

The Suwannee River: A Coastal Plain Watershed in Transition

Organizations collaborating on this prospectus include:
University of Florida, Florida State University, University of South Florida,
University of Central Florida, University of Georgia, USGS, USDA, and SRWMD

Overview

The Suwannee River flows through a diverse watershed relatively unimpacted by urbanization but in transition to more intense land-use practices. It thus provides excellent opportunities to study the effects of ongoing changes in land use and water supply on varied hydrological processes. Much background information is available on the hydrology, hydrogeology, geology, chemistry, and biology of the watershed. Several major on-going monitoring programs are supported by state and federal agencies. Four characteristics, discussed in greater detail below, make the Suwannee River watershed ideal for a Hydrologic Observatory:

Unregulated and rural – The Suwannee River is one of few major rivers in the United States with largely unregulated flow through rural areas and is relatively unimpacted with regard to water quality, leading to its designation as one of twelve National Showcase Watersheds.

At Risk and in Transition – Land use is trending toward increased urbanization and intensive agriculture with an apparent coupled increase in nutrient loads and decline in water quality. In addition, population growth is fueling increased groundwater withdrawals from the Floridan aquifer for local consumption affecting water supply. Inter-basin transfers from the lower Suwannee River to south Florida have been suggested as one solution to south Florida's growing water crisis.

Three Distinct Hydrologic Regimes – The Suwannee River watershed comprises three distinct but linked hydrologic landscape units. The upper Suwannee River interacts with the surficial aquifer but is largely separated from the Floridan aquifer by a confining unit. The middle Suwannee River interacts with both surficial aquifers and the unconfined karstic Floridan aquifer. The lower Suwannee River discharges to a deltaic estuary as surface water along with diffuse submarine groundwater discharge.

Extensive Existing Data Infrastructure – Some discharge data exists from the turn of the 19th century to the present. More recently, the USDA Agricultural Research Service through the Southeast Watershed Research Laboratory (SEWRL) has monitored the Little River watershed in Georgia at the headwaters of the Suwannee River since 1965, and the Suwannee River Water Management District (SRWMD) has monitored the Suwannee River watershed in Florida since 1972. Other groups (USGS, Suwannee River Partnership, and individual university investigators) have long worked on specific, local geological, hydrological, and biological problems within the watershed

I. Spatial Extent of Hydrologic Observatory

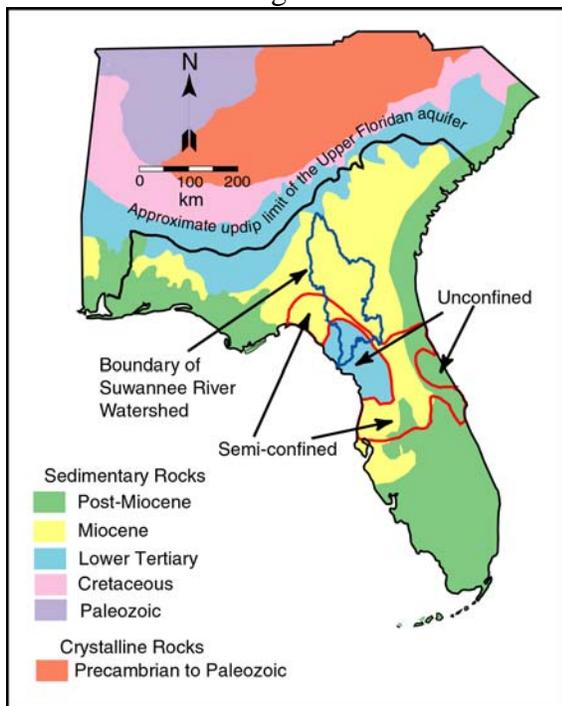
A. Scientific Rationale for Design

As a National Showcase Watershed (www.epa.gov/owow/showcase/suwanneeriver/), the Suwannee River watershed provides an unprecedented opportunity to observe how a relatively unimpacted watershed in the United States is responding to increased urbanization, water

demands, nutrient loads, and other stresses from rapid land use changes. The watershed covers ~27,700 km² of the coastal plain in southern Georgia and north-central Florida stretching along 394 km of the main stem of the Suwannee River (Fig. 1). The predominant land uses in the watershed are silviculture and minor agriculture. Other than a dike surrounding the Okefenokee Swamp and the Reed Bingham Reservoir, the river and its tributaries have no impoundments, diversions, or flood control structures. Minimal human impacts make the Suwannee watershed an ideal example to compare with other more highly impacted and/or urbanized watersheds in the observatory network. Observations from the Suwannee River watershed would provide an opportunity to observe the functional aspects of a relatively healthy hydrologic system. Information from this watershed could be used to understand critical linkages in unimpacted areas and be applied to restoration highly impacted systems

Although relatively unimpacted at present, rapid population growth throughout the southeastern United States has begun altering the characteristics of the Suwannee River watershed. The upper watershed is the site of some of the most rapid population growth in Georgia, and population increased by 22% from 1990 to 2000 in the lower watershed, consisting of ten northern Florida counties. Rapid population growth has been accompanied by increased groundwater use. The USGS estimates that groundwater withdrawals have increased from 3.5 to 5.7 x 10⁴ m³/day between 1975 and 2000 within the region monitored by the SRWMD. Rapid population growth outside the watershed also may have future impacts; inter-basin transfers from the lower Suwannee River to south Florida have long been suggested as one solution to south Florida's growing water crisis (Florida Council of 100, 2003). Along with increasing population and groundwater withdrawals, the predominant land use in the lower watershed is changing from silviculture to more intensive agriculture such as row crops and dairy and poultry farms. These changes correspond to subtle signs of reduction of discharge and degradation of water quality, including long-term declines in spring discharge and increases in nitrate concentrations. Mechanisms controlling the linkages between the changing land use and nascent degradation of water quantity and quality have yet to be established.

In selected regions across the watershed, numerous on-going monitoring and/or research



programs address the connections between land and water use, water quality, water and nutrient fluxes, and ecosystem structure and function. The USGS, SRWMD, and USDA-SEWRL, for example, collect a variety of biological, meteorological, surface water and groundwater data within selected regions of the watershed, but

Figure 1. Generalized geologic map of the southeastern United States showing the boundary of the Floridan aquifer and the distribution of Miocene rocks which act as a confining unit for the Floridan aquifer. The red lines represent the boundaries of the confined, semi-confined, and unconfined portion of the Floridan aquifer. The topographic boundary of Suwannee River watershed, which is expanded in Figure 2, is shown as a blue line.

at present no centralized program exists to link, compare, or otherwise coordinate these efforts. A hydrologic observatory in the watershed would provide that centralized program by coordinating the collection of uniform data, expanding data collection to cover gaps between the agencies, and facilitating the up-scaling of results to the entire watershed. The centralized program developed by the creation of a hydrologic observatory would also provide the opportunity to ask and answer questions that only emerge at large scales and through the synthesis of large data sets.

B. Physical Site Characteristics

Climate in the watershed is warm and humid with mean annual precipitation of 130 to 150 cm. Precipitation shows a distinct gradient from the north, where mean monthly precipitation varies little throughout the year, to the south, where more than half of the annual precipitation occurs between June and September. Elevated summer precipitation in the south has minor influence on river discharge because of high rates of evapotranspiration. During the fall dry period, occasional tropical storms generate intense bursts of precipitation, causing rapid, but relatively short-lived increases in river discharge. Winter months in the lower watershed tend to be dry, but global weather patterns during El Niño years can produce extremely wet winters during which high amounts of precipitation and low rates of evapotranspiration can create month-long increases in river discharge. The variations in rainfall through the year, over seasons and during intense storms provide useful natural perturbations of river discharge, groundwater elevations, and water quality to study the physical and chemical behavior of the hydrologic system.

hydrologic system.

The watershed can be considered three separate, but linked hydrologic landscape units: the upper watershed where the underlying Floridan aquifer is confined, the middle watershed where the underlying Floridan aquifer is unconfined, and the lower watershed and estuary which extends tens of kilometers into the

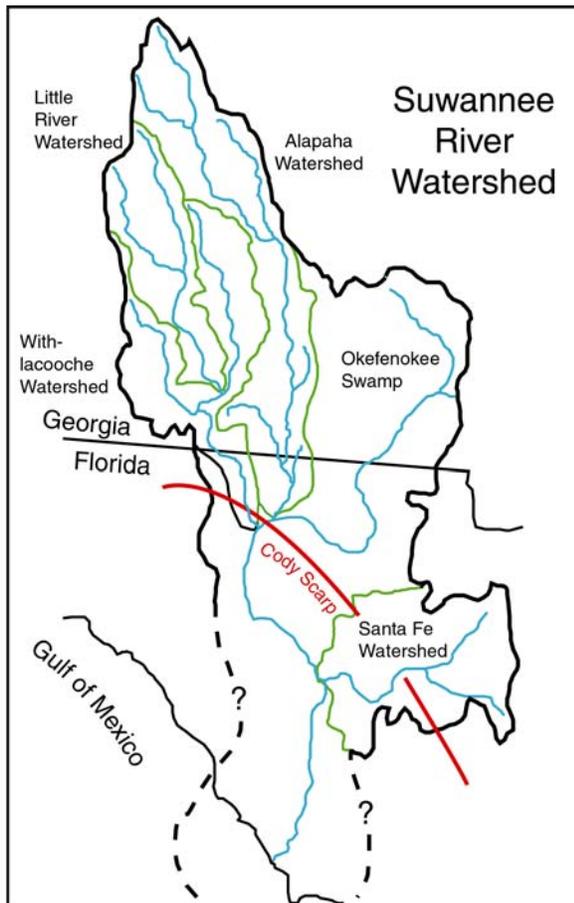


Figure 2. Outline of the Suwannee River watershed and sub-watersheds of tributaries. The Cody Scarp represents the boundary between the confined and unconfined Floridan aquifer. The watershed boundaries at the estuary are dashed and shown as broader than expected from topographic relief because ground and surface water divides may not coincide in the region and because the geographic region of the Gulf that is influenced by discharge from the river is unknown. Green lines represent boundaries of sub-watersheds. Blue lines represent the main stem channels of the various rivers in the watershed. Location of the watershed is shown in Figure 1.

Gulf of Mexico (Fig. 2). The boundary between the upper and middle watershed is the Cody Escarpment, which represents the erosional edge of the Miocene Hawthorn Group, a low permeability unit that confines the Floridan aquifer. The upper Suwannee watershed is dominated by surface drainage which interacts with shallow, surficial aquifers (Katz and Raabe, 2004). Deep recharge to the underlying Floridan aquifer is limited by the Hawthorn Group (Fig. 1). Consequently, wetlands, lakes, and streams are common. Water and sediment discharges tend to be more variable and water tends to be more acidic in the upper than the lower watershed.

The hydrology and hydrogeology of the middle watershed is dominated by the unconfined Floridan aquifer, the largest and most productive carbonate karst aquifer in the world. Below the Cody Escarpment, the Hawthorn Group has been removed by erosion. Here, the Hawthorn Group is between 0 and 30 m thick, and the Floridan aquifer is considered unconfined to semi-confined. All streams crossing the Cody Escarpment sink into the subsurface with the exception of the Suwannee River, which nevertheless becomes a losing stream immediately south of this boundary. The sinking streams control the groundwater chemistry and evolution of porosity and permeability of the carbonate aquifer through dissolution reactions. Groundwater returns to the surface within the watershed from over 100 of the more than 300 named springs scattered across north-central Florida (Rosenau et al., 1977). These springs include the highest density of first magnitude springs (defined as discharging $>2.8 \text{ m}^3/\text{sec}$) in the world. Nine of Florida's 27 first magnitude springs discharge within the watershed, representing more than 10% of all the first magnitude springs in the nation. All of the large springs discharge from water-filled conduits in the karst aquifer and many of these conduits have been explored and mapped using cave diving techniques. The conduits are home to wide variety of stygobitic fauna, many of which are endemic and rare. Unlike other intensely studied karst aquifers, the Floridan aquifer has not been deeply buried or altered. It retains high primary matrix porosity and thus at small scales groundwater flow behaves as typical groundwater flow through a porous medium. At large scales, flow through the Floridan aquifer is dominated by conduits typical of most karst aquifers. The combination of sinking streams, spring discharges, and high primary porosity allow unparalleled access and opportunities to study surface water and groundwater interactions and water flow and solute transport through the subsurface.

The deltaic estuary consists of the lower 16 miles of the Suwannee River, Suwannee Sound, and the adjacent Gulf of Mexico waters influenced by the surface water and groundwater discharge, extending north to Horseshoe Cove, south to the Cedar Keys, and tens of kilometers offshore, depending on river discharge conditions. The upper estuary, comprising both oligohaline and mesohaline zones, is bordered by tidal freshwater swamp and brackish marsh habitat. The lower and nearshore estuary is a mosaic of saltmarsh, tidal creeks, and mudflats. Seagrasses are much less abundant within this estuary when compared to other estuaries along Florida's Big Bend coast, primarily due to the highly colored surface water which limits light penetration (Bledsoe, 1998) though possibly also due to the highly variable salinity. Although the Suwannee River discharges directly to the Gulf of Mexico, relatively high radium concentrations in estuary and offshore waters indicate substantial discharges from submarine springs and seeps (Burnett et al., 1990). Presumably, submarine groundwater discharge is accompanied by discharge of nutrients and carbon. Thus, the estuary is likely to be an ideal location to study the potential importance of the "subterranean estuary" to the biogeochemistry of the inner shelf (Moore, 1999).

C. An Integrated Sub-Watershed Approach

Water-related processes in each of five priority topic areas – the links between hydrological and biogeochemical cycles, the transport of chemical and biological contaminants, the influences of hydrological processes on ecosystem functions, the effects of hydrological extremes, and the sustainability of water resources – are likely to differ between the hydrologic landscape units that make up the Suwannee River watershed. Processes within each unit could be characterized and understood through intensive study of individual sub-watersheds within each unit. For example, the Little River watershed, currently being monitored by USDA-SEWRL, or the middle Suwannee River currently being monitored by the SRWMD, could provide example cases for the confined and unconfined portions, respectively, of the watershed. Through study of these and other individual sub-watersheds, the characteristics of stores within the hydrologic units, and the fluxes and flow paths between the stores could be assessed. Other areas, such as the Okefenokee Swamp and the Santa Fe River watershed, need also to have integrated and focused study and monitoring programs developed to complete the characterization of the entire Suwannee River watershed. Surface water and groundwater inputs to downstream watersheds depend in part on upstream watersheds, and thus individual sub-watersheds are linked through the main stem of the river. Climate variations across the region and through time will also have to be assessed as an input function to the hydrology of each of the sub-watersheds. The goal of the observatory would be to combine an understanding of these sub-watersheds into an integrated characterization of the hydrology, fluxes of mass and energy, and flow paths between the stores of the Suwannee River watershed. Ultimately, these results would be compared and linked to other observatories in the network.

II. Existing Data Infrastructure

A. Upper Suwannee River

The major ongoing research and monitoring program in the upper Suwannee River watershed has been led by the USDA Agricultural Research Service through SEWRL (<http://www.cpes.peachnet.edu/sewrl/>). The laboratory, created in 1965, is one of six watershed hydrology research centers in the nation. The initial focus of the SEWRL was the 334 km² Little River watershed, where over 30 years of data are available from eight nested watersheds ranging from 2.6 km² to the overall watershed. Routine data collection and available information includes:

- Rainfall data at 52 locations.
- Stream stage at eight sites.
- Ground water elevations at three sites.
- Remote sensing data on crop water demand in experimental plots.
- Soil moisture sensing.
- Detailed topographic, land-use, and soil maps of the watershed.
- Participation in the Soil Moisture Experiment, evaluating the use of microwave satellite data to depict changes in soil moisture.
- Gathering historic land use information from the NRCS database and satellite archives.
- In partnership with the University of Georgia, and USGS sampling on an additional 1222 km² of the Little River (to Reed Bingham State Park), a 344 km² watershed in the headwaters of the Alapaha River, and a 321 km² watershed in the headwaters of the Withlacoochee River.

B. Middle Suwannee River

The Florida portion of the Suwannee River watershed, from the Georgia-Florida border to the coast is monitored by the SRWMD (<http://www.srwmd.state.fl.us/>). The SRWMD is one of five state water management districts that were organized in 1972 around major watersheds in the state of Florida to maintain and regulate water quality and quantity within their boundaries. To assess the quality and quantity of water in the region, the SRWMD maintains the [Water Assessment Regional Network \(WARN\)](#) to monitor river, lake, and groundwater levels, river discharge, rainfall, and surface and groundwater quality conditions. A summary of the network is provided below:

- Water levels are measured in 21 lakes at varying frequencies.
- Stream and river stage and discharge are measured at 51 sites (19 are USGS sites) at varying frequencies.
- Flood Warning Network of 23 automated river gauges are monitored in real time.
- Surface water quality samples are collected monthly, bimonthly or quarterly at 67 sites including 20 springs. Water chemistry analyses include field parameters, physical parameters, nutrients and major ions.
- Biological sampling of surface water is conducted quarterly for benthic invertebrates, periphyton, phytoplankton, and coliform bacteria at 29 sites.
- Groundwater levels are measured at 1028 wells. The majority of these wells are only measured during record high or low periods, however 181 are measured monthly and 73 have continuous recorders.
- Two groundwater quality networks monitor physical/biological parameters, major ions, minor ions, and nutrients: 1) the Trend network consists of 97 wells sampled quarterly with more intense spatial coverage in areas with water quality concerns; 2) the Status network consists of 146 wells sampled once per year.
- Rainfall is manually observed from 55 monthly stations, and 23 daily stations. Automated tipping bucket rain gauges are located at an additional 31 sites. Two weather stations measure the parameters necessary to estimate evapotranspiration.

The USGS conducts numerous interdisciplinary studies in the watershed. Several on-going or recently completed studies are:

- The evaluation of manatee habitats; nitrate sources and microbial pathogens in spring waters.
- The status of amphibians, freshwater fishes and mussels, and federally endangered clam species.
- The relationship between land use and aquatic system health using GIS methodologies;
- Long-term and large-scale trends in mercury bioaccumulation in fish.
- Exchanges of water between the Upper Floridan aquifer and the lower Suwannee and Santa Fe Rivers (numerical ground-water flow modeling).
- The mapping of vegetation and soils of riverine and tidal floodplain forests.
- The abundance and diversity of benthic macrofauna in the river and estuary.

University researchers also conduct numerous studies in the watershed. A representative list includes:

- An interdisciplinary study by hydrologists, soil scientists, horticulturalists and engineers to monitor and model the effect of alternative water and nutrient management strategies and climate change scenarios on agricultural productivity and groundwater quality at privately owned poultry, dairy and row crop operations.
- A hydrogeologic study of the interactions of ground and surface water and the influence of conduit-controlled flow in highly porous and permeable matrix rocks.
- A data set of 64 nearly cloud-free Landsat MSS, TM, and ETM+ scenes (Orbital Path 17, Row 39), that includes nearly all the lower Suwannee and Santa Fe river basins, from 1972 to 2003 and at several times of the year.
- A combined chemical and biological study of water chemistry, phytoplankton and benthic algae at multiple locations along the river and in selected springs from 1997-2004.
- A study of flow paths and rates from septic systems.

C. Suwannee Estuary

Other than monitoring by the SRWMD, the Suwannee River estuary has had fewer long-term research and monitoring programs than the upper and middle portions of the river. Much of the work has been conducted by individual university investigators and thus lacks long-term monitoring aspects of the other portions of the watershed. Some representative research and monitoring programs include:

- Monthly water quality (TN, TP, Chlorophyll, color, dissolved oxygen, Secchi depth, and light attenuation) measurements at 10 fixed sampling sites from 1997 to 2004.
- Mapping of oyster reef and seagrass, tidal marshes and wetlands, and fishery habitats.
- Water chemistry and the effects of eutrophication on phytoplankton, benthic algae and bivalve communities from 1997-2004.
- Remote sensing in subtidal and intertidal habitats, fish habitat suitability and analysis of dynamic and stationary habitat components, and Gulf sturgeon life history and critical habitat parameters.
- Salinity characteristics and freshwater flow in the estuary and Gulf of Mexico.
- Assessment of groundwater inputs near the mouth of the Suwannee River.
- Stable isotopes of carbon and nitrogen to track the biogeochemical pathways of these elements and their interaction with shellfish communities.
- Salinity induced flocculation of dissolved organic matter and the potential significance of resultant organic aggregates in estuarine food webs.

D. Watershed-wide programs

No program currently exists to collate, coordinate, and compare data collected from the broad range of site-specific and regional monitoring and research programs in the Suwannee River watershed. A new program is currently under development at the USGS in collaboration with Florida Department of Environmental Protection, the SRWMD, University of Florida and other collaborators to integrate USGS research priorities for geology, biology, and water-related studies across the watershed. A planning workshop for the USGS initiative (gulfsci.usgs.gov/suwannee/) has been organized for September 22-24, 2004. Participants in the workshop will discuss their current research emphases and priorities. The workshop is also designed to determine where gaps in information exist and the primary research needs. Development of the USGS initiative will be done in collaboration with the principals of a

proposal for a Suwannee River hydrologic observatory to ensure that the two programs are highly complementary and to eliminate potential redundancies.

The Suwannee River Partnership

(<http://www.srwmd.state.fl.us/features/suwannee+river+partnership/mission.htm>) was formed in 1999 as a coalition of 48 federal, state, and regional agencies, local governments, and private industry representatives. The partnership works to limit increases in nitrate levels and to reduce nitrate levels that have begun to increase in the surface waters and groundwater throughout the watershed. Although technical expertise in the partnership resides within individual partner organizations, the partnership provides good links to stakeholders within the watershed. The partnership should also provide valuable access to various sites within the watershed.

III. Proposed Core Data Collection

Core data will be collected in the watershed to augment data currently being collected by the SRWMD, the SEWRL, the USGS, and individual programs led by University investigators. The data collection will be designed to quantitatively measure fluxes between stores, residence times within the stores, and flow paths among the stores within the watershed. The specific focus for measurement of core data will be on nutrient, water and sediment fluxes and mass balances and will be measured within several sub-watersheds distributed above and below the Cody Scarp and in the estuary. Data from each sub-watersheds will be compared across the Suwannee River watershed and to other observatories within the network. Measurement frequencies will vary from real-time to annual or longer depending upon the type of data. A very general description of data that will need to be collected for the observatory include:

- Weather stations and eddy covariance flux towers in sufficient density to estimate evapotranspiration;
- Remote sensing of precipitation through radar;
- Soil moisture sensing through tensiometers, TDR probes, microwave remote sensing;
- Stream flow and nutrient concentrations and fluxes;
- Groundwater head and nutrient concentrations and fluxes, including nested piezometers in the estuary to estimate submarine groundwater discharge rates;
- Lake and wetland water levels and nutrient concentrations in multiple locations;
- Tide heights and tidal prisms and nutrient concentrations in the upper and lower estuary;
- GIS coverages including, but not limited to, topography, hydrography, surficial geology, Hawthorne Formation depth and thickness, Floridan aquifer depth and thickness, land cover, land use, and water use;
- Lidar imaging of topography;
- Ground penetrating radar imaging of subsurface topography;
- Satellite and airborne remotely sensed imagery (e.g. landsat, aviris, microwave etc.); and
- Monitoring of flora and fauna of the sub-watersheds including stygobytic fauna.

IV. Example Science Questions

A variety of questions could be addressed in the Suwannee River hydrologic observatory that center around fluxes of mass between various stores in the watershed including atmosphere, land surface, and subsurface, how fluxes vary through hydrologic landscape units within the watershed, the residence times of mass in each stores, and their influences on ecosystem

structure and function. Broad questions focusing on the nutrient and water distributions in the watershed include:

- What are the fluxes of water, dissolved constituents, and sediment within and between three contrasting hydrologic landscape units (confined uplands, unconfined karst aquifer, and estuary) of the Suwannee River watershed and estuary? What are the natural controls of these fluxes? How will changes in land-use patterns in the watershed affect the fluxes?
- How are nutrient cycles linked to the hydrological cycle within the Suwannee River watershed? How are nutrient cycles coupled to each other? Is there hysteresis in nutrient flow from one hydrologic landscape unit to another or through changing weather and climate patterns? Will nutrient cycling characteristics change with evolving land-use practices?
- What are the best measurement and modeling techniques to link water, sediment, and nutrient dynamics through each distinct environment of the Suwannee River watershed? Are separate models needed for confined, unconfined and estuarine segments of the watershed, and if so, how can these separate models be linked?

These questions can be broken into more specific questions with some questions addressed generally across the watershed, and with others specific to portions of the watershed.

A. Watershed-wide questions

- How effective and what are the economic impacts of conservative farming practices?
- What is the optimum configuration of land uses to protect the natural hydrology and ecology of the Suwannee River Basin. What is the best way to merge data and models to predict the impact of current and future land and water use strategies?
- What are phosphorous sorption capacities of soils?
- What are the links between nutrient loading, eutrophication, primary production, carbon sequestration, increasing microbial activity, release of greenhouse gases, and global climate change?
- How do land-use changes impact the water cycle components of evapotranspiration, runoff, and infiltration?

B. Upper Suwannee River

- How does land use affect surface water quality?
- To what extent does irrigation water from the confined Floridan aquifer influence surface water discharge, water budgets of shallow aquifers, and water chemistry in surface water and shallow aquifers?
- What are the effects of irrigation ponds on the hydrologic budget?

C. Middle Suwannee River

- What are the relative contributions to the unconfined Floridan aquifer of flow from the confined portion of the Floridan aquifer, local diffuse recharge, and focused recharge (e.g., sinking streams) in terms of water volume, water quality, including roles in introducing chemical and biological contaminants?
- How do contributions change through time and with changing surface water discharge conditions?

- What effect does mixing of surface and ground water have on dissolution and karstification of the Floridan aquifer?
- Do surface water and ground water divides coincide in karstic areas?

D. Suwannee Estuary

- How are nutrient and other contaminant loads to estuaries influenced by changes in flow regimes?
- What factors limit phytoplankton production in adjacent nearshore coastal waters?
- Do these factors change depending on hydrologic variations in the Suwannee River watershed?
- How do temporal changes in riverine discharge influence estuarine biological production in adjacent nearshore coastal waters?
- Are the frequency and duration of phytoplankton blooms linked to river discharge characteristics?
- Is diffuse groundwater seepage a significant source of nutrients and/or other contaminants to the estuary?
- Is the magnitude of diffuse groundwater seepage in the estuary largely dependent on variations in hydrology and climate in the Suwannee River watershed?
- Do changes in riverine discharge and diffuse groundwater seepage rates result in shifts in the floral and faunal communities within the Suwannee River estuary?
- What is the magnitude of submarine ground water discharge and its influence on chemistry of estuaries?

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