Estuarine River Data for the Ten Thousand Islands Area, Florida, Water Year 2005

By Michael J. Byrne and Eduardo Patino

Prepared as part of the
U.S. Geological Survey Greater Everglades Priority Ecosystem Science Initiative
In cooperation with the South Florida Water Management District

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Conversion Factors, Acronyms, and Abbreviations

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
mile	1.609	kilometer
square mile (mi^2)	2.590	square kilometer (km^2)
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
Fahrenheit (°F)	°C = (°F - 32)/1.8	Celsius (°C)

ADAPS Automated Data Acquisition and Processing System

ADVM Acoustic Doppler Velocity Meter

ADCP Acoustic Doppler Current Profiler

ppt part per thousand

SOFIA South Florida Information Access

TTI Ten Thousand Islands

USGS U.S. Geological Survey

Vertical coordinate information is referenced to an arbitrary datum.

Horizontal coordinate information is referenced to North American Datum of 1983 (NAD 83)

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Abstract

The U.S. Geological Survey collected stream discharge, stage, salinity, and water-temperature data near the mouths of 11 tributaries flowing into the Ten Thousand Islands area of Florida from October 2004 to June 2005. Maximum positive discharge from Barron River and Faka Union River was 6,000 ft^3/s and 3,200 ft^3/s, respectively; no other tributary exceeded 2,600 ft^3/s. Salinity variation was greatest at Barron River and Faka Union River, ranging from 2 to 37 ppt, and from 3 to 34 ppt, respectively. Salinity maximums were greatest at Wood River and Little Wood River, each exceeding 40 ppt. All data were collected prior to the commencement of the Picayune Strand Restoration Project, which is designed to establish a more natural flow regime to the tributaries of the Ten Thousand Islands area. The 15-minute time series data are available online at *http://sofia.usgs.gov/exchange/dehydrology.html*

Introduction

The Ten Thousand Islands area (TTI) is an estuary that encompasses the northwestern section of Everglades National Park and all of the Ten Thousand Island National Wildlife Refuge (fig. 1). Over two-thirds of this estuary is composed of a mangrove forest, making it part of the largest mangrove community in the United States (U.S. Fish and Wildlife Service, 1999). Mangroves are salt-tolerant trees that prevent erosion and trap sediment by impeding water flow. Mangrove trees and oysters are considered important ecosystem components (Savarese and Volety, 2001) of the TTI area, because they help sustain the ecological structure and function of the estuary by providing food, living space, and foraging sites for other organisms in the estuary. The mangrove and oyster communities depend on freshwater discharge from the tributaries to help regulate the salinity levels in the estuary.

Channelization of river beds and flow obstruction by road improvements have changed the quantity, timing, and distribution of freshwater flows to the marshes and estuaries of the TTI area. Barron River Canal and Faka Union Canal are part of two canal systems that have increased freshwater inflows and nutrient loads to downstream bays and reduced their salinities. Consequently, marshes and estuarine bays adjacent to these two canal systems have experienced reduced freshwater inflows and increased salinities.

Overland sheetflow through the wetlands of the Picayune Strand, the headwaters of the TTI area (fig. 1), was altered by the construction of 48 mi. of canals and 273 mi of roads. The canals and roads were built for a community (Southern Golden Gate Estates) that was planned but never constructed, and efforts are underway to restore the predevelopment hydrology to the area (Browder and Wang, 1987). Restoration efforts are underway to return the Picayune Strand to predevelopment conditions. The Picayune Strand Restoration Project (U.S. Army Corps of Engineers, 2004) has been initiated to restore predevelopment hydrology of the TTI area and provide flood protection to the local communities by plugging canals, degrading roads, and building protective levees and hydrologic pump stations to improve overland sheetflow. As part of this project, nine culverts were added along US 41 to increase the spread of freshwater discharge to downstream areas.

In 2004-05, the U.S. Geological Survey (USGS), in cooperation with the South Florida Water Management District and as part of the USGS Greater Everglades Priority Ecosystem Science Initiative, measured discharge, stage, salinity, and water temperature in the tributaries of the TTI area. All data for this effort were collected prior to the commencement of the Picayune Strand Restoration Project. These baseline data will be used to determine the success of the restoration.

Purpose and Scope

The purpose of this report is to present the discharge, stage, salinity and water-temperature data collected near the mouths of eleven tributaries of the TTI area from October 2004 to June 2005. The report summarizes the methods of data collection, processing, and editing, as well as the computation of discharge. Presented in detail are the analyses made to establish the relations between index velocity (and in some cases, gage height) and mean water velocity for the computation of discharge at each of the sites.

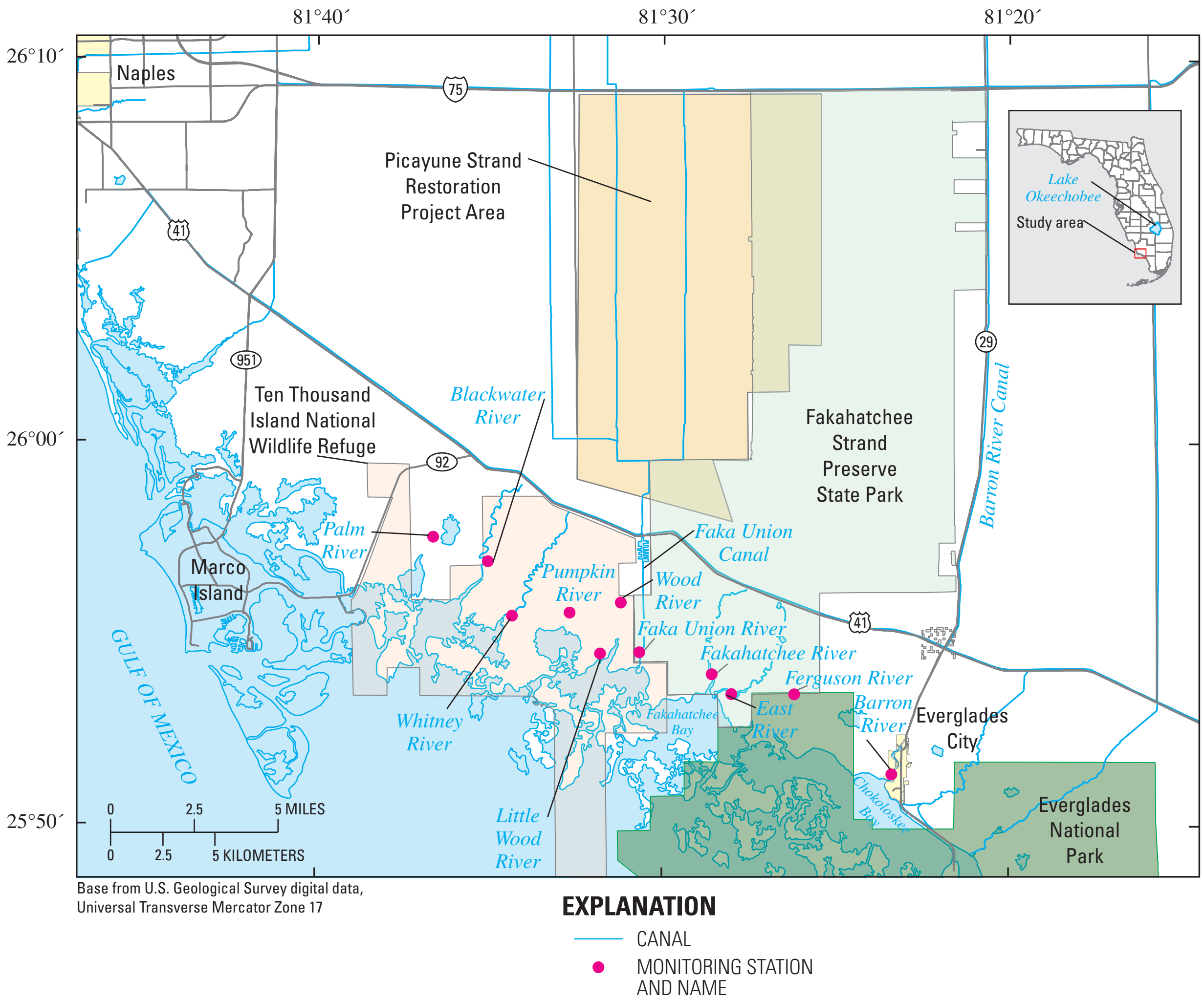

Figure 1. Ten Thousand Island study area and location of the instrumented sites.

Description of Study Area

The TTI area extends about 20 mi from County Road 92 to Everglades City, and is about 5 mi wide from the outer islands to US 41 (fig. 1). Inhabitants have relied on this estuary for its diverse marine fauna for thousands of years as evidenced by one of the ancient shell middens found along Pumpkin River. The marine fauna of the TTI area are dependent on a mixture of freshwater, from numerous tributaries, and saltwater to maintain a natural range in salinity.

Faka Union Canal and Barron River Canal currently convey most of the freshwater to the TTI area. Most of the land currently drains into Faka Union Canal and Barron River Canal (U.S. Army Corps of Engineers, 2004), which has substantially reduced salinity and increased nutrient loads in Faka Union Bay and Chokoloskee Bay, respectively. Numerous tributaries provide inflows the TTI area, and 11 of these were measured as a part of this study. The width and depth of each tributary, as measured at the monitoring station, is shown in table 1.

Acknowledgments

Many people assisted in the collection of data for this project. USGS employees Lars Soderqvist, Craig Thompson, Clinton Hittle, Jessica Gabaldon, Jeff Woods, Marc Stewart and Mark Zucker helped install sites, collect data and make discharge measurements. The authors thank USGS volunteer for science Germaine Ploos for making a number of discharge measurements with the USGS staff. Lars Soderqvist and Craig Thompson quality assured the data and created discharge ratings.

Table 1. Location of Ten Thousand Island monitoring stations.

[Horizontal coordinate information referenced to the North American Datum of 1983; ddmmss, degrees, minutes and seconds]

Site Name	USGS site identification number	Latitude (ddmmss)	Longitude (ddmmss)	Channel width and depth at station (feet)	Period of record
Barron River	255122080232100	255122	0812321	250 × 12	Oct. 2004 - May 2005
Blackwater River	255654081350200	255654	0813502	100 × 7	Oct. 2004 - May 2005
East River	255327081275900	255327	0812759	350 × 5	Oct. 2004 - Mar. 2005
Faka Union River	255432081303900	255432	0813039	200 × 8	Oct. 2004 - Jan. 2005
Fakahatchee River	255358081283300	255358	0812833	320 × 5	Oct. 2004 - Jan. 2005
Ferguson River	255327081261000	255327	0812610	45 × 7	Oct. 2004 - Feb. 2005
Little Wood River	255443081314700	255430	0813147	140 × 5	Oct. 2004 - June 2005
Palm River	255732081363700	255732	0813637	140 × 8	Oct. 2004 - Mar. 2005
Pumpkin River	255534081324000	255534	0813240	70 × 5	Oct. 2004 - Mar. 2005
Whitney River	255529081342000	255529	0813420	150 × 5	Oct. 2004 - Mar. 2005
Wood River	255550081311100	255550	0813111	70 × 8	Oct. 2004 - June 2005

Methods of Investigation

The following sections describe the methods and procedures used to measure index velocity, stage, salinity and water-temperature data, and the methodology used to compute discharge at the tributaries. The data were recorded in 11 tributaries of the TTI area from October 2004 to June 2005 (table 1).

Field Data Collection

Hydrologic monitoring stations were constructed in water 3-4 ft deep near the banks and mouths of the tributaries. Data collected at monitoring stations included index velocity, stage, specific conductance (for salinity calculations), and water temperature. The Ferguson River station monitoring setup shown in figure 2 is typical of those used at all sites. This was the only station located upstream near the freshwater marsh-estuarine transition zone.

Figure 2. Monitoring station site at Ferguson River near bank of red mangroves. Depth of instrumentation is 4 feet.

Discharge measurements were made over a range flow conditions to develop velocity calibration ratings. Index velocity is defined as the water velocity measured by an *in situ* acoustic Doppler velocity meter (ADVM), and is an accurate indicator of mean stream velocity. All parameter data were recorded at 15-minute intervals and stored internally.

Stage data were recorded to monitor water depth and to calculate stage-dependent cross-sectional areas at all monitoring stations. Stage was measured with a submersible pressure sensor or up-looking acoustic transducer and referenced to a local (arbitrary) datum. Accuracy of stage values is defined as 0.01 ft (Sontek, undated; Yellow Springs Incorporated, undated). Index velocity was measured with an acoustic Doppler velocity meter (ADVM). The accuracy of the ADVM instrument is defined as ± 1 percent or 0.016 ft/s (Sontek, undated).

Conductance and water-temperature data were recorded at all monitoring stations, and salinity was calculated from these data using default algorithms (Greenberg, 1995). Salinity accuracy is defined as ± 1 percent, or 0.1 parts per thousand (ppt). Water temperature accuracy is defined as ± 0.15 percent and recorded in degrees Celsius (Yellow Springs Incorporated, undated). Protocols for the use, maintenance, and calibration of water-quality sensors are described in Wagner and others (2000).

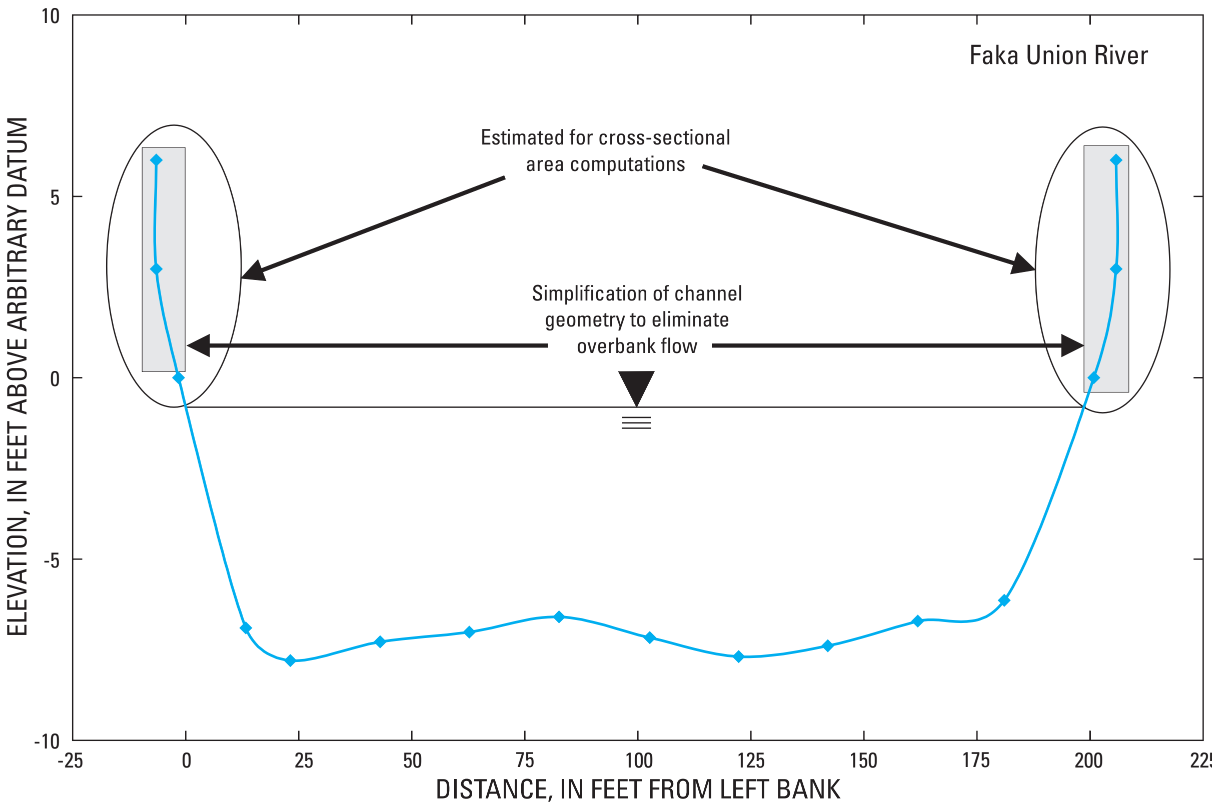

Figure 3. Cross-sectional area of the Faka Union River.

Boat mounted acoustic Doppler velocity profilers (ADCPs) were used to measure discharge at all 11 monitoring stations. Discharge and flow direction were determined from information provided by the ADCP and computer software. The mean velocity of each measured stream was then calculated by dividing the total discharge value by the cross-sectional area corresponding to the stage value at the time of measurement (fig. 3). Continuous discharge data are calculated using index velocity and cross-sectional area ratings described later.

Computation of Continuous Discharge

Continuous discharge data were computed using established cross-sectional area and velocity ratings, applied to time-series data of index velocity and stage. Both types of ratings and the computation of continuous discharge data are described in the following sections.

Stage-Area Ratings

ADCP channel-depth soundings at specific distances across the width of each stream were used with simultaneous stage readings to develop relations between stage and total cross-sectional area. Area was computed with stage as the dependent variable using an area rating table stored in the USGS data base Automated Data Processing System (ADAPS).

Overbank flow may occur during extreme high water conditions, extending the actual flow cross-section beyond the main channel of the stream. To maintain consistency and accuracy in calculated discharge values, a fictitious “wall” was placed about 5 ft from the bank edges, as shown in figure 3. Calculated discharge using these cross-sectional areas, therefore, only represents flow through the main stream channel, with overbank flow treated as a separate body of water not described within the scope of this study.

Index Velocity Ratings and Discharge Relations

Index velocity ratings are defined as established relations between the mean water velocity for each stream, obtained from ADCP measurements, and the index velocity data recorded simultaneously by the ADVM. Multivariate regression analyses are performed to determine relations between index velocity and mean stream velocity, and the best-fit equation is then used for discharge computations. The regression equations are evaluated based on the coefficient of determination (R^2), which is a measure of the explained variability in calculated values (dependent variable).

The following basic equation model (Patino and Ockerman, 1997; Hittle and others, 2001) was used to determine the velocity relations for nine of the monitoring stations within the TTI area:

$$V = V_x (X_i + Y_i H) + C \, , \tag{1}$$

where

V is mean water velocity (from ADCP measurements),

V_x is the acoustic index velocity (measured by *in situ* ADVM); the subscript indicates water velocity parallel to river banks,

X_i is a regression coefficient,

Y_i is a regression coefficient associated with stage,

H is stage, and

C is the intercept or constant.

Depending on the significance of stage within the equation model described above, two forms of the equation model (the basic form just shown and a simpler form) were used to calculate discharge for the tributaries flowing into estuaries of the TTI area.

Monitoring sites at seven tributaries used the simplest form of the equation model, because acoustic index velocity was the only significant variable necessary to describe the mean velocity of the stream. For these streams, equation 1 takes the following form:

$$V = V_x X_i + C \, . \tag{2}$$

The calibrated forms of equation 2 for each of the seven sites are shown in figure 4.

The East River and Faka Union River velocity ratings include stage as a predictive variable and use the basic form of equation 1 shown earlier (fig. 5). The calibrated forms of equation 1 for East River and Faka Union River are as follows:

Monitoring site	Equation	Coefficient of determination (R^2)
East River	$V = V_i (0.953 + 0.099H) + 0.115$	0.986
Faka Union River	$V = V_x (1.75 - 0.36H) - 0.026$	0.979

The equations for Barron River include additional variables and take different forms based on flow direction. For positive stream velocity (ebb tide) and negative stream velocity (flood tide), the Barron River equation has the following respective forms:

$$V = V_y Z_i + V_5 T_i + Y_i H + C \tag{3}$$

$$V = V_x X_i + V_y Z_i + V_5 T_i + Y_i H + C \, , \tag{4}$$

where

V_y is the acoustic index velocity (measured by *in situ* ADVM); the subscript indicates water velocity perpendicular to river bank,

V_5 is the acoustic index velocity (measured by *in situ* ADVM); the subscript indicates a subsection of the x water velocity,

Z_i is a regression coefficient associated with velocity perpendicular to river bank, and

T_i is a regression coefficient associated with subsection of the x water velocity.

The calibrated forms of equations 4 and 5 are as follows:

Monitoring site (flow direction)	Equation	Coefficient of determination (R^2)
Barron River (positive direction)	$V = -0.81V_y + 0.92V_5 - 0.67H + 1.33$	0.95
Barron River (negative direction)	$V = 0.58V_x - 0.48V_y + 0.28V_5 - 0.21H + 0.44$	0.96

Palm River discharge was estimated using data from Blackwater River due to problems with data collected at the Palm River station. To develop the discharge relation for Palm River (fig. 6), regression analyses were performed using measured discharge data at Palm River and computed discharge data from Blackwater River.

Hydrologic Conditions—Discharge, Tidal Fluctuations, and Salinity

As noted earlier, hydrologic conditions in the TTI area are largely controlled by Barron River Canal and Faka Union Canal, which respectively drain into Barron River and Faka Union River. The maximum positive discharge measured at Barron River and Faka Union River was 6,000 ft^3/s and 3,200 ft^3/s, respectively; discharge at all other tributaries was less than 2,600 ft^3/s (fig. 7 and table 2). The general monthly tidal magnitude was greatest at Barron River (4,000 ft^3/s) followed by Little Wood River (2,000 ft^3/s). Monthly tidal magnitudes were lowest at Wood River and Whitney River, each less than 50 ft^3/s. The period of data collection primarily spans the dry season, and discharge ranges presented herein do not include wet-season discharge magnitudes which are typically higher. Consequently, the ranges presented do not accurately represent the extent of seasonal flows at any of these stations.

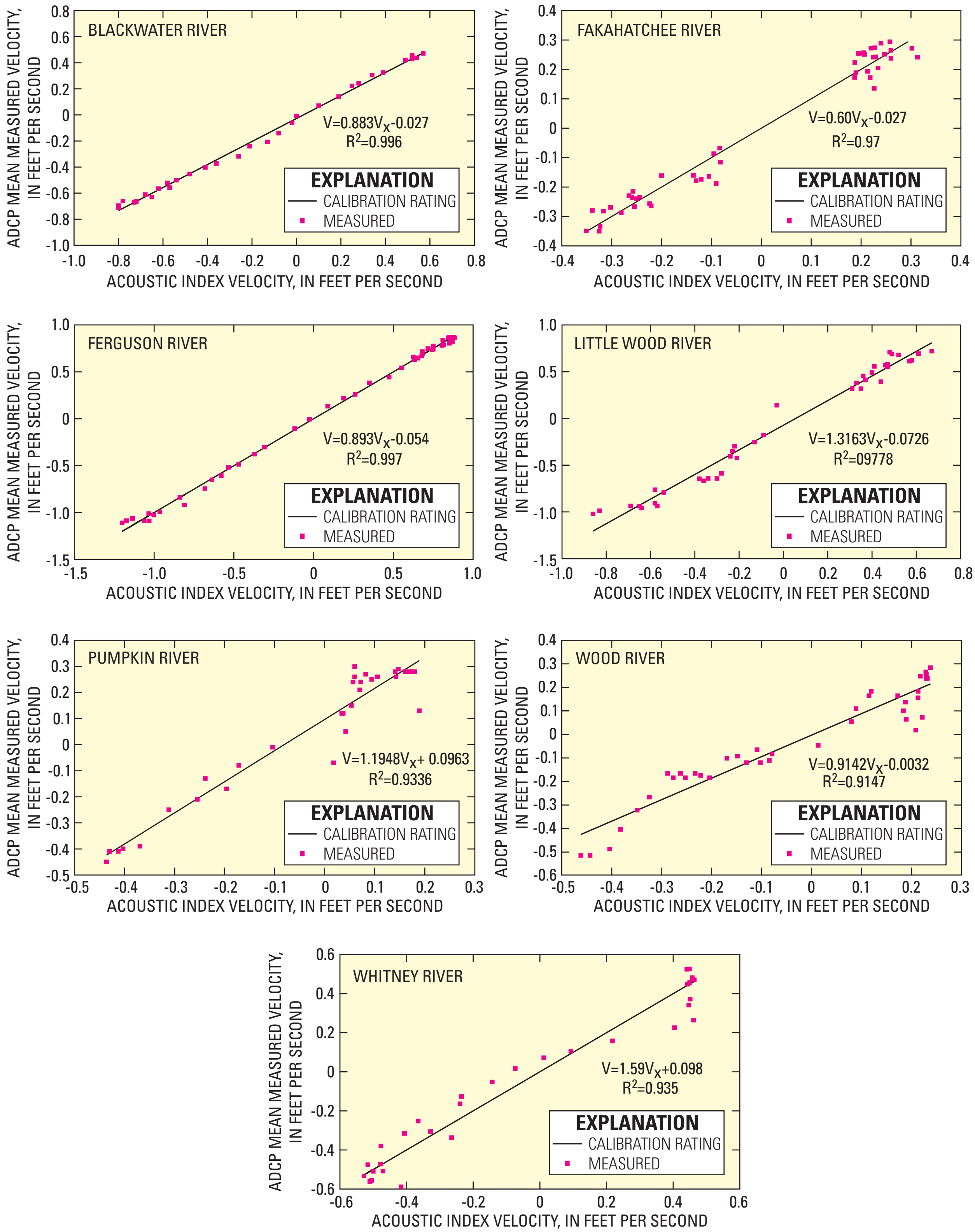

Figure 4. Velocity relations for the Blackwater River, Fakahatchee River, Ferguson River, Little Wood River, Wood River, Pumpkin River, and Whitney River monitoring stations. R^2 is coefficient of determination.

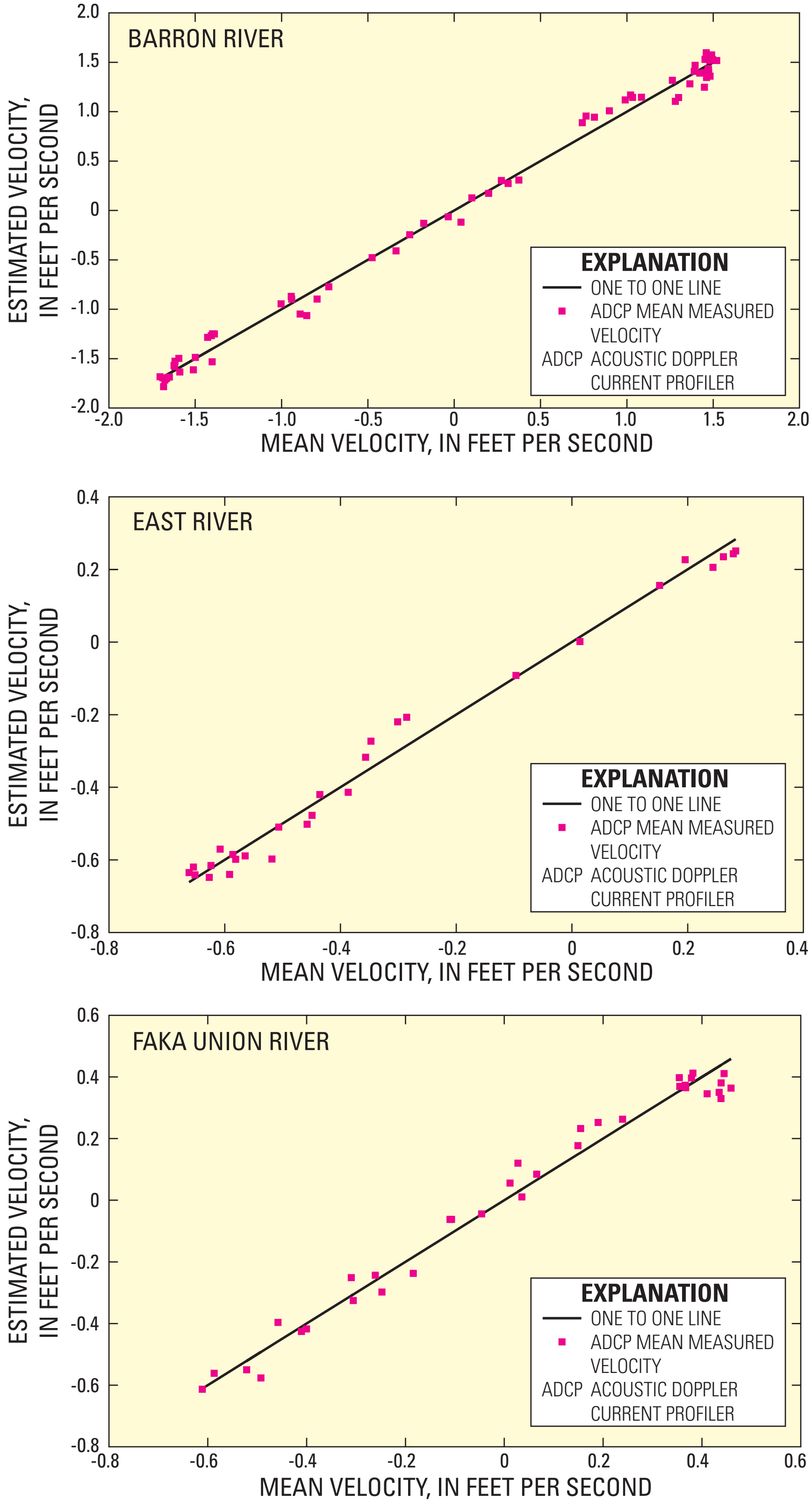

Figure 5. Mean measured to estimated velocity relations for the Barron River, East River, and Faka Union River monitoring stations. Velocity relation models for these sites incorporate stage and are shown in the text.

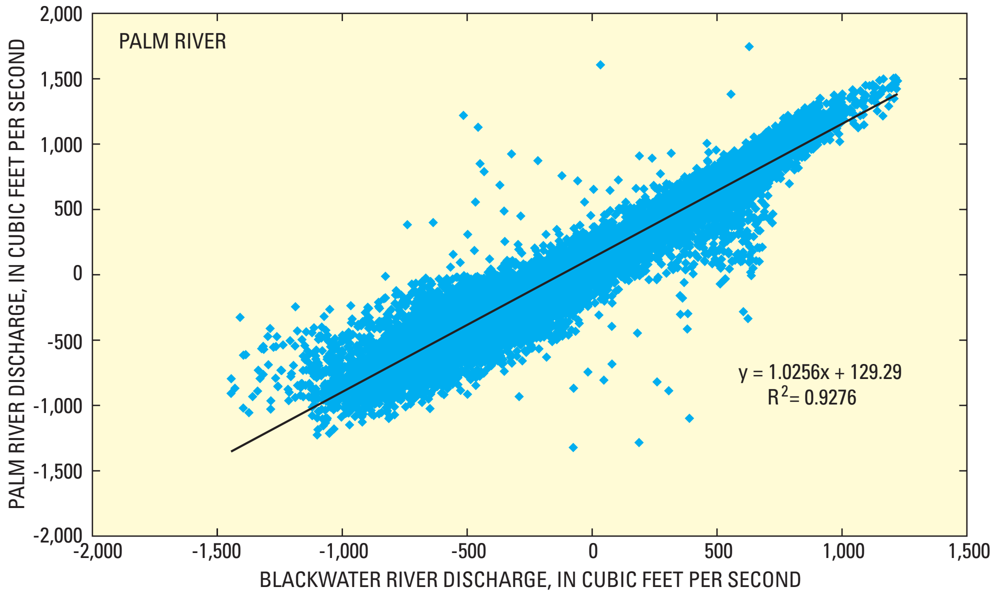

Figure 6. Discharge relation for Palm River, based on measured discharge at Palm River and computed discharge at Blackwater River. R^2 is coefficient of determination.

Table 2. Discharge and salinity ranges for the tributaries of the Ten Thousand Islands area.

[ft^3/s, cubic foot per second; ppt, part per thousand]

Site name	Discharge		Salinity	
	Minimum (ft^3/s)	Maximum (ft^3/s)	Minimum (ppt)	Maximum (ppt)
Barron River	-5,600	6,000	2	37
Blackwater River	-1,400	1,200	26	36
East River	-8,000	2,600	7	37
Faka Union River	-4,500	3,200	5	34
Fakahatchee River	-1,500	410	12	37
Ferguson River	-760	570	9	36
Little Wood River	-3,200	2,900	21	43
Palm River	-1,350	1,400	22	36
Pumpkin River	-6,100	2,600	29	38
Whitney River	-1,600	830	23	36
Wood River	-1,200	520	19	40

As shown in table 2, salinity ranges were greatest at Barron River (2-37 ppt) and Faka Union River (3-34 ppt). Salinity maximums were greatest at Little Wood River and Wood River, each exceeding 40 ppt. Barron River, East River, Faka Union River, and Ferguson River experienced the lowest salinity minimums (table 2). The median salinity typically was lower at Ferguson River than at all other monitored streams (fig. 8). This pattern may be attributed to location of the monitoring station, which is further into the freshwater marsh-estuarine transition zone than the other stations. Monthly gage height ranges were similar for all streams, averaging about 4 ft (fig. 9). Typical daily tidal ranges for all streams were 1-2 ft.

Data Availability

The quality-checked and edited 15-minute discharge, stage, salinity and water-temperature data documented in this report can be downloaded from the data exchange page of the USGS South Florida Information Access (SOFIA) website: *http://sofia.usgs.gov/exchange/dehydrology.html*.

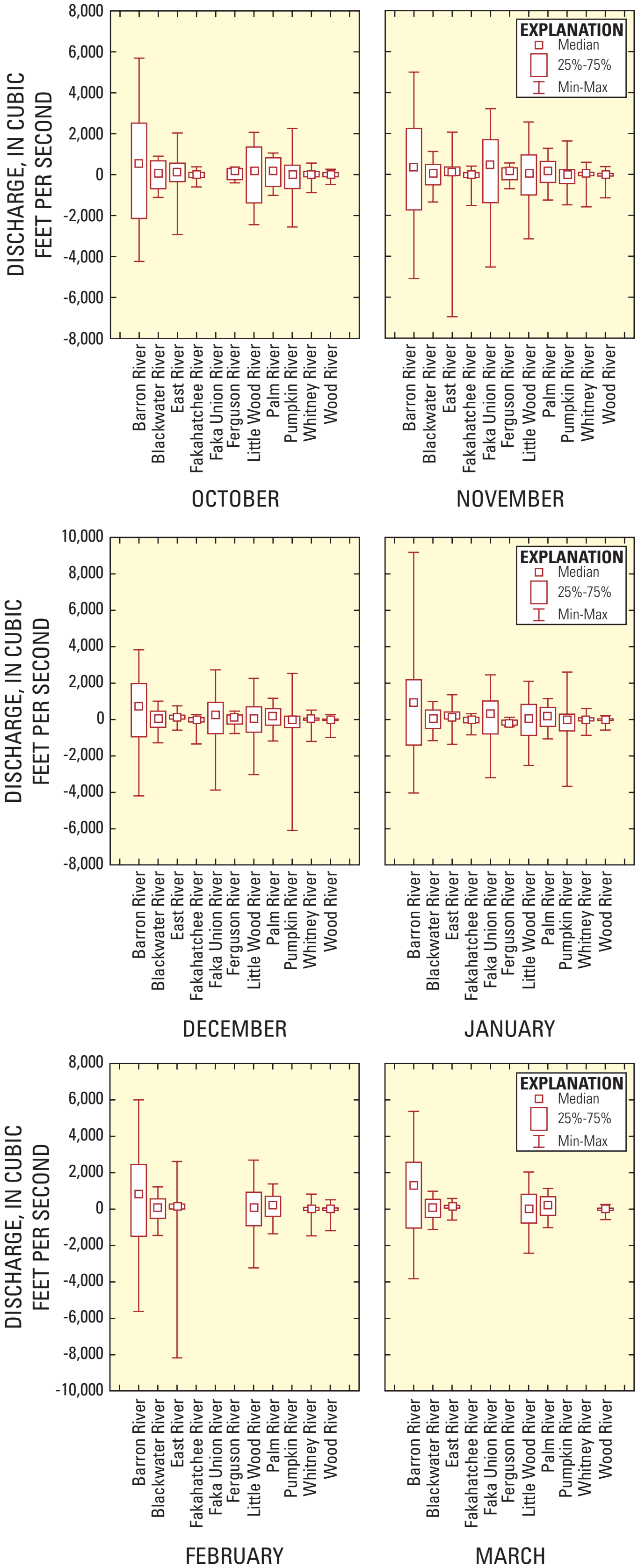

Figure 7. Discharge for the tributaries from October 2004 to March 2005.

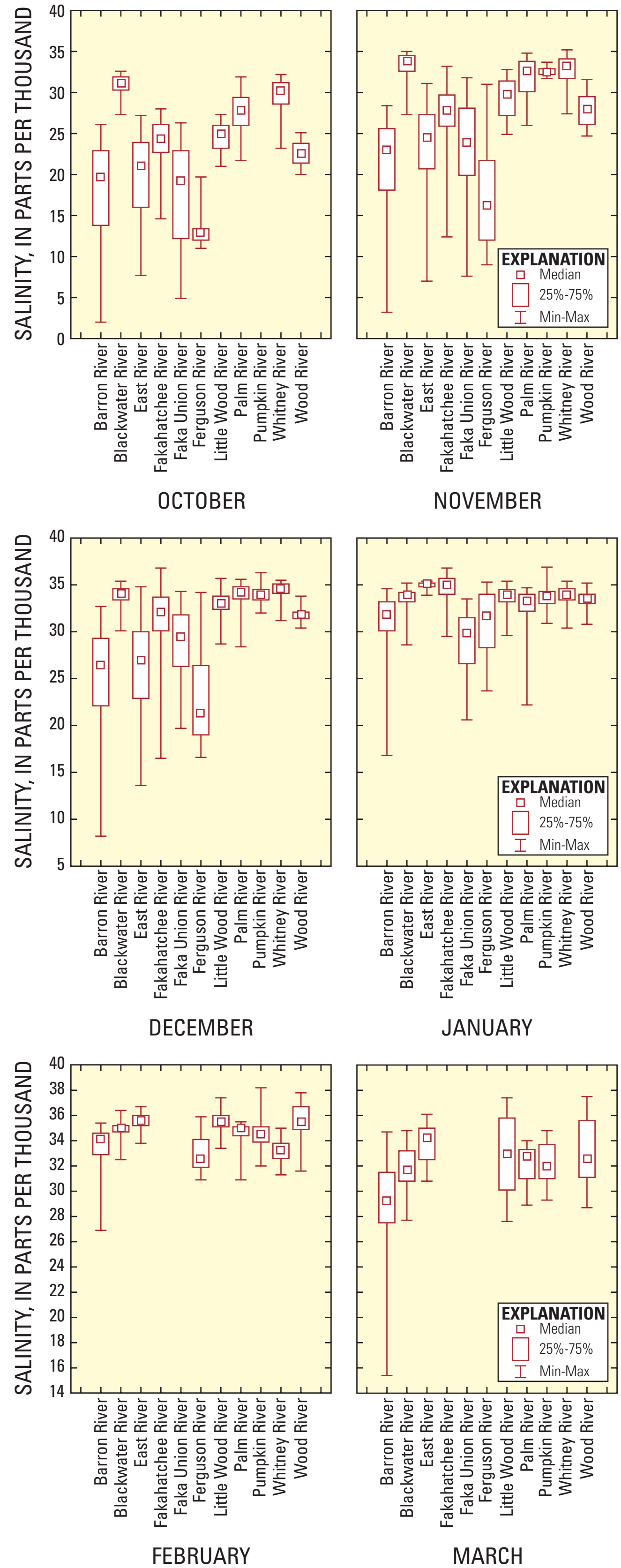

Figure 8. Salinity for the tributaries from October 2004 to March 2005.

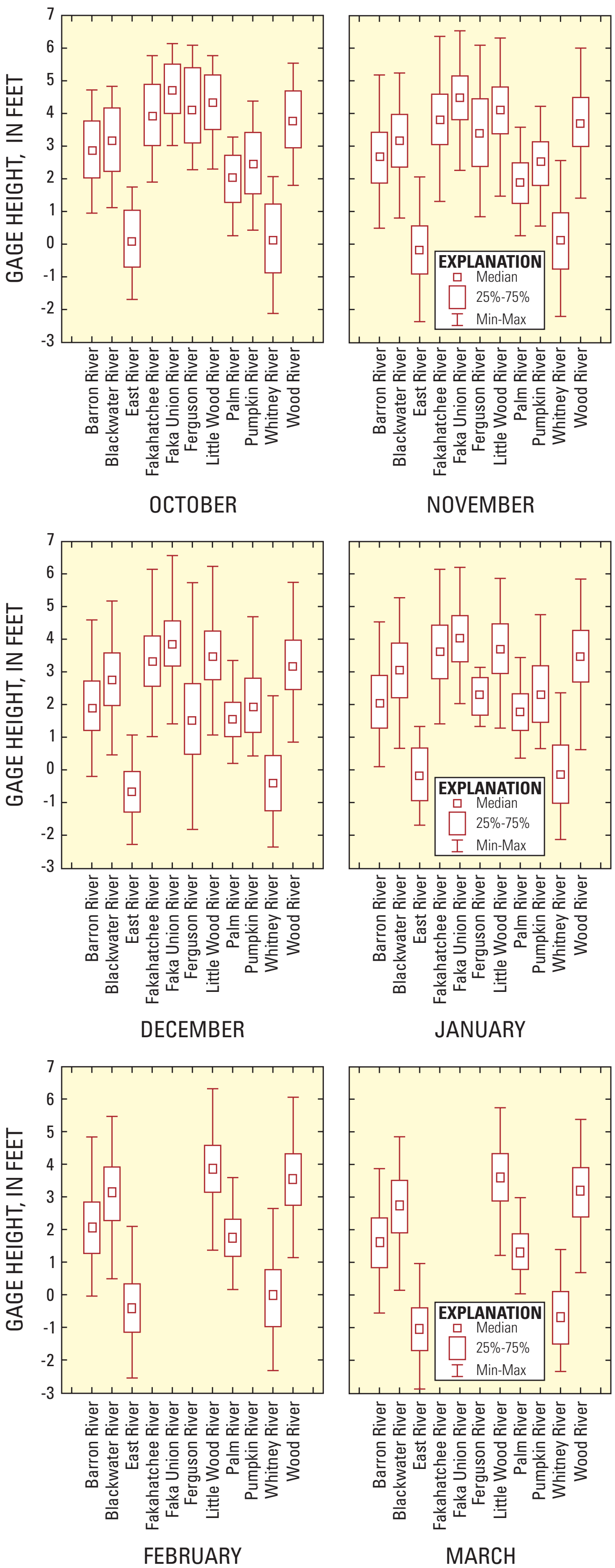

Figure 9. Gage height for the tributaries from October 2004 to March 2005.

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