are used to identify the occurrence and track the movement of the freshwater/saltwater transition zone. With continued monitoring we can assess long term trends, seasonal and annual variation, surface water-groundwater interaction, the influence of pumping on chloride levels, and eventually use the information for model development. Network and data management, quality assurance, and documentation are integral parts of this project and will allow for the reporting of reliable information. The resulting

documentation of the freshwater/saltwater interface in South Carolina's coastal aquifers will provide guidance for decision-makers to implement sustainable groundwater management strategies that can ensure future availability of this important resource.

Davis, William, Jack Beers
CDM Smith
UTILIZING GIS TO HELP MANAGE A MAJOR DISASTER PROGRAM: CASE STUDY - THE OCTOBER FLOOD IN SC AND FEMA SUBSTANTIAL DAMAGE INSPECTIONS (T5,S3)
The historic flooding in October 2015 that caused widespread damage to communities throughout South Carolina triggered a timely response that would not have been possible without the aid of a state-of-the-art data collection and management system. Within days of the flooding, CDM Smith was retained as a contractor by FEMA to conduct Substantial Damage Inspections in communities across the state. In the span of four weeks, nine, two-member teams inspected approximately 5,000 structures. The teams used GPS-enabled tablets with a customized application to facilitate data entry. The inspections were uploaded in real-time and processed off-site. Existing County GIS data served as the backbone for identifying and locating inspection sites by both office and field staff. The existing GIS coupled with the real-time inspection data was published via an ArcGIS Online Web Application, enabling up-to-the minute access by both FEMA and the affected communities. This served to prevent delays in the recovery process and speed up funding to impacted communities. Finalized Substantial Data Estimates (SDE) were compiled and uploaded for each community using the latest version of FEMA's SDE software. This presentation will discuss how existing GIS and custom mobile platforms were efficiently deployed to rapidly collect, store, analyze, manage, and disseminate data following a natural disaster, and how they can be used to support future recovery efforts, monitor and manage the state's resources, and enhance other environmental programs.

***Dearth, Nicole[1],** Joe Jones[1], Rebecca Mortensen[1], Cameron Doll[2], Dianne I. Greenfield[1,2]
[1]University of South Carolina, [2]SC Department of Natural Resources
+DEVELOPMENT AND APPLICATION OF A SANDWICH HYBRIDIZATION ASSAY FOR ASSESSING CULTURED AND NATURAL POPULATIONS OF THE HARMFUL CYANOBACTERIUM MICROCYSTIS AERUGINOSA
Cyanobacteria are responsible for the largest number of harmful algal blooms (HABs) worldwide. The genus Microcystis is a major contributor to these HABs, and species such as *M. aeruginosa*, produce the potentially-lethal hepatotoxin microcystin that causes liver failure in human, pet, and wildlife through direct bloom contact in recreational water or consumption of contaminated drinking water. Stormwater detention ponds, such as those found along the South Carolina (SC) coast, often harbor these blooms, particularly during the summer when waters are warm and often stagnant. Since stormwater detention ponds are commonly constructed within residential and recreational areas and have close proximities to humans and pets, Microcystis blooms pose threats to public health. Identification of Microcystis blooms is commonly done using light microscopy, but this is very time consuming, and it is complicated by its tendency to form dense colonies and morphological similarity between species. Molecular techniques overcome these limitations by facilitating rapid and accurate cell identification and quantification. Sandwich hybridization assay (SHA), the technique considered here, directly (e.g., no amplification or purification of genetic material) identifies and quantifies planktonic species using ribosomal RNA (rRNA) (large sub-unit-LSU)- targeted oligonucleotides in ~1.5 hours. SHA utilizes two DNA probes, a species or genus specific capture probe, and a more group-specific signal probe that bind to the targeted rRNA sequence to create a "sandwich" wherein results are measured by absorbance. SHA has been applied to other HAB genera, but not Microcystis. Using a regional strain of *M. aeruginosa*, the goal of this project is to develop SHA for use with *M. aeruginosa*, thereby facilitating the monitoring and tracking of bloom events in South Carolina coastal systems and potentially worldwide. A multi-specific cyanobacteria bloom in a stormwater detention pond on James Island, SC was monitored this summer from the end of April to July. The main species of the bloom were *M. aeruginosa, M. botrys, M. wesenbergii, Anabaena sp.*, and *Anabaenopsis sp*. Samples were taken for SHA, chlorophyll a, nutrients, and toxins, and temperature, salinity, dissolved oxygen, and pH were recorded at the time of sampling. Samples from this bloom will serve as the environmental samples tested with the newly developed capture probe.

Dickes, Lori[1], Jeffery Allen[1], Monika Jalowiecka[2], Katie Buckley[1]
[1]Clemson University, [2]University of South Carolina
A POLICY OVERVIEW OF STORMWATER POND MANAGEMENT IN SOUTH CAROLINA'S EIGHT COASTAL COUNTIES (T3B,S2)
As is the case with numerous environmental issues today, stormwater management lies within a network of layers of regulatory and policy oversight. These layers begin at the highest federal levels of law and continue down to neighborhoods and individuals responsible for stormwater ponds. As South Carolina coastal communities continue to experience economic and population growth, understanding the broader policy context of stormwater pond management is important. This study was aimed at compiling the state-of-the-knowledge of stormwater pond management policy for the eight coastal counties of South Carolina. In order to enhance researchers and policymakers understanding of the strormwater policy and regulatory environment, this analysis utilized a mixed methods approach. A mixed methods approach allows researchers to explore different components of a particular research question by deploying more than one methodological tool. This research employed three primary qualitative techniques, a policy instrument scan, a regional online survey and a local policy and economic managers focus group. Results indicate that while potentially strong policy exists at all

levels (federal, state and local), there are numerous gaps in policy implementation and proper stormwater pond management at the local level. Recommendations include: require more LID practices both for new development and re-development, improved pond maintenance, more progressive and restrictive design criteria, research and development of alternative pond management methods, strong prescriptive regulation, need for public/private partnerships, state regulators to adapt new design criteria and provide regular training opportunities to engineers preparing stormwater plans and plan reviews, increased education programs for developers and home owner associations (HOA's) as well as programs aimed at better communication between state regulatory agencies and local governments and stormwater pond owners. This document helps lay the foundation for future stormwater pond policy studies that can assist policy makers, managers, stakeholders and other decision makers to more fully understand issues impacting water resource management in South Carolina.

Dickson, Edward
AECOM

OCTOBER 2015 DAM INUNDATION: HOW THE FLOOD CHANGED THE CONVERSATION AROUND DAM INUNDATION MAPPING (T5,S2)

In the aftermath of the dam failures that occurred across the State of South Carolina, a significant number of homes and businesses were substantially damaged by the resulting flood wave. Many of these structures are located in areas that are outside of the extents of the FEMA floodplain. In the days and weeks that followed, high water mark data collected by a variety of agencies allowed the magnitude of the flooding to be quantified and documented. This presentation will seek to highlight some of the hardest hit areas, providing context for the benefits of including considerations of the potential inundation resulting from dam failure in the analysis of flooding risk in areas downstream.

Durkee, John
Water Environment Consultants

USING MODELS TO IMPROVE YOUR NPDES LIMITS (T4,S4)

After providing some background information, this presentation provides methods for applying hydrodynamic and water quality models to improve NPDES discharge limitations. Initial draft permit limits are often based on calculations or models that include conservative assumptions to protect water quality in the receiving water. Many of these assumptions are due to limited availability of more accurate information, but they may also be based on standard permitting procedures or policies. The conservative nature of these analyses can substantially reduce the NPDES permit limitations and therefore increase the operating and capital costs for treatment. It is important to carefully review the calculations and modeling used to determine the permit limitations. In some cases, a more detailed modeling analysis, including the use of a different model, can provide a more accurate evaluation of water quality impacts. In any case, the cost associated with review or enhancement of the calculations and modeling is typically much less than the avoided operating and/or capital costs. The presentation provides a recommended stepwise approach to reviewing model-based permit limits, applying more detailed modeling analyses, and even collecting field data to support development of refined models. The presentation briefly covers the basics of NPDES permit limit development and runs through several non-modeling site-specific factors for consideration in NPDES limit adjustments including reasonable potential calculations, 7Q10 flow adjustments, alternative toxicity test species, and instream data collection/studies. After providing this background information, the presentation focuses on the use of specific models commonly used to determine NPDES permit limits, including CORMIX, QUAL2E, and EFDC. Several examples/case studies are provided throughout.

Ellerbe, Frances, Ben Hammond, Deb Sahoo
Woolpert Inc

THE RAPID AND COMPREHENSIVE ANALYSIS OF STORM EVENTS FROM CONTINUOUS WATER QUALITY MONITORING DATASETS (T4A,S1)

Continuous water quality monitoring produces a dataset, which offers a wealth of opportunity for exploring watershed processes and how they impact the observed water quality in streams. Continuous datasets are often so large in size that it becomes difficult to conduct a comprehensive analysis that leverages all of the collected information to arrive at sound conclusions. When monitoring is conducted for the purpose of assessing stormwater impacts on stream health, these challenges multiply. No two storm events in a watershed are identical, and it is difficult to parse out the effect that each storm characteristic - be it precipitation total, average rainfall intensity, antecedent dry period, or any other factor - has on the resultant water quality. By developing a storm analysis tool to automate the identification and analysis of every storm event recorded in a continuous dataset, these challenges are addressed. This developed algorithm takes as an input a continuous water quality monitoring dataset, and uses the stream flow values to separate storm events, calculate rainfall and water quality characteristics for each storm, and produce a set of summary figures and an output table. By implementing this storm analysis tool, the user is instantly provided with a summary of the water quality response to every storm event that has impacted the watershed in the period of record. Furthermore, the user can readily visualize the results through automated plots of every identified storm event as well as summary figures, which show the overall storm response trends in the watershed. The applications of this algorithm are far reaching, with the ability for users to adjust input parameters to suit various watershed sizes and characteristics. This storm analysis tool provides an efficient method for water quality analysts to maximize the value of a collected dataset, resulting in a more robust understanding of the impacts of stormwater on the watershed of concern. This presentation will begin with a detailed discussion of the automated analyses included in the developed tool, followed by the presentation of analytical results from a 5-year continuous water quality dataset collected in the Upstate of South Carolina by Greenville County's Land Development Division.

***Ellis, Kathryn**[1], Timothy Callahan[1], Dianne Greenfield[2,3], Denise Sanger[3], and Joshua Robinson[4]

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HYDROLOGICAL ASSESSMENTS OF TIDAL CREEKS TO INFORM NUTRIENT MANAGEMENT RECOMMENDATIONS (T7,S4)

The purpose of this study is to provide regulatory agencies with information about the hydrology of tidal creeks by developing mathematical relationships between time, stage, and discharge. Currently, there are no stage-discharge or time-discharge relationships for these creeks, or many other similar creeks in the South Carolina Coastal Plain, so this information will fill an existing gap. The results will be used to evaluate biological responses (e.g., algal blooms) in coastal waters to identify linkages to flow and nutrient (nitrogen and phosphorus) dynamics in the waters; in other words, can nutrient delivery rate (mass flux) predict biological responses in coastal wetlands? There are four study sites: two in the Ashepoo-Combahee-Edisto (ACE) Basin and two in the Charleston Harbor system. Opportunistic sampling, with the goal to encompass as large a range of measurements as possible, is occurring over a two-year period (2015-2016) to measure volumetric discharge in each creek with an acoustic Doppler current profiler (ADCP) unit. Additionally, the discharge data, combined with information from a related effort to collect nutrient and phytoplankton data, will be used to calculate presumptive Total Maximum Daily Load (TMDL) estimates for these sites. A runoff model will be used to estimate the potential water entering the creeks from the land surface; this quantity will be compared to the total volume of water that enters or exits the creeks (the tidal prism) to better understand how runoff may affect the environmental health and algal ecology in these creeks.

***Emmons, Maggie**, Sarah E. Rothenberg, Michael Bizimis, Bill Stangler

University of South Carolina

ASSESSING THE EFFECTS OF SANITARY SEWAGE OVERFLOWS FROM THE 1,000-YEAR RAIN EVENT ON METAL CYCLING IN THE CONGAREE WATERSHED (T4B,S1)

During the 1,000-year rain event in Columbia, South Carolina, untreated sewage was released into the Congaree Watershed due to the flooding of wastewater treatment plants and sanitary sewage overflows. Although the October 2015 flooding event was historic, sewage overflows have been an ongoing issue within the Midlands, ranking as one of the top water quality problems impacting the Congaree, Lower Broad and Lower Saluda rivers. Untreated sewage and wastewater effluent are sources of dissolved organic matter and trace metals, which may impair the surface waters that are used for drinking water and/or recreation. The increased input of dissolved organic matter has the potential to influence the biogeochemical cycling of metals in aquatic environments. Mercury methylation, a microbially-mediated process, is of particular concern because the formation of the more toxic methylmercury involves the bioavailability of inorganic mercury (II) which is partially controlled by dissolved organic matter. In the five months following the October 2015 flooding, surface water and sediment samples were collected at three locations that were heavily impacted in Richland County, South Carolina, including Crane Creek, Stoops Creek and Gills Creek. During the sampling period, two significant, active sewage overflows were discovered: one from the Columbia/Metro wastewater bypass at Crane Creek which released over a million gallons of untreated sewage into the environment and the other from a broken sanitary sewage pipe in Stoops Creek. Water samples collected at the three sites, including samples directly taken from the two sanitary sewage overflows, are currently being analyzed for filtered (<0.2µm) metal concentrations and unfiltered and filtered (<0.2µm) total mercury and methylmercury concentrations. To a first order, the metals show dissolved concentrations that mimic crustal (rock) inputs. Nevertheless, trends were observed for some dissolved metal concentrations (e.g. Zn, Pb, Ba, Mn, Fe) with each site having specific and consistent metal signatures, indicating potential local sources. Further details from this study on the dissolved metal, total mercury and methylmercury concentrations from each sampling site will be presented to illustrate the effects of sewage runoff from wastewater treatment plants and intermittent sanitary sewage overflows on the transport of trace metals to downstream watersheds and mercury methylation.

Farris, Amanda[1], Kirsten Lackstrom[1], Kirstin Dow[1,2], Janae Davis[3], David Eckhardt[1], Sumi Selvaraj[1,2]

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WHAT CAN CITIZEN SCIENTISTS TELL US ABOUT DROUGHT? USING THE COMMUNITY COLLABORATIVE RAIN, HAIL, AND SNOW (COCORAHS) NETWORK TO IMPROVE THE MONITORING AND REPORTING OF DROUGHT IMPACTS IN THE CAROLINAS (T5B,S5)

Drought impacts data can be used to improve understanding of drought vulnerabilities and to develop and target strategies for drought response and mitigation. Online tools such as the national Drought Impact Reporter provide a valuable repository of drought impacts information. However, observers typically submit one-off impact reports, when drought conditions are severe or extreme, rather than report on a consistent basis, which would allow for a better understanding of how and when drought impacts emerge and evolve. In collaboration with the National Integrated Drought Information System (NIDIS), the National Drought Mitigation Center (NDMC), and the Community Collaborative Rain, Hail & Snow (CoCoRaHS) network, the Carolinas Integrated Sciences and Assessments (CISA) developed an experimental method of drought monitoring and reporting by citizen scientists. Project goals include 1.) collecting information about on-the-ground drought conditions to improve the identification of drought onset, intensification, and recovery and 2.) assessing the usefulness of information provided by citizen scientists for drought monitoring and decision making. Volunteers were asked to submit weekly condition monitoring reports to describe how recent weather conditions affected environmental, social,

and economic systems in their communities. CoCoRaHS observers throughout the Carolinas have submitted over 1,500 reports since September 2013. CISA researchers analyzed report content according to drought impact categories and other variables of interest. Interviews were conducted with representatives from the North and South Carolina state climate offices and drought committees, the CoCoRaHS national office, the National Drought Mitigation Center, National Weather Service Weather Forecast Offices, and county-level soil and water conservation districts. The goal of the interviews was to obtain feedback on report content and analysis and assess how the information might be incorporated into drought monitoring and related decisions. Interviews revealed that a range of intrinsic and extrinsic factors mediate the usefulness and usability of condition monitoring report content. For example, intrinsic factors related to the reliability (e.g., whether a volunteer regularly reported precipitation and conditions) and saliency (e.g., the type and extent of details provided about dry conditions) of the reports. Drought stage and time of year, as well as the organizational and management context of the interviewees, also affected how they used the information. Feedback from these interviews led to a revised reporting format on the CoCoRaHS website. The new form includes a quantitative metric to supplement the qualitative reports. Additionally, a web map has been developed to spatially display reports in conjunction with other decision-relevant information (e.g., precipitation measurements, current US Drought Monitor map, etc.). As these tools are utilized by a variety of agencies and organizations, as well as CoCoRaHS observers, CISA will continue to evaluate the project's effectiveness in improving the monitoring and reporting of drought impacts.

Feaster, Toby
US Geological Survey

LOW-FLOW STATISTICS UPDATES IN SOUTH CAROLINA (T4,S2)

The annual minimum 7-day average streamflow with a 10-year recurrence interval, often referred to as the 7Q10, have a long history of being an important low-flow statistic used in water-quality management in South Carolina as evidenced by its adoption into South Carolina law in 1967. State agencies, such as the South Carolina Department of Health and Environmental Control (SCDHEC) and the South Carolina Department of Natural Resources, use such low-flow statistics to determine Wasteload Allocations for National Pollutant Discharge Elimination System discharges, develop Total Maximum Daily Loads for streams, prepare the State Water Plan, and restrict the quantity of water that can be transferred out of basin. Low-flow statistics such as the 7Q10 are not static values and are affected by such factors as the number of years of record available for use in computing the statistic along with the hydrologic conditions captured in that record. Consequently, it is critical to effectively measure and document base-flow data for use in updating low-flow statistics on a regular basis, preferably about every 10 years. In 2008, the US Geological Survey (USGS), in cooperation with SCDHEC, initiated a study to update low-flow statistics at continuous-record streamgaging stations operated by the USGS in South Carolina. Prior to that, low-flow statistics in South Carolina had not been updated in a systematic way since 1987. The investigation was accomplished on a basin-by-basin approach based on the major river basins in South Carolina. The results have been documented in five USGS Open-File Reports for the following basins: 1.) Pee Dee River; 2.) Broad River; 3.) Saluda, Congaree, and Edisto Rivers; 4.) Catawba-Wateree and Santee Rivers; and 5.) Savannah and Salkehatchie Rivers. Findings from these assessments will be discussed along with the plans for a final USGS report that provides a comprehensive evaluation of the low-flow analyses.

Feaster, Toby
US Geological Survey

THE FLOOD OF OCTOBER 2015 AND OTHER MAJOR FLOODS IN SOUTH CAROLINA (T5,S1)

Heavy rainfall occurred across South Carolina during October 1-5, 2015, as a result of an upper atmospheric low-pressure system that funneled tropical moisture from Hurricane Joaquin into the State. The storm caused major flooding in the central and southern parts of South Carolina. Almost 27 inches of rain fell near Mount Pleasant in Charleston County during this period. US Geological Survey streamgages recorded peaks of record at 17 locations and 15 other locations had peaks that ranked in the top 5 for the period of record. In the Pee Dee River Basin, a new period of record peak flow occurred on October 6, 2015 for station 02136000, Black River at Kingstree. This was the largest peak flow recorded at this station in 87 years with the previous maximum peak occurring on June 14, 1973. Annual maximum peak-stage data contained in reports of the National Weather Service indicates the October 2015 peak stage is the largest since 1893. Station 02175000, Edisto River near Givhans, South Carolina, peaked on October 8, 2015. This was the largest peak flow recorded since 1925 and based on peak-stage data, was likely the largest flood since at least 1904. For a historical perspective, maximum flood peaks of record from other USGS stations with long-term records will be compared to the maximum flood peaks from the October 2015 flood. Other historical information also will be included to help describe the various flood events.

Finneran, Kevin, Jolanta Niedzwiecka, Sarah Hennessy, Kelsey Herring, Alexander Rogier
Clemson University

COMBINED BIOLOGICAL AND CHEMICAL APPROACHES IN GROUNDWATER REMEDIATION (T2,S3)

This presentation will discuss strategies and technologies for in situ and ex situ remediation that combine biological processes with chemical reactions for faster and more complete contaminant transformation. Recently, researchers and practitioners alike have recognized that combining biological and chemical technologies can lead to better overall contaminant reduction, oxidation, or detoxification. This presentation will focus on biological metabolism and secondary chemical reactions, as well as chemical remediation strategies followed by stimulated microbial processes. Contaminants that will be discussed

include chlorinated solvents, explosives and munitions, and metals/radionuclides. Work conducted by several Clemson graduate and undergraduate research assistants will be highlighted.

Flite III, Oscar P., Jason W. Moak, Shawn E. Rosenquist
Phinizy Center for Water Sciences
RESULTS OF A CONTINUOUS LAGRANGIAN RIVER CRUISE ON THE SAVANNAH RIVER TO DETERMINE OVERALL METABOLIC ACTIVITY OF THIS ECOSYSTEM (T4A,S1)
Continuously measuring biogeochemical cycles from the same packet of water as it flows downstream (Lagrangian perspective) as opposed to measuring these cycles continuously from a fixed position in a river system (Eulerian perspective) provides a significantly better understanding of the overall ecosystem metabolism. The goal of this research was to develop a Lagrangian perspective of the Savannah River and its biogeochemical processes by traveling with, and continuously collecting data from, the same packet of water as it flowed from RM 190 (approximately 2 miles above NSBL&D) to RM 45 (near Ebenezer Creek). Our intention was to focus on the carbon and oxygen dynamics to develop an understanding of the rate and amount of organic material that was processed by the entire river community. This research was conducted from a 30ft pontoon houseboat that was equipped with continuous instrumentation for measuring the partial pressure of CO2 in air and water (pCO2), water temperature, dissolved oxygen, specific conductance, pH, and turbidity. Discrete samples were collected periodically along the cruise and subsequently analyzed for 3 day-biochemical oxygen demand (BOD3), ammonia (NH3), nitrate (NO3)/nitrite (NO2), total nitrogen (TN), dissolved (DOC) and total organic carbon (TOC), total (TP) and dissolved phosphorus (DP), and the C13 isotopic signature of dissolved (DOC13) and particulate carbon (POC13) as well as dissolved inorganic carbon (DIC13). Overall trends showed increases in temperature, specific conductance, pH, and turbidity in the downstream direction. Carbon dioxide and dissolved oxygen trends were inversely proportional along the transect with a rapid increase and steady decline in aqueous pCO2 with observable diurnal fluctuations. For most of the cruise, the CO2 in water was supersaturated with respect to the air, except for the afternoons on the final two days. At its maximum, the water was nearly 5x supersaturated with CO2 relative to the air while toward the end of the trip, the water was maximally undersaturated. Stable isotope data helped elucidate the overall metabolic dynamics of this river system. In essence, the Savannah River had discrete, high productivity and high respiration patches that result from metalimnetic reservoir releases, shallow shoals habitat, point source discharges, and an increase in algal growth in the downstream direction. In addition, measured metabolic rates were significantly higher than rates developed using discrete long-term biochemical oxygen demand methods (120-day bottle test). Resolution of this data set provides an important and significant contribution to the overall understanding of the biogeochemical cycling of nutrients in this river system and shows that Lagrangian sampling exceeds Eulerian sampling schemes for such insight.

Flite, Oscar[1], Chalisa Nestell-Fabillar[1], Kelsey Laymon[1], Jason Moak[1], Damon Mullis[1], Katie Johnson[1], John Hains[2]
[1]*Phinizy Center for Water Sciences,* [2]*Clemson University*
+WATER QUALITY TRENDS IN FOUR SAVANNAH RIVER NAVIGATION CUTOFFS (OXBOWS) OVER A ONE-YEAR PERIOD
The Savannah River was altered to improve navigation from the 1950's through the 1970's. Alterations to improve navigation consisted of dredging a channel between river meanders to decrease the number of tight bends in the river. As a result, 42 navigation cutoffs were created, effectively decreasing the length of the Savannah River by nearly 40 miles. Over time, many of the excised sections of river have become completely cut off from main channel river flow, except during flood events, so water levels in these cutoffs are dependent upon groundwater and rainwater during non-flood regimes. Water quality in these cutoff systems can deteriorate if the water exchange rate is decreased or eliminated, thereby impacting the biota stranded within these systems. We assessed the hydrology and water quality trends over a one-year period in four Savannah River cutoffs; two that had visible surface water connections and two that did not. We continuously measured groundwater and surface water levels as well as groundwater and surface water temperature at each site. Periodic water column profiles of temperature, specific conductance, dissolved oxygen and pH were conducted throughout the year as well. Overall, all lakes showed similar trends despite connectedness to the river. Each lake was stratified relative to dissolved oxygen with the upper layers of all lakes exceeding 100% saturation in summer and the lower lake depths below 50% saturation. Temperature and specific conductance profiles showed evidence of a stable water column in all lakes with warmer, more dilute upper water and cooler, more concentrated lower water. Flooding events completely mixed each lake. This study showed that water quality will decline in the lower waters of these cutoff lakes, despite connectedness, over time. However, a management strategy of periodic flooding for this regulated river system will improve dissolved oxygen concentrations, meeting state standards throughout the water column, for up to two months or more after flooding.

Foote, Jeremy[1], David C. Shelley[1,2], Frank Henning[1,2], T.J. Callahan[3]
[1]*Congaree National Park,* [2]*NPS Old-Growth Bottomland Forest Research and Education Center,* [3]*College of Charleston*
RECONSTRUCTING THE OCTOBER 2015 FLOOD ON CEDAR CREEK AT CONGAREE NATIONAL PARK (T4B,S1)
The value of high-quality, long-term data sets can be limited by data gaps due to infrastructure damage during extreme events. One solution, as a preventative measure, is to have secondary, redundant "insurance" data. A good

example is found on Cedar Creek in Congaree National Park (CONG). USGS site 02169672 at CONG "Bridge B" on Cedar Creek ("BB" hereafter) has high quality, more-or-less continuous stage data since 1994. BB infrastructure was damaged during the extreme October 2015 flood, however, resulting in critical data gaps. This project reconstructed those data gaps using stage data from the Congaree Surface Water Observation Network (CSON), which is an in-house research-and-education effort sponsored by the NPS Old-Growth Bottomland Forest Research and Education Center and the College of Charleston. Modeling results, while not official data of record, are very useful for assessing the 2015 event in a long-term context of an old-growth floodplain forest ecosystem. CSON site C2 ("C2" hereafter) is located near the South Cedar Creek canoe landing ~two linear miles downstream from BB. Absolute bank elevations are ~4' lower at C2 than at BB. C2 infrastructure consists of a 2" PVC stilling well installed in 2010 and instrumented with a Solinst Levelogger gold data logger. Hourly C2 data were processed to summarize daily maximum stage, compatible with USGS data. C2 and BB records provide good, overlapping data and similar hydrographs for 1,581/1,805 days (87%) for the period 01/22/2011 to 09/30/2015. These overlapping data were used to model the relationship. Daily maximum stage data gaps at BB were then reconstructed for the period 10/1/2015 to 12/31/2015. The minimum maximum C2 stage recorded from 10/01/2015 to 12/31/2015 was 7.38'. The October 2015 flood at C2 peaked at 21.17' on 10/06/15, 2.98' (~16%) higher than the previous C2 "flood of record" (18.19' on 05/09/13). Accordingly, modeling equations needed to focus on high-stage hysteresis and extrapolated outside of the previously known system boundaries. Eight hundred overlapping data points from 01/22/2011 to 09/30/2015 for C2 stages >7.38' were modeled. Data were randomly sub-sampled into two 400-point sets for training and testing the model respectively. Several mathematical functions were used to explore the relationship. Functions were evaluated for reasonable behavior at higher stages as opposed to the simple "best fit" [R2] during training. A 2nd order polynomial (R2=0.92) was selected as it well approximates a linear (though offset by ~4') relationship through C2 stages of 30'. This would make intuitive sense if the floodplain was dammed up to form a lake. Preliminary model results suggest that the October 2015 flood at BB crested at ~17.73 feet. This was 2.66' (~18%) higher than the previous BB flood of record (15.07' on 03/23/03). From 1994-2015, thirty-six BB floods peaked >10'. Only four of these were fall floods (all also related to hurricanes), and only one peaked in October. Extrapolation of frequency distributions for high magnitude events (BB peak stages with recurrence interval >1 year) from 1994-2014 suggests that the recurrence interval of the October 2015 flood was ~335 years.

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HOW EXTREME WAS THE OCTOBER 2015 PRECIPITATION EVENT IN SOUTH CAROLINA? (T5,S1)

Extreme rainfall and flooding in October 2015 caused loss of life and property, and infrastructure failure across South Carolina and the southeast coast of North Carolina. How extreme the event was is critical information for the design and operation of infrastructure. NOAA Atlas 14 provides a point-based precipitation frequency estimate with 30-second spatial resolution from 5-minute through 60-day durations at average recurrence intervals of 1 to 1,000 years. It has been used as an engineering standard to infer how extreme of a rainfall event by comparing observed rainfall depths at stations against the estimates at corresponding locations in Atlas 14. However, the volume of rainfall received in an area (e.g., an 8-digit Hydrological Unit Code (HUC)) is the most important factor that causes infrastructure failure or damage. Therefore, the inference of how frequent a certain amount of rainfall received in an area is essential, which is not provided directly by NOAA Atlas 14. Our study examines the occurrence probability of the extreme event in USGS HUCS of South Carolina that were greatly affected by the October 2015 storm. We adapted a Generalized Extreme Value (GEV) distribution to estimate Intensity-Duration-Frequency (IDF) curves for these areas based on the annual maximum total extracted from the daily 4-km gridded PRISM precipitation dataset from January 1, 1981 and ending on December 31, 2015. We developed a bootstrapping approach to overcome the insufficient sample sizes (i.e., 35 years of annual maximum totals) for robust estimation of GEV distribution parameters, especially for the estimation of long return periods. The approach borrowed spatially across the southeastern United States, where the conditions that led to the October 2015 flooding event in South Carolina could have plausibly occurred because of similar geographic and synoptic conditions. We compared the return periods of the annual maximum 1-day, 2-day, and 4-day totals estimated by the point based approach (i.e., atlas 14) and our areally-based approach. We found that both point-based and areally-based approaches suggested longer return period as the duration increased. The areally-based approach showed longer return periods than the point based approach. The four-day total exceeded a 1,000-year event in selected basins. This study captures the characteristics of extreme rainfall events for entire basins rather than individual stations or locations. It improves estimates in the tails of the frequency distribution and provides valuable information regarding adaptation of infrastructure to future climatic extremes.

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+CLEMSON WOW PROJECT: SUCCESSES OF A WATER QUALITY OUTREACH PROGRAM

The What's in Our Waters (WOW) program was designed by graduate students from the Biology and Environmental Toxicology programs at Clemson University (CU) in June 2013. The goals of the program are to introduce high

school students to monitoring and reporting on the conditions of local streams thus teaching students the importance of responsible citizen science, conducting water quality research using the scientific method, and the relevance of science communication with the public. WOW has established a successfully running model with the AP Environmental Science class of a local high school in Central, South Carolina. Students learn about water quality indices, sample and analyze data from a local stream, and report findings at a local symposium. The programs' success and the collected data are useful for both educators working to evolve environmental education and as well as researchers working to increase interest in citizen science. The structure of this program brings attention to South Carolina's water resources and alters students' perceptions of science and scientists.

***Garcia Chance, Lauren,** John Majzstrik, Natasha Bell, Daniel Hitchcock, Sarah White
Clemson University

+WATER QUALITY EFFECTS OF FLOATING TREATMENT WETLAND SYSTEMS TO REMEDIATE PLANT PRODUCTION RUNOFF

Plant production in greenhouse and container nurseries typically generates runoff water with excess nutrients. Runoff water either flows offsite or is captured and reused for irrigation. Floating treatment wetland systems (FTWs) can remove nutrients from water streams prior to release or reuse. From May to October 2015, 100-gallon tanks had one of eight treatment combinations. Treatments consisted 2 nutrient loading rates (high: 10 ppm nitrogen (N) or low: 3 ppm N, 17-3-17 water soluble fertilizer) in combination with tanks (1) without plants or floating mats, (2) without plants with floating mats, and floating mats planted with (3) Pontederia cordata L. (pickerelweed) or (4) Juncus effusus L. (soft rush). Each treatment was replicated 4 times (32 experimental units). Tanks were drained and refilled every week to maintain N levels. Water samples were collected weekly and analyzed using four types of analyses: total organic carbon (TOC), inductively coupled plasma emission spectrophotometer (ICP-ES), ion chromatography (IC), and a flow injection analysis (FIA). Furthermore, water pH, temperature, and EC were recorded three times per week. Findings indicate that FTWs reduced water temperature, reduced DO, and regulated pH fluctuations. Tanks with planted FTWs removed up to 2.25 times the amount of phosphorous than those not treated. This resulted in reduced algal blooms in tanks supporting FTWs when compared to the open control tanks. Furthermore, tanks planted with Pontederia cordata removed a greater load of phosphorous than those planted with Juncus effusus by up to 3x. Similar findings for nitrogen were noted as well, indicating FTWs are a viable option for mitigating nutrients in nursery and greenhouse runoff.

Greenfield, Dianne[1,2], Erik M. Smith[1], Andrew Tweel[2], Denise M. Sanger[2]
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UPDATING THE STATE-OF-THE-KNOWLEDGE: ECOLOGICAL FUNCTION OF STORMWATER DETENTION PONDS WITHIN THE COASTAL LANDSCAPE (T3B,S2)

South Carolina has one of the most rapid coastal population growth and urbanization rates in the nation. As a consequence of development, elevated stormwater runoff has increased the transport and volume of non-point source nutrient inputs, especially nitrogen (N) and phosphorous (P), into watersheds and surface waters. To mitigate runoff, stormwater ponds are constructed as a best management practice (BMP) to reduce coastal flooding and offset impervious surface cover. Stormwater ponds also act as buffers between urban areas, residential/golf course communities, and surrounding water bodies. Given the number of South Carolina managers and researchers engaged in stormwater pond activities, combined with coastal growth, there is a need for a broad synthesis of current pond knowledge. A comprehensive 'State-of-the-Knowledge' Report is available. However, since that report was written, advances have been made in our understanding of stormwater pond function. As part of a Stormwater Pond Collaborative headed by the SC Sea Grant Consortium, an updated 'State-of-the-Knowledge' Report is being developed. This presentation reviews our current understanding of how stormwater ponds act as ecosystems and their ecological relationships within the coastal landscape. This chapter included peer-reviewed literature, technical reports, student theses, conference presentations, and websites. There were five categories of findings. First, the physics and biogeochemistry of stormwater ponds are far more complex than initially suspected. Despite a general tendency for ponds to be nutrient-enriched, the mechanisms by which macronutrients (N, P) are taken up and cycled by microbes and phytoplankton, regulate community composition, and algal bloom formation, remain elusive as do the role(s) of micronutrients (e.g., trace metals, vitamins) and capacity for pathogens to proliferate. Second, the ecological role(s) of various vegetation categories (herbaceous, emergent, floating) for providing essential functions (habitat, shading, nutrient cycling, etc.) are unclear because botanical efforts have largely focused on shoreline/erosion management and/or mitigating invasive species. Third, virtually nothing is understood about food web processes, particularly the functioning of higher trophic tiers (zooplankton, insects, invertebrates, fish, birds, other vertebrates). This includes ponds serving as habitats or facilitating population growth of invasive and/or parasitic species. Combined, these represent significant gaps in our understanding of stormwater pond ecological function. Fourth, aside from the most recent inventory, little is understood about how the landscape shapes ecological processes within and among ponds. This is important given continued pond construction across the coastal zone. Finally, virtually nothing is known about how future climate,

acidification, precipitation, and sea level rise scenarios will impact the stormwater pond ecological function, representing a significant gap in both our understanding of ponds and capacity to prepare for predicted conditions. Recommendations for future directions included increasing emphases on nutrient and microbial/algal processes; integration of genomics and molecular tool development to understand processes, toxins/exogenous compounds, and populations; research on native and non-native vegetation; elucidating trophic, pathogenic, and parasitic interactions. Research focusing on how nutrient enrichment, climate change, and sea level rise, will affect stormwater pond ecology and overall functioning across a changing coastal landscape is also urgently needed.

Harder, Scott, Joseph A. Gellici, Andrew Wachob, C. Alex Pellett
SC Department of Natural Resources
SOUTH CAROLINA STATE WATER PLAN UPDATE (T1,S1)
Economic development, environmental protection and public health are critical quality of life issues that depend on a reliable supply of water. Increased water demand and climate variability (drought) are two major factors that have the potential to limit future water availability in the state of South Carolina. The development of a comprehensive water-resources management plan for the state is vital for ensuring that an adequate and reliable supply of water will be available to sustain all future uses. The South Carolina Department of Natural Resources (DNR) is tasked with developing water planning and policy initiatives in the State and has initiated a long-term process to update the State Water Plan, last published in 2004. This long-term process comprises five steps or stages that include the development of 1.) surface water availability assessments, 2.) groundwater availability assessments, 3.) water-demand forecasts, 4.) regional water plans, and 5.) the state water plan. In August 2014, the DNR and the South Carolina Department of Health and Environmental Control (DHEC) awarded a contract to CDM Smith, Inc. to develop surface water availability assessments for each of the eight major river basins in South Carolina. Assessments will be used to determine surface-water availability in each basin, predict where and when water shortages might occur, test alternative water-management strategies, and evaluate interbasin transfers and withdrawal permits. The surface-water assessments are scheduled to be completed by the fall of 2016. In February 2016, the DNR and the US Geological Survey entered into an agreement to do an assessment of the groundwater resources and an update to the South Carolina Coastal Plain groundwater flow model. The purpose of the assessment is to determine groundwater availability of each major aquifer and to assess the effects that future water use and climate variability have on groundwater. The assessment and model are scheduled to be completed by the spring of 2018. The DNR and the US Corps of Engineers (Charleston District) are currently (April 2016) in discussions to initiate a collaborative project to develop a water-demand forecasting methodology suitable for use throughout the state. Water demands will be forecasted for the municipal, industrial, agricultural, and energy sectors over a 50-year planning horizon. Upon completion of the assessments and forecasts, basin advisory councils will be established for each of the eight major river basins. Councils will be composed of a diverse group of stakeholders and, with oversight from the DNR and DHEC, will be responsible for developing regional water plans to address future water availability issues specific to each basin. The surface and groundwater assessments will be tools available to the councils to test alternative management strategies. Upon completion of the regional plans, the DNR will update the state water plan based on an appraisal of the regional plans. The state water plan will focus on water-resource policy and program recommendations.

Hardesty Norris, Jessica
Biohabitats
+USING GREEN INFRASTRUCTURE TO MEET ENVIRONMENTAL AND SOCIAL EQUITY GOALS IN CHARLESTON
In the wake of a daytime shooting that left one young man dead in the middle of peewee football practice, leaders on James Island, a sea island community that is today rapidly becoming a built-out suburb of Charleston, are coming together to re-vision one of its historic parks. Originally focused on recreational programming and better lights and security, the Thomas Johnson Park Committee is now focused on bringing stormwater retention and biofiltration in as a strong element of the park redesign. The committee's preliminary outreach to the regulatory agencies involved has become a crash course in how anachronistic regulatory processes can slow innovation and early adoption of novel stormwater approaches. This poster presents the engineering opportunities, preliminary concepts, and regulatory hurdles that are facing the Thomas Johnson Park project. It also highlights the visionary leadership from within the historically black church and neighborhood association that is bringing together municipal divisions in a collaboration that has the potential to lower barriers to stormwater innovation and partnership in the long term.

Harrison, Sayward, Xiaoming Li, Yao Zhang, & Molly Beman
University of South Carolina
BUILDING DISASTER-RESILIENT COMMUNITIES: STAKEHOLDER PERSPECTIVES ON RISK, RESPONSE, AND RECOVERY FOLLOWING THE 2015 SC FLOODS (T1,S4)
The catastrophic 2015 flooding of South Carolina yielded loss of life and property in a region already rife with many economic, health, and educational disparities. Yet the community response to the disaster was overwhelmingly positive, and examples soon emerged that highlighted the capacity of local residents to respond quickly to changing events and to develop support systems to aid in the lengthy flood recovery process. Thus the event provides a unique opportunity to examine the concept of "community resilience" in the face of natural disaster. Community resilience can broadly be defined as the sustained ability of a community to withstand, respond

to, and recover from adversity. There is general consensus that creating resilient communities requires engaging stakeholders at multiple levels, including individual residents, community leaders, non-profit organizations, and local government. Collaboration and information sharing across such diverse groups may help communities to prepare for and respond effectively when disaster strikes. This presentation will share results of a study that sought to identify resilience characteristics that enabled the community of Columbia, South Carolina to respond to immediate and long-term challenges of the 2015 flooding. In-depth, semi-structured interviews were conducted with 35 key community stakeholders who were directly impacted by the flooding, including residents, government officials, community leaders, first responders, and journalists. Community stakeholders discussed their perceptions of flood risk and flood preparation prior to the event. Stakeholders next recounted direct experiences with the flooding and identified protective factors that were helpful in immediate flood rescue and response. Finally, stakeholders provided information about long-term recovery efforts. Qualitative analysis was used to identify common themes and characteristics that stakeholders identified as critical for effective response and recovery. Important community resilience characteristics included community "connectedness", pre-existing community partnerships, effective inter-organization communication, and shared hope for the future. Stakeholders also identified challenges to resiliency including a lack of awareness of flood risk and poor understanding of local infrastructure and geography. Such barriers limited the capacity of some residents to respond quickly and effectively to the flooding threat. Implications for policy as well as disaster response and management systems will be discussed. Findings also highlight the need for public education efforts to inform communities of flood risk and prepare in advance for future disasters.

Hawkins, Gary, Laura W. Goss
University of Georgia

+EDUCATING THE PUBLIC FROM K-12 TO ADULTS ON THE IMPORTANCE OF WATER RESOURCE MANAGEMENT USING HANDS-ON ACTIVITIES

Water resource education occurs at many different levels. This ranges from K-12 education to teachers to adults. At the University of Georgia (UGA), the authors have been working for years to educate the public on water issues ranging from the water cycle to soil erosion and deposition to improving soils for water resource management. The water cycle is one of the standards at the elementary school level. The authors have use an 8X10 foot display of the water cycle to teach students the different phases of the cycle, how they interact and how they are connected. Not only are the different parts of the cycle explained, but the facilitators also play a game with the students to help them better connect everyday items with the water cycle. In the middle school, soil erosion and deposition is an important standard. The authors have developed and presented a complimentary presentation with some examples and slides to the 6th grade students to help reinforce what the teachers were teaching. To better provide the teachers with water resource materials and ideas, the authors have worked with the regional educational service agency (RESA) to conduct water resource trainings which includes hands-on activities to provide the teachers with activities they can use to help the students better understand water resource concepts as well as contribute to their STEAM courses. Adult education consist of water festivals where the authors have used hands-on activities to explain the causes and effects of pollution on water resources. Rainfall simulators have been used at farmer based meetings to show and explain the effects of cover crops and groundcover on the reduction of erosion and water infiltration. On this poster you can see some of the different ways we use at UGA to connect people from students to adults with water resources.

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+DEVELOPMENT OF ONLINE TOOLS FOR ORNAMENTAL CONTAINER NURSERY WATER CONSERVATION, REMEDIATION, AND REUSE

Ornamental container production is a multi-billion dollar industry in South Carolina. Nursery water needs and availability can be highly variable, whether seasonally in terms of microclimatic conditions and crop production requirements, or potentially more serious issues concerning longer term drought and flood scenarios that may persist. In the interest of grower success in terms of high quality plants and high production yield, efficient water resource management is critical. Irrigation water use issues can arise from both water quantity and quality standpoints - water quantity problems may include (1) lack of available water for irrigation, (2) lack of pond storage capacity, (3) increased runoff from production areas, and (4) unreliable connectivity to surface versus groundwater sources. Potential water quality issues include (1) sediment from runoff to ponds, (2) high nutrient and/or pesticide leaching, and (3) plant pathogen distribution and infestation. A movement toward nursery water remediation and reuse is one strategy for conservation; the challenge is that recycled water may be susceptible to plant pathogens and thus promote infestation. Various remediation technologies - including floating treatment wetlands and vegetative buffers - have been and continue to be under investigation. Decision support systems (DSSs) for growers are being developed at varying system scales, including the individual container scale (soil moisture dynamics and chemical breakthrough curves), the management unit or field scale (irrigation efficiency, surface water runoff, treatment technologies, etc.), and system-wide scales (irrigation water disinfection, water budgets for production areas and ponds, etc.). This presentation will focus on tool development methodologies and outreach applications for growers.

Hitchcock, Daniel
Clemson University Baruch Institute
STORMWATER DECISION-MAKING IN COASTAL SOUTH CAROLINA: IS SCIENCE INFORMING REGULATIONS? (T3A,S2)
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. 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 summarizes 10 years of research dedicated to the assessment of ecohydrological criteria 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 first-order watersheds with low gradient topography and shallow groundwater are being refined with the goal of defining pre-development conditions. Research efforts also have focused on the seasonal influence of evapotranspiration on water table elevation as it drives highly variable watershed discharges throughout the year. 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. Results have implications for watershed planning and site engineering, including stormwater management and design. These results also have implications to guide the prioritization of conservation and restoration efforts. With a better understanding of these ecohydrological relationships through quantification of these complex processes, improved coastal water resource management may be achieved to protect from flooding, water quality impairment, and the degradation of ecological health of downstream receiving waters.

Holbrook, Kendall Flint[1], W.E. Spearman[2], J.W. Parris[3], J.C. Hayes[4]
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REGULATIONS OF STORMWATER IN SOUTH CAROLINA, HISTORY AND DEVELOPMENT OVER 45 YEARS (T3,S5)
Did you know that South Carolina began regulating Stormwater Erosion and Sediment Control more than 40 years ago, 45 to be exact! 2016 marks the 45th anniversary of the enactment of the County Sediment Control Act (48-13-10) and the 25th year since the passage by the SC General Assembly of the SC Stormwater Management and Sediment Reduction Act in 1991 (48-14-10). This Act is still the primary regulation for Stormwater and Erosion Control today in South Carolina. It is the reason Storm Water Utilities as funding sources for local Stormwater Programs exist today. It all began through the efforts of the South Carolina Land Resources Commission under the leadership of Executive Director, John W. Parris. It would be nice to say that the evolution from the 1971 County Sediment Control Act to the 1991 Stormwater Management and Sediment Reduction Act was smooth and easy. This paper tracks the trials and tribulations along the way for the evolution from 1971 to 1991 and beyond. There has been much progress in the past 50 years related to Stormwater Erosion and Sediment Control Regulation. This paper chronicles the efforts during this time to develop and implement rules at the state level for stormwater, erosion and sediment controls. During the boom in the 1960s and 1970s when many subdivisions began to develop and the country was embracing the suburban lifestyle, little attention was paid to natural stormwater conveyances and control of sediment. As a result, when we entered the 1980s and 1990s, surface water quality and quantity became a concern. Many of those living in homes built in the 1970s were impacted as development increased. Floodplains were encroached upon, and streams filled with sediment. Residents who once had a quiet babbling brook in their backyard saw it suddenly turned into a raging torrent of muddy water flooding their homes during small rain events. This began to heighten public awareness, and the public wanted accountability. Often calls fell on deaf ears at the local level and eventually would be elevated to elected state officials who were also at a loss for answers. Other states had progressed along a similar path but were still in the infancy of regulating stormwater. We worked to glean lessons learned and how to structure requirements such that future generations are protected as we developed and implemented new laws and regulations. This presentation details the history of South Carolina's stormwater regulations from the early 1970s to present day and discusses the importance of the development of the stormwater program in South Carolina and how it may progress forward. We will share many stories and real life experiences that we experienced along the way. We will share many negotiations required to get to compromise. It will be a dynamic exchange of information that will enlighten the younger generation who now live by these rules and ones that have followed.

Hollis, Erika[1], L. Beth Button[2], Jack Turner[2]
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USING VOLUNTEER MONITORING TO IMPROVE WATER QUALITY IN UPSTATE SOUTH CAROLINA (T3A,S1)
The Georgia Adopt-A-Stream (GA AAS) volunteer water quality monitoring program has flowed into the Upstate of South Carolina because of tributaries of teamwork! In the absence of a state operated volunteer monitoring program, a variety of partners have joined efforts to bring GA AAS to Upstate South Carolina. The purpose of AAS is to raise awareness of water quality issues by collecting quality baseline data and observations on the condition of local streams, while creating partnerships with local governments and organizations, and providing volunteers with the tools and training to take action to protect water quality. Volunteers in the GA AAS program are eligible to get trained and certified to collect any or all of the following water quality parameters: visual stream monitoring, chemical monitoring (dissolved oxygen (DO), pH, temperature, and conductivity), bacterial monitoring (*E. coli*), macroinvertebrates monitoring, and amphibian monitoring. Each certification requires a volunteer to attend a free training workshop where they learn the proper USEPA approved protocols for sample collection and data

recording. Once trained, the volunteers are responsible for purchasing their own supplies and equipment for monitoring. All data collected is entered into an online database that is available to the public: (*http://www.georgiaadoptastream.com/db/index.html*). Recently there has been a strong interest to create a similar water quality monitoring program in South Carolina. In 2014, several partners joined forces to strategically expand the GA AAS program into the Upstate region of South Carolina. With approval and support from GA AAS staff, Upstate Forever, Clemson Extension, and USC Upstate Watershed Ecology Center have been leading the efforts to bring the AAS program to South Carolina. Additional financial support and resources have been provided by Clemson University, Anderson University, Southern Wesleyan University, Greenville Technical College, Anderson County Stormwater Department, Pickens County Stormwater Department, City of Greenville Zoo, City of Greenville Stormwater Department, and Lake Conestee Nature Park. Since 2014, Upstate partners have trained approximately 175 volunteers through 15 AAS training workshops. These certified volunteers are now actively monitoring 48 sites across the region. Because we recognize purchasing equipment and supplies can be a substantial financial burden to volunteers, as a typical kit can cost $900, several Upstate partners have received grants to help cover the costs for these supplies. Through this collaborative process partners have provided sampling equipment and supplies to monitor 41 sites in Upstate South Carolina.

Hollowell, Rebeckah, Dr. Calvin Sawyer, Jeremy Pike, Dr. Charles Privette
Clemson University

+AN INTEGRATIVE STUDY OF PAST STREAM RESTORATION PROJECTS IN THE UPSTATE OF SOUTH CAROLINA FOR USE IN FUTURE STREAM RESTORATION PROJECTS: PRELIMINARY ANALYSIS AND RESULTS

Development and urbanization have become increasingly prevalent in today's society. This has led to an increase in environmental impacts. Historical land use also has caused major environmental impacts. One way to compensate for environmental impacts is through the use of mitigation, i.e. stream restoration, wetland restoration, enhancement efforts, conservation efforts, or preservation efforts, etc. Stream restoration aims to create a planned management activity that will re-establish natural functions of a stream system prior to any disturbance. Stream restoration activities include, but are not limited to, the building of in-stream structures for channel stability, implementing natural stream patterns, providing accessible floodplains for storm-water, and establishing natural stream-side vegetation. A limitation to stream restoration is monetarily inclined causing only a small portion of a stream to be restored. This results in other sections of the stream being left unrestored and could lead to possible issues of in-sizing and the restorative process being unsuccessful. Stream degradation due to agricultural land use in the past, an increase in channelization, and dredging with the removal of streamside or riparian vegetation is present in South Carolina streams today. This results in incisement of streams, bank instability, diminished water quality, and increased sedimentation in stream channels. There has also been a lack of post-construction monitoring of stream restoration projects in order to access successful restoration. The proposed research located in the upstate of South Carolina will provide the academic, regulatory, and design community with a local dataset that identifies and quantifies stream restoration projects from roughly fourteen years and three years of completion for vast variables associated with each project. The proposed research will study these two past restoration projects for various criteria and apply knowledge from each to future restoration projects.

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ADAPTIVE WATER RESOURCE MANAGEMENT FOR PROBLEM ALGAE (T6,S6)

The Anderson Regional Joint Water System (ARJWS) has experienced intermittent taste and odor problems in raw and finished water from the treatment plant on the Six and Twenty Creek arm of Hartwell Lake, Anderson, South Carolina, making it difficult or impossible to provide the quality drinking water (odor-free) that customers expect. An adaptive management strategy was implemented that began with identifying the source of taste and odor problems as terpene alcohols [2-methylisoboneol (MIB) and geosmin] produced by benthic algae (e.g. blue-green algae and diatoms). With MIB concentrations reaching over 2,000 parts per trillion in Hartwell Lake in the summer of 2014, an immediate algaecide application plan was developed based on results from a laboratory study of responses of taste-and-odor producing algae to candidate algaecides. A peroxide formulation algaecide and a chelated copper formulation algaecide (both registered for application to drinking water by the US EPA) were applied to the bottom two feet of the water column. Approximately 160 acres of the Hartwell Lake littoral zone (from the water line to the 25' depth contour) and 4 acres around the ARJWS water intake structure were treated. Pre- and post-treatment concentrations of copper were measured in water near the intake and in the areas of algaecide application. By seven days after treatment, total copper concentrations returned to background concentrations (20.6 µg Cu/L) at the water intake. The peroxide-based algaecide, was applied to 4 acres around the water intake structure. The degradation products of this algaecide when applied to water are oxygen and water. Prior to treatment, hydrogen peroxide was not detected in the treatment area. Fourteen hours after application, hydrogen peroxide concentrations ranged from 2.7 to 3.7 mg/L and by three days after treatment, hydrogen peroxide was not detected. MIB and geosmin concentrations declined significantly in the raw water after the algaecide applications. Pre-treatment MIB concentrations ranged from 102 to 106 ng/L, and declined to 14 ng/L twelve days after treatment. Geosmin decreased from 14 ng/L prior to treatment to 5 ng/L twelve days after treatment. To refine plans for future algaecide applications (e.g., 2015), results were

supplemented with a regimen of toxicity tests of water and sediments using sensitive, sentinel fish and invertebrate species to establish margins of safety for non-target species potentially exposed to algaecides. In addition, a hydrological study of the watershed above the ARJWS intake structure was conducted to help identify specific taste and odor source areas and hydraulic time of travel. A refined management strategy was implemented beginning in May 2015, targeting specific areas of the lake with prescribed algaecide applications. Since initiating 2015 algaecide applications, taste and odor has been controlled in ARJWS source water while protecting valued Hartwell Lake aquatic resources.

Hughes, William
US Geological Survey

+WATERSHED MODELING AND DEVELOPMENT OF ECOLOGICAL FLOWS IN THE APALACHICOLA-CHATTAHOOCHEE-FLINT RIVER BASIN, ALABAMA, FLORIDA, AND GEORGIA

Over the last 50 years, the Apalachicola-Chattahoochee-Flint (ACF) Basin in Alabama, Florida, and Georgia has undergone extensive development of water resources for municipal and industrial supplies, power generation, and agriculture. Concurrent with this development, there has been increasing conflict over the use of water in the ACF system, resulting in legal battles over the rights to this valuable resource. The US Geological Survey (USGS) is studying the ACF basin as part of the Department of Interior's initiative titled "Water: Sustain and Manage America's Resources for Tomorrow" (WaterSMART) that has provided improved water-availability information and developed new tools to support water management decisions. This federally funded, four-year study has three major components that build on USGS data collection and modeling capabilities: estimating water use, modeling surface and groundwater flow, and modeling ecological flow relations. The water use component developed a site-specific database of water use for the ACF Basin, developed new methods for estimating agricultural withdrawals, and compiled available water-use projections. Calculations of net water use were improved by obtaining information on interbasin transfers, determining septic-tank return flows, and estimating consumptive use by thermoelectric plants. The hydrologic modeling component consists of a surface-water model for the entire ACF Basin using the USGS Precipitation-Runoff Modeling System (PRMS) and a MODFLOW groundwater model for the lower Chattahoochee and Flint River Basins. These models are linked to provide improved simulation of groundwater/surface-water interactions in the lower part of the Basin. The ecological flows component uses multi-state, multi-season ecological models to predict changes in fish and mussel species occupancy based on variations in flow conditions associated with climate change, land-use change, and changes in water withdrawals or discharges.

Hunt, Melody, M. Richard DeVoe, Susan Lovelace, Andrea Sassard
SC Sea Grant Consortium

THE SOUTH CAROLINA STORMWATER PONDS RESEARCH AND MANAGEMENT COLLABORATIVE: DEVELOPING A INTEGRATED AND SUSTAINABLE ECONOMIC AND NATURAL RESOURCE STRATEGY FOR THE CONSTRUCTION, USE, AND MAINTENANCE OF STORMWATER PONDS (T3B,S1)

Stormwater ponds are the most common best management practice (BMP) for controlling runoff from developed areas in coastal South Carolina. Engineered primarily to control the quantity of runoff from developed landscapes, stormwater ponds are becoming more prevalent in coastal communities where rapid development is attempting to meet increasing population demands. Despite their widespread use, many information gaps exist related to their overall effectiveness, long-term functionality, maintenance requirements and costs, and potential impacts on adjacent landscapes. In response to these information needs, the SC Sea Grant Consortium has brought together scientists and resource managers to form the SC Stormwater Pond Research and Management Collaborative (Collaborative). Created in 2014, the Collaborative is attempting to 1.) satisfy the information needs and concerns of existing local communities, homeowners' associations (HOAs), businesses, and industries surrounding stormwater pond design, ecology, use, efficiency, effectiveness, and management, 2.) characterize coastal stormwater ponds to understand their functionality, durability, benefits, and costs, and 3.) ultimately develop new and innovative practices to ensure that current and future stormwater ponds function without concerns about possible ecological impacts or additional economic costs associated with their management, use, and maintenance. A key aspect of this effort is to work with stormwater constituencies to both understand information needs and provide relevant science-based information. To guide the activities of the Collaborative, and help engage the stormwater community, the Consortium has created a Stormwater Pond Advisory Council to provide advice and guidance. This group is comprised of diverse interests including: stormwater managers and consultants, stormwater pond practitioners, realtors, government officials, scientists, and outreach specialists. Scientists and staff from Consortium member institutions have been engaged to help identify further research and stakeholder information needs which can be used to improve overall understanding, design, management and maintenance of stormwater ponds. The Consortium received initial funding from the State of South Carolina and the NOAA National Sea Grant College Program to generate three products: 1.) an inventory and classification of existing stormwater ponds in the eight coastal counties of South Carolina; 2.) a State of the Knowledge Report, which synthesizes current knowledge regarding stormwater ponds within coastal South Carolina and; 3.) a strategy for public awareness and outreach messaging. These products are currently being completed and analyzed to identify and prioritize key needs and applied to information and management requests. The completed products are also being used to prepare a major stormwater pond research and management prospectus for

use in securing additional funding support to address the many data and information gaps we have regarding these prominent features of South Carolina's coastal landscape.

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USING SIMULATION-BASED OPTIMIZATION TO GUIDE ALLOCATIONS OF SURFACE AND GROUND WATER RESOURCES FOR AGRICULTURAL WATER USE (T2,S2)

Simulation-based optimization has been used in multiple contexts to evaluate water resource problems, including well field design, evaluation of groundwater supply and hydraulic capture, and irrigation management strategies. In this talk, we discuss the use of simulation-based optimization to guide agricultural management decisions in the face of limited availability of water. As surface water remains the primary water source in South Carolina, we consider both surface water routing and water stored in groundwater aquifer as water sources in our model. We describe our strategy for obtaining feasible solutions that potentially satisfy the often competing objectives of regional stakeholders. Our algorithm uses the One Water Hydraulic Model extension to the MODFLOW groundwater software package (MF-OWHM) as the simulation tool and several different optimization strategies to evaluate outcomes for a variety of objective functions. We discuss numerical results for a model farm and provide possible extensions of this work to consider new economically and environmentally defined objectives.

Johnson, Anne Marie, Cindy Lacy
SC Department of Health and Environmental Control

UTILIZATION OF THE SC WATERSHED ATLAS FOR WATER RESOURCE PLANNING AND MANAGEMENT (T1,S5)

Early in 2016, the South Carolina Department of Health and Environmental Control (SCDHEC) made public the SC Watershed Atlas, a GIS-based web application that brings the agency's comprehensive and extensive watershed and water quality information into a user-friendly, searchable, statewide map application. The application includes more than 90 data layers, including: watershed descriptions, SCDHEC's Bureau of Water permits, advisories, public water supply, water quality monitoring stations, water quality assessments, use support status, water classifications, watershed boundaries (10- and 12- digit HUCs), National Wetland Inventory, floodplains, county parcels, ecoregions, National Land Cover Dataset, Municipal Separate Storm Sewers and TMDLs. Layer popups provide additional information. A selection of basemaps, measuring tools, map making and printing capabilities, search choices, Google 360 StreetView and a help section are included in the Atlas. The Atlas was developed by the agency's GIS department for the watershed management program. The purpose for development was to replace the Watershed Water Quality Assessment documents and to improve access to timely watershed data and information. The Assessments, a key component of the agency's water quality management strategy, were published for each of the state's eight major river basins on a rotating five-year cycle. These were used by watershed stakeholders, local, state and federal government, water resource professionals, policy makers, academia and concerned citizens. The Assessments provided users with water quality information that included trend data, use support status and permitting activities for each watershed. With the creation of the Atlas, this spatial information is now updated as it becomes available. Water quality assessments and trends, however, are updated every two years in concurrence with the 303(d) list. By bringing together current information from various Water programs, users now have easy access to the same information the agency utilizes in water resource management strategies and processes. Fortuitously, this unique resource was available to staff just prior to the October 2015 historic floods. The Atlas proved to be instrumental in providing critical data to the agency. Staff were able to quickly map and view satellite imagery of any permitted dam, provide information and perspective for concerned citizens, and state and federal officials, locate areas of concern downstream of the dams, and contact dam owners. Additionally, the Atlas was used in conjunction with a mobile collector application developed by SCDHEC and utilized by both the US Army Corps of Engineers and agency staff to provide initial evaluations of dam conditions statewide. The SC Watershed Atlas facilitates transparency, collaboration and broader participation in the watershed water quality management process. Some of the uses envisioned for the Atlas and already underway include: to assist stakeholders with water quality concerns and inquiries, guide local planning for water quality protection, aid in the daily regulatory function of government agencies, and provide scientific background and current data for water quality research across the state. The site can be accessed at *www.scdhec.gov/watershed*.

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+DIATOM DIVERSITY IN SAVANNAH RIVER OXBOWS: A PILOT AND EXPLORATORY SURVEY

Currently, 2.5% of the global water is freshwater, of which only 1.2% is surface water. In 2005, United States Geological Survey (USGS) calculated fresh surface water withdrawals for Georgia and South Carolina to be 7,470 and 4,200 million gallons per day respectively (Kenny et al. 2009). According to the United States Army Corps of Engineers (USACE), the Savannah River is a surface water resource that provides potable water to more than 1.5 million people in Savannah, Augusta, Beaufort, Hilton Head, and other municipalities (USACE, 2013). Due to the scarcity and necessity of this resource, it is imperative that the quality of freshwater resources is routinely monitored, measured, and evaluated. From the 1950s-70s, 42 sections of the Savannah River were excised from the main flow by the USACE in order to facilitate commercial navigation. These excised sections, or navigation cutoffs, are believed to function as natural oxbow lakes and

provide unique habitats that can either be lentic or lotic depending on the degree of connectivity with the river. In the Savannah River, navigation cutoffs have been shown to be important to overall riverine fish species diversity and biomass and are preferred locations for recreational fishing (Schmitt and Hornsby, 1985). However, the degree of connectivity can have important impacts on water quality (Williams et al., 2016), which could have an impact on fish populations. Gathering baseline data on these differing cutoff habitats could yield better insight into how the food web in these systems function, the role oxbow systems play in the overall riverine ecosystem, and how USACE river flow management might help support or sustain these systems. Traditional ways of assessing water quality include investigating biological, physical, and chemical parameters. Although, macroinvertabrates have proven sensitive to geomorphological or physical changes in traditional biological monitoring, diatoms may provide a more sensitive biological indicator when examining narrow gradient changes in water chemistry (Feio et al. 2007). This sensitivity is thought to stem from their diverse and ubiquitous nature and relatively short generational longevity (approx. one day for some species). Diatoms are also relatively easy to identify to species level as compared to other algal groups. As primary producers, pollutants and disturbances can influence their assemblages, which can impact aquatic food webs. Therefore, insight about diatom assemblages could yield a better understanding to overall ecosystem health and water quality than other biological indicators. This pilot study aimed to gather baseline data on diatom assemblages and diversity in four navigation cutoffs along the Savannah River (Miller Lake, Conyers lake, Whirligig, and Possum Eddy). Two had a surface water connection to the river (Miller and Whirligig) and were considered lotic; and two were considered disconnected from the river (Conyers and Possum Eddy) and were therefore lentic. Sampling cutoffs under both regimes allowed us to investigate possible differences in taxa due to connectivity. This exploratory pilot study aimed to: 1) Identify species that were present at each site; 2) Create a picture key or guide of the species found at each site; 3) Answer the question: Are sites with similar regimes (lentic or lotic) similar in diatom taxa? 4) Provide evidence for the importance of the continuation of this project for long term monitoring (quarterly), which will allow a more precise analysis of diatom diversity along the Savannah River.

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STORMWATER INFRASTRUCTURE AND CHANNEL INTEGRITY: HOW TO ASSESS TRIBUTARIES IN THE WATERSHED OF AUGUSTA-RICHMOND COUNTY AND OTHER URBAN AREAS (T3,S6)

Urbanization in the city of Augusta has resulted in an increase in impervious surfaces, which can negatively affect recharge zones with an increase of transported pollutants (i.e., runoff), flooding events, sedimentation, and erosion. These impacts can decrease aquifer recharge and evapotranspiration and affect the quality of surface waters. Augusta-Richmond County depends on both types of water resources for potable water, irrigation, and production. Spirit Creek, Rocky Creek, Butler Creek, Rae's Creek, Little Spirit Creek, and McBean Creek are major tributaries that form Richmond County's watershed and are also located in the recharge area for the Cretaceous aquifer. Given the importance of the amount and quality of these resources, continued watershed assessments are imperative. In the 2000-2001 water quality assessments, the Georgia Environmental Protection Division GAEPD found both Rocky Creek and Butler Creek impaired and reported Rocky Creek for fecal coliform bacteria and toxicity. In 2014, the GAEPD listed Butler Creek, Rae's Creek, Spirit Creek, and Rocky Creek in the 305(b)/303(d) integrated report for violating water quality criteria for supporting designated uses. On this list however, Rocky Creek was found impacted for fish and macroinvertebrate communities, as well as fecal coliform bacteria. The GAEPD reported probable sources for these impairments as urban related runoff and nonpoint sources such as sedimentation. As a result of these and other studies, a TMDL Implementation Plan was recommended for continued monitoring. The city of Augusta has also made various efforts to protect these resources through ordinances, regulations, and community programs (e.g., Groundwater Recharge Area Protection Ordinance, Soil Erosion and Sediment Control Ordinance, Stormwater Management Ordinance, Flood and Damage Prevention Ordinance, Community Greenspace Program). Although some TMDLs address erosion issues as well as pollutants in water bodies, they may not account for geomorphic responses from current stormwater infrastructure and/or regime alterations for management purposes. Insight about existing conditions could facilitate mitigation of negative impacts from impervious surfaces. Therefore, the Phinizy Center for Water Sciences, in conjunction with the Augusta-Richmond County Engineering Department, is developing and piloting a protocol for visually assessing urban streams by identifying stressors responsible for geomorphic effects and rating channel responses by accounting for stormwater infrastructure and areas prone to flooding, sedimentation, erosion. We hope that these efforts prove useful for follow-up assessments by providing a rating standard for streams that are already under altered hydrological regimes. The following details the visual stream assessment protocol we have piloted for Rocky Creek. This assessment was conducted over 41 transects covering 7.5 miles. Information such as, presence, location, type and size of structures (e.g., stormwater outfalls, sewage pipes, pumps, dams, and septic tanks) was gathered and criteria such as channel condition (degradation), bank stability (widening), buffer zones (area type and density of surrounding vegetation), sedimentation and erosion (deposition and aggradation), water appearance and odor, and dominant bed material were rated qualitatively and recorded. Given these criteria can be modified for site-specific influences, we think this approach will be helpful to policy makers and practitioners in other urban areas by pinpointing and prioritizing areas of concern and standardizing qualitative methods.

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MANAGEMENT DECISION IMPLICATIONS RESULTING FROM ANALYSIS OF STORMWATER BEST MANAGEMENT PRACTICE EFFICACY ACROSS TEMPORAL AND VARYING SPATIAL SCALES (T3,S4)

As a result of rising fecal coliform levels, the SC Department of Health and Environmental Control (SCDHEC) issued a shellfish harvesting classification downgrade in the headwaters of the May River, Bluffton, South Carolina. In response to the closure, the Town of Bluffton (Town) formally partnered with the University of South Carolina-Beaufort (USCB) to establish a water quality laboratory and robust weekly, grab sample program. The purpose of the program was to identify key areas with potential to improve water quality in the May River via stormwater Best Management Practices (BMPs) and to evaluate the efficacy of these BMPs within the context of the watershed. Based upon the results of the sampling program, a relatively small, undeveloped, upland drainage was identified as a potential source of fecal coliform entering the river. With support from 319 grant funds awarded by SCDHEC and a land donation from New Riverside LLC, the Town constructed a 1.25 acre pond to treat drainage from a 300 acre wooded, sub-basin in the headwaters of the May River. Completed in the summer of 2013, the Town and USCB have continued post-construction monitoring to quantify the bacterial removal efficiency of the pond and its downstream impact. Enough data have been collected to evaluate not only the efficacy of the pond to reduce fecal coliform concentrations, but to also assess the impact of the pond downstream. There is statistically significant evidence ($p = 0.000002$) that the mean fecal coliform concentration of the influent (3,567 CFU/100 mL) is greater than that of the effluent (653 CFU/100 mL). Additionally, there is statistically significant evidence ($p = 0.0064$) that at a sampling location approximately 600 feet downstream there was a higher mean fecal coliform concentration pre-pond construction (2,624 CFU/100 mL) than post-pond construction (1,558 CFU/100 mL). However, this statistically significant reduction is lost at the next sampling location approximately 1,400 feet downstream and near the confluence with May River ($p = 0.0954$; pre-pond concentration = 2,406 CFU/100 mL and post-pond concentration = 1,863 CFU/100 mL). Such information has management decision implications at multiple levels. For instance, BMP site selection is clearly important, as an otherwise effective BMP constructed in the wrong location may not have the intended impact on a receiving waterbody. From a design standard level, perhaps a series of BMPs installed across a larger spatial scale would be superior to an isolated one at maintaining or improving water quality downstream. Lastly, data on BMP efficacy may also challenge the dependence on modeled pollutant removal efficiencies to safeguard water quality and emphasize the importance of empirical validation whenever possible.

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ASSESSMENT OF STREAM QUALITY IN THE PIEDMONT AND APPALACHIAN MOUNTAIN AREA OF THE SOUTHEASTERN UNITED STATES (T2,S2)

During the spring and summer of 2014, the US Geological Survey (USGS) National Water-Quality Assessment Program (NAWQA) assessed stream quality across the Piedmont and southern Appalachian Mountain region in the southeastern United States. The goal of the Southeast Stream Quality Assessment (SESQA) is to characterize multiple water-quality factors that are stressors to aquatic life - contaminants, nutrients, sediment, and streamflow alteration - and the relation of these stressors to ecological conditions in streams throughout the region. Two important anthropogenic factors affecting water quality in the region are urbanization and streamflow alteration; therefore, these factors were targeted in the assessment. Findings from the assessment will provide communities and policymakers with information about which human and environmental factors are the most critical in controlling stream quality, and, thus, provide insight about possible approaches to protect and improve stream quality. The targeted design of the assessment used streamflow and land-use data to identify and select sites that reflected a range in the amount of urbanization and streamflow alteration. One hundred fifteen sites were selected and sampled across the region for as many as 10 weeks during April, May, and June 2014 for contaminants, nutrients, and sediment. This water-quality "index" period culminated with an ecological survey of habitat, periphyton, benthic macroinvertebrates, and fish at all sites. Sediment was collected during the ecological survey for analysis of sediment chemistry and toxicity testing. Fifty-nine sites were on streams in watersheds with varying degrees of urban land use, 5 were on streams with numerous confined feeding operations (CAFOs), and 13 were reference sites with little or no development in their watersheds. The remaining 38 "hydro" sites were on streams in watersheds with relatively little agricultural or urban development but with hydrologic alteration, such as a dam or reservoir. This presentation will provide a detailed description of and preliminary findings from the specific study components of the SESQA that included surveys of ecological conditions, routine water sampling, deployment of passive polar organic compound integrative samplers (POCIS) of pesticides and contaminants of emerging concern, and synoptic sediment sampling and toxicity testing at all urban, CAFO, and reference sites.

Kaemmerlen, Betsy, Maren Frisell, Dean Audet, Sean Arruda
Fuss & O'Neill, Inc.

AN INNOVATIVE APPROACH TO STORM DRAINAGE: THE SHANDON GREEN INFRASTRUCTURE PROJECT (T3A,S2)

The Shandon neighborhood in Columbia, South Carolina is a fully built out, 700-acre residential neighborhood that experiences severe flooding due to an undersized storm drain network. Five of the neighborhoods main roadway intersections routinely flood several times per

year. Even during moderate storm events, several feet of water accumulates on these neighborhood roads and in homeowners' lawns, resulting in impassible and unsafe conditions. In 2011 a plan was developed that involved installing conventional drainage improvements (larger pipes) to address the flooding issues in the Shandon neighborhood. However, due to the high cost estimates and potential for conveying the flooding issues downstream, the City investigated alternative options for the neighborhood. In 2012, an alternative plan was developed for the neighborhood which evaluated several types of green infrastructure controls including, but not limited to, porous pavement, subsurface infiltration, infiltrating catch basins, dry wells, and bioretention basins. Based on a hydraulic and hydrologic study of the watershed and existing site constraints, it was recommended that an innovative combination of porous pavement, subsurface infiltration and bioretention be used in the neighborhood to most effectively and efficiently manage stormwater. The proposed plan included replacing existing pavement in the parking lanes on each side of the street with porous pavement, installing modular storage infiltration systems under the parking lanes, and installing bumpouts with bioretention basins at the ends of each street, which also helps serve as a traffic calming mechanism. Due to the severity of flooding issues experienced in this neighborhood, a proposed plan using a combination of green infrastructure controls was determined to be the most cost-effective alternative capable of meeting the capacity requirements to manage the design storm flows given the other project constraints. Based on the demonstrated benefits of green infrastructure over the conventional drainage system, the City decided to proceed with design and construction of the proposed green infrastructure improvements for four streets as a pilot project within the neighborhood. Final designs and construction documents were completed for the pilot project in 2013 and construction of the improvements of two streets at one of the intersections was completed in the summer of 2015. This project had several challenging site constraints including utility main and lateral locations, steep onsite slopes, and existing trees and other structures to remain, that required innovative design approaches. The engineers worked with the City, utility owners, and modular storage product manufacturers to develop a manufacturer-guaranteed design for an application that had never been implemented before. Today, the intersection where the improvements were made has not experienced the flooding issues that it once did. During storms, which, in previous years, would have resulted in ponding of feet of water, there is little gutter flow along the streets, and the water is directly infiltrating through the porous pavement and infiltration chambers. Additional phases of this project shall utilize the excellent infiltration rates of the soil to eventually solve the neighborhood's flooding issues.

Kimura, Susana Y., Amy A. Cuthbertson, Susan D. Richardson
University of South Carolina

+IDENTIFICATION AND QUANTIFICATION OF PRIORITY DISINFECTION BY-PRODUCTS IN SOUTH CAROLINA USING HIGH RESOLUTION MASS SPECTROMETRY

Disinfectants used to control microorganisms in water treatment processes can also react with naturally occurring organic matter, bromide and iodide in source waters that are then incorporated to form brominated and iodinated disinfection by-products (DBPs). Occurrence studies have shown that waters with higher levels of bromide and iodide shift the DBP speciation from chlorinated to more brominated and iodinated DBPs, increasing the toxicity of the water. Because of the complex nature of DBPs, their stability in water samples, the availability of analytical standards, and the extensive number of individual DBPs identified, occurrence studies are usually limited to a small subset of DBPs. The objectives of this study are to comprehensively evaluate water treatment processes and their influence on DBP speciation by simultaneously 1) quantifying haloacetonitriles, halonitromethanes, haloketones, haloacetaldehydes, and iodomethanes and 2) accurately identifying unknown DBPs with one single analytical method. Samples were extracted with liquid-liquid extraction (LLE) and analyzed using gas chromatography with a multi-mode inlet (MMI) and high resolution time-of-flight mass spectrometry (GC-TOF-MS). The MMI provides an increase in sensitivity and stability for analytes that decompose at high injection port temperatures and the TOF-mass spectrometer has a resolution up to 50,000, which allows for the identification of unknown priority DBPs.

Lackstrom, Kirsten, Gregory J. Carbone, Daniel L. Tufford, Aashka Patel
Carolinas Integrated Sciences & Assessments (CISA), University of South Carolina

CLIMATE AND WATER RESOURCES IN THE CAROLINAS: APPROACHES TO APPLYING GLOBAL CLIMATE CHANGE INFORMATION TO LOCAL AND REGIONAL QUESTIONS (T5,S4)

A wide range of resource managers, community planners, and other stakeholders are increasingly asking for information regarding how climate change will affect South Carolina's freshwater and coastal resources. They are interested in using this information for decisions related to infrastructure design, water system planning, vulnerability assessments, and ecosystem management. While climate change data and information is also becoming increasingly available, many uncertainties around future climate change and its potential impacts often hinder its application. Furthermore it is often not available in a format or at a scale that is easily translated to local- and regional-resource management decisions. This presentation highlights decision-maker questions about climate change in the Carolinas, approaches to using global climate change information, and opportunities to bridge the gap that often exists between scientific research and applications. Examples and insights are drawn from the Carolinas Integrated Sciences & Assessments (CISA)

program based at the University of South Carolina. CISA conducts applied research to address climate-related topics that are most salient and relevant to policy and management needs in the Carolinas. We have found that climate change questions are often specific and center on, for example, which climate model to use or what impacts to expect. In general, there is no one "best" model that depicts future climate conditions, nor can climate science provide accurate predictions for specific locations and impacts. However, climate change projections can be used in conjunction with a variety of other tools and resources, such as vulnerability assessments and historical climate observations, to inform planning processes. Improved understanding of the system of concern, and the linkages to climate, can help decision makers and researchers alike to develop the most relevant and informative analyses for climate-related questions. Ongoing engagement, as well as a willingness to experiment and share lessons learned, between and across the resource management and science communities, will help to advance the climate change dialogue in the Carolinas and enhance the use of the climate change information.

Lackstrom, Kirsten
Carolinas Integrated Sciences & Assessments (CISA), University of South Carolina

DEVELOPMENT OF A DROUGHT EARLY WARNING SYSTEM FOR THE COASTAL CAROLINAS: SESSION INTRODUCTION (T5B,S5)

The Coastal Carolinas Drought Early Warning System (DEWS) is one of several National Integrated Drought Information (NIDIS) regional DEWS programs in place across the United States. Launched in 2012, the Coastal Carolinas DEWS has focused on 1.) improving understanding of the unique vulnerabilities and impacts of drought on coastal ecosystems and 2.) developing tools, information, and other resources that will help managers and decision makers integrate drought- and coastal-resource management activities. This presentation will, first, provide an overview of progress and accomplishments to date. Priority project areas and goals for the Coastal Carolinas DEWS were developed at a stakeholder scoping workshop in summer 2012. Over fifty individuals from federal and state agencies, community agencies, non-profit organizations, and academia contributed to this initial effort. Since then specific projects have addressed a variety of drought-related needs and topics. Accomplishments include: the development of a citizen science network that provides drought impacts information; the development and refinement of a Coastal Salinity Index (CSI) that uses salinity data to characterize drought conditions in coastal environments; assessments of ecological indicators of coastal drought and their potential use for drought monitoring and management; and the development of a web-based atlas focused on drought and climate variability in the Carolinas. Second, the presentation will introduce plans for ongoing and future activities as articulated in a new Coastal Carolinas DEWS strategic plan. In summer 2016 stakeholders will reconvene to assess progress, refine priorities, and identify next steps for the Coastal Carolinas DEWS. This presentation will highlight major initiatives stemming from the strategic planning process. It will also discuss opportunities for organizations and agencies at state and local levels to participate and engage in ongoing and planned activities.

Ladner, David, Katherine Holtmann, Rawya Al-Dulaimi, Kimberly Bui, Jonathan Degen, Mckenna Dove, Nina Gallimore, Michael Knapp, Alison Markley, Holly Mettlen, Rachel Shugart, Aidan Vatalaro
Clemson University

MAPPING SOUTH CAROLINA DRINKING WATER QUALITY FOR ALIGNMENT WITH HEALTH-RECORD DATABASES IN EPIDEMIOLOGICAL STUDIES (T6,S4)

Many population-scale health considerations depend on the quality of drinking water available to the public. When epidemiologists develop theories about positive and negative health outcomes (such as questions of why some sub-populations have higher life expectancies than others, or why certain diseases affect certain sub-populations) it is useful to know the makeup of the population's drinking water. In South Carolina there is currently no single source of information that can be used to map water quality to geographical locations. This project is the first to pull that information together into a single database. Drinking water providers from around the state were contacted and asked to provide water quality reports from several years (where available) for their utilities. Data included pH, temperature, hardness, alkalinity, and other parameters. They were also asked to provide the geographical information system (GIS) data of their distribution systems to determine the zip codes to which they delivered water; this is critical for aligning water quality data to epidemiological data, since many health databases are organized by zip code. The project is on-going with the goal of completing a state-wide drinking water distribution system map. Collaboration with epidemiologists is occurring to organize the information in the most usable formats.

Lamb, William
Amec Foster Wheeler

KINLEY CREEK WATERSHED STUDY: SOLVING DIFFICULT FLOODING PROBLEMS IN AN URBAN WATERSHED (T3,S5)

Frequent flooding of homes and business in the Kinley Creek Watershed in Lexington County, South Carolina, has been inundating the watershed's residents since the 1970s. Much of the 7-square-mile watershed was developed in the 1960s and 1970s, prior to the implementation of State and Local stormwater management regulations. A combination of increased runoff from urbanization and homes built in the floodplain have resulted in the semi-annual flooding of many homes and businesses. Under the Planning Assistance to the States program, Lexington County, the US Army Corps of Engineers, and Amec Foster Wheeler partnered to study the long-term issues relating to flooding along Kinley Creek, and two of its tributaries, K1 and K2. In August of 2015, just months prior to the October 2015 flood, the study was completed, detailing

specific solutions for dealing with the on-going flooding problems. The study analyzed a variety of alternatives for effectiveness, feasibility, and costs, but comprehensive solutions are complex and expensive. In the wake of the October 2015 flood, solving the problems of the Kinley Creek watershed has become a top priority for the County and its residents. This presentation will discuss the wide variety of flood reduction alternatives analyzed in the study, the logic behind the alternatives analysis, the proposed solutions, and how the shift in public awareness after the October 2015 flood might be the key to implementing a comprehensive solution.

Lamm, Maria, Andrea Bolling
SC Department of Natural Resources, Richland County Floodplain Manager

OCTOBER 2015 FLOODING IMPACTS ON FLOODPLAIN MANAGEMENT AT THE STATE AND LOCAL LEVEL (T5,S2)

The October 2015 flood impacted how floodplain management is viewed and handled in South Carolina. This presentation will go into more detail about the flood event and the direct impact to State and local floodplain management. We will review what information was available to state and local governments prior to the flood event, what the state and local governments roles are pre and post event and lessons learned from the flood event. Also, how the flood event will impact local government decisions regarding recovery. These impacts include flood damage prevention ordinance requirements and enforcement, interpretation of mapping, and preparation. SCDNR Flood Mitigation Program is the State Coordinating office for the National Flood Insurance Program and manage South Carolina's Floodplain mapping program.

Landmeyer, James, Bruce G. Campbell
US Geological Survey

ASSESEMENT OF GROUNDWATER QUALITY OF ATLANTIC COASTAL PLAIN AQUIFERS, AIKEN COUNTY, SOUTH CAROLINA (T2,S1)

Groundwater pumped from the Atlantic Coastal Plain (ACP) aquifers meets most of the potable and irrigation demands for Aiken County, but a comprehensive assessment of groundwater-quality conditions for Aiken County does not exist. This lack of an assessment of groundwater-quality conditions, even basic indicators such as pH, temperature, and dissolved oxygen, precludes County water managers and others from making informed decisions about where to place new wells (e.g., avoid areas where groundwater may contain high iron or radium isotope concentrations), how deep to drill wells, and what depth intervals should be screened to avoid in-well mixing of groundwater of different reduction/oxidation (redox) characteristics. As such, a comprehensive compilation of groundwater-quality data for Aiken County would be useful to water managers that want to minimize costs associated with groundwater treatment or others interested in groundwater quality. In fiscal year 2015 the US Geological Survey (USGS), in cooperation with Aiken County, Breezy Hill Water and Sewer Company, Inc., Gilbert-Summit Rural Water District, and Montmorenci-Couchton Water and Sewer District, started a 3-year project to investigate the availability of the groundwater resources of Aiken County. A major component of the project is to develop a groundwater-flow model of the ACP beneath Aiken County. Because groundwater availability is dependent upon water quality and water-quality characteristics can be useful during model calibration, the study will provide these data in two ways. First, existing water-quality data will be compiled, and second, we will sample multiple public-supply wells across the County for basic physical properties and chemical composition of the groundwater. At select wells, additional water-quality parameters, such as inorganics, radionuclides, and volatile organic compounds, also will be sampled and analyzed.

Landmeyer, James
US Geological Survey

OCCURRENCE OF ELEVATED BROMOFORMS IN DRINKING WATER PRODUCED FROM DEEP PUBLIC-SUPPLY WELLS, WILLIAMSBURG COUNTY, SOUTH CAROLINA (T2,S3)

The occurrence of elevated total trihalomethane (TTHM) concentrations in public-supply wells is not very common. This is because the concentration of disinfection byproduct precursor compounds, such as total organic carbon, is typically much lower in groundwater systems compared to surface-water systems. Therefore, the recent occurrence of concentrations of TTHMs that exceed the maximum contaminant level of 0.080 milligrams per liter in drinking water produced from public-supply wells that tap the deep McQueen Branch aquifer in Williamsburg County, South Carolina, warrant scientific scrutiny. Moreover, the TTHMs detected were dominated by bromoforms rather than chloroforms, adding additional interest regarding the source of the bromide. This talk will discuss preliminary results of groundwater-quality sampling conducted during 2016.

Laymon, Kelsey, Damon L. Mullis, Checo Colón-Gaud, Chalisa Nestell, Jason Moak, and Oscar P. Flite III
Phinizy Center for Water Science

COMPARISON OF BENTHIC MACROINVERTEBRATES COLONIZING THREE TYPES OF PASSIVE SAMPLERS FOR NON-WADEABLE STREAMS (T4,S6)

A comparative analysis of benthic macroinvertebrate assemblages colonizing three types of passive samplers was performed from four sites on the Savannah River. Passive samplers provide an alternative method for assessing macroinvertebrate communities in large streams where traditional sampling techniques may not be feasible or effective. Macroinvertebrate bioassessments are a common method for the evaluation of a waterbody's ability to sustain biological communities. Despite the widespread use of macroinvertebrate bioassessment, a standardized method for sampling non-wadeable streams within Georgia and South Carolina has not been developed. This study was conducted to determine the effectiveness, biases, and ease of use of three types of passive samplers. Three replicates of mesh bags filled with leaves (leaf packs),

mesh bags filled with woody debris (snag bags), and masonite board (Hester-Dendy) passive samplers were deployed during the fall of 2014 at four sites within the Savannah River (N=36). After 30 days, samplers were retrieved and macroinvertebrate assemblages were assessed for differences in: Composition Metrics (%EPT, %Diptera, %Chironomidae), Functional Feeding Group Structure (%gatherer, %filterer, %predator, %scraper-grazer, %shredder), and Tolerance Metrics (%intolerant taxa, %tolerant taxa, Hilsenhoff Biotic Index). Results indicate that there was little difference in the communities collected from each sampler. As a result, all three passive samplers appear to provide efficient means of collecting macroinvertebrates as part of a bioassessment program. However, Hester-Dendy samplers accumulated very little organic debris making sample processing more efficient and had a standard surface area, which allowed for an easy and accurate comparison of benthic macroinvertebrate density.

***Liberatore, Hannah K.**[1], Susan D. Richardson[1], Jeanne M. VanBriesen[2], Michael J. Plewa[3], David B. Burnett[4], Leslie H. Cizmas[4]
[1]University of South Carolina, [2]Carnegie Melon University, [3]University of Illinois Urbana-Champaign, [4]Texas A&M University

+IMPACT OF HYDRAULIC FRACTURING ON DRINKING WATER: DISINFECTION BY-PRODUCTS

Since the energy crisis of the 1970s, the US has struggled to reach energy independence for national and financial security and energy sustainability. Shale oil and gas is seen as a critical component of the solution, and its development is widespread in the US However, bromide and iodide are naturally present in shales, and can be released at high levels and enter drinking water sources under some management practices, causing formation of toxic brominated and iodinated disinfection by-products (DBPs) at downstream drinking water plants. DBPs are linked to adverse health effects, including bladder cancer, miscarriage, and birth defects. While most research focuses on chemicals used in the fracking process, little is known regarding impacts of production-water disposal on drinking water. Hydraulic fracturing (HF) produced waters were subjected to chlorination and chloramination, simulating drinking water treatment. Samples were then acidified and extracted by liquid-liquid extraction with dichloromethane. Gas chromatography with mass spectrometry (GC/MS) was used to identify iodinated and brominated DBPs formed during disinfection. Comprehensive identification of treated samples using high resolution mass spectrometry (HRMS) led to the discovery of a new class of iodinated phenols that have never been reported for any drinking water sample. These include iodophenol, iodomethylphenol (iodocresol), iododimethylphenol (iodoxylenol), diiodophenol, diiodocresol, diiodoxylenol, triiodophenol, triiodocresol, and triiodoxylenol. Several isomers were observed for each. HRMS was critical to their identification, distinguishing between iodocresols and iodobenzoquinones, which are isobars. In fact, one of the iodocresols-diiodocresol-showed a good NIST library match with an electron ionization (EI) mass spectrum of 2,6-diiodobenzoquinone. However, the accurate mass of 359.8503 revealed that the molecular formula of this compound was actually C7H6OI2, and not C6H2O2I2 (m/z = 359.8139) that was indicated by the library match. Without HRAM capability, these compounds would have likely been misidentified. In addition to these new iodinated compounds, bromophenols and bromocresols were also observed. The presence of 2-iodophenol, 4-iodophenol, 4-iodo-2-cresol, and 2,4,6-triiodophenol have been confirmed by retention time matches with authentic standards. Mammalian cytotoxicity and genotoxicity experiments have shown these compounds to be cytotoxic, but not genotoxic. Future work will include simulated drinking water experiments with HF waters diluted with river water to better reflect real-world situations. Retention time confirmation will continue to identify the remaining isomers of iodophenols, iodocresols, and iodoxylenols. Mammalian cell cytotoxicity and genotoxicity experiments will also be used to assess the toxicity of the disinfected and raw HF waters.

Libes, Susan[1], Kelly Hall[1], Albert Taylor[1], Robert Steffens[2], Ken Harth[3], Emma Boyer[4], Christine Ellis[4], Tom Garigen[5],Dave Fuss[5], Tracy Jones[6], John Adair[3]
[1]Coastal Carolina University, [2]Murrells Inlet 2020, [3]Town of Surfside, [4]Winyah Rivers Foundation, [5]Horry County Stormwater, [6]Georgetown County Stormwater

RAPID REPORTING IN LONG-TERM MONITORING PROGRAMS FOR DETECTION OF ILLICIT DISCHARGES BY NPDES SMS4 COMMUNITIES (T3A,S1)

The Clean Water Act's National Pollution Discharge Elimination System (NPDES) Phase II stormwater rule requires that regulated communities develop and maintain illicit discharge detection and elimination (IDDE) programs. This is challenging for small municipalities, aka SMS4's, due to limited budgets and lack of scientifically trained staff. To address this, the eight SMS4's of the Myrtle Beach Urbanized Area have been collaboratively funding since 2006 a suite of long-term water-quality monitoring programs performed biweekly by volunteers and a state-certified university lab (EQL). Rapid reporting to support IDDE is conducted on two timescales: 1.) once an aberrant observation is noted by volunteers, field, or lab analysts, the EQL emails the stormwater managers, and 2.) within 2 to 4 weeks post sampling, the EQL emails a narrative and quantitative "provisional" report. Both rely on the use of site-specific norms established from prior results. In the case of the volunteers, annually updated site-specific norms are provided to enable them to identify unusual (25th or 75th percentile exceedances) or highly unusual (10th or 90th percentile exceedances) results. These statistics are also posted on the web apps that provide public access to the data. The "provisional" reports also consider: 1.) long-term trends, 2.) rain data from NOAA's CoCoRaHS program and from areal estimates using watershed-scale Nexrad imagery, 3.) regulatory water quality criteria and other benchmarks, such as USEPA recommendations, 4.) discharge and water quality data from continuous USGS sensors, 5.) monitoring data collected by state regulators, and 6.) reports from municipal staff and the volunteer program's

field leaders regarding anthropogenic activities, such as land disturbances from construction. The "provisional" report format was developed collaboratively by the EQL, volunteers and stormwater managers. Case studies will be presented to show how this has resulted in identification of illicit discharge sources. The provisional reports are archived in annual spreadsheets and the results synthesized for submission to NPDES Phase II permit regulators. IDDE has increased since implementation of this reporting protocol due to: 1.) tightening of site-specific norms supported by the increasing size of the datasets, and 2.) more effective integrated data analysis arising from increased experience of the group in working together. Another valuable outcome has been detection of infrequent sensor and sampling issues by comparing volunteer data to the certified lab's discrete samples and USGS's continuous measurements. The latter is of particular interest as the volunteer and USGS measurements are not recognized by SCDHEC under their lab certification program and hence have not been acceptable for 305(b) reporting and formulation of 303(d) lists. This is problematic given the temporal and spatial limitations in certified water quality data being collected in South Carolina and the US EPA's recommendations for public engagement through volunteer water quality monitoring as part of SMS4's stormwater management programs.

Mack, Chris
AECOM
EFFECTIVE STRATEGIES FOR COMMUNICATING RISK (T1,S4)
We live in a world today where communication travels immediately and can significantly impact the outcome of a situation, goal, or common interest positively or negatively. People process information differently especially during low-stress or high-stress situations or when they feel they are being supported or threatened. Choice of words, delivery, tone, body language, gestures, competence, memory, and messaging all interact dynamically and can alter the outcome of an intended message especially when the topic involves risk communication. Risk communication matures and is ongoing. This presentation explores research and techniques for effective risk communication with several case studies involving flood plain management.

Majsztrik, John1[1], Daniel Hitchcock[2], David Sample[3], Saurav Kumar[4], Sarah White[1]
[1]Clemson University, [2]Belle W. Baruch Institute of Coastal Ecology and Forest Science, [3]Virginia Polytechnic Institute and State University, Hampton Roads Agricultural Research and Extension Center, [4]University of Texas at El Paso
+WATER TREATMENT TECHNOLOGIES FOR SPECIALTY CROPS
Irrigated specialty crop production can generate 2,000 to 10,000 gallons per acre or more of water runoff per day. Growers are often reluctant to reuse this water due to perceived or real concerns related to pathogen and/or agrichemical transport to another location on-site. If allowed to run off of an operation, these pathogens and chemicals may negatively impact surface and groundwater leading to possible environmental degradation. One way to reduce environmental impacts is through on-site water remediation and recycling. Specialty crop producers desire science-based information regarding cost and efficacy for various water-related treatment technologies, but reliable data are not always available. Researchers funded via a Specialty Crops Research Initiative (SCRI) grant are working with specialty crops growers in the United States to test various treatment technologies and to determine the costs and benefits of their use. Increasing water recycling rates for ornamental production will potentially benefit producers by increasing water quality and quantity, and may also have environmental benefits as well, through the potential reduction of contaminants in surface and groundwater. This poster provides an overview of water treatment technologies, which have the potential to be used for specialty crop production.

Martin, Ronnie
SC Department of Health and Environmental Control
CLEAN WATER ACT IMPLEMENTATION ASSESSMENT: HOW ARE STATES IMPLEMENTING AND ARE THERE OPPORTUNITIES TO IMPROVE EFFICIENCY? (T1,S3)
The Federal Clean Water Act (CWA) of 1972 is the principal law concerning pollution activity in the nation's streams, lakes, and estuaries. Congress enacted the most recent major amendments to the Clean Water Act in 1987. Since then, the Environmental Protection Agency (EPA), states, and others have been working to implement the program changes and additions mandated by the law. At issue today, 30 years after amendment, is the level of progress being made to achieve the goals of the act and whether this progress can be applied across state lines to encourage further advancement toward a common objective. This study determines how the four states of the Governors' South Atlantic Alliance (GSAA), North Carolina, South Carolina, Georgia, and Florida, implement the Clean Water Act by way of state regulation and policy. Through vastly different protocol and procedures, each state has made the Clean Water Act their own. With this ownership comes inevitable levels of efficiency and inefficiency when implementing such a broad regulation. The states perform a balancing act with revenue and growth on one side and water quality and the environment on the other; while Uncle Sam keeps watch close by. Therefore, examining how the states meet (or do not meet) CWA requirements allows certain applications to manifest themselves as more effective at meeting basic goals. The objective of the GSAA Clean Coastal and Ocean Waters (CCOW) technical team, for which this study was organized, is to share water quality improvement processes, especially across state lines and within shared watersheds. This study focuses on the water quality regulations and processes of South Carolina first. From there, evaluation of other GSAA states allows for comparison of water policies across state lines. I compiled data through employee interviews within the South Carolina Department of Health and Environmental Control (SCDHEC) Bureau of Water and outside research among state and local agencies. The data was used to create a catalog of Clean Water Act implementation procedures

within South Carolina. A second catalog was created for the GSAA states that allows for quick referencing of CWA implementation processes. I used the catalogs as the basis for determining what worked best where and how to share that information among state participants.

Martin, Will, Ashok Mishra, and Nigel Kaye
Clemson University

IMPACT OF CLIMATE CHANGE ON SITE RAINFALL-RUNOFF CHARACTERISTICS (T3,S6)

In general, global climate models predict a warmer moister atmosphere and a resulting increase in rainfall. This is particularly true for South Carolina where annual rainfall totals are predicted to increase and extreme rainfall events to become more frequent. As such, there is the possibility that future design rainfall events will occur under wetter conditions than in the past. This, in turn, will lead to less infiltration and greater runoff for a given design storm depth. Continuous rainfall-runoff simulations were conducted using downscaled CMIP-5 rainfall data sets to calculate daily runoff totals for each model and each simulation year dating from 1950-2099. The daily runoff total was calculated using the runoff curve number (RCN) model with the RCN adjusted to account for dry, normal, or wet antecedent moisture conditions. The 132 CMIP-5 data sets were separated based on the model's representative concentration pathway (RCP). For a given RCP each separate model was taken to represent a separate realization of both rainfall and runoff. Statistical analysis of the rainfall and runoff data allowed calculation of the predicted rainfall and runoff depth for a set of standard return periods, which were then used to fit an effective curve number for each simulation year. The results for Clemson showed that, while the number of days per year for which the antecedent moisture condition was wet increased substantially over time, the effective curve number did not vary significantly. However, the results also indicated that design storms already typically occur under wet conditions and that the use of RCN III (RCN for wet conditions) should be considered. Detailed results will be presented for the climate-induced change in wet days and effective runoff curve number for Clemson, Columbia, and Charleston.

***Mayer, Caitlyn**, Adem Ali
College of Charleston

FIELD SPECTROSCOPY AS A TOOL FOR ENHANCING WATER QUALITY MONITORING IN COASTAL WATERSHEDS: ACE BASIN, SOUTH CAROLINA (T4,S3)

The Ashepoo, Combahee, Edisto (ACE) Basin National Estuarine Research Reserve System (NERRS) in South Carolina is one of the largest undeveloped estuaries in the Southeastern United States. This system is monitored and protected by several government agencies, to ensure its health and preservation. However, as populations in surrounding cities rapidly expand and land is urbanized, the surrounding water systems may decline from influx of contaminants leading to hypoxia, fish kills and eutrophication. In order to assess the health of coastal watersheds, water quality can be used as a key index to evaluate the stressors posed on the environment. Obtaining water quality measurements using conventional methods are labor intensive, costly and time consuming, and lack the spatial and temporal resolutions of spaceborne sensors, making it difficult to monitor water quality dynamics in real-time. In response to increasing terrestrially derived constituents from agriculture and urbanization the ACE Basin may potentially be exposed to higher fluxes of sediments and nutrients, which can degrade the water quality. Preliminary results indicate higher levels of chlorophyll, ranging from 2.94-12.19 µg/L, in comparison to other South Carolina Estuaries, which may suggest accelerated nutrient input. Therefore it is imperative to seek more accurate methods of monitoring this coastal system. Remotely sensed methods are used globally to monitor water systems and can produce an instantaneous synopsis of the water quality. Currently there are no remote sensing-based models of biogeochemical processes for the ACE Basin. In order to produce models with accurate readings of current and historic spectral, biogeochemical and temporal dynamics of coastal water quality, algorithms developed using in-situ water quality and hyperspectral measurements from 10 different sites were used to calibrate Visible-Infrared (VIR) spectral signatures from Landsat 8 and Sentinel II. A historical comparison of the relationships between urbanization, nutrient influx and water quality over time were also made, using USGS and SWMP water gage data, along with historical Landsat imagery. Models developed from this study will be used to retrieve water quality data at higher spatial and temporal resolution. This will enhance monitoring methods and may be used by water managers, and coastal resource managers to respond to environmental concerns more efficiently.

McKinney, Sean, Brett Kelly, Julia Riley, Chris Dukes
Clemson University

+NEIGHBORHOOD WATCH: ADAPTIVE MANAGEMENT MONITORING TO ASSESS URBAN STREAM RESTORATION

The Hunnicutt Creek Restoration Project is an ongoing student/faculty research effort started in 2013 with the goal of reestablishing natural functions and conditions of a healthy watershed on Clemson University's main campus. Monitoring and removal of invasive species within the upper reaches of the watershed is an important part of restoring a natural and more aesthetically pleasing system. Additionally, we are monitoring the key factors of an aquatic ecosystem that indicate habitat viability and overall water quality, including levels of bacteria, dissolved oxygen, pH, conductivity, and the quantified species richness of amphibians and macro-invertebrates. This data allows us to understand the efficacy of the restoration project on the Hunnicutt Creek watershed.

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WATER RESOURCES IN SAVANNAH RIVER BASIN: HISTORICAL ASSESSMENT & PROJECTED CLIMATE CHANGE SCENARIOS ANALYSIS (T5A,S5)

The Savannah River Basin (SRB) is well known for

abundant water resources and bio-diversity, but in the recent decades, this 'water rich' region has experienced periodic water shortages due to recurring severe droughts as well as unusual climate variability. Therefore using the past information as well as projected climate change scenarios it is possible to investigate regional hydrology to quantify the status of water resources. In this study we will use (develop) a hydrologic model (i.e., Soil and Water Assessment Tool) for investigating the possible climate change impacts in SRB. The climate change impacts will be investigated using the model outputs from the Coupled Model Inter Comparison Project Phase 5 (CMIP5) based on four RCP scenarios, such as, RCP2.6, RCP4.5, RCP6, and RCP8.5. This study will investigate the climate change impact on regional hydrologic components, such as, precipitation, stream flow and evapotranspiration that controls the water availability within SRB.

Mizzell, Hope[1], Jennifer Simmons[2], Tanner Arrington[3]
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ONLINE INTERACTIVE JOURNAL OUTLINES 2015 SOUTH CAROLINA HISTORIC RAIN AND FLOODING (T5,S1)

The historic heavy rainfall event of Oct. 1-5, 2015, produced record rainfall rates and totals in South Carolina. Finding information about that event is now easier due to a new online interactive journal from the SC Department of Natural Resources (DNR) State Climatology Office. The online interactive rain and flooding journal, *http://www.dnr.sc.gov/flood2015*, provides a chronological summary of the rain and flooding, a synoptic description of what caused the unprecedented rainfall, high resolution animated maps, rainfall and hydrologic maps of average return intervals, rankings and records, a photo account, and information on DNR's Law Enforcement Division and Flood Mitigation Program activities during the flooding. The SC State Climate Office hopes the site will help everyone better understand the State's vulnerability to flood so that we can work together to be more aware and resilient.

By the Numbers: Examples of Information Found in the Journal

- Highest 96 –Hour Rainfall: Mount Pleasant 6.4 NE SC (COCORAHS) 27.19 inches.
- 16 COOP Stations set new 24-hour Rainfall Records for October
- Charleston received 11.5" of rain on Oct. 3rd setting new 24-hour rainfall record for any station in October
- Georgetown Airport received 26.99" setting new October monthly record for any station across the state
- 4 streamflow gages set new all-time record peaks: Gills Creek at Columbia highest in 50 years, Smith Branch at N. Main at Columbia highest in 38 years, Black River at Kingstree highest in 87 years, Edisto River near Givhans highest in 81 years
- 158 South Carolina DNR Law Enforcement Officers were involved in boating, security and evacuation missions. 930 Rescues/Assists were made in the first nine days of the event.

Important Flood Safety Information

- Over half of all flood-related drownings occur when a vehicle is driven into hazardous flood water.
- Second highest percentage of flood-related deaths is due to walking into or near flood waters.
- People underestimate the force and power of water. 6 inches of fast-moving flood water can knock over an adult. It takes just 2 feet of rushing water to carry away most vehicles. It is NEVER safe to drive or walk into flood waters.
- Homeowners' insurance does not cover flood damage.
- South Carolina has 199,300 National Flood Insurance Program policies which ranks 6th in the nation. If you live in a Special Flood Hazard Area or high-risk area and have a Federally- backed mortgage, your mortgage lender requires you to have flood insurance.
- Anyone can be vulnerable to flooding. Even if you live in a low-risk area you can purchase flood insurance so long as your community participates in the National Flood Insurance Program (NFIP). People outside of the high-risk flood areas file 20-percent of all NFIP claims.

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+PRELIMINARY RESULTS OF FISH POPULATION SURVEYS IN SAVANNAH RIVER OXBOW LAKES

The Savannah River has undergone major modifications by humans since the 1800's, including the construction of several dams. The Savannah River was dredged and straightened to facilitate commercial barge traffic through 1979. During the straightening process, the US Army Corps of Engineers excavated over 30 navigation cuts across meander necks, creating numerous oxbow lakes and shortening the river by 24 km, and effectively doubling the total number of natural oxbow lakes along the river. Today, these oxbow lakes have various levels of connectivity to the mainstem, depending on river flow, which is largely regulated by the US Army Corps of Engineers Thurmond Dam. We examined fish populations in four oxbow lakes, three of which are natural, and two of which remain connected to the mainstem river at baseflow. We captured 1,798 fish representing 15 families, 24 genera, and 39 species using boat electrofishing. Analyses revealed no significant differences in catch per unit effort or biomass with respect to lake, sampling event, or oxbow connectedness.

Moody, Shelby, John B. Nelson
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+RARE PLANT SPECIES MANAGEMENT AND CONSERVATION, STACHYS CAROLINIANA

Stachys caroliniana, a member of the mint family (Lamiaceae), was described as a species new to science, in November 2014. This plant effectively represents one of the rarest plant species in the world, known from a single population, the type locality, which is on Cat Island, a portion of the Tom Yawkey Wildlife Center in Georgetown County. Due to the October 2015 Flood from Hurricane Joaquin, this population was covered by approximately 2' of water. An initial population density count was taken

of this species in the following November and December, totaling 400 individual plants. It was important to obtain this data immediately because the biology of this plant is poorly known, and the effects of a major flood event on this population are far from completely understood. Additional data collection will be performed through the growing seasons of 2016 and 2017 as a way of assessing changes in population density, structure, and areal extent, especially as a result of changes in competition with surrounding vegetation. Different management approaches will be used to assess the best practice that yields a high density and healthy population of Stachys caroliniana. Considering that this plant is currently only found from one population, it is very likely that the Endangered Species Act will come into play for this species. It is essential to identify best management practices to develop a successful management plan in order to conserve this species.

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RAINWATER HARVESTING: PROGRAM EVALUATION TO UNDERSTAND REAL WORLD ATTITUDES, PERCEPTIONS, AND USER APPLICATION OF THE PRACTICE (T3A,S3)

Rainwater harvesting is a best practice used to encourage awareness of and resident participation in stormwater management in the landscape. Evaluations from rainwater harvesting programming, including lectures, workshops, and rain barrel sales, offer an opportunity to explore user attitudes, perceptions, and the application of the practice. The Clemson Extension Service used evaluation data from 2013-2015 programs to gauge knowledge of and behavior change in 300 individuals who engage in the practice. Results provided information on motivators of use, current maintenance practices, and lessons learned for stormwater management professionals on increasing behavior adoption in the community. As part of this presentation, resulting outreach tools will be highlighted that may assist practitioners and educators in providing guidance to client groups and increasing the practice and effectiveness of rainwater harvesting throughout South Carolina.

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+FLOATING TREATMENT WETLANDS: EFFECTS OF VARYING COVERAGE ON EUTROPHIC POND MESOCOSMS

Floating treatment wetlands (FTWs) are an emerging application of ecological engineering that have promising water quality improvement and habitat creation applications. However, the literature is sparse regarding design, construction, habitat creation, and effects on water quality. In order to determine nitrogen and phosphorus processing rates and the effects of relative percent cover on water quality, eutrophic pond mesocosms received three treatments (0%, 33% and 66% FTW coverage) in triplicate over 30 d. Initial total nitrogen was 16.5 mg/L, all in the form of urea. Initial phosphate was 1.86 mg/L. The experiment was conducted under ambient conditions July-August in coastal South Carolina, where applications of this technology have been rapidly expanding over the last decade despite the lack of firm design and application guidance. Results indicated FTW have mixed effects on water quality of eutrophic ponds. The diurnal temperature range was increasingly dampened with increasing coverage. The diurnal dissolved oxygen range was the lowest with 66% coverage, but 33% coverage was higher than the open water ponds. Nutrient processing occurred in all treatments. Results have provided insight on how eutrophic pond water quality may respond to the incorporation of FTWs.

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+STORM EVENT ANALYSIS AT NESTED WATERSHED SCALES: TURKEY CREEK, SANTEE EXPERIMENTAL FOREST, SOUTH CAROLINA

We have used a set of metrics for storm runoff events (rainfall, runoff, runoff-rainfall ratio, duration of runoff event, peak flow rate, baseflow, initial water table depth, and initial flow rate) to characterize stream flow behavior of a minimally disturbed forested watershed (Turkey Creek) that can serve as a reference of a pre-development scenario. The Turkey Creek watershed (52 km^2), in the Lower Coastal Plain of South Carolina, is a 3rd order watershed that includes two 1st-order sub-watersheds, Eccles Church (2.4 km^2) and Conifer (1.2 km^2) nested within it. The objectives of this study were to 1.) characterize the watershed conditions based on the land use/land cover, soil drainage class, geologic and topographic characteristics and 2.) compare stream flow patterns using above metrics in the small and larger watersheds for assessing scaling effects. Physical and chemical hydrograph separation methods were used on stream flow data for the 2011-2015 period. The annual rainfall at the site ranged from 959 mm in 2011 to 2237 mm in 2015, with mean annual of 1449 mm. Preliminary results using data from 14 storm events showed a statistically significant difference in direct runoff depth between the smaller Conifer and the larger Turkey Creek watershed. The smaller watershed also had a statistically larger mean peak flow rate than Turkey Creek. No significant difference was found between watersheds for direct runoff or runoff-rainfall ratio. However, the smaller watershed had larger mean values for the outflow metrics compared to Turkey Creek. This is most likely due to the smaller area and lower-permeability soils resulting in a shorter water residence time. The chemical separation results show baseflow contribution making up 58-65% of average stream flow in contrast with only 35-41% from the physical hydrograph separation method. We infer that the type of storm event (originating from the ocean versus land), may complicate the isotopic signatures in the runoff water and we continue to explore explanations of this difference between the physical and chemical hydrograph separation methods. Also, for the smaller watershed with a larger percentage of more permeable soils, the data show

evidence for a longer time to peak flow rate following storm events, which suggests the role of groundwater infiltration may provide an overall dampening function to stream flow behavior in response to storm events. The results from this study can be extended to other locations in the Coastal Plain that are experiencing land use change due to population growth, for example.

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SOUTH CAROLINA POND MANAGEMENT APPROACHES AND COSTS: AN ECONOMIC STATE-OF-KNOWLEDGE REVIEW AND SYNTHESIS (T3B,S3)

The state of South Carolina has experienced tremendous population growth along its Coastal region. If left unchecked, the rapid growth will continue to place undue strain on the region's resources including its intra-coastal waterways (and tributaries) and marsh habitats and other marine ecosystems. The environmental quality of these resources depends largely on the management and control of stormwater runoff and transport - much of which is associated with urban and suburban real estate development. Stormwater ponds or catchments are one of the more commonly employed water management tools used to collect and filter runoff, sediment, and other harmful pollutants before the runoff is discharged into the ecosystem, and as a flood protection measure to control stormwater runoff. In this particular report, we examine the economic aspects of stormwater pond management. More specifically, we offer a comprehensive review of the economics literature (including a discussion of the public goods aspect of stormwater runoff), a stakeholder survey, and a theoretical model to explain the optimal level of stormwater pond management. We find that there still remains a tremendous amount of uncertainty related to stormwater pond management including: 1.) regulatory uncertainty and the general lack of compliance enforcement; and, 2.) a general lack of understanding of who the resource (stormwater runoff) belongs to. Additionally, we conclude that the lack of knowledge regarding SWP maintenance and costs leads to lower annual levels of selected maintenance. Given this uncertainty, we posit that South Carolina stormwater ponds are likely managed non-optimally, which can adversely affect the State's many watersheds and marine ecosystems.

Mullis, Damon, Kelsey Laymon, Jason Moak, Oscar Flite
Phinizy Center for Water Sciences

⁺EFFECTS OF OXBOW CONNECTIVITY AND FLOODING ON THE STRUCTURE AND FUNCTION OF MACROINVERTEBRATE COMMUNITIES

Oxbow lakes are important parts of riverine ecosystems. These lakes exhibit various degrees of connectivity to the main river channel with some always connected and others only being connected during flood stage. This connectivity can be important in the transfer of energy, sediment, organic matter, and organisms within alluvial river systems. In an attempt to understand how these varying degrees of connectivity influence ecosystem attributes we analyzed macroinvertebrate community structure and functional groups within four oxbow lakes along the Savannah River. Two of these oxbows are always connected to the main channel and two are only connected during flood stage. We collected dip-net samples between July 2015 and May 2016, with two sampling events before flooding, during flooding, and after flooding. We were unable to detect any significant differences in macroinvertebrate communities between the lakes always connected and lakes connected only during flood stage. However, there were significant differences in functional feeding groups between flood stages, with shredders increasing linearly from 29% of the community before flooding to 41% of the community after the flooding receded. Collector-filters decrease from 59% before flooding to 7% during flooding, before returning to 33% after the flood. Diversity decreased during flooding with polypedilum dominating 56% of the community. Hisenhoff IBI (Index of biotic integrity) improved from 7.7 before flooding to 7.0 during, before returning to 7.7 after flooding receded. Our results indicate that floodplain inundation has consequences on the functional role that macroinvertebrate communities play in the processing of organic matter within oxbow lakes. The pattern in shredder abundance could be contributed to an increase of leaf material into the lakes during floodplain inundation, with shredder contributions to the total community continuing to increase after flooding recedes. Another significant change in macroinvertebrate community was the colonization of the oxbow lakes with riverine taxa during flooding, accounting for the improving IBI score seen during this period. In general, flood stage appears to be a significant driver of change in macroinvertebrate communities within oxbow lakes. However, more sampling is needed to account for natural seasonal variation in these communities.

Mullis, Damon, Kelsey Laymon, Chalisa Nestell, Jason Moak, Oscar Flite
Phinizy Center for Water Sciences

THERMAL REGIME BELOW THURMOND DAM AND ITS RELATIONSHIP TO THE LONGITUDINAL ORGANIZATION OF MACROINVERTEBRATE ASSEMBLAGES (T4,S6)

Dams modify downstream water temperatures by releasing hypolimnetic (cold) or epilimnetic (warm) water from thermally stratified pools or reservoirs. These modified riverine thermal regimes have been widely recognized to have negative effects on aquatic communities. The purpose of this study is to characterize the relationship between macroinvertebrate assemblages and the thermal regime of ~187 miles of the Savannah River beginning 8 miles below the hypolimnetic Thurmond Dam through 3 epilimnetic low head dams, which comprise 27 miles of river beginning 13 miles below Thurmond Dam: Stevens Creek Dam, Augusta Diversion Dam, and New Savannah Bluff Lock & Dam (NSBLD), until the river becomes tidally influenced 27 miles before it empties into the Atlantic Ocean. To accomplish this, we examined temperature data taken at 15-minute intervals from 9 monitoring stations equipped with multiparameter sondes and characterized the thermal regime of each site by comparing mean temperatures and thermal variability (coefficient of variation) at multiple temporal scales (yearly, monthly, weekly, and daily).

In addition, macroinvertebrates were collected at each site quarterly using Hester-Dendy multi-plate samplers and differences in diversity, composition metrics (% EPT [Ephemeroptera, Plecoptera, and Trichoptera], % Chironomidae) and Tolerance Metrics (% tolerant taxa, % intolerant taxa, Hilsenhoff Biotic Index) were assessed. Mean annual water temperature and variability was lowest at the site just below Thurmond Dam and increased in a downstream direction. In contrast, mean water temperatures from Thurmond Dam releases were generally warmer than downstream sites from November to January on a monthly scale. Monthly temperature variability had seasonal effects, peaking in April and October and being most stable in June and December at most sites. At the monthly time scale, there were no significant differences in temperature variability between sites; however, at the weekly and daily temporal scales there were significant differences with the most stable thermal regime at the site just below Thurmond Dam, and drastically increasing 13 miles downstream before significantly decreasing linearly until reaching the lowest monitoring site. Macroinvertebrate diversity was lowest just below Thurmond Dam and progressively increased with distance from the dam before reaching the tidally influenced sampling site. In addition, %EPT taxa were consistently 0% just below Thurmond Dam and increased with distance from it until reaching as high as 90% of the assemblage at the lowest non-tidal site. Many studies have documented similar effects of dams on macroinvertebrate assemblages and contribute them to changes in physical habitat, food resources, and altered seasonal thermal regimes. Our results suggest that in addition to these effects, as a river recovers from releases from dams, temperature fluctuations at short temporal scale (i.e. weeks, days) may be acting as a disturbance, attributing to the negative impacts dams have on downstream aquatic communities.

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[+]WATER QUALITY EFFECTS OF SWITCHGRASS INTERCROPPING IN A PINE FOREST IN COASTAL NORTH CAROLINA

The production of switchgrass (Panicum Virgatum) from managed pine forest is hypothesized to increase production and profit per acre of pine land. The objective of this study was to investigate the water quantity and quality effects associated with the establishment of switchgrass intercropping in a coastal North Carolina pine forest. Three 25 ha sites were established in coastal North Carolina. Young pine trees with intercropped switchgrass (IC) and switchgrass only (SG) sites established in 2009 were the treatments, and mature thinned pine with understory (MP) was used as a reference site. A paired watershed experimental design approach was used for assessing effects of treatments using calibration equations. The three experimental phases evaluated were: site preparation for switchgrass establishment (siteprep: 2009-12), switchgrass growth without fertilizer applied (pre-fert: 2012-14), and switchgrass growth with fertilizer applied (post-fert: June 2014 to current). During siteprep, silvicultural operations like pine harvesting, shearing, bedding, and planting of pine seedlings on IC and gradual pine harvesting, shearing and root raking on SG treatments were carried out. N and P fertilizers were applied in June 2014 on all the sites and in June 2015 for only IC and SG sites. Switch grass was harvested in December of 2014 and 2015. Nitrogen, P, total organic carbon (TOC), and total suspended sediment (TSS) were monitored in drainage out flow which was measured on all the watersheds during 2009-2015. NO3-N concentrations for IC and SG significantly increased ($p < 0.05$) compared to MP after pine harvesting (site prep) probably due to mineralization of harvested plant materials. Both the phosphate loads and NO3-N concentrations and loads treatment effects significantly decreased on IC and SG compared to the MP from siteprep to pre-fert, likely due to increasing plant uptake rates. Mean phosphate concentrations on all the sites decreased from siteprep through pre-fert to post-fert likely due to the fixation of P by Fe and Al at low pH. Mean NH4-N and NO3-N concentrations for MP were greater ($p< 0.05$) than those for IC and SG for post-fert likely due to greater N application rate on MP. The TKN, NH4-N, and NO3-N concentrations for SG were greater than for the IC during post-fert likely due to their greater retention on IC. Mean NO3-N concentrations on IC for site prep was greater ($p< 0.05$) than for the post-fert. The mean TSS concentrations on IC for both pre-fert and post-fert were significantly greater ($p < 0.05$) than that for the siteprep likely due to retention of water by the newly formed beds during siteprep. The TSS concentration on SG for siteprep and post-fert were significantly ($p <0.05$) greater than pre-fert likely due to reduced cover during siteprep and switchgrass harvesting during post-fert. The mean TOC concentration on SG was greater ($p<0.05$) than that on IC during post-fert. The magnitude of nutrients and TSS concentrations for all the sites also varied with flow and rainfall during the study period. The results from this study showed that switchgrass intercropped pine forest had minimal or no impacts on drainage nutrients.

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ENVIRONMENTAL JUSTICE GUIDELINE COMPARISONS WITH COINCIDENT FISH CONSUMPTION ADVISORY WATERBODIES IN SOUTH CAROLINA (T1,S3)

With the signing of Executive Order (EO) 12898 by President William J. Clinton in 1994, environmental justice (EJ) finally became a focus of United States (US) federal agencies. After years of grass roots efforts and growing out of the civil rights movement, the federal government had a directive to identify, address, and mitigate adverse or disproportionate burdens/impacts

on minority, low-income, and native populations. Toxic release inventory (TRI) sites, hazardous waste locations, landfills, brownfields, etc. have traditionally been the focus of EJ concern. However, fish consumption advisory waterbodies in the study area of South Carolina are also a concern. Fish consumption advisories are recommendations about what types and how much fish to consume, as well as what waterbodies to catch or avoid certain species. Therefore, this study attempts to analyze similarities and differences between six governmental EJ guidelines and the potential EJ populations they identify. Specifically, identified communities were studied in terms of their spatial coincidence with impacted waterbodies in the state in 2000 and 2010. Contingency tables, similarity indices, and GIS were utilized to compare and contrast governmental guidelines, identified EJ populations, and fish consumption advisory waterbodies in South Carolina. As many of the impacted waterbodies and EJ-identified populations in South Carolina are located south of Interstate 20, there were no statistical differences observed between agency guidelines even when accounting for Census year. Geographically, there were many similarities in terms of impacted waterbodies and coincident EJ populations in the state. As there were no significant differences between guidelines in this study, recommendations were made to identify which guidelines to utilize in South Carolina.

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EMPLOYING VIRTUAL BEACH SOFTWARE, HISTORIC IN SITU, REMOTELY SENSED, AND COASTAL OBSERVATION SYSTEM DATA FOR BACTERIA FORECAST WATER QUALITY MODELING IN SARASOTA, FL (T4A,S1)

A research partnership between the University of South Carolina, University of Maryland Center for Environmental Science, and the Southeast Coastal Ocean Observing Regional Association is built upon and a geographic footprint is expanded from the Grand Strand Area of South Carolina to the beach waters around Sarasota, Florida in this study. Daily bacteria forecasts were developed and automated for 12 beach areas in the Sarasota area. Because it requires limited programming/statistical skill and is relatively easy to operate/understand, Virtual Beach (VB) software was utilized for this project. Designed and developed by the Environmental Protection Agency (EPA), VB provided a suite of statistical tools to create robust model forecasts for this project. Using roughly 82 variables, multiple linear regression (MLR) models were created for each of the 12 study sites. With incomplete data for some variables of interest, techniques were utilized to increase the number of records available for VB modeling runs. A website application (app) was developed for each beach location to show its associated bacteria forecast. The app provides daily recommendations about swimming and recreation in beach waters around the study areas. Results, forecasting techniques, and the web app will be presented and accessible to local stakeholders for critique and usage.

Osborne, Robert, Morgan Young, Pam Kenel
Black & Veatch

INCORPORATING RESILIENCE INTO WATER RESOURCE PLANNING (T1,S1)

Recent extreme weather-related events from floods to droughts have many calling for planning a more resilient future. What does that mean? Can resilience be measured? Does resilience change how we manage and plan for our water resources? The term resilience developed from the field of ecology in the 1970s, to describe the ability of a system to function and recover in the face of change. Frameworks for incorporating resilience into planning have been percolating in academia since that time, but now many organizations are beginning to incorporate resilience metrics into their planning activities. This presentation will focus on recent examples of how Black & Veatch assisted clients with incorporating resilience into their planning efforts. For example, a risk-based framework was recently developed for assessment and enhancement of system resilience for one of the major metropolitan areas in the US with a population of about 5 million. The objective of the study was to identify and prioritize water system infrastructure improvements that would enhance the overall reliability of the system throughout the region during emergency events. The study followed a risk-based approach considering failure scenarios and probability and consequence of occurrence, combined with Monte Carlo assessment of cost/benefit of potential improvements. Improvements considered included raw water storage and transfer, treated water transfer and network interconnections. For another water utility, Black & Veatch helped to develop a methodology used to quantify system resilience. This presentation will compare and contrast risk-based resilience frameworks and focus on water resource planning applications. These results will be summarized to ensure they are useful to a diverse audience.

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A BOTTOM-UP APPROACH FOR ASSESSING THE LONG-TERM RELIABILITY OF WATER SUPPLY IN A CHANGING CLIMATE (T5,S4)

Information about the implications of climate change for water resource management is most commonly produced through a "top-down" analysis by driving hydrologic and water system models with climate model outputs. The resulting information is, however, often not useful for decision making because of uncertainty associated with model projections or lack of specificity or fit with resource management concerns. To address some of these limitations, new approaches have emerged that begin with analyzing a system's or an action's vulnerability to changes in climate in place of climate change projections. While these approaches differ methodologically, they are usually designed to (either implicitly or explicitly) identify actions

that work well over a wide range of futures. Information resulting from such assessments is expected to have enhanced relevance to decision making, however their application has been demonstrated in limited contexts. We assess the effectiveness of one such approach known as "Decision Scaling" (Brown et al., 2011) for informing traditional long-range water supply planning using the case study of a local water utility in North Carolina. The approach involves combining hydrologic and water system modeling, stochastic analysis, and stress-testing to assess the sensitivity of the water supply to climate and identify magnitudes of change that could threaten this system's ability to perform within acceptable thresholds. These thresholds are identified by the water utility managers as critical changes in system performance that would call for alternative planning-related actions. The information gained from this system-specific vulnerability analysis then informs the tailoring of climate change projections and communication of decision-relevance of uncertainty in the projections.

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+EVALUATING A COMMERCIAL SODIUM HUMATE PRODUCT FOR THE REDUCTION OF BIOAVAILABLE COPPER AND ZINC IN SURFACE WATER

The presence of dissolved organic matter (DOM) in an aquatic system provides an opportunity for the natural detoxification of cationic metals such as copper or zinc. DOM provides macromolecules which strongly attract cationic metals, making them biologically unavailable for uptake by aquatic organisms. We have been working with a commercially-available agricultural humate product, Borregro HA-1, to ascertain its usefulness as a remediation tool for decreasing the bioavailability of metals in industrial effluents. We tested this concept through a series of acute copper and zinc bioassays using the indicator organisms, Ceriodaphnia dubia. In our tests, Borregro HA-1 was added to reconstituted laboratory water with very low hardness (<15 mg/L as CaCO3) and to a moderately hard reconstituted water (70-90 mg/L as CaCO3). Enough Borregro HA-1 was added to achieve a final dissolved carbon concentration of 2.62 mg C/L, a concentration which matched the receiving stream of interest. Results, measured by nominal LC50 concentrations, indicated that Borregro HA-1 additions reduced the toxicity of copper at both hardness levels, but there was no change in zinc toxicity. For each experiment, Diffusive Gradient in Thin Film (DGT) probes were deployed in surrogate test vessels in side-by-side exposures to further model the bioavailability of these metals under test conditions.

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+THE WATER USE DASHBOARD

The Water Use Dashboard is an interactive web app used to search, explore, and download datasets relevant to water use in South Carolina and surrounding areas. Water resource management is complex, involving a variety of dynamic and inter-related physical, ecological, socioeconomic, and political variables. High quality data resources are publicly available online, but the requirements in terms of time and data management skills needed to analyze and understand these data sets are unnecessarily high. This inhibits decision-making and stakeholder buy-in to water management processes. Enter the Water Use Dashboard (currently under development). The Dashboard provides a single point of access for a variety of relevant datasets. Datasets can be subset, filtered, and aggregated within the viewer. Users can explore the datasets with an intuitive and efficient interface. Relevant statistical derivatives are automatically calculated on user-specified subsets of the data. Users can download the data, including metadata documentation. The dashboard is a cost-effective tool for water resources management in South Carolina. It facilitates technical review of model inputs, public distribution of surface-water and ground-water model outputs, QAQC of water use and discharge data, stakeholder review of demand projections, and water planning in general. This platform provides a solid foundation for water resource management moving forward.

Petkewich, Matthew, Celeste A. Journey, Paul A. Conrads, Jimmy M. Clark
US Geological Survey

+UTILIZATION OF AN AUTONOMOUS UNDERWATER VEHICLE TO SUPPORT TASTE-AND-ODOR ASSESSMENTS IN A DRINKING-WATER SUPPLY RESERVOIR IN SOUTH CAROLINA, 2013-2015

The US Geological Survey, in cooperation with the Charleston Water System, conducted an investigation to better understand the water quality and flow dynamics in the Bushy Park Reservoir and how these conditions may influence taste-and-odor episodes caused by geosmin and methylisoboneol. Bushy Park Reservoir, located near Charleston, South Carolina, is the major drinking water supply for the Charleston area. Spatial changes in water quality were assessed using discrete water samples combined with data collected with an autonomous underwater vehicle equipped with a multiparameter sonde. Spatially dense, georeferenced data from the sonde collected bimonthly were used to qualitatively identify locations and conditions for elevated chlorophyll and phycocyanin concentrations and changes in stratification. Discrete water-quality samples were collected and used to verify and calibrate the sonde measurements and to quantitatively evaluate the water quality during taste-and-odor episodes. Bushy Park Reservoir experienced a spring (April) taste-and-odor episode in 2014 and 2015 with geosmin as the dominant taste-and-odor compound. However, throughout the spring and summer, the investigation identified a persistent occurrence of low-level (less than 25 nanograms per liter) taste-and-odor concentrations. The taste-and-odor occurrence exhibited an inverse relation between geosmin and methylisoboneol concentrations that occurs spatially in the reservoir, whereby geosmin concentrations tended to be highest near the headwaters of the reservoir and methylisoborneol tended to be highest near the dam. Relation between the temporal and spatial changes in flow, water chemistry

(discrete and spatial data) and phytoplankton community structures and taste-and-odor occurrence were evaluated. The results of that evaluation will be presented.

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DEVELOPING SEDIMENT MANAGEMENT GUIDELINES FOR THE BROAD RIVER BASIN (T7,S6)

Sediment has been listed as one of the most harmful pollutants to in-stream habitat and associated aquatic life. Within the Southeastern United States past land use activities, primarily agricultural related, and ongoing land conversion has added to in-stream sedimentation and increased stream bank instability and erosion. In 2012, the South Carolina Department of Natural Resources lead an effort to develop sediment management guidelines to enhance habitat and aquatic resources in the Broad River Basin, South Carolina. The Broad River Basin is unique in the fact that it lies primarily in the Piedmont physiographic region of the Carolinas. Piedmont streams and rivers are often characterized by transport-limited conditions, high turbidity, sandy mobile bottoms, coarse shoals and unstable banks. Conditions such as these typically cannot support specific designated uses of the river resulting to impaired biotic conditions. Data needed to quantify complex relationships between fluvial sediment and in-stream habitat are scarce in Piedmont streams and rivers and a discernible data gap exists in the Broad River Basin. Our objective here was to assess associations between sediment flux, grain size, stream fish and aquatic invertebrate assemblages. We collected over 800 suspended-sediment samples, and 700 bed material samples over a 24-month period from June 2012 to June 2014. In-stream habitat (current velocity and depth) was assessed at each field site where and when fish and aquatic invertebrates were sampled. We examined the biological assemblage structure in respect to sediment load and bed material using ordination. The biological community showing strong relationships with coarse substrate size and reduced suspended sediments were considered 'sediment sensitive species' and were used in further modeling of sediment variables by the relative presence of these organisms by site or sample. These were predominately represented by benthic fishes (suckers, minnows and darters) and benthic aquatic invertebrates (mayfly, stonefly and caddisfly). Our results indicate that Kings Creek, the least developed and highest forested watershed, contributed the lowest annual sediment loading where Lawson Fork Creek contributed the greatest. Lawson's Fork Creek represented the watershed with the highest percentage of urban land cover and isotopic analysis indicated that the majority of sediment within this watershed was contributed by stream bank erosion. Stream bank erosion was estimated at an average rate of 1 foot annually, indicating that the majority of the tributaries were in a state of widening which ultimately decreases sediment transport capacity. Results also indicated significant relationships between suspended sediments and substrate size with land cover variables indicating threshold values of increased sediment variables at specific land-cover levels. Reductions in the relative abundance of sediment sensitive species were associated with increased annual sediment loadings and suspended sediments and reduced particle size. These same sensitive species were consistent in identifying a threshold level for suspended sediment of 20 mg/L, above which abundances of these species were reduced. Furthermore, these same species indicated a threshold for the median substrate particle size of 25 mm, indicating that coarser substrate supported a higher diversity of life.

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MODELING AN URBAN STREAM'S RESPONSE TO PRECIPITATION, A CASE STUDY IN AUGUSTA, GEORGIA (T4,S3)

Understanding the water balance is essential for municipalities tasked with managing stormwater systems and maintaining water quality standards of local streams. As watersheds become increasingly urbanized, runoff regimes change due to increased impervious surfaces and urban drainage systems. Drainage systems convey stormwater to local streams, which become part of the major drainage system. Local streams are often modified to accommodate increased flows, but the higher frequency and magnitude of high flows, as well as reduced base flows, impact sediment transport, habitat characteristics, and water quality. To better understand the hydrology of the Rock Creek, a tributary of the Savannah River in Augusta, Ga, rainfall and stream level monitoring stations have been installed at two sites on the creek. Each station was equipped with a rain gauge and water level logger that continuously recorded data on 15-minute intervals. At both sites, discharge was measured at a range of flows to develop a stage-discharge rating curve. We used these data to develop a model to predict how the stream responds to a given rain event including estimated peak flow, the rate of rise to peak flow, and the rate of fall to base flow. We also highlight the difficulties of assessing hydrology in an urban stream due to stochastic events and the pronounced response of a small stream to changes in the system. Ultimately, we plan to incorporate this process into a larger rain gauge network to help understand how much water drains to a creek for a given amount of rain, what the capacity of a creek is to carry that water, and how stormwater is impacting water quality.

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INTEGRATED ENERGY-WATER PLANNING IN THE EASTERN INTERCONNECTION (T1,S2)

Water is an essential resource to the thermoelectric power sector, which is the largest user of water in the United States. As water-related issues continue to grow due to drought, climate change, and tension between multiple sectors, it is becoming increasingly important that water resources are considered in long-term energy planning.

This study seeks to evaluate projected implications on water resources as energy demand grows and new power plants are built. Capitalizing on recent energy-demand projections from the Eastern Interconnection Planning Collaborative (EIPC) we are identifying watersheds at highest risk for future water stress. Three future policy scenarios-business as usual, federal portfolio standard, and carbon reduction-are being compared. Energy expansion is calculated for each region defined by the North American Electricity and Environment Model (NEEM). This work will enable the energy sector to factor watershed stress into future energy expansion, which is not currently done.

Rabon, Edward, Dan Liebert
SC Department of Health and Environmental Control
MONITORING THE EFFECTS OF THE SOUTH CAROLINA FLOOD EVENTS IN CHARLESTON HARBOR IN OCTOBER 2015 (T5,S3)
SCDHEC was conducting a study of nutrient and chlorophyll a levels in two tributaries of Charleston Harbor, the Ashley and Wando Rivers. Coincidentally, the historic flood resulting from rains in central and coastal South Carolina on October 3-5 was detected by continuous monitors deployed in the Ashley and Wando Rivers. Continuous records show extreme reductions in salinity that persist to present (October 22nd) and suggest changes in water quality will persist well into November.

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+A MULTIPLE METHOD APPROACH TO EVALUATE LANDWARD MIGRATION OF SEAWATER INTRUSION IN THE FLORIDAN AQUIFER
The Floridan aquifer of the Southeastern United States is an important freshwater resource for private and commercial groundwater users. Within the past few decades, certain parts of the aquifer have experienced saltwater intrusion, which has affected the viability of this critical freshwater resource. Groundwater withdrawals, variability in recharge and discharge rates, and sea level rise has caused saltwater to advance into this and other freshwater coastal aquifers. While the South Carolina Department of Natural Resources (SCDNR) monitors conductivity in several coastal Floridan aquifer wells, a comprehensive hydrochemical saltwater intrusion study of the aquifer in the Berkeley-Charleston-Dorchester tri-county region of South Carolina has not been conducted since the publication of a SCDNR report in 1985. The goal of this current project, conducted in cooperation between SCDNR and the College of Charleston, is to inspect the water quality in Floridan aquifer wells in the tri-county region to determine the extent of saltwater intrusion within the aquifer. Objectives of this project include analyzing and mapping the location of the freshwater-saltwater interface, using hydrochemical analyses to identify signal elements of saltwater intrusion in the aquifer, and providing updated information regarding the groundwater resources of the Floridan aquifer in the study area. In-situ hydrochemical data from Floridan wells and associated geospatial analyses have indicated the areas of the study region likely impacted by saltwater intrusion, and current and future work will include analysis of well water for strontium, bromide and boron to serve as signal elements. Correlations between these elements and chloride concentrations will also be established to strengthen a model of saltwater intrusion. These results about the properties of the Floridan aquifer are in high demand for many stakeholders, including municipalities, agricultural operations, industrial activities, and natural resource managers who depend on a stable source of groundwater as public and private water supplies.

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SPARTANBURG COUNTY CONTINUOUS WATER QUALITY MONITORING PROGRAM - PARTNERING FOR RESULTS (T4,S2)
In continued efforts to protect local watersheds and water quality in Spartanburg County, a coalition referred to as the "Spartanburg Water Quality Partners" was formed to collaborate and share resources related to public education/outreach and public involvement. This group consists of four core agencies: Spartanburg County's Stormwater Management Department, Spartanburg Soil & Water Conservation District, USC-Upstate's Watershed Ecology Center, and Clemson Extension's Spartanburg office. The coalition also includes many affiliate partners in the Spartanburg area. In addition to supporting the partnership's educational efforts, two of the affiliate members have joined forces with Spartanburg County to develop a local water quality monitoring network, which provides valuable information about the health of streams in the Spartanburg County area. Spartanburg County (County), the City of Spartanburg (City), and Startex, Jackson, Wellford, and Duncan (SJWD) Water District have a need for real-time surface water quality data. SJWD relies on water quality information collected upstream of the intake for the water treatment facility to evaluate options such as adjusting treatment dosing or temporarily suspending withdrawal of water at the intake during inclement or undesired conditions. As permitted small Municipal Separate Storm Sewer Systems (MS4s), the County and the City are required to conduct various permit activities to minimize potential water quality impacts from their urbanized areas, including maintaining compliance with existing/future total maximum daily loads (TMDLs). The installed water quality monitoring network helps both MS4s meet these requirements. All three entities also have a need for stream flow data to better manage their respective contributions and impacts (both positive and negative) on local receiving waters. The network began with the installation of two permanent water quality monitoring stations on the Middle Tyger River in 2013 and has now expanded to include a total of seven permanent water quality monitoring stations and six continuous rainfall gages that span the North Tyger River and Lawson's Fork Creek (a tributary to the Pacolet River) watersheds as well. Operated and maintained by Woolpert Inc., each water quality station is outfitted with a multi-parameter YSI data sonde to record 15-minute data for temperature, turbidity, pH, dissolved oxygen, specific

conductivity, depth (i.e. river stage) and ammonium. Each monitoring station includes a datalogger and cellular modem used to transmit data to a dedicated website and to provide email/text alarm functionality. To supplement the sensor data, manual grab samples for the analysis of various parameters and field discharge measurements are collected to expand and fully leverage the overall dataset for watershed assessment. The monitoring data has provided many benefits including the ability to approximate annual pollutant loads, to detect and track potential illicit discharges, to evaluate river conditions for water quality treatment, to conduct post-storm assessments, and to collect data for future floodplain model calibrations. The data is also being used by the National Weather Service to assist with Spartanburg area rainfall/flood alerts. The established monitoring network provides numerous benefits to all of the Spartanburg Water Quality Partners, and will continue to do so for many years to come.

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AN ENGINEERING METHODOLOGY TO QUANTIFY THE HYDRAULIC AND HYDROLOGIC PERFORMANCE OF GREEN ROOFS (T3A,S2)

Stormwater permits typically require a design engineer to quantify both rainfall retention and runoff detention to comply with local standards. Although the qualitative stormwater benefits of green roof systems are widely known, their quantitative hydraulic and hydrologic performance during individual storm events is not. As a result, engineers and regulators are reluctant to claim specific stormwater benefits for a green roof, and instead rely on stormwater ponds, infiltration basins, and underground storage to meet retention and detention requirements. Consequently, green roofs are typically viewed as unessential infrastructure. However, if the stormwater management benefits of a green roof were quantified, and a green roof were implemented as a critical component of a project's permitted stormwater management system, it would become an indispensable project element. Building on the work of Martin and Kaye (SCWRC 2014) the research team ran a series of experiments to evaluate the retention, detention, and drawdown characteristics of a modular green roof system. Two sets of experiments were run. In the first, a prescribed rainfall rate was continuously poured over the green roof system and the time varying storage in the system was recorded by measuring the weight of the system over time. A second set of tests were run in which the green roof system was flooded and the drawdown measured over time. The long term drawdown was also quantified by periodic measurements of the mass retained in the months following the testing. Additional tests were run using empty modules (no growth medium of vegetation) to examine the role of outlet geometry on the hydraulic behavior. Experimental results will be presented for hydraulic performance of the green roof system and the individual modules without plant material. The results will be compared to a theoretical model for system performance that treats the green roof as a detention pond. Design considerations for improving green roof stormwater management performance will also be discussed.

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A HISTORICAL PERSPECTIVE OF NUTRIENT LEVELS, SOURCES, AND PROCESSING IN THE SAVANNAH RIVER BASIN (T6,S6)

In response to the initiative of the US EPA to develop nutrient criteria for US waterbodies, both South Carolina and Georgia have formulated plans and are continuing to plan for nutrient criteria for their water bodies, particularly rivers and streams. This process will soon affect one shared water body in particular, the Savannah River. The DO TMDL process for the Savannah has evidenced that having a large amount of data on the front end of the criteria development process is highly desirable and might streamline the process of working toward compliance with basin stakeholders down the road. A large set of historical data and a rigorous analysis of that data to make it relevant to current needs will be an invaluable part of determining proper nutrient criteria for the river. This type of perspective can aid in avoiding the adoption of a criteria that might become difficult to attain. For instance, adopting a criteria based heavily on one from a pristine reference condition or another "similar" river system that might not have quite the same natural ecological conditions, climate patterns, or intractable impacts could prove costly for South Carolina and Georgia in the long run. It is imperative that we take a careful look at the historical conditions, particular ecological position, and intractable alterations to the river before settling on numbers. These numbers will drive decisions for years to come that affect both the ecology of the river and the economy of the region. In addition to a historical review of nutrients, the Georgia planning process has called for a comparison of historic nutrient data (causal), which is more prevalent, to biological community information (responsive), which is far sparser. This review takes a comprehensive look at as much available historic nutrient data as could be located, dating back over 75 years. In addition, biological community data collected by Phinizy Center over the last 10 years is included for comparison as is DO data for the Savannah River from continuous monitors similar to the data collected by GAEPD for other major rivers to look for DO fluctuations characteristic of algal activity. This data is then applied along a backdrop of the historical alterations that have affected the biochemistry of the river including the amount of nutrients it receives and the way that those nutrients are processed. These alterations include such events as dam construction; major land use changes; major alterations in drought release schedules; extreme flow conditions; additions, eliminations, or major changes in effluent streams entering the river; and the initiation of permitting and regulation of those effluents. Lastly, an evaluation is done of how this historic perspective and the comparison of causal and responsive data informs the current task of developing a nutrient criteria that is

appropriate for the Savannah River, supports a sustainable conditions for the river, and that can be reasonably worked under by all of the Savannah River's many stakeholders.

Ruhlman, Melanie
Save Our Saluda
SAFE YIELD AND MINIMUM FLOW DETERMINATIONS IN THE UPPER SALUDA RIVER WATERSHED (T1,S6)
The 2010 South Carolina Surface Water Withdrawal, Permitting Use, and Reporting Act requires water users withdrawing more than three million gallons per month for consumptive use to obtain a permit from the South Carolina Department of Health and Environmental Control (SCDHEC). Permitted users must adhere to minimum instream low flow requirements and have a drought contingency plan during low flow periods. New agricultural users are exempt from the review and permitting process and only have to register the amount they wish to withdraw. All agricultural uses are presumed to be reasonable and such water rights are secured in perpetuity. No public notice is required and drought contingency plans are not required. Requirements to leave minimum flows for maintenance of water quality, for protection of fish and wildlife, and for navigability and recreational uses do not apply to registered agricultural users, who may withdraw surface water up to the defined safe yield level without notice or review. The existing law describes "safe yield" as the amount of water available for withdrawal from a particular surface water source in excess of the minimum instream flow or minimum water level and defines it as 80% of the average mean daily flow for the period of record. Safe yield, as defined by the South Carolina law, was determined for nine USGS gaging station locations in the Upper Saluda River Watershed above Lake Greenwood. The Saluda River Watershed originates from its headwaters in the South Saluda River near Table Rock, the Middle Saluda River near Caesar's Head and Jones Gap, and the North Saluda River above Poinsett Reservoir. The three branches join above Saluda Lake and flow downstream to Lake Greenwood. Headwater areas are situated largely in northern Greenville County, which contains a large number of agricultural water users. The percentage of streamflow readings that occurred below calculated safe yield level was determined for each gaging station location. Percentages were variable, and with one exception, ranged from 50 to 68 percent. The period of record for the nine gages was also variable and ranged from 8 to 78 years. Minimum flows, as defined by the law, were also determined for each gage site, and percent occurrence of streamflows below these thresholds were similarly calculated for select years, including drought periods. These data suggest that defined safe yield levels are not available for more than half the time and that the use of safe yield as an upper threshold for future registration and permitting decisions could lead to over-allocation of our state's surface water resources.

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UNRAVELING THE DISSOLVED OXYGEN TMDL TRUTH USING CONTINUOUS WATER QUALITY MONITORING IN SOUTH CAROLINA (T3,S5)
A dissolved oxygen TMDL was put into effect for the Gills Creek watershed in 2010, prescribing the City of Columbia, which is a Phase I MS4 in South Carolina, a 60% BOD5 reduction at the South Carolina Department of Health and Environmental Control (SCDHEC) sampling locations. The reduction numbers were based on a relatively small number of dissolved oxygen samples which did not characterize the complete spectrum of in-stream dissolved oxygen concentrations in the City of Columbia's portion of the Gills Creek watershed. In order to assess changes in in-stream water quality occurring within the City's jurisdiction and accurately understand the conditions associated with low dissolved oxygen levels, the City implemented a long-term continuous in-stream water quality monitoring program. The City uses data sondes to monitor various in-stream physio-chemical characteristics such as flow, conductivity, pH, dissolved oxygen, turbidity, and temperature at 15-minute intervals at three different strategic locations and communicates this data via remote telemetry to a real-time display. In the research presented here, 15-minute continuous datasets were analyzed to characterize the conditions that resulted in lower in-stream dissolved oxygen concentrations for the 2014-2015 permit year. Various statistical and visualization tools such as raster plots, probability plots, and box & whisker plots were employed to mine the continuous data. The dataset was also analyzed to quantify water quality parameters, particularly dissolved oxygen, in different flow regimes. Initial results suggested lower dissolved oxygen concentrations were a function of the operation of various controlling structures in the main stem of Gills Creek during the warm months (June-August). More than 90% of the daily average dissolved oxygen values were above SCDHEC's standard of 5 mg/L. Results obtained from this research can be used to better evaluate the need for water quality improvements in the Gills Creek Watershed.

Samadi, S.
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EMBRACING UNCERTAINTY: A CASE STUDY EXAMINING BAYESIAN ALGORITHM TO CONCEPTUAL AND DISTRIBUTED HYDROLOGY MODELS OVER A COMPLEX ENVIRONMENTAL SYSTEM (T4,S3)
This paper examines the concept of equifinality (or parameter nonuniqueness) using simple to more complex hydrology models to provide acceptable fits to observational data. A parsimonious daily-step Hydrological MODel (HYMOD), a well-known Hydrologic Engineering Center-Hydrologic Modelling System (HEC-HMS), and the Soil and Water Assessment Tool (SWAT) are linked to the generalized likelihood uncertainty estimation (GLUE) to calibrate daily streamflow observation at upstream outlet of the Waccamaw watershed in the southeastern United States (SEUS). HYMOD employed a nonlinear tank connected with three identical linear tanks in parallel to

represent the surface and groundwater flow by optimizing five parameters. The standard conceptual soil moisture accounting (SMA) approach is applied to compute the effect of canopy interception, surface depression storage, infiltration, evapotranspiration, as well as soil water and groundwater percolation (overall 37 parameters) in the HMS model. SWAT used one-parameter soil moisture depletion coefficient along with the Muskingum channel routing method to simulate streamflow using 18 parameters. An inverse error variance with a shape factor of Beven and Binley, (1992) is then proposed to measure the closeness between model prediction and observation in both distributed and conceptual hydrology models. Analysis suggests groundwater layer storage, percolation rates and storage coefficient were the most sensitive parameters in HMS whereas soil and hydraulic properties were identified as the most non- unique parameters in SWAT. HYMOD as a simple conceptual hydrology model demonstrated sensitivity in most parameters including the maximum storage capacity and the degree of spatial variability of the soil moisture capacity within the watershed. It is demonstrated that the concept of equifinality has been hardly (or never) achieved by a simple hydrology model, revealing existing uncertainty in the physics of a heterogeneous environmental system that simple hydrology model has less skill to capture these complexities. This case study argues that it is no longer appropriate to ignore uncertainty, instead seek to embrace uncertainty, and this research demonstrated both complicated and simplified examples of such.

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+NON-STATIONARY INTENSITY-DURATION-FREQUENCY CURVES FOR DRAINAGE INFRASTRUCTURE COPING WITH THE OCTOBER 2015 CATASTROPHIC FLOODS IN THE CAROLINAS

Non-stationarity in hydrological extremes has emerged as a prevailing issue in water resources engineering and stormwater drainage design, underscoring the need to better characterize the statistical assumptions underlying classical extreme value frequency analysis. The focus of this study is on developing probabilistic stationary and non-stationary rainfall and runoff intensity-duration-frequency (IDF) curves for the major catchments in the Carolinas by incorporating large scale modes as covariates in the extreme probability distribution. Two nested (stationarity versus non-stationarity) extreme value analysis (EVA) models were fitted to the short- (i.e. 24-hr) and long-duration (daily, monthly, seasonal and annual) intense rainfall and flash floods by incorporating linear/non-linear combination of large-scale oscillations (i.e. the El Niño-Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO)). The likelihood ratio test for stationary and nonstationary models indicated that incorporation of large scale modes in parameters estimation of extreme distribution is statistically significant and the null hypothesis of stationarity should be rejected. Application of various heavy-tailed probability distributions including the generalized extreme value (GEV), the Generalized Pareto (GP), and the Point Process (PP) functions revealed upward trends in most climate and streamflow gauges with changes in the location (mean), scale (standard deviation) and shape (skewness) parameters. Further, the stationary return levels (2, 20, 50,100, 500, and 1000 years) computed by Monte Carlo method were much lower than those under non-stationary assumption. Given the non-stationary behavior of extremes, current IDF curves can substantially underestimate the magnitudes and frequency of intense rainfall and floods, indicating the susceptibility of the storm drainage and flood control structures in the Carolinas that were designed under assumptions of a stationary climate.

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SC Sea Grant Consortium

CREATION OF A VISUALIZATION AND ACCESS PORTAL FOR COASTAL SOUTH CAROLINA WATER MONITORING AND SAMPLING LOCATIONS (T1,S5)

An integrative visualization portal for sharing and coordinating coast-wide, multidisciplinary water monitoring efforts is being developed by the SC Sea Grant Consortium, through partnership with state and federal agencies and academia, in response to the major flooding in South Carolina during October 2015. When examining the short and long-term effects of the flood on South Carolina coastal and marine ecosystems, residents, and infrastructures, the water quantity impacts are highly visible; however, it is important to also understand and communicate water quality impacts. In response to the lack of a central location where information about ongoing water monitoring can be found, the SC Sea Grant Consortium initiated discussions with research and technical representatives from academic institutions and government agencies to explore the need for a permanent platform to identify sampling locations, data being collected, and frequency of sampling by these institutions. Such a platform will allow for information-sharing among institutions and with the general public. Additionally, interest in having the platform illustrate both long-term monitoring programs occurring in the state and short-term monitoring in response to events was evident. With guidance from the institutional representatives, a web-based visualization portal is being built that will allow users to display the locations and details of monitoring sites in coastal South Carolina watersheds and waterways. Consortium staff investigated both free and cost-based options for developing and hosting the visualization portal. We hosted a webinar to allow scientists and staff to evaluate these options and to determine the best platform for reaching a broad audience, while still providing utility to technical users. Desirable features were identified, such as easy-to-use tools for broader audiences interested in the nature of ongoing monitoring efforts, as well as tools for advanced users to search, filter, and download information. Ultimately, we are leveraging existing resources, including ESRI's ArcGIS Desktop geographic information system (GIS) software and ArcGIS Online, for data management, tool creation, and web-hosting. Part of building the tool is creating a framework for scientists to easily submit and update site metadata and

geospatial information as needed. The data collection framework will be based on guidelines from the National Water Quality Monitoring Council and input from group members. When adding sites to the portal, scientists will provide the following information: 1.) contact details; 2.) reason for sampling; 3.) frequency and period of record; 4.) location; 5) sampling parameters. Once portal users identify sites of interest, they will be provided with the contact information for the scientist associated with each site so they can request additional information or data. Monitoring data will not be served directly from the portal; it will remain with the host institution's database.

***Schildtknecht, Cara,** Susan M. Libes, Adam Leaphart, Jeff Barley
Coastal Carolina University

+MURRELLS INLET ESTUARY MICROBIAL SOURCE TRACKING STUDY

SC Department of Health and Environmental Control approved a Total Maximum Daily Load for fecal coliform in 2005 that required an 80% load reduction in Murrels Inlet estuary. To identify sources of fecal bacteria coliform a volunteer monitoring program was initiated in 2010. Biweekly measurements of *E. coli* have documented consistently elevated levels at three tributary termination sites. A microbial source tracking study was undertaken in order to identify and eliminate human-sourced fecal bacteria sources. The objective of this study was to determine whether human-sourced fecal bacteria are present in the identified subwatersheds. Five sample sites were selected including the three tributary termination sites identified by the volunteer monitoring as having elevated levels of fecal bacteria concentrations as well as two upstream sites. Samples of water and sediment were collected during three dry and three wet events during the summer and fall of 2015 when fecal bacteria concentrations were expected to be highest. Samples were then analyzed for tracers including human-sourced bacteroides, bacteriodes, *E. coli* and total coliforms, fecal coliforms, caffeine, turbidity, and salinity. The study revealed higher fecal bacteria concentrations and higher turbidity levels during rain events than during dry events. There is minimal evidence to attribute the elevated bacteria concentrations to human sources. Because significant contributions of fecal bacteria were found, further source tracking upstream should be performed to identify the source of contamination. Additional genotypic assays should be performed to determine the source of fecal bacteria.

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+SOUTH CAROLINA STORMWATER DETENTION PONDS: SEDIMENT ACCUMULATION AND NUTRIENT SEQUESTRATION

Wet detention ponds are common storm water control structures employed throughout the South Carolina coastal region. These ponds receive runoff waters carrying both suspended sediments and nutrients. As sediments accumulate in these ponds, water volume is reduced leading to a decrease in runoff retention. Periodic dredging is required to maintain pond function, but dredging is costly and there is little data available to support how often pond dredging is required. This research has two main goals. The first is to quantify the rate of bulk sediment accumulation, and subsequent volume loss, using lead-210 sediment dating and bulk sediment accumulation measurements. The second goal is to quantify the role these ponds play in regional carbon, nitrogen, and phosphorus cycling. In addition to bulk nutrient and carbon analyses, biomarkers will be used to determine organic matter origin (i.e., aquatic verses terrestrial). We hypothesize that watershed development density and pond management regime greatly influences pond water quality, sediment nutrient sequestration, and the sources of organic matter to pond sediments.

Scott, Geoffrey[1], M. Baalousha[1], S. McNeal[1], D.E. Porter[1]. S. Norman[1], M. H. Fulton[2], E.F. Wirth[2], P. L. Pennington[2], and M. Uyaguari[3]
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AN ASSESSMENT OF NPS RUNOFF POLLUTION IN COASTAL STORMWATER PONDS OF SC AND THE POTENTIAL FOR DEVELOPMENT OF ANTIBIOTIC RESISTANT MICROBES (T3B,S2)

NPS runoff in highly urbanized coastal areas may result in significant levels of being discharged into stormwater ponds, tidal creeks and estuarine habitats. Traditionally environmental monitoring programs have measured legacy contaminants pollutants (trace metals, PAHs, and pesticides/PCBs) but not Contaminants of Emerging Concern (CECs). CECs present many challenges in terms of monitoring and assessments (e.g. lack of analytical methods and toxicological studies). These challenges are exacerbated because many CECs interact with metabolic pathways to produce adverse outcomes through nontraditional toxicological evaluations. Antibiotics are a major class of CECs that pose significant environmental risks which may lead to the development of both toxic effects at high doses > Minimum Inhibitory Concentration (MIC) and development of antibiotic resistance at doses < MIC. Antibiotics have been measured at 48% of 139 US surface waters tested in national monitoring programs. The spread of antibiotic resistance (ABR) has generally been attributed to the use of antibiotics in both livestock and medicine which may result in environmental discharges from wastewater treatment plants (WWTPs), confined farm animal operations (CAFOs) and aquaculture practices. In addition, there is mounting evidence that chemical contaminants such as trace metals may enhance antibiotic resistance in some bacterial species such as *E. coli*. This may be a particular problem in stormwater ponds which may concentrate many chemical contaminant such as trace metal and PAHs as well as Contaminants of Emerging Concern (CECs) such as antibiotics. The

objective of this study was to assess the potential hazards posed by chemical contaminants that may enhance antibiotic resistance in the environment. An assessment of legacy pollutants and CECs was conducted in coastal region of South Carolina by examining reported sediment contaminant levels in stormwater ponds and estuarine tidal creeks. Reported sediment contaminant concentrations were compared to Sediment Quality Guidelines (SQGLs) to assess their potential to cause adverse effects on aquatic and benthic species. Also regional National Status and Trend reporting data were evaluated to assess actual toxicity data within the region with SQGL predictions. In addition, concentrations of antibiotics in WWTP effluent and surface waters were monitored along with ABR levels in bacteria (and levels of the BLAm-1 gene) at several locations in South Carolina and around the US. Results found the presence of several antibiotics in effluent and surface waters (Triclosan and tetracycline) that posed significant environmental risks at WWTPs and aquaculture operations, respectively. High rates of ABR in *E. coli* bacteria (5-22%) were found in WWTPS and CAFOs in South Carolina. The BLAm-1 gene was found to survive WWTP disinfection and was discharged into the marine environment, accumulating in sediments at levels > 1000 times found in WWTP effluent, posing a potential hazard for gene transfer to other microbial species including Vibrio bacteria. Risk assessment methods for assessing the potential for development of ABR will also be discussed along with interactions of legacy pollutants to enhance antibiotic resistance, which may be a significant issue in stormwater ponds and estuarine sites that may contain high levels of chemical contaminants.

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TOP-DOWN AND BOTTOM-UP CONTROLS OF PHYTOPLANKTON ASSEMBLAGES IN TWO SOUTH CAROLINA ESTUARIES (T7,S4)

Accelerated population growth and urbanization along the South Carolina coast has resulted in nitrogen (N) and phosphorus (P) loading into receiving aquatic systems. Prior research suggests that phytoplankton biomass and numbers of harmful algal bloom (HAB) species increase in response to N, particularly urea and in developed and developing waterways. However, the extent that phytoplankton responses vary in tidal creeks within a single estuary remains unclear. Despite emerging evidence of the importance of bottom-up (resource) factors (e.g. nutrients), there is a fundamental lack of understanding about the importance of top-down (e.g. grazing) control on South Carolina phytoplankton productivity. This study investigates phytoplankton assemblage responses in tidal creeks to N-form (ammonium, nitrate, and urea) and the effects of zooplankton (copepods and ciliates) grazing on net phytoplankton growth. Results will be coupled with streamflow analyses as part of a broader project to investigate how nutrient delivery (rate and volume) affects coastal biological responses and will aid regulatory managers in the development of estuarine nutrient standards. This study uses a paired site design within two estuaries: Charleston Harbor and the Ashepoo-Combahee-Edisto (ACE) Basin. Two tidal creeks per estuary were selected such that one site is located in a comparatively more developed river system and the second is in a relatively less impacted system. Charleston Harbor sites include Bull and Horlbeck Creeks. Bull Creek is located on the Ashley River, which has experienced elevated concentrations of nutrients and fecal coliform bacteria, whereas Horlbeck Creek is located on the Wando River which contains the least amount of upland development of the three Charleston Harbor rivers6. ACE Basin sites include Big Bay and Wimbee Creeks. Big Bay Creek is located on the South Edisto River which has shown increasing total phosphorous (TP) concentrations and high Enterococcus bacteria, and Wimbee Creek is located on the Combahee River, where land cover includes wetlands, forest, and open water. Basic water quality, nutrients, phytoplankton (biomass, as pigment and biovolume and community composition), and zooplankton (taxonomic classification and abundances) from monthly sampling as well as in situ nutrient addition bioassays (spring and summer, 2015-2016) are being measured. Experiments are conducted using two treatment groups: one with unfiltered water, and one with 153 mm mesh-filtered water to exclude adult copepods. Bioassay deployments are partnered with a YSI data sonde and an ISCO autosampler to monitor ambient conditions over a complete tidal cycle. Preliminary data (2015) showed that N-additions increased phytoplankton biomass and growth, indicating sites are susceptible to N-inputs, particularly during the summer. Furthermore, filtered treatments typically exhibited higher growth rates than unfiltered treatments, potentially due to the removal of adult copepods. Ciliate abundances coincided with phytoplankton biomass, suggesting that microzooplankton may play an important role within these systems. Dilution experiments will be conducted during the summer of 2016 to estimate grazing rates and further discern the potential importance of micro- and mesozooplankton as South Carolina phytoplankton population and biomass controls.

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POLLUTANT REMOVAL PERFORMANCE IN STORMWATER DETENTION PONDS TYPICAL OF COASTAL SOUTH CAROLINA (T3,S4)

Wet detention ponds are the most commonly employed management practice for controlling stormwater runoff from developed landscapes in coastal South Carolina. Intended and designed primarily as water quantity control structures to minimize localized flooding, they are increasingly expected to serve as a means of controlling water quality impacts to adjacent receiving waters through the removal/retention of pollutants. Although expected removal capabilities for common pollutants are listed in state and county stormwater guidance documents, actual

measures of pollutant removal performance in detention ponds from coastal South Carolina do not currently exist. In addition, no regionally relevant studies have attempted to constrain the relative roles of surface runoff (piped inflow and overland sheetflow) versus groundwater inputs to coastal detention ponds, despite conditions that suggest groundwater may play a significant role in watershed hydrologic budgets. Pond effectiveness in reducing four major pollutants of concern (total phosphorus, total nitrogen, total and inorganic suspended sediments, and fecal bacteria as most probable numbers of *E. coli*) was determined by intensive storm event sampling of inflows and outflows of three individual ponds over a period of two years. None of the study ponds had engineered forebays, littoral shelves, vegetated buffers, or other innovated designs. Rather, ponds were selected in consultation with county stormwater managers to be representative of the large number of ponds typical of the planned unit developments built over the last two decade along the South Carolina coast. For each pond, piped inflow and outflow sampling was accomplished with automated samplers triggered by the onset of precipitation that sampled over the course of the hydrograph to allow for the calculation of event mean concentrations of nutrients and sediments. The strict holding time requirements for *E. coli* sampling, however, often resulted in single time-point collections for this parameter. Sheetflow sampling was accomplished by deploying self-sealing stormwater collectors buried flush at the edges of ponds where overland runoff into the pond was observed to occur. Shallow groundwater sampling was accomplished by manual pumping of water from transects of wells installed perpendicular to the pond edges. Across all ponds and rain events, concentrations of all pollutants were generally highest in overland sheetflow, followed by piped inflows, followed by groundwater. All surface input sources had significantly higher concentrations of pollutants than did outflow waters. Estimates of pollutant removal efficiencies ranged from: 63-71% for total phosphorus; 40-47% for total nitrogen; 67-87% for sediments; and 82-98% for *E. coli*. These ponds thus met or greatly exceeded, in the case of *E. coli*, expected pollutant removal capabilities for wet detention ponds despite their lack of more innovative design features. The finding that overland sheetflow can be a significant route of pollutant delivery to residential ponds suggests that use of vegetated buffers and littoral shelves may contribute to further increases in the effectiveness of pond pollutant removal capacity. The large percentage of nitrogen not removed by ponds remains a concern, however, given the potential for this nutrient to fuel excess productivity of downstream marine waters.

***Soto Pérez, Jeniffer,** Vijay Vulava
College of Charleston
+GEOCHEMICAL FATE AND TRANSPORT OF DIPHENHYDRAMINE IN NATURAL SOILS
Common pharmaceuticals like diphenhydramine have been detected in streams and groundwater sources as a result of sewage overflows, runoff, or treated wastewater discharge. In this study we investigated the geochemical behavior of diphenhydramine in natural soils and determined the reactivity to major soil components. Diphenhydramine is a common antihistamine used to treat allergies and common cold symptoms, reduce cough, induce sleep, and treat motion sickness. It is a polar organic molecule with a reactive amine functional group and two benzene rings, and has aqueous solubility of 3.060 g/L and pKa of 8.98, which causes the molecule to be positively charged in low acidic pH range. The main objective of this study was to determine sorption and transport behavior of diphenhydramine in natural soils. Laboratory tests were performed using two types of uncontaminated soils. An organic-rich A-horizon (organic matter 6-8%), and a clay-mineral-rich B-horizon (clay mineral content ~20%) to perform batch sorption isotherm and column transport experiments. Diphenhydramine was analyzed utilizing high performance liquid chromatography (HPLC) and liquid chromatography mass spectrometry (LC-MS) methods. Sorption studies performed using batch reactor technique showed nonlinear correlation between soil-bound and aqueous diphenhydramine in both organic and clay-rich soil. However, diphenhydramine sorbed stronger to clay-rich soils than to organic-rich soils. This could be due to the ionic bonding between the amine functional groups in diphenhydramine molecular structure and the negative charge present on clay mineral (predominantly kaolinite) surfaces in soil. Breakthrough curves obtained from glass chromatography experiments confirmed that diphenhydramine was strongly retained in B-horizon soil. The results suggest that natural mineral-rich soils can filter chemical compounds like diphenhydramine.

Starker, Chris
Upstate Forever
DIVING INTO DEVELOPMENT STANDARDS TO FIND STORMWATER REMEDIES THAT SAVE MONEY AND IMPROVE SAFETY (T3A,S3)
Impervious cover in a watershed results in increased surface runoff. Even as little as 10% impervious cover can degrade streams. Upstate Forever reviewed paving and stormwater management requirements to identify standards that may be requiring excess, unnecessary pavement related to street width, parking ratios, sidewalk and driveway specifications, and other aspects of paved surfaces in the land development process. The objective is to limit the amount of impervious cover generated by new development. The ultimate goal is to reduce the amount of stormwater runoff while minimizing the infrastructure costs associated with development. Connected streets, narrower street widths, and alternative pavement edge treatments can increase safety by encouraging vehicles to travel safe speeds, minimize clearing and grading, and reduce stormwater runoff while providing ample access for emergency vehicles, residential vehicles, and parking. No other surface in a watershed produces more runoff and delivers it faster than a parking lot. A one-acre asphalt parking lot produces 16 times as much stormwater runoff as a one-acre meadow. Given the prevalence of parking lots in the urban and suburban landscape, alternative designs can save money and reduce stormwater. Driveways can account for as much as 20% of the impervious cover in a typical residential subdivision. By specifying

narrower driveways, using permeable paving materials, and allowing two-track driveways or gravel and grass surfaces, communities can reduce the typical 400 to 800 square feet of impervious cover created by each driveway.

Stroud, Andrew
City of Columbia
THE CITY OF COLUMBIA STORMWATER MANAGEMENT PROGRAM AND INTEGRATING WATER QUALITY COMMUNITY OUTREACH AND EDUCATION WITH A VOLUNTEER ADOPT-A-STREAM PROGRAM (T3A,S1)
Since the City of Columbia established its Stormwater Management program in 2010, the program has developed a progressive water quality monitoring program in the Gills Creek, Rocky Branch, Kinley Creek and Smith Branch watersheds. To comply with the City's National Pollutant Discharge Elimination System (NPDES) permit, the City started monitoring in all impaired water bodies. To understand the water quality in these impaired watersheds, the City launched continuous water quality monitoring stations at strategic locations throughout the city. The continuous water quality monitoring provides uninterrupted record of data with each water body. The water quality parameters collected by these stations are dissolved oxygen, pH, specific conductivity, turbidity, and temperature. The City also has a rain gage network and is in the process of development of flow measurements with a SonTek IQ. This analysis of data will help us develop a relationship between hydrologic process and water quality. With the development of the City's water quality program, the City is always looking to do further outreach and education. Partnering with Gills Creek Watershed Association (GCWA), the City is in the planning process for implementing a volunteer water quality monitoring program. The Georgia Environmental Protection Division started the Georgia Adopt-a-Stream program. The adopt-a-stream program can be customized to fit the needs of municipalities and volunteer groups. The municipalities get the benefit of additional sampling that may lead to illicit discharge detections. The adopt-a-stream program also promotes community involvement in water resource management, non-point source pollution awareness, and water quality questions. The City's Stormwater Management program plans to work with GCWA by purchasing water quality monitoring kits for volunteer use. All data collected by the volunteer groups will be shared with the City and the Georgia Adopt-a-Stream website which houses all volunteer data. The City and GCWA believe this is a great opportunity for data collection in areas the City is not currently collecting data and most importantly community involvement in water quality and environmental stewardship.

Swanger, Lisa
Coastal Carolina University
+ENHANCING STORMWATER PUBLIC EDUCATION AND INVOLVEMENT EFFORTS THROUGH UNDERGRADUATE STUDENT INTERNSHIPS AND PROJECTS
The Coastal Waccamaw Stormwater Education Consortium (CWSEC) was established in 2004 to assist small municipal separate storm sewer systems (SMS4s) located within the Myrtle Beach Urbanized Area to meet federal requirements for stormwater public education and involvement associated with the National Pollutant Discharge Elimination System Phase II permit program. This includes the development and delivery of effective stormwater and watershed education programs for diverse audiences within the Waccamaw River Basin and coastal watersheds along South Carolina's northern coast. Through mutually beneficial internships and independent study courses supervised by the CWSEC Coordinator, Coastal Carolina University (CCU) undergraduate students are given the opportunity to receive professional hands-on stormwater education and outreach experience with the public and local schools, while assisting CWSEC to enhance their reach to local communities. One of the key focus areas of the Environmental Education Internship is to coordinate CWSEC's Storm Drain Marking Program with the goal of increasing public awareness regarding the transport of pollutants via stormwater into local waterways through the installation of decals near storm drain devices. This program also includes an optional presentation using an interactive watershed model prior to the marking activity. The environmental science independent study course instructs students each fall and spring semester to complete projects relating to stormwater / watershed education and outreach for coursework credit. Enrolled students take an active leadership role in all stages of the project, including background research, project development and coordination, and communication with the appropriate target audiences. Three recent projects include the Grand Strand's Canines for Clean Water spokesdog contest, a pet waste public education program; educational material recommendations for the Murrells Inlet Watershed Plan; and an experiential learning watershed mapping activity for local schools using GPS devices. Continuing forward, a new spring 2017 independent study project is planned to offer students the opportunity to assist with CWSEC's NOAA climate stewards project focused on incorporating climate science concepts into previously developed stormwater lessons and rain garden maintenance activities for local schools in an effort to promote increased school and community awareness and engagement. Such undergraduate internship and course opportunities are valuable for not only providing aspiring professionals real-world experience, but also ensuring the continuation and advancement of CWSEC's efforts in the future.

Thepaut, Benjamin, James Landmeyer, John Shelton
USGS South Atlantic Water Science Center
STREAMGAGING TOWARD THE FUTURE: CONTINUOUS NITRATE MONITORING, WACCAMAW RIVER WATERSHED, SC (T7,S5)
The US Geological Survey, South Atlantic Water Science Center, Conway Field Office is located in Horry County on the northeastern coast of South Carolina and maintains streamgages at 27 locations in the Santee and Pee Dee River basins. These streamgages or monitoring stations house equipment which record parameters such as stage, velocity, water temperature, specific conductance, pH,

dissolved oxygen, and turbidity in real time. Data are typically recorded at 15-minute intervals and transmitted via satellite every hour for display on the USGS web pages at: *http://waterdata.usgs.gov/sc/nwis/rt*. The stations are located in diverse hydrologic environments that range from fresh to brackish to marine water-quality conditions. Additionally, some of the stations are tidally affected. The stations are currently designed to easily accept additional equipment to monitor other water-quality parameters. This ability of the USGS stations to incorporate additional parameters is timely and beneficial as the South Carolina Department of Health and Environmental Control is currently developing nutrient concentration criteria for estuaries, rivers, and streams. The presentation will focus on the proposed collection of continuous nitrate (NO3-) data at the existing streamgage Crabtree Swamp at Conway, South Carolina (USGS Station Number 02110701). Objectives include the validation of deployment strategies, determining baseline nutrient concentrations in tidal and fresh black-water systems, and an assessment of the inputs of nutrients into this system.

Torak, Lynn J., Jaime A. Painter
USGS South Atlantic Water Science Center
INTEGRATING IRRIGATION METERING AND IMAGERY ACQUIRED FROM UNMANNED AIRCRAFT SYSTEMS WITH GEOSTATISTICAL ANALYSES TO ENHANCE AGRICULTURAL PRODUCTION AND CONSERVE ENERGY AND WATER RESOURCES IN SOUTH CAROLINA (T4,S2)
South Carolina boasts more than 25,000 farms, occupying nearly 5 million acres of the State's landscape, with each farm requiring water to meet their unique agricultural needs. Diversity in South Carolina's climate, from the mountains in the Upstate to the flatlands of the Coastal Plain, and variations in soil composition and water-holding ability, oftentimes across individual fields, pose a perennial challenge to farmers to maintain agricultural production and marketability each year. Climatic extremes and limited energy and water resources threaten the health of the farming industry, which is essential to the food supply of South Carolina, the Nation, and the World. Valuable information about the patterns and amounts of water used to irrigate crops amidst the diverse climatic and soil conditions of South Carolina can be derived from a purposefully designed and implemented metering program. Thermal infrared (TIR) imagery acquired from low-altitude flights of unmanned aircraft systems (UAS) in agricultural regions can identify areas of crop stress and low agricultural production stemming from adverse soil-moisture conditions caused by over- or under-irrigation. Knowledge of the distribution of soil-moisture conditions on individual fields can direct precision-agricultural practices, such as variable-rate irrigation, to enhance agricultural production while simultaneously conserving energy and water resources. At the core of these two diagnostic tools - metering and UAS imagery - lies the analytics of geostatistical techniques that can identify, mathematically represent, and estimate agricultural water use and soil-moisture conditions accordingly on unmetered fields or where imagery might not exist. Recent applications of geostatistical analyses applied to the agricultural metering program implemented in Georgia and to UAS-TIR imagery acquired in southwestern Georgia are presented to demonstrate their value in identifying irrigation water use and to enhancing agricultural production while conserving energy and water resources for the farming industry of South Carolina.

***Turner, Ashley,** Vijay Vulava
College of Charleston
+GEOCHEMICAL FATE AND TRANSPORT OF SILDENAFIL IN NATURAL SOILS
In recent years, pharmaceutical drugs have become of increasing concern to the health of our environment. As a result of wastewater treatment plant discharge and various sources of surface runoff, pharmaceuticals can be found in trace amounts in our most common water resources. Sildenafil, a drug marketed to treat erectile dysfunction, is amongst the top 20 most prescribed pharmaceutical products in the US Sildenafil is a complex polar organic molecule with multiple amine functional groups, which gives it acid-base functionality. The most common pKa of this molecule is approximately 6.0 and water solubility ranges from 3.5 to 4.6 mg/L. The goal of this project is to examine the sorption and transport behavior of sildenafil in natural organic matter- (OM) and clay-rich soils. Soils used for this study were collected from undisturbed forested areas in Francis Marion National Forest, Charleston, South Carolina. A series of batch sorption isotherm and column transport experiments were conducted with these soils. Sildenafil was analyzed using high performance liquid chromatography (HPLC) and liquid chromatography mass spectrometry (LC-MS) techniques. Batch sorption isotherm experiments showed nonlinear trends in both OM- and clay-rich soil types. Sorption data showed that sildenafil sorbs more strongly to the clay-rich soils than to the OM-rich soils. This suggests that sildenafil behaved as a cation and preferentially sorbed with the negatively-charged clay minerals. The transport behavior of sildenafil as determined by experiments with soil-packed glass chromatography columns confirmed this behavior. The resulting breakthrough curves show that sildenafil is strongly retarded in clay-rich soils. Our studies do not show degradation or transformation of sildenafil in soils. The results from this study can guide environmental management of pharmaceutical chemical effluents and disposal.

Tweel, Andrew, Erik M. Smith[2], Denise M. Sanger[1], Erin Koch[1]
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A STORMWATER POND INVENTORY FOR THE EIGHT COASTAL COUNTIES OF SOUTH CAROLINA (T3B,S1)
Although common landscape features of most development practices nationwide, stormwater ponds are particularly prevalent in the Southeast coastal plain due to the region's shallow water table, flat topography and storm-driven rainfall events. Knowledge of the total number, relative distribution and cumulative surface area of stormwater ponds within coastal South Carolina is currently poorly constrained. This represents a key information gap in determining how the creation and use of ponds as a stormwater management

practice has changed the hydrology and associated material transport within the coastal zone. The objectives of this work were to create an inventory of the current number, size and geographic distribution of small artificial water bodies ("ponds") in the eight coastal counties of South Carolina, to attempt to classify these ponds based on their surrounding landscape attributes, and then to conduct a retrospective inventory analysis for select regions of the South Carolina coast to estimate rates of pond construction. Based on 2013 aerial imagery, the most recent year available, the eight coastal counties contain a total of 21,594 ponds, which collectively comprise a cumulative area of 29,395 acres. Only 9,269 of these ponds, representing 43% of the total, were determined to be associated with development-related land uses (i.e., residential or commercial development, golf courses, or a combination of residential and golf), and thus can be assumed to have been created specifically for stormwater management. The remaining ponds were associated with agricultural or rural land uses. Horry, Charleston and Beaufort counties have the highest number of ponds, collectively containing 64% of all ponds and 75% of the development-related ponds within the eight coastal counties. The majority of all ponds, and especially those associated with developed landscapes, are situated within 1 mile of major surface receiving waters. In both the greater Charleston region and along the Grand Strand (Georgetown and Horry counties), the total area represented by ponds increased at a rate of more than 4 percent per year between 1994 and 2013. Ponds, especially those associated with coastal development, are thus increasing rapidly along South Carolina's coast and the majority of them are likely intimately linked to downstream receiving waters. As such, the proliferation of ponds in coastal South Carolina has likely had a significant impact on coastal hydrology as well as the transport and transformations of material carried by stormwater runoff to coastal receiving waters.

***Van Brunt, Sarah,** Ashley Willis, Ellen Featherstone
Clemson University

+CLEAN WATER^3: AN UNDERGRADUATE EXPERIENCE

Through a partnership between the Clemson University Professional Internship and Co-Op (UPIC) program and the USDA Specialty Crop Research Initiative (SCRI) Clean WateR^3 grant, undergraduate students took part in a comprehensive research internship including laboratory, greenhouse, and field studies. Undergraduate students began the internship by researching academic literature within the focus areas of water remediation techniques in order to develop foundational knowledge about the research on which they worked. Interns then utilized the information to help PhD students conduct experiments pertaining to their literature reviews. Students carried out laboratory and greenhouse trials studying 1) *Phytophthora spp.* and wetland plant susceptibility, 2) pH and alkalinity effects on wetland plant nutrient uptake, and 3) the use of floating treatment wetland plants to remove excess nitrogen and phosphorous from the water column. Students also helped to implement water quality and flow equipment and to monitor runoff from a local nursery. Their experiences with these laboratory and greenhouse experiments, as well as field monitoring and data retrieval, in conjunction with the knowledge gained from the literature review, served to guide designs for effluent remediation. Over the course of the three-month internship, students gained a critical understanding of remediation techniques available to green industry professionals, laboratory and field practices, and professional networking.

Vandelay, Angela, Kelli Garcia
Amec Foster Wheeler

DEVELOPMENT OF WATERSHED PLANS (T1,S6)

EPA's Stormwater Phase II Rule established a Municipal Separate Storm Sewer Systems (MS4) stormwater management program intended to improve the Nation's waterbodies by reducing the quantity of pollutants that stormwater collects from urbanized areas and discharges through storm sewer systems into waterbodies during rain events. The current South Carolina Small Municipal Separate Storm Sewer Systems (SMS4) permit requires municipalities to conduct Total Maximum Daily Load (TMDL) monitoring to shed light on its potential contribution to water quality impairments. After a minimum of two years of TMDL monitoring, the SMS4 must analyze its monitoring results in order to develop a required TMDL Implementation Plan. We will investigate the approach an SMS4 may take developing their TMDL Implementation Plan based on the type of monitoring implemented, the areas for which the SMS4 is responsible (i.e. in the SMS4's jurisdiction and control) vs. the rest of the watershed, land use, the pollutant(s) of concern and its sources. This information must be evaluated to determine the actions the SMS4 can take to reduce its municipal separate storm sewer system loading to a waterbody. Similarly, watershed based plans (WBPs) present a more comprehensive look at sources affecting water quality in a watershed. WBPs identify pollutants in a watershed (not only the municipal separate storm sewer contributions), determine the sources of those pollutants and describe what needs to be done to address all sources to help improve water quality in the waterbody. Watershed Based Plans are specifically required when applying for 319 Funding. We will discuss the preparation of bacteria and macroinvertebrate Watershed Based Plans for Twenty-five Mile Creek Watershed and how these plans have led to $547,000 of Best Management Practices (BMPs) being installed in the watershed., Then we will compare the similarities and differences between TMDL Implementation Plans and WBPs and the benefits of each type of plan. Referencing the EPA's nine elements of a Watershed Based Plan (WBP), we will discuss the potential outline and procedure for developing WBPs and TMDL Implementation Plans. Elements of a WBP and TMDL Implementation Plan to be covered will include identification of pollutant sources; BMPs needed to control pollutants; estimated load reductions from identified BMPs; funding needs and potential sources of funding; outreach strategy; timeline; milestones; criteria to evaluate load reduction; and criteria to evaluate the effectiveness of the plan. Stormwater Managers will learn the benefits and uses of TMDL implementation plans and watershed plans and how each type of plan can benefit their community.

***Vesely, William**, Timothy J. Callahan, Vijay M. Vulava
College of Charleston

USING DISSOLVED ORGANIC CARBON CONCENTRATION AND CHARACTER DATA TO ASSESS LAND USE CHANGE EFFECTS ON COASTAL WATERS (T7,S4)

We are studying the high-productivity terrestrial and estuarine ecosystems of the southeastern US coastal zone and the carbon and water cycles in this region. We investigated the water quality of coastal waters in South Carolina with a focus on how rapid land use and land cover change in the Charleston, South Carolina region may be influencing aquatic dissolved organic carbon (DOC). We show that analysis of DOC and its chemical nature helps us understand the role of DOC in coastal ecosystems that are under anthropogenic stress. Synoptic sampling of water from tidal creeks, rivers, and shallow groundwater in the Charleston, South Carolina region has been ongoing since 2015. Sampled areas include the Francis Marion National Forest (freshwater), the Filbin and Noisette Creek watersheds (fresh-brackish and saltwater urban stream systems, respectively, in North Charleston, South Carolina), the Ashley River (a brackish to saltwater estuarine river), Charleston Harbor (saltwater), and the Ashley-Combahee-Edisto (ACE) Basin (brackish to saltwater estuarine rivers). Filtered and acidified water samples were analyzed for DOC concentration (mg/L) using a Total Organic Carbon (TOC) Analyzer. The fraction of aromatic carbon was determined by analyzing water samples on a UV-Visible Spectrophotometer and normalizing absorbance by DOC concentration to determine specific absorbance (SUVA) of the organic carbon. The SUVA value is a surrogate measure of the percent aromaticity of organic carbon, which may reflect decomposing of terrestrially-derived humic material (e.g., leaf litter). Preliminary results indicate that (i) water salinity is inversely correlated with DOC concentrations and has no relationship with aromatic properties, (ii) DOC and SUVA values are correlated to land cover and not land usage, (iii) DOC in forested systems had significantly larger fraction of aromatic carbon, and (iv) DOC is easily mobilized in more-developed watersheds by rain events. This study provides a broad look at DOC concentrations and character in natural waters with varying salinity in coastal South Carolina. We will present analytical results of the sampling campaign as well as watershed maps to help visualize the DOC-surface water dynamics in coastal waters around the Charleston and ACE Basin estuaries. These data will be useful to scientists and coastal resource managers who are working to understand and mitigate the impacts of coastal land development on aquatic ecological health and water quality in this region.

Vogel, Kenneth, Ashok Mishra
Clemson University

⁺IMPACTS OF DROUGHT ON WATER QUALITY WITHIN THE SAVANNAH RIVER BASIN

Droughts affect water quantity and quality in almost every region of the world, whether it results from minimal precipitation or low stream flows and with climate change, the magnitude and prevalence will increase. These prolonged periods of abnormally low rainfall and very low stream flows result in drastic changes to water quality, but to what extent of the indicators of water quality are less recognized. This paper focuses on how droughts affect the indicators of water quality, such as pH, suspended solids, turbidity, fecal coliform, along with other indicators. Time series of water quality indicators from the Savannah River basin in the Southeast United States were gathered from existing water quality data, and the measurements taken during drought and low flow periods were analyzed. This analysis was compared to water quality indicators during normal flow periods. An empirical relationship was found between the drought and low precipitation with water quality. This study further analyzes the changes in water quality based on the intensity of the drought period. We used drought indices such as Palmer Drought Severity Index (PDSI) and Standardized Runoff Index (SRI) to quantify drought events in our analysis.

Vulava, Vijay, Barbara Beckingham, Timothy Callahan
College of Charleston

SOURCES, FATE, AND TRANSPORT OF CONTAMINANTS IN ENGINEERED STORMWATER STRUCTURES: A COASTAL SOUTH CAROLINA PERSPECTIVE (T3B,S3)

The objective of this study was to delineate processes that influence the fate and transport of contaminants in stormwater ponds, summarizing and integrating the fundamental and practical knowledge from the fields of hydrological and pollution sciences. Specific examples and lessons learned in settings with geological and geographical relevance to coastal South Carolina are the main focus. The physiographic region known as the Atlantic Coastal Plain of the Southeast US (seaward of the Fall Zone along the line of Aiken-Columbia-Fort Mill in South Carolina) has been "replumbed" over the past four decades due to extensive water management installations commonly known as stormwater ponds. Under increasing development pressures, coastal South Carolina has and continues to undergo land use transitions tending toward residential and urban development with increased impervious cover. Regulatory policy requires creation of artificial depressions in the form of dug ponds and lakes that are sized to sequester a given volume of stormwater that would be shed from the developed property greater than that under pre-development conditions. Stormwater ponds are often the default solution to manage increased runoff from development projects because of regulatory rules, and in this region many of these systems take the form of "wet detention ponds". The bit-by-bit approach to development has resulted in more than 30,000 constructed stormwater ponds in the eight coastal counties of South Carolina. What has not been clear is the water balance impact of these human-made receiving waters (larger fraction of surface water, smaller fraction of groundwater infiltration as recharge) and the transport and fate of pollutants into and within stormwater ponds. One important concern is that stormwater runoff is a primary vector of contamination into receiving bodies of water. The contamination in water is present in diverse forms - physical (sediment, nanoparticles, other particulate matter, etc.), chemical (nutrients, trace metals, complex organic chemicals, etc.), and biological (pathogens) forms. Contaminant fate in the environment is governed by complex physical and biogeochemical processes, most of which are basically understood (nature of contaminant, sorption, degradation,

and transformation processes, and transport). However, there are no holistic studies that address water quality issues in these systems - most existing studies focus on a small subset of processes or contaminants. More broadly focused studies are, therefore, needed. It is clear that cross-cutting perspectives will be crucial to addressing key questions about the role stormwater ponds play in this dynamic physical, ecological, and human-dominated coastal system. We will present a review of past on ongoing studies that aim to understand the impacts of stormwater ponds on the water cycle and contaminant transport, and discuss gaps in the knowledge base and how future studies may improve understanding of these systems.

Wachob, Andrew
SC Department of Natural Resources
+POTENTIOMETRIC SURFACE MAP OF THE BLACK CREEK (CROUCH BRANCH) AQUIFER OF SOUTH CAROLINA - NOVEMBER 2015
In an effort to assess groundwater conditions in South Carolina's Coastal Plain aquifers, and to identify areas where declining groundwater levels may become problematic, the South Carolina Department of Natural Resources (SCDNR) maintains a program to regularly map the potentiometric surface of the State's major Coastal Plain aquifers. Potentiometric surface maps, which indicate static groundwater-level elevations throughout an aquifer, are a valuable tool for assessing groundwater conditions and can help identify areas where excessive pumping has lowered groundwater levels to an extent that groundwater management strategies should be developed and implemented. Comparing potentiometric maps of the same aquifer created at different times can also reveal regional trends in groundwater levels. The Black Creek (Crouch Branch) aquifer is one of the three major aquifers of the Coastal Plain of South Carolina and is an important source of water for many public, industrial, and agricultural supplies. Presented here is the most recent potentiometric map developed by SCDNR for the Black Creek (Crouch Branch) aquifer, using water-level measurements collected from 104 wells in late 2015. The potentiometric surface of the Black Creek (Crouch Branch) aquifer for November 2015 shows that the generally southeastward groundwater flow is affected by potentiometric lows in the eastern half of the State. Compared to previous potentiometric maps, the 2015 map shows little change in water levels in the western half of the Coastal Plain and in the aquifer's updip regions in the eastern half of the State. The large cone of depression centered in Georgetown County continues to expand and deepen, and significant water-level declines are also occurring in the Myrtle Beach area of Horry County. The potentiometric lows in Georgetown and Horry Counties may lead to saltwater intrusion into the aquifer in these areas.

Wagner, Chad[1], Stephen Harden[2], Kristen B. McSwain[2]
[1]US Geological Survey, [2]South Atlantic Water Science Center
EFFECTS OF LAND-APPLIED BIOSOLIDS ON SURFACE-WATER LOADS AND GROUNDWATER QUALITY IN THE JORDAN LAKE WATERSHED, NORTH CAROLINA (T6,S6)
The practice of applying biosolids from municipal wastewater treatment plants to agriculture fields is becoming more commonplace across much of the Piedmont and Coastal Plain of North Carolina. The impact of land-applied municipal biosolids to agriculture fields on the delivery of nutrients, bacteria, metals and contaminants of emerging concern to surface water and groundwater is largely unknown. The US Geological Survey and North Carolina Division of Water Resources partnered through the Non-point Source Grant 319 Program on a study of paired agricultural watersheds in Orange County, NC that was designed to better understand the transport of nutrients, metals, bacteria and emerging contaminants from biosolids application fields to groundwater and surface water. Results are useful for developing and implementing Total Maximum Daily Loads (TMDLs) for nutrient-impaired watersheds and to provide a scientific basis for evaluating the effectiveness of current regulations. In order to characterize the impact of land-applied biosolids on groundwater and receiving surface water, the study addressed the following elements: 1.) assess the offsite transport of nutrients and bacteria in groundwater and overland runoff from the biosolids application fields to receiving streams, 2.) compute and compare surface water nutrient and bacteria loads for both a watershed with and without biosolids land application, 3.) conduct chemical analysis of biosolids and soil from agriculture fields with and without biosolids application and 4.) evaluate contaminants of emerging concern as potential indicators of constituents derived from wastewater treatment plant biosolids in surface water and groundwater. There were no exceedances of the 10 elements with designated US Environmental Protection Agency (EPA) ceiling concentrations for land-applied biosolids in any of the biosolids samples. Treatment processes and storage techniques used by the treatment plant were found to be effective in eliminating Escherichia coli and fecal coliform bacteria from biosolids. Shallow groundwater in the transitional zone wells, which were located adjacent to and topographically downgradient from all the biosolids land-application fields, were found to be statistically different and had higher nitrate concentrations (medians greater than 12 milligrams per liter) than all the other wells sampled as part of the study. Surface-water nutrient concentrations and yields, primarily nitrate, were higher at the monitoring site downstream from the biosolids land-application fields than the other study sites that drained watersheds without biosolids land application. The largest differences in concentrations between sites were measured at baseflow conditions. Contaminants of emerging concern were detected in approximately 40 percent of the laboratory analyses of the biosolids samples and more frequently in soil samples from the biosolids land-application fields relative to the soil samples from the background field. However, contaminants of emerging concern detected in the laboratory analysis for this study do not appear to be good indicators of human-waste contaminants derived from land-applied biosolids

in groundwater or surface water because the number of detections and concentrations at the background wells and surface-water monitoring sites are similar to or higher than those at wells and monitoring sites adjacent to or downstream from the biosolids land-application fields.

***Waldorf, Austin**, Richard Peterson[1], Erik Smith[2], Philip Weber[1], Leigha Peterson[1]

[1]Coastal Carolina University School of Coastal and Marine Systems Science, [2]University of South Carolina Baruch Marine Field Laboratory

DETERMINING THE HYDRAULIC EFFICIENCY OF STORMWATER DETENTION PONDS IN COASTAL SOUTH CAROLINA THROUGH THE QUANTIFICATION OF HYDROLOGIC BUDGETS (T3,S4)

Stormwater detention ponds are a commonly used best management practice in coastal South Carolina due to their ability to retain pollutants and mitigate impacts to downstream receiving waters. These ponds are used for their potential to moderate peak flow intensity and allow for an internal residence time that enhances pollutant removal through a number of physical, chemical, and biological processes. The importance of controlling stormwater runoff has increased dramatically over time due to development of impervious surfaces in coastal areas, leading to reduced infiltration and intensified overland flow. Stormwater detention ponds are designed based on theoretical hydraulic specifications, yet field based studies are rarely performed to determine their efficiency. This study examined three stormwater detention ponds in coastal South Carolina to determine hydraulic efficiencies. This required quantification of high resolution hydrologic budgets, encompassing all input and output pathways to/from the ponds. The input pathways included surface inflow (piped drainage and overland sheetflow), direct precipitation, and groundwater discharge. Output pathways included evaporation and surface discharge over a weir structure. Groundwater interactions with stormwater ponds can be important, yet are often understudied and oversimplified due to complexities in spatial and temporal variability. We used the naturally occurring radioactive isotope Rn-222 as a tracer to determine groundwater inputs into the stormwater pond, due to its higher concentration in groundwater than in receiving surface waters (often 2-4 magnitudes greater). The average proportion of water introduced to the ponds by each input pathway during rain events was determined. During examined rain events, a majority of the total inflow was contributed by piped inflow (43-62%), followed by overland sheetflow (16-37%) and direct precipitation (16-19%), while groundwater contributed the least (1-4%). While groundwater inputs represented a minimal proportion of the total inflow into the stormwater ponds during rain events, it represented a much larger proportion of total inflow (up to 30%) through the duration of the study due to it representing the only input source during non-rainy periods. Hydrologic results and possible impacts on pond performance from the large rain event caused by Hurricane Joaquin were also investigated. Results from this study were compared to theoretical design plans for stormwater detention ponds to determine pond performance. Analysis of performance could help with management of stormwater and lead to improvements in the function of stormwater detention ponds to control water quantity and quality in the future.

Walker, Hope[1], Billy Cothran[2]

[1]Black & Veatch, [2]SJWD Water District

WHAT HAPPENS WHEN THE DAM BREAKS? SJWD'S EMERGENCY ACTION PLAN PROGRAM (T6,S4)

South Carolina changed in October of 2015. Rains came, dams failed, and we didn't realize how detrimental the impacts could be. Since then, many water leaders in our state are beginning to focus on the efficacy of our dam safety program. One major component of our dam safety program is the requirement for high hazard dams to have an Emergency Action Plan (EAP). According to the Federal Emergency Management Agency (FEMA 608, 2007) there are over 8,300 state-regulated high-hazard potential dams in the United States, of which approximately 40 percent do not have an Emergency Action Plan (EAP). The agency states that "the absence of an EAP at most state-regulated dams is recognized by FEMA as a deficiency in national emergency preparedness." While DHEC regulations do require an EAP for high hazard dams, there is currently no means for them to require their submittal unless certain conditions are met such as the dam owners applying for a construction permit for a dam upgrade. Therefore, in most cases, dam owners must take it upon themselves to develop an EAP. With the importance of emergency preparedness in mind, SJWD took the initiative to develop a detailed EAP for their Lake Apalache Dam in 2012. The purpose of the EAP was to reduce the risk of human life loss or property damage in the event of a dam failure. In order to create a well-documented, user friendly plan, SJWD had to coordinate with a variety of stakeholders including local fire departments, local and statewide emergency management officials, SCDHEC, the National Weather Service, the Department of Natural Resources, etc. Through coordination with multiple stakeholders, SJWD has created a highly efficient plan. Since the successful completion of the Lake Apalache EAP, SJWD has also completed an EAP for their Lyman Lake Dam and is currently in the process of completing a combined EAP for their Lake Cooley and North Tyger Reservoir Dams. This presentation will include an overview of the process involved with developing SJWD's Emergency Action Plans and lessons learned from working with multiple state and county agencies and stakeholders.

Wallover, C. Guinn, Michael P. Griffin, W. Cory Heaton, Daniel R. Hitchcock, Kimberly Counts Morganello, Benjamin A. Powell, Jack Whetstone

Clemson University

MASTER POND MANAGER: A MODEL APPROACH FOR BETTER POND MANAGEMENT OUTREACH (T3A,S3)

Poorly managed pond systems threaten ecologic and human health, as well as the statewide economy, thus it is imperative to provide the outreach and knowledge tools needed for communities to implement beneficial pond maintenance strategies. To address this need, the Clemson University Cooperative Extension Service, Center for Watershed Excellence, and Clemson Online developed

the Master Pond Manager certification program to provide a comprehensive approach to stormwater and recreational pond management in South Carolina. The goals of the program are to provide: 1.) a packaged information toolset of best management practices to improve stormwater and recreational pond function and water quality and provide for downstream waterway protection; 2.) a marketable recognition for businesses through obtainment of the certification title; and 3.) a tool that can be used by governments tasked with enforcing post-construction pond maintenance through stormwater permitting. The Master Pond Manager program curriculum and certification is offered through a hybrid course structure, using online classroom and in-person field training. Target audiences include community associations and pond owners, management professionals, and county and municipal employees; as a result of the diverse participant background and role in pond ownership and maintenance, the Master Pond Manager course is designed to be tailored to the individual and offered through multiple tracks. Since its launch in Spring 2015, more than 70 participants have taken part in the Master Pond Manager program. The unique approach to course delivery allowed for self-paced learning and increased program access to participants across South Carolina and the greater southeast US region. Short and long-term program evaluations demonstrate gain in participant knowledge, behavior change, and best management practice adoption toward improved pond function and downstream waterway health. The success of the Master Pond Manager program demonstrates a new approach towards communicating and encouraging water resource management in South Carolina.

Weist, Jay[1], Gregory Nadeau[1], Michael Harrelson[2]
[1]WorleyParsons, [2]Santee Cooper

CASE STUDY ELECTRIC UTILITY COMPLIANCE - NEW EPA EFFLUENT LIMITATIONS GUIDELINES (T1,S2)

Due to recent United States Environmental Protection Agency (EPA) amendments to the Steam Electric Power Generating Point Source Category, 40 CFR Part 423 Effluent Limitations Guidelines (ELG) and standards; updated Coal Combustion Residual (CCR) regulations; and the Department of Health & Environmental Control (DHEC) implementation of the EPA and South Carolina state regulations, Santee Cooper will be required to make modifications at the Cross Generating Station (CGS) for long term operation of the station. The paper presents a case study of one approach to planning, optimizing, integrating plant modifications and new process systems into current plant operations for a response to the new ELG standards. Planning includes: data collection, analysis, baseline documentation. Optimization includes: existing plant practice and processes review; stream flow reduction, reuse/recycle or removal; approach to operations. Integration includes: identifying modifications and new process systems; planning design, procurement and construction; implementation, start-up, commissioning of modifications and new systems

Wenerick, William
SC Department of Health and Environmental Control

STREAM ASSESSMENT TOOLS FOR COMPENSATORY MITIGATION (T2,S2)

Compensatory mitigation for impacts to streams, and aquatic ecosystems in general, has an established conceptual framework with numerous permits and certifications issued each year that require credits representing ecological losses due to authorized unavoidable impacts. As a result, stream restoration is undertaken to provide credits that represent ecological lift, offsetting required credits and compensating for losses. Success depends on not only being able to insure that structural restoration goals are met (such as stream channel pattern, dimension and profile), but also functional restoration goals. But success is challenging, even more so when it comes to streams compared to wetlands. Therefore stream assessment tools are needed that are science-based and supported with data, including data from direct measurements of stream functions, or in other words rates of ecological processes, such as leaf litter breakdown or whole stream metabolism, etc. Rapid assessment tools are also needed for practitioners, but particularly for regulators because they must make decisions that are both timely and defensible. This presentation will explain how an existing rapid stream assessment tool is used to implement stream compensatory mitigation requirements in South Carolina, and explain findings from a study in South Carolina comparing results obtained using this and other rapid assessment tools to both desktop assessment data and long-term biological monitoring data. Biological monitoring data are generally considered as the deciding factor by DHEC when determining the ecological condition of flowing waters and assessing aquatic life use support. DHEC hopes this presentation will generate discussion and lead to improved stream assessment tools, an improved mitigation process, and ultimately improved environmental outcomes.

Werth, David[1], Alexis Johnson[2]
[1]Savannah River National Laboratory, [2]University of Florida

QUANTIFYING THE EFFECT OF COMPROMISED WATER RESOURCES ON OPERATIONS AT THE DEPARTMENT OF ENERGY'S SAVANNAH RIVER SITE (T5A,S5)

The Savannah River National Laboratory (SRNL) is developing a site sustainability plan for the Department of Energy's Savannah River Site (SRS) in South Carolina in accordance with Executive Order 13693, which charges each DOE agency with "identifying and addressing projected impacts of climate change" and "calculating the potential cost and risk to mission associated with agency operations". The plan will comprise i) projections of climate change, ii) surveys of site managers to estimate the effects of climate change on site operations, and iii) a determination of adaptive actions. The primary risks related to water availability that are currently being assessed include compromised energy generation (from both on-site and external facilities), increased forest fire danger, the viability of threatened and endangered species on site, and the maintenance of surface water impoundments (which must be maintained to avoid the release of contaminants sequestered beneath them). Climate change projections for SRS are obtained from multiple sources, including

an online repository of downscaled global climate model (GCM) simulations of future climate and downscaled GCM simulations produced at SRNL. Taken together, we have projected data for temperature, precipitation, humidity, and wind - all variables with a strong influence on site operations. We examine shifts in the mean and extremes for precipitation and temperature, looking for periods of sharply reduced water availability. The effects of these episodes on site operations, and what mitigating actions may be required, are estimated from similar observed episodes in the past. SRNL is working to engage site facility managers and facilitate a "bottom up" approach to climate change resilience planning, where the needs and priorities of stakeholders are addressed throughout the process. We make use of the Vulnerability Assessment Scoring Tool, an Excel-based program designed to accept as input various climate scenarios ('exposure'), the susceptibility of assets to climate change ('sensitivity'), and the ability of these assets to cope with climate change ('adaptive capacity'). These are combined to produce a series of scores that highlight vulnerabilities. While the tool has previously been applied for transportation-related activities in coastal areas facing storm impacts and sea level rise, the basic principles allow for adaptation to facilities and operations such as those at SRS. Working with site managers, we have selected the most important assets, estimated their expected response to climate change, and prepared a report highlighting the most endangered facilities. Results of this study will aid in driving future management decisions and promoting sustainable practices at SRS.

Westphal, Kirk[1], Frances A. Bui[1], Lauren Klonsky[1], Shayne Wood[1], Daniel Johnson[2]
[1]CDM Smith, [2]Metropolitan North Georgia Water Planning District

REDUCING THE RISKS OF CLIMATE UNCERTAINTY ON WATER (T5A,S5)

CDM Smith worked with the Metropolitan North Georgia Water Planning District (MNGWPD) to assess the potential impacts of climate variability on water resources and infrastructure within the 15-county planning region. This region includes the Atlanta, Georgia Metropolitan Area, home to more than 5.5 million people. Over the past 15 years, the region has experienced three multi-year droughts followed by years of significant and record rainfall requiring local governments and utilities to shift between drought protection and flood management strategies. The increased frequency and severity of these weather aberrations demonstrate the need to incorporate climate resiliency in the MNGWPD's future water resource management and planning. The difficulty facing planners is not knowing what climate conditions to plan for. To address this common problem, this study avoided predictive approaches to climate adaptation. The goal was not to predict future climate trends, but to evaluate a range of possible trends and, with simple models, test the resilience of existing resources and facilities across this range. Those that demonstrated vulnerability across the entire range (at risk regardless of how the climate trends) were prioritized for immediate response, while those that demonstrated vulnerability to just one or two specific types of extreme conditions were identified for future management if or when such a trend actually developed. Key interim findings from the study suggested that water supply, water quality, and increased flooding were the most common risks associated with almost any possible future climate scenario. This was determined with simple models that were developed to test possible ranges of precipitation and temperature, downscaled and grouped from the collection of available Global Circulation Models (GCMs). Supplemental analysis suggested that drought severity and frequency is also a likely outcome regardless of exactly how the climate will trend. Ultimately, the study resulted in a list of recommended preemptive measures (from drought management plans to green infrastructure) to help protect the most vulnerable resources regardless of future climate trends, and a plan to develop triggers for specific responses to the climate as it actually evolves. This resulted in a cost-effective plan that can immediately be integrated into the District's regional planning efforts, as well as an analytical template that can be easily adapted to other communities not only in the southeast, but across the United States.

White, Sarah
Clemson University

+CLEAN WATER^3: INTEGRATING EXTENSION AND RESEARCH TO HELP SPECIALTY CROP GROWERS REDUCE, REMEDIATE, AND RECYCLE WATER

Water resources are precious and limiting in many areas of the United States. Use of alternative water resources (reclaimed or recycled water) for specialty crop production may help reduce strain on limited potable water resources while supporting continued producer economic viability over coming years. Industry-wide use of alternative water resources is limited by infrastructure costs and concerns related to contaminant (e.g. disease, pesticide, and salt) presence. The Clean WateR^3 (R^3 = Reduce, Remediate, Recycle) scientists and extension faculty are developing a suite of online tools (model systems) to aid the producer decision process. The foundational data for these web-based tools are from on-farm and laboratory research evaluating a suite of treatment technologies (best management practices) and current water management practices that will be used independently or in combination to address individual needs of specialty crop operations throughout the United States. The sociology team interviewed 20+ growers to determine how management decisions are made and is working to make recommendations on how to present information resources online (cleanwater3.org) and at workshops and field-days to encourage grower adoption. The economic team interviewed select eastern and western United States growers to develop economic cost estimation protocols and a life cycle inventory to support development of carbon and water footprints. Economic and biological data will be integrated for online decision making tools, helping growers understand how a change in practice influences water use and economic indicators. Project outcomes will help growers treat and reuse operational water to save valuable water resources, and reduce the environmental impact of runoff water. USDA-NIFA-SCRI # 2014-51181-22372

Williams, Jonathan[1], Jimmy Bagley[2]
[1]HDR, [2]Catawba-Wateree Water Management Group / City of Rock Hill

RAW WATER INTAKE CONTINGENCY PLANNING FOR RESILIENT WATER SUPPLY - CATAWBA-WATEREE WATER MANAGEMENT GROUP (T6,S4)

Water, wastewater, and stormwater utilities face ever increasing resource limitations, aging infrastructure, growth pressures, regulatory changes affecting water quantity and quality, and tight budgets. Coupled with climate change, sea level rise and other environmental threats, this becomes a juggling act that requires a reliable, long-range vision supported by a current and comprehensive plan-one that is tailored to key regional and local values, yet is still affordable and provides sustainable solutions. Consideration of resiliency measures in utility master planning, project design and construction proactively plans for potential future events and adaptively manages our systems to prepare for the future. These resiliency measures should be achievable, practical and viewed as essential for the future of our communities. While many resiliency measures are achieved through the built environment (construction projects) others may be achieved through proactive planning for potential emergencies through the development of robust contingency plans. Case Study - Catawba Wateree Water Management Group Raw Water Intake Contingency Plan: The Catawba-Wateree Water Management Group (CWWMG) is a 501(c)(3) non-profit group whose membership consists of 18 public water suppliers and Duke Energy. CWWMG members meet regularly to formulate strategies and projects to help understand and address the Catawba-Wateree River Basin's water challenges. From 2013 to 2015, the CWWMG completed a project to develop water supply intake contingency plans for each of the members within the Catawba-Wateree River Basin. Following the 2006-2009 drought of record in the Catawba-Wateree River Basin, the CWWMG recognized the need to evaluate and identify contingency opportunities for large public water supply intake owners whose raw water intakes could inoperable due to reduced water storage during a severe drought, when usable reservoir storage becomes depleted or in the event of a catastrophic intake failure. In response to this need, HDR completed a series of technical evaluations for 16 different water utilities' existing intake capabilities, water supply intake capabilities and future options, and temporary emergency pumping protocols, in order to develop robust contingency plans for these utilities to access water through alternative means in the event their intake or raw water pump station is unusable. These evaluations of raw water intake contingency opportunities and intake contingency plan development were completed in two phases. Phase 1 included an evaluation of existing intake conditions for all eighteen CWWMG public water suppliers, while Phase 2 included the development of raw water intake contingency plans for sixteen of the eighteen CWWMG public water suppliers, with activities as outlined, below.

- Phase 1 - Evaluation of Existing Conditions for CWWMG Members (2013 to 2014)
  - Evaluated and confirmed raw water intake capabilities for CWWMG members
  - Evaluated CWWMG members' existing contingency plans/measures
  - Completed a preliminary evaluation of existing water supply interconnections
  - Prioritized CWWMG member's need for a raw water intake contingency plan
- Phase 2 - Raw Water Intake Contingency Plan Development for CWWMG Members (2014-2015)
  - Developed formal raw water Intake contingency plans for 16 CWWMG water suppliers
  - Identified and reported on joint contingency response project opportunities for the CWWMG membership.

Williams, Joshua
SC Department of Natural Resources

+RECENT UPDATES TO THE SOUTH CAROLINA GROUNDWATER MONITORING NETWORK

The South Carolina Department of Natural Resources (SCDNR) maintains a network of wells to monitor groundwater level and salinity intrusion of the major aquifers within the State. The network consists of a total 163 wells, 16 of which reside in the Piedmont and Blue Ridge Provinces and 147 in the Coastal Plain Province. One hundred-sixteen wells are equipped with automated data recorders (ADRs), which measure and record hourly water level, ten of which are equipped with conductivity data loggers, which measure and record hourly conductivity and temperature. Thirty-three wells are measured manually on a bimonthly basis. The network's data are used to identify long-term trends in groundwater, monitor drought conditions, calibrate hydrologic models and determine relationships between saltwater intrusion and water levels or stream stage. Multiple updates have been made to the network recently. During the past year, 24 wells were transferred from South Carolina Department of Health & Environmental Control (SCDHEC), four real-time monitoring telemetry systems have been installed, and a total of 6 new wells were drilled on the coast. The network is also in the final stages of being linked to the National Ground-Water Monitoring Network.

Wylie, Jerry, Ted Volskay, Todd Plating, Matt Huddleston
SynTerra Corporation

COAL COMBUSTION RESIDUALS: ENVIRONMENTAL RISK AND REMEDY (T1,S2)

Coal combustion residuals (CCR), commonly known as coal ash, are created when coal is burned by power plants to produce electricity. Coal ash is a prevalent industrial waste generated in the United States, with several sites in the Carolinas having coal ash impoundments and landfills. Coal ash can contain constituents such as mercury, selenium, and arsenic. Without proper management, these constituents can contaminate waterways, groundwater, drinking water, and air. EPA finalized national regulations to provide a comprehensive set of requirements for the safe disposal of CCR from coal-fired power plants. The federal CCR rule establishes technical requirements for CCR landfills and surface impoundments, and addresses risks from coal ash disposal, e.g., leaking of contaminants into groundwater, blowing of contaminants into air as dust, and the possible failure of coal ash surface impoundments. This rule also supports the responsible recycling of CCRs by distinguishing safe, beneficial use from disposal. This presentation will provide an overview of the federal CCR rule and outline the CCR compliance activities we are conducting at current and former coal-fired power plants. Activities include site assessments focused on groundwater flow characterization and the nature and extent of coal ash constituents occurring in groundwater, soil, surface water, and sediments. Based on the assessments, remediation plans are being developed in coordination with regulatory agencies. Remediation plans are based in part on human health and ecological risk assessments that determine whether the occurrence of specific coal ash constituents necessitates remedy.

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