South Carolina Water Resources Research Institute
Annual Technical Report
FY 2012

Introduction

The South Carolina Water Resources Center uses its operating funds to carry out its mission as a liaison between the US Geological Survey, the university community and the water resources constituencies across the state and region. This is accomplished by serving as a water resources information outlet through our website, by serving as a research facilitator through our annual grants competition and by operating as a catalyst for research and educational projects and programs across South Carolina. The Water Center also serves as a conduit for information necessary in the resource management decision-making arena as well as the water policy arena of the state

The SCWRC is involved with numerous water issues across the state including membership on an ad-hoc statewide committee identifying policy issues related to the primary water concerns of communities due to stressors of economic and population growth. The Water Center is also collaborating with multidisciplinary teams investigating natural system/social system interactions, with a particular emphasis on the impact of water resources given the inherent uncertainties of climate change across the region. In addition, the Water Center has been increasingly involved in discussions with groups across the state concerning the economic and social impacts of shoreline change.

Over the past four years, The SCWRC completed 3 studies along the Savannah River Basin studying the economic impacts of changing lake levels due to drought and other circumstances. These were sponsored by the US Army Corps of Engineers and Duke Energy. This work has led to multidisciplinary discussions with researchers in both South Carolina and Georgia to develop opportunities for more basin wide analysis. Currently a team at the SCWRC is developing an NSF proposal with engineers and statisticians from Clemson University and climatologists from other states to undertake a basin wide study of current and future supply and demand conditions using an experimental design framework estimating multiple climate, population, land use and water policy changes across the basin.

The SCWRC has reaffirmed relationships with key individuals from the South Carolina Department of Natural Resources, the South Carolina Department of Health and Environmental Control and South Carolina Sea Grant Consortium in order to advise these state agencies that have critical roles in managing the water resources of the state. As an outcome of those meetings, the SCWRC has continued work as a committee member on the Savannah River Basin Advisory Committee for SCDHEC. In addition, the SCWRC is an advisory member of Clemson University's Intelligent River program, a program funded through the National Science Foundation and Clemson University that is designing real time monitoring for South Carolina's rivers. The SCWRC also sits on the South Carolina Sea Grant Consortium's Program Advisory Board and is actively involved on a project with Sea Grant to investigate alternatives to beach renourishment for communities threatened by sea level rise. Researchers at the SCWRC recently submitted a proposal to SC Seagrant to study the economic and fiscal impacts of shoreline change in several communities across the state.

The Water Center has worked closely on human population growth management issues in several areas of South Carolina including intensive land cover change and water quality and quantity studies in various watersheds. Numerous civic leaders have commented on the importance of the model in regard to both managing growth and development and protecting natural resources, especially receiving waters. The SCWRC was asked over the past year to participate in several state speaking series describing this model and relating this to climate change and other resource management issues.

Finally, The SCWRC has been an active participant in the South Carolina Water Conference Planning Committee. The South Carolina Water Conference was held in October of 2012. The Water Center is a sponsor, evaluates presentations, moderates all water policy tracks, and encourages graduate student presentations and research. This year, the conference had over a day and half of water policy presentations

with well received research that is valuable to the state and region.

Research Program Introduction

The SCWRC is part of the only federally mandated research network that focuses on applied water resources research, education, training and outreach. The SCWRC provides a direct and vital link between federal water interests and needs, and the academic expertise located within the South Carolina's research universities. This provides a mechanism for ensuring state, regional, and national coordination of water resources research, the education of future water professionals, and the transfer of results and outcomes to state and federal water professionals. The matching requirements of the program ensures that the state of South Carolina directly invests in water research and training.

The SCWRC continues to be involved with numerous water issues across the state and region assisting in identifying policy issues related to primary water concerns. As one example, drought conditions across the region over the past decade have left communities concerned about the potential impacts of the scarcity of this key resource. Over the past four years, The SCWRC completed 3 studies along the Savannah River Basin studying the economic impacts of changing lake levels due to drought and other circumstances. These were sponsored by the US Army Corps of Engineers and Duke Energy. This work has led to multidisciplinary discussions with researchers in both South Carolina and Georgia to develop opportunities for more basin wide analysis.

These discussions are also fuelled by the concern that without the appropriate research and dialogue between the states, this multi-state resource could become a contentious legal issue as other states have experienced. Currently a team at the SCWRC is developing an NSF proposal with engineers and statisticians from Clemson University and climatologists from other states to undertake a basin wide study of current and future supply and demand conditions using an experimental design framework estimating multiple climate, population, land use and water policy changes across the basin.

The SCWRC continues to work closely with the Strom Thurmond Institute's Economic Modeling Laboratory. The SCWRC and the Economic Modeling Lab recently submitted proposals to South Carolina Seagrant for research focused on valuing the economic costs/benefits of shoreline change and shoreline management structures. In order to justify ongoing beach renourishment many states and regions have undertaken comprehensive economic impact analysis of beach re-nourishment projects by modeling the importance of beaches as a tourism destination. These studies are generally ably to demonstrate the positive benefits of beach renourishment projects because of the direct, indirect and induced impacts resulting from increased tourism, increased sales, income, and employment, local and state fiscal gains, and property value enhancement. However, these studies assume there are significant flows of outside visitors to states beaches and are a primary driver of beachfront related economic and real estate activity.

We propose to study how do communities that do not have these significant flows of outside visitors' value and then manage their shoreline. In traditional beach renourishment analyses the gains originate largely from outside tourism but where do the gains originate without this major driver? Private communities are still impacted by chronic erosion, sea level rise, and concerns over sustainable shoreline development and management. Moreover, without public beach access these communities are not candidates for federal subsidies and/or loans targeted towards beach re-nourishment. As a result, research that begins to understand the impact of shoreline change by modeling the value and options of shoreline characteristics and management can advance our knowledge of potential climate change impacts now and in the future.

Two SCWRC/USGS funded projects are finishing up in 2013: 1) "Effects of water pollution on fish health in the Savannah River " with Peter van den Hurk (Clemson University) as principal investigator and Michael Paller (Augusta State University) as Co-Principal Investigator; and 2) "A Modeling Study of Water Shortages in the Savannah River Basin: Sensitivity of Water Availability to Evaporative Loss and Climate Change" with

Nigel Kaye (Clemson University) as principal investigator and John Saylor (Clemson University) as co-principal investigator.

This year the Water Center is funding two research studies through its 2013-2014 USGS competitive research program: 1) “Enhancing satellite measurements of water surface temperature using a thermal model of the lake surface for improved evaporation estimates” with John Saylor (Clemson University) as principal investigator and Nigel Kaye (Clemson University) as co-principal investigator; and 2) “Effects of Pharmaceutical Photodegradation Products in Freshwater On Local Amphibians” with Allison Welch (College of Charleston) as principal investigator and Wendy Cory (College of Charleston) as co-principal investigator.

Effects of Water Pollution on Fish Health in the Savannah River

Basic Information

Title:	Effects of Water Pollution on Fish Health in the Savannah River
Project Number:	2012SC80B
Start Date:	5/1/2012
End Date:	4/30/2013
Funding Source:	104B
Congressional District:	SC-003
Research Category:	Not Applicable
Focus Category:	Water Quality, Toxic Substances, Surface Water
Descriptors:	
Principal Investigators:	Peter Van Den Hurk, Michael H. Paller

Publication

1. The results will be presented later this year at the annual meeting of the Society for Environmental Toxicology and Chemistry in Nashville, November 17-21, 2013.

Progress Report, June 18, 2013

"Effects of water pollution on fish health in the Savannah River."

Peter van den Hurk, Clemson University, Michael Paller, Augusta State University

Funded by:

South Carolina Water Research Center

Introduction

In 2009 the Savannah River was ranked in the top ten of America's most contaminated rivers by Environment America, a leading conservation organization. Because of the major economic impact this river has on surrounding counties and states, water quality and ecosystem health are of great concern. The Savannah River provides a large number of services, like providing drinking water, supporting recreational activities (fishing and boating), supply of cooling water and dilution and natural cleansing of liquid wastes from industries and waste water treatment plants. Some major industrial manufacturing plants discharge their wastewater on the river in the Augusta area, in addition to contaminants originating from other point sources like wastewater treatment plants and non-point sources like urban run-off and atmospheric deposition. Also, legacy contaminants discharged by the Department of Energy's Savannah River Site are still of concern in the middle part of the river.

Over the last decade, several studies have investigated the concentrations of heavy metals like mercury and selenium in the Savannah River ecosystem. These studies have led to fish consumption advisories, especially because of elevated mercury levels in fish fillets. However, very little is known about the concentrations and effects of organic pollutants in the Savannah River. Given the knowledge about the sources, these pollutants may contribute significantly to poor fish health in the river. We proposed to sample largemouth bass (*Micropterus salmoides*) and sunfish species (*Lepomis sp.)* to investigate the effects of pollutants on the health of these top predator species. Fish health will be assessed through measuring a suite of health parameters that include somatic indices, blood and bile analysis and expression of detoxifying enzymes and proteins in liver.

The main objective of this study is to obtain a current overview of the exposure to, and health effects of environmental pollutants on fish species in the Middle Savannah River. This will provide critical information to environmental managers and conservation organizations, and creates a venue to educate local interest groups about the health of the river. In addition, the project has created opportunities to involve undergraduate and graduate students in applied environmental research, and created new research collaborations between environmental investigators from Augusta State University, USC Aiken, the Savannah River National Laboratory and Clemson University.

Field collections and biomarker assays

Fish were collected from 14 sites along the Savannah River, ranging from just below the Strom Thurmond Reservoir, down to the Johnson Landing boat ramp, due west of Allandale, SC. We collected around 185 fish in total, most of them were sunfish species in addition to 32 largemouth bass. Of all the fish we collected a blood sample, and liver and gall bladder samples were preserved. Bile was collected from the gall bladders, and was analyzed for fluorescence as a measurement for metabolites of polynuclear aromatic hydrocarbons (PAHs). To normalize these data the total protein content was also measured in the bile samples. We are in the process now of analyzing the bile samples for estrogenic compounds, using an estrogen receptor binding assay after deconjugating these compounds through an enzymatic reaction, followed by extraction. The liver samples will be homogenized and analyzed for cytochrome P450-1A activity, using the EROD assay. In addition glutathione-S-transferase (GST) activity was measured in the liver homogenates as a general indication for oxidative stress. Samples will also be analyzed using the TBAR assay, which is indicator for cell membrane damage as a result of oxidative stress. Blood samples will be analyzed for inhibition of acetylcholinesterase as a marker for pesticide exposure, and plasma samples of male fish will be screened for expression of vitellogenin, a female yolk protein that is induced in male fish by exposure to environmental estrogens.

Preliminary Results

The results of the bile fluorescence show that in in the city of Augusta, and downstream of the outfall of the paper mill significantly higher concentrations of PAHs are found. The higher concentrations in Augusta are clearly related to higher urbanization in this area, and may be related to road run-off. Recent findings have demonstrated that especially run-off from parking lots and driveways that have been treated with seal coats contribute large amounts of PAHs to receiving urban creeks. The outfall of the paper mill has likely higher PAH concentrations as a result of the breakdown of natural organic material is paper pulp. Despite the retention of paper mill effluent in large basins before discharge into the river this is not sufficient to break down these PAHs.

Products

The results will be presented later this year at the annual meeting of the Society for Environmental Toxicology and Chemistry in Nashville, November 17-21, 2013.

Personnel involved

In addition to the principal investigators (Paller and Van den Hurk), two graduate students in the Environmental Toxicology at Clemson University are involved in the project: Phenny Mwanga was part of the sampling crew and David Wyker will be involved in sample analysis. Furthermore assistance in the field and the lab was provided by faculty from the University of South Carolina Aiken: Virginia Shervette generously donated time and equipment to assist in the sampling program, and Michelle Harmon provided access to lab equipment to prepare blood samples for further analysis.

A Modeling Study of Water Shortages in the Savannah River Basin: Sensitivity of Water Availability to Evaporative Loss and Climate Change

Basic Information

Title:	A Modeling Study of Water Shortages in the Savannah River Basin: Sensitivity of Water Availability to Evaporative Loss and Climate Change
Project Number:	2012SC81B
Start Date:	5/1/2012
End Date:	4/30/2013
Funding Source:	104B
Congressional District:	SC-003
Research Category:	Not Applicable
Focus Category:	Management and Planning, Drought, Models
Descriptors:	
Principal Investigators:	Nigel Kaye, John R Saylor

Publications

1. Phillips, R., Saylor, J. R., & Kaye, N.B. Inclusion of evaporation physics in modeling of water availability in the Savannah River Basin" South Carolina Water Resources Center 2012 Conference (2012) (Poster - 2nd Place)
2. Phillips, R., Saylor, J. R., & Kaye, N.B. The eff ect of uncertainty in evaporation rates on water availability in the Savannah River Basin" (In preparation)
3. Phillips, R., Saylor, J. R., Kaye, N.B., & Gibert, J. A comparison of remote sensing estimates of lake evaporation with pan evaporation measurements along the Savannah River Basin" (In preparation)
4. White, M., Phillips, R., Saylor, J. R., & Kaye, N.B., A statistical analysis of daily and monthly evaporation rates from the Savannah River Basin using surface temperature obtained from the MODIS sensor" (In preparation)

Savannah River Basin Evaporation Research

June 21, 2013

RE: SCWRC/NIWR Annual Reports

Dear Lori,

Since the start of this project our goal has been to determine what specific conditions will cause a failure in water availability prediction methods due to uncertainties in evaporation prediction, future water use due to population and industry growth, and changing climatic conditions within the Savannah River Basin. We have been working vigorously in researching this topic and are winding down as we complete the last segments of the project. Provided below is a brief summary/update of the work we have completed to date, future work to be completed, and publications resulting from the research.

Upon beginning the project, much of our work was focused on current data and approaches of estimating evaporation with much higher accuracy than previous researchers. In order to reduce the uncertainties in evaporation prediction, we decided the best approach would be to estimate reservoir evaporation from each of the Savannah lakes using multiple mass transfer based evaporation parameterizations with remotely sensed satellite data, in particular surface temperature measurements. Remotely sensed surface temperature data is readily available and can be obtained directly or indirectly from many satellite platforms. Our research has focused on remotely sensed surface temperature obtained from the MODIS sensor on board NASA's Terra and Aqua satellites.

Using MODIS derived surface temperature data and upper air meteorological measurements obtained via airport weather stations, estimates of evaporation from each lake at four times throughout the day from July 2002 to present have been generated. Typically evaporation estimates are calculated using daily averages and are calculated once per day; however, we believe estimating evaporation at multiple points throughout the day will help capture the diurnal cycle of evaporation and reduce the uncertainty in the prediction of lake evaporation. The current evaporation estimates used by the USACE when performing reservoir models and developing water availability plans are obtained via pan evaporation observations. Therefore, we have decided to include pan based lake evaporation estimates as a baseline comparison with the mass transfer, satellite based evaporation estimates. After examining the data, it was difficult to characterize the underlying trends and differences between the estimates. As a result, long-term evaporation trends for each lake and evaporation model have been generated. Analysis of these results has yielded not only differences among the underlying trends between models, but differences in the trends from lake to lake.

Differences among long-term evaporation trends have lead us to believe that the current USACE water availability model may be sensitive to evaporation. In order to determine the uncertainties in water availability prediction, we have decided to perform a sensitivity analysis of the current water availability model used by USACE with respect to evaporation predictions. In order to perform this step the current water availability model was obtained from USACE. This model was developed within a program named HEC-REsSim and incorporates the current drought contingency/water management plan, along with reservoir and power plant operational data. Using this model and the aforementioned evaporation estimates, we have been able to simulate

historical reservoir elevations for each of the Savannah lakes and record yearly minimum lake elevations resulting from each evaporation parameterization. Upon preliminary examination of the results, we have found that under normal climate conditions (i.e. non-drought periods) reservoir elevations are relatively insensitive to evaporation predictions; however, under drought conditions, the predicted reservoir elevations are quite sensitive to evaporation predictions. So far, we have seen differences in predicted elevations on the order of ± 5-10 feet. Analysis of these results are still underway and continue to be a major component of the research.

After evaluating the effect of evaporation predictions on current water availability predictive tools, our next effort has been to understand the effects of population and industry growth along the basin coupled with evaporation. Since water consumption and evaporative loss represent the major loss of water within the basin, we believe future water use will have a negative effect on the predictive capabilities of the HEC-ResSim model. In researching this component of the project, future water withdrawal rates have been analyzed and obtained for each major diversion located within the Savannah River Basin and have been incorporated within the current HEC-ResSim model (i.e. current hydrology setting), as well as the aforementioned evaporation estimates. This step has produced simulated reservoir elevations as a function of evaporation predictions and future water use. The results are similar to the previous reservoir elevations; however, the effect of future water use seems to increase the variability in reservoir predictions under drought conditions. In evaluating these effects on the current water availability model, we are continuing our analysis and hope to provide concrete results upon project completion.

The last component of the project is to couple the effects of changing climate conditions with evaporation predictions and future water use within the current water availability model. In order to complete this aspect, we have been researching and analyzing current approaches of obtaining down-scaled climate change data for the Savannah River Basin. There are several pros and cons associated with each approach and this will play a role in the final method chosen for the project. Once we obtain the climate change data for the basin, we will incorporate the data within HEC-ResSim, along with evaporation estimates and future water use, and simulate reservoir elevations as discussed earlier. With the simulated reservoir elevations we hope to understand the effect of changing climate conditions on the uncertainty of the current water availability model.

Publications

1. Phillips, R., Saylor, J. R., & Kaye, N.B. "*Inclusion of evaporation physics in modeling of water availability in the Savannah River Basin*" South Carolina Water Resources Center 2012 Conference (2012) (Poster - 2nd Place)
2. Phillips, R., Saylor, J. R., & Kaye, N.B. "*The effect of uncertainty in evaporation rates on water availability in the Savannah River Basin*" (In preparation)
3. Phillips, R., Saylor, J. R., Kaye, N.B., & Gibert, J. "*A comparison of remote sensing estimates of lake evaporation with pan evaporation measurements along the Savannah River Basin*" (In preparation)
4. White, M., Phillips, R., Saylor, J. R., & Kaye, N.B., "*A statistical analysis of daily and monthly evaporation rates from the Savannah River Basin using surface temperature obtained from the MODIS sensor*" (In preparation)

Sincerely,

Ryne C. Phillips, John R. Saylor, & Nigel B. Kaye

Information Transfer Program Introduction

NONE

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	2	0	0	0	2
Masters	2	0	0	0	2
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	5	0	0	0	5

Notable Awards and Achievements

None

Publications from Prior Years