USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Ecological Impacts of Water Management Decisions for the Apalachicola-Chattahoochee-Flint River Basin in a Changing Climate

Focus Categories: Ecology, Climatological Processes, Management and Planning

Keywords: Ecosystem processes, climate change, basin-wide analysis for water management, solute transport, flow regime, Apalachicola-Chattahoochee-Flint River Basin.

Duration: March 2000 - February 2001

Federal funds requested: $17,000

Non-federal funds pledged: $34,711

Principal Investigator: Judy L. Meyer, University of Georgia, Athens, GA

Congressional district: District 11

Statement of critical regional water problems

Flow levels and timing in the Apalachicola-Chattahoochee-Flint River Basin has been a major area of concern for a number of agencies, non-governmental conservation organizations, recreation associations, and corporations. With the Interstate Water Plan, Georgia, Alabama, and Florida are trying to reach a compromise regarding the amount of water allocated to various sections of the river basin in order to satisfy a large number of conflicting demands including: recreational needs, corporate needs, hydropower needs, drinking water supply needs, pollution control needs, and ecosystem needs. While the agencies involved in the allocation decisions have data on the needs of specific species and functions that are economically quantifiable and important or that are federally mandated, little is known about the flow requirements needed for critical ecosystem services that are difficult to quantify economically and/or overlooked by management agencies. We propose to examine the relationship between flow and the uptake of nutrients and production and loss of organic matter. These critical ecosystem services are both difficult to quantify economically and often overlooked by management agencies, but are essential to both in-stream and downstream water quality and ecosystem integrity. These data should help management agencies involved in the Interstate Water Plan, as well as federal agencies involved in dam re-licensing to evaluate the influence of flow regime and the consequences of management decisions to critical ecosystem services in the context of a changing climate.

Statement of the results, benefits, and/or information expected to be gained.

We expect to be able to provide a more holistic view of flow regime and ecosystem function for a regulated river system in the Southeast. This research should help illustrate the influence of flow regime on ecosystem services such as nutrient uptake and organic matter processing. These ecosystem functions are essential to ecological integrity and water quality control of both in-stream and downstream systems, but little is known about the impact of management decisions regarding flow regime on these processes. By examining the influences of both management strategies and climate on flow regime, we hope to provide information that is useful to federal and state management agencies and non-governmental conservation organizations in developing management strategies for this basin currently and for the future.

Nature, scope, and objectives

The quantity and timing of river flow is critical to the ecological integrity of river systems (Poff et al. 1997). Flow is strongly correlated with physical and chemical characteristics of the river such as channel shape, water temperature and velocity, and habitat type and complexity (Jowett and Duncan 1990, Poff et al. 1997). Five main components of the flow regime impact ecological processes: magnitude of discharge at critical time periods, frequency of the various discharge magnitudes, duration of time associated with a particular discharge, timing or predictability of discharge events of particular magnitudes, and the rate of change of hydrologic conditions (Richter et al. 1996, Poff et al. 1997). These five components of the flow regime influence the ecological dynamics of river systems directly and indirectly by affecting water quality, energy sources, physical habitat, and biotic interactions (Karr 1991, Poff et al. 1997).

The use and movement of nutrients and energy in an ecosystem is a fundamental process, and in rivers the transport and transfer of nutrients is tightly linked with the physical movement of water. In flowing waters, nutrient cycles are longitudinally extended to become spirals (Webster and Ehrman 1996). The length of the spiral is primarily determined by uptake length, which is strongly correlated with stream velocity (Newbold et al. 1983, Meyer and Edwards 1990, Webster and Ehrman 1996). Moreover, greater hydrologic variability can lead to large variations in the turnover lengths of nutrients (Meyer and Edwards 1990). Therefore, flow can directly influence the movement of nutrients in a system, and changes in flow will influence the transport of nutrients to downstream ecosystems.

The fixation of energy through production and the subsequent release through respiration are also primary ecosystem functions, and the addition or loss of energy to the system can influence energy flows in downstream systems. In order to determine net addition or loss of energy to the system, net daily metabolism can be calculated. Net daily metabolism is defined as the difference between gross primary productivity and total system respiration (Bott 1996). Metabolism has been shown to vary with high stream discharge as a result of shifts in primary production (Uehlinger and Naegeli 1998). However, relationships between net daily metabolism and low flow conditions are uncertain, particularly in large river systems. In a regulated river, such as the Apalachicola-Chattahoochee-Flint (ACF) River Basin, alterations of flow regime can be the result of management decisions as well as environmental changes such as those predicted to occur with climate change. We propose to evaluate the impacts of changes in flow regime to the river ecosystem within the ACF Basin. We will evaluate the various management schemes proposed by the ACF Water Allocation Formulae, such as the State of Georgia's (1998) proposal, on the five components of flow regime discussed above. Also, we will use decision support models developed by Georgakakos et al. (1999) coupled with scenarios of future climate (Canadian Climate Model) to evaluate the impacts of climate change on flow regime of the ACF Basin. We propose to evaluate the relationship between flow and critical ecosystem functions such as nutrient uptake length and net daily metabolism in order to predict how changes in flow regime affect ecosystem function.

Methods, procedures, and facilities

We will quantify the changes in flow regime through the use of the Indicators of Hydrologic Alteration (IHA) program (Richter et al. 1996). This program takes daily stream flow values and calculates indices relating to the five components of flow regime critical for ecological processes: magnitude, frequency, duration, timing, and rate of change of hydrologic conditions. Specifically, IHA determines mean monthly flow and the inter-annual variability of the mean flow for each month. IHA determines the magnitude of the 7, 30, and 90-day minima and maxima and the inter-annual variability of each of these flows. In terms of frequency, IHA calculates the mean number and duration of low and high pulses in the system. In terms of timing, the program also calculates the day on which the minimum and maximum occur and the inter-annual variability of these events. The program indicates the rate of change of a system by calculating the number of reversals in hydrologic condition.

We have conducted preliminary research on the changes of the flow regime in the Chattahoochee River as a result of predicted climate change and changes in water demand as part of the Water Resources Sector Assessment Team of the National Assessment of the Consequences of Climate Variability and Change. Georgakakos et al. (1999) decision support models predicted flow for the ACF basin at a variety of locations under current climate conditions and 2050 water demand and under 2050 predicted climate conditions and 2050 water demand. Our analyses of these predicted flow conditions through IHA suggest that flows will be lower for most of the year and especially in the summer months (Figure 1). These data also show that the 30-day and 90-day minima will be significantly lower under future management strategies (Figure 2). Under future climate conditions and future water demand, the 7, 30, and 90-day minima will be significantly lower (Figure 2). Moreover, Livingston et al. (1997) demonstrated that low flow conditions in Apalachicola River had negative impacts on the Apalachicola Bay. Therefore, we will focus our research on impacts of low-flow conditions on ecosystem function.

We will determine the relationship between flow and ecosystem function through measures of nutrient uptake length and net daily metabolism at two sites within the ACF

Basin. The first site will be on the main stem Chattahoochee River below Atlanta, Georgia. The second site will be on the main stem Apalachicola River near Chattahoochee, Florida or Blountstown, Florida.

We will measure uptake length of nutrients using the methods of Webster and Ehrman (1996). We will use the effluent of sewage treatment plants as our source of nutrients and the conservative tracer, fluoride or chloride (Marti et al. 1999). We will measure the uptake length of phosphorus (soluble reactive phosphorus, SRP) and nitrogen (ammonium, NH_4) at both sites over a range of discharges. Concentrations of SRP and NH_4 will be determined using the methods of Wetzel and Likens (1992) and chloride or fluoride will be determined with an ion chromatograph (UGA Soil Ecology Lab). These data will enable us to relate nutrient uptake length to river discharge under a range of low flow conditions. Finally, we will extrapolate this relationship to the flow regime predicted under the different management strategies and climate conditions to determine how nutrient uptake and transport could be affected by these changes in flow regime.

We will determine net daily metabolism by determining diel dissolved oxygen concentrations at one station over at least 24 hours (Meyer and Edwards 1990). We will continuously measure dissolved oxygen and temperature using a Hydrolab. Oxygen concentrations will be corrected for diffusion using the equations of Owens et al. (1964) and gross primary productivity and community respiration will be calculated using standard methods (Meyer and Edwards 1990). Metabolism measurements will be taken during a variety of different flows, but focused on low flow periods. We will then determine the relationship between flow and metabolism and use this information to evaluate the consequences of different predicted flow regimes for ecosystem metabolism as described above.

There are many studies that have looked at the impact of flow regime below dams from the perspective of a specific species (e.g. Tennant 1976, Stalnaker 1993, Stalnaker et al. 1995, Jager et al. 1993, 1997). Recently, researchers have started viewing rivers as complex systems where among-species interactions and species responses to flow regimes vary over space and time (Meyer et al. In press). These holistic approaches recognize that a variety of flows are necessary to maintain species diversity and dominance in both aquatic and riparian communities and have been used in management of flows for a variety of purposes: recovery of endangered fish species (Glen Canyon, Arizona by Collier et al. 1997; Green River, Utah by Stanford 1994; Pecos River, New Mexico, by Roberston 1997), restorating riparian plant communities (Olman River, Alberta, Canada by Rood et al. 1995, Owens River, California by Hill and Platts 1998), enhancing native fish communities (Putah Creek, California by Moyle et al. 1998) and restoring channel-floodplain connections (Kissimmee River, Florida by Toth 1995). However, the relationship is less certain between flow regime and critical services provided by river ecosystems such as processing of organic matter and uptake and transport of nutrients. We propose to develop a more holistic view of rivers and flow regime by examining the consequences of management decisions to critical ecosystem services in the context of climate change.

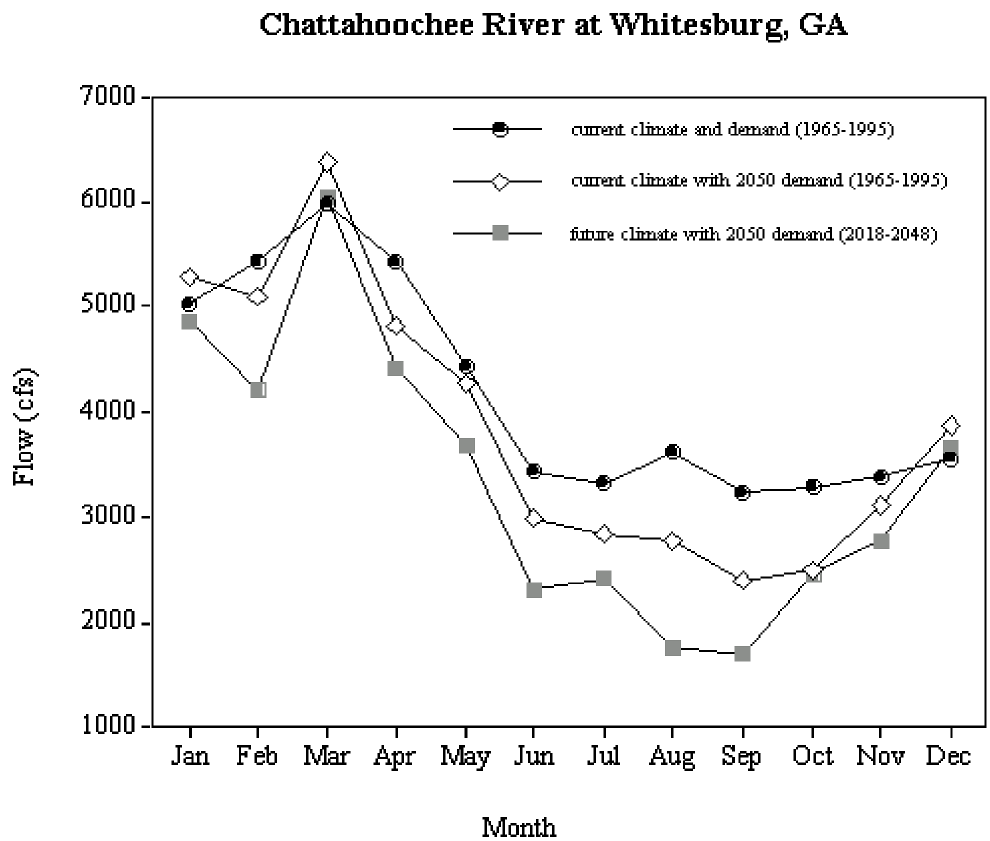

Figure 1. Mean monthly flow of the Chattahoochee River at Whitesburg, GA under three climate anc management scenarios: 1. current climate and management (1965-1995), 2. current climate (1965- and 2050 water demand, 3. predicted future climate (2018-2048) and 2050 water demand. Flow da provided by A. Georgakakos, Georgia Institute of Technology.

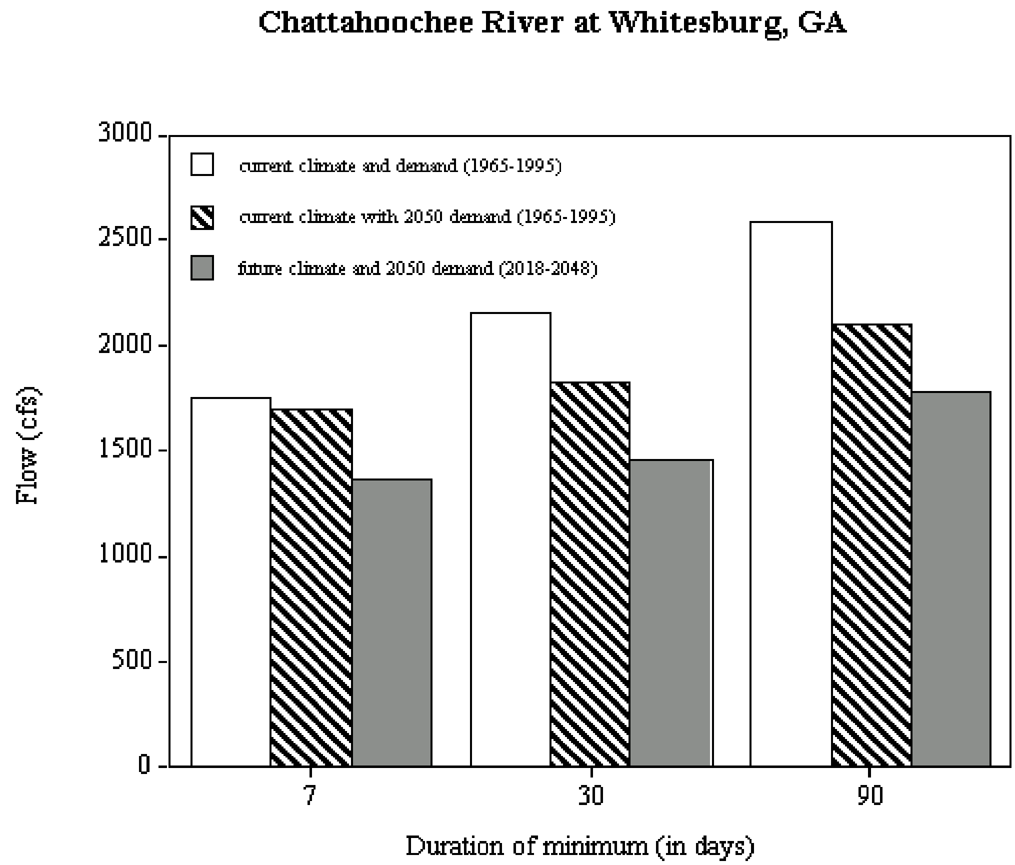

Figure 2: 7, 30, 90 day minimum flows of the Chattahoochee River at Whitesburg, GA under three climate and management scenarios: 1. current climate and management (1965-1995), 2. current climate (1965-1995) and 2050 demand, 3. predicted future climate (2018-2048) and 2050 water dem Flow data provided by A. Georgakakos, Georgia Institute of Technology.

Related Research: The following works, as cited above, are examples of research relevant to our proposed project.

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