A Recommended Method to Protect Instream Flows in Georgia

by

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EXECUTIVE SUMMARY

The increasing demand for water to support Georgia's growing human population creates significant challenges for natural resource managers responsible for protecting the state's fish and wildlife. Heavy dependence on surface water supplies for municipalities, industry, and agriculture has severely depleted and/or altered natural stream flows, adversely impacting aquatic habitat. Georgia's present policy protects stream flow from being depleted below the 7Q10 flow (a ten-year frequency drought event), but there is an overwhelming consensus among aquatic resource managers that higher flows are necessary to support the fish and wildlife, recreation, and aesthetics that Georgia’s citizens expect from their natural environment. The 7Q10 flow was not intended to define adequate base flows for aquatic habitat requirements or other instream uses; its purpose was to protect aquatic life downstream from point source discharges during expected low flow conditions by providing a basis for calculating instream concentrations of specific pollutants in such discharges.

The American Fisheries Society reports that the number of North American freshwater fishes believed to be endangered, threatened, or of special concern has increased by 45% during the past decade, and cites alteration of natural stream flows as the primary cause of deteriorating stream fishery resources. Dams, stream channelization, and water withdrawals impact the timing, duration, and magnitude of flows. Flow reductions alter water temperatures and channel morphologies and thus may destroy critical habitat for various life stages of numerous aquatic species. Establishing historic low flows as the acceptable minimum tends to perpetuate and legitimize worse case conditions and limit fish populations to whatever the degraded habitat can support. The result is lost productivity and resource decline below reasonable public expectations.

Instream flow requirements for fisheries and methods to protect stream flows have been the subject of extensive study. This report provides a thorough literature review of these efforts, which range from simple "office" methods that establish general statewide guidelines to more time-consuming and expensive field methods that may be necessary to develop site-specific recommendations for controversial projects. Many states have developed comprehensive instream flow policies that require considerably greater flows than 7Q10, and several of these are summarized. Finally, a revised policy based on broadly applicable office methods is proposed for Georgia. The proposed standard provides significantly better protection for native stream fishes than the current policy, is simple to understand and apply, and is scientifically defensible.

Several methods were used to develop flow recommendations for 31 test streams, based on historical stream gage records at sites distributed throughout all of Georgia's physiographic regions. These sites were analyzed by physiographic region for broadly applicable relationships among parameters such as average annual discharge, mean monthly flow, and the 7Q10 flow, in order to define a flow policy that would provide generally good habitat quality for most aquatic organisms. This is a subjective approach, but it is soundly based on the work of numerous researchers who have spent decades defining actual flow regimes that meet specific aquatic habitat needs.

Analyses of Georgia's flow records indicate that adequate protection from harmful low flows can be afforded most streams by using a combination of methods that have been widely tested in other states. For most of the state's unregulated streams, the recommendation of 30% of average annual discharge originally developed by D. L. Tennant appears to be adequately protective, yet simple to apply. Other categories of streams, although composing only a small percentage of the state's total, require separate flow regimes to assure adequate protection. These stream categories, described in detail below, are trout streams, regulated streams (except those with peaking hydropower projects), "special case streams," and streams with peaking hydropower facilities.

In Georgia's Blue Ridge Province streams, correlations between drought flows and percentages of average discharge were not consistent with those from streams in other portions of the state, suggesting a more conservative approach is needed. Because most of these are trout streams which are already given special status in water quality regulations, applying a more protective flow assessment method is appropriate. The need to protect trout streams from high summer temperatures provides further justification for a separate method. Both the New England Aquatic

Base Flow Method (August median flow) and a widely used modification (September median) are often used for eastern trout streams. The September median flow is recommended as an acceptable compromise between the inadequate 7Q10 standard and the slightly more protective August median flow. Since September median flows appear comparable to August low flows in most trout streams, this recommendation should adequately protect these streams both from dewatering and high temperatures.

While it is critical to prevent stream flows from dropping below naturally occurring levels in order to maintain minimum wetted areas, periodic high flows are also necessary to maintain normal channel morphology and prevent sediment from destroying stream habitat diversity. In unregulated streams, natural storm events provide needed high flows, but projects (such as large dams and diversions) that regulate total stream flow need methods to ensure both acceptable minimum flows and periodic higher flows. These are provided for in the recommended policy.

Site-specific field studies may be required to determine adequate flows in special case streams or stream reaches identified for special protection on a case-by-case basis by fisheries biologists. Examples of these would include the habitat of protected species, certain anadromous species, and higher quality trout waters. Instream flow recommendations for such streams should be formulated only after collecting the site-specific information needed to assess flow requirements.

A separate method is also recommended for the final category of peaking hydropower projects. These projects typically cause frequent, rapid changes in stream flow and can have profound effects on downstream aquatic ecosystems. A generalized statewide flow policy may not adequately protect aquatic life and stream channel integrity downstream of these facilities. To evaluate such potentially significant impacts, and to determine whether more complex flow regimes are required to protect downstream resources, field studies using the state-of-the-art Instream Flow Incremental Methodology (IFIM) should be required.

Recommended protective flows for Georgia's streams are summarized below. Flow recommendations should be based on at least ten years of continuous flow records where possible. In all cases these are recommended instantaneous flows rather than average flows over various time periods.

Category/sub-category	Season	Recommended Protective Flow
Unregulated Streams		
Warm water streams	All	30% average annual discharge
Trout streams	All	September median flow
Regulated Streams	July through November	30% average annual discharge
	January through April	60% average annual discharge
	May, June, December	40% average annual discharge
Special Case Streams: Approved field studies to determine flow requirements		
Peaking Hydropower Projects: Site-specific IFIM studies to determine flow requirements		

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INTRODUCTION

A growing population is placing increasing demands on Georgia's generally abundant, but limited water resources. As surface water supplies are developed, natural flows are altered, often resulting in significant losses of irreplaceable aquatic habitat. Resource managers responsible for protecting flows for fisheries, wildlife, recreation, and aesthetics face an increasingly difficult task. Many states facing similar problems have developed comprehensive instream flow management strategies (Estes 1984, Reiser et al. 1989, Orth and Leonard 1990). There is presently a great need in Georgia for a comprehensive instream flow policy based on a simple, biologically justifiable method to determine the flows necessary to protect aquatic resources.

Instream flow requirements for fisheries have been the subject of extensive investigations and numerous techniques have been developed for establishing acceptable flows (Orsborn and Allman 1976, Stalnaker and Arnette 1976, Wesche and Rechard 1980, Estes 1984, Reiser et al. 1985). This report reviews instream flow requirements for fisheries and the available assessment methodologies. The objective of this review was to recommend an instream flow policy for Georgia that would meet the following criteria: 1) provide significantly better protection for native stream fishes than is currently provided, 2) be simple to understand and apply, 3) be scientifically defensible, and 4) could be readily incorporated into state water quality regulations so that it would have the force of law.

JUSTIFICATION FOR AN INSTREAM FLOW POLICY

Instream flow may be defined as the amount of water flowing past a given point within a stream channel during one second (Estes 1994). With the exception of those in Alaska, very few rivers remain within the United States where instream flow values have not been permanently altered during some point in the annual cycle (Tyus 1992, Estes 1994). Dams, stream channelization, surface and ground water withdrawals, and diversions impact the natural timing, duration, and most importantly the magnitude of instream flows. Reductions of instream flows alter water temperatures, channel morphologies, and the delicate balance between available habitat and the various life stages of individual fish species (Miller 1961, Orsborn and Allman 1976, Stalnaker 1979, Ono et al. 1983, Carlson and Muth 1989). Unless adequate flows are reserved for fish, repetitive low flow events will control fish populations (Layher 1983). The net result is lost productivity and a decline in fisheries resources.

According to the American Fisheries Society, alterations of natural stream flows are the primary causes of the historic trend of deteriorating stream fishery resources in North America (Peters 1982, Tyus 1990). At least 40 North American freshwater fishes have become extinct during the last decade due to man-induced alterations of physical habitat and the successful establishment of non-indigenous species (Miller et al. 1989).

Many authorities believe that the destruction and modification of aquatic habitats and associated communities are reaching crisis proportions (Williams and Neves 1992). Williams and Miller (1990) considered 28% of North America's native fishes to be rare or extinct. Forty percent of the continent's mollusks are federally listed or are candidates for protection. According to the American Fisheries Society, the number of North American freshwater fishes believed to be endangered, threatened, or of special concern has increased by 45% during the past decade (Williams et al. 1989). Fifty-six of Georgia's 334 fish taxa (17%) are presently recommended for protection (Bart et al. 1991). The conservation and protection of aquatic species and their habitats have become major challenges facing resource managers. Despite reasons for pessimism, many of the world's best opportunities for the protection of biological diversity are found in North America (Williams and Neves 1992).

In western states, fishery resources have long been recognized as beneficial uses of water (Reiser et al. 1989), and these states were the first to set instream flow standards for their protection (McKinney and Taylor 1988). More recently, southeastern states have begun to develop similar standards (Filipek et al. 1987, Bulak and Jobsis 1989, Reiser et al. 1989, Reed and Mead 1990). Instream flow assessment methods range from simple and relatively inexpensive to costly ones requiring several years to complete. New methods are being developed and older ones refined to address regional needs.

Georgia's present instream flow policy is based on the 7Q10 flow [Georgia Department of Natural Resources (GaDNR) 1993]. The 7Q10 and other terms related to flow are defined in the Glossary of this report. As a minimum, permitted water users are required to release or pass the 7Q10 flow, the non-depletable flow, or other appropriate instream flow limit, as established by the director of the Environmental Protection Division (EPD) of GaDNR. No permit is required for water withdrawals of less than 100,000 gallons per day (1.2 gallons per second), even if this is all or most of the flow in a headwater or drought-stricken stream. There are no specific flow requirements below water withdrawals for farm use.

There is clear consensus among aquatic biologists on the need to reserve more water for instream habitat requirements than is provided by the 7Q10 flow (Tennant 1976, Stalnaker 1979, Wesche and Rechard 1980, Estes and Orsborn 1986, Bulak and Jobsis 1989, Orth and Leonard 1990, NCWRD 1992). The 7Q10 flow is by hydrological definition a ten-year drought event, and it has been associated with catastrophic reductions in available habitat for fish and other aquatic life (Tennant 1976, Trihey and Stalnaker 1985, Bulak and Jobsis 1989, Orth and Leonard 1990). These flows were not intended to establish base flow conditions for aquatic organisms. The 7Q10 flow is a standard used to establish effluent limits that prevent pollutant concentrations from exceeding acceptable concentrations under extreme low flow conditions (Christopher C. Estes; Alaska Dept. of Fish and Game; Anchorage, Alaska; personal communication). It was not intended to establish base flow conditions for protecting aquatic habitat. Establishing the acceptability of historic low flows may perpetuate and legitimize worse case conditions (Filipek et al. 1987).

Several recent developments have further emphasized the need for a reevaluation of Georgia's instream flow policy. Twelve regional water supply reservoirs planned by the state may soon require instream flow assessments to protect downstream aquatic environments (GaDNR 1990). Similar assessments may be needed for several state-planned public fishing areas. Two large hydropower projects have recently been relicensed by the Federal Energy Regulatory Commission, and another is scheduled for 1996. The number of fish species included in the recently revised state list of threatened and endangered species further emphasizes the increasing concern resource managers have for the deterioration of stream habitat and aquatic communities.

INSTREAM FLOW METHODOLOGIES

Originally developed in the arid western states, most instream flow assessment methodologies in use today have been available since the early 1970's. The Aquatic Services Branch (formerly the Cooperative Instream Flow Services Group) of the U.S. Fish and Wildlife Service (USFWS) in Fort Collins, Colorado, was initially staffed in 1976 and presently serves as the focus for the development of more advanced techniques. Many other state and federal agencies have also been involved in the development and application of the various methods (Orsborn and Allman 1976, Stalnaker 1979, Wesche and Rechard 1980, Estes 1984, Stalnaker et al. 1994).

More effective methods for assessing instream flow needs have been developed within the last twenty years, but choosing the most appropriate method is difficult and subject to disagreement because of wide variations in meteorological, hydrological, and geological conditions across the United States (Stalnaker and Arnette 1976, Stalnaker 1979, Wesche and Rechard 1980, Loar and Sale 1981, Estes 1984, Trihey and Stalnaker 1985, Lamb 1989). It is therefore important to evaluate historic stream flow records carefully before selecting a method to apply to a given region.

Current instream flow assessment techniques may be divided into "office" or "desktop" methods, which use primarily flow records and basin-wide information as input variables, and "field" methods which require site-specific flow measurements. Examples of both office and field methods are described in the following sections.

Office Methods

Office methods are the simplest and were the first to be developed. They are based on the assumption that, by analyzing flow records and historical trends, a flow recommendation can be made that mimics the natural flow regime. Maintaining a semblance of the natural flow pattern should in turn protect fisheries resources. Although site visits are not required, some office methods have been modified to incorporate the collection of site-specific measurements. Office methods are often used in long-range planning or to recommend flows for non-controversial projects (Wesche and Rechard 1980, Estes 1984, Bulak and Jobsis 1989, Lamb 1989, Reed and Mead 1990). They may also be used to establish general statewide instream flow guidelines (Filipek et al. 1987, Bulak and Jobsis 1989).

Tennant Method

The most widely used office methodology is the Tennant method (formerly referred to as the Montana method) (Tennant 1976, Wesche and Rechard 1980, Reiser et al. 1989, Sale et al. 1991). This technique evolved after 17-years of work on hundreds of streams generally north of the Mason-Dixon line and east of the Rocky Mountains. The primary conclusion from field studies of the Tennant method was that available aquatic habitat was generally similar for streams having the same percentage of mean annual flow, regardless of stream physiography. As a result, various fixed percentages of mean annual flow were correlated with habitat characteristics and assigned to habitat quality categories ranging from optimum to severely degraded. Separate fixed percentages were applied to the October-March and April-September periods, and provisions were made for short-duration flushing flows.

A fixed percentage of mean monthly flow was introduced in 1980 as a modification of the Tennant method. This modified approach has since become one of the most widely used techniques in the United States (Reiser et al. 1989, Mathews and Bao 1991).

Tennant's field studies indicated that 10% of mean annual flow represents the minimum instantaneous flow needed for short-term survival of most aquatic life. At these flow levels habitat is degraded, stream substrate is about 50% exposed, and side channels and gravel bars are substantially dewatered. Instream cover is generally unavailable to fish which are crowded into pools, and migration passage over shallows may become difficult. Fish become subject to overharvest, recreational boating is curtailed or eliminated, and aesthetics are degraded. In Tennant's study, streams with 10% of mean annual flow still exceeded the 7Q10 flow in 77% of the cases, a clear indication of the general inadequacy of the 7Q10 as an instream flow standard.

According to Tennant, 30% of mean annual flow is required to maintain generally good habitat quality for most aquatic organisms. In test streams, average depths increased from 1.0 to 1.5 feet and velocities from 0.75 to 1.5 feet per second as flows increased from 10% to 30% of mean annual flow. Most substrates were covered, side channels contained some water, gravel bars were partially inundated, and stream banks provided cover for fish and wildlife. Many runs and pools had adequate depths to provide cover. From a subjective evaluation, fishing quality, recreational boating, and stream aesthetics were maintained at acceptable levels.

Sixty-percent of mean annual flow is the base flow level which Tennant recommends to provide excellent habitat for most aquatic life forms. Test stream widths, depths, and velocities were near optimal, and most channel substrates were covered, including riffles and shoals. Side channels, backwaters, and near-shore cover elements were inundated. Water levels were excellent for aesthetics and most recreational activities.

In summary, Tennant's studies imply that widths, depths, and velocities of most streams will be satisfactory for most aquatic organisms at flow levels near 30% of mean annual flow. Using Tennant's method, the 30% value should be considered a generally acceptable target level when planning water allocations for instream flows designed to protect aquatic resources. As suggested by Tennant and others, this flow should be validated by careful analysis of daily, monthly, and annual flow records, with special emphasis on low flow events (Tennant 1976, Wesche and Rechard 1980, Estes 1984, Bulak and Jobsis 1989). Tennant recommends collecting photographic evidence at flows ranging from 10% to 100% of mean annual flow. Where additional documentation is warranted, he suggests collecting width, depth, and velocity data at several representative transects at each flow (Tennant 1976).

Annear and Conder (1984) found flow recommendations based on 30% of mean annual flow to be more unbiased than those developed from more complex site-specific, habitat-based methods. The Tennant method has produced flow recommendations similar to those provided by more costly, habitat-based approaches (Newcomb 1981, EA Engineering, Science, and Technology, Inc. 1986, Estes and Orsborn 1986). Orth and Leonard (1990) compared several of the most widely used instream flow assessment methods in field studies on four streams in the James River

Basin of Virginia. These studies generally verified Tennant's original observations but suggested that good habitat quality on large streams may be provided by instream flows below 30% mean annual discharge. The authors suggest a flow of 20% mean annual discharge as reasonable for most streams in the James River Basin, when calculated separately for four fish life history seasons. The 20% figure provided 40% of optimal habitat in the smallest streams and near optimal conditions in the largest streams.

Criticisms of the Tennant method include its reliance on flow records which are not directly available for ungaged streams or may be of insufficient duration. Tennant's field methods, wh ere applied, are ambiguous and prone to subjective interpretation. The method also provides only minimal guidance in evaluating flow-habitat tradeoffs (Wesche and Rechard 1980, Annear and Conder 1984, Estes 1984, Lamb 1989).

South Carolina Method

Using Tennant's basic assumptions, the South Carolina Department of Natural Resources (SCDNR) developed the guidelines in Table 1 as a "general" or statewide method (Bulak and Jobsis 1989). Separate recommendations are provided for periods of high flow (January-April), low flow (July-November), and increasing or decreasing flows (May, June, and December), which assure some conformity to natural seasonal flow variations. Separate recommendations are also provided for Coastal Plain and Piedmont physiographic regions. The individual percentages were derived by comparing wetted perimeter calculations (see Glossary) with photographs taken at different flows on nine critical stream segments.

Available habitat at 20% of mean annual daily flow was generally adequate to protect fisheries resources during low flow periods in both Piedmont and Coastal Plain streams in South Carolina. The fixed percentages recommended for high flow periods are based on striped bass passage over shoals in the Piedmont and on flood plain inundation, as well as general spawning considerations in the Coastal Plain. Instream flow recommendations for periods of increasing or decreasing natural flows are transitional between those for the high and low flow seasons. The authors emphasized that these flow recommendations are designed to protect, not enhance fishery resources. The studies conducted by SCDNR generally support the broad applicability of the Tennant method.

Table 1. Instream flow method adopted by the South Carolina Department of Natural Resources.

Region	Season	Recommended Flow
Piedmont		
	July through November (low flow)	20% of mean annual daily flow
	January through April (high flow)	40% of mean annual daily flow
	May, June, December (increasing or decreasing flow)	30% of mean annual daily flow
Coastal Plain		
	July through November (low flow)	20% of mean annual daily flow
	January through April (high flow)	60% of mean annual daily flow
	May, June, December (increasing or decreasing flow)	40% of mean annual daily flow

The South Carolina instream flow policy categorizes the fixed percentage method as a "general" method to be used where site-specific information is unavailable, inappropriate, or where the developer decides not to conduct a detailed, habitat-based study. Projects where site-specific studies may be required include dams, diversions, and water withdrawals. Site-specific studies are always required where endangered species are present. The Instream Flow Incremental Methodology (IFIM) of the U. S. Fish and Wildlife Service is required to provide flow recommendations for large magnitude projects such as hydropower facilities. The appropriate instream flow methodology is generally determined by the value of the resource and the projected impact of the development.

Arkansas Method

In an effort to develop a comprehensive instream flow policy in Arkansas, state agencies analyzed all methodologies in relation to cost, manpower requirements, and necessary level of training. Requirements for as many as 60 instream flow recommendations in one year limited the options to a simple, cost effective, yet biologically justifiable technique. The result was a modification of the widely used and well documented Tennant method (Filipek et al. 1987). The modification uses mean monthly (instead of annual) flows because researchers felt that the original Tennant method did not adequately address seasonal flow variability across the full range of Arkansas streams.

The Arkansas method (Table 2) divides the year into three seasons, based on stream physical-biological processes: November-March (channel clean and recharge), April-June (fish spawning), and July-October (fish production). The methodology evolved through a review of hydrologic records, years of experience reviewing flow-habitat relationships, and a knowledge of seasonal processes as applied to Arkansas streams.

Table 2. The Arkansas method for providing adequate instream flows for various seasons of the year, based on physical/biological processes.

Physical/Bio. Process	Season	Recommended Flow
Channel Clean and Recharge	November-March	60% of mean monthly flow
Fish Spawning	April-June	70% of mean monthly flow
Fish Production	July-October	50% of mean monthly flow (or median monthly flow)

Flows recommended during the clean and recharge season are designed to flush sediments and septic waste products as well as recharge the fertility of the system through the influx of organic nutrients. Spawning flows are established to prevent the stranding of eggs and fry, reduce silt deposition in spawning areas, and provide adequate oxygen to developing early life stages. These higher flows are also required to inundate the flood plain in low gradient streams and to stimulate the upstream spawning migrations of species such as walleye (*Stizostedion vitreum*), white bass (*Morone chrysops*), and redhorse suckers (*Moxostoma* sp.). Recommended flows during the production (low flow) season must reserve adequate waste assimilative capacity and prevent the crowding of fish populations which may result in increased stress, disease, and predation.

Draft North Carolina Method

The State of North Carolina is in the final stages of developing formal instream flow policies and methodologies. Draft documents provided by the North Carolina Division of Water Resources (NCDWR) outline a policy based on three primary office methods and two field methods. Office methodologies consist of a regression technique developed from numerous wetted perimeter studies as well as the New England aquatic base flow and 7Q10 methods. The regression technique is still in the development stage and is presently used only for Piedmont streams with moderate habitat quality. The aquatic base flow method is more conservative and is used for moderate quality streams outside the Piedmont. The 7Q10 flow may be recommended for streams or hydropower bypass reaches possessing poor fish habitat. Streams with high habitat quality, regardless of location, require site-specific studies (NCDWR 1992).

Field methods utilized by NCDWR are the wetted perimeter method and the IFIM. Characteristics of streams which require field studies are good habitat quality, exceptional biological diversity or resource value, or the presence of endangered species or other outstanding fishery resources. Field studies are also required where the projected impacts of development are significant or where the developer rejects the recommendation provided by the office method. Due to the time and expense involved, the IFIM is required only for hydropower operations, streams with exceptional resource value, and for controversial projects (NCDWR 1992).

Draft Virginia Method

The State of Virginia draft instream flow policy divides streams into "special case" and "non-special case" streams. Special case streams include those with species that are threatened, endangered, or of special concern, and all streams where anadromous species could be reestablished. Regulated streams and primary trout waters are also included in this category. Special case streams are evaluated more extensively than non-special case streams but no specific methodologies are recommended. An IFIM study may be required for special case streams where the requisite information is unavailable to evaluate instream flow needs (LaRoche 1990).

A tentative statewide or standard method has been developed to provide minimum flow recommendations for non-special case streams. The method provides recommendations according to stream size and is based on monthly exceedence flows for high, low, and intermediate flow periods. If the developer wishes to withdraw more water than the standard method allows, an IFIM study may be recommended. Withdrawals resulting in flows below 10% average annual discharge are unacceptable in all cases (LaRoche 1990).

New England Aquatic Base Flow Policy

Possibly the simplest of all instream flow assessment methods, the New England technique simply selects the median August stream gaging flow as the aquatic base flow (Larson 1981). The aquatic base flow is augmented for spawning and incubation by recommending the lowest median monthly flow during the period when spawning and incubation normally occur. Although designed for New England waters, it has been adapted for use in other states and is one of the most widely used of all assessment methodologies (Reed and Mead 1990, Sale et al. 1991). One regional modification has been the substitution of the September for the August median flow (Reed and Mead 1990).

Orth and Leonard (1990) found that flow recommendations developed from the New England method did not correspond to the same habitat quality in all stream sizes and some recommendations on larger streams provided excessive flows. The method provided fairly reasonable flow recommendations for other stream sizes, but they were often inconsistent seasonally. Mathews and Bao (1991) noted similar inconsistencies for Texas streams.

Flow Duration Methods

The method developed by the Northern Great Plains Resources Program (1974) uses monthly flow duration curves developed from statistically "normal" flow years. The instream flow recommendation for each month is the flow with a 90% exceedence probability (10 percentile flow).

The Hoppe method (Hoppe 1975) establishes fixed percentages of daily flow duration curves as recommendations for food production and cover, spawning, and the flushing of fines. Recommended flow exceedence probabilities for these activities are 80%, 40%, and 17%, respectively. Neither of these methods provides solid documentation for the biological rationale behind the specific percentage figures (Wesche and Rechard 1980, EA Engineering, Science, and Technology, Inc. 1986). Mathews and Bao (1991) criticized both methods for providing inconsistent and often unrealistically low recommendations for Texas streams.

Texas Method

The Texas method uses a hydrodynamic model to simulate velocity distributions and a physical habitat-flow model to determine minimum maintenance flow needs of target fish species. The resulting relationships are analyzed by regression methods (Mathews and Bao 1991).

The regression techniques require region-specific biological and hydrological inputs which may be unavailable in some areas. The method considers riverine fishes as primary target species, flow requirements of target species critical life stages, and the natural stream flow pattern. The computer program required to utilize the method has not been modified for use outside of Texas, but is adaptable to modifications that would facilitate its use in other states (Mathews and Bao 1991; Raymond Mathews, Texas Water Dev. Board, Austin, Texas, personal communication).

Field Methods

Field methods may be required for significant stream resources, unique fisheries, potentially controversial development projects, or where project bargaining and rigorous legal defensibility are required (Wesche and Rechard 1980, Lamb 1989). Field methods are costly and require site-specific habitat measurements for various analyses of flow-habitat relationships. The most widely used and accepted field methods are the modified Tennant (Tennant 1976), wetted perimeter techniques (Nelson 1980), Physical Habitat Simulation (Bovee and Milhous 1978), and the IFIM (Bovee 1982).

Modified Tennant Approach

With this method, all of Tennant's procedures are repeated and, in addition, key habitats are observed at various percentages of mean annual flow. Width, depth, velocity, and substrate characteristics are quantified at a number of transects for each flow and compared with Tennant's fixed percentage recommendations. Pertinent photographs are taken at each flow to prepare a photographic regression of flow versus habitat. Habitat requirements of important fish species are evaluated, and the resulting flow recommendation reflects empirical observations as well as Tennant's general guidelines.

The modified Tennant method is sometimes used where time and cost constraints exist, but where field measurements are required to adequately justify a recommendation or wh ere special concerns have been identified. This method requires a great deal of professional judgment and provides little guidance to evaluate flow-habitat tradeoffs (Tennant 1976, Wesche and Rechard 1980, Lamb 1989, Estes 1994).

Wetted Perimeter Methods

Wetted perimeter may be defined as the boundary distance measured perpendicular to the flow across the bottom and sides of a channel cross section that is in contact with the water at the time of the measurement (Stalnaker et al. 1994; Christopher C. Estes, Alaska Dept. of Fish and Game, Anchorage, Alaska, personal communication). In a plot of wetted perimeter versus discharge, an inflection point is often found below which small decreases in flow produce large decreases in wetted perimeter. The inflection point is therefore a surrogate for minimally acceptable habitat, and the flow at this point is the recommended flow. Wetted perimeter analyses are often made from single or multiple transects using the IFG-4 or Water Surface Profile (WSP) hydraulic simulation models developed by the USFWS. Transects are normally placed at critical habitats and the assumption made that adequate flows at these areas will protect other habitats as well.

Inflection points may be difficult to detect, and a number of methods for analysis have been suggested (White 1976, Nelson 1980, Annear and Conder 1984). Annear and Conder (1984) found that wetted perimeter techniques were generally biased and tended to overestimate flow requirements. Despite criticisms, wetted perimeter techniques are among the most widely used and accepted of all methods and provide more defensible documentation than simpler office methods (Lamb 1989).

Physical Habitat Simulation Model

This method, abbreviated PHABSIM, is "a method of evaluating the availability of physical microhabitats in streams with different conditions of discharge and channel configuration" (Bovee et al. 1979, Stalnaker et al. 1994). The methodology was developed by the Aquatic Systems Branch of the USFWS and has three basic components: field data collection on habitat variables at a number of transects, hydraulic simulation, and habitat suitability or preference curves for life stages of individual fish species. At the core of PHABSIM are the IFG-4 and WSP hydraulic simulation models and the HABITAT sub-model. Output is the individual and composite weighted usable area (WUA) response variable and several hydraulic response variables, such as wetted perimeter (Wesche and Rechard 1980). PHABSIM may be used to provide instream flow recommendations using a variety of optimization procedures, even though the models were not originally designed to provide single value flow recommendations (Loar and Sale 1981, Bovee 1982, Annear and Conder 1984, Orth and Leonard 1990).

PHABSIM provides more flexibility than previously described methods. It is incremental in nature and allows analysis of a full range of flow-habitat interactions and tradeoffs. Past experience has shown it to be more scientifically and legally defensible than simpler methods (Wesche and Rechard 1980). Field data collection may range from limited to extensive and can be tailored to budget and manpower constraints. The Bureau of Land Management and some states recommend PHABSIM as the method of choice for controversial projects or where a number of management options must be analyzed (U.S. Dept. of Interior 1979, Estes 1984, Lamb 1989). Although more expensive than simpler instream flow assessment techniques, PHABSIM requires less investment than the IFIM. It is normally used to evaluate hydropower projects (Bovee 1985), to analyze controversial projects or unique streams (Washington Dept. of Ecology 1987), or to gather information for federal licenses (Cavendish and Duncan 1986).

Although a state-of-the-art modeling approach, PHABSIM remains controversial. The Illinois Natural History Survey's extensive experience with the method has shown the hydraulic simulation models to be generally unreliable predictors of flow patterns. The individual species habitat suitability curves available from the Aquatic Systems Branch were also not applicable to regional conditions. The output as composite WUA indices may obscure flow-habitat relationships for important species (Wiley et al. 1987). Orth and Leonard (1990) suggest that the methods for developing instream flow recommendations from PHABSIM are poorly standardized for multi-species analysis. Annear and Conder (1984) found instream flow recommendations developed from PHABSIM to be biased low on large streams and high on small streams. They suggested that habitat suitability curves may have been responsible for the biases rather than the model. Other criticisms of PHABSIM are similar to those applied to the IFIM (Mathur et al. 1985, EA Engineering, Science, and Technology, Inc. 1986) and relate generally to the inability of present computer models to account for the complexity of natural systems. Most authors, however, agree on the utility of the PHABSIM approach when applied and analyzed with a knowledge of its limitations and a substantial understanding of the system being modeled (Estes 1984).

Instream Flow Incremental Methodology

The IFIM is a comprehensive, incremental methodology which incorporates the PHABSIM models but attempts a more multifaceted approach to the analysis of instream flows. The methodology typically includes replicate habitat sampling, the development of habitat suitability criteria through biological sampling, sediment and water routing studies, hydraulic analysis, as well as physical, habitat, temperature, and water quality simulations (Sale 1985). Special studies may be required to investigate issues such as the impacts to wetlands, the effect of entrainment, or the unique requirements of endangered or threatened species. The entire process may involve a number of state and federal agencies as well as specialists in a variety of scientific fields. The result should be an ability to predict changes through time to all aspects of the riverine ecosystem downstream of project operations over a complex range of operational scenarios (Lamb 1989). The complexity, time investment, and cost of this methodology are normally justified only for large, controversial projects where difficult negotiations over flow-habitat tradeoffs are expected (Stalnaker and Arnette 1976, Trihey and Stalnaker 1985, Estes 1994). Hydropower projects provide the best examples where the IFIM is normally required.

Criticisms of the IFIM and PHABSIM focus on a lack of evidence for a predictable response of fish populations to changes in weighted usable area, the primary output of these methodologies (Mathur et al. 1985, Shirvell 1986, Orth 1987, Orth and Leonard 1990). The American Fisheries Society passed a resolution in 1989 which states, in part, that the "IFIM has been widely applied to cold water stream trout and salmon populations, but no regionally acceptable approach to warm water stream habitat assessment in the southeast is presently available" (Mathews et al. 1990).

More complex models will be required to assess instream flow needs in relation to biological responses (Loar and Sale 1981). Until improved methods are developed, flow recommendations should be conservative in order to protect stream resources (Orth 1987). At present, the IFIM constitutes the state-of-the-art in stream flow assessment and is the most scientifically and legally defensible method available (Filipek et al. 1987). It is an invaluable process for involving many agencies and scientific disciplines in an attempt to evaluate flow requirements.

OTHER INSTREAM FLOW CONSIDERATIONS

Gaged Stream Flow Records

Many instream flow assessment methodologies are based on the assumption that fishery resources will be protected by reserving a portion of historical flows (Wesche and Rechard 1980, Estes 1984). If gaging stations are located downstream of significant water withdrawals, the flow records will represent depleted conditions which may support only degraded fisheries. Eastern states have a larger percentage of relatively undeveloped streams than western states, and the problem of severely depleted flows due to withdrawals is not as persistent (Lamb 1989).

Where a large percentage of stream flow has been appropriated, the natural flow regime should be reconstructed by accounting for water diversions and stream modifications before applying a fixed percentage instream flow recommendation (Bayha 1978). Reserving a portion of severely depleted flows will perpetuate degraded aquatic environments. Where appropriations of stream flows are less significant, fish populations may have adjusted substantially to altered conditions and may even be enhanced if development projects also result in the reduced frequency of low flow events (Lamb 1989). In this situation, a fairly subjective decision must be made whether to use stream flows recorded before or after development.

Where certain stream flow data are unavailable, techniques have been developed for transferring these data from gaged to ungaged streams. These techniques involve the computation of channel geometry, interpolation from known to unknown flow data, or correlations with adjacent streams (Hedman and Kastner 1974, Tennant 1976, Bovee 1982). A number of manuals outlining accepted methods of calculating instream flow data have been published by the U.S. Geological Survey (Timothy C. Stamey, hydrologist, U.S. Geological Survey, Atlanta, Georgia, personal communication). Hydrograph simulation models are available for obtaining annual stream flows on ungaged streams (Annear and Conder 1984). Previous instream flow recommendations may also be extrapolated by drainage area to a new location (Reed and Mead 1990).

Flushing Flows

Periodic high or flushing flows move bed load, remove sediment, inundate the flood plain, and maintain channel characteristics (Stalnaker 1979, Reiser et al. 1985). The U.S. Forest Service (1984) noted that annual high flows are needed to maintain channel structure in alluvial streams and suggested a channel maintenance flow of 78% of mean annual flow on the Bighorn River (Romm and Bartoloni 1985). Tennant (1976) recommended periodic flows of 200% of mean annual flow to remove sediment and other bed load material, but provided no guidance on timing or duration. Hoppe (1975) suggested a 48-hour flushing flow at the 17% exceedence probability of the flow duration curve.

Provisions for flushing flows are more prevalent on highly regulated western streams where managing agencies have the necessary storage capacity to release large volume flows on demand (Filipek et al. 1987). In the southeast, various modifications of the Tennant approach provide for seasonally high flows designed to mimic the natural hydrograph, but specific provisions for large volume flushing flows are less common. Instream flow policies developed by the states of Arkansas (Filipek et al. 1987) and South Carolina (Bulak and Jobsis 1989) stipulate late winter-spring flows of 60% mean monthly flow and 40% average annual discharge, respectively. Although far below flood level, these flows are of bank-full magnitude on some streams and may inundate the flood plain on lower gradient streams. They are generally considered adequate to transport finer sediment (Filipek et al. 1987).

Large volume flows capable of removing sediment from gravel are obviously more important where a large number of lithophilic spawners are found. Requirements for flushing flows may therefore be quite site-specific. Bovee (1982) suggested that if a flushing flow is indicated, an authority on sediment transport should be consulted to determine the flow required to remove fines without removing gravel.

Hydropeaking Operations

Hydropeaking facilities are usually designed to augment base power supply during peak electricity demand periods. This rapid response to demand is possible because hydropower generators operate at full capacity immediately after startup while steam generating plants require up to 30 days to reach full capacity (South Carolina Water Resources Commission 1983).

Hydropeaking operations are characterized by rapid stream stage fluctuations. As an example, water levels seven miles below the Buzzard Roost hydropower plant in South Carolina increase by eight feet during full power generation and are reduced to less than the 7Q10 flow after six hours of no generation (Bulak and Jobsis 1989). Rapid flow fluctuations of this magnitude impact all life forms in the affected area and alter channel characteristics through increased bank erosion, bed aggradation/degradation, channel armoring, and other processes (Simon 1979, Cushman 1985). With the increasing trend to more hydropeaking operations, the rate of change in stream flows and the magnitude of high flows may be as great a concern to fisheries managers as minimum flow. Simple minimum flow recommendations are inadequate in this environment (Stalnaker 1990). More complex flow scenarios are required to protect downstream resources and these must necessarily be analyzed within the incremental project bargaining framework of the IFIM.

Water Quality

Poor water quality as well as inadequate quantities can limit sport fish abundance, degrade aesthetics, and detract from the recreational experience. Reductions in stream flows may result in decreased dissolved oxygen concentrations, increased biological oxygen demand, and reductions in the dilution rates and assimilation of pollutants such as chlorine, chlorinated organics, and heavy metals (Filipek et al. 1987, Wiley et al. 1987). Water quality should always be a consideration when establishing an instream flow recommendation. Water quality modeling should precede and be incorporated into flow recommendations where an obvious present or potential pollution problem exists (Orth and Leonard 1990). Water quality is second only to fisheries issues as an objective of instream flow studies (Sale et al. 1991) and is almost always an important concern in the IFIM process (Sale 1985).

Water quality requirements are more clearly defined than those for fish habitat. The impacts of flow reductions on a number of water quality parameters may be fairly accurately modeled to determine the potential for water quality violations (Wiley et al. 1987). The results of such modeling may provide fisheries managers with substantial legal justification for an instream flow recommendation.

Instream Flows for Endangered Species and Wilderness Areas

Instream flow recommendations which merely preserve habitat where fish species are threatened with extinction may result in continued decline (Tyus 1992). A management philosophy of recovery is needed, with flow recommendations based on empirical studies, simulations, and subjective evaluations (Maguire 1986, Soule' 1987). Instream flow needs of endangered species can only be determined by the integration of all life history stages with detailed microhabitat and seasonal flow requirements (Tyus 1992). These requirements are not readily simulated with existing models, and the general problem of determining the requirements of endangered species is not easily resolved. The fisheries manager should at least be aware, however, of the limitations of existing methodologies in this area and the need for additional data when confronted with the flow needs of endangered species.

Studies to date suggest that less than virgin or pristine flows are required for recreation (Shelby et al. 1992) and conservation (Tennant 1976, Bulak and Jobsis 1989, Orth and Leonard 1990). Preservation of the "natural" qualities of wilderness area streams is an entirely different goal, and there is a general lack of consensus on flow requirements necessary to maintain this natural character (Brown 1991). Recommendations for wilderness area streams have varied considerably and range from 30% to 90% of mean annual virgin flows (Jackson et al. 1987, Van Haveren et al. 1987, Shelby et al. 1990, Vandas et al. 1990). The limited research available indicates higher flow requirements in wilderness areas to meet more multifaceted needs than are typically reserved for recreation and conservation. Current management trends also suggest that virgin flows may not typically be required. Clearly, streams in wilderness areas or those otherwise possessing unique natural character should be given special consideration when assessing instream flow requirements (Brown 1991).

AN INSTREAM FLOW POLICY FOR GEORGIA

A policy statement for establishing instream flow requirements should be based on a methodology that is broadly applicable, inexpensive to apply, and scientifically defensible (Metzger and Haverkamp 1983). Georgia's current instream flow policy meets the first two of these requisites, but does not meet the last since the 7Q10 represents a drought flow which causes significant degradation of stream communities if allowed to occur frequently or for extended periods. Such impacts are not defensible in light of Georgia EPD Rules and Regulations for Water Quality Control (GaDNR 1993) which address the need to improve and maintain the biological integrity of state waters, and were developed to satisfy the U.S. Environmental Protection Agency's (EPA) directive to meet requirements of the Federal Clean Water Act (U.S. EPA 1990).

A number of office methods were used to calculate flow recommendations for 31 test streams (Figure 1) in an effort to determine which offers the best protection for Georgia streams, and ultimately to recommend a method or methods that would meet the four criteria established to fulfill the objective of this study (see page 1). Using the various methods, flow recommendations were calculated from U. S. Geological Survey gaging records (Stokes and McFarlane 1993) and tables summarizing comparisons at 16 representative sites are placed in the Appendix to this report. The sites were distributed throughout all of Georgia's physiographic regions and average annual discharges (AAD) ranged from 5.0 to 13,500 cfs. Results indicated that Tennant's original method (Tennant 1976), with some modifications similar to those developed in Arkansas (Filipek et al. 1987) and South Carolina (Bulak and Jobsis 1989) would provide adequate habitat protection for most of the state's streams. Recommended flows for various categories of streams, with justifications, are provided below.

Unregulated Streams

Various water withdrawal/diversion projects and impoundments alter stream flows in a variety of ways, but the greatest potential for adverse impacts occurs during periods of naturally low flows, when usable habitat can be especially vulnerable to flow reductions or other modifications. Development projects will have

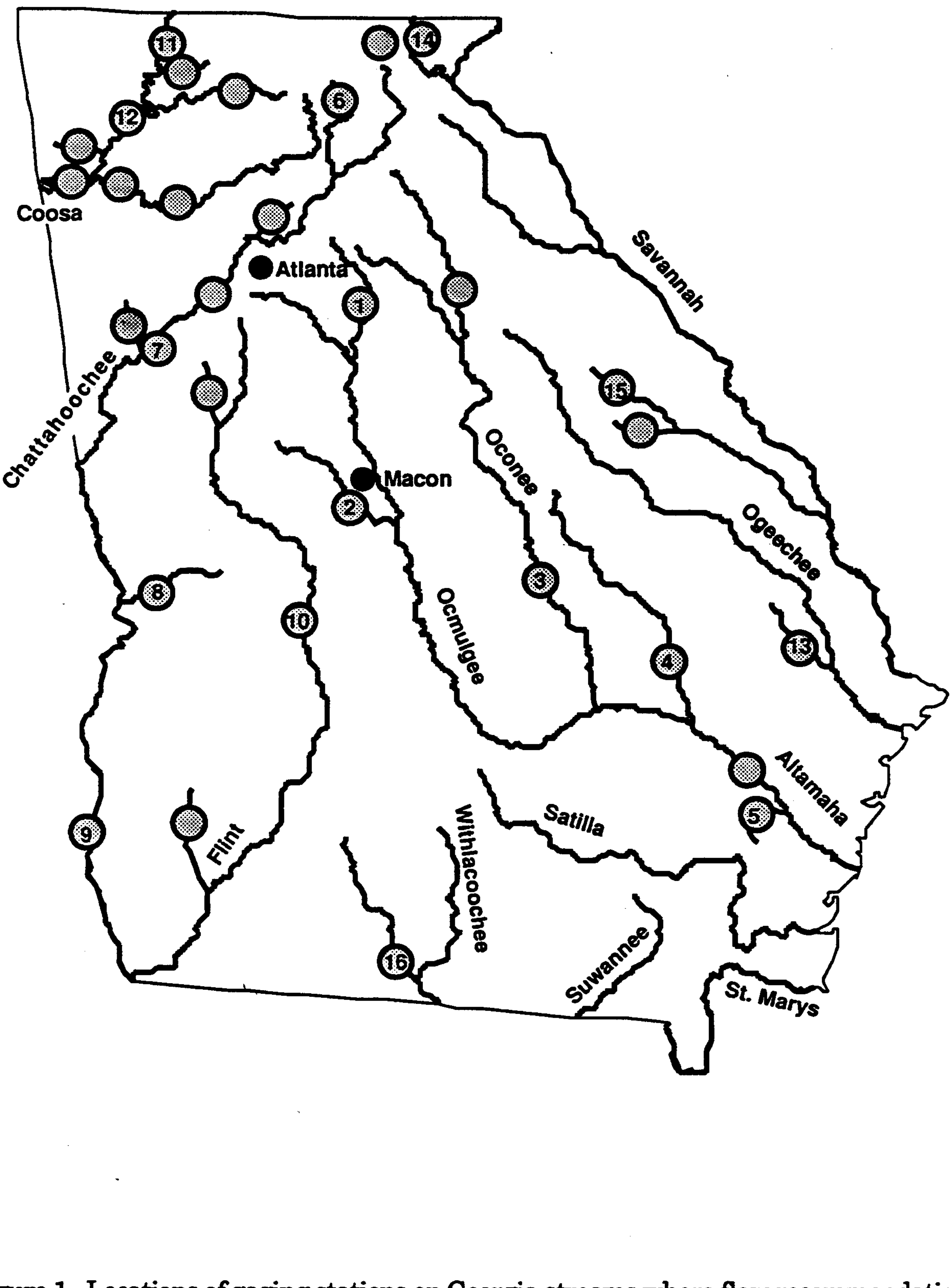

Figure 1. Locations of gaging stations on Georgia streams where flow recommendations were compared using several instream flow protection methods. Numbered locations correspond to table numbers in the Appendix.

little impact on seasonal flushing flows that maintain normal channel morphology unless they are capable of regulating most or all of the flow, as is the case with large dams and diversions. Consequently, there is no need to require seasonal high flows on unregulated streams, and a policy governing flow requirements can be simplified by recognizing this fact.

Warm Water Streams

Tennant's original recommendation of 30% AAD appears to be the best method for protecting Georgia's unregulated warm water streams. The extensive literature review conducted for this report clearly documents the broad applicability of the Tennant method to Georgia's warm water streams, and this was verified by an analysis of flow records from streams across the state (Appendix Tables A1-A16). The same analysis also indicated that the 20% AAD value recommended by the South Carolina method (Bulak and Jobsis 1989) for the low flow season would provide less protection than 7Q10 flows in some Georgia streams. Thirty-percent of AAD is the lowest flow which would afford adequate protection for the full range of warm water streams found in Georgia. Although the Arkansas method (Filipek et al. 1987) may provide a somewhat higher level of protection by specifying a percentage of mean monthly flow for various seasons, the differences are minor in most streams during the low flow season. The Arkansas method lacks the ease of application and understanding of the Tennant method and thus probably has less chance of being accepted by both regulators and developers.

Trout Streams

Many Blue Ridge Province streams in north-central and northeastern Georgia, most of which are high gradient trout streams, exhibit relationships among flow parameters such as average annual discharge, mean monthly flow, and the 7Q10 flow which are dissimilar to such relationships in streams in other regions of the state. As a result, relationships between fixed percentages of average discharge and available fish habitat are inadequately documented, and a more conservative methodology such as the aquatic base flow is needed to assure protection. Some researchers have reached similar conclusions regarding mountain streams in western North Carolina (James Mead, North Carolina Division of Water Resources, Raleigh, North Carolina, personal communication).

Flows in Georgia trout streams typically are lowest in September, but highest water temperatures usually occur in late July or early August. Water temperature during this critical summer period defines the lower elevation limit of trout habitat in this southern-most area of the eastern United States that is capable of supporting natural trout populations. It is therefore imperative to protect August flows because abnormally low flows at a time when water temperatures are highest may have a greater impact on trout populations through stream warming than from dewatering of habitat.

The regional modification of the aquatic base flow recommended by Reed and Mead (1990) for mountain streams in North Carolina (September median flow) would provide less protection for most Georgia trout streams than the original New England Aquatic Base Flow Method (August median flow) because it would be based on somewhat lower flows. However, since September median flows appear to be comparable to normal August low flows, this modification should still provide a reasonable level of protection without placing unnecessary restrictions on other water users. Since trout streams are separately classified and clearly delineated in water quality regulations, applying this simple yet relatively conservative method (September median flow) to already designated trout streams would achieve a good compromise between the need for additional protection in the Blue Ridge Province and the need for a defensible policy that is easy to understand and apply.

Regulated Streams

For regulated streams, the requirement for seasonal flow variability must be reconciled with the need for simplicity in a statewide policy designed to establish general guidelines. Flow requirements for Georgia's regulated streams are based on the same low flow, high flow, and increasing or decreasing flow seasons specified by the South Carolina method, except that for simplicity the same flows are specified for all physiographic provinces. Analysis of flow records statewide showed only minor differences in seasonal flow patterns between streams in the Coastal Plain, Piedmont, and Ridge and Valley provinces.

The rationale for using the Tennant method to protect low flows in unregulated streams (30% AAD) has already been discussed, and the same rationale applies to regulated streams because of the same need to protect aquatic habitat from dewatering. While the 20% AAD low flow season recommendation adopted by South Carolina was demonstrated inadequate for Georgia based on flow records, the same records provide no reason to doubt that South Carolina's recommendations for the intermediate and high flow seasons (40% and 60%, respectively) would be adequate for Georgia. South Carolina's recommendations are based on field evaluations of flow-habitat relationships (Bulak and Jobsis 1989), and should be considered adequate for Georgia's hydrologically similar streams until better field data are available.

Special Case Streams

A general or statewide instream flow policy must address the special flow requirements of more significant or unique stream resources. These "special case" streams or reaches possess characteristics which require careful field study before appropriate flows can be determined and would be identified on a case-by-case basis by the Wildlife Resources Division of GaDNR, or other appropriate state agencies. They could include the habitat of threatened or endangered species, candidate species, species of special concern, certain anadromous species, and higher quality trout waters. Stream reaches containing unique sport fisheries and wilderness area streams may also be considered in this category.

Final instream flow requirements for special case streams should be formulated only after collecting the requisite site-specific information, but the general or statewide method may be applied until site-specific studies have been completed. Information needs in each case should be determined by Fisheries Section personnel. The appropriate assessment methodology must be tailored to the particular scenario and studies, where warranted, conducted by experienced consultants. Fisheries Section personnel should be closely involved in the planning, implementation, and analysis phases of these investigations. Special case streams would constitute a very limited portion of the state's total waters, but should be given careful study before determining allowable water uses.

Peaking Hydropower Projects

A separate strategy is required for peaking hydropower projects. Since these projects cause frequent, rapid, and often pronounced changes in stream flow, a generalized flow policy designed for statewide use may not be adequate to protect aquatic life and stream channel integrity. In addition to requirements for adequate base flows, there is often a need to address flow seasonality, the rate of change in flow, and a variety of other issues. To adequately evaluate the full range of potential impacts, and to determine whether complex flow scenarios are required to protect downstream resources, peaking hydropower projects should be evaluated using the best available field research methodologies (currently the IFIM).

Summary

A summary of the proposed instream flow policy for Georgia streams is provided in Table 3. All flow requirements represent instantaneous flows, rather than daily, monthly, or other time period averages. Averaging over various time periods may result in periodic low or even no flow (Tennant 1976).

Table 3. Recommended instantaneous instream flows to protect aquatic life in Georgia streams.

Category/sub-category	Season	Recommended Protective Flow
Unregulated Streams		
Warm water streams	All	30% average annual discharge
Trout streams	All	September median flow
Regulated Streams	July through November	30% average annual discharge
	January through April	60% average annual discharge
	May, June, December	40% average annual discharge
Special Case Streams: Approved field studies to determine flow requirements		
Peaking Hydropower Projects: Site-specific IFIM studies to determine flow requirements		

A review of the literature suggests that the recommended general methodology will protect, but not enhance, stream resources. Flow reductions substantially below those provided by these guidelines may be expected to result in the degradation of stream ecosystems. These guidelines should be used to develop a policy for instream flow in Georgia in order to protect flows in all fresh waters of the state.

An important provision of Georgia's instream flow policy should be that, if alternative flow regimes are allowed, justification is provided through site-specific documentation using one or more approved field methodologies. All alternative flow assessment methodologies should be approved by the Fisheries Section.

Any proposed change in the state's method of protecting aquatic resources will take some acclimation time for both regulators and water users. If the method proposed in this report is adopted, it will be a significant step toward meeting Federal Clean Water Act goals of protecting instream biological integrity. It is important to remember that this method represents a compromise between what is optimal biologically for all streams and the need for guidelines which are easy to understand and acceptable to all concerned parties.

There remains a need to further evaluate stream flow characteristics across the state and to better assess the effects of altered flow regimes on fish communities, macroinvertebrates, and stream channel morphology. Such continued evaluation is needed to understand a wide range of flow-related issues vital to the long-term protection of stream ecosystems. As new information becomes available, methods for protecting stream ecosystems should be refined. While recognizing this fact, it should be emphasized that the policy proposed in this report is based on the best scientific data currently available, and delays in implementation will lead to further losses of aquatic species and continued habitat degradation.

As aquatic systems continue to be impacted by increasing human population pressures, opportunities to improve protective mechanisms for most ecosystems will shrink. Understanding these basic concepts will help all citizens recognize the need to replace outdated stream flow protection policies before further opportunities are lost.

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GLOSSARY OF FLOW TERMINOLOGY

The following definitions apply to terms used in this report to express volume of stream flow. Unless specific references are given, all definitions were formulated by the authors from generally accepted usage of the terms.

Aquatic base flow or New England Aquatic Base Flow Method: The median monthly flow during the month of August (Larson 1981).

Average annual discharge: The average instantaneous flow throughout the year, averaged for the period of record. This can be calculated by adding all the daily flows (the average flow for each day) throughout each year and dividing by the number of days in the year. Average flows for all years are then added and the number is divided by the number of years of record. This is the same as the mean annual flow.

Instantaneous flow: The amount of water flowing past a given point during one second. (Christopher C. Estes, Alaska Dept. of Fish and Game, Anchorage, Alaska, Personal communication).

Mean annual flow: The same as average annual discharge.

Mean annual daily flow: The same as average annual discharge.

Mean monthly flow: The average instantaneous flow throughout a single month, for the period of record. This can be calculated by adding all the daily flows throughout the month (January for example) and dividing by the number of days in the month. Average flows in that month (January) would then be averaged for all years for which records are available for that month (average of all January flows).

Mean monthly flow for a season: Calculated the same as the mean monthly flow except it is calculated for a number of months or other specific time period.

Median monthly flow: The average instantaneous flow during a day, compared to which half the remaining daily flows in that month are greater and half are less.

Non-depletable flow: "The 7Q10 flow plus an additional flow needed to ensure the availability of water to downstream users" (GaDNR 1993). The non-depletable flow is calculated by adding the 7Q10 flow to the pro-rata share of the downstream withdrawal, using the drainage area ratio method. For example, if the 7Q10 flow is 100 cfs and the actual stream flow is 110 cfs, an upstream user permitted for 10 cfs could not withdraw the entire 10 cfs if another permitted withdrawal existed farther downstream. In such a case, the upstream user would allow 100 cfs plus a pro rata share of the remaining 10 cfs to pass for the downstream user.

Regulated flow: Stream flow that is controlled by a project that is capable of storing enough water to substantially alter the downstream flow regime, or hydrograph. Projects that regulate flow include dams built for flood control, peaking power generation, navigation releases, or water supply.

7Q10 (Seven-Q-ten): The lowest average stream flow expected to occur for seven consecutive days with an average frequency of once in ten years (GaDNR 1993). The 7Q10 is a flow statistic used to simulate drought conditions in water quality modeling to evaluate waste load allocation.

Wetted perimeter: The boundary distance measured perpendicular to the flow across the bottom and sides of a channel cross section that is in contact with the water at the time of the measurement (Stalnaker et al. 1994; Christopher C. Estes, Alaska Dept. of Fish and Game, Anchorage, Alaska, personal communication).

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APPENDIX

Table A1. Analysis of flow records from the Alcovy River, along with comparisons of the instantaneous flows in cubic feet per second (cfs) and corresponding percent of average annual discharge (AAD) reserved by various methods to protect instream flow from excessive withdrawals. Data are from USGS gage number 02208450, located in the Piedmont Physiographic Region (Altamaha River Basin) near Covington, Georgia. The drainage area above this gage is 185 square miles and the average stream gradient is 8.4 feet per mile.

	Gaged Flow		Arkansas		So. Carolina		Sept. Median		Georgia		7Q10	
Month	Average	Median	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD
January	358	379	215	89	96	40	95	40	144	60	10	4
February	392	405	235	98	96	40	95	40	144	60	10	4
March	436	363	262	109	96	40	95	40	144	60	10	4
April	354	310	248	103	96	40	95	40	144	60	10	4
May	248	222	174	72	72	30	95	40	96	40	10	4
June	158	133	111	46	72	30	95	40	96	40	10	4
July	130	102	65	27	48	20	95	40	72	30	10	4
August	141	144	71	29	48	20	95	40	72	30	10	4
September	112	95	56	23	48	20	95	40	72	30	10	4
October	132	98	66	28	48	20	95	40	72	30	10	4
November	158	143	95	40	48	20	95	40	72	30	10	4
December	259	199	155	65	72	30	95	40	96	40	10	4

AAD is equal to 240 cfs - based on a 21 year period of record through 1992.

Table A2. Analysis of flow records from Tobesofkee Creek, along with comparisons of the instantaneous flows in cubic feet per second (cfs) and corresponding percent of average annual discharge (AAD) reserved by various methods to protect instream flow from excessive withdrawals. Data are from USGS gage number 02213500, located in the Piedmont Physiographic Region (Altamaha River Basin) near Macon, Georgia. The drainage area above this gage is 182 square miles and the average stream gradient is 9.6 feet per mile.

	Gaged Flow		Arkansas		So. Carolina		Sept. Median		Georgia		7Q10	
Month	Average	Median	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD
January	285	265	171	91	76	40	52	28	113	60	8.5	4
February	357	361	214	113	76	40	52	28	113	60	8.5	4
March	424	356	254	135	76	40	52	28	113	60	8.5	4
April	320	250	224	118	76	40	52	28	113	60	8.5	4
May	182	142	128	67	57	30	52	28	76	40	8.5	4
June	105	94	73	39	57	30	52	28	76	40	8.5	4
July	104	81	52	28	38	20	52	28	57	30	8.5	4
August	86	71	43	23	38	20	52	28	57	30	8.5	4
September	60	52	30	16	38	20	52	28	57	30	8.5	4
October	64	41	32	17	38	20	52	28	57	30	8.5	4
November	93	59	56	29	38	20	52	28	57	30	8.5	4
December	198	141	119	63	57	30	52	28	76	40	8.5	4

AAD is equal to 189 cfs - based on a 56 year period of record through 1992.

Table A3. Analysis of flow records from the Oconee River, along with comparisons of the instantaneous flows in cubic feet per second (cfs) and corresponding percent of average annual discharge (AAD) reserved by various methods to protect instream flow from excessive withdrawals. Data are from USGS gage number 02223500, located in the Coastal Physiographic Region (Altamaha River Basin) near Dublin, Georgia. The drainage area above this gage is 4,400 square miles and the average gradient is 3 feet per mile. Flow at this site is regulated by lakes Oconee and Sinclair; data presented here include records before and after regulation, which began in 1953.

	Gaged Flow		Arkansas		So. Carolina		Sept. Median		Georgia		7Q10	
Month	Average	Median	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD
January	6,863	6,181	4,118	84	2,939	60	1,716	35	2,939	60	570	12
February	8,614	7,908	5,168	106	2,939	60	1,716	35	2,939	60	570	12
March	10,095	8,390	6,057	124	2,939	60	1,716	35	2,939	60	570	12
April	7,435	6,241	5,205	106	2,939	60	1,716	35	2,939	60	570	12
May	4,377	3,435	3,064	63	1,959	40	1,716	35	1,959	40	570	12
June	3,346	2,460	2,342	48	1,959	40	1,716	35	1,959	40	570	12
July	3,204	2,553	1,602	33	980	20	1,716	35	1,469	30	570	12
August	3,040	2,370	1,520	31	980	20	1,716	35	1,469	30	570	12
September	2,270	1,716	1,135	23	980	20	1,716	35	1,469	30	570	12
October	2,502	1,986	1,251	26	980	20	1,716	35	1,469	30	570	12
November	2,489	2,138	1,493	30	980	20	1,716	35	1,469	30	570	12
December	4,547	3,322	2,728	56	1,959	40	1,716	35	1,959	40	570	12

AAD is equal to 4,898 cfs - based on a 95 year period of record through 1992.

Table A4. Analysis of flow records from the Ohoopee River, along with comparisons of the instantaneous flows in cubic feet per second (cfs) and corresponding percent of average annual discharge (AAD) reserved by various methods to protect instream flow from excessive withdrawals. Data are from USGS gage number 02225500, located in the Coastal Physiographic Region (Altamaha River Basin) near Reidsville, Georgia. The drainage area above this gage is 1,110 square miles and the average gradient is 3.8 feet per mile.

	Gaged Flow		Arkansas		So. Carolina		Sept. Median		Georgia		7Q10	
Month	Average	Median	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD
January	1,452	1,271	871	87	601	60	270	27	601	60	34	3
February	2,154	1,940	1,292	129	601	60	270	27	601	60	34	3
March	2,468	2,060	1,481	148	601	60	270	27	601	60	34	3
April	1,709	1,444	1,197	120	601	60	270	27	601	60	34	3
May	734	644	514	51	400	40	270	27	400	40	34	3
June	497	323	348	35	400	40	270	27	400	40	34	3
July	533	317	266	27	200	20	270	27	300	30	34	3
August	623	327	312	31	200	20	270	27	300	30	34	3
September	455	270	227	23	200	20	270	27	300	30	34	3
October	418	170	209	21	200	20	270	27	300	30	34	3
November	353	136	212	21	200	20	270	27	300	30	34	3
December	812	314	487	49	400	40	270	27	400	40	34	3

AAD is equal to 1,001 cfs - based on a 61 year period of record through1992.

Table A5. Analysis of flow records from Penholoway Creek, along with comparisons of the instantaneous flows in cubic feet per second (cfs) and corresponding percent of average annual discharge (AAD) reserved by various methods to protect instream flow from excessive withdrawals. Data are from USGS gage number 02226100, located in the Coastal Physigraphic Region (Altamaha River Basin) near Jesup, Georgia. The drainage area above this gage is 210 square miles and the average stream gradient is 1.3 feet per mile.

	Gaged Flow		Arkansas		So. Carolina		Sept. Median		Georgia		7Q10	
Month	Average	Median	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD
January	252	191	151	81	113	60	79	42	113	60	0	0
February	341	331	204	109	113	60	79	42	113	60	0	0
March	381	225	228	121	113	60	79	42	113	60	0	0
April	220	100	154	82	113	60	79	42	113	60	0	0
May	87	36	61	33	75	40	79	42	75	40	0	0
June	120	42	84	45	75	40	79	42	75	40	0	0
July	167	113	83	44	38	20	79	42	56	30	0	0
August	233	159	117	62	38	20	79	42	56	30	0	0
September	182	79	91	48	38	20	79	42	56	30	0	0
October	96	28	48	26	38	20	79	42	56	30	0	0
November	44	4	26	14	38	20	79	42	56	30	0	0
December	132	32	79	42	75	40	79	42	75	40	0	0

AAD is equal to 188 cfs - based on a 35 year period of record through 1992.

Table A6. Analysis of flow records from the Chestatee River, along with comparisons of the instantaneous flows in cubic feet per second (cfs) and corresponding percent of average annual discharge (AAD) reserved by various methods to protect instream flow from excessive withdrawals. Data are from USGS gage number 02333500 located in the Mountain Physiographic Region (Apalachicola River Basin) near Dahlonega, Georgia. The drainage area above this gage is 153 square miles and the average stream gradient is 28.7 feet per mile.

	Gaged Flow		Arkansas		So. Carolina		Sept. Median		Georgia		7Q10	
Month	Average	Median	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD
January	460	408	276	76	146	40	174	48	218	60	69	19
February	530	498	318	87	146	40	174	48	218	60	69	19
March	605	553	363	100	146	40	174	48	218	60	69	19
April	530	504	371	102	146	40	174	48	218	60	69	19
May	410	385	287	79	109	30	174	48	146	40	69	19
June	302	280	211	58	109	30	174	48	146	40	69	19
July	269	221	134	37	73	20	174	48	109	30	69	19
August	259	217	129	36	73	20	174	48	109	30	69	19
September	209	174	104	29	73	20	174	48	109	30	69	19
October	202	179	101	28	73	20	174	48	109	30	69	19
November	249	214	149	41	73	20	174	48	109	30	69	19
December	363	294	218	60	109	30	174	48	146	40	69	19

AAD is equal to 364 cfs - based on a 57 year period of record through 1992.

Table A7. Analysis of flow records from the Chattahoochee River, along with comparisons of the instantaneous flows in cubic feet per second (cfs) and corresponding percent of average annual discharge (AAD) reserved by various methods to protect instream flow from excessive withdrawals. Data are from USGS gage number 02338000, located in the Piedmont Physiographic Region (Apalachicola River Basin) near Whitesburg, Georgia. The drainage area above this gage is 2,430 square miles and the average stream gradient is 4.1 feet per mile. Flow at this site is regulated by Lake Lanier; data presented here include records before and after regulation, which began in 1956.

	Gaged Flow		Arkansas		So. Carolina		Sept. Median		Georgia		7Q10	
Month	Average	Median	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD
January	4,961	4,015	2,977	75	1,586	40	2,737	69	2,379	60	1,400	35
February	5,313	4,681	3,188	80	1,586	40	2,737	69	2,379	60	1,400	35
March	6,173	5,486	3,704	93	1,586	40	2,737	69	2,379	60	1,400	35
April	5,448	4,806	3,814	96	1,586	40	2,737	69	2,379	60	1,400	35
May	4,229	3,873	2,960	75	1,190	30	2,737	69	1,586	40	1,400	35
June	3,243	3,011	2,270	57	1,190	30	2,737	69	1,586	40	1,400	35
July	3,222	3,078	1,611	41	793	20	2,737	69	1,190	30	1,400	35
August	3,206	3,250	1,603	40	793	20	2,737	69	1,190	30	1,400	35
September	2,807	2,737	1,404	35	793	20	2,737	69	1,190	30	1,400	35
October	2,586	2,564	1,293	33	793	20	2,737	69	1,190	30	1,400	35
November	2,920	2,452	1,752	44	793	20	2,737	69	1,190	30	1,400	35
December	3,398	2,927	2,039	51	1,190	30	2,737	69	1,586	40	1,400	35

AAD is equal to 3,965 cfs - based on a 44 year period of record through 1992.

Table A8. Analysis of flow records from Upatoi Creek, along with comparisons of the instantaneous flows in cubic feet per second (cfs) and corresponding percent of average annual discharge (AAD) reserved by various methods to protect instream flow from excessive withdrawals. Data are from USGS gage number 02341800, located in the Piedmont Physiographic Region (Apalachicola River Basin) near Columbus, Georgia. The drainage area above this gage is 342 square miles and the average stream gradient is 6.5 feet per mile.

	Gaged Flow		Arkansas		So. Carolina		Sept. Median		Georgia		7Q10	
Month	Average	Median	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD
January	665	664	399	89	180	40	174	39	269	60	70	16
February	768	715	461	103	180	40	174	39	269	60	70	16
March	1,004	909	602	134	180	40	174	39	269	60	70	16
April	733	608	513	114	180	40	174	39	269	60	70	16
May	377	342	264	59	135	30	174	39	180	40	70	16
June	259	250	181	40	135	30	174	39	180	40	70	16
July	259	210	129	29	90	20	174	39	135	30	70	16
August	263	245	132	29	90	20	174	39	135	30	70	16
September	197	174	99	22	90	20	174	39	135	30	70	16
October	182	166	91	20	90	20	174	39	135	30	70	16
November	246	217	148	33	90	20	174	39	135	30	70	16
December	428	349	257	57	135	30	174	39	180	40	70	16

AAD is equal to 449 cfs - based on a 25 year period of record through 1992.

Table A9. Analysis of flow records from the Chattahoochee River, along with comparisons of the instantaneous flows in cubic feet per second (cfs) and corresponding percent of average annual discharge (AAD) reserved by various methods to protect instream flow from excessive withdrawals. Data are from USGS gage number 02343801, located in the Coastal Physiographic Region (Apalachicola River Basin) near Columbia, Alabama. The drainage area above this gage is 8,210 square miles. 7Q10 is not applicable at this highly regulated location. Flow is regulated by lakes Andrews, George, Harding, West Point, and Lanier.

	Gaged Flow		Arkansas		So. Carolina		Sept. Median		Georgia		7Q10	
Month	Average	Median	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD
January	13,860	12,980	8,316	78	6,378	60	6,383	60	6,378	60	NA	NA
February	16,100	15,910	9,660	91	6,378	60	6,383	60	6,378	60	NA	NA
March	19,130	19,360	11,478	108	6,378	60	6,383	60	6,378	60	NA	NA
April	14,870	13,820	10,409	98	6,378	60	6,383	60	6,378	60	NA	NA
May	10,360	8,541	7,252	68	4,252	40	6,383	60	4,252	40	NA	NA
June	7,837	8,208	5,486	52	4,252	40	6,383	60	4,252	40	NA	NA
July	7,128	6,472	3,564	34	2,126	20	6,383	60	3,189	30	NA	NA
August	7,327	7,307	3,663	34	2,126	20	6,383	60	3,189	30	NA	NA
September	6,488	6,383	3,244	31	2,126	20	6,383	60	3,189	30	NA	NA
October	6,572	5,875	3,286	31	2,126	20	6,383	60	3,189	30	NA	NA
November	7,396	5,955	4,438	42	2,126	20	6,383	60	3,189	30	NA	NA
December	10,770	8,776	6,462	61	4,252	40	6,383	60	4,252	40	NA	NA

AAD is equal to 10,630 cfs - based on a 17 year period of record through 1992.

Table A10. Analysis of flow records from the Flint River, along with comparisons of the instantaneous flows in cubic feet per second (cfs) and corresponding percent of average annual discharge (AAD) reserved by various methods to protect instream flow from excessive withdrawals. Data are from USGS gage number 02349500, located in the Coastal Physiographic Region (Apalachicola River Basin) near Montezuma, Georgia. The drainage area above this gage is 2,900 square miles and the average stream gradient is 3.8 feet per mile.

	Gaged Flow		Arkansas		So. Carolina		Sept. Median		Georgia		7Q10	
Month	Average	Median	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD
January	4,896	4,701	2,937	83	2,120	60	1,488	42	2,120	60	680	19
February	5,889	5,416	3,533	100	2,120	60	1,488	42	2,120	60	680	19
March	6,732	5,966	4,039	114	2,120	60	1,488	42	2,120	60	680	19
April	5,696	4,777	3,987	113	2,120	60	1,488	42	2,120	60	680	19
May	3,350	2,830	2,345	66	1,414	40	1,488	42	1,414	40	680	19
June	2,414	2,300	1,690	48	1,414	40	1,488	42	1,414	40	680	19
July	2,397	2,082	1,199	34	707	20	1,488	42	1,060	30	680	19
August	2,120	2,067	1,060	30	707	20	1,488	42	1,060	30	680	19
September	1,570	1,488	785	22	707	20	1,488	42	1,060	30	680	19
October	1,663	1,360	832	24	707	20	1,488	42	1,060	30	680	19
November	2,000	1,719	1,200	34	707	20	1,488	42	1,060	30	680	19
December	3,519	2,808	2,111	60	1,414	40	1,488	42	1,414	40	680	19

AAD is equal to 3,534 cfs - based on a 72 year period of record through 1992.

Table A11. Analysis of flow records from the Conasauga River, along with comparisons of the instantaneous flows in cubic feet per second (cfs) and corresponding percent of average annual discharge (AAD) reserved by various methods to protect instream flow from excessive withdrawals. Data are from USGS gage number 02384500 located in the Mountain Physiographic Region (Mobile River Basin) near Eton, Georgia. The drainage area above this gage is 252 square miles and the average stream gradient is 25.7 feet per mile.

	Gaged Flow		Arkansas		So. Carolina		Sept. Median		Georgia		7Q10	
Month	Average	Median	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD
January	764	716	458	96	192	40	123	26	288	60	36	8
February	1,083	956	650	135	192	40	123	26	288	60	36	8
March	810	809	486	101	192	40	123	26	288	60	36	8
April	520	412	364	76	192	40	123	26	288	60	36	8
May	467	232	327	68	144	30	123	26	192	40	36	8
June	292	168	204	43	144	30	123	26	192	40	36	8
July	211	203	106	22	96	20	123	26	144	30	36	8
August	153	164	77	16	96	20	123	26	144	30	36	8
September	172	123	86	18	96	20	123	26	144	30	36	8
October	231	137	116	24	96	20	123	26	144	30	36	8
November	354	226	212	44	96	20	123	26	144	30	36	8
December	733	536	440	92	144	30	123	26	192	40	36	8

AAD is equal to 480 cfs - based on an 11 year period of record through 1992.

Table A12. Analysis of flow records from the Oostanaula River, along with comparisons of the instantaneous flows preserved by various methods to protect instream flow from excessive withdrawals. Data are from USGS gage number 02387500, located in the Mountain Physiographic Region (Mobile River Basin) near Resaca, Georgia. The drainage area above this gage is 1,600 square miles and the average stream gradient is 16 feet per mile. Flow at this site is regulated by Carters Lake and re-regulation dam; data presented here include records before and after regulation, which began in 1975.

	Gaged Flow		Arkansas		So. Carolina		Sept. Median		Georgia		7Q10	
Month	Average	Median	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD
January	4,229	3,695	2,537	90	1,126	40	855	30	1,688	60	340	12
February	5,100	4,751	3,060	109	1,126	40	855	30	1,688	60	340	12
March	5,349	4,933	3,209	114	1,126	40	855	30	1,688	60	340	12
April	4,259	3,887	2,981	106	1,126	40	855	30	1,688	60	340	12
May	2,853	2,227	1,997	71	844	30	855	30	1,126	40	340	12
June	1,990	1,646	1,393	50	844	30	855	30	1,126	40	340	12
July	1,854	1,429	927	33	563	20	855	30	844	30	340	12
August	1,441	1,191	721	26	563	20	855	30	844	30	340	12
September	1,133	855	567	20	563	20	855	30	844	30	340	12
October	1,123	838	562	20	563	20	855	30	844	30	340	12
November	1,630	1,069	978	35	563	20	855	30	844	30	340	12
December	2,929	2,236	1,757	62	844	30	855	30	1,126	40	340	12

AAD is equal to 2,814 cfs - based on a 100 year period of record through 1992.

Table A13. Analysis of flow records from Black Creek, along with comparisons of the instantaneous flows in cubic feet per second (cfs) and corresponding percent of average annual discharge (AAD) reserved by various methods to protect instream flow from excessive withdrawals. Data are from USGS gage number 02202600, located in the Coastal Physiographic Region (Ogeechee River Basin) near Blitchton, Georgia. The drainage area above this gage is 232 square miles and the average stream gradient is 6 feet per mile.

	Gaged Flow		Arkansas		So. Carolina		Sept. Median		Georgia		7Q10	
Month	Average	Median	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD
January	372	266	223	120	112	60	82	44	112	60	1	0
February	433	462	260	139	112	60	82	44	112	60	1	0
March	342	165	205	110	112	60	82	44	112	60	1	0
April	221	253	155	83	112	60	82	44	112	60	1	0
May	128	52	90	48	75	40	82	44	75	40	1	0
June	107	16	75	40	75	40	82	44	75	40	1	0
July	98	6	49	26	37	20	82	44	56	30	1	0
August	175	35	88	47	37	20	82	44	56	30	1	0
September	120	82	60	32	37	20	82	44	56	30	1	0
October	50	14	25	13	37	20	82	44	56	30	1	0
November	81	10	49	26	37	20	82	44	56	30	1	0
December	133	31	80	43	75	40	82	44	75	40	1	0

AAD is equal to 187 cfs - based on a 13 year period of record through 1992.

Table A14. Analysis of flow records from the Tallulah River, along with comparisons of the instantaneous flows in cubic feet per second (cfs) and corresponding percent of average annual discharge (AAD) reserved by various methods to protect instream flow from excessive withdrawals. Data are from USGS gage number 02178400 located in the Mountain Physiographic Region (Savannah River Basin) near Clayton, Georgia. The drainage area above this gage is 56.5 square miles and the average gradient is 72.8 feet per mile.

	Gaged Flow		Arkansas		So. Carolina		Sept. Median		Georgia		7Q10	
Month	Average	Median	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD
January	229	219	138	73	76	40	88	47	88	47	42	22
February	270	225	162	86	76	40	88	47	88	47	42	22
March	289	271	173	92	76	40	88	47	88	47	42	22
April	260	229	182	96	76	40	88	47	88	47	42	22
May	218	202	153	81	57	30	88	47	88	47	42	22
June	169	160	118	63	57	30	88	47	88	47	42	22
July	126	112	63	33	38	20	88	47	88	47	42	22
August	134	118	67	35	38	20	88	47	88	47	42	22
September	109	88	55	29	38	20	88	47	88	47	42	22
October	120	99	60	32	38	20	88	47	88	47	42	22
November	145	132	87	46	38	20	88	47	88	47	42	22
December	197	188	118	62	57	30	88	47	88	47	42	22

AAD is equal to 189 cfs - based on a 29 year period of record through 1992.

Table A15. Analysis of flow records from Brier Creek, along with comparisons of the instantaneous flows in cubic feet per second (cfs) and corresponding percent of average annual discharge (AAD) reserved by various methods to protect instream flow from excessive withdrawals. Data are from USGS gage number 02197520, located in the Piedmont Physiographic Region (Savannah River Basin) near Thomson, Georgia. The drainage area above this gage is 55 square miles and the average stream gradient is 10.1 feet per mile.

	Gaged Flow		Arkansas		So. Carolina		Sept. Median		Georgia		7Q10	
Month	Average	Median	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD
January	89	94	53	116	18	40	5	11	28	60	12	26
February	101	90	61	132	18	40	5	11	28	60	12	26
March	123	98	74	160	18	40	5	11	28	60	12	26
April	78	62	54	118	18	40	5	11	28	60	12	26
May	34	27	24	52	14	30	5	11	18	40	12	26
June	16	9	11	25	14	30	5	11	18	40	12	26
July	15	10	8	17	9	20	5	11	14	30	12	26
August	14	5	7	15	9	20	5	11	14	30	12	26
September	9	5	5	10	9	20	5	11	14	30	12	26
October	13	3	6	14	9	20	5	11	14	30	12	26
November	16	10	9	20	9	20	5	11	14	30	12	26
December	42	29	25	55	14	30	5	11	18	40	12	26

AAD is equal to 46 cfs - based on a 26 year period of record through 1992.

Table A16. Analysis of flow records from Okapilco Creek, along with comparisons of the instantaneous flows in cubic feet per second (cfs) and corresponding percent of average annual discharge (AAD) reserved by various methods to protect instream flow from excessive withdrawals. Data are from USGS gage number 02318700, located in the Coastal Physiographic Region (Suwannee River Basin) near Quitman, Georgia. The drainage area above this gage is 269 square miles and the average stream gradient is 6.3 feet per mile.

	Gaged Flow		Arkansas		So. Carolina		Sept. Median		Georgia		7Q10	
Month	Average	Median	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD	Flow	% AAD
January	469	287	281	111	152	60	20	8	152	60	0	0
February	778	697	467	185	152	60	20	8	152	60	0	0
March	770	556	462	183	152	60	20	8	152	60	0	0
April	404	207	283	112	152	60	20	8	152	60	0	0
May	88	43	61	24	101	40	20	8	101	40	0	0
June	59	29	42	16	101	40	20	8	101	40	0	0
July	122	31	61	24	51	20	20	8	76	30	0	0
August	133	56	66	26	51	20	20	8	76	30	0	0
September	40	20	20	8	51	20	20	8	76	30	0	0
October	4	1	2	1	51	20	20	8	76	30	0	0
November	28	3	17	7	51	20	20	8	76	30	0	0
December	159	9	96	38	101	40	20	8	101	40	0	0

AAD is equal to 253 cfs - based on a 13 year period of record through 1992.