INSTREAM FLOW STUDY

PHASE II:

Determination of Minumum Flow Standards to
Protect Instream Uses in Priority Stream Segments

A Report to the South Carolina General Assembly

Report Number 163

South Carolina Water Resources Commission
1201 Main Street, Suite 1100
Columbia, South Carolina

May 1988

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by
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SUMMARY

South Carolina contains an extensive river system which supports diverse populations of fish and wildlife and serves as an important resource to man. Man's interests in streams include both instream and offstream use activities and values. Instream uses occur within natural stream channels and are dependent upon flows of adequate volume and depth. These uses and interests include navigation, recreation, wastewater assimilation, water quality maintenance, habitat for fish and wildlife resources, hydroelectric power generation, and aesthetics. Offstream uses remove water from the stream channel and include such activities as water withdrawals for industrial, municipal, agricultural, and thermoelectric power generation purposes.

Streamflows are affected by both natural factors and man's activities in the river basin. Significant reductions in streamflows adversely impact or eliminate instream uses. In South Carolina, instream use problems result primarily from regulated releases from hydroelectric power projects, and diversions or withdrawals of large portions of flow. Projected growth in offstream water demands and peak electric power needs could further limit available streamflows and impact instream uses.

While the concern for protecting instream uses began in the arid western states, eastern states are now recognizing the need for instream flow protection because of escalating offstream water demand and hydroelectric development. In the Southeast, instream flow concerns are addressed to a limited extent through existing Federal permit and license

procedures (Section 401 Water Quality Certification, Section 404 Permit, Section 10 Permit, and operating licenses and exemptions for hydroelectric power projects); however, many states have conducted special studies, developed policies, and enacted legislation to help further protect instream flows. The State of Georgia has one of the most comprehensive means of protecting streamflows through a statewide surface water withdrawal permit program. Although no comprehensive program exists in South Carolina, instream flows may be additionally protected through the Interbasin Transfer of Water Permit, Construction in Navigable Waters Permit, and drought management activities as authorized in the Drought Response Act of 1985.

In 1983, the General Assembly by Joint Resolution (R115, H2549) directed the Water Resource Commission to identify and prioritize streams in need of low flow protection and recommend minimum flow requirements to protect instream uses. The Commission initiated the Instream Flow Study to develop necessary information to address this directive. Phase I of the study involved the identification and ranking of streams for which minimum flows need to be established, and Phase II involved the determination of minimum flow requirements to protect instream uses for the priority stream segments identified in Phase I. The Water Resources Advisory Committee composed of 23 members representing a broad spectrum of public and private water-related interests was established to provide advice during the study process. While much of the input from committee members was incorporated into the study plan and final reports, not all members were necessarily in full agreement with study methods and findings.

Phase I was completed in 1985 and a report was provided to the General Assembly at that time. During that phase, over 500 stream segments were evaluated and ranked based on their potential for instream use impacts due to low flows. Natural and man-induced factors which affect flows, and relative importance of each segment were considered. Fifteen priority stream segments were identified as having the greatest need for streamflow protection.

During Phase II, site specific data were collected at 31 study sites on nine of the 15 priority stream segments. Six segments (Saluda 1, Saluda 2, Saluda 4, Catawba 2, Wateree 1, and Wateree 2) were located in the Piedmont physiographic region and had flow regulated to some extent by hydroelectric projects. Three segments (Coosawhatchie, Jeffries Creek, and Whippy Swamp) were located in the Coastal Plain and experienced little or no regulation of flow.

Numerous existing instream flow assessment methods were reviewed prior to developing the study methodology. Several methods were utilized to determine minimum flow needs at each study site for each of six, instream use categories (navigation, water quality, fishery resources, run-of-river hydroelectric power production, threatened and endangered species, and unique ecological characteristics). Recommended minimum flow requirements for each stream segment were determined by selecting the highest minimum flow value of all use categories of all study sites within a segment. This procedure assured the protection of all instream uses at an acceptable minimum level throughout the segment.

Recommended minimum flow requirements were determined for each priority stream segment for three time periods:
January-April;

July-November; and May, June, and December (Table 7). Threatened and endangered species were identified on Catawba 2, Wateree 2, and Saluda 1; however, flow requirements to adequately protect these species were not determined because of the need for extensive additional studies.

In general, the minimum flows needed to protect fishery resources were sufficient to also protect all other instream uses, therefore the minimum flow requirement for fisheries was also that for the segment. However, minimum flow requirements for navigation and unique ecological characteristics determined the overall minimum flow requirement for five stream segments during certain time periods. Based on historic monthly flow data for the study segments, sufficient flow has been available in most of the Piedmont segments to meet recommended minimum flow requirements, even during the driest months on record. Streamflows in the Coastal Plain stream segments, however, may occasionally fall below the recommended minimum flow requirements and impair instream uses.

The minimum flow requirements recommended in this report do not represent optimum flow conditions for the respective instream uses, but rather, protect instream uses at an acceptable minimum-level below which some uses would be impaired or eliminated. Because the scope of this study was to determine flow standards to protect only instream uses, potential impacts of the recommended standards on offstream uses were not considered. Therefore, additional studies are needed to quantify economic and operational impacts of the recommended minimum flow requirements on offstream uses and upstream peaking hydroelectric power projects.

Although streamflows are naturally variable and occasional low flows may preclude some instream uses, water uses that withdraw, divert, or withhold water from stream channels can increase the frequency, duration, and severity of low flow occurrences. Only through the implementation of minimum flow standards can adverse impacts to instream uses due to man's activities be avoided or reduced to acceptable levels. In the absence of a comprehensive program to manage streamflows, instream uses may be protected to a limited extent in South Carolina by including minimum flow conditions on existing State and Federal permits and licenses for projects that affect streamflows. The methods and results from this study provide a guide for the protection of instream uses for stream segments throughout South Carolina.

ACKNOWLEDGEMENTS

The successful completion of this study required considerable cooperation and assistance from several individuals and organizations. Foremost, grateful appreciation is extended to all the members of the Water Resources Advisory Committee. Their input and review of study plans and results throughout the course of the study was extremely valuable and provided a diversity of perspectives. The members' attendance and participation at Committee meetings is also much appreciated.

Many of the study sites occurred downstream of hydroelectric power plants and, thus, required close coordination with Duke Power Company and South Carolina Electric and Gas Company to safely collect field data. The willing cooperation of these companies to provide regulated releases from their hydroelectric projects is greatly appreciated.

Special recognition is due Mr. Jim Bulak with the S.C. Wildlife and Marine Resources Department for coordinating his agency's data analysis and input to fishery resources needs. Thanks are also extended to Mr. Doug Rayner and Mr. John Cely for their review and input regarding endangered species.

Many Water Resources Commission staff members provided valuable assistance during the study. Mr. Buddy Atkins and Mr. Joe Dennis were an essential part of the study team and deserve special recognition for their many months of assistance in field data collection, data analysis and interpretation, and review of the manuscript. Also assisting in field studies were Mr. Terry Steinert and Mr. Phil Fields. Mr. Danny Johnson provided invaluable guidance and encouragement throughout the study and assisted in all aspects. Ms. Karen Shelley assisted in writing and preparation of the report. The drafts and final report were typed by Mrs. Chris Wood.

INTRODUCTION

South Carolina has over 11,000 miles of rivers and streams. These flowing waters support diverse plant and animal populations in and along their channels, and serve as a vital resource to man for water supply, waste assimilation, power generation, recreational opportunities, and aesthetic enjoyment. Man's use of waters flowing within stream channels falls into two general categories, offstream uses and instream uses. Offstream uses remove water from the stream channel and, depending on the use type, may return some portion back to the channel. Offstream water uses include such activities as industrial processing, domestic water supply, agricultural irrigation, and condenser cooling for thermoelectric power plants. Instream-uses include such activities and interests as navigation, recreation, wastewater assimilation, water quality maintenance, aesthetics, hydroelectric power generation, and maintenance of fish and wildlife resources. The presence of a sufficient amount of water in the stream channel is needed to perpetuate these uses.

Current and projected population and economic growth is placing increasing demands on streams for offstream uses and instream uses alike. However, as withdrawals of water escalate, streamflows become limited and instream uses may become impaired or eliminated. While the full extent of the instream flow problem in South Carolina is not yet known, specific instream use problems have been identified in several streams. Many low-flow problems in South Carolina occur in streams where flows are highly regulated by peaking hydroelectric power facilities. Because power is only generated during periods of peak electric demand, the water used to generate electricity is released through these facilities only when power demands are high. Such releases typically occur during brief periods each day and result in highly variable flows and frequent low-flow conditions downstream. In addition, the withdrawal or diversion of large portions of flow from major stretches of some streams has greatly impaired, and sometimes eliminated, important instream uses in the affected stream channels.

Concern for protecting instream water uses first developed in western states where water supplies are more limited than in the East and where water is.allocated to users under the appropriation doctrine of water rights. Historically, water was allocated to offstream uses based on economic benefit and chronology of use, with little consideration of instream uses. Many western states have since recognized the need to protect instream uses and have developed provisions to reserve a portion of streamflow for these uses. While eastern states generally have abundant supplies of water, the concern for protecting instream uses has intensified because rapidly growing offstream water use demands and hydroelectric development have increased the frequency of instream use conflicts. Many states in the East have recognized the need to protect instream uses and have initiated studies, developed policies, and enacted legislation to ensure the maintenance of suitable flows to support these important uses. In the Southeast, instream flow concerns are addressed primarily through existing federal permit and license procedures (e.g.

Environmental Protection Agency 401 Water Quality Certification and Federal Energy Regulatory Commission hydroelectric project licenses and exemptions). However, many states have conducted special studies and enacted legislation to help protect instream uses.

The State of Georgia probably has one of the most comprehensive means of protecting streamflows through its state surface water withdrawal permitting program. All withdrawals greater than 100,000 gallons per day (on a monthly average) require permits by the State. Minimum flow requirements are included on these permits and withdrawals may be curtailed when streamflows fall below the required minimum.

North Carolina has developed policies and procedures to address instream flow considerations and routinely conducts site specific studies to determine minimum flow requirements. Furthermore, the State has the authority to designate “capacity use areas” in regions where surface water supplies are determined to be limited. In such areas, permits are required for all water withdrawals in excess of 100,000 gallons per day and minimum flow requirements may be included as permit conditions. Although no surface water capacity use areas currently exist in North Carolina, the need for such areas is increasing and one area is currently being evaluated.

Virginia has recently completed an instream flow study (Camp, Dresser and McKee, 1986) and is considering procedures to implement study recommendations. Also, a Water Study Commission has been established to help address instream flow concerns, and a public education program initiated regarding the importance of instream uses.

The Tennessee Water Quality Control Act authorizes that state to permit any activity which alters the “physical, chemical, radiological, biological, or bacteriological properties of any waters of the state;” and to specifically permit diversions of water for the purpose of electric power generation. The State of Tennessee includes minimum flow requirements on state “Aquatic Resource Alteration Permits” which are required for all significant withdrawals and diversions for hydroelectric power projects.

In 1984, Alabama conducted a study to assess streamflows and water quality impacts from hydroelectric projects (Alabama Department of Environmental Management, 1984). Results indicated low flow impacts below hydroelectric projects throughout the state. Subsequent to the report, legislation has been proposed, although not enacted, to develop a comprehensive water management program which included the protection of instream flow.

In South Carolina, the importance of maintaining instream water uses was recognized in a management plan for the Yadkin-Pee Dee River Basin which recommended that the States of North Carolina and South Carolina “...develop criteria for protecting all instream uses of water” (U.S.

Water Resources Council, 1981). The Water Law Review Committee appointed by Governor Richard W. Riley in 1982 also recognized the importance of instream uses, stating that: "A minimum amount of water should be maintained to support instream needs in rivers, streams and lakes. The State should, giving due consideration to existing uses, determine instream flow needs and consider those needs in reviewing present and future development" (Governor's State Water Law Review Committee, 1982).

The Water Law Review Committee submitted the following specific recommendations regarding instream flow needs.

"1. That the State adopt a policy recognizing the need to maintain minimum stream flows;
2. That an agency, or agencies, be directed to determine the appropriate procedures for the establishment of instream flow requirements;
3. That the State agencies be directed to consider the maintenance of minimum stream flow under their existing authority until comprehensive instream flow legislation can be developed and implemented;
4. That legislation to provide for the establishment and maintenance of instream flows be developed and implemented in a timely manner;
5. That all future construction affecting the flow of a stream or river be designed to accommodate minimum instream flow needs."

The S.C. Water Resources Commission further addressed the issue of instream flows in the State Water Assessment (S.C. Water Resources Commission, 1983). In addition to identifying existing and potential areas with instream flow conflicts, the Commission concluded that:

> "There is a general lack of recognition of the significance of instream flow needs", and

> "Adequate legal and institutional bases do not exist for the management of instream flows."

In 1985, the General Assembly approved two bills that provided a level of protection for instream.uses during drought and at sites of major interbasin transfers of water. The Drought Response Act of 1985 identifies instream use requirements as one of a few "essential water uses" for which water use cannot be curtailed during periods of severe drought [S.C. Code Section 49-23-70(c) (1976), as amended 1987]. The Interbasin Transfer of Water Act of 1985 requires the S.C. Water Resources Commission, in making permit determinations of water transfers, to:

> "Protect present, and consider projected stream uses of the losing river basin generally and of the losing river specifically, including but not limited to, present agricultural, municipal, industrial and instream uses, and assimilative needs" [S.C. Code Section 49-21-30 C(1) (1976), as amended 1987], and

“Consider whether the project shall have any beneficial or detrimental impact on navigation, hydropower generation, fish and wildlife habitat, aesthetics, or recreation” (S.C. Code Section 49-21-30 C(12) (1976), as amended 1987].

Also, the Act specifies:

“The permit shall require that the interbasin transfer shall cease or decrease when the actual flow of the losing basin is less than a specified minimum required to protect against adverse effects to the basin.” [S.C. Code Section 49-21-30 F (1976), as amended 1987], and

“No transfer of water may be permitted at any time which shall cause the remaining flow in the losing river basin to be less than the statistical low flow that occurs for seven consecutive days, once every ten years as established prior to the interbasin transfer.” [S.C. Code Section 49-21-30 E (1976), as amended 1987]

In other words, interbasin transfers of water must be decreased or discontinued when instantaneous flows in the stream of withdrawal reach the minimum flow requirement, and that minimum flow requirements will always be equal to or greater than the seven-day, ten-year low flow (7Q10).

Regulation 19-450 under which the State Budget and Control Board's permitting program for construction activities in navigable waters is administered requires a permit for any construction, alteration, or flow modification in, on, or over navigable waters of the State. Conditions placed on this permit may include minimum instream flow requirements.

The S. C. Department of Health and Environmental Control recognizes the importance of maintaining instream flows to protect water quality. Minimum flow conditions are sometimes placed on 401 Water Quality Certifications issued by that agency for federally permitted projects affecting the State's waters. Also, the State's Water Classifications and Standards (Regulation 61-68) were revised in 1985 to include the protection of streamflows. In the discussion of antidegradation rules, Section C(b) states:

"Existing uses and water quality necessary, to protect these uses are presently affected or may be affected by instream modifications or water withdrawals. Consistent with each riparian landowner's right to reasonable use of water, the streamflows necessary to protect existing uses and the water quality supporting these uses shall be maintained."

Minimum instream flows have also been protected in South Carolina by including such conditions in Federal Energy Regulatory Commission (FERC) Operating Licences and Exemptions for hydroelectric power projects. The State and Federal agencies primarily responsible for protecting instream uses and interests in South Carolina are the S.C. Water Resources Commission, S.C. Department of Health and Environmental Control, S.C. Wildlife and Marine Resources Department, and U.S. Fish and Wildlife Service. These agencies routinely review FERC license applications for hydroelectric power projects and provide comments to the FERC regarding minimum flow releases from proposed projects to protect instream uses.

STUDY OVERVIEW

In 1983, the South Carolina General Assembly in recognizing the importance of instream uses enacted a Joint Resolution (R115, H2549) authorizing a study of the instream flow problem in South Carolina (Appendix A). In the Joint Resolution, the General Assembly recognized that instream uses are "...individually and collectively linked to the continued economic well-being of industries, the health, safety, and welfare of all South Carolinians, and the general attractiveness of South Carolina for future development." In addition, the General Assembly found that "...the effects upon and need for protection of instream uses of water ... will increase." The resolution directs the S.C. Water Resources Commission to "...identify and list the streams and watercourses of the State for which minimum flow levels need to be established, and prepare proposed streamflow standards".

In response to the Legislative directive, the S.C. Water Resources Commission initiated the Instream Flow Study. The study was divided into two phases. Phase I involved the identification and listing of streams for which minimum flows need to be established, and Phase II entailed the determination of minimum flow standards to protect instream uses in the priority streams identified in Phase I.

At the beginning of the study, a committee was established to help advise the Commission during the study. The Water Resources Advisory

Committee (initially called the Instream Flow Advisory Committee) was composed of 23 members representing a broad spectrum of water-related interests including local, State, and Federal government agencies and entities, industry, electric power companies and environmental and professional organizations (Table 1). Committee members and other interested parties were kept informed of study progress and were requested to review and comment on major aspects of the study through written correspondence and periodic meetings. Their input was highly valued and generally incorporated into the study plan. However, committee members served in an advisory capacity only and had no voting authority. Therefore, not all members are necessarily in full agreement with study methods and findings.

Phase I of the study was completed in 1985 and a report was provided to the General Assembly (de Kozlowski, 1985). In the first phase a mathematical procedure was developed to rank streams in priority order based on their potential for instream use problems due to low flows. Natural and man-induced impacts on flows and the relative importance of each stream were considered in the ranking process. Over 500 stream segments were evaluated, of which 15 were identified as having the greatest need for streamflow protection. These priority stream segments included Whippy Swamp, Black Mingo Creek, Jeffries Creek, Combahee River, Sparrow Swamp, South Saluda River, and portions of the Waccamaw River, Saluda River, Coosawhatchie River, Wateree River, Catawba River, and Broad River.

Table 1. Organizations and associated representatives comprising theWater Resources Advisory -Committee..

Organization	Representative
S.C. Department of Health and Environmental Control	Russ Sherer
S.C. Wildlife and Marine Resources Department	Ed Duncan
S.C. Coastal Council	Stephen Snyder
S.C. Department Parks, Recreation and Tourism	Bill McMeekin
S.C. Land Resources Conservation Commission	Penny Kimrey
Governor's Office	Bill Marshall
S.C. Department of Agriculture	William H. Busbee
S.C. State Development Board	Russ McCoy
U.S. Geological Survey	Carroll Barker
U.S. Army Corps of Engineers Charleston District	David Harris
U.S. Army Corps of Engineers Savannah District	Leroy Crosby
U.S. Fish and Wildlife Service	Diane Duncan
Soil Conservation Service	Brian Schmidt
State Farm Bureau	Larry McKenzie
Electric Utilities	Jim Hendricks (Duke Power Company)
Environmental Groups	Betty Spence (S. C. Wildlife Federation)
State Chamber of Commerce	Nick Odom (Springs Mills, Inc.)
State Council of Governments	Bill James
Water Pollution Control Federation	Doug Wendel (Grand Strand Water and Sewer Authority)
S.C. Electric & Gas Company	Jack Preston
Municipalities	Dawkins Dennis (City of Newberry)
Municipal Water Supply	John Bettis (Charleston Commissioners of Public Works)

Phase II of the study was initiated in 1984 with development of the study methodology, and field studies were conducted from 1985 through 1987. This report presents the results of Phase II of the Instream Flow Study.

Description of Study Sites

Studies were conducted on nine of the original 15 priority stream segments identified in Phase I. Three segments were eliminated because of tidal influences and three because of time limitations and low priority ranking. Six of the study segments were located in the Piedmont portion of the State and three were in the Coastal Plain (Figure 1). Study segments ranged in length from five miles to 30 miles. Streamflow of all Piedmont stream segments was regulated to some extent by releases from hydroelectric projects, while Coastal Plain segments experienced little or no regulation of flows.

Following reconnaissance of these segments, thirty-one study sites were established to collect site-specific data to determine minimum flow requirements for each stream segment. The study sites were located primarily at sandy and rocky shoal areas because these areas are the first and most affected by reduced flows and serve as critical sites for fish and boat passage. These are also important locations for fish food organisms and fish spawning activities. Data from up to six study sites per stream segment were collected. Table 2 provides location descriptions of each of these sites.

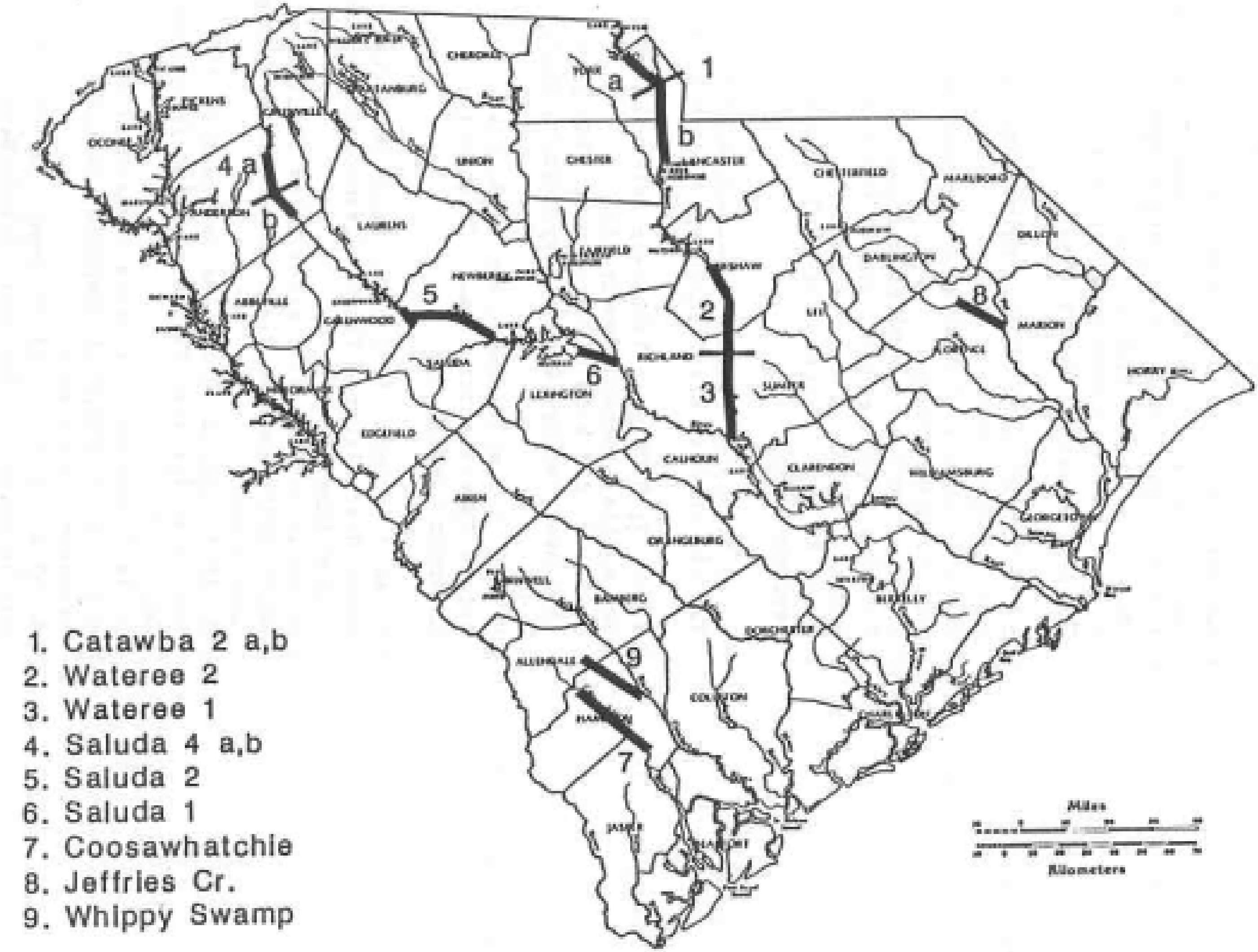

Figure 1. Location of priority stream segments studied.

Table 2. Location description of study sites.

Stream Segment	Site Number	Location Description
Catawba 2(a)	1	River Mile (R.M.) 135.7; approx. 0.5 mile downstream from U.S. Hwy 21 bridge, York County
Catawba 2(b)	2.1	R.M. 115.9; at Lansford Canal State Park, Chester/Lancaster County line
	2.2	R.M. 114.8; at Lansford Canal State Park, Chester/Lancaster County line
Wateree 2	1	R.M. 75.4; approx. 0.75 mile below Wateree Dam, Kershaw County
	2	R.M. 74.7; approx. 1.5 miles below Wateree Dam, Kershaw County
	3	R.M. 73.7; approx. 4.5 miles upstream of U.S. Hwy 1 bridge near Camden, Kershaw County
	4	R.M. 66.2; 1000' upstream of I-20 bridge, Kershaw County
Wateree 1	1	R.M. 25.3; approx. 1000' downstream of U.S. Hwy 378 bridge, Richland/Sumter County line
Saluda 4(a)	1	R.M. 125.3; USES gage 1630 near Felzer on Greenville/Anderson County line
	2	R.M. 124.8; 0.5 mile downstream of USGS gage 1630 near Pelzer, Greenville/Anderson County line
Saluda 4(b)	3	R.M. 110; 0.5 mile downstream of Holidays Bridge Hydroelectric Plant, Greenville/ Anderson County line
Saluda 2	1.1	R.M. 64.3; approx. 1.75 miles below Buzzards Roost Hydroelectric Plant, Greenwood/Newberry County line
	1.2	R.M. 64.3; approx. 1.75 miles below Buzzards Roost Hydroelectric Plant, Greenwood/Newberry County line
	2	R.M. 58.7; approx. 0.5 miles upstream of S.C. Hwy 39 bridge near Chappels, Saluda/Newberry County line
	3	R.M. 56.1; approx. 2.1 miles downstream of S.C. Hwy 39 bridge at Chappels, Saluda/ Newberry County line
	4	R.M. 53.0; approx. 5 miles downstream of S.C. Hwy 39 bridge at Chappels, Saluda/Newberry County line

Table 2., cont'd.

Stream Segment	Site Number	Location Description
Saluda 1	2	R.M. 8.6; Corley Island approx. 0.75 miles below Hope Ferry Landing, Lexington County from U.S. Hwy 21 bridge, York County
	3	R.M. 7.9; approx. 1.4 miles below Hope Ferry Landing, Lexington County
	4.1L	R.M. 3.8; just below I-26 bridge, Richland/ Lexington County line (left channel)
	4.1R	R.M. 3.8; just below I-26 bridge, Lexington County (right channel)
	4.2	R.M. 3.5; below I-26 bridge, Lexington County
	5	R.M. 2.8; at USGS gage 1690, Richland/Lexington County line
Coosawhatchie	1.1	R.M. 34.2; approx. 500' downstream of U.S. Hwy 601 bridge near Hampton, Hampton County
	1.2	R.M. 34.0' approx. 500' upstream of U.S. Hwy 601 bridge near Hampton, Hampton County
Jeffries Creek	1	R.M. 5.6; approx. 500' downstream of County Road 24 bridge, Florence County
	2	R.M. 6.0; approx. 0.25 mile upstream of County Road 24 bridge, Florence County
	3	R.M. 10.9; approx. 200' downstream of S.C. Hwy 327 bridge, Florence County
	4	R.M. 11.0 approx. 100' upstream of S.C. Hwy 327 bridge, Florence County
Whippy Swamp	1	R.M. 12.0; approx. 600' upstream of County Road 28 bridge, Hampton County
	2	R.M. 8.6; approx. 600' downstream of County Road 43 bridge, Hampton County
	3	R.M. 1.7 approx. 600' upstream from County Road 13 bridge, Hampton/Allendale County line

REVIEW OF EXISTING INSTREAM FLOW METHODS

Numerous methods have been developed to assess minimum flow requirements for instream uses (Table 3). Most of these methods were developed for the protection of fishery resources, but other instream uses have also been addressed. Since comprehensive reviews are available which categorize the methods and describe their advantages and disadvantages (Wesche and Rechard, 1980; Loar and Sale, 1981; Camp, Dresser and McKee, 1986; EA Engineering, Science, and Technology, Inc., 1986), there is no attempt to repeat these previous efforts in this report: The following discussion, based largely on Loar and Sale (1981), briefly reviews the major categories and types of instream flow assessment methods currently available.

The assessment of instream flow needs can be categorized into four levels of analysis based on 1) resolution, 2) data needs, and 3) cost required for the analyses. These heirarchical divisions of analysis are also useful in categorizing instream flow methods (Table 3).

Requirements for data and cost of the methods in each level escalate as a function of complexity (Figure 2). The methods are categorized into levels according to their data requirements, which range from the use of historical records without field data to developing hydraulic ratings based on single-transect field surveys, to modeling with multipletransect, habitat rating methods. All of the methods involve certain subjective assumptions about stream environments and the behavior of riverine ecosystems.

Table 3. Major instream flow methods by level of analysis (Sources: Camp, Dresser and McKee, 1986; EA Engineering, Science, and Technology Inc., 1986)

Level	Type/Name	References	Use
I	Fixed Percentage		
	-Tennant Method (Montana Method)	Tennant 1975,1976	fish, aesthetics, recreation
	Constant Yield		
	-New England Method (NEFRP)	USFWS 1981, Knapp 1980, Larsen 1980	fish
	-Connecticut River Basin Method	Robinson 1969	
	Flow Duration		
	-Hoppe Method	Hoppe 1975, Hoppe & Finnell 1970	fish
	-Iowa Method	Dougal 1979	
	-NGPRP Method	NGPRP 1974	fish
	-Washington Base Flow Method		Collings 1974
	7Q10 Method		water quality
II	Habitat-Discharge		
	-Wetted Perimeter Method (Washington Rearing Method)	Collings 1974	fish
	-USFS Region 2 Cross Method (Colorado Method, Critical Area Method)	Russell & Mulvaney 1973, Silvey 1976	fish
	-USFS Region 4 Method	Dunham & Collotzi 1975	fish
	Usable Width		
	-Oregon Method	Thompson 1972, 1974	fish
	-Weighted Usable Width Method	Sams & Pearson 1963	fish
III	Preferred Area		
	-Washington Spawning Method	Collings 1972,1974	fish
	-Waters Method (California Method)	Waters 1976	fish
	IFG Incremental Methodology	Bovee 1982, Hyra 1978	fish, recreation

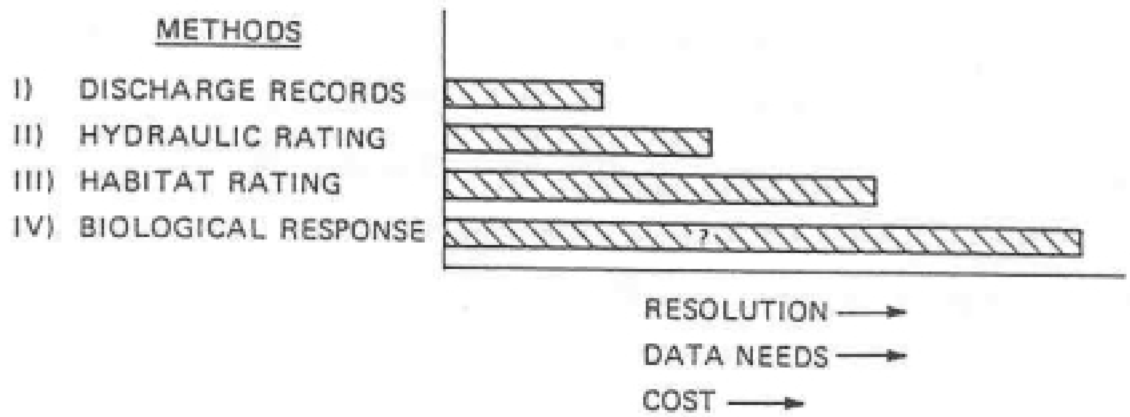

Figure 2. Four levels of analysis for assessing instream flow needs (from Loar and Sale, 1981).

The levels are classified according to the objectives of their respective methods. Level I studies provide simple, cursory assessments without field work, based on a set of assumptions about minimum flows necessary to preserve stream biota. Level II studies attempt to substantiate some of these assumptions through field measurements to determine the response of physical parameters to changes in streamflow. Level III analyses go a step further to illustrate the response of biological indicators to changes in discharge. Finally, the as-yet-undeveloped Level IV analyses would seek to actually measure biological responses to changes in flow.

Methods included in the first level require no site-specific field survey work. These use existing historical discharge records to determine mean or median flows of a particular stream site, from which minimum flow recommendations are derived based on a chosen reference flow. Level I methods are considered office methods, and can be conducted at very low cost. Level I analyses are often used for reconnaisance purposes to arrive at simple and rapid assessments or to serve as an overview of the range of conditions one might expect with a more detailed assessment. However, because site-specific factors are generally not considered, a relatively large possibility for error exists in the selection of instream flow requirements.

Level II analyses require collecting site-specific data at one or more flows from a single transect representative of a stream reach (such as from a riffle, run, pool, etc.). With direct field measurements, the response of physical parameters in the aquatic environment to changes in streamflow is determined. Water surface elevations may be measured at different flows, or, to decrease the need for field work, data from one flow may be used to calibrate a hydraulic model that predicts water surface elevations at other flows. Instream flow recommendations are then made based on the relationship between flow and various habitat parameters of a site, such as mean depth, width, velocity and wetted perimeter. These studies are more costly to perform than those of Level I, but the supporting field data improves their resolution. Level II analyses are valuable in assessing hydraulic conditions in ecologically significant areas affected by flow regulation. However, in most cases the instream flow recommendations produced at this level would not be based on detailed knowledge of the habitat requirements of any species, and may not be representative of species preferences.

Level III analyses incorporate subjective habitat ratings based on species-specific requirements using data from multiple transects of representative stream reaches. Habitat suitability curves are generated and habitat indices determined. Biological response curves are then developed to show the relationship between habitat and discharge. Level III analyses are significantly more costly and complex than those of Levels I and II. The complexity of the different methods within Level III varies with the size and flow characteristics of the stream and the degree of resolution desired.

Currently in the research-and-development stage, Level IV analyses would employ multiple transects and habitat ratings to model and predict biological responses to flow regulation. Unlike the other methods, these would attempt to eliminate many of the implicit assumptions, and to actually measure biological responses to changes in flow. Responses could be evaluated as survivorship or fecundity of individuals, production of a given species, or alterations in community structure or function. Examples of applications are not yet available, although in 1980 the Susquehanna River Basin Commission initiated efforts to develop a fish population model that included usable area parameters.

A brief description of the major instream flow assessment methods by category follows.

Fixed Percentage

One of the simplest and most widely used instream flow methods is the *Tennant, or* Montana Method. Minimum flow requirements are determined for aquatic resources (fisheries, recreation, and aesthetics) based on fixed percentages of mean annual flow. The method was developed following studies on hundreds of warmwater and coldwater streams located in northern, mid-western, and western states.

Various degrees of resource protection are attained by using different percentages of average flow (Table 4). Following flow calculations, site visits are recommended at flows approximating 10, 30, and 60 percent of average flow to observe and photograph different habitat types (riffles, runs, pools, etc.). Based on field observations, a minimum instream flow is determined which is considered the most appropriate and reasonable and which best provides protection of the aquatic resources. While field observations are recommended, this method is often used without them, and minimum instream flow determinations are based on Tennant's brief description of flows and associated percentage of average flows (Table 4).

The advantage of this method is that it provides a quick assessment of instream flow needs. However, the mean flow statistic may not be representative of actual conditions due to the skewed nature of stream flow events. The median flow may prove a more accurate measure of central tendencies in hydrologic data..

Table 4. Instream flow regimens for fish, wildlife, recreation, and related environmental resources (from Tennant, 1976).

Narrative Description of Flows	Recommended Base Flow Regimens Oct - Mar	Apr - Sept
Flushing or Maximum	200% of the average flow	
Optimum Range	60% - 100% of the average flow	
Outstanding	40%	60%
Excellent	30%	50%
Good	20%	40%
Fair or Degrading	10%	30%
Poor or Minimum	10%	10%
Severe Degradation	10% of average flow to zero flow	

Constant Yield

Constant yield type methods provide minimum flow recommendations based on median monthly flows and a constant yield per basin area (i.e. runoff per square mile). The most common method in this category is the New England Method (NEFRP). For unregulated streams with drainage areas greater than 50 square miles and historical flow records of 25 years or more (within 10 percent accuracy of gage), the median monthly flow for spawning and incubation periods is used to evaluate instream flow needs. For engaged streams, flow needs are estimated by calculating a constant yield factor (runoff per basin area) for low-flow periods for the entire region, and applying that to a specific site. The instream flow recommendation from this procedure is called the aquatic base flow and is equal to the August median monthly flow for the New England region where the method was developed. The September median monthly flow is generally used to determine the aquatic base flow in the Southeast because September is typically the month with the lowest median flow.

The aquatic base flow has been recommended as the minimum instantaneous discharge immediately below dams during normal runoff conditions. During low flow periods when inflow to the reservoir is less than the aquatic base flow, a minimum release equal to the inflow is requested. The aquatic base flow is assumed to be adequate for all periods of the year unless additional releases are necessary for fish spawning and incubation. Because it is based on monthly statistics, the method is useful in adjusting for seasonal variability in flow needs. Another advantage is that the method does not require extensive field surveys.

Flow Duration

Flow duration curves show the percentage of time that streamflow has been equalled or exceeded at a particular site during the period of years flows have been recorded. Methods in this category include the Hoppe Method, Iowa Method, Washington Base Flow Method, and Northern Great Plains Resource Program (NGPRP) Method. The NGPRP Method modifies flow records by using a Student's t distribution to identify and remove the extremes of flood and drought. After the set of historical flows are normalized in this way, instream flow recommendations are made for each month based on flows that equal or exceed a chosen percentile of the observations in the record. The 90th percentile is typically used, although the State of Iowa uses an 84th percentile low-flow statistic.

The procedure is repeated for each month, excluding those in which high flows occur (i.e. spring months). The median flow of record is used as the instream flow recommendation in high flow months. Hoppe and Finnell (1970) include equations to extrapolate flows to sites above or below U.S. Geological Survey gaging stations based on watershed area.

Flow duration analyses that utilize seasonal percentile flows are the preferred approach. While the method requires no field work, it does require at least 20 years of flow records. In addition, recommended minimum percentiles are region-specific, and may not necessarily protect aquatic conditions in other regions.

_7010 Method

The seven-day, ten-year low flow (7010) is a commonly used flow, defined as the lowest average flow over seven consecutive days with a probability of occurring once every ten years. It is often used by state water quality agencies in determining treatment requirements for wastewater discharges. The 7010 flow is considered conservative in protecting water quality because the frequency of occurrence is very low and adequate waste assimilation at average flows is assured. Therefore, water quality conditions should be protected at flows equal to or exceeding 7010 flows through state water quality permitting programs.

While 7010 has been used as a minimum flow requirement to protect all instream uses, its applicability should be limited to maintaining water quality standards. Even then; the use of 7QlO has questionable application in streams with poorly sustained low flows (such as Coastal Plain streams where 7010 flows approach zero) and highly regulated streams, where historical regulation can greatly affect flow statistics.

Habitat-Discharge

Methods in this category assess minimum flow needs based on the relationship of flow to physical, flow-dependent parameters, such as surface width, wetted perimeter, depth, velocity, or cross sectional area. The advantage of these methods is that they account for site-specific effects related to flow, whereas previous methods do not.

The relationship between flow (discharge) and a physical parameter is typically graphed as a habitat-discharge curve. The graph is interpreted either in terms of relative change from some reference flow, such as 25 percent of bank full flow (75 percent habitat retention), or in absolute terms, such as identifying the point of greatest habitat loss (Figure 3). For the latter, the break point, or inflection point, denotes the threshold below which conditions rapidly diminish.

The most common habitat-discharge type method is the Wetted Perimeter Method. This method provides information on the amount of streambed that is covered with water at different flows. Wetted perimeter is defined as the length of wetted contact between the stream and its channel, measured perpendicular to the direction of flow. Transects placed across critical locations of the stream segment are surveyed to determine streambed profiles. Relationships between water surface elevations and flow are determined from field measurements and/or modeling techniques. For each transect, a graph depicting wetted perimeter as a function of flow is developed (Figure 3). The minimum instream flow requirement is determined for each transect by identifying the point on the curve where there is a substantial decrease in wetted perimeter with change in flow. This point is refered to as the inflection point or break point. The flow corresponding to the inflection point on the curve is used as the minimum instream flow value. Flows below this point could result in severe degradation of aquatic habitat.

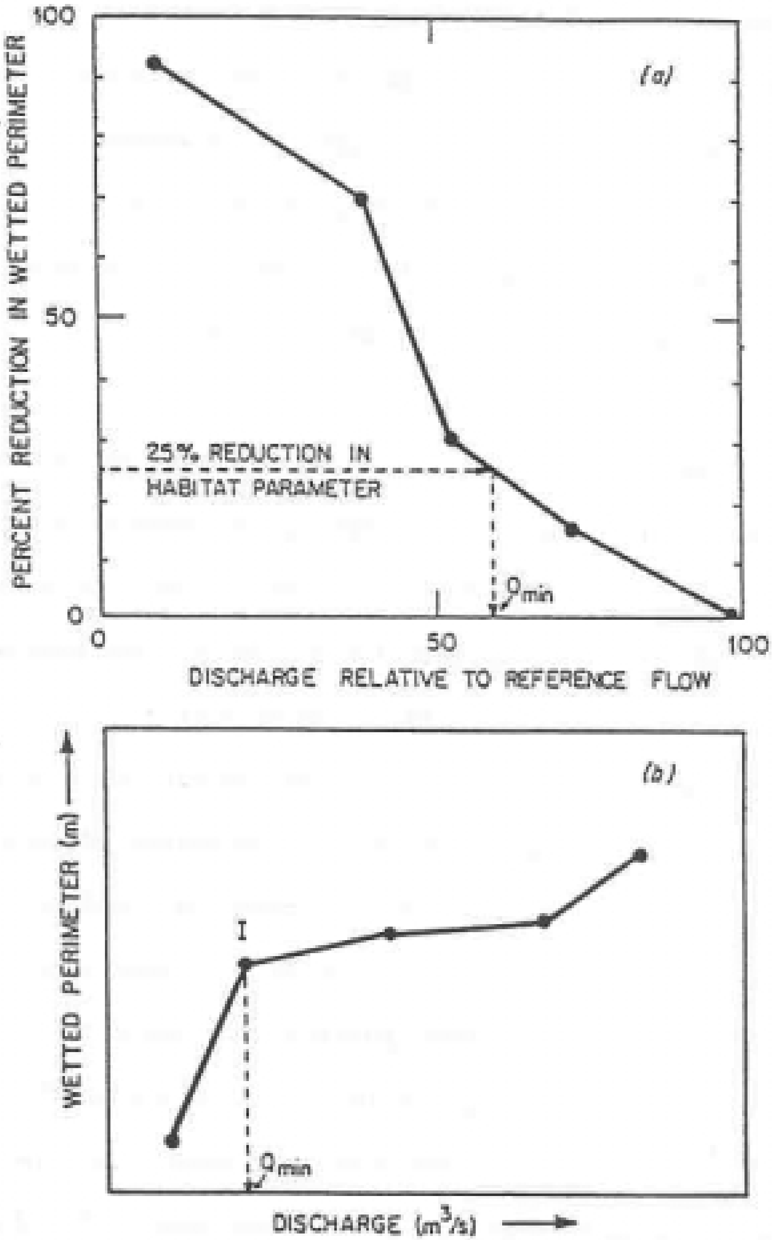

Figure 3. Examples of habitat-discharge relationships, showing (a) percent habitat retention criterion, and (b) inflection point criterion (from Loar and Sale, 1981).

Transects are placed at riffle and shoal sites. These areas are important locations for fish spawning activities and passage upstream. Therefore, dewatering of these sites could severely impact fish migration and reproduction. In addition, riffle and shoal areas are the first to be affected by reduced flows so are the most critical areas to study. These areas also show distinct inflection points on the wetted perimeter-flow curves.

Advantages of the wetted perimeter method include: (1) site specific instream flow determination, (2) minimal field work compared to other methods requiring field data collection, and (3) the ability to demonstrate changes in habitat availability (wetted perimeter) with changes in flows. For these reasons this method is one of the more popular methods for determining flow requirements for fisheries resources.

A principal concern for the use of this method is that it does not consider the depth of water covering the wetted portion of the streambed. If the wetted area is too shallow, then fish will be unable to utilize it for spawning, feeding, or passage. In the strictest application of the method, water depth is not considered; however, sufficient data is collected at each transect to graph the streambed profile and determine water depths at various flows. Therefore, for a given transect, water depth above a critical wetted portion of the stream channel can be determined at the identified minimum flow level, if desired. Another concern is that the selection of the breakpoint is somewhat subjective and its distinction is dependent on the shape of stre-ambed profile (Figure 4).

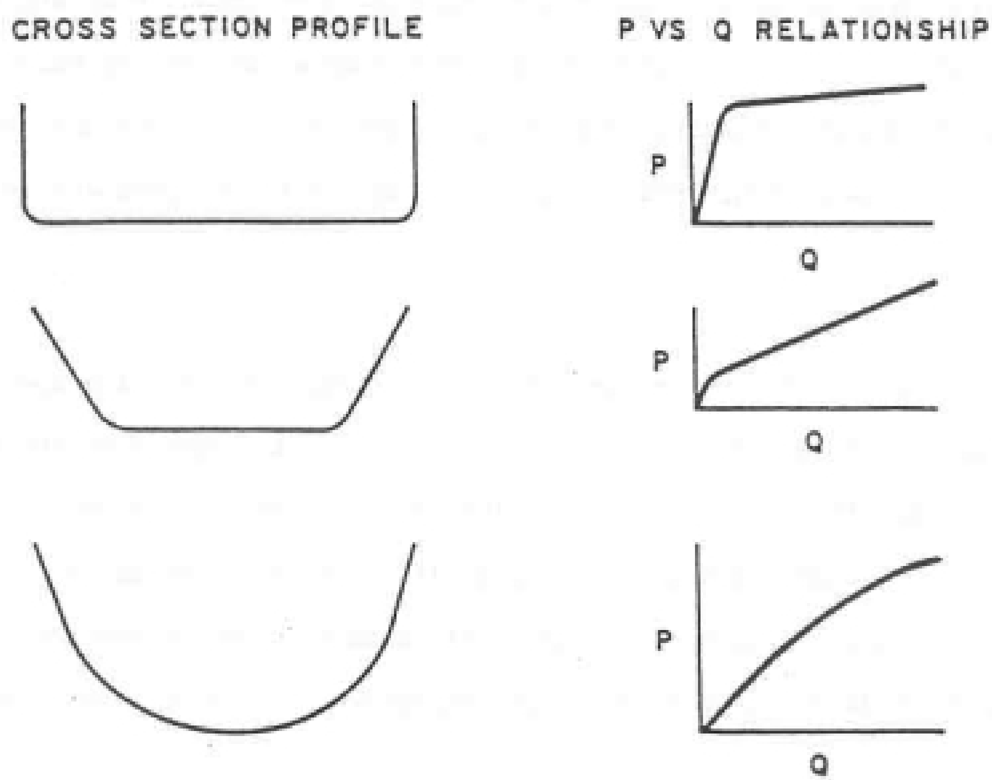

Figure 4. The wetted perimeter-discharge curves (P vs. Q) and corresponding channel cross-sectional profiles (from Bovee and Milhous, 1978).

The U.S. Forest Service (USFS) has developed a few habitat evaluation methods using various regional approaches used to describe aquatic habitat. Principle among these for determining minimum instream flow needs are the USES Region 2 Cross Method and the USFS Region 4 Method. In general, these two methods use the physical parameters of mean velocity, wetted perimeter, cross-sectional area, maximum depth or hydraulic radius. A habitat-discharge curve is prepared for the parameter of interest, and a habitat retention criterion (at least 80 percent of the index flow habitat value) or an inflection point criterion is applied to produce instream flow recommendations (Wesche and Rechard 1980, Loar and Sale 1981).

Distinct differences exist between these regional approaches. Whereas the Region 4 Method utilizes multiple transects, the Region 2 Cross Method uses one representative critical area, usually delimited as the shallowest cross-section in the reach being investigated (Wesche and Rechard, 1980). In addition, the Region 4 Method applies habitat rating values to different water stages.

Usable Width

This type of method assesses, as usable or unusable, the velocities and depths associated with flows required for fish passage, spawning, incubation, and rearing. The Usable Width Method requires collection of data from transects placed in limiting habitat of a stream channel (e.g. restrictions to passage or spawning beds). Transect data is collected at several flows, and habitat-discharge curves are constructed with usable width as the flow-dependent variable. Instream flow recommendations are based on the percentage of total stream width that is "usable" by target fish species.

The method was developed in Oregon to determine minimum acceptable flows for salmonid fishes. Criteria used in Oregon for fish passage were flows at which usable width was at least 25 percent of the total transect width and continuous for at least 10 percent of the total width. The minimum flow recommendation at critical spawning transects is a suitable flow over 80 percent of the available gravel (Thompson, 1972).

A variation of the usable width method is the Weighted Usable Width Method. Instead of habitat being usable or unusable, this latter method utilizies weighting factors (ranging from 0.0 to 1.0) to denote the relative degree of usability. Also, this method requires uniform subdivision of the stream transects.

A major advantage of the usable width methods is that periodicity charts can be constructed and seasonal flow recommendations made that indicate the requirements of critical life stages that need protection. However, because the weighting is subjective, local site-specific preferences of fish must be accurately represented. Weighting factors should therefore be assigned based on opinions of fisheries experts or on probabilities of fish presence.

Preferred Area

This method involves quantifying instream habitat on a two-dimensional, areal basis rather than on width. Its principle use has been to quantify the area of streambed available for salmon spawning at different flows. No hydraulic simulation modeling is used to predict conditions at flows other than those observed.

To determine preferred depths and velocities specific to spawning, and therefore the portions of a stream suitable for spawning, four transects are run across a potential spawning site. Isopleth maps of the streambed are drawn to illustrate the distribution of hydraulic parameters at a fixed flow. The procedure is repeated for a minimum of five different streamflow conditions, and, based on biological criteria a response curve of suitable spawning area versus discharge is developed. The preferred flow is that which provides the maximum suitable area. Instream flow recommendations are in the form of habitat retention criteria, set at the flow which maintains 75 percent of the maximum spawning area.

IFG Incremental Methodology

This “state-of-the-art” method was developed by the Cooperative Instream Flow Service Group (IFG) of the U.S. Fish and Wildlife Service to simulate stream conditions analagous to actual field conditions. The habitat evaluation procedures are known as the Incremental Methodology.

The procedure utilizes a computer model to analyze data collected from multiple transects, each subdivided into a matrix of rectangular cells, placed across representative or critical stream reaches. Through interpolation, the physical habitat parameters of mean velocity, mean depth, and mean substrate type are simulated by the model. Computer models to predict changes in water quality and temperature have recently been developed. By weighting these habitat parameters in terms of preferences of various life stages of target species, species-specific suitability functions can be calculated. IFG source files may be used to develop suitability functions necessary to calculate weighted usable area, but site-specific habitat suitability indicies for target species are encouraged. Using the computer package (PHABSIM), habitat suitability is used to compute weighted usable area. Serving as an index of habitat quantity and quality, weighted usable area for each target species life stage (spawning, fry, juvenile and adult) is ultimately plotted against flow (Figure 5). Instream flow recommendations can then be made on fixed percentile habitat quality or on a habitat-duration basis.

Though complex in data requirements and operation, this methodology is designed to provide a thorough representation of habitat suitability with relation to flow. The major assumption of this methodology (and other habitat response methods) is that a direct relationship exists between available habitat and fish production. However, validation of this relationship has been questioned (EA Engineering, Science, and Technology, Inc., 1986).

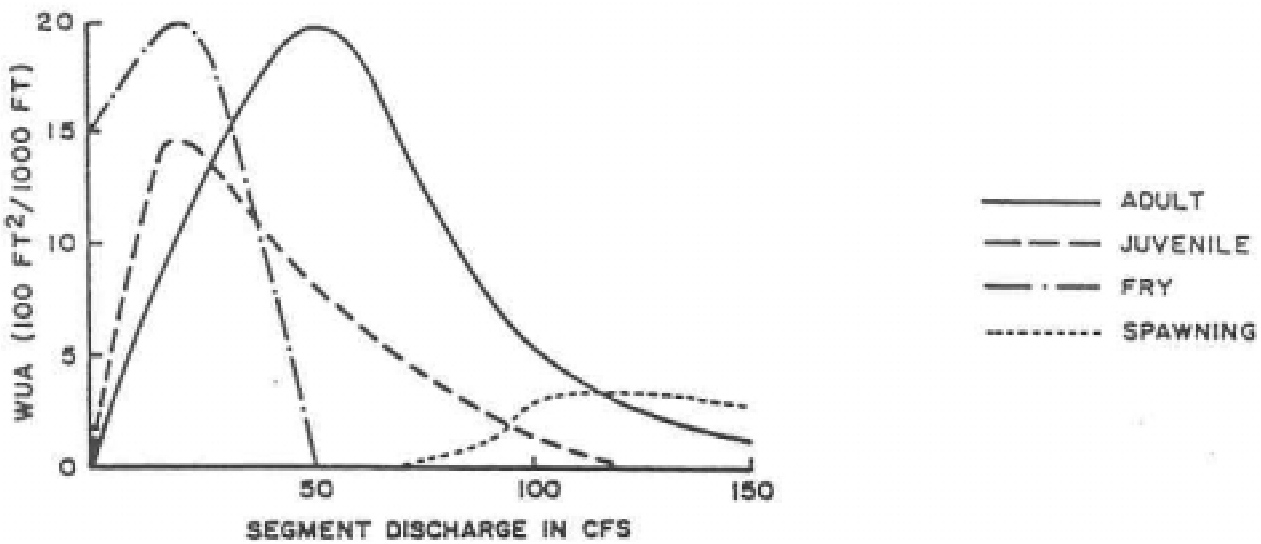

Figure 5. Example of weighted usable area versus discharge curves (from Bovee, 1982).

METHODS

Development of Study Methodology

The study plan for Phase II was developed with the assistance of the Water Resources Advisory Committee. Committee members reviewed existing instream flow methods and provided initial recommendations for study plans, and later reviewed and commented on draft methodologies.

Based in part on Committee comments and review of the literature, a study plan that implemented, evaluated, and modified several different methods was selected over a single method approach for the following reasons:

(1) All existing methods-have been developed and used primarily in northern and western states. Since there are some regional differences in stream characteristics, the applicability of these methods must be tested on southeastern streams before adoption and implementation.

(2) Characteristics, such as slope, substrate, and cross-sectional profile, are often very different between streams located in separate physiographic regions of South Carolina (Coastal Plain, Piedmont, Blue Ridge). Existing methods must be tested on streams occurring in each of these regions. Then, if necessary, these methods should be modified to compensate for differences in stream characteristics to best assess instream flow needs.

(3) South Carolina has constitutionally and legislatively declared an interest in maintaining public use of navigable streams. Methods to assess minimum flow needs for navigation, however, are not readily available. The S.C. Water Resources Commission, which is the agency principally responsible for maintaining navigability in designated streams, developed a draft method to identify minimum flow needs for navigation. While the draft method appeared reasonable and workable, it needed to be tested on several streams and further refined based on field observations.

(4) Most states which maintain minimum levels of instream flow either do so primarily to protect fishery resources or have found that flows which protect fish habitat also protect other instream uses and interests. Consequently, most existing methods are designed to identify flow needs for maintaining fish habitat. While the maintenance of fishery resources is an important consideration, other uses and interests in South Carolina streams are also important. Before the premise that flows which support fisheries also support other uses could be accepted, minimum flow needs had to first be identified for each recognized instream use and compared.

A preliminary study plan was developed which included several existing instream flow methods (Tennant, Wetted Perimeter, Usable Width, 7Q10) and a draft method to determine minimum flow requirements to support navigation. The trial study methodology was implemented and, based on field observations, the individual methods and overall methodology were evaluated and refined. The final methodology was used to determine minimum flow requirements for priority stream segments.

Study Methodology

Each stream segment was visually surveyed during low flow conditions to identify shallow areas (shoals, riffles, sandbars) *that* appeared to restrict navigation and fish passage and\or experienced extensive aquatic habitat loss at low flows. The total length of all Piedmont stream segments were surveyed by boat and the most restrictive shoals were selected as study sites. The smaller Coastal Plain streams (Whippy Swamp, Jeffries Creek; and Coosawhatchie River) were surveyed by wading portions of the stream segments from bridge crossings. Because numerous *shallow* sandbars of relatively equal restriction to passage occur in these stream segments, representative shallow areas located close to bridge crossings were selected as study sites. To help assess minimum flows needed along the entire stream segment, study sites were selected from the upper, middle, and lower portion of all segments where possible.

Temporary bench marks were established at each study site, and streambed profile and water surface elevations were surveyed. Streamflow was measured using U.S. Geological Survey techniques. U.S. Geological Survey gaging stations were used to determine streamflows where they were in close proximity to a study site. At least two additional site visits were made to measure water surface elevations (stage) at various streamflows discharges) in order to develop stage-discharge relationships at each site. During each site visit, the relative degree of navigability was noted and photographs were taken to document study site characteristics during different flows.

All field data was double checked for accuracy, transferred to summary sheets, and entered into a computer for calculations of stage-discharge regression equations, wetted perimeter, and for graphical display of study site cross-sections and wetted perimeter data.

Instream uses and interests were identified for each study site using data compiled during Phase I. Minimum flow requirements were determined for all appropriate instream uses for each study site using the following methods.

1. Navigation

   South Carolina Navigation Method

2. Water Quality

   Seven-day, ten-year low flow (7Q10)

3. Fishery Resources

   a. Tennant Method

   b. Wetted Perimeter Method

   c. Usable Width Method

   Results from the above three methods were reviewed by the S.C. Wildlife and Marine Resources Department and final minimum flow requirements for fishery resources were determined by that agency.

4. Hydroelectric Power Production (run-of-river) Minimum turbine capacity.

5. Threatened and Endangered Species
Assessment of ecological requirements needed to protect species of concern.

6. Unique Ecological Characteristics
Wetted perimeter and cross-section analysis.

Recommended minimum flow requirements for each priority stream segment were determined by selecting the highest minimum flow value of all use categories of all study sites within a segment. This procedure is based on the premise that by protecting the most sensitive instream use, all others are also protected. Exceptions to this procedure occurred when field observations indicated that lower flows adequately protected specific instream uses, or when results at a particular study site were exceptionally higher than other sites due to atypical channel morphology. The results from this methodology should protect instream uses at an acceptable minimum level.

Methods Description

Navigation

The method used to determine minimum flow requirements for navigation was developed by the S.C. Water Resources Commission and is based on State law that protects the right of navigation by small pleasure or sport fishing boats on designated State navigable waters. The method was tested and modified during the study. The final method yields reasonable results that adequately protect navigation at a minimal level. Actual navigation of the streams at the recommended minimum flows requires staying within the deepest channel and experiencing occassional difficulty in shoal and shallow areas; however, passage of difficult areas should not require getting out and pulling the boat past obstructions. Instream flow requirements for navigation were determined as follows:

(1) Identify all shallow areas and shoals where navigation may be most restricted at low flows. omit large shoals where passage using a 14 foot Jon-boat is determined to be too difficult at low flows but too dangerous at higher flows.

(2) Survey the streambed profile and water surface elevations, and measure flow at each critical site. After measuring water surface elevation (stage) and flow (discharge) at each site for at least three different flows, develop stage-discharge relationships.

(3) Determine the desired level of navigation at each site based on the following categories:

(a) One-way navigation

Passage of a 14 foot Jon-boat without a motor in the downstream direction only. This would apply to passage through rocky shoals in Piedmont streams and shallow areas in small Coastal Plain streams.

(b) Two-way navigation

Passage of a 14 foot Jon-boat with a motor in either direction. This level of navigation is expected in runs and pools of Piedmont streams and in the most critical sites of large Coastal Plain streams.

(4) Graphically display the streambed profile and visually determine the minimum water surface elevation and compute the associated flow that provides the desired level of navigation using the following criteria:

(a) One-way navigation

A minimum depth of one foot across a channel 10 feet wide or across 10 percent of total stream width, whichever is greater. Minimum depth does not need to occur across a continuous 10 percent of stream width, but each point of passage must be at least 10 feet wide.

For example, for a study site 200 feet wide, the minimum level for navigation may be that at which two 10 foot wide channels have a minimum depth of one foot, instead of a single 20 foot wide channel with a minimum depth of one foot.

(b) Two-way navigation

A minimum depth of two feet across a channel 20 feet wide or across 20 percent of total stream width, whichever is greater. Minimum depth does not need to occur across a continuous 20 percent of stream width, but each point of passage must be at least 10 feet wide.

(5) List the minimum flows needed to support the desired level of navigation at each site and select the highest of these flows as the minimum flow needed to maintain navigation throughout the stream segment. The final minimum flow determination may be adjusted based on field observations and navigation experienced at known flows.

Water Ouality

The S. C. Department of Health and Environmental Control assures the protection of water quality standards and aquatic life in streams at flows equal to or greater than the seven-day, ten-year low flow (7Q10) through its National Pollutant Discharge Elimination System Permit Program and 401 Water Quality Certification process. Therefore, the 7Q10 flow was selected as the minimum flow needed to adequately protect water quality conditions.

Fishery Resources

Three methods were used to assess minimum flow requirements to protect fishery resources. These were the Tennant Method, Wetted Perimeter Method, and Usable Width Method. Each method was used as described earlier, with the following modifications:

(1) Tennant Method

Flows equal to 10 percent and 30 percent of average annual flow were calculated for each priority stream segment. Each study site was observed and photographed at a variety of flows; however, special effort was made to observe the sites at 10-30 percent of average flow. Photographs-of the study sites at different flows were reviewed with fishery biologists of the S.C. Wildlife and Marine Resources Department. Minimum flow determinations were based, in part, on conditions described by Tennant (1976) at 30 percent of average flow:

> “This is a base flow recommended to sustain good survival habitat for most aquatic life forms. Widths, depths, and velocities will generally be satisfactory. The majority of the substrate will be covered with water, except for very wide, shallow riffle or shoal areas. Most side channels will carry some water. Gravel bars will be partially covered with water and many islands will provide wildlife nesting, denning, nursery, and refuge habitat. Streambanks will

provide cover for fish and wildlife denning habitat in many reaches. Many runs and most pools will be deep enough to serve as cover for fishes. Riparian vegetation will not suffer from lack of water. Large fish can move over riffle areas. Water temperatures are not expected to become limiting in most stream segments. Invertebrate life is reduced but not expected to become a limiting factor in fish production. Water quality and quantity should be good for fishing, floating, and general recreation, especially with canoes, rubber rafts, and smaller shallow draft boats. Stream esthetics and natural beauty will generally be satisfactory."

(2) Wetted Perimeter Method

As defined earlier, wetted perimeter is the length of wetted contact between the stream and its channel, measured perpendicular to the direction of flow. Transects were located at shallow areas (riffles, shoals, and sand bars) on each stream segment. These sites were selected because shallow areas are the first to be affected by reduced flows, show distinct break points on the wetted perimeter/flow curves, and are critical locations for fish food organisms, fish spawning activities, and fish passage upstream.

Temporary bench marks were established at each study site and the sites were surveyed for streambed profile and water surface elevations. Streamflow data was derived from flow measurements at the study site or from a U.S. Geological Survey gage, when one was in close proximity to the site. At least two additional site visits were conducted to measure water surface elevations and streamflow.

All survey and discharge data were double checked for accuracy and entered into a computer for graphical output of each transect and development of stage-discharge relationships at each site. Wetted perimeter (in linear feet) was calculated at 0.1 foot increments from the bottom of the streambed to the highest elevation of the cross-section. Graphs were then developed plotting wetted perimeter versus flows associated with the 0.1 foot increments of water surface elevations (Appendix C). Minimum flow requirements were determined for each site by identifying the break point below which wetted perimeter rapidly decreased with decrease in flow.

(3) Usable Width

Cross-sectional data derived from all study sites selected for navigability and wetted perimeter analyses were used to determine usable width. Depth and width criteria for the passage of striped bass (Piedmont streams) and red-breast sunfish (Coastal Plain streams) were provided by the S.C. Wildlife and Marine Resources Department. The criteria for passage of these fishes through shallow areas were:

Striped bass (Morone saxatilis)

Depth - 1.5 ft

Width - 10 ft

Red-breast sunfish (Lepomis auritus)

Depth - 1 ft

Width - 8 ft

Minimum water surface elevations that adequately provided a channel of the appropriate depth and width were determined with assistance of computer graphics. The flow which corresponded to the minimum water surface elevations was calculated and used as the minimum flow requirement.

Hydroelectric Power Production (run of river facilities only)

The minimum flow requirement to protect this use category was based on minimum turbine capacity, which is the minimum flow at which the facility can economically generate power. These flows were provided by the licensed operators, Duke Power Company (Holidays Bridge Hydroelectric Plant) and Soft Care Apparel, Inc. (Upper and Lower Pelzer Hydroelectric Plants). Only run-of-river facilities were included because operation of these facilities is directly dependent upon inflow. Therefore, when streamflow is less than turbine capacity this use is eliminated. Peaking hydroelectric plants were not included because they generally have sufficient water in reservoir storage to continue operation even during brief periods of low flow.

Threatened and Endangered Species

Endangered species personnel at the S.C. Wildlife and Marine Resources Department were consulted regarding identification of and ecological requirements for species of concern. Flows to satisfy species needs would be determined for each stream segment as needed.

Unigue Ecological Characteristics

Cypress-tupelo swamps associated with Coastal Plain streams were the predominant unique ecological characteristics considered in this category. Because periodic flooding of these. areas is important to continued viability, flood elevations were identified using the Wetted Perimeter Method and streambed profiles. The flood elevations were used as the minimum flow requirements for the January through April time period for streams with these resources.

RESULTS

A total of 33 study sites were established on nine priority stream segments. Two sites were eliminated from final analysis because of errors in the original site survey. Two of the original stream segments, Catawba 2 and Saluda 4, were divided into subsegments following data analysis (Figure 1). This division was made because streamflows in the lower portions of the segments were substantially greater due to tributary inflow, and results from all methods consistently indicated the need for higher minimum flow in the lower site than the upper. Separate minimum flow requirements, therefore, were determined for each subsegment. The upper portion of Catawba 2 (Catawba 2a) extends from the Lake Wylie Dam to the confluence of Sugar Creek, and the lower portion (Catawba 2b) extends from Sugar Creek to the headwaters of Fishing Creek Reservoir. The upper portion of Saluda 4 (Saluda 4a) extends from the Piedmont Hydroelectric Plant to S.C. Highway 47 bridge, and the lower portion (Saluda 4b) extends from the Holidays Bridge Hydroelectric Plant to U.S. Highway 76 bridge.

Minimum flow requirements adequate to provide minimal protection for each instream use occurring in the priority stream segments are presented by study site in Tables 5 and 6. Streambed profiles and wetted perimeter graphs for each study site are presented in Appendices B and C, respectively. Recommended minimum flow requirements to protect all instream uses for each priority stream segment are presented in Table 7. All minimum flow requirements are instantaneous flows in cubic feet per second.

Table 5. Instantaneous minimum instream flow determinations (in cubic feet per second) by site for all water use categories except fishery resources.

Stream Segment	Site[a]	Water Quality	Navigation	Hydropower	Unique Ecology[c]
Catawba 2(a)	1	710	1100	-	-
Catawba 2(b)	2.1+	900	3300	-	-
	2.2	900	1300	-	-
Wateree 2	1	490	930	-	-
	2+	490	1100	-	-
	3	490	930	-	-
	4*	490	800	-	-
Wateree 1	1*	800	680	-	-
Saluda 4(a)	1	168	300	165(Pelzer)	-
	2	168	nub	-	-
Saluda 4(b)	3	200	340	125 (Holidays Bridge)	-
Saluda 2	1.1	320	360	-	-
	1.2	320	560	-	-
	2	320	300	-	-
	3	320	510	-	-
	4*	320	210	-	-
Saluda 1	2	285	460	-	-
	3	285	440	-	-
	4.1-L	285	nn	-	-
	4.1-R*	285	34	-	-
	4.2	285	390	-	-
	5	285	470	-	-

Table 5. Cont'd

Stream Segment	Site a	Water Quality	Navigation	Hydropower	Unique Ecology c
Coosawhatchie	1.1	0.03	nn	-	190
	1.2*	0.03	nn	-	180
Jeffries Cr.	1*	0.1	1	-	51
	2	0.1	15	-	73
	3	0.1	21	-	80
	4	0.1	19	-	78
Whippy Swamp	1	1.4	11	-	99
	2*	1.4	7	-	-
	3	1.4	22	-	100

a + indicates that site includes all or part of a man-made rock dam which affects calculations.

* indicates that site is not critical for navigation and/or fish passage.

b nn indicates that site is "not navigable".

c flows indicate level at which adjacent cypress-tupelo swamp is flooded based on wetted perimeter method and cross-section analysis.

Table 6. Instantaneous minimum instream flow determinations (in cubic feet per second) by site for fishery resources.

Stream Segment	Sitea	Tennant 10%	Tennant 30%	Wetted Perimeter	Usable Width	Wildlife Dept. Recommendation (Jul-Nov)	(Jan-Apr)	(May, Jun, Dec)
Catawba 2(a)	1	461	1380	1100	820	922	1840	1380
Catawba 2(b)	2.1+	606	1820	ndb	150	1210	2420	1820
	2.2	606	1820	1600	1100	1210	2420	1820
Wateree 2	1	644	1930	840	930	1290	2580	1930
	2+	644	1930	1100	2600	1290	2580	1930
	3	644	1930	950	910	1290	2580	1930
	4*	644	1930	500	200	1290	2580	1930
Wateree 1	1*	700	2100	680	360	1400	2800	2100
Saluda 4 (a)	1	78	235	220	260	168	336	252
	2	78	235	280	12	168	336	252
Saluda 4 (b)	3	96	287	340	37	192	384	288
Saluda 2	1.1	199	597	310	310	398	796	597
	1.2	199	597	250	560	398	796	597
	2	199	597	250	250	398	796	597
	3	199	597	nd	240	398	796	597
	4*	199	597	150	300	398	796	597
Saluda 1	2	293	879	900	390	586	1170	879
	3	293	879	410	350	586	1170	879
	4.1-L	293	879	440	70	586	1170	879
	4.1-R*	293	879	610	16	586	1170	879
	4.2	293	879	390	260	586	1170	879
	5	293	879	540	470	586	1170	879

Table 6 Cont'd

Stream Segment Sitea		Tennant 10%	30%	Wetted Perimeter	Usable Width	Wildlife Dept. Recommendation (Jul-Nov)	(Jan-Apr)	(May, Jun, Dec)
Coosawhatchie	1.1	19	57	50	50	38	114	76
	1.2	19	57	nd	nd	38	114	76
Jeffries Cr.	1	26	78	14	1	52	156	104
	2	26	78	15	13	52	156	104
	3	26	78	11	21	52	156	104
	4	26	78	nd	19	52	156	104
Whippy Swp.	1	14	41	nd	11	28	84	56
	2*	14	41	15	7	28	84	56
	3	14	41	60	22	28	84	56

a + indicates that site includes all or part of a man-made rock dam which affects calculations.

*
indicates that site is not critical for navigation and/or fish passage.

b nd indicates "not determined" because (1) break point was not evident or (2) site not suitable for this method, e.g. man-made structures.

Table 7. Recommended instantaneous minimum instream flow requirements (in cubic feet per second) by priority stream segment a.

Minimum Flow Requirement

Stream Segment	Jul-Nov	Jan-Apr	May, Jun, Dee
Catawba 2(a)	1100	1840	1380
(b)	1300	2420	1820
Wateree 2	1290	2580	1930
Wateree 1	1400	2800	2100
Saluda 4 (a)	300	336	300
(b)	340	384	340
Saluda 2	400b	796	597
Saluda 1	586	1170	879
Coosawhatchie	38	190	76
Jeffries Cr.	52	156	104
Whippy Swp.	28	100	56

a For stream segments in which flows are regulated by hydroelectric power projects, releases from the projects should be such as to maintain minimum flow requirements. However, during periods of drought when inflows to the projects are less than the minimum flow requirements, discharges from the hydroelectric projects should equal water available from inflow and in storage above an acceptable lake level.

Endangered and threatened species were identified on Catawba 2 (rocky shoal spider lily), Wateree 2 (bald eagle), and Saluda 1 (rocky shoal spider lily). Flow requirements to protect these species are unknown at this time and are, therefore, not included in the minimum flow requirements presented. However, flow requirements for endangered and threatened species should be considered prior to possible implementation of minimum flow standards on these stream segments.

b The minimum flow requirement of 400 cfs represents the minimum flow necessary to support navigation. This flow was determined following application of the navigation method and extensive field navigation experiences at known flows. Because of the atypical shape of the channel at Sites 1.2 and 3, application of the navigation method resulted in flows substantially higher than at other sites on the segment and higher than needed to meet minimal passage requirements.

The S.C. Wildlife and Marine Resources Department is the State agency primarily responsible for managing the States fishery resources. Therefore, results from each of the fishery resources methods (Tennant, Wetted Perimeter, and Usable Width) were provided to that agency for evaluation and final minimum flow recommendations. Appendix D presents the S.C. Wildlife and Marine Resources Department analysis of the study data and resultant “Working Instream Flow Policy” to protect fishery resources in South Carolina. That policy includes the following instantaneous minimum flow requirements:

Piedmont streams

July-November = 20% of mean annual streamflow
Jan.-April = 40% of mean annual streamflow
May, June, Dec. = 30% of mean annual streamflow

Coastal Plain streams

July-November = 20% of mean annual streamflow
Jan.-April = 60% of mean annual streamflow
May, June, Dec. = 40% of mean annual streamflow

The “Wildlife Department Recommendations” to protect fishery resources in the priority stream segments presented in Table 6 were based on the above working policy and were used as the minimum flow requirement for fishery resources protection in the overall segment analysis.

Endangered and threatened species were identified on three stream segments. These species were the bald eagle (Haliaeetus leucocephalus), which is on the Federal Endangered Species List, and the rocky shoals spiderlily (Hvmenocallis coronaria), which is currently undergoing Federal status review as a threatened species. An important population of bald eagles is located on Wateree 2, and populations of the rocky shoal spiderlily occur on Catawba 2b and Saluda 1. Flow requirements to adequately protect these species were not determined during the course of the study because extensive field investigations were required which were beyond the scope of this study. However, flow requirements for these species should be considered by consultation with endangered species personnel at the S. C. Wildlife and Marine Resources Department prior to possible implementation of minimum flow standards on these stream segments.

During the July to November time period, overall flow requirements for all stream segments (Table 7) were determined primarily by the flow needs for navigation and fishery resources because these uses required the highest minimum flows. Minimum flows for Coastal Plain stream segments (Wateree 1, Whippy Swamp, Jeffries Creek, and Coosawhatchie) were all determined by fishery resources needs. Of the seven Piedmont stream segments, minimum flow requirements for two segments (Saluda 1 and Wateree 2) were determined by fishery resources needs, three segments (Saluda 4a, Saluda 4b, and Catawba 2a) were determined by navigation needs, and two segments (Catawba 2b and Saluda 2) were determined by both navigation and fishery resources (less than 10 percent difference in minimum flow requirements). During the other two time periods (May, June, December; January-April), overall minimum flow requirements for all stream segments were determined primarily by fishery resources needs. Exceptions included Saluda 4a and Saluda 4b during May, June, and December where navigation needs determined the minimum, and Coosawhatchie River and Whippy Swamp during January to April where unique ecological characteristics determined the overall minimum flow requirements.

Table 8 shows the relationship between recommended minimum flow requirements and historic streamflows for each stream segment. The relationship to available flows is presented as a percentage of mean annual flow, mean monthly flow for the individual time periods, and daily flow duration.

In general, Coastal Plain stream segments required a larger portion of available flow to protect instream uses than Piedmont segments. This is indicated by a higher percentage of mean monthly flows and lower percentage of daily flow duration for the Coastal Plain streams. While this regional difference is due in part to the higher flow criteria used to protect fishery resources and unique ecological characteristics in Coastal Plain streams, physiographic differences are still evident when availability data for flows of equal percent mean annual flow are compared (e.g. 20 percent and 40 percent mean annual flow).

Table 8. Minimum flow requirements by stream segment in relation to available flow.

Stream Segment	Time Period	Min. Flow Requirement (cfs)	Percent of Mean Annual Flow	Percent of Mean Monthly Flow	Percentl Flow Duration
Catawba 2(a)					
	Jul-Nov	1100	24	31	88
	Jan-Apr	1840	40	32	73
	May, Jun, Dec	1380	30	32	82
Catawba 2(b)					
	Jul-Nov	1300	21	32	90
	Jan-Apr	2420	40	35	78
	May,Jun,Dec	1820	30	33	84
Wateree 2					
	Jul-Nov	1290	20	29	87
	Jan-Apr	2580	40	29	75
	May,Jun,Dec	1930	30	35	82
Wateree 1					
	Jul-Nov	1400	20	32	97
	Jan-Apr	2800	40	41	84
	May,Jun,Dec	2100	30	37	91
Saluda 4(a)					
	Jul-Nov	300	38	53	89
	Jan-Apr	336	43	31	84
	May,Jun,Dec	300	38	40	89
Saluda 4(b)					
	Jul-Nov	340	35	49	91
	Jan-Apr	384	40	29	87
	May,Jun,Dec	340	35	37	91
Saluda 2					
	Jul-Nov	400	20	28	96
	Jan-Apr	796	40	29	82
	May,Jun,Dec	597	30	33	90
Saluda 1					
	Jul-Nov	586	20	20	84
	Jan-Apr	1170	40	39	69
	May,Jun,Dec	879	30	35	76

Table 8. Cont'd

Stream Segment	Time Period	Min. Flow. Requirement (cfs)	Percent of Mean Annual Flow	Percent of Mean Monthly Flow	Percent[1] Flow Duration
Coosawhatchie					
	Jul-Nov	38	20	38	65
	Jan-Apr	190	100	60	33
	May,Jun,Dec	76	40	56	51
Jeffries Cr.					
	Jul-Nov	52	20	40	79
	Jan-Apr	156	60	42	48
	May,Jun,Dec	104	40	65	61
Whippy Swp					
	Jul-Nov	28	20	39	65
	Jan-Apr	100	71	44	40
	May,Jun,Dec	56	40	58	50

[1]Percent of time mean daily flows for period of record equalled or exceeded the minimum flow requirement (Bloxham, 1979).

Piedmont stream segments exhibited relatively consistent flow requirements for all time periods in terms of proportion of mean monthly flow. Percent of mean monthly flow for these segments generally ranged from 28 to 41 percent. Exceptions occurred at Saluda 4a, Saluda 4b, and Saluda 1 where flow requirements for the July to November time period were equal to 53, 49, and 20 percent of mean monthly flows, respectively. Coastal Plain streams were less consistent with percent of mean monthly flow ranging from 38 to 65 percent for the three time periods.

Minimum flow requirements for Piedmont streams ranged from 69 to 97 percent and averaged 85 percent of daily flow duration for all time periods. That is, flows in these segments have in the past equaled or exceeded the recommended minimum flow requirements, on average, 85 percent of the time. In addition, these minimum flow requirements were always greater than 84 percent of daily flow duration for the critical July to November time period. Minimum flow requirements for Coastal Plain streams, however, ranged from 33 to 79 percent and averaged 55 percent of daily flow duration.

Figures 6-16 compare monthly minimum flow requirements to hydrographs of monthly flow variability. In general, minimum flow requirements for Piedmont stream segments were similar to the minimum monthly means for the period of record. Exceptions include Saluda 1, Saluda 4a, and Saluda 4b. This data indicates that, on a monthly average, sufficient flow is available to adequately support instream uses, even during the driest

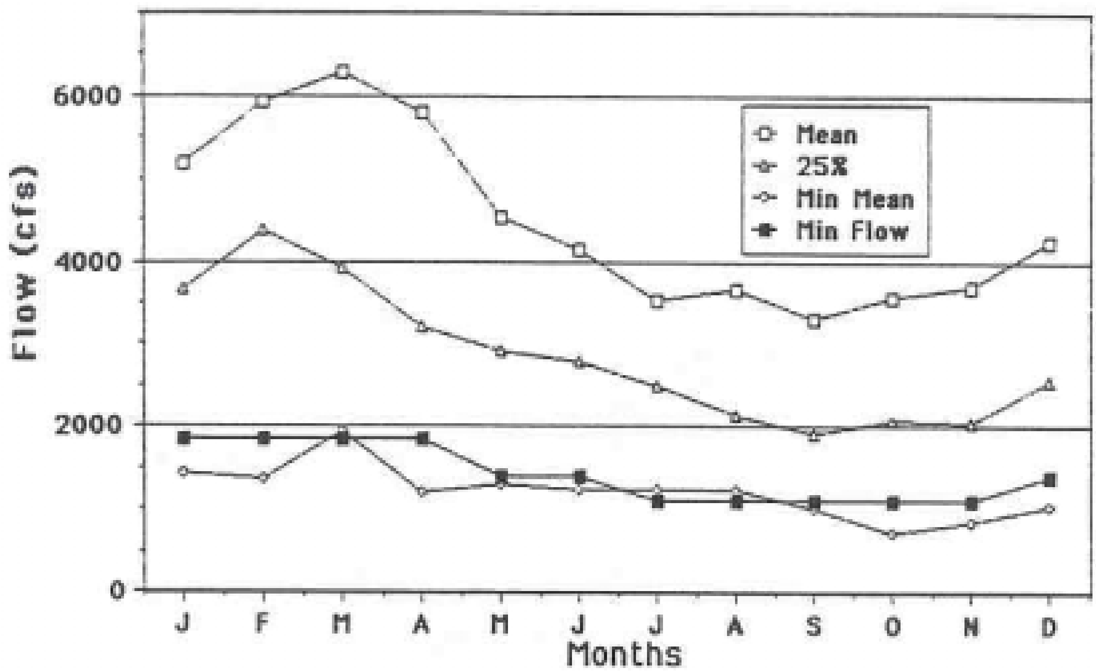

Figure 6. Recommended minimum flow requirement (Min Flow) versus monthly flow variability for Catawba 2a.

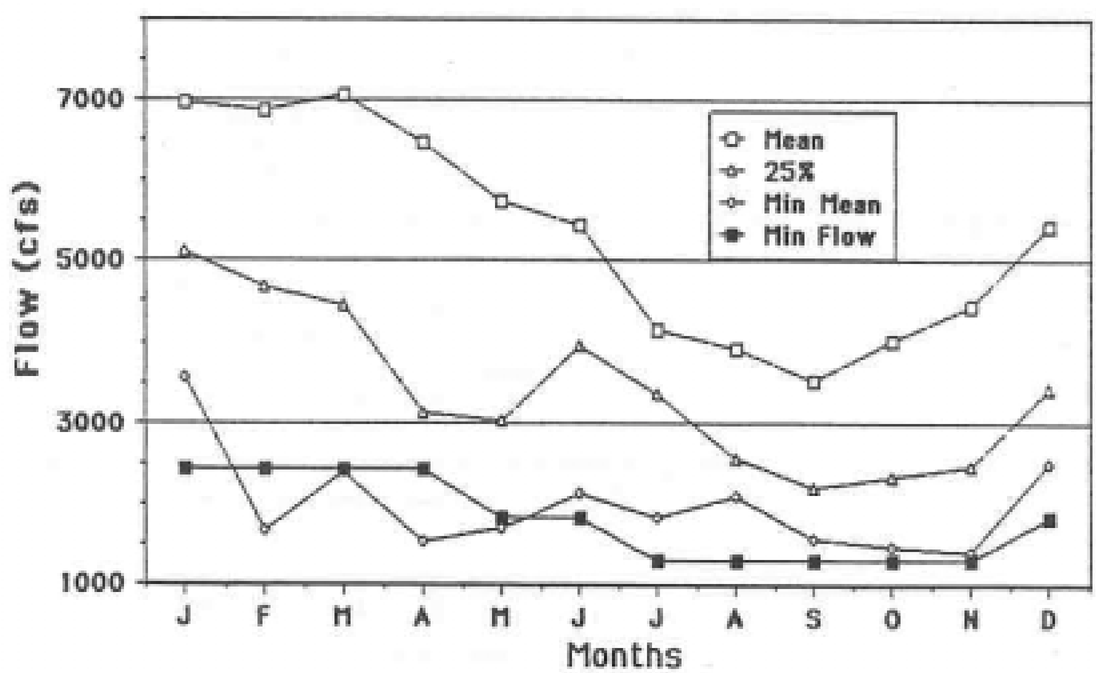

Figure 7. Recommended minimum flow requirement (Min Flow) versus monthly flow variability for Catawba 2b.

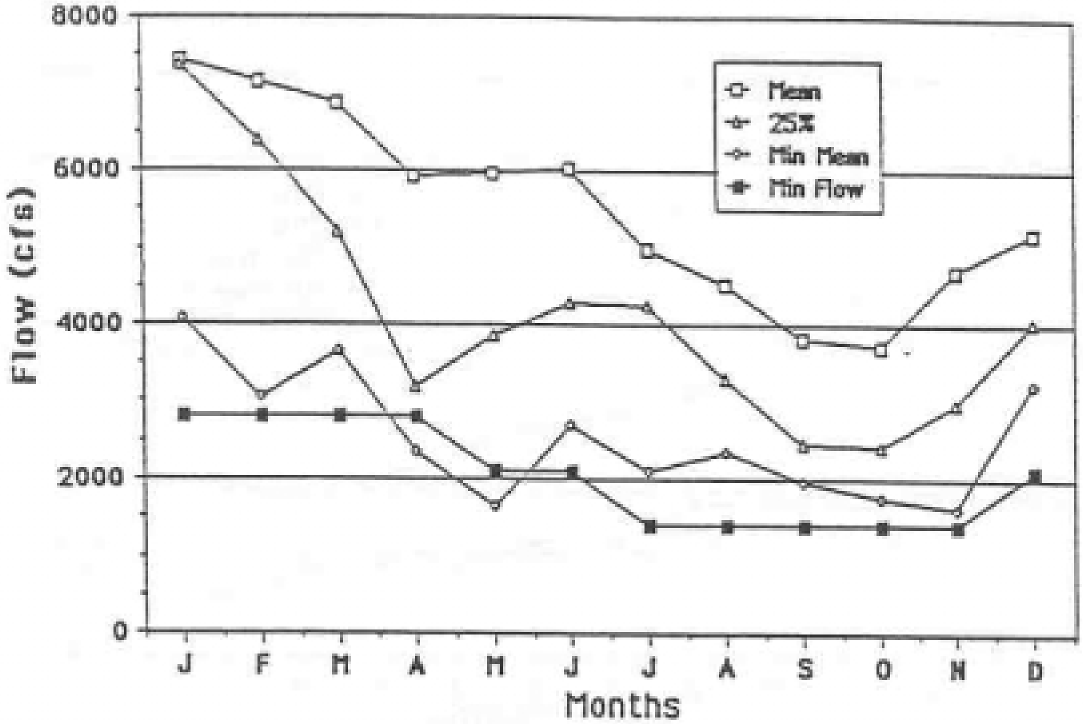

Figure 8. Recommended minimum flow requirement (Min Flow) versus monthly flow variability for Wateree 1.

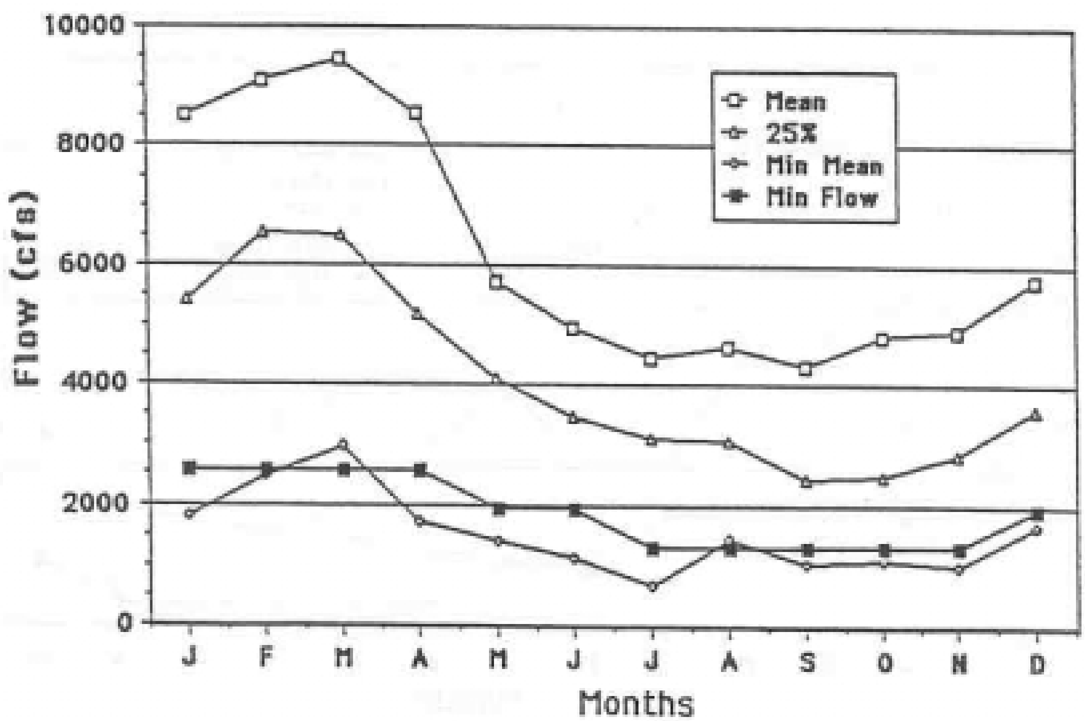

Figure 9. Recommended minimum flow requirement (Min Flow) versus monthly flow variability for Wateree 2.

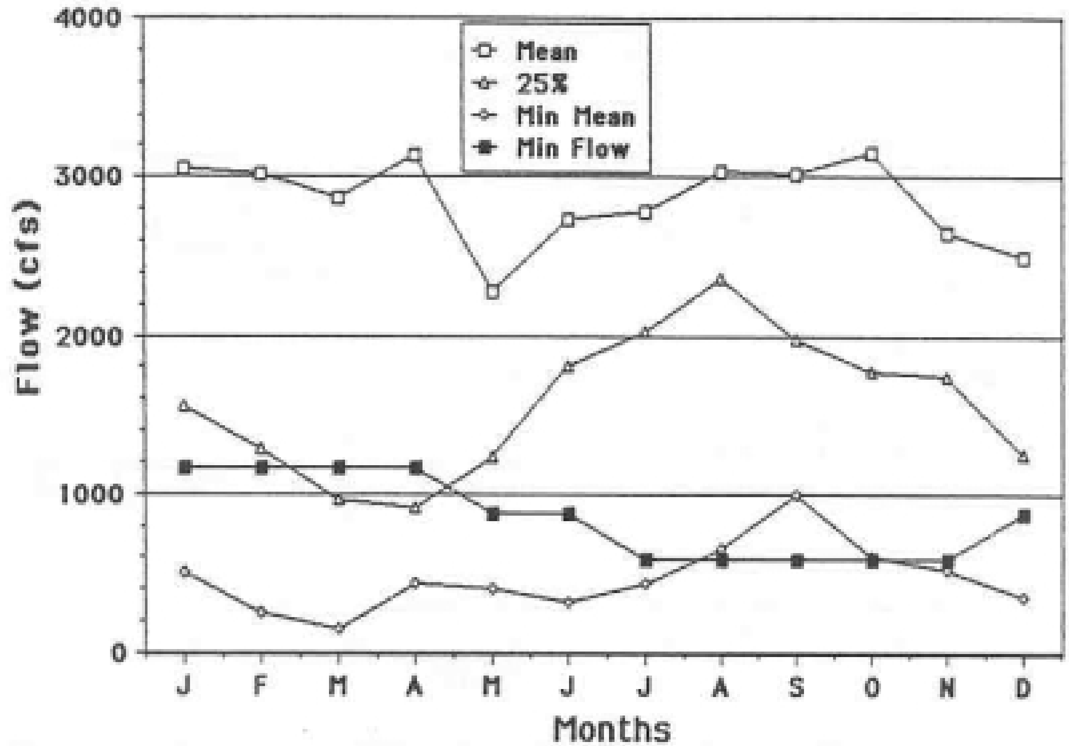

Figure 10. Recommended minimum flow requirement (Min Flow) versus monthly flow variability for Saluda 1.

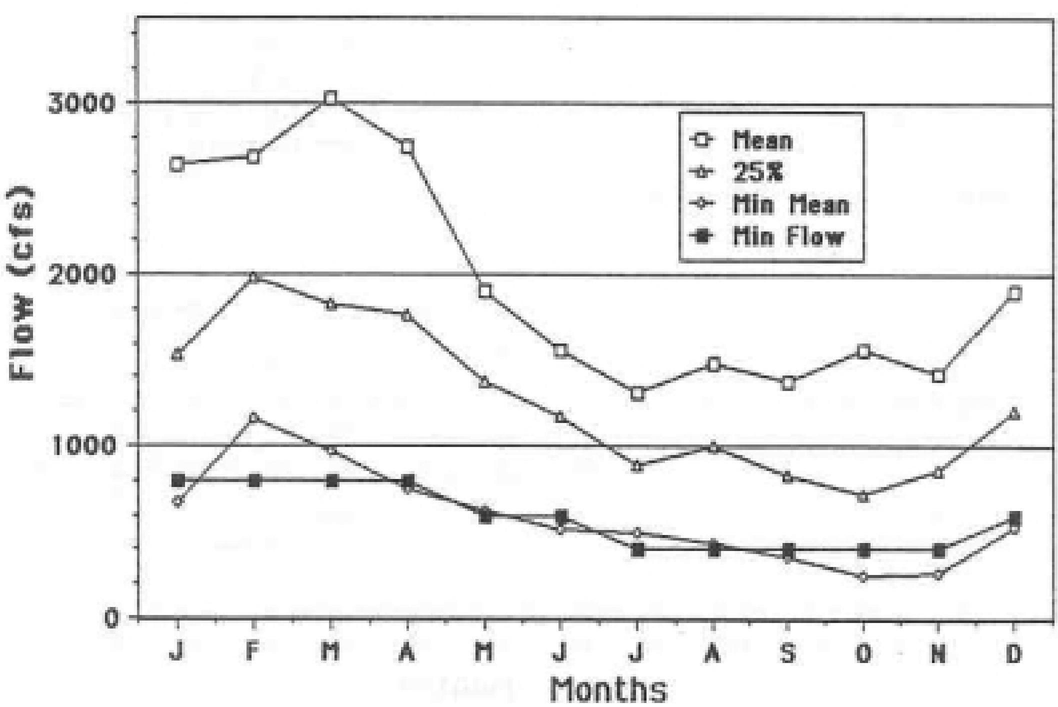

Figure 11. Recommended minimum flow requirement (Min Flow) versus monthly flow variability for Saluda 2.

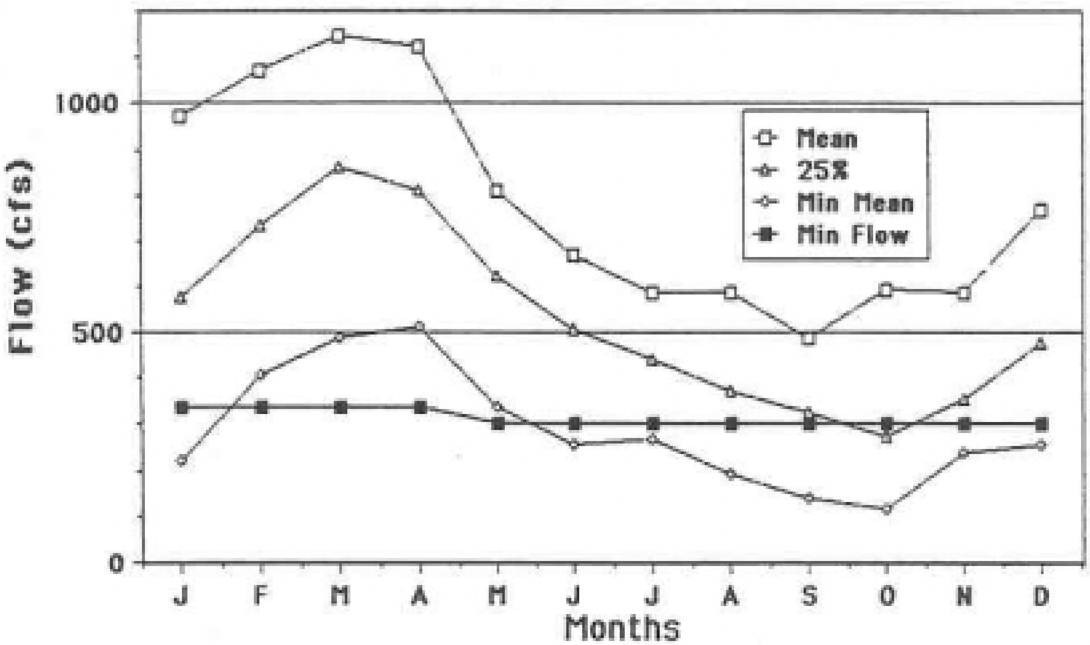

Figure 12. Recommended minimum flow requirement (Min Flow) versus monthly flow variability for Saluda 4a.

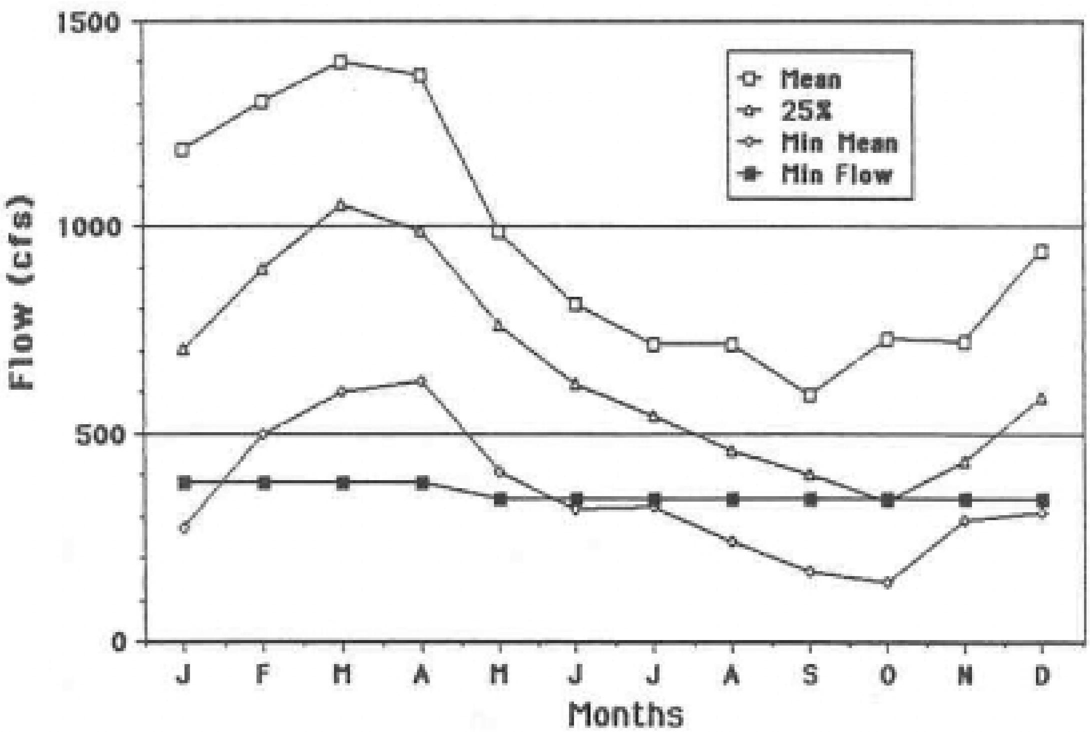

Figure 13. Recommended minimum flow requirement (Min Flow) versus monthly flow variability for Saluda 4b.

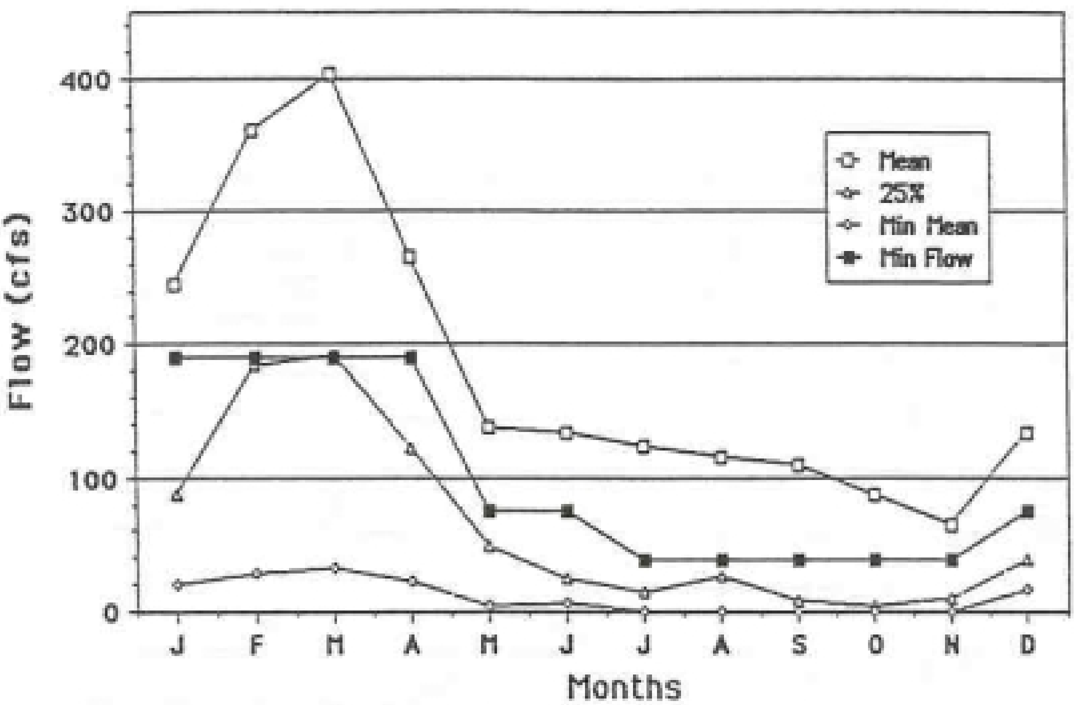

Figure 14. Recommended minimum flow requirement (Min Flow) versus monthly flow variability for Coosawhatchie.

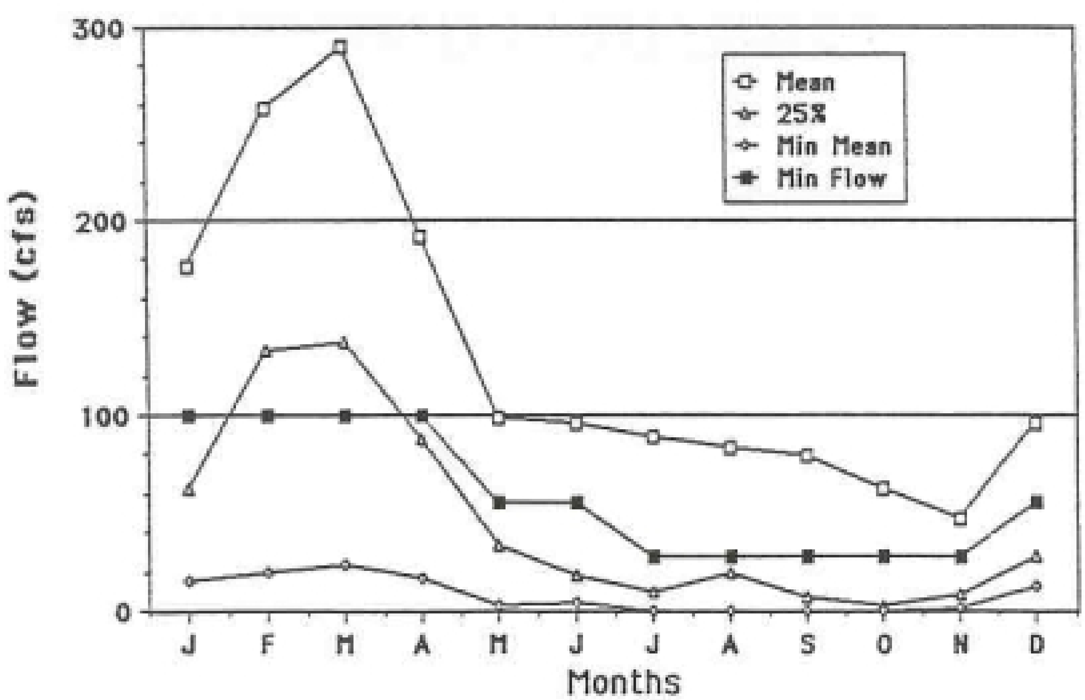

Figure 15. Recommended minimum flow requirement (Min Flow) versus monthly flow variability for Whippy Swamp.

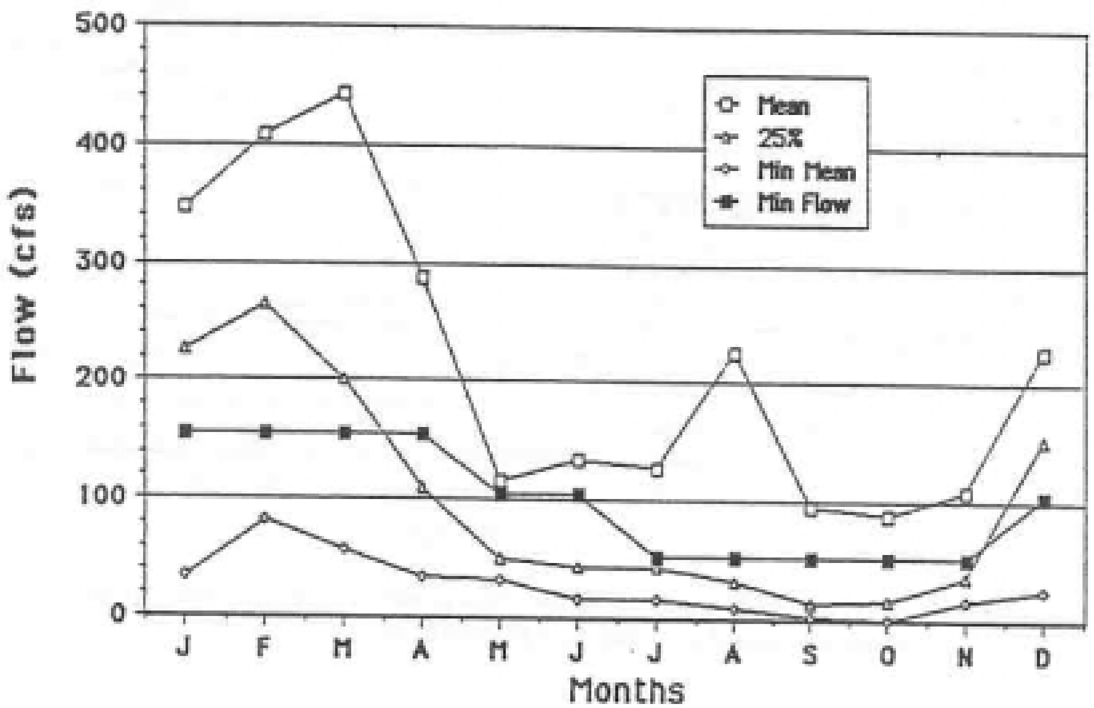

Figure 16. Recommended minimum flow requirement (Min Flow) versus monthly flow variability for Jeffries Creek.

months of record. However, instream uses on Saluda 1, Saluda 4a, and Saluda 4b can expect to be adversely impacted for much of the year based on historical flow patterns.

Recommended minimum flow requirements for Coastal Plain streams were always higher than minimum monthly means and also higher than 25th percentile of mean monthly flows for most of the year. This data indicates that occassionally streamflows will be insufficient to adequately maintain all instream uses.

DISCUSSION

The objectives of the Instream Flow Study were to 1) identify priority stream segments in need of minimum flow protection, and 2) determine minimum flow standards to protect instream uses. Phase I of the study accomplished the first objective and identified priority stream segments in which streamflows could become excessively low due to natural conditions and/or man-induced factors.

The second objective was accomplished in this second phase of the study. The recommended minimum flow standards listed in Table 7 are believed to protect instream uses at an acceptable minimum level. It is important to note that these minimum flow requirements do not provide optimum conditions for the instream uses, but rather represent the minimum flow below which some instream uses would be adversely impacted or eliminated. Also important to note is that while the standards are designed to protect instream uses, potential impacts to offstream uses and peaking hydroelectric power projects were not considered. Therefore, additional studies are needed to quantify economic and operational impacts of the recommended minimum instream flow requirements to affected offstream uses and hydroelectric power projects.

Streamflows are naturally variable and affected by several factors including precipitation, evaporation, ground water discharge, topography, and inflow from tributaries and upstream sources. While ample flows may usually be available to satisfy both instream and offstream uses, streamflows during dry periods may fall below recommended minimum flow requirements and instream uses will be adversely impacted. These low flow events occur naturally and are unavoidable; however, water uses that withdraw, divert, or withhold water from streams can increase the frequency, duration, and severity of such impacts. Only through the implementation of minimum flow standards can adverse impacts to instream uses due to man's activities be avoided or reduced to acceptable levels.

Most of the priority stream segments investigated occur directly below hydroelectric power projects. Because almost all the flow within these segments is regulated by releases from the hydroelectric projects, the minimum flow requirements for the segments may be achieved by minimum release requirements from the projects. One concern regarding possible implementation of minimum flow requirements in such segments is that minimum flow requirements would cause upstream lake elevations to fall to undesirable levels during drought conditions, when inflow to the lake is less than the minimum flow requirement. The purpose of minimum flow requirements contained in this report is not to protect instream uses during times when natural conditions would normally preclude their use, but rather to protect instream uses when sufficient flows should be available but are not due to man's activities. Therefore, during periods of drought when inflow to a hydroelectric or other flow altering project is less than the minimum flow requirement and lake elevations are at a minimum acceptable level, the project would be expected to release only the amount of water available from inflow to the project. Through this mechanism, both instream uses and inlake uses could be maintained at acceptable levels.

Run-of-river hydroelectric projects that discharge inflow as a normal operational procedure would not be adversely affected by minimum flow requirements, and in fact, could benefit because sufficient base flows would be maintained to allow continuous operation. However, the current operations of peaking hydroelectric power facilities would require modification to satisfy minimum flow requirements.

While this study has identified minimum flow requirements that should adequately protect instream uses, no comprehensive program currently exists in South Carolina to implement these standards. However, instream uses may be protected to a limited extent by including minimum instream flow conditions on appropriate State and Federal permits and licenses for projects that may affect instream flows. Such permits include 1) Federal Energy Regulatory Commission operating licenses and exemptions for hydroelectric power projects, 2) State Budget and Control Board Permit for construction activities in navigable waters, 3) S.C. Water Resources Commission Interbasin Transfer Permit, and 4) S.C. Department of Health and Environmental Control 401 Water Quality Certification (for projects requiring Federal permits and licenses). The S.C. Water Resources Commission, S.C. Department of Health and Environmental Control, S.C. Wildlife and Marine Resources Department, and U.S. Fish and Wildlife Service routinely review and comment on applications for these permits and, when appropriate, could request that instream flow conditions be included. Although additional studies are needed to help refine the recommended minimum flow requirements identified in this report, the requirements are based on the best available data and could be used as a guide by State agencies to protect instream uses through existing regulatory programs. In addition, one or more of the methods used in this study would be useful in assessing minimum flow requirements for instream uses for stream segments throughout South Carolina.

Instream use protection is recognized as an important component of water resource management in South Carolina, as well as the rest of the nation. The protection of these uses through the preservation of instream flows is essential for the future use and continued viability of our riverine resources in South Carolina.

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APPENDIX A

Joint Resolution (R115, H2549)

(R 115. 112549)

A JOINT RESOLUTION TO REQUIRE THE SOUTH CAROLINA WATER RESOURCES COMMISSION TO IDENTIFY AND LIST THE STREAMS AND WATERCOURSES OF THE STATE FOR WHICH MINIMUM FLOW LEVELS NEED TO BE ESTABLISHED AND PREPARE PROPOSED STREAMFLOW STANDARDS.

Be it enacted by the General Assembly of the State of South Carolina:

Legislative findings

SECTION 1. The General Assembly finds:
(a) A substantial increase has occurred in the number of significant withdrawals of water from the various streams and watercourses of this State.
(b) These withdrawals, if continued without due regard for their cumulative effect on streamflows, could adversely affect, to a serious and significant degree uses dependant upon those streams and watercourses, including fish and wildlife resources, recreation, water quality, hydropower generation, aesthetics, navigation, and ecosystem maintenance.
(c) Fish and wildlife resources, recreation, water quality, hydropower generation, aesthetics, navigation, ecosystem maintenance, agriculture, and other concerns are individually and collectively linked to the continued economic well-being of industries, the health, safely, and welfare of all South Carolinians, and the general attractiveness of South Carolina for future development.
(d) As greater demands are placed upon South Carolina's water resources to meet off-stream uses such as industrial, agricultural, and domestic water supply, the effects upon and need for protection of in-stream uses of water identified hereinabove will increase.

Commission must Identify and list streams and water courses

SECTION 2. The South Carolina Water Resources Commission must identify and list those streams and watercourses throughout the State for which minimum flow levels need to be established in order to assure the continued viability of stream-related use as identified in Section 1. In determining the the criteria to be used to identify the above streams, the Commission must consult with the Wildlife and Marine Resources Department, the Department of Health and Environmental Control, the Department of Parks, Recreation and Tourism, the Department of Agriculture, the State Development Board, the Coastal Council, and with all affected state and local governments. The Commission must include this identification list those streams and watercourses the Commission determines are significant, along with a statement of findings as to why that stream or watercourse was selected. The identification list required by this section must rank the streams and watercourses beginning with those in which the need for establishing minimum flow levels is the greatest. The Commission must compile information for each watercourse as to current and projected water use. The Commission, in its discretion, may revise the list and may add or delete streams or watercourses as circumstances require following notice of such proposed action by publication in a newspaper of general circulation in the affected area. The initial identification list required by this section must be completed no later than January 1, 1985.

Streamflow standards

SECTION 3. The Commission must prepare proposed streamflow standards for each stream or watercourse determined to have a significant need for regulation. In developing the standards for each stream the Director must consult with those governmental entities identified in Section 2. The Commission must also consult with any private individuals, groups, or organizations as deemed advisable by tile Commission. The Commission must complete the preparation of proposed standards for all streams on the initial identification list no later than January 1, 1987.

Time effective

SECTION 4. This act shall take effect upon approval by the Governor.

In the Senate House the 24th day of May
In the Year of Our Lord One Thousand Nine Hundred and Eighty Three
Michael R. Daniel.
President of the Senate
Ramon Schwartz. Jr.,
Speaker of the House of Representatives

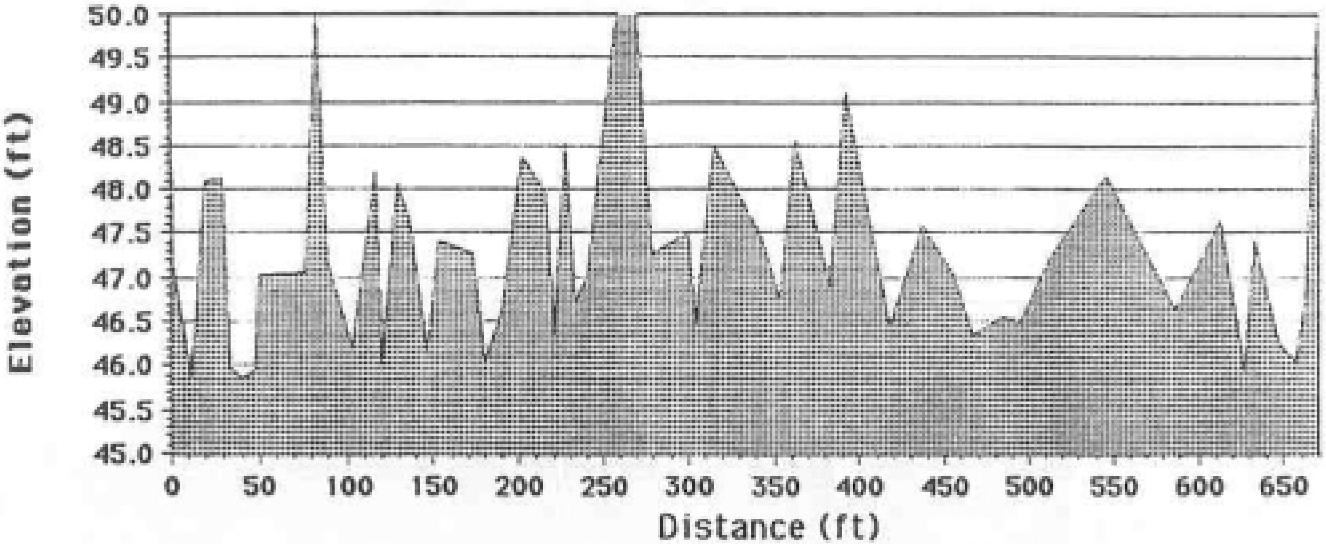
Approved the 26th day of May, 1983

Richard W. Riley

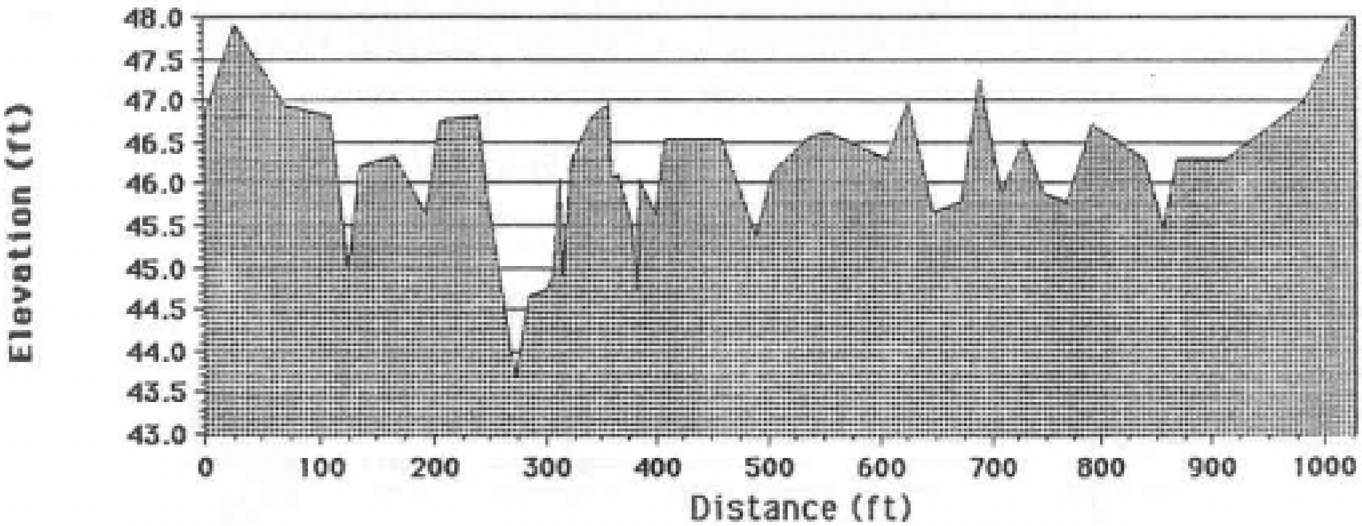
APPENDIX B

Study Site Cross-sections

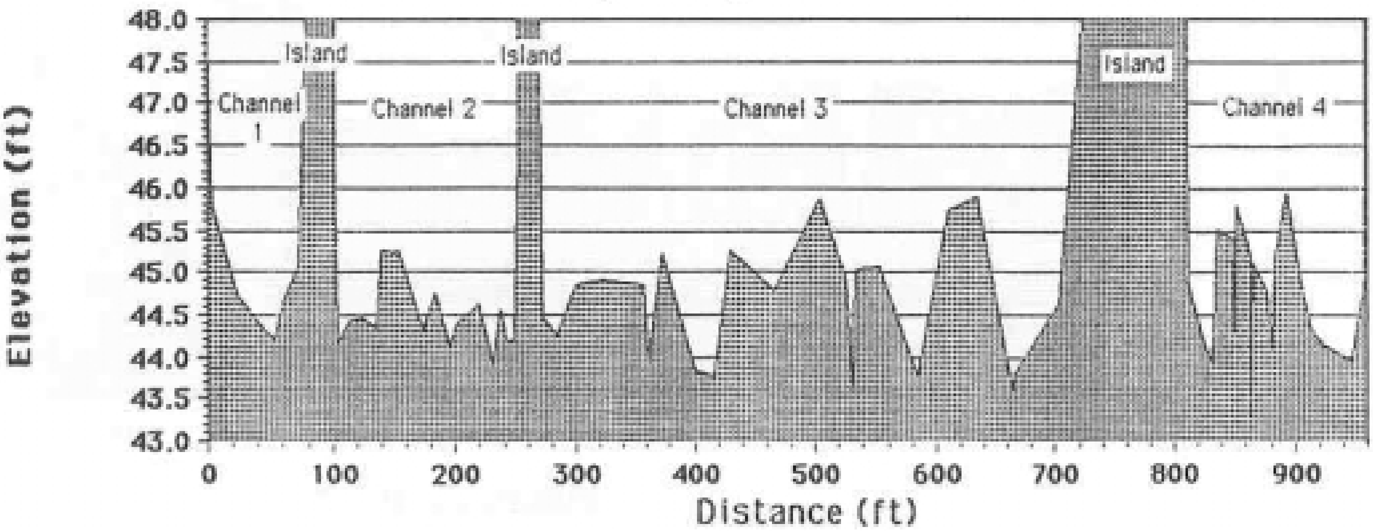
Catawba 2, Site 1



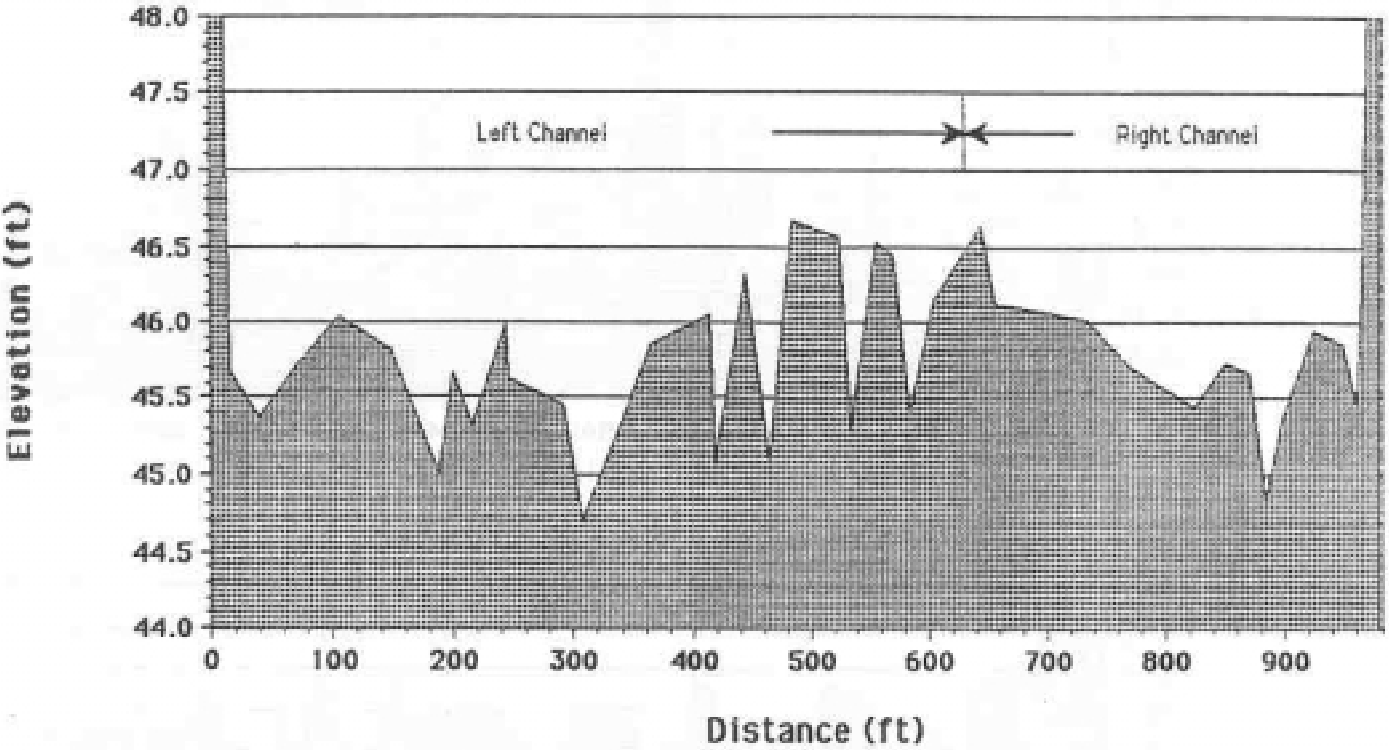
Catawba 2, Site 2, Transect 1



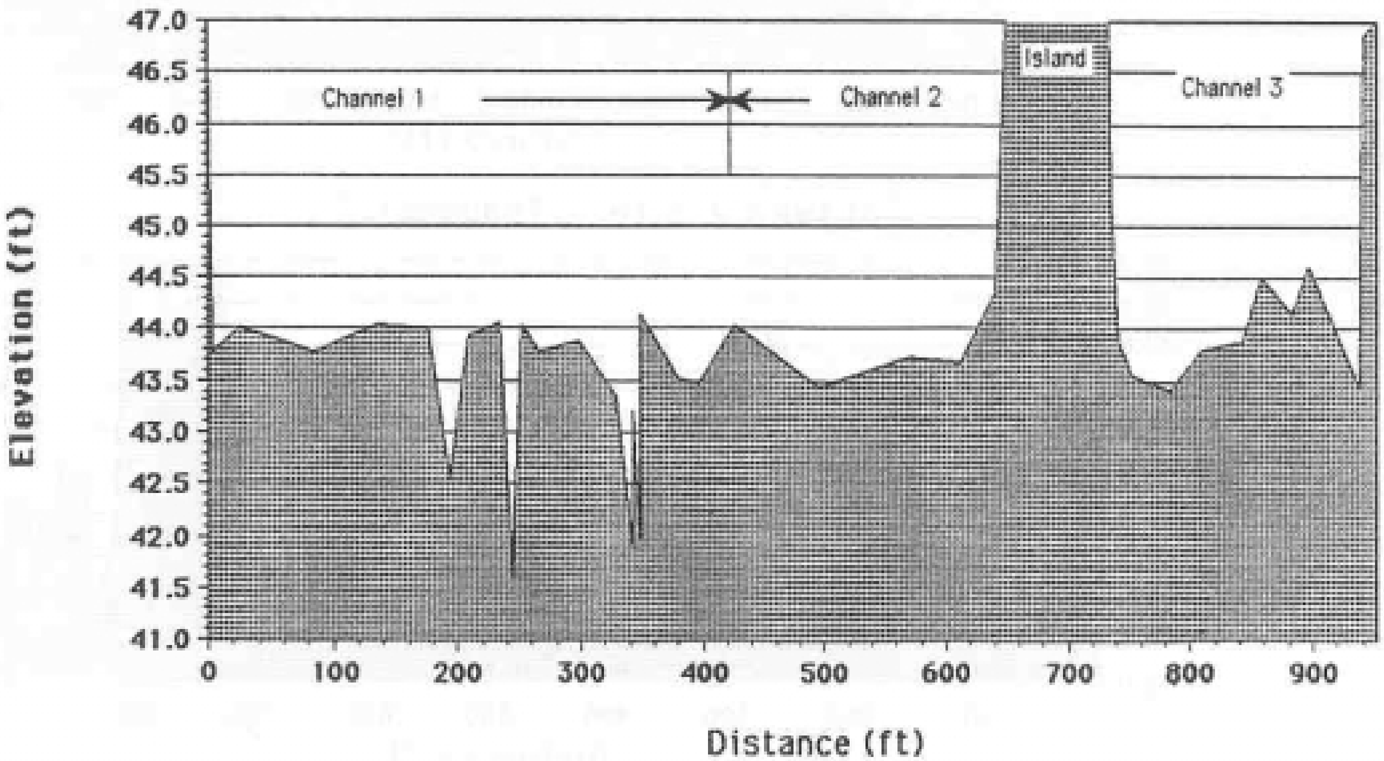
Catawba 2, Site 2, Transect 2



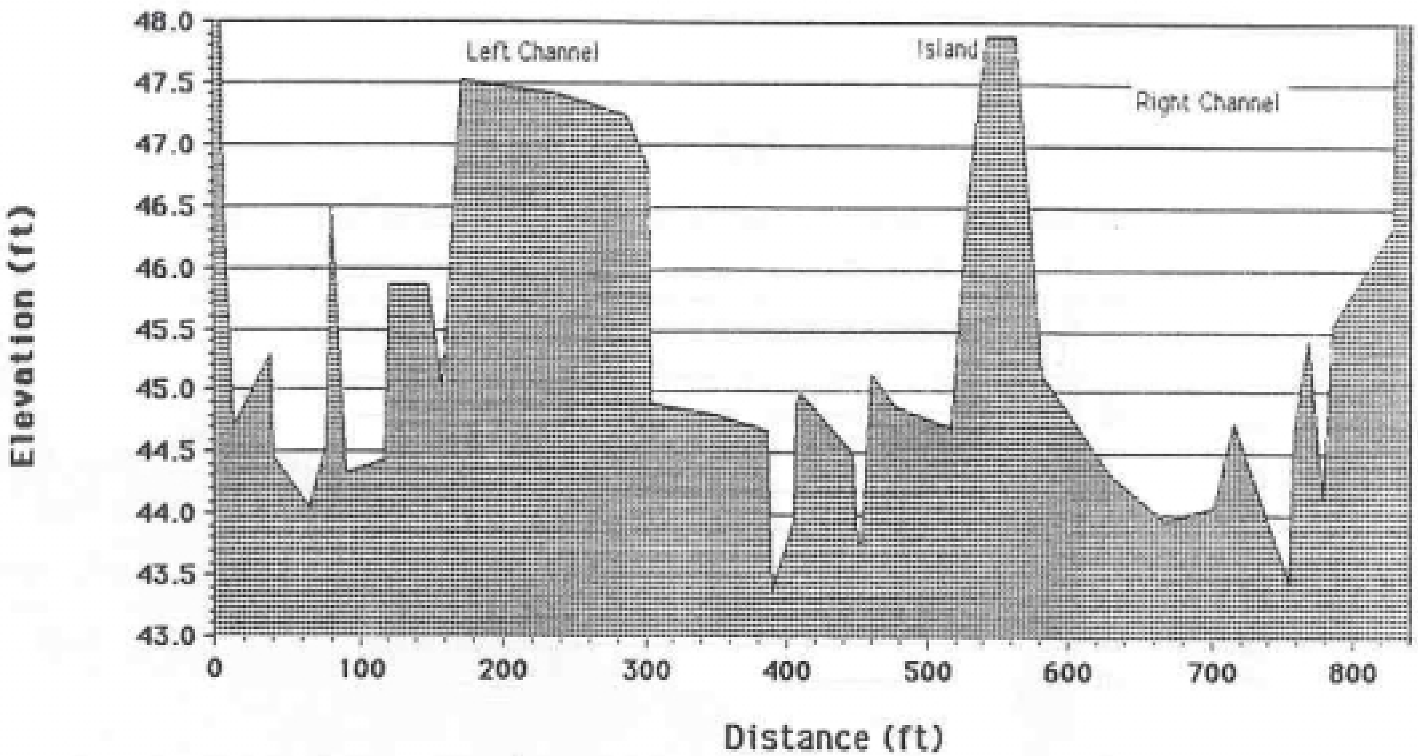
Wateree 2, Site 1



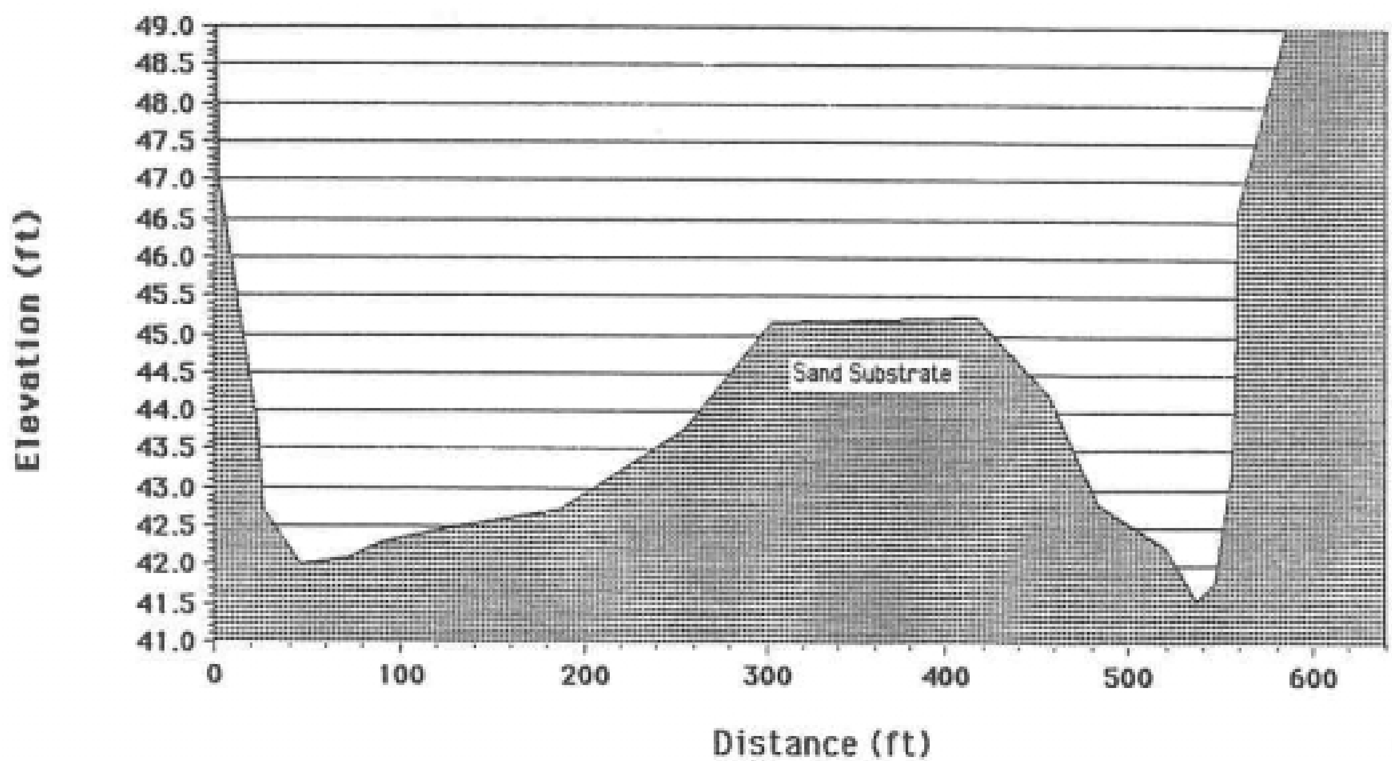
Wateree 2, Site 2



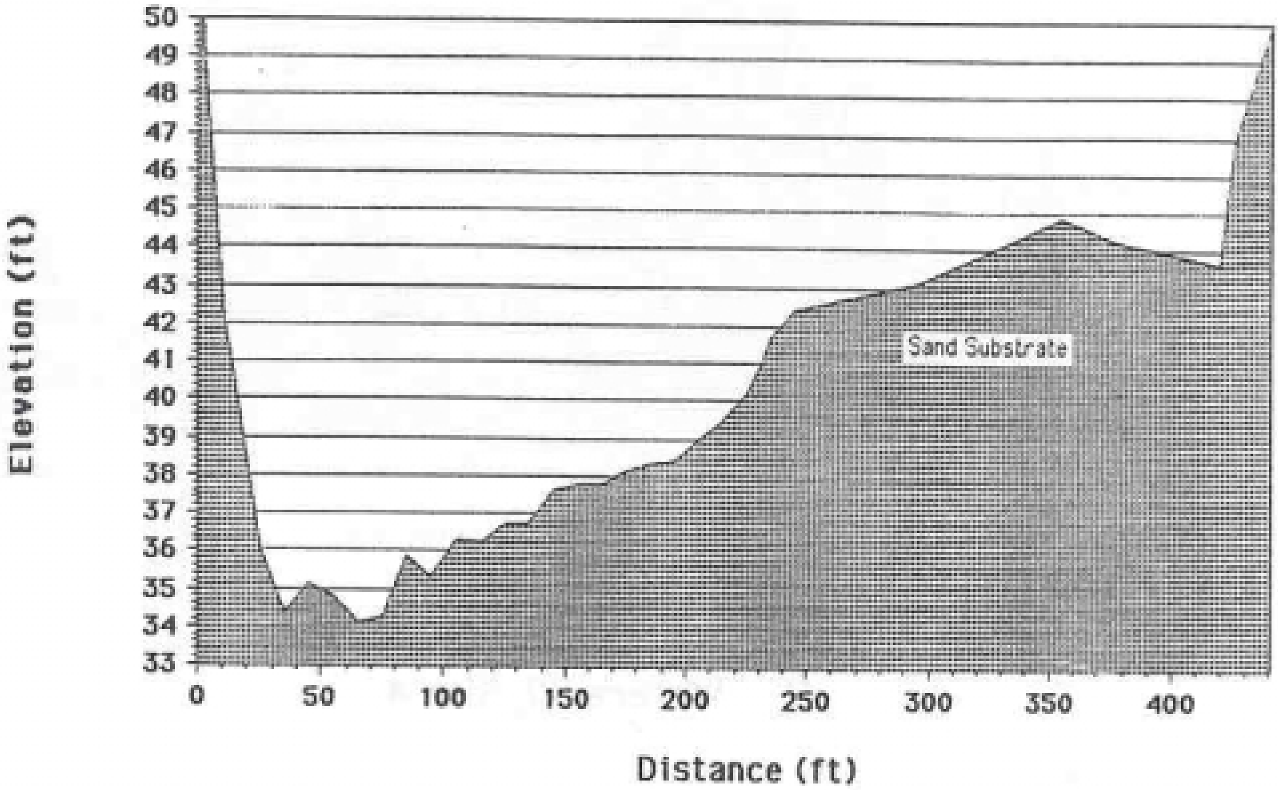
Wateree 2, Site 3



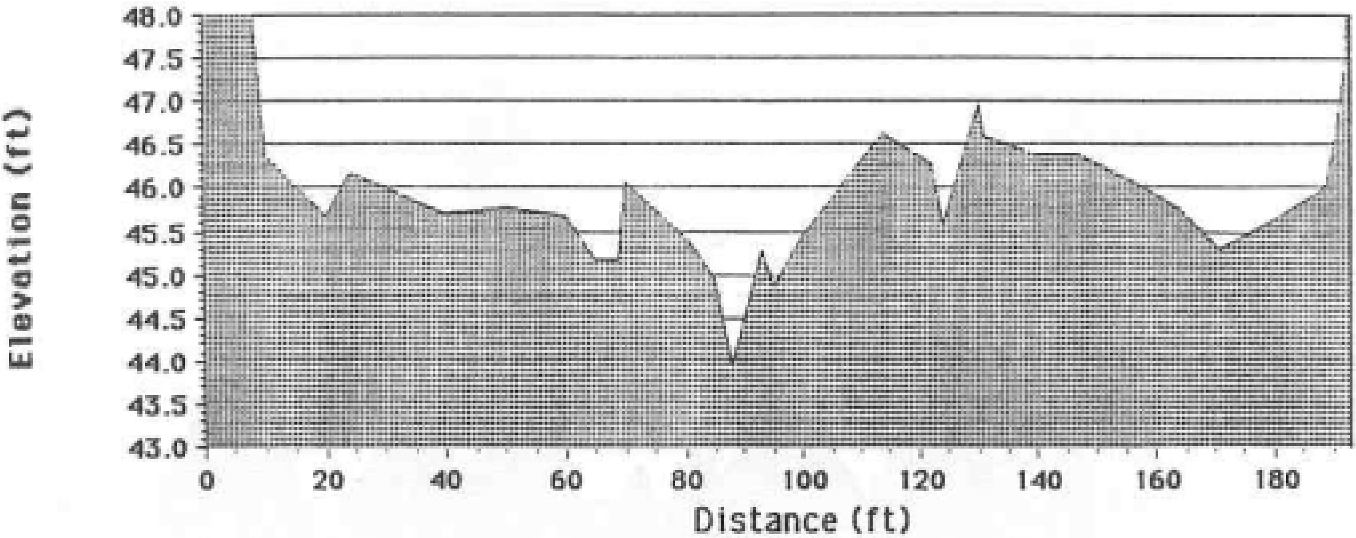
Wateree 2, Site 4



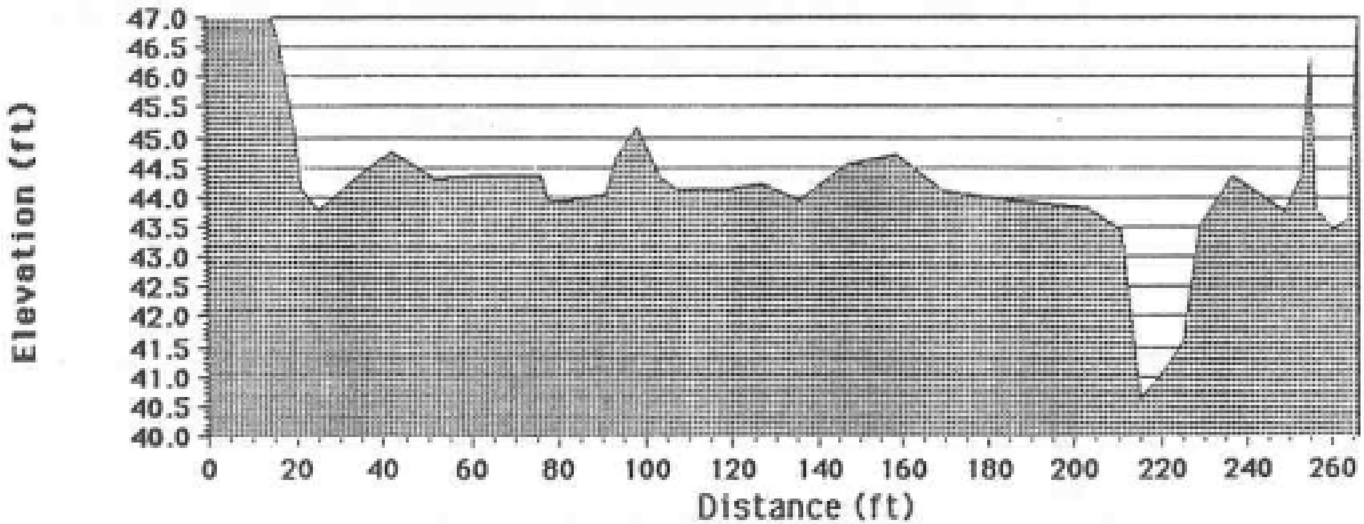
Wateree 1, Site 1



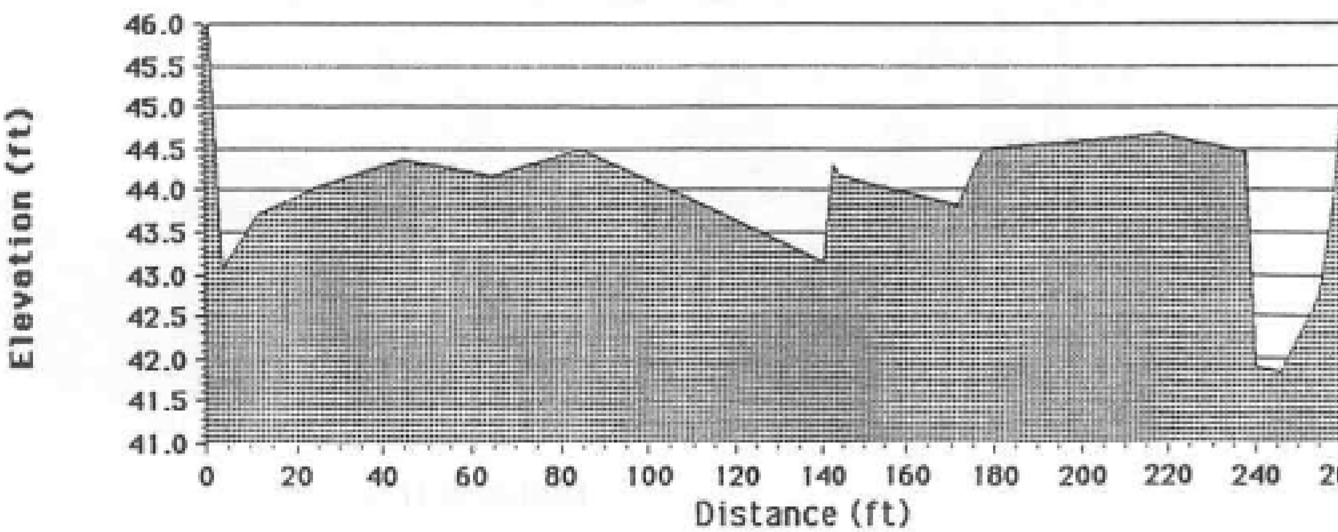
Saluda 4, Site 1



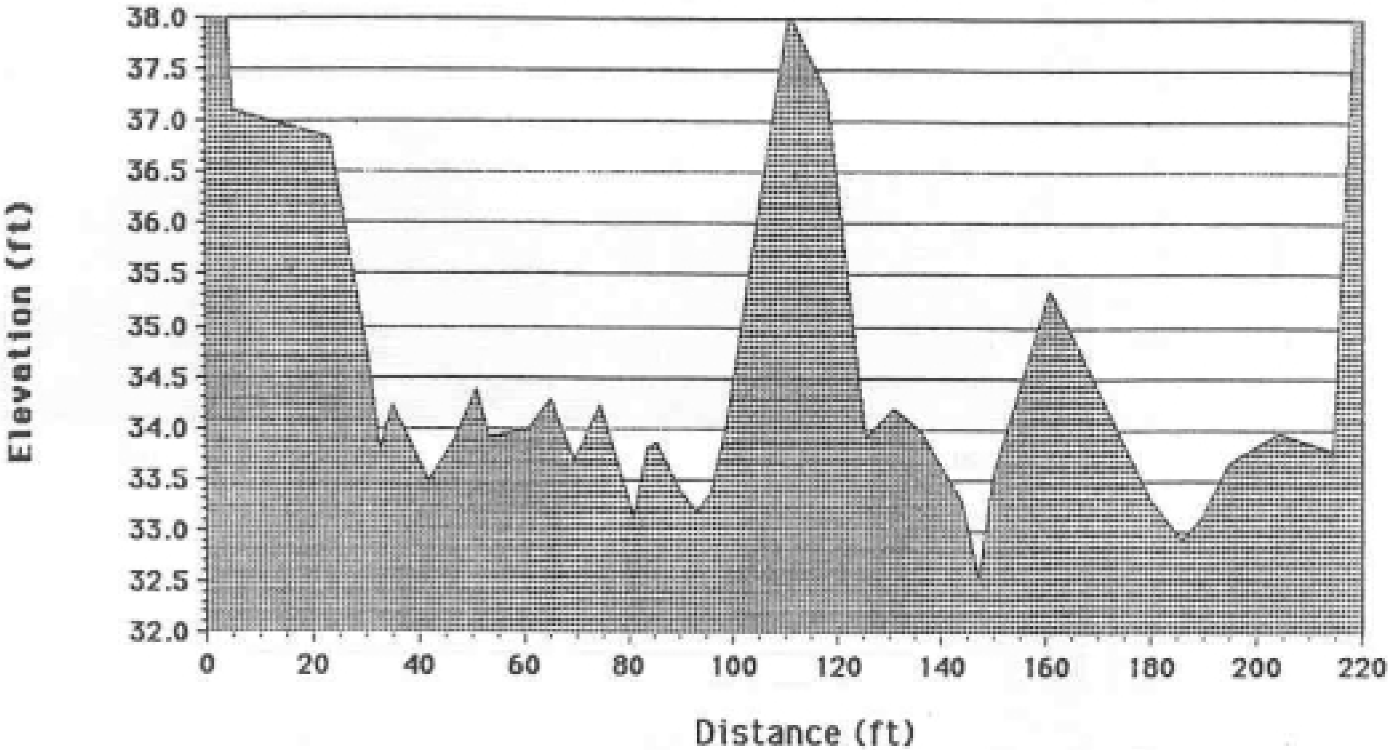
Saluda 4, Site 2



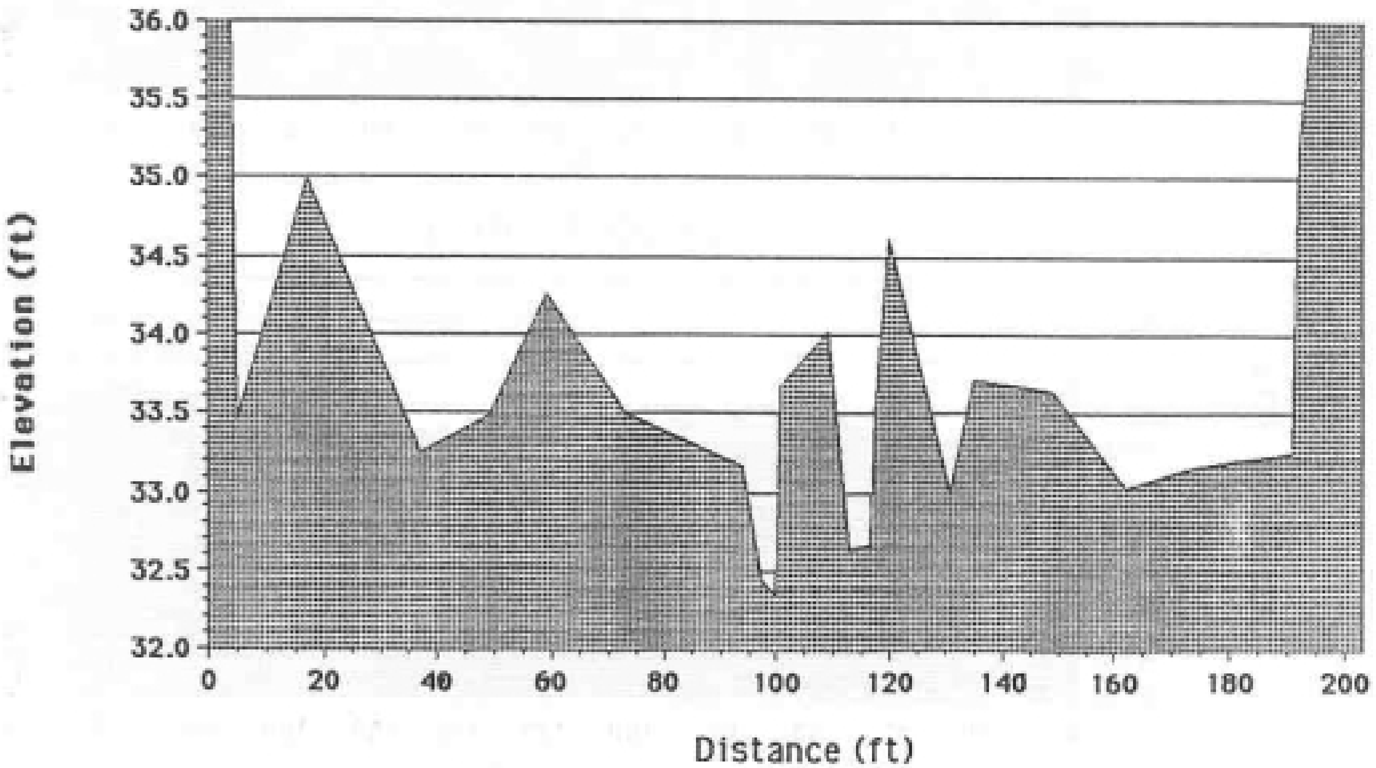
Saluda 4, Site 3



Saluda 2, Site 1, Transect 1



Saluda 2, Site 1, Transect 2



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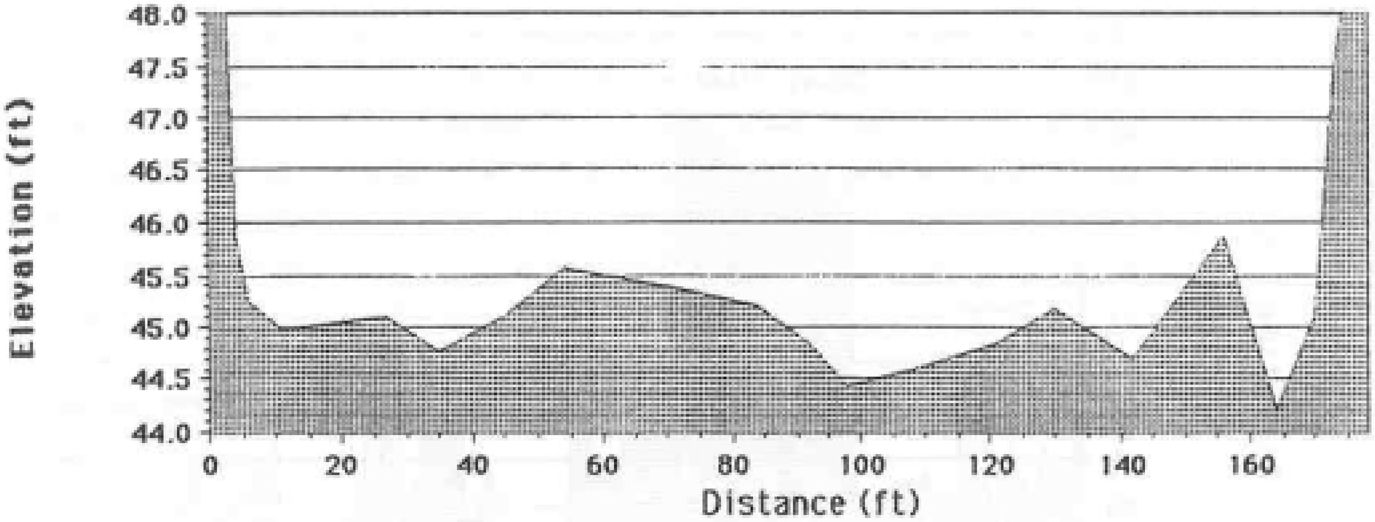

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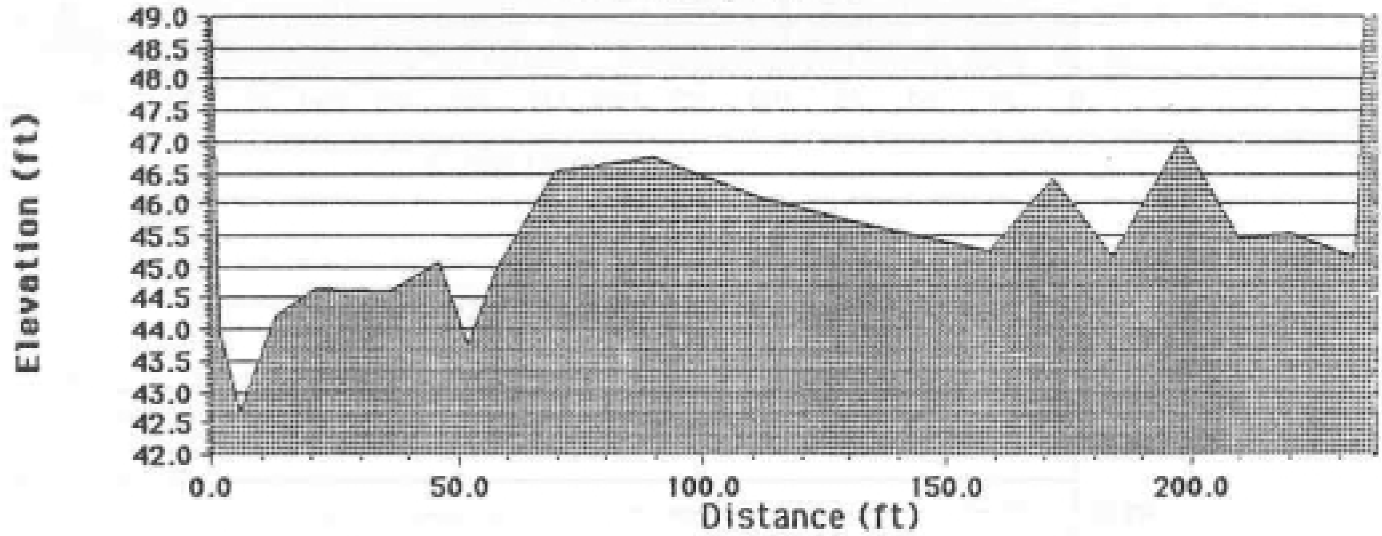
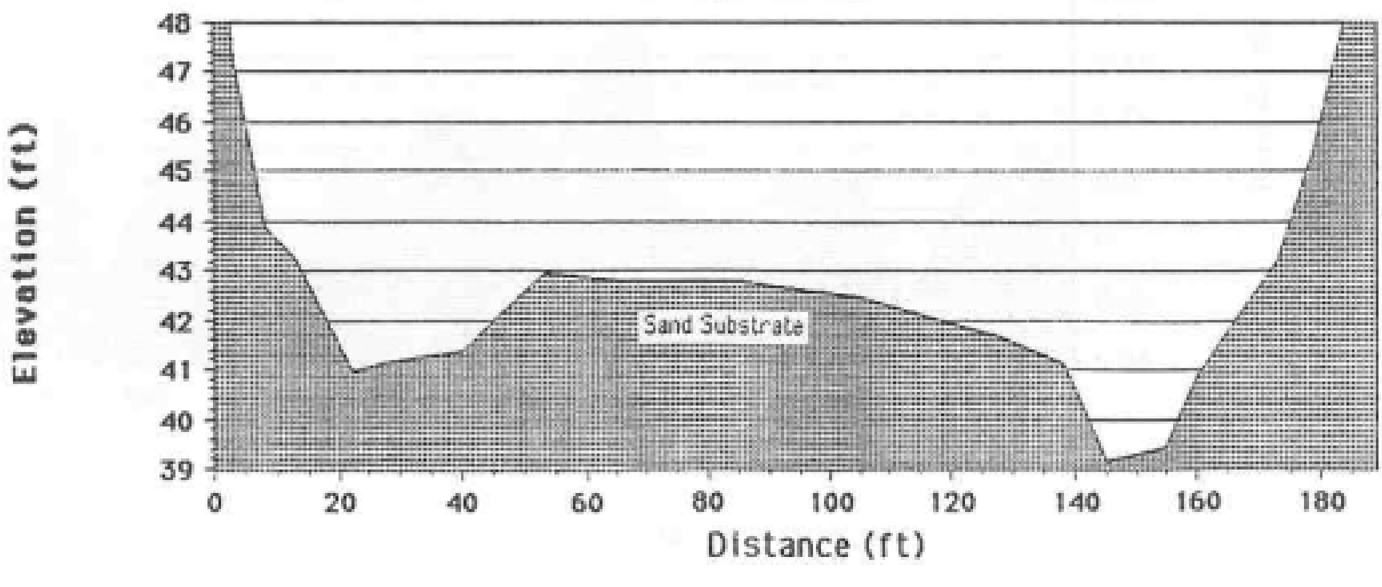
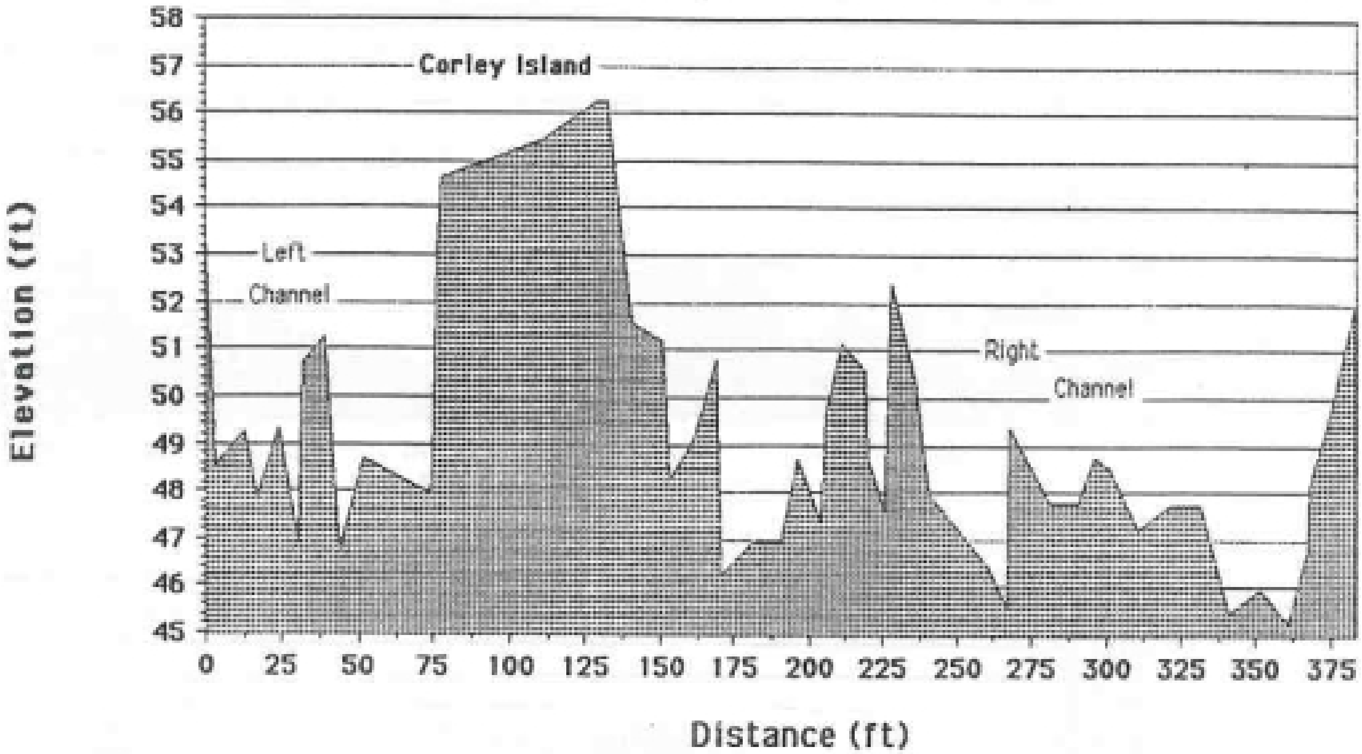


Saluda 2, Site 4



Saluda 1, Site 2



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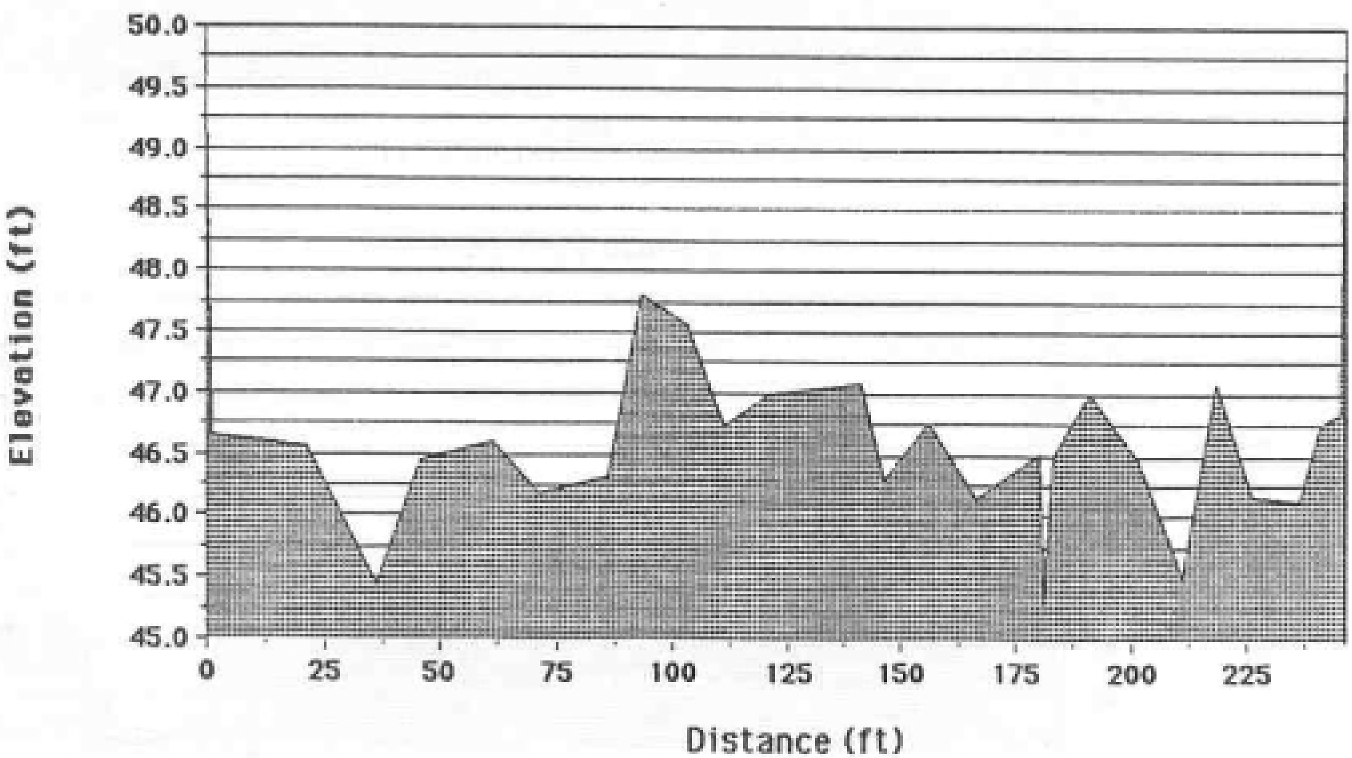
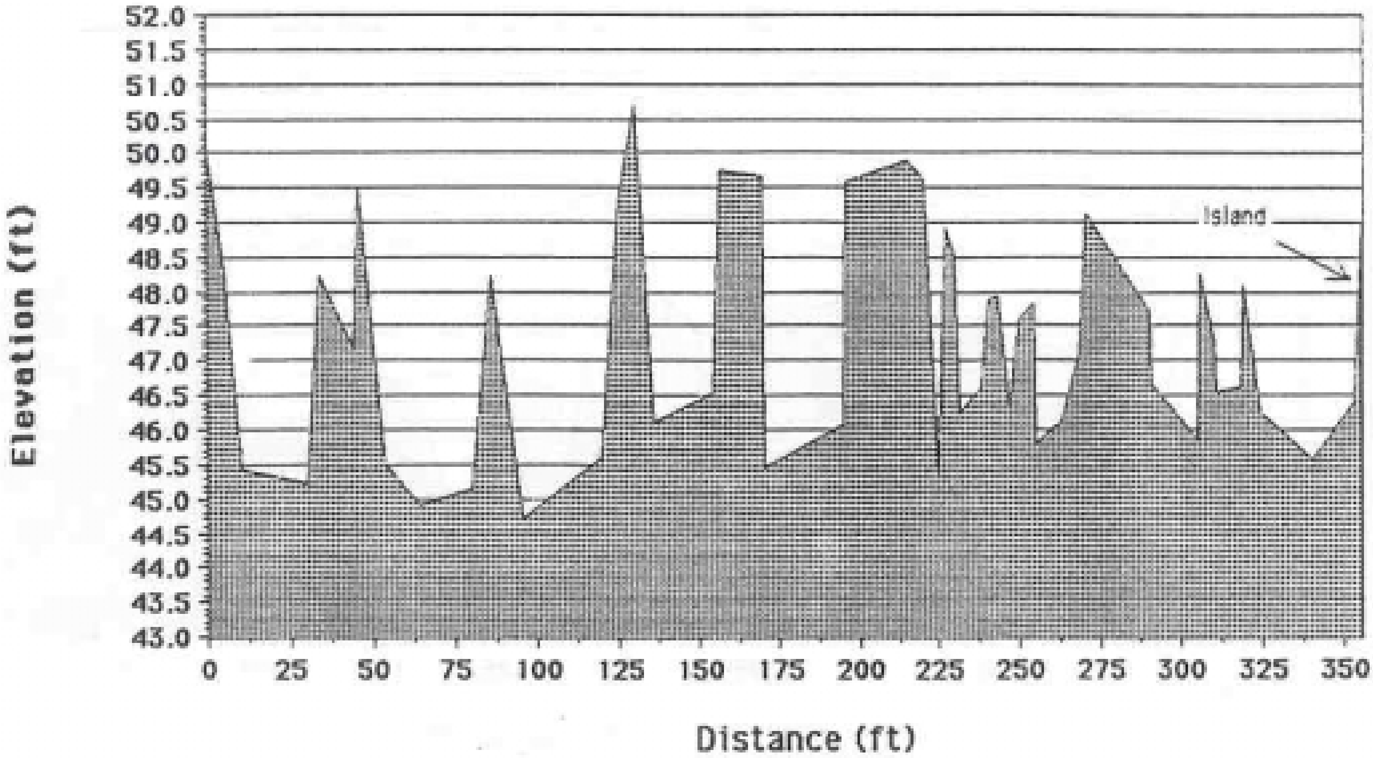
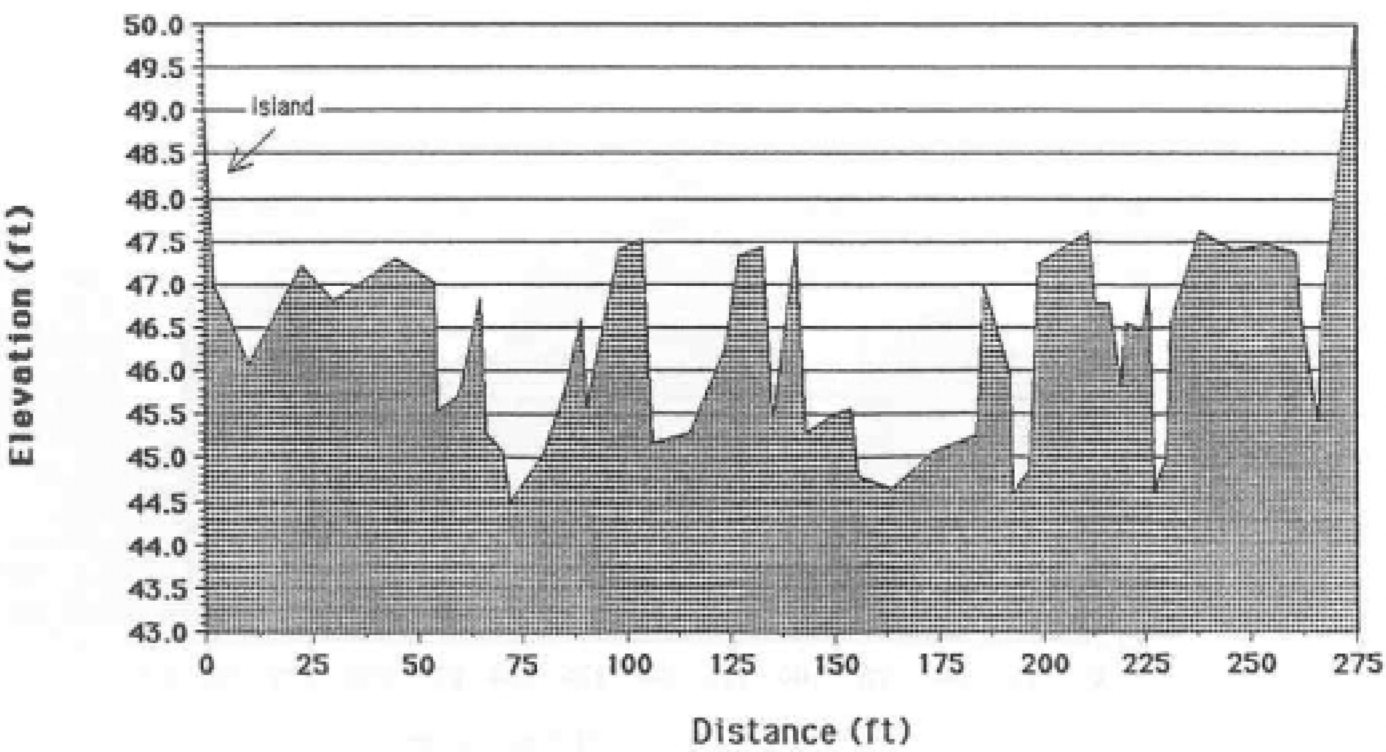


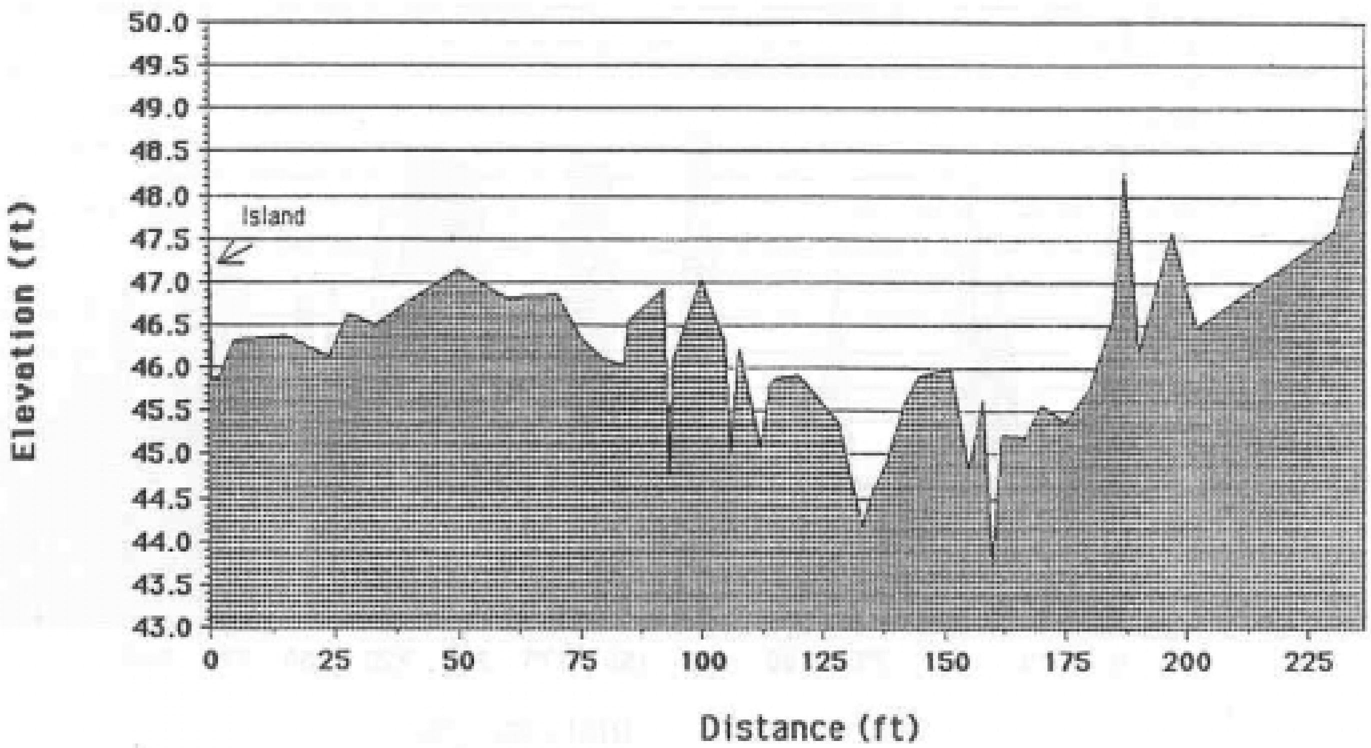
Saluda 1, Site 4, Transect 1, Left Channel



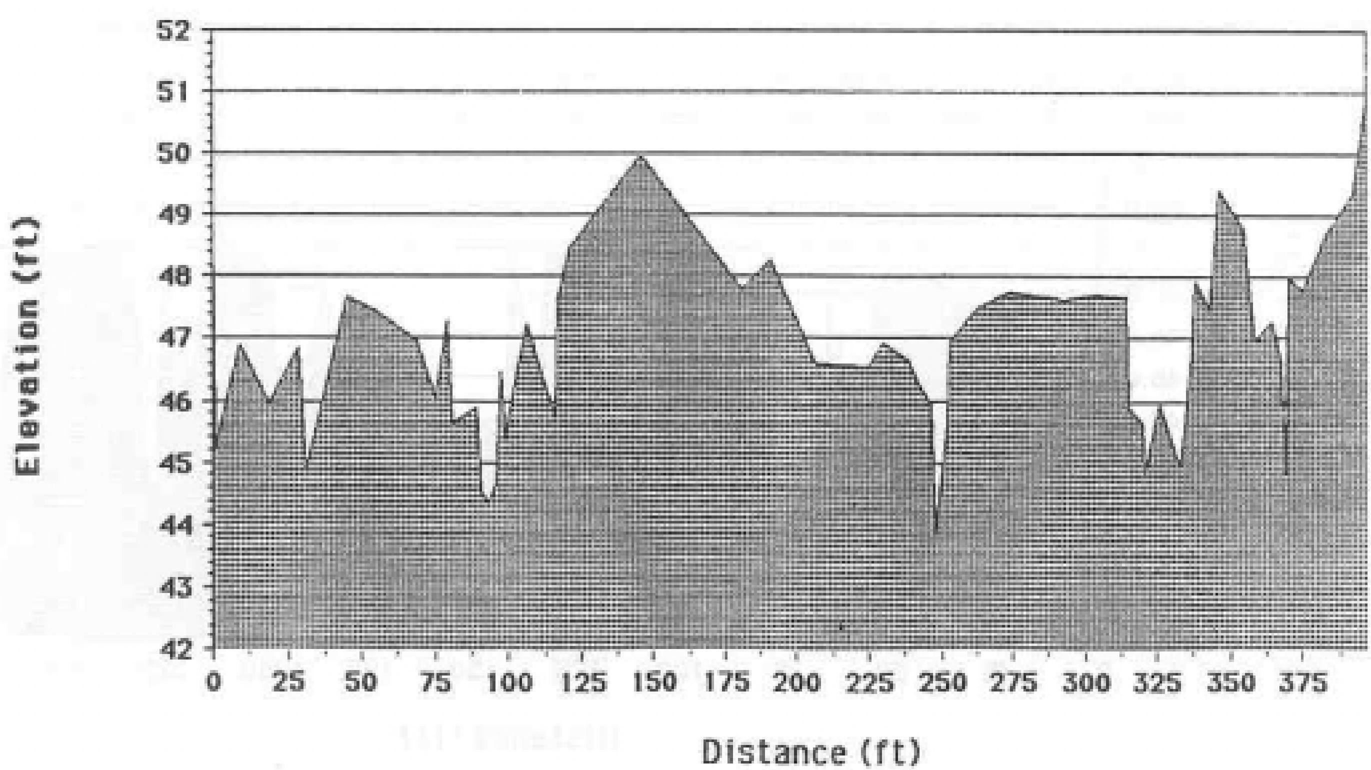
Saluda 1, Site 4, Transect 1, Right Channel



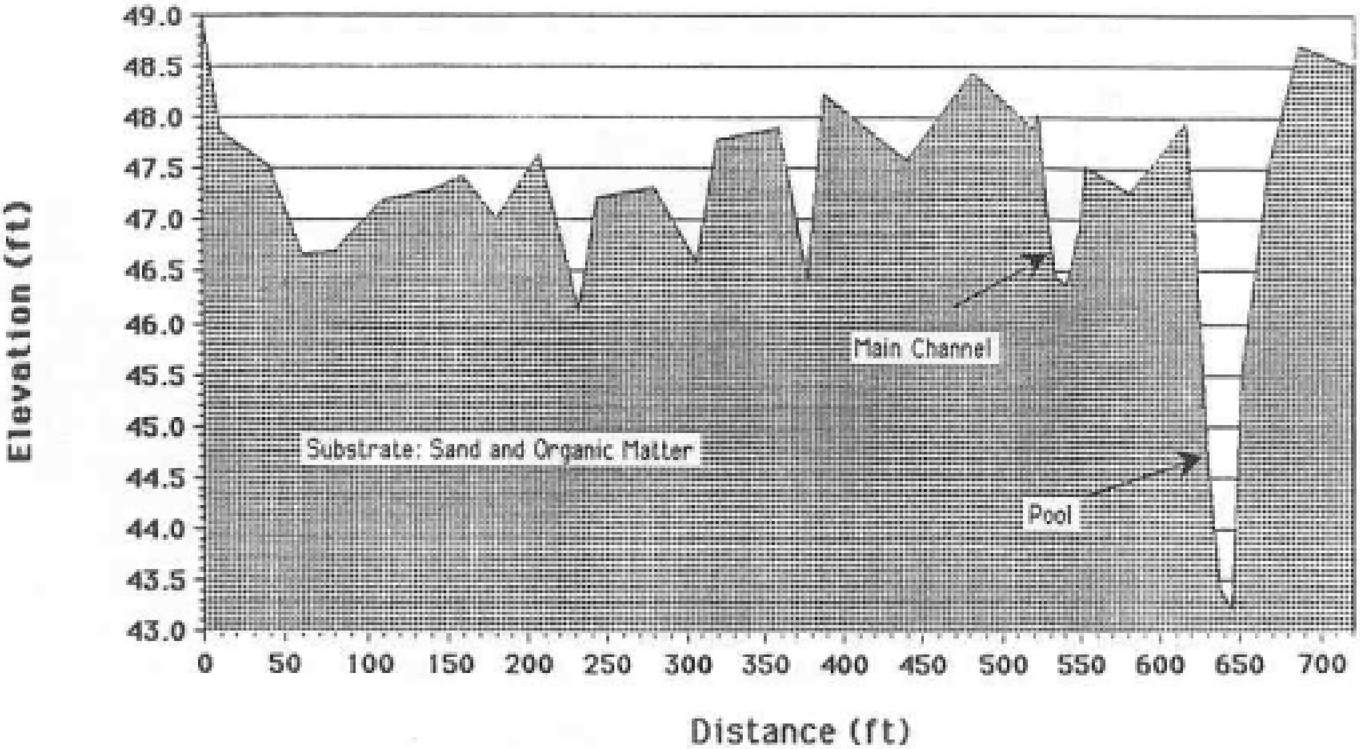
Saluda 1, Site 4, Transect 2



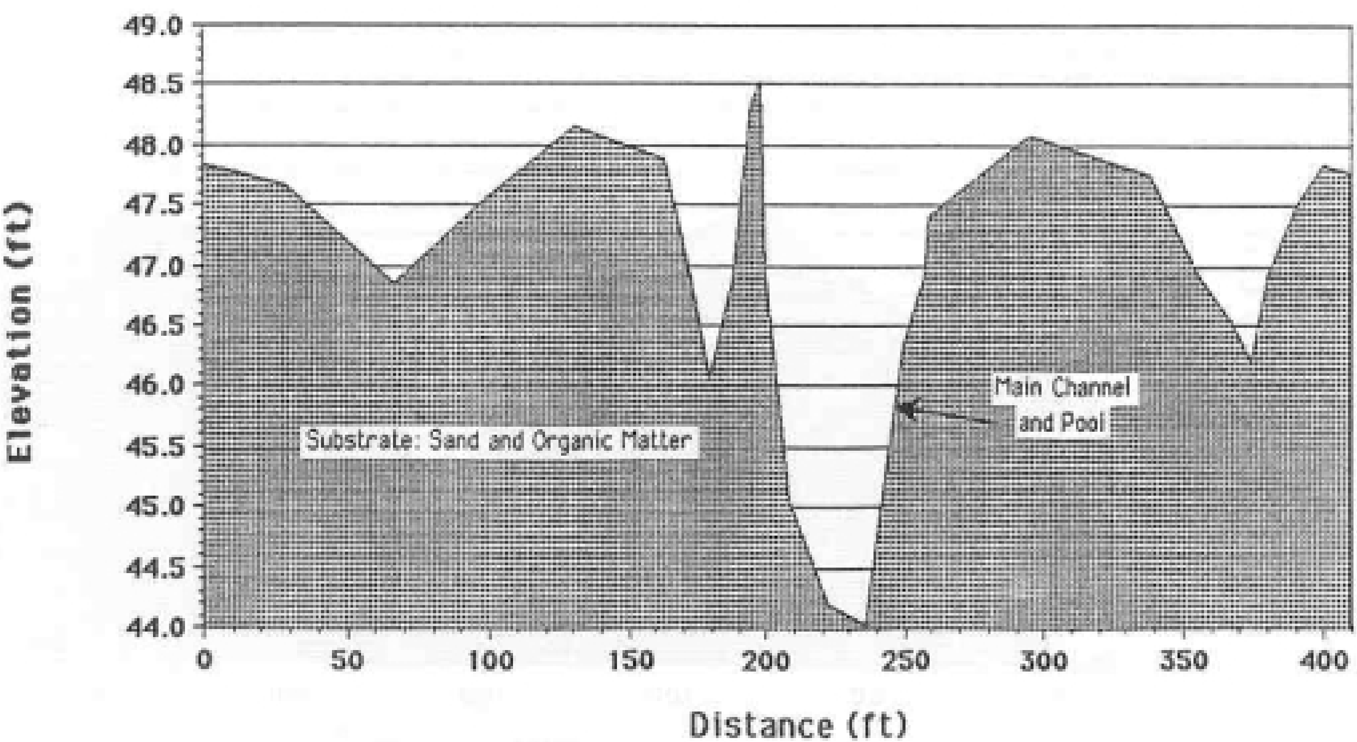
Saluda 1, Site 5



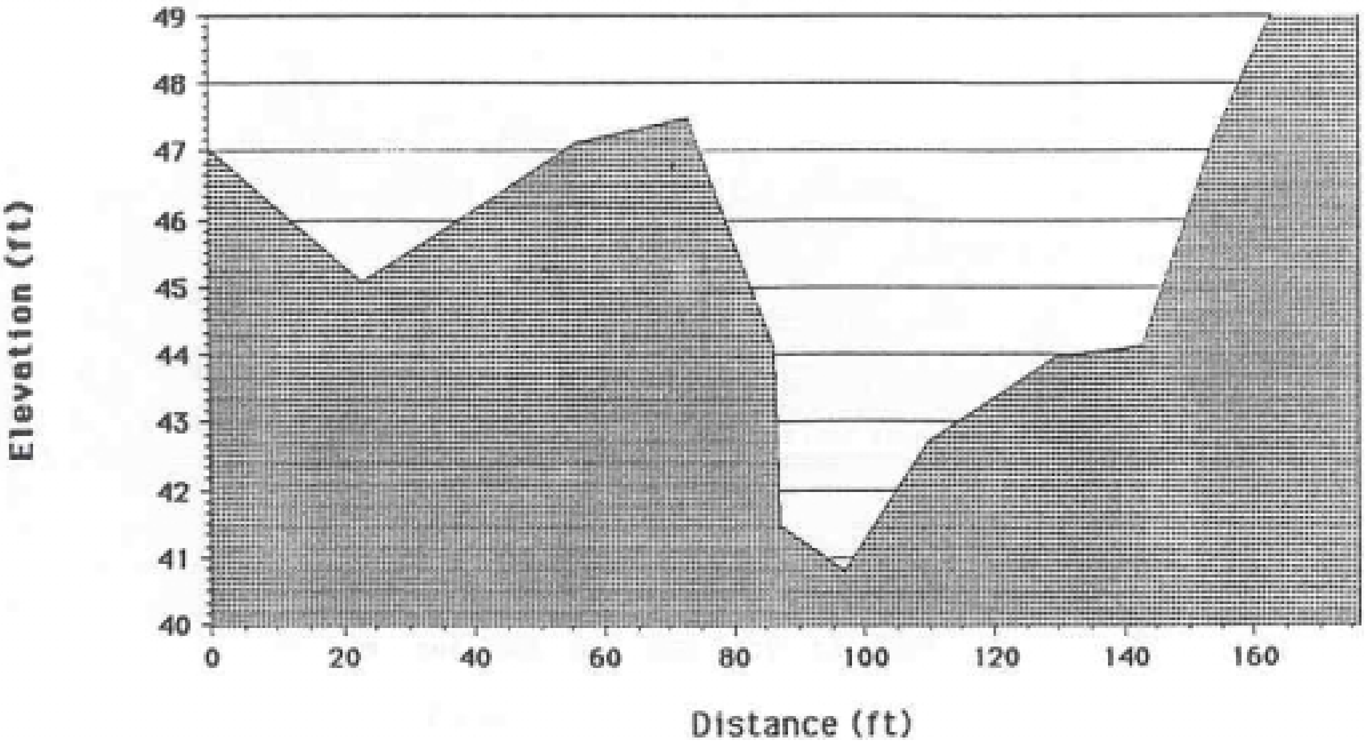
Coosawhatchie, Site 1, Transect 1



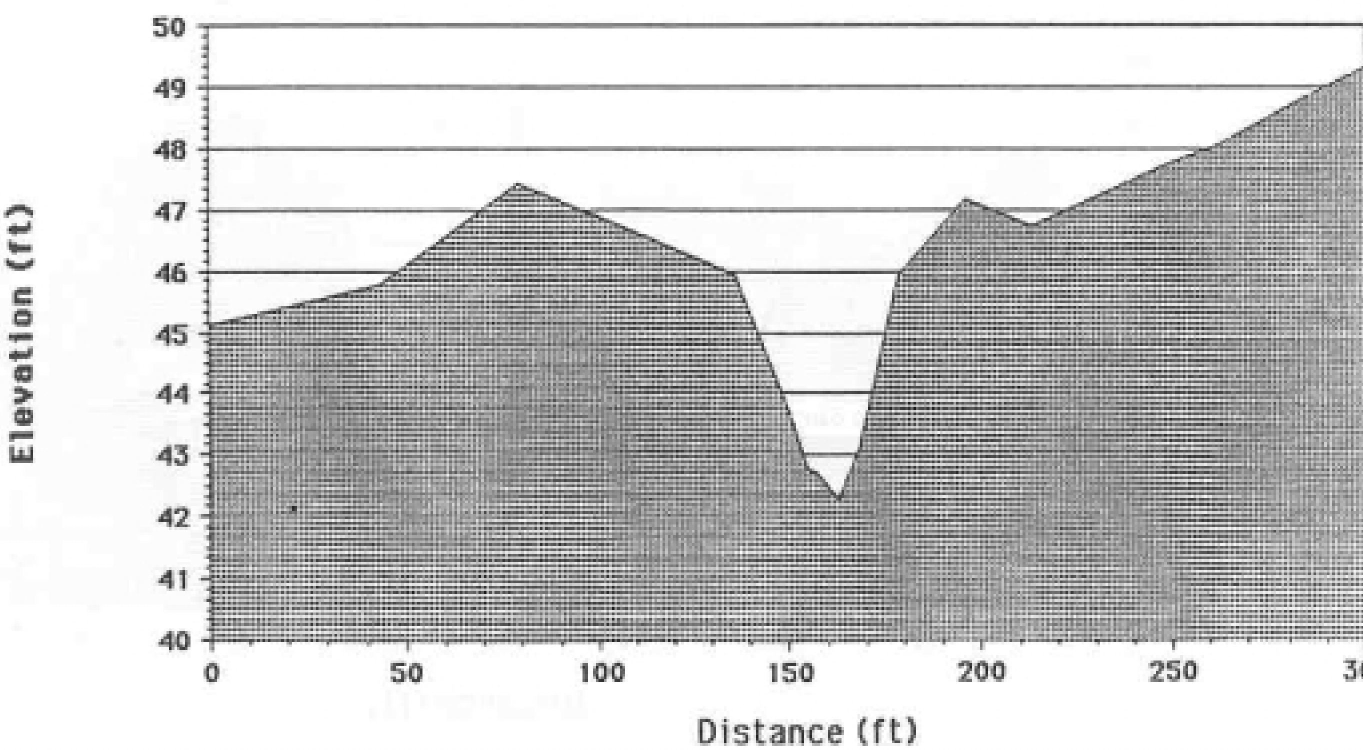
Coosawhatchie, Site 1, Transect 2



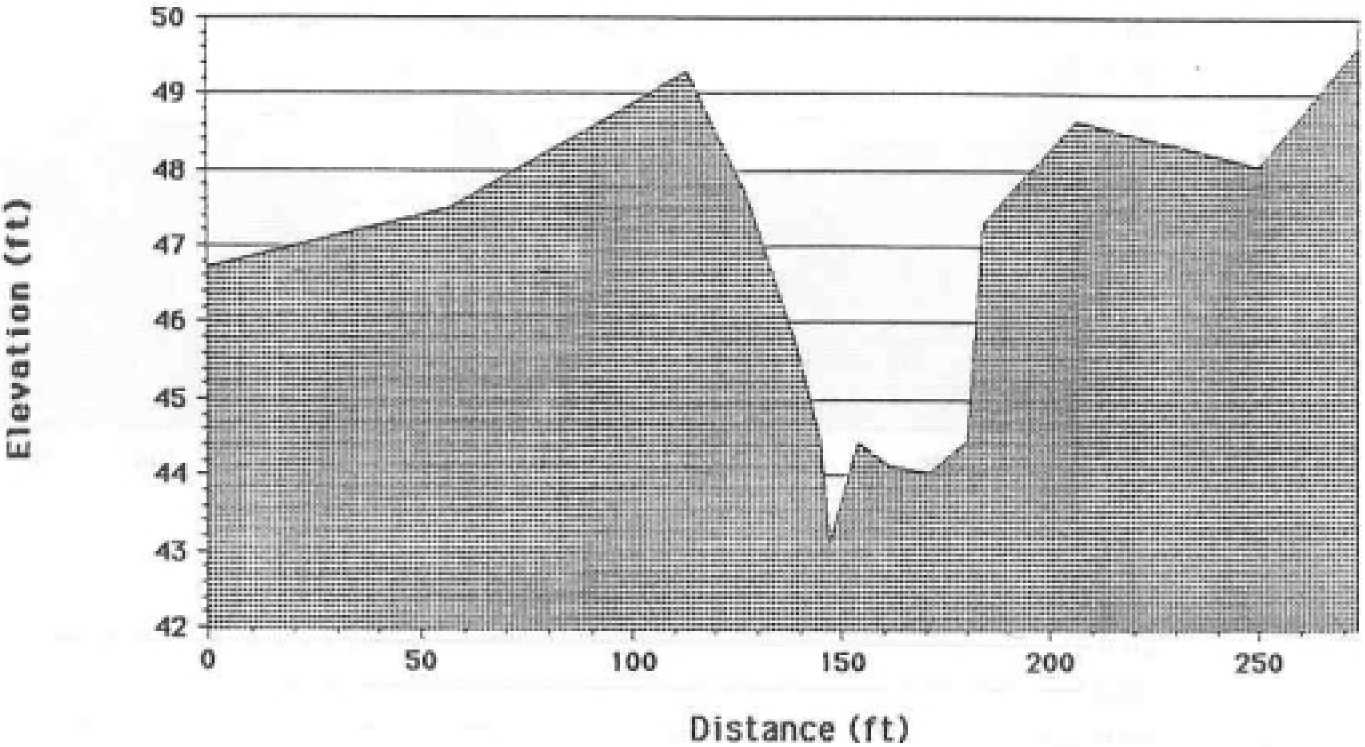
Jeffries Creek, Site 1



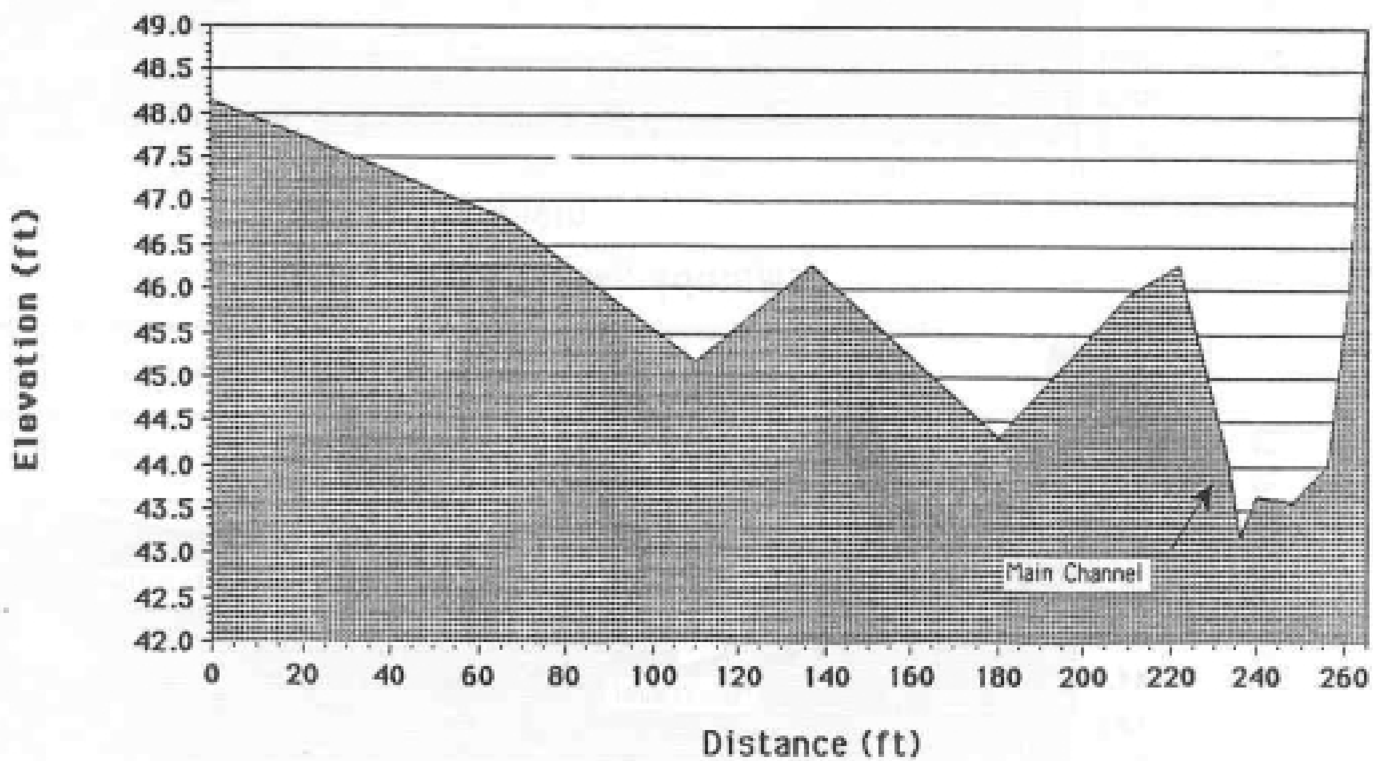
Jeffries Creek, Site 2

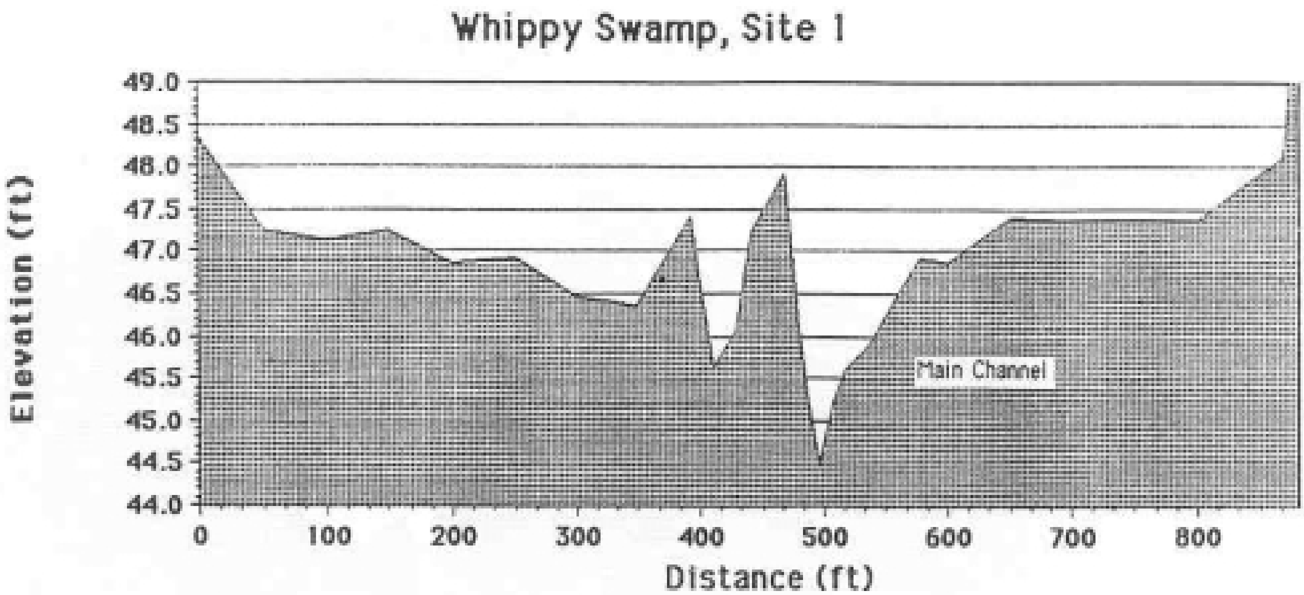


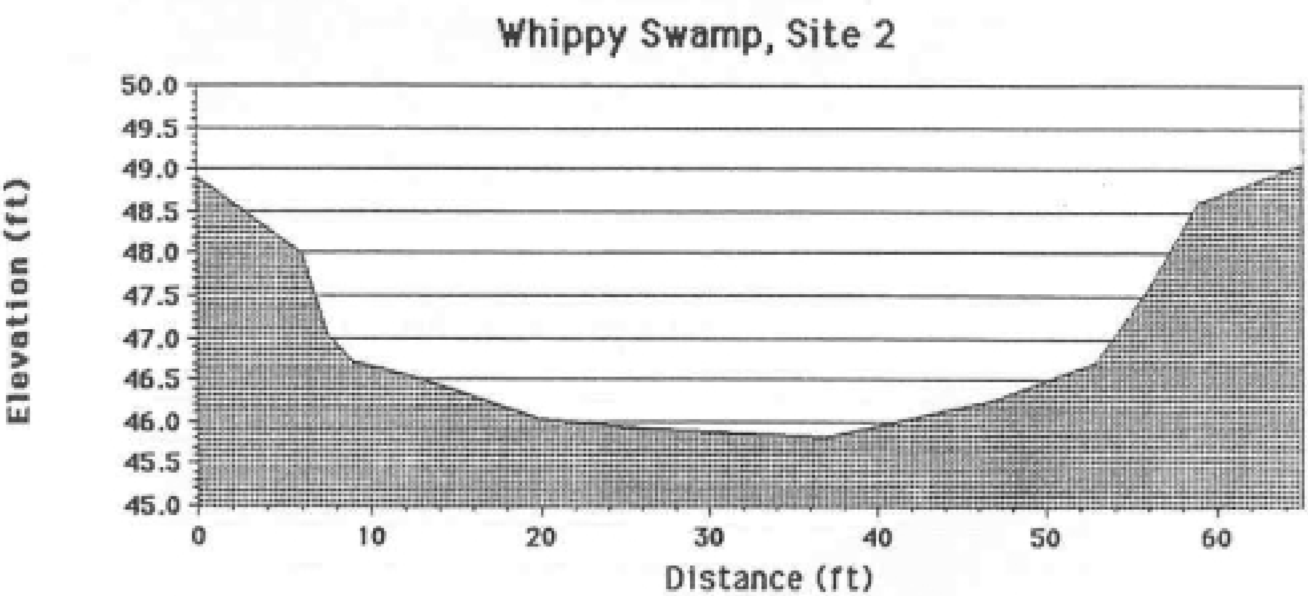
Jeffries Creek, Site 3

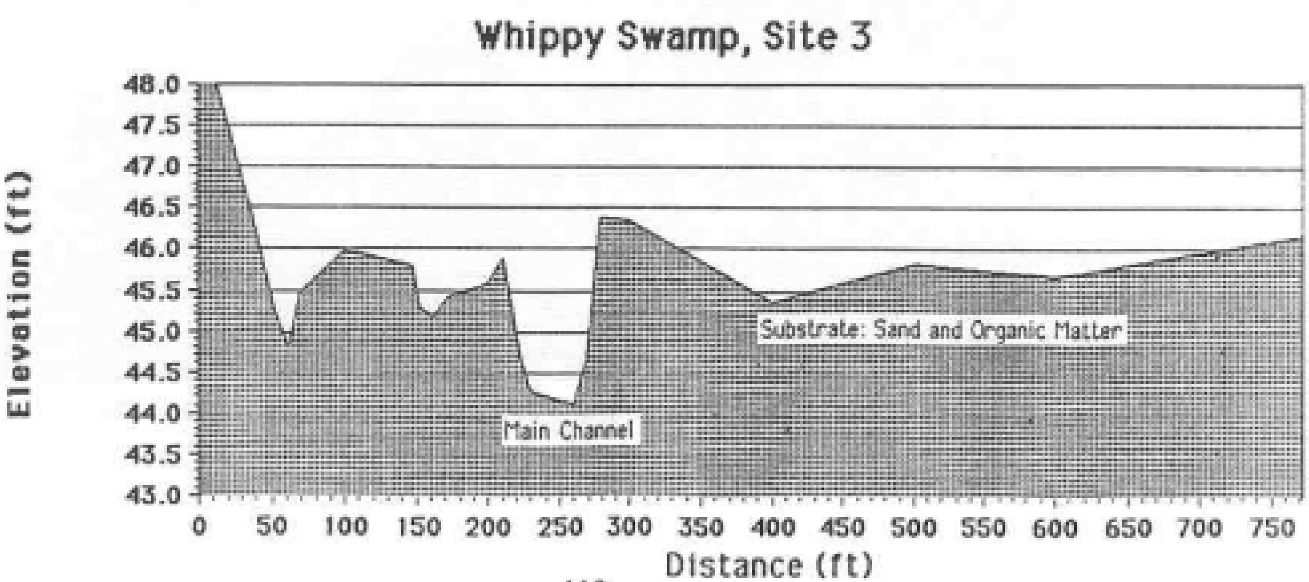


Jeffries Creek, Site 4



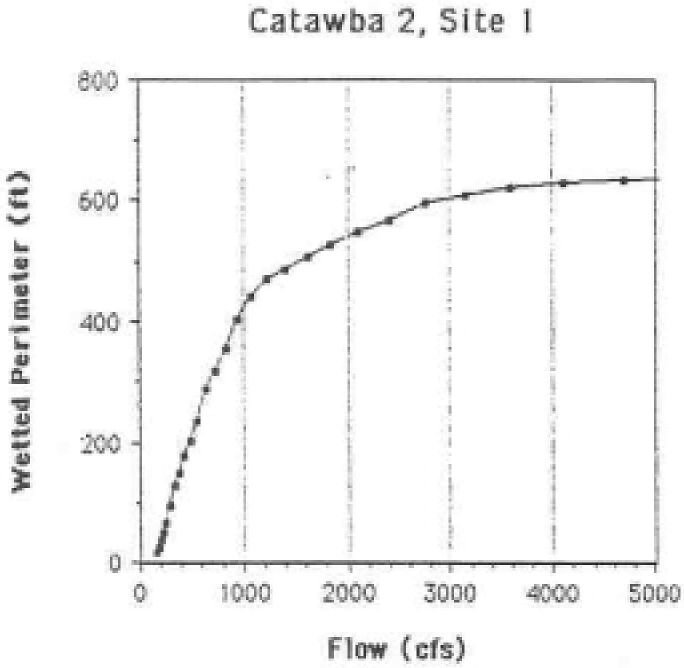

Whippy Swamp, Site 1
Elevation (ft)
49.0
48.5
48.0
47.5
47.0
46.5
46.0
45.5
45.0
44.5
44.0
0
100
200
300
400
500
600
700
800
Distance (ft)
Main Channel

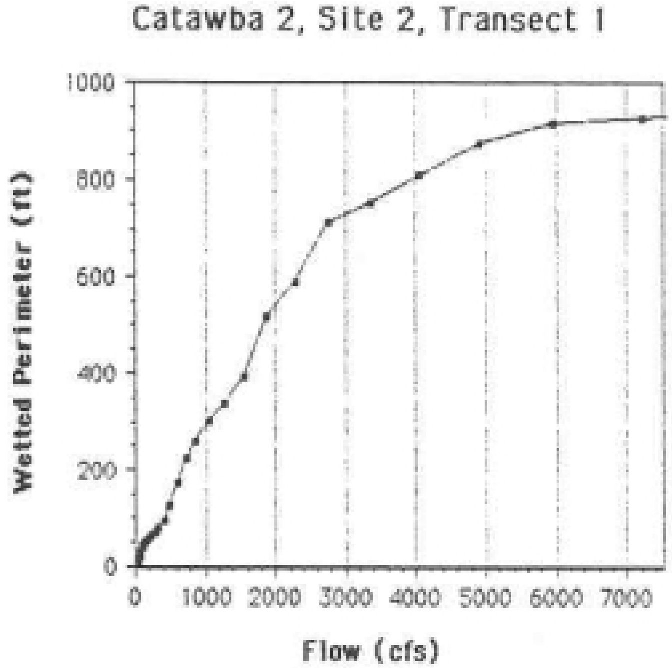

Whippy Swamp, Site 2
Elevation (ft)
50.0
49.5
49.0
48.5
48.0
47.5
47.0
46.5
46.0
45.5
45.0
0
10
20
30
40
50
60
Distance (ft)

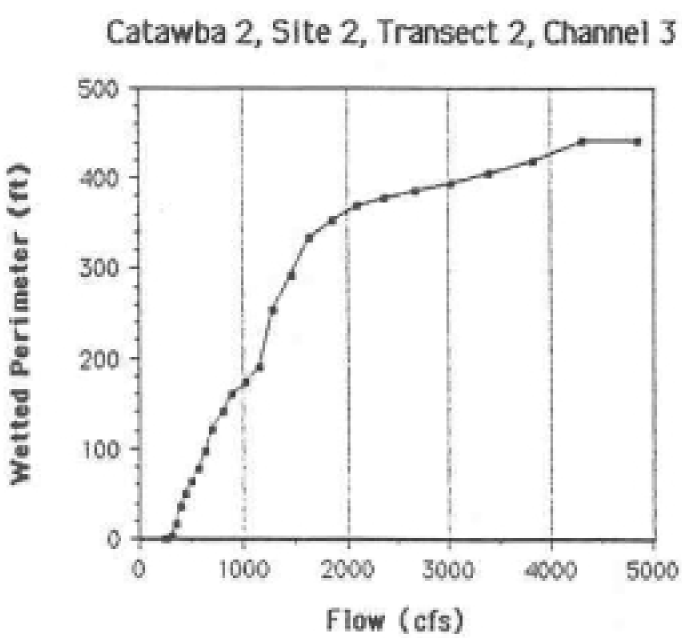

Whippy Swamp, Site 3
Elevation (ft)
48.0
47.5
47.0
46.5
46.0
45.5
45.0
44.5
44.0
43.5
43.0
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
Distance (ft)
Substrate: Sand and Organic Matter
Main Channel

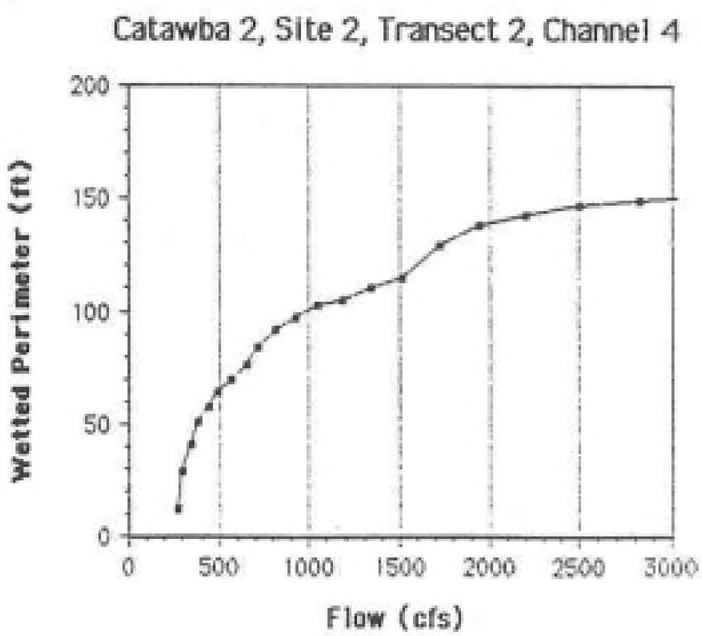
APPENDIX C

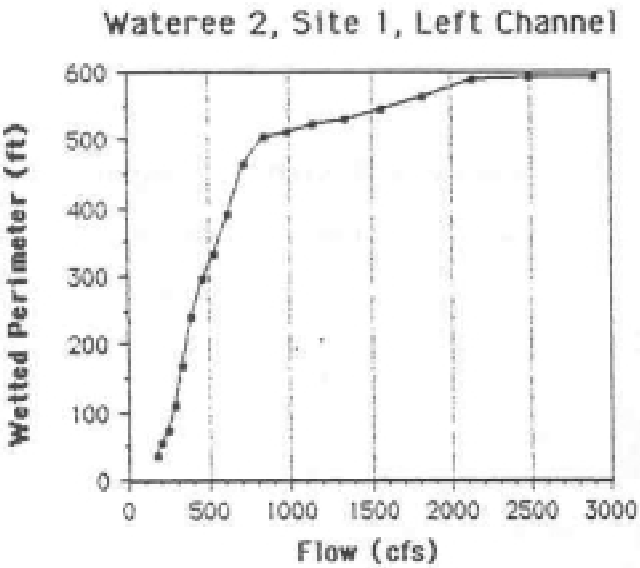
Wetted Perimeter Curves

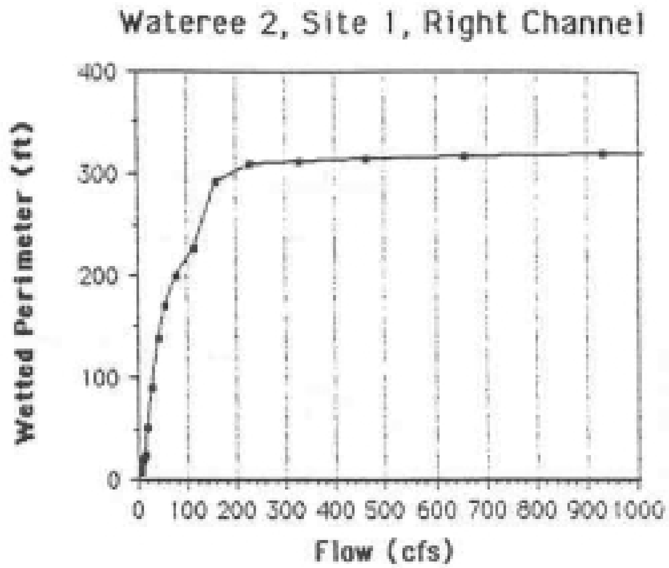

Catawba 2, Site 1
Wetted Perimeter (ft)
Flow (cfs)
0
200
400
600
800
1000
2000
3000
4000
5000

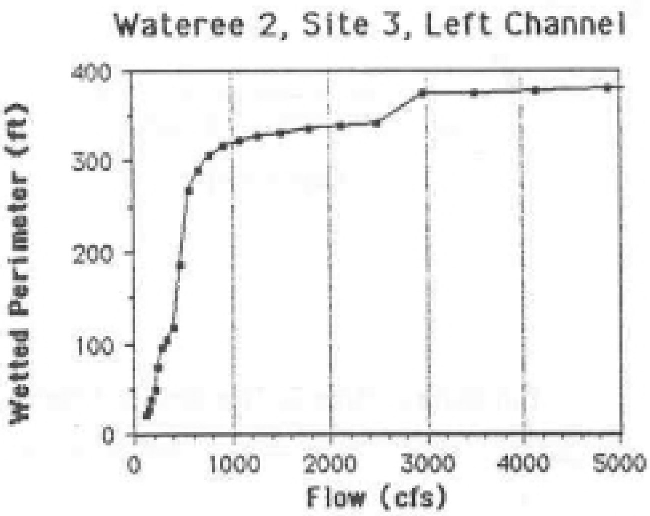

Catawba 2, Site 2, Transect 1
Wetted Perimeter (ft)
Flow (cfs)
0
200
400
600
800
1000
2000
3000
4000
5000
6000
7000

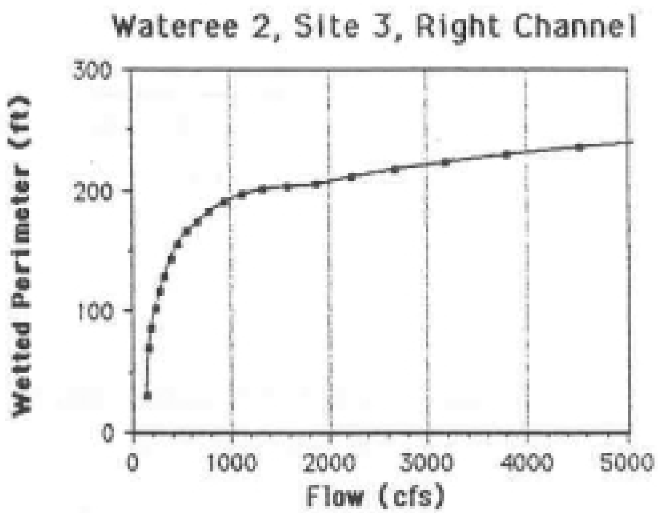

Catawba 2, Site 2, Transect 2, Channel 3
Wetted Perimeter (ft)
Flow (cfs)
0
100
200
300
400
500
1000
2000
3000
4000
5000

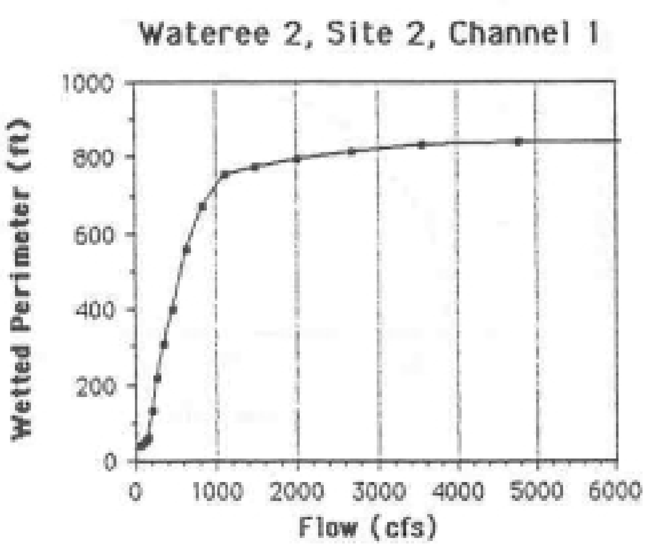

Catawba 2, Site 2, Transect 2, Channel 4
Wetted Perimeter (ft)
Flow (cfs)
0
50
100
150
200
500
1000
1500
2000
2500
3000

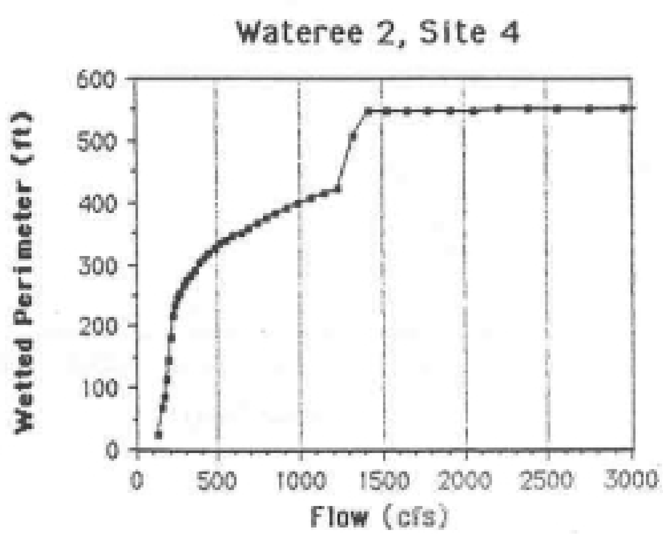

Wateree 2, Site 1, Left Channel
Wetted Perimeter (ft)
0
100
200
300
400
500
600
0
500
1000
1500
2000
2500
3000
Flow (cfs)

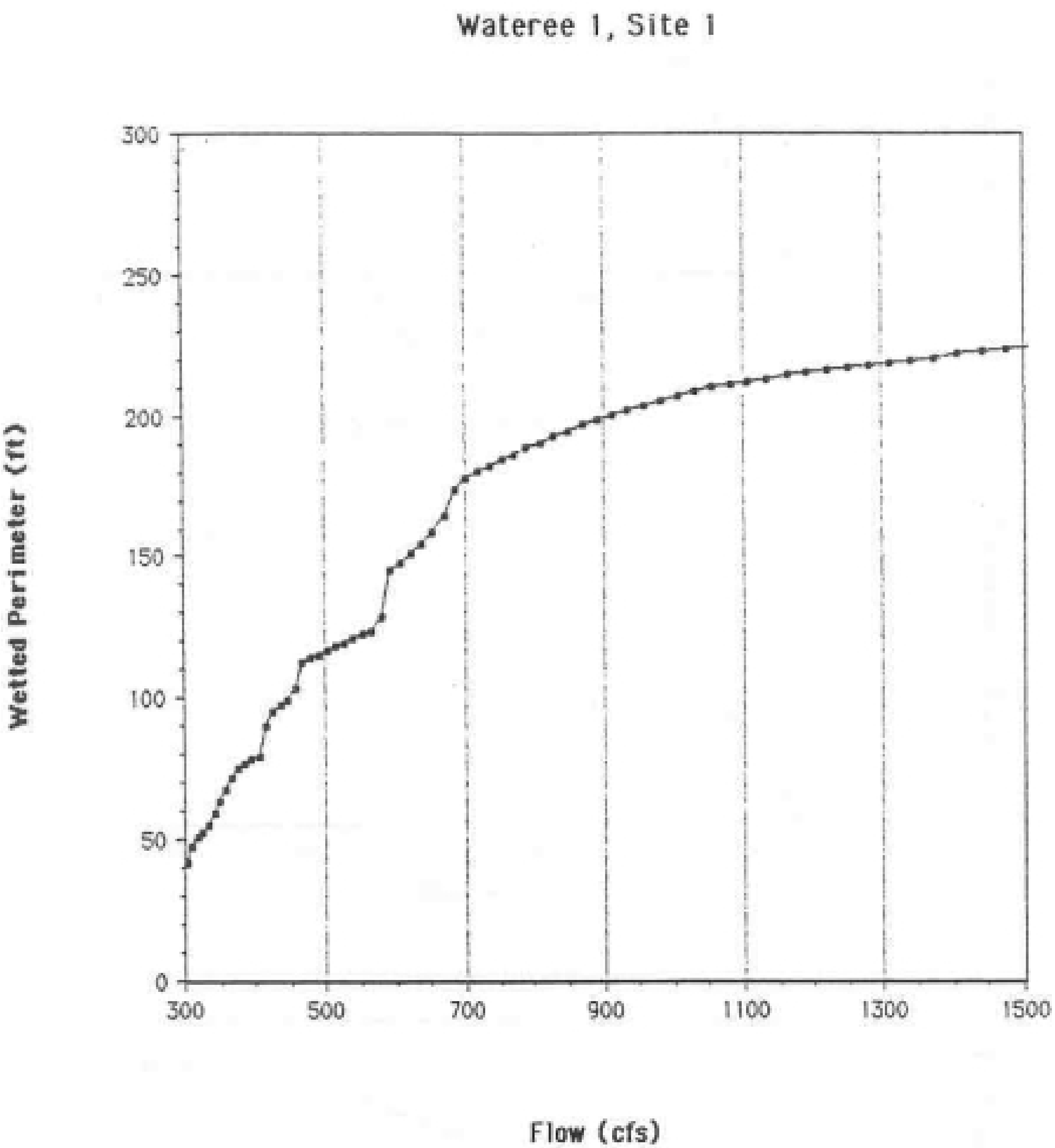

Wateree 2, Site 1, Right Channel
Wetted Perimeter (ft)
0
100
200
300
400
0
100
200
300
400
500
600
700
800
900
1000
Flow (cfs)

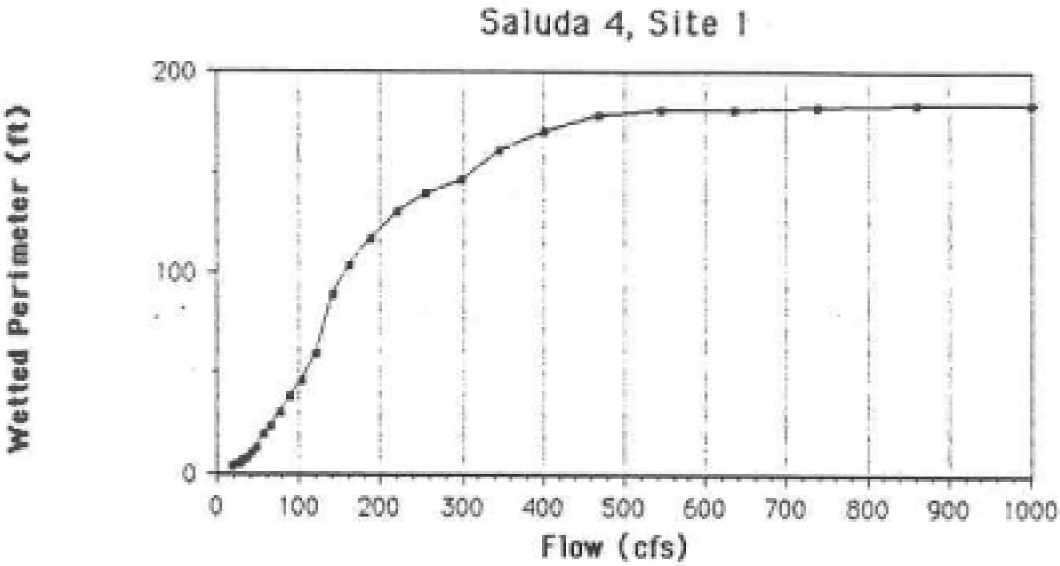

Wateree 2, Site 3, Left Channel
Wetted Perimeter (ft)
0
100
200
300
400
0
1000
2000
3000
4000
5000
Flow (cfs)

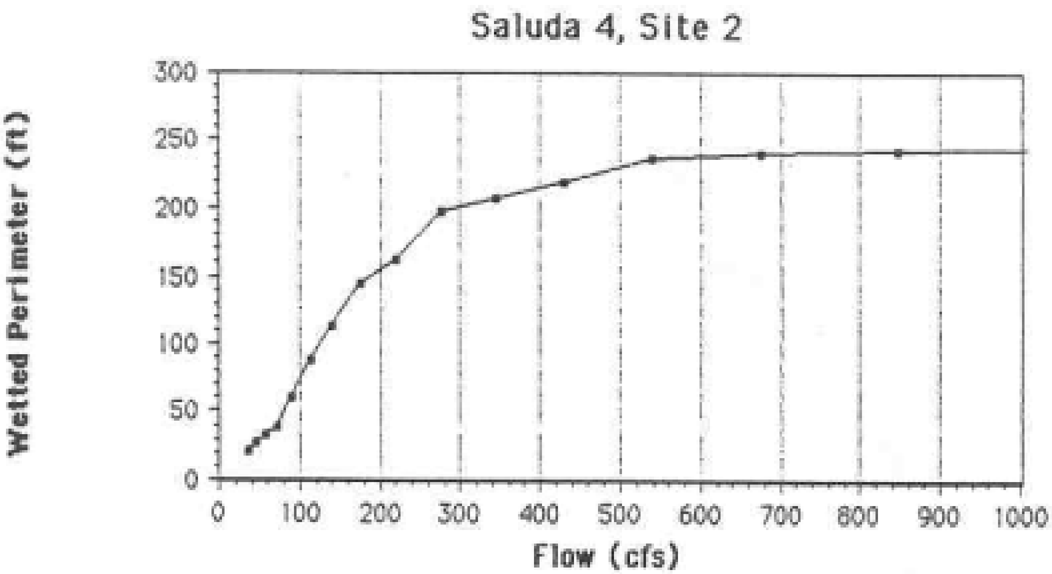

Wateree 2, Site 3, Right Channel
Wetted Perimeter (ft)
0
100
200
300
0
1000
2000
3000
4000
5000
Flow (cfs)


Wateree 2, Site 2, Channel 1
Wetted Perimeter (ft)
0
200
400
600
800
1000
0
1000
2000
3000
4000
5000
6000
Flow (cfs)


Wateree 2, Site 4
Wetted Perimeter (ft)
0
100
200
300
400
500
600
0
500
1000
1500
2000
2500
3000
Flow (cfs)


Wateree 1, Site 1
Wetted Perimeter (ft)
300
250
200
150
100
50
0
300
500
700
900
1100
1300
1500
Flow (cfs)


Saluda 4, Site 1
Wetted Perimeter (ft)
0
100
200
0 100 200 300 400 500 600 700 800 900 1000
Flow (cfs)


Saluda 4, Site 2
Wetted Perimeter (ft)
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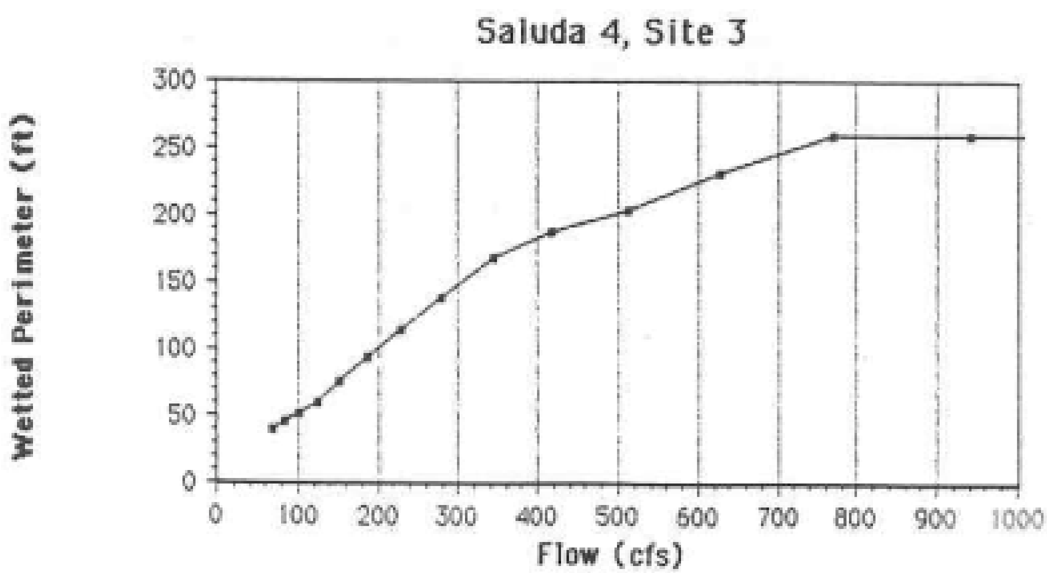
0 100 200 300 400 500 600 700 800 900 1000
Flow (cfs)


Saluda 4, Site 3
Wetted Perimeter (ft)
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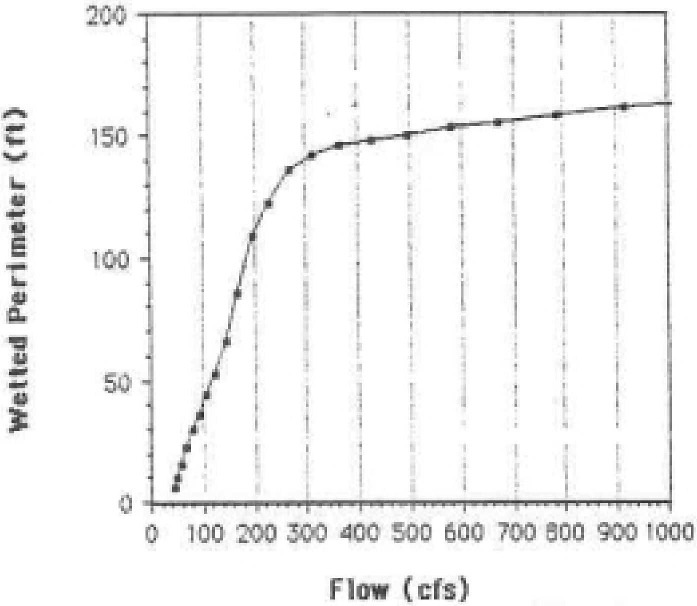
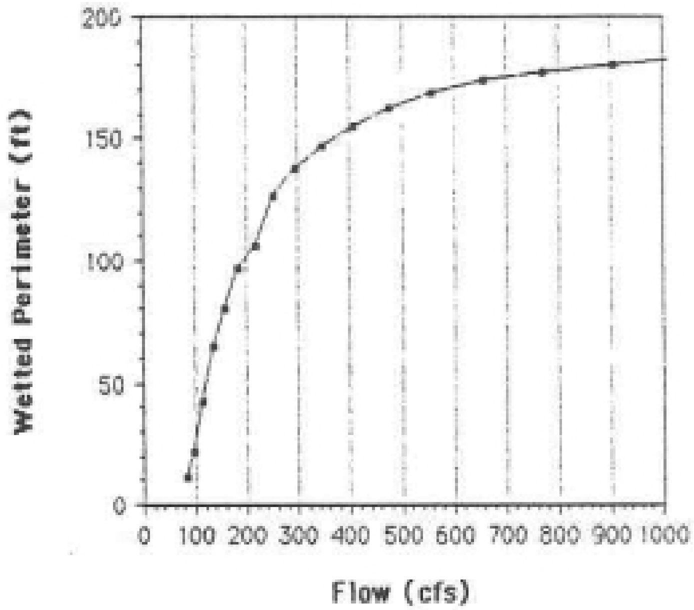
0 100 200 300 400 500 600 700 800 900 1000
Flow (cfs)

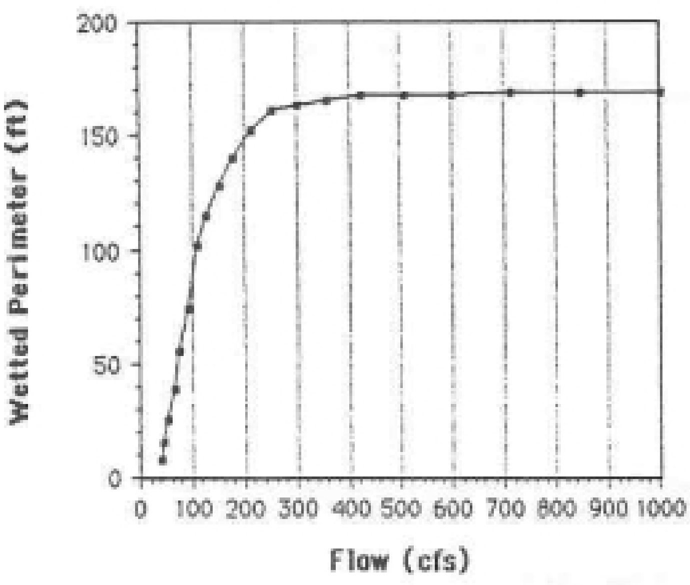
Saluda 2, Site 1, Transect 1



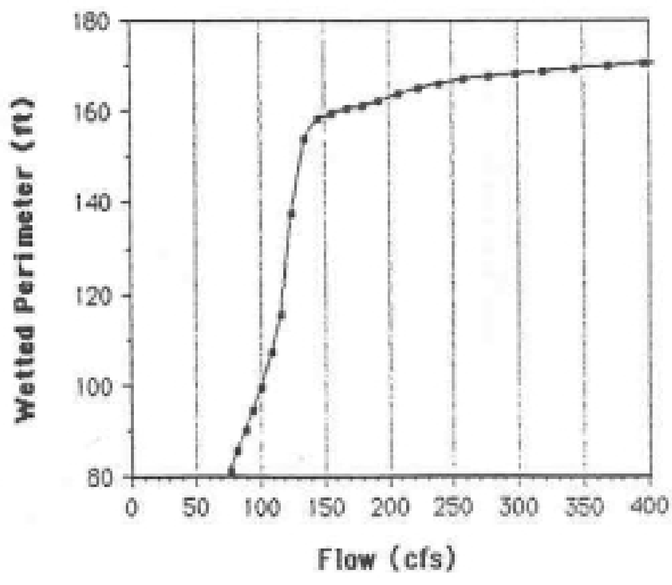
Saluda 2, Site 1, Transect 2



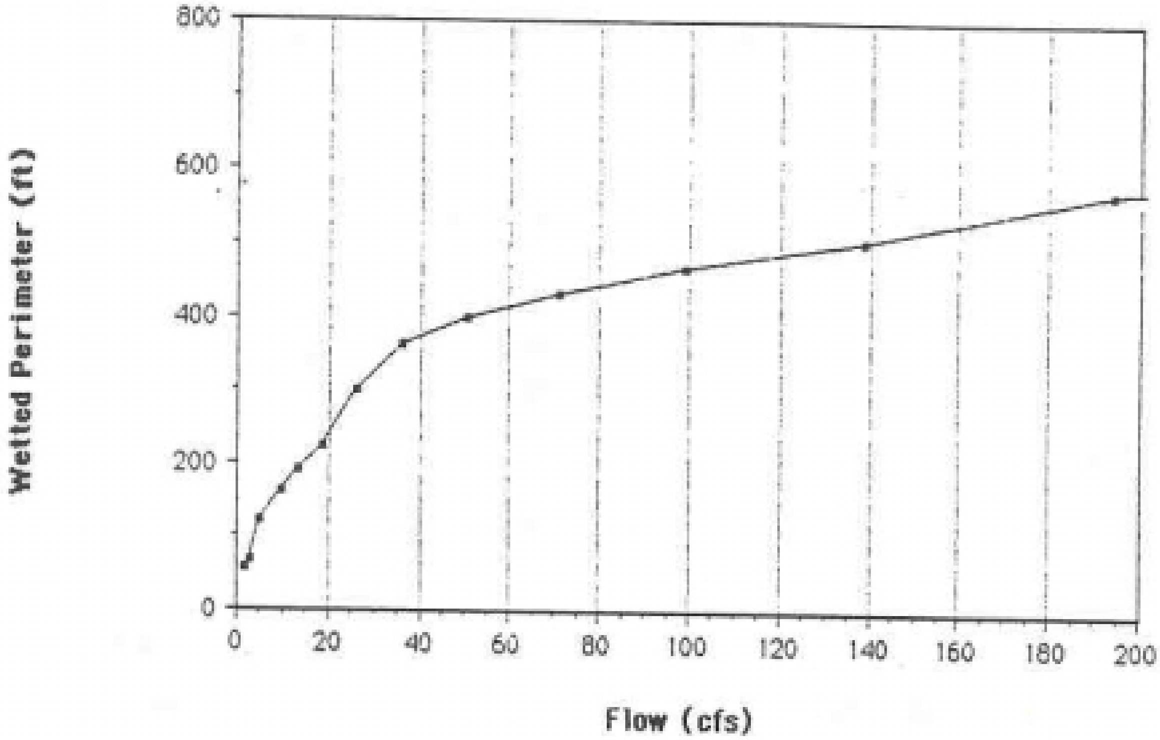
Saluda 2, Site 2



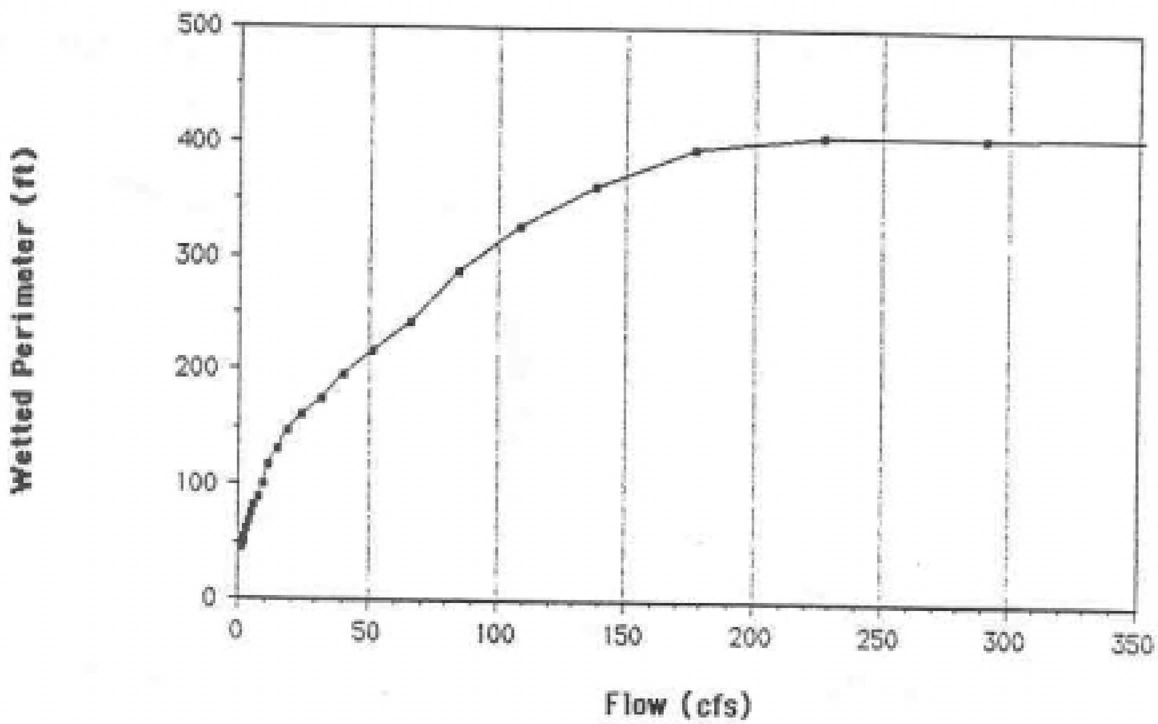
Saluda 2, Site 4



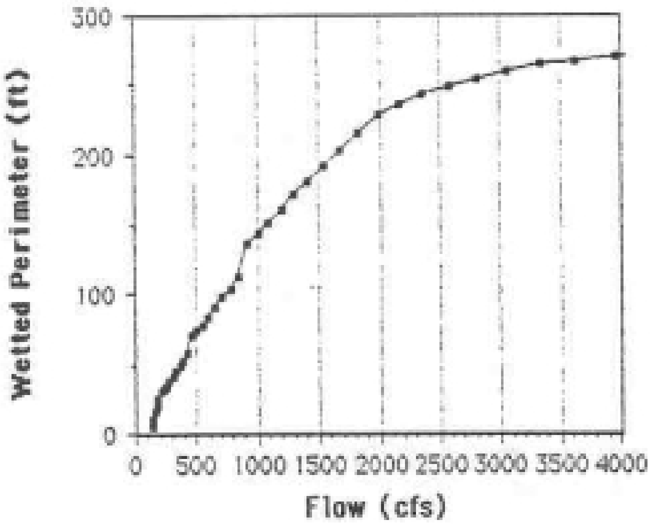
Coosawhatchie, Site 1, Transect 1



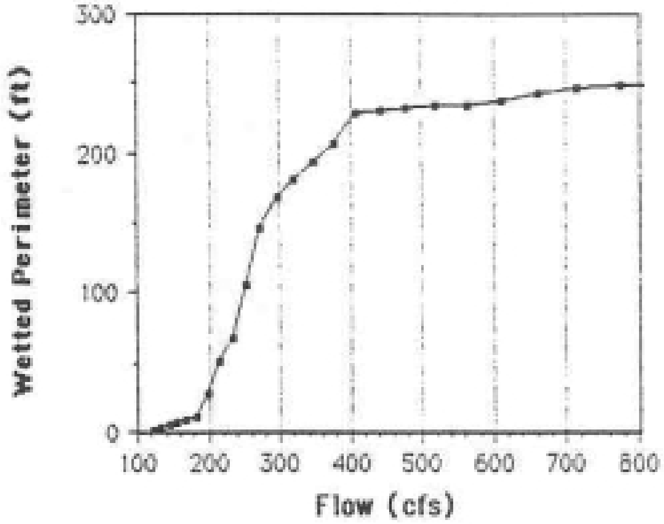
Coosawhatchie, Site 1, Transect 2



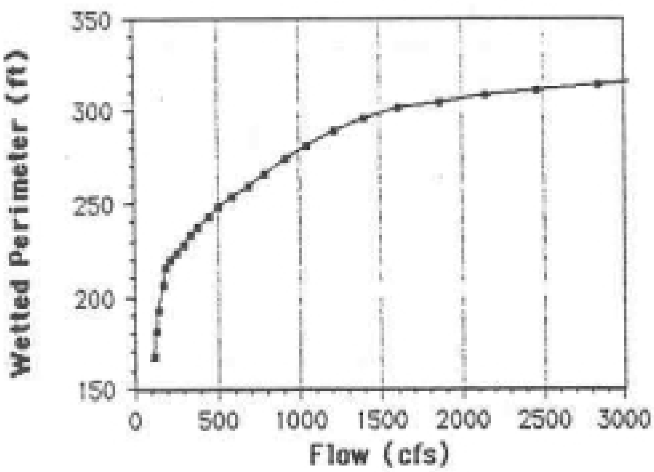
Saluda 1, Site 2



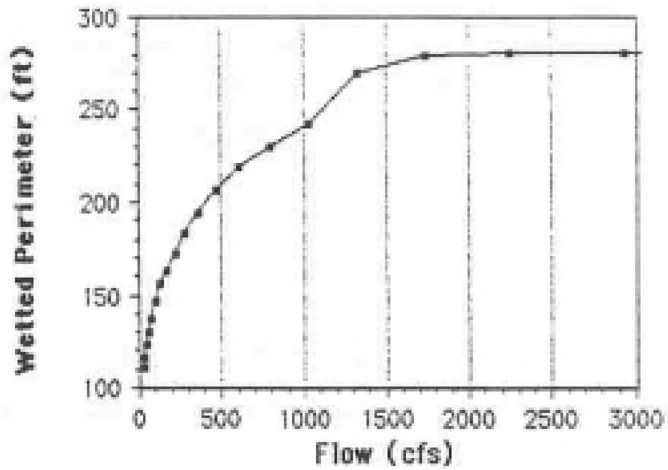
Saluda 1, Site 3



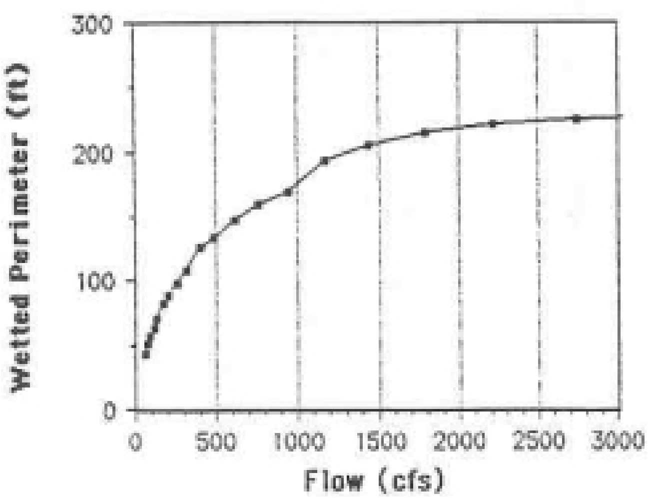
Saluda 1, Site 4, Transect 1, Left Channel



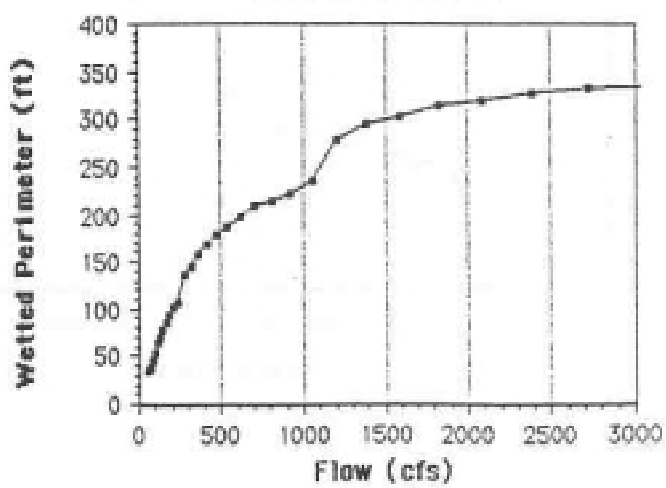
Saluda 1, Site 4, Transect 1, Right Channel

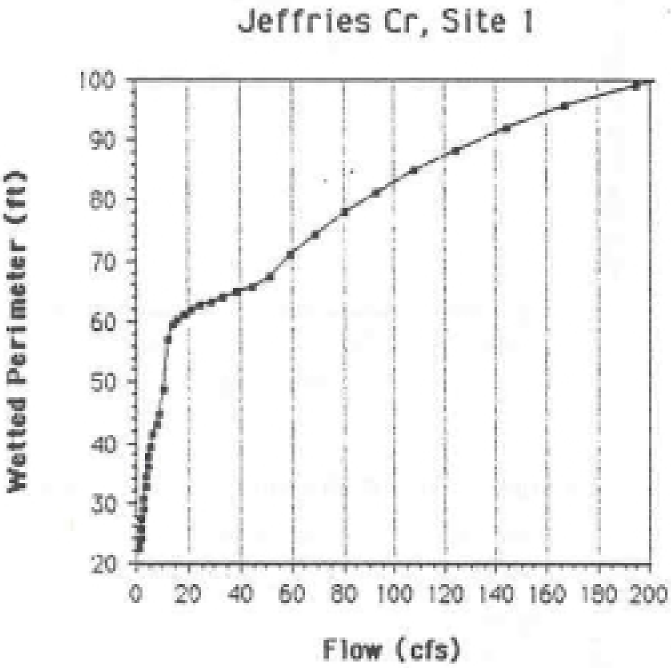


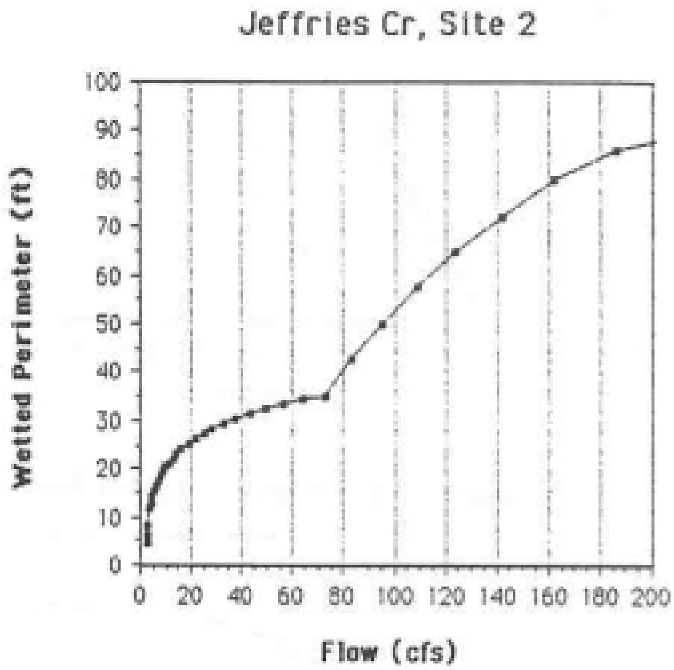
Saluda 1, Site 4, Transect 2

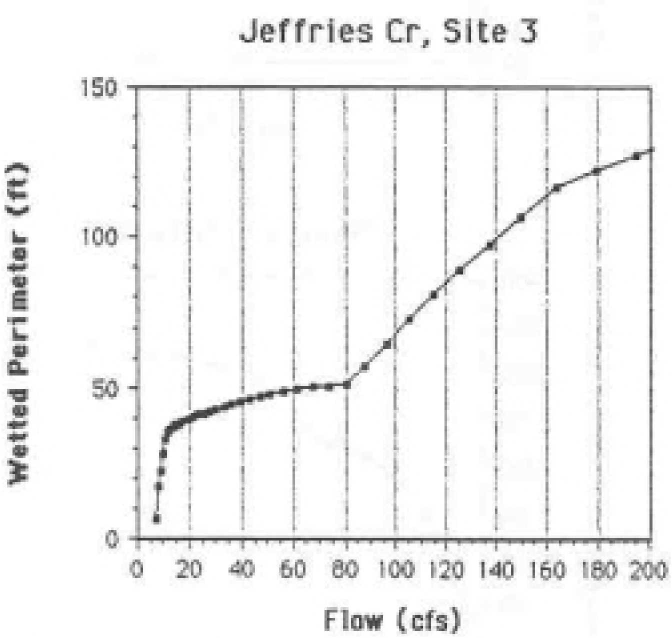


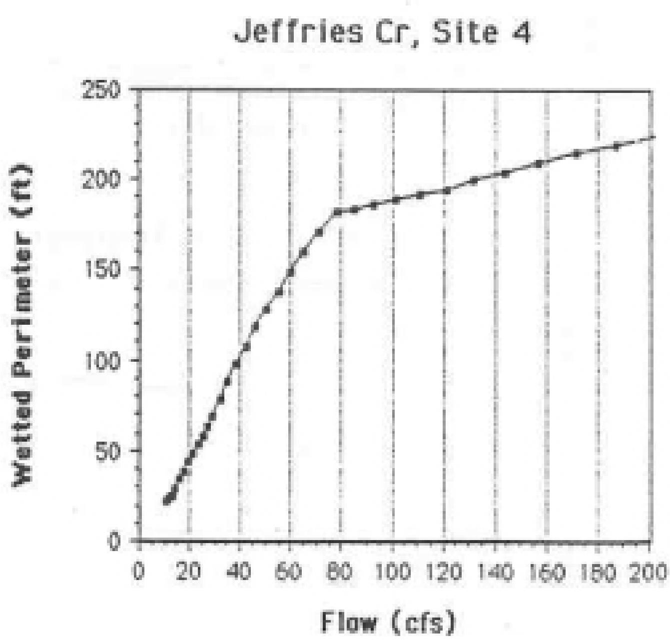
Saluda 1, Site 5

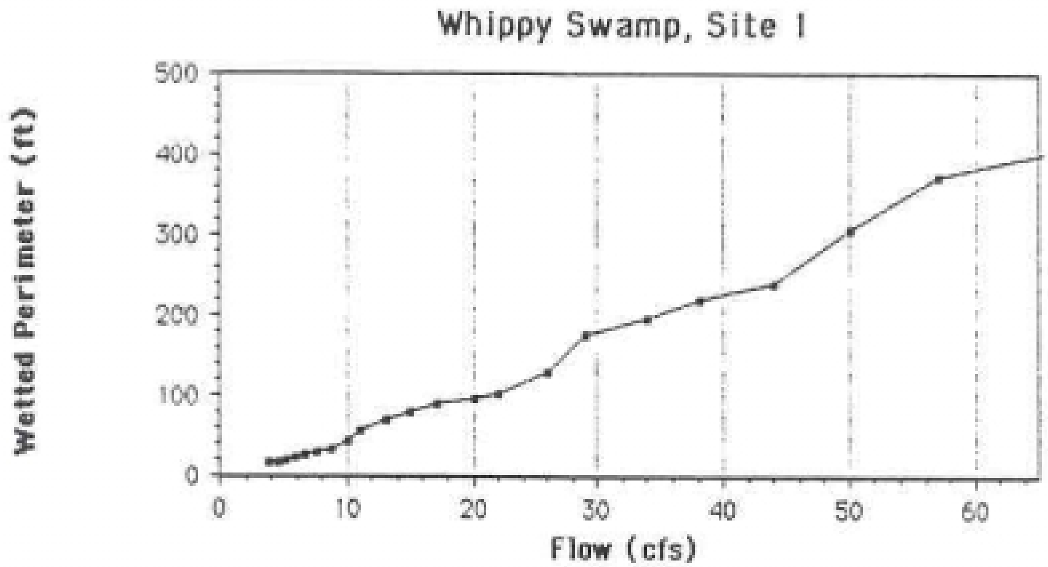


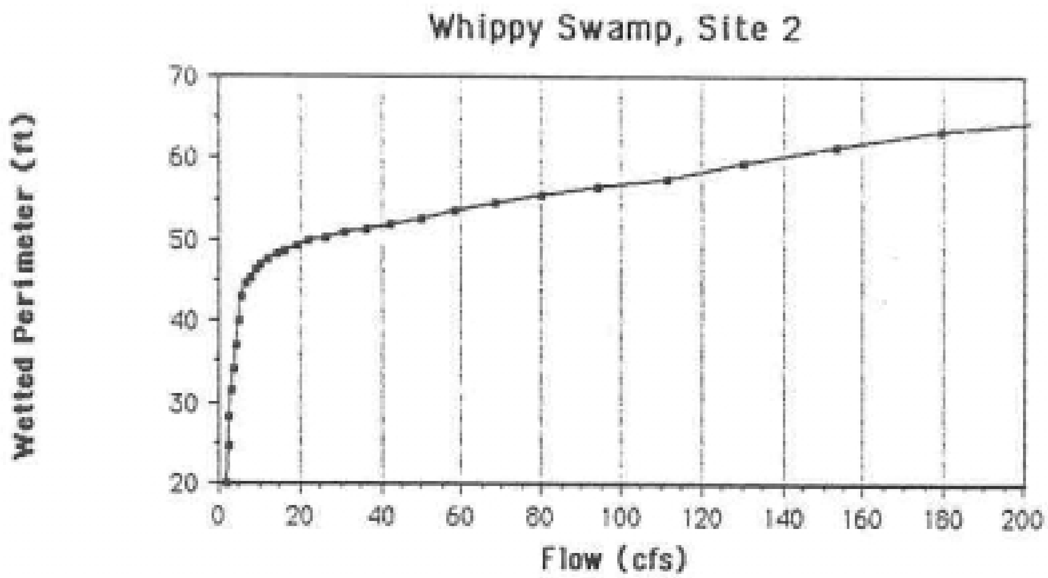

Jeffries Cr, Site 1
Wetted Perimeter (ft)
Flow (cfs)

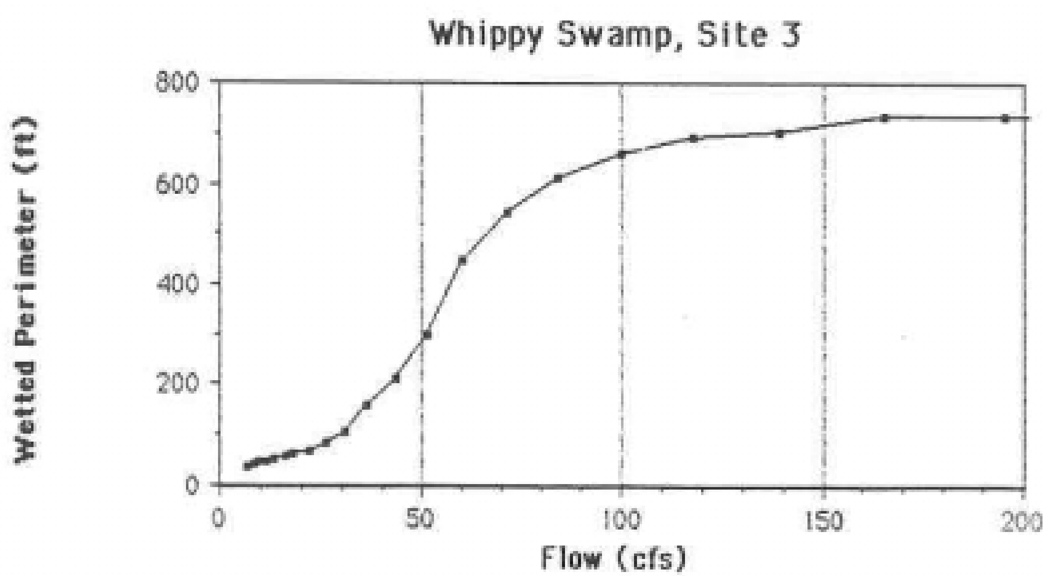

Jeffries Cr, Site 2
Wetted Perimeter (ft)
Flow (cfs)


Jeffries Cr, Site 3
Wetted Perimeter (ft)
Flow (cfs)


Jeffries Cr, Site 4
Wetted Perimeter (ft)
Flow (cfs)


Whippy Swamp, Site 1
Wetted Perimeter (ft)
Flow (cfs)
0
100
200
300
400
500
0
10
20
30
40
50
60


Whippy Swamp, Site 2
Wetted Perimeter (ft)
Flow (cfs)
20
30
40
50
60
70
0
20
40
60
80
100
120
140
160
180
200


Whippy Swamp, Site 3
Wetted Perimeter (ft)
Flow (cfs)
0
200
400
600
800
0
50
100
150
200

APPENDIX D

S.C. Wildlife and Marine Resources Department
Working Instream *Flow Policy*
(Study Data Analysis and Minimum Instream *Flow* Recommendations)

Working Instream Flow Policy

South Carolina Wildlife and Marine Resources Department

Introduction

“Stated simply, fish need an adequate supply of water... modification of natural flow regimes of streams affects fishes throughout their life cycle”. Sudden increases in streamflow can cause bottom scouring, decrease channel stability and impact reproductive behavior and spawning success of fish. Reduced streamflows can impact spawning success, decrease available habitat, negatively affect water quality and increase silt deposition. Modifications in streamflow can detrimentally impact spawning migrations of resident and anadromous fishes thus lowering the productive potential of a stream or river. Realizing these and other potential impacts of streamflow alteration on fish communities, **the Department’s basic policy shall be to oppose any water management or any water withdrawal activity that changes natural streamflow characteristics or fails to consider impacts on fishery resources.**

Historically, water releases from existing water projects have rarely been a legal requirement. Increasing awareness of the societal and economic values of fishery resources has initiated a change in this attitude, highlighted by federal passage of S.426 - the Electric Consumers Protection Act of 1986 which mandated revisions in the Federal Power Act. These revisions require that “each license shall include conditions for... protection, mitigation and enhancement (of fish and wildlife including related spawning grounds and habitat) subject to conditions based on recommendations received from ...State Fish and Wildlife Agencies".

The South Carolina Legislature, realizing the importance of multi-disciplinary streamflow management, requested the South Carolina Water Resources Commission (WRC) to identify instream flow requirements for 10 stream segments identified as critical. Three sites are regulated stream reaches in the Saluda River basin, four regulated reaches are in the Catawba-Wateree drainage while 3 sites are unregulated Coastal Plain streams. Criteria used to identify instream flow needs included water quality, navigation, hydropower and fishery resources.

Perceiving that the Department will continue to pay close attention to instream flow questions in the future, information generated during the WRC study was used to generate a general policy that would protect fishery resources in all waters of the state when natural streamflow cycles could not be maintained.

Data obtained during the WRC study address hydrology and habitat availability as a function of discharge. The data does not relate biological responses to streamflow alterations.

Therefore, derived instream flow recommend at ions found in this policy represent the initial position of the Department in situations where water management constraints require alteration of natural streamflows. Site inspection by a fishery biologist to determine the general applicability of policy guidelines to a particular stream reach is required in all cases. The Department will consider objective data demonstrating the acceptability of alternative streamflows. Instream Flow Incremental Methodology (IFIM) developed by U.S. Fish and Wildlife Service is the Department's preferred methodology. The Department requests that any potential applicant employ a study plan which has been reviewed by the Department prior to initiation of sampling and/or data analysis. The Department will in certain situations initiate work to gather site specific information on flow effects on fishery resources and will use these data to refine general policy and make site specific recommendations as needs require. Specific situations where endangered species will be impacted by instream flow alterations will be given special consideration.

Methods

Tennant, wetted perimeter and useable width methods were used to evaluate instream flow needs of fishes at all study sites. The Tennant method basically states that increasing the percent of the mean annual daily flow released on an instantaneous basis will improve fisheries. Mean annual daily flow is defined as the average volume of water discharged instantaneously over a representative water year. The percent of mean anuual daily flow required during the spawning season is greater than during the remainder of the year.

The wetted perimeter method defines the increased availability of habitat as discharge is increased. In the WRC study, wetted perimeter data were derived at critical shoal habitats where navigation was hindered at low flows. Interpretation of wetted perimeter data requires relating streamflow to habitat availability. An inflection point of the relation identifies where maximal habitat is obtained with minimal input of water. Ocassionally, multiple inflection points can occur making interpretation of data more subjective. In Coastal Plain streams, inflection points can identify the discharges required to inundate the flood-plain.

Useable width defined the minimum discharge needed to pass migrating fish through shoal habitats. In Piedmont streams, where striped bass are generally of prime importance, habitat suitability information indicated a depth of 1.5 feet was the minimum depth required for spawning. A required shoal passage width of 10 feet was estimated. In Coastal Plain streams, redbreast sunfish are a key species. A rectangular area 1 foot deep by 8 feet wide was defined as the required useable width.

Instream flow determination require knowledge of the magnitude and temporal variation in the hydrologic cycle. Streamflow determinations for study sites were generally obtained from U.S. Geological Survey (USGS) data. Hydrologic data for Whippy Swamp was generated by WRC using standard techniques for ungaged stations.

An assessment of the percentage of average discharge occuring each month was performed for Piedmont and Coastal Plain streams. USGS gaging sites used to establish the Piedmont curve were Saluda River at Pelzer, Saluda River at Chappells, Saluda River at Columbia, Catawba River at Catawba and Wateree River at Camden. A Coastal Plain hydrograph was prepared using USGS data from Edisto River at Branchville, Little Pee Dee River at Galivant's Ferry, Lynches River at Effingham and Coosawhatchie River at Hampton. Whippy Swamp data generated by WRC was also employed. The obtained hydrograph was used, along with knowledge of spawning seasons, to identify major hydrologic/biological periods during a year.

Instream flow determinations for each of the ten critical sites were performed for fishery resources using the following general procedure:

1) The 7Q10 (the lowest mean streamflow for 7 consecutive days expected to occur in a 10 year period) was calculated since present water quality regulations are based on this flow.

2) Mean annual daily flow was determined for each stream

segment and 10, 20 and 30% streamflows were calculated.

3) Wetted perimeter information was graphed and a visual determination of inflection point was made for each study site. Wetted perimeter requirements were then defined for each river segment.

4) Color slides depicting varying streamflows at almost all study sites were inspected by a fisheries biologist to make a subjective determination of flows required to protect the existing fishery resource.

5) Data from steps 1-4 were used to define instantaneous streamflows required during months of low flow (July -November); Piedmont and Coastal Plain streams were treated seperately.

6) Useable width criteria were used at each site to calculate minimum discharge required to pass the species of concern during the spawning season.

7) Tennant values of 20, 40 and 60% of mean annual daily flow were calculated.

8) In Coastal Plain streams, transect data at study sites were used to estimate the discharge which initially produces overbank flow.

9) Data from 6-8 were used to define discharges required during high flow months (January - April).

10) Streamflows midway between high and low flow periods values were then calculated for time periods (May, June, December) with intermediate streamflow requirements.

Results

Inspection of the mean annual hydrograph indicated three distinct periods (Table 1). These are:

1) High flow (mean monthly flow > mean annual daily flow) = January through April.

2) Low flow (mean monthly flow = 50 to 80% of mean annual daily flow)= July through November.

3) Increasing or decreasing flows (months where flows are 80 to 100% of mean annual daily flow and occur between high and low flow periods)= May and June (decreasing); December (increasing).

Piedmont and Coastal Plain streams behaved similarly although high and low flow periods were more severe in the unregulated, Coastal Plain study sections.

Low Flow Period - Piedmont

Site specific data are presented in Table 2. The average inflection point for wetted perimeter data obtained at the 5 study sites was .20 of mean annual daily flow (sd=.08).

Visual inspection of color slides indicated flows approximately 10% of mean annual daily flow were inadequate to protect

Table 1. Percent of mean annual daily flow by month in selected Piedmont and Coastal Plain streams of South Carolina.

Month	Piedmont	Coastal Plain
January	122	1.31
February	126	175
March	132	1.91
April	126	143
May	92	78
June	85	68
July	75	67
August	78	67
September	72	65
October	81	58
November	77	51
December	92	85

Table 2. Site-specific data used to assess instantaneous instream flow requirements of Piedmont streams for July through November. Streamflows are in cubic feet per second.

			Streamflow					
			mean annual daly flow	Tennant Method			wetted perimeter	% WP of
Stream Name	Site *	7Q10	(MADF)	10%	20%	30$	(WP)	MADF
Saluda	1	168	783	78	156	235	180	.23(min)
at Pelzer	2	168	783	78	156	235	280	.36(max)
	3	203	956	9	192	287	340	.36
	mean	180	841	84	168	252	267	.32
Saluda	1.1	320	1991	199	398	597	280	.14
at Chappells	1.2	320	1991	199	398	597	290	.15(max)
	2	320	1991	199	398	597	250	.13
	3	320	1991	199	398	597	-	-
	4	320	1991	199	398	597	150	.08(min)
	mean	320	1991	199	398	597	243	.12
Saluda	1.2	260	2929	293	586	879	360	.13(min)
at Columbia	2	260	2929	293	586	879	900	.31(max)
	3	260	2929	293	586	879	410	.14
	4.1-R	260	2929	293	586	879	400	.14
	4.1-L	260	2929	293	586	879	800	.27
	4.2	260	2929	293	586	879	700	.24
	5	260	2929	293	586	879	450	.15
	mean	260		293	586	879	575	.20
Catawba	1	710	4614	461	922	1384	1100	.24
Rock Hill= 1	2.1	900	6060	606	1.212	1818	1800	.30(max)
Catawba= 2	2.2	900	6060	606	1212	1818	1300	.21(min)
	mean	837	5578	558	1115	1673	1400	.25
Wateree	1	490	6444	644	1288	1933	840	.13
at Camden	2	490	6444	644	1288	1933	1000	.16(max)
	3	490	6444	644	1288	1933	800	.12(min)
	4	490	6444	644	1288	1933	750	.12
	mean	490	6444	644	1288	1933	844	.13
Wateree at Eastover	1	800	7000+	700	1400	2100	685	.10

* Specific site locations are available from S.C. Water Resources Commission.

fisheries. Flows of 20% were generally adequate while flows of 30% were adequate.

Low Flow Period - Coastal Plain

Site specific data are presented in Table 3. The average inflection point for wetted perimeter data obtained at the 4 study sites was .27 of mean annual daily flow (sd=.11). Visual inspection of color slides indicated that flows of .10 of mean annual daily flow were adequate to protect fisheries in Jeffries Creek. In Whippy Swamp and Coosawhatchie River, which have less well-defined channels than Jeffries Creek, flows of 20% of mean annual daily flow were required to protect fishery resources.

High Flow Period - Piedmont

Site specific data are presented in Table 4. Using a 1.5 ft. deep X 10 ft. wide fish passage area, required flows at the critical shoal ranged from .39 to .70 of mean annual daily flow (mean=.52; sd=.13). If a 1.0 ft. deep X 10 ft. wide passage was assumed acceptable,.required flows at the critical shoal ranged from .15 to .32 of mean annual daily flow (mean=. 24;sd=.07).

High Flow Period - Coastal Plain

Site specific data are presented in Table 5. Useable width data indicated that streamflows needed for fish passage at the

Table 3. Site-specific data used to assess instantaneous instream flow requirements for Coastal Plain streams in July-November. Streamflows are in cubic feet per second.

Streamflow

Stream Name	Site*	7Q10	mean annual daily flow (MADF)	Tennant Method 10%	20%	30%	wetted perimeter (WP)	% WP of MADF
Whippy	1	1.4	136	14	28	41	60	.44.
	2	1.4	136	14	28	41	15	.11
	3	1.4	136	14	28	41	60	.44
	mean	1.4	136	14	28	41	45	.33
Jeffries	1	0.1	259	26	52	78	15	.06
	2	0.1	259	26	52	78	100	.39
	3	0.1	259	26	52	78	120	.46
	4	0.1	259	26	52	78	80	.31
	mean	0.1	259	26	52	78	79	.31
Coosawhat-chie	1	0.0	189	19	38	57	50	.26
	2	0.0	189	19	38	57	80	.42
	mean	0.0	189	19	38	57	65	.34

* Specific site locations are available from S.C. Water Resource Commission.

Table 4. Site-specific data used to assess instantaneous instream flow requirements of Piedmont streams for January through April. Streamflows are in cubic feet per second.

Streamflow									
		mean annual daily flow		Tennant Method		useable width (UW)		% UW of MADF	
Stream Name	Site*	(MADF)	20%	40%	60%	1.5X10	1.0X10	1.5X10	1.0X10
Saluda	1	783	156	312	470	546	250	.70	.32
at Pelzer	2	783	156	312	470	12		.02	
	3	956	192	384	574	102		.11	
Saluda	1.1	1991	398	796	1194	673	312	.34	.16
at Chappell	1.2	1991	398	796	1194	1243	559	.62	.28
	2	1991	398	796	1194	600	254	.30	.13
	3	1991	398	796	1194	512	237	.26	.26
	4	1994	398	796	1194	35		.02	
Saluda	1.2	2929	586	1172	1757	1326	802	.45	.27
at Columbia	2	2929	586	1172	1757	596	387	.20	.13
	3	2929	586	1172	1757	518	347	.18	.12
	4.1-R	2929	586	1172	1757	142		.05	
	4.1-L	2929	586	1172	1757	58		.02	
	4.2	2929	586	1172	1757	753	256	.26	.09
	5	2929	586	1172	1757	924		.32	
Catawba	1	4614	922	1844	2766	1608	823	.35	.18
at Catawba	2	6060	1212	2424	3636	401		.07	
	3	6060	1212	2424	3636	2361	1148	.39	.19
Wateree	1	6444	1288	2576	3864	933			.15
at Camden	2			2926	995		.45		.1.5
	3			914			.14		
	4			202			.03		
Wateree at Eastover		7000	1400	2800	4200				

* Specific site locations are available from S.C. Water Resource Commission.

Table 5. Site-specific data used to assess instantaneous instream flow requirements for Coastal Plain streams January-April. All streamflows are in cubic feet per second.

		Streamflow						
		mean annual	Tennant Method			useable width method		estimated streamflow at initial
Stream Name	Site	daily flow (MADF)	20%	40%	60%	= 1'x8'	% MADF	flood (%)
Whippy	1	136	28	56	84	11	.08	100 (.74)
	2					7	.05	
	3					22	.16	
Jeffries	1	259	52	104	156	1	.01	80 (.31)
	2					13	.05	
	3					21	.08	
	4					19	.07	
Coosawhatchie	1	189	38	7	114	51	.27	194 (1.02)
	2							

* Specific site locations are available from S.C. Water Resource Commission.

critical shoal ranged from .08 to .27 of mean annual daily flow. Floodplain inundation data showed considerable variability. From .31 to 1.02 of mean annual daily streamflow was required to overflow banks at the transect sites.

Discussion.

An initial overview of instream flow requirements at selected sites was obtained. Although each stream segment had individual characteristics, sufficient similarity existed to formulate a general policy defining instream flow requirements for fishery resources. Variability in the percent of mean annual daily flow required at each stream segment pointed out the need to visually inspect study sites to confirm the relevance of policy values.

The data demonstrate that calculations of 7Q10 flows on regulated streams do not reflect 7Q10 flows that would occur if natural flow regimes existed. For example, Table 2 shows the Wateree River and Saluda River drainages had greater 7Q10 flows for sections upstream of impoundments (Rock Hill and Chappells, respectively) than for sections downstream of the impoundments (Camden and Columbia, respectively). This is in spite of the downstream sections having larger drainage areas and higher mean annual daily flows. These differences are caused by reservoir storage and release patterns and indicate that the utility of 7Q10 flow on regulated streams is questionable.

Data gathered during this study indicated instream flows should be determined for three distinct time periods: 1) low flow July -November, 2) high flow January - April and intermediate flows 3) May, June and December. Distinction of these time periods will help insure that natural seasonal variability of streamflow is maintained.

The spawning season for South Carolina fishes generally begins in February and ends in June with each species having distinct temporal and spatial requirements. Selecting instream flows that conform to the seasonal variation in flow is important since fish have evolved to spawn in synchrony with the seasonal hydrologic cycle.

Piedmont and Coastal Plain fishes have different spawning and life history requirements. Piedmont fishes are attracted to upstream spawning grounds by the magnitude of flows. Floodplain utilization is minimal while efficient passage through shoals is important. Coastal Plain fish species are more adapted to utilize floodplain habitat which is innundated to varied extents each season. Fish passage requirements are generally less stringent due to species composition. Based on these differences and habitat restrictions in summer, instream flow requirements for Piedmont and Coastal Plain streams were considered seperately.

Greater flows are needed during high flow months in Coastal Plain streams to insure adequate flood potential is available. In the Piedmont the magnitude of flows required to attract fish to upstream spawning grounds is important. Passage through rocky shoals is also critical. In all study sites, 20% of mean annual daily flow was required to maintain habitat during summer months.

Only small non-regulated Coastal Plain streams were considered. Instream flow determinations on large Coastal Plain streams will require site inspection before any determination of policy applicability can be made.

Instream Flow Recommendations

Coastal Plain -

July-November	**20% of mean annual daily flow**
January-April	**60% of mean annual daily flow**
May, June, December	**40% of mean annual daily flow**

Piedmont

July-November	**20% of mean annual daily flow**
January-April	**40% of mean annual daily flow**
May, June, December	**30% of mean annual daily flow**

Policy values are designed to protect, but not enhance the

State’s fishery resources. The resulting instream flow recomendations conform closely to Tennant's "desktop" method. Sufficient data were collected using site specific field surveys conducted by the WRC to substantiate policy criteria for South Carolina streams. If changes from this recommended flow regime are requested for a particular stream, an IFIM study, approved and overviewed by the Department, will be conducted by the requestor. The section and requestor will then objectively consider the results from the IFIM study to make final instream flow determinations. Policy flow recommendations are not valid once a site specific. IFIM study is successfully completed as determined by the Department.

Summary of Policy

1) The Department will generally oppose any modification of natural streamflow characteristics.

2) If other water management concerns necessitate streamflow modifications, the Department's policy is to insure the following instantaneous streamflows:

Piedmont Streams

July-November = 20% of mean annual daily streamflow
January-April = 40% of mean annual daily streamflow
May, June, December = 30% of mean annual daily streamflow

Coastal Plain Streams

July-November = 20% of mean annual daily streamflow
January-April = 60% of mean annual daily streamflow
May, June, December = 40% of mean annual daily streamflow

3) In no case should water withdrawals be allowed from the State's streams that would reduce streamflow below these levels.

4) On regulated streams, when inflows to the reservoir are less than desired instream flows, instantaneous outflows should equal instantaneous inflows..

5) These criteria are based on water budgets for the states rivers as of Sept. 31, 1987 and include the available historical record of these water budgets; mean annual daily flow has been used because it uses the existing water budget; all future calculations for individual stream segments should also use mean annual streamflow as calculated on Sept. 31, 1987.