Assessment of Hydrological, Biological and Environmental Components of the Lower Ogeechee River Ecosystem

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1. Project Title: Assessment of Hydrological, Biological and Environmental Components of the Lower Ogeechee River Ecosystem

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3. Funding Requested: $1,067,491

Total Direct Costs: $1,009,924
F&A (Indirect Costs): $57,566 (15% off-campus rate with exclusions for real property, capital equipment and F&A on subcontracts)

4. Project Start Date and Completion Date: 1 Dec 2013 to 31 Dec 2016

5. Project Location: Lower Ogeechee River; USGS Cataloging Unit 03060202; Counties: Bulloch, Jenkins, Screven

6. Executive Summary

This research proposal is in response to a call for proposals to investigate ecological processes in the Ogeechee River watershed. Research described in the proposal is "basic research" and is meant to provide more than short-term monitoring of chemical loads in the Ogeechee River. In fact, the research is designed to ensure a long-term holistic approach for research conducted on the Ogeechee River. The proposed project consists of two research themes carried out by two distinct teams of researchers. One group from the Department of Geology & Geography at Georgia Southern University (GSU) will focus on atmospheric and terrestrial processes in the watershed while the other, from the Department of Biology at GSU in conjunction with the Southeastern Natural Sciences Academy (SNSA), a 501(c)(3) non-profit research and education center located in Augusta, GA, will focus on the in-stream processes of the Ogeechee River.

The terrestrial (Geology & Geography) portion of the proposed study will involve deployment of multiple suites of field instruments to measure meteorological variables, biogeochemical variables, and geohydrological variables. The objectives of this portion of the research include:

- Installation of long-term forest ecohydrological monitoring infrastructure which will provide information regarding both canopy and root system processes in the forested portion of the Ogeechee River watershed →Proposed outcome: Data sets and analytical products that provide highly detailed information about the partitioning of rainfall in the Ogeechee watershed and information concerning the biological and chemical alterations of rain water as it interacts with vegetation in the watershed
- Installation of equipment to observe meteorological conditions across the Ogeechee River watershed →Proposed outcome: Provide a high temporal resolution data set of

basic hydrometeorological variables including rainfall rates, air temperature, and evaporation, thus allowing for the calculation of local scale indices describing drought, flood, and other disturbance regimes

- Acquisition and analysis of regional scale meteorological and climatological data sets from the National Climatic Data Center (NCDC) and the Southeast Regional Climate Center (SERCC) →Proposed outcome: Calculation of drought indices for the southeast region and the lower coastal plain in particular
- Installation of shallow wells at the Ogeechee river study site to provide information regarding the subsurface flow of water and to allow for chemical analysis of subsurface water on the Ogeechee flood plain →Proposed outcome: Provide accurate estimates of baseflow into the Ogeechee River and provide accurate estimates of chemical composition of sub-surface water entering the Ogeechee River from the flood plain

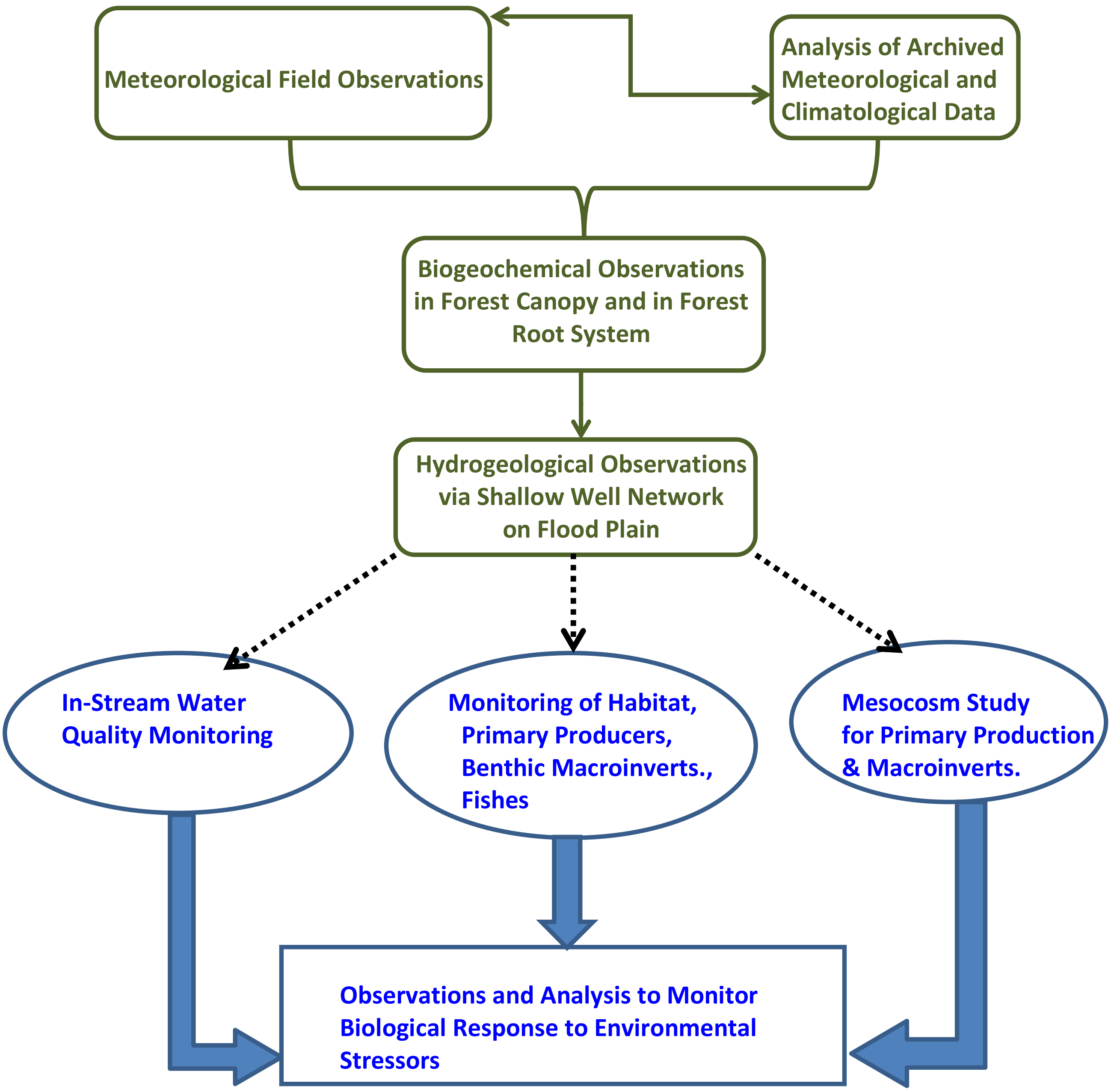
The in-stream (Biology) portion of the study will also involve deployment of field instrumentation for the observation of ecological variables at multiple scales. The primary objectives of this portion of the research are:

- Continuous water quality monitoring via a network of sondes deployed in the Ogeechee river channel →Proposed outcome: Production of a high temporal resolution data set that will provide metrics for determining the Ogeechee River's ability to support a healthy aquatic community
- Chemical monitoring of the watershed to include oxygen demand substances, nutrients, chlorophyll a, along with Algal Growth Potential (AGP) tests →Proposed outcome: Development of a robust tool to allow Ogeechee River Basin stakeholders access to water

quality data and an understanding of potential nutrient enrichment of the Ogeechee watershed.

- Biological monitoring of in-stream and riparian habitat, abundance of primary producers in the stream channel, as well as surveys of benthic macroinvertebrates and fish communities in the Ogeechee River →Proposed outcome: Development and distribution of a broad data archive that will provide stakeholders and scientists with highly refined biological information from which decisions about the health of the Ogeechee river can be based
- Field mesocosm studies in the Ogeechee river channel to address primary production and macroinvertebrate biomass and diversity →Proposed outcome: Accumulation of biological measurements and assessments at scales (cellular, molecular and organismal) not previously observed in the Ogeechee River system. This new data set will allow stakeholders to view the river system and ecosystem health from multiple organismal scales thus allowing better decision making concerning the health of the Ogeechee River
- Monitoring of biological response to environmental stressors, which will monitor the developmental stress on zebrafish embryos, assess water toxicity and determine stress levels using biomarkers →Proposed outcome: Obtain baseline measurements of biomarkers at regular temporal intervals and from these data produce a time-series that will track seasonal changes in both stressors and stress response in the Ogeechee River

The two themes of this proposed research (GEO and BIO) are intimately linked as they both track markers and processes that are important for the ecological health of the river system. The final portion of the proposed study integrates all data collected by project scientists into a geocoded data base and makes data available in a geo-referenced, time-referenced, and variable referenced formats. The use of Geographic Information System software and hardware to build this data archive will allow for high-level scientific analysis by project researchers and ease of access for other stakeholders and decision makers. The workflow diagram below provides a guide for the conduct of the proposed research.



Flow Diagram of work to be conducted in support of this project. **Green** shapes represent the tasks performed by the research team from Geology and Geography at GSU, shapes in Blue are those tasks to be undertaken by the Biology team from GSU.

7. Project Background:

Project Purpose:

This study will take a watershed approach and research will be conducted by Geology & Geography and Biology led teams. The purpose of this study is to establish the effect of natural and anthropogenic loadings, to the Ogeechee River, in an effort to determine the environmental stressors that may be present as a result of changes in system hydrology and water quality and their subsequent effects on ecosystem health. It is anticipated that this information can be used in future water planning and monitoring to enhance regional water planning and to serve as a foundation for future research of the Ogeechee River by Georgia Southern University.

Processes impacting the river system extend well beyond the stream channel (Newson 1994), including those occurring on the floodplain that are of great importance for explaining variations in discharge, chemical and sediment loading of the stream channel. It is in this extended context that we propose to analyze the ecological conditions of the Ogeechee River near Statesboro, Georgia (hereafter referred to as the study area). The overall goal of this portion of the study is to quantify the hydrologic flux and the flux of various chemical elements from atmosphere to forested flood plain to subsurface to stream channel in the context of varying climatic conditions and disturbance. A team of geoscientists will observe, analyze, and model variables related to surface hydrology, forest biogeochemistry, sub-surface hydrogeochemistry, and the climatology of the study area. We will quantify the mass, thermal, and chemical flux from the atmosphere through the forest canopy system to the subsurface hydrological unit. A transect of deep wells from the river to the flood plain of the Ogeechee River will be installed to quantify the mass flux and chemical load in subsurface flow from the forested flood plain to the river channel. We will also determine the multi-scale precursors to drought in the Ogeechee River basin and monitor the local effects of regional scale drought conditions.

The quality and quantity of surficial and groundwater reaching the coastal plain rivers causes many of the rivers in the southeastern United States to be blackwater systems, in which the water is tea-colored due to an abundance of dissolved organic matter from the floodplain. Although these systems can be characterized by relatively low amounts of dissolved oxygen and mild acidity compared to clear water rivers, they still maintain a diversity of organisms, including recreationally and commercially important fisheries, and the species that make up their food webs (Dahlberg and Scott 1971; Benke et al. 1984). These physicochemical characteristics make blackwater systems more sensitive and susceptible to environmental changes. Organisms inhabiting the Ogeechee River have developed coping mechanisms at the physiological and biochemical levels to prevent irreparable damage during periods of naturally reoccurring environmental stress. However, it might be that these coping mechanisms are being exceeded. As an example, due to seasonal changes in climate and river discharge, the extent and duration of periods of warmer, oxygen depleted waters creates an even greater challenge to these aquatic organisms. Added chemicals that rapidly degrade can potentially worsen existing environmental conditions. When one also considers potential exposure to point-source contaminants, the extraction of surface and subsurface waters and the structural alteration of the aquatic network due to deforestation it becomes apparent that the organisms of the Ogeechee River Basin are challenged with both natural and anthropogenic stressors on a regular basis. This exposure to multiple stressors is likely to result in a compounding negative effect on many species, impairing their ability to survive exposure to fluctuations in environmental conditions that would otherwise not be life threatening. A team of biologists will investigate linkages among environmental changes and ecosystem health, by monitoring water quality in the Ogeechee River ecosystem during different flow and temperature regimes (i.e. seasonally). We will also measure primary and secondary producers, fish species composition and water toxicity. Using experimental mesocosm (controlled natural environment) approaches, we will investigate the effects of various environmental conditions, both natural and anthropogenic, on biodiversity and the biochemical and developmental changes induced by these environmental stressors. This approach will allow researchers to identify early warning signals of stress to the aquatic organisms.

Land Acquisition.

Access to study sites along the Ogeechee River is key to completing the research. The acquisition of property as a field laboratory is necessary to conduct the floodplain and mesocosm studies. It would be the university's intention, once land is acquired, to conduct long-term studies on the Ogeechee River using the property as a focal point for field experiments.

Geology & Geography—Biogeochemical Observations and Analysis.

Forest canopies can drastically alter a river's water flow in a variety of ways, including: mitigation of flood frequency and impact (Xiao et al., 1998), control of stream water chemistry (Inamdar et al., 2011) and related in-stream ecological processes (Cummins et al., 1983; Cook et al., 2006), connectivity between the run-off landscape and stream channel (Burt & Pinay, 2005), and even quality of treated drinking water (Beggs & Summers, 2011). These impacts are intimately tied to how forest canopies interact with rainfall (by physically "partitioning" the precipitation) and soil water (through root uptake and transpiration), yet each process has historically been examined independently. To align with objectives contained within regional water plans regarding enhanced surface water resource availability, and to advance our understanding of stream responses to forest ecosystems, these measurements can be coupled to generate a complete hydrologic budget. We propose to install a long-term forest ecohydrological monitoring site (which considers both physical (canopy) and physiological (root) partitioning) on the Ogeechee flood plain to conduct a more holistic study of the natural perturbations and anthropogenic disturbances altering the Ogeechee River system.

When rain falls through the forest canopy, it is physically partitioned into a spatially-diffuse drip input (throughfall), a concentrated input at the base of the tree stem (stemflow), or a stored and evaporated output (interception loss). The portion of rain that reaches the surface (throughfall + stemflow) and contributes to soil water is termed "net precipitation." Prior to entering surface water bodies, storm-based soil water must percolate through the forest rooting zone where the physiological process of water uptake partitions meteoric water fluxes yet again, allowing only a fraction of net precipitation to contribute to streamflow, whereas the majority of net precipitation is returned to the atmosphere through transpiration (Morier et al. 1997, Wang and Yakir 2000, Williams et al. 2004). Questions remain regarding the interdependence of physical and physiological partitioning of meteoric flux through forested watersheds, especially regarding their influence in the dynamic near-stream saturated zones and adjacent hillslopes.

Studies addressing these questions have been performed in other regions of the US but little is known about these processes in the Ogeechee River watershed. As part of this proposed study a site of forest ecohydrological monitoring instruments will be installed in the Ogeechee watershed. Data gathered from this monitoring site will provide detailed understanding of how spatio-temporal variability of net precipitation and transpiration fluxes across the Ogeechee watershed influence subsurface hydrologic flow pathways that ultimately control baseflow and stormflow in the river channel.

The instrumentation for this portion of the proposed study will be deployed at three 50 x 50 meter (m) forest plots situated within the Ogeechee floodplain. Mass flux within the forest canopy on the floodplain will be determined from data provided by stemflow collars, throughfall load cell gauges, canopy and litter interceptometers, soil matric potential blocks, and sap flow sensors. All throughfall and stemflow collectors, soil moisture, and sap flow sensors will be interfaced with Campbell Scientific CR1000 dataloggers and AM16/32B multiplexers. Stemflow collars will capture all water that flows down the tree stem and divert stemflow water into a chemically-inert container which will be continuously weighed and sampled for chemical analyses. Throughfall collectors/monitors will also be placed in each plot and sampled for chemical analysis. Throughfall drip and stemflow water infiltration through the unsaturated zone and into the stream or unconfined groundwater will be monitored with matric potential sensors and sampled using gravity lysimeters.

Interception losses will be estimated using three interception loss models: the modified Liu analytical model (Carlyle-Moses et al., 2010); the revised Gash model (Gash et al., 1995); and the WiMo model (Hörmann et al., 1996), and validated using newly-developed direct canopy water storage monitoring devices (accelerometers) (Selker et al., 2011). These models all rely on meteorological conditions monitored above the canopy, and such measures will be integrated from meteorological monitoring equipment installed on a tower reaching above the canopy. Direct canopy water storage via accelerometer-based interceptometers will be installed across a size gradient of representative trees in the forest stand. Forest floor litter interception and leachate will be monitored with an interception trap (Gerrits et al., 2006) which can be rotated between the sites.

Forest transpiration will be monitored indirectly using thermal dissipation (Granier 1985). A subset of representative trees within each plot will be instrumented with sapflow sensors. Since this is a long-term monitoring effort, sapwood area will be determined from diameter-sapwood area relationships of non-measurement trees. Species-specific calibrations will be applied to measured data to improve accuracy of the estimates (Sun 2011, Steppe 2009). Diameter-sapwood area relationships and leaf area index will be used to scale individual tree transpiration estimates to the forest stand. As transpiration and precipitation partitioning both depend on leaf phenology which is, in turn, tied to meteorological conditions, phenological conditions will be monitored using phenocams affixed to the above-canopy meteorological tower.

Geology & Geography—Subsurface Hydrogeochemical Observations and Analysis.

Surficial groundwater aquifers are natural sources of freshwater to river systems along gaining segments of rivers. This groundwater, called *baseflow discharge*, sustains rivers during times of drought. The chemistry of groundwater baseflow is impacted by forest cover (see section above) and can be quite different from the chemistry of the river water, especially if the bulk of the river's discharge is supplied by precipitation and runoff.

To study the influences of precipitation on local groundwater recharge as well as long-term patterns in the surficial groundwater aquifer, we will install three (3) wells perpendicular to flow of the river. Additionally piezometers will be installed on either side of the transect to determine hydraulic gradient. The well transect will attempt to traverse contrasting vegetation types of the study site. The well transect will be used to investigate how contrasting vegetation types (see Ecohydrology section) impact the nutrient dynamics of the surficial aquifer as well as how those nutrient characteristics change along the groundwater flow path. Long-term monitoring of the groundwater wells for head (water depth) will supply valuable information about the state of the surficial aquifer and how heavy rainfall and drought conditions impact the water table of the aquifer (see Climatology section). These data can be used to make informed decisions about land-use management practices to reduce impacts to 7Q10 low flow conditions. Furthermore, recommendations regarding land-use regimes that optimize groundwater recharge will improve upstream and downstream baseflow to the Ogeechee River, a goal that is aligned with regional water planning.

The three wells will be installed using a drilling rig and will range in depth from approximately 20 to 50 feet. Continuous sampling will be performed during the drilling to determine the hydrostratigraphy (i.e., subsurface geology) along the transect. Completed wells will consist of 3 inch PVC casing with a 5 foot slotted PVC screen along with a standard sand pack, bentonite seal, concrete annular seal and surface pad, and lockable well head. Each well will have a dedicated data logger for measuring hydraulic head and temperature on a continuous basis, whereas water samples will be collected on a monthly basis for the duration of the proposed project. During this monthly sampling, standard water quality parameters including temperature, conductivity, dissolved oxygen, and pH will be measured in each well. In addition to the sampling strategy described above, groundwater samples will also be analyzed at the Hydrogeochemistry Lab at Georgia Southern for general chemistry (Li^{+}, Na^{+}, K^{+}, NH_4^{+}, Mg^{2+}, Ca^{2+}, F^{-}, Cl^{-}, NO_3^{-}, PO_4^{3-}, SO_4^{2-}) using ion chromatography.

In addition to understanding the groundwater flow and nutrient dynamics of the surficial aquifer, we further propose to install a long-term monitoring site at the land-water interface of the Ogeechee River to periodically determine groundwater and nutrient fluxes of baseflow discharge directly from the surficial aquifer to the river. Such data will link nutrient loading of the river (via baseflow) with land-use practices at the study site and will serve to align with regional water planning objectives. The land-water interface will have continuous, high-resolution monitoring of surface and bottom water temperature, as well as water depth using dedicated data loggers. These parameters will supply overall information regarding the state of the river system and its response to precipitation events and drought.

Groundwater fluxes will be determined through measurement of radon dissolved in the groundwater. Radon is a naturally-occurring geochemical tracer that has been widely used in groundwater discharge studies in various geological systems including rivers (see Hoffman et al 2011, for example). Radon is produced by decay of uranium naturally found in aquifer materials. Once radon is produced, it dissolves into groundwater systems and behaves as a chemically inert and radioactive-conservative tracer of groundwater discharge. Radon is released in predictable quantities from the aquifer materials, thereby enriching groundwater relative to river water, making radon an excellent tracer of groundwater discharge to river systems. ^{222}Rn will be measured at the long-term study site using a commercially available radon in air detector (RAD-7) that has been modified to detect radon in water (Lane-Smith et al, 2002). Additional water quality parameters including water temperature, depth, pH, dissolved oxygen, and salinity will be collected periodically at shorter temporal intervals in concert with ^{222}Rn to determine fluxes of groundwater discharge.

River water at the land-water interface will be collected simultaneously with the surficial aquifer samples and analyzed for the same parameters as the surficial aquifer samples. This will allow the identification of temporal similarities and differences in chemistry along the flow path. The results of these measurements will supplement in-stream water quality and biota analysis. If a prominent groundwater discharge zone is discovered in the study site (through use of radon) and can be directly sampled, the samples of the discharging water will also be collected. These nutrient concentrations will be used to calculate Redfield Ratios for the terrestrial ecosystem (Redfield, 1934; Cleveland and Liptzin, 2007) and compared to the nutrient characteristics of riparian vegetation in the study area.

Geology & Geography—Meteorological and Climatological Observations and Analysis.

River systems may respond quite rapidly to changes in the local climatology. In particular fluvial systems respond to changes in rainfall on temporal scales from minutes to seasons. High intensity rainfall concentrated on a portion of a watershed can lead to increased runoff to the river channel and increases in baseflow to the channel, the combination of which can lead to elevated discharge and in extreme cases overbank flooding. In physiographic regions such as the lower coastal plain of Georgia rivers may also respond to precipitation over longer time frames. Season-long rainfall above the climatological mean can result in increased discharge in the stream channel and, if persistent, rainfall events may push the river's flood hydrograph to flood stage for long periods of time.

Conversely, drought may lead to reduced stream flow thus encouraging hydrological and ecological stress for the river system. Very short term absences of rainfall may have little impact on the flow characteristics of a river system such as the Ogeechee River, however longer periods with rainfall deficits will eventually lead to lower discharge in the stream channel. Drought conditions impact a river's flow regime by limiting (or eliminating) runoff to the channel and decreasing the volume of baseflow to the stream. The likelihood of vegetation disturbance from increased fire activity and pest infestation increases during drought conditions and this disturbance regime on the landscape can change the chemical and material load of water entering the stream channel via surface and subsurface flow (Bond et al. 2008; Newson 1994).

It is important to establish the very basic climatic and stream flow parameters for the proposed study of the ecology of the Ogeechee River. To do this will require the installation of one full-scale weather monitoring station in the forest canopy of the research site adjacent to the Ogeechee River. This full-scale weather station will continuously record and archive air temperature, dew point temperature, relative humidity, precipitation, barometric pressure, wind direction, wind speed, and soil moisture. A second limited-observation weather station will be sited in an open (non-forested) section of the study site to record air temperature, dew point temperature, wind speed, wind direction, and precipitation. Data collected from these weather stations will serve other portions of the proposed research including the ecohydrology section of the study and will be used in concert with region weather observations to calculate various drought indices for the Ogeechee River basin. Rainfall data collected at the site along with volume samples (from the hydrogeology section of this proposal) will be utilized along with Unites States Geological Survey (USGS) stream flow observations to calculate hydrographs for the Ogeechee River. The hydrographs will provide quantitative and graphical representations of river flow that will inform stakeholders of the basic climatic and fluvial condition of the study area. Additionally, the observations of stream flow and rainfall at the study site in concert with stream flow and precipitation observations archived regionally will provide researchers with the fundamental data needed to carry out higher-order analyses of ecological, hydrological, biological, and chemical processes in the Ogeechee River watershed. The analysis of stream flow on the Ogeechee River also contributes to regional water planning objectives.

Archived data for the calculation of drought indices include daily, monthly, and annual rainfall and air temperature data for the southeastern United States from the National Climatic Data Center (NCDC) in Asheville, NC and from the Southeast Regional Climate Center (SRCC) in Chapel Hill, NC. Drought indices to be calculated include: The Percent of Normal Index (PNI), The Standardized Precipitation Index (SPI), and the Palmer Drought Severity Index (PDSI). Each of these drought indices can be calculated at various spatial and temporal scales. For this analysis three spatial scales will be incorporated: Region (southeast US); State (Georgia); Watershed (Ogeechee). Time scale calculations will vary with each index. The analysis regional drought conditions also contribute to regional water planning objectives.

In addition to the statistical analysis of point data from the site and from the region, large (synoptic) scale atmospheric composites will be developed to identify the tropospheric circulation patterns that precede and coincide with drought and pluvial conditions over the lower coastal plain of Georgia. Composite data for upper-level tropospheric pressure levels is available from the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) Reanalysis project. This data set will allow for long-term analysis of multiple atmospheric variables and provide the climatic and meteorological context for both real-time and historical drought in the Ogeechee basin (Richard et al. 2001).

Geology & Geography—Geospatial Data Management.

For each data set collected during this proposed project individual data archives will be generated. These single variable archives will be brought together in a manner that will allow both scientific analysis and stakeholder access. The backbone of the both the scientific data sets and the publicly accessible data products will be Geographic Information Science (GIS) and web-based data access (WBDA). The data collected by various sensors deployed across the flood plain and in the Ogeechee stream channel will be geo-referenced and archived by sensor type, time of observation, and location (latitude and longitude). As many of the research scientists require data at very fine temporal scales, the raw data collected at temporal intervals of less than daily will be exclusively available to the research team until the data is quality controlled and properly formatted for publishing peer-reviewed research articles. Once these high temporal resolution data are quality controlled and publications submitted these data will be made freely available to the public. To ensure stakeholders have access to information in a timely manner, the data manager of the proposed study will release daily, weekly, or monthly summaries of all data collected. The data however will be released with the caveat that it is not quality controlled and the users will assume the risk of using such data.

By using GIS technology in building the data archive both scientists and stakeholders will have the luxury of searching and acquiring data from a geo-referenced coordinate system making spatial analysis of the data less daunting. The spatial data base will be developed using ESRI GIS software and Adobe web building and hosting software. The data server will be housed on external drives at Georgia Southern University. The GIS data files created can be used for both spatial/statistical analysis and cartographic purposes and can be utilized at the single point scale or scaled-up to larger domains. GIS in general and the ESRI software in particular is well suited for geographical analysis of watersheds, river systems, point data, and regional data layers (Aspinall and Pearson 2000).

Biology – Physical, Chemical and Biological Monitoring.

To characterize the in-channel water quality and biota of the Ogeechee River Basin, and to provide contextual information, both continuous and monthly monitoring will occur at 6 sites. Each site will consist of a 100-150 m reach (dependent on the wetted width, typically a reach is on average 5x to 7x the wetted width). Sites will be approximately 100m upstream from landings or bridges to avoid impacts on flow and other biases.

Continuous Water Quality Monitoring:

Instantaneous water quality data is important for gauging real time events, allowing for adaptive management actions when needed, and providing baseline information on the status of our water resources. Since all watersheds are in constant flux, continuous monitoring keeps pace with the changes that go on within a river basin (e.g. climate change, urbanization, deforestation, agriculture, wastewater processes, etc.). The compilation of these data into long term data sets are imperative to providing an analysis of trends in order to determine if water quality is increasing or decreasing in response to those changes.

Four continuous monitoring stations, which will provide for the collection of temperature, pH, dissolved oxygen, and conductivity data, will be installed. Each station will be equipped with a Yellow Spring Instruments (YSI) 6820V2 Multi-parameter water quality logger (Fig. 1) and an EcoNet Data Acquisition System (Fig. 2) that will allow for real time access to the water quality data from each site through a website hosted by YSI. These stations will be in conjunction with two stations already established and maintained by GAEPD at Rocky Ford Road and Hwy 301. Once installed, the sonde and data maintenance program will begin.

Figure 1. YSI 6820 multiparameter probe.

Figure 2. Econet Data Acquisition System.

Rivers can be inhospitable environments for water quality instrumentation. Equipment can be taken out by floating trees during flood events, deployment buoys can be used for small arms target practice, and there can be excessive buildup of aquatic vegetation and aquatic insects on the water quality probes. To collect good, reliable, quality data, each site must be visited at a minimum of one time per month. During those visits, data being collected will be verified to see that it is still accurate with secondary handheld instrumentation and the unit will be swapped out with a fresh, recalibrated instrument. This quality control is crucial so that subsequent data analysis can be as accurate as possible. The protocols used are consistent with regulatory protocols, therefore the data collected can be used to calibrate and/or validate regulatory modeling efforts, the primary tools used to assess water quality and water quantity conditions in river basins. In addition, the water quality data will provide insight into the ability of the stream to support a healthy aquatic community.

Site selection will be based upon reconnaissance with the following considerations: basin coverage, accessibility to each site, points of interest (e.g. tributaries, discharges, and biologically sensitive areas), installation options, and equipment safety and security. We will also seek input of permanent site locations through discussions with basin stakeholders during a public education workshop (Table 1). Eight potential locations are shown in Figure 3.

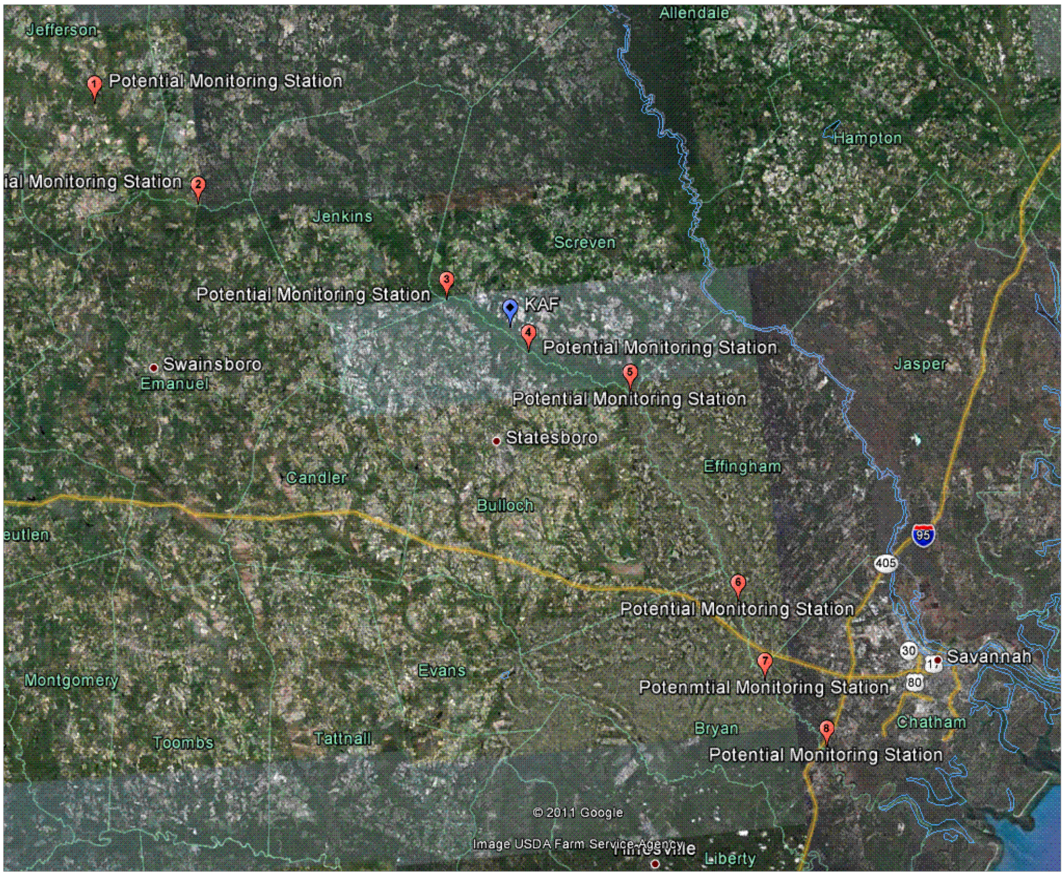


Figure 3. Potential monitoring stations within the Ogeechee River Basin.

Chemical Monitoring:

While continuous data is important, it can serve a much more important role in providing a context or "data backbone" upon which other parameters, which cannot be measured continuously, can be sampled, analyzed, and assessed. In essence, the continuous data connect the discrete sampling events in time and provide an understanding of the conditions of the river at the time the discrete samples are collected.

Each of the six permanent continuous monitoring sites will serve as sampling locations for a suite of discrete chemistry analyses. Water samples will be collected on a **monthly** basis for the following parameters: Total Organic Carbon and Dissolved Organic Carbon (EPA 415.1), Total Kjeldahl Nitrogen (EPA 351.2), Dissolved NH4 (EPA 350.1), Dissolved NO3 and Dissolved NO2 (EPA 353.2), Total and Dissolved Phosphorus (EPA 365.1), 5-day Biochemical Oxygen Demand (EPA 5210 B), water column and periphytometer chlorophyll *a* concentrations (ethanol extraction), and chloride (EPA 105 A). At each site, fecal coliform and *E. coli* concentrations (EPA approved Colilert method) will be analyzed **six times per year (once every other month),** Algal Growth Potential Tests will be performed **quarterly for two years**, and Long Term Biochemical Oxygen Demand (GAEPD protocol) samples will be collected and analyzed **annually**. While samples are being collected from each site, light profiles (LiCor), Secchi depth, and discharge measurements will be taken. Discharge will only be measured if the site is not at a

USGS gauge location and measurements will be made with an Acoustic Doppler Current Profiler.

In addition, concentrations of common ions (Li^+, Na^+, K^+, NH_4^+, Mg^{2+}, Ca^{2+}, F^-, Cl^-, NO_3^-, PO_4^{3-}, SO_4^{2-}) will be analyzed using ion chromatography from replicate water samples collected **quarterly** from the following 6 sampling stations: near Scarborough Landing, Rocky Ford, Lakeview Road Crossing, near Highway 301 crossing, Williams Landing, and Hwy 24 Crossing. These samples will be collected at the same time of the biological samples listed below.

Quarterly Biological Monitoring:
The following assessments will be conducted using a multi-habitat approach:

Habitat - Habitat measurements of wetted width, average depth, % substrate composition, water velocity, discharge, % canopy cover, and length of riparian buffer will be recorded at each of the 6 locations.

Primary producers – Primary producer abundance will be estimated from measurements of algal pigments (chlorophyll a) from artificial substrates and water column samples and will provide insight to the availability of basal resources and the potential for nutrient pollution in the system. Artificial substrates (e.g., unglazed tiles) will be placed in the stream at the beginning of the study period. Each stream reach will include a total of 4 replicate blocks with 4 sample substrates (e.g., tiles) in each block. On each sampling occasion one tile will be removed from each replicate block, placed in labeled bags and returned to the laboratory for sample processing. At the laboratory, all materials will be scrubbed from artificial substrates, rinsed and diluted to a known volume that will be filtered on to a glass fiber filter and analyzed for chlorophyll a using standard methods (APHA 1998). Additional samples from the water column will be taken at each stream segment during sampling occasions and processed as described above to determine primary producer biomass as phytoplankton.

Benthic macroinvertebrates –Consumer community structure and overall function will be estimated from macroinvertebrate samples from stream substrates (organic and inorganic) following the Standard Operating Procedures as described in the Georgia Macroinvertebrate Collection Protocol (GMCP) for wadeable streams. Aquatic invertebrates are commonly used as indicators of biotic integrity in assessments of habitat condition, because they have diverse life cycles (ranging from short to long) and can be sensitive to many stressors (Burton et al. 1999). They are diverse taxonomically and trophically, therefore, they potentially integrate changes in ecosystem health over space and time (Wallace and Webster 1996). Macroinvertebrate samples will be processed to assess community diversity metrics (i.e., richness, evenness, # EPT taxa, etc.), trophic structure (Functional Feeding Groups), tolerance/intolerance (% sensitive taxa, % dominant taxon), and overall system health or condition (GA EPD Multi-metric Index; Index of Biotic Integrity [IBI]; Barbour et al. 1999).

Benthic invertebrates will be collected using D-frame dip nets. At each reach a composite sample will be taken, representative of all reach habitats available for benthic macroinvertebrates (vegetated margins, woody debris with organic matter, and streambed substrates). Each composite sample will consist of a series of scoops/jabs (~20 per site) and the number of scoops will be representative of the proportion of the habitat in each reach. After collection, macroinvertebrates will be stored in labeled plastic bags, preserved in ~10% formalin and transported to the laboratory for sample processing. In the laboratory, macroinvertebrates will be identified to the lowest possible taxonomic level (usually genus for insects and family or order for non-insects), and classified into functional feeding groups (Wallace and Webster 1996; Merritt et al. 2008).

Fish Communities –Fish sampling will be an essential component of the monitoring plan based on the use designation for water bodies in the Ogeechee River. Fish assemblages will be monitored in coordination with Georgia Wildlife Resources Division by use of pulsed direct current electrofishing (backpack electrofisher), seines and dipnets at each stream reach using GA DNR Standard Operating Procedures (GA DNR 2005) for biomonitoring of fish communities. Electrofishing will be conducted by research teams of 3-4 staff members, one controlling the unit while the other 2-3 staff members are responsible for netting the specimens and transporting them to buckets for field identification. Electrofishing runs will be conducted at all wadeable and potential fish habitats with a single pass technique. All specimens will be identified to the species-level in situ; however, voucher specimens may be retained at times for laboratory verification, or museum voucher collections. Sampled assemblages will be analyzed using the Index of Biotic Integrity (IBI; Barbour et al. 1999) and associated metrics (e.g., species composition and richness, trophic composition, fish abundance and condition). Riverine species indicative of high water quality will be established through sampling and comparison to historical collections (Dahlberg and Scott 1971; Swift et al. 1986; Schmitt 1988).

Continuous and long-term data is necessary for understanding and protecting our water resources. In order to continue to understand how the Ogeechee River system functions, SNSA will reach out to stakeholders in the basin in an effort to have them join in supporting this important monitoring network. Starting in the second year of the funding cycle, the SNSA will seek funding opportunities to continue this program.

Biology – Mesocosm Experiment. A series of field (mesocosm) studies will be conducted to address primary production and macroinvertebrate biomass and diversity. Mesocosm studies will allow for assessment beyond the traditional monitoring measurements (i.e., individual and community levels) to more detailed measurements at the organismal level (i.e., cellular and molecular) (Cash et al. 2003, Matthews et al. 2006).

A site will be chosen with relatively secure (from tampering) conditions and a minimum of 16 mesocosm stream channels constructed (allows for 3 factor design with replication). These mesocosms will be constructed as stream-side channels with water pumped through the mesocosms. Level of flow would replicate water movements at river edges and backwaters. We will seed mesocosms with tiles, crayfish, mussels, and snails taken from one of the sampling stations in the river to have the community develop naturally in the mesocosms. The treatment conditions presented sequentially over time would include pulses of low molecular weight compounds (for example, ammonia, formaldehyde) delivered via pumps or drips that upon degradation will likely lower dissolved oxygen levels, alter pH, and serve as potential stressors of biota. Levels of the compounds will not exceed concentrations found elsewhere in the river or significantly increase levels downstream of the mesocosm experiment.

Data obtained from the mesocosms will include measurements of water quality (pH, dissolved oxygen, temperature, and conductivity) and biota (primary producer abundance, macroinvertebrate diversity and density) as well as measurement of biomarkers of environmental stress in fish and macroinvertebrates (see Table 2 for description of biomarkers to be analyzed).

Biology- Biological Responses to Environmental Stressors:

To characterize the water quality of the Ogeechee River system and its effect on organism health, we will monitor developmental stress on zebrafish embryos, assess water toxicity using Microtox analysis and determine the effect of water quality on organism health through using biomarkers of stress.

Toxicity– Sediment and grab water samples taken quarterly at six study sites and from the mesocosms will be measured for toxicity. Toxicity will be determined using the Microtox 500 Analyzer which provides a fast, convenient, reliable and cost effective way to measure toxicity in aquatic systems without using large fish or invertebrates (Johnson 2005). The Microtox can be used for many applications including wastewater influent/effluent sampling, sediment and soil testing, monitoring of remediation processes, monitoring of industrial processed water, drinking water monitoring, and toxicity identification evaluations (Johnson 2005). The test involves exposing a luminescent bacterium, *Vibrio fischeri*, to aqueous samples, and measuring the change in light output by the test organisms under standard conditions (AZUR 1998) using standard procedures (APHA 1998). Difference in light output (between the sample and the control) is attributed to the effect of the toxicant on the organisms (AZUR 1998). The amount of light remaining is used to determine relative toxicity, which can then be compared to the toxicity of a standard reference, such as zinc sulfate (AZUR 1998). As the toxicant concentration increases, bacterial light emissions decrease in a dose-dependent manner (AZUR 1998). This test has also been adapted for testing sediments and will be conducted using methods according to the US EPA Assessment and Remediation of Contaminated Sediments (ARCS) Program.

Zebrafish Studies - Zebrafish embryos are an excellent model species for detecting aquatic environmental stressors because: (1) it is a small freshwater species easily grown and maintained in different environments, (2) it has a short generation time and breeds year round, (3) embryos are transparent and develop rapidly enabling easy monitoring using light microscopy, (4) several genetically modified (transgenic) varieties of zebrafish whose organs fluoresce are available that would allow for direct evaluation of different gene expression, physiology and organ development in live developing embryos, and (5) zebrafish development (e.g., Kimmel 1989; Westerfield 1997) and ecological toxicity data are readily available from several studies (e.g., Dave & Xiu 1991; Ozoh 1979). Zebrafish have been used as a model to test different contaminants such as heavy metals, persistent organic pollutants, endocrine disrupting chemicals etc., (Wu et al., 2009; Berg et al., 2011; Lee et al., 2012). Several of these contaminants have been shown to trigger stress-responses in zebrafish, which have served as a biomarker for monitoring pollution in aquatic environments (Hallare et al. 2005; Hafeli et al., 2001; Wu et al., 2009).

Growth and Sexual Maturity: To determine the potential long-term effect of river water on the development and physiology of Ogeechee River aquatic fauna, we will raise and maintain zebrafish embryos in Ogeechee River water. We will assess the effects of Ogeechee River water by measuring the following two criteria: (1) weight of individual fish grown in different treatment groups and (2) age at which majority of fish from different treatment groups are able to reproduce (lay fertile eggs). Simultaneous growth of embryos in typical laboratory water will be used as a control for this study. We will perform these studies on water samples collected from the six different study sites. Since these experiments will be conducted in laboratory settings, it will be difficult to maintain dissolved oxygen, pH and temperature similar to field conditions. However, we will attempt to collect water samples under different flow regimes. Any adverse changes in the aquatic environment, will directly affect the ability of the fish to grow (body weight) and reach their sexual maturity. We will maintain at least three colonies growing in different treatment groups to account for any skewed sex ratios in a given population. We will set up pairwise mating of fish within each colony to record their reproductive efficiency. If they lay fertile eggs, they will be considered to have reached their sexual maturity. If they fail to produce fertile eggs, they will be rested and mated weekly until they reach sexual maturity. They will be mated at least five times, before they are considered infertile. Further, to understand the genetic and epigenetic impact of Ogeechee River system on aquatic fauna, we will perform a zebrafish embryo development assessment on embryos obtained from Ogeechee River water grown adult zebrafish. This experiment will highlight unknown genetic or epigenetic effect of water pollutants on aquatic fauna.

Early Developmental Stress: Two important systems in the body that are directly affected by pollutants and environmental stressors are the vascular and nervous systems. We will use transgenic zebrafish that express green fluorescent reporter proteins in developing nervous system (*Tg(isl1:gfp)*) and vascular system (*Tg(fli1a:gfp)*) to assess the acute effects of river water quality in their development and function. Water samples will be collected quarterly from the six study sites, and zebrafish embryos will be immediately immersed in 4-5 dilutions of river water and allowed to develop. To prepare dilutions, each water sample will be mixed with laboratory water. Salt concentrations in the water will be adjusted to normal range to prevent defective development due to abnormal variations. Laboratory water will be used as a control for all these studies. At least 20 normally developing embryos will be transferred into each well on 6-well plates. The plates will be incubated at 28.5°C with saturated humidity to avoid evaporation. The embryos will be inspected microscopically at 24, 48, 72 and 96 hours post fertilization (hpf) for lethal and sub-lethal deviations from normal vascular and nervous system.

Laboratory Studies to Determine Tolerance Levels of Organisms to Environmental Stressors: Representative fish and macroinvertebrates collected from upstream sites and transported back to Georgia Southern University where they will be held under conditions that replicate the water conditions (temperature and DO) from the collection site. These organisms will be used in a series of exposure trials (described in Table 1 below) that will investigate the tolerance level of the organism in response to various combinations of environmental stressors.

Table 1: Description of exposure trials that will be used to test the tolerance level to various environmental stressors (CT_{max}, P_{crit} and/or LD_{50}).

Environmental Variable	End Point	Description
↑Temperature	CT_{max}	Temperature at which fish loses equilibrium (loss of consciousness). Oxygen levels maintained by bubbling water with air.
↓DO	P_{crit}	Partial pressure of oxygen at which fish loses equilibrium. Temperature maintained at control levels.
Ammonia	LD_{50}	Dosage which results in the death of 50% of test group
Formaldehyde	LD_{50}	Dosage which results in the death of 50% of test group
THPC	LD_{50}	Dosage which results in the death of 50% of test group
↑Temp + ↓DO	Revised CT_{max} + P_{crit}	Temperature and DO level at which fish loses equilibrium
↑Temp + ↓DO + Ammonia	Revised LD_{50}	Dosage which results in the death of 50% of test group when combined with reduced temperature and oxygen
↑Temp + ↓DO + Formaldehyde	Revised LD_{50}	Dosage which results in the death of 50% of test group when combined with reduced temperature and oxygen
↑Temp + ↓DO + THPC	Revised LD_{50}	Dosage which results in the death of 50% of test group when combined with reduced temperature and oxygen

Active Biomonitoring Approach (Fish Transplantation Study): The transplantation of a group of hatchery raised fish (individuals raised under controlled, non-impacted conditions) to various sites along the Ogeechee River will allow for *in situ* analysis of the effect of varying water quality on organismal health. Following the fish transplantation methodology described in Oikari 2006 and Ji et al. 2010, hatchery raised juvenile bluegill (*Lepomis macrochirus*) will be obtained and held at Georgia Southern University for at least two weeks prior to transplantation to evaluate fish health. Fish will then be transferred from the laboratory in to the Ogeechee River at the six study sites (three upstream from KAF and three downstream from KAF). Fish will be placed in groups of 20 into fully enclosed cages (0.7 m wide x 1.5 m high) that will be suspended in the water column about 20 cm below the water surface and secured in place. These fish cages will be placed adjacent to the water chemistry biomonitoring sites allowing for simultaneous collection of physic-chemical water quality (temperature, DO, pH and conductivity) as well as chemical analysis from the bottom sediment. 5 fish will be sampled from each cage at 7, 14, 21 and 28 days post deployment. Upon sampling tissues will immediately be dissected from fish on site, flash frozen in liquid nitrogen to preserve biological integrity and transported back to

Georgia Southern in a frozen state. Samples will be stored at -80°C until analysis of common biomarkers of stress in aquatic organisms (Livingstone 2001) (Table 2). Additionally, levels of biomarkers of stress will be measured in 5 non-transplanted hatchery raised bluegill collected from the holding tanks at Georgia Southern in order to correct for any stress induced by the transplantation procedure. The use of antioxidant defense mechanisms and sites of oxidative damage (Table 2) as biomarkers of stress has become a common approach when investigating the impact of environmental change on aquatic organisms. Exposure to stressors (both natural and anthropogenic) has been shown to increase levels of oxidative damage, which is often associated with impaired cellular or higher biological function (Livingstone 2001).

Table 2. List of biomarkers of environmental stress that will be measured in organisms sampled from the Ogeechee River.

Biomarker	Description
EROD	Ethoxyresorufin-O-deethylase (EROD) activity is a well established and sensitive biomarker that can be used as an early indicator of chemical exposure. Elevated levels would indicate an individual that is experiencing environmental stress.
GSH	Reduced glutathione (GSH) is involved in processes essential for the synthesis and degradation of proteins, formation of DNA, regulation of enzymes, and protection of cells against antioxidants. Elevated GSH levels would indicate an individual that is experiencing environmental stress
CAT	Catalase (CAT) is a key antioxidant enzyme that is responsible for preventing oxidative damage to lipids (which are a key component of healthy cell membranes). Elevated CAT levels would indicate an organism that is experiencing environmental stress
MDA	Malondialdehyde (MDA) is an endproduct formed as a result of oxidative damage to lipids. It is a sensitive diagnostic index of oxidative injury to cells and is an indicator that the organism's coping mechanisms to environmental stress (antioxidant defenses such as GSH and CAT) have begun to fail.
DNA Damage	Oxidative damage can cause fragmentation of DNA, and mismatched repair. Appearance of DNA damage is also evidence that the organism's coping mechanisms to environmental stress have begun to fail.

Community outreach, and education

The community outreach and education will incorporate local media outlet publicity, annual public education workshops, annual funding of Adopt-A-Stream test kits through the local Ogeechee Riverkeeper and development of an annual report. Throughout the planning and implementation process, SNSA, in conjunction with GSU, will develop publicity through local media outlets throughout the year. The first will be an announcement of the program after execution of the contract. Soon thereafter, a public education workshop will be developed to present the details of the monitoring, research, and outreach program. Once all the continuous monitoring sites are online, the local media will be contacted to reveal the online data stream and direct traffic to the web portal.

Ogeechee River research progress and results will be presented at GSU beginning Spring 2015 in conjunction with “Research Week” activities. These presentations will be open to the public.

Involving citizen scientists is one of the best ways to get people interested in their watersheds; the Adopt-A-Stream program has been doing that for 30 years. In order to involved local stakeholders, basic test kits used in the Ogeechee River Adopt-A-Stream program will be funded for three years. The funds to cover the costs of the test kits for 22 Adopt-A-Stream sites within the Ogeechee River Basin will be administered through the Ogeechee Riverkeeper.

As part of the overall program, an annual report on data results from the monitoring program will be developed that included the research findings, research highlights from student research projects, Adopt-A-Stream results, and a summary of the community and education outreach elements. GSU along with SNSA will publicly announce the release of the annual report and will hold an annual public education workshop a few weeks after the report has been released.

While there are many stakeholders that will use the instantaneous and long-term datasets, local, state, and federal regulators will benefit from river monitoring programs as well. For example, drought is most likely an issue that will be long-lived within southeastern river systems, so decisions as to “how much water the river needs” and “how does NPDES function with extreme low flows” must be answered in order to balance economic vitality and a healthy river ecosystem. Water quality and water quantity data will be essential to intelligently and equitably answering those questions.

8. Deliverables:

Geology & Geography Deliverables:

1. *(Deliverable at Project end date)* Data base with www access including: Long-term (36 month) observations of:
   a. Multiple components of forest hydrometeorological inputs to the forested ecosystem on the Ogeechee River flood plain
   b. Biogeochemical flux from flood plain forest to soil and subsurface
   c. Subsurface geochemical flux across flood plain gradient (from well transect)
   d. Subsurface discharge volume and chemical load to the Ogeechee River channel
   e. Phenological variables from vegetation on the Ogeechee River flood plain
   f. Surface meteorological analysis of rainfall and temperature variability on the Ogeechee River flood plain

2. *(Deliverable at Project end date)* Geospatial data base and cartographic products including:
   a. Multi-scale (region, state, drainage basin) drought analysis including statistical analysis of drought and the calculation of multiple drought indices
   b. Atmospheric circulation composites related to drought
   c. Maps, transects, time-series and spatial analyses of combined data sets collected by researchers during this 36-month study
   d. Submit final Data Organization Matrix

3. *(Deliverable at monthly intervals)* Monthly progress reports, annual summary reports, and a final close-out report detailing the biogeochemical, hyrogeochemical, and climatological research activities at the study site.

4. *(Deliverable post Project end date)* A minimum of four peer reviewed publications stemming from on-site data collection and analysis of biogeochemical, hyrogeochemical, and climatological parameters in the Ogeechee River ecosystem

5. *(Deliverable post Project end date)* A minimum of four conference presentations including data, analysis and synthesis of research conducted in the Ogeechee ecosystem and implications of analysis findings for ecosystem health

Biology Deliverables:

Summary: To achieve a complete assessment of aquatic system health, assessments and tests at several levels of biological organization will be conducted to ensure a full description of both short and long term effects on aquatic ecosystems.

1. A project website will be hosted and maintained through Georgia Southern University's Biology Department. The website will be developed to provide project information (project description, sample station monitoring data (pH, temp, oxygen, conductivity), staff, activities, and project updates). Our intention is to provide data to inform management of the river. (Website running by Jan. 31st, 2014; website content updated quarterly until project end date).

2. Development of algal, macroinvertebrate and ichthyofauna metrics for the assessment of streams in the Ogeechee River Basin and associated sub-watersheds. Development of intensive assessments (i.e., cellular to ecosystem level responses) in combination with traditional rapid assessment tools to provide an integrated approach to help establish criteria for the evaluation of freshwater ecosystems. This particular goal coincides with EPA's 2011-2015 Strategic Plan's Goal #2 (Protect America's Waters), Objective 2.1 (Protect Human Health – by reducing exposure to contaminants in drinking water, fish and shellfish, and recreational waters, including protecting source waters), Objective 2.2 (Protect and Restore Watersheds and Aquatic Ecosystems – by enhancing the quality of rivers, lakes, streams, and wetlands on a watershed basis, and protect urban, coastal, and ocean waters). Submit final Data Organization Matrix. (By project end date).

3. Monthly progress reports and final close-out reports, four graduate thesis documents, four manuscripts submitted to peer-review journals, and a minimum of two to three presentations in professional meetings locally, regionally and nationally (in year 2 and 3 of the study.) Published papers and presentation abstracts will be made available to any interested party. Monthly progress reports will be due by the last day of the month, manuscripts will be prepared by the project end date, presentations will be prepared by occurrence, published papers will be provided within one month of publication in either electronic or print format.

4. Participating university scientists will develop curricular materials based on the Ogeechee River Research for their respective courses, for example in Animal Physiology, Aquatic Ecology, Developmental Biology, Toxicology, and Ichthyology.

9. Timelines:

Geology & Geography Schedule of Work and Timeline

The research schedule below is divided into seasons that are three months in duration. The proposed project will last for 36 months and thus there are 12 total temporal analysis units accounted for in this schedule. The seasons are partitioned as follows: Winter (January-February-March), Spring (April-May-June), Summer (July-August-September), Fall (October-November-December). Season one is projected to be winter season 2014. The research teams will be identified as Biogeochemistry (B), Subsurface Hydrogeochemistry (H), and Climate (C). Detail of the field equipment installation including well drilling is addressed in the sections above. Details method used for data collection and analysis are also detailed in the above sections.

Season	Task	Research Team
February 2014	Begin purchase field equipment; Begin well installations; Begin installation of meteorological station; Begin construction of forest ecohydrology sites; Begin development of geo-spatial data archive hardware, software, and protocols	B, H, C
June 2014	Continue with all installation activities; Begin data collection from well transect; Begin archiving meteorological data; Begin data collection per rainfall episode from forest ecohydrology suite of instruments	B, H
August 2014	Continue with subsurface sampling (from well transect); Continue data collection per rainfall episode from forest ecohydrology suite of instruments	B, H
November 2014	Continue with subsurface sampling (from well transect); Continue data collection per rainfall episode from forest ecohydrology suite of instruments; Begin phenological observations; Begin chemical analysis of 2014 data from ecohydrology and subsurface hydrogeochemical sampling; Begin data collection for drought analysis; Release the first annual geo-spatial data set by way of GIS server and searchable data archive	B, H, C
February 2015	Continue with subsurface sampling (from well transect); Continue data collection per rainfall episode from forest ecohydrology suite of instruments; Continue phenological observations; Continue chemical analysis of 2015 data from ecohydrology and subsurface hydrogeochemical sampling; Continue data collection for drought analysis; Continue calculation of drought indices and atmospheric composites; Complete annual report; Begin manuscript preparation and development of conference presentations	B, H, C
June 2015	Continue with subsurface sampling (from well transect); Continue data collection per rainfall episode from forest ecohydrology suite of instruments; Continue chemical analysis of 2015 data from ecohydrology and subsurface hydrogeochemical sampling; Continue data collection for drought analysis; Begin calculation of drought indices and atmospheric composites	B, H, C
November 2015	Continue with subsurface sampling (from well transect); Continue data collection per rainfall episode from forest ecohydrology suite of instruments; Continue chemical	B, H

	analysis of 2015 data from ecohydrology and subsurface hydrogeochemical sampling;	
April 2016	Continue with subsurface sampling (from well transect); Continue data collection per rainfall episode from forest ecohydrology suite of instruments; Continue phenological observations; Continue chemical analysis of 2016 data from ecohydrology and subsurface hydrogeochemical sampling; Release the second annual geo-spatial data set by way of GIS server and searchable data archive	B, H
August 2016	Continue with subsurface sampling (from well transect); Continue data collection per rainfall episode from forest ecohydrology suite of instruments; Continue phenological observations; Continue chemical analysis of 2016 data from ecohydrology and subsurface hydrogeochemical sampling; Continue data collection for drought analysis; Continue calculation of drought indices and atmospheric composites; Complete annual report; Continue manuscript preparation and development of conference presentations	B, H, C
October 2016	Continue with subsurface sampling (from well transect); Continue data collection per rainfall episode from forest ecohydrology suite of instruments; Continue chemical analysis of 2016 data from ecohydrology and subsurface hydrogeochemical sampling; Continue data collection for drought analysis; Continue calculation of drought indices and atmospheric composites	B, H
November 2016	Continue with subsurface sampling (from well transect); Continue data collection per rainfall episode from forest ecohydrology suite of instruments; Continue chemical analysis of 2016 data from ecohydrology and subsurface hydrogeochemical sampling;	B, H
December 2016	Submit final Data Organization Matrix. of Final Reports; Preparation of peer-reviewed manuscripts for submission; Preparation of conference presentations; Finalize and distribute data sets to interested parties. Prepare final geo-spatial products for release via www; Close project	B, H, C

Biology Schedule of Work and Timeline Please note the project ends Dec 31, 2016

MILESTONE	STARTING DATES	COMPLETION DATES
Execute contract between GSU and King Finishing America. Execute subcontract between GSU and SNSA.	DEC/2013	JAN/2014
Recruitment of graduate assistants (needs to occur before grant start date)	SPRING/2014	SUMMER/2014
Lab monitoring of levels of stress on organisms	JUL/2014	AUG/2016
Recruitment and hire of undergraduate student assistants;	AUG/2014	SEPT/2016

Submit Monthly Reports to King Finishing America for transmittal to the EPD	MAR/2014	DEC/2016
Project website design, development and launch	MAR/2014	DEC/2014
Physiochemical (temp, pH, DO) (continuous and monthly) and biological (seasonal, 4 times/yr) monitoring at selected sites	JUN/2014	DEC/2016
Active biomonitoring of stress levels of fishes	JUN/2014	JAN/2016
Mesocosm site selection finalized and construction completed including initial sample processing, and preliminary analyses to test for among mesocosm differences	MAY/2015	OCT/2016
Preparation of conference proceedings; 2-3 oral and/or poster presentations annually in years 2 and 3	MAR/2015	DEC/2016
Submit final Data Organization Matrix. Submit final project close-out report to the GAEPD; End of fiscal year	DEC 1, 2016	DEC 31, 2016

10. Project Personnel:

Geology and Geography Team

Doug P. Aubrey, Ph.D., University of Georgia, 2012, Assistant Professor; Plant Physiology, Biogeochemistry, Physiological Ecology

Jacque L. Kelly, Ph.D., University of Hawaii-Manoa, 2012, Assistant Professor; Geochemistry, Subsurface Hydrology, Remote Sensing

James S. Reichard, Ph.D., Purdue University, 1995, Associate Professor; Hydrogeology, Field Methods, Geochemistry

Dr. Wei Tu, Ph.D., Texas A&M, 2002, Associate Professor; Geographic Information Science, Spatial Statistics, Spatial Database Management

S. Jeffrey Underwood, Ph.D., University of Georgia, 1999, Professor; Climatology, Hydrometeorology, Satellite Meteorology

John T. Van Stan, Ph.D., University of Delaware, 2012, Assistant Professor; Ecohydrology, Forest Biogeochemistry, Instrumentation Development

Biology Team

Risa Cohen, Ph.D., University of California, Los Angeles; Associate Professor Dept. of Biology; Aquatic Ecology; Toxicology

Jose C. Colon-Gaud, Ph.D., Southern Illinois University; Assistant Professor Dept. of Biology; Aquatic Ecology; Invertebrate Ecology

Oscar Flite, Ph.D., Clemson University; Vice President for Research, Southeastern Natural Sciences Academy; Biogeochemical Processes and Bioremediation

Johanne Lewis, Ph.D., Memorial University of Newfoundland; Assistant Professor Dept. of Biology; Physiology; Environmental Stressors

Vinoth Sittaramane, Ph.D., University of Missouri, Columbia; Assistant Professor Dept. of Biology; Developmental Biology; Environmental Stressors

Stephen Vives, Ph.D., University of Wisconsin, Madison; Professor Dept. of Biology; Aquatic Ecology; Ichthyology

11. Literature Cited:

APHA. 1998. American Public Health Association. Standard Methods for the Examination of Water and Wastewater. (20th ed.), Washington D.C., (Part 8050 B).

Aspinall, R. and Pearson, D., 2000. Integrated geographical assessment of environmental condition in water catchments: Linking landscape ecology, environmental modeling and GIS, *Journal of Environmental Management*, 59: 299-319.

AZUR, 1998. Microtox Acute Toxicity Test protocol.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Beggs & Summers, 2011. Character and chlorine reactivity of dissolved organic matter from a mountain pine beetle impacted watershed. *Environmental Science & Technology*, 45: 5717-5724

Berg, V., J.L. Lyche, C. Karlsson, B. Stavik, R. Nourizadeh-Lillabadi, N. Hardnes, J. Utne Skaare, P. Alestorm, E. Lie and E. Ropstad. 2011. Accumulation and effects of natural mixtures of persistent organic pollutants (POP) in zebrafish after two generations of exposure. J. of Toxicology and Environmental Health, Part A. 74: 407-423.

Benke, A.C. and Meyer, J.L. 1988. Structure and function of a blackwater river in the southeastern U.S.A. Verh. Internat. Verein. Limnol. 23:1209-1218.

Benke, A.C., T.C. Van Arsdall, Jr., D.M. Gillespie, and F.K. Parrish. 1984. Invertebrate productivity in a subtropical blackwater river: the importance of habitat and life history. Ecol. Monogr. 54: 25-63.

Bond, N.R., Lake, P.S., and Athington, A.H., 2008. The impacts of drought on freshwater ecosystems: and Australian perspective, *Hydrobioligia*, 600: 3-16.

Burt & Pinay, 2005. Linking hydrology and biogeochemistry in complex landscapes. Progress in Physical Geography, 29: 297-316.

Burton, T. M., D. G. Uzarski, J. P. Gathman, J. A. Genet, B. E. Keas, and C. A. Stricker 1999. Development of a preliminary invertebrate index of biotic integrity for Lake Huron coastal wetlands. Wetlands 19: 869-882.

Carlyle-Moses et al., 2010. Modelling rainfall interception loss in forest restoration trials in Panama. Ecohydrology, 3: 272-283.

Cash, K.J., J.M. Culp, M.G. Dubé, R.B. Lowell, N.E. Glozier, and R.B. Brua. 2003. Integrating mesocosm experiments with field and laboratory studies to generate Weight-of-Evidence risk assessments for ecosystem health. Aq. Ecosystem Health & Mgmt. 6:177-183.

Cleveland and Liptzin, 2007. C:N:P stoichiometry in soil: is there a ‘‘Redfield ratio’’ for the microbial biomass?. Biogeochemistry 85: 235-252.

Cook et al., 2006. How do temperature, dissolved organic matter and nutrients influence the response of Leptodiaptomis ashlandi to UV radiation in a subalpine lake? Freshwater Biology, 51: 1827-1837.

Cummins et al., 1983. Organic matter budgets for stream ecosystems: problems in their evaluation. In: Stream Ecology (Eds. JR Barnes & GW Minshall). Plenum Press, New York, 299-353.

Dahlberg, M.D. and D.C. Scott. 1971. The freshwater fishes of Georgia. Bull. Ga. Acad. Sci. 29:1-64.

Dave, G. and R.Q. Xiu. 1991. Toxicity of mercury, copper, nickel, lead and cobalt to embryos and larvae of zebrafish, *Brachydanio rerio*. Arch. Envrion. Contam. Toxicol. 21: 126-34.

Edwards, R.T. and J.L. Meyer. 1987. Metabolism of a sub-tropical low gradient blackwater river. Freshwater Biology 17: 251-283.

Gash et al., 1995. Estimating sparse forest rainfall interception with an analytical model. Journal of Hydrology, 170: 79-86.

GA DNR. 2005. Georgia Department of Natural Resources; Standard operating procedures for conducting biomonitoring on fish communities in wadeable streams in Georgia.

Georgia EPD 2007. Standard operating procedures for macroinvertebrate biological assessment of wadeable streams in Georgia.

Gerrits et al., 2006. Measuring forest floor interception in a beech forest in Luxembourg. Hydrology and Earth System Sciences Discussions, 3: 2323-2341.

Granier, A. 1987. Evaluation of transpiration in a Douglas-fir stand by means of sap flow measurements. Tree Physiology, 3: 309-319.

Hafeli, N., P. Schwartz and P. Burkhardt-Holm. 2011. Embryotoxic and genotoxic potential of sewage system biofilm and river sediment in the catchment area of a sewage treatment plant in Switzerland. Ecotoxicity and Environmental Safety 74: 1271-1279.

Hallare, A.V., R. Pagulayan, N. Lacdan, H.R. Kohler, R. Triebskorn. 2005. Assessing water quality in a tropical lake using biomarkers in zebrafish embryos: developmental toxicity and stress protein responses. Environmental Monitoring and Assessment 104: 171-187.

Hofmann et al., 2011. A novel method using a silicone diffusion membrane for continuous 222Rn measurements for quantification of groundwater discharge to streams and rivers. Environmental Science and Technology, 45: 8915-8921.

Hörmann et al., 1996. Calculation and simulation of wind controlled canopy interception of a beech forest in northern Germany. Agricultural and Forest Meteorology, 79: 131-148.

Inamdar et al., 2011. Storm-event patterns and sources of dissolved organic matter (DOM) for stream runoff in a forested mid-Atlantic watershed. Journal of Geophysical Research-Biogeosciences.

Ji, Y., G. Lu, C. Wang, W. Song and H. Wu. 2010. Fish transplantation and stress-related biomarkers as useful tools for assessing water quality. J. Exp. Sci.. 22: 1826-1832.

Johnson, B. T. 2005. Microtox acute toxicity test. In: Blaise C. and Ferard J.-F. eds. Small-scale Freshwater Toxicity Investigations, Vol. 1, 69-105. Springer.

Kimmel CB. 1989. Genetics and early development of zebrafish. Trends in Genetics 5: 283-288.

Lane-Smith et al., 2002. Continuous Radon-222 measurements in the coastal zone. Sea Technology, 43: 37-45.

Lee, O., A. Takesono, M. Tada, C.R. Tyler and T. Kudoh. 2012. Biosensor zebrafish provide new insights into potential health effects of environmental estrogens. Environmental Health Perspectives. 120: 990-996 .

Livingstone, D.R. 2001. Contaminant-stimulated reactive oxygen species production and oxidative damage in aquatic organisms. Marine Pollution Bulletin 42: 656-666.

Matthews, W.J., K.B. Gido, G.P. Garrett, F.P. Gelwick, J. Stewart, J. Schaefer. 2006. Modular experimental riffle-pool stream system. Trans. Am. Fish. Soc. 135: 1559-1566.

Merritt, R.W., K.W. Cummins, M.B. Berg 2008. An Introduction to the Aquatic Insects of North America. 4th Edition. Kendall/Hunt Publishing. Dubuque, Iowa.

Meyer, J.L. 1986. Dissolved organic carbon dynamics in two subtropical blackwater rivers. Arch. Hydrobiol. 108: 119-134.

Meyer, J.L. 1990. A blackwater perspective on riverine ecosystems. BioScience 40: 643-651.

Moreira et al. 1997. Contribution of transpiration to forest ambient vapor based on isotopic measurements. Global Change Biology, 3: 439–450.

Newson, M.D. 1994. Hydrology and the river environment. Clarendon Press.

Niemi, G., D. Wardrop, R. Brooks, S. Anderson, V. Brady, H. Paerl, C. Rakocinski, M. Brouwer, B. Levinson, and M. McDonald. 2004. Rationale for a new generation of indicators for coastal waters. Env. Health Persp. 112: 979-986.

Oikari, A. 2006. Caging techniques for field exposures of fish to chemical contaminants. Aq. Toxicology 78: 370-381.

Ozoh, P.T.E. 1979. Malformations and inhibitory tendencies induced to *Brachydanio rerio* (Hamilton-Buchanan) eggs and larvae due to exposures in low concentrations of lead and copper ions. Bull. Environ. Contam .Toxicol. 21: 668-75.

Redfield, 1934. On the proportions of organic derivations in sea water and their relation to the composition of plankton. James Johnstone Memorial Volume, University Press of Liverpool: 177-192.

Richard, Y., Fauchereau, N., Poccard, I., Rouault, M., and Trzaska, S., 2001. 20th Century drought in southern Africa: Spatial and temporal variability, teleconnections with oceanic and atmospheric conditions, International Journal of Climatology, 21: 873-885.

Schmitt, D.N. 1988. A fisheries survey of the Ogeechee River. DNR Report, Project F-30-15: 1-65.

Selker et al., 2011. The answer is blowing in the wind: using wind induced resonance of trees to measure time varying canopy mass, including interception. American Geophysical Union, Fall Meeting, presentation #HG11G-1155.

Smock, L.A. and E. Gilinsky. 1992. Coastal plain blackwater streams. pp. 271-313 in C.T. Hackney, S. M. Adams and W.H. Martin (eds.), Biodiversity of the southeastern United States. Joyn Wiley & Sons, Inc.

Steppe et al. 2010. A comparison of sap flux density using thermal dissipation, heat pulse velocity and heat field deformation methods. Agricultural and Forest Meteorology, 150: 1046-1056.

Sun et al. 2012. A simple calibration improved the accuracy of the thermal dissipation technique for sap flow measurements in juvenile trees of six species. Trees - Structure and Function, 26: 631-640.

Sutton, K.T. and R.A. Cohen. 2012. APG-containing product reduces dissolved oxygen in freshwater pond mesocosms: implications for benthic macroinvertebrate abundance. Fundam. Appl. Limnol. 180: 291-298.

Swift, C.C., C.R. Gilbert, S. A. Bortone, G. H. Burgess & R. W. Yerger. 1986. Zoogeography of the freshwater fishes of the southeastern United States: Savannah River to Lake Pontchartrain. pp. 213-265 in C.H. Hocutt and E.O. Wiley (eds.), The zoogeography of North American Freshwater Fishes. John Wiley & Sons, Inc.

Triebskorn, R., J. Böhmer, T. Braunbeck, W. Honnon, H. Köhler, R. Lehmann, A. Oberemm, J. Schwaiger, H. Segner, G. Schüürmann, and W. Traunspurger. 2001. The project VALIMAR (VALIdation of bioMARkers for the assessment of small stream pollution): objectives, experimental design, summary of results, and recommendations for the application of biomarkers in risk assessment. J. Aq. Ecosys. Stress and Recovery 8:161-178.

Vitvar et al., 2002. Estimation of baseflow residence times in watersheds from the runoff hydrograph recession: method and application in the Neversink watershed, Catskill Mountains, New York. Hydrological Processes, 16: 1871-1877.

Wallace, J. B. and J. R. Webster. 1996. The role of macroinvertebrates in stream ecosystem function. Annual Review of Entomology 41: 115-139.

Wang X-F, Yakir D. 2000. Using stable isotopes of water in evapotranspiration studies. Hydrological Processes, 14: 1407–1421.

Westerfield, M., E. Doerry, A.E. Kirkpatrick, W. Driever and S.A. Douglas. 1997. An online database for zebrafish development and genetics research. Seminars in Cell Developmental Biology 8: 477-88.

Williams et al. 2004. Evapotranspiration components determined by stable isotope, sap fl ow and eddy covariance techniques. Agricultural and Forest Meteorology, 125: 241–258.

Wu. L, L. Chen, J. Hou, Y. Zhang, J. Zhao and H. Gao. 2009. Assessment of sediment quality of Yangtze River Estuary using zebrafish (*Danio rerio*) embryos. Environmental Toxicology 25: 234-242.

Xiao et al., 1998. Rainfall interception by Sacramento's urban forest. Journal of Arboriculture, 24: 235-244.

12. Cost Estimates and Justifications

Land Acquisition

A total of $200,000 has been set aside for the acquisition of the land discussed in Section 8 of this proposal

Composite Cost Estimate

The cost estimate for the land acquisition and the biology and geology and geography components of the proposed effort can be found on page 34. A schedule of projected monthly expenditures is included on page 39.

GEORGIA SOUTHERN UNIVERSITY
COMPREHENSIVE PROPOSAL BUDGET

FOA: EPD Combined
Due:
Routing Due to ORSSP by

A.	**SENIOR PERSONNEL**	ACAD/SUM	AMOUNT	PERCENT EFFORT						
				CAL	ACAD	SUMR	**YEAR 1**	**YEAR 2**	**YEAR 3**	**Total**
1	Risa Cohen	Academic Yr.	$ 61,472	0%	0%		$ -	$ -	$ -	$ -
	1 month summer	Summer	$ -			11%	$ 6,762	$ 6,762		$ 13,524
2	Jose C. Colon-Gaud	Academic Yr.	$ 57,060	0%	0%		$ -	$ -	$ -	$ -
	1 month summer	Summer	$ 19,001			11%	$ 6,277	$ 6,277		$ 12,554
3	Johanne Lewis	Academic Yr.	$ 57,060	0%	0%		$ -	$ -	$ -	$ -
	1 month summer	Summer	$ 19,001			11%	$ 6,277	$ 6,277		$ 12,554
4	Vinoth Sittaramane	Academic Yr.	$ 58,000	0%	0%		$ -	$ -	$ -	$ -
	1 month summer	Summer	$ 19,314			11%	$ 6,380	$ 6,380		$ 12,760
5	James Reichard	Academic Yr.	$ 63,491	0%	0%		$ -	$ -	$ -	$ -
	1 mo summer	Summer	$ -			11%	$ 7,048	$ 7,048	$ -	$ 14,096
6	Jacque Kelly	Academic Yr.	$ 59,000	0%	0%		$ -	$ -	$ -	$ -
	1 mo summer	Summer	$ 19,647			11%	$ 6,549	$ 6,549		$ 13,098
7	Wei Tu	Academic Yr.	$ 58,608	0%	0%		$ -	$ -	$ -	$ -
	1 mo summer	Summer	$ 19,516			11%	$ 6,505	$ 6,505		$ 13,010
8	John Van Stan	Academic Yr.	$ 59,000	0%	0%		$ -	$ -	$ -	$ -
	1 mo summer	Summer	$ 19,647			11%	$ 6,549	$ 6,549		$ 13,098
9	Doug Aubrey	Academic Yr.	$ 57,000	0%	0%		$ -	$ -	$ -	$ -
	1 mo summer	Summer	$ 18,981			11%	$ 6,327	$ 6,327		$ 12,654
				Sum Senior Personnel:			**$ 58,673**	**$ 58,674**	**$ -**	**$ 117,347**
B.	**OTHER PERSONNEL**		AMOUNT	PERCENT EFFORT						
				CAL	ACAD	SUMR				
10	Post Doctoral Associates		$ -	0%	100%		$ -	$ -	$ -	$ -
11	Graduate Students	Biology	$ -				$ 30,000	$ 60,000	$ 30,000	$ 120,000
12	Undergraduate Students	Biology	$ -				$ 3,807	$ 7,613	$ 3,806	$ 15,226
13	Other		$ -				$ -	$ -	$ -	$ -
14	Other		$ -				$ -	$ -	$ -	$ -
15	Other		$ -				$ -	$ -	$ -	$ -
16	Undergraduate Students	Geology & Ge	$ -				$ 5,220	$ 5,220	$ 5,220	$ 15,660
				Sum Other Personnel:			**$ 39,027**	**$ 72,833**	**$ 39,026**	**$ 150,886**
				Total Salaries:			**$ 97,700**	**$ 131,507**	**$ 39,026**	**$ 268,233**
C.	**FRINGE BENEFITS (Values based upon fringe calculator)**									
1	Risa Cohen	16.89%					$ 1,142	$ 1,142	$ -	$ 2,284
2	Jose C. Colon-Gaud	19.93%					$ 1,251	$ 1,251	$ -	$ 2,502
3	Johanne Lewis	16.89%					$ 1,060	$ 1,060	$ -	$ 2,120
4	Vinoth Sittaramane	16.89%					$ 1,078	$ 1,078	$ -	$ 2,156
5	James Reichard	16.89%					$ 1,190	$ 1,190	$ -	$ 2,380
6	Jacque Kelly	19.93%					$ 1,305	$ 1,305	$ -	$ 2,610
7	Wei Tu	16.89%					$ 1,099	$ 1,099	$ -	$ 2,198
8	John Van Stan	16.89%					$ 1,106	$ 1,106	$ -	$ 2,212
9	Doug Aubrey	19.93%					$ 1,261	$ 1,261	$ -	$ 2,522
10	Post Doctoral Associates						$ -	$ -	$ -	$ -
11	Graduate Students	1.45%	Biology				$ 435	$ 870	$ 435	$ 1,740
12	Undergraduate Students	1.45%	Biology				$ 55	$ 110	$ 55	$ 220
13	Other						$ -	$ -	$ -	$ -
14	Other						$ -	$ -	$ -	$ -
15	Other									
16	Undergraduate Students	0.0145	Geology & Ge				$ 76	$ 76	$ 76	$ 228
				Total Fringe Benefits:			$ 11,058	$ 11,548	$ 566	23,172
				Total Salaries & Fringes:			**$ 108,758**	**$ 143,055**	**$ 39,592**	**$ 291,405**
D.	**CAPITAL EQUIPMENT (Exceeding $5000)**									
	Land Acquisition						$ 200,000			$ 200,000
	Weatherstation-Geology & Geo						$ 12,600	$ -	$ -	$ 12,600
	hydrogeochemical-Geology & Geo						$ 24,950			$ 24,950
	Biogeochemical-Geology & Geo						$ 21,500	$ -	$ -	$ 21,500
				Total Capital Equipment:			**$ 259,050**	**$ -**	**$ -**	$ 259,050
E.	**TRAVEL**									
	Domestic-Biology						$ 2,000	$ 2,000	$ 2,000	$ 6,000
										$ -
				Total Travel:			**$ 2,000**	**$ 2,000**	**$ 2,000**	**$ 6,000**
F.	**PARTICIPANT SUPPORT COSTS**									
	Stipends						$ -	$ -	$ -	$ -
	Travel						$ -	$ -	$ -	$ -
	Subsistence						$ -	$ -	$ -	$ -
	Other						$ -	$ -	$ -	$ -
				Total Participant Support Costs:			**$ -**	**$ -**	**$ -**	**$ -**
G.	**OTHER DIRECT COSTS**									
	Materials & Supplies-Biology						$ 15,790	$ 11,376	$ 5,000	$ 32,166
	Materials & Supplies-Biogeochemical-Geology						$ 28,783	$ -	$ -	$ 28,783
	Materials & Supplies-Hydrogeochemical-Geology						$ 25,421	$ -	$ -	$ 25,421
	Subcontracts-TBD	Algal growth testing $900 each X 6 sites X 4 per yr/2 yrs						$ 24,100	$ 21,600	$ 45,700
	Subcontracts-SNSA						$ 155,933	$ 82,733	$ 82,733	$ 321,399
	Software license							$ -	$ -	$ -
	Tuition, Fees, Insurance						$ -	$ -	$ -	$ -
	Rental Facilities						$ -	$ -	$ -	$ -
	Other						$ -	$ -	$ -	$ -
	*Other (MTDC Excluded Costs - Tuition, Fees, Insurance)						$ -	$ -	$ -	$ -
	*Other (MTDC Excluded Costs - Rental Facilities)						$ -	$ -	$ -	$ -
	*Other (MTDC Excluded Costs - Amount of Subcontracts over $25,000)						$ 155,933	$ 106,833	$ 104,333	$ 367,099
				Total Other Direct Costs:			**$ 225,927**	**$ 118,209**	**$ 109,333**	**$ 453,469**
H.	**TOTAL DIRECT COSTS**						**$ 595,735**	**$ 263,264**	**$ 150,925**	**$ 1,009,924**
I.	**FACILITIES AND ADMINISTRATIVE COSTS**		Rate	Base						
			0%	GSU's TDC with Exclusions			$ -	$ -	$ -	$ -
			15%	Modified Total Direct Costs			$ 27,113	$ 23,465	$ 6,989	$ 57,566
				Total Direct Costs			$ -	$ -	$ -	$ -
				Other						$ -
				Total F&A Costs:			**$ 27,113**	**$ 23,465**	**$ 6,989**	**$ 57,566**
J.	**TOTAL AMOUNT REQUESTED**						**$ 622,848**	**$ 286,729**	**$ 157,914**	**$ 1,067,491**

Geology and Geography <u>Cost Justification for Biogeochemistry Section</u>

Personnel: We have included summer salary for 5 faculty, 1 month per year for each of 2 years. Since these are 9-month faculty, fringe has been calculated at actuals rates. We have included hourly wages for undergraduate students to assist in the research. Fringe for undergraduate hourly students is calculated at 1.45%.

Materials:
Stemflow collection system $3,600.00
9 stemflow collection systems consisting of 1" PVC piping, 2.5" OD flexible vinyl tubing, chemically-inert HDPE collection bins, and load cell. Material costs *c.* $400 per system

Throughfall trough system $3,600.00
9 throughfall trough systems consisting of 12"x10' PVC pipe, HDPE collection funnel and bottle, and load cell. Material costs *c.* $400 per system.

Accelerometer-based interceptometers $1,950.00
15 rechargeable accelerometers from Gulf Coast Data Concepts, LLC, model # X-16-2 with self-recording datalogger and USB interface. Costs $130 per sensor

Litter interceptometers $2,935.00
1 litter interceptometer consisting of a contained logger-strain gauge system ($2295) and stacked aluminum collection/leachate bin structure ($640).

Soil moisture monitoring system $3,375.00
3 soil moisture monitoring systems include nine 253-L matric potential/three 107 temperature probes. Costs $90 and $105 per matric and temperature sensor, respectively.

PVC gravity lysimeter network $720.00
6 per site (18 total) lysimeters composed of ~$40 materials (3" PVC pipe and slotted PVC pipe).

Portable soil water sensor $960.00
1 HS2-20 portable water sensor.

Phenocams $2,700.00
2 Phenocams (StarDot NetCam 1.3 MP camera, $900) with VariFocal zoom lens (LEN-MV4510CS Megapixel model, $130), heavy-duty outdoor housing ($190) and tower-pole attachment ($130).

Sapflow sensors $9,000.00
24 sap flow sensors @ each site; includes materials for fabrication, installation, and labor.

Deep cycle marine batteries $1,300.00
Deep cycle marine batteries ($100.00 each) to power sap flow sensors and dataloggers at each site and battery charger ($100.00).

Datalogging equipment (incl. multiplexers) $8,080
Each site will require one CR1000 datalogger (3 @ $1440) and two AM1632B multiplexers (6 @ $545). A CR1000KD Keypad ($295) and a SC115 Flash Memory ($195) will be used to retrieve data.

Equipment:
Plant canopy analyzer $12,500.00
1 LAI-2200TC plant canopy analyzer designed for use under forest canopies.

GandG Cost Justification for Subsurface Hydrogeochemistry Section

Materials:
Floating Dock needed to collect water samples and deploy long-term monitoring equipment.
Floating Dock (Year 1) $2000.00
Floating Dock Installation (Year 1) $2000.00
TOTAL Dock $4000.00

2 MiniDivers to collect river water temperature and river water depth data. Devices are self-logging and self-powered. One MiniDiver will be deployed at the bottom of the river and the other will be deployed at the surface. $525 each plus shipping. MiniDivers (Year 1) $1021.00

Supplies for radon analyses to calculate groundwater fluxes. 2 kg of Drierite 8 Mesh, $160 per bottle. 2 kg of Drierite 4 Mesh, $160 per bottle. One bottle of each per year is required. Radiacwash (to clean radon bottles).
Drierite (Year 1) $320.00
Drierite (Year 2) $320.00
Radiacwash (Year 2) $ 35.00
TOTAL Radon Supplies $675.00

Supplies for DIN analyses. Filters to remove particulate matter from samples (case of 125). Liquinox (to clean nutrient bottles). Sample tape to clearly label bottles.
0.45 micron GC-F syringe filters (Year 1) $400.00
Liquinox (Year 2) $80.00
Sample Tape (Year 1) $40.00
TOTAL DIN supplies $520.00

DIN samples of river water and groundwater. One sample of each per month at $35 each. Groundwater sample will be collected from the well closest to the river. ($35 X 12/year X 2 (1 for river, 1 for GW) + 3 duplicates = $945per year).
DIN samples of water plus blind duplicates (Year 1) $945.00
DIN samples of water plus blind duplicates (Year 2) $945.00
TOTAL DIN samples of water $1890.00

Nutrient analyses of riparian vegetation. Three samples per month at $35 each. ($35 X 12/year X 3 (to account for sample variation) + 4 duplicates = $1400 per year).

Nutrient analyses of riparian vegetation plus blind duplicates (Year 1)	$1400.00
Nutrient analyses of riparian vegetation plus blind duplicates (Year 2)	$1400.00
TOTAL nutrient analyses of riparian vegetation	$2800.00

1 Heratherm GP Oven 60L for drying riparian vegetation.

Oven (Year 1)	$1848.00

1 deep cycle marine battery ($100.00 each) to power RAD-7 (radon detector)

Deep cycle marine battery (Year 1)	$100.00

3 MiniDivers to monitor water temperature and well head (water-level in the well). Devices are self-logging and self-powered. One MiniDiver will be deployed in each well. $525 each.

MiniDivers (Year 1)	$1575.00

DIN samples of groundwater from wells farthest from river. One sample of each per month at $35 each. ($35 X 12/year X 2 (2 additional wells) + 3 duplicates = $1400 per year)

DIN samples of water plus blind duplicates (Year 1)	$945.00
DIN samples of water plus blind duplicates (Year 2)	$945.00
TOTAL DIN samples of water	$1890.00

Well Sampling

Solinst Data loggers (3 @ $645)	1,935
Consumable Lab Supplies (filters, sample vials, reagents)	1,950
Replacement pH and ORP probes	$750
Sample Bottles	$200
Subtotal	$4,835

Equipment:

Three (3) Monitoring Wells

mobilization	$12,500
drilling and installation (3 @ $4,150/well)	$12,450
continuous sampling (150ft @ $30/ft)	$4,500
Subtotal	$29,450

Biology Cost Justification

We have included summer salary for 4 faculty, 1 month per year for each of 2 years. Since these are 9-month faculty, fringe has been calculated at actual rates. There are 4 graduate assistantships at $15,000 per year, staggered over the 3 year grant period. We have included hourly wages for undergraduate students to assist in the procurement and processing of samples. Fringe for the graduate assistantships and undergraduate hourly students was calculated at 1.45%. We have included $2000 per year to support travel from campus to the sampling sites on the river. We have $15,790 in supplies for year one, $11,376 in year two, and $5,000 in supplies for year three. Algal growth studies will also be subcontracted out to be conducted at 6 sites four times a year in years 2 and 3. The off-campus F&A rate of 15% has been applied to the budget except for capital equipment and land acquisition.

Southeastern Natural Sciences Academy

A subcontract to Southeastern Natural Sciences Academy will allow continuous monitoring with real-time access to be implemented, as well as discrete chemical monitoring, and community outreach and education.

Schedule of Estimated Expenditures

Jan-2014	Feb-2014	Mar-2014	Apr-2014	May-2014	Jun-2014	Jul-2014	Aug-2014	Sep-2014	Oct-2014	Nov-2014	Dec-2014	Year 1
$12,994	$277,735	$27,080	$33,980	$29,267	$36,225	$46,637	$46,752	$36,224	$25,818	$25,700	$24,436	$622,848
Jan-2015	Feb-2015	Mar-2015	Apr-2015	May-2015	Jun-2015	Jul-2015	Aug-2015	Sep-2015	Oct-2015	Nov-2015	Dec-2015	Year 2
$19,434	$19,549	$19,549	$19,550	$19,664	$28,315	$36,851	$36,852	$28,200	$19,665	$19,550	$19,550	$286,729
Jan-2016	Feb-2016	Mar-2016	Apr-2016	May-2016	Jun-2016	Jul-2016	Aug-2016	Sep-2016	Oct-2016	Nov-2016	Dec-2016	Year 3
$16,456	$16,456	$15,306	$14,156	$14,156	$11,569	$10,391	$10,391	$11,569	$14,156	$13,810	$9,498	$157,914
											Total	$1,067,491

13. Glossary

Glossary Terms

baseflow - water in a stream that comes from groundwater. It sustains the stream during periods of no precipitation

benthic - relating to, or occurring at the bottom of a body of water.

biomarker - A characteristic that is objectively measured and evaluated as an indicator of normal biologic or stress response processes

chlorophyll a - major pigment (green) in plants and algae involved in process of photosynthesis (converting sunlight and carbon dioxide to sugar and oxygen)

ecohydrology - Interdisciplinary field of study concerned with the interaction between ecosystems and water (including mass and energy transport functions of the water cycle)

embryo - A vertebrate animal at early stages of development prior to birth or hatching

electrofishing – apparatus worn as a backpack, towed on a small floating barge, or mounted on a boat; delivers electricity to the water to stun fishes; frequency and voltage are controlled to minimize fish mortality

epigenetic - Heritable changes caused by the activation or deactivation of genes without any change in the underlying DNA sequence of the organism

fluoresce - Exhibiting the property of fluorescence (strikingly bright/glowing)

flux - The rate of flow of fluid, particles, or energy

geo-referenced - A feature with a defined location in physical space in terms of a map projection or a coordinate system

GIS - A geographic information system (GIS) is composed of people, hardware, software, and data for obtaining, managing, analyzing, and displaying all forms of geographically referenced information

hydraulic gradient - The change in total head with a change in distance in a given direction

hydrogeology - The study of the interrelationships of geologic materials and processes with water, especially groundwater

hydrography - science that deals with the physical aspects of all waters on Earth's surface

hydrologic budget - An accounting of the inflow to, outflow from, and storrage in a hydrologic unit such as a drainage basin, aquifer, soil zone, lake, or reservoir; the relationship between evaporation, precipitation, runoff, and the change in water storage

Index of Biotic Integrity (IBI) – a multimetric index that integrates characteristics of the fish community, population, and individual organisms to assess the "quality" of a sample site

interception loss - defined in text

luminescent - emits visible light

macroinvertebrate - an invertebrate organism (animal) that is large enough to be seen without the use of a microscope

mesocosm = experimental system between field and laboratory study; relatively large experimental systems reflecting semi-realistic conditions (i.e. designed to simulate key components of an ecosystem)

meteoric water - water that is derived from the atmosphere

net precipitation - defined in text

phytoplankton - algae, typically microscopic, that are suspended in the water, that are not independent of water movement

Primary producer - organism that is capable of producing sugar from carbon dioxide using sunlight energy; forms base of food web

throughfall - defined in text

species diversity – determined by a formula that sums the number of different species and weights by the evenness of species' abundances

species richness – the total number of different species sampled

stemflow - defined in text

Redfield ratio - atomic ratio of carbon, nitrogen, and phosphorus found in plankton throughout deep oceans (C:N:P = 106:16:1)

saturated zone - The zone in which the voids in a rock or soil are filled with water

storm flow - defined in text

transgenic fish - A fish in which one or more DNA sequences from another species have been introduced by artificial means

transpiration - the process by which plants give off water vapor through their leaves

unconfined groundwater - water in an aquifer that is in direct communication with the atmosphere (i.e. is not confined under pressure beneath relatively impermeable rocks)

unsaturated zone - the zone between the land surface and the water table

zebrafish - It is a member of the minnow family of fishes. The zebrafish is a model organism used to study the development of vertebrates

14. Appendix. Data Organization Matrix

The description below details the construction of a matrix to contain data summaries that will be collected and reported by project scientists. The data are varied in their units of measure, the timing of their observation, and the calculation of central tendency, therefore researchers are asked to create an index for each variable that will have a mid-point and directional index values (positive and negative) that will give stakeholders an indication of the state of the variable at each observation interval. The data and the matrix are intended to be organizational tools for Ogeechee River stakeholders and others interested in the hydrology, biology, and ecology of the river system. The data are provided by scientists from Georgia Southern University and Southeastern Natural Sciences Academy. The scientists, Academy and the University are not responsible for the use of the data by stakeholders.

Description of Matrix: The data organizational matrix will consist of a number of variables each representing observations made in the field during the 36-months while Ogeechee River Project is underway. The observations will be made by scientist working terrestrially (on the Ogeechee flood plain) and aquatically (in the river itself). As the project matures the variables will be given names that are explanatory of their scientific significance. In the matrix list below the variables are given generic names based on the methodologies described in the body of this proposal.

Matrix Variable List

Drought Index
Ecohydrology Index
Geohydrology Index
Water Quality Index
Habitat Index
Primary Producer Index
Benthic Macroinvertebrate Index
Fish Community Index

Mesocosm Biomass and Diversity Indices
Zebra Fish Stress Index

To further explain the composition of the matrix the **Drought Index** will be used as an example. As the project matures each of the variables will be explained by the scientist making observations in a fashion similar to the example below.

Example (Drought Index): The amount of precipitation (primarily rainfall) in the Ogeechee River watershed plays a role in a number of processes in the river system including controlling the volume of water in the river channel at a particular time and place. To measure the impact of precipitation on the Ogeechee River a number of drought indices will be calculated. For this example the Palmer Drought Severity Index (PDSI) will be described.

The PDSI is effective in determining long term drought and uses zero as an indicator of normal conditions (rainfall at or near the 30 year average for the location in question). The PDSI is an index so it simply reports negative or positive changes in drought conditions along a spectrum from -4 to +4 (it does not report inches of rainfall). A negative number from the index represents drought and a positive number indicates an excess of precipitation. The index suggests increasing drought severity as one moves in the negative direction and moisture excess with movement in the positive direction on the scale. The scale below is commonly used to interpret the PDSI.

PDSI Classification

4.00 or more	Extremely wet
3.00 to 3.99	Very wet
2.00 to 2.99	Moderately wet
1.00 to 1.99	Slightly wet
0.50 to 0.99	Incipient wet spell
0.49 to -0.49	Near normal
-0.50 to -0.99	Incipient dry spell
-1.00 to -1.99	Mild drought
-2.00 to -2.99	Moderate drought
-3.00 to -3.99	Severe drought
-4.00 or less	Extreme drought

The PDSI can be calculated weekly or monthly and in the case of the Ogeechee River the index will initially be calculated monthly. Therefore stakeholders can view the movement of the index from month to month and follow the trend in drought or moisture excess in the watershed. Stakeholders who make decisions based on drought severity will want to set a PDSI threshold and upon reaching the threshold take their planned action. (End of Example)

As some variables listed above will be observed only once or twice per year these indices will have fewer points of change compared to variables that are observed and reported more frequently. As stated above each of the generic variables will receive a more descriptive name and will be reported in the data organizational matrix on the project web page as observations are made and data quality control measures are applied by the project scientists. It is hoped that by year two of the project all variables will be active in the matrix.