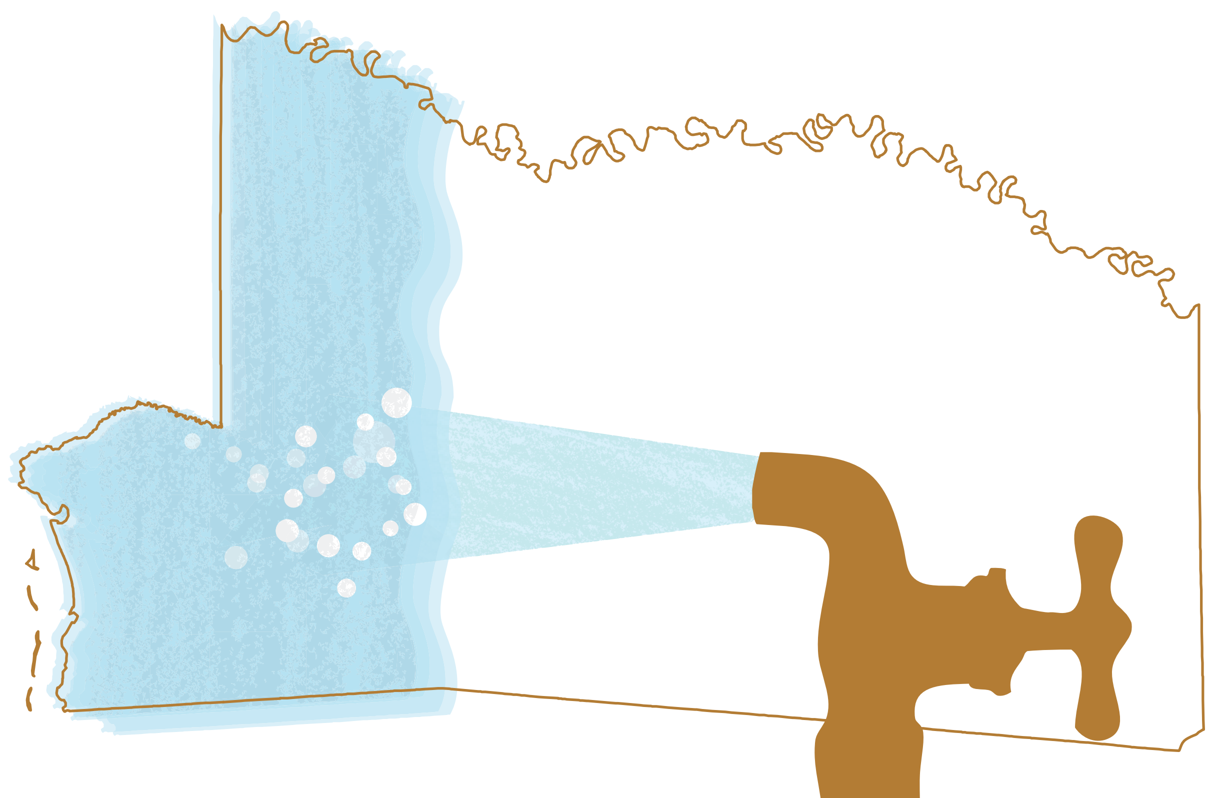
2016

Mississippi Water Resources Conference

Jackson Hilton

Jackson, MS



2016

Mississippi Water Resources Conference

Hilton Jackson Jackson, MS

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Contents

Poster Session

Contents

Posters (continued)

Water Treatment/Management

Contents

Contents

Water Quality

Outputs and Outcomes

Contents

Contents

Contents

Collaborative Initiatives

Policy/Planning

POSTER SESSION

Julius Adenihun *Mississippi State University*	Developing a Habitat Suitability Model for Oyster Restoration in St. Louis Bay
Christopher Douglas *University of Mississippi*	Prediction of Bacteria in Recreational Waters Using Artificial Neural Network Modelling
Lily Dowlatabadi *Mississippi State University*	Remediation of Oriented Strand Board (OSB) Process Water
Dr. Gary Feng *USDA-ARS*	Crop Water Requirement, Rainfall Deficit and Irrigation Demand of Major Row Crops in Mississippi Delta
Jeremy Foote *Mississippi State University*	An Examining of the Changes in the Hydrological Environment Around a Surface Lignite Coal Mine Over the Last 20 Years
Nicole Hornslein *Mississippi State University*	Water Use of Dominant *Pinus Taeda* and Mid-canopy *Liquidambar Styraciflua* and Consequent Implications of Forest Cuccession
Ritesh Karki *Mississippi State University*	Application of AnnAGNPS for Evaluating the Nutrient Loading Control of an On-Farm Water Storage (OFWS) System in East Mississippi
Jing Liao *Mississippi State University*	Utilizing My Maps Feature in Google Maps as a Nultipurpose Watershed Planning Tool for the Escatawpa River
Katy Limpert *Mississippi State University*	Ecological Significance of Phyllosphere Leaf Traits on Throughfall Hydrology, Biogeochemistry and Leaf Litter Among Quercus Species in the Southeastern United States
Martin A. Locke *USDA-ARS-NSL*	Research Program at the USDA-ARS National Sedimentation Laboratory: At the Interface of Agricultural and Natural Resource Management
Tyler Lynn *NASA DEVELOP*	Natchez Trace Ecological Forecasting and Water Resources: Utilizing NASA Earth Observations to Assess Current and Historic Wetland Extent along the Natchez Trace Parkway
Emily Mealins *Mississippi State University*	Potential Solutions for Dealing with High Iron Content in Filter Backwash Water of a Municipal Water Treatment System
Andrew O’Reilly *University of Mississippi*	Simulation of Transient Groundwater Recharge in Deep Water-table Settings: A Simple Water-Balance/Transfer-Function Model
Ying Ouyang *USDA Forest Service*	Characterization of Surface Water Auality in Sunflower River Watershed, Mississippi

POSTER SESSION

Jonathon Rogers *Mississippi State University*	Towards an Understanding of Surface and Groundwater Exchange Through Tailwater Recovery System
Tadesse Sinshaw *University of Mississippi*	Prioritizing the Restorability of Impaired Water Bodies: A Case Study of Four Watersheds in the Delta Region in the State of Mississippi
Julianna N. Stratton *Mississippi State University*	Multidisciplinary Remediation: An Analysis of Chlorinated Metabolites in Groundwater Contaminated by Pentachlorophenol Following 15 Years of Air/Biosparging, Phytoremediation, and In-Situ Chemical Oxidation Protocols
Sam Testa III *USDA-ARS-NSL*	Brown Pathways in Green Systems: Source, Habitat and Nutrient Effects on Organic Matter Breakdown in Mississippi Delta Agricultural Bayous
Dr. Kristine L. Willett *University of Mississippi*	Spatial and Temporal Trends for Mercury Concentrations in Fish from Three North Mississippi Lakes and Human Health Risk Assessment
Benliang Zhao *South China Agricultural University*	A New Absorbent from Chemically Modified Powder of Bidens Pilosa and its Characteristics for Cd Removal from Solutions

Developing a Habitat Suitability Model for Oyster Restoration in St. Louis Bay

Adenihun, J.; Linhoss, A.; Camacho, R.

Oyster formations in the Northern Gulf of Mexico are declining rapidly due to over-harvesting, pollution, and changes in hydrology. Oysters depend on a number of environmental factors including water depth, the availability of hard substrate, salinity, temperature, dissolved oxygen, and PH. Oyster reefs provide important ecosystem services including fish habitat, water filtration, storm protection, sequestering carbon, providing food security, forming an economic industry, and as a cultural symbol. Oyster reef restoration can add value to the U.S economy with a sack of oysters fetching up to $40 at market. The objective of this research is to use a hydrodynamic model coupled with a water quality model to simulate conditions that are important for oyster reefs along the Gulf Coast of Mississippi. We will use the existing Environmental Fluid Dynamics Code (EFDC) and Water Quality Analysis Simulation (WASP) models that have been developed for Bay St. Louis, Mississippi. EFDC simulates water quality parameters that are required to run the WASP model, such as velocity, flow rate, temperature, diffusion, dispersion, and salinity. Meanwhile, WASP model generates parameters that are important for the growth of oyster reefs in the Northern Gulf of Mexico, such as dissolved oxygen, phosphorus, nitrate, nitrite, phosphorus, and total suspended solids. We will develop a habitat suitability model for oysters based on the exiting mapped locations of oyster reefs along with environmental parameters that are important for oyster growth and survival.

Prediction of Bacteria in Recreational Waters Using Artificial Neural Network Modelling

Douglas, C.

Many scientists and government agencies rely on fecal indicator bacteria (FIB) to determine the risk of exposure to pathogens in water. If there is a presence of these indicator bacteria, pathogenic microorganisms may also be present. These bacteria in recreational water bodies pose a health threat to people if ingested during activities such as swimming or from the consumption of marine life. The most commonly tested FIB are total coliforms, fecal coliforms, Escherichia coli, fecal streptococci, and enterococci. The measurement of bacteria can be time consuming (up to 48 hours) and expensive, creating a difficulty in warning the public of a potential risk. Ideally, a predictive model could determine the FIB concentration in real-time, eliminating the current delays. Many analytical, statistical, process-based, and empirical models exist for water quality prediction, but produce a low level of precision. Artificial neural network (ANN) models create a better model for predicting water resource variables because they are often capable of modeling complex systems of behavioral rules or underlying physical processes that are often difficult to simulate. An ANN is a computational model based on the biological neural networks. ANNs consist of processing units known as neurons or nodes that are joined by weighted connections. The connections are adjusted by determining an error quantity between the newly predicted output and the actual output and then applying the correction to each weighted node allowing the network to "learn" as it applies the correction for all data in the model. By modeling the ANN using easily recorded inputs to predict indicator bacteria, the concentration of bacteria can be provided almost instantaneously through the model. Due to the non-linear behaviors of most water quality parameters and the learning capabilities of ANNs, the development of a model could provide an adequate method for determining the risk for pathogen exposure in a timely manner.

Remediation of Oriented Strand Board (OSB) Process Water

Dowlatabadi, L.; Borazjani, H.

The process of manufacturing OSB involves a pressing process that releases water and extractives from wood. This type of water is known as process water and contains wood extractives, phenol/urea formaldehyde resins, terpenes, and other organic compounds which increase the biological oxygen demand (BOD) and total suspended solids (TSS). In order to discharge this water, it must be treated to reach a regulated discharge levels for BOD and TSS. A 30 day laboratory study with bioreactors filled with OSB process water and treated with air only, air plus fertilizer and air with fertilizer and duckweed were conducted to evaluate the removal of BOD and TSS from this type process water. Three untreated controls were used in this experiment. Significant reduction of BOD occurred for all treated replicates after 30 days. No significant differences observed among treated samples. For TSS, again all treated treatments showed significant reduction but reactors treated with only air showed the highest reduction of TSS. Bacterial population remained sufficient throughout this experiment.

Introduction

Treating wastewater is an important aspect for wood processing plants. In recent years, the production of OSB (Oriented Strand Board) and other materials such as Wafer board (WB) worldwide has grown dramatically (over 50%) [Steinwender et al., 2009]. These two are referred to as flake boards because of their composition of being reconstituted wood panel products. OSB is manufactured by obtaining strands and wood wafers taken from logs at the plant and aligning each of the 3-5 layers, blended with resin, in a perpendicular fashion to give OSB a far superior flexible property unmatched in regular wafer boards [Steinwender et al., 2009]. These types of engineered boards are commonly used for sheathing, single layer flooring, and underlayment in light frame construction [EPA, 2003].

Trees have high water content, so the process of making OSB and other boards which involve pressing, results in the water being released [Mangum, 2001]. The wastes generated from the production of OSB type products includes wood, water, resins, waxes and organic compounds such as terpenes, resin acids, phenol formaldehyde resins, and other wood leachates [Diehl et al., 2003]. These are all commonly combined with water to create a wastewater that must then be treated for proper discharge. The amount of these wastes that remains in the water affects the biological oxygen demand (BOD). The BOD will determine whether the wastewater can be properly discharged [Diehl et al., 2003]. BOD will determine the degree of water pollution and is the most important measurement taken for treatment plants [Hach et al., 1997]. Because bacteria within bodies of water will oxidize organic matter and will consume oxygen faster than it is dissolved back in from the air causing significant depletion of oxygen and it will negatively affect the ecosystem of the river leading to a high mortality rate of fish and other living organisms[Hach et al., 1997]. This makes it an important factor to monitor prior to release.

Current wastewater strategies to decrease BOD include aerated ponds and bioreactors. These two techniques incorporate air to help stimulate microbial breakdown. Filtration can also be used after coagulation and flocculation treatment [Ali and Skreerishnan, 2001; Huang et al., 2004; Pokhrel and Viraraghavan, 2004]. Although these processes do work, they tend to be costly as well as create a need for disposal of the filter cakes and spent filtrate produced from the process of coagulation and flocculation [Mangum, 2001]. The use of aquatic plants is another process that has been considered and experimented with as a way to alleviate cost and disposal. There have been many positive results using aquatic plants to remove heavy metals in addition to filtering the process water [Koner et al., 2003; White, 2008; Masbaugh et al. 2005; Keith et al. 2006, Ran et al. 2004]. One such positive treatment facility is in Columbus, MS at a local paper manufacturing facility that uses three steps to successfully to treat wastewater. These steps include a cooling pond which is fed into an aerated pond that suspends solids, which is then fed to a cattail artificial wetland that reduces BOD level before being discharged [White, 2008]. In this study, the use of Common Duckweed (Lemma gibba) will be explored to potentially help decrease BOD.

Objectives

Air sparging is a technique used to remediate wastewater, and can be defined as introducing air beneath the surface of water to begin volatilization and biodegradation [Hinchee, 1994]. The main objective with air sparging is to provide oxygen which will trigger biological breakdown processes [Hinchee, 1994]. In this experiment, air sparging was used in order to provide oxygen for microbial breakdown of organic compounds and to determine that if it is a reliable treatment technique to decrease BOD and TSS. The use of fertilizer and Common Duckweed will also be used to find their correlating effects on decreasing BOD and total suspended solids (TSS).

Materials and Methods

Wastewater Characterization

The wastewater used in this study was obtained from an engineered wood manufacturing plant in northeast Mississippi. The wastewater was untreated and contained resin, a small amount of fertilizer and other organic compounds present in wood extractives. The wastewater was plated on day zero on nutrient agar to find a bacterial count. The total counts can be found in table 1.

Table 1. Bacterial counts, BOD, TSS and pH for samples.

Treatments	Bacterial Counts (colonies/ml)	BOD (PPM)	Total Suspended Solids (PPM)	pH
C	3,633	240	847	6.78
A	3,800	240	847	6.78
AF	3,867	240	847	6.78
AFD	3,700	240	847	6.78

Note: Treatment ID refers to the treatment. C=Control, A=Air, F=Fertilizer, D=Duckweed

Treatment Conditions

Twelve 4L bioreactors (tanks) were placed under a chemical ventilation hood where 1.5L of OSB wastewater was randomly and evenly distributed among all of them. Tanks were kept at room temperature. Environmental conditions such as temperature, light, and aeration were controlled to ensure proper homogeneity in the experiment. Samples were taken from each tank for bacterial counts as well as biological oxygen demand (BOD) and total suspended solids (TSS) for day zero. Three tanks were just air sparged (A). Three had the addition of air sparging and fertilizer (AF), and the last three had air sparging, fertilizer, and the addition of Common Duckweed (AFD). Three containers were set aside as a control with no treatment(C). Final samples were taken after thirty days. Deionized water (DI) was added to each tank daily for water loss (due to evaporation) to keep the initial water level.

Biological Oxygen Demand (BOD)

Biological Oxygen Demand (BOD) is the amount of oxygen present for utilization of bacteria to use when they oxidize organic matter, measured in mg/L or parts per million (ppm) [Hach, 1997]. This organic matter consists of carbohydrates (cellulose, starch, sugars), proteins, resins, petroleum hydrocarbons, etc. [Hach, 1997]. These accumulate in water during manufacturing processes and will either dissolve or become suspended particulate matter. BOD samples were run by an outside analytical laboratory according to EPA Standard method 5210B [Clerceri et al., 1998]. Two samples of the wastewater were taken on day zero and sent to a lab to determine the amount of oxygen required for the microbial decomposition of the organic matter in the wastewater. This procedure was incredibly helpful for the monitoring of water quality and was useful in the comparison to day thirty, in which it showed how much oxygen was consumed by microorganisms and was performed using the procedure as [Walker, 1992] describes.

Total Suspended Solids

Total suspended solids are an analytical method used to determine concentrations of suspended solid-phase material [Gray et al., 2000]. It is important with water quality because it indicates negative effects the water may have on the ecosystem when discharged [Zhang et al., 2013]. Suspended solids are organic and inorganic materials such as sediment, algae, metals, nutrients etc., with a grain size larger than 2 μm suspended in water [Zhang et al., 2013]. These suspended materials can change turbidity, reduce dissolved oxygen, and harm wildlife [Zhang et al., 2013]. Some of the suspended solids are natural from the environment while others are the result of effluent water from industrial activities such as making OSB wood. In this experiment, samples of each treatment were taken and filtered through filter paper using a funnel and vacuum. The initial weights of the filter papers were taken and once dry at 100C for eight hours, were reweighed again. The difference between the weights indicated the TSS found in the treatment water.

pH Analysis

The pH of each sample was determined using an expandable Orion research ion analyzer. The initial pH of the wastewater was tested and found to be 6.78 and reduced slightly to 6.67 at day thirty. The procedure was followed as Walker (1992) reported.

Bacterial Counts

As seen in Figure 1, bacterial counts were taken for each treatment. All samples were plated on nutrient agar petri dishes and incubated for 48 at 27C hours and then counted. Bacterial counts are important because they help to understand the processes occurring in the water. Higher levels of bacteria indicate higher rates of microbial decomposition. Increased bacteria is healthy and good up to a point with water and after that, it can become harmful which is why bacteria counts are another important indication for the health of water. These comparative numbers show which treatment is best when compared to day thirty bacterial counts.

Statistical Analysis

A completely random design statistical analysis was performed using SAS where the means was separated and used to compare treatments.

Results and Discussion

The initial identical samples revealed a BOD average of 240 mg/l. Final BOD for the control was an average of 138.33 mg/l while air was found to be 45 mg/l. Air plus fertilizer was 49 mg/l and the air/fertilizer/duckweed was 75 mg/l. All treatment including controls showed a surprisingly significant decrease in the BOD (table 2 and figure 1). All treated samples had significantly lower BOD levels than controls but no significant differences were observed among treated samples. Initial pH was measured at 6.78 and final pH was found to be an average of 6.68 at the conclusion of the experiment showing no significant changes for pH levels of any samples. Bacteria counts were also taken at the beginning of the experiment as well as at the conclusion of 30 days. Initial and final bacteria counts for the control, were 3,633 colonies/ml and 6,833 col/ml, for the air was 3,800 col/ml and 29,000 col/ml. For air and fertilizer were 11,600 col/ml and 79,666 col/ml. Last, air/fertilizer/duckweed was 3,700 col/ml and 127,166 col/ml (table 3 and figure 2). This shows that there was significant bacteria available for all treatments. BOD showed to have the largest change from the initial tests with a substantial decrease which could be due to the large release of VOC's present in the water (table 3, 4 and figure 2). A high increase in bacteria count shows that there was a natural microbial activity going on within the water and that the air/fertilizer/duckweed had the highest increase in bacterial counts.

Total suspended solids were also taken after the 30 days to get an understanding of the initial and final status of the treated water. Day 0 results found the water to be at 847 mg/l. After 30 days, the control was 871 mg/l while the air treatments were slightly lower at 696 mg/l. The air/fertilizer treatments were 716 mg/l and the air/fertilizer/duckweed was 740 mg/l. Although the results show that there wasn't a large difference in suspended solids throughout the course of this study for treatments but sparging of air into processwater showed most significant change (table 4 and figure 7).

Table 2. Shows table of BOD averages of all treatments measured in mg/l and percent reduction. C=Control, A=Air, AF= Air/Fertilizer, AFD=Air/Fertilizer/Duckweed

Treatments	Day 0	Day 30	% Reduction
Initial	240	-	-
C	240	138	42.5%
A	240	45	81.3%
AF	240	49	79.5%
AFD	240	75	68.8%

Table 3. Shows summarized bacterial counts (col/ml). C=Control, A=Air, AF= Air/Fertilizer, AFD=Air/Fertilizer/Duckweed

Treatment	Day 0	Day 30
C	3,633	6,833
A	3,800	29,000
AF	3,867	79,667
AFD	3,700	127,167

Table 4. Total suspended solids in ppm. Initial= Day 0 control, C=Day 30 Control, A=Day 30 Air, AF=Day 30 Air/Fertilizer, AFD=Day 30 Air/Fertilizer/Duckweed.

Treatments	Day 0	Day 30	% Reduction
Initial	847	-	-
C	847	874	-3.1%
A	847	696	17.82%
AF	847	716	15.46%
AFD	847	740	12.63%

Conclusion

This study was designed to test the uses of air, fertilizer, and duckweed and to examine their effects on the reduction of OSB process water. This study found that the process water with low initial bacteria counts and high BOD can be treated to much lower levels. The process water was reduced from about 240 mg/l to the lowest (air) 45 mg/l which shows a significant change.

It was also determined that all treatments resulted in a decrease in suspended solids and an increase in bacterial activity. Air proved to be the most effective at treating the water with the lowest BOD and suspended solids. The duckweed treatment was not as effective as the other two showing higher BOD and TSS levels but surprisingly higher number of colonies resulted. A higher suspended solids and BOD levels for duckweed treatment was possibly due to the increase in organic matter from dead plant tissues and root exudates. Highest bacterial counts for duckweed, far surpassing the other treatments was possibly due to duckweed's exudates providing extra nutrients for the microbes. The addition of fertilizer showed an intermediate range of values when compared to the duckweed and air. Overall, it was determined that the use of air by itself is enough to reduce BOD significantly and should be considered a major part of any remediation on this type of process water.

Acknowledgment
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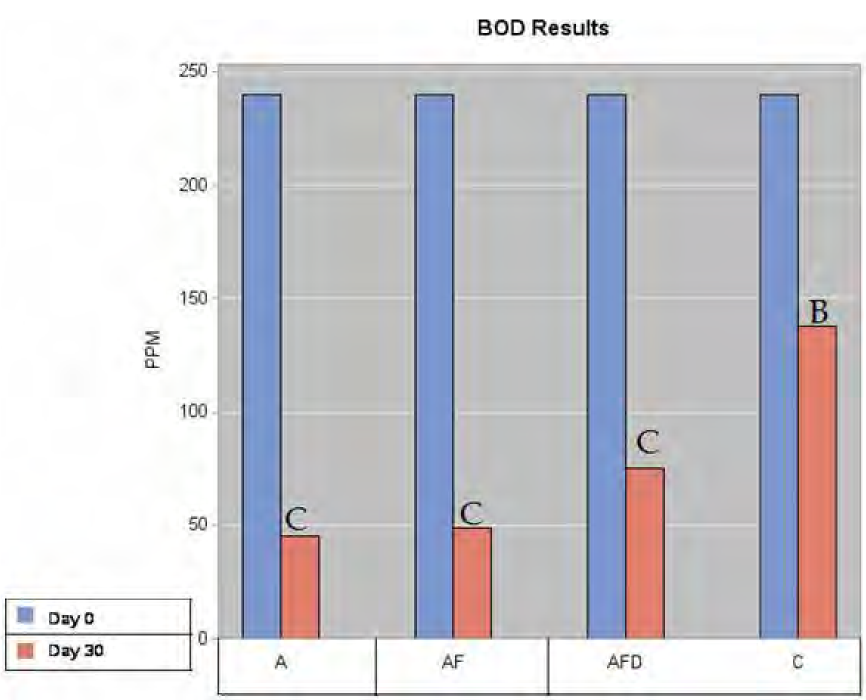

Figure 1. Shows distribution of BOD results. C=Control, A=Air, AF= Air/Fertilizer, AFD=Air/Fertilizer/Duckweed.

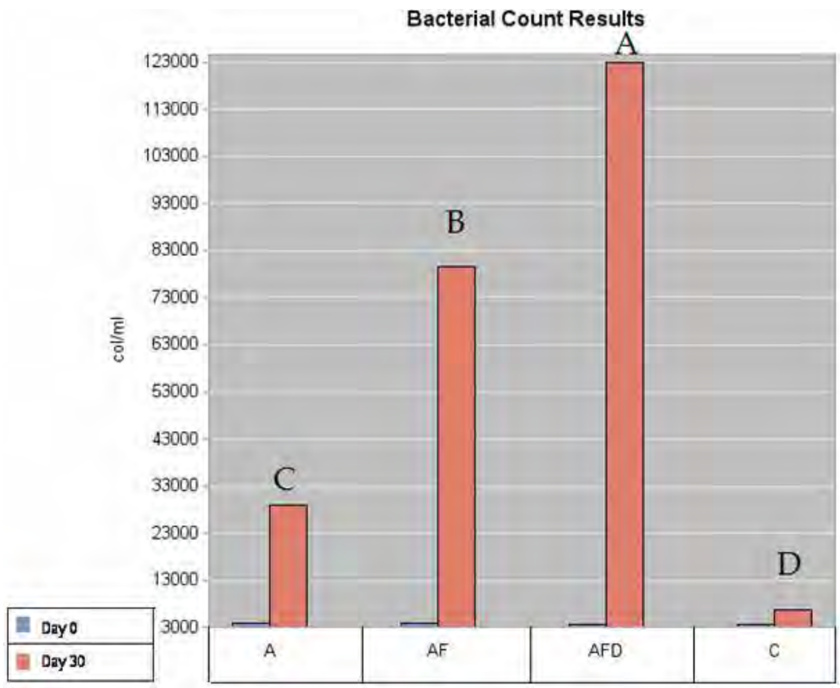

Figure 2. Distribution of bacterial counts. C=Control, A=Air, AF= Air/Fertilizer, AFD=Air/Fertilizer/Duckweed.

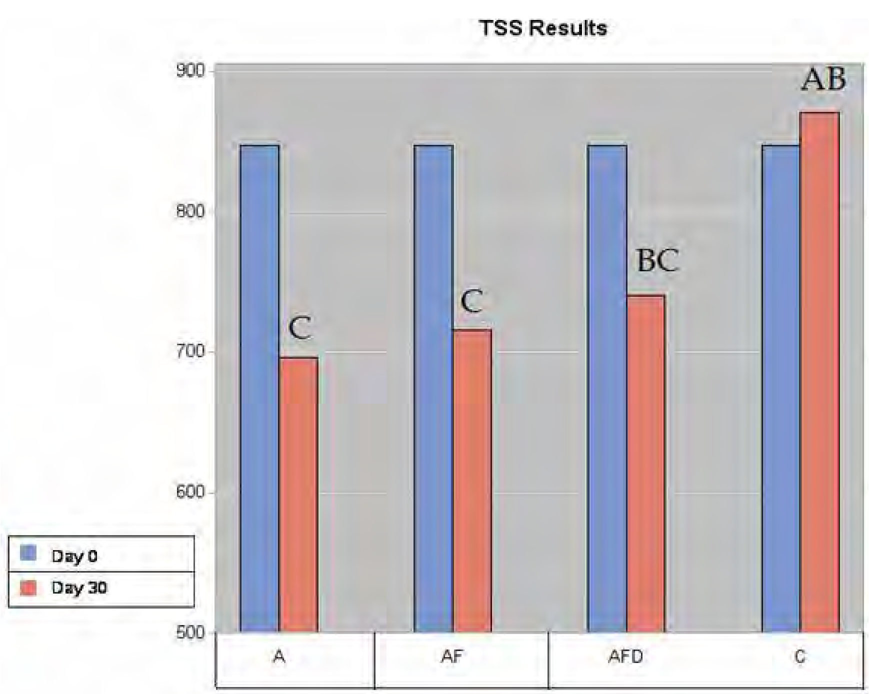

Figure 3. Distribution of total suspended solids. C=Control, A=Air, AF= Air/Fertilizer, AFD=Air/Fertilizer/Duckweed.

Crop Water Requirement, Rainfall Deficit and Irrigation Demand of Major Row Crops in Mississippi Delta

Tang, Q.; Feng, G.; Ouyang, Y.; Jenkins, J.

The Mississippi Delta is the most productive region in the state where 67% of the state croplands is located. Because irrigation can stabilize and increase crop yield and profit, irrigated acreage is rapidly increasing. Currently, irrigated croplands are not over 30% of its croplands yet, which already consumed groundwater down to the alarming level due to lack of knowledge regarding rainfall deficit and crop water requirement in the region. Objective of this study was to determine rain water deficit, crop water requirement and irrigation demand for improving irrigation management of crops grown in the MS Delta. We developed a STELLA soil water balance model and utilized weather records at Stoneville station for 100-years period, 1915 to 2015. The analysis showed average annual rainfall was 1290 mm with a mean annual reference evapotranspiration (ETo) value of 1202 mm. Most rainfall occurred off-growing season in January to April, November and December, their mean monthly rainfall was 124, 123, 130, 134, 120, and 133 mm, while less rain was received in August (66 mm), September (80 mm), October (81 mm), May (81 mm), June (90 mm), and July (94 mm). Soybean, corn and cotton were typically planted in early May, late March, and late May, harvested in mid-September, late August, and late October in the MS Delta. Rainfall during the growing season for soybean, corn and cotton was 400, 510, and 435 mm, accounted for 31%, 40% and 34% of annual rainfall over the 100-years period. Early seeding can make crops receive more rainfall, therefore, reduce degree and days of water stress during growing season. Averaged evapotranspiration (ETc) of soybean, corn and cotton was 546, 588, 552 mm. Rainfall is no longer to meet water requirement of soybean, corn and cotton since the 6th, 8th, and 7th weeks after planting, which resulted in rainfall deficit (difference between ETc and rainfall) of 262, 237, and 228 mm, respectively, on average over the last 100 years. As expected, more pan evaporation (E) was measured in May (199 mm), June (213 mm), July (205 mm), and August (189 mm). High linear correlation between monthly E and ETo was found (ETo=0.7829E-0.0468, R^2=0.98). Monthly ETo can be estimated in terms of the equation by monthly E values which can be easily measured. Results obtained from the 100 years-long historical time-series data can be applied to improve irrigation scheduling, water resources planning and better design cropping system in the MS Delta.

An Examining of the Changes in the Hydrological Environment Around a Surface Lignite Coal Mine over the Last 20 Years

Foote, J.

The population and industrial complexes of Choctaw County utilizes much of its water from an aquifer system in the Tertiary age Wilcox unit of the Mississippi Embayment. Utilizing 20 years of surface and ground water physical chemistry (P-Chem) analysis, potentiometric groundwater records of Choctaw County public water wells as well as industrial P-Chem analysis and surface and ground water level records from an industrial complex, this study examined the changes to the hydrosphere that has taken place since 1995. Analysis of the hydrosphere shows that over the last 20 years, there has been a drop in the potentiometric surface of Mississippi section of the Lower Wilcox Aquifer system. The analysis also shows changes in the surface water physical chemistry of the hydrosphere. These changes include a decrease in the concentration of free CO_2 and chloride, and fluctuations of Alkalinity. Comparisons between groundwater records taken from the industrial complex and other locations around Choctaw County, show little variation in the physical chemistry.

Water Use of Dominant *Pinus Taeda* and Mid-Canopy *Liquidambar Styraciflua* and Consequent Implications of Forest Succession

Hornslein, N.

As southeastern forests undergo succession from *Pinus taeda* (loblolly pine) to hardwoods, differences between water use for these different tree types could alter future conditions of water available in the ecosystem. Investigating loblolly pine and sweetgum (*Liquidambar styraciflua*) transpiration rates is a necessary step in order to determine if significant changes in water availability in the system will occur during succession. This will have future implications for streamflow, groundwater, and flooding. We hypothesize that sweetgum will use more water per unit sapwood area than loblolly pine and that sweetgum will be more responsive to environmental parameters including soil moisture and atmospheric vapor pressure deficit than loblolly pine. This study was performed in an aging loblolly pine plantation undergoing hardwood succession located on clay soils that experience occasional flooding in central Mississippi. The sap flow of 15 loblolly pines and 12 sweetgums were measured from July to November, 2015 using thermal dissipation probes. The trees sampled vary in size with DBH values ranging from 10.16 cm to 40.13 cm in sweetgums and 35.56 cm to 60.45 cm in loblolly pines. Additionally, environmental variables of vapor pressure deficit and soil moisture were measured to compare with tree-level water use. The slope of sap flow vs. soil moisture was higher in pines, demonstrating that they were more responsive to soil moisture than sweetgums. Both species demonstrated more significant relationships between sap flow and soil moisture than with vapor pressure deficit. On average, during the summer growing season, pine water use was approximately 571 kg m^{-2} sapwood area day^{-1} whereas sweetgum water use was approximately 793 kg m^{-2} sapwood area day^{-1}. Therefore, forest succession from loblolly pine to hardwoods such as sweetgum would result in higher tree water-use leaving less available water in the system.

Application of AnnAGNPS for Evaluating the Nutrient Loading Control of an On-Farm Water Storage (OFWS) System in East Mississippi

Karki, R.; Tagert, M.; Paz, J.; Bingner, R.

Irrigation tailwater and storm runoff events from agricultural watersheds are a major source of nutrient loading in rivers and streams. According to the 2012 Mississippi Quality Assessment Report, nitrogen, phosphorus, sediments, and biological oxygen demand are the major pollutants of the Middle Tombigbee-Lubbub Watershed, which includes the study area. An On-Farm Water Storage (OFWS) system is a constructed best management practice (BMP) consisting of a tailwater recovery ditch or terraces and a water storage pond. These OFWS systems have demonstrated the ability to both reduce downstream nutrient loading and provide water for irrigation by capturing and recycling irrigation tailwater and rainfall runoff. The Annualized Agricultural Non-Point Source (AnnAGNPS) surface runoff model is a continuous simulation, daily time step, pollution loading model. This poster will present the preliminary results from the application of AnnAGNPS to estimate nitrate and phosphorus losses from a small agricultural watershed in East Mississippi over a one-year period from fall 2014 to fall 2015. Storm runoff events were captured using an ISCO auto sampler and will be used to calibrate and validate the model results. AnnAGNPS will also be used to estimate the nitrogen and phosphorus loads captured by the OFWS system during the study period. In addition, alternative management practices that could potentially decrease nutrient losses from the agricultural fields will be evaluated using the model.

Utilizing My Maps Feature in Google Maps as a Multipurpose Watershed Planning Tool for the Escatawpa River

Liao, J.; Pote, J.; Wax, C.; Linhoss, A.

This project involved using a tool to coordinate and track activities impacting an entire watershed and producing a synoptic map giving a snapshot in time. This allows multiuser analysis and discussion for setting priorities in future development. The Escatawpa River was selected to demonstrate this capability. Issues addressed were both water quality and water quantity. It has become growingly important to address the accumulation of activities in the entire watershed. For example, in terms of water quality, elevated bacterial counts can impact oyster harvest. In terms of water quantity, decreased flow raises salinity levels impacting the estuarine and coastal ecosystem of the Mississippi Sound. This project mapped activities along the length of the Escatawpa River and its tributaries that might explain variations in water quality and quantity of the river. The method chosen for this multipurpose study was My Maps feature in Google maps. My Maps is an interactive tool that allows users to position markers and leave annotations. The markers have different colors and shapes to help the user stay organized. Furthermore, the users can go back and forth between different types of maps such as satellite and terrain. In this study, several categories were examined which included tributaries, impact analysis, gage stations, golf courses, and septic systems. The categories are differentiated based on color, and the subcategories are separated based on shape. Each marker is assigned its respective color and shape. Furthermore, each marker has a description section to record observations and to keep track of discoveries. These information could be used to prioritize targeted areas of concern and accumulated effects of activities. Discrepancy between terrain and satellite maps were of particular interest, since they could reflect either a flaw in mapping or a change over time. Usually, the discrepancy revolved around bodies of water missing or existing in one type of map and not in the other.

Ecological Significance of Phyllosphere Leaf Traits on Throughfall Hydrology, Biogeochemistry and Leaf Litter among *Quercus* Species in the Southeastern United States

Limpert, K.; Siegert, C.; Karunarathna, A.

Quercus (oak) is a dominant species in many forest ecosystems across the United States that contribute vital ecosystem services through water and nutrient cycling. The recent decline of *Quercus*, largely due to fire suppression and forest mesophication, has the potential to alter forest hydrological and biogeochemical cycling. Given the prevalence, persistence, and diversity of *Quercus* leaves in forest ecosystems, it is likely that this species strongly mediate nutrient cycling when present. The objective of this study was to (1) quantify canopy-derived nutrients contributed to forest ecosystems and (2) determine interspecific temporal distribution of *Quercus* leaf fall in an oak-hickory forest in Mississippi. Beginning in Fall 2014, throughfall quantity and chemistry were measured during individual storm events under each of the four focal *Quercus* species and two non-*Quercus* (*Carya*) species and canopy litterfall was collected weekly to quantify changes in canopy leaf area index (LAI) and timing of species-specific leaf fall rates.

Throughfall depths decreased as leaves were lost but were greatest in *Quercus* species compared to *Carya* and were highest in *Q. shumardii*, and *Q. stellata*. The average total kjeldahl nitrogen (TKN) content of throughfall was highest in *Q. shumardii* (1.44 mgL^{-1}) and *Q. stellata* (1.65 mg L^{-1}) compared to other *Quercus* and non-*Quercus* species. *Q. stellata* had the greatest total organic carbon (TOC) for the majority of rain events with the largest amount reaching 119.43 mg/L^{-1}. *Quercus* species contributed larger amounts of essential anions (Cl^{-1}, NO^{3-}, SO_4^{-2}). During the winter of 2014-2015, *Q. shumardii* had the highest leaf retention although non-oak species had a higher leaf retention in general. Leaf fall varied during the winter of 2015-2016 with *Q. alba* species having longer leaf retention compared to other *Quercus* and *Carya* species. *Quercus shumardii* had the lowest average C:N amounts (43.99 mg L^{-1}) in leaf litter content compared to the other *Quercus* species. Non-oak species had a considerably lower average C:N ratio (*Carya* spp. 32.58 mg L^{-1}).

Research Program at the USDA-ARS National Sedimentation Laboratory: At the Interface of Agricultural and Natural Resource Management

Locke, M.; Dabney, S.

For over 50 years, the USDA-ARS National Sedimentation Laboratory, Oxford, MS, ("Sed Lab") has served as a center for research on sediment and erosion issues and is currently the lead USDA-ARS facility addressing (1) watershed erosion and sedimentation processes, and (2) watershed ecological functions as impacted by agricultural practices. The Sed Lab consists of two research units: (1) Water Quality and Ecology, and (2) Watershed Physical Processes. The research program emphasizes interdisciplinary studies dealing with physical, chemical, and biological processes related to natural resources in agricultural watersheds, and assessing strategies for sustaining and enhancing the integrity and function of agro-ecosystems. Specific topics of study include: (1) soil erosion, transport and deposition of sediment in watersheds including stream stability and bank protection; (2) agricultural practice and stream structure impacts on water quantity, water quality, and ecosystem services; (3) movement and fate of chemicals within the landscape; (4) ecosystem integrity of streams and adjacent riparian zones, lakes and wetlands; and (5) processes controlling surface and groundwater movement. The NSL also serves as the lead research facility in the Lower Mississippi River Basin for the USDA-ARS Long Term Agro-ecosystem Research (LTAR) network.

Natchez Trace Ecological Forecasting and Water Resources: Utilizing NASA Earth Observations to Assess Current and Historic Wetland Extent Along the Natchez Trace Parkway

Lynn, T.

This project partnered with the National Park Service (NPS) to produce needed land cover mapping products for the Natchez Trace Parkway and to address community concerns involving the past, current, and future wetland conditions of this area. The parkway occurs in Mississippi, Alabama, and Tennessee. Beavers have altered current and historic wetland conditions in the study area by changing streamflow along adjacent rivers and tributaries. While the ecological services provided by these beavers can benefit wetland ecosystems, indiscriminate and excessive dam building has caused issues with flooding, property damage, and road maintenance within the parkway. NASA Earth observations (Landsat 5 Thematic Mapper, 7 Enhanced Thematic Mapper Plus, and 8 Operational Land Imager) and ERDAS IMAGINE were used to generate a time series of land use/land cover (LULC) classification maps from October 1992 to January 2015 showing wetland status occurring along the parkway. A projected LULC classification map was also produced using TerrSet Land Change Modeler software. This LULC time series and modeled projection will aid the NPS in wetland conservation and beaver management plans throughout the Natchez Trace Parkway.

Potential Solutions for Dealing with High Iron Content in Filter Backwash Water of a Municipal Water Treatment System

Mealins, E.; Tagert, M.

A small drinking water system in central Mississippi uses traditional processes to purify and filter water at their five different water treatment plants. The ground water that the system pumps from the well has a naturally high iron content. When the water goes through the treatment process, the iron flocculates and is eventually captured by large filters. The filters are backwashed regularly, and the backwash discharge is pumped to an onsite basin (an excavated retention pond) in a corner of the property. Currently, the basin is a relatively open system, and it occasionally overfills and spills off of the property. While not harmful to human health at current levels, the area is not aesthetically pleasing during the time the filters are backwashed and shortly thereafter. A design solution for this problem is needed that will effectively keep all of the backwash discharge on site in order to prevent future spillovers. The iron and water may be separated so that the iron can be excavated and used for different potential markets, while the water can be reused for other eco-friendly purposes such as watering the grass on the property. Several potential solution methods are being investigated and will be presented.

Simulation of Transient Groundwater Recharge in Deep Water-Table Settings: A Simple Water-Balance/Transfer-Function Model

O'Reilly, A.

Deep water-table settings are areas where the water table is below the reach of plant roots and virtually all water that is not lost to surface runoff or evapotranspiration eventually becomes groundwater recharge. To simulate transient recharge in these areas, a simple water-balance/transfer-function (WBTF) model was developed. The WBTF model represents a one-dimensional column from the top of the vegetative canopy to the water table and consists of two components: (1) a water-balance module that simulates the water storage capacity of the vegetative canopy and root zone; and (2) a transfer-function module that simulates the traveltime of water as it percolates from the bottom of the root zone to the water table. Input data requirements include two time series for the period of interest—precipitation (or precipitation minus surface runoff if surface runoff is not negligible) and evapotranspiration—and values for five parameters that represent water storage capacity or soil-drainage characteristics. A limiting assumption of the WBTF model is that the percolation of water below the root zone is a linear process. That is, percolating water is assumed to have the same traveltime characteristics, experiencing the same delay and attenuation, as it moves through the unsaturated zone. This assumption is more accurate if the moisture content, and consequently the unsaturated hydraulic conductivity, below the root zone does not vary substantially with time. Results of the WBTF model were compared to those of the U.S. Geological Survey model VS2DT (a physics-based, variably saturated flow model) and to field-based estimates of recharge. Field-based estimates of daily recharge were computed for a 334-day period by analysis of water-table fluctuations at a site with well drained sand and a water table that ranged from 2 to 3.5 meters below land surface. Recharge was simulated for 1- to 2-year periods for eight hypothetical field sites by using VS2DT and synthesized values of precipitation, evapotranspiration, and soil properties for combinations of two soil types (sand and loamy sand) and four water-table depths (2.5, 5, 10, and 20 meters). The WBTF model reproduced independent estimates of recharge reasonably well for the range of soil types and water-table depths tested: coefficient of determination (r^2) was 0.80 and standard error (SE) was 3.2 millimeters per day for the field-based estimates of recharge; and r^2 ranged from 0.73 to 0.90 and SE ranged from 0.48 to 1.6 millimeters per day for VS2DT-simulated recharge.

Characterization of Surface Water Quality in Sunflower River Watershed, Mississippi

Ouyang, Y.; Moran, M.; Parajuli, P.; Zhao, B.

Characterization of water quality is essential to evaluate river pollution due to natural and/or anthropogenic inputs of point and non-point sources. In this study, surface water quality from three monitoring stations at Big Sunflower River Watershed (BSRW) located in Mississippi during the years from 2013 to 2015 was estimated using the YSI meter and laboratory analysis. Results showed that dissolved oxygen was negatively correlated to water temperature, while total dissolved solid was fairly correlated to water temperature. In general, the concentrations of nitrate-nitrogen ($NO_{3-}N$) and total phosphorus (TP) were highest in spring. Our study further revealed that the minimum, mean, and maximum concentrations in the streams were, respectively, 0.019, 2.31, and 6.43 mg/L for $NO_{3-}N$, 0.01, 0.08, and 0.16 mg/L for TP, and 2.38, 5.81, and 13.29 mg/L for potassium (K).

Towards an Understanding of Surface and Groundwater Exchange Through Tailwater Recovery System

Rogers, J.; Baker, B.; Czarnecki, J.

A long-term trend of depletion of groundwater levels are the result of significant withdrawals from the Mississippi Alluvial Aquifer for irrigation purposes. Tailwater recovery systems, a best management practice to re-use surface water for irrigation purposes, are being implemented by many agricultural producers throughout the Mississippi Alluvial Valley, however, there is very little scientific evidence that proves these systems have the ability to reduce aquifer depletion. To investigate surface-groundwater interactions in these systems, steel piezometers equipped with multiple loggers that measure temperature, atmospheric pressure, and depth were installed in two tailwater recovery systems.It's anticipated that the collection of this data will be appropriate to develop a ground and surface water flow and heat transport mode using VS2DH resulting in the current area of interest that these systems potentially serve as a recharge mechanism. The magnification of ground and surface water exchange could provide the additional data for those estimating Aquifer levels, as well as, assist policymakers in implementing techniques to appropriately manage this critical resource. In addition, the collection of surface and groundwater samples was endeavored to determine any water quality impacts resulting from ground and surface water exchange.

Using Deuterium and Oxygen-18 Stable Isotopes to Understand Mechanisms of Stemflow Generation as a Function of Tree Species and Climate

Siegle-Gaither, M.; Siegert, C.; Keim, R.

Stemflow (SF) is a type of rain partitioning from the forest canopy that redirects intercepted water down tree trunks. Through this mechanism, SF leaches nutrients from the canopy and bark to deliver highly enriched water to the base of the tree. Few studies have examined the species-specific effects of bark structure and storm meteorological conditions on SF generation by means of stable hydrogen (δD) and oxygen $\delta^{18}O$) isotopic tracers. This study explores these relationships in an oak-hickory stand and a pine plantation in central Mississippi. The species selected for this project have unique bark characteristics and variable effects on rainfall partitioning centered on their geographic distribution. Specifically, SF volume and isotopic composition are measured over a one-year period. The objectives of this study are (i) to determine origins and pathways of stemflow water using stable water isotopes, (ii) to identify differences in stemflow generation mechanisms between tree species, and (iii) to identify differences in stemflow generation mechanisms between storm events.

Stemflow collars were installed on seven species of trees with three trees per species. Water samples were collected within 12-24 hours after individual storm events. Tree characteristics such as species, height, and bark thickness were measured. Laser ablation spectroscopy was used to analyze δD ad $\delta^{18}O$ in the water samples collected. Preliminary results show that bark thickness was greatest in *Pinus taeda* (1.74 ±0.09cm), followed by *Quercus alba* (1.56 ±0.08cm), *Q. stellata* (1.19 ±0.13cm), *Q. shumardii* (0.95 ±0.08cm), *Q. pagoda* (0.95 ±0.05cm), *Carya glabra* (0.83 ±0.09cm), and *C. ovata* (0.56 ±0.10cm) (n=24 for all species except *P. taeda* where n=40). Additional preliminary results suggest that the isotopic composition of stemflow is distinct from that of throughfall and bulk precipitation. A better understanding of isotopic composition (δD and $\delta^{18}O$) and stemflow generation mechanisms will allow for more accurate hydrological and biogeochemical models to be established.

Prioritizing the Restorability of Impaired Water Bodies: A Case Study of Four Watersheds in the Delta Region in the State of Mississippi

Sinshaw, T.; Surbeck, C.

The restorability potentials of four impaired water bodies (Lake Washington, Harris Bayou, Coldwater River, and Steele Bayou) in the Delta region of Mississippi were compared in this study using the EPA Recovery Potential Screening (RPS) tool. A variety of selected indicators under ecological, stressor, and social fields were used. Each of the studied water body's restorability potential was ranked based on the most influential indicator score, the summary index scores of the three fields, and the integrated recovery potential (IRP) score of the three fields. Restorability scores were calculated using two scenarios: (1) with indicators assigned with equal weights and (2) with indicators assigned with unequal weights.

Agricultural activity, covering 65 to 80% of the total land use of the four water bodies, was found as the most stressful single indicator. In that regard, Harris Bayou was determined to be the most difficult to restore. Based on the summary index scores, Steele Bayou and Lake Washington were determined to have the most and the least favorable biophysical conditions for restorability, respectively. The Coldwater River was determined to have the highest social capacity for restorability. The water bodies were also compared based on an overall integrated recovery potential (IRP) score of the three fields. Coldwater River and Steele Bayou were found as the first and second most restorable water bodies in both the equally and unequally weighted scenarios. Harris Bayou and Lake Washington were ranked as third and fourth, respectively, in the equally weighted scenarios, and fourth and third, respectively, in the unequally weighted scenarios. A remarkable rank change between Harris Bayou and Lake Washington in the unequally weighted scenario implies the sensitivity of restorability potential score to the assigned indicator weight. Based on this rationale, this research suggests further study on the EPA RPS tool to understand the sensitivity of the restorability potential based on indicator weights.

Introduction

Water bodies not meeting their designated use are listed as impaired as stated by Section 303(d) of the Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) Water Quality Planning and Management Regulations (40 CFR part 130). The Mississippi Department of Environmental Quality (MDEQ) has identified several impaired water segments in the state of Mississippi. To ensure the continuation of the community and environmental benefits of the state water resources, agencies are charged to restore the quality of impaired water bodies. All the identified impaired water bodies cannot be restored at one time due to the limited capacity of agencies in charge. Therefore, it is important to set a prioritized restoration plan.

This study conducted a recovery potential screening of four water bodies deemed important in the Yazoo Basin of Mississippi: Lake Washington, Harris Bayou, Coldwater River, and Steele Bayou (Figure 1). The major impairments in these water bodies are sediments and nutrients, which are harmful to fish and wildlife. This screening was aimed at comparing the four water bodies in order to determine the best candidate for restoration and re-attainment of water quality standards.

Methodology

The US EPA has developed a technical assistance tool known as the Recovery Potential Screening (RPS). This tool is aimed at assisting states to consider where to invest their efforts for a greater likelihood of success, based on the traits of their own geographic area's environment and communities. A summary of the USEPA RPS approach is presented in Figure 2.

The watersheds of the four waters are already mapped GIS datasets by the United States Geological Survey (USGS). Compilation of the data required for screening and analysis of the results was performed on the basis of existing geospatial units.

Indicator selection and measurement:
The RPS tool demonstrated more than 200 metrics that likely indicate the success of a restoration effort. The recovery potentials of the four water bodies were compared using measurable ecological, social, and stressor metrics. Candidate indicators were selected based on their relation to nutrient and sediment impairments and availability of data for all watersheds (Table 1). The selected indicators were measured both quantitatively and qualitatively. The equivalent quantitative values of qualitatively described indicators were inferred from the supporting literature. A higher value of ecological and social indicators implies a better recovery potential. A higher stressor indicator is associated with a lower recovery potential.

Weight assignment:
Equal and unequal weights were assigned to selected indicators (Table 2). Equal weights were assigned with an assumption that all selected indicators have an equal level of relevance to the success of a restoration effort. However, in practice, different indicators would likely have different levels of relevance to a restoration effort for sediment and nutrient impaired waters. To account for this, we assigned different weights for additional scenarios based on the amount of literature supporting the relation between the indicator and its relation to restoration.

Table 1. Indicators used for recovery potential ranking of the four water bodies

Ecological Field		**Stressor Field**		**Social Field**	
Indicator	**Code**	**Indicator**	**Code**	**Indicator**	**Code**
Natural land cover (%)	Eco1	Agriculture land cover (%)	Stressor1	Population size	Social1
Forest land cover (%)	Eco2	Urban land cover (%)	Stressor2	TMDL or other plan existence	Social2
Wetland land cover (%)	Eco3	Aquatic barriers	Stressor3	Recreational resource	Social3
Number of impairments	Eco4	Seasonal relative water level change	Stressor4	High school graduates, 2008-12	Social4
Approximate watershed shape	Eco5			Bachelor's degrees, 2008-12	Social5
Watershed size	Eco6			Persons below poverty level, 2008-2012	Social6
				Non-employer establishments, 2012	Social7
				Land area in square miles, 2010	Social8
				Persons per square mile, 2010	Social9

Table 2. Weights assigned for equally (shown in column labeled as "Equal") and unequal (shown in column labeled as "Unequal") weighted scenario

	Weight			Weight			Weight	
Indicator	**Equal**	**Unequal**	**Indicator**	**Equal**	**Unequal**	**Indicator**	**Equal**	**Unequal**
Eco1	1	2	Stressor1	1	2	Social1	1	1
Eco2	1	2	Stressor2	1	2	Social2	1	1
Eco3	1	1	Stressor3	1	1	Social3	1	1
Eco4	1	1	Stressor4	1	1	Social4	1	1
Eco5	1	1.5				Social5	1	1.5
Eco6	1	1.5				Social6	1	1
						Social7	1	1
						Social8	1	1
						Social9	1	1

Results and Discussion

The results of these screening calculations were compared based on the most influential indicator score, summary index scores, and integrated recovery potential (IRP) scores.

Ranking based on influential indicator score:

The percent of the agricultural land cover was selected as the most influential indicator because of the following reasons. Excess nutrients and sediments are related to agricultural activities. The RPS tool supports this rationale with more than 70 documents (the maximum amount of literature support compared to other indicators). Streams and lakes throughout the state of Mississippi are receiving excessive amounts of nutrients and sediments from agricultural land. This is due to the higher percent of the agricultural land use of the four watersheds, covering 65 to 80 percent of the total land. Therefore, the restoration efforts of these water bodies are likely most influenced by agricultural activities. According to this single index (agricultural land use) ranking, Coldwater River, Lake Washington, Steele Bayou, and Harris Bayou are ranked as having the most to least potential for restorability, respectively (Table 3).

Rank based on ecological, stressor, and social summary index scores:

This approach clusters indicators as a summary index within each field (ecological, stressor, or social context) and ranks waters using the corresponding comparative values. This kind of analysis enables the focus on one individual field, without considering the two other fields. For the sake of this analysis, the ecological and stressor fields were classified as condition-based indicators. Condition-based denotes the biophysical factors that strengthen the restorability capacity (ecological) or that stress the restorability capacity (stressor). A community-based restorability capacity represents the social conditions desirable for restoration success.

A 3D bubble plot of summary indices was used to demonstrate the community-based and condition-based capacities (Figure 3a for equally weighted and Figure 3b for unequally weighted scenarios). A higher ecological and social index and a lower stressor index scores mean a higher recovery potential or a favorable biophysical condition and community capacity. The upper-left quadrant of the 3D

Table 3. Ranking based on the single most influential indicator (agricultural land cover)

	Lake Washington	Harris Bayou	Coldwater River	Steele Bayou
Agricultural land cover (%)	69	79.39	67.1	71.5
Restorability rank	2	4	1	3

bubble plot (higher ecological potential with lower stressor indices) holds a subset of watersheds of higher restorability. None of the four water bodies' summary scores fall in the upper-left quadrant. Steele Bayou and Lake Washington were located in the upper-right quadrant, which implies relatively higher restorability in the context of the ecological index and relatively lower restorability in the context of the stressor index. Coldwater River and Harris Bayou were located in the lower-left quadrant with lower restorability in the context of the ecological index and higher restorability in the context of the lower stressing index. The upper-right and lower-left quadrants were further compared in the context of the social summary index, represented by the size of the bubble. Coldwater River had the highest social index score, followed by Steele Bayou, Lake Washington, and Harris Bayou, respectively.

The summary index scores for equally and unequally weighted scenarios were also separately compared using a 3D bubble plot. When more weight was assigned to land use indicators, the Coldwater River location moved slightly to the upper-left quadrant, which implied that its ecological restorability capacity was increased. However, the high agricultural land cover made Harris Bayou and Steele Bayou more stressed than they were in the equally weighted scenario.

Rank based on integrated recovery potential (IRP) scores:

This approach ranks each of the four water body's recovery potential from highest to lowest based on their IRP scores. The three summary indices were aggregated to the IRP scores (Figure 4). Based on the IRP scores, Coldwater River had the highest restorability potential in both equally and unequally weighted scenarios. Although it was ranked first in both scenarios, the restorability capacity remarkably decreased from 2.74 in equally weighted to 2.26 in unequally weighted. The decrease in score is due to more stress associated with the assigned double weight on the percent of agricultural land cover. From this result, it is possible to conclude that the restorability score is more sensitive to stressor index than ecological and social indices. Steele Bayou was ranked as the second most restorable water body, and the scores were approximately the same in both the equally and the unequally weighted scenarios. A remarkable ranking change was observed between Harris Bayou and Lake Washington when unequal weights were assigned. As stated earlier, Harris Bayou had the lowest restorability rank based on the agricultural land cover. Therefore, the assigned double weight in the unequally weighted scenario added a double stressor to Harris Bayou's restorability and decreased its RPI score from 1.56 to 1.39 and its rank from 3 to 4.

Conclusions

This study demonstrated how the recovery potentials of water bodies with common impairment types (nutrients and sediments) can be prioritized. The relative recovery potential scores were used to understand how the water bodies differ in restorability. From a single indicator index ranking, it was possible to identify an indicator that is potentially stressful to restoration. A summary index of the ecological, stressor, and social fields indicate the biophysical and community conditions of a watershed for a success of a restoration effort. A higher ecological and a lower stressor index mean a favorable biophysical condition for restoration. A higher social summary score also implies a better community capacity. Indicator weights have significant effects on recovery potential ranking. This study suggests further study to understand the relative relevance of each indicator to a given restoration effort.

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Acknowledgement

We are grateful to Mr. Pradip Bhowal of the Mississippi Department of Environmental Quality for his motivation and thoughtful comments on this study.

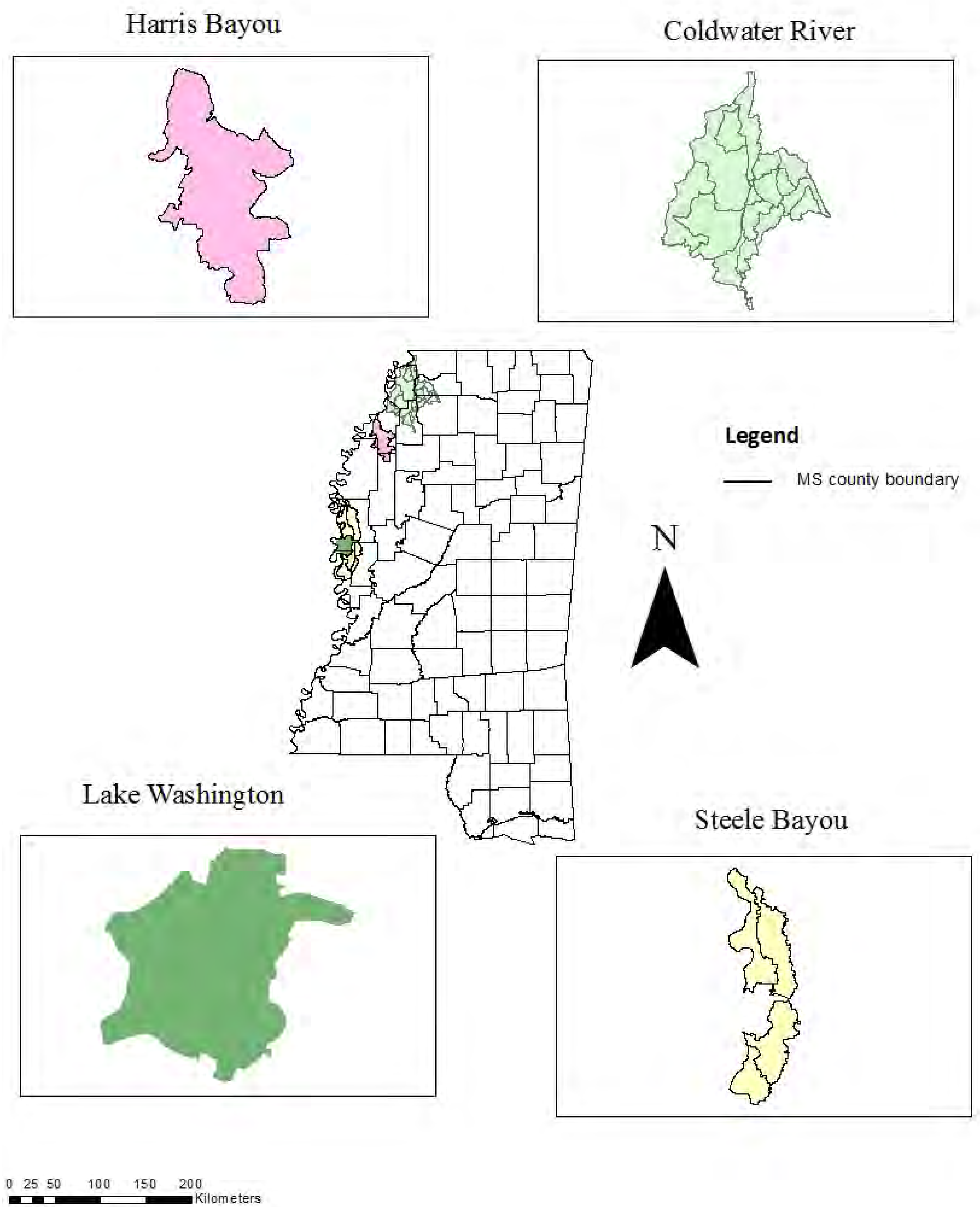


Figure 1. Watershed boundaries of the four studied water bodies in the Delta region of Mississippi.

Prioritizing the Restorability of Impaired Water Bodies: A Case Study of Four Watersheds in the Delta Region in the State of Mississippi
Sinshaw, T.; Surbeck, C.

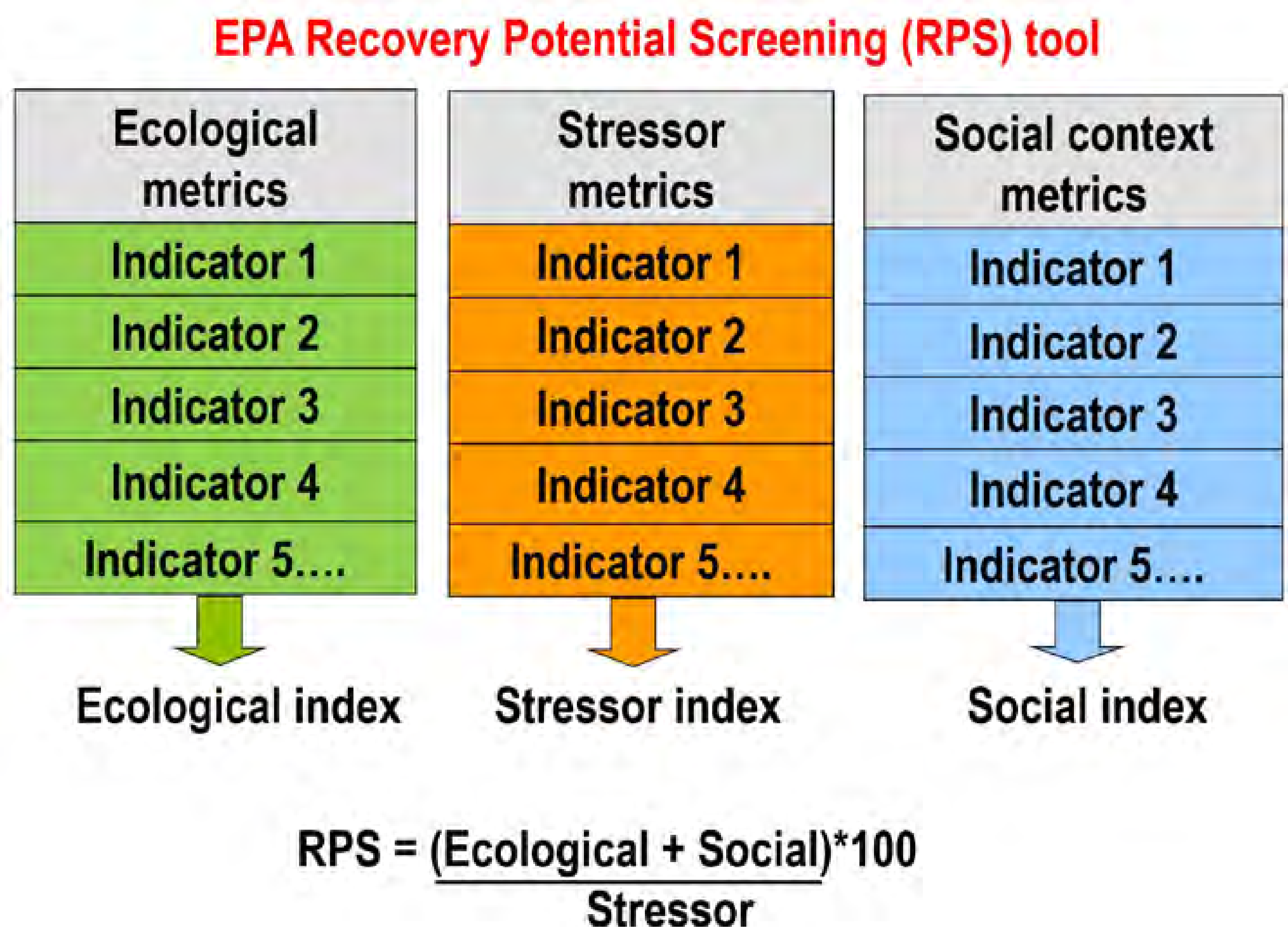
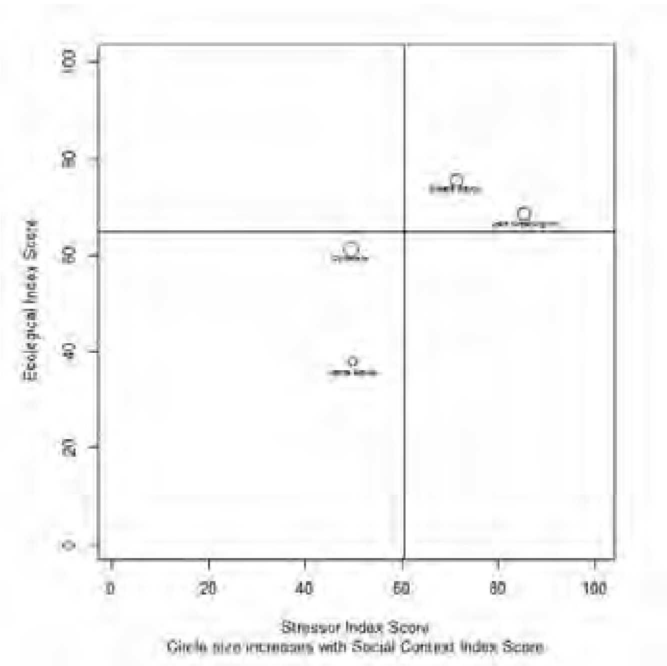


Figure 2. A basic approach of the USEPA recovery potential ranking. Metrics represents indicators under each field.

a.



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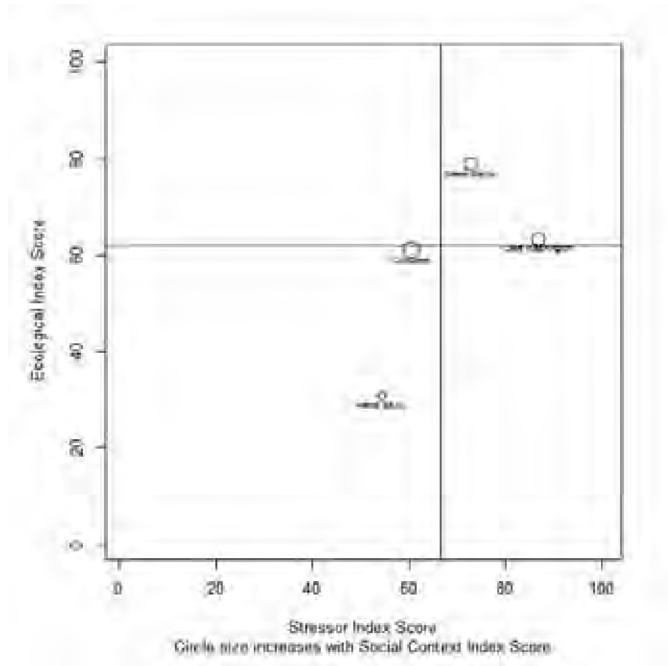

Figure 3a. A 3D bubble plot of summary indices for equally weighted scenario.
Figure 3b. A 3D bubble plot of summary indices for unequally weighted scenario.

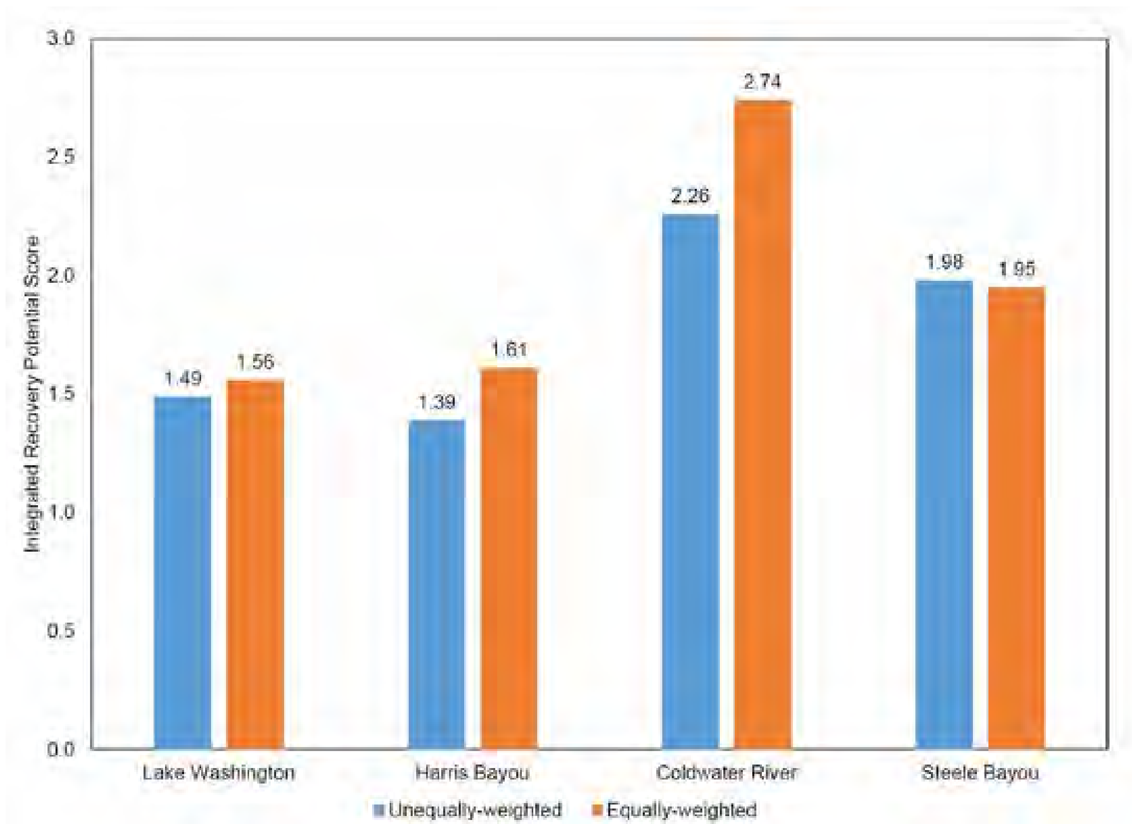

Figure 4. Integrated Recovery Potential scores for equally weighted and unequally weighted scenarios.

Multidisciplinary Remediation: An Analysis of Chlorinated Metabolites in Groundwater Contaminated by Pentachlorophenol Following 15 Years of Air/Biosparging, Phytoremediation, and In-Situ Chemical Oxidation Protocols

Stratton, J.; Stokes, C.

Pentachlorophenol (PCP, Penta) got its foothold as a wood preservative in the United States because it extends the lifetime of wood products up to 40 years, even in adverse conditions. It is also an effective herbicide and biocide. Because of this effective nature against pests, it was applied as a protectant in many areas of agriculture and manufacturing. The site utilized in this study has been a receiver of penta wastewater from a wood product treating facility. To comply with mandated cleanup, injection wells for air injection were installed in 2000. These were used until 2011, when they upgraded the airsparging system and included enhanced biosparging. Shortly after this, 400 hybrid poplar and cottonwood trees were planted in the area for an added aspect of phytoremediation. The latest remediation protocol for the site utilizes in-situ chemical oxidation (ISCO) with dilute hydrogen peroxide, started in 2015. A set of nine wells were sampled monthly following ISCO treatment. Metabolites were extracted from water samples using a novel modified liquid microextraction protocol, followed by analysis on an Agilent GC 6890 to determine the presence of chlorinated compounds resulting from the degradation of penta (ongoing through April 2016). We expect to determine the concentration of chlorinated metabolites, analyze the spatial distribution of these compounds across the site, and make recommendations as to the future of remediation treatments for this location.

Introduction

Pentachlorophenol (Penta) was first created in 1841[1]. The manufacture of penta on a commercial scale did not occur until 1936, when its properties as a wood preservative became understood[1]. It is an effective herbicide and biocide[1]. [2]. Penta got its foothold as a wood preservative because it extends the lifetime of wood products up to 40 years, even in adverse conditions[2]. The industrial form of penta has been known to have dangerous impurities such as dibenzofurans. These impurities are part of the danger found with penta[2, 3]. Penta is now a pollutant of concern worldwide. Its long and widespread usage means that penta can be found in many environments, especially near manufacturing and usage sites. The acute LD-50's for small laboratory animals and domestic livestock are between 27 and 300 mg/kg of body weight[3].

In fact, links between cancer and penta have been well established and cannot be blamed solely on the impurities of the chemical [2-4]. The EPA has even placed limits on the allowable amounts of penta that can be consumed through water in the United States (0.03 µg/L) [5].

While penta is still being used for wood treatment in the United States, it can only be used for the treatment of wood utility poles and cross arms [6]. Its continued use, despite the adverse environmental and ecological effects, is a testament to it utility and cost effectiveness. However, due to the harm that this chemical can cause, the handling of wood waste and waste waters are heavily monitored and scrutinized. Another question is, after so many decades of unrestricted usage, how do we go about remediation of the most contaminated sites?

The site used in this study has been under penta remediation for the last 16 years. Thus far it has undergone air sparging, enhanced biosparging, poplar/cottonwood phytoremediation, and ISCO treatment with hydrogen peroxide into iron rich soil. This study's objectives were to determine the general location of any remaining penta contamination following subsequent remediation treatments by employing a novel micro-extraction protocol that is sensitive to small amounts of chlorinated phenolic compounds to detect trace levels of products.

Site Description

The site sampled for this study was located in central Mississippi, adjacent to a wood product treatment facility that has used penta for treatment of utility poles in the past. The site was a disposal and storage area for penta waste for a few decades prior to the 1970's, before the current company took over management of the mill [7, 8]. Before the hazards of penta were completely understood, treated utility poles were allowed to drip dry on concrete log runs with the effluent running into the nearby soil. The site also stored used pressure treatment fluid wastewater in a lagoon, which was later filled in with uncontaminated soil [8]. At the time of this study, the mill was not using penta but was producing dimensional lumber [9].

The site has been undergoing remediation for a significant groundwater contamination since 2000 [8]. To clean up the site, 5 air sparging wells were installed on the site to create a "curtain" of air treatment before the plume traveled to a nearby property[7]. The wells were between 40 and 60 ft. (12.2 to 18.3 m) from each other, utilizing 2 in (5.08 cm) diameter, schedule 40 PVC pipes. There is a 5 ft. (1.5 m) mesh screen at the bottom of the well. The wells were between 23 and 29 ft. (7.0-8.8 m) below the surface. Between the wells installation and 2011, the site was air sparged. This original system was used until 2011, when they upgraded the air sparging blower system but left all the original wells in place [7, 8, 10]. This upgraded system was used to do enhanced biosparging with injections of nutrients, such as nitrogen, bio-available phosphate, potash and other micronutrients, during December of 2011[10].

From 2011 to 2012, approximately 100 hybrid poplar and cottonwood trees were planted in the area to add phytoremediation. Some trees were lost due to native wildlife and were replaced in March of 2016. A fence near the border of the property was added to discourage loss. From 2015 to 2016, ISCO was started by pumping hydrogen peroxide down into the approximate location of the plume using the sparging set up. Wells MW35 and MW13 were up the hill from the other wells. They were near the reported old lagoon site. The lagoon portion of the site was cleaned as a separate project and, at the time of this study, there were mature pine trees growing in the area. The ground water in the area flows down the hill, through the site, and into a nearby stream.

The site has also undergone both phytoremediation with the cottonwood/poplar hybrids mentioned in the site description, as well as in-situ chemical oxidation with hydrogen peroxide. The ISCO treatment carried out at the site utilized 55-gallon (approximately 208.2 L) barrel drums of 35% hydrogen peroxide being pumped into the air sparging system at the rate of one barrel every few weeks, weather permitting. This continued from November 2015 to April 2016. The hydrogen peroxide was injected through the air sparging system at monitoring well 43 in a 10:1 ratio until a 55-gallon barrel had been emptied (approximately 3 days).

Groundwater Sampling Protocol

From January through April of 2016, approximately every 2 weeks, 500 mL of groundwater was extracted from existing monitoring wells located throughout the affected area. Groundwater was sampled from wells by use of a hand-operated vacuum pump (Blackstone Laboratories), and ¼ inch polyethylene tubing. Tubing the length of each well remained in place throughout the sampling period (the depth of each monitoring well is between 4.72 m to 9.75 m deep) [10]. Amber glass wide-mouth bottles (Fisher Scientific) were fitted to the pump assembly via an adapter hose containing a support spring, through which the ¼ in tubing from the well was passed, into the bottle mouth. Hose clamps were used to seal connection points. Vacuum pressure was applied with the hand pump, which raised groundwater through the tubing from inside the well, capturing enough water to fill the 500-mL amber jar. Once the jar was filled, the vacuum was released and the jar was taken off the pump assembly. The samples were transported to the lab in a cooler filled with ice. The tubing and adaptor hose were rinsed with an equal amount of deionized water taken from the lab, before sampling continued. The pH and temperature of the samples were recorded before being stored in the refrigerator until extractions could be done.

Samples were transported to laboratory on the day of collection, on ice, and stored at 2° C until extraction. Temperature and pH were recorded after collection and before extraction. Samples were allowed to settle any debris by settling overnight in a refrigerator.

Sample Extraction

The novel microextraction procedures used in this thesis were based on those set forth in Faraji et al.[30]. This microextraction method was selected for its ability to concentrate phenolic compounds during extraction from water samples, resulting in reduced extraction time and increased sensitivity from traditional liquid-liquid extraction methods. Before each extraction, temperature and pH measurements were taken again. Out of each 500 mL of water samples taken, 50 mL total was utilized. Five replicates, each containing 10mL in a screw top cylindrical vial, were completed at the same time for each well. Then 2.3 µL of 2000 µg/mL (in methanol) 2,4,6-tribromophenol (TBP) (Supelco) were added to each replicate as an internal standard. Half a milliliter of 5% potassium carbonate (K_2CO_3) solution (Sigma-Aldrich, BioXtra ≥99.0%) and 40 µL of acetic anhydride were added along with a small magnetic stir bar, approximately 2mm in size, to derivatize the replicates. The five replicates were then placed on a stir plate together. Samples were allowed to stir at maximum speed for two minutes. After two minutes, each sample was transferred to a hot water bath (approximately 55° C), heated by a stirring hot plate. Once a vortex was created in the vial, 10 µL of 1-undecanol ($C_{11}H_{24}O$) was added to the surface at the bottom of the vortex as the extraction solvent. The vial was then recapped and stirred for 15 mins at a speed that could maintain all 5 vortexes. After this time, vials were transferred to an ice bath until the 1-undecanol solidified (approximately 20 mins). The 1-undecanol was retrieved using a sterile metal spatula and placed into a 2 mL amber glass chromatography vial containing a 0.25 mL clear glass insert. To each extracted sample, 50 µL of methanol was added as a disperser solvent to the 1-undecanol for gas chromatography. The vials were sealed and refrigerated until they could be analyzed for phenolic compounds that had been extracted by the 1-undecanol.

In addition to water samples, microextractions using the proposed method were performed with penta, 2,4,6-TBP, 1-undecanol, methanol, and EPA phenolic analytical standards. The EPA Standards mix contained 4-chloro-3-methylphenol, 2-chlorophenol, 2,4-dichlorophenol, 2,4-dimethylphenol, 2,4-dinitrophenol, 2-methyl-4,6-dinitrophenol, 2-nitrophenol, 4-nitrophenol, penta, phenol, and 2,4,6-trichlorophenol (Supelco). These standards were used for identification of peaks and to test the reliability of the microextraction method.

Gas Chromatography Protocol

Gas chromatographic analysis of the extracted samples was based on the method described in Fattahi et al.[11]. For sample analysis, an Agilent 6890 Plus Gas Chromatograph with a G2397A Electron Capture Detector (GC ECD) was used to obtain the necessary sensitivity for phenolic metabolites. An Ultra 2 capillary column from Agilent Technologies (length 25 meters, internal diameter 0.2 mm, film 0.33 µm) was used. The front inlet was kept at 280 °C, and the detector was held at 300 °C. The temperature programming on the column was set to start at 100 °C and increase every two minutes (at a rate of 5 °C/min) to 210°C. Helium was the carrier gas (50 cm sec^{-1}) and nitrogen (60 mL min^{-1}) was used as the makeup gas.

Statistical Analysis

Identified penta peaks were analyzed with Chemstation Reports, utilizing peak retention time as the identifying factor of the chemicals. The reported limit of detection for the ECD method was 0.010 µg L^{-1}[11]. Statistical analysis was completed by the IBM SPSS program. Friedman's ANOVA was used in the analysis of data.

Results

Peaks of interest were the peaks of penta, 2,4,6-TBP and any other chlorinated peaks that may have been detected. During GC-ECD analysis, it was found that penta eluted at approximately 22.0 mins, 2,4,6-TBP eluted at approximately 21.8 mins, and 1-undecanol eluted at 15.4 mins on the GC-ECD. These times were used to identify the peaks that were found in the extracted ground water samples. In extracted samples trace amounts of other chlorinated compounds were not detected utilizing the ECD across replicates or samples. Because this site has been under remediation treatment for so long, it is postulated that less chlorinated compounds may have been utilized by microorganisms as energy sources. Because of noise generated in the GC-ECD spectrum, it is possible that some trace peaks were not identified. Considering that only one well had detectable amounts of penta, it is also possible that any detectable amounts of chlorinated compounds generated during the breakdown of penta are at such low levels, they cannot be reliably detected with the method described here. However, extracted phenolic EPA standards generated consistent ECD spectra each time. This leads us to believe that the metabolites or breakdown products of penta are in trace and undetectable amounts in the ground water samples. Of all the wells sampled, the only well with any penta peak detected was MW44.

The only well containing detectable amounts of penta was MW44. Samples collected during March 16th, 2016 did not report any penta contamination. This was included in the analysis as there were no outliers in the data. Friedman's two-way analysis of variance by ranks found that the mean peak area of penta did significantly change over the sampling dates, $x^2(7)=27.360$, $p=.000$.

The sampling dates were compared pairwise with one another. It was found that samples collected from March 16th, 2016 and April 28th,2016 ($p=0.001$) were significantly different as were February 4th, 2016 and April 28th, 2016 ($p=0.017$).

The main sources of contamination at this site were the wastewater holding pond (lagoon) and the concrete drip pads. Much of the subsequent remediation efforts have been dedicated to the mobility concerns of the penta located near the old holding pond, as this area was of initially significantly higher concentration. However, MW44 is considered an "up gradient monitoring well" and therefore is upstream of the "curtain" of the injection wells in the ground water flow of the site[12]. MW44 is understandably the only well with detectable penta chemicals still in the soil because it is the only up gradient monitoring well that is close enough to the concrete drip pads and was also in line for drifting penta from other sources. Metabolites of penta were also scarce and in low enough concentrations that our method did not detect them. This is most likely due to the last 16 years of remediation that was conducted at the site. According to the quarterly reports from 2014, 7 out of the 11 wells tested were at a detectable limit when attempting to locate penta alone with EPA standard extraction methods [13]. This indicates to us that our method is sensitive and that the discrepancies from the 2014 monitoring report to our 2016 study are generally due to the sites successful remediation.

Discussion of Application of Microextraction Protocol

This method needs refinement before it can be used for quantification with environmental groundwater samples. However, for qualification, this method seems to be effective for heavily chlorinated phenols. To improve the method, a more sophisticated approach to retrieving the 1-undecanol from the sample is required or way to offset/calculate the loss of 1-undecanol, and the use of GCMS in addition to GC-ECD would be strongly recommended.

First, the largest obstacle for quantification of data was the retrieval of the 1-undecanol after it had solidified. The 1-undecanol contains the chemicals of interest. However, due to the chemical properties of 1-undecanol (i.e. its freezing point of 2-4°C) the removal of it from the rest of the sample is an intricate process. If the 1-undecanol broke from a single 10μL solid droplet, it became nearly impossible to regain the smallest bits. This may prove a problem for quantification of chlorinated phenolic compounds and could explain, in part, the large variance that was experienced in the peak height. With no way to know exactly how much 1-undecanol was lost in each replicate it is unlikely that one can quantify using this exact protocol without an egregious amount of error. If there were a better method of retrieving the 1-undecanol, it could be highly useful for the quantification of data.

Finally, an ECD was selected because of its sensitivity to chlorinated and phenolic compounds. However, it would have been better had the samples been analyzed on a Gas Chromatograph with Mass Spectrometer (GCMS) concurrently with the ECD analysis. This comparison could have found many other factors that might have affected retention times, and given us a better idea of what else was inside of our environmental samples. Using GCMS a running in tandem with the GC ECD, would have been a more effective method of detecting exactly what can be found in each well.

In addition to adding GCMS, a tighter resolution for the small chlorinated compounds on the ECD would have been useful. As was noted previously, the retention time between the internal standard of TBP and penta in the sample were very close together, improved resolution would have allowed separation of the compounds of interest. TBP was chosen as the internal standard, as it is a common choice of internal standard from the literature, and is not known to have an issue with elution timing when used with penta [10, 11, 13]. Fattahi et al, utilized acetone as their disperser solvent to where as we chose methanol. This could have made it so that the GC ECD temperature programing was not better attuned to our process.

Conclusions

While the method needs refinement to be able to be used quantitatively, it can be used to qualify the data and to determine which monitoring wells were still detectably contaminated. According to our findings, due to years of sequential remediation utilizing bio- and air sparging, phytoremediation, and ISCO treatment, the study site is nearing EPA acceptable standards for groundwater across the entire site. The levels of chlorinated phenolic compounds produced from penta degradation appear to be below detection levels for the method described here.

It can be understood from these results that the penta plume is localized in a detectable amount around MW44, perhaps under the concrete drying pads. However, under current method limitations, exact quantification cannot be determined. With revision, the method could still be useable for quantification for future ventures. Future work will include a direct comparison of the standard EPA 3510C method in analyzing trace compounds from this site versus the method described here, optimized for detection of small chlorinated phenols. It is believed that further optimization of this method will provide a useful analysis alternative to the EPA standard when only small quantities of groundwater are available to analyze.

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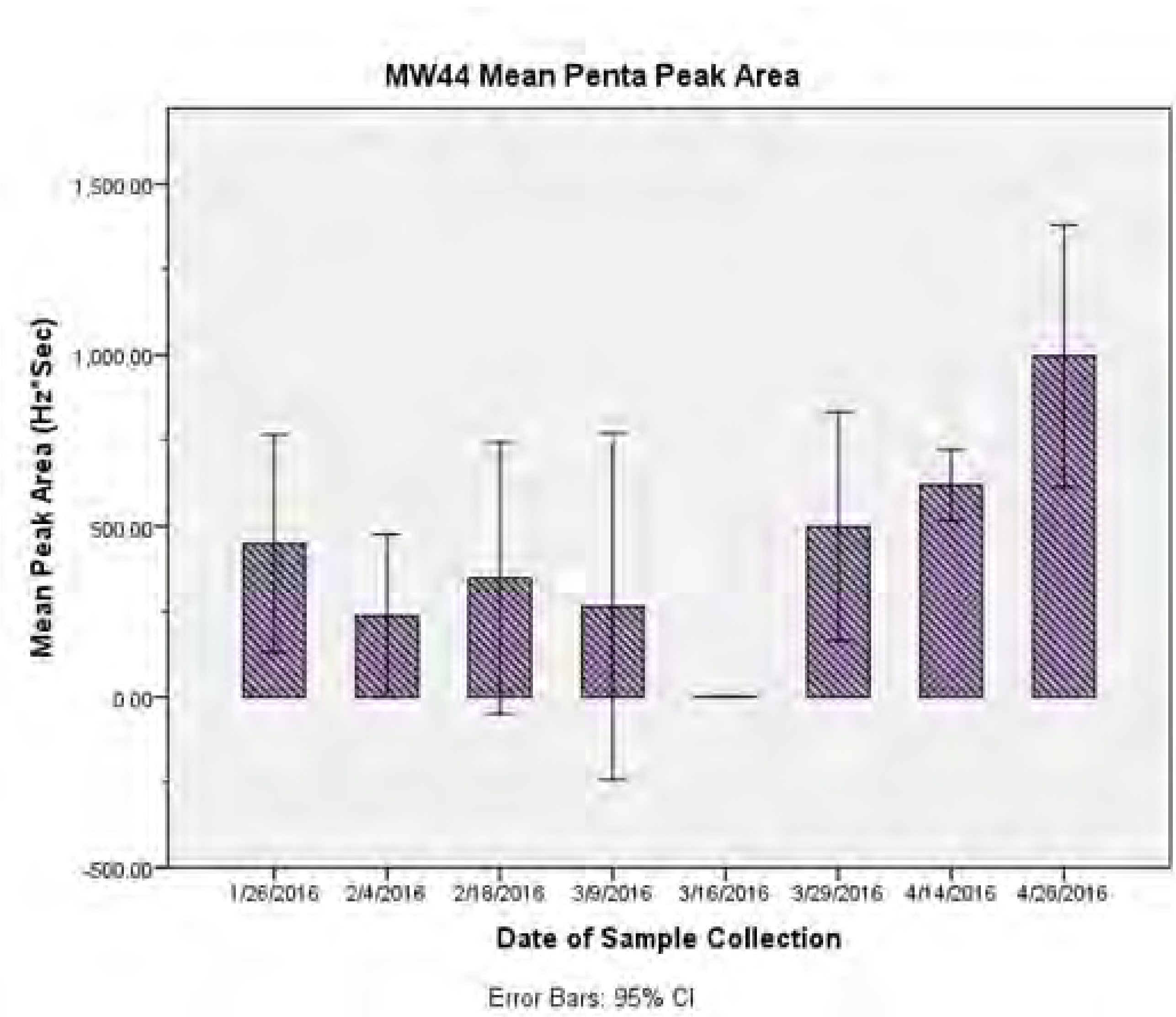
MW-17
ND
MW-43
0.012
MW-42
0.0014
MW-52
0.064
MW-41
ND
1.5
MW-14
0.0035
MW-44
7.7
MW-13
0.0095
MW-15B
ND
Concrete Log Runs
Legend:
-Monitoring Well (MW)
-Air Sparging Well
-Ground Water Direction
-Inferred PCP Contour (mg/L)
-Inferred Non-Detect Isoconcentration Contour
-Area of Phytoremediation


MW44 Mean Penta Peak Area
Mean Peak Area (Hz*Sec)
1,500.00
1,000.00
500.00
0.00
-500.00
1/26/2016
2/4/2016
2/18/2016
3/9/2016
3/16/2016
3/29/2016
4/14/2016
4/26/2016
Date of Sample Collection
Error Bars: 95% CI

Brown Pathways in Green Systems: Source, Habitat and Nutrient Effects on Organic Matter Breakdown in Mississippi Delta Agricultural Bayous

Testa III, S.; Taylor, J.; Lizotte, R.; Dillard, K.

Excess nutrient runoff can impact agricultural water bodies but little is known about the role of agriculturally derived organic matter in mediating water quality impacts associated with nutrient enrichment in agricultural landscapes. We compared source, habitat and nutrient enrichment effects on breakdown rates of agricultural field (corn residue) and riparian (willow oak) organic matter in natural bayou ecosystems and stream mesocosms. Field data indicated that breakdown rates for corn were high ($k = 0.0321 \pm 0.0027\ d^{-1}$) compared to willow oak ($k = 0.0109 \pm 0.0033\ d^{-1}$) in bayous, and, for both species, more hydrologically dynamic inflow sites had significantly lower breakdown rates than lentic sites. Mesocosm results indicated corn residue breakdown rates did not increase with phosphorus (P) enrichment, increased with nitrogen (N) enrichment, but were highest when mesocosms were enriched with N and P (N+P). Willow Oak had much lower breakdown rates than corn residue in mesocosms, confirming species effects observed at field sites. The highest oak breakdown rates were observed in mesocosms enriched with N and P which were significantly higher than control or P enriched streams. Oak breakdown rates in N enriched mesocosms were also significantly higher than control streams but intermediate between P enriched and N+P enriched mesocosms. Respiration rates for corn residue were double that of willow oak and enrichment effects varied with time, but there was clear experimental evidence that N + P enrichment increased respiration for both species. Our results demonstrate that changes from riparian species to more labile crop residue sources of organic matter, combined with nutrient runoff, may impact agricultural water bodies by increasing microbial respiration associated with faster organic matter breakdown rates. However, reductions in nutrient runoff from agricultural areas, as well as increasing buffers of natural vegetation through agricultural best management practices, have the potential to reduce high inputs of crop residue and decrease microbial respiration rates associated with corn residue and nutrient enrichment in bayous of alluvial plain agroecosystems.

Spatial and Temporal Trends for Mercury Concentrations in Fish From Three North Mississippi Lakes and Human Health Risk Assessment

Willett, K.; Cizdziel, J.; Meals, K.; Brewer, S.; Thornton, C.

Total mercury (Hg) concentrations were determined in the skeletal muscle of 310 fish collected during 2013 and 2014 from three northern Mississippi lakes (Sardis, Enid and Grenada) that are extensively used for fishing and recreation. Large-mouth Bass (LMB), Channel Catfish (CC), White Crappie (WC), and Gizzard Shad (GS), that represent a range of trophic levels, were studied. Creel data indicated anglers harvested 372,711 kg of WC, 26,735 kg of CC, and 14,871 kg of LMB, the three most targeted species of fish, from the lakes. Median Hg concentrations (ng/g) were highest in LMB (443, n=64), followed by CC (211, n=72), WC (192, n=101), and GS (49, n=73). Fish-Hg concentrations were lower than those reported in fish >10 years ago, but there were significant differences between lakes consistent across species. Grenada fish-Hg concentrations were higher than those from Enid and Sardis. Because existing consumption advisories for CC are length-based, the lack of a significant relationship between length and Hg concentration indicated that the recommendations may not be protective enough. Furthermore, five different risk assessment paradigms yielded hazard quotient values suggesting that existing fish consumption advisories may be insufficient to protect adults, and especially children, from exposure to Hg.

A New Absorbent From Chemically Modified Powder of Bidens Pilosa and Its Characteristics for Cd Removal From Solutions

Zhao, B.; Zhang, J.; He, T.; Guan, A.; Gu, N.; Ouyang, Y.

Bidens pilosa is a harmful invasive plant species in many countries. In this study, a cadmium (Cd) adsorbent for water treatment was developed by modifying the Bidens pilosa powder with chemical agents including hydrochloric acid, hydrogen nitrate, sodium hydroxide, sodium carbonate, sodium bicarbonate and potassium permanganate to test the Cd removal efficiency. Results demonstrated that the modified Bidens pilosa (MBP) powder with potassium permanganate was an effective adsorbent to extract Cd from a solution. To further assess the potential application of the MBP in polluted water, characteristics of the MBP and its related interference ions effect were investigated. Results showed that: 1) the Cd removal efficiency exceeded 97% when the dosage of the MBP was > 1g/L; 2) the Cd removal efficiency remained at about 99% when the initial Cd concentration was < 100 mg/L; 3) the Cd removal efficiency of the MBP was > 95% when the pH ranged from 2.5 to 5.5; 4) more than 90% of Cd in the polluted water was removed by the MBP in 5 minutes and about 100% of Cd was removed after 1 h; 5) the addition of Mg ion had no significant negative effect on Cd removal when the concentration of Mg ion was below 50 mg/L; and 6) the Cd removal efficiency was significantly decreased when the concentration of Zn or Cu ion was 100 mg/L. This study proved that the MBP is an effective absorbent for Cd removal from polluted water. Being a harmful invasive plant, the utilization of the MBP is beneficial to the control of Bidens pilosa. Further study is warranted to investigate the ions competitive effect provided that the MBP is used for wastewater treatment.

Water Treatment/Management

Bailey Rainey *(Mississippi State University)*	Wastewater Management Issues of Small Communities in the Jourdan River Watershed
Veera Gnaneswar Gude *(Mississippi State University)*	Bio-Inspired Energy and Water Recovery From Low Substrate Wastewaters
Jeff Steinwinder and Edith Martinez-Guerra *(Mississippi State University)*	Solar Powered Multi-Stage Natural Vacuum Low Temperature Desalination Process
Jason Barrett *(Mississippi State University)*	Mississippi Private Well Populations

Wastewater Management Issues of Small Communities in Jourdan River Watershed

Rainey, B.; Gude, V.; Truax, D.; Martin, J.

Wastewater treatment and nutrient removal alternatives for large size communities are very well-established and are feasible in many cases. When it comes to the small rural and especially for low-income disadvantaged communities, this is not the case, particularly with regard to nutrient removal. The alternatives for small communities are often viewed as cost-prohibitive and unreliable. While this is partly true, careful selection and implementation of appropriate technologies can result in high performance, energy and cost efficient and environmental-friendly solutions. Assessment of water and wastewater is very crucial to safeguard public health and the environment. However, water quality data on fresh and marine waters in the Mississippi coastal region, especially in Jourdan watershed are still sparse and uncoordinated. Therefore, monitoring these parameters is important for safety assessment of the environment and human public health and the water bodies. We have identified a few small and decentralized communities in the Jourdan River watershed area to assess the current wastewater treatment and management practices and their impacts on the receiving water bodies. This presentation will discuss the preliminary evaluation and understanding on the local water quality issues of the watershed.

Introduction

While wastewater treatment and nutrient removal at the municipal level is well established, some areas in Mississippi contain communities with homes that are too widespread to feasibly utilize municipal systems. Instead, these homes use on-site wastewater treatment systems, which are not as effective. Alternatives to these systems are often cost prohibitive or cannot be used because of space restraints. Without these alternatives as viable options for rural communities, the less effective systems are being used far beyond their useful life leading to failure and the discharge of insufficiently treated wastewater into rivers and groundwater. This report will focus on the effect these failing units are having on the Jourdan River watershed located near the Gulf Coast in Hancock County, where more than half of the on-site units are failing.

The Jourdan River Watershed

The Jourdan River starts just north of Hancock County, runs south through the county, and discharges into Bay St. Louis. This watershed has been identified as a priority watershed with impaired waters because its waters do not meet one or more water quality standards and are considered too polluted for their intended uses. Figure 1 shows the designated priority watersheds in southern Mississippi, including the Jourdan River watershed.

Due to the recent increase in urban growth and development in the area, there is a potential for groundwater contamination during heavy rainfall from the fertilizers and other chemicals applied to lawns. Agricultural runoff also contributes to the water quality issues in the watershed, but the main contributing factor is point source contamination from failing on-site septic systems. In Hancock County, more than half of these on-site units are failing, as shown by Table 1.

Reasons for the high number of failing units may include insufficient funding to repair or replace them once they have reached the end of their design life and a lack of knowledge on proper operation and maintenance procedures. A major contributor, though, to the failure of these units is their installation where the soil is unsuitable. Approximately two-thirds of all land area in the U.S. is estimated to be unsuitable for the installation of septic systems. Relative soil suitability in Hancock County is only 8%. Another reason

Table 1: On-Site Treatment Units within the Gulf Region (MDEQ, 2007)

Map	County	"No. of On-Site Treatment Units"	"Estimated Failing Units"	"Percentage of Units Failing"	"Estimated Flow from Failing Units (MGD)"
1	George	6597	990	15%	0.196
2	Hancock	12020	7212	60%	1.428
3	Harrison	24019	9608	40%	1.902
4	Jackson	22664	11332	50%	2.244
5	Pearl River	15953	6381	40%	1.263
6	Stone	3899	1560	40%	0.309
	Totals	85152	37083		7.342

on-site systems are failing correlates to their length of use. A properly maintained conventional septic system can be expected to perform for 20-30 years. If the owner does not have the funding to replace the unit once it reaches the end of its useful life, treatment levels will decline and failure will soon follow. Improper maintenance will lead to the failure of a unit. Issues associated with this include inadequate filtration of the effluent through the soil before it reaches the groundwater table and clogging of the drain field. These failing units are discharging inadequately treated sewage and wastewater into the watershed's groundwater and streams. This has led to water quality issues, health issues, and, during the warmer months, as increased risk of hypoxia in the Gulf. The water quality issues in the Jourdan River watershed are already substantial enough for the basin to be designated a priority watershed, and the primary concerns for the Jourdan River have been identified as faulty septic systems. In the warmer months, the Dead Zone in the Gulf of Mexico can be attributed in part to these failing systems as well. The high levels of nitrate and other nutrients in the improperly treated effluent being transported to the Gulf feed the algal blooms that thrive in warm temperatures. This causes a lack of oxygen in the waters, killing the organisms that regularly live there.

Comparing the Conventional Septic System to Current Alternatives

In order to improve the water quality, the failing units that are impairing it need to be replaced, ideally with alternative systems that provide a higher level of treatment; however, common alternatives are considered cost prohibitive, and they require more routine maintenance than the conventional septic system. On-site treatment systems are used to treat wastewater on the property in areas where it is not feasible or possible to get the wastewater to a centralized treatment plant. They are most often used in small rural communities where the homes and properties are too spread out for a centralized treatment facility to be economically feasible. They are also common in small industrial facilities and businesses (Davis & Cornwell, 2008).

Conventional Septic Systems

The most common type of on-site treatment system is the conventional septic system. The three main components in a convention septic system are the septic tank, the distribution device, and the absorption field. First, a pipe carries the wastewater from its place of discharge to the septic tank either by means of gravity or with the use of a pump. In the septic tank, grease and solids are separated from the raw sewage and partially decomposed through biological decomposition. Grease floats to the top and for a scum layer, and heavy solids that are not digested settle to the bottom as sludge. The size of the tank depends on the wastewater flow, but it needs to be large enough to retain the wastewater and allow for partial decomposition for at least 24 hours. After primary treatment in the septic tank, the distribution device equally distributes the effluent throughout the absorption field. This is a series of subsurface trenches that hold perforated pipes settled between layers of drainrock. The size of the absorption field depends wastewater flow

and the permeability of the soil in the field area. In the absorption field, the septic tank effluent seeps through the soil which allows for further bacterial treatment and filtration. During operation, bacteria produce a layer of slime at the bottom of the trench called the clogging mat. This layer slows the movement of water to the surrounding soil which maintains aerobic conditions essential for proper treatment of the effluent. Typically, the following levels of treatment can be expected from a properly functioning conventional system with a drainfield:
BOD5 = 10 mg/L
TSS = 10 mg/L
Fecal coliforms – usually less than 200 per 100 mL

When properly operated and maintained, conventional septic systems can function effectively for 20 to 30 years. The most common cause of failure in conventional systems in improper maintenance. Based on the size of the septic tank and the volume of sewage, the scum and sludge need to be pumped from the tank every 2 or 3 years. Because the rate of decomposition in the tank is slow, the levels of scum at the top and sludge at the bottom can build up and lead to an increase in distribution of solids to the absorption field. If too many solids reach the field, it could become clogged and lead to an early failure. Other causes for failure include hydraulic overloading or the introduction of substances that are toxic to the soil bacteria (Davis & Cornwell, 2008).

The advantages of this type of system include low installation cost as compared to other types of units, the return of nutrients from the wastewater to the soil, and that they allow for water reuse in a certain capacity. Disadvantages, however include possible odor problems, negative public perception, the introduction of pathogens into the groundwater through malfunctioning systems, and that they don't allow for nitrogen removal without the use of additional treatment. The costs associated with these systems are relatively low with only $1,500 to $4,000 for the system itself and the installation, and $250 to $550 per year for the operation and maintenance of the system (EPA, Septic Tank - Soil Absorption Systems, 1999).

Current Alternatives

While the conventional septic system is the most common, there are alternative types of on-site treatment systems. Another commonly used system is the aerobic treatment system. With this alternative, oxygen is incorporated into the wastewater inside the treatment tank in order to increase the rate at which the solids are broken down.

Aerobic systems

Another commonly used system is the aerobic treatment system. With this alternative, oxygen is incorporated into the wastewater inside the treatment tank in order to increase the rate at which the solids are broken down, providing a higher level of treatment. Aerobic systems mirror many of the steps and activities performed by municipal sewage plants. These systems are a good alternative for homeowners on lots with a high groundwater table or close to a body of water that might be polluted through the use of a conventional septic system with a drainfield. Aerobic systems employing a chlorinator and spray heads are a good option for landowners who don't want to clear trees to create a drainfield. From the aerobic treatment tank, the effluent is passed through a chlorinator to the final treatment tank. At this point, the resulting treated effluent is clean enough to be discharged via sprinklers directly over the absorption field. One of the disadvantages of using an aerobic system over a conventional system is the requirement for more routine maintenance (Pipeline, 2005).

Sand Filter Systems

Intermittent and recirculating sand filter systems are types of aerobic treatment systems. They provide secondary treatment and are often used along with a conventional septic system to pretreat the tank effluent before it is sent to the absorption field if the unsaturated depth or permeability of the soil is unsuitable for proper treatment. "Sand filters remove contaminants in wastewater through physical, chemical, and biological processes. Although the physical and chemical processes play in important role in the removal of many particles, the biological processes play the most important role in sand filters." Sand filters consist of a primary treatment system and the filter. The primary treatment system is most often a septic tank, but could be any other sedimentation system. The filter consists of a granular material, most often sand, over an underdrain system. The wastewater is dosed onto the surface of the granular material and allowed to percolate through to the bottom of the filter. The dose should be such that the mate-

rial is not saturated, and the wastewater is able to flow in a thin layer around the grain particles. This allows sufficient contact between the wastewater and the air.
At the end of the intermittent cycle, the wastewater is passed on to a drainfield for further treatment through filtration. At the end of the recirculating cycle, a portion of the wastewater is sent back through the sand filter system (Davis & Cornwell, 2008).

Intermittent Sand Filter System
Typically, the following levels of treatment can be expected from a properly functioning intermittent sand filter system:
BOD5 = 95% removal
TSS = 85% removal
Nitrification of 80%+ of the applied ammonia

The costs associated with this type of unit are substantially higher than those associated with the conventional system with the total capital cost at roughly $10,000, and the annual operation and maintenance costs totaling $155 per year, plus the cost for power. The major disadvantage associated with this type of unit is that it doesn't allow for nitrogen removal. In order for this to be achieved, a recirculating filter should be used (EPA, Intermittent Sand Filters, 1999).

Recirculating Sand Filter System
Typically, the following levels of treatment can be expected from a properly functioning recirculating sand filter system:
BOD5 = 95% removal
TSS = 95% removal
Almost complete nitrification is achieved
Denitrification has been shown to occur
Frequently used where nitrogen removal is necessary

The costs associated with this type of unit are higher still than those of the intermittent sand filter system. The total capital cost associated with recirculating sand filter systems can exceed $25,000, and the yearly costs associated with the operation and maintenance of the unit can reach upwards of $350 per year, plus the cost of power to run the system (EPA, Recirculating Sand Filters, 1999). Table 2 compares the different types of on-site systems discussed.

The conventional septic system is the most commonly used system because of the lower capital and operating costs. If other, more cost-effective, wastewater treatment and nutrient removal technologies are introduced, there is a higher chance these systems will actually be utilized, and the water quality in the watershed area can be improved.

Conclusion
There are several challenges associated with replacing the failing conventional on-site septic systems in the Jourdan River watershed. The first of which is to identify these units. Most records of specific, privately owned and operated on-site septic systems are not made available to the public. Assistance from the MDEQ, MSDH, USGS, and other organizations in possession of this information is required. Another challenge is to find or develop alternatives that offer the higher level of treatment necessary to improve the water quality in the watershed area without the high cost associated with the current alternatives. Once the data is analyzed, and the treatment parameters are defined for new alternative systems, research and development on these systems can be continued.

Table 2: Comparing the Conventional Septic System to Current Alternatives

System	Cost		Treatment Levels			
	Installation	Annual	BOD5	TSS	Nitrification	Denitrification
Conventional	$1,500 - $4,000	$250 - $550	10 mg/L	10 mg/L	-	-
"Intermittent Sand Filter"	$10,000	$155 + Power	95% Removal	85% Removal	80% +	-
"Recirculating Sand Filter"	$25,000 +	$350 + Power	95% Removal	95% Removal	Near Complete	Up to 50%

Acknowledgements
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Figure 1: Priority Watersheds in Southern Mississippi (MDEQ, Citizen's Guide to Water Quality in the Coastal Streams Baisn, 2008).

Bio-Inspired Energy and Water Recovery From Low Substrate Wastewaters

Stuart-Dahl, S., Gude, V.G.

In this research, low substrate synthetic wastewaters with chemical oxygen demand (COD) less than 300 mg/L were treated at different concentrations in microbial desalination cells. A process optimization model was utilized to study the performance of the photosynthetic microbial desalination cells. The variables include substrate concentrations, total dissolved solids, and microalgae concentration in the cathode chamber. Relationships between the COD concentrations, microalgae and salt concentrations were evaluated. Power densities and potential energy benefits from algal biomass growth were discussed. The results from this study demonstrated the reliability and reproducibility of the photosynthetic microbial desalination process performance followed by a response surface methodology optimization. This research confers the suitability of MDCs for treating low substrate wastewaters such as agricultural wastewaters, anaerobic digester effluents and septic tank effluents for net energy production and water desalination.

Introduction

The energy and water production issues are intertwined and cannot be addressed in isolation. Wastewater treatment and desalination, in particular, are energy consuming processes which can have detrimental effects on the environment. Integrated solutions that utilize waste sources to generate energy, which in turn power freshwater production are attractive options to address the current energy and water issues. In this context, bioelectrochemical systems have evolved as a novel technology to convert wastes into valuable forms of energy. Bioelectrochemical systems can be employed to generate clean electricity or high value energy-chemical products from various wastewater sources and organic/inorganic wastes that can serve as fuel feedstock for electroactive bacteria. Microbial desalination cells (MDCs) are based on an integrated configuration in which, wastewater and saline water sources can be treated simultaneously without any external power input or mechanical energy or pressure application. This process offers multiple benefits of energy and resource (water and nutrients) recovery while eliminating environmental pollution.

To eliminate the environmental issues associated with abiotic anodes and cathodes in bioelectrochemical systems, this research focuses on developing a complete biological system. This system is powered by the biochemical reactions mediated by two different microbial species in anode (bacteria) and cathode (microalgae) chambers. The oxidation of organic matter by anaerobic bacteria in the anode chamber results in release of electrons which are transferred through the external electric circuit to the cathode chamber containing microalgae where the reducing process takes place. Microalgae in bioelectrochemical systems (as media in anode and cathode chambers) produce several benefits: i) they serve as electron donors (at anode); ii) they remove organic matter (heterotrophic algae at anode); iii) they produce electron acceptors (photosynthetic algae at cathode) and (iv) they can be used for carbon sequestration (Gude et al. 2013). Figure 1 shows the working principle of an algal microbial desalination cell. The process details can be found in our previous publications (Kokabian and Gude 2013).

In this research, we have evaluated the feasibility of utilizing low substrate wastewaters as an electron donor in microbial desalination cells supported by the microalgae biocathode chamber. The issues related to reliability and reproducibility were addressed through a series of experiments. These were followed by a set of experiments designed using a response surface methodology model.

The following sections describe the optimization studies of algal microbial desalination cells for simultaneous energy and water recovery.

Materials and methods

Microbial consortium in the anode compartment was collected from the aerobic sludge of the wastewater treatment plant in Starkville, Mississippi. The sludge was allowed to acclimatize to anaerobic conditions in synthetic wastewater containing 300 mg L^{-1} of COD for over 150 days. The microbial consortium was grown in air and algal cathode MFCs prior to its transfer into the air and algal MDCs respectively. The synthetic wastewater in the anode chamber has the following composition: glucose 468.7 g L^{-1}, KH_2PO_4 (4.4 g L^{-1}), K_2HPO_4 (3.4 g L^{-1}), NH_4Cl (1.5 g L^{-1}), $MgCl_2$ (0.1 g L^{-1}), $CaCl_2$ (0.1 g L^{-1}), KCl (0.1 g L^{-1}), $MnCl_2 4{\cdot}H_2O$ (0.005 g L^{-1}), and $NaMo.O_4{\cdot}2H_2O$ (0.001 g L^{-1}).[5] The COD concentration used in the MDC anode chamber was 500 mg L^{-1}. The microalgae *Chlorella vulgaris* used in the cathode compartment was grown in the following mineral solution: $CaCl_2$ (25 mg L^{-1}), NaCl (25 mg L^{-1}), $NaNO_3$ (250 mg L^{-1}), $MgSO_4$ (75 mg L^{-1}), KH_2PO_4 (105 mg L^{-1}), K_2HPO_4 (75 mg L^{-1}), and 3 ml of trace metal solution with the following concentration was added to 1000 ml of the above solution: $FeCl_3$ (0.194 g L^{-1}), $MnCl_2$ (0.082 g L^{-1}), $CoCl_2$ (0.16 g L^{-1}), $Na_2MoO_4{\cdot}2H_2O$ (0.008 g L^{-1}), and $ZnCl_2$(0.005 g L^{-1}). *Chlorella vulgaris* sp. was chosen due to its tolerance for high levels of CO_2 and high efficiency in utilizing CO_2 through photosynthesis. A known volume of this algal consortium with a known cell density was transferred into the cathode chamber.

The cylindrical-shaped MFC chambers were made of plexiglass and the anode and cathode chambers were separated by an ion exchange membrane. Carbon cloth was used for anode and cathode electrodes. The volume of the anode and cathode chambers was 60 ml after inserting the electrodes. The MDC reactors were prepared by inserting a desalination chamber (30 mL) between anode and cathode chambers in MFC reactors. Cation exchange membrane (CEM, CMI 7000, Membranes international) separated the cathode and desalination part while an anion exchange membrane (AEM, AMI 7001, Membranes international) separated the anode and desalination chambers. The volume of the desalination chamber was about 200 ml with a salt concentration of 10 g L^{-1} NaCl. The volume of the algae chamber was maintained at 100 ml to represent a passive algae biocathode. No external mechanical aeration was provided. Thus, the volume ratios in the photosynthetic MDC system were 2.0 : 1.0 : 2.0 for anode, desalination and cathode chambers respectively.

The voltage was recorded using a digital multimeter (Fluke, 287/FVF) and a 10 k ohm resistor was used in closed circuit tests. The current was calculated using the Ohm's law, $I = V/R$. The power density was calculated (using $P = V \times I$) as per the anode/cathode chamber volume or the electrode surface. COD tests were carried out according to the standard methods.[21] Electrical conductivity, TDS removal and salinity removal were recorded using a conductivity meter (Extech EC400 ExStik Waterproof Conductivity, TDS, Salinity, and Temperature Meter). The pH of the samples was measured using a pH meter (Orion 720A+ advanced ISE/pH/mV/ORP). Dissolved oxygen was measured using a YSI 5100 system. Algae growth was monitored by measuring the optical density of the algal medium with a Spectronic®20 Genesys spectrophotometer at a wavelength of 620 nm. Measurements were taken at regular intervals and three replicates were measured per sample. The desalination rate (Q_D, mg h^{-1}) was calculated by $Q_D = (C_0 - C_t)/t$, where C_0 and C_t are the initial and the final TDS of saltwater in the middle chamber over a batch cycle of time *t*. Illumination on the algae cathode chamber was provided by CFL white light at 60 W (276 μmol m^{-2} s^{-1}) (Kokabian and Gude 2013).

A central composite model with three levels of process variables at three factorial subset deign proposed by Gilmour (2006) was used to optimize the MDC process. These were represented by a cube with six replications at the center which offer better approximation of the true error which substantially helps determination of significance of process variables. The symmetry in design with regard to the center offers equal importance to all levels of all parameters. The process variables were COD (chemical oxygen demand): 100-300 mg/L; TDS (total dissolved soilds): 10-30 mg/L; and microalgae concentrations measured as absorbance: 0.1-0.3 (dimensionless). The process variable details for the three factorial model are provided in Table 1.

Table 1. Experimental design based on RSM for photosynthetic microbial desalination cell process optimization

Run order	COD (mg/L)	TDS (mg/L)	Microalgae absorbance (-)
1	200	20	0.2
2	100	30	0.3
3	300	10	0.1
4	200	20	0.2
5	100	10	0.3
6	300	30	0.1
7	300	20	0.2
8	200	20	0.2
9	200	10	0.2
10	200	20	0.2
11	100	20	0.2
12	200	30	0.2
13	300	10	0.3
14	200	20	0.1
15	100	10	0.1
16	300	30	0.3
17	200	20	0.2
18	100	30	0.1
19	200	20	0.3
20	200	20	0.2

Results and discussion

The experimental studies were conducted in two phases in which the first phase evaluated the reproducibility of the outcomes of the microbial desalination cells (Figure 2). Three identical MDC reactors were developed and loaded with similar process conditions. Two sets of tests were conducted over 2-day process time. The process conditions were fixed at 200 mg/L of COD, 20 mg/L of TDS and 0.2 microalgae absorbance. Results shown in Figure 2 demonstrate the reproducibility of the MDCs. The voltage production with time and cumulative voltages were in acceptable range for all the tests. For example, a maximum voltage production rate ranging between 0.15 and 0.17V was observed among the two different tests in the six MDC reactors. The cumulative voltages were between 240 and 320 V, with the optimum voltage around 260 V.

Figure 3 shows the voltage production and cumulative voltage output profiles for eight different test conditions in MDCs using response surface methodology as shown in Table 1. It can be noted that higher voltage was produced for higher COD concentrations due to availability of organic matter over a long period of time. Some tests were repeated to confirm the response of the process parameters where

The interdependence of COD (mg/L), TDS (mg/L) and microalgae concentration (absorbance) and their effect on the voltage production are depicted in Figures 4a and 4b. A voltage production of 200 V can be achieved at 250 mg/L, TDS of 20 mg/L and microalgae absorbance of 0.2. Higher TDS and COD concentrations did not necessarily increase the voltage output probably due to increased ionic transfer. The relationship between the desalination rate (or the increase in the volume of desalinated water as percentage in the middle chamber) and the TDS (mg/L) and algae absorbance are shown in Figure 4c and 4d. Higher TDS and COD concentrations favored desalination rate as shown in Figures 4c and 4d. The desalination rate was 18% at a TDS concentration of 25 (mg/L) and COD of 300 (mg/L).

The relationship between various parameters affecting the salt removal and microalgae growth are shown in Figure 5a, 5b, 5c, and 5d. As shown in Figure 5a, higher COD and TDS concentrations favor higher TDS removal (desalination rate). However, an inverse relationship can be observed for microalgae absorbance vs. TD removal. Lower microalgae concentrations are suitable for higher TDS removal because the desalination process between the salt and biocathode chamber is more dominated by the diffusion process where the concentration difference serves as the driving force whereas between the anode and salt chamber the desalination process is more favored by the electron release and proton transfer process. Microalgae growth was higher at COD and TDS concentrations of 200-250 mg/L and 20-25 mg/L respectively. In addition microalgae growth rate was higher for lower initial microalgae concentrations (see Figure 5c).

Energy aspects of the algal MDCs

Wastewater treatment requires about 0.5-2 kWh of energy per unit depending on the process. Chemical energy stored in wastewater can be efficiently harvested to make it an energy-producing process rather than an energy-consuming process while eliminating environmental pollution (Gude et al. 2013). Contrary to conventional desalination methods, MDC is considered energy gaining process. MDCs produce bioelectricity while desalinating the saline water due to ionic migration. It is estimated that about 1.8 kWh of bioelectricity can be generated in MDCs by treating $1m^3$ of wastewater while a reverse osmosis technology requires 2.2 kWh of electricity for the same amount of water desalination. Combining the energy produced by the MDCs and the energy saved by the desalination, a total 4 kWh/m^3 of energy savings can be realized. In a case where UMDC is utilized as a pretreatment process for RO process, MDCs can reduce 30% of dissolved solids which will reduce the RO energy requirements from 3.7 to 3.5 kWh/m^3. In systems integrated with algal harvesting, the energy recovery benefits could be even higher, because algae have an energy content of 5-8 kWh/kg dry weight. This energy can be recovered in the form of biofuels such as biogas, biohydrogen, and biodiesel (Kokabian and Gude 2013).

Conclusions

This study demonstrated the use of response surface methodology as a tool for optimizing the benefits of the algal microbial desalination cell technology. Experimental studies elucidated the issues related to reproducibility and reliability of the process outcomes. RSM optimization method allowed for deriving relationships between the different process parameters. Understanding the interdependence and simultaneous responses of process variables in MDCs is very important for their large scale development. A maximum voltage of 0.17 V was produced from low substrate synthetic wastewater and a desalination rate of up to 30% is feasible in photosynthetic MDCs. This study proved that simultaneous energy and water recovery can be feasible from low substrate wastewaters, however, pilot-scale studies are required for proper evaluation of techno-economic feasibility.

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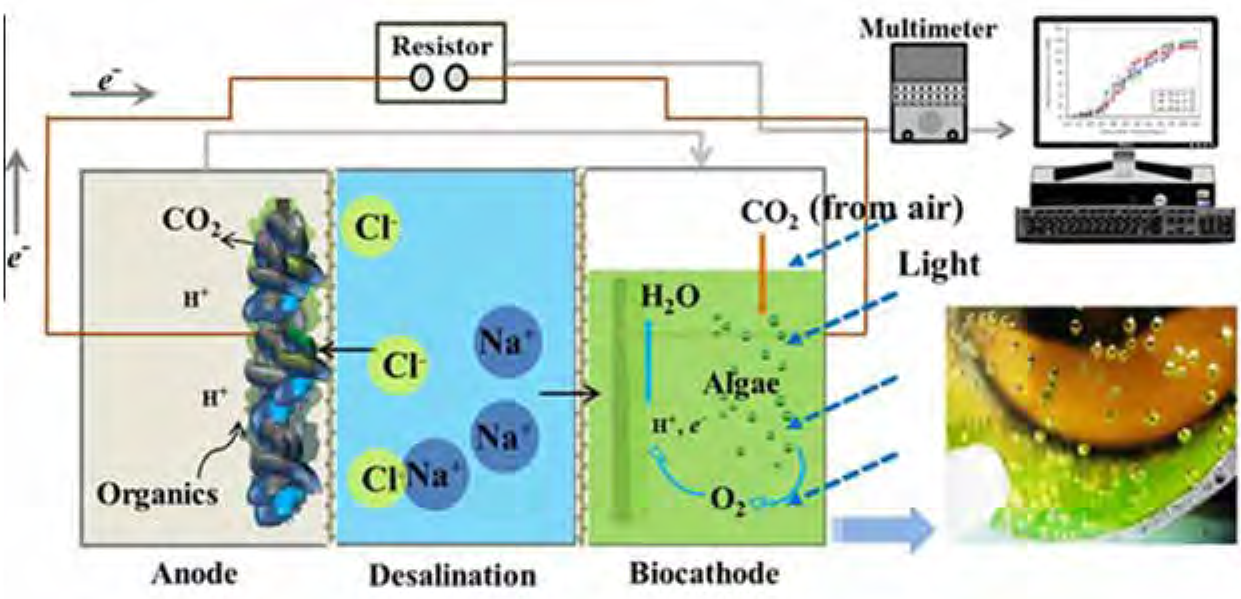

Figure 1. Schematic of the working principle of photosynthetic microbial desalination cell system with micro-algae biocathode.

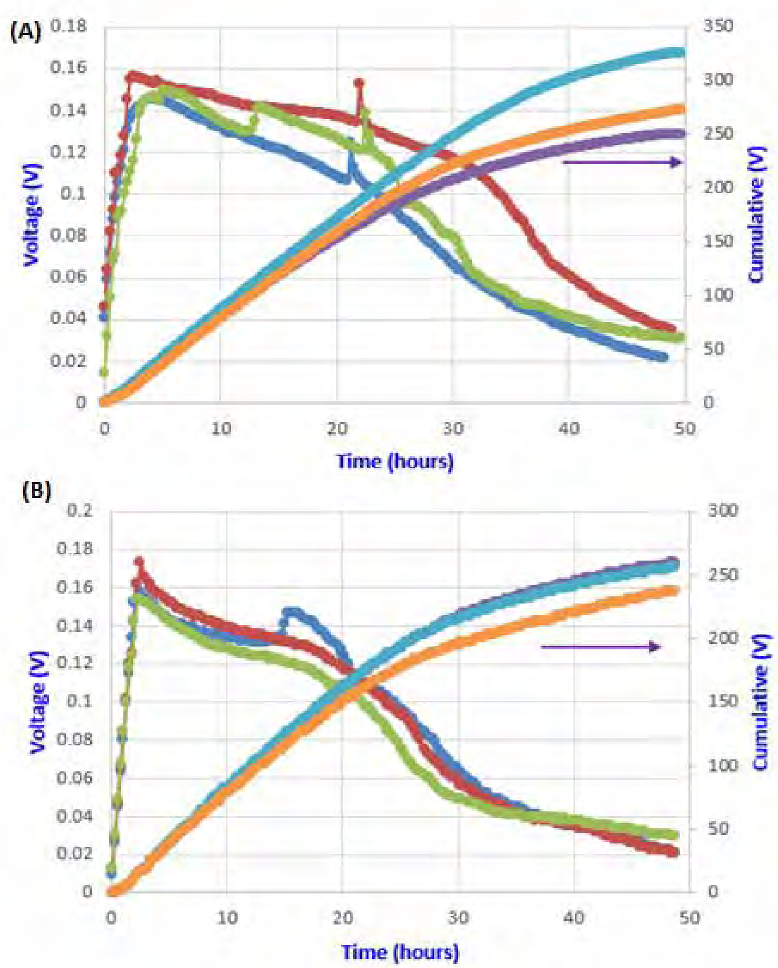

Figure 2. Voltage production and cumulative voltage profiles for three different MDCs in two sequential tests (total 6 tests at 200 mg/L COD, 20 mg/L TDS, and 0.2 absorbance).

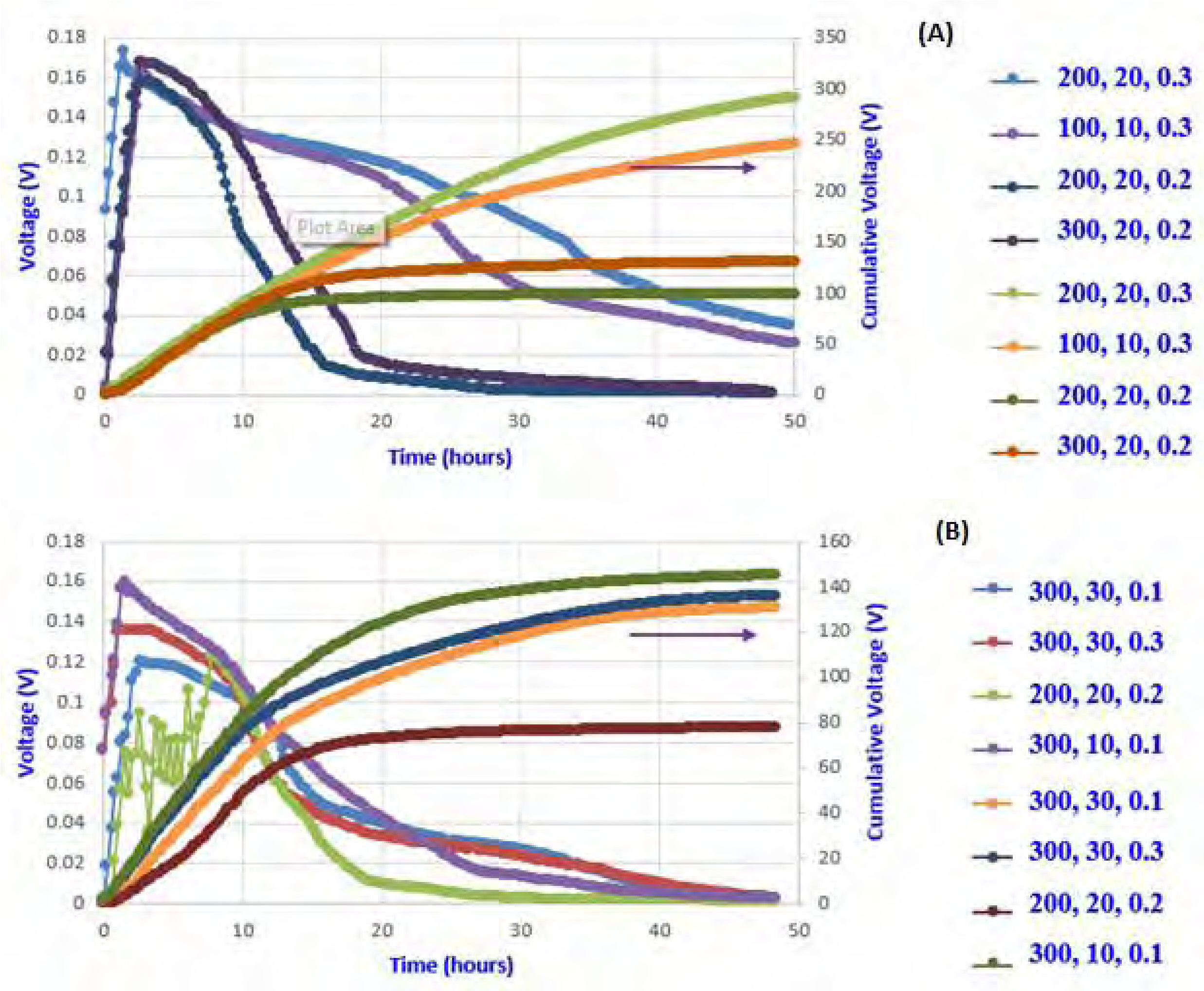

Figure 3. Voltage production and cumulative voltage output profiles for eight different test conditions in photosynthetic MDCs.

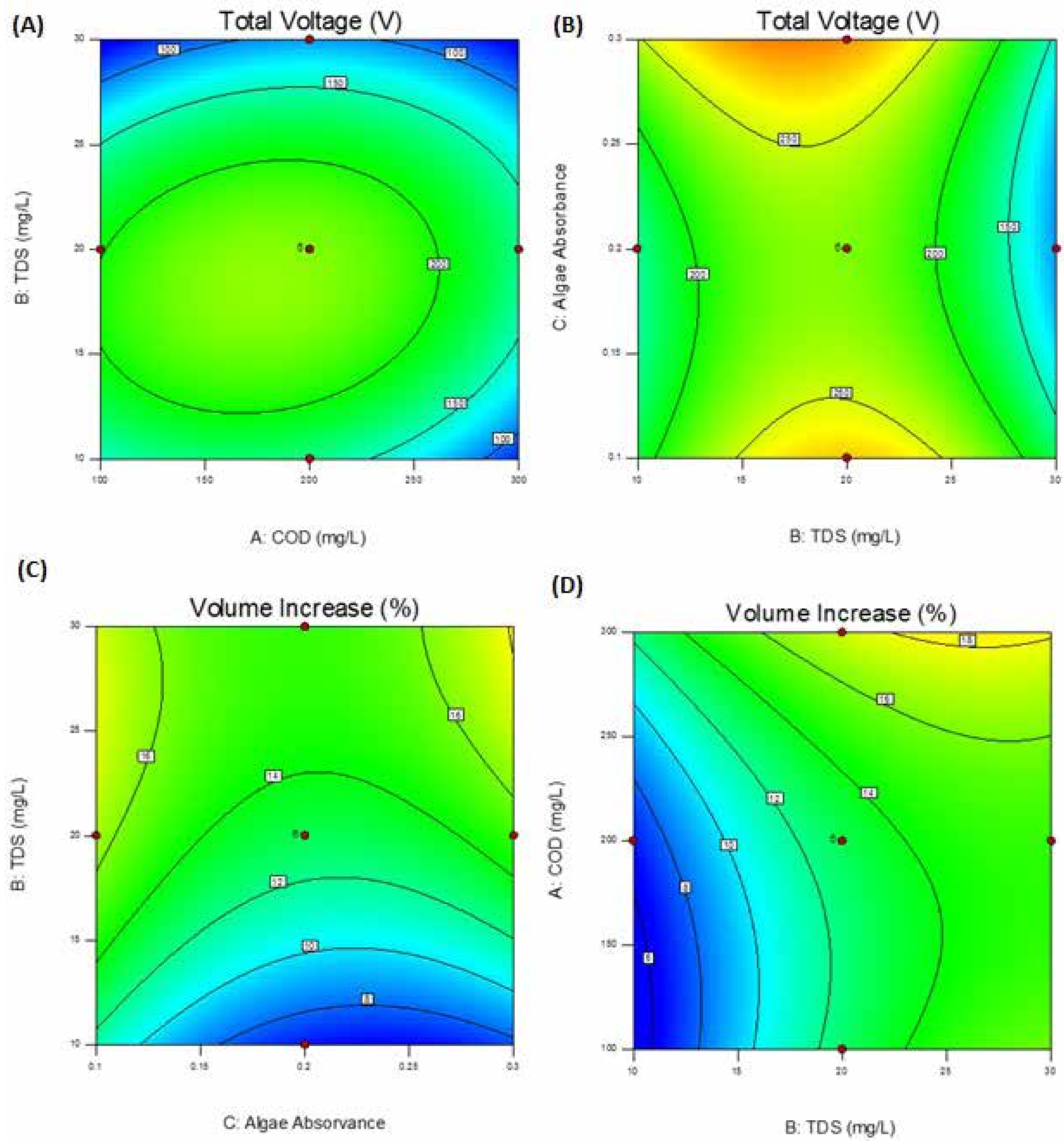

Figure 4. The relationship between the voltage production (total voltage, V) and the process conditions (COD (mg/L); TDS (mg/L), and microalgae absorbance (dimensionless)) using RSM optimization model.

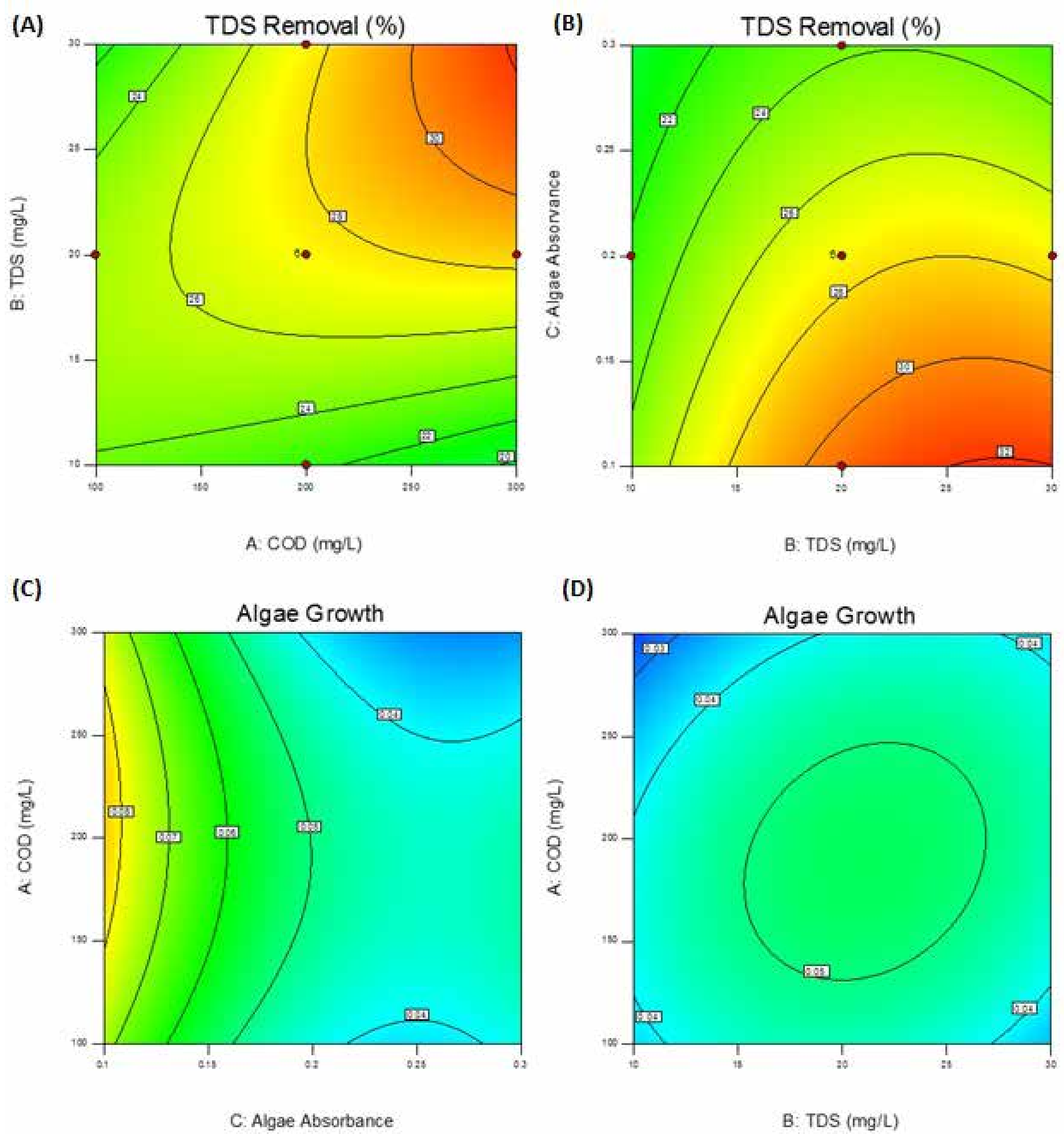

Figure 5. The relationship between the TDS removal (%), microalgae growth and the process conditions (COD (mg/L); TDS (mg/L), and microalgae absorbance (dimensionless)) using RSM optimization model.

Solar Powered Multi-Stage Natural Vacuum Low Temperature Desalination Process

Steinwinder, J.; Martinez-Guerra, E.; Guerra, H.; Spiller, B.; Byrd, C.; Solis, M.; Gude, V.

Desalination has emerged as a viable alternative for water supply in many water-stressed regions of the world. In US, some of the states such as California, Texas and Florida are faced with major challenges of ensuring adequate water supplies to meet the demands as a result of population growth, severe drought, decreasing aquifer levels and increasing industrialization. Desalination can be performed through membrane and thermal processes, both of which are energy-intensive. Powering desalination processes through conventional energy sources is not a sustainable approach as these sources are not renewable. Utilization of renewable energy such as solar energy for water desalination is an ideal approach for thermal desalination processes.

In this research, a low temperature desalination process operating at near-vacuum pressures was studied. Near vacuum pressures are created by exploiting the barometric head and gravitational force. As a result, this process reduces the specific energy consumption for freshwater production due to reduced heat losses to the ambient. This allows for efficient utilization of solar energy and better economics.

Preliminary data analysis of a multi-stage (3 stages) low temperature desalination process powered by a low grade heat source is presented in this paper. The total output from the three stage unit was 30 L/d-m^2. The energy efficiency of the three stage desalination unit over the heating and non-heating periods has exceeded 72%. Solar collectors will be used to provide the thermal energy required for the desalination process. Our preliminary economic analysis shows that when this desalination system is powered by a low grade flat plate solar collector heat source, the desalination costs are less than \$7/m^3 which falls in the acceptable range for small scale desalination systems of similar capacity. When using a cheap waste heat source purchased at \$0.5/GJ, the desalination costs can be reduced to \$3/m^3. Because most small-scale domestic desalination systems are designed in combination with a renewable energy source such as solar energy, this process can provide a sustainable alternative for freshwater production for remote and coastal communities.

Introduction

The need for freshwater can never be overstressed. Global agencies (including WHO, UNDP, UNICEF etc.) expect that 24 of the least developed countries, many of them along coastal areas without access to water and electricity, need to more than double their current efforts to reach the Millennium Development Goals (MDGs) for basic health, sanitation, and welfare. Desalination of available brackish or seawater sources is an ideal option for freshwater production. However, existing desalination technologies are energy-intensive and cost-prohibitive. Low temperature desalination using waste heat sources or solar collectors is an attractive option, because the energy demands can be provided with low cost and minimum environmental pollution (Kalogirou 2005, Gude et al. 2010).

We have developed a novel low temperature thermal desalination system which operates under natural vacuum using low grade/waste heat sources such as process waste heat and low grade flat plate solar collectors. The process operates under near vacuum conditions created by natural gravity and barometric head. Two 33 ft. saline and freshwater columns together construct the low temperature desalination process to automatically draw the feed and produce freshwater by use of waste heat in the evaporator. Thus the process operates continuously without any external mechanical energy for pumping (Gude et al. 2012).

Here, we investigate the technical feasibility of a multi-effect low temperature desalination process with higher thermodynamic efficiency and low environmental impact. Current research is based on the proof-of-concept demonstration study experience and our current knowledge to expand the use of energy recovery (by multi-effect design) in the desalination process to increase the output rates and to reduce the process/energy footprint and costs. The research will be conducted through three experimental tasks to demonstrate the low temperature desalination under natural vacuum: the tasks are: 1) Design and development of novel multi-effect desalination unit powered by solar collectors; 2) Demonstrate the new desalination process (multi-stage experiments at different feed rates, brine withdrawal rates, and evaporation temperatures using solar collectors); and 3) Demonstrate the process with solar/PV thermal collectors for combined energy-water production.

Experimental studies

The three stage design includes heating and condensing surfaces in successive stages for energy recovery/reuse and product recovery enhancement. Design and manufacturing of a three stage desalination unit was completed. A second unit is under construction for simultaneous evaluation of heat sources derived from solar collectors and photovoltaic thermal collectors. Solar collectors were installed for the demonstration of solar energy driven desalination process.

Two photovoltaic modules capable of producing approximately 250 W (together) of electricity were purchased from a commercial vendor. These were modified to include cooling water circulation system to extract the heat accumulated by the photovoltaic module surface. The heat extracted from the photovoltaic modules will be used for desalination purpose. This task has been completed and the modified modules are available for demonstration. Figure 1 shows the experimental setup and the project development stages for low temperature desalination process. For verification of working principle of the proposed three-stage desalination unit design, we have first evaluated the use of a waste heat source. The experimental setup consists of a laboratory water heater with controllable water temperature which served as a heat source for our preliminary experimental studies. A series of experiments were conducted to evaluate the effect of heat source temperature and process performance. The temperature and energy supply and water production profiles for the two stage low temperature desalination unit. The heat source temperature was varied between 60 and 80°C at a 10°C interval to account for the effect of heat source temperature on the desalination unit. A photograph of the experimental setup for a low grade heat source (laboratory water heater) is shown in Figure 2. Operating pressure and temperature data were collected using a data acquisition system at 5-min interval.

Results and Discussion

The temperature profiles and freshwater production rates for waste heat source temperature at 70°C are shown in Figure 3. The energy supply and thermal energy efficiency trends with and without heating period are shown Figure 4. The freshwater production continued even after the heat supply has been stopped due to the storage of sensible heat in the mass of water in each stage.

We have conducted a series of experiments with different hot water source temperatures at 50°C, 60°C, and 70°C respectively. Evaporation and condenser areas were 0.31 m^2 respectively for all the stages. A coil-type heat exchanger was used to supply heat in the first stage. Representative temperature profiles are shown in Figure 1c. The experiments were run for a total period of 18 hours which includes 10 hours of heating and 8 hours of cooling (no heat supply) periods. The freshwater production rates increased with increase in the source water temperatures. These were 160, 230, and 260 mL/hr at 50°C, 60°C, and 70°C respectively. The total output from the three stage unit was 30 L/d-m^2. The energy efficiency of the three stage desalination unit over the heating and non-heating periods has exceeded 72%. Efficiency can be further increased with proper insulation and further fine-tuning of the process. The productivity of the unit is at least 2.5 higher than the solar still productivity per given area and the specific energy consumption is 2.5 times lower than other solar still processes. Further controlling the vacuum conditions have the potential to almost double the current productivity (Gude and Khandan 2009). The salinity of distilled water less than 30 ppm (mg/L) representing a salt removal of

99.9% while the feed water had a concentration of 20000 ppm (mg/L). pH of the distilled water was less than 7.6.

Summary and recommendations

This study demonstrated the feasibility of utilizing low-grade heat sources for a multi-stage low temperature desalination process. The results show that the energy recovery and reuse and therefore the specific energy consumption of thermal desalination process can be improved by operating at low temperatures. Experimental studies will be continued to evaluate solar collectors and photovoltaic thermal collectors as heat sources for desalination. Electricity production with and without the modification to the photovoltaic thermal collectors will be measured. Through experimental studies, critical factors related to the design of large scale production units such as evaporator and condensing surface areas, heat exchanger surface areas and flow rates will be determined. Saline water and brine flow rates will be optimized to enhance energy recovery within the system.

Acknowledgements

The authors gratefully acknowledge the funding support from USEPA through grant SU836130. This research was also supported by the Office of Research and Economic Development (ORED), Bagley College of Engineering (BCoE), and the Department of Civil and Environmental Engineering (CEE) at Mississippi State University and the United States Environmental Protection Agency (USEPA) under P3 (People, Planet, and Prosperity) Awards program through the grants SU835721 and SU835722.

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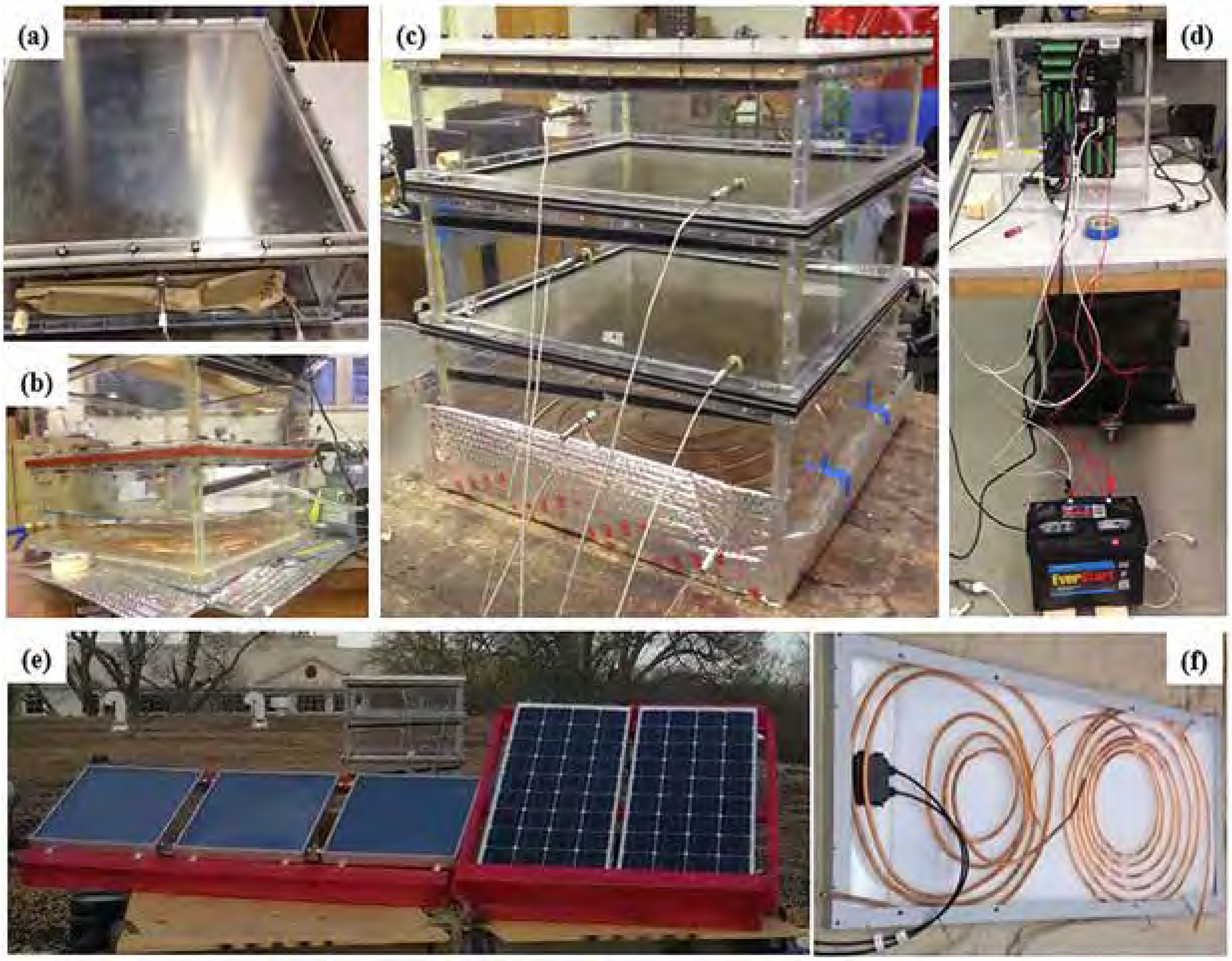

Figure 1. Project development stages: (a) low temperature desalination unit with an aluminum condenser; (b) two-stage unit separated by aluminum condenser; c) three-stage low temperature desalination unit and coil type heat exchanger; (d) data acquisition systems; (e) solar collector and photovoltaic thermal collector installation on the roof top of the walker engineering building (department of civil and environmental engineering); and (f) fabrication and modification of PV-thermal collectors.

Figure 2. Low temperature desalination unit powered by waste heat source, photo image of the experimental setup.

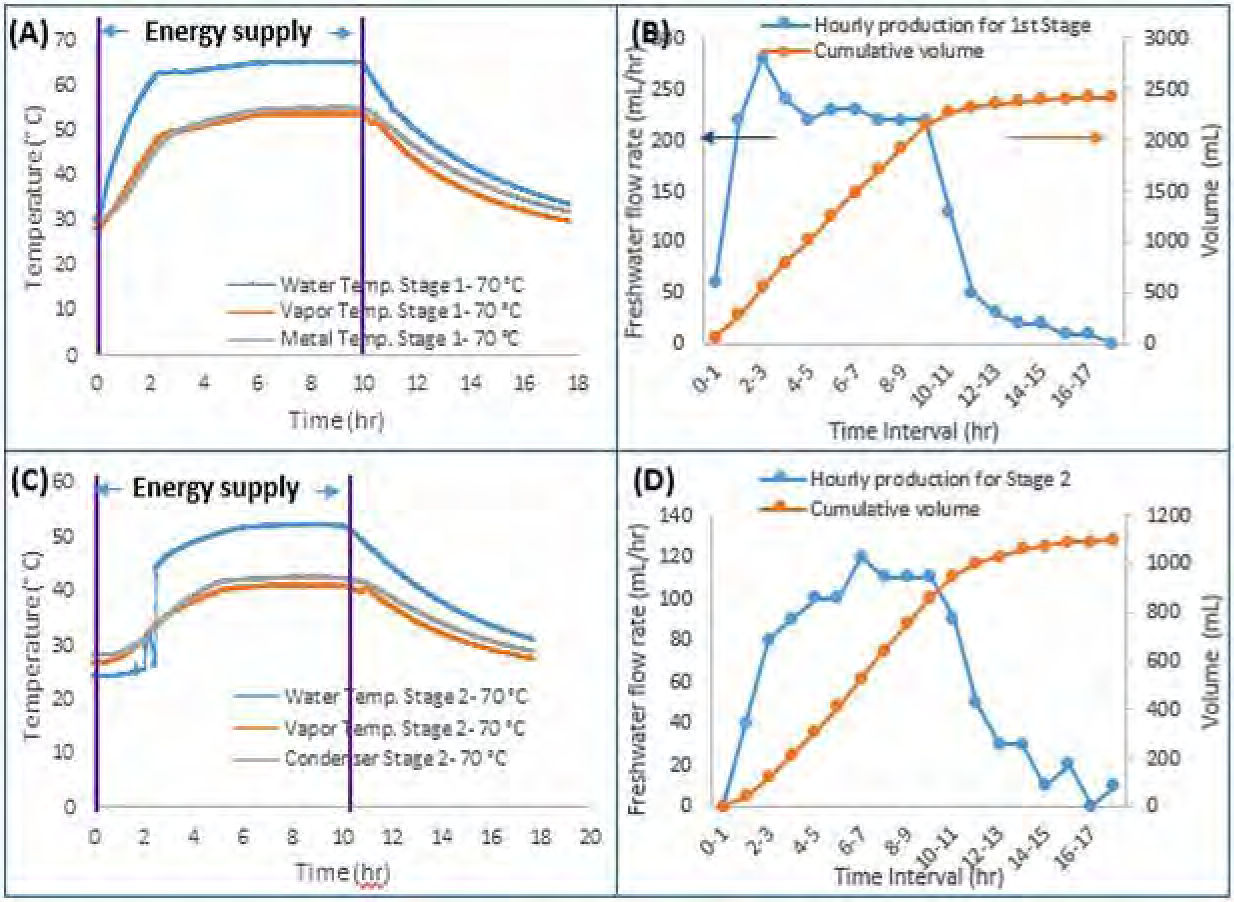

Figure 3. Temperature and freshwater production profiles for the three-stage desalination unit at a hot water source temperature of 70°C: (a) temperature profiles in stage 1 and (b) hourly freshwater production rates and cumulative volume in 10 hour heat supply window.

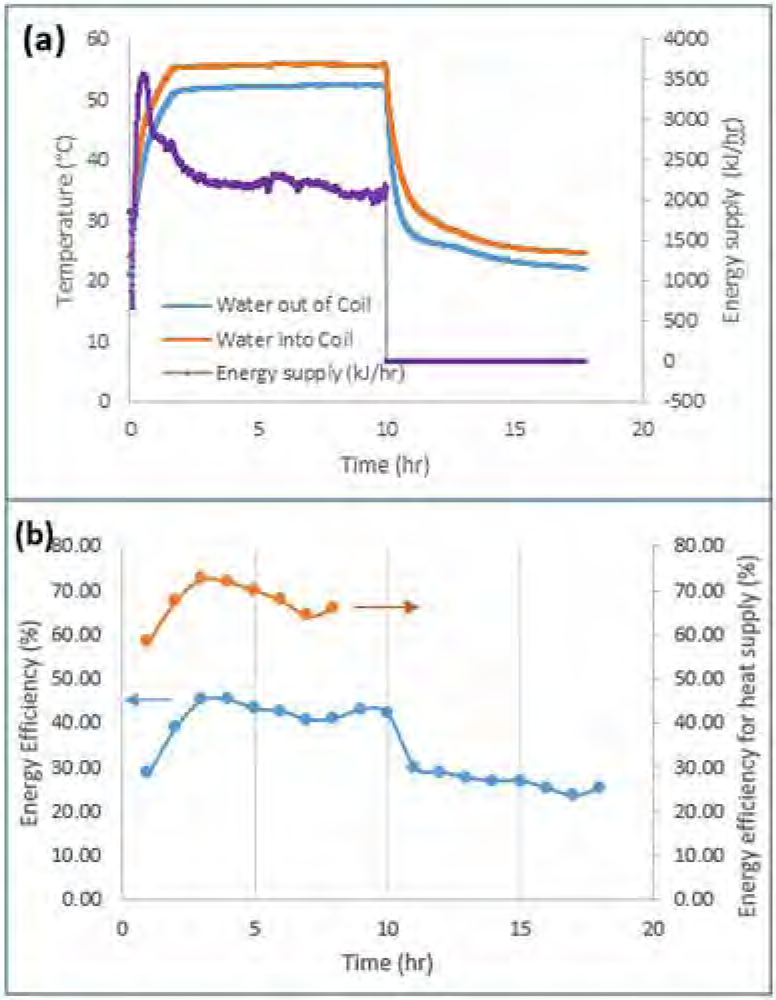

Figure 4. Energy supply and efficiency trends for the multi-stage desalination unit at a heat source temperature of 75℃.

Mississippi Private Well Populations

Barrett, J.

Most residents of Mississippi are served by one of the over 1,200 public water systems. Having access to a public water system provides citizens with safety and quality of water through the regulatory enforcement of the Mississippi State Department of Health-Bureau of Public Water Supply. Mississippi citizens on private wells do not have the luxury of knowing the quality and/or quantity of their water on a regular basis. Unfortunately, a reliable method for determining the population that depends on a private well for their water supply has not existed since the 1990 census. This presentation will compare currently available methods and present a new methodology for estimating private well usage in Mississippi. This method uses connections reported to the Safe Drinking Water Information System adjusted to account for non-residential connections, along with census data to generate improved estimates that are quite different from other available sources. This method has been used to generate well usage estimates for all counties in Mississippi. The concluding data can be utilized to better strategize water infrastructure improvements and well monitoring programs. This study should be of interest to representatives of local municipal water systems, local communities, and rural water associations for potential expansion of their water systems. The expansion of a public water system may achieve multiple goals. Additional customers generate more revenue of the public water system, as well as provide a larger customer base in which to spread costs. The regulatory oversight of public water systems should promote and produce a safer drinking water supply for Mississippi residents.

Delta Water Resources

Jeannie Barlow *(U.S. Geological Survey)*	Water Availability in the Mississippi River Alluvial Plain: Optimized Monitoring and Modeling for Water Management
Larry "Jason" Krutz *(Mississippi State University)*	Irrigation Water Management Strategies That Improve Crop Yield and/or On-Farm Profitability
J.R. Rigby *(USDA-ARS)*	Managed Aquifer Recharge and the Mississippi River Alluvial Aquifer: On-Farm and Regional Perspectives
Kay Whittington *(Mississippi Department of Environmental Quality)*	Mississippi's Approach to Address Declining Groundwater Levels
Paul Parrish *(Mississippi Department of Environmental Quality)*	Real Time Groundwater Monitoring: Mississippi River Valley Alluvial Aquifer and the Underlying Tertiary Aquifers of the Mississippi Delta
Gary Feng *(USDA-ARS)*	Prediction of Future Agricultural Water Needs in the Mississippi Delta and Blackland Prairie Under Surface Water Supply and Groundwater Pumping Scenarios
John L. Madison *(U.S. Army Corps of Engineers)*	Harvesting Excess Water From the Rivers of Little Tallahatchie, Big Sunflower, and the Buffalo
Kaitlin Voll *(University of Mississippi)*	Variable Pathways and Geochemical History of Seepage Under the Mississippi River Levee

Water Availability in the Mississippi River Alluvial Plain: Optimized Monitoring and Modeling for Water Management

Barlow, J.; Haugh, C.

The Mississippi River alluvial plain in northwestern Mississippi (referred to as the Delta), once a floodplain to the Mississippi River covered with hardwoods and marshland, is now a highly productive agricultural region of large economic importance. Water for irrigation in the Delta is supplied primarily by the Mississippi River Valley alluvial aquifer, and although the aquifer has significant storage capacity, there is evidence that the current rate of water use is exceeding the available supply. Groundwater modeling has shown that increasing withdrawals from the aquifer are having a direct impact on the interaction between the groundwater and surface-water systems. Groundwater level declines in the aquifer have resulted in decreased discharge to streams within the Delta to the extent that many stream reaches are presently net-losing streams throughout the year. This decrease in available groundwater discharge is directly impacting many ecosystem services such as maintaining baseflow conditions in streams; regulating temperature regimes for aquatic biota; and buffering contaminant transport at the streambed interface. To better understand and optimize water management and monitoring activities in the Delta, the U.S. Geological Survey and the Mississippi Department of Environmental Quality are collaborating to update and enhance an existing regional groundwater flow model. The model will be used to develop and assess conjunctive water-management optimization scenarios as well as improve and optimize current and future monitoring activities within the Delta. Key revisions include updating the model through 2014 with more recent water use, precipitation and recharge data, and streamflow and water-level observations. In fiscal year 2016, the updated model will be used to develop selected alternative water-supply scenarios to assess relative impacts to the alluvial aquifer and identify data needs for future optimization modeling.

Irrigation Water Management Strategies that Improve Crop Yield and/or On-farm Profitability

Krutz, L.; Pickelmann, D.; Atwill, R.; Leininger, S.; Bryant, C.; McNeal, J.; Wood, W.; Henry, M.; Roach, D.

The Row-crop Irrigation Science Extension and Research (RISER) program has demonstrated how Irrigation Water Management (IWM) practices including computerized hole selection, surge irrigation, soil moisture sensor (SMS) technology, and alternate wetting and drying (AWD) reduces irrigation water use up to 40% while improving profitability by $40/acre. However, very few Mid-South irrigators are using IWM practices. The objectives of this session are to 1) illustrate how computerized hole selection and surge irrigation improves irrigation application efficiency; 2) describe how SMS technology improves irrigation scheduling decision for initiation and termination; 3) inform practitioners how AWD impacts water use, yield, weed control, and N uptake 4) examine on-farm case studies where IWM practices significantly improved corn, soybean and rice yield/profitability.

Managed Aquifer Recharge and the Mississippi River Alluvial Aquifer: On-farm and Regional Perspectives

Rigby, J.; Barlow, J.

Groundwater from the Mississippi River Valley Alluvial Aquifer (MRVAA) is the primary source for irrigation in the Delta. Withdrawals in excess of recharge in recent decades have resulted in declining groundwater levels, particularly near the central Delta. Irrigated agriculture has reached the point such that to achieve sustainability the aquifer must be managed carefully as a finite, yet renewable, resource. Management of groundwater resources is most often associated with managing withdrawals, e.g., through more efficient water use and development of alternative surface water resources. Equally, though, aquifer recharge is a part of the management equation. Managed Aquifer Recharge (MAR) is increasingly the guiding paradigm for groundwater resources in arid regions. MAR has not received the same attention in humid regions where the supply of water usually far exceeds the demand. In an intensively developed system like the MRVAA, however, emphasis on managing recharge is a crucial component of sustainable water resources. This presentation will examine the hydrologic dynamics of recharge to the MRVAA at farm and regional scales. The merits and challenges of a suite of techniques for managing aquifer recharge including recharge basins, vadose wells, aquifer storage and recovery, and groundwater transfers will be outlined as they relate to the MRVAA.

Mississippi's Approach to Address Declining Groundwater Levels

Whittington, K.

Groundwater levels in the aquifer used for irrigation in the Mississippi Delta are declining as irrigation demands have increased. By law, the Mississippi Department of Environmental Quality (MDEQ) is charged with conserving, managing, developing, and protecting the state's water resources. MDEQ is working with those in the Delta through the Delta Sustainable Water Resources Task Force to identify solutions. A Voluntary Metering Program is being implemented to get accurate withdrawal information and irrigation water management practices proven to save water, time, and money are being promoted. Progress must be made now with voluntary measures while all options continue to be investigated.

Real Time Groundwater Monitoring: Mississippi River Valley Alluvial Aquifer and the underlying Tertiary aquifers of the Mississippi Delta

Parrish, P.

This Mississippi Delta in the northwest quarter of Mississippi is largely agricultural. It has long been an Office of Land and Water Resources (OLWR) priority for monitoring and research. This focus comes from the high concentration of wells and water use in this portion of the state. There are approximately 23,430 permitted groundwater wells statewide. The Mississippi Delta has 19,410 of those permits. Due to this high water use, hydrologic factors, and geologic factors, there have been growing concerns about dewatering the aquifer. Groundwater model results indicated the need for more information on the possible exchange of groundwater between the Mississippi River Valley Alluvial Aquifer (MRVA), mainly used for irrigation, and the underlying drinking water Tertiary aquifers in the Mississippi Delta. OLWR began mapping areas where there are possible close proximity of sands between the aquifers. The Delta Drilling Project, initiated between the Office of Geology and OLWR, has provided several locations for sand to sand contact. With this research came the impetus for a Delta-wide monitoring network. The traditional monitoring network of semi-annual survey wells would not be adequate for this type of investigation. Real-time monitoring is an innovative technology that has become more affordable. OLWR needs measurements throughout the year (especially during pumping season) to evaluate any exchange of water between aquifers. Paired well nests were installed in five locations to begin the project. These pairs are located around the center of the regional cone of depression where close proximity sands had been mapped. Instrumentation was installed in one location on October 29, 2015. OLWR has ordered two more sets of instrumentation. The data collected include both water quality and water quantity parameters (water level, conductivity, and temperature). These parameters are sent by cellular transmission in data packets every 15 minutes. The data is housed by McCrometer, which manufactures the instrumentation, and is available through a web portal. OLWR will track fluctuations in the parameters especially during high use periods when heads may drastically differ. This will provide more data on upward recharge and any downward losses to help improve modeling inputs and better manage both drinking water and agricultural water in the Mississippi Delta. OLWR hopes to have at least one well pair in each Delta County and to provide web access for stakeholders in the future.

Prediction of Future Agricultural Water Needs in Mississippi Delta and Blackland Prairie under Surface Water Supply and Groundwater Pumping Scenarios

Feng, G.; Ouyang, Y.; Reginelli, D.; Jenkins, J.

The total area of Mississippi is approximately 30 million acre, grain crops take 4.6 million acre lands. Mississippi western Delta (5 million acre in total) and eastern Blackland Prairie (total 3 million acre) are two major agricultural regions where 80% of the MS croplands are planted. The Delta region accounts for 67% of the state croplands, over 90% of irrigation water is pumped from groundwater. The ongoing irrigation depletion of groundwater which has already declined to the alarming level in the Delta threaten agricultural productivity and sustainability. Enhancement of surface water supply is the solution to reduction of groundwater usage in the state which is rich with rainfall and surface. Sustainable conjunctive use of surface and ground water resources for irrigation requires knowledge of crop water requirement and deficit as well as prediction of future agricultural water needs. Soybean, corn and cotton are planted on 65% of croplands in Mississippi. Therefore, irrigation water needs of the three dominant crops were predicted. Patterns and trends of rainfall, reference evapotranspiration (ETo), water deficit and irrigation requirement in Delta (1915-2015) and Blackland Prairie (1894-2014) were analyzed using time series statistical models for annual, seasonal, and monthly periods. An AutoRegressive, Integrated, and Moving Average (ARIMA) approach was used to develop monthly and annual models for rainfall and ETo prediction. The ARIMA models forecasted 1319 mm of mean annual rainfall and 1203 mm of mean annual ETo in the two regions from 2016 to 2024. Those models predicted that soybean, corn and cotton need irrigation of 7.1, 6.6 and 6.9 inch yr-1. In 2014, there are 283,535 and 31,654 ac of cotton, 382,935 and 71,428 ac of corn, 1,595,363 and 217,640 ac of soybean in the Delta and Blackland Prairie, respectively. Totally, the three major row crops need 1.3 million acre feet of water in Delta and 0.2 million acre feet in the Blackland Prairie for irrigation each year. Surface water as an alternative option must be taken to place irrigation agriculture on a sustainable path. Our STELLA pond hydrological process model predicted that the ratio of pond size to irrigated crop land is 1:18. There are approximately 251,983 and 77,186 acre of surface water in the Delta and Blackland Prairie. If 19% and 16% of those surface water is used for irrigation in the two regions, at least 37% (481,155 acre feet) and 100% (185,837 acre feet) of groundwater could be saved in the MS Delta and Blackland Prairie, respectively.

Harvesting Excess Water From the Rivers of Little Tallahatchie, Big Sunflower, and the Buffalo

Madison, J.

Considerable research has been conducted to assess the potential for harvesting rainwater during the off- season in the South, particularly in the State of Alabama (Tyson, T.W., 1999). The correct management strategy for utilization of groundwater and surface runoff is proper allocation of water resources within a catchment. A management strategy utilizing levee embankment ponds for production and rainwater storage has been beneficial in reducing the amount of effluent discharge by as much as 90% and groundwater use by as much as 75% (Cathcart, 1999). Early research (Cathcart et al., 2007) pertaining to rainwater harvesting and storage technologies demonstrated the importance of the implementation of management strategies for conserving groundwater resources. This research will be based upon the utilization of excess floodwaters from Big Sunflower, Little Tallahatchie, and Buffalo rivers using modeling approaches of simulating floodwater capturing methodologies including the use of pumps, siphons, and diversion techniques of streams or rivers along the Mississippi River Basin to augment the water needs for irrigation during the growing seasons (Pote, J., et al. 1988). Additionally, this research will examine 64 years of precipitation data, flood stages, duration of flooding, and will utilize the use of rating curves and back calculations to determine missing data points in the precipitation and flow data records. Data will be obtained from the United States Geological Survey (USGS) and the Army Corps of Engineers (USACE) for the Big Sunflower, Little Tallahatchie, and Buffalo Rivers.

Variable Pathways and Geochemical History of Seepage Under the Mississippi River Levee: Observations From the 2011, 2015, and 2016 Floods

Davidson, G.; Voll, K.; Corcoran, M.; Kelley, J.

During flood stage on the lower Mississippi River, water levels on the river side of a levee can be several meters higher than the surrounding land surface, creating steep hydraulic gradients that drive seepage of water beneath the levees. Sand boils form when sediment is eroded and transported to the surface on the opposite side of a levee, leaving open conduits that can compromise the structural integrity of the levee. The flow path of seepage beneath the levee may be deep or shallow, depending on the surficial geology, with deeper flow pathways found where a levee sits on top of low-permeability channel-fill deposits. For levees over the Mississippi River Valley alluvial aquifer, deeper flow pathways may encounter anoxic water with distinct geochemistry, raising the possibility that flow pathways for individual seeps or sand boils can be elucidated based on their geochemical signatures. Exploratory sampling north of Vicksburg, MS, from the river, from relief wells, and from sand boils during the 2011, 2015, and 2016 flood events shows considerable promise. Relief wells and a small number of sand boils had high iron and arsenic concentrations, consistent with deeper water being driven up to the surface. Most of the sand boils analyzed had iron and arsenic concentrations more similar to river water, consistent with shallow pathways through sandbar deposits. Many sand-boil samples also showed evidence of redox reactions during transit, not just simple mixtures of river water and groundwater. In select relief wells and sand boils, sampling was repeated after three weeks of continuous flow (2015), and again during a subsequent flood (2016), to identify short term geochemical and isotopic changes that may occur as flood waters move increasingly into the subsurface. Preliminary results show significant changes in tritium concentration over time.

Water Quality

Kevin Dillon *(University of Southern Mississippi)*	Water Quality in Bangs Lake: Effects of Recurrent Phosphate Spills to a Coastal Estuary
Eric L. Sparks *(Mississippi State University)*	Improving Water Quality Through Cost-Effective Marsh Restoration
Matt Hicks *(U.S. Geological Survey)*	Collection of Water Quality, Biological, and Algal Community Data to Support Nutrient Criteria Development
Derek Faust *(Mississippi State University)*	Optimizing Carbon to Nitrogen Ratios to Improve Nitrogen Removal in Agricultural Drainage Ditches
Alina Young *(Mississippi Department of Environmental Quality)*	Developing Numeric Nutrient Criteria for Mississippi's Surface Waters
Kim Caviness-Reardon *(Mississippi Department of Environmental Quality)*	Refining Designated Uses for Mississippi's Surface Waters
Joshawa Billiot *(Mississippi Department of Environmental Quality)*	Agricultural Chemical Monitoring Program Overview
John Warner *(Mississippi Department of Environmental Quality)*	Source Water Assessment Program

Water Quality in Bangs Lake: Effects of Recurrent Phosphate Spills to a Coastal Estuary: Year 2

Dillon, K.; Caffrey, J.; Carmichael, R.; Dzwonkowski, B.; Holcomb, S.; Berry, T.; Baine, G.; Sleek, J.; Capps, R.

In 2015 we continued to examine the effects of industrial phosphate spills to Bangs Lake in the Grand Bay National Estuarine Research Reserve. Higher phosphate concentrations in sediments and porewater were measured in Bangs Lake compared to the reference site in Bayou Heron (while other nutrient concentrations were similar or lower). Peaks in particulate organic phosphorus (POP) concentrations in southeastern Bangs Lake corresponded in time to at least one known major phosphate spill (2005). In an effort to examine transport of a contaminant plume we also conducted a fluorescent dye tracer study using fluorescein in the northern portion of Bangs Lake. Transport and dilution rates on the day of the study were strongly affected by tidal action and a very strong western wind. Although the known source of phosphorus to the estuary is on the western side of Bangs Lake, hydrological processes that flush sediments and nutrients from the Lake may concentrate finer sediments and associated particulate phosphorus in the southeastern part of the Lake. Pb 210/ Cs dating conducted on the sediment cores were corroborated by Th isotope data, which confirmed greater pollution associated with spill material from the facility at sites in Bangs lake. Phytoplankton nutrient bioassay experiments showed that phytoplankton in Bangs Lake were very strongly limited by nitrogen. Preliminary results suggested that both ammonium and nitrate were effective at stimulating growth, and grazing by microzooplankton was sometimes significant. Benthic microalgae in Bangs Lake appeared to be decreasing, although they were still generally higher than at the reference site. Benthic microalgal growth was not stimulated by addition of ammonium, phosphate or both.

Improving Water Quality Through Cost-Effective Marsh Restoration

Sparks, E.; Cebrian, J.

Marshes provide many ecosystem functions and services that are integral for coastal health. One of the most valuable ecosystem services provided by coastal marshes is the removal excess nutrients prior to entering coastal waters. Unfortunately, marsh degradation has led to drastic reductions in the capacity of marshes to provide this nutrient buffering service. As an attempt to mitigate for this reduced nutrient removal capacity, many restoration projects have been and will continue to be conducted. However, the majority of these projects are limited in evaluation of the ecosystem services they provide, cost-effectiveness, and how climate change will affect them. Given the high cost associated with these projects, evaluating the cost-effectiveness and resilience of different designs is necessary for making restoration a more ubiquitous and effective practice. We constructed and evaluated experimental marshes at the Grand Bay and Weeks Bay National Estuarine Research Reserves to test the effectiveness of different initial planting densities at removing nutrient pollution. At the Grand Bay site, we had initial planting densities of 0%, 50%, and 100% of Juncus roemerianus (black needlerush). At the Weeks Bay site, we created marshes in abandoned canals and, within them, planted black needlerush at 5 different densities (0%, 25%, 50%, 75%, and 100%). In half of the Weeks Bay plots, we simulated short term sea-level rise to approximate levels projected at 2030. At both sites we compared porewater concentrations of dissolved inorganic nitrogen (DIN) and used this measurement as a proxy for nutrient removal across all plots. Our findings indicate the 50%, 75%, and 100% planting densities suppress porewater DIN concentrations to similar levels and at significantly greater levels than the 0% and 25% planting densities. Therefore, the 50% planting density is suggested as the most cost-effective design for nutrient removal. Effects of short term sea-level rise on DIN concentrations varied by marsh location, but, in general, did not have a large effect. This information can be used by managers to design more cost-effective restoration projects that take into account the potential effects of sea-level rise.

Collection and Analysis of Water Quality and Benthic Macroinvertebrate and Algal Community Data to Support Nutrient Criteria Development in Northwestern Mississippi

Hicks, M.

The Mississippi Department of Environmental Quality (MDEQ) is in the process of developing scientifically defensible nutrient criteria to protect designated uses of three types of waterbodies: lakes, streams/rivers, and estuaries/coastal waters. Data collection and analysis efforts in support of nutrient criteria have been ongoing in some ecoregions in the State since about 2002, and separate Technical Advisory Groups (TAGs) have been formed to oversee criteria development for each waterbody type. Developing nutrient criteria has proven to be particularly challenging in the Mississippi Delta region in northwestern Mississippi. Reference or best attainable conditions have not been fully identified in this region, and complex relations between nutrient concentrations and biological integrity are not well understood. In 2015, the U.S. Geological Survey (USGS) partnered with MDEQ and the U.S. Environmental Protection Agency (USEPA) to conduct a study in wadeable streams that originate in the Bluff Hills along the eastern boundary of the Mississippi Delta for the primary purpose of supporting nutrient criteria development. The main scope of the study involves collection of algal community and biomass data along with concurrent and antecedent physical, chemical and other biological data to characterize stressor-response relationships. The study purpose, strategy, design, and timelines will be presented.

Optimizing Carbon to Nitrogen Ratios to Improve Nitrogen Removal in Agricultural Drainage Ditches

Faust, D.; Kröger, R.; Miranda, L.; Cox, M.; Moore, M.; Rush, S.

The annual occurrence of a hypoxic zone in the Gulf of Mexico is caused by nitrogen loads from the Mississippi River Basin, which includes agricultural drainage ditches. The objectives of these studies were: (1) evaluate how organic carbon amendments affect nitrate-nitrogen removal in agricultural drainage ditch systems using laboratory microcosms, (2) determine effects of organic carbon amendments and flow rate on nitrate-nitrogen removal in a semi-controlled field setting using experimental drainage ditches, and (3) assess relationships between organic carbon and nitrogen content of overlying water, pore water, and sediments of drainage ditches throughout the Lower Mississippi Alluvial Valley. In laboratory experiments, nitrate-nitrogen removal in dissolved and particulate organic carbon treatments was greater than 90% compared to as low as 60% in control treatments. The optimal carbon-to-nitrogen ratio of organic carbon amendments for efficient nitrate-nitrogen removal was 5:1. Experiments in experimental drainage ditches revealed that flow substantially lowered the ability of organic carbon amendments to remove nitrate-nitrogen with a maximum percent nitrate-nitrogen reduction of 31.6% in a dissolved organic carbon treatment, although implementation of low-grade weirs in experimental drainage ditches did result in removal of nitrate nitrogen in all treatments and at all flow rates. Examining the nitrogen and organic carbon contents in agricultural drainage ditches throughout the Lower Mississippi Alluvial Valley revealed that organic carbon content in overlying water, pore water, and sediments are lower than observed in other wetland-like ecosystems and indeed may be limiting denitrification and other nitrogen removal processes. Increasing organic carbon content overall could be achieved by using organic carbon amendments, but this body of research highlights that additional studies are necessary to ensure successful implementation of organic carbon amendments that reach their greatest potential as a management practice to effectively remove nitrate-nitrogen in the realistic settings of agricultural drainage ditches.

Developing Numeric Nutrient Criteria For Mississippi's Surface Waters

Young, A.

Over the last 50 years, the amount of nitrogen and phosphorus entering our surface waters across the nation has increased significantly. The degradation of water quality associated with excess levels of nitrogen and phosphorus in our surface waters has been extensively studied and documented. In Mississippi, like many other states, excessive amounts of nutrients, including nitrogen and phosphorus, have been a major cause of surface water impairments. In 2001, EPA developed an Action Plan requiring that all states develop numeric nutrient criteria in order to protect our waters from nutrient pollution impacts. Since 2001, the Mississippi Department of Environmental Quality (MDEQ) has been working diligently to develop appropriate and protective numeric nutrient criteria for Mississippi's waters including (1) the development and implementation of MS's Nutrient Criteria Development Plan, (2) collecting extensive data to derive scientifically defensible nutrient criteria, and (3) developing robust tools to assess the biological condition of our waters. In 2010, MDEQ formed the MS Nutrient Technical Advisory Group (TAG) consisting of members of state, federal, and research scientists to aid the agency in deriving these criteria providing technical knowledge and regional expertise to the criteria development process. In an effort to be more scientifically defensible, MDEQ is applying the multiple lines of evidence approach for nutrient criteria development. The multiple lines of evidence approach involves looking at several lines of analysis, such as distributional analysis, stressor-response, scientific literature, and water quality models to establish a final endpoint. MDEQ is currently working to develop numeric nutrient criteria for the various water body types around our state which have been categorized into (1) Non-Delta Lakes and Reservoirs, (2) Coastal and Estuarine Waters, (3) Non-Delta Streams, and (4) Delta Waters. Non-Delta Lakes and Reservoirs will be the first water body type in which numeric nutrient criteria will be established. MDEQ is aiming for a public notice date no later than June 30, 2016. MDEQ will continue with criteria development efforts within the remaining water body types in a sequential manner. MDEQ recognizes the complexities that will be faced when implementing numeric nutrient criteria across the various water programs within MDEQ. Therefore, the agency is has established an internal nutrient criteria implementation work group that is developing a Nutrient Criteria Implementation Plan to describe how the criteria will be incorporated into programs such as permitting, water quality assessment, water quality monitoring, total maximum daily loads (TMDLs), and waste load allocations (WLAs). MDEQ, along with the support of the TAG and the engagement of stakeholders, continues to make great strides in developing nutrient criteria for Mississippi's surface waters.

Refining Designated Uses For Mississippi's Surface Waters

Caviness-Reardon, K.

Water quality standards are required by the Clean Water Act and include three essential components: (1) designated uses for the water bodies, (2) criteria (either narrative or numeric) to support those uses, and (3) an antidegradation policy. Water quality standards establish the water quality goals for a water body. Designated uses are a critical component of water quality standards because they specify what a specific water body is being used for in order to define the appropriate water quality goals provide a way to evaluate whether or not these goals are being attained. Mississippi currently has a very simple water body classification structure. Within recent years, the Mississippi Department of Environmental Quality (MDEQ) has identified the need to examine the current water body classification structure and investigate further refinement of the existing water body classification structure. In 2014, MDEQ completed a preliminary analysis to consider potential options for refinement of the current structure. Further refinement of water use classifications will allow MDEQ to provide a more accurate distinction between water bodies around the state and allow for more appropriate criteria (or goals) to be established for those various water bodies. . Water use classification (or designated use) is the basic foundation of the water quality standards program, and improving the accuracy of water body classifications within Mississippi is a program priority for MDEQ's Water Quality Standards Program.

Agricultural Chemical Monitoring Program Overview

Billiot, J.

Agriculture is Mississippi's number one industry. A wide variety of agricultural compounds are used to support this industry. Since over ninety percent of the population of Mississippi relies on groundwater for drinking water, there has been concern that the groundwater resources of Mississippi may be impacted and degraded by the use of pesticides and herbicides.
In an effort to better determine the impact of agricultural chemicals on groundwater resources, the Agricultural Chemical (AgChem) Groundwater Monitoring Program was designed in 1986 and implemented in March of 1989. Since the inception of the program, over 2,100 samples have been taken from wells around the state and analyzed for more than 100 herbicides and pesticides. Of the samples collected to date, 96.6% have no detectable concentrations of agricultural chemicals present. Of these samples with detects, only four were found to have concentrations exceeding the maximum contaminant levels (MCLs) set by the United States Environmental Protection Agency (EPA). Results indicate that Mississippi's groundwater quality is relatively unaffected by agricultural activities.

Source Water Assessment Program

Warner, J.

The 1996 amendments to the Safe Drinking Water Act mandated states to develop and implement a Source Water Assessment Program (SWAP). The purpose of this program was to notify Public Water Systems (PWS) and customers regarding the relative susceptibility of their drinking-water supplies to contamination. Congress intended for these susceptibility assessments to encourage efforts that would enhance the protection of PWSs by managing identified potential contaminant sources of concern. In 1998, the Mississippi State Department of Health (MSDH) contracted with MDEQ to develop and administer the SWAP in Mississippi. OLWR's Source Water Assessment Program was designed to identify and properly manage potential contaminant sources in Wellhead Protection Areas from which PWS wells capture their water over a specific period of time. OLWR staff ran countless computer simulations and undertook an extensive data review of Mississippi primary drinking water aquifers in order to come up with meaningful Wellhead Protection Areas and a ranking system was implemented in order to inform PWSs of their relative susceptibility.

Outputs and Outcomes

Tyler Lynn *(NASA DEVELOP)*	Natchez Trace Ecological Forecasting and Water Resources: Utilizing NASA Earth Observations to Assess Current and Historic Wetland Extent Along the Natchez Trace Parkway
Michael Manning *(U.S. Geological Survey)*	Data-Collection Efforts by the U.S. Geological Survey During the Winter Flood of 2015 on the Lower Mississippi River
Luis Laurens *(Mississippi State University)*	A Demonstration Project: Measurement of Sediment Oxygen Demand and Nutrient Fluxes in on Eckie's Pond, MS
Xiaojing Ni *(Mississippi State University)*	Evaluation of Crop Rotation and BMPs on Water Quality and Quantity Using SWAT

Natchez Trace Ecological Forecasting and Water Resources: Utilizing NASA Earth Observations to Assess Current and Historic Wetland Extent Along the Natchez Trace Parkway

Lynn, T.

This project partnered with the National Park Service (NPS) to produce needed land cover mapping products for the Natchez Trace Parkway and to address community concerns involving the past, current, and future wetland conditions of this area. The parkway occurs in Mississippi, Alabama, and Tennessee. Beavers have altered current and historic wetland conditions in the study area by changing streamflow along adjacent rivers and tributaries. While the ecological services provided by these beavers can benefit wetland ecosystems, indiscriminate and excessive dam building has caused issues with flooding, property damage, and road maintenance within the parkway. NASA Earth observations (Landsat 5 Thematic Mapper, 7 Enhanced Thematic Mapper Plus, and 8 Operational Land Imager) and ERDAS IMAGINE were used to generate a time series of land use/land cover (LULC) classification maps from October 1992 to January 2015 showing wetland status occurring along the parkway. A projected LULC classification map was also produced using TerrSet Land Change Modeler software. This LULC time series and modeled projection will aid the NPS in wetland conservation and beaver management plans throughout the Natchez Trace Parkway.

Data-Collection Efforts by the U.S. Geological Survey During the Winter Flood of 2015 on the Lower Mississippi River

Manning, M.

In December 2015, the National Weather Service (NWS) began to predict and warn communities in flood prone areas that the Mississippi River would reach record flood levels in many areas. Based on these predictions, the U.S. Geological Survey (USGS) began to deploy flood-measuring crews at many locations on the Mississippi River to confirm and document these higher streamflow's. As flood waters moved southward along the main stem of the Mississippi River, several USGS teams from offices within the Lower Mississippi-Gulf Water Science Center measured streamflow at several locations in the Lower Mississippi River system. In addition to the USGS, other agencies involved with streamflow measurements and flood forecasting in the Lower Mississippi main stem reaches included the NWS, as well as, the U.S. Army Corps of Engineers - St Louis, MO, Memphis, TN, Vicksburg, MS, and New Orleans, LA, districts. By mid- to late-January 2016, approximately 72 non-routine streamflow measurements were made at various locations in the Mississippi River main stem system. These measurements were used to confirm stage-discharge ratings and support NWS flood-forecast models as the crest moved into the lowermost reaches of the Mississippi River basin near New Orleans, LA. These streamflow data, in combination with other hydrologic measurements, are widely used by local, State, and Federal agencies to predict flood-inundated areas, as well as, to maintain and operate flood-control structures that are used to divert or reduce major flooding near New Orleans, LA. In addition to numerous flow measurements, several USGS crews collected flow-weighted water-quality samples and maintained continuous water-quality monitors that measured water temperature, salinity, pH, dissolved oxygen, nitrate, and turbidity, to characterize changes in water quality due to increased flow. The Tennessee Department of Environmental Conservation (TDEC) assisted the USGS with water-quality-data collection at Memphis, TN. In mid-January, near peak streamflow on the Mississippi River at Vicksburg, MS, a group of USGS scientists from more than 9 offices throughout the Nation, collaborated to collect extensive streamflow, bathymetry, water velocity, and bedform data at that site to help advance new research regarding the use of remotely-sensed data collected from onsite video, Predator drone recordings, and satellite imagery to compute streamflow. This research effort will help expand the understanding of flood dynamics, as well as, potentially reducing the physical manpower required to measure flood events in the field.

A Demonstration Project: Measurement of Sediment Oxygen Demand and Nutrient Fluxes in on Eckie's Pond, MS

Laurens, L.; Ortega, S.; Martin, J.; Ramirez-Avila, J.; Martin, J.

One of the processes long known to impact the water quality of surface waters is the oxygen demand by, and nutrient release from, sediments. Sediment oxygen demand (SOD) and nutrient releases, due to the mineralization (diagenesis) of organic materials in bottom sediments, can contribute to eutrophication, harmful algal oxygen blooms and hypoxia. SOD and nutrient releases are commonly measured using one of two alternative techniques: by in- situ deployment of chambers on the bottom of the water body; or, by the collection of sediment core samples which are transported to the laboratory where SOD and nutrient fluxes are measured under controlled conditions. The main objective of this study was to develop the capability of using the core method, based on methodologies developed by the Horn Point Laboratory at University of Maryland and extensively used in Chesapeake Bay, and to compare results to chamber measurements at a selected site on campus at Mississippi State University, Eckie's pond. Other goals included the development of standard operating procedures (SOP's) for all the processes and the completion of a laboratory setup. The developed methodology could then be applied to other selected Mississippi water bodies to provide flux measurements in support of related oxygen and nutrient management studies. Overall research goal considers long term measurements of sediment fluxes, sediment diagenesis, and water column concentrations in order to evaluate factors influencing sediment diagenesis, to support evaluation and development of diagenesis models such as that included in the USEPA Water Analysis Simulation Program.

Evaluation of Crop Rotation and BMPs on Water Quality and Quantity using SWAT

Ni, X.

Corn after soybean is a common crop rotation practices in the Mississippi Delta. Several Best Management Practices are also implemented in the Big Sunflower River Watershed (BSRW). Placement of BMPs and crop rotation practices will affect water quality and quantity in the BSRW. This study will simulate the impacts of different placements of BMPs and corn after soybean rotation in the BSRW using SWAT model. Soil and Water Assessment Tool (SWAT) model was calibrated at Harris Bayou, validated at Bogue Phalia and verified at BSRW using 17 years of stream flow, sediment and nutrient data. Model performances during calibration, validation and verification were ranged from 0.61 to 0.63 for R^2, 0.46 to 0.62 for NSE. Results of different crop rotation practices and their effects on water quality and quantity will be evaluated and presented in the conference.

Tools and Models

Thomas Strange *(Covington Civil & Environmental , LLC)*	MDEQ's Mississippi Comprehensive Ecosystem Restoration Tool
Duane Woodward *(Central Platt Natural Resources Conservation District)*	Surface and Groundwater Modeling in the Platt River Watershed to Support Water Resource Management
Anna Linhoss *(Mississippi State University)*	A Comparison of Five Forest Interception Models Using Global Sensitivity and Uncertainty Analysis
Dave R. Johnson *(U.S. Army Corps of Engineers)*	Application of a Spreadsheet Model to Groundwater Use in the Yazoo River Basin

MDEQ's Mississippi Comprehensive Ecosystem Restoration Tool

Strange, T.

As a result of the Deepwater Horizon Oil Spill (DWH), Mississippi is working to restore the health and ensure sustainability of the coastal landscape affected by the spill. To ensure sustainable restoration is achieved, the National Fish and Wildlife Foundation (NFWF) Gulf Environmental Benefit Fund (GEBF) agreed that an ecosystem restoration plan was needed in Mississippi. They approved to fund the development of the Mississippi Restoration Plan. One of primary goals of the Plan is to develop the Mississippi Comprehensive Ecosystem Restoration Tool (MCERT), which is a science-based tool for identifying and examining ecological resources and stressors at a landscape/seascape scale and that allows for improved restoration planning and informed decision making. MCERT represents a suite of geospatial analysis models that provide data products to describe the terrestrial landscape and the marine and water quality conditions in south Mississippi.
Two of the MCERT components deal directly with water quality and watershed characterization. The water quality model integrates the Soil and Water Assessment Tool (SWAT). We calculated a 2006-2013 simulation of water, sediment, and nutrient flow in the Pearl, Pascagoula, and Mississippi Coastal basins, as well as indices of change between these and the outputs from an earlier 1987-1994 simulation of the same area to highlight broad indicators of water quality change within the study area using three primary parameters: sediment, nitrogen, and phosphorus at the subwatershed and stream reach level. Stream gauge data from the USGS and observed sediment and nutrient loading data points from the MDEQ are used to calibrate the model to better reflect field conditions. The watershed characterization component of the tool uses derived spatial data, including environmental resource and stressor/threat data, as inputs and aggregates the information to characterize subwatersheds by quantifying the amount, weighting, scoring, and normalizing of the input data. Within each subwatershed, various datasets are assigned values and are adjusted, normalized, and ranked relative to one another. Data inputs include but are not limited to SWAT outputs, dam storage ratios, protected areas, T & E species presence, ecological hubs and corridors, and a landscape development index (LDI). The Mississippi Restoration Team uses these tools to identify hotspots and areas of interest as well as simulate best management practices to quantify restoration scenarios across the landscape. Manipulation of climatic, hydrologic, and land use inputs offers further potential for modeling future scenarios, incorporating both agricultural and non-agricultural management practices, at various spatial and temporal scales.

Surface and Groundwater Modeling in the Platte River Watershed to Support Water Resource Management

Woodward, D.

COHYST is a cooperative hydrologic study of the Platte River drainage basin in the central part of Nebraska. One objective of COHYST is to develop a comprehensive suite of tools to aid in conjunctively managing surface and groundwater to: 1) maintain the region's extensive irrigation economy; and 2) protect the river habitats used by endangered species. These tools must provide decision-makers with reliable quantitative information about the hydrologic consequences of alternative water management strategies. There also is a need to quantify past hydrologic changes, such as accounting for historic depletions of streamflow.

COHYST 2010 is the second generation of modeling tools within COHYST that involves developing an integrated computer-based model of basin hydrology to be used to calculate the effects of different management scenarios on stream flows and the regional aquifer. Phase I of COHYST 2010 involved design of the modeling work, and development of an observation based water budget for the study area to be used in model calibration. Phase 2 of COHYST 2010 had the objective of building the quantitative tools. Phase 3 is application of the tools to management scenarios and time period updates to the tools.

The Phase 2 tools were completed in 2014 and included a Watershed model, Surface Operations Model, and a MODFLOW groundwater model. We are in Phase 3 of the COHYST 2010 work effort. Models are being updated thru 2010 and the 2014 Model documentation is being edited to include model changes and integration work. An updated Stream depletion analysis along with Basin Water Supply and Basin Water Demands analysis are nearing completion. Conjunctive water management projects are also being simulated for project development.

A Comparison of Five Forest Interception Models Using Global Sensitivity and Uncertainty Analysis

Linhoss, A.; Siegert, C.

Interception by the forest canopy plays a critical role in the hydrologic cycle by removing a significant portion of incoming precipitation from the terrestrial component. While there are a number of existing physical models of forest interception, few studies have summarized or compared these models. The objective of this work is to use global uncertainty and sensitivity analysis to compare five mechanistic interception models including the Rutter, Rutter Sparse, Gash, Sparse Gash, and Liu models. Using a one-hour continuous rainfall simulation and input probability distribution functions of values from the literature, our results show that gross precipitation [PG], the free throughfall coefficient [p], canopy cover [Cc], canopy storage capacity [S], and trunk storage capacity [St] are the most important model inputs. On the other hand, the climatic variables that determine evaporation have relatively low levels of importance in modeling interception based on our rainfall simulation scheme. As such, future modeling efforts should aim to breakdown inputs that are the most influential in determining model outputs into easily measurable physical components. Additionally, low, medium, and high one-hour rainfall scenarios were simulated to determine the sensitivity of input parameters to variable rainfall conditions. Under the low rainfall scenario [PG] was the most important parameter across all five models. Under medium and high rainfall scenarios, parameters that described canopy storage ([S] and [St]) and canopy heterogeneity ([p] and [Cc]) became more important. Because this study compares models, the choices regarding the input probability distribution functions are applied across models, which enables a more definitive ranking of model uncertainty.

Application of a Spreadsheet Model to Groundwater Use in the Yazoo River Basin

Johnson, D.

Both the USGS and MS-DEQ have developed intricate groundwater models for the Yazoo Basin in Mississippi. The difficulty in using these models is the amount of time that is required to run the model. A less accurate but faster Excel model was developed to simulate groundwater utilization in the Yazoo Basin. The Excel model can be used to screen many more alternatives than the MERAS model, which then can be applied to the most attractive alternatives. The Excel model was used to explore a range of possible management scenarios to extend the life of the groundwater resources in the Mississippi Delta.

Agricultural Water Management

Austin R. Omer *(Mississippi State University)*	Assessment of Tailwater Recovery System and On-farm Storage Reservoir Water and Nutrient Harvesting
Juan Perez-Gutierrez *(Mississippi State University)*	Towards an Improved Understanding of On-farm Water Storage Systems in Mississippi: How Much Water is Lost from These Systems?
Saseendran S. Anapalli *(USDA-ARS)*	Quantifying Water Dynamics in a No-till Vs. Conventional-till Corn Field in the Mississippi Delta
Ruixiu Sui *(USDA-ARS)*	Eddy Covariance Systems for Water Management Research and Agroecosystem Monitoring

Assessment of Tailwater Recovery System and On-farm Storage Reservoir Water and Nutrient Harvesting

Omer, A.

The Lower Mississippi Alluvial Valley is economically important due to its highly productive agricultural land. However, producers in this region face two predominant environmental issues that are inherently linked to the intensity of the agricultural industry in this region. First, intensive agriculture practices have resulted in increased surface transport of nutrient-laden sediments, contributing to eutrophication in receiving waters and to the Gulf of Mexico Hypoxic Zone. Second, current water withdrawals from the Mississippi Alluvial Aquifer for irrigation are not sustainable. These issues threatening environmental resources necessitate use of best management practices and groundwater conservation. This research investigates systems of best management practices as water resource conservation methods. Such practices include surface water capture and irrigation reuse systems. Referred to as tailwater recovery systems (TWR), this practice consists of a tailwater recovery ditch which may be paired with on-farm storage reservoirs (OFS). Seven case studies of different TWR were monitored for nutrients during the 2014 and 2015 growing season at: inflow, edge of field, TWR, OFS, and overflow locations. Investigations highlight functionality for nutrient recycling, and descriptions of nutrient loss mitigation. Preliminary results for seven TWR in 2014 and 2015 show a mean of 94.05 mega liters of water being recycled applying a mean of 0.86 kg/ha total nitrogen and 0.2 kg/ha total phosphorus back onto the tillable landscape. These systems are proving successful in holding water on the landscape, recycling that water, and therefore nutrients; thereby preventing those nutrients from being lost to downstream waters. This suggests that TWR, or systems with similar water holding capacity, have potential for water resource conservation in the Lower Mississippi Alluvial Valley.

Towards an Improved Understanding of On-farm Water Storage Systems in Mississippi: How Much Water Is Lost from These Systems?

Perez-Gutierrez, J.; Paz, J.; Love M. Tagert, M.

On-farm Water Storage (OFWS) systems can mitigate downstream nutrient-enrichment pollution originating from agricultural landscapes. In the Mississippi Delta, an OFWS system usually combines tail-water recovery (TWR) ditches and on-farm reservoirs. The surface runoff and irrigation tail water is collected by ditches, and most of this water is pumped to reservoirs to be stored for future irrigation needs. The remainder of the in-ditch water evaporates, infiltrates, or flows out of the system. Previous studies have focused their attention on the spatial and temporal water quality changes throughout OFWS systems to quantify their nutrient reduction capacity. However, less attention has been placed on measuring the volume of water that is effectively lost from these systems, which is important to investigate so we can better understand the net environmental benefits of using OFWS systems. This study presents preliminary results of water quantity monitoring at the outlet pipe of an OFWS system implemented on a farm located in Porter Bayou Watershed, Mississippi. This data obtained from this study will help to better quantify and provide additional insight on the benefits of OFWS for nutrient reduction and water storage in agricultural watersheds.

Quantifying Water Dynamics in a No-till Vs. Conventional-till Corn Field in the Mississippi Delta

Anapalli, S.; Fisher, D.; Reddy, K.; Sui, R.; Gowda, P.

Conventional-till (CT) cropping system reportedly conserve less soil water compared with no-till (NT) soil-residue management. Reductions in evapotranspiration (ET) and runoff (RO) result in increasing infiltration rates of precipitation and irrigation water inputs; however, location-specific benefits from such systems vary with soil texture and presence or absence of restrictions to water movement such as hard pans in the soil profile. One of the primary benefits of NT over CT comes from its potentially decreasing the ET loss of water from the system. Also of importance is the amount of water infiltrated into the soil and available for crop uptake, and how much water is percolated beyond the root zone of the crop contributing to ground water re-charge as this ground water is the main irrigation water source in the region for crop production. Limited research on ET and soil water dynamics beyond the crop root zone in these cropping systems in the Mississippi Delta region preclude farmer tillage recommendations in cropping systems, especially under corn, a relatively new crop in the region. To fill this gap, we embarked on a research program to monitor ET and soil water dynamics along with crop growth physiology changes in corn under NT and CT in a Dundee silt loam soil at Stoneville, MS. The ET estimation is by solving an energy balance equation representing a crop canopy-land surface for latent heat flux from estimates of sensible, soil heat, and net radiation fluxes. Soil heat flux was quantified from measurements of heat flux using a soil heat flux plate installed at a depth of 8 cm and soil temperature and moisture measurements above the plate. The sensible heat was quantified by modeling aerodynamic and boundary layer resistance corrected for atmospheric stability and wind speed effects from measurements of net radiation, air temperature and relative humidity, land surface-canopy temperature, and wind speed at a constant height of 1 m above the crop canopy, and similar data from a nearby eddy-covriance station. We have tested the ET algorithm developed, with simulataneous measurements of ET using a field lysimeter (3X3X2.4m) and energy balance in the center of a 4.4 ha cotton field at Bushland, TX, and found good agreement between the two estimates.

Eddy Covariance Systems for Water Management Research and Agroecosystem Monitoring

Sui, R.; Reddy, K.; Anapalli, S.; Murrell, C.

Three eddy covariance (EC) systems were set up in the Mississippi Delta for agroecosystem monitoring and assessment, and evapotranspiration (ET) measurement. One EC system is located in Stoneville, MS and two others in Arcola, MS. The EC system consisted of a CH_4 analyzer for measuring methane gas flux, CO_2/H_2O analyzer for measuring carbon dioxide and water vapor fluxes, three-dimensional sonic anemometer for determining wind speed in three dimensions, and biomet (biological & meteorological) sensors to collect ancillary data for filling measurement gaps and interpreting flux results. Installation and preliminary field tests of the EC systems have been completed. The systems are being used to collect data for research on water management technologies and climate change impact on agroecosystems in the Mississippi Delta.

Background

There is around 1300 mm of annual precipitation in Mississippi. However, uncertainty in amount and timing of precipitation during the crop growing season becomes a serious risk to Mississippi producers. To reduce the risk and optimize crop yield, the producers have become reliant on supplemental irrigation. In recent years, irrigated acreage is rapidly increasing in Mississippi. Almost all irrigation water in this region is pumped from the Mississippi River Valley Alluvial Aquifer, and excessive withdrawals of underground water have resulted the level of the aquifer declining. Novel irrigation techniques and tools are needed for improving water use efficiency to maintain Mississippi water resource sustainability. Eddy covariance (EC) method is capable of measuring exchanges of carbon dioxide, water vapor, methane, and energy between the surface of the earth and the atmosphere. Eddy covariance systems have been widely used for monitoring agroecosystems and measuring crop evapotranspiration (ET) for irrigation scheduling. Objectives of this project were to use EC systems to monitor the agroecosystem and measure evapotranspiration for research on water management technologies and agroecosystem assessment.

System Description

A basic EC system consists of a variety of gas analyzers, including a LI-7700 CH_4 Analyzer (LI-COR, Linclon, NE), LI-7540 CO_2/H_2O Analyzer (LI-COR), and three-dimensional (3D) sonic anemometer (CSAT3, Campbell Scientific, Logan, UT, USA; WindMaster, Gill Instruments, Lymington, UK). In addition to these basic instruments, biomet (biological & meteorological) sensors may be used in an EC system to collect ancillary data for filling measurement gaps and interpreting flux results. The LI-7700 CH_4 Analyzer has a calibration range from 0 to 25 ppm at -25 °C, and 0 to 40 ppm at 25 °C. The linearity is within 1% of the reading across the full calibration range. Measurement resolution is 5 ppb RMS noise at 10 Hz, 2000 ppb CH_4. LI-7540 CO_2/H_2O Analyzer is capable of making simultaneous CO_2 and H_2O flux measurements in the free atmosphere. The CO_2/H_2O Analyzer has a calibration range of 0 to 3000 ppm for CO_2 and 0 to 60 mmol/mol for H_2O. Measurement accuracy is within 1% of the reading for both CO_2 and H_2O. The sonic anemometer is a three-dimensional sonic sensing device that measures three orthogonal wind components and the speed of sound. In eddy covariance systems, it measures the turbulent fluctuations of horizontal and vertical wind, which are then used to calculate momentum flux and friction velocity. The CSAT3 3D sonic anemometer has a programmable measurement rate from 1 to 60 Hz in instantaneous measurements. The offset error of orthogonal wind components u_x, u_y, and u_z is < ±8 cm s^{-1}, < ±8 cm s^{-1}, and < ±4 cm s^{-1}, respectively. The WindMaster 3D sonic anemometer (model 1590-PK-020) has a sampling rate up to 32 Hz.

Its measurement range is 0 to 45 m/s with an accuracy of < 1.5% RMS.

System Installation

Three EC systems have been installed in the Mississippi Delta, one in Stoneville, MS (hereinafter referred to as System 1) and two others in Arcola, MS (hereinafter referred to as Systems 2 and 3) as shown in Fig. 1. System 1 is located in a Research Farm of the USDA-ARS Crop Production Systems Research Unit (33.44331749N, 90.88650123W) and is shown in Fig. 2. This system is surrounded by a variety of crop fields and catfish ponds, which represent a typical agroecosystem in Mississippi. System 1 consists of a LI-7700 open-path CH_4 analyzer for measuring methane gas flux, LI-7540 open-path CO_2/H_2O analyzer for measuring carbon dioxide and water vapor fluxes, CSAT3 3D sonic anemometer for measuring wind speed, and biomet sensors to collect ancillary data. The biomet sensors include a net radiometer, soil heat flux plates, soil temperature sensors, and precipitation gauge. System 1 was designed for long-term Mississippi Delta agroecosystem monitoring and assessment. System 2 was installed in the center of a 210-ac field (33.27581111N, 90.90645W) under corn or soybean cultivation. System 2 includes the same open-path CO_2/H_2O analyzer, CSAT3 3D sonic anemometer, and the biomet sensors as in System 1. There is no CH_4 analyzer in System 2 since it was designed for determining ET for water management research. System 3 has the CH_4 analyzer, CO_2/H_2O analyzer, and WindMaster 3D sonic anemometer. There are no biomet sensors involved in System 3 yet because the location of this system was geographical close to the location of System 2 (Fig. 1) and meteorological conditions for these two systems should be similar. System 3 was installed in the center of a 235-ac field (33.27649444N, 90.90653056W), planted to soybean or rice. System 3 is used to determine the crop ET and methane gas flux emitted from the field, especially as rice is grown in the field.

Installation of these three EC systems in the Mississippi Delta has been completed. The systems are being used to collect data and preliminary results indicate that the systems are performing well. A couple of issues with solar power panel and biomet sensors have occurred and were resolved during system installation and testing. Using these EC systems, we expect to obtain accurate ET and other agroecosystem data for our research on development of water management technologies and climate change impact on agroecosystems in Mississippi Delta region.

Acknowledgement

Thanks go to Mr. Jonnie Baggard, Mr. Jason Corbitt, Mr. Efren Ford, Mr. Ben Thornton, and Mr. Luther Franklin for their assistance with this project.

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Figure 1. Locations of three eddy covariance systems setup in Mississippi Delta.

Figure 2. Eddy covariance system in Stoneville, MS for long-term agroecosystem monitoring and assessment.

Mississippi Water Resources

Pat Phillips *(Mississippi Department of Environmental Quality)*	Overview of Water Availability in Mississippi
Lyndsey Henley *(Mississippi Department of Environmental Quality)*	Current Surface Water and Groundwater Studies in the Central Mississippi Region
John Banks *(Mississippi Department of Environmental Quality)*	Regional Overview of Work by the Water Resources Division in Northeast Mississippi
James Hoffman *(Mississippi Department of Environmental Quality)*	Evaluations of Groundwater Resources of Southern Mississippi

Overview of Water Availability in Mississippi

Phillips, P.

The abundant water supplies in Mississippi constitute one of the most important and valuable natural resources in the state. These resources contribute directly to the quality of life and economic prosperity of the state. Throughout the state, there is a need for accurate assessment of groundwater resources to allow wise long-range planning and development. The water resources available in areas of the state can vary significantly depending on various hydrogeologic conditions that may affect baseflow in streams, water quality, and the amount of water local aquifers can supply. The highly variable nature of these resources means that a concerted effort must be maintained to collect related groundwater and surface water data that will allow proper decisions to be made regarding the management and development of the state's water resources.

In Mississippi, precipitation averages about 54 inches annually. About 10% of this infiltrates to the water-saturated zone and becomes groundwater. Fresh groundwater in Mississippi occurs principally in unconsolidated sand and gravel deposits interbedded with thick, extensive layers of clay that form aquifer boundaries and is available throughout the state. Groundwater supplies 90% of water used in the state, for everything from drinking water supplies, agriculture, fish culture, to commercial and industrial uses.

The total volume of fresh water stored in Mississippi's aquifers, which has been conservatively estimated to be in excess of 6 billion acre-feet, dwarfs the total volume of all surface water resources, but surface water is still a valued source of water supply in the state. Mississippi has 10 major river basins with 86,000 miles of streams. Surface water supplies drinking water to five entities: the City of Jackson, the City of Corinth, Short Coleman Water Association, the NE MS Regional Water Supply District, and the Jackson County Port Authority. Surface water is also used for agriculture, industries, and wildlife management, among other uses.

Current Surface Water and Groundwater Studies in the Central Mississippi Region

Henley, L.

The Central Mississippi Region encompasses twenty counties and is home to many major cities, including the Jackson Metro area. Both surface water and groundwater studies are currently being conducted in the Central Region. The Office of Land and Water Resources conduct streamflow measurements in order to obtain surface water discharges to complement data collected by the Office of Pollution Control for the M-BISQ (Mississippi Benthic Index of Stream Quality) Program. The 2015-2016 M-BISQ study has approximately forty sites selected within the central region of the state. Regional groundwater studies are also performed by the Office of Land and Water Resources – Water Resources Management Division. The data collected for the regional studies include water level measurements, which are used to create potentiometric surface maps and hydrographs, water quality samples, and using geophysical logs to create geologic cross-sections and maps. Due to rapid expansion in Madison County in both the residential and industrial sectors, Central Region studies are presently being focused on the Gluckstadt area. Primary aquifers utilized in Madison County, specifically in the Gluckstadt area, are the Cockfield and Sparta Aquifers, with some minor use of the Meridian-Upper Wilcox aquifer. Population, water use, and water level data will be assessed to determine any impacts on water availability in the area.

Regional Overview of Work by the Water Resources Division in Northeast Mississippi

Banks, J.

Groundwater and surface water resources in the northeast region are monitored by a regional hydrogeologist assigned to the twenty counties included in the area. Historically, the primary focus in the region has been monitoring of water levels in the area's aquifers. Potentiometric mapping of the Paleozoic and Cretaceous aquifers was completed in 2011. Work in the region involves aquifer characterization, including subsurface mapping, water quality sampling and continued water level monitoring. A study of the Wilcox aquifers in Lafayette County will be completed when water quality sampling at selected locations is finished and the data have been analyzed. Smaller, more localized projects for water supply analyses have also been completed, including monitoring water levels in the Tupelo area and in the Wilcox aquifers of Choctaw County. OLWR also works with the Office of Pollution Control collecting surface water discharges for the M-BISQ (Mississippi Benthic Index of Stream Quality), with approximately 56 sites selected within the northeast region of Mississippi. Beginning in July, 2015, each of the four regions is responsible for adequately characterizing the water resources for one area in the region per fiscal year. These areas can be from the size of a small town to as large as a county. Characteristics to be analyzed include water availability, water quality, and water use.

Evaluations of Groundwater Resources of Southern Mississippi

Hoffman, J.

Virtually all water used for public and domestic drinking water supplies in southern Mississippi is derived from underground sources. Much of the area is underlain by a thick section of fresh water-bearing sediments and multiple aquifers are available at most locations. Although some wells in Wayne and Jones Counties are screened in other aquifers, the most widely used aquifers in southern Mississippi are developed in beds of sand that occur within sediments above the Vicksburg Group. Southwest of a line from Warren County through Wayne County, these sediments dip in a general gulfward direction at rates ranging from 30 to 100 feet per mile and form a wedge thickening southward to more than 5,000 feet in southern Hancock County and southwestern Wilkinson County. The aquifers within this interval have been termed the "Miocene aquifer system". Because these deposits range from late Oligocene to Pliocene age, it is proposed that the name Grand Gulf aquifer system is more appropriate. Fresh water is available from these aquifers nearly everywhere within the 17,000 square mile area of their occurrence, even extending out from the coast beneath the barrier islands along Mississippi Sound and beyond, possibly as deep as 2,500 feet at Ship and Cat Islands. For years, there was little effort to systematically subdivide the many sand intervals that function as separate aquifers within the Grand Gulf system, an interval often consisting of 2,000 feet of fresh water-bearing sediments. Because of the growing need to make informed decisions concerning water use, staff initiated a study to delineate the individual aquifer units within the Grand Gulf system from interpretations of borehole geophysical logs. Office of Land and Water staff members have measured water levels and collected water samples in wells throughout southern Mississippi for many years. In early 1992, investigation of the potential for intrusion of saltwater into the aquifers that are sources of drinking water along the coast started. Results of this investigation found no evidence of saltwater intrusion in the confined aquifers that are sources of water supplies along the coast. In 2011, after reports of increased mineral leasing activity in southwestern Mississippi associated with fracking and its attendant requirements for water, the staff began a study focusing on potential groundwater availability in Amite and Wilkinson Counties that identified the specific aquifer intervals already being used for public and domestic drinking water supplies and those which might supply water for fracking without resulting in adverse impacts upon others.

Ecology/Hydrology

Jason Taylor *(USDA-ARS-NSL)*	Exoenzyme Activity and Algal Biomass Responses to Experimental Nutrient Gradients Identify Factors Driving Nutrient Limitation of Algal Biomass in an Agriculturally Influenced Oxbow Lake
Richard Lizotte *(USDA-ARS-NSL)*	Nutrient and Phytoplankton Changes in Roundaway Lake After a Managed Hydrologic Drawdown
Claire Rose *(U.S. Geological Survey)*	Relation Between Water Level and Biological Health in Alabama Streams
Bill Wolfe *(U.S. Geological Survey)*	Effects of Water Use on Fish Biodiversity: A Decision Support Framework
Cory Shoemaker *(Mississippi State University)*	Effects of Land Use on Wetland Plant Diversity in Mississippi
Evelyn Windham *(Mississippi State University)*	Functions of Wetland Plant Assemblages in Water Quality Improvement
Courtney Siegert *(Mississippi State University)*	Interspecific Ecological and Meteorological Controls on Forest Canopy-driven Hydrology and Biogeochemistry in the Southeastern United States
Lindsey M.W. Yasarer *(USDA-ARS-NSL)*	Land-use Impacts on Water Quality in Beasley Lake Watershed, Mississippi Using AnnAGNPS

Exoenzyme Activity and Algal Biomass Responses to Experimental Nutrient Gradients Identify Factors Driving Nutrient Limitation of Algal Biomass in an Agriculturally Influenced Oxbow Lake

Taylor, J.; Jenkins, M.; Lizotte, R.; Locke, M.; Dillard, K.; McChesney, D.; Testa III, S.; Bryant, C.

The development of robust algal biomass-nutrient enrichment relationships for lakes within the Mississippi Delta is challenging due to a lack of undisturbed conditions. However, examining long-term water quality datasets linked to best management practices, combined with nutrient enrichment experiments may provide insight into factors that limit algal biomass. We examined seasonal patterns in nutrients, sediments and chlorophyll α (chl. α) over several years in Beasley Lake. Implementation of conservation practices within the watershed resulted in significant reductions in sediments and nutrients, particularly phosphorus (P), within the lake. However, chl. α concentrations continue to remain higher than recommended criteria during the growing season despite reductions in lake P concentrations. Seasonal patterns in activity of exo-enzymes associated with mineralization of nitrogen (N) and P suggest that nutrient demand is greatest at the end of the growing season when algal biomass is high and nutrient inputs are low. Experimental algal bioassays indicated that both chl. α and FDA (a measure of overall microbial activity) increased according to Michaelis-Menten dynamics with increasing dissolved N and P. We only observed maximum chl. α below recommended 20 µg/L concentrations when dissolved inorganic N (DIN = NH_4-N + NO_2-N + NO_3-N) concentrations were below 0.2 mg/L despite high soluble reactive P (SRP) of 0.345 mg/L. In contrast, chl. α concentrations were always higher than the management target when DIN was not limiting (1.6 mg/L) despite very low SRP concentrations (0.015 mg/L) which suggests that N may be the primary limiting nutrient in Delta oxbows. Acid Phosphatase Activity (APA), an exoenzyme associated with mineralization of P, decreased with SRP and increased with DIN enrichment suggesting that P demand was related to availability and N:P ratios. In contrast, NAG and LAP, two exoenzymes associated with mineralization of N, increased rather than decreased with DIN enrichment and were correlated with chl. α. Chlorophyll α and FDA peaked at N:P ratios of 16:1 indicating that optimal elemental ratios for eutrophic oxbow lakes are similar to those observed in marine environments and some freshwater lakes. From a water resource management and monitoring perspective, our results suggest that exoenzyme activities may provide additional insight into complex relationships between nutrients and algal biomass in oxbow lakes. Furthermore, management practices that reduce N inputs to agricultural water bodies may be key to reducing chl. α concentrations below recommended goals for maintaining ecological integrity of Mississippi Delta oxbow lakes.

Nutrient and Phytoplankton Changes in Roundaway Lake After a Managed Hydrologic Drawdown

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A late summer drawdown of Roundaway Lake in the Mississippi Delta was initiated to help improve downstream flows within the Big Sunflower River. Although such water releases are important to help improve downstream water quality, a better understanding of the changes and processes within the contributing water bodies is needed to aid water resource management decisions. Consequently, we examined the influence of the lake drawdown on surface water nutrients and phytoplankton within the system before, during, and after drawdown. Lake drawdown was initiated on September 15, 2015 and was completed within six days when outflow was <5% of peak flows and channel water depths decreased by 40%, 28%, and 82% at upstream, lake, and downstream sites, respectively. Surface water samples for nutrient and phytoplankton analysis were collected on days -7, -1, 0, 1, 2, 3, 6, 13, 20, 28, and 34 at all three sites. Nutrients included soluble reactive phosphorus (SRP), dissolved inorganic nitrogen (NH_4-N, NO_2-N, and NO_3-N), total nitrogen (TN), total phosphorus (TP), and dissolved organic carbon (DOC). Phytoplankton measurements were: chlorophyll a and in-vivo chlorophyll (phytoplankton biomass); in-vivo phycocyanin (blue-green algal biovolume); chlorophyll:phycocyanin ratio (Chl:PC, blue-green algal bloom); phytoplankton photosynthetic activity (Chl Fv/Fm); and blue-green algal photosynthetic activity (PC Fv/Fm). Surface water nutrient responses were modest with the exception of SRP. Bimodal changes in SRP occurred with decreases at all sites during the initial drawdown phase (days -1 to 6) followed by increasing SRP levels 13 to 34 days after drawdown. No clear trends were observed for dissolved inorganic nitrogen while TN increased with time and changes in turbidity and TP varied with turbidity. Regression analysis identified some of the physical and chemical factors driving phytoplankton responses to the drawdown. Chlorophyll a was associated with TN and N:P ratios (R^2 = 0.571), in-vivo chlorophyll was associated with depth, TN, and N:P ratios (R^2 = 0.785), and in-vivo phycocyanin was associated with SRP, TN, and N:P ratios (R^2 = 0.750). Blue-green algal blooms (Chl:PC) were associated with SRP, NO_3-N, and C:N ratios (R^2 = 0.645). Chl Fv/Fm and PC Fv/Fm were associated with C:N ratios (R^2 = 0.351) and NO_3-N + C:N ratios (R^2 = 0.338), respectively. These results will provide valuable information that will help water resource managers make better informed decisions to sustain surface water resources and ecosystem integrity of Mississippi Delta rivers and lakes.

Connecting Water Level to Biological Health in Alabama Streams

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Water is critical to the survival of aquatic biota, but little has been done to quantify the minimum water level in a stream that provides adequate support for aquatic biological communities. Most research in this field has focused either on connections between various streamflow measures and aquatic habitat, linkages between aquatic habitat and the biological health of streams, or using the annual or monthly 7Q10 or other low-flow measures to establish minimum flows. Resource managers need a better understanding of the interaction and linkages between streamflow, water level, channel morphology, physical habitat availability (streambed), and biological health to establish scientifically-defensible flow requirements. The proposed analysis will be based on existing streamflow, channel morphology, physical habitat availability, and biological health (richness, diversity, or IBI score) data at each site. The analysis will include, but is not limited to: daily value streamflow time series, streamflow measurement data (cross-section data), game and non-game fish community data, available habitat data, and stream cross-sectional surveys. Existing data from 15 to 20 streams in different physiographic regions of Alabama will then be used to answer the following questions: ▪ Is physical habitat quantity maximized at low, yet consistent streamflow? ▪ Is the streamflow associated with maximized physical habitat predictable and does it vary regionally according to published geologic and physiographic boundaries? ▪ Does biological health of fish communities appear to be correlated with the amount of time streamflow is lower than that associated with the maximized physical habitat?

Effects of Water Use on Fish Biodiversity: A Decision-Support Framework

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Despite increasing awareness of the importance of streamflow variability to fish communities and efforts to create regional standards for environmental flows, methods are lacking that explicitly translate water-use decisions into predicted ecological outcomes. The U.S. Geological Survey has developed ecological limit functions in the Tennessee River basin relating hydrologic departure from reference conditions to species richness for key fish groups based on trophic and habitat characteristics. These ecological limit functions have been incorporated into a hydrologic accounting framework to allow water-resource managers to examine the consequences for fish biodiversity of water-use decisions, such as withdrawals for municipal or agricultural use. This approach allows various management scenarios to be compared, with the goal of maintaining ecological health of streams and conserving fish biodiversity while optimizing water availability for human use.

Effects of Land Use on Wetland Plant Diversity in Mississippi

Shoemaker, C.; Windham, E.; Ervin, G.

Restoration of former agricultural lands to wetlands has increased in the past 25 years, with public and private programs subsidizing the conversion of marginal farmland into wetlands. These wetlands were constructed with structural and functional goals in mind, such as increasing biodiversity and water quality within local and regional watersheds. While successful in terms of area restored, restored wetlands frequently do not meet desired management goals; often, these wetlands resemble highly degraded wetlands in terms of structure and function. While on-site parameters and management recommendations have recently received much attention, desired structural and functional components continue to fall short of management expectations. This study examined relationships between wetland site characteristics, measures of plant diversity, and land use. Data were collected in a total of 30 restored and naturally occurring wetlands in the Delta region of Mississippi during the 2014 and 2015 growing seasons. Wetland sites were surveyed twice during each growing season (May and August) from 50 evenly spaced observation points per wetland. Lower levels of plant diversity were observed in natural, compared to restored wetlands, with hydroperiod and management activities clearly affecting assemblages. Additionally, land use impacted observed plant community metrics, with the prevalence of agricultural and developed lands showing a negative relationship with plant species diversity. Wetland plant diversity showed a strong positive correlation with fallow land cover surrounding wetlands, with fallow land most often corresponding to land placed in conservation easements. Results thus suggest that low-intensity land use buffers associated with conversation easements are having a positive impact on wetland plant species diversity in the Mississippi Delta.

Functions of Wetland Plant Assemblages in Water Quality Improvement

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As wetland restoration continues, an understanding of drivers of natural wetland function becomes increasingly important for effective wetland restoration planning. Many studies have shown that wetlands act as filters for nutrient rich waters, in part due to macrophyte properties. Differences in plant characteristics such as biomass production, root oxygen release, and surface area available for microbial colonization have been suggested as possible contributors to greater nutrient removal. Thus, it is assumed that water quality parameters will vary among plant species assemblages, and that differences observed will correlate with one or more aspects of plant species biology or ecology that may prove useful in planning future restorations. Differences have been found in nitrogen removal rates among plant species in studies of monocultures grown in mesocosms mimicking wastewater treatment constructed wetlands, but almost no research has been done on assemblages in natural or restored wetlands. This study aims to identify the differences in water quality improvement among plant assemblages in natural and restored wetlands. Thirty natural and restored wetlands in the Mississippi portion of the Mississippi Alluvial Valley were sampled four times. Dissolved oxygen, temperature, pH, conductivity, turbidity, and oxidation-reduction potential were measured on-site, and water samples weretaken for analysis of nitrogen and total suspended solid content.Results showed that water quality parameters such as nitrate and phosphate concentrations, and pH were significantly correlated with plant growth form, in addition to being influenced by wetland type or by nutrient inputs on the surrounding landscape.

Interspecific Ecological and Meteorological Controls on Forest Canopy-derived Hydrology and Biogeochemistry in the Southeastern United States

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During storm events, as precipitation moves through the forest canopy it is transformed in both quantity and quality, thus delivering highly enriched water to the forest floor. Throughfall is spatially distributed beneath the forest canopy while stemflow is localized to the roots and soils in the immediate vicinity of individual tree trunks. Previous research has demonstrated that storm characteristics (e.g., intensity, duration, and magnitude), canopy structural parameters, and species composition have a significant control on canopy-derived nutrient fluxes. However, in the southeastern United States, contributions of the forest canopy to nutrient cycling have largely been overlooked, although the magnitude of tree biodiversity in the region separates these forests from their more-studied counterparts. Therefore, a field study was established in an oak-hickory forest in Mississippi to categorize the interspecific control on canopy-mediated nutrient cycling during precipitation events. Throughfall collectors and stemflow collars were located underneath the canopies of four oak (Shumard, Southern Red, Post, and White) and two hickory species (Shagbark and Pignut), with three replicates for each species. Hydrologic flux and nutrient samples were collected following individual precipitation events beginning in Fall 2014 and continue to present. Meteorological characteristics and precipitation chemistry were collected at a nearby open site.

Preliminary results indicate that stemflow volumetric flux was significantly different between species ($p<0.001$) but throughfall volumetric flux was not ($p=0.624$). Among the oak species, Shumard oak partitioned an average of 73.6% of incident precipitation into throughfall and 1.6% into stemflow, the largest among all species, with the remaining 24.8% partitioned into canopy interception. Mean concentrations of total nitrogen (TN) in throughfall were greatest in Shumard oak (1.44 mg/L) and post oak (1.39 mg/L) while stemflow concentrations were greatest in shagbark hickory (1.81 mg/L) and white oak (1.20 mg/L) and intermediate in Shumard oak (0.96 mg/L). Dissolved organic carbon (DOC) concentrations in throughfall were significantly different than precipitation ($p=0.038$) but not between species ($p=0.342$), while DOC concentrations in stemflow were significantly different than precipitation ($p<0.001$) and between species ($p<0.001$). Results suggest that Shumard oak canopies facilitate the largest hydrologic fluxes in oak-hickory forests that correspond to intermediate biogeochemical fluxes of nitrogen, enabling this species to directly modify the substrata and its growing conditions. Improved understanding of species-specific roles in nutrient cycles in highly diverse southern forests is critical to developing effective management strategies to mitigate shifts in species composition and ecosystem functions as regional climates change.

introduction

Deciduous forests represent a significant land cover classification in much of the temperate US and contribute meaningful ecosystem services such as carbon sequestration, water and air purification, storm water management, recreational retreats, in addition to providing valuable timber products. These services are constrained by forest health, which can be measured via several parameters including net primary production and biomass accumulation, evapotranspiration, resiliency to disturbance, and forest nutrient balances (Long et al., 2009; Pan et al., 2009; Wear and Huggett, 2011; Woodall et al., 2013). These services are ultimately constrained by the external climate from which forests derive water and nutrients.

Within the forest canopy, there are distinct pathways in which precipitation and nutrients reach the forest floor and move throughout a watershed (Figure 1). Throughfall is water that passes through the forest canopy and is deposited to the forest floor. Throughfall is a spatially and temporally variable hydrologic flux that is influenced by a host of variables including: physiological and morphological traits related to forest composition; seasonality and the presence of foliage; precipitation characteristics; and meteorological conditions. Variability in canopy density may arise from several inherent physiological traits such as crown density, crown cover percentage, and leaf area index (LAI), which contribute to throughfall variability, especially in tropical forests where species diversity is high (Park and Cameron, 2008). In temperate forests, species with denser canopies like Acer rubrum (red maple) have significantly smaller throughfall fluxes than shallower canopies like Quercus prinus (chestnut oak) (Alexander and Arthur, 2010). The presence of foliage increases throughfall variability by providing additional surfaces for drip points and decreases overall throughfall flux by providing additional surfaces for interception (Helvey and Patric, 1966; Peterson and Rolfe, 1982).

Precipitation characteristics including magnitude, intensity, and duration are considered abiotic factors that influence throughfall partitioning. The strong correlation between throughfall and precipitation magnitude has been documented in forest types around the world such as Amazonian rainforests (Marin et al., 2000), coniferous arid forests (Shachnovich et al., 2008), semi-arid oak forests (Carlyle-Moses et al., 2004), and temperate rainforests (Link et al., 2004; Oyarzún et al., 2011). Precipitation intensity is positively correlated with throughfall partitioning, whereby the mechanism of more and faster falling raindrops disturb foliar surfaces and reduce canopy retention capabilities (Ponette-González et al., 2010; Staelens et al., 2008). Longer duration storm events reduce the spatial variability of throughfall (Loescher et al., 2014) in addition, longer duration events are typically associated with lower vapor pressure deficits, which inhibit intra-storm evaporation from the canopy and contribute to throughfall (Llorens et al., 1997).

Stemflow is rainfall that has been captured by the forest canopy and funneled down woody surfaces to be deposited at the base of the trunk. Stemflow has much longer residence times and therefore is an important pathway in nutrient cycling. Physiological and morphological traits of a species are much more important for stemflow generation because the residence time of stemflow on forest surfaces is much greater and persists for a longer period of time. Levia et al. (2010) monitored stemflow flux at 5-min intervals within storm events and found that stemflow yield was more similar within trees of the same species than within trees of the same basal area. It was also observed, that within a species, stemflow yield was correlated to tree size (Levia et al. 2010) and that smaller trees were more efficient at generating stemflow (Siegert and Levia, 2014). Carlyle-Moses and Price (2006) found a similar relationship between rough and smooth bark species during smaller precipitation events, but during larger events, once the bark storage capacity of the rough bark species was reached, stemflow generation exceeded all other dominant canopy trees regardless of bark thickness. Seasonality also plays a key role in stemflow production not only by changing the canopy composition in terms of foliage presence but also through meteorological influences. The presence of foliage interferes with stemflow production in much the same manner as it does for throughfall production—by providing additional canopy surfaces for interception.

Only a few studies have documented the effects of rainfall intensity on stemflow production. When rainfall intensity exceeds the flowpath capacity of branches and trunks, the pathways overflow and contribute to throughfall, thus reducing total stemflow production (Herwitz, 1987). During high intensity storms, obstructions on woody surfaces by rough morphology can slow down pathways and also create drip points, reducing stemflow production (Carlyle-Moses and Price, 2006; Herwitz, 1986). Wind speed and direction also influence stemflow production. Van Stan et al. (2011) found that smaller trees gained more access to incident rainfall when it was inclined due to increased wind speeds and were thereby able to generate more stemflow than under conditions of vertical rainfall. In tropical forests where canopy roughness is much greater and a emergent trees are common, inclined rainfall plays a significant role at wetting tree trunks along vertical gradients and generating stemflow (Herwitz and Slye, 1995).

Throughfall and stemflow pathways may become enriched with nutrients and other solutes via washoff of dry deposition during antecent dry periods or canopy leaching. Dry deposition, in either gaseous or particulate form, accumulates in the forest canopy between rainfall events. The mechanism by which the forest canopy intercepts dry deposited materials are controlled by canopy architecture and leaf surface area and is highly specific to the material and the associated deposition velocity (Katul et al., 2011). Canopy leaching comes from internal forest structures and is controlled by phenoseasons (Levia et al., 2011; Van Stan et al., 2012; Zhang et al., 2006), canopy structure (Beier et al., 1993), forest composition (Pryor and Barthelmie, 2005), and canopy-dwelling flora and fauna (Levia, 2002). These movements are influenced by a suite of internal and external forcings that ultimately control the amount of solutes deposited to the forest floor. Internal forest characteristics that have been shown to influence enrichment of nutrients along subcanopy hydrologic pathways include bark microrelief (Levia et al., 2011), canopy geometry (Levia and Herwitz, 2005), stand age (Buttle and Farnsworth, 2012), and canopy hydrophobicity (Holder, 2007). External forest characteristics include precipitation characteristics (Hofhansl et al., 2012), precipitation phase (Levia, 2003), seasonality (Van Stan et al., 2012), and proximity to pollution sources (Avila and Alarcon, 1999). Changes in precipitation characteristics such as magnitude, duration, and intensity or in overall storm tracks have the potential to alter the movement of water and nutrients in forests.

Across the eastern portion of the United States, the vast majority of forest types are dominated by oak species. As such, oaks are a crucial component of forest hydrology and biogeochemical cycling, influencing both the temporal and spatial distribution of water and nutrients in forests. However, the biogeography of oak species in forests across the United States is changing due to anthropogenic management of fire regimes (Brose et al., 2001; Nowacki and Abrams, 2008), accelerated mammalian browsing (Abrams, 2003; Cote et al., 2004), insects (Stephen et al., 2001), disease (Bruhn et al., 2000), and climatic disturbances leading to a broad decline of oaks (Clinton et al., 1993; McEwan et al., 2011; Voelker et al., 2008). In order to predict and manage oak decline, it is first necessary to understand and quantify the role of oaks to forest nutrient cycling. Therefore, the objectives of this study are to quantify the importance of oaks versus co-dominant hickories in their role in regulating water and nutrient cycles in a southeastern deciduous forest.

Study Site

This research was conducted at a field site located at Sessums Natural Area in Oktibbeha County, MS (33°25'27.8"N 88°45'36.6"W) in a 15 hectare catchment (Figure 2). Dominant canopy trees at the site include white oak (*Q. alba*), post oak (*Q. stellata*), cherrybark oak (*Q. pagoda*), Shumard oak (*Q. shumardii*), shagbark hickory (*Carya ovata*) and pignut hickory (*C. glabra*). Leaf area index (LAI) of the stand is 5.77 m^2 m^{-2}. The site is located at the contact point between the Demopolis chalk formation to the northeast and the Ripley formation to the southwest. Soils at the site are silty clay loams ranging from somewhat poorly drained (Kipling) to well drained (Sumter) depending on landscape position (NRCS 2013). Annual summer temperatures (JJA) range from 23.5℃ to 27.7℃ with an average monthly precipitation of 11.0 cm. Annual winter temperatures (DJF) range from 6.6 ℃ to 14.4˚C with an average monthly precipitation of 13.9 cm (20 year average) (SRCC 2014).

Methods

Four oak species and two hickory species (see Table 1) were selected for the study. Three trees from each species were selected for monitoring throughfall and stemflow fluxes. Underneath the discrete canopy of each tree, a 1L high density polyethylene bottle fitted with a 20.3 cm diameter funnel was deployed to capture throughfall. Each tree was also outfitted with stemflow collars by longitudinally cutting high density polypropylene (HDPE) tubing, which was sealed to the trees with silicone caulk and drained into large collection bins. Volumes were measured following discrete rainfall events greater than 5 mm, and grab were collected for nutrient analysis. Open precipitation was monitored at the nearby Mississippi State University Dairy Farm. Precipitation amount, duration, and intensity were measured with a tipping bucket rain gauge (Onset HOBO RG3-M, Dallas TX) and grab samples for chemical analysis were collected from a 1L HDPE collector, of the same design as throughfall collectors.

To convert volumetric measurements of precipitation and

Table 1. Summary of tree species characteristics including diameter at breast height (DBH), basal area, canopy area, specific leaf area, and bark thickness of the 18 trees selected for monitoring in this study.

Tree Species	DBH (cm)	Basal Area (m^2)	Canopy Area (m^2)	Specific Leaf Area (cm^2/g)	Bark Thickness (mm)
Southern Red Oak	61.5	0.3	60.7	122.9	0.92
	65.5	0.3	170.5		
	78.7	0.5	306.1		
Shumard Oak	48.5	0.2	24.1	263.3	1
	70.9	0.4	65.7		
	76.7	0.5	53.1		
White Oak	49.5	0.2	77.1	85.7	1.22
	61.5	0.3	122.5		
	88.9	0.6	198.1		
Post Oak	49.3	0.2	151.3	115.1	1.19
	58.7	0.3	126.7		
	69.3	0.4	164.3		
Pignut Hickory	18.0	0.0	23.3	285.6	0.85
	36.3	0.1	11.8		
	77.5	0.5	194.6		
Shagbark Hickory	25.9	0.1	15.0	-	0.42
	31.5	0.1	56.9		
	49.8	0.2	74.8		

throughfall into comparable depth equivalents, the following equation was used:

$$D = \frac{V}{A} \qquad (1)$$

where D is the depth of throughfall or precipitation (cm), V is the measured volume of water collected during an event (cm^3), and A is the area of the 20.3 cm diameter funnel (324.3 cm^2). Stemflow volumes were converted to depth equivalents based on the canopy area of each collecting tree. Depth equivalents were then compared to rainfall amounts to determine each tree's stemflow partitioning. Funneling Ratios (FR) (Herwitz, 1986) were determined by

$$FR = \frac{SF}{P_g \times BA} \qquad (2)$$

where *SF* is stemflow volume (mL), *Pg* is precipitation (cm), and *BA* is the basal area of each tree (cm^2).

Samples were returned to the laboratory, filtered to remove particulates greater than 0.45µm, and stored at 4°C within 24 hours. Total organic carbon (TOC) concentrations were determined using spectrometry methods with a HACH Low Range Total Organic Carbon Test kit and processed on a HACH DR5000 Spectrophotometer (Loveland, CO). Inorganic nitrogen components, NO_{3-} and NH_{4+} were determined using colorimetry methods on a Bran+Luebbe Autoanalyzer 3 (Mequon, WI).

Results and Discussion

The distribution of incident rainfall by the forest canopy was highly variable and dependent on tree species. In all tree species, throughfall comprised the majority of canopy partitioning, where pignut hickory and post oak partitioned the largest amount of incident rainfall into throughfall (85.3% and 84.3%, respectively) while Shumard oak and white oak partitioned the least (71.6% and 72.3%, respectively) (Figure 3, Table 2). Throughfall volumetric flux was strongly correlated with rainfall amount, with the strongest correla-

Table 2. Summary of throughfall (TF), interception (I), and stemflow (SF) partitioning as a percent of incident rainfall, stemflow funneling ratio (FR), dissolved organic carbon (DOC) concentrations, and dissolved inorganic nitrogen concentrations (DIN=NO_{3-} + NH_{4+}) in throughfall and stemflow for each of the six tree species of this study. [Note that the percent partitioning values for TF, I, and SF are averages across all storms and do not sum to 100%.]

Species	%TF	%I	%SF	FR	TF DOC (mg/L)	SF DOC (mg/L)	TF DIN (mg/L)	SF DIN (mg/L)
Southern Red Oak	82.3	13.1	0.3	0.27	15.62	41.01	0.96	0.93
Shumard Oak	71.6	25.1	1.0	0.29	13.21	34.26	1.69	0.88
White Oak	72.3	18.3	0.2	0.12	21.71	77.33	0.67	1.29
Post Oak	84.3	6.9	0.2	0.31	25.32	73.89	0.65	0.75
Pignut Hickory	85.3	12.1	1.0	0.62	17.23	37.51	0.56	1.22
Shagbark Hickory	74.9	17.3	3.6	0.44	20.74	35.10	0.60	1.12
Rain					6.16		3.18	

tions observed for southern red oak (r^2=0.92) and pignut hickory (r^2=0.88) and slightly weaker correlations observed for white oak (r^2=0.78) and post oak (r^2=0.79) (Figure 4). The latter two species had the largest average canopy areas (Table 1) but were characterized by large canopy gaps and a high degree of spatial heterogeneity, which has been shown to be more difficult to model (André et al., 2011).

Stemflow partitioning represented a very small portion of canopy partitioning, where southern red oak, white oak, and post oak diverted the smallest portion to partitioning (0.3%, 0.2%, and 0.2%, respectively) while shagbark hickory overwhelmingly diverted the largest (3.6%) (Figure 5, Table 2). While shagbark hickory bark tends to flake outwards and provide drip points (Herwitz, 1986), the capacity of this species to generate stemflow may be compensated by the thinner bark (Table 2) and therefore lower bark water storage capacity (Van Stan et al., 2016). Stemflow volumetric flux was much more variable than throughfall flux, as it is influenced by an array of tree traits and rainfall conditions, therefore the relationship between stemflow volume and rainfall amount was considerably weaker. However, stemflow volume was most well correlated with rainfall amount for Shumard oak (r^2=0.81) and to a lesser degree for all other tree species, with the weakest correlation for white oak (r^2=0.28) (Figure 5). To a degree, stemflow generation in smoother-barked species is more strongly correlated to rainfall amount than generation in species with rougher bark, such as the distinction between Shumard oak and pignut hickory on one end of the spectrum and white oak on the other (Table 1). In species with very smooth bark, such as American beech, the ease of generating stemflow can actually lead to higher inter-storm variability and less predictive models (Siegert and Levia, 2014). Pignut and shagbark hickory were most efficient at generating stemflow, with funneling ratio values of 0.62 and 0.44, respectively (Table 2). Although oak species had smaller average funneling ratios, the variability and range were similar to those observed in hickory species, with the exception of white oak (FR=0.12) (Figure 6).

Dissolved organic carbon fluxes in throughfall and stemflow can be derived from both atmospheric deposition and canopy exchange (Arisci et al., 2012; Moreno et al., 2001). In throughfall, DOC concentrations were all greater than DOC concentrations observed in rainfall, but only marginally so (Figure 7). White oak and post oak DOC concentrations were significantly higher in throughfall than rainfall but no other significant differences between species were observed (Table 3). In stemflow, DOC concentrations were much greater than those observed in throughfall or rainfall, as is commonly observed in the literature (Arisci et al., 2012; Guo et al., 2005; Inamdar et al., 2013). However, given the difference in volume between throughfall and stemflow, total flux of DOC is typically greater in throughfall (Neu et al., 2016). In addition to significantly larger DOC concentrations in stemflow relative to rainfall, many interspecific stemflow concentrations were also significantly different (Table 3). Stemflow DOC concentrations in species from the white oak subsection (white oak and post oak) were significantly greater different than those in the red oak subsection (southern red oak and Shumard oak) as well as

Table 3. Comparison of Total organic carbon (TOC) concentrations in rainfall compared to throughfall and stemflow using pairwise t-test. P-values are given in the table below and bolded values are significant (α=0.05). SRO=Southern red oak, SO=Shumard oak, WO=White oak, PO=Post oak, PH=Pignut hickory, SH=Shagbark hickory.

	Rain	SRO	SO	WO	PO	PH
Throughfall						
SRP	1.000	-	-	-	-	-
SO	1.000	1.000	-	-	-	-
WO	0.088	1.000	1.000	-	-	-
PO	0.012	1.000	0.464	1.000	-	-
PH	0.863	1.000	1.000	1.000	1.000	-
SH	0.181	1.000	1.000	1.000	1.000	1.000
Stemflow						
SRP	0.003	-	-	-	-	-
SO	0.025	1.000	-	-	-	-
WO	<0.001	0.002	<0.001	-	-	-
PO	<0.001	0.005	<0.001	1.000	-	-
PH	0.013	1.000	1.000	<0.001	0.002	-
SH	0.019	1.000	1.000	<0.001	<0.001	1.000

the hickories (pignut and shagbark), but no significant difference was observed between the red oaks and hickories (Table 3). The rougher bark characteristics of white oak and post oak leads impedes stemflow drainage and increases the residence time of stemflow, which allows for additional canopy exchange/leaching (Levia et al., 2010).

For inorganic nitrogen species, NO_{3-} and NH_{4+}, no significant differences were observed between rainfall, throughfall, and stemflow (Figures 7 and 8). In all instances, inorganic nitrogen was less in throughfall and stemflow compared to rainfall (Table 3), which could be attributed to canopy uptake (Lovett and Lindberg, 1986).

Conclusion

Vegetative canopies transform incident rainfall in both quantity and quality, redistributing water and nutrients to the forest floor. In forest ecosystems where many species are present such as oak-hickory forests, the impact of specific tree species on this redistribution process is evident. All tree canopies reduced incident rainfall by partitioning water into throughfall, stemflow, and interception. Throughfall partitioning was similar across study species both in terms of quantity (71.6% to 85.3%) and quality (DOC: 13.21 mg/L to 25.32 mg/L; DIN: 0.56 mg/L to 1.69 mg/L) while stemflow partitioning displayed significant interspecific differences. In this study, species with thin bark such as shagbark hickory and species with smooth bark such as Shumard oak produced the largest volumetric fluxes of stemflow. In contrast, species with rough bark such as white oak and post oak were associated with the highest concentrations of DOC in stemflow, due to longer residence time and canopy exchange. These traits enable trees to directly modify the substrata and the surrounding growing space. Improved understanding of species-specific roles in water and nutrient cycles in highly diversity southern forests will play a critical role in developing effective management strategies to mitigate shifts in species composition and ecosystem functions as regional climates change.

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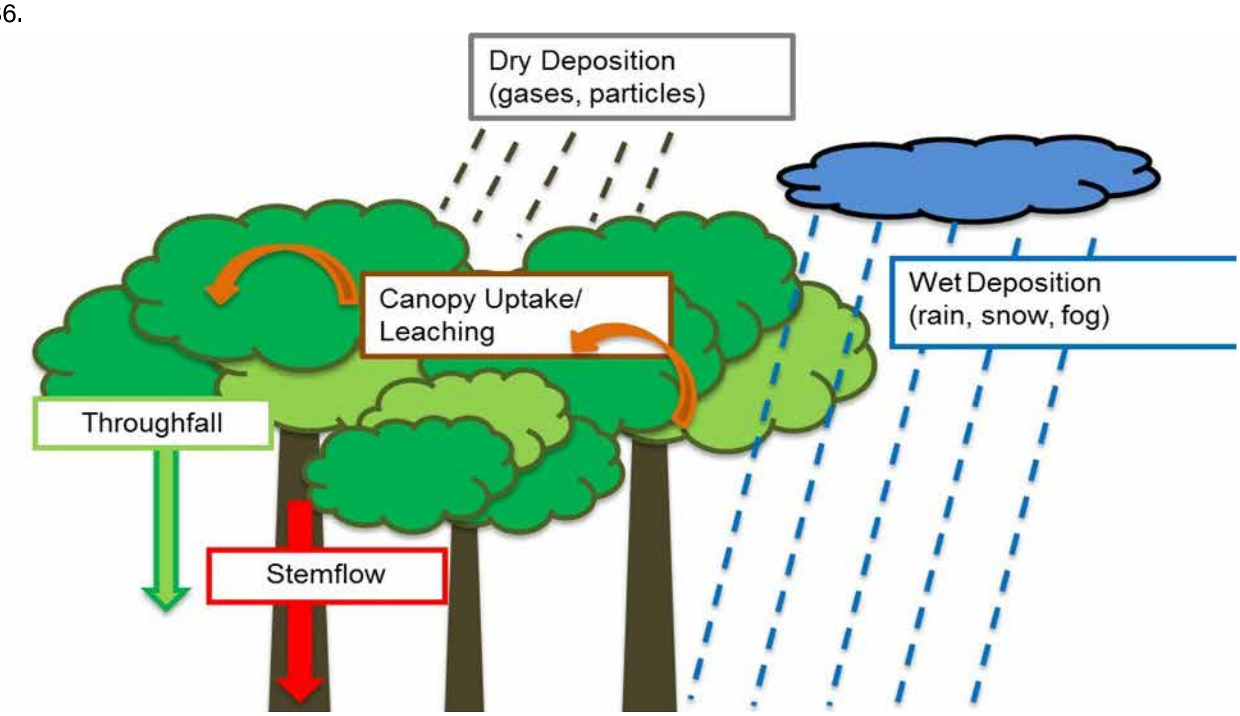

Figure 1. Schematic of hydrologic and biogeochemical flowpaths in forest ecosystems.

Figure 2. Location of experimental study plot in eastern Mississippi.

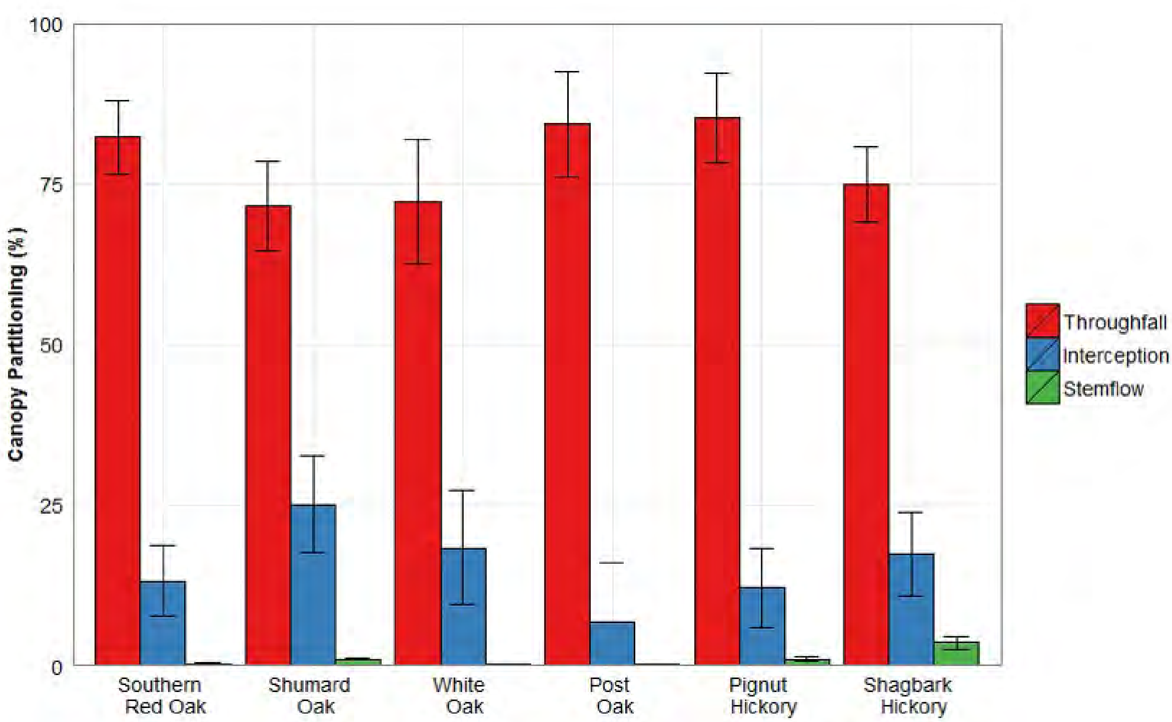

Figure 3. Average partitioning of rainfall into throughfall, interception, and stemflow with standard error bars for each of the 6 tree species in this study.

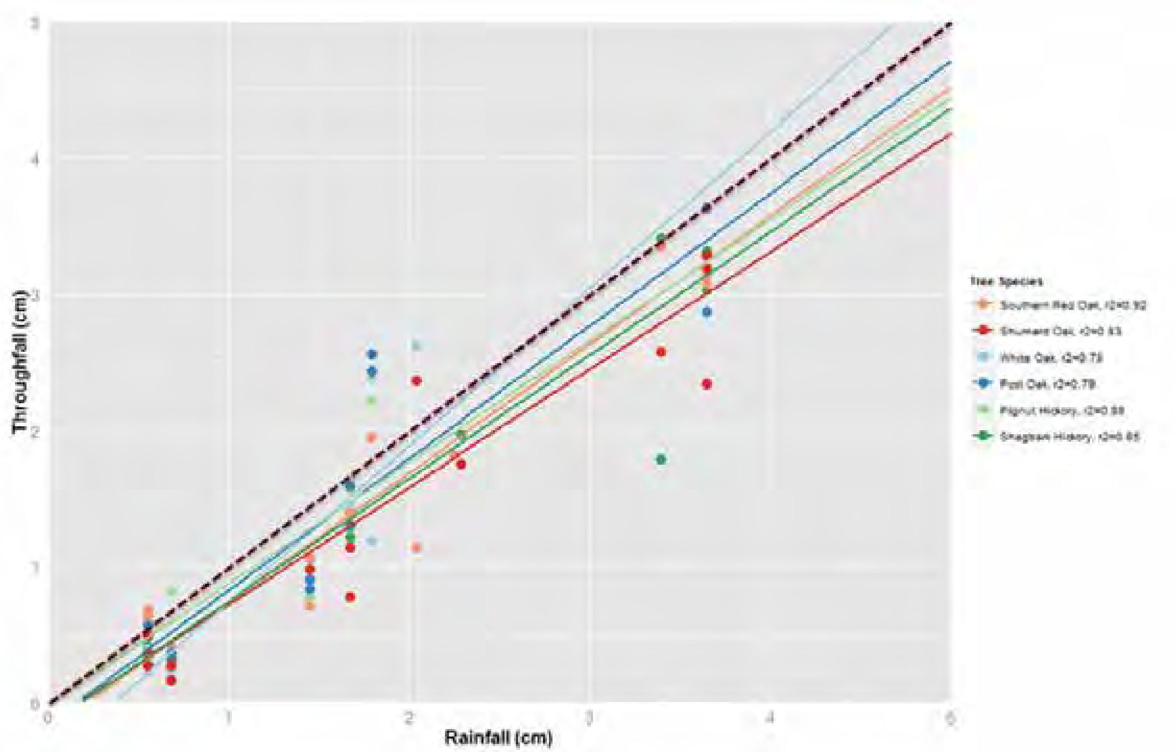

Figure 4. Throughfall volumetric flux in relation to rainfall amount for each of the 6 tree species in this study. The dotted black line represents the 1:1 line, such that points plotted below the line indicate that throughfall was less than rainfall.

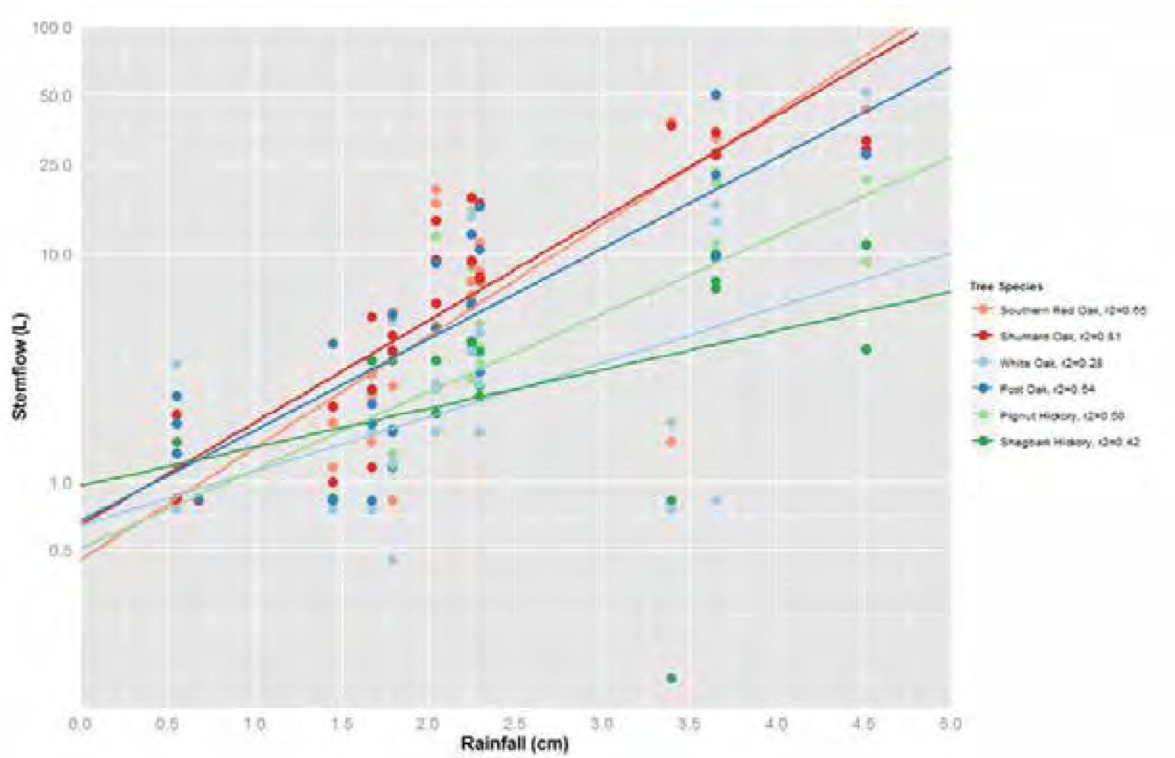

Figure 5. Stemflow volumetric flux in relation to rainfall amount for each of the 6 tree species in this study.

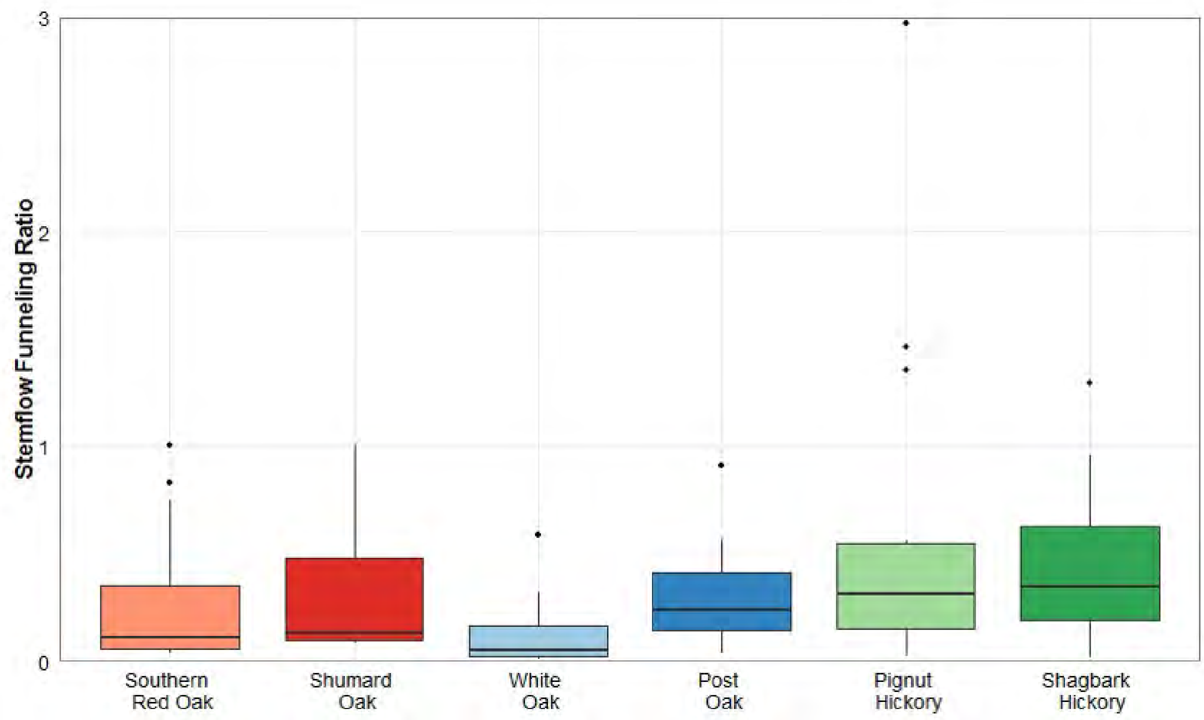

Figure 6. Stemflow funneling ratio for each of the 6 tree species in this study. Boxplots illustrate the distribution of TOC concentrations with the horizontal black bar representing median concentrations, the box representing the first and third quartiles, the whiskers representing 1.5 times the interquartile range, and the circles representing outliers.

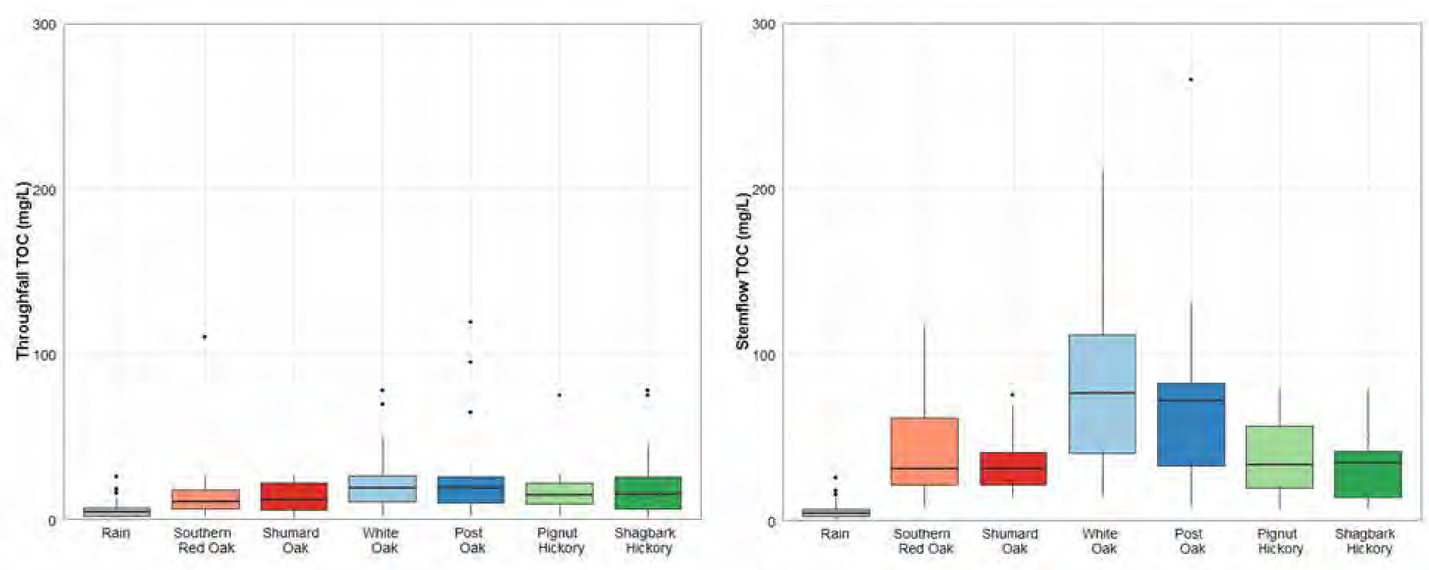

Figure 7. Total organic carbon (TOC) concentrations of rainfall compared to throughfall (left) and stemflow (right) for each of the 6 tree species in this study. Boxplots illustrate the distribution of TOC concentrations with the horizontal black bar representing median concentrations, the box representing the first and third quartiles, the whiskers representing 1.5 times the interquartile range, and the circles representing outliers.

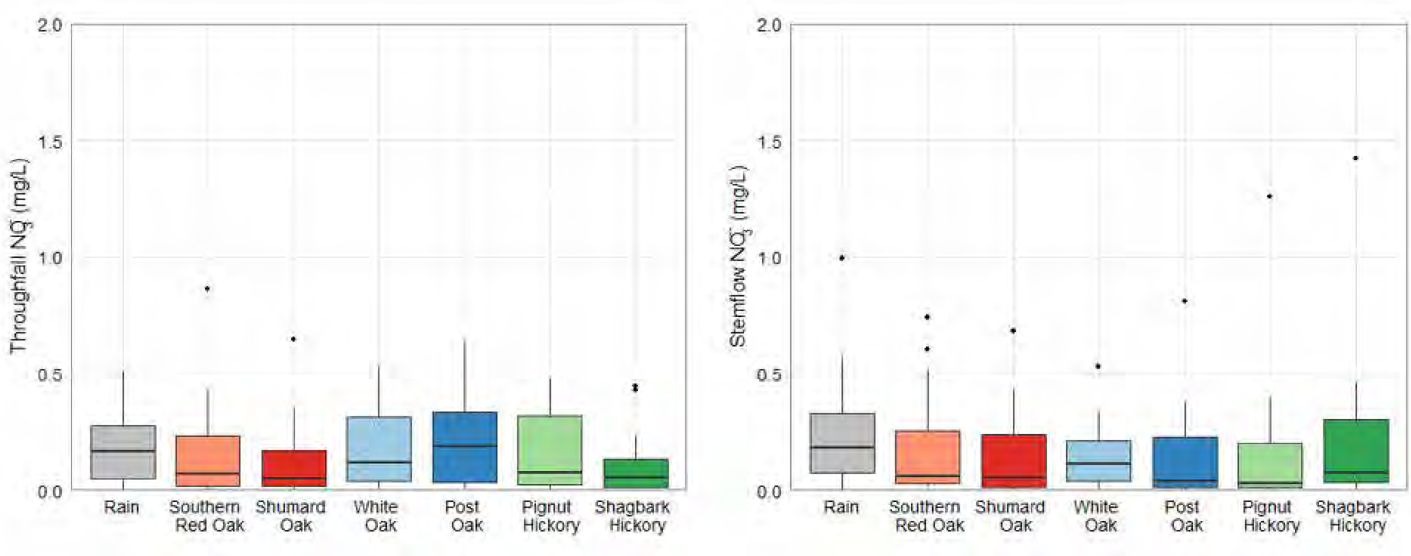

Figure 8. Nitrate (NO_{3-}) concentrations of rainfall compared to throughfall (left) and stemflow (right) for each of the 6 tree species in this study. Boxplots illustrate the distribution of NO_{3-} concentrations with the horizontal black bar representing median concentrations, the box representing the first and third quartiles, the whiskers representing 1.5 times the interquartile range, and the circles representing outliers.

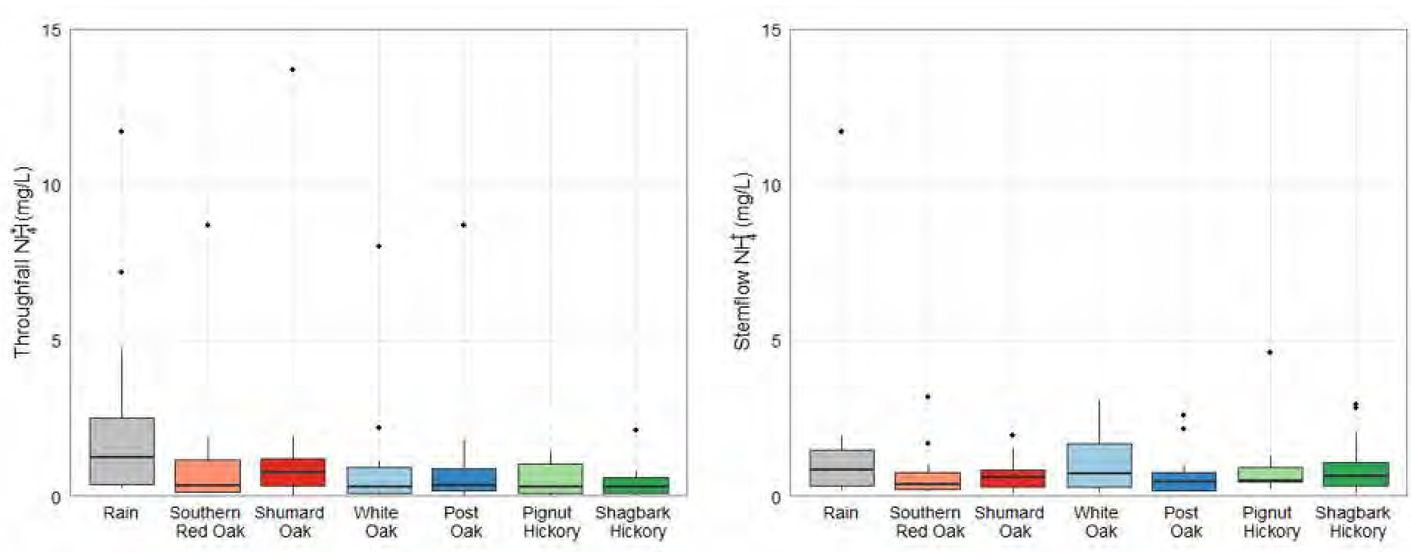

Figure 9. Ammonium (NH_{4+}) concentrations of rainfall compared to throughfall (left) and stemflow (right) for each of the 6 tree species in this study. Boxplots illustrate the distribution of NH_{4+} concentrations with the horizontal black bar representing median concentrations, the box representing the first and third quartiles, the whiskers representing 1.5 times the interquartile range, and the circles representing outliers.

Land-use Impacts on Water Auality in Beasley Lake Watershed, Mississippi Using AnnAGNPS

Yasarer, L.; Bingner, R.; Locke, M.; Lizotte, R.

Land-use in agricultural watersheds has a fundamental role in shaping hydrologic processes, erosion, and nutrient export. However, changing land-use can be a challenge when assessing the effects of specific agricultural management practices on overall watershed water quality. On a practical level, this challenge often arises from a lack of data describing field-scale land-use and management practices over time. In this study, detailed land-use and management data from 1995-2009 are utilized to conduct AnnAGNPS watershed simulations for Beasley Lake Watershed located in the Mississippi Delta. AnnAGNPS is capable of estimating field-scale sediment and nutrient export on various spatial and time scales, which allows for spatial and temporal analysis of the effects of land-use change. Two major changes in land-use occurred in the watershed over the study period: 1) a change from predominantly cotton to soybean-rotations in 60% of total watershed cropland, and 2) a change from predominantly cotton to Conservation Reserve Program (CRP) practices in 23% of total watershed cropland. The impacts of these two land-use changes will be examined by comparing nutrient and sediment export at the field-level, as well as overall watershed loads throughout the study period. Results from this study will help understand the effect of overall land-use changes on pollutant loads impacting water quality in the Mississippi Delta, where a general decrease in cotton land-use has occurred from 1999 – 2009, coinciding with an increase in soybean and corn land-use. The information from this study can be helpful to conservationists when developing management plans that incorporate effective conservation practices to improve watershed water quality.

Water Use

Chris Hawkins *(Mississippi Department of Environmental Quality)*	Office of Land & Water Resources: Overview of Water Use in Mississippi
Ronn Killebrew *(Mississippi Department of Environmental Quality)*	Tapping Into Underground Water in Mississippi
Mary Love Tagert *(Mississippi State University)*	Irrigation in North Mississippi?
Dusty Myers *(Mississippi Department of Environmental Quality)*	An Overview of Dam Safety and Impoundment Permitting

Office of Land and Water Resources: Overview of Water Use In Mississippi

Hawkins, C.

Currently, there are approximately 23,000 groundwater withdrawal permits and 2,600 surface water permits that are active in the state. Seventy-six percent of these permits are issued for irrigation purposes, with the other twenty-four percent leaning heavily on public water supply and other various beneficial uses. The Mississippi Water Law states that all water, whether occurring on the surface of the ground or underneath the surface of the ground, is among the basic resources of this state, belongs to the people of this state, and is subject to regulation. The general welfare of the people of the State of Mississippi requires that the water resources of the state be put to beneficial use to the fullest extent of which they are capable, that the waste or unreasonable use, or unreasonable method of use of water be prevented, and that the conservation of such water be exercised. With only a few exceptions, anyone who wishes to use the waters of the state must obtain a permit from the Mississippi Environmental Quality Permit Board. The OLWR is charged with the task of permitting all groundwater and surface water withdrawals in the state. Other laws that impact the use of water in Mississippi include water well licensing and impoundments, which are also regulated by the OLWR.

Tapping Into Underground Water in Mississippi

Killebrew, R.

An adequate supply of safe water is essential to the public health and welfare. The use of that supply through properly constructed and maintained water wells is an important component in the protection of our groundwater resources. The MDEQ Office of Land and Water Resources is responsible for licensing and regulating all drillers and pump installers operating in the state. Individuals desiring to engage in the business of water well contracting in the state must obtain a water well contractor's license. Those who drill boreholes or wells must obtain a restricted driller's license that will be valid only for a specified drilling purpose. Individuals who service or install water well pumps must obtain a pump installer's license. All licensees must meet specific requirements and demonstrate their competency in drilling and/or pump installation by passing various tests administered either by the MDEQ or by the National Groundwater Association (NGWA). Driller's logs submitted in accordance with our laws and regulations are essential in providing important information for the characterization of our resources and for the proper abandonment of wells.

Irrigation in North Mississippi?

Tagert, M.; Karki, R.; Paz, J.

The majority of water permits in the state of Mississippi, by far, are for groundwater wells used to supply water for irrigated cropland in the Delta. These wells are fed by the shallow Mississippi River Valley Alluvial Aquifer (MRVAA), which is easily accessible and has supplied water for irrigation since roughly the 1970's. Groundwater levels in the MRVAA have been declining in recent years as the number of irrigated acres in the Mississippi Delta continues to increase each year. As a result, much attention has been placed on maintaining the sustainability of the MRVAA and thus the sustainability of agriculture in the Mississippi Delta. However, an increasing number of producers in North Mississippi have been implementing irrigation to reduce risk during periods of drought and also to increase crop yields. North Mississippi producers face somewhat unique challenges when converting from dryland production to an irrigated system. This presentation will better quantify irrigation practices in North Mississippi and discuss some of the challenges and opportunities North Mississippi producers encounter when implementing irrigation.

An Overview of Dam Safety and Impoundment Permitting

Myers, D.

There are approximately 7,000 dams in the State of Mississippi that form lakes that are 5 acres or greater in surface area. The State Dam Safety program which is part of the Department of Environmental Quality's Office of Land and Water Resources is responsible for regulating these dams. These dams and lakes not only pose potential threats to lives and property, but can also alter the flow regime of Mississippi streams. Dams which are on inventory are classified as high, significant, or low hazard depending on what would be flooded downstream if the dam were to fail. One aspect of permitting impoundments includes consideration of impacts to minimum flows. Many impoundments are small and located in the upper reaches of watersheds. The small watersheds they impound typically have very low 7Q10 flows and have not been required to have minimum flow devices installed to bypass the 7Q10.

Collaborative Initiatives

Kim Caviness-Reardon *(Mississippi Department of Environmental Quality)*	The Gulf of Mexico Alliance Water Resources Team Update
Wes Burger *(Mississippi State University)*	Hypoxia Task Force's Land Grant University Initiative, SERA-46
Tim Schauwecker *(Mississippi State University)*	Catalpa Creek Watershed Restoration & Protection Project and Watershed DREAMS Center

The Gulf of Mexico Alliance Water Resources Team Update

Caviness-Reardon, K.

The Gulf of Mexico Alliance (GOMA) was established in 2004 by the Gulf State Governors in response to the President's Ocean Action Plan. It is a State-led network of partners working together on projects related to the priority issues identified by the Governors of the five Gulf States. GOMA is a partnership of the five U.S. Gulf States, federal agencies, academic organizations, businesses, and other non-profits in the region. GOMA's mission is to significantly increase regional collaboration to enhance the environmental and economic health of the Gulf of Mexico. In 2014, after careful consideration and evaluation, the GOMA Alliance Management Team elected to modify the priorities supported by the GOMA partnership. Important to note is that none of the existing focus areas were eliminated, but were redistributed within the new team structure. One of the new teams to emerge from GOMA's restructure is the Water Resources Team, a combination of the former Nutrients and Water Quality Teams. The GOMA Water Resources Team is led by the Mississippi Department of Environmental Quality and will focus its efforts within three areas: (1) protection of human health, (2) protection of aquatic health, and (3) protection of economic health. The team will be focusing on various water resources issues across the Gulf including but not limited to hypoxia, nutrient pollution, pathogens, harmful algal blooms, freshwater inflows, and ultimately, working to increase understanding regarding how impacts to human health and aquatic health tie in directly to the economic health of the region. GOMA is currently developing Governors' Action Plan III for Healthy and Resilient Coasts, the third in a series of action plans to address issues common to all five Gulf States in a voluntary and cooperative way.

Hypoxia Task Force's Land Grant University Initiative, SERA-46

Burger, W.

Catalpa Creek Watershed Restoration & Protection Project and Watershed DREAMS Center

Schauwecker, T.

The Catalpa Creek Watershed is located in Oktibbeha and Lowndes counties in the northeast region of Mississippi and is part of the larger Tombigbee River Basin. The 28,928 acre watershed contains 31 miles of mainstream perennial stream length. At the HUC-12 level, the watershed includes part of the Mississippi State University Campus, the MSU South Farm research facility and dairy farm, as well as a number of privately owned lands. Research activities of the university and continued development and construction of university lands appear to be a primary driver of stream, ecosystem, and water quality degradation. Catalpa Creek is currently listed by the Mississippi Department of Environmental Quality (MDEQ) as impaired by sedimentation and a TMDL has been developed that sets challenging targets for sediment load reductions. Two MSU facilities on the South Farm are permitted point sources – the Poultry Science Research Center and the Ag Center and Horse Park. MDEQ has ranked the watershed as having a high stressor potential, which means compared to other watersheds in the area Catalpa Creek is a watershed in need of restoration. MDEQ supports four sites in the watershed to monitor its biological health. A comprehensive suite of management practices has been selected to address the agricultural resource concerns identified for the watershed – sedimentation, grazing lands, sustainable forestry, and declining wildlife habitats. In addition to the agricultural resource concerns, urban storm water management is a key need for the watershed and a focus for restoration and protection. MSU's Master Plan (MSU, 2010) contains numerous urban storm water management techniques and approaches, which will be leveraged into the project. The project has a number of unique features. These include an education, experiential learning, and outreach approach that begins by better understanding the behaviors, perceptions, and beliefs of watershed stakeholders; creation of experiential learning opportunities for students; a comprehensive monitoring and assessment approach that includes traditional physical/chemical water quality monitoring, macroinvertebrate habitat assessments, use of indicator species to evaluate ecosystem restoration progress; and social indicators to understand improvements in stakeholder behaviors and perceptions and the effectiveness of educational and outreach activities. Other unique features include analyses and designs to restore the structure and function of Catalpa Creek and for siting storm water retention basins to mitigate downstream storm water impacts. Also, incorporated into the project is a focus on watershed sustainability. Probably, the most ambitious component of the project is to leverage these restoration and protection activities into the establishment of a Watershed DREAMS (Demonstration, Research, Education, Application, Management and Sustainability) Center. Supported by over 18 university units, it is envisioned that the DREAMS Center will demonstrate innovative applied research, sustainable water resources management, and effective and quantifiable education and experiential learning for students, educators, and federal/state conservation agencies and organizations.

Policy/Planning

Catherine Janasie *(National Sea Grant Law Center at UM School of Law)*	A Dynamic Legal Case Study: Mississippi v. Tennessee - The Interstate Dispute Over Groundwater Resources
Clifford Ochs *(University of Mississippi)*	Introducing the Mississippi Water Security Institute (MSWSI)
Shawn Clark *(Mississippi Department of Environmental Quality)*	Mississippi's Priority Framework

A Dynamic Legal Case Study: Mississippi v. Tennessee - The Interstate Dispute Over Groundwater Resources

Janasie, C.

Water is one of the most essential natural resources globally, nationally, and locally. In the United States, access to and management of water resources are becoming more deliberated, and often contested, as states strive for stakes in this shared natural resource. As the legal framework looks to respond to evolving water issues, interstate disputes are in the forefront as pending United States Supreme Court cases. This talk will discuss existing water laws and policies throughout the continental United States and distinguish between regulation of surface water and groundwater. When people think of water, images of surface water like the Mississippi River come to mind, but a large amount of the water we use on a day-to-day basis is groundwater. The role of states in managing water resources, and especially groundwater, is heating up as consumption and science advance. While states can, and do, work together to share interstate water resources, the Supreme Court of the United States must preside over cases where states disagree. This talk will provide a general overview of water law and the interstate water disputes currently before the Supreme Court, notably Mississippi v. Tennessee. While interstate water disputes are common, Mississippi v. Tennessee is a significant legal case because the Supreme Court has never before decided a state dispute over groundwater. This talk will provide an overview of each state's argument and how interstate water disputes have traditionally been treated by the Supreme Court. In conclusion, the talk will discuss the relevance of pending litigation, as well as thoughts on the future of water law.

Water Law provides the framework that guides our decisions about who gets to use freshwater. Water Law is generally state law - states get to determine their own rules on how to allocate the water within their borders. It is also a system that focuses on use, not conservation. What matters under the law is who is using water for what purpose, and some uses are more protected than others. For instance, domestic uses are more protected than industrial or agricultural uses.

Water Law is also an area of law that is split in a couple of fundamental ways, as surface water and groundwater are governed by two separate sets of legal principles. For groundwater, the rules vary by state under a handful of different legal doctrines. However, surface water has a stark regional difference, with the eastern and western United States following different doctrines. The West has always had water supply issues, and a legal doctrine known as prior appropriation developed to deal with this scarcity. In the prior appropriation system, the state issues water rights to users on a time-based priority basis as certain amounts of each waterway are doled out to individual users. You can think of those users in line with a bucket of water at a stream. Each person gets to fill up their bucket with the amount of water the state has given them, then the next person gets to fill up their bucket, and on and on, until everyone the state has given a right to gets their turn. But, if the stream dries up before your turn, you are out of luck. Your right is completely contingent on whether there is any water left in the stream to use.

In comparison, the East has always been viewed as water rich, and the law recognizes this. Those who live on waterways are considered riparians, and they can use the water abutting their property however they like so long as the use is reasonable and doesn't affect other riparians. This means until there is a problem, there is very little monitoring or control over how much water a riparian owner is using. But, as the eastern United States starts to face water scarcity issues, problems with the riparian system are emerging.

Groundwater has its own set of rules that are distinct from the rules governing surface water use. Here in Mississippi, a lot of the water we use comes from groundwater. However, most water policy has developed around surface water. Surface water is easier to manage - we know how much water there is and when it will run out. It is easy to see overuse because the river or stream runs dry. Since we historically could not see groundwater resources or understand their dynamics, we have allowed them to be used at a rate that exceeds their natural replenishment rate. Add this to the fact that many places have enough groundwater to supply desired uses for long periods of time, which created the illusion that the resource is limitless. But, when we over pump groundwater, there are serious consequences, such as the need for deeper wells to access the water, subsidence, environmental impacts, and saltwater intrusion.

Finally, disputes over interstate water bodies are treated differently under the law. While Water Law is mostly a matter of state law, when two or more states disagree on how to share water resources between them, federal rules apply. Interstate water disputes are common, and sometimes states can negotiate agreements as to how to share water resources that cross state borders. But when states can't reach an agreement among themselves, the disputes can only be resolved by the Supreme Court of the United States (SCOTUS), as the Court has original jurisdiction in all cases in which a state is a party. In suits between states, SCOTUS serves as a trial court and appoints a special master to run a trial-like process. The special master hears the parties' initial motions and evaluates the evidence. The special master then makes findings of fact, conclusions of law, and recommends a decision for the Court. SCOTUS then decides whether or not to follow the special master's recommendation.

Currently, Mississippi and Tennessee are in a dispute concerning groundwater from the Memphis Sands Aquifer, which underlies several states including Mississippi and Tennessee. Mississippi and Tennessee both pump water from this aquifer. The City of Memphis pumps its water very close to the Mississippi-Tennessee border. Mississippi has challenged this use before by suing the City of Memphis for monetary damages. In 2009, the 5th Circuit Court of Appeals dismissed Mississippi's lawsuit ruling that Mississippi had framed its case incorrectly. The court determined that the aquifer was an interstate resource, so Tennessee, which was not named in the suit, was a necessary party. Further, since it was an interstate dispute, original and exclusive jurisdiction belonged to SCOTUS.

The Supreme Court recently agreed to hear Mississippi's case against Tennessee, along with the City of Memphis and the Memphis Light, Gas, and Water Division, regarding the use of the aquifer. The states of Mississippi and Tennessee have very different theories for the case. Tennessee, referring to the previous 5th Circuit decision, is claiming the water is an interstate resource, and thus, the Court needs to determine how much each state is entitled to. However, Mississippi is claiming that Tennessee is actually pumping water from under Mississippi and that this water would never leave Mississippi but for Tennessee's pumping. Like its previous lawsuit, Mississippi is treating the water in the aquifer as Mississippi property, not as an interstate resource, and is asking for damages for the water Tennessee has taken.

Both the state of Tennessee and the Solicitor General asked the Court to not hear the case for a couple of reasons. First, they argued that the case was an interstate dispute, and thus, the groundwater needs to be apportioned by the Court between the two states. Therefore, Mississippi is not entitled to money damages. Second, there is no present injury to Mississippi because there is still enough water in the aquifer for both states to use.

In Mississippi v. Tennessee, the Court has appointed a special master, who is now running the trial-like process. The parties have submitted briefs on initial motions, and oral arguments have yet to be scheduled. A threshold issue will be whether the special master agrees with Tennessee's theory of the case and determines that this should treated as an interstate water dispute or with Mississippi's, which would allow the state to collect monetary damages. Either decision would be groundbreaking law.

If the Court agrees with Tennessee, it would apply the law it has developed in previous interstate disputes. However, the Court has never decided a dispute between two states over groundwater. If the aquifer is determined to be an interstate resource, the Court will consider who has the right to use the water. How would the Court do this? Think about the states being seated at a table, each with a glass, while the Court holds a pitcher of water. The Court then pours out the water telling each state how much they get. But the Court will not simply split the water equally - it takes certain factors into account. While the Court has never ruled on an interstate dispute over groundwater, we can look to previous cases to see what factors SCOTUS has used in the past in determining interstate disputes over water.

The Supreme Court has developed common law to resolve disputes over the allocation and pollution of interstate rivers through the doctrine of equitable apportionment. The Court created the doctrine in 1907 in Kansas v. Colorado, 206 U.S. 46 (1907). Through equitable apportionment, the Court can resolve the rights of disputing states to use an interstate water source, and in making this determination, the Court is not bound by the laws of the individual states.

The Court has stated that equitable apportionment is a flexible doctrine, and it will consider all relevant factors of case, as well as the harms and benefits to each state, so that a just result is reached. The doctrine's basis is that each state is entitled to "equality of right," not equal amounts of water. In previous cases, the Court has given factors that will inform its decision. These factors include:

1. Physical and climatic conditions;
2. Consumptive use of water in the several sections of the river;
3. Character and rate of return flows;
4. Extent of established uses and economies built on them;
5. Availability of storage water;
6. Practical effect of wasteful uses on downstream areas;
7. Damage to upstream areas compared to the benefits to downstream areas if upstream uses are curtailed.

Many of these factors deal with characteristics of surface water, not groundwater. It is therefore difficult to predict precisely how the Court will apply its prior decisions to the *Mississippi v. Tennessee* case. But equity will most likely be a major factor, along with which state needs the water the most now and for what purpose. The Court will also likely consider whether giving the water to that state will hurt the other state too much. Thus, it could be that Memphis taking a lot of water from under northern Mississippi is ok if Memphis needs the water now. It would all depend on what the Court thought was fair.

As stated above, a threshold issue in the case will be whether the court accepts Tennessee's or Mississippi's theory of the case - that is whether the aquifer is an interstate water that needs to be apportioned or whether Mississippi owns the groundwater within its borders and is entitled to monetary damages. In February 2016, Tennessee submitted a motion for a Judgment on the Pleadings, arguing that the case should be terminated since Mississippi has not asked for an apportionment. Once this motion is decided, we will have a better understanding of how the case will or will not proceed.

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Introducing the Mississippi Water Security Institute (MSWSI)

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Through a generous grant from the Robert M. Hearin Foundation, The University of Mississippi Sally McDonnell Barksdale Honors College has established the Mississippi Water Security Institute (MSWSI). MSWSI is developing an intensive two-week workshop on water security issues in the state, which will be offered to a select group of undergraduate students in honors programs in Mississippi. With abundant natural resources and a growing population, Mississippi is an increasingly favorable place to invest, start a business, and raise a family. MSWSI recognizes that with population and economic growth there will be increasing demand on our freshwater resources. The term "water security" refers to challenges inherent in promoting and linking strong business development with community health with natural resource protection. Clearly, this is a challenge requiring communication among multiple fields and interests - the business community, agriculture, law and public policy, urban planning, engineering, and conservation. Reflecting this complex mosaic of water security concerns, the workshop will facilitate interdisciplinary study and problem solving, and include travel, guest speakers, and independent research. Students in the workshop will become knowledgeable in the availability and quality of freshwater resources in Mississippi, learn to assess how these resources can be used wisely in support of business and community development, and environmental stewardship, and work on skills to effectively communicate what we learn to a broad constituency. In this talk, we will present the framework of our first workshop in May, 2016.

Mississippi's Priority Framework

Clark, S.

The Mississippi Department of Environmental Quality (MDEQ) has developed a new collaborative framework for implementing the Clean Water Act. The new framework is designed to help coordinate and focus various efforts to advance the effectiveness of the water program. Given resource constraints and competing program priorities leveraging resources and coordinating efforts is crucial. This new framework does not change regulation, policy or issue new mandates. It is intended to provide focus for MDEQ water programs to better manage the activities and promote collaboration to achieve water quality goals for the streams, rivers, lakes and estuaries of Mississippi.