SECTION 5

5.0 Flow-Habitat Relationships: Establishment of Hydrologic Shifts

5.1 Approach and Rationale

This section identifies the physical, physiological, and habitat-limiting criteria for each of the major habitats of interest in the Lower Suwannee River MFL study area and quantifies relationships between river flow and habitats to guide the establishment of Minimum Flows and Levels (MFLs) for the Lower Suwannee River including Manatee and Fanning springs based on the results of the analyses and previous studies described in Sections 3 and 4. Manatee and Fanning springs feed the Lower Suwannee River below Wilcox and either contribute to or receive water from the Lower Suwannee depending on flow conditions. Therefore, it is imperative when considering MFLs for the Lower Suwannee River to examine the relationships between flows and levels in the Lower Suwannee and stage and flows in Manatee and Fanning springs since the geographic and hydrographic characteristics are inextricably related.

An empirical data analysis approach was used to evaluate the relationships between flows at Wilcox and downstream habitat availability. The intent was to quantify the effects of upstream discharge including antecedent flow conditions on downstream habitat availability and estimate the associated risk of reductions in river flows for each habitat of interest due to any perturbation, natural or anthropogenic. In the case of Manatee and Fanning springs, which are considered Class II manatee refuge springs, it is important to preserve a thermal refuge during winter months and provide adequate water depth to allow access to the thermal refuge. Therefore, the amount of flow required to provide adequate access to the thermal refuge was assessed. For the other 4 major habitat types (i.e., tidal swamp, SAV, tidal creeks and oyster beds), all expressed some degree of sensitivity to changes in estuarine salinities so salinity during low flow conditions became the determinant criterion for the estuarine portion of the Lower Suwannee. Spring discharge is an important contributor to river flow at times of low flow. Therefore, spring discharge was included for MFL consideration in the warm, low-flow season (May to October).

The threshold criterion established for each habitat type of interest was based on the best available information including published literature and empirical evidence. A key underlying concept in establishing these criteria was the evaluation of risk. Risk was established for manatee habitat based on access to a thermal refuge. Risk was established for downstream estuarine habitat based on exposure to a threshold salinity value. It is important to note the conservative nature of our established estimates of risk. For each of the habitats, criteria were selected to minimize the potential risk to the biological organisms of interest. The conservative nature of the assessments was based on identifying conditions where the biological organism under consideration would begin to encounter conditions that were physiologically stressful. These conditions occur in the natural system periodically as a function of climatological variation. Further, two of the organisms, manatee and fishes, are motile and can relocate to areas that are more preferential. Only under chronic conditions would exceedance of these criteria pose a threat to actual loss of habitat.

Several important tools were developed to guide selection of MFLs for the Lower Suwannee River system.

A thermal model was developed to describe the extent of the thermal refuge under varying river flow and spring flow conditions for Manatee springs and river flow was related to stage and discharge at Manatee and Fanning springs to allow for adequate depth for manatee passage and to support river flows during the low-flow season.

Regression analysis was used to relate salinity isohaline locations in the river passes to flow using data collected on full moon high tides. By sampling on spring tides, these salinity profiles represented the maximal upstream incursion of salinity into the estuary under normal environmental conditions.

ArcGIS was used to quantify available habitat for several of the habitats of interest.

A river mile system was constructed to relate the location of various salinity isohalines to habitats in and along the Lower Suwannee River such that exceedances of a particular habitat salinity requirement would constitute potential risk for a certain proportion of the total available habitat in the Lower Suwannee River and estuary.

Attempts were made to validate the inference regarding isohaline location and subsequent potential risk for each habitat type of interest by comparing regression results with independent analysis of other datasets in a weight of evidence approach.

5.2 Springs Target Habitat Analysis

5.2.1 Introduction

Manatee and Fanning springs were given first consideration in establishing MFLs for the Lower Suwannee River system because, as described in Section 3, the flow of the springs is inextricably related to the flow of the river. These springs are located upstream from the portion of the Lower Suwannee usually susceptible to salinity influences so requirements pertaining to MFLs for the springs might directly impact the downstream assessment of the estuarine portion of the Lower Suwannee.

As discussed in Section 4, the Florida Manatee is an endangered species that must be protected by federal and state law. In providing adequate flow and passage for this species, other habitats are concurrently protected based upon the “best available data” criterion.

Manatee Habitat Requirements

It has been recommended that the most critical need for manatee survival in Florida is the availability of adequate amounts of warm-water habitat during the winter (Warm-Water Task Force, 2004). Manatee thermal refuge appears to be the primary factor of concern for development of MFLs for Manatee and Fanning springs.

The Warm-Water Task Force (2004) recommended that thermal refuges maintain a temperature of $\geq 68^{o}$ F (20 ^{o} C). This recommendation was also made by the USGS Sirenia Project for consideration at Manatee spring (Langtimm et al., 2003). This temperature criterion was also used by the St. Johns River Water Management District for the development of MFLs for Volusia Blue spring (Newfields Inc., 2004), with protection of manatee thermal refuge being a primary consideration for that spring system.

A second consideration for manatee thermal refuge, after temperature, is water depth. Langtimm et al. (2003) recommended minimum depths of 5 to 7 ft (1.5 to 2 m) for adequate manatee passage/thermal refuge volume. This was also the minimum recommended depth recommended for Volusia Blue Spring (Newfield, Inc., 2004).

As noted in Chapter 4, the main thermal refuge at Manatee Springs is the outflow plume of warm spring discharge at the confluence of the spring run and the river. Maintenance of adequate depths in this region is largely a function of the river flow. Maintenance of Manatee Spring flow is important to preserve the size of the plume in the river, and thus a minimum flow criterion is needed at Manatee.

Fanning Spring is different. The spring and spring run are the main thermal refuge, but water levels are primarily controlled by water levels in the adjacent Suwannee River (Section 3.2.3). Maintenance of manatee thermal refuge at Fanning Spring is a function of water depths in the spring run, which are a function of stage in the river (Section 3.2.3).

5.2.2 Thermal Refuge Analyses for Manatee and Fanning Springs

5.2.2.1 Data Sources

The data sources used for the thermal refuge analysis are as follows:

Manatee Spring

- Bathymetry: collected by Florida Geological Survey over April 4-5, 2005.
- Temperature: collected at six fixed sites (Figure 3-16) by USGS.
  1) Upstream of spring mouth on piling, 30 minute frequency, 12/19/03 - 06/17/04
  2) In spring run, 30 minute frequency, 12/19/03 - 06/17/04
  3) Buoy 1, ~180m downstream of spring mouth
     1m, 15 minute frequency, 03/09/04 - 06/17/04
     2m, 15 minute frequency, 12/18/03 - 06/17/04
  4) Buoy 2, ~105m downstream of Buoy 1
     1m and 2m, 15 minute frequency, 03/10/04 - 06/17/04
  5) Buoy 3, ~95m downstream of Buoy 2
     1m and 2m, 15 minute frequency, 12/18/03 - 06/17/04
  6) Buoy 4, ~50m downstream of Buoy 3
     1m and 2m, 15 minute frequency, 12/18/03 - 06/17/04
- Water surface elevation, upstream and downstream, USGS
- New Clay Landing, upstream of Manatee Spring, 15 minute frequency, 02/19/04 - 06/25/04
- Fowlers Bluff, downstream of Manatee Spring, 15 minute frequency, 02/19/04 - 06/17/04
- Spring discharge, USGS, period of record
- Manatee sighting data, Florida Park Service (1993-present)
- Manatee sighting data, USGS (2003)

Fanning Spring

- Bathymetry: collected by WRA, June 2005
- Spring discharge, USGS, period of record
- Manatee sighting data, Florida Park Service (1996-present)
- Manatee sighting data, USGS (2003)

5.2.2.2 Water-Temperature Data

Water-temperature data were only available for Manatee Spring. Data to evaluate manatee winter thermal refuge came from several locations in relation to the Manatee Spring discharge into the river. Water-temperature data were collected by the USGS at Manatee Spring in the spring run and at several locations in the plume at the confluence of the spring run with the Suwannee River (Source: SRWMD). Data were collected mainly with continuous recording probes. Supplemental water-temperature data were collected during synoptic discharge runs with acoustic doppler instruments.

5.2.2.3 Spring Bathymetry Data

Spring bathymetry data at Manatee Spring were collected by the Florida Geological Survey under contract to the Florida Park Service. They used a GPS correlated acoustic depth finder and custom designed capture software to record position and depth information at one second sampling intervals. Additional bottom imaging was conducted using sidescan sonar to image the river bottom sediments. This data sidescan sonar product provides an aerial view of the river bottom in a wide swath looking sideways from the vessel centerline. Bathymetric soundings were simultaneously collected while sidescan operations were underway. Vertical control was achieved by correlating the depth of water below the transducer to river level data from nearby monitoring stations. Several river level gages are operated by the USGS within the vicinity of and at the vent of Manatee spring. River level data were downloaded at the end of survey operations from the USGS National Water Information System Web Site and used to calibrate the depth values for changes in river level caused by tides and spring discharge. This calibration ensures that data collected over the course of several days are vertically correlated to the same base plane, regardless of the river stage. Bathymetry data at Fanning Spring were collected in June 2005 by a licensed survey firm under contract to Water Resources Associates, using conventional rod and level techniques. The survey data were set to elevations in the National Geodetic Vertical Datum (1929) using a nearby benchmark.

5.2.2.4 Manatee Sighting Data

Manatee-sighting data were provided by the Florida Park Service for both Manatee and Fanning springs. Manatee sightings at Manatee spring have been taken by park personnel since 1993, and at Fanning spring since 1996. Note that these records may include repeated sightings of the same animal. They are based upon the single highest count of individuals seen on any given day, i.e. if a ranger sees 3 in the morning, and 5 in the afternoon, the total count on the day is 5. Therefore, these data do not reflect the actual manatee population size using the spring, rather they are a general index of manatee abundance.

Additional manatee data came from a study conducted for SRWMD by the USGS Sirenia Project (Langtimm et al., 2003). They summarized characteristics of the regional (Northwest Florida) manatee population and their main winter refuges (Crystal and Homosassa rivers). This population has been exhibiting a clear increasing trend in numbers over the last 30 years. As noted earlier, Manatee Spring was identified as an important secondary, winter-refuge area, primarily during the late fall and late winter, when manatees are either traveling to or dispersing from the main winter-refuge sites and must find a short-term thermal refuge when early- or late-season cold fronts affect the region. They also presented actual “hard counts” of manatee abundance in the Suwannee River and Manatee Spring, based on aerial surveys and identification of discrete individuals. Some of their data on individual manatees go back 30 years. One female manatee (‘CR071’) has returned to Manatee Spring repeatedly during the winter since 1976. A total of 21 distinct individual manatees have been recorded using Manatee Spring since the mid-1970’s. This report (Langtimm et al., 2003) also presented recommendations for manatee habitat considerations with respect to developing MFLs for Manatee Spring.

Manatee sightings data indicate that peak use of Fanning and Manatee springs occurs between December and March (Figures 5-1 and 5-2), indicating the value of the springs as winter warm-water habitat. Manatee sightings data from Fanning Spring indicate that more sightings are made when the spring stage exceeds 2.71 feet msl (Figure 5-3). This equates to a depth of at least 5 feet (1.5 m) in the shallowest part of the Fanning spring run. Sightings probably decline at higher stages because more river water is intruding into the spring, lessening its value as thermal refuge.

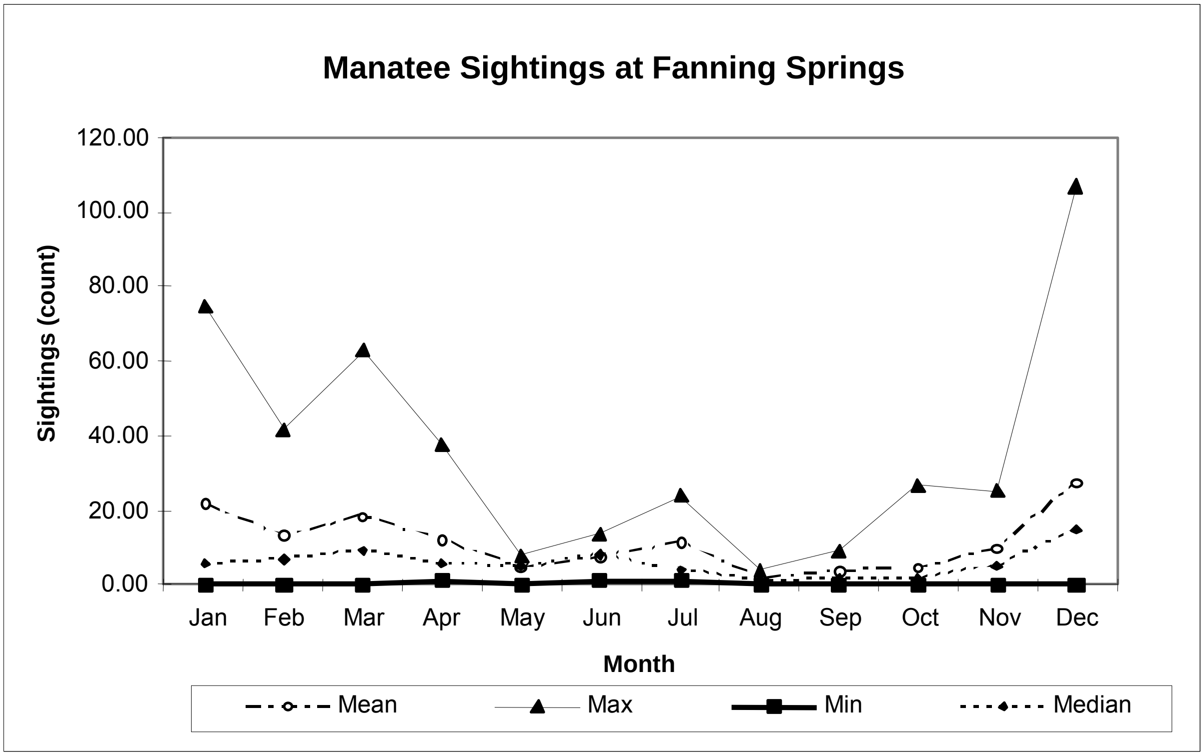


Figure 5-1. Plots of monthly manatee sightings at Fanning Springs. Source: Florida Park Service.

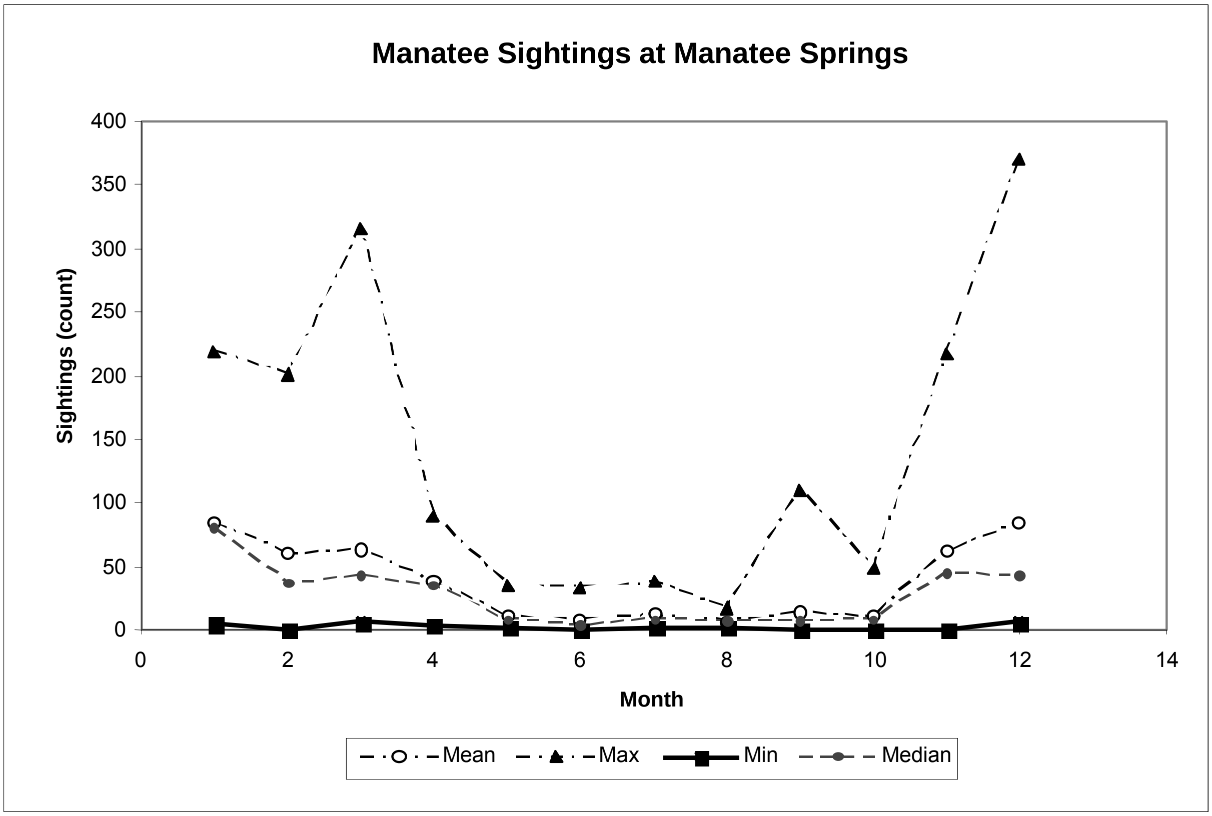


Figure 5-2. Plots of monthly manatee sightings at Manatee Springs. Source: Florida Park Service.

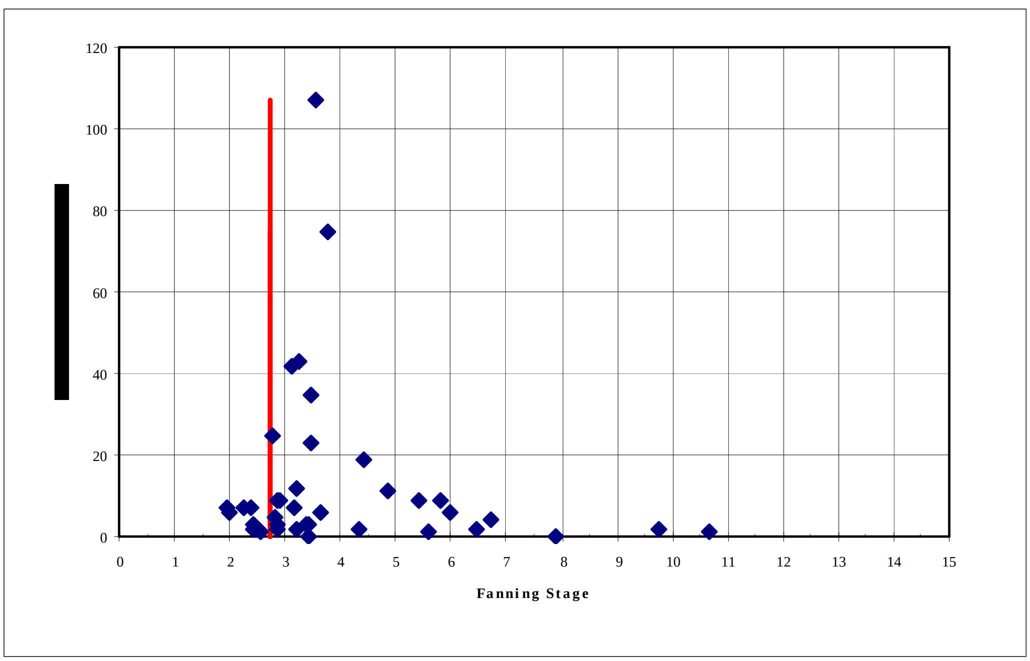


Figure 5-3. Plot showing manatee sightings in Fanning spring versus stage. Vertical line indicates depth of 5 feet in the spring run at a stage of 2.71 feet in the spring pool.

5.2.2.5 Thermal Model Description for Manatee Spring

To aid in MFL development, a temperature model was developed for that portion of the Suwannee River in which the temperature effects of the spring discharge are most likely discernable (Figure 5-4). The affects on temperatures in the river of various scenarios of river flow and spring flow were examined using CE-QUAL-W2. CE-QUAL-W2 is a two-dimensional, laterally averaged, hydrodynamic model developed and supported by the US Army Corps of Engineers, Waterways Experiment Station (Cole and Wells, 2000). The mechanistic model predicts water-surface elevations, velocities, salinity, and temperature.

The model provides predictions that are laterally averaged (across the entire water body perpendicular to the direction of horizontal flow), so that the model integrates any lateral differences in velocities, temperatures, or modeled constituent concentrations. The model accommodates multiple inflows and time-varying boundary conditions for surface elevation, temperature, and constituent concentrations.

5.2.5 Model Development

To identify the effects of the spring discharge on temperature in the river, the temporal domain of the model was limited to the February - April 2004 period, during which river temperatures ranged from 55°F (13°C) to 75°F (24°C). With the relatively constant spring-water temperature of 72°F (22°C), the effects on temperatures in the river were expected to be most evident during this period. However, temperature observations at the fixed buoys showed that water temperature was below 68°F (20°C) until the middle of March, so that the effects of the warmer spring water were not detected at the buoy locations.

The model spatial domain was limited to the nearshore region in the vicinity of the spring mouth, the most likely location of the spring plume (D. Hornsby, pers. com.). The length of the domain along the axis of the river is 2,195 ft., with the width of the domain approximately 82 ft. The model domain was divided into 11 grid cells, with the highest resolution grid cells from the mouth of the spring downstream for approximately 330 ft. This highly resolved region represents the area most likely affected by the plume (Figure 5-4). Cells 1-8 were each one layer deep. Cells 9-11 were two layers deep. The surface layer in each of the 11 cells was 5 ft. deep.

Note the distribution of the plume is flow sensitive. At high flows the plume is closer to the eastern shore and more extended downstream than at low river flows where it is more wider into the river.

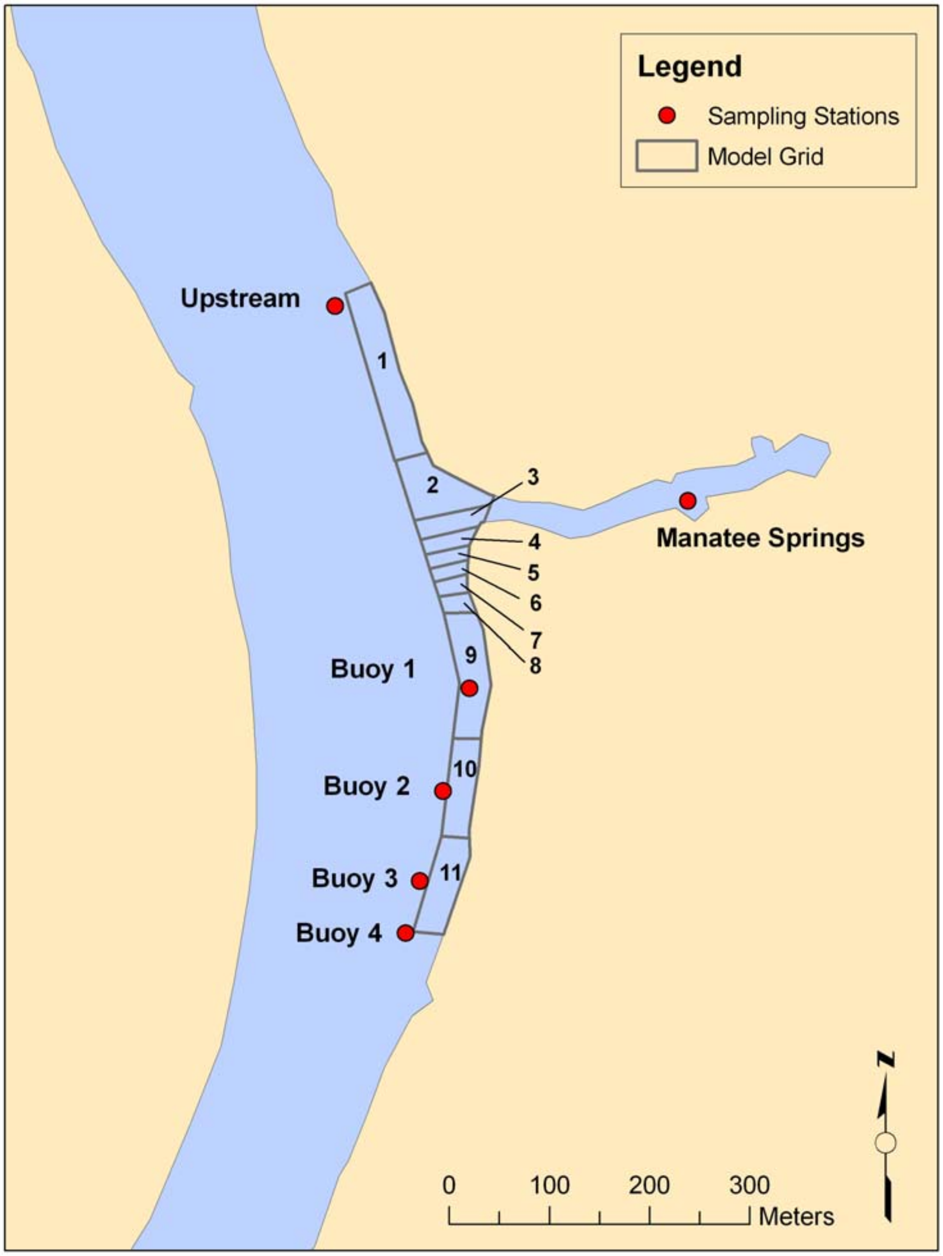


Figure 5-4. Temperature sampling sites and model grid for Suwannee River near Manatee Spring. Upper grid shows horizontal along-stream layout with numbered gridcells.

5.2.2.5.2 Model Calibration

The model was calibrated using data for the period February 20 – April 30, 2004. During this period, Manatee Spring flow ranged from 124 cfs to 168 cfs (Figure 5-5), while river flow ranged from 4,200 cfs to 12,500 cfs (Figure 5-6). As river flow declined and spring flow increased, the relative proportion of Manatee Spring flow as a fraction of the total river flow increased from 1% to 3.5% (Figure 5-7). From a mass-balance perspective, the effect of Manatee Spring on river water temperature increases as the proportion of the total river flow made up of spring discharge increases.

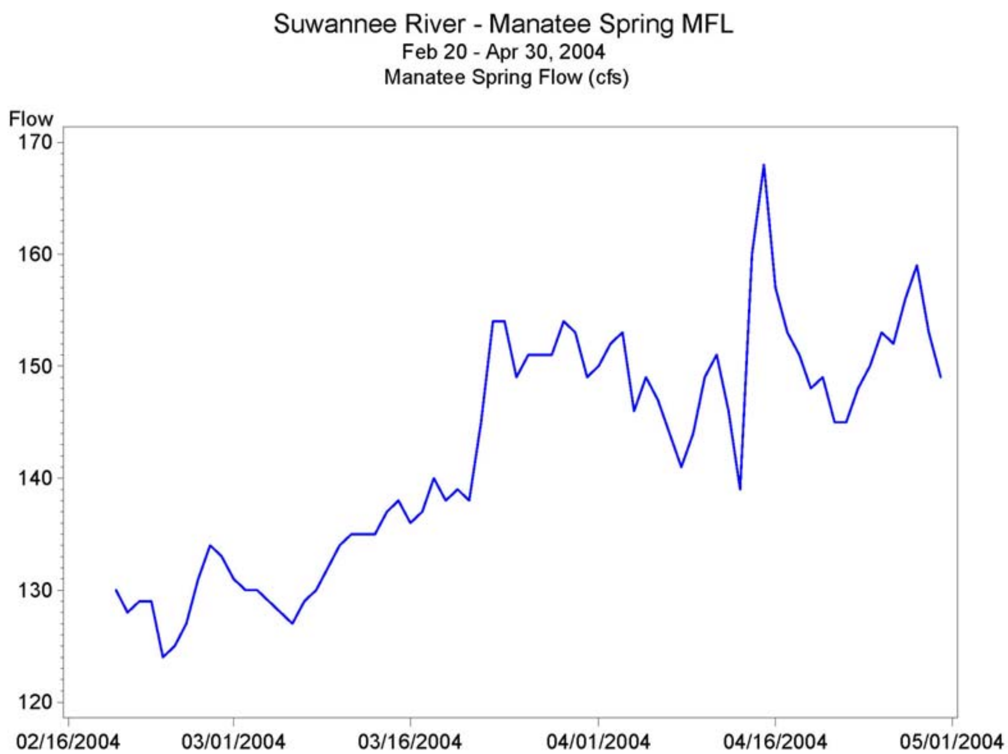


Figure 5-5. Manatee Spring flow, 2/20/04-4/30/04.

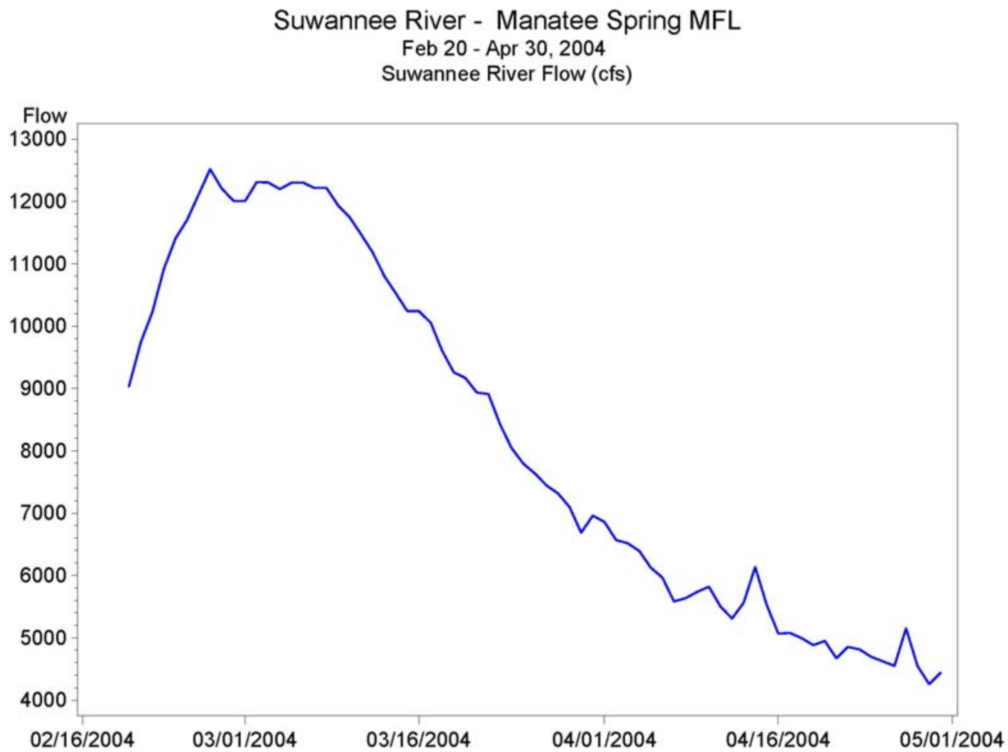


Figure 5-6. Total river flow (Suwannee River near Wilcox + Fanning Springs near Wilcox), 2/20/04-4/30/04.

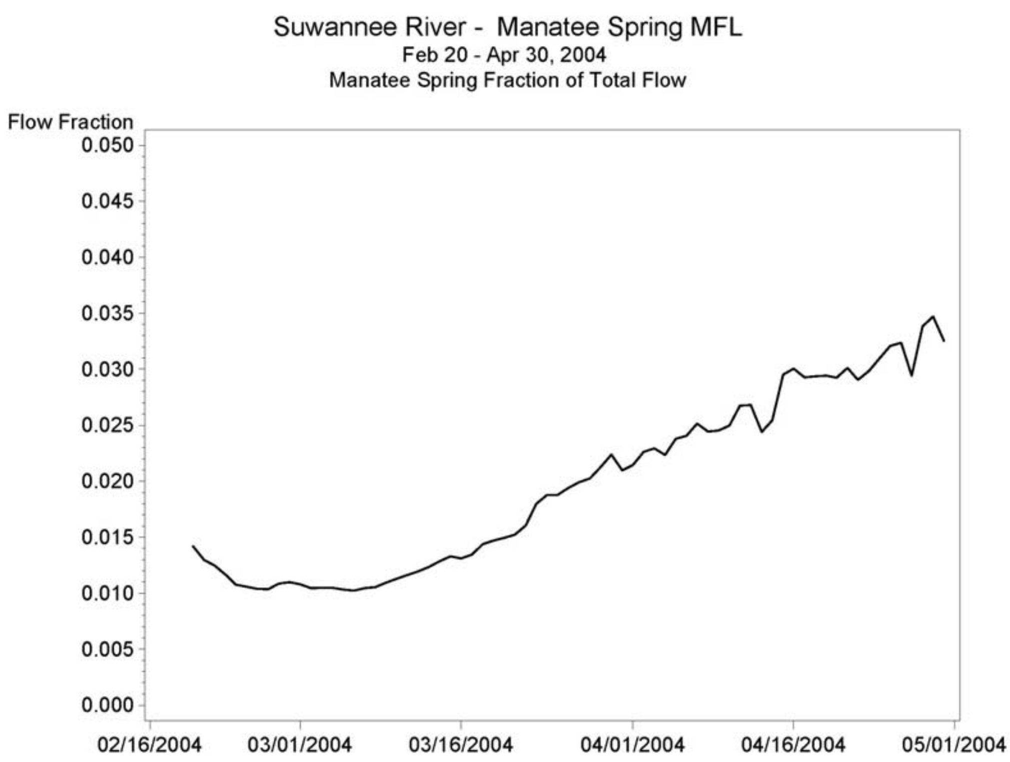


Figure 5-7 Fraction of total river flow made up of Manatee Spring flow, 2/20/04-4/30/04.

The river flow into the model was estimated using the total river flow and the bathymetry. The river-flow estimate into the northern model domain was derived by scaling the flow into the domain by the fraction of the river cross-sectional area represented by the northern face of the model domain. The portion of the river within the northern domain of the model is very shallow. This area was estimated at approximately 2% of the total river cross-sectional area, so that the flow into the northern model domain was set to 2% of the total river flow. The bathymetry shows increasing depths along the eastern shore south of the mouth of the spring, suggesting that the amount of flow through the model domain increases in the southern portion of the grid. Additional inflows into the southern cells of the domain (cells 9-11) were included to account for this increase in depth, based on the relationship of the total river volume across the river to the cell volume. This resulted in an additional 3.5% of the river flow going in to cell 9, an additional 6.5% of the river flow going in to cell 10, and another 6% of the river flow going in to cell 11.

The model output was compared to observed data collected at Buoy 1, Buoy 2, and Buoy 3. Appendix F shows the comparisons of daily mean temperatures at both 1m and 2m at each of the buoys. The model accurately predicts the observed temperatures during this period.

5.2.2.5.3 Model Scenarios

To examine the effects on temperature in the river as a function of river flow and spring flow, a baseline flow regime was selected, with variations on this regime selected for comparison. Monthly discharge estimates were developed for the springs based on river and local groundwater levels for the period February 1993 – September 2004 (Section 3.2.3.3). The baseline flow regime was selected as the median monthly flow for the river just upstream of Manatee Spring (Suwannee River near Wilcox + Fanning Springs near Wilcox) and the median monthly flow at the AVM gage at Manatee Spring. Variations included modifying the Manatee Spring flow to the 25th and 75th percentile while keeping the total river flow at the median, and modifying the river flow to the 25th and 75th percentile while keeping the Manatee Spring flow at the median. These scenario definitions are shown in Table 5-1.

Table 5-1. Thermal Modeling Scenario Definitions.

Scenario	River Flow	Manatee Spring Flow
Baseline (Scenario 1)	50th percentile	50th percentile
Scenario 2	50th percentile	25th percentile
Scenario 3	50th percentile	75th percentile
Scenario 4	25th percentile	50th percentile
Scenario 5	75th percentile	50th percentile

The monthly flow rates for February-April are shown in Table 5-2. Data for Fanning and Manatee Springs are for the period of record for those gages (see Tables 2-12 and 2-13). This period was drier then normal (see Section 3.2); long-term median discharge for these springs is greater than shown in Table 5-2.

Table 5-2. Suwannee River and Manatee Spring monthly flow rates.

Month	River Flow (cfs) (Suwannee+Fanning)			Manatee Spring Flow (cfs)		
	25th	50th	75th	25th	50th	75th
February	6915	11406	16645	110	128	143
March	8550	14412	19792	132	137	149
April	8398	13379	19854	146	150	153

Elevation and temperature boundary conditions were the same for all scenarios, and were set by observed conditions for February 20 – April 30, 2004.

5.2.2.6 Flow Analyses for Manatee Protection at Manatee Springs

As for the calibration, time-series graphs of daily mean predicted temperatures were plotted. The temperatures within each grid cell were examined. The temperature time series are shown in Appendix F. As expected, scenarios with a higher ratio of Manatee Spring flow to total river flow (Scenarios 3 and 4) show warmer temperatures than the baseline.

The effects of the Manatee Spring inflow on temperatures are not seen in the cells upstream of the mouth of the spring run, cells 1 and 2 (Appendix F; Figures F-7 and F-8). The effects are seen in all cells downstream of the mouth, especially at lower temperatures.

The metric of primary interest in evaluating the scenario results is the volume of water greater than 68°F (20°C). This defines the available volume for manatee refuge during colder periods. For each scenario, the proportion of the volume in cells 3-8 greater than 68°F was estimated on a daily basis. Appendix F illustrates a comparison for each scenario to the baseline (Figure F-21).

The greatest increase in volume of water greater than 68°F as compared to the baseline is found in Scenario 4, where the river flow is 25th percentile. This is as expected, as this scenario maximizes the ratio of spring flow to river flow.

The two scenarios with river flow at the median and Manatee Spring flow at the 25th and 75th percentiles do not differ greatly. This is the result of the relatively small change in the ratio of Manatee Spring flow to the total river flow, from approximately 0.9% to 1.1%, as spring flow goes from 25th to 75th percentile. However, comparison of these scenarios to the baseline does indicate that a decrease in Manatee Spring flow below the median results in a decrease in the volume of water with temperature of 68°F or more.

Given these results, a potential minimum flow for Manatee Spring during the cold season (November-March) would be the median monthly flow for the period from 2001 to present. For these months, the median monthly flows are as follows:

November	130.5 cfs
December	132.0 cfs
January	141.0 cfs
February	128.0 cfs
March	137.0 cfs

The seasonal median flow, based on AVM data from the Manatee Spring gage, is approximately 130 cfs.

5.2.3 Stage (Level) Analysis for Manatee Protection at Fanning Spring

The criteria for manatee refuge access at Fanning Spring was based on stage in the spring and spring run. On June 20, 2005, a land surveying company retained by WRA collected several cross-sectional profiles across the Fanning Spring run. This survey was utilized to identify the "sill" within the thalweg of the spring run, in order to address manatee passage issues. The elevation of the thalweg within these profiles ranged from a low of –3.81 feet NGVD to as high as –2.29 feet NGVD) (see Appendix C for cross-sections). Since the 5-foot passage criterion has been suggested for manatee passage, a 5-foot depth was added to -2.29 resulting in a stage of 2.71 feet NGVD. This stage provides adequate protection from significantly adverse impacts to manatee habitat for Fanning spring. Figure 5-8 compares the distribution of stage at Fanning Spring by month with the possible cold season MFL criterion of 2.71 feet NGVD.

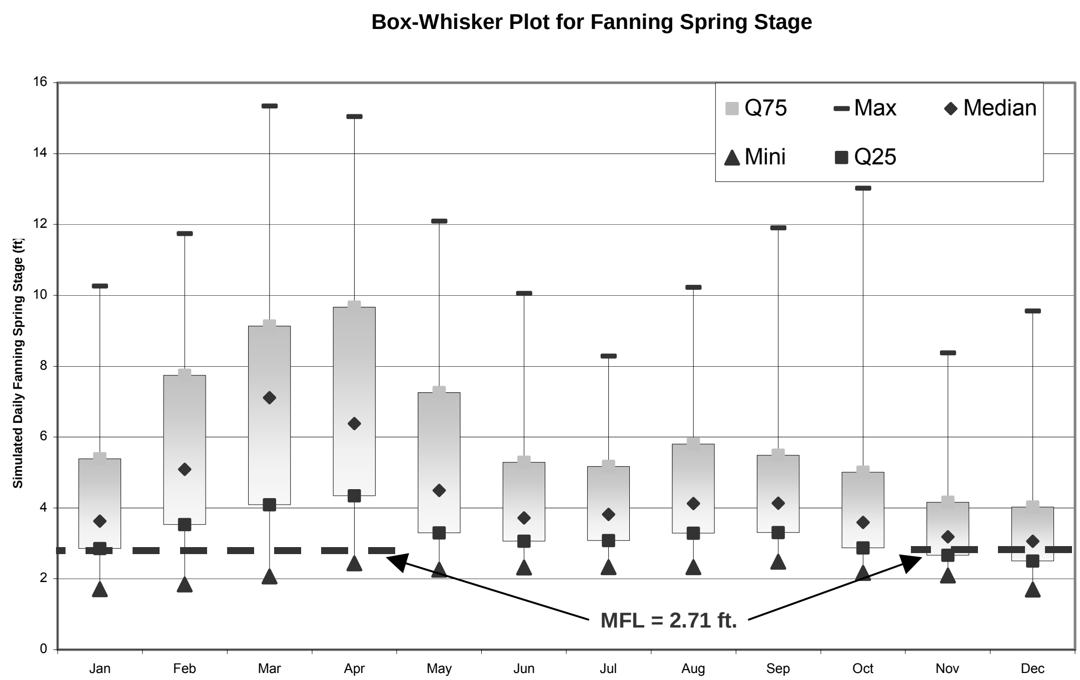


Figure 5-8 Distribution of Fanning spring Stage with cold-season reference line at 2.71 feet NVGD.

Stage at Fanning Springs is dependant on stage within the Suwannee River (see Section 3.2.3.3.1), which is not a simple function of flow, particularly at low river stage/discharge (Figure 5-9). At a stage of 2.34 ft (which equates to 2.71 feet NGVD at Fanning Spring), discharge at the Wilcox gage ranges from about 2000 cfs to about 9000 cfs. Therefore, it is not possible to state a unique discharge value for Wilcox that corresponds to an exact stage of 2.71 feet NGVD at Fanning Spring. However, it is possible to calculate a probability that stage will be 2.71 feet NGVD or greater at Fanning Spring for a given Wilcox discharge. As manatee passage is only of critical concern during the winter months, the probability of Fanning stage exceeding 2.71 feet NGVD for a range of Wilcox flows was determined for the cold months only (November – April).

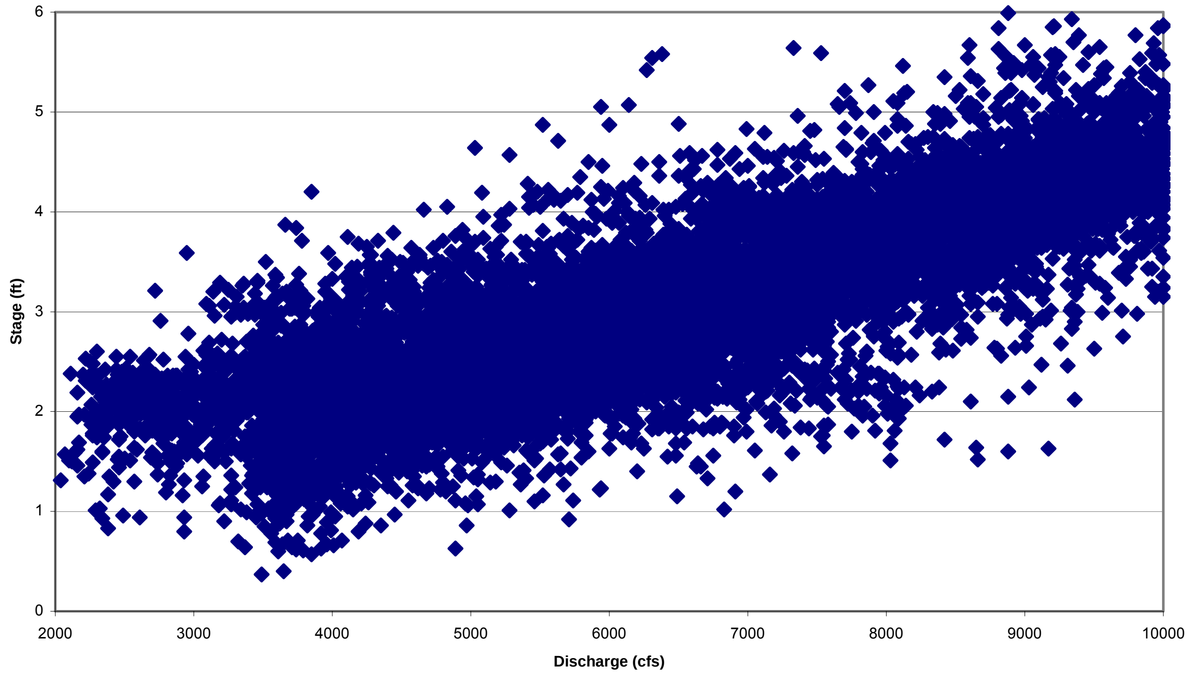


Figure 5-9. Stage-discharge graph for the Wilcox gage at low stage/discharge.

As discussed in Section 3, the historic dataset for the Wilcox gage does not contain stage data between 1941 and 1951 for days when the stage was below approximately 5 feet NGVD. To avoid skewing the results of the following analysis, only stage and discharge data for the Wilcox gage from after February 1951 were used. This stage and discharge data were first sorted from highest to lowest discharge, keeping the stage value for a given day with the corresponding discharge. The data pairs where then ranked from first to last by discharge and assigned an exceedance probability based on this ranking, in the same manner that the flow duration curve for Wilcox was developed (Figure 3.2).

Next, the range in stage was analyzed for a series of flow values with a set interval of exceedance probabilities (i.e. exceedance probability of 0.5, 0.55, 0.6, etc.). For example, the median discharge within this data set is 8,620 cfs. Within a 1 % range of the median discharge (exceedance probability of 0.495 to 0.505, discharge from 8,530 cfs to 8,710 cfs), the stage at Wilcox has varied between 1.52 and 5.67 feet NGVD. By sorting and ranking by the stage, it is determined that the stage at Fanning Spring is above 2.71 feet NGVD 97 % of the time for the median discharge at Wilcox during the cold season.

The resulting probability distribution for a range of flows at Wilcox is shown in Figure 5.10. This figure can be utilized to determine the reduction in the percent of time Fanning Spring run is passable by manatees for a given reduction in Suwannee River flow as measured at the Wilcox gage.

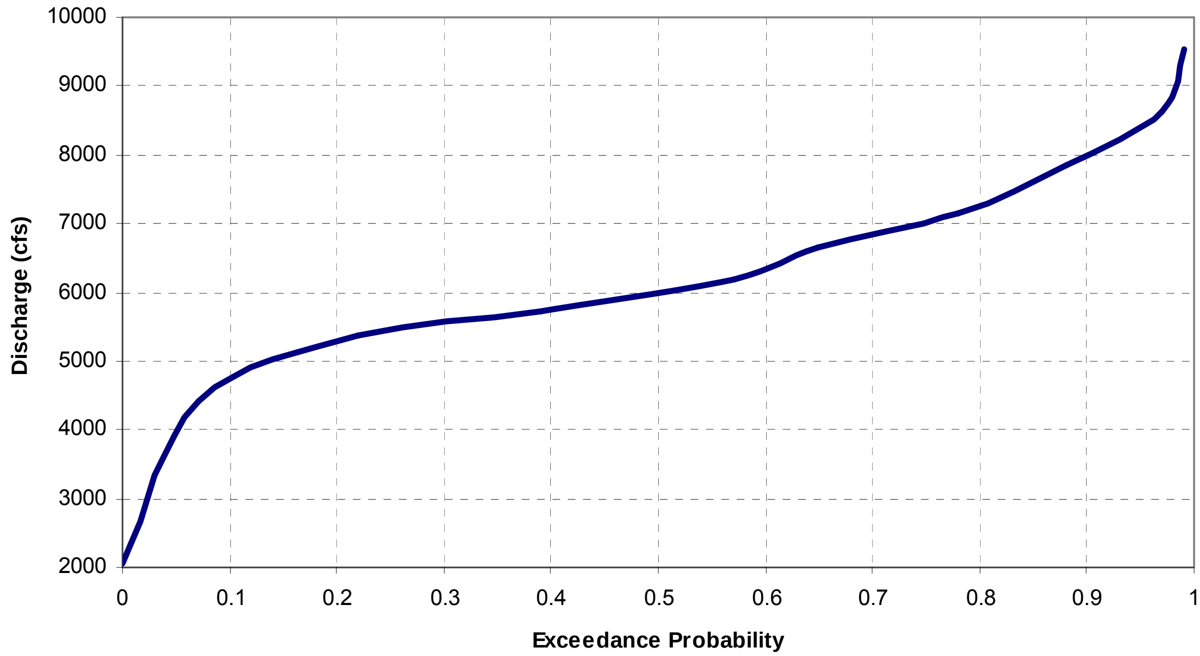


Figure 5-10. Probability that the stage at Fanning Spring will be greater than 2.71 ft. NGVD for a given discharge at the Wilcox gage (cold season only).

5.3 Lower Suwannee River Target Habitat Analyses

5.3.1 Quantifying Relationships between Flow and Salinity for Downstream Habitats

5.3.1.1 Data sources

Several data sources were used to develop salinity-flow regressions.

- Daily average discharge data were obtained for USGS gage number 02323500 (Suwannee near Wilcox) from 1984-2004.
- Salinity data from longitudinal surveys conducted at fixed station locations in the Lower Suwannee River by SRWMD in co-operation with the Florida Game and Fish Commission (GFC) at high slack tide 1993-1995 (Figure 5-11) were used to develop isohaline regressions.
- Four USGS fixed station gages located in East and West pass of the Suwannee River were also used to represent daily average or daily maximum salinity at the surface, mid-water, and bottom depths.
- In Suwannee Sound, the SEAS salinity collections throughout Suwannee Sound and in the Lower Suwannee River were used to assess monthly median salinities as a function of flows. Hourly tidal measurements taken at the NOAA Cedar Key Station from 1997-2003 were used to correct salinity for tidal state when possible.

5.3.1.2 Relating Flow and Isohaline Location

Regression relationships were developed between flow at Wilcox and isohaline location in the Lower Suwannee River. The flow at Wilcox was regressed on salinity by considering the flow rate in cubic feet per second (cfs) on the date when the salinity data were recorded as well as antecedent flows. Derived flow variables included:

- Daily flows as well as various transformations of flows (e.g. logarithmic, inverse, and power transformations such as flow$^{1/2}$).
- Lag flows to 15 days: For example lag1 flow is the flow on the date prior to the salinity sample date.
- Cumulative flows to 8 lagged days: For example, cum4 is the sum of the flow on the sample date and the three previous days flow.
- Lag average flows in 15 day intervals to 90 days: for example lag average 7 is the sum of the flow on the sample date and 6 days prior to sampling divided by 7.

Salinities and salinity isohalines could then be related to various antecedent flows as well as the sample date flows at Wilcox. A hypothetical relationship between flow and the location of a given isohaline (e.g., 5 ppt surface isohaline) is shown in Figure 5-12.

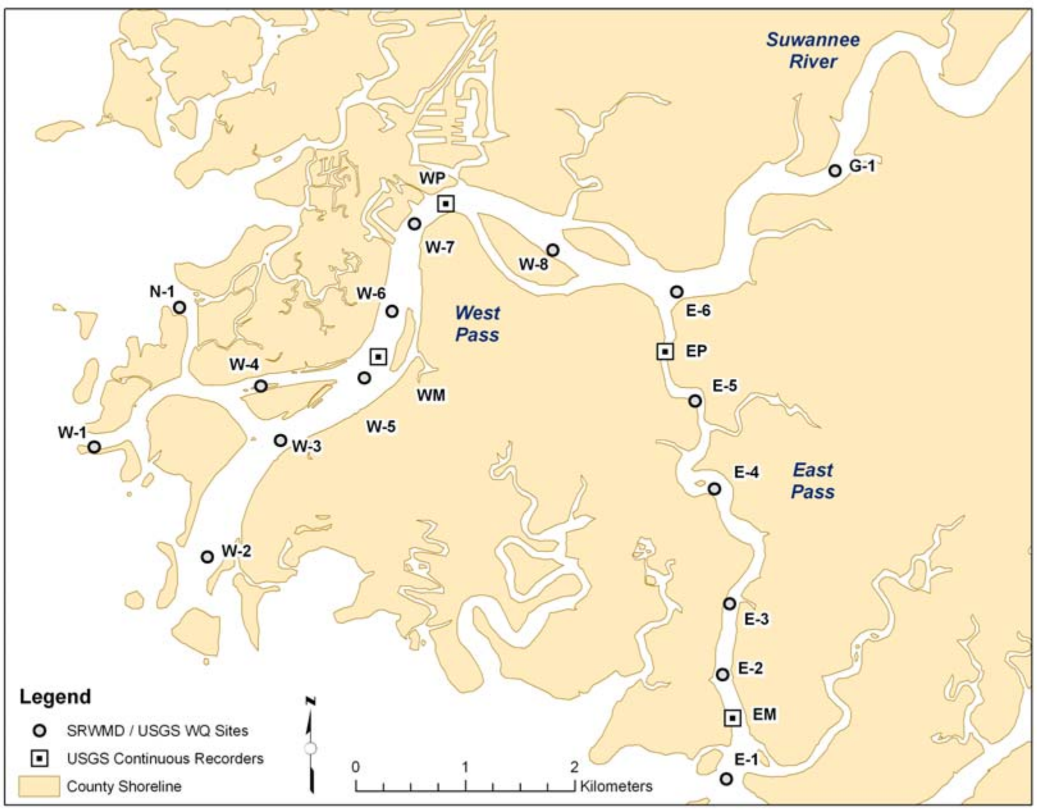


Figure 5-11. Salinity sampling stations used by the SRWMD and USGS to characterize salinity in the Lower Suwannee River.

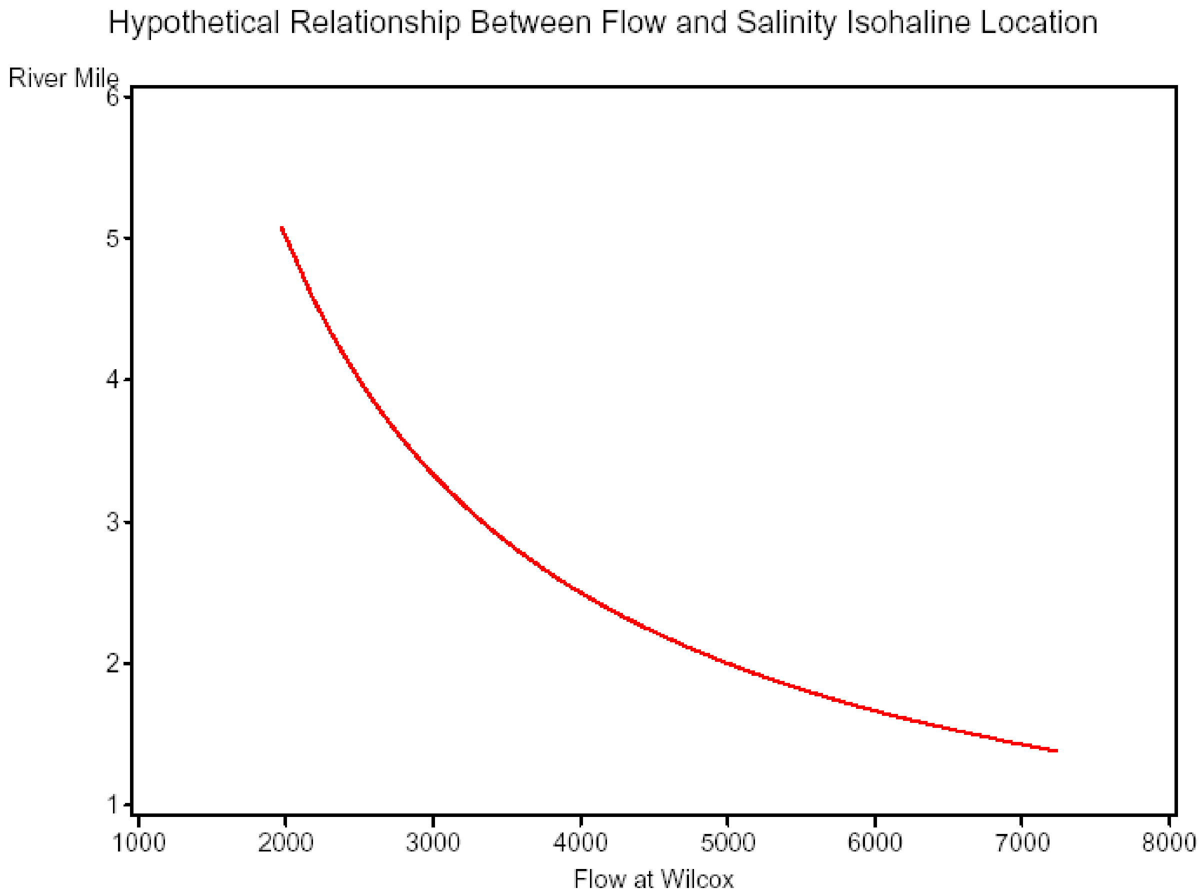


Figure 5-12. Conceptual relationship between flow at Wilcox and the location of an isohaline in the Lower Suwannee River.

5.3.1.3 Quantification of Habitat

Important habitats (as identified in Section 4.0) were quantified using geo-referenced habitat data when available. ArcGIS allows the user to calculate total areas for polygon or line coverages. Geo-referenced data were available for tidal swamp and SAV habitats. A river mile system was constructed for the Lower Suwannee based on District georeferencing (Figure 5-13: also see Appendix G for details). Quantification of each habitat type began at the downstream limit of that habitat. Cumulative percentages of the total acreage were calculated at ¼ mile intervals from the downstream limit. Linear interpolation was used to calculate percentages between ¼ mile intervals when necessary. This allowed for the cumulative percentages to be directly related to a location in the Lower Suwannee (Figure 5-14). Tidal creek habitat was evaluated by counting the total number of access points, defined as the mouth of each creek, and calculating cumulative percentages of the total number of creek access points for each ¼ mile interval starting at the downstream limit.

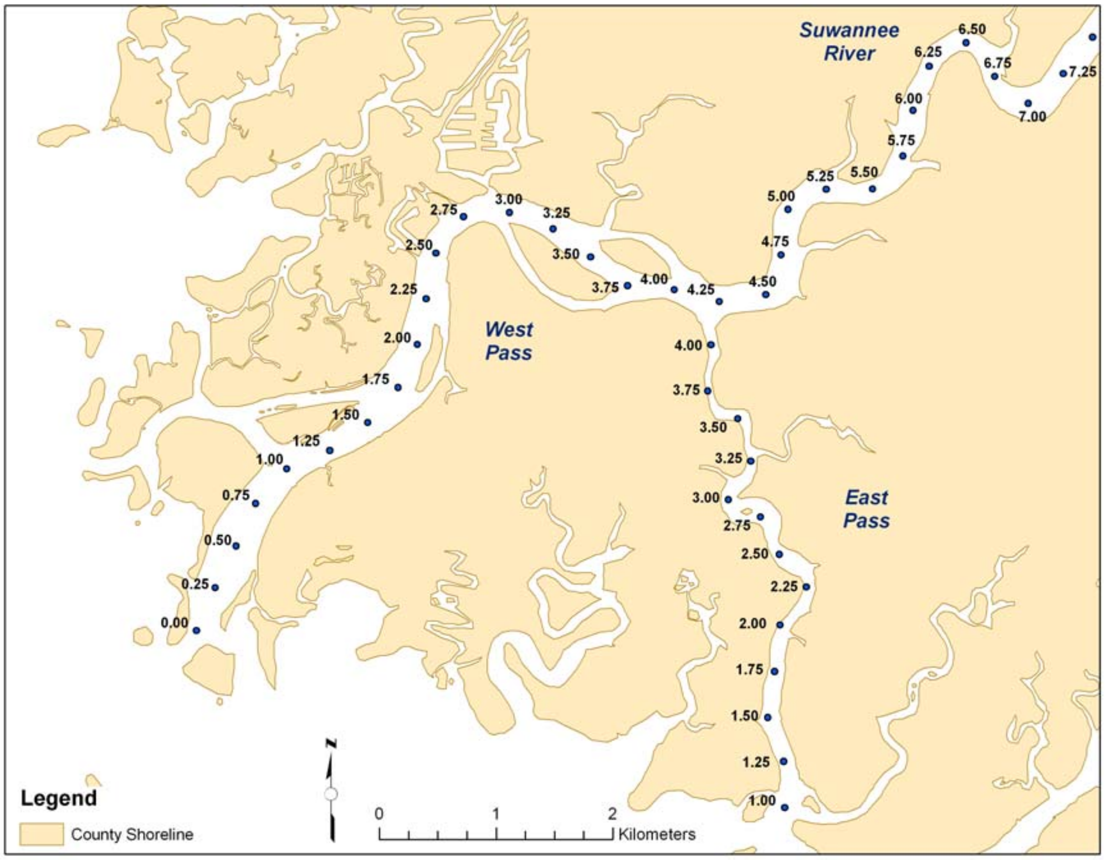


Figure 5-13. River mile system used to quantify habitat in the Lower Suwannee River.

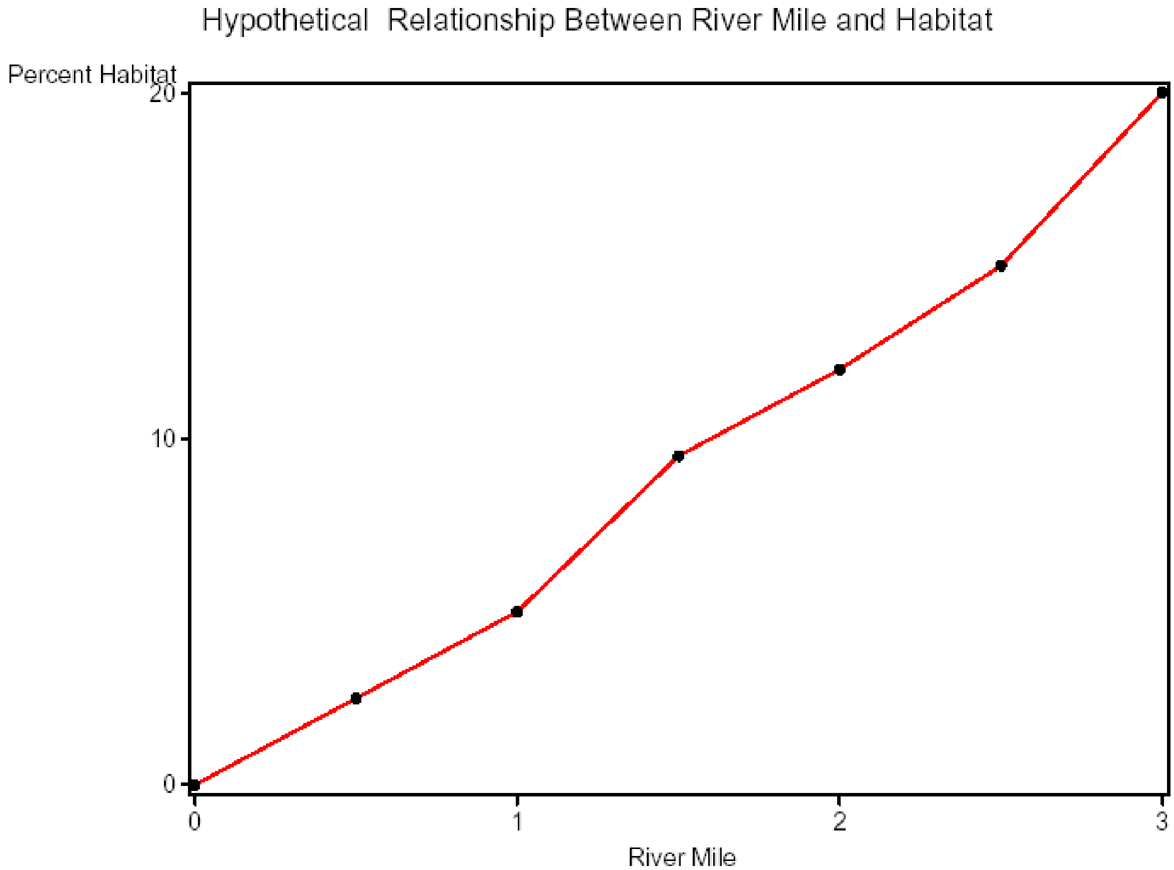


Figure 5-14. Conceptual relationship between river mile and cumulative habitat distribution.

5.3.1.4 Estimating Habitat at Risk with Changes in Flow

Estimations of flow-isohaline location relationships were used to identify the upstream incursion of a specific isohaline under varying flow conditions. River locations associated with 0 to 15 % of the total habitat were identified as risk points for each habitat type of interest. A regression equation could then be used to solve for the flow required to keep a particular isohaline below each of the risk points (Figure 5-15).

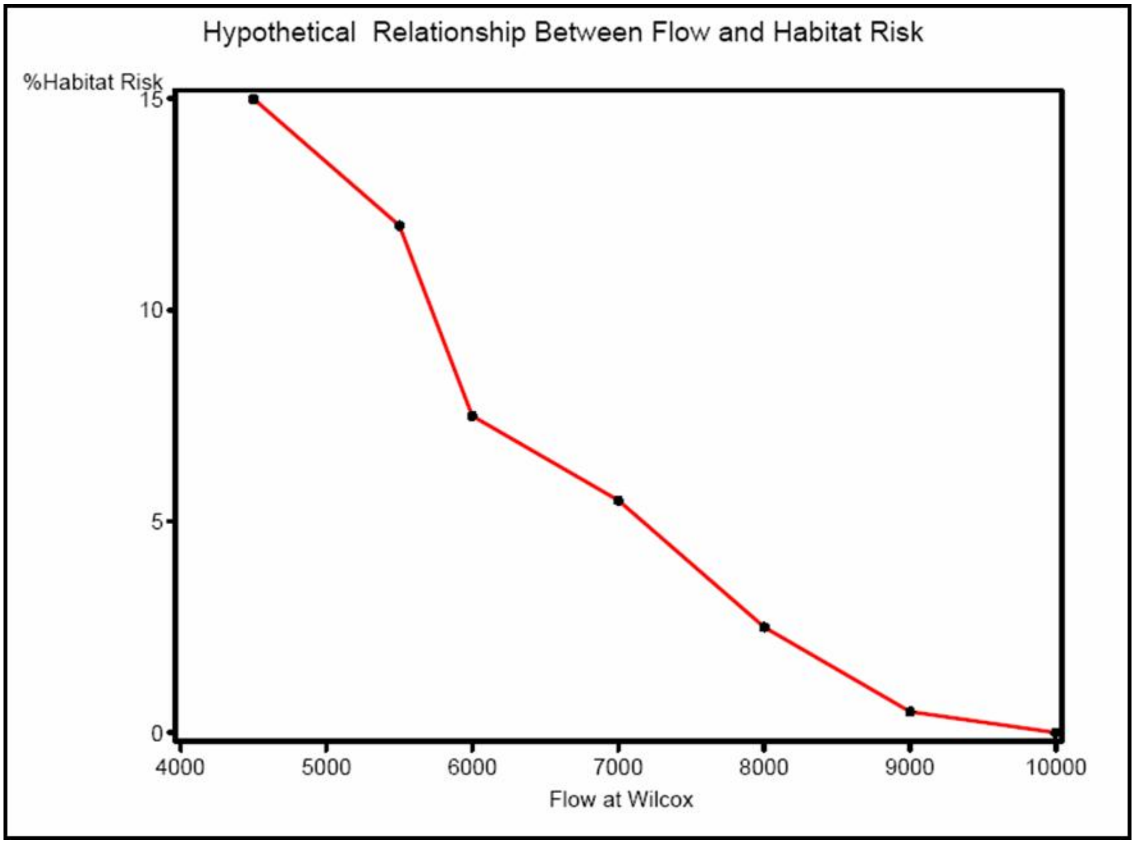


Figure 5-15. Conceptual relationship between flow and associated risk of habitat loss.

5.3.2 Upper Estuary Submerged Aquatic Vegetation

5.3.2.1 Data Sources

Studies on submerged aquatic vegetation (SAV) in the upper estuary were conducted for the SRWMD by Mote Marine Laboratory (Mote) (Estevez and Sprinkel, 1999; Estevez, 2000b; 2002) and by Golder Associates (2000). Mote sampling sites are shown in Figure 4-6 of Golder and Associates (2000). These 16 sites were selected jointly by Mote and District scientists during a pre-study reconnaissance. Placement of sites was systematic, extending from the downstream limit of SAV in East, Alligator, and Wadley passes up to the confluence with the Gopher River, where salinity never penetrates under ordinary climatic and river flow conditions. The overall goal of the Mote SAV study was to describe the characteristics of SAV where it occurred in the upper estuary and relate to salinity regimes, as opposed to making broader generalizations about SAV in the upper estuary, which would have required a probability based site selection procedure.

At all 16 sites, SAV characteristics of frequency, cover and abundance by species were measured using 0.25 m^2 quadrats and the non-destructive Braun-Blanquet method. This involves assigning a score to each species of SAV observed in the quadrats based on the following scale:

Braun-Blanquet Score	Estimated Cover
1	< 5%
2	5-25 %
3	25-50 %
4	50-75%
5	75-100%

Quadrats were deployed haphazardly about the grassbed at each site during sampling. Sampling was conducted 4 times on a quarterly schedule from March 1998 to January 1999. The 16 sites were re-visited in June 2000 and July 2002 during a severe drought.

Additional SAV data were collected at a subset of six of the 16 study sites. Six (6) quadrats of 0.0625 m^2 area were haphazardly deployed about the grassbed at each site, and all SAV within the quadrat was harvested for determination of dry weight standing crop. In the laboratory, collected plant material was separated by individual plant species and then divided into leaf (above ground) and root (below ground) components by species. This material was air-dried for 24 hours, and then further dried at 75-80^{O}C in ovens to obtain dry-weight standing crop.

SAV was mapped by Golder Associates (2000) in late spring and summer of 2000. Mapping was conducted using “in-the-field” technology. A Trimble® AgGPS 132 Global Positioning System unit was linked to a laptop computer with software which linked the GPS system to ESRI® GIS software. The edges of individual grass beds were delineated in the field by walking the perimeter of each bed with the GPS unit. The hardware and software recorded this polygon on the laptop computer. Various attributes of the grassbed (species composition, dominant species, salinity, etc.) could then be entered into the computer to build the GIS attribute database. Because the mapping effort was conducted during an extreme drought, there were areas known to historically support SAV which were now unvegetated. SRWMD staff located these for Golder Associates field personnel, and areas of unvegetated substrate in depths <3 ft (0.9 m) were delineated during dead low tide to conservatively estimate the amount of “potential” or “historic” SAV habitat. A river mile system was developed and used to help calculate the cumulative acreage of SAV in West Pass, moving from the downstream limit up to the confluence with East Pass.

5.3.2.2 Spatial Extent of SAV

Golder Associates (2000) delineated 27.1 acres (0.11 km^2) of SAV in the upper estuary during the drought of 2000 (Figure 5-16). An additional 4.4 acres of “potential/historical” SAV cover was conservatively identified in areas known to previously support SAV on a long-term basis. The majority of the SAV acreage is found in West Pass (Figure 5-16), from about river mile 1.5 (where Wadley and Alligator Passes split) up to the confluence with East Pass.

SAV generally grows in relatively shallow areas where depths are typically $\leq$3 ft at low tide. For purposes of MFL development, the downstream limit of SAV coverage in West Pass is regarded as river mile 1.0.

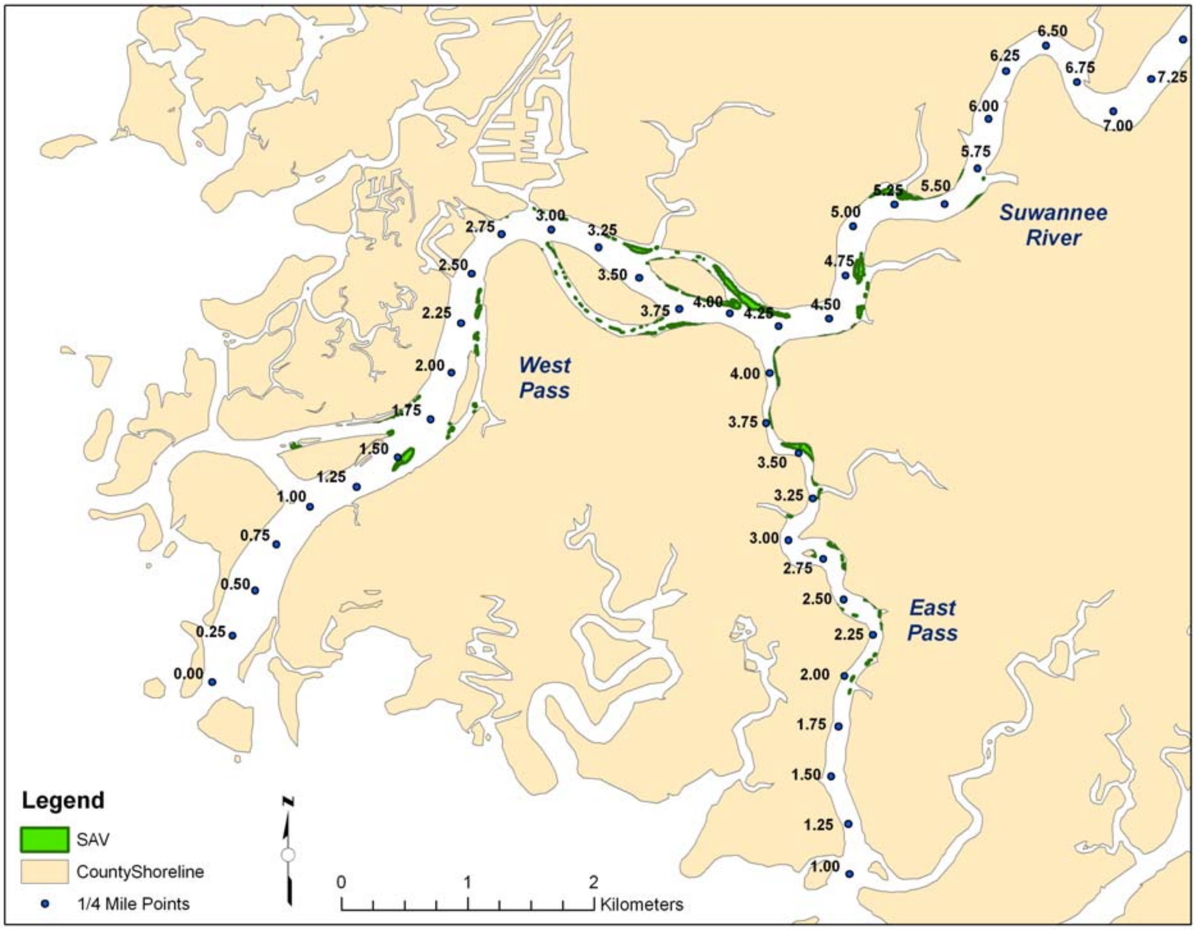


Figure 5-16. Map of the upper Suwannee estuary showing river mile system and SAV/potential SAV polygons mapped by Golder Associates in summer 2000.

5.3.2.3 SAV Habitat Requirements

The dominant species found in the upper estuary SAV beds are fresh-water plants, which are able to tolerate moderate levels of salinity. The dominant plant in these beds, *Vallisneria americana*, has been the subject of several studies. Haller et al. (1974) found that growth of *Vallisneria* ceased at 6.66 ppt salinity (i.e., ~7 ppt) in a greenhouse experiment. Twilley and Barko (1990), in an outdoor microcosm study, found that growth of *Vallisneria* was not significantly affected by salinities of up to 12 ppt. Doering et al. (1999) conducted laboratory studies of *Vallisneria* salinity tolerance and found that growth began to decline at salinities $\geq$9 ppt, and that growth ceased at salinities of 15 ppt.

As noted earlier, the downstream limit of *Vallisneria*-dominated beds in West Pass of the Suwannee estuary is approximately river mile 1.0. This area has a mean high-tide salinity of about 12 ppt (Mattson and Krummrich, 1995). During outgoing and low tides, salinity is lower (down to 0 ppt). Approximately 4 acres of SAV disappeared from the lower reaches of West Pass during the drought of 1999-2002. Figure 5-17 shows the Braun-Blanquet abundance data from the three surveys (1998-99; 2000 and 2002). Note how *Vallisneria* disappeared downstream of Station 7 in June 2000. A small amount of recovery occurred at selected downstream sites in July 2002, but other sites continued to be unvegetated (Figure 5-16).

This loss of SAV is presumed to be primarily due to increased salinity. Tidal currents in the passes are particularly strong, and the water column is generally well mixed, so dissolved oxygen was probably not a problem. Water clarity was much better than usual during the drought, and little periphyton growth was observed on the grasses, so light limitation can be largely ruled out.

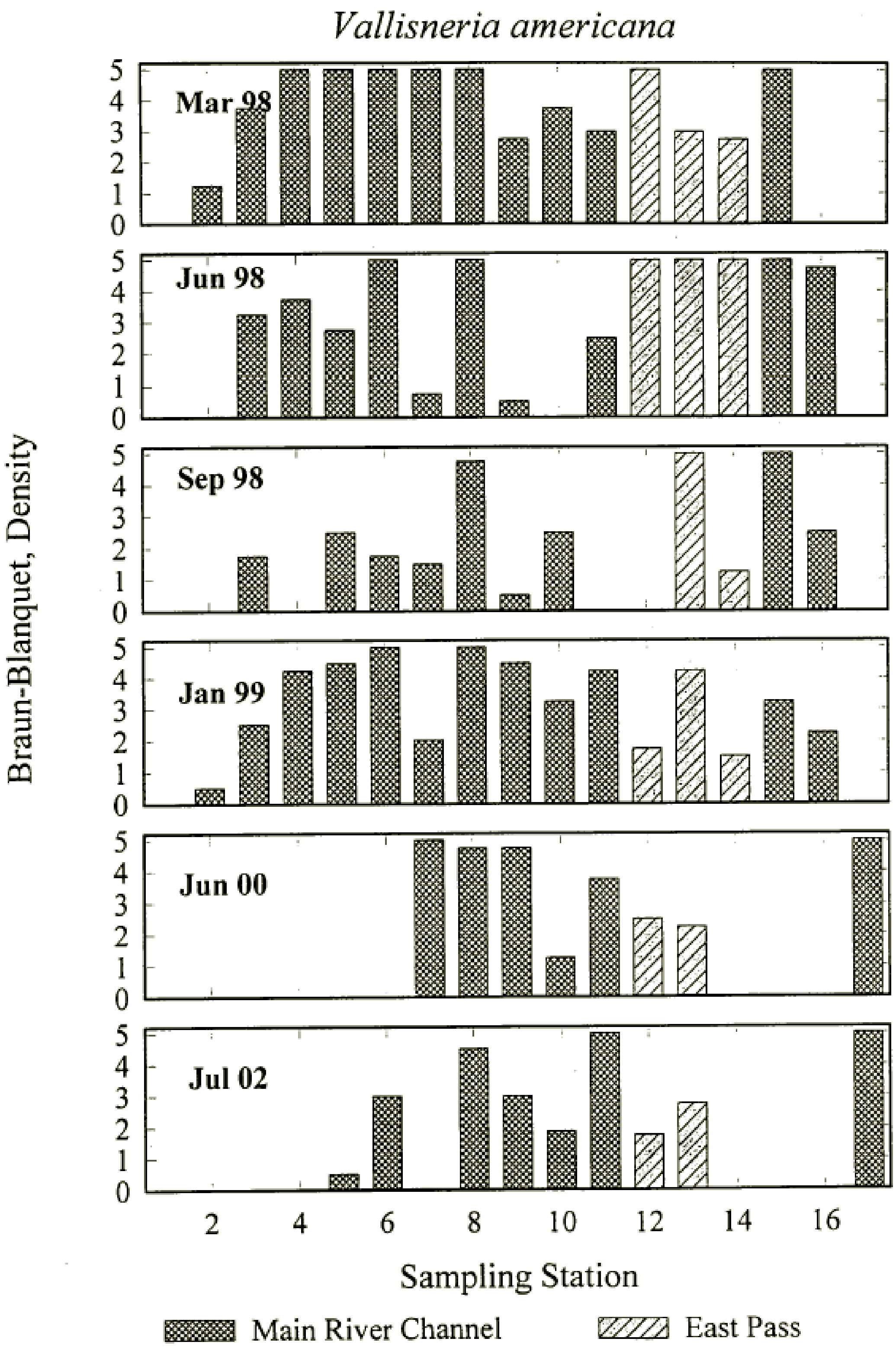


Figure 5-17. Braun-Blanquet abundance data of *Vallisneria americana* from surveys conducted by Mote Marine Laboratory in 1998-99; 2000; and 2002. Source: Estevez, 2002.

Based on the field observations in the Suwannee estuary, supplemented by the work of Doering et al. (1999), a critical salinity threshold of 9 ppt was chosen for analysis. In order to maintain the downstream limit of SAV at its present location, this salinity threshold was regarded as a conservative limit that would not stress *Vallisneria* beyond its normal tolerance.

5.3.2.4 Estimating Location of 9 ppt Isohaline

Salinity data collected by the SRWMD/FWCC in 1993-1995 were used to develop a regression model relating flow at Wilcox to the location of the 9 ppt isohaline (Figure 5-18). Analyses were restricted to Wadley and West Pass, since the majority of the SAV coverage in the upper estuary is found in West Pass. Salinities are uniformly lower in East Pass, compared to West Pass (Tillis, 2000; Mattson and Krummrich, 1995), so salinity criteria to protect SAV in West Pass should be equally protective in East Pass.

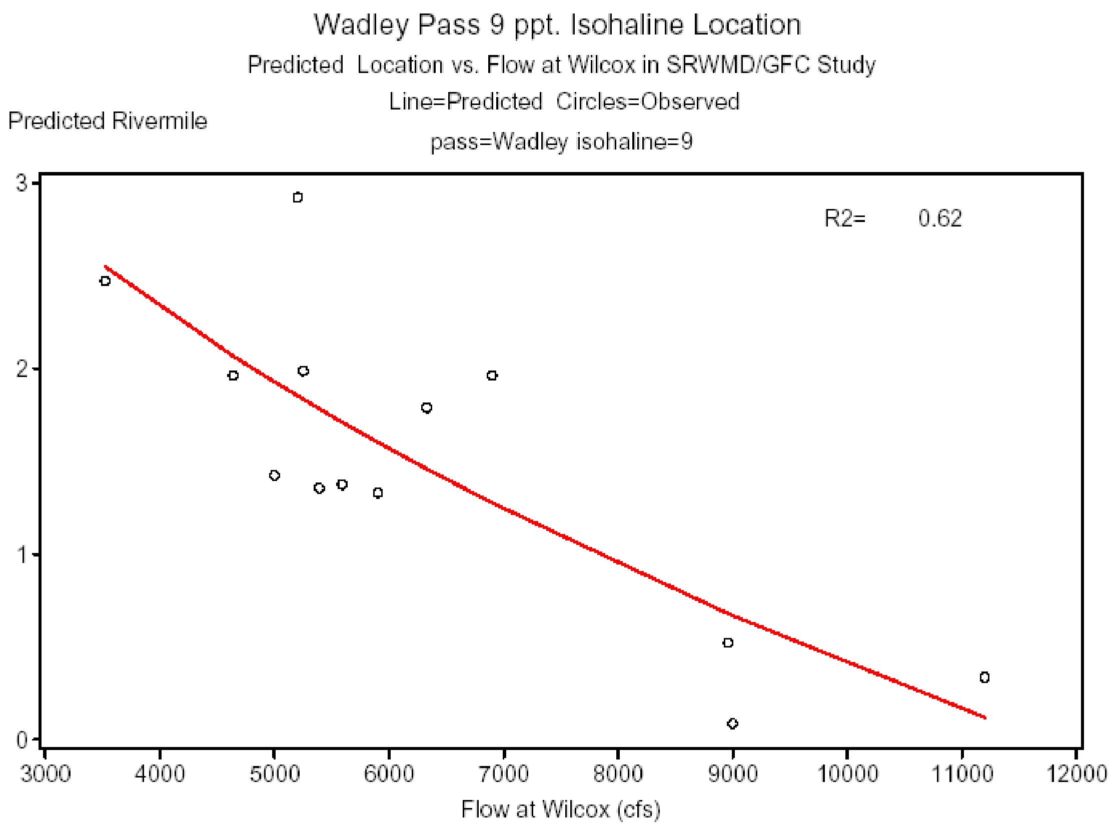


Figure 5-18. Plot of regression model relating flow at Wilcox to the location of the 9 ppt surface isohaline in Wadley Pass and West Pass.

The isohaline regression relationship developed for the 9 ppt isohaline in West Pass was validated against predicted and observed salinities at the WM continuous recorder (river mile 1.82). This validation exercise is described in more detail in Appendix H. The isohaline regressions predicted a 9 ppt isohaline at river mile 1.82 for a flow of 5,320 cfs at Wilcox. This compared well with the average flow (5,353 cfs) for predicted daily maximum mid-water salinities at WM between 8.5 and 9.5 ppt. Further validation was achieved by comparing regression results with salinity flow regressions from individual fixed station which all suggested that the 9 ppt isohaline predictions in West pass provided valid inference for establishing SAV habitat risk.

5.3.2.5 Estimating SAV Habitat at Risk

Flows below 6,200 cfs were associated with a rapid increase in the amount of SAV habitat at risk (Figure 5-19). This area corresponds to a shallow flat located at river mile 1.5 just below station W-5 (Figure 5-20). This is an area is known to be affected by the drought of 2000 which resulted in the area recorded as barren substrate in the Golder (2000) census (Figure 5-20).

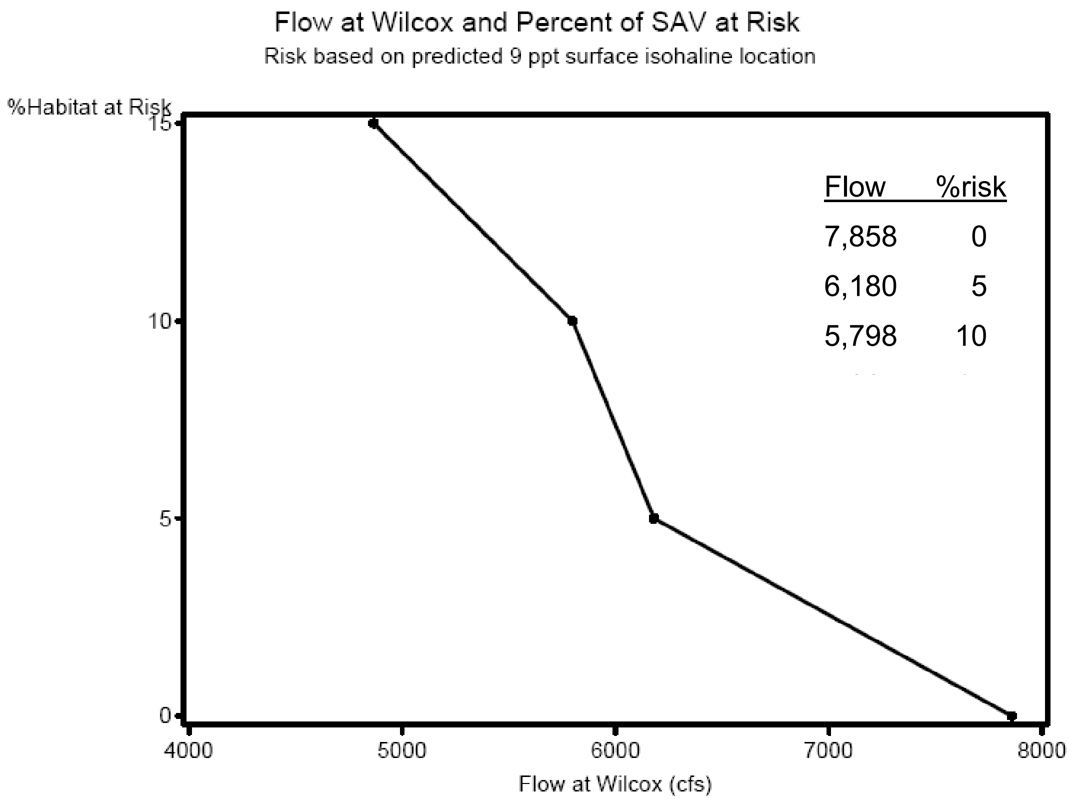


Figure 5-19. Relationship between flow at Wilcox and predicted percentage of SAV at risk.

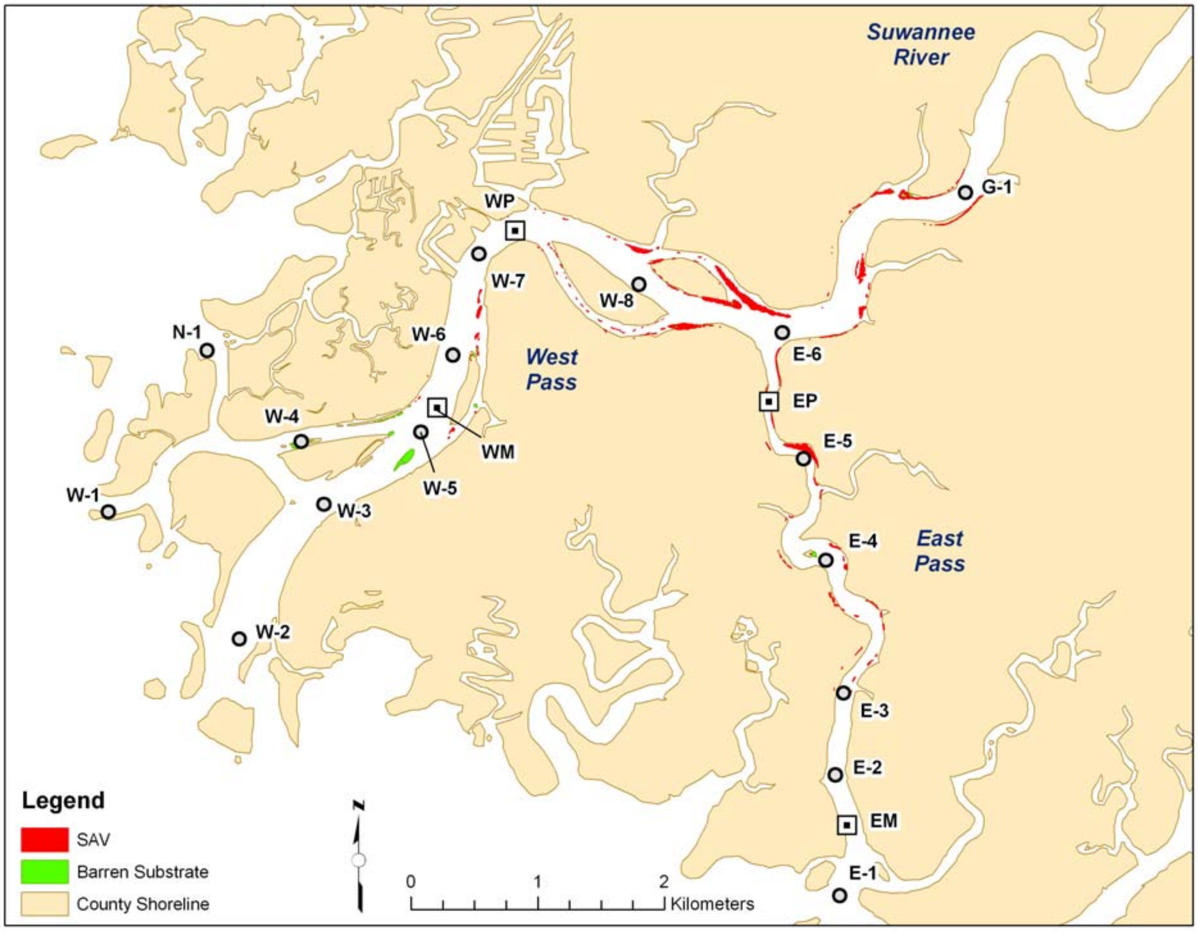


Figure 5-20. Map showing effects of drought on SAV habitat in the Lower Suwannee River as a result of drought of 2000.

5.3.3 Tidal Freshwater Swamps

5.3.3.1 Data Sources

Light et al. (2002) identified a "Lower Tidal" reach of the Lower Suwannee River study area, which for purposes of this report, is considered to be the tidal fresh-water zone of the upper Suwannee estuary. Six intensive study transects were established in forests of the Lower Tidal reach (Table 5-3). The transects were belt transects, with a width of 16.5 feet (5 meters) if over 1,320 feet (400 meters) in length and a width of 33 to 42.9 feet (10 to 13 meters) if less than 1,320 feet long. These judgments were made by the investigators based on their experience in forested wetland sampling in order to obtain a large enough sample of trees to census. Detailed descriptive data on the location of transects are provided in Lewis et al. (2002).

Table 5-3. Basic descriptive information on the six tidal freshwater swamp study transects in the upper Suwannee estuary (Light et al. 2000).

Reach	Transect Name	Abbreviation	Location (river km)	Length in feet (meters)
Lower Tidal	Turkey Island	TI	19.8	1359.3 (411.9)
	Sandfly North	SN	13	291.4 (88.3)
	Sandfly Hammock	SH	12.6	498.3 (151)
	Barnett Creek	BC	11.3	711.5 (215.6)
	Lock Creek	LK	5.1	480.2 (145.5)
	Demory Creek	DM	4.8	175.6 (53.2)

The locations of the intensive study transects were all on public land and were not made in a completely random fashion. Transects had to be located on public land for two main reasons:

- So that permanent transects could be established which could be visited reliably in the future (eliminating the possibility that a future landowner on private lands would bar access); and
- Public land typically had the best examples of reasonably intact, minimally impacted wetland forest, which would remain so in the future.

By distributing the transects at upstream, middle, and downstream ends of the Lower Tidal Reach, and by extending transects across a wide range of topographic and soils conditions (from the river bank to upland), a wide range of variability in the data was captured. The data from the intensive transects were supplemented with plant community and soils observations at 150 additional observation sites (some systematically selected, some randomly selected). The data from these supplemental sites verified the information derived from the transects, and thus the data from the transects is considered to reasonably describe the range of conditions and forest types found in the upper Suwannee estuary.

Land surface elevations along each transect was determined using a surveyor’s level and rod. Elevation measurements were made approximately every 16.5 feet (5 meters) and also at locations of topographic breaks, at the edge of standing water, and other “points of interest”. Elevations along each transect were tied to a temporary benchmark which was eventually referenced to the National Geodetic Vertical Datum (NGVD) by a licensed professional surveyor. All elevation data were then referred to this datum. Horizontal locations were measured using a portable Precise Lightweight Global Positioning System Receiver with a typical accuracy under tree cover of 19.8 to 49.5 feet (6 to 15 meters) and fiberglass measuring tapes.

Hydrologic data in the study area were derived from seven continuous record USGS surface water gage sites as shown in Table 3 in Light et al. (2002). Most of the flow data used in the floodplain wetland study came from the Branford and Fort White gages (Light et al., 2000). The other five gages were primarily used to supply stage data for construction of rating curves on each transect. Additional water-level measurements were made by tape-down from reference points (“RP’s”) established at the riverbank end of each transect and in selected surface water features (creeks, sloughs, floodplain ponds) on each transect. These were nails driven into trees and marked with a metal tag. Over the course of the study, about 400 separate water level measurements were made at the transects under a wide range of hydrologic conditions.

Soils data were collected on all intensive study transects to generally characterize soil types associated with the different forest types. The number of borings per transect ranged from 8 to 13 on longer transects and 3 to 6 on shorter transects. Soil profiles were described to a depth of 5 to 6.6 feet (1.5 to 2 meters), typically using a 3-inch bucket auger. Soil profiles were also examined in a few cases with a 1-inch coring tube sampler, or a 108-inch muck probe. Soil moisture was also evaluated at all transects and observation sites as dry, saturated, or inundated. Inundation meant the soil was covered with standing water. Saturation was evaluated by firmly squeezing a handful of soil. If free water was squeezed out, the soil was considered saturated. Approximately 600 soil moisture observations were made over a wide range of hydrologic conditions. Twenty-one surface soil samples and 11 subsurface soil samples were collected for salinity analyses, which were conducted by the National Soil Survey Center in Nebraska.

Vegetation sampling was divided into three strata; canopy, subcanopy, and shrub/groundcover. A canopy plant was defined as a woody plant with a stem diameter at breast height (dbh; 1.4 meters above ground surface) of ≥4 inches (10 cm) and a height of 10 feet (3 meters) or taller. Subcanopy plants were those woody plants with a dbh of 0.8 to $<$ 4 inches (2 to 9.9 cm) and a height ≥10 feet (3 meters). Woody plants smaller than this and all herbaceous plants were considered part of the shrub/groundcover layer. The dbh of all canopy and subcanopy plants was measured on each belt transect using a pair of calipers. Trees with swollen bases or buttressing were measured above the swelling. Estimates of percent cover of groundcover were made as well. Tree species identifications were made in the field concurrent with each dbh measurement. Where necessary to confirm identification, leaves, seeds, branches, etc. were collected for subsequent examination in the laboratory.

In addition to the field studies, forested wetland communities were mapped using NAPP digital ortho-photo quadrangles taken in 1994. These were false-color infrared images at a scale of 1:40,000. Initially, photo signatures were related to plant communities on the intensive study transects. A decision matrix was developed based on canopy composition to make a determination of a particular forest type (Table 6 in Light et al., 2002). Once the specific signatures of all the forest community types on the photos were confirmed, the remainder of the floodplain was mapped. Classification accuracy of the mapping was determined by visiting 111 randomly-selected verification sites, in conjunction with the decision matrix.

Rating curves were developed for each intensive study transect, relating river stage at the transect to flows at Branford-Fort White. These formed the basis for understanding the hydrology associated with each forest type and for evaluating the impacts of potential flow reductions. First, rating curves were developed for selected long-term gages using continuous daily values of stage at the gage related to daily flow at Branford-Fort White (Figure 5-21). Appropriate time-lags were determined and a line fit to aggregated daily values of flow and stage (in increments from 1,000 to 90,000 cfs). Then, the transect ratings were developed by linear interpolation using river mile distances. Table 4 in Light et al. (2002) lists the detailed methods and data sources by transect.

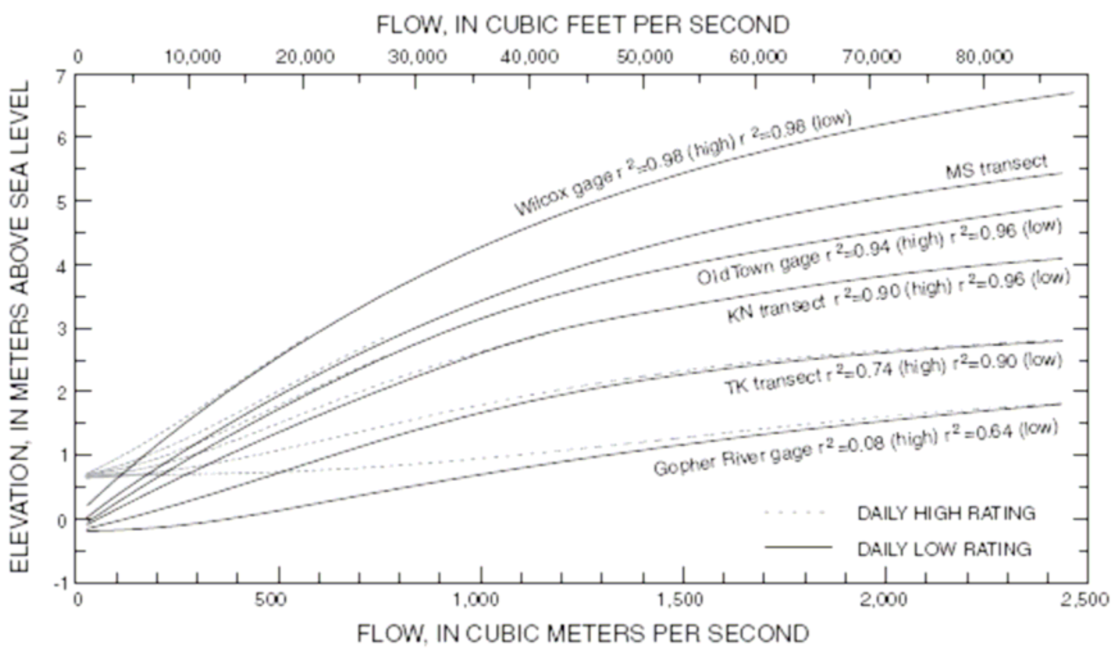


Figure 5-21. Daily high and low stage at gages and tidal transects in relation to flow in the lower Suwannee River, Florida. Flow is combined flow of Suwannee River at Branford and Santa Fe River near Fort White.

Light et al. (2002) identified four different forest types in the upper estuary (Table 5-4); Lower Tidal swamps 1 and 2 (LTsw1 and 2), Lower Tidal mixed forest (LTmix), and Lower Tidal hammock (LTham = hydric hammock). The swamps were flooded daily by high tides, with the mixed forests being flooded several times a month during the spring tides at the full and new moons. Hammocks were occasionally flooded by river flooding. Soils in all lower tidal forest types were primarily continuously saturated mucks, with some sand in the hammocks.

Table 5-4. Summary of plant community and soil characteristics in the Lower Tidal forest types. Adapted from Light et al. (2002).

Forest type	Dominant canopy species	Total no. canopy and subcanopy species	Total acreage unaltered forest acres (hectares)	Primary soil texture in root zone
LTsw1	Nyssa biflora; Fraxinus profunda; Taxodium distichum	25	3,343 (1,353)	Muck
LTsw2	Nyssa biflora; Fraxinus profunda; Taxodium distichum	23	3,309 (1,339)	Muck
LTmix	Fraxinus profunda; Nyssa biflora; Magnolia virginiana	28	2,572 (1,041)	Muck
LTham	Sabal palmetto; Pinus taeda	34	1,525 (617)	Muck, sand

Light et al. (2002) considered salinity the primary limiting factor influencing the community structure of the lower tidal forests and in setting the downstream limit of the "tree line", where tidal forest grades into tidal marsh. Salinity came from several sources; intrusion of saline water via the river channel at low flows, marine aerosols, and deposition of salt water from storm surges during hurricanes and tropical storms. Maximum salinities in isolated standing water on the Barnett Creek transect ranged from approximately 2 to 5 ppt, but fell to zero during a flood event in 1998. Salinities of up to 2 ppt were measured in isolated standing water on the Sandhill Hammock transect. Subsurface soil conductivities were generally equivalent to or higher than surface soil conductivities (Figure 23 in Light et al., 2002).

5.3.3.2 Spatial Extent of Tidal Fresh-Water Swamps in the Upper Estuary

A total of 6,652 acres (2,692 ha) of swamps (LT Swamps 1 & 2) were mapped by Light et al. (2002) in the upper estuary. These were combined and termed "Tidal Swamps" in subsequent analyses. The focus was on swamps, since they are inundated daily by high tide floodwaters and would thus be most susceptible to impacts from changes in salinity. The other two forest types are inundated only by the higher spring tides, or during flood or storm events.

Figure 5-22 presents a map of the forest types in the lower half of the Lower Tidal Reach (up to the Gopher River confluence). This area was chosen since the forests in this area of the upper estuary would be most susceptible to salinity intrusion due to reduced river flows. Areas further upstream would only be affected during severe, infrequent droughts, or the amounts of flow reduction would be unrealistically high to cause salinity intrusion further upstream than the area shown in Figure 5-20.

5.3.3.3 Tidal Swamp Habitat Requirements

Important considerations for development of freshwater inflow criteria, which provide for the protection of tidal fresh-water swamps, included maintaining the tree canopy composition in the Lower Tidal Swamp and Mixed forest types. Some information is available on the salinity tolerances of some of the dominant trees in these swamps. Table 5-5 presents a summary of the literature reviewed to determine salinity tolerances of the dominant trees in the tidal swamps. Pezeshki et al. (1987) found that bald cypress seedlings exhibited reduced photosynthetic rates and stomatal conductance at salinities of 2 ppt and higher.

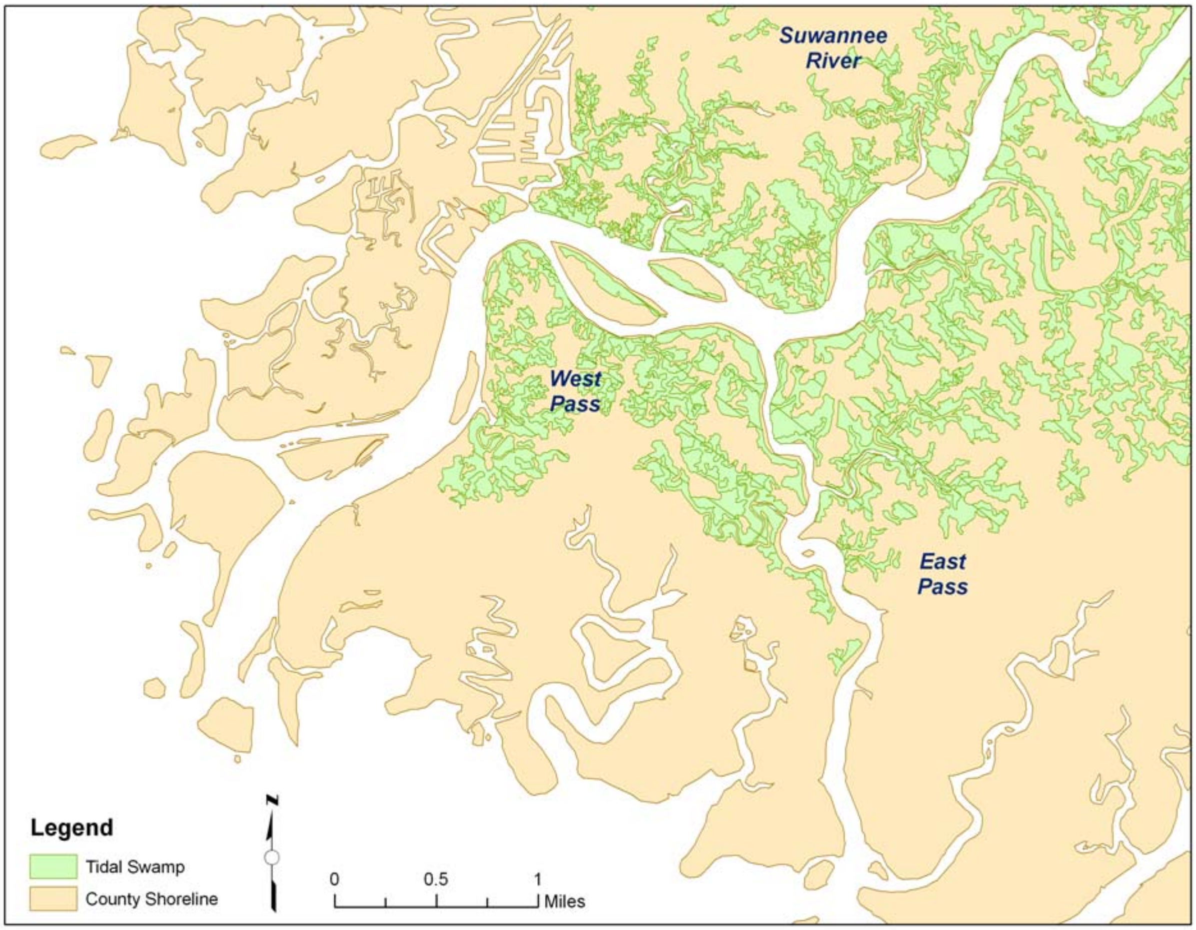


Figure 5-22. Map showing the extent of tidal swamp in the upper Suwannee estuary. Shown is the extent of combined "Lower Tidal Swamp 1 and Swamp 2" of Light et al. (2002).

Table 5-5. Summary of literature reviewed to determine salinity tolerance of the dominant trees (or similar species) found in tidal swamps of the upper Suwannee estuary.

Source	Tree Taxa	Salinity	Notes
Brinson et al. 1985	Green ash; Swamp tupelo; Water oak; Red maple; Slippery elm; Sweetgum; Red bay (adult, canopy trees)	Average soil pore water salinities of 0.75 ppt to 5.8 ppt	Monitored soil pore water salinity for 22 months at four sites in tidal freshwater swamps in the Pamlico River estuary, N. Carolina. Highest canopy species diversity and evenness were found at the two more upstream sites, with lower salinities (mean < 2 ppt). Swamps managed to persist in areas with mean salinities up to about 6 ppt. Higher density of dead snags was seen in downstream, higher salinity sites.
Allen et al., 1997	Baldcypress (seedlings)	Salinities from 0 to 8 ppt in increments of 2 (0, 2, 4, 6, 8)	Laboratory analyses of salinity tolerances of cypress from locations in Alabama and Louisiana. Highest mean leave, stem and root biomass at 0 and 2 ppt. Declines in net photosynthetic rate at salinities > 4 ppt. Strains from brackish locations had better salinity tolerance than those from freshwater locales.
Pezeshki et al., 1990	Mixed tidal wetland forests of Louisiana (adult trees and seedlings)	Approx. <1 to about 7-8 ppt	Review paper summarizing prior work. Water tupelo shows large reductions in photosynthesis and stomatal response at ~3 ppt. Green ash showed reductions at <1 ppt, with progressively larger reductions at increasing salinities up to about 7-8 ppt.
McCarron et al., 1998	Seedlings of: Swamp tupelo; Buttonbush	0, 2 and 10 ppt	Laboratory experiments on seedlings of tupelo and cypress. Swamp tupelo watered with 2 ppt exhibited reduced % survival. Watering with 10 ppt or flooding with 2 and 10 ppt resulted in death of all tupelo seedlings. Buttonbush survived watering and flooding with 2 ppt, exhibited reduced survival when watered with 10 ppt and total mortality when flooded with 10 ppt. Physiological changes associated with watering with 2 ppt were minimal for both species.

Table 5-5. Continued.

Williams et al., 1998	Seedlings of: Cabbage palm; Red cedar; Live oak; Sugarberry; Elm (mixed spp.); Florida maple; Loblolly pine; Sweetgum	0, 2, 4, 8, 15, and 22 ppt	Six-month greenhouse experiment using plants from Florida coastal hammock forests. Maple and elm were stressed by 2 ppt and died at all higher salinities. Live oak, Sugarberry and Sweetgum slightly stressed at 2 ppt, moreso at 4 ppt. Sweetgum and Sugarberry died at 8 ppt and Live oak at 15 ppt. Cabbage palm and Cedar stressed at 8 and 15 ppt. Cedar dead at 22 ppt.
Pezeshki et al., 1987	Baldcypress (seedlings)	0, 2, 4, 6, and 7 ppt	Laboratory experiment on cypress seedlings. Plants flooded with 2 ppt exhibited reduced photosynthetic rates and stomatal conductance but recovered somewhat during the experiment. Seedlings exposed to 4 ppt and up exhibited significantly reduced physiologic responses and no recovery over the course of the study. All salinity treatments resulted in leaf injury (chlorosis, "burn", etc.).
South Florida Water Management District, 2002	Seedlings of Baldcypress	30 ppt	Literature review from Loxahatchee River MFL Report. One study on cypress seedlings indicated those 6 months old were more sensitive than older seedlings (18 months or more), in that no 6 mo old seedlings survived flooding with 30 ppt for 2 days, while 90% of 18 mo old seedlings survived 2 days of flooding with 30 ppt.

Progressively greater reductions in these physiological responses were seen up to 7 ppt. Leaf yellowing (chlorosis) was observed in seedlings in all salinity treatments. Williams et al. (1998) demonstrated that seedlings of elm, Florida maple, and sweetgum exhibited reduced survival at 2 ppt and little or no survival at 4 ppt and higher. Cabbage palm, red cedar, and live oak exhibited reduced survival at 4 ppt and higher (Williams et al., 1998). Based on their work evaluating the effects of sea-level rise on coastal wetland forests, Williams et al. (1999) inferred that adult trees were more salt tolerant, based on the existence of "relict" stands in areas of higher salinity, and that dieback of the forests occurred first due to elimination of seedling recruitment. Based on the above, and the review in Table 5-5, average salinities of high tide waters flooding the swamps should be kept $\leq$2 ppt, with briefer periods of higher salinity tolerable.

Based on available electro-shocking data collected in East Pass by the FWCC, the fish communities in the river channel associated with the distribution of tidal freshwater swamp appear to be dominated by freshwater fish taxa (Figure 5-9). The tree line in East Pass is located near their Station E4 (Fig. 5-9). The proposed salinity target of 2 ppt appears to be adequate to maintain the structure and function of these fresh-water fish communities in the upper estuary. The fish data indicate that the proposed salinity target would allow for the persistence of a fish community still dominated by freshwater taxa, suggesting that the fauna associated with the swamps should be sustained (Figure 5-23).

5.3.3.4 Estimating Location of the 2 ppt Isohaline

The salinity data used for the SAV flow isohaline regressions was also used for assessment of risk to tidal swamp habitat as a function of flow. A regression relationship was developed to predict the 2 ppt isohaline location as a function of flow (Figure 5-24). No statistical difference was observed in the isohaline-pass relationship for the 2 ppt isohaline (Appendix I) so the model predicted the location in all passes.

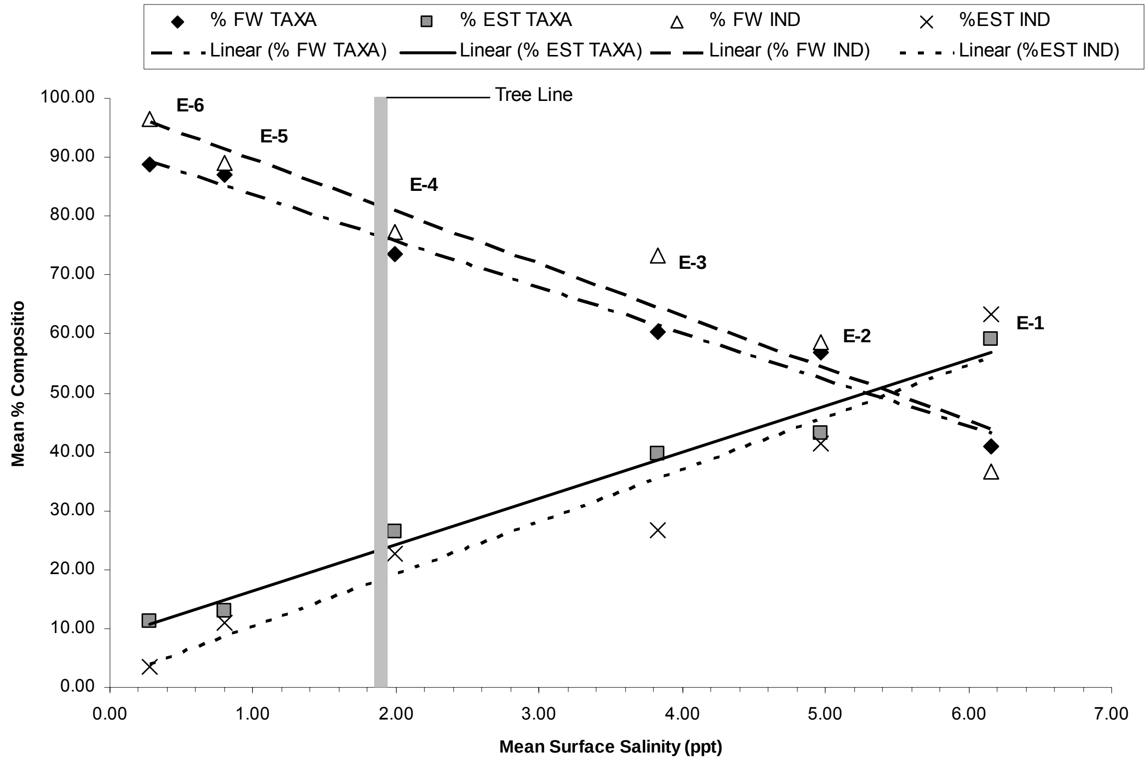


Figure 5-23. Composition of the fish community in East Pass (as %taxa and %individuals at six sites sampled in the Pass by the FWCC in 1993-95, shown in relation to the treeline. Source: Mattson and Krummrich, 1995.

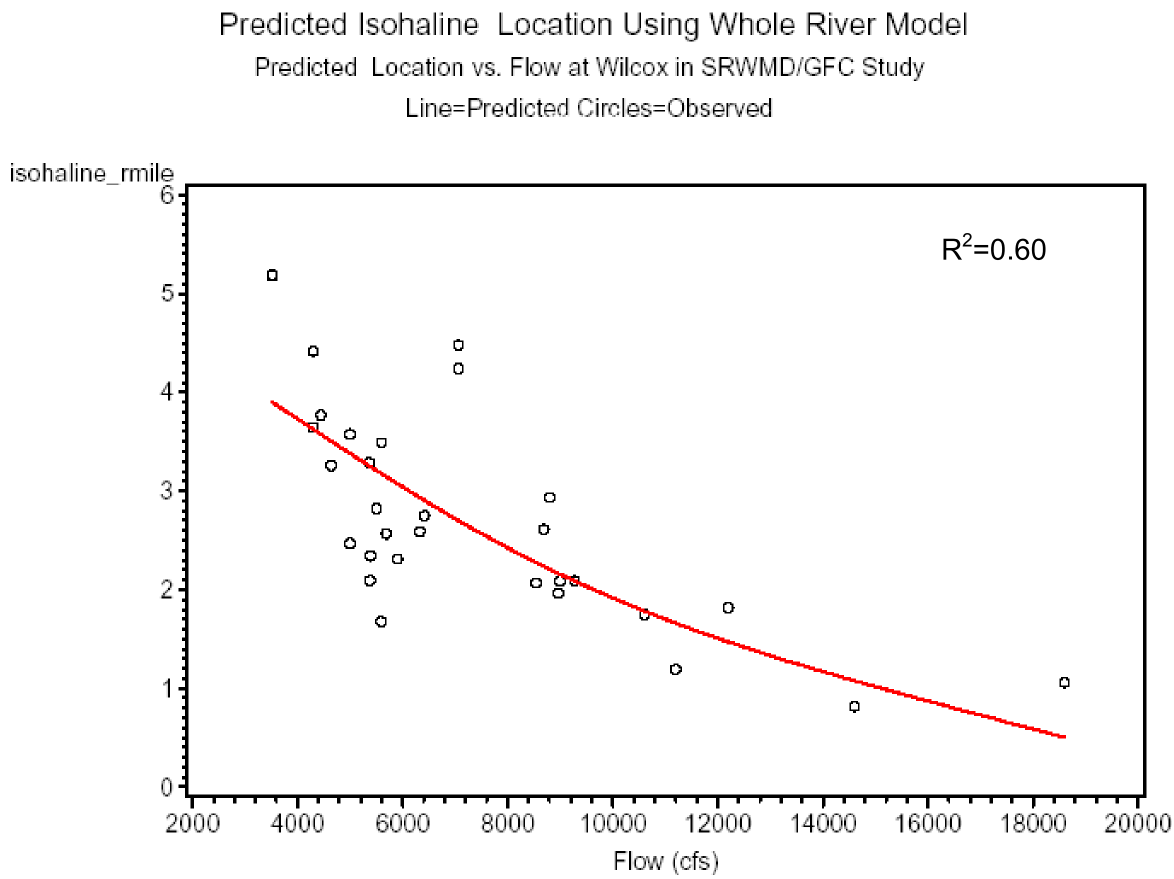


Figure 5-24. Regression relating the location of the 2 ppt isohaline to river flow at Wilcox in the upper Suwannee estuary.

5.3.3.5 Estimating Tidal-Swamp Habitat at Risk

The risk to tidal-swamp habitat with exposure to salinities above 2 ppt was evaluated based on calculations of the cumulative amount of shoreline lined by tidal swamp. Shoreline length was used instead of total area of tidal swamp coverage since these are the areas that would be impacted first. Further, much of the total area for tidal swamp occurred greater than one half mile from the shoreline so the uncertainty of risk also increased with distance from shore. Therefore, to reduce this uncertainty, we chose to use shoreline length instead of total area. The highest rate of change in tidal-swamp habitat loss was observed for flows less than 6,800 cfs (Figure 5.25).

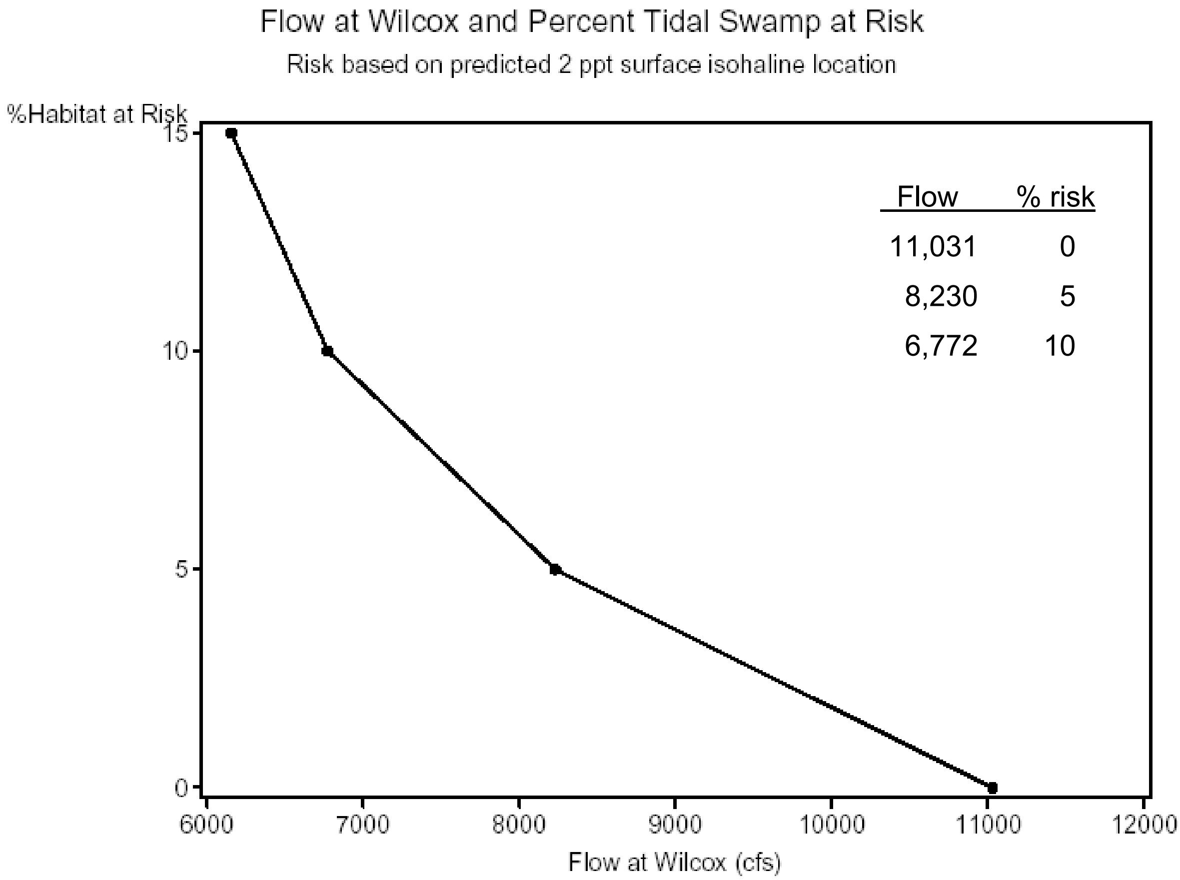


Figure 5-25. Estimates of flow associated risk for Tidal Swamp habitat.

5.3.4 Tidal Creeks

5.3.4.1 Data Sources

SRWMD created a detailed coverage of tidal creeks on the Hog Island delta and fringing East and West Passes up to the Gopher River. The centerline of all tidal creeks on Hog Island and fringing East and West Passes was delineated, using 1999 USGS digital ortho-photos (false color infra-red; scale 1: 24,000). The shorelines of the Passes were also delineated. This was overlain with another coverage, created by Janicki Environmental, segmenting the passes into 0.25-mile increments (see Appendix G).

Juvenile fish data from the FWCC Fisheries Independent Monitoring Program, collected between 2001 and 2003, were used to evaluate and determine a critical salinity for subsequent analysis. Data from tidal creek samples collected within east and west pass using 21m seines set along the river banks were used to identify biologically based salinity zones for the Lower Suwannee River using multivariate analysis described by Bulger et al. (1993) and Christensen et al. (1997). Briefly, Principal Components Analysis (PCAwas used to derive 5 PCA axes, which represent commonalities in salinity ranges among the species captured in the seine catch. Ontogenetic shifts in salinity requirements with increasing size was accounted for by delineating size classes for fish <40 mm in standard length from those equal or greater than 40 mm. If fewer than 30 total individuals of a particular species were collected over the survey period, then those species were removed prior to analysis. Individual salinity increments were plotted against factor loads derived using Varimax rotation (SAS, 1989) to identify salinity zones using a threshold correlation value of 0.60.

5.3.4.2 Habitat Requirements

Salinity tolerances have been described for many common fish and invertebrate taxa in the Lower Suwannee River (Table 5-6; Heard, 1982; Gosner, 1978). Based on Rogers et al. (1984), salinities of $\leq$10 ppt may be critical for recruitment of many fish taxa. Additionally, creeks in very low-salinity areas ($\leq$ 5 ppt) are important nursery habitat for commercial and recreational fishery species (Rozas and Hackney, 1983).

From the multivariate analysis described in Section 5.4.1, a critical salinity of $\leq$5 ppt was chosen as a group which may be most sensitive to changes in flow regime and salinity patterns (Figure 5-26). This category represented the classic “oligohaline” zone for estuarine environments and exhibited a fairly narrow range indicating potential for a high degree of sensitivity to habitat alterations.

Table 5-6. Common invertebrates found in Suwannee estuary tidal marshes and tidal creeks and their characteristic salinity ranges. Sources: Heard, 1982; Gosner, 1978; SRWMD data.

TAXON	SALINITY RANGE	TAXON	SALINITY RANGE
Polychaeta		**Crustacea**	
Neanthes succinea	5 - 30 ‰	*Chthamalus fragilis*	>15 ‰
Laeonereis culveri	0 - 35 ‰	*Balanus subalbidus*	"freshwater to oligohaline"
Namalycastis abiuma	0 - 20 ‰	*Taphromysis bowmani*	0 - 30 ‰
Stenoninereis martini	0 - 30 ‰	*Mysidopsis almyra*	0 - 25 ‰
Parandalia americana	"oligohaline to mesohaline"	*Hargeria rapax*	0 - >40 ‰
Scoloplos fragilis	> 10 ‰	*Halmyrapseudes bahamensis*	>10 ‰
Heteromastus filiformis	<15 - >30 ‰	*Almyracuma* sp.	"fresh to brackish"
Hobsonia florida	"oligohaline and mesohaline"	*Cyathura polita*	<1 - 20 ‰
Streblospio benedicti	<5 - >25 ‰	*Uromunna reynoldsi*	<1 - 15 ‰
Ficopomatus miamiensis	<2 - >25 ‰	*Asellus* spp.	"freshwater"
Mollusca		*Grandidierella bonnieroides*	<1 - >40 ‰
Neritinea usnea	<1 - > 40 ‰	*Corophium louisianum*	<1 - >25 ‰
Littoridinops palustris	0 - >25 ‰	*Hyalella azteca*	"freshwater"
Littoridinops monroensis	"fresh and brackish"	*Orchestia* spp.	"euryhaline"
Assiminea succinea	"moderate to high salinities"	*Palaemonetes pugio*	<1 - >30 ‰
Cerithidea spp.	"moderate to high salinities"	*Clibanarius vittatus*	10 - >35 ‰
Littorina irrorata	"mesohaline"	*Callinectes sapidus*	<1 - >35 ‰
Melongena corona	12 - >30 ‰	*Panopeus obesus*	<10 - >35 ‰
Sayella spp.	"mesohaline"	*Rhithropanopeus harrisii*	0 - 20 ‰
Melampus bidentatus	0 - 50 ‰	*Sesarma reticulatum*	"euryhaline"
Detracia floridana	"brackish marshes"	*Sesarma cinereum*	"euryhaline"
Polymesoda caroliniana	<15 ‰	*Uca longisignalis*	"mesohaline"
Geukensia demissa	"mesohaline"	*Uca minax*	"freshwater to low salinity"
Cyrenoida floridana	<1 - >25 ‰	*Uca speciosa*	"mesohaline to polyhaline"
Tagelus plebius	"mesohaline"		

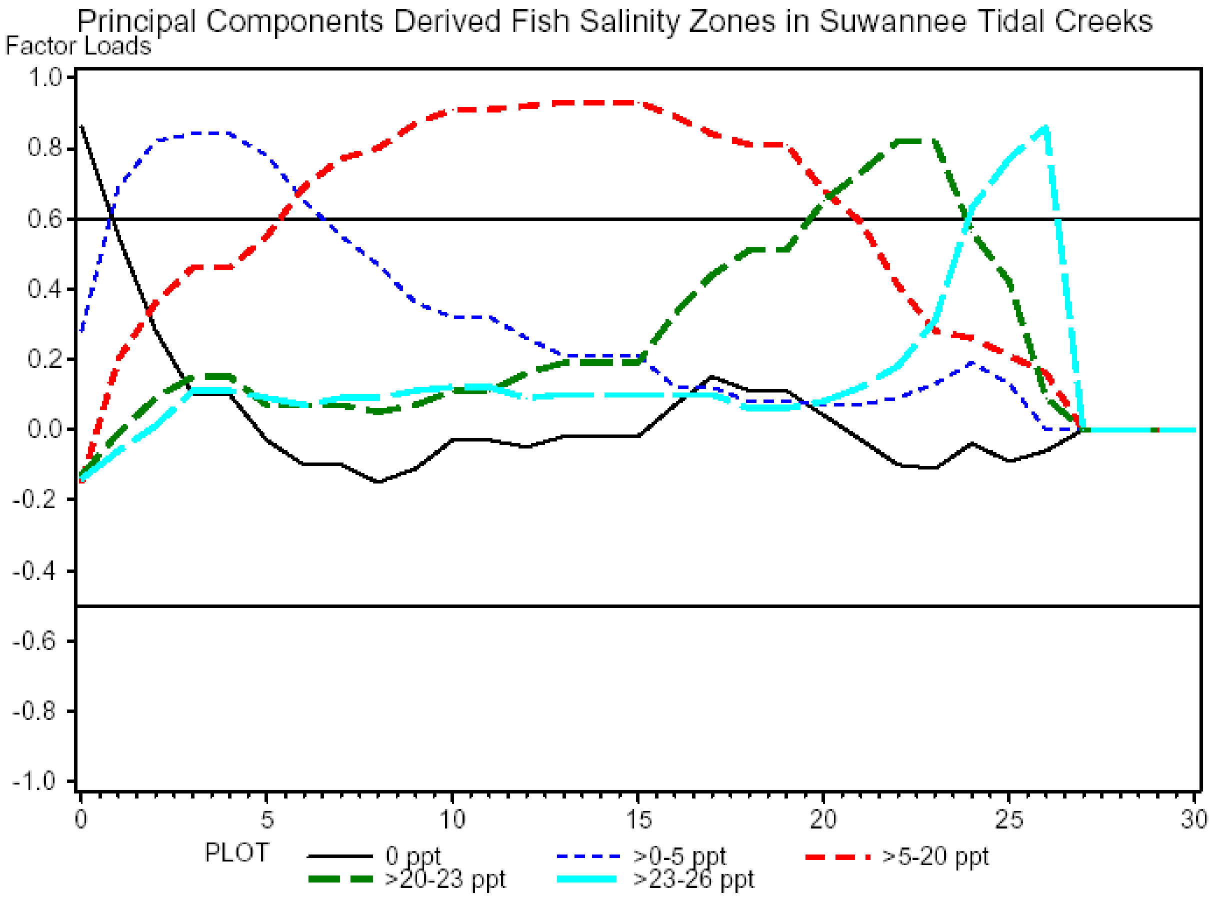


Figure 5-26. Biologically based salinity zone classifications using Principal Components Analysis on tidal creek fish data collected by the FIM program in the Lower Suwannee River 2001-2003.

5.3.4.3 Spatial Extent of Tidal Creeks

The cumulative number of tidal creek connections was counted starting at the downstream limit of the Lower Suwannee River. These tidal creek connections were assumed to represent access to the network of tidal creeks in the delta, for fish and invertebrates entering the river via the passes (Figure 5-27). Wadley Pass, a dredged channel, was excluded from regression analysis.

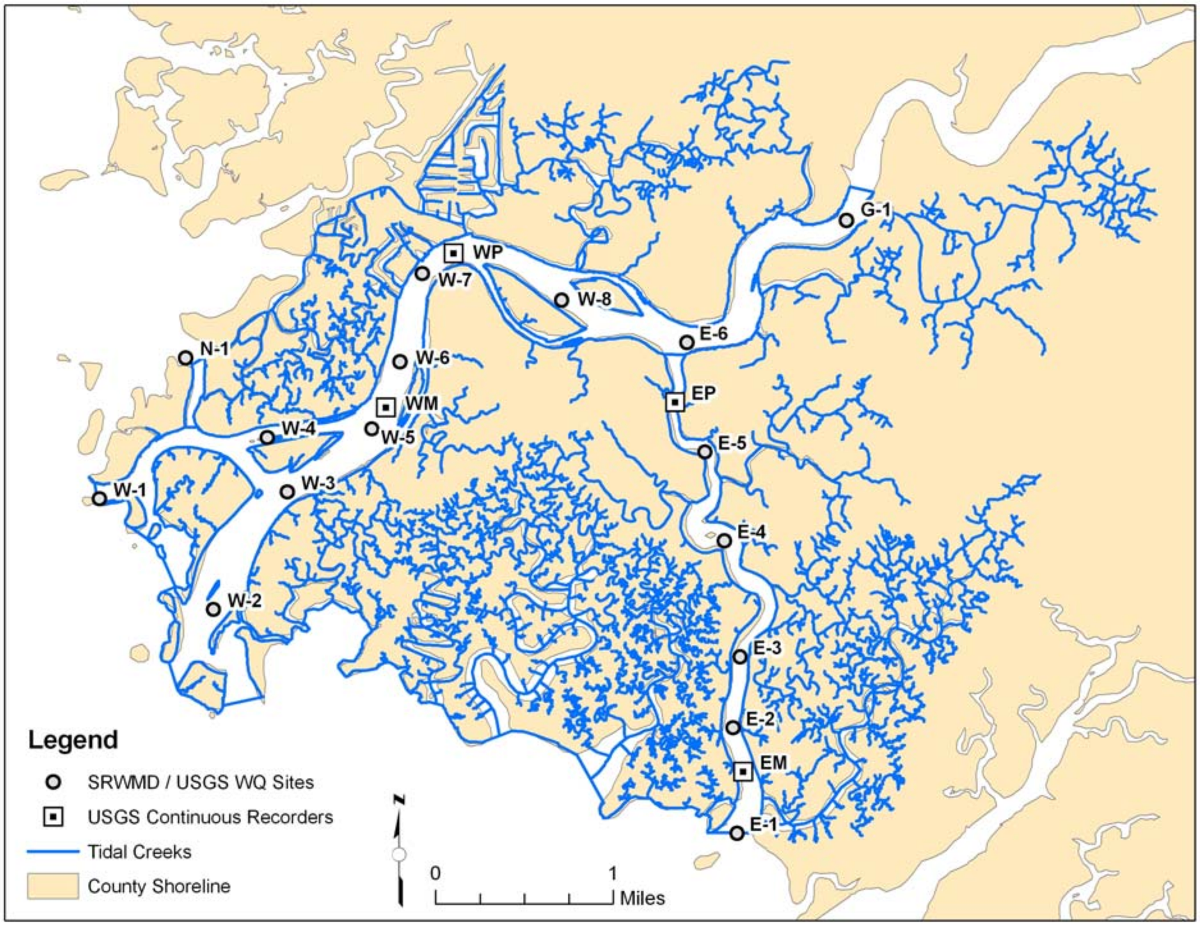


Figure 5-27. Map showing tidal creek coverage and related FWCC and USGS salinity stations used for the analysis of tidal creek habitat.

5.3.4.4 Estimating Location of 5 ppt Isohaline

Establishing the relationship between the 5 ppt isohaline as a function of flow was complicated by the dynamics of the estuarine system near the mouth of each pass. Large variability in location of the isohaline for a given flow condition also played a role in the limitations of the regressions. Antecedent flows, specifically the average flow of the week prior to the sample collection date was incorporated into the analysis to capture some of the variation associated with the effects of antecedent flows (Figure 5-28; see Appendix I for details). Tillis (2000) had similar problems in establishing isohaline relationships for the 5 ppt isohaline, especially in East Pass. When the 5 ppt isohaline was observed within the river, the maximal upstream incursion was generally above river mile 1 such that the valid range of the flow isohaline relationship was for isohaline locations above river mile 1. However, nearly 25% of the tidal creek connections occurred below river mile 1 in the Lower Suwannee River.

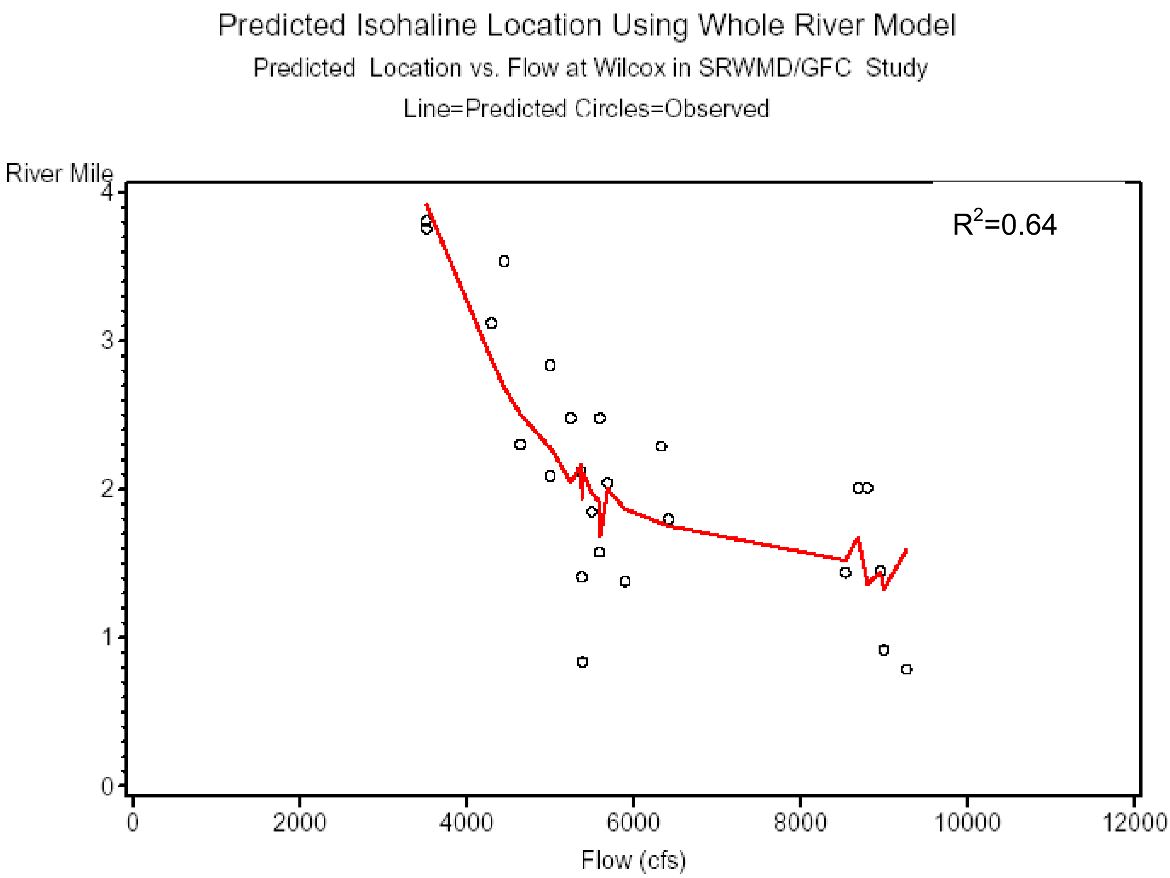


Figure 5-28. Predicted location of the 5 ppt isohaline as a function of flow at Wilcox.

5.3.4.5 Estimating Tidal Creek Habitat at Risk

Flows above the long-term median at Wilcox are required to keep the 5 ppt isohaline below the 15% risk point for tidal creeks (Figure 5-29). It is highly likely that the mouths of these creeks are regularly exposed to much greater salinities than the 5 ppt criterion established for risk assessment. Further, since these relationships are based on full moon incursions, the salinities will be much lower on average and especially on outgoing tides such that fish may access the tidal creeks at times when the salinity is more preferable.

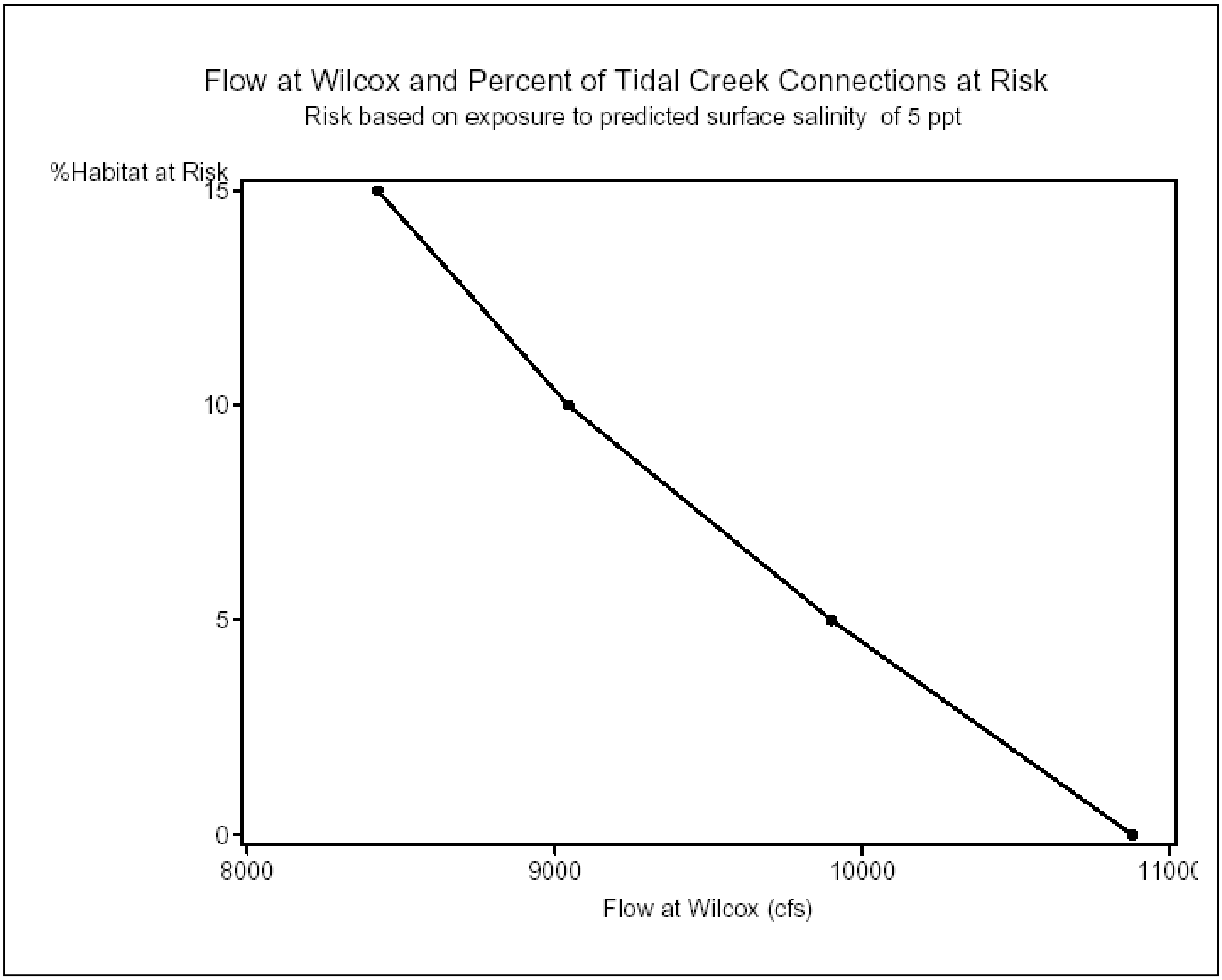


Figure 5-29. Flow associated risk for tidal creek access points in the Lower Suwannee River.

5.3.5 Oyster Bars and Reefs

5.3.5.1 Data Sources

Oyster data in the Suwannee estuary were collected in a study by Baker et al. (2003). Thirty-six oyster study sites were systematically selected. Similar to other habitat studies, the objective was to evaluate characteristics of oyster habitat where it occurred, and relate to salinity, rather than make broader generalizations about the distribution of oyster habitat in the Suwannee estuary. Considerations in site selection included distributing sites across a range of salinity regimes, from those near the river mouth exposed to fresh water a large portion of the time, to those located far from the freshwater discharge of the river. Sites were also distributed across three reef "strata", identified from preliminary surveys in the estuary: inshore bars at tidal creeks; middle reefs (Lone Cabbage and Half Moon), and outer reefs (Suwannee Reef).

Study sites were sampled during low tides. Several types of sampling were conducted at each study site. First, the site was divided into high intertidal and low intertidal strata. This was determined based on inspection in the field at each sampling site; the "break" typically occurring at the reef crest. Locations of sampling quadrats at each site were determined randomly by proceeding in a random direction (right or left) along the tidal stratum for a randomly determined distance from 1-10 meters. Live oyster cover was determined using a minimum of six replicate samples (more if cover was very sparse). Cover was determined using a 1 m^2 grid divided into 100 subsections 10 by 10 cm each in area. Cover was measured by counting the number of subsections lying over live oyster and expressing as a proportion of 100. Oyster density was measured using a 0.25 m^2 quadrat (1 m^2 where live cover/density was very sparse), from which all live oyster was harvested down to dead shell. Live oysters were counted as adult ($\geq$ 76 mm shell length), sub-adult (50 to <76 mm shell length), and juvenile ($\geq$25 to <50 mm shell length). Counts of four major oyster reef associate animals were also made in the oyster density quadrats: the mussels *Brachiodontes spp*. and *Ischadium recurvum*, and the crabs *Eurypanopeus depressus* and *Petrolisthes armatus.*

Oyster community parameters were related to salinity using data from the SEAS monitoring program collected 2000-2002 and data from Phlips and Bledsoe (2002) collected in the estuary in 1999-2001. Monthly surface salinity measurements from these studies were incorporated into a GIS coverage of the salinity sampling sites. Surface salinity was used since depths in much of Suwannee Sound are quite shallow and these data reflected the salinities that the oyster reefs were most exposed to (Baker et al., 2003). ArcGrid® was used to generate salinity contours using the field data, and salinity characteristics at each individual oyster study site were estimated from this coverage by interpolation using the inverse distance-weighted method. Mean salinity for the periods 12 months and 24 months prior to the oyster survey was determined for comparison with oyster reef community characteristics.

5.3.5.2 Spatial Extent of Sampling

Salinity data sources were described in Section 3. Salinity data to evaluate oyster habitat characteristics were provided by the Shellfish Environmental Assessment Section (SEAS) (Figure 5-30). Rather than identify salinity-flow relationships for each of the fixed stations, we decided to assess the covariance patterns of these stations using PCA (Janicki Environmental, 2005b). Principal Components Analysis allowed us to identify stations that react similarly to changes in Suwannee flows such that stations could be grouped for analysis. Three salinity zones were delineated using PCA (Figure 5-31):

The river zone; including sampling stations located in the river and in tidal creeks directly associated with riverine outflow;

An Inshore Reef zone; including stations located in the estuary in direct proximity to the outflow from Alligator and East Pass; and

An “Offshore” zone; including stations in the estuary located farther from and more indirectly related to the Suwannee effluent.

Orlando et al. (1993) identified a similar zone scheme in the Suwannee estuary based on their analysis of SEAS data.

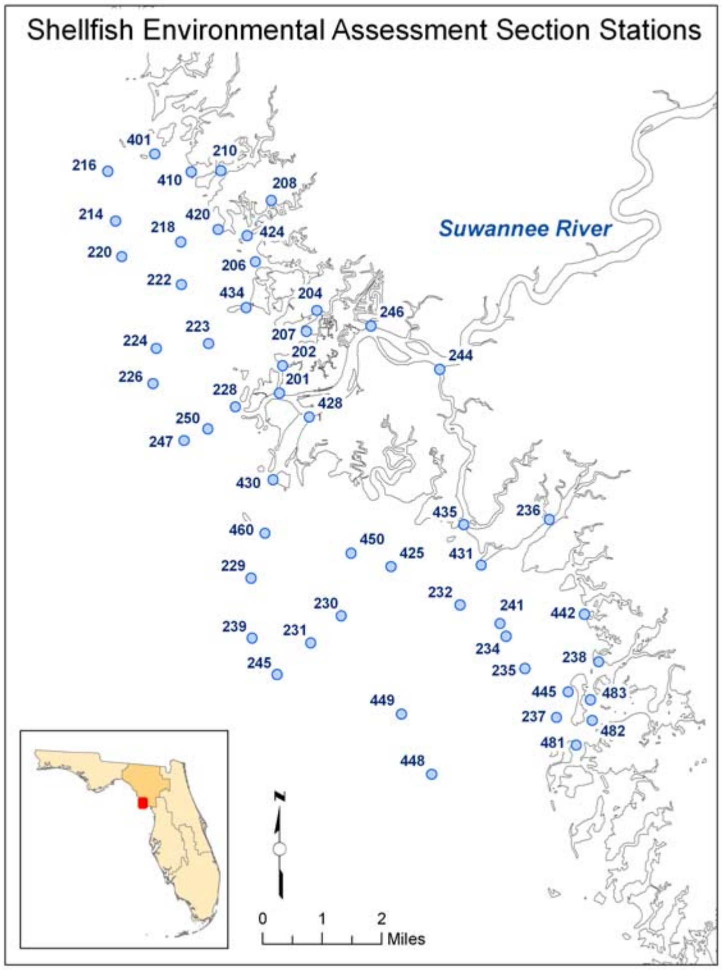


Figure 5-30. Sampling stations of the SEAS program used to assess Suwannee Sound salinities.

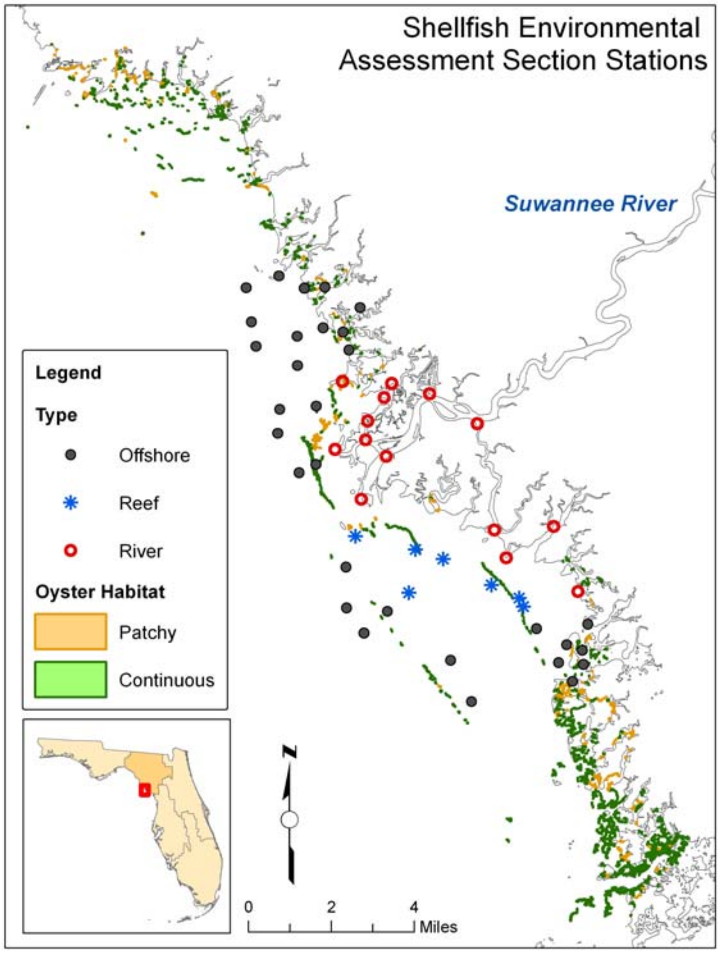


Figure 5-31. Grouping of SEAS stations used for estimating salinity flow relationships in Suwannee Sound.

5.3.5.3 Habitat Requirements

Baker et al. (2003) evaluated oyster-habitat characteristics in the Suwannee estuary in relation to salinity and relative tidal elevation. They found highest oyster- habitat characteristics (% cover, juvenile, sub-adult, and adult density) occurred at mean salinities <20 ppt, for periods 1 year and 2 years prior to their survey (Figure 5-31 adapted from Figures 4 and 5 in Baker et al., 2003). Based on the oyster- field data from the Suwannee estuary, it will be important to maintain an adequate area of habitat with mean annual salinities of ≤20 ppt in order to maintain the existing coverage and health of oyster reefs in the estuary.

Available information in the literature supports this proposed optimal salinity target of ≤20 ppt for oyster. Burrell (1986) recommended that “moderate salinities (those less than 15 ppt)” be maintained for “a significant period during the year” to exclude most oyster predators and diseases and maintain oyster reef community structure. Stanley and Sellers (1986) indicated that highest oyster abundance in Gulf of Mexico oyster populations occurred between 10-20 ppt. Oyster reefs with highest densities in Apalachicola Bay were found where mean salinities were 20-23 ppt (Livingston et al., 2000). This appeared largely due to the exclusion of dominant oyster predators (Livingston et al., 2000).

Dominant associated macroinvertebrates in the Suwannee oyster reefs were the crabs *Eurypanopeus depressus* and *Petrolisthes armatus* and the mussels *Brachiodontes spp.* and *Ischadium recurvum* (Baker et al. 2003). The abundances of *E. depressus* and *I. recurvum* were negatively associated with mean annual salinity at a statistically significant level in both the high and low intertidal strata sampled by Baker et al. (2003). Of additional significance is that these two taxa appear to be obligately associated with oyster habitat (Baker et al., 2003 – Table 10a & b; also Heard, 1982), indicating that they are key indicator taxa. The xanthid crab *E. depressus* is listed as occurring in salinities generally below 20 ppt (Ryan, 1956; Gosner, 1978).

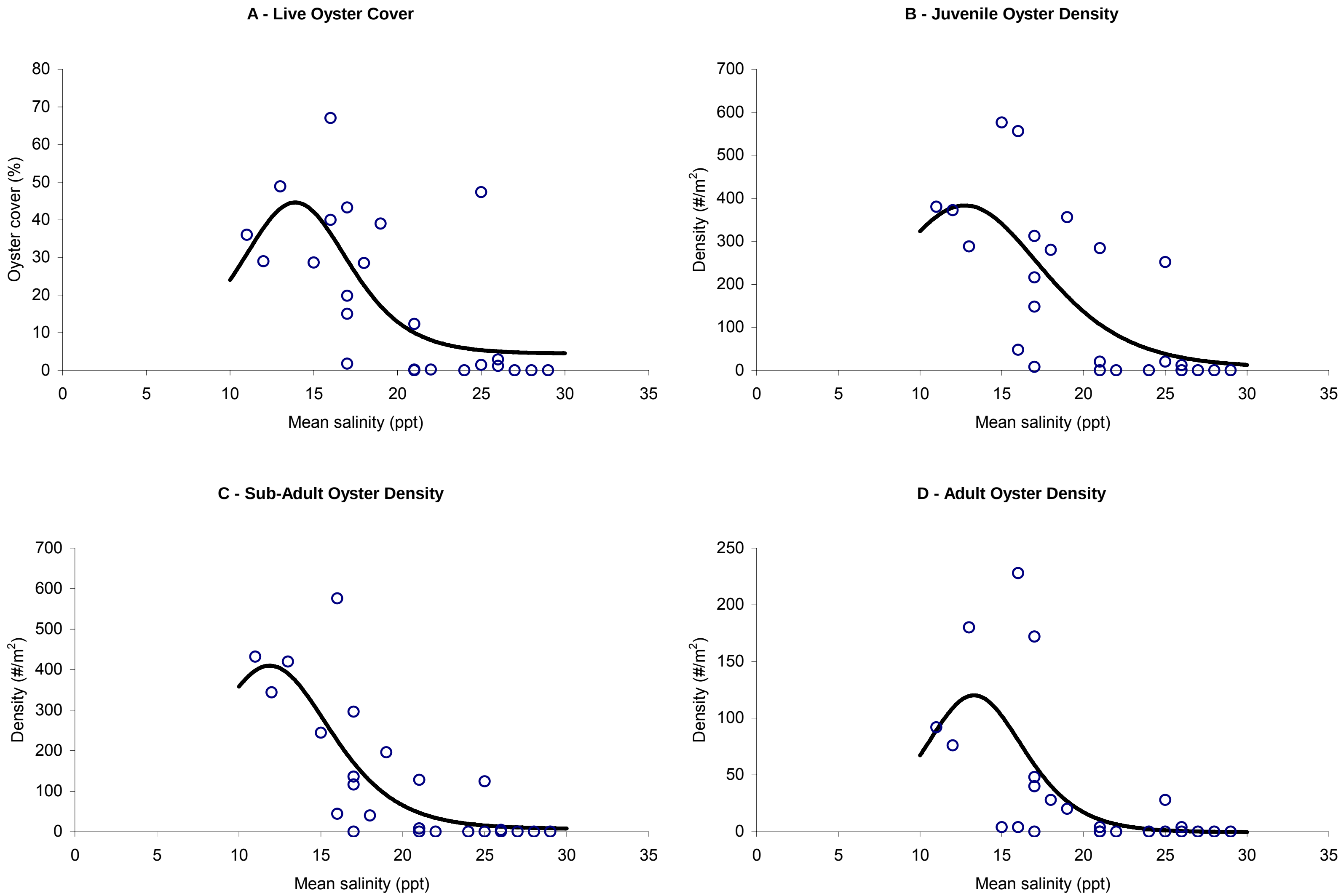


Figure 5-32. Plots relating oyster reef community characteristics to mean salinity one year prior to collection of the oyster data. Adapted from Baker et al., 2003.

5.3.5.4 Estimating Exceedance of 20 ppt Surface Salinity

Salinity-flow regressions were developed to predict the median surface salinities for each of the three regions identified by PCA as a function of flow at Wilcox. To account for tidal influence on the salinity-flow relationship, only samples collected after 1996 were used for the regression analysis since the period of record for the tidal data began in 1996. Once salinity-flow relationships were established for each of the groups, the long-term flow record was used to estimate the change in the probability of an annual average surface salinity of 20 ppt. The long-term average flow (10,166 cfs) was used as the baseline probability (see Appendix J for details). Risk was estimated as a change between 0 and 15 percent in the exceedance threshold of the 20 ppt criterion for surface salinity. Only the Inshore Reef and Offshore zones were evaluated since the River zone median

Table 5-7. Summary of PCA analysis of SEAS salinity data in the Suwannee estuary. From Janicki Environmental, 2005b.

Region	Median Salinity (ppt)	Minimum Salinity (ppt)	Maximum Salinity (ppt)
River	3.6	0	32.8
Inshore/Reef	14.3	0	32.2
Offshore	19.8	0	36.0

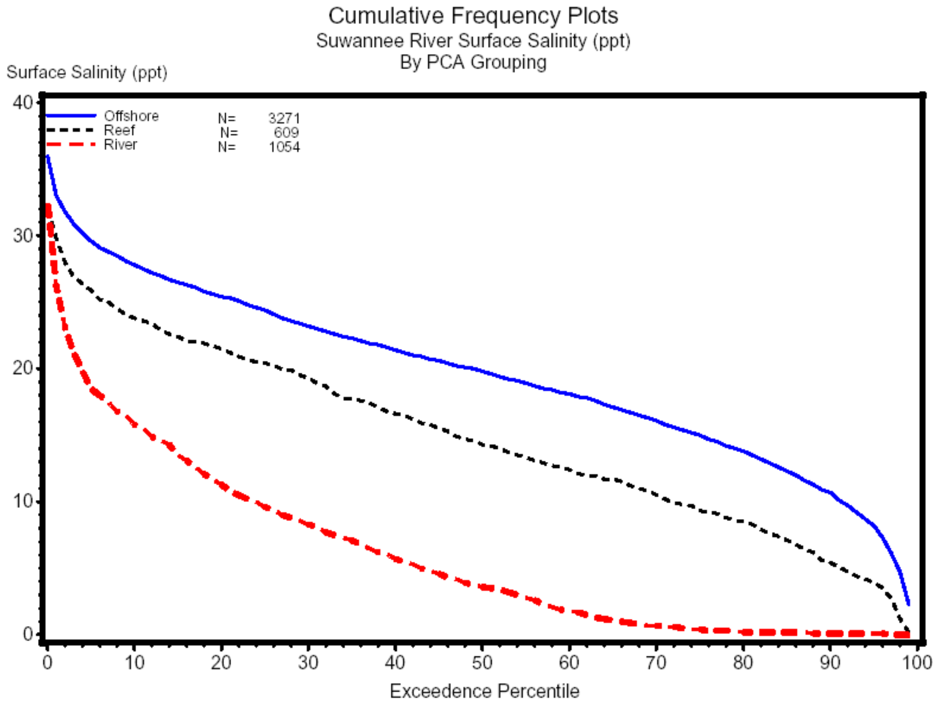


Figure 5-33. Exceedance frequency plots for each of the PCA groups for the Suwannee Estuary.

The Inshore Reef group displayed an inflection point in the risk estimates for flow less than 6,800 cfs coinciding with a 5% increase in the number of years the average annual salinity would exceed 20 ppt (Figure 5-34). The results of estimating risk for the Offshore group suggested that Offshore surface salinities were at the 20 ppt threshold approximately 50% of the time based on the study period of record (1997-2003). Therefore, a 15% change in the probability of annual average exceedance was associated with flows that were still above the long-term median flow for Wilcox (Figure 5-35). Thus, the use of the 20 ppt threshold for the assessment of risk for the Offshore group appears to be unrealistic.

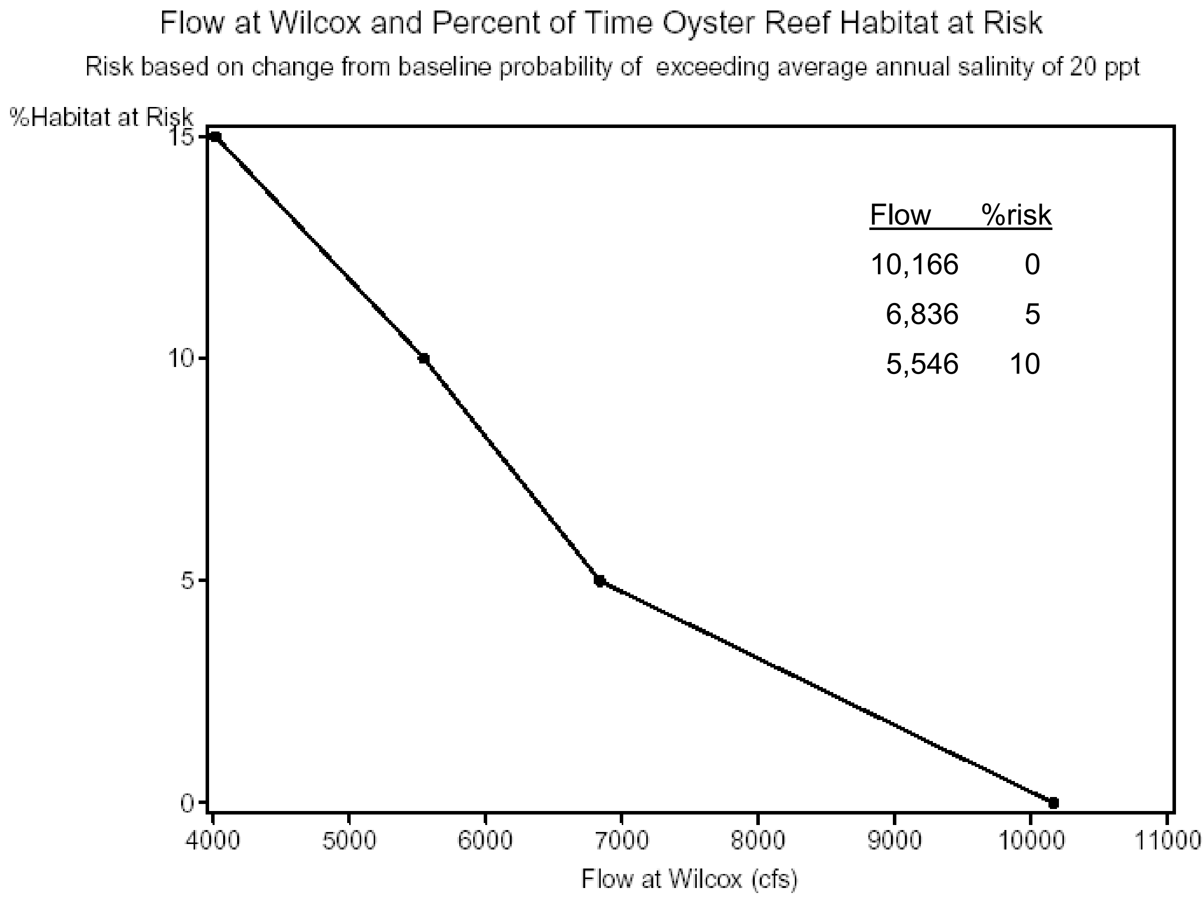


Figure 5-34. Flow associated risk of an annual average salinity of at least 20 ppt in the Inshore Reef group.

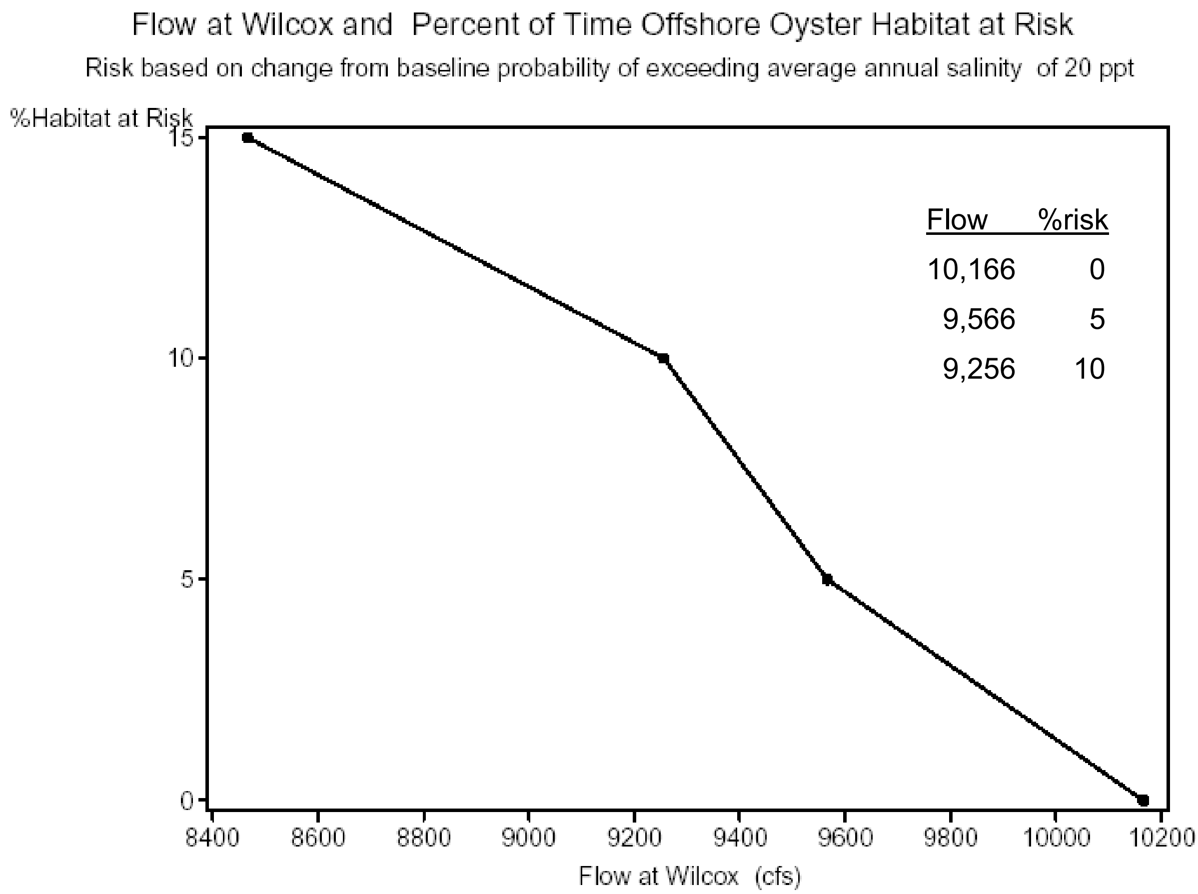


Figure 5-35. Flow associated risk of an annual average salinity of 20 ppt in the Offshore group.

5.3.6 Other Important Habitats

5.3.6.1 Riverine Upper Tidal Bottomland Hardwood Swamps

Light et al. (2002) studied relationships between hydrology, soils, and canopy/subcanopy vegetation in floodplain wetland forests of the 10-year floodplain of the lower Suwannee River. They confined their study to the 10-year floodplain because the vast majority, if not all, of the wetlands structured by riverine flooding are below the 10-year flood elevation. Land areas above this elevation are mostly developed (i.e., cleared for agriculture, managed pine plantation, or residential land use), or consist of upland ecosystems structured by other environmental forces, such as fire.

5.3.6.1.1 Methodology and Analysis

Two intensive study transects were established in the Upper Tidal portion of the system as shown in Figure 4-5. The most intensive data collection occurred on these, including land surface elevation, water-level measurements, soil conditions, and vegetation (canopy, subcanopy, and groundcover). Basic information on the transects is shown in Table 5-8. As described in Section 5.3.3, transects were belt transects, with a width of 16.5 feet (5 meters) if over 1,320 feet (400 meters) in length and a width of 33 to 42.9 feet (10 to 13 meters) if less than 1,320 feet long. These judgments were made by the investigators based on their experience in forested wetland sampling in order to obtain a large enough sample of trees to census. Detailed descriptive data on the locations of the transects is provided in Lewis et al. (2002). The rationale for selecting transect locations was discussed in Section 5.3.3.

Table 5-8. Basic descriptive information on the two forested wetland study transects in the Upper Tidal Reach of the lower Suwannee Study area.

Reach	Transect Name	Abbreviation	Location (river km)	Length in feet (meters)
Upper Tidal	Manatee springs	MS	42.5	3,329.7 (1,009)
	Keen/Keen Island	KN/KI	31.2	2,422.5/330 (734.1/100)

Land surface elevations, soils data, and canopy and subcanopy vegetation data were collected as described in Section 5.3.3, the only difference being that no soil salinity data were collected. Hydrology on the transects was related back to the combined flow of the Suwannee River at Branford and the Santa Fe River near Fort White ("Branford-Fort White flow"), using the rating curves in Figure 5-36.

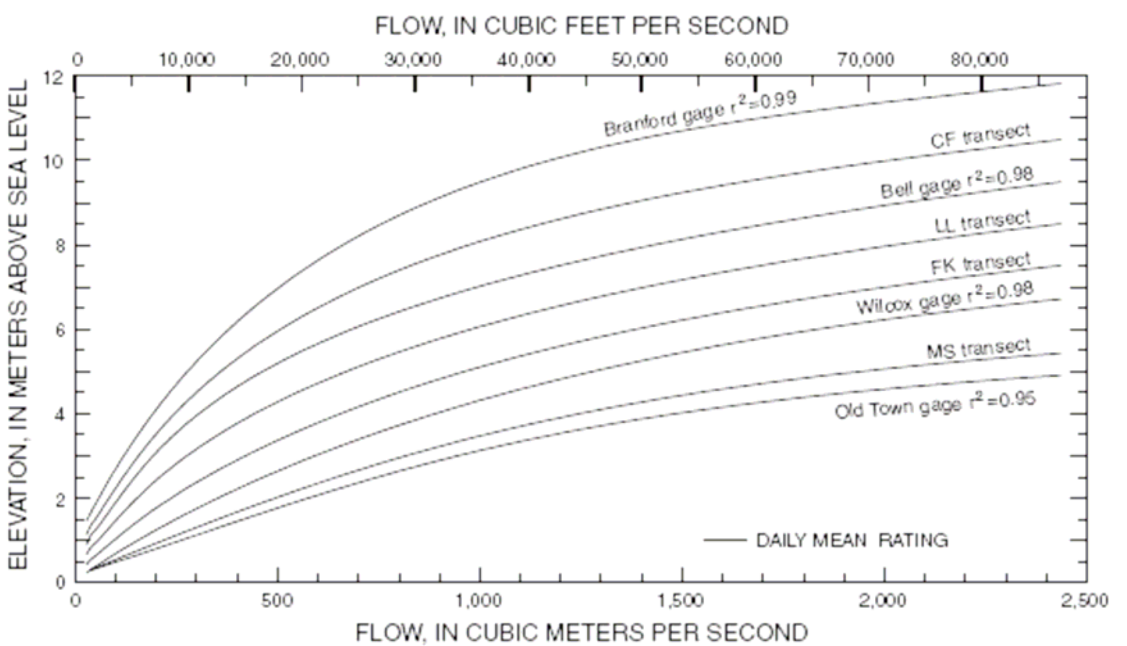


Figure 5-36. Daily mean stage at gages and riverine transects in relation to flow in the lower Suwannee River, Florida. Flow is combined flow of Suwannee River at Branford and Santa Fe River near Ft. White.

Light et al. (2002) identified four forest types in the Upper Tidal Reach, four forest types were identified: Upper Tidal Swamps 1 and 2 (Utsw1 and Utsw2), Upper Tidal Mixed Forest (Utmix) and Upper Tidal Bottomland Hardwood (UTblh). Description and summary of the soils data in the various forest types were provided in Howell (1999) and Light et al. (2002). Floodplain soils exhibited high variability, with 7 soil orders and 18 taxonomic subgroups. Histosols was most common soil type in the Upper Tidal Reach. Soil profiles in the swamps were dominated by clays and mucky clays. Profiles in bottomland hardwood communities were more dominated by sand or mucky sand.

A summary of general plant community and soil characteristics in each forest type is presented in Table 5-9. The extent to which a particular tree species dominates the composition of a forest is indicated by its “importance”, based on relative basal area for canopy species and relative density for subcanopy species Bald cypress (*Taxodium distichum*) was an important tree in riverine and upper tidal swamps. Various oaks (*Quercus* spp.) were important in the riverine and upper tidal bottomland hardwood forest types. Pumpkin ash (*Fraxinus profunda*) and Water tupelo (*Nyssa aquatica*) were important trees in upper tidal swamp and mixed forests. In general, most of the wetland forest types were in a largely unaltered condition (not affected by logging or clearing as observable on the aerial photography). The proportion of altered forest was higher in the “higher drier” forest types; UTmix and UTblh (Figure 26 in Light et al., 2002).

Table 5-9. Summary of plant community and soil characteristics in the Upper Tidal forest types. Adapted from Light et al. (2002).

Forest type	Dominant canopy species	Total no. canopy and subcanopy species	Total acreage unaltered forest acres (hectares)	Primary soil texture in root zone
Utsw1	Nyssa aquatica; Taxodium distichum; Fraxinus profunda	22	2,217 (897)	Muck
Utsw2	Nyssa aquatica; Taxodium distichum; Fraxinus profunda	33	2,686 (1,087)	Muck
Utmix	Taxodium distichum; Fraxinus profunda; Quercus laurifolia	31	944 (382)	Loam, muck, & sand
UTblh	Quercus laurifolia; Sabal palmetto	35	1,196 (484)	Sand

5.3.6.2 Flood depths in Upper Tidal Forests.

Inundation and soil saturation appear to be less important in maintaining plant community composition in Upper Tidal forest types because soils tend to be almost constantly saturated in most types and inundation and saturation due to tides becomes increasingly more important than variation in these due to river flows (Light et al., 2002). Consequently criteria for Upper Tidal forests will focus on the 5-year/14 day threshold flood depth. This flood appears to be more important in maintaining plant community composition in the forest types; especially the Upper Tidal Bottomland Hardwood Swamps, at the highest, driest range of the riverine wetlands.

5.3.7 Riverine Snag (Wood) Habitat

The ecological importance of wood habitat in southeastern coastal plain streams was reviewed in Section 4. The Southwest Florida WMD (SWFWMD, 2002) identified riparian wood as an important habitat for development of MFLs for the upper Peace River. Estevez and Sprinkel (2000) conducted surveys of wood habitat at six study transects on the Lower Suwannee River (Figure 4-5) near Manatee Springs.

5.3.7.1 Methodology and Analysis

Wood was surveyed at six bank transects selected systematically by SRWMD scientists and the consultant's Principal Investigator. As noted in the Methods section of Estevez and Sprinkel (2000), the purpose of this wood study was to identify relationships between the vertical distribution of wood and river stage where accumulations of wood occurred, rather than to make general statements about the distribution/occurrence of wood in broad reaches of the lower river study area. The goal was to determine if a quantitative relationship between river stage and some wood metric could be developed which could be used to set MFL criteria. The six bank study sites are considered to be "index" sites, similar to a shoal or other key river cross section used to relate habitat conditions to flow. The results from the wood sites are related back to an upstream gage to serve as a general indicator of the relationship between river stage and a wood metric where wood occurs. The six bank transects were distributed over about 1.5 river miles.

At each bank transect, an adaptation of the line-intercept method was employed as used in forestry (Van Wagner, 1968 and references therein). A line of known length was extended perpendicular from the bank towards the river channel centerline, to the maximum extent of occurrence of wood in the river channel, or to a depth that could not be sampled. The line was kept level using a string level and/or measuring down to the water surface. Surveys at each bank transect began at the top of bank and progressed down-bank at 1.65 feet (0.5 meter) intervals. Within each 0.5 m increment, where a piece of wood intercepted the line transect (or the vertical plane formed by the line), its diameter was measured. Various rules must be followed (Van Wagner, 1968), and all were adhered to in this sampling effort:

1. The sample line must be of known length;
2. If the sample line crosses the end of a piece of wood, tally only if the central axis of the wood is crossed;
3. If the sample line passes exactly through the end of a piece's central axis, tally every second such piece;
4. Ignore any piece whose central axis is parallel with the sample line; and
5. If the sample line crosses a curved piece more than once, tally each crossing.

A piece of wood was counted where it was intercepted within a particular 0.5 m stratum; i.e., it was not counted multiple times. Diameter was measured using a forester's dbh tape for larger wood debris and estimated with a drafting template for smaller diameters (generally < 2 inches). From these data, the surface area and volume of wood intercepted by the sample line can be determined (after Wallace and Benke, 1984):

For wood surface area: $\hat{X}sa = (\pi^2 / 2L)\sum^{n} d_i$;

where '$\hat{X}_{sa}$' is mean surface area, L is the length of the sample line, d_i is the diameter of a piece of wood intercepted by the sample line and n is the number of pieces of wood intercepted by the sample line.

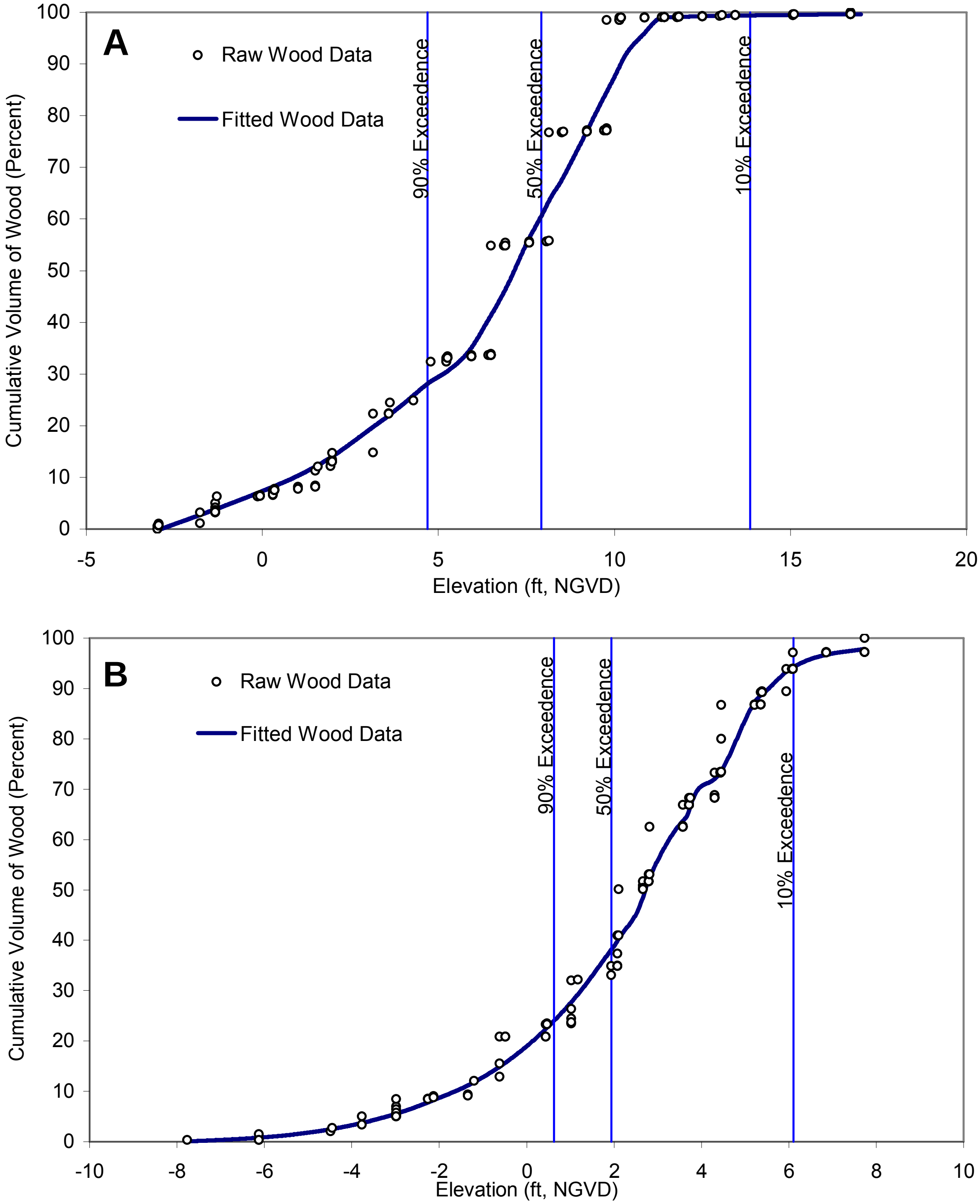
For wood volume: $\hat{X}v = (\pi^2 / 8L)\sum^{n} d_i^2$;

Where '$\hat{X}_v$' is mean volume, and L, n and d_i are as above.

Vertical locations at each bank transect were standardized to the top of bank at the transect, to water level on the day the bank transect was surveyed (based on water level at the closest gage related to a temporary staff gage placed at the wood transect site), and to NGVD using either the measured river stage or surveying from a known benchmark nearby.

5.3.7.2 River Stage and Wood Volume

A significant relationship was discovered between proportional surface area and volume of submerged wood and river stage (Figure 5-32). These relationships appear to be more than a coincidence. Estevez and Sprinkel (2000) compared the Suwannee wood data to a survey of wood, using a similar line-intercept technique, in the Ogeechee River, Georgia, about 100 miles north of the Suwannee River basin. There were differences in size and geomorphology of the river channel between these two studies; the Ogeechee is a smaller river system, and the Georgia study measured wood across the entire stream channel, whereas this study was confined to bank transects due to the size of the Suwannee River. Basic patterns of vertical wood dispersion were similar



Data fitted using a Loess-type (locally-weighted least-squares) procedure with B-spline smoothing as implemented in TableCurve 2D (v 5.0) by SPSS Inc

Figure 5-37. Relationships between river stage and volume of submerged wood habitat at locations on the Suwannee River (adapted from Estevez and Sprinkel, 2000). (A) Suwannee River near Eula Boat Ramp, and (B) Suwannee River near Manatee springs. Vertical lines indicate flow exceedance percentiles at Bell and Wilcox gages, respectively.

between the two streams, suggesting that the relationships seen in Figure 5-37 reflect some type of real pattern, not a sampling artifact. Estevez and Sprinkel used volume to relate to river stage because volume tended to exaggerate wood abundance, making the observation of a pattern easier to see.

Wood data were related to river stage using rating curves developed with HEC-RAS at a typical channel cross section selected in at each study location where the wood data were collected; half of the six transects located upstream and half downstream of the selected cross section. The rating curves related stage at the wood collection sites to streamflow at Wilcox (Figure 5-37). The Wilcox-Manatee rating curve was based on minimum daily stages at Wilcox.

The important consideration for wood habitat is to develop minimum flow criteria that allow for the persistence and availability of this habitat at average and low streamflows. MFLs to protect wood habitat must maintain inundation of adequate amounts of riparian wood habitat in order to make it available for fish and benthic invertebrate populations. Flows at which 50% of the wood is inundated may represent available wood during “average” flow conditions. Flows necessary to maintain the community composition and structure of the benthic invertebrate communities on snags must also be considered.

The flow reductions proposed to maintain adequate amounts of wood habitat should be adequate to maintain the structure and composition of attached benthic invertebrate communities. Data from the District’s long-term water quality monitoring program, using Hester-Dendy samplers (which imitate wood habitat) at the site SUW150C1 (Suwannee River at Rock Bluff), indicate that the proportion of “filtering collector” invertebrates in the benthic community in the Eula region is positively related to flow (Figure 5-39). These types of invertebrates include many aquatic insects such as *hydropsychid* caddisflies, *tanytarsid* midges, and blackflies, all of which are important as food base for riverine fishes, particularly sunfish such as Redbreast and Spotted sunfish (Benke et al., 1985).

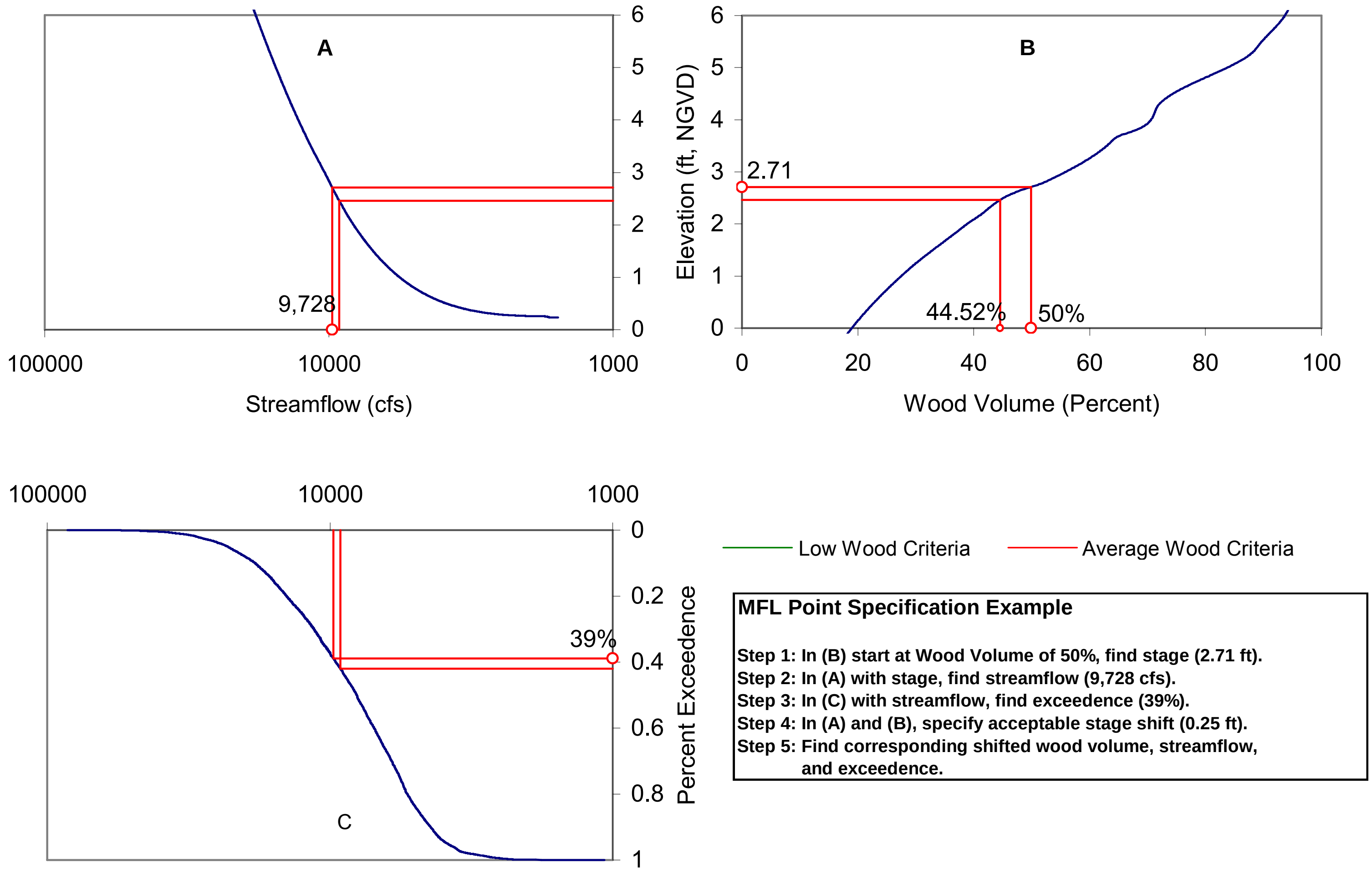


Figure 5-38. Estimated streamflow with a 0.25-foot shift in stage for submerged wood at Manatee study site. (A) The stage-discharge rating for stage at Manatee and flow at Wilcox from HEC-RAS model, (B) The relationship between wood volume and stage at Manatee, (C) The long-term FDC for Wilcox.

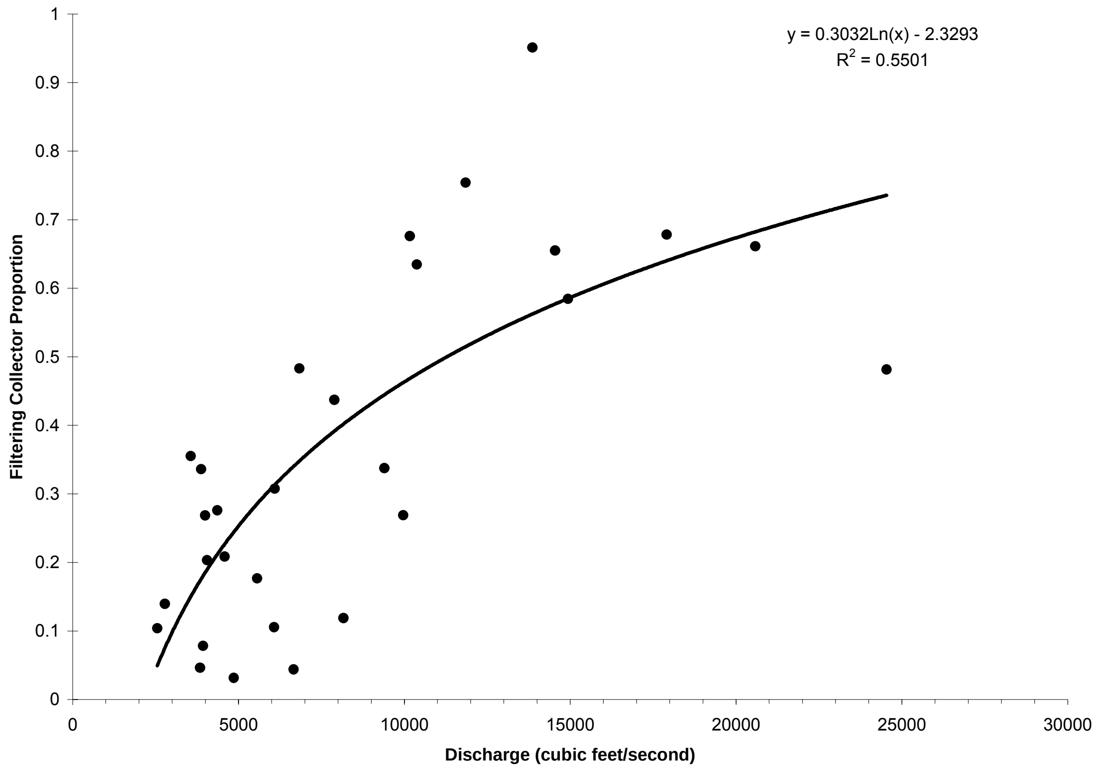


Figure 5-39. Relationship between river flow and proportion of filtering collector invertebrates on Hester-Dendy samplers at SRWMD long term site SUW150C1 – Suwannee River at Rock Bluff.

5.3.8 Tidal Marshes

Of the tidal- marsh habitats found in the Suwannee estuary, the lower salinity marsh types (oligohaline and tidal freshwater) will be most susceptible to changes caused by increased salinity due to water withdrawal. However, even the higher-salinity salt marshes could be impacted from elevated salinities caused by flow reductions. The "brown marsh" phenomenon in coastal Louisiana involves dieback of *Spartina alterniflora*, one of the most salt-tolerant tidal marsh plants. This dieback appears to be associated with stress induced during drought, with sustained periods of elevated salinity (www.LAcoast.gov/brownmarsh), thus, maintenance of adequate levels of freshwater inflow will be important for the conservation of all types of tidal marsh ecosystems in the Suwannee estuary. Important considerations for setting fresh-water flows which maintain the salinity fields needed to protect tidal marsh communities include the plant species composition in low-salinity marsh types (oligohaline and tidal fresh water) and the salinity tolerances of the dominant plants and animals in the marshes.

5.3.8.1 Methodology and Analysis

Clewell et al. (1999) conducted surveys of land surface elevation, soils, soil and water salinity and tidal marsh plant communities at seven intensive transects located across the delta area of the Suwannee estuary. The locations of the intensive transects were selected to span a range of marsh types, from brackish to mesohaline. These lower-salinity marsh systems will be most susceptible to adverse ecological impact from reductions in freshwater inflow. Tidal marshes north or south of the river mouth, along the coast, were not sampled because those are classic "salt" marshes, dominated by halophytes, which will be less sensitive to changes in salinity caused by reductions in fresh-water inflow.

Three intensive transects were located in West Pass and two in East Pass. Two other intensive transects, Salt Creek and Dan May Creek, were located in areas less influenced by the fresh-water flow of the Suwannee in order to separate out the effects of reductions in fresh-water inflow from other phenomenon, such as sea level rise. Transects ranged from 399 feet (121 meters) to 604 feet (183 meters) in length and extended from the shoreline of the river or creek into the interior marsh. Shoreline vegetation surveys were also conducted along transects 100 feet (30 m) in length (laid parallel to the shoreline) on both sides of the river channel at 15 sites sampled monthly for salinity by Mattson and Krummrich (1995) in 1993-95.

Land-surface elevation was measured on each intensive transect using a tripod-mounted level and survey rod. Additional readings were taken where the transect crossed features such as small tidal creeks. Horizontal distances were measured using a fiberglass tape and locations of all sampling sites were recorded with a differential GPS unit. Soils were sampled at 100 feet intervals on each of the intensive transects, and at the midway point (50 feet) on the shoreline vegetation transects. Soil samples were obtained using a 3-inch bucket auger. A standard posthole digger was occasionally used when larger samples were needed. Typically, soil profiles were sampled to a depth of 2 feet (1.2 meters). Soil parameters surveyed were pH, conductivity, moisture content, percent saturation, bulk density, organic matter, texture, and redox potential. Methods were described in detail in Clewell et al. (1999).

Tidal marsh plant community data were collected at the intensive transects and shoreline transects using a 0.5 m^2 circular quadrat. The occurrence of all plant species within the quadrats was recorded. On the intensive transects, plant community measurements were made in groups of 20 quadrats clustered in a rectangular area 100 feet long by 12 feet wide centered over the transect centerline. Six equally spaced groups of 20 quadrats were collected along each intensive transect. Plant data were expressed as frequency of occurrence, or number of observations of a plant species out of the 20 quadrats. On the shoreline vegetation transects, 20 quadrats equally spaced along the 100 feet length of the transect were collected, with plant data again expressed as frequency of occurrence (number of quadrats) of a plant species.

One hundred fifty-eight plant taxa in 75 families were identified in various plant communities on the Suwannee delta. Most of these were tidal marsh species, and others were found in tidal freshwater swamps, maritime hammocks, and submerged vegetation beds. Dominant groups were sedges and grasses in the monocots and composites (Asteraceae) and Apiaceae (=Umbelliferae; carrot family) in the dicots. Using the intensive transect data, regressions of occurrence of more common marsh plant taxa versus soil conductivity and various other soil parameters indicated that conductivity (= salinity) explained a considerable fraction of the variation in plant species occurrence. This result was confirmed with Canonical Correspondence Analysis, which indicated that conductivity was a major variable explaining the distribution of plant communities and plant taxa in this region of the Suwannee estuary (Figure 5-32 in Clewell et al., 1999). These results indicate the importance of salinity in structuring tidal marsh plant communities.

5.3.8.2 Cladium/Juncus ratios

Very little data exist on the actual salinity tolerances of the dominant plants growing in the oligohaline and tidal freshwater marshes. *Cladium*-dominated marshes in the Suwannee estuary appear to be exposed to higher salinities of up to 12-15 ppt during extreme droughts (Clewell, 2000). These result in loss of fresh-water plant taxa in oligohaline marshes intolerant of these salinities, but dominants such as *Cladium, Scirpus americanus*, and *Saururus cernuus* appear to persist (Clewell, 2000). A summary table in Odum et al. (1984 – their Table 5), indicates that a number of the plants found in the tidal fresh-water marshes (*Pontedaria cordata*, *Scirpus validus*, *Typha sp., Bohmeria cylindrica*, and other plants common in Suwannee estuary marshes) can occur in salinities ranging over 3-7 ppt, suggesting that they can tolerate some periods of elevated salinity. Other dominants in the Suwannee marshes, such as *Zizania aquatica* and *Cicuta mexicana*, appear to be much less tolerant of salinity (Odum et al., 1984; Clewell, 2000), but the proposed targets for tidal fresh marshes are within the ranges currently experienced in these regions of the Suwannee estuary. Overall, the data available appear to indicate that the proposed tidal marsh salinity targets will be adequate to sustain the various marsh types. Although the classic "Venice" system of salinity zonation in an estuary describes the oligohaline zone as areas with a mean annual salinity of < 5 ppt, more recent, biologically based salinity classifications place the oligohaline zone as lying between mean annual salinities of 2-14 ppt (Bulger et al., 1993) and 0-8 ppt (Christensen et al., 1997). The above targets for mean and maximum annual salinity lie within these zones.

Clewell et al. (1999) demonstrated a significant relationship between maximum salinity at a location and the ratio of occurrence of *Cladium jamaicense* (reflecting lower salinity marshes) and *Juncus roemerianus* (reflecting higher salinity marshes) in shoreline marshes fringing East and West passes in the Suwannee estuary (Figure 5-40). Between salinities of 6 and 12 ppt (seasonal maximum measured mid-river channel),

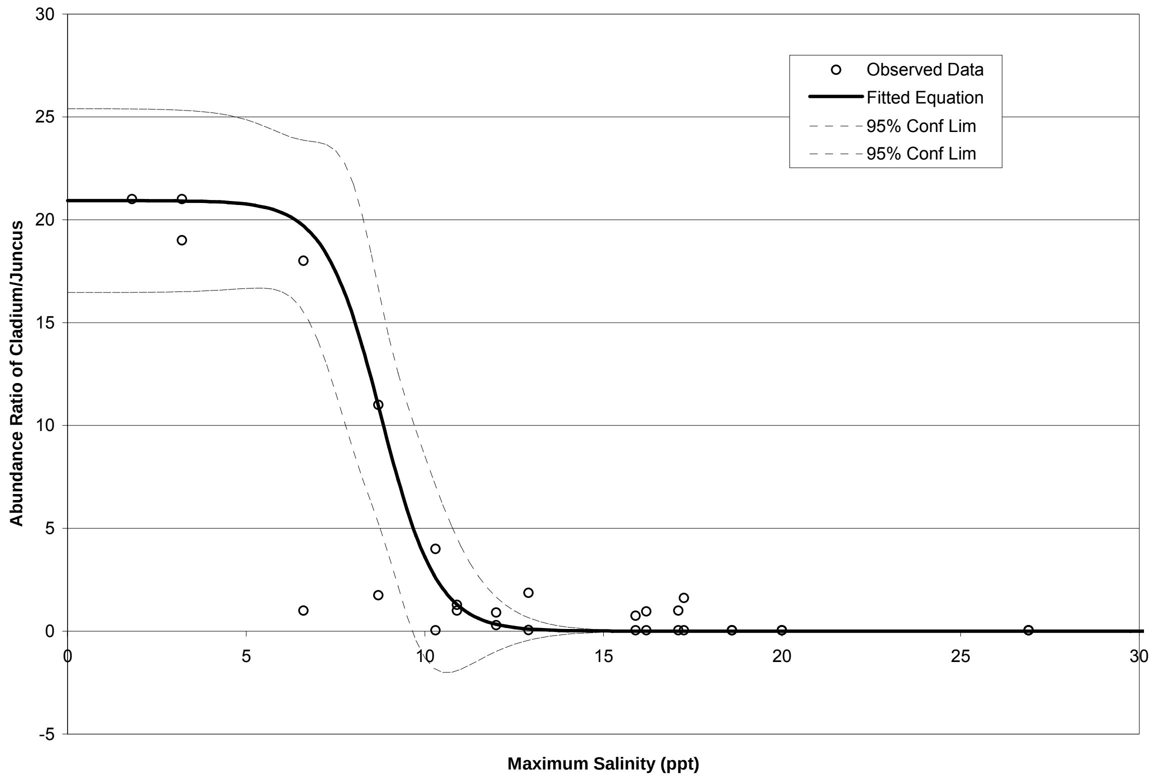


Figure 5-40. Relationship maximum salinity at sampling sites in East and West Passes and the ratio of occurrence of *Cladium* to *Juncus*. Adapted from Clewell et al. (1999).

shoreline communities shifted from a *Cladium*-dominated to a *Juncus* dominated marsh community. An increase of 10% in the maximum salinity is proposed as an allowable shift. This results in relatively small changes to the *Cladium/Juncus* ratio, suggesting minimal changes to plant community composition in the shoreline and adjacent marshes. The ratio shifts from <1 (indicating *Cladium* dominant) to >1 (*Juncus* dominant) at a maximum salinity of about 12 ppt (Clewell et al., 1999). The proposed maximum salinity targets are all ≤12 for oligohaline marshes.

Salinity tolerances of many of the dominant animal taxa found in the tidal marshes of the Suwannee estuary are generally quite broad (Table 5-6; Heard, 1982; PBS&J, 2003), and thus the marsh fauna should not be adversely affected by the proposed salinity targets. Two characteristic taxa are the olive nerite snail (*Neritina usnea*) and the freshwater fiddler crab (Uca minax). The olive nerite is reported to tolerate an exceptionally wide range of salinities of (Heard, 1982; PBS&J, 2003), indicating that the abundant populations of this snail should not be affected by the proposed salinity shifts. Similarly, the proposed shifts remain in the salinity ranges where abundance of *U. minax* is maximal; mostly <12 ppt (Figure 5-41).

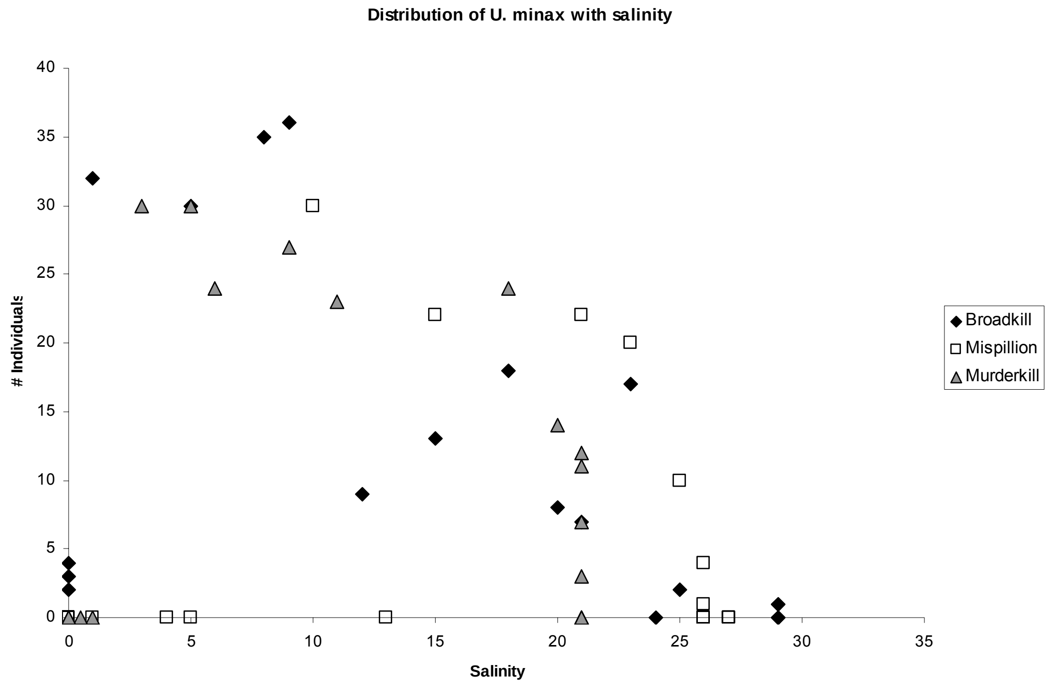


Figure 5-41. Distribution of *U. minax* with salinity in three river estuaries in Delaware. Data from Miller and Mauer, 1973.

Additionally, the benthic invertebrate communities commonly found in these tidal creeks appear to be characterized by species with broad salinity tolerance. Horlick and Subrahmanyam (1983) described a tidal creek benthic community in the St. Mark's estuary, and found many of the taxa listed in Table 5-7, including polychaetes such as *Streblospio benedicti*, various estuarine amphipods (*Ampelisca spp*., *Grandidierella spp.*, *Gammarus spp*.), isopods (*Cyathura polita*), and snails (*Bittium varium*, *Cerithidea costata*). Based on this information, the proposed tidal creek salinity criteria appear to be adequate to maintain the composition and diversity of benthic fauna and fish communities of the tidal creeks.

5.3.9 Integrating Relationships between Habitat Availability and River Flow

5.3.9.1 Assumptions and Considerations

In evaluating the relationships established between the flow at Wilcox and downstream habitat availability, it is important to recognize the assumptions under which the consideration of MFLs were based. Our approach was to assume that the habitat requirements to provide adequate thermal refuge for manatee was the priority factor in selecting MFLs for the Lower Suwannee River. Since the manatee habitats were located upstream from the portion of the Lower Suwannee River usually exposed to the influence of salinity, we assessed the springs requirements first. We then *a priori* assess the downstream habitats in relation to the springs requirements, assuming all these downstream habitats had equal ecological value. A weight of evidence approach was considered in assessing the relative applicability of each of the downstream habitat assessments. The criterion established for each of the habitats was assessed relative to what we observed in the long-term data record for the Suwannee River. For example, the data for SAV showed empirical evidence of the effects of drought conditions on the downstream limit of SAV in the West Pass of the Lower Suwannee River. Further, we were able to validate salinity-flow predictions based on the synoptic surveys to independent data collected at continuous recorders over a different period of record. This gave us more confidence in our assessment of the effects of flow on the location of the 9 ppt isohaline. Therefore, we were able to give more weight to estimates associated with risk to SAV habitats than to other estuarine habitats considered. The fact that SAV is a static habitat located within the river gives further credence to the validity and reliability of estimates of risk compared to tidal swamp habitats which include vegetation located up to a mile away from the river bank.

The conservative nature of our assessments minimized the possibility that acute exposures to threshold conditions would not result in a loss of habitat for the organism of interest. While there remains uncertainty in the precise location of an isohaline at any given time in the Lower Suwannee River, we can predict the average location of the maximal extent of salinity incursion into the Lower Suwannee with confidence. This approach allowed us to estimate the risk based on a change in the average condition representing a chronic exposure and is consistent with the empirical evidence of measured biological response to habitat perturbations.

Tidal Creek habitats were considered for assessment but relationships between flow and the 5 ppt isohaline location were more difficult to quantify over the range of locations of tidal creek access points. Further, little data were available on the salinities and fish collections in the backwater tidal creek areas within the Lower Suwannee River since these areas are difficult to access. The fact that fishes are motile and can to some extent choose the habitat they wish to utilize and avoid conditions that stress their osmoregulatory capacity resulted in giving less weight to the 5 ppt threshold when assessing the impacts of flow on risk of habitat degradation.

While no dedicated sampling program existed to relate salinity in Suwannee Sound to flows from the Lower Suwannee River, we were able to relate flows to median salinities for groups of stations sampled by a long-term water quality monitoring program in the sound. The groups we delineated using objective techniques corresponded well with knowledge of the dynamics of interaction between the Lower Suwannee and the Suwannee sound. An Inshore Reef zone resulted from the PCA analysis that corresponds to the location of several major oyster bars in Suwannee sound. This zone extended to the south, which is the dominant flow pattern of fresh water entering the sound from the river. The criterion for oyster habitat established based on published literature was a threshold annual average surface salinity of 20 ppt. Median salinities for the Inshore Reef group were well below 20 ppt and predictions suggested that the average annual salinities would only be above 20 ppt during drought conditions. The offshore group approach 20 ppt under normal conditions and therefore represents a zone relatively insensitive to changes in the frequency of exceedance of the 20 ppt threshold.

Given these considerations, protection of manatee habitat, the limiting target habitat criteria for establishing MFLs for Manatee and Fanning Springs, should be used to establish an MFL for the Lower Suwannee River during the high flow, winter months period (i.e., November through April) and risk to SAV habitat should considered as the limiting target habitat criteria to establish a MFL that covered the remaining months of the year (i.e., May through October). This approach is in reflection of the river-spring flow relationship discussed in this section and in Section 3. In both cases, the recommended flow or level that should avoid significant adverse environmental impact to the manatee habitat in the springs are also protective of the river habitat during the high flow, winter period. Conversely, the high flow, warmer months MFL in the river should avoid a significantly adverse environmental impact in the springs.

5.4 Critical Flows to Maintain Thermal Refuge and Passage and Lower Suwannee River Habitats

5.4.1 Manatee Spring

To avoid a significantly adverse impact to the thermal refuge for manatee at Manatee spring a minimum spring flow of 130 cfs was identified. This flow is based on modeling of the relationships of river and spring discharge during the winter months. While spring flows drop below the 130 cfs during other months of the year, the critical condition is access to the thermal refuge during the winter months.

5.4.2 Fanning Spring

Manatee passage at Fanning spring requires a minimum 2.71 ft. (NGVD) spring stage equivalent to provide enough depth for the 5.0 foot fully grown manatee passage requirement into the spring pool The probability that stage at Fanning Spring will be greater than 2.71 feet NGVD for a given discharge can be determined from Figure 5.10.

5.4.3 Lower Suwannee River

Downstream habitat considerations in the Lower Suwannee resulted in flow associated risk estimates for each habitat type of interest (Table 5.10). Inflection points were noted for three of the habitat types (i.e., SAV, Tidal Swamps, and Inshore Reef oyster habitats). These inflection points correspond to flows at Wilcox between 6,000 and 7,000 cfs. By averaging the flows associated with each inflection point, a critical flow of 6,596 cfs would be derived. Given that the weight of evidence for SAV appears to be more robust for SAV and since SAV is known to be important habitat for macroinvertebrates and fishes and is a food source for manatee, protecting this habitat is recommended to be the prime consideration for MFL establishment. Figure 5-42 presents a fine scale estimate of flow associated risk for SAV for risk points between 0 and 5%. With flows of 6,515 cfs it is estimated that 3.5 % of the SAV would be at risk. Averaging estimates of the average inflection point and the 3.5% risk estimate would equate to an estimate of 6,555 cfs. As stated previously, the conservative nature of the risk assessments was based on identifying conditions where the biological organism under consideration would begin to encounter conditions that were physiologically stressful and meet the conditions of a potentially significant adverse environmental impact. Therefore, these habitats are periodically exposed to conditions above the threshold values established for risk. In this way, we assume that some degree of risk is allowable but attempt to minimize this risk for the target habitats. Again, chronic exceedance conditions would be required to pose a threat to actual loss of habitat.

Table 5-10. Flow associated risk estimates for 0 to 15 % of each habitat type.

	Percent Habitat at Risk			
Habitat Types	**0%**	**5%**	**10%**	**15%**
	Flow (cfs)			
SAV	7,858	6,180	5,798	4,867
Tidal Swamp	11,031	8,230	6,772	6,157
Tidal Creeks*	10,878	9,899	9,043	8,424
Oyster Reef	10,166	6,836	5,549	4,016
Oyster Offshore*	10,166	9,566	9,256	8,466

Shaded cells indicate location of inflection points in risk estimates

* Indicates habitats given less weight in application to MFL

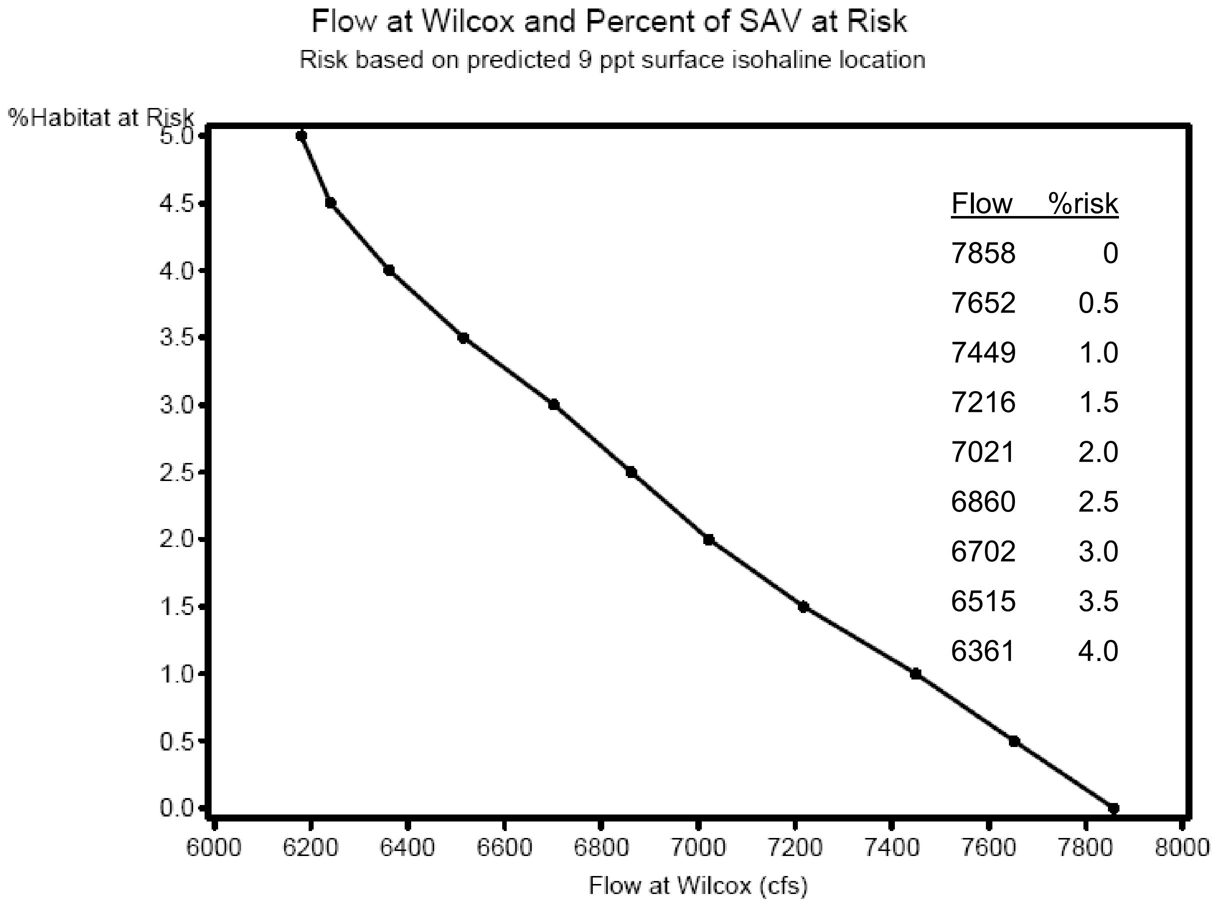


Figure 5-42. Flow associated risk for SAV in 0.5 % increments form 0 to 5%.

5.4.4 Sustaining River Low Flow Conditions During the Dry Season

As noted in Section 3.3.2.4.4, Manatee and Fanning springs contribute as much as 8 percent of the total discharge during low-flow periods in the Lower Suwannee River below Wilcox (Figure 3-44). The proposed MFLs for the Lower Suwannee River and estuary during the warm, low-flow season are supported, in part, by spring discharge. Figures 3-45 and 3-46 present monthly spring flow and stage relationships with discharge at the Wilcox gage. Based on the equations developed to characterize these relationships (Figures 3-45, 3-46), a series of potential MFLs can be considered for the warm season. Table 5-11 presents possible MFLs for warm season (May – October) conditions at the springs. Note that the R^2 values for discharge estimations are weak.

Table 5-11. Warm season calculated stage and discharge conditions at Fanning and Manatee springs. Stage and discharge values for each river discharge value are based on the equations presented in Figures 3-45 and 3-46.

Suwannee River Discharge at Wilcox (cfs)	Approximated Stage at Fanning Spring (ft., NGVD)	Approximated Discharge at Fanning Spring (cfs)	Approximated Stage at Manatee Springs (ft., NGVD)	Approximated Discharge at Manatee Springs (cfs)
6,000	3.7	86	1.9	144
6,200	3.7	85	2.0	144
6,400	3.8	84	2.0	145
6,600	3.9	83	2.1	146
6,800	4.0	82	2.2	147
7,000	4.1	81	2.2	148
7,200	4.1	79	2.3	149
7,400	4.2	78	2.3	149
7,600	4.3	77	2.4	150
Goodness of regression data fit (R^2)	0.960	0.244	0.960	0.537

Shaded values equate to LSR flow that reflects a 3.5% loss of SAV as discussed in Section 5.4.2.3

SECTION 6

6.0 Summary and MFL Recommendations

6.1 Summary

The Suwannee River is widely regarded as a natural river system with high conservation and recreational value. The Nature Conservancy (Master et al., 1998) classified the Suwannee/Santa Fe drainages as "critical watersheds to protect freshwater biodiversity" and has been designated by the state as an Outstanding Florida Water (OFW) and the Lower Suwannee River is part of the Big Bend Aquatic Preserve.

The Lower Suwannee River is the second largest river system in Florida by drainage area and mean annual flow. Major tributaries of the river are the Withlacoochee and Alapaha Rivers, which are located mostly in Georgia, and the Santa Fe River in Florida. In total, approximately 57% of the basin is located in Georgia.

6.1.1 Lower Suwannee River Study Area

That portion of the Suwannee River Basin downstream of the Wilcox Gage at Fanning Springs comprises the drainage basin associated with the MFL study area. For purposes of establishing MFLs for the Lower Suwannee River system, all river flow measurements are made from the long term USGS Wilcox gage. This portion of the basin includes, in part, the ground-water basins for Manatee and Fanning Springs. As discussed in Section 3.0, the flows of the river and springs systems are inextricably linked (Figure 6-1). The river flow controls the springs flow throughout the year allowing discharge from the springs during the low flow periods and the river flows back into the springs during high flow periods. Establishing the MFLs for the river and springs simultaneously was required to provide effective and coordinated regulation of each waterbody's MFL.

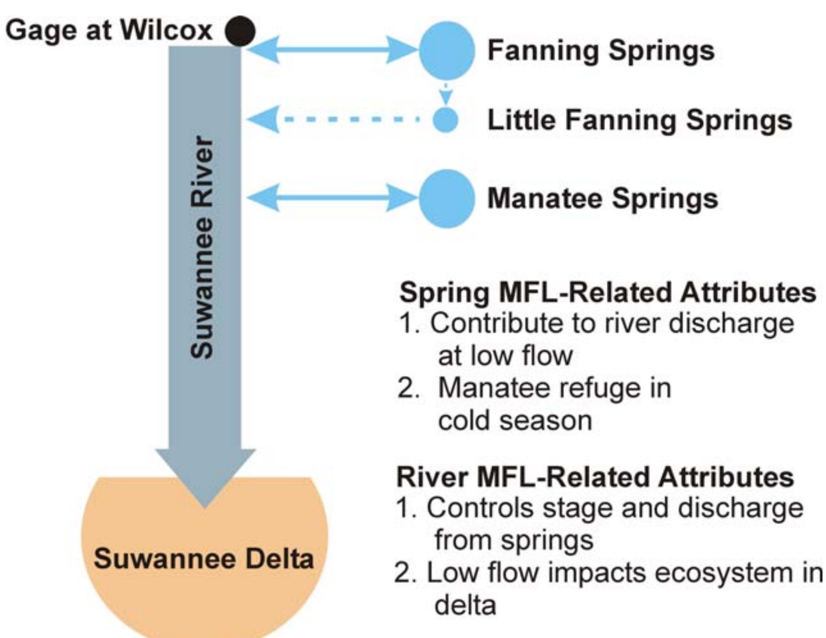


Figure 6-1. Lower Suwannee System Flow Relationships.

6.1.2 Fanning Spring

Fanning Springs State Park is located in the city of Fanning Springs, Levy County, Florida. The park is a State Recreation Area with two springs (Fanning and Little Fanning) located within the park. Much like the river, the springs are important to the natural and scenic beauty of the area. The Fanning Spring is also an important thermal refuge for manatees, which frequent the spring throughout the year, especially during the cold, winter months of November through April. The spring is classified as a Category 2 manatee refuge.

Median discharge for the period of record is 90 cfs and average discharge is 94 cfs. According to the Division of Recreation and Parks (2003), the most important designated species in the park is the Florida manatee. Discharge and stage in Fanning Spring and its run are controlled by stage of the Suwannee River. Manatee visit the park at any time of the year, but it primarily is used as a thermal refuge during colder months (November through April).

6.1.3 Little Fanning Spring

Little Fanning Spring is a spring with discharge that has ranged from 1 to 30 cfs (based on 9 measurements from 1987 to 2004). According to District staff (Hornsby, 2005, personal communication), the spring has been observed to not be flowing on numerous occasions. Median discharge is 18 cfs, and average is 16 cfs. Discharge from Little Fanning Spring is a function of the stage of the Fanning Spring pool. Stage in the Little Fanning Spring run is controlled by river stage. Little Fanning spring flow will be controlled by the flow from Fanning spring and therefore an MFL will be established in conjunction with the Fanning Spring MFL.

6.1.4 Manatee Spring

Manatee Spring State Park is located near the city of Chiefland, Levy County, Florida. Manatee Spring consists of a spring "bowl" and run approximately 1,200 feet in length. Median discharge for the period of record is 204 cfs and average discharge is 189 cfs. The spring is classified as a Category 2 manatee refuge.

6.2 MFL Evaluation Procedure

The evaluation performed for the establishment of MFLs for the three priority water bodies (Lower Suwannee River and Estuary, Fanning Spring and Manatee Spring) were conducted with the following approach:

1. Compile all "best available information" relative to the water bodies;
2. Evaluate information to determine flow and/or level relationships for each waterbody to adverse impacts to the water resource or related ecology;
3. Identify the limiting target criteria that, if protected from a significant adverse impact, will protect all other applicable criteria;
4. Recommend an MFL that will protect the waterbody and related ecology from "significant harm".

6.3 MFL Ecologic Evaluation

After careful compilation of all "best available information" to evaluate the three water bodies, the analyses to determine the most limiting habitat to be protected from a significant adverse impact were conducted using the following eight habitats of interest:

1. Manatee Thermal Refuge
2. Upper Estuary Submerged Aquatic Vegetation
3. Tidal, Fresh-water Swamps
4. Tidal Creeks
5. Oyster Bars and Reefs
6. Upper Tidal Bottomland Hardwood Forests
7. Riverine Woody Snag Habitat
8. Tidal Marsh Habitat

6.3.1 MFL Water Resource Value Conclusions (Tables 6-1 thru 6-3)

1. Recreation and aesthetic values were the limiting water resource values for the Manatee and Fanning springs MFLs in addition to the wildlife habitat value in the form of manatee thermal refuge for the cold season (Nov-Apr).
2. Estuarine resources in the form of submerged aquatic vegetation was the limiting water resource value for the Lower Suwannee River in addition to the wildlife habitat value in the form of manatee thermal refuge for the cold season (Nov-Apr).

6.4 Recommended MFLs

6.4.1 Manatee Spring – Recommended MFL

To avoid a significantly adverse impact to the thermal refuge for manatee at Manatee Spring a minimum spring flow of 130 cfs during cold season (November–April) is recommended. This flow is based on modeling of the relationships of river and spring discharge during the cold season (November–April). In addition, throughout the year, the historic flow regime will not reduced by more than 10% (Figure 6-2). This is based on evaluation of the relationship of spring discharge to river stage, avoidance of significant adverse impact to the recreation and aesthetic values of the spring, manatee thermal refuge in the cold season (Nov-Apr) and available water in the springshed. (Table 6-1).

Table 6-1. Recommended MFL for Manatee Spring

	NOVEMBER 1- APRIL 30	ANNUAL
Minimum Flow	130 cfs	Flow regime that will maintain 90% of historic flow regime

In order to test if the recommended MFL avoids significant adverse impacts to each of the water resource values found in Chapter 62-40.473 F.A.C. Each recommended MFL was evaluated with respect to the ecological and human use value for each water body as discussed in Section 1-4 and summarized in Table 6-2.

Table 6-2. Manatee Spring Recommended MFL.
Summary considerations for each water resource value

ECOLOGIC & HUMAN USE VALUE	IS VALUE APPLICABLE TO WATER BODY?	REQUIREMENTS TO AVOID SIGNIFICANTLY ADVERSE IMPACT	DOES RECOMMENDED MFL ADDRESS VALUE?
Recreation in and on the water	Yes	Full pool that minimizes "dark water" intrusion from river	Yes
Fish and wildlife habitats and the passage of fish	Yes	130 cfs during cold season to maintain thermal refuge	Yes
Estuarine resources	Yes	Maintain acceptable flows to river in dry period to avoid significant adverse impacts	Yes
Transfer of detrital material	No	NA	NA
Maintenance of freshwater storage and supply	Yes	Availability of water for future use	Yes
Aesthetic and scenic attributes	Yes	Full pool that minimizes "dark water" intrusion from river	Yes
Filtration and absorption of nutrients and other pollutants	No	NA	NA
Sediment loads	No	NA	NA
Water quality	No	NA	NA
Navigation	No	NA	NA

Blue shading indicates limiting (most sensitive to flow reduction) value

6.4.2 Fanning Spring/Little Fanning– Recommended MFL

Manatee passage at Fanning Spring requires a minimum 2.71 ft. (NGVD) spring stage equivalent to provide enough depth for the 5.0 foot passage requirement during the cold season (November–April) for fully grown manatee to enter the spring pool. The recommended Lower Suwannee River median flow of 7,600 cfs in the cold season will control the spring run elevation and allow the 2.71 feet (NGVD) level to be met 85% of the time (7,600 cfs equates to average monthly stage of 4.3 ft). In addition, throughout the year, the historic flow regime for Fanning Spring will not reduced by more than 10% (Figure 6-3). This is based on evaluation of the relationship of spring discharge to river stage, avoidance of significant adverse impact to the recreation and aesthetic values of the spring, manatee thermal refuge in the cold season (Nov-Apr) and available water in the springshed. (Table 6-3).

Table 6-3. Recommended MFL for Fanning/Little Fanning Spring.

	NOVEMBER 1 – APRIL 30	ANNUAL
Minimum Level	2.71 ft. NGVD in Fanning spring run to be met 85% of the time	Flow regime that will maintain 90% of historic flow regime

Table 6-4. Fanning/Little Fanning Spring Recommended MFL.
Summary considerations for each water resource value

ECOLOGIC & HUMAN USE VALUE	IS VALUE APPLICABLE TO WATER BODY?	REQUIREMENTS TO AVOID SIGNIFICANTLY ADVERSE IMPACT	DOES RECOMMENDED MFL ADDRESS VALUE?
Recreation in and on the water	Yes	Full pool that minimizes “dark water” intrusion from river	Yes
Fish and wildlife habitats and the passage of fish	Yes	Minimum 5.0 ft. depth in Fanning spring run for manatee passage during cold season	Yes
Estuarine resources	Yes	Maintain acceptable flows to river in dry period to avoid significant adverse impacts	Yes
Transfer of detrital material	No	NA	NA
Maintenance of freshwater storage and supply	Yes	Availability of water for future use	Yes
Aesthetic and scenic attributes	Yes	Full Fanning spring pool that minimizes “dark water” intrusion from river	Yes
Filtration and absorption of nutrients and other pollutants	No	NA	NA
Sediment loads	No	NA	NA
Water quality	No	NA	NA
Navigation	No	NA	NA

Blue shading indicates limiting (most sensitive to flow reduction) value

6.4.3 Lower Suwannee River– Recommended MFL

Downstream habitat considerations in the Lower Suwannee River resulted in flow-associated risk estimates for each habitat type of interest. Given that the weight of evidence for SAV appears to be more robust and since SAV is known to be important habitat for macroinvertebrates and fishes and is a food source for manatee, protecting this habitat is recommended to be the prime consideration for MFL establishment. With flows of 6,515 cfs it is estimated that 3.5 % of the SAV would be at risk. Averaging estimates of the average inflection point and the 3.5% risk estimate would equate to an estimate of 6,555 cfs (6,600 cfs rounded). Therefore, the recommended Minimum Flow is 6,600 cfs for the warm period (May-October). The cold season (November to April) MFL is recommended at 7,600 cfs which will maintain the Fanning Spring 2.71 feet NGVD elevation approximately 85 % of the time, a reduction of 12% over current conditions. (Figure 6-5)

Table 6-5. MFL for Lower Suwannee River at Wilcox Gage.

	NOVEMBER 1 – APRIL 30	MAY 1 – OCT 31
Minimum Flow	7,600 cfs	6,600 cfs

Table 6-6. Warm season calculated stage and discharge conditions at Fanning and Manatee springs. Stage and discharge values for each MFL value are based on the equations presented in Figures 3-45 and 3-46.

LSR WARM SEASON MINIMUM FLOW (cfs)	APPROXIMATED MONTHLY AVERAGE STAGE @ FANNING SPRING (ft., NGVD)	APPROXIMATED MONTHLY AVERAGE DISCHARGE @ MANATEE SPRINGS (cfs)
6,600	3.9	146

Figure 6-2. Percent of time stage at Fanning spring is greater than 2.71 ft for selected monthly median cold season Wilcox discharges

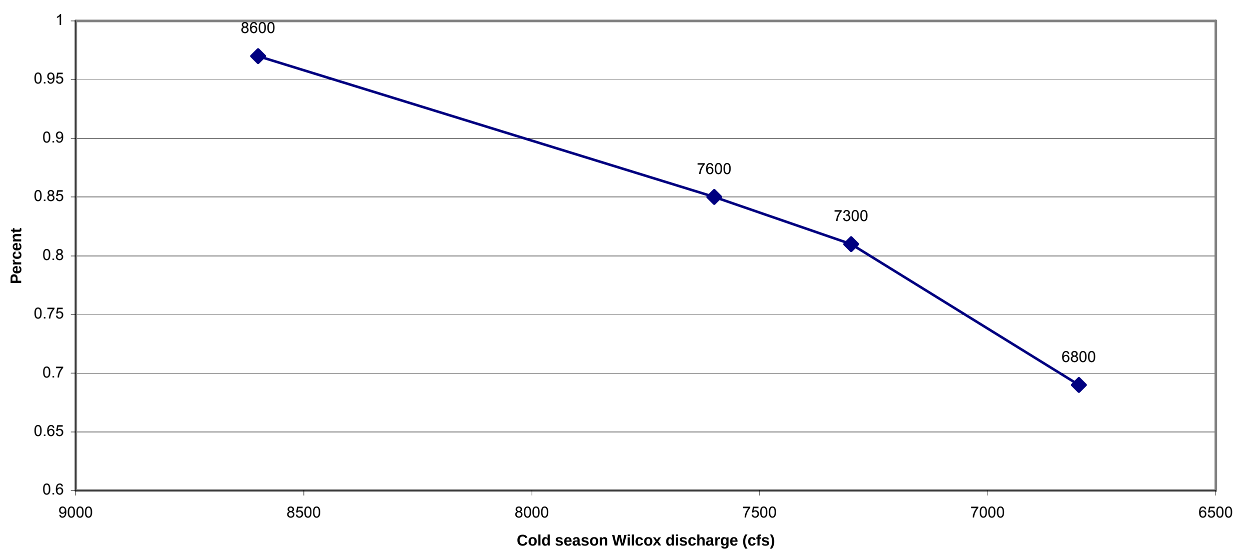


Table 6-7. Lower Suwannee River Recommended MFL.
Summary considerations for each water resource value

ECOLOGIC & HUMAN USE VALUE	IS VALUE APPLICABLE TO WATER BODY?	REQUIREMENTS TO AVOID SIGNIFICANTLY ADVERSE IMPACT	DOES RECOMMENDED MFL ADDRESS VALUE?
Recreation in and on the water	Yes	Sufficient flow for swimming, boating, fishing, kayaking and canoeing.	Yes
Fish and wildlife habitats and the passage of fish	Yes	Maintain manatee thermal refuge areas in springs	Yes
Estuarine resources	Yes	Avoid significant adverse impacts to limiting target resource SAV	Yes
Transfer of detrital material	Yes	Adequate flow to transport material from floodplain to river	Yes
Maintenance of freshwater storage and supply	Yes	Availability of water for future use	Yes
Aesthetic and scenic attributes	Yes	Flowing river	Yes
Filtration and absorption of nutrients and other pollutants	Yes	Flood flows moving into wetlands	Yes
Sediment loads	Yes	Transport sediment loads at higher flows	Yes
Water quality	Yes	Salinity movement limited to avoid significant adverse impacts to ecosystem	Yes
Navigation	NA	NA	NA

Blue shading indicates limiting (most sensitive to flow reduction) value

6.5 RECOMMENDATIONS

Based upon the scientific investigations performed for the Lower Suwannee River, Manatee and Fanning/Little Fanning springs in accordance with applicable Florida Statutes, the following recommendations are made for MFL establishment by the District:

1. A seasonal MFL regime be established for the Lower Suwannee River system that includes Manatee and Fanning Spring/Little Fanning Springs.
2. A Minimum Flow of 130 cfs be established for Manatee Spring for the period of November 1 – April 30. In addition, throughout the year, the historic flow regime will not reduced by more than 10%.
3. A Minimum Level of 2.71 feet (NGVD) in the Fanning spring run be established for Fanning Spring/Little Fanning Spring for the period of November 1 – April 30, to be met 85% of the time. In addition, throughout the year, the historic flow regime for Fanning Spring will not reduced by more than 10%.
4. A Minimum Flow of 7600 cfs median flow be established for the Lower Suwannee River for the period of November 1 – April 30.
5. A Minimum Flow of 6600 cfs median flow be established for the Lower Suwannee River for the period of May 1 – October 31.
6. The District 40B-2 water use permitting Basis of Review should be modified to include additional information required from the applicant to address issues for withdrawals that may impact the medium and higher flows for the Lower Suwannee River including Manatee and Fanning/Little Fanning Springs.