# FRESHWATER SUPPLY POTENTIAL OF THE ATLANTIC INTRACOASTAL WATERWAY NEAR MYRTLE BEACH, SOUTH CAROLINA

By William J. Carswell, Jr., Curtis L. Sanders, Jr., and Dale M. Johnson

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U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 88-4066

Prepared in cooperation with the

CITY OF MYRTLE BEACH

CITY OF NORTH MYRTLE BEACH

GEORGETOWN COUNTY WATER AND SEWER DISTRICT

GRAND STRAND WATER AND SEWER AUTHORITY

MYRTLE BEACH AIR FORCE BASE

Columbia, South Carolina

1988

DEPARTMENT OF THE INTERIOR

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## ABSTRACT

The demand for freshwater in Horry and Georgetown Counties in northeastern South Carolina is increasing steadily with population growth and development. In some parts of the Myrtle Beach area, ground-water levels in production wells have been lowered to depths greater than 150 feet below sea level. As part of an investigation to find alternative sources of freshwater, the Atlantic Intracoastal Waterway (AICW) in the vicinity of Myrtle Beach was evaluated as a potential water supply. Freshwater entering the AICW from the major tributaries is adequate for drinking water purposes if treated. The city of Myrtle Beach proposed construction of a surface water treatment plant with its intakes located in the vicinity of 10th Avenue North at AICW mile 363.3.

An unsteady-flow model was used to simulate the daily discharge in the AICW from October 1981 to September 1986 to assess the likelihood of saltwater intrusion into the vicinity of the proposed intakes during periods of low tributary inflow. A MOVE.1 regression equation was developed to relate the average 7-day discharge in the AICW to the 7-day discharge of four major tributary streams. Streamflow records (climatic-years 1954-1986) of the tributary streams and the 7-day discharge regression equation were used to develop a 7-day low-flow frequency curve for the AICW. The estimate of the $7Q_{10}$ (7-day, 10-year low flow) in the AICW is 192 cubic feet per second.

The record of the tributary streams and the relation of 7-day average discharges in the AICW to the 7-day discharges of the tributary streams were also used to simulate 7-day average discharges for the AICW for each day of the 1954-86 period of record. A flow duration hydrograph of these simulated discharges indicated that a lower water supply can be expected during the months of August through October.

A relation was established between the mile position of the saltwater-freshwater interface and specific conductance recorded at Vereen's Marina near S.C. Highway 9. The relation was used with specific conductance data for 1982-85 to synthesize maximum daily inland migrations of the interface for the period. A relation was then established between synthesized 7-day averages of the position of the maximum inland migration of the saltwater-freshwater interface and the 7-day average discharges of the AICW.

On the basis of this relation, the location of the saltwater-freshwater interface for the $7Q_{10}$ discharge is estimated to be at mile 355.5. If a steady-state discharge of 45 cubic feet per second is withdrawn from the

AICW during the period the $7Q_{10}$ discharge is experienced, the saltwater-freshwater interface could move upstream to mile 356.2, which is 7.1 miles seaward of the proposed withdrawal location at mile 363.3. Thus, the investigation indicated that the AICW can provide a reliable supply of fresh water at the proposed withdrawal location in the vicinity of Myrtle Beach, even during the $7Q_{10}$ low flow event.

## INTRODUCTION

The demand for freshwater near the coast in Horry and Georgetown Counties, South Carolina, has been increasing steadily with population growth and development. Maximum freshwater usage in 1982 was approximately 25 Mgal/d (million gallons per day) and is projected to be approximately 60 Mgal/d by the year 2000 (CH2M Hill, 1984). In general most water-supply development has centered on the deep Black Creek aquifer with only minor development of surface water and the shallow ground-water aquifer. Preferential development of ground water has been due in part to its abundance and lower cost, especially for small isolated communities (Zack, 1977).

Ground-water development has been limited to some extent by water quality. Water from sands within the major aquifer, the Black Creek system, contains concentrations of fluoride that exceed the maximum concentration limit for drinking water imposed by the U.S. Environmental Protection Agency and endorsed by the South Carolina Department of Health and Environmental Control (SCDHEC, 1981). In some areas, water from the water-table aquifer contains objectionable concentrations of iron greater than the secondary contaminant level for iron used by SCDHEC (1981).

In some areas of Horry and Georgetown Counties the ground-water resource is threatened because of improperly constructed and abandoned wells that provide an avenue for saltwater contamination. In some areas ground-water levels have been excessively lowered owing, in part, to well interference from pumpage. In the Myrtle Beach area, water levels in production wells have been drawn down to depths greater than 150 feet below sea level (Aucott and Speiran, 1985).

The potential of shallow aquifers in the immediate Myrtle Beach area to supply adequate quantities of potable water is limited (Speiran and Lichtler, 1986), and the chemical quality and excessive drawdown of the deeper Black Creek aquifer make its future reliability as the principal source of freshwater questionable. The freshwater flows in the Atlantic Intracoastal Waterway (AICW) may provide a reliable permanent source of potable water for the Myrtle Beach area.

In 1981, the U.S. Geological Survey, in cooperation with the Georgetown County Water and Sewer District, the Grand Strand Water and Sewer Authority, the Cities of Myrtle Beach and North Myrtle Beach, and the Myrtle Beach Air Force Base, initiated a study to determine the freshwater supply potential of the AICW. The study was concentrated in the vicinity of Myrtle Beach. A reconnaissance of the AICW from Bucksport to Little River Inlet by Johnson (1977) indicated that the freshwater upstream from the saltwater-freshwater interface was probably of quality suitable for most uses. An analysis by

PRC Consoer Townsend, Inc. (1982) of the freshwater upstream from the saltwater-freshwater interface indicated that the freshwater could be treated and used for drinking water.

## Purpose and Scope

This report describes the results of a study to evaluate the freshwater supply potential of the AICW in the vicinity of Myrtle Beach. The study includes calculation of daily discharge, estimating the magnitude and frequency of low flows, and determining the effects of water-supply withdrawals on the position of the saltwater-freshwater interface in the AICW in the vicinity of Myrtle Beach.

## Description of Study Area

The study area includes much of eastern South Carolina, but is centered on that reach of the AICW from Myrtle Beach to near Little River, South Carolina (fig. 1). Extensive swamps border much of the near-coast part of the major streams in the Pee Dee River basin. The flow system near the coast is very complex (fig. 2). The majority of the flow of the Pee Dee River enters the AICW through Bull Creek. Freshwater flows both north and south in the AICW and discharges to the Atlantic Ocean at Winyah Bay and Little River Inlet.

The drainage area of the Pee Dee River basin is approximately 18,500 mi$^2$. Based on data from streamflow gaging stations on the Pee Dee River and major tributaries, the average discharge for the basin is in excess of 15,000 ft$^3$/s (cubic feet per second) (table 1).

Table 1.--Gaging stations on major tributary streams of the Atlantic Intracoastal Waterway in the vicinity of Myrtle Beach, South Carolina

| Station number | Station name | Drainage area (square miles) | Average discharge (cubic feet per second) |
|---|---|---|---|
| 02110500 | Waccamaw River near Longs | 1,110 | 1,220 |
| 02131000 | Pee Dee River at Pee Dee | 8,830 | 9,870 |
| 02132000 | Lynches River at Effingham | 1,030 | 1,040 |
| 02135000 | Little Pee Dee River at Galivants Ferry | 2,790 | 3,200 |

The AICW in the study reach is basically a canal with well-defined banks that has been excavated to a minimum of 12 feet below mean low tide. The flow in the AICW near Myrtle Beach is governed by the flow of four major streams (see fig. 1) in the Pee Dee River basin (the Waccamaw, Pee Dee, Little Pee Dee, and Lynches Rivers) and by Atlantic Ocean tidal fluctuations.

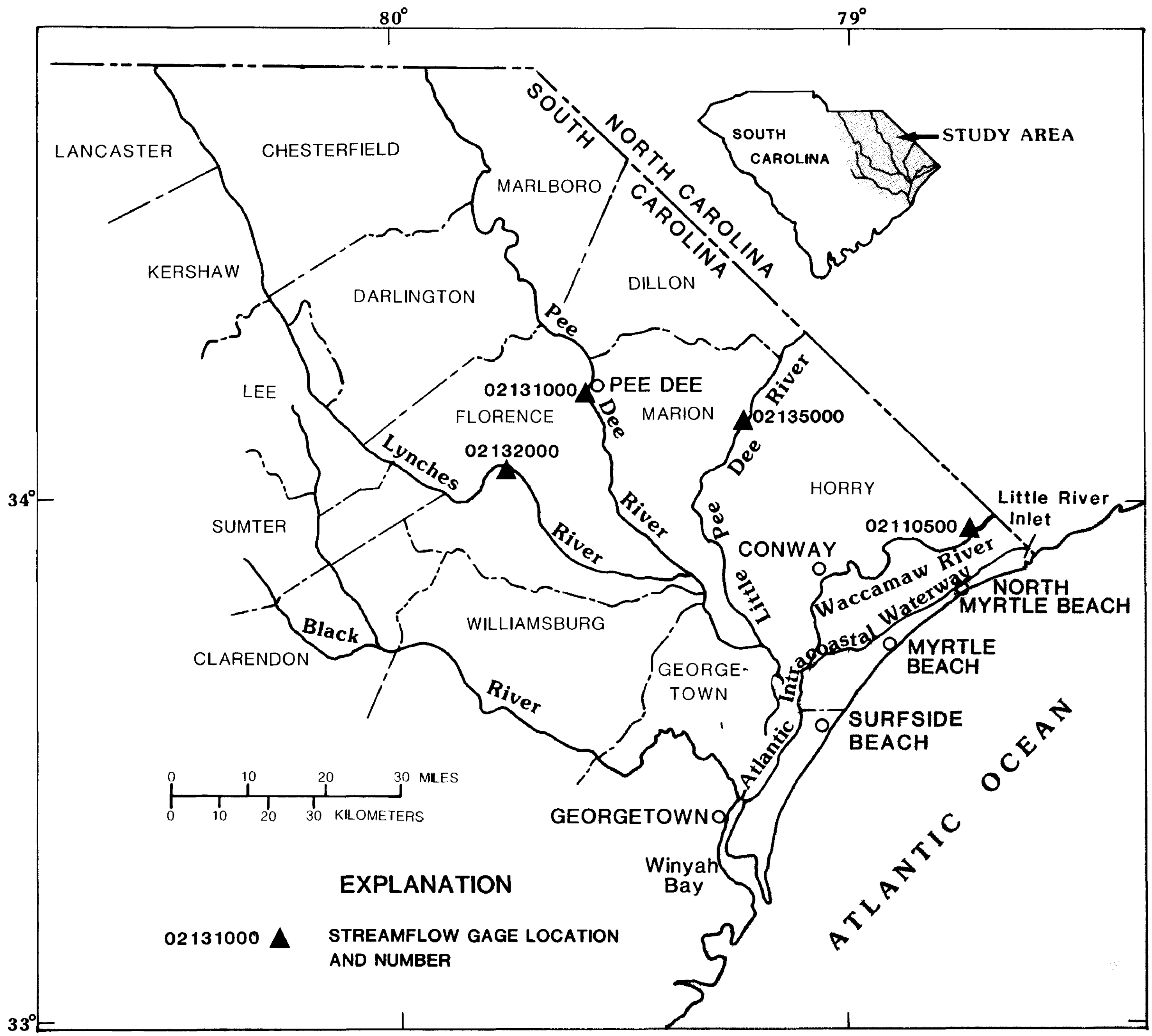


Figure 1.--Location of study area and streamflow gaging stations on major tributaries.

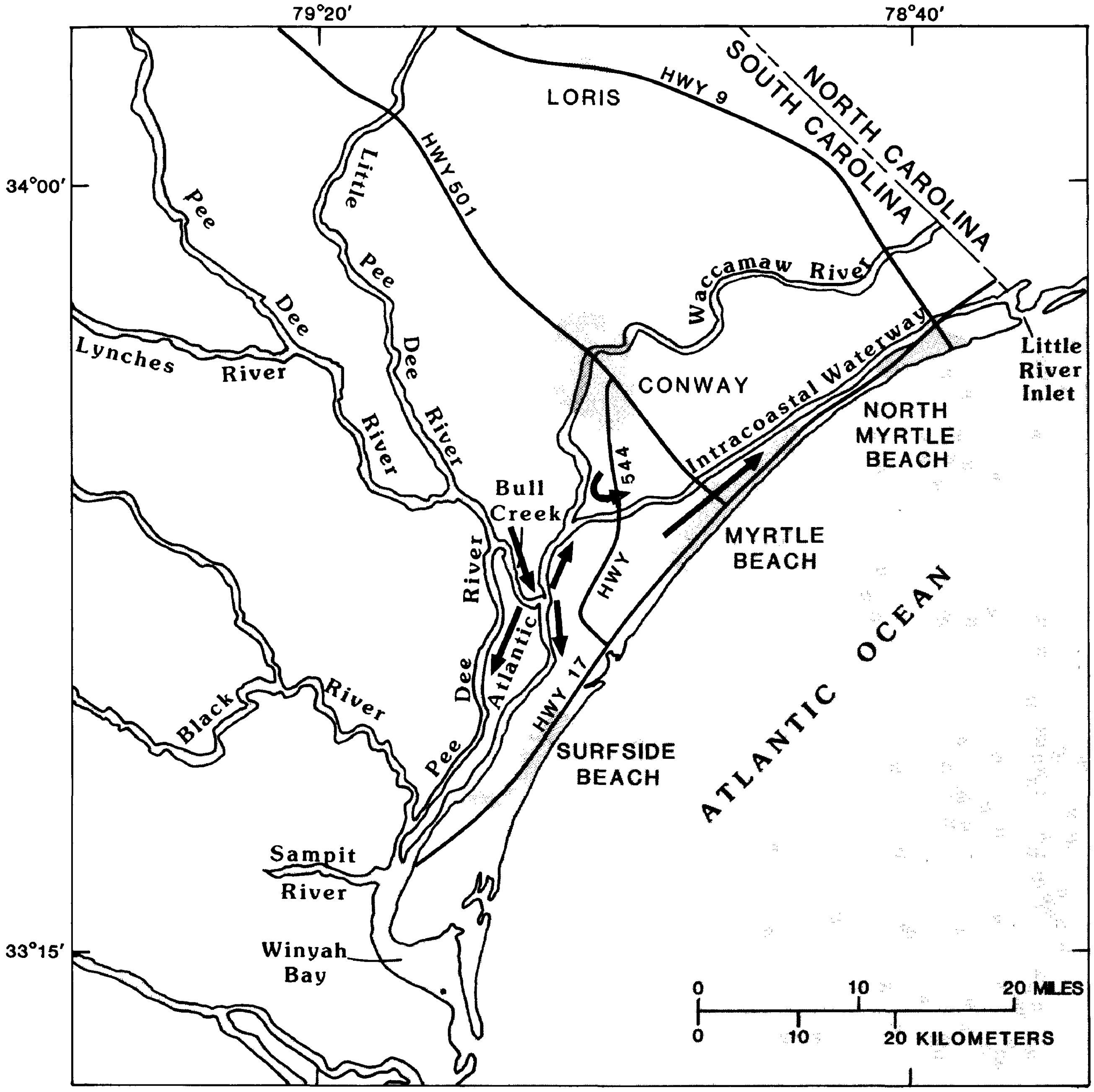


Figure 2.--Generalized direction (indicated by large arrows) of daily mean discharge in the flow system near the coast.

Saltwater intrusion in the northern reach of the AICW in the study area is caused by southerly movement of saltwater from the Atlantic Ocean via the Little River. Vertical stratification caused by density differences between the saltwater and freshwater generally results in a saltwater-freshwater interface when freshwater inflow is high, as shown in figure 3. Because of its greater density, saltwater moves along the channel bottom, whereas the less dense freshwater tends to flow over the saltwater. The interface between freshwater and saltwater may be well defined or may exist as a zone of gradual transition. Even where the interface is well defined, some mixing between freshwater and saltwater takes place because of turbulence caused by channel obstructions, wind, or other factors.

The extent of saltwater intrusion and the type of interface that exists depends on several factors. Among these are tides, currents, freshwater discharge, sea level, winds, depth, and configuration of the estuary. The primary factors affecting saltwater intrusion and type of interface in the northern reach of the AICW in the study area are freshwater inflow and tide stage. The first factor, downstream (northerly) flow of freshwater, tends to push intruding saltwater downstream. Saltwater encroachment is least during periods of high freshwater flow. The second factor affecting location of the saltwater wedge is the tide stage. When tide stage is higher than stream stage, the saltwater migrates upstream. After the peak of the tide cycle, upstream movement of the saltwater slows and eventually ceases. Saltwater movement reverses as the tide stage begins to fall. This pattern of movement of the saltwater is repeated with each tide cycle. As a result, salinity in the AICW fluctuates both vertically and longitudinally along the channel.

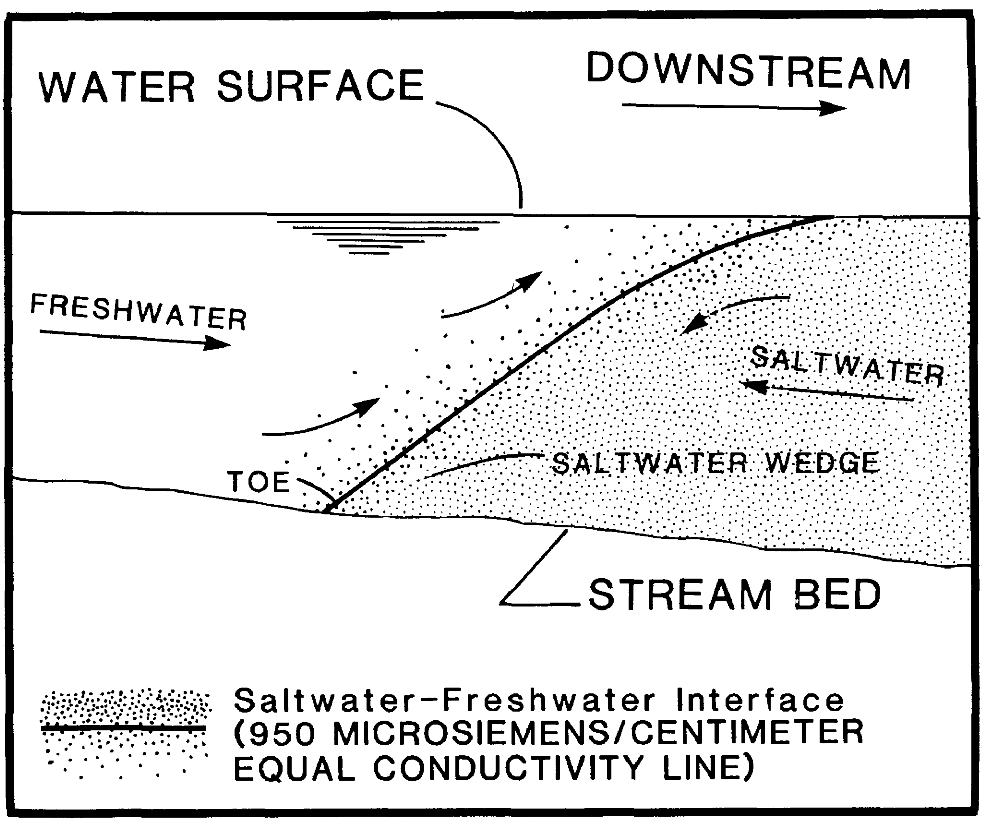


Figure. 3.--Vertical stratification between saltwater and freshwater.

## Data-Collection Network

A data-collection network was designed to monitor changes in water discharge and specific conductance in the AICW. Stage data collection began in October 1981 and was continued as shown in table 2. Stage data, recorded at 15-minute intervals, were collected at four gaging stations and specific conductance data, recorded at 1-hour time intervals, were collected at five locations (fig. 4). The periods of record are given in table 2 for the data-collection locations in the AICW during the 1982-86 water years.

Table 2.--Periods of record for continuous-record data-collection locations on the Atlantic Intracoastal Waterway, 1982-86 water years

| Station number | Station name | River mile | Data available | Period of record |
|---|---|---|---|---|
| -- | Little River | 344.0 | Specific Conductance | June 17, 1982 to Sept. 30, 1983 |
| 02110777 | Highway 9 | 347.3 | Stage | Feb. 18, 1982 to Sept. 30, 1986 |
| | | | Specific Conductance | April 14,1986 to Sept. 30, 1986 |
| 02110730 | Vereen's Marina | 348.5 | Specific Conductance | Feb. 18, 1982 to Sept. 30, 1986 |
| 02110770 | North Myrtle Beach Airport | 351.4 | Specific Conductance | Apr. 26, 1982 to Sept. 30. 1983 |
| 02110755 | Briarcliffe Acres | 354.1 | Stage | Oct. 1, 1981 to May 9, 1983 |
| | | | Specific Conductance | Oct. 2, 1981 to Sept. 30, 1986 |
| 02110760 | Myrtlewood Golf Course | 361.4 | Stage | Oct. 2, 1981 to Sept. 30, 1986 |
| 02110725 | Highway 544 | 371.0 | Stage | Sept 13, 1982 to Sept. 30, 1986 |

Data were also collected to determine the location of the saltwater-freshwater interface for various streamflow and tide-stage conditions. Periodic measurements of specific conductance by boat were made to determine the extent of saltwater intrusion. Measurements

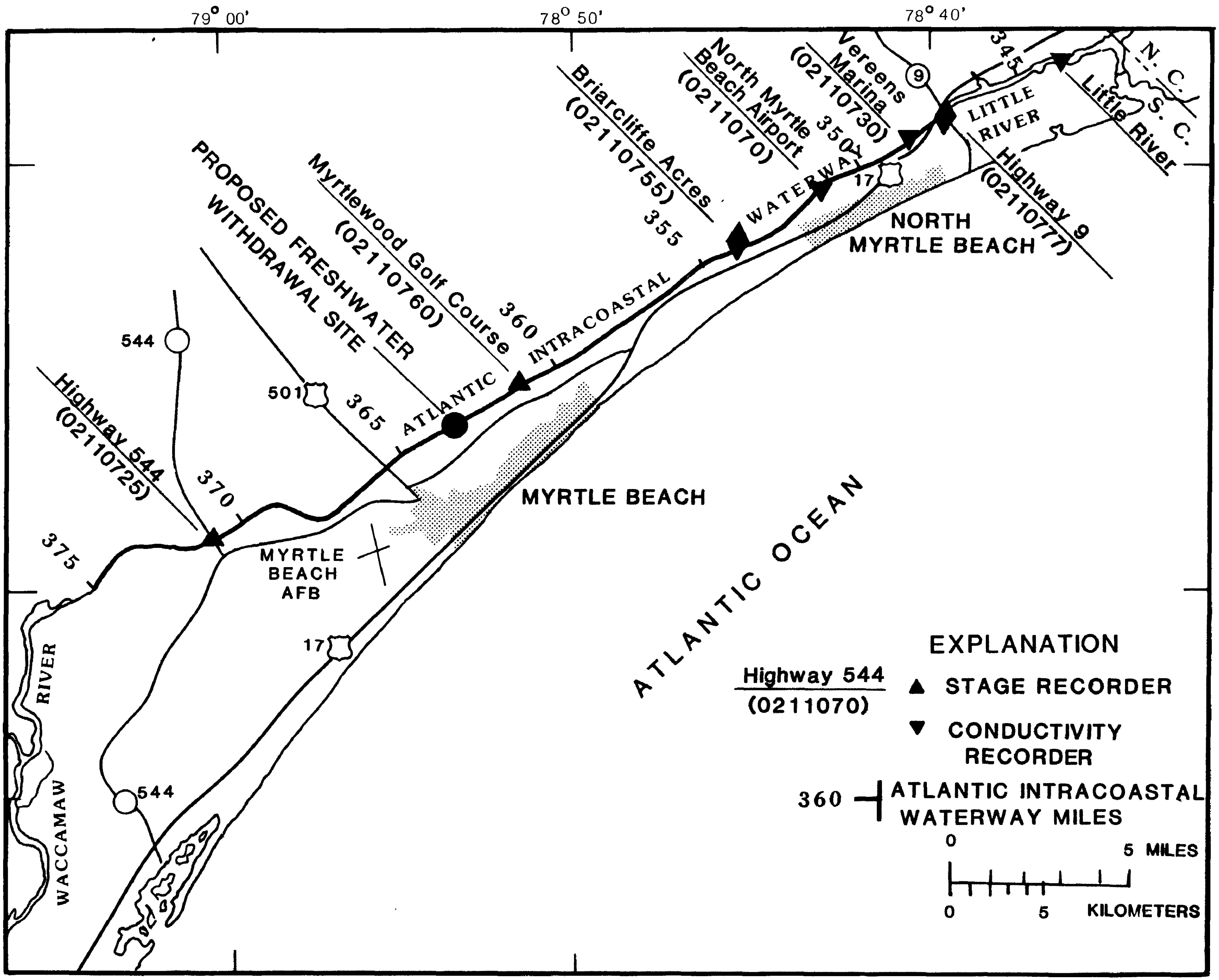


Figure 4.--Location of continuous stage and specific conductance recorders in the Atlantic Intracoastal Waterway.

were made at high tide near the time of slack water. The maximum intrusion of saltwater occurs shortly after high-slack water. Specific conductance was determined from the water surface to the channel bottom.

Eight water discharge measurements, each with a duration of approximately 12.5 hours or one tidal cycle, were made during the 1982-86 water years. The measurement of February 13, 1984 was not useable because of stage recorder malfunctions. The daily mean discharges and range of tidal stages experienced at Myrtlewood Golf Course (02110760) on days of useable discharge measurements are shown in table 3.

Table 3.--Daily mean discharges of the Atlantic Intracoastal Waterway and ranges of tide stages at Myrtlewood Golf Course (02110760) on days of discharge measurements of the Atlantic Intracoastal Waterway

| Date of Measurement | Mean daily Atlantic Intracoastal Waterway (cubic feet per second) | Tide elevations at Myrtlewood Golf Course during measurements, above mean sea level (feet) | |
|---|---|---|---|
| | | High | Low |
| October 16, 1981 | 423 | 2.2 | -0.1 |
| March 19, 1982 | 2,170 | 1.0 | -0.4 |
| June 28, 1983 | 896 | 2.0 | 0.1 |
| May 7, 1985 | 439 | 2.1 | 0.1 |
| October 16, 1985 | 482 | 3.4 | 1.3 |
| March 20, 1986 | 1,300 | 2.1 | 0.4 |
| September 18, 1986 | 612 | 3.1 | 1.4 |

Two boats were used to make each discharge measurement along a tagline strung across the channel at either the Briarcliffe or Myrtlewood gage. Depth, velocity, and time observations were taken at uniformly spaced stations along the tagline. After each traverse of the channel, both boat crews returned to their starting position, and continued traversing for approximately a tidal cycle, always measuring at the same stations. A station velocity was computed by averaging the 0.2- and 0.8- depth velocity observations for each station of the traverse. The station depth was obtained by sounding. A station width was obtained by subtracting the distance to the station to the left of the current station from the distance to the station to the right of the current station and dividing by two. The station discharge was then obtained by multiplying the station velocity by the station depth and width. Relations of station discharge to time were established for each station of the measurement section, from which station discharges were interpolated and summed for 5- or 15-minute time increments to produce a total discharge for each time increment.

## BRANCH-NETWORK FLOW MODEL

The U.S. Geological Survey BRANCH model, used to calculate flow in the study area, is a one-dimensional, unsteady-flow computer model (Schaffranek and others, 1981). The BRANCH model solves the one-dimensional equations of continuity and motion:

$$B(\partial z/\partial t) + (\partial Q/\partial x) - q = 0 \ , \qquad (1)$$

$$(\partial Q/\partial t) + \left[\partial(\beta Q^2/A)/\partial x\right] + gA(\partial z/\partial x) + (gk/AR^{4/3})\ Q\ |Q|$$

$$-\varepsilon B U_\sigma^2 \cos\sigma = 0 \ . \qquad (2)$$

where: B = channel top width, in feet;
z = water-surface elevations, in feet;
t = time step, in seconds;
Q = discharge, in cubic feet per second;
x = longitudinal distance along the channel, in feet;
q = lateral inflow, in feet per second;
A = cross-sectional area, in square feet;
g = gravitational acceleration, in feet per second per second;
k = flow-resistance coefficient;
R = hydraulic radius, in feet; and,
$U_\sigma$ = wind velocity occurring at an angle $\sigma$, in feet per second.

The coefficient $\beta$, known as the momentum or Boussinesq coefficient, is expressed as:

$$\beta = \quad u^2 dA/U^2 A \ , \qquad (3)$$

and is used to adjust for any nonuniform velocity over the channel cross section. In this coefficient, u represents the velocity of water passing through a finite elemental area, dA, and U is the mean flow velocity in the entire cross-sectional area, A.

The coefficient $\varepsilon$ is the dimensionless wind-resistance coefficient which can be expressed as:

$$\varepsilon = C_d(\rho_a/\rho) \quad , \qquad (4)$$

in which $C_d$ is the water-surface drag coefficient, $\rho_a$ is the atmospheric density, and $\rho$ is the water density.

In derivation of equations (1) and (2), it is assumed that the flow is essentially homogeneous in density and that hydrostatic pressure is present at any point in the channel. The channel is assumed to be reasonably straight, the geometry simple, and the gradient mild and uniform. The frictional resistance is assumed to be approximated by the Manning formula. Approximate solutions can be obtained for the nonlinear partial-differential equations by finite difference techniques.

A weighted four-point finite-difference approximation of the nonlinear partial differential equations is used in the BRANCH model. The finite difference technique is described in detail by Schaffranek and others (1981). A weighted four point implicit solution scheme is used because it can be applied with unequal time steps, varied throughout the range of approximation from box-centered to a fully-forward scheme, and its stability-convergence properties can be controlled. The flow equations are linearized and solved by implicit means. An iterative technique is used to solve for the unknown quantity.

The model uses values computed at the current time level as the initial condition for computing the next time-step quantities and proceeds step by step to the designated end of the simulation. Initial values of stage and discharge are required to start the simulation. These values can be obtained by measurement, computed from another source, derived from a previous unsteady flow simulation, or estimated.

## ATLANTIC INTRACOASTAL WATERWAY FLOW MODEL

The BRANCH model requires that either the water-surface elevation or the water discharge be known at the boundaries of the network being simulated. Water-surface elevations from gages at Highway 544 (02110725), Myrtlewood Golf Course (02110760), Briarcliffe Acres (02110755), and Highway 9 (02110777) were used as the boundary conditions for the AICW flow model.

The Myrtlewood-to-Briarcliffe boundary condition was used from October 1981 until October 14, 1982. The Highway 544-to-Highway 9 boundary condition was used from October 15, 1982 to September 30, 1986. The Highway 544-to-Myrtlewood and Myrtlewood-to-Highway 9 boundary conditions were used for periods when data were missing at either the Highway 544 or Highway 9 gage and data were available for the Myrtlewood gage during the 1983-86 water years.

Flow records were generated for the AICW by applying the BRANCH model to four combinations of boundary conditions at the four stations where stage data were collected (figs. 4 and 5).

The increase in drainage area between Highway 544 and Highway 9 is approximately 79 square miles. Roughly 93 percent of this area is rural and roughly 7 percent is urban. Tributary inflow from the rural area was not considered significant because roughly 29 percent of the rural area is designated as swamps on U.S. Geological Survey topographic maps and the remainder is flat, heavily wooded, and poorly drained. Inflow from the urban areas may be significant during periods of local flooding, but was ignored in the study. Point source inflows and outflows were not considered significant enough to require their inclusion in the study.

Cross-section geometry for use in the model was determined by surveying above the water surface and by soundings and by fathometer below the water surface. Cross-sectional areas varied from 303 to 1,830 $ft^2$ at mean sea-level elevations. Top widths varied from 198 to 360 feet. Sea-level datum was used for water-surface elevations and cross-section geometry. The

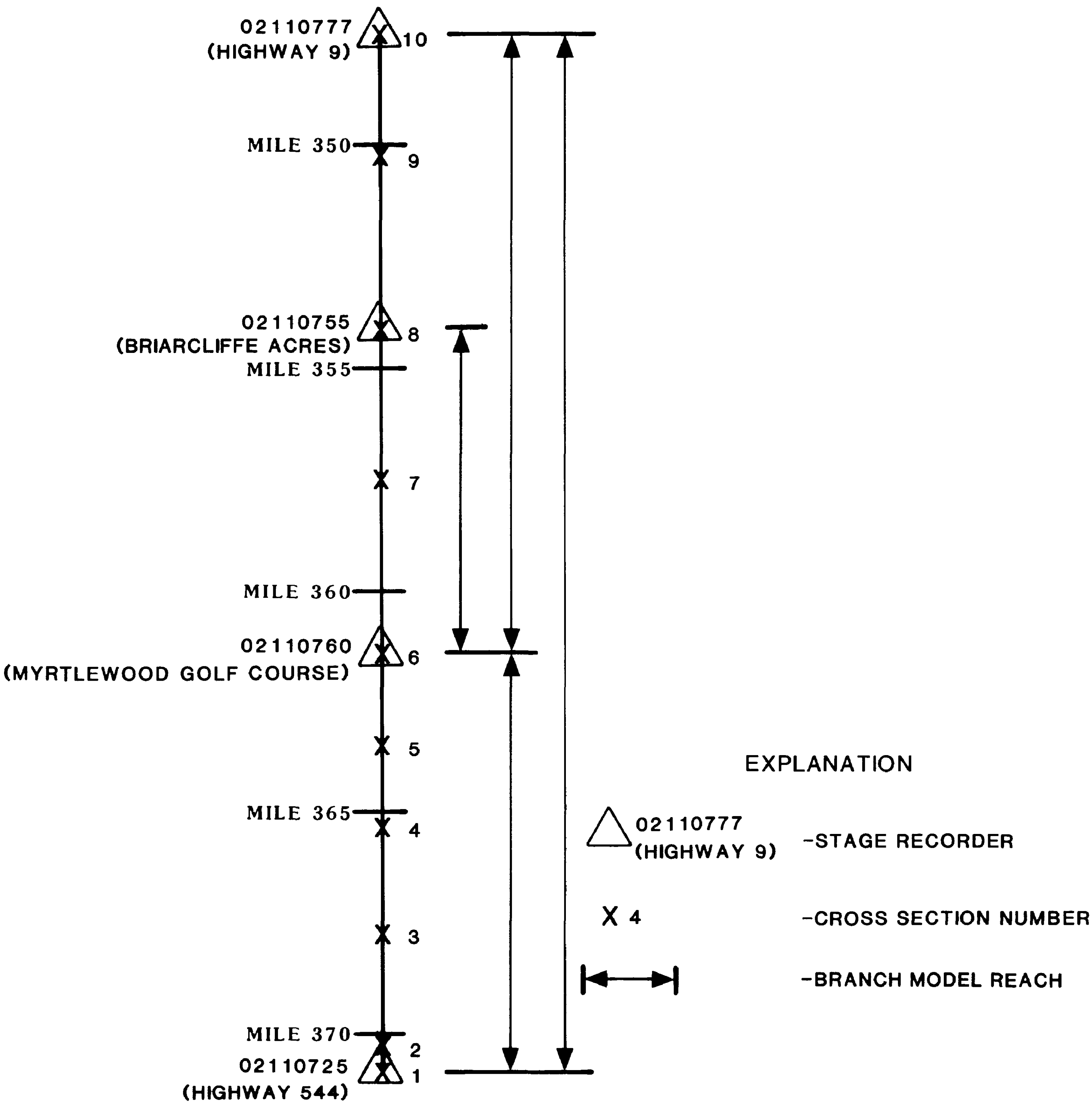


Figure 5.--The configuration of the BRANCH model for the Atlantic Intracoastal Waterway near Myrtle Beach, South Carolina.

distance between cross sections was determined along the thalweg from National Oceanic and Atmospheric Administration Nautical Chart 11534 (U.S. Department of Commerce, 1983).

## Simulation of Water Discharge

Measured discharge for a complete tidal cycle was used to calibrate the model for the four combinations of boundary conditions. The Myrtlewood-to-Briarcliffe model and the Highway 544, Myrtlewood, and Highway 9 models are described below in detail.

A comparison of measured and simulated discharges from 5:00 a.m. to 6:00 p.m. on March 19, 1982 for the Myrtlewood-to-Briarcliffe boundary conditions, is shown in figure 6. Simulated discharges compare favorably with measured discharges. The simulated discharges range from 4,350 $ft^3/s$ to -748 $ft^3/s$, whereas the measured discharges range from 4,280 $ft^3/s$ to -558 $ft^3/s$. The mean simulated discharge is 3.0 percent greater than the mean measured discharge. The phase of the simulated discharge is approximately 15 to 30 minutes ahead of the measured discharge.

In model calibration for the Myrtlewood-to-Briarcliffe boundary conditions, the best agreement between simulated and measured discharges was obtained using a friction-resistance coefficient of 0.024. This value compares favorably with the resistance coefficient of 0.026 estimated based on field observation of channel conditions. The simulations were performed with a 15-minute time step and a value of 1.00 for the discretization weighting factors. The convergence criterion of 15 $ft^3/s$ was satisfied in an average of four iterations.

The Myrtlewood-to-Briarcliffe model was verified using measured discharge data from 7:00 a.m. to 4:15 p.m. on October 16, 1981. A comparison of measured and simulated discharges for October 16 is shown in figure 7. The simulated discharges range from 4,450 $ft^3/s$ to -5,910 $ft^3/s$; whereas, the measured discharges range from 4,360 $ft^3/s$ to -6,050 $ft^3/s$. The mean simulated discharge was 2.7 percent less than the mean measured discharge.

The calibrated and verified model was used to simulate the daily mean discharge at the Briarcliffe Acres gage for the period October 1981 to October 14, 1982. The results of the simulation are shown in table 4.

Flow records were computed after October 14, 1982, using three combinations of boundary conditions at Highway 544, Myrtlewood Golf Course, and Highway 9. A wider range of five discharge measurements used to calibrate the model for these boundary conditions showed that the model could not define discharges as accurately as indicated by the 1981 and 1982 measurements, particularly in the range of discharges from -2,000 $ft^3/s$ to +2,000 $ft^3/s$.

Although the model could have been calibrated to fit any one measurement closely, the calibrations could not be verified with the same accuracy by the other measurements. A close calibration for a single measurement adjusts for specific conditions of the single measurement, such as wind, high or low tides or fresh-water inflow, complexity of the tide-stage waves

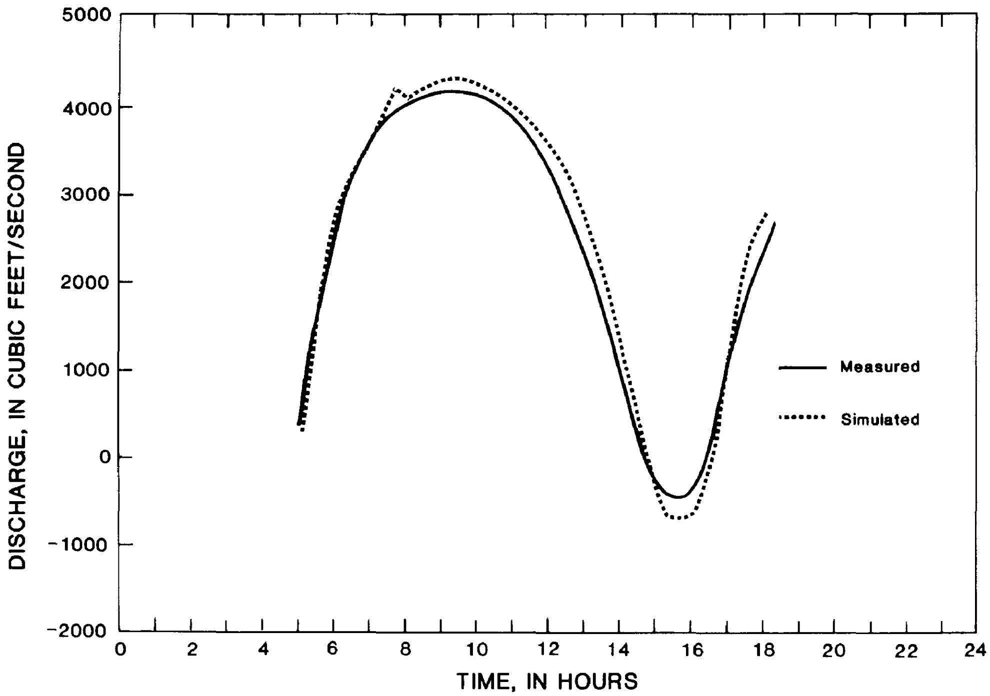


Figure 6.--Comparison of measured and simulated discharges in the Atlantic Intracoastal Waterway near Briarcliffe Acres (02110755), March 19, 1982.

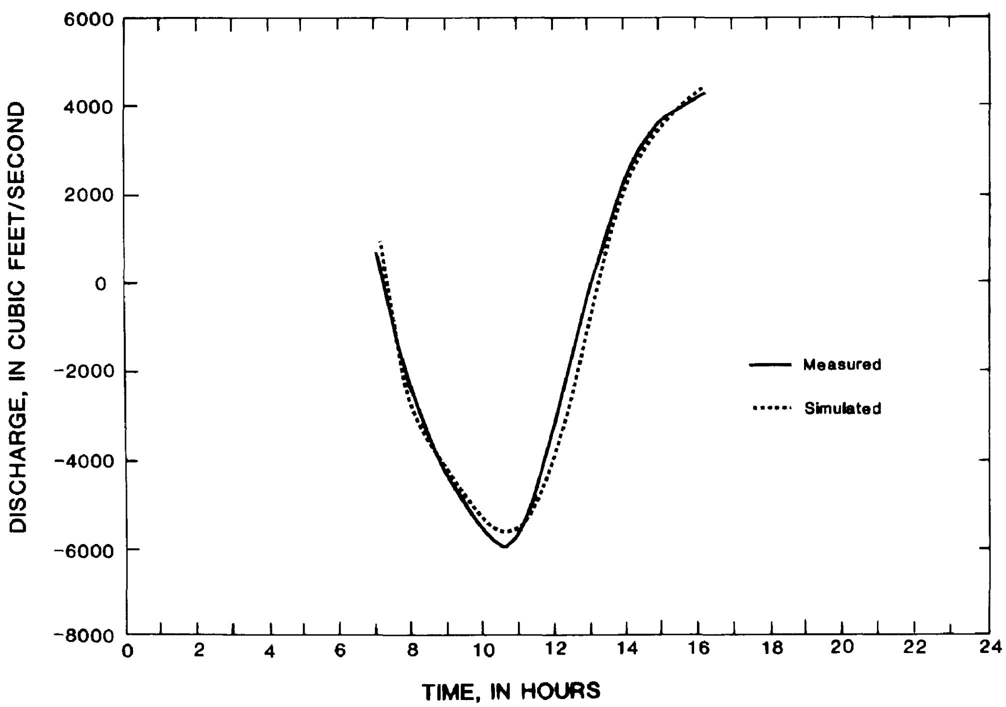


Figure 7.--Comparison of measured and simulated discharges in the Atlantic Intracoastal Waterway near Briarcliffe Acres (02110755), October 16, 1981.

Table 4.--Daily mean discharge in cubic feet per second, for the Atlantic Intracoastal Waterway near Briarcliffe Acres (02110755) and Myrtlewood Golf Course (02110760), 1982 water year (Oct. 1981-Sept.1982)

| Day | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | April | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | a | 1,130 | a | a | a | a | 1,110 | 2,010 | 656 | 580 | 755 | 195 |
| 2 | a | 856 | a | a | a | a | 926 | 1,630 | 756 | 484 | 621 | 162 |
| 3 | 464 | 485 | a | a | a | a | 726 | 1,780 | 545 | 570 | 826 | 150 |
| 4 | 596 | 413 | a | a | a | a | 745 | 1,330 | 674 | 483 | 1,000 | -10 |
| 5 | 728 | 150 | a | a | a | a | 410 | 1,370 | 898 | 243 | 1,150 | 167 |
| 6 | 479 | 75 | a | 1,440 | a | a | 1,410 | 1,460 | 1,120 | 710 | 1,080 | 607 |
| 7 | 299 | 157 | a | 1,770 | a | a | 371 | 1,400 | 964 | 507 | 1,040 | 526 |
| 8 | 208 | 59 | a | 1,460 | a | a | 259 | 1,360 | 791 | 109 | 958 | 587 |
| 9 | 337 | 167 | a | 1,860 | a | 2,200 | 1,030 | 1,330 | 1,050 | 215 | a | 558 |
| 10 | 252 | 589 | a | 2,050 | a | 2,400 | 648 | 1,390 | 1,260 | 406 | a | 649 |
| 11 | 0 | 493 | 37 | 2,400 | a | 2,370 | 661 | 1,280 | 1,170 | 514 | a | 711 |
| 12 | -39 | 471 | 137 | 2,670 | a | 2,450 | 901 | 1,560 | 1,240 | 535 | a | 412 |
| 13 | 174 | 708 | 245 | 3,100 | a | 2,830 | 857 | 1,450 | 1,720 | 593 | a | 246 |
| 14 | 215 | 1,130 | 416 | 3,580 | a | 2,760 | 445 | 857 | 1,640 | 778 | a | 159 |
| 15 | 469 | 1,410 | 897 | a | a | 2,680 | 598 | 616 | 1,250 | 923 | a | -11 |
| 16 | 423 | 659 | 378 | a | a | 2,780 | 950 | 1,170 | 1,120 | a | a | 115 |
| 17 | 613 | 714 | 493 | a | a | 2,670 | 842 | 811 | 1,280 | a | 703 | 103 |
| 18 | 731 | 790 | 681 | a | a | 2,000 | 435 | 378 | 658 | a | 621 | 367 |
| 19 | 681 | 409 | 798 | a | a | 2,170 | 577 | 42 | 1,960 | a | 703 | 446 |
| 20 | 416 | 409 | 743 | a | a | 1,530 | 597 | 142 | 1,220 | a | 820 | 395 |
| 21 | 274 | 244 | 646 | a | a | 1,540 | 696 | 224 | 1,610 | 544 | 639 | 504 |
| 22 | 173 | 145 | 664 | a | a | 1,440 | 357 | 143 | 1,880 | 608 | 427 | 436 |
| 23 | -26 | 182 | 492 | a | a | 914 | 537 | -48 | 1,810 | 1,290 | 966 | 587 |
| 24 | -123 | 229 | 377 | a | a | 1,310 | 794 | 352 | 1,510 | 1,240 | 807 | 851 |
| 25 | 80 | a | 355 | a | a | 1,220 | 652 | 455 | 2,420 | 1,090 | 716 | 654 |
| 26 | 474 | a | 543 | a | a | 1,470 | 1,390 | 492 | 2,180 | 1,150 | 315 | 937 |
| 27 | 394 | a | 794 | a | a | 1,440 | 1,740 | 559 | 1,660 | 1,580 | 739 | 569 |
| 28 | 451 | a | a | a | a | 1,450 | 1,950 | 996 | 1,250 | 1,320 | 547 | 388 |
| 29 | 536 | a | a | a | | 1,650 | 1,330 | 1,020 | 1,100 | 1,070 | 97 | 431 |
| 30 | 692 | a | a | a | | 1,680 | 1,780 | 621 | 814 | 1,010 | 603 | 462 |
| 31 | 1,090 | | a | a | | 1,510 | | 375 | | 974 | | |

"a" denotes no record.

Table 4.--Daily mean discharge in cubic feet per second for the Atlantic Intracoastal Waterway near Briarcliffe Acres (02110755) and Myrtlewood Golf Course (02110760), 1983 water year (Oct. 1982 - Sept. 1983)--Continued

| Day | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | April | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | a | a | a | 1,040 | 1,350 | 4,720 | 7,210 | 2,390 | 958 | 925 | 474 | 235 |
| 2 | a | a | a | 1,380 | 1,230 | 4,710 | 6,880 | 2,110 | 992 | 870 | 373 | 382 |
| 3 | a | a | a | 1,730 | 2,170 | 4,420 | 6,950 | 1,820 | 990 | 842 | 251 | 344 |
| 4 | a | a | a | 1,640 | 1,560 | 4,360 | 6,520 | 1,600 | 817 | 642 | 248 | 219 |
| 5 | a | a | a | 1,640 | 1,370 | 4,260 | 6,050 | 1,320 | 643 | 511 | 176 | 124 |
| 6 | a | a | a | 1,660 | 1,370 | 4,030 | 5,610 | 1,180 | 350 | 522 | 173 | 122 |
| 7 | a | a | a | 1,540 | 1,510 | 4,170 | 5,200 | 1,060 | 472 | 447 | 133 | 230 |
| 8 | a | a | a | 1,380 | 1,370 | 4,050 | 4,770 | 960 | 600 | 817 | 198 | 235 |
| 9 | a | a | a | 1,320 | 1,230 | 3,750 | 4,520 | 1,200 | 482 | 854 | 355 | 284 |
| 10 | a | a | a | 1,440 | 1,030 | 3,650 | 4,170 | 1,490 | 874 | 877 | 389 | 500 |
| 11 | a | a | a | 1,490 | 2,170 | 3,620 | 3,980 | 1,530 | 1,050 | 892 | 366 | 510 |
| 12 | a | a | a | 1,210 | 1,810 | 3,450 | 3,520 | 1,240 | 1,370 | 1,020 | 401 | 494 |
| 13 | a | a | a | 1,160 | 1,630 | 3,040 | 3,490 | 1,040 | 1,740 | 1,000 | 184 | 320 |
| 14 | a | a | a | 1,340 | 2,110 | 3,170 | 3,480 | 1,360 | 1,520 | 914 | 487 | 278 |
| 15 | a | a | a | 1,580 | 2,500 | 3,330 | 3,540 | 1,150 | 1,340 | 728 | 382 | 17 |
| 16 | a | a | a | 1,320 | 2,950 | 2,810 | 3,900 | 1,190 | 1,400 | 666 | 437 | 617 |
| 17 | a | a | a | 1,260 | 3,340 | 3,280 | 3,650 | 923 | 1,270 | 729 | 476 | 537 |
| 18 | a | a | a | 1,500 | 3,350 | 5,450 | 3,730 | 1,210 | 999 | 841 | 299 | 597 |
| 19 | a | a | a | 1,400 | 3,540 | 5,730 | 3,950 | 1,360 | 1,070 | 676 | 321 | 313 |
| 20 | a | a | a | 1,140 | 3,680 | 5,280 | 4,030 | 1,140 | 852 | 453 | 63 | 398 |
| 21 | a | a | a | 989 | 3,630 | 5,290 | 3,770 | 916 | 727 | 271 | 360 | 297 |
| 22 | a | a | a | 825 | 3,760 | 5,460 | 3,830 | 738 | 461 | 169 | 340 | 267 |
| 23 | a | a | a | 1,470 | 3,830 | 5,110 | 2,750 | 673 | 797 | 142 | 406 | 374 |
| 24 | a | a | a | 1,180 | 3,800 | 5,090 | 3,810 | 531 | 867 | 468 | 212 | 711 |
| 25 | a | a | a | 890 | 3,920 | 5,690 | 3,550 | 561 | 798 | 500 | 266 | 597 |
| 26 | a | a | a | 847 | 4,030 | 5,760 | 3,110 | 818 | 570 | 350 | 440 | 750 |
| 27 | a | a | a | 665 | 3,790 | 6,200 | 3,270 | 821 | 960 | 592 | 538 | 623 |
| 28 | a | a | a | 803 | 3,430 | 6,830 | 3,120 | 788 | 896 | 641 | 576 | 538 |
| 29 | a | a | a | 744 | | 6,940 | 2,910 | 1,090 | 677 | 604 | 513 | 645 |
| 30 | a | a | a | 952 | | 7,010 | 2,650 | 983 | 758 | 701 | 391 | 515 |
| 31 | a | | a | 1,380 | | 7,170 | | 854 | | 578 | 335 | |

"a" denotes no record.

Table 4.--Daily mean discharge in cubic feet per second for the Atlantic Intracoastal Waterway near Briarcliffe Acres (02110755) and Myrtlewood Golf Course (02110760), 1984 water year (Oct. 1983 - Sept.1984)--Continued

| Day | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | April | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 605 | 229 | 518 | 1,250 | 2,010 | 2,710 | 2,300 | 2,110 | 597 | 438 | 1,790 | 511 |
| 2 | 671 | 146 | 507 | 1,510 | 2,120 | 2,650 | 2,800 | 2,020 | 839 | 771 | 1.960 | 578 |
| 3 | 374 | 151 | 469 | 1,460 | 1,940 | 2,680 | 2,830 | 2,010 | 788 | 626 | 1,850 | 484 |
| 4 | 103 | 305 | 543 | 1,340 | 1,790 | 2,880 | 2,880 | 2,290 | 891 | 507 | 1,650 | 323 |
| 5 | 75 | 274 | 457 | 1,310 | 1,970 | 3,250 | 3,850 | 2,010 | 972 | 488 | 1,550 | 202 |
| 6 | 164 | 651 | 857 | 1,340 | 1,680 | 3,710 | 3,760 | 2,150 | 1,040 | 516 | 1,680 | 166 |
| 7 | 163 | 503 | 566 | 1,050 | 1,540 | 3,830 | 3,730 | 1,970 | 992 | 401 | 1,640 | 337 |
| 8 | 577 | 819 | 897 | 1,240 | 1,680 | 4,050 | 3,830 | 1,720 | 917 | 235 | 1,680 | 483 |
| 9 | 735 | 806 | 937 | 1,200 | 1,730 | 4,110 | 3,950 | 1,570 | 859 | 363 | 1,640 | 590 |
| 10 | 662 | 1,000 | 1,040 | 1,160 | 1,610 | 3,810 | 4,040 | 1,460 | 809 | 631 | 1,610 | 753 |
| 11 | 728 | 736 | 989 | 1,150 | 1,440 | 3,760 | 4,000 | 1,470 | 915 | 518 | 1,710 | 1,080 |
| 12 | 686 | 421 | 1,060 | 992 | 1,190 | 3,590 | 4,100 | 1,310 | 800 | 405 | 1,850 | 579 |
| 13 | 711 | 493 | 1,170 | 830 | 964 | 3,560 | 3,920 | 1,300 | 700 | 442 | 1,620 | 351 |
| 14 | 681 | 505 | 891 | 814 | 1,120 | 3,630 | 3,740 | 1,240 | 600 | 488 | 1,570 | 574 |
| 15 | 583 | 420 | 1,200 | 534 | 925 | 3,160 | 3,670 | 1,180 | 525 | 658 | 1,430 | 641 |
| 16 | 482 | 413 | 1,060 | 654 | 730 | 2,990 | 3,770 | 1,700 | 450 | 473 | 1,270 | 801 |
| 17 | 505 | 208 | 1,100 | 764 | 845 | 2,620 | 3,840 | 1,660 | 375 | 716 | 1,290 | 920 |
| 18 | 397 | 377 | 1,130 | 758 | 997 | 2,890 | 3,740 | 2,030 | 286 | 697 | 1,300 | 857 |
| 19 | 225 | 437 | 1,470 | 990 | 1,130 | 3,170 | 3,570 | 1,910 | 258 | 685 | 1,210 | 837 |
| 20 | 293 | 376 | 1,810 | 1,340 | 1,350 | 3,160 | 3,670 | 1,610 | 445 | 730 | 1,100 | 664 |
| 21 | 263 | 448 | 1,660 | 1,780 | 1,370 | 3,910 | 3,550 | 1,420 | 655 | 840 | 946 | 510 |
| 22 | 387 | 366 | 2,560 | 2,180 | 1,660 | 3,730 | 3,320 | 1,470 | 592 | 830 | 1,150 | 356 |
| 23 | 514 | 350 | 2,510 | 2,330 | 2,310 | 3,300 | 3,410 | 1,320 | 671 | 837 | 913 | 337 |
| 24 | 918 | 431 | 2,650 | 2,480 | 2,910 | 2,830 | 3,390 | 948 | 692 | 781 | 712 | 374 |
| 25 | 582 | 709 | 2,070 | 2,420 | 2,780 | 2,820 | 2,810 | 1,200 | 688 | 740 | 321 | 377 |
| 26 | 368 | 442 | 1,800 | 2,300 | 2,710 | 2,910 | 2,520 | 936 | 684 | 733 | 427 | 524 |
| 27 | 789 | 728 | 1,990 | 2,400 | 2,530 | 2,090 | 2,330 | 564 | 704 | 868 | 311 | 545 |
| 28 | 858 | 666 | 1,880 | 2,430 | 3,380 | 2,220 | 2,020 | 489 | 518 | 779 | 606 | 763 |
| 29 | 615 | 693 | 1,610 | 2,320 | 3,230 | 3,290 | 1,860 | 700 | 433 | 979 | 696 | 1,070 |
| 30 | 360 | 454 | 1,480 | 2,100 | | 2,190 | 2,050 | 722 | 361 | 1,170 | 547 | 686 |
| 31 | 388 | | 1,420 | 2,300 | | 2,110 | | 462 | | 1,620 | 443 | |

"a" denotes no record.

Table 4.--Daily mean discharge in cubic feet per second for the Atlantic Intracoastal Waterway near Briarcliffe Acres (02110755) and Myrtlewood Golf Course (02110760), 1985 water year (Oct. 1984 - Sept. 1985)--Continued

| Day | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | April | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1,070 | 438 | 535 | 373 | 576 | 1,860 | 466 | 372 | 339 | 192 | 997 | 1,760 |
| 2 | 1,090 | 593 | 475 | 307 | 507 | 1,770 | 132 | 132 | 107 | 118 | 755 | 2,110 |
| 3 | 734 | 325 | 577 | 264 | 308 | 1,270 | 128 | 103 | 0 | 196 | 1,100 | 2,130 |
| 4 | 901 | 492 | 383 | 367 | 557 | 1,380 | 237 | -95 | 0 | 325 | 1,400 | 2,110 |
| 5 | 717 | 752 | 152 | 453 | 642 | 1,460 | 289 | 300 | 500 | 489 | 1,580 | 2,050 |
| 6 | 545 | 548 | 817 | 309 | 1,300 | 905 | 487 | 443 | 715 | 541 | 1,590 | 1,860 |
| 7 | 615 | 315 | 157 | 727 | 1,070 | 1,160 | 431 | 439 | 524 | 426 | 1,660 | 1,720 |
| 8 | 875 | 388 | 389 | 488 | 1,330 | 1,450 | 549 | 481 | 807 | 347 | 1,600 | 1,560 |
| 9 | 802 | 398 | 494 | 692 | 1,350 | 1,300 | 568 | 609 | 630 | 380 | 1,800 | 1,650 |
| 10 | 808 | 414 | 501 | 925 | 1,370 | 1,380 | 574 | 761 | 543 | 365 | 1,700 | 1,560 |
| 11 | 708 | 733 | 503 | 1,080 | 1,240 | 1,340 | 726 | 557 | 572 | 191 | 1,470 | 1,150 |
| 12 | 803 | 475 | 554 | 1,030 | 1,740 | 1,310 | 652 | 475 | 482 | 341 | 1,400 | 822 |
| 13 | 748 | 692 | 767 | 1,000 | 1,520 | 920 | 408 | 416 | 460 | 348 | 1,310 | 1,290 |
| 14 | 640 | 443 | 782 | 964 | 1,660 | 966 | 486 | 270 | 571 | 344 | 986 | 1,100 |
| 15 | 556 | 549 | 580 | 732 | 1,870 | 808 | 483 | 137 | 669 | 107 | 836 | 895 |
| 16 | 864 | 476 | 485 | 435 | 2,000 | 784 | 303 | 214 | 616 | 139 | 701 | 1,030 |
| 17 | 921 | 332 | 485 | 555 | 2,160 | 715 | 131 | 382 | 188 | 47 | 609 | 1,040 |
| 18 | 693 | 303 | 386 | 300 | 2,210 | 786 | 559 | 309 | 301 | 266 | 724 | 1,040 |
| 19 | 451 | 331 | 259 | 496 | 2,250 | 481 | 486 | 471 | 184 | 480 | 751 | 1,050 |
| 20 | 333 | -35 | 184 | 494 | 2,300 | 525 | 425 | 615 | 295 | 537 | 861 | 890 |
| 21 | 272 | 119 | 216 | 476 | 2,430 | 363 | 376 | 606 | 444 | 500 | 1,100 | 752 |
| 22 | 292 | 168 | 400 | 446 | 2,600 | 725 | 406 | 604 | 517 | 526 | 1,040 | 723 |
| 23 | 217 | 325 | 191 | 459 | 2,370 | 922 | 407 | 697 | 571 | 377 | 1,060 | 645 |
| 24 | 168 | 492 | 542 | 583 | 2,430 | 682 | 368 | 578 | 523 | 508 | 1,030 | 209 |
| 25 | 130 | 655 | 711 | 585 | 2,210 | 536 | 454 | 426 | 538 | 1,180 | 1,060 | -31 |
| 26 | 391 | 580 | 555 | 459 | 2,100 | 742 | 469 | 603 | 163 | 867 | 1,060 | 278 |
| 27 | 647 | 531 | 661 | 556 | 1,920 | 987 | 612 | 692 | 16 | 626 | 986 | 709 |
| 28 | 790 | 523 | 589 | 460 | 1,770 | 888 | 427 | 485 | 257 | 586 | 1,020 | 455 |
| 29 | 870 | 459 | 559 | 656 | | 774 | 229 | 326 | 209 | 815 | 1,040 | 529 |
| 30 | 632 | 432 | 528 | 689 | | 701 | 451 | 75 | 449 | 902 | 1,510 | 622 |
| 31 | 532 | | 350 | 692 | | 588 | | 386 | | 880 | 1,750 | |

"a" denotes no record.

Table 4.--Daily mean discharge in cubic feet per second for the Atlantic Intracoastal Waterway near Briarcliffe Acres (02110755) and Myrtlewood Golf Course (02110760), 1986 water year (Oct. 1985 - Sept. 1986)--Continued

| Day | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | April | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 536 | 598 | 1,340 | 772 | 976 | 951 | 1,410 | 516 | 536 | 209 | 260 | 798 |
| 2 | 457 | 804 | 2,100 | 852 | 912 | 983 | 1,080 | 248 | 392 | 322 | 191 | 1,020 |
| 3 | 401 | 694 | 1,680 | 961 | 657 | 868 | 861 | 181 | -8 | 2 | 271 | 783 |
| 4 | 207 | 1,210 | 2,110 | 623 | 523 | 593 | 862 | 333 | 643 | 299 | 114 | 699 |
| 5 | 345 | 1,040 | 2,110 | 746 | 426 | 508 | 749 | 314 | 471 | 832 | 39 | 762 |
| 6 | 168 | 706 | 2,210 | 423 | 350 | 507 | 649 | 155 | 452 | 596 | 322 | 805 |
| 7 | 379 | 598 | 1,700 | 391 | 484 | 351 | 517 | 28 | 476 | 513 | 372 | 911 |
| 8 | 483 | 530 | 1,650 | 500 | 259 | 332 | 339 | -75 | 512 | 366 | 347 | 1,030 |
| 9 | 554 | 397 | 1,970 | 470 | 573 | 537 | 489 | 167 | 307 | 426 | 252 | 1,020 |
| 10 | 499 | 718 | 1,870 | 365 | 635 | 592 | 547 | 659 | 336 | 265 | 254 | 1,070 |
| 11 | 297 | 734 | 1,800 | 358 | 1,010 | 473 | 507 | 554 | 48 | 612 | 386 | 761 |
| 12 | -90 | 593 | 1,880 | 761 | 766 | 366 | 619 | 380 | 507 | 670 | 439 | 519 |
| 13 | 345 | 578 | 2,170 | 726 | 928 | 593 | 585 | 315 | 412 | 613 | 425 | 322 |
| 14 | 469 | 647 | 2,390 | 683 | 810 | 846 | 577 | 481 | 326 | 512 | 287 | 325 |
| 15 | 482 | 801 | 2,120 | 442 | 906 | 987 | 743 | 460 | 390 | 415 | 156 | 284 |
| 16 | 482 | 838 | 2,520 | 844 | 1,040 | 919 | 506 | 475 | 475 | 351 | 299 | 244 |
| 17 | 476 | 1,090 | 2,350 | 803 | 1,050 | 1,000 | 581 | 367 | 271 | 278 | 706 | 65 |
| 18 | 552 | 802 | 2,080 | 678 | 949 | 1,120 | 434 | 185 | -171 | 113 | 305 | 612 |
| 19 | 873 | 877 | 1,820 | 596 | 689 | 1,530 | 343 | 98 | 138 | -20 | 150 | 592 |
| 20 | 629 | 790 | 1,730 | 382 | 578 | 1,300 | 265 | -66 | 82 | -66 | 564 | 481 |
| 21 | 402 | 687 | 1,590 | 363 | 734 | 1,070 | 285 | 0 | 57 | 334 | 878 | 331 |
| 22 | 387 | 939 | 1,420 | 425 | 550 | 1,110 | 82 | -25 | 504 | 442 | 865 | 358 |
| 23 | 269 | 635 | 1,260 | 394 | 603 | 1,020 | 102 | 100 | 607 | 404 | 923 | 499 |
| 24 | 354 | 983 | 1,100 | 428 | 627 | 1,010 | 77 | 313 | 551 | 380 | 1,130 | 669 |
| 25 | 392 | 1,160 | 1,170 | 577 | 744 | 955 | 152 | 234 | 412 | 410 | 1,250 | 495 |
| 26 | 258 | 1,230 | 918 | 892 | 490 | 1,110 | 306 | 545 | 510 | 636 | 1,430 | 365 |
| 27 | 720 | 1,210 | 1,030 | 878 | 891 | 1,140 | 411 | 644 | 849 | 432 | 1,300 | 294 |
| 28 | 678 | 1,070 | 920 | 395 | 809 | 1,180 | 657 | 651 | 666 | 363 | 1,110 | 150 |
| 29 | 530 | 1,110 | 915 | 730 | | 1,580 | 546 | 497 | 424 | 286 | 699 | 326 |
| 30 | 701 | 1,250 | 872 | 774 | | 1,550 | 444 | 473 | 340 | 260 | 918 | 294 |
| 31 | 749 | | 883 | 952 | | 1,490 | | 534 | | 324 | 1,280 | |

"a" denotes no record.

originating from opposite ends of the study area passing each other within the reach, and so forth. The particular conditions for one measurement might never be duplicated again. Therefore, the model was calibrated to average the five measurements of the 1983-86 period to encompass as wide a range of conditions as possible. The average percent difference between computed and measured values of volume and discharge are listed in table 5. Three measurements were made at Briarcliffe Acres and two at Myrtlewood Golf Course.

As shown in table 5, flood-tide discharges less than -2000 $ft^3/s$ and ebb-tide discharges greater than +2,000 $ft^3/s$ were simulated within -11.0 percent and +8.0 percent respectively. The average discharge variation of the five measurements for the three boundary conditions for these ranges of discharge varied from -2.6 percent to +5.3 percent; therefore, the calibrated model simulations reasonably balanced measured discharges greater than 2,000 $ft^3/s$ in either direction.

Table 5 shows that volumes for flood-tide discharges less than -2,000 $ft^3/s$ and for ebb-tide discharges greater than 2,000 $ft^3/s$ were simulated within -7.7 percent and +10.5 percent. The average volume variation of the five measurements for the three boundary conditions ranged from -4.5 percent to +2.2 percent; therefore, the calibrated model simulations reasonably balanced measured volumes for discharges greater than 2,000 $ft^3/s$ in either direction.

Measured and simulated volumes of discharges between -2,000 $ft^3/s$ and 2,000 $ft^3/s$ were not as accurate as those of discharges outside this range for two reasons:

1. Discharge could not be as accurately measured because of low velocities and undetected reversals of flow in the vertical when the tide changed direction.

2. Discharge could not be as accurately simulated by the model because a one-dimensional model may not adequately account for reversal of flow in the vertical or horizontal dimension when the tide changes direction. Also, the model is very sensitive to small datum errors at the low water-surface slopes that coincide with lower discharges (see "Sensitivity of the Model" section).

Most of the volume transfer is in the range of discharges greater than 2,000 $ft^3/s$ in either direction, rather than in the intervening range of discharge. Approximately 20 percent of the time discharge is in the less accurate -2,000 $ft^3/s$ to 2,000 $ft^3/s$ range; thus, substantially less than 20 percent of the total volume is in the range of less accurate comparison of measured and simulated volumes.

Table 5 shows that except for the Myrtlewood-to-Highway 9 boundary condition of the March 20, 1986 measurement, differences between simulated and measured volumes of flood and ebb tides varied from -8.0 percent to 9.8 percent. Table 5 also shows that variations in the volumes of flood and ebb tides tended to cancel, except for the March 20, 1986 measurement. The percent differences between simulated and measured volumes for flood and ebb tides reflect the total effect of inaccuracies in all the flow categories

Table 5.--Location of measurements and average percentage differences between simulated and measured discharges and volumes for five measurements and three boundary conditions for the Atlantic Intracoastal Waterway near Myrtle Beach, South Carolina

| Boundary condition and date of measurement | Location of measurement | Average percentage difference between computed and measured values of: Flood-tide discharges less than -2,000 cubic feet per second | Ebb-tide discharges greater than 2,000 cubic feet per second | Volumes of flood-tide discharges less than -2,000 cubic feet per second | Volumes of ebb-tide discharges greater than 2,000 cubic feet per second | Volumes of flood-tides | Volumes of ebb-tides | Average of flood- and ebb-tides |
|---|---|---|---|---|---|---|---|---|
| Highway 544 to Highway 9: | | | | | | | | |
| June 28, 1983 | Briarcliffe Acres | -2.4 | 3.0 | 2.8 | -3.5 | 1.6 | -2.2 | -0.3 |
| May 7, 1985 | Briarcliffe Acres | -9.8 | 0.0 | 9.8 | -0.2 | 8.8 | 1.4 | 5.1 |
| Oct. 16, 1985 | Briarcliffe Acres | 3.6 | 0.8 | -3.9 | -0.9 | -3.9 | -0.2 | -2.0 |
| Mar. 20, 1986 | Myrtlewood Golf Course | 1/ | -7.0 | 1/ | 6.6 | 17.8 | 7.1 | 12.4 |
| Sept. 18, 1986 | Myrtlewood Golf Course | 1.0 | -0.4 | -1.6 | 0.0 | -2.4 | 2.8 | 0.2 |
| Average | | -1.9 | -0.7 | 1.8 | 0.4 | 4.4 | 1.8 | 3.1 |
| Highway 544 to Myrtlewood Golf Course: | | | | | | | | |
| Mar. 20, 1986 | Myrtlewood Golf Course | 1/ | -1.2 | 1/ | 1.1 | -15.9 | -9.8 | -12.8 |
| Sept. 18, 1986 | Myrtlewood Golf Course | 5.3 | 1.9 | -4.5 | -1.9 | 9.8 | -1.5 | 4.2 |
| Average | | 5.3 | 0.4 | -4.5 | -0.4 | -3.0 | -5.6 | -4.3 |

1/ Flood tide discharges less than -2,000 $ft^3/s$ were not experienced.

Table 5.--Location of measurements and average percentage differences between simulated and measured discharges and volumes for five measurements and three boundary conditions for the Atlantic Intracoastal Waterway near Myrtle Beach, South Carolina--Continued

| | | Average percentage difference between computed and measured values of: | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Boundary condition and date of measurement | Location of measurement | Flood-tide discharges less than -2,000 cubic feet per second | Ebb-tide discharges greater than 2,000 cubic feet per second | Volumes of flood-tide discharges less than -2,000 cubic feet per second | Volumes of ebb-tide discharges greater than 2,000 cubic feet per second | Volumes of flood-tides | Volumes of ebb-tides | Average of flood- and ebb-tides |
| Myrtlewood Golf Course to Highway 9: | | | | | | | | |
| June 28, 1983 | Briarcliffe Acres | -3.3 | 0.0 | 3.6 | -0.6 | -0.2 | 1.3 | 0.6 |
| May 7, 1985 | Briarcliffe Acres | -2.4 | 0.0 | 3.0 | -0.1 | 1.4 | 0.6 | 1.0 |
| Oct. 16, 1985 | Briarcliffe Acres | 8.0 | -5.7 | -7.7 | 3.9 | -8.0 | 7.8 | -0.1 |
| Mar. 20, 1986 | Myrtlewood Golf Course | 1/ | -11.0 | 1/ | 10.5 | -30.3 | 32.9 | 1.3 |
| Sept. 18, 1986 | Myrtlewood Golf Course | 0.4 | 3.4 | -1.9 | -2.9 | -4.1 | 0.0 | -2.0 |
| Average | | 0.7 | -2.6 | -0.8 | 2.2 | -8.2 | 8.5 | 0.2 |

1/ Flood tide discharges less than -2,000 cubic feet per second were not experienced.

and are within limits of accuracy expected for modeling of the complex flow conditions of the AICW.

The simulations for the Myrtlewood-to-Highway 9 boundary conditions were performed with a 15-minute time step and a value of 0.85 for the discretization weighting factors. The convergence criterion of 95 $ft^3/s$ was satisfied within five iterations.

Calibration was achieved by selecting friction resistance coefficients of 0.0153 for cross-sections 1 to 5, 0.0207 for cross-section 6, and 0.0216 for cross-sections 7-10, for the combinations of the Highway 544, Myrtlewood Golf Course, and Highway 9 boundary conditions. A field estimate of the friction-resistance coefficient for the Myrtlewood-to-Briarcliff reach was 0.026. However, the International Organization for Standardization (1983), and Horton (1916) report coefficients of 0.016 and 0.017 respectively for straight, uniform, clean earth channels or canals such as the AICW. The range of calibrated friction-resistance coefficients of 0.0153 to 0.024 seems reasonable in comparison with documented values.

The calibrated and verified model was used to simulate the daily mean discharge at the Myrtlewood Golf Course gage for the period October 15, 1982, to September 30, 1986. Daily mean discharges are for all practical purposes the same whether computed at Briarcliffe Acres or Myrtlewood Golf Course. Daily mean discharges are shown in table 4.

## Sensitivity of the Model

An analysis of the Myrtlewood Golf Course to Briarcliffe Acres model was made to determine the sensitivity of simulated discharge to water-surface fall and wind velocity -- the two primary driving forces. Solutions were determined by simulating daily discharge for a given period of record and specified constant wind speed and direction or datum change. A sufficient number of simulations were performed to develop relations between simulated discharge unaffected by wind or datum and the change in discharge due to the effect.

In the sensitivity analysis for errors in datum, stage at the Briarcliffe Acres gage was varied to produce, for each time step, an increased or decreased water surface fall which ranged from $\pm 0.01$ to $\pm 0.10$ ft through the modeled reach. Results show that the difference between simulated base discharge and datum-affected discharge increases as the absolute value of the datum increases (fig. 8).

For a base discharge of 500 $ft^3/s$ and a datum change of $\pm 0.03$ ft, the change in discharge is approximately 100 $ft^3/s$ or 20 percent. If a base discharge of 200 $ft^3/s$ is selected for the same datum change, the change in discharge is approximately 96 $ft^3/s$ or 48 percent. Thus, simulations of flow are sensitive to small errors in stage data, particularly at low daily mean discharge values.

The flow of the AICW can also be significantly affected by wind conditions. The effect of wind direction on simulated discharge for

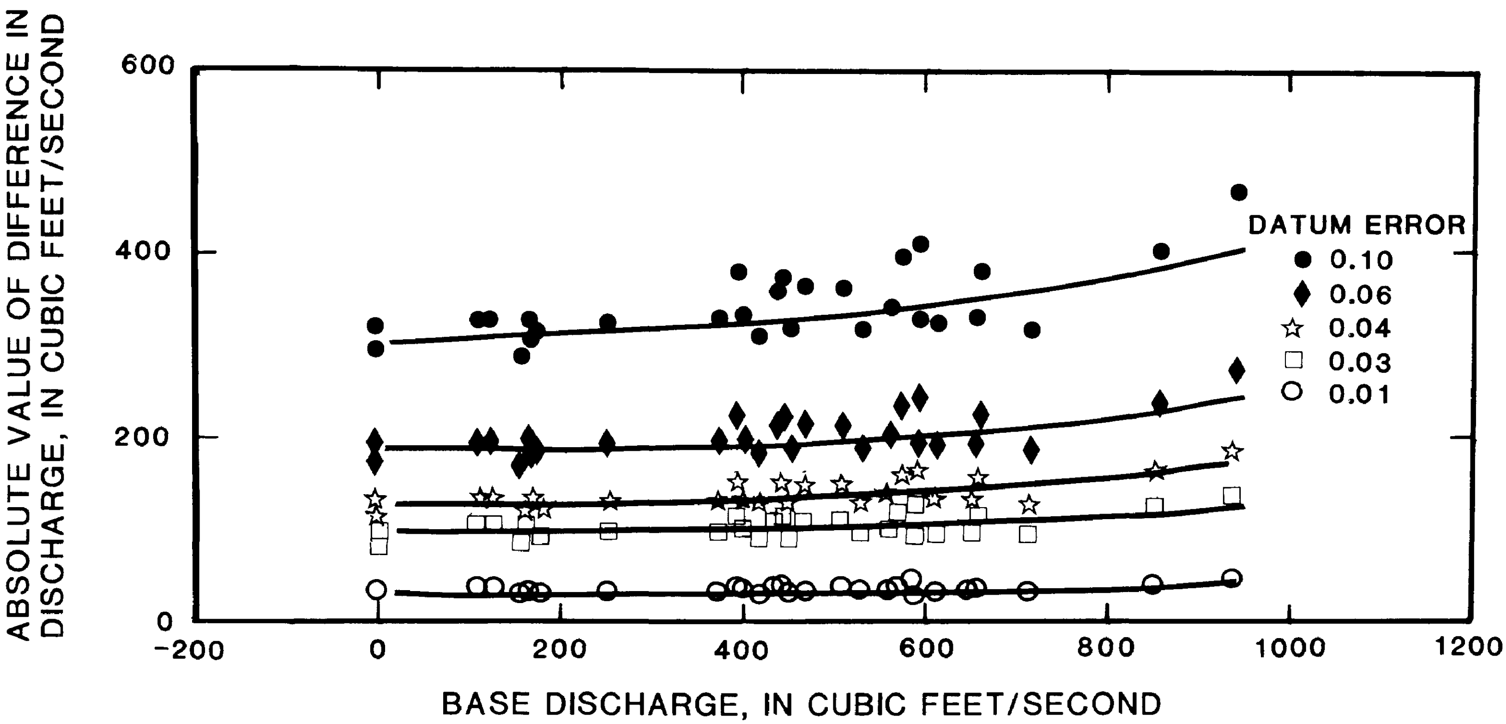


Figure 8.--Effect of datum errors on simulated daily mean discharge at Briarcliffe Acres gage (02110755).

selected wind speeds is shown in figure 9. Channel orientation in the modeled reach is 45 degrees. The maximum increase in simulated discharge occurs when the wind is toward 45 degrees, as measured from north; the maximum decrease occurs when wind is toward 225 degrees. Wind has no effect on discharge when it is toward 135 degrees or 315 degrees. For example, wind from 45 degrees at 5 mi/hr (miles per hour) increased simulated discharge approximately 60 $ft^3/s$.

Wind was not considered in the model calibration and the simulations due to the paucity of data. In the Myrtle Beach area, average wind speed in each of the months of January, April, July, and October is approximately 3 mi/hr. The average wind direction for each of the months of January, April, July and October is 90, 24, 9 and 182 degrees, respectively. By using these average wind conditions and information in figure 9, the wind effect on mean daily discharge is generally less than 20 $ft^3/s$. The model was also found to be sensitive to wind effect for the Highway 544, Myrtlewood, and Highway 9 boundary conditions. Future modeling efforts in the AICW need to include wind speed and direction in the simulation, especially if discharge data are to be used as input to a transport model.

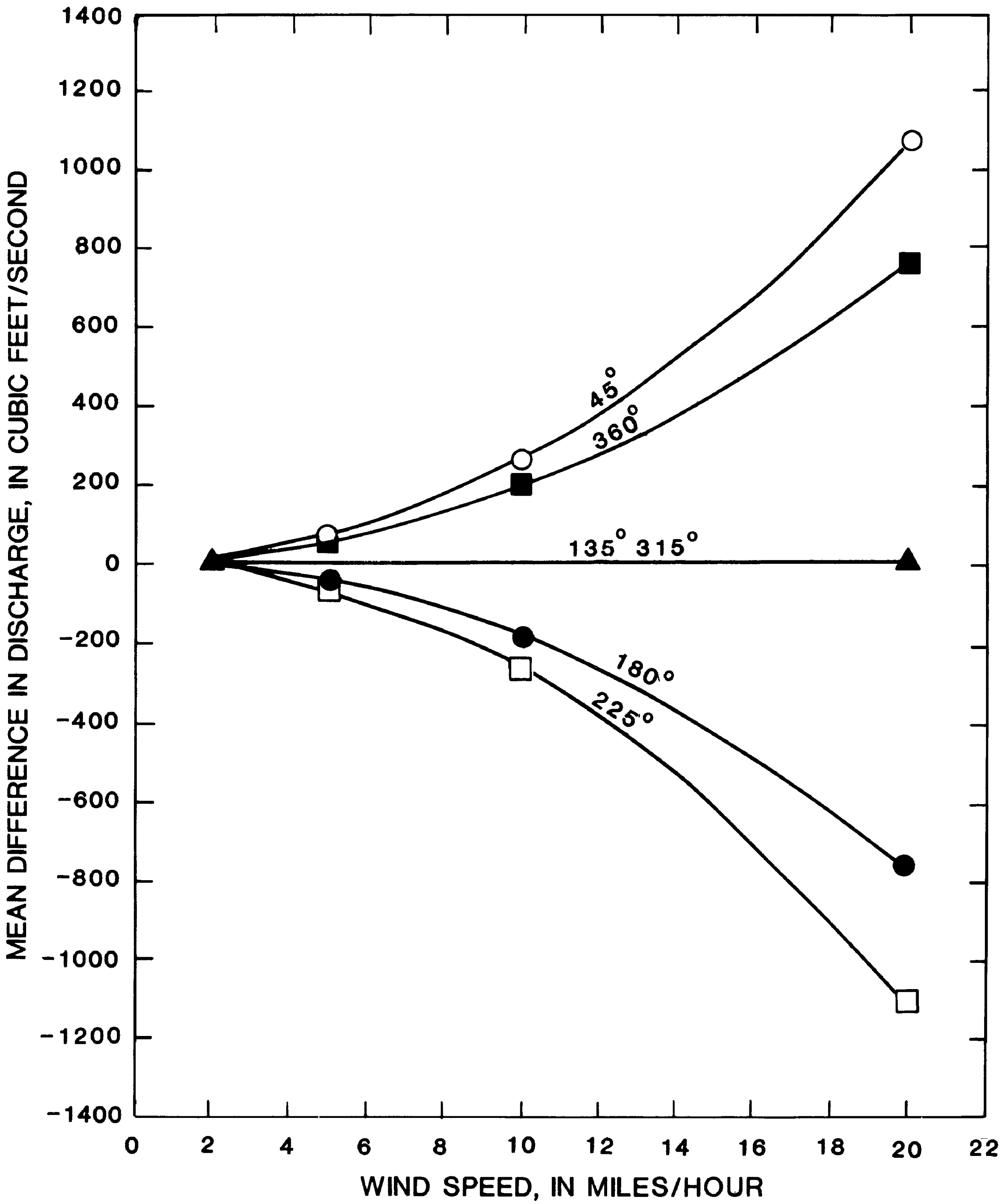


Figure 9.--Effect of wind speed and direction on simulated discharge at Briarcliffe Acres gage (02110755).

The daily mean discharges in the AICW were determined by the BRANCH model simulation for the 1982-86 water years. This period of record is not long enough to produce a low-flow frequency curve for the AICW. Therefore, it was necessary to develop a relation between flows in the AICW and flows in the major tributary streams that have a longer period of record. A discharge relation as described by Riggs (1972) was used to extend the AICW flow record.

Running seven day average discharges for the 1982-85 water years at the gaging stations on the Waccamaw, Pee Dee, Little Pee Dee, and Lynches Rivers and the AICW (fig. 1) were used to develop the relation because of the large variability of simulated daily discharge in the AICW. The MOVE.1 regression method documented by Hirsch (1982) was used to establish a relation of the the log-transformed 7-day average discharges of the AICW to the log-transformed sum of the 7-day average discharges of the tributary streams, lagged by four days. The MOVE.1 regression method was used because it preserves variance better than the ordinary least squares method. The relation is shown in figure 10 and can be expressed by the equation:

$$Q_A = 0.121\ Q_T^{\ 0.944} \qquad (5)$$

where $Q_A$ = AICW 7-day average discharge,

$Q_T$ = sum of the 7-day average discharges of the tributary streams, lagged by four days.

The use of a 4-day lag between the discharge at the gaging stations on each of the four tributary streams and the discharge at the AICW provided the best fit for the relation. The standard deviation of the residuals of equation 5 is 33 percent. The correlation coefficient is 0.91, and the coefficient of determination is 0.83. Limits of the input data from which the equation was derived are 208 $ft^3/s$ and 4,360 $ft^3/s$ for AICW 7-day average discharges.

Equation 5 was verified by using it in computing 7-day average discharges for the 1986 water year and comparing the computed discharges to 7-day average discharges simulated by the BRANCH model (see figure 11). The standard deviation of the differences between discharges computed using the BRANCH model and equation 5 was within 27 percent of equation 5. A bias of 7 percent was significant at the 3 percent level of confidence, according to a T-test. However, this bias was not considered to be realistically significant because of the large standard deviation of the residuals of equation 5.

Equation 5 was used to calculate a longer period of record for use in the development of a 7-day average discharge low-flow frequency curve for the AICW. Seven-day running average discharges of the tributary streams were summed for each day of the concurrent 1954-86 climatic year period of record. The minimum 7-day summed tributary discharge was determined for

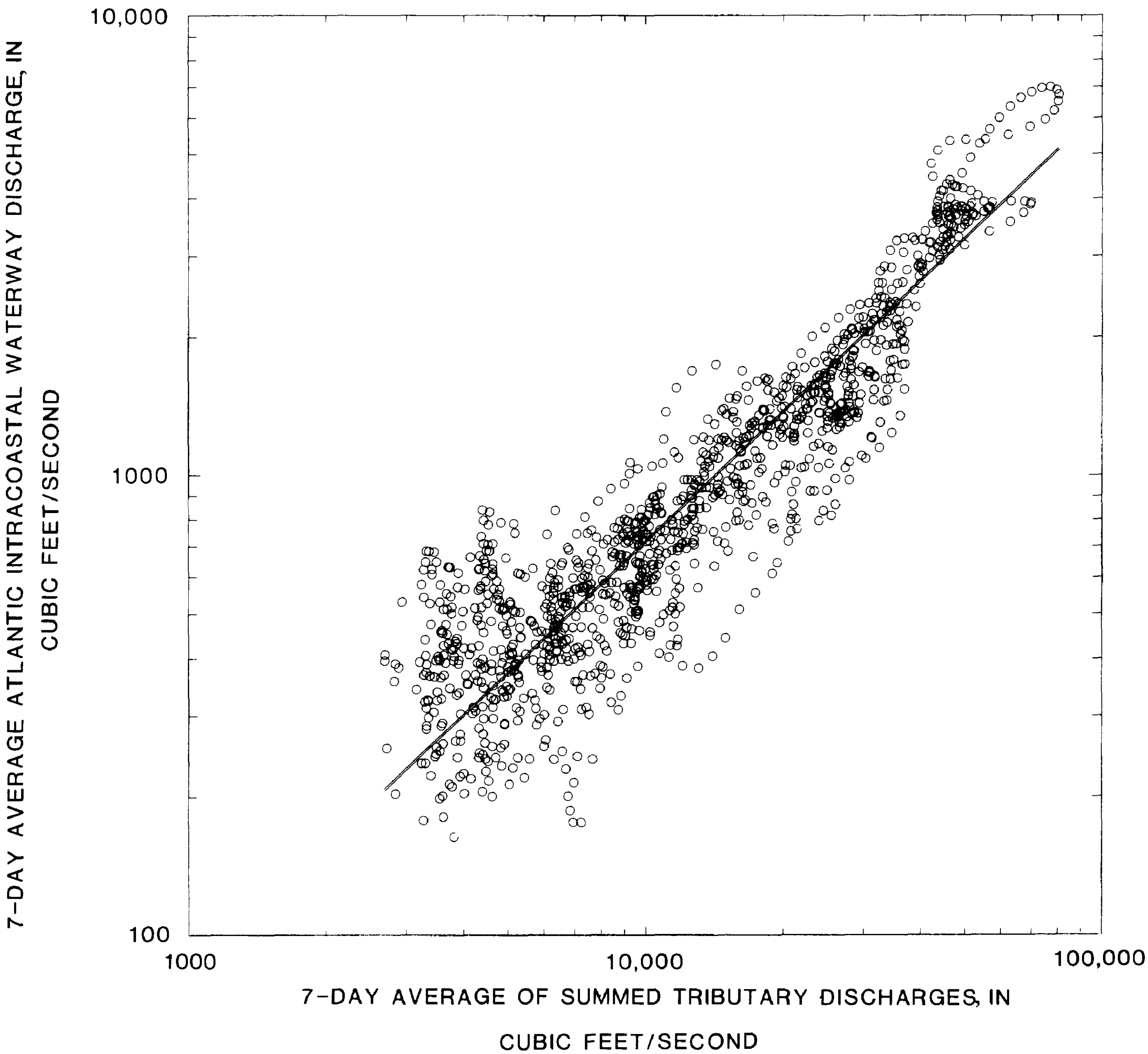


Figure 10.--Relation of 7-day average discharges of the Atlantic Intracoastal Waterway to 7-day averages of summed tributary discharges lagged four days, for 1982-85 water years.

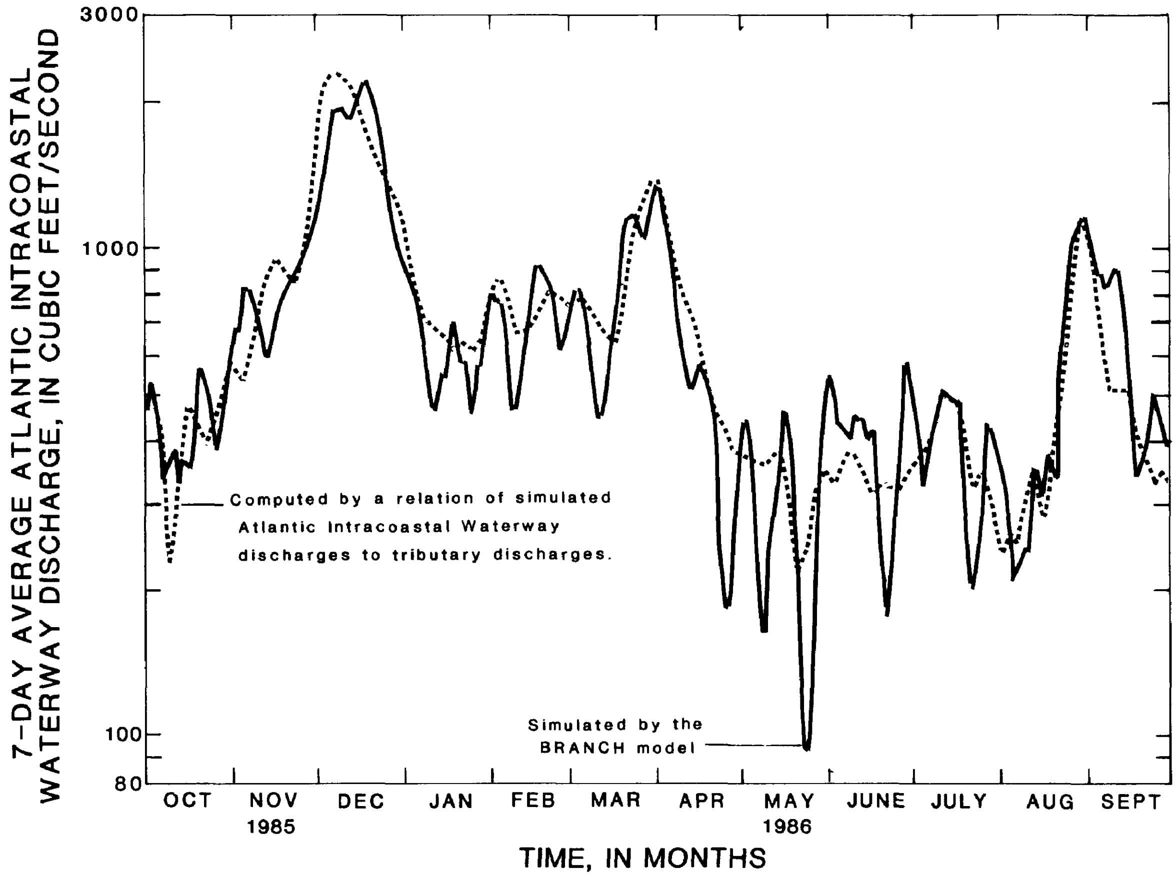


Figure 11.--The comparison of 7-day average discharges computed by a relation of simulated and tributary discharges with simulated 7-day average flows for the 1986 water year for the Atlantic Intracoastal Waterway near Myrtle Beach, South Carolina.

each climatic year of the period of record. The climatic year ends on March 31 and begins on April 1 of the preceding year to avoid dividing the summer-fall dry season. For each climatic year, the minimum 7-day average discharge of the AICW was determined by entering the minimum summed 7-day average discharge of the tributary streams into equation 5. In computing the minimum 7-day discharges, equation 5 was extrapolated from 208 $ft^3/s$ to 90 $ft^3/s$ for AICW 7-day average discharges.

A recurrence interval (RI) was calculated for each minimum 7-day average discharge using the formula:

$$RI = (N+1)/m, \qquad (10)$$

where N is the number of years of record, and m is the rank order of the discharge.

The 7-day average minimum discharges were plotted on a log-normal-probability graph and the low-flow frequency curve was drawn graphically (fig. 12). The low-frequency curve should not be used to obtain minimum discharges for recurrence intervals greater than 20 years, because of the short period of simulated discharge and the use of an extended record.

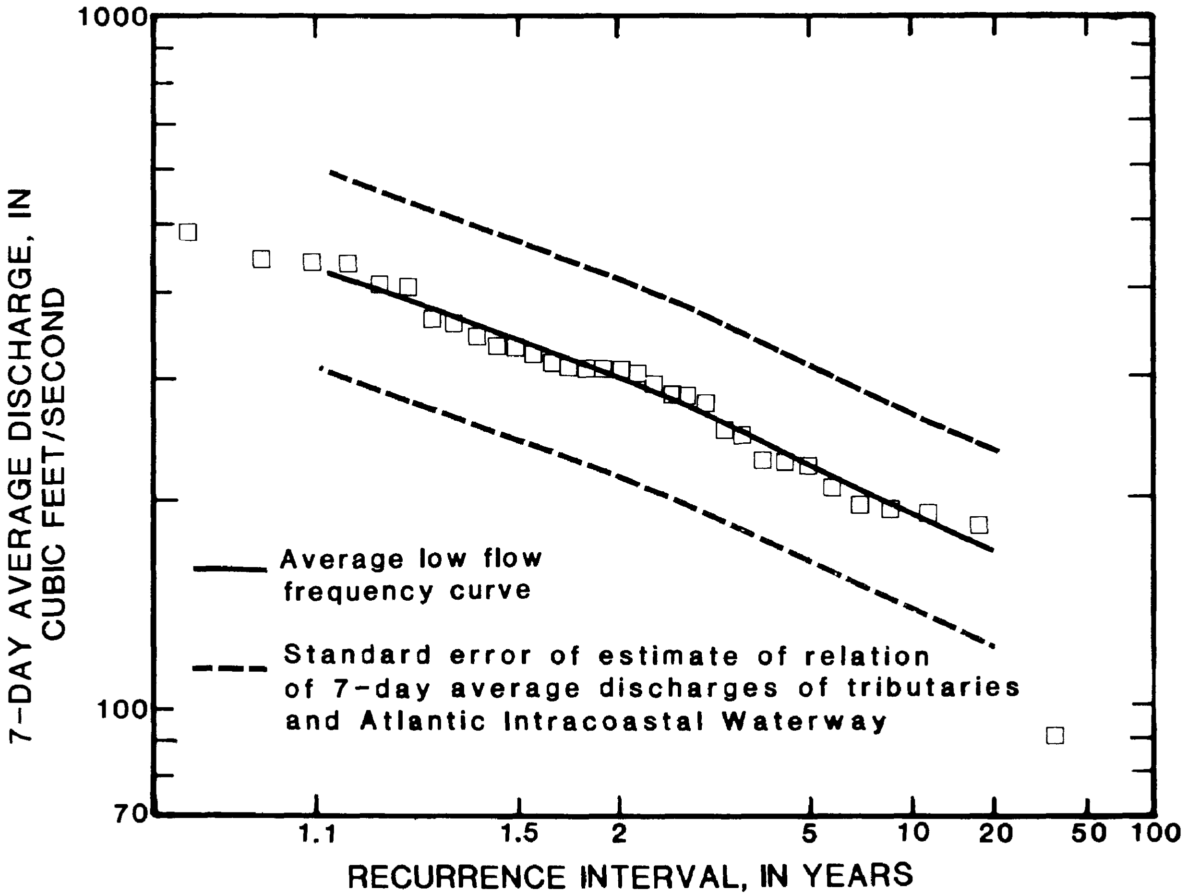


Figure 12.--Seven day low-flow frequency curve for the Atlantic Intracoastal Waterway near Myrtlewood Golf Course (02110760), South Carolina.

The scatter about the regression line in figure 10 is caused by the effects of tide and wind on flows in the AICW in addition to errors inherent to any such regression. Inspection of figure 11 shows that equation 5 somewhat smooths out a 15-day tidal cycle. Therefore, a low-flow frequency relation developed using 7-day average discharges calculated from equation 5 may provide higher discharges for higher recurrence intervals than one developed from measured minimum 7-day average discharges.

The standard errors of estimate of equation 5 were used to construct lines about the low-flow frequency curve in figure 12 to illustrate the range of accuracy of the data from which it was derived. The standard error of estimate can be interpreted to mean that approximately two thirds of the data lies within 33 percent of the regression. The bounds of the standard error of estimate in figure 12 may represent an approximate range of tide and wind effect about equation 5.

## LOCATION OF SALTWATER-FRESHWATER INTERFACE

Specific conductance was used as an indicator of the concentration of the chloride ion of the water in the AICW. Water samples collected in the study reach were analyzed for specific conductance and chloride ion concentration and the data were used to establish the relation between specific conductance and chloride concentration (fig. 13). Specific conductance ranged from approximately 70 µS/cm (microsiemens per centimeter) for freshwater taken several miles upstream from the saltwater-freshwater interface to approximately 50,000 µS/cm for Atlantic Ocean seawater.

A specific conductance of 950 µS/cm for water in the AICW is approximately equal to a chloride concentration of 250 mg/L (milligrams per liter) which is the maximum allowable concentration for secondary drinking water standards (U.S. Environmental Protection Agency, 1981). For purposes of this study, a specific conductance of 950 µS/cm was selected as the indicator of the location of the saltwater-freshwater interface.

Water discharge significantly affects the vertical distribution of specific conductance in the AICW. During low flow the vertical distribution of specific conductance near the deepest part of a given cross section is relatively homogeneous, whereas during high flow the vertical distribution of specific conductance changes dramatically in the zone of transition from freshwater to seawater (fig. 14). As is apparent from figure 14, specific conductance near the surface can be reduced by more than an order of magnitude during high flows. Because of the variance in vertical distribution of specific conductance, the location of the saltwater-freshwater interface is further defined for this study as a specific conductance of 950 umhos/cm approximately 1 foot above the channel bottom. Defining the saltwater-freshwater interface in this manner provides the location of the maximum intrusion of water that exceeds the chloride concentration for secondary drinking water standards, with minimal effect from variations in the slope of the saltwater-freshwater interface.

Figure 15 shows the effect of water discharge on the specific conductance gradient as measured 1 foot above the channel bottom. During high flow the zone of transition from freshwater to Atlantic Ocean seawater is short and the longitudinal specific conductance gradient is steeper than the gradient during low flow.

The location of the saltwater-freshwater interface at high-slack water for the 1982 water year is shown in figure 16a. The interface location is based on readings taken at approximately bi-weekly intervals. Also shown in figure 16b are the daily mean discharges for the 1982 water year. This general comparison of interface location and water discharge shows that as the daily mean discharge decreases, the saltwater-freshwater interface moves southward and as discharge increases, the interface moves toward the north.

The change in specific conductance at a point in a cross section is also affected by water discharge and is closely related to the stage at the cross section. The change in specific conductance with change in discharge and stage at the Briarcliffe Acres gage is shown in figure 17. The data presented are for the period September 16-18, 1982. The highest specific conductance values at the Briarcliffe Acres gage for the 1982 water year were recorded during this period. Specific conductance changes closely follow stage changes with maximum specific conductance occurring less than two hours after the maximum stage.

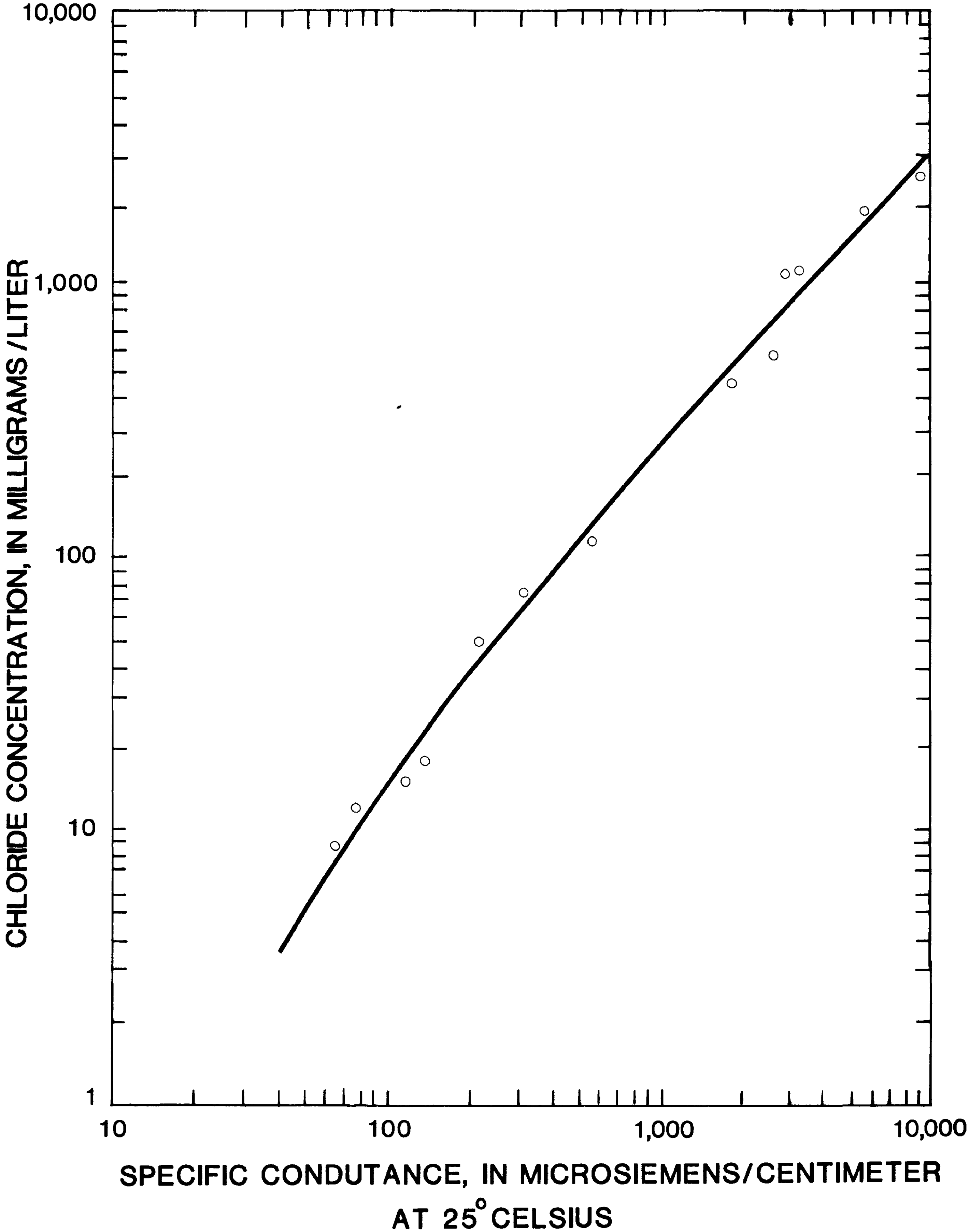


Figure 13.--Relation between specific conductance and chloride concentrations in the Atlantic Intracoastal Waterway.

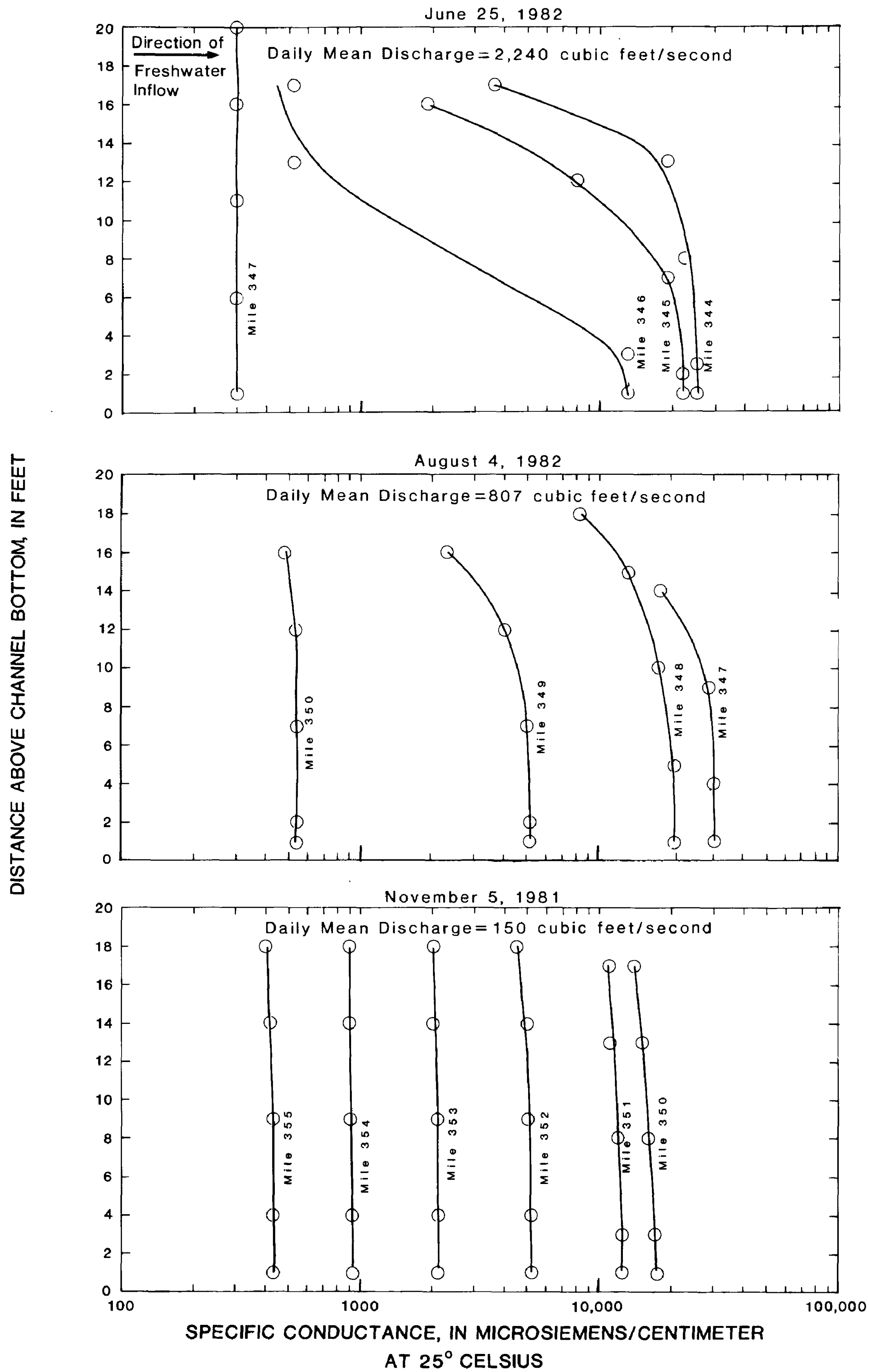


Figure 14.--Vertical change in specific conductance at indicated Atlantic Intracoastal Waterway mile points for different daily mean discharges.

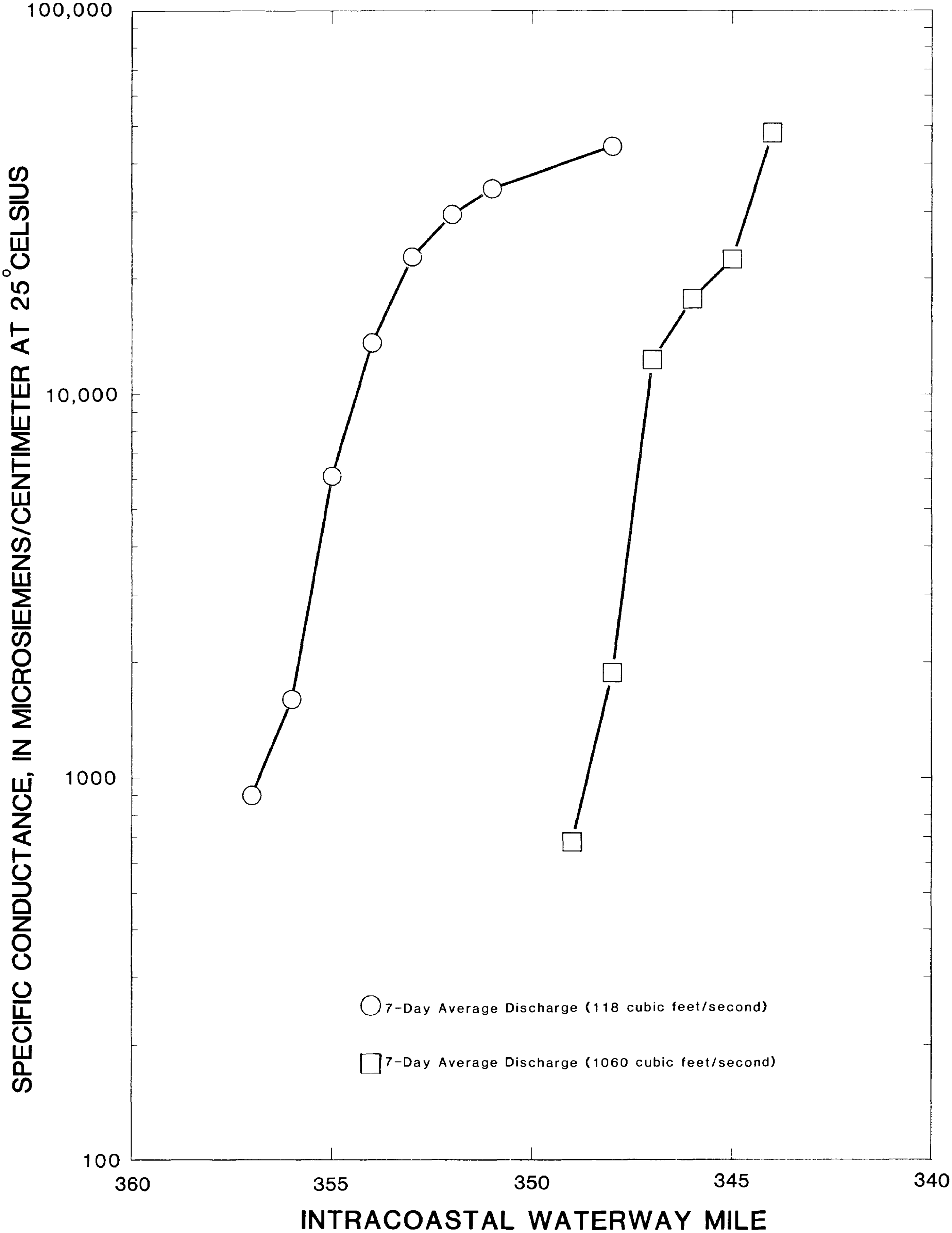


Figure 15.--Longitudinal change in specific conductance for indicated average discharge in the Atlantic Intracoastal Waterway.

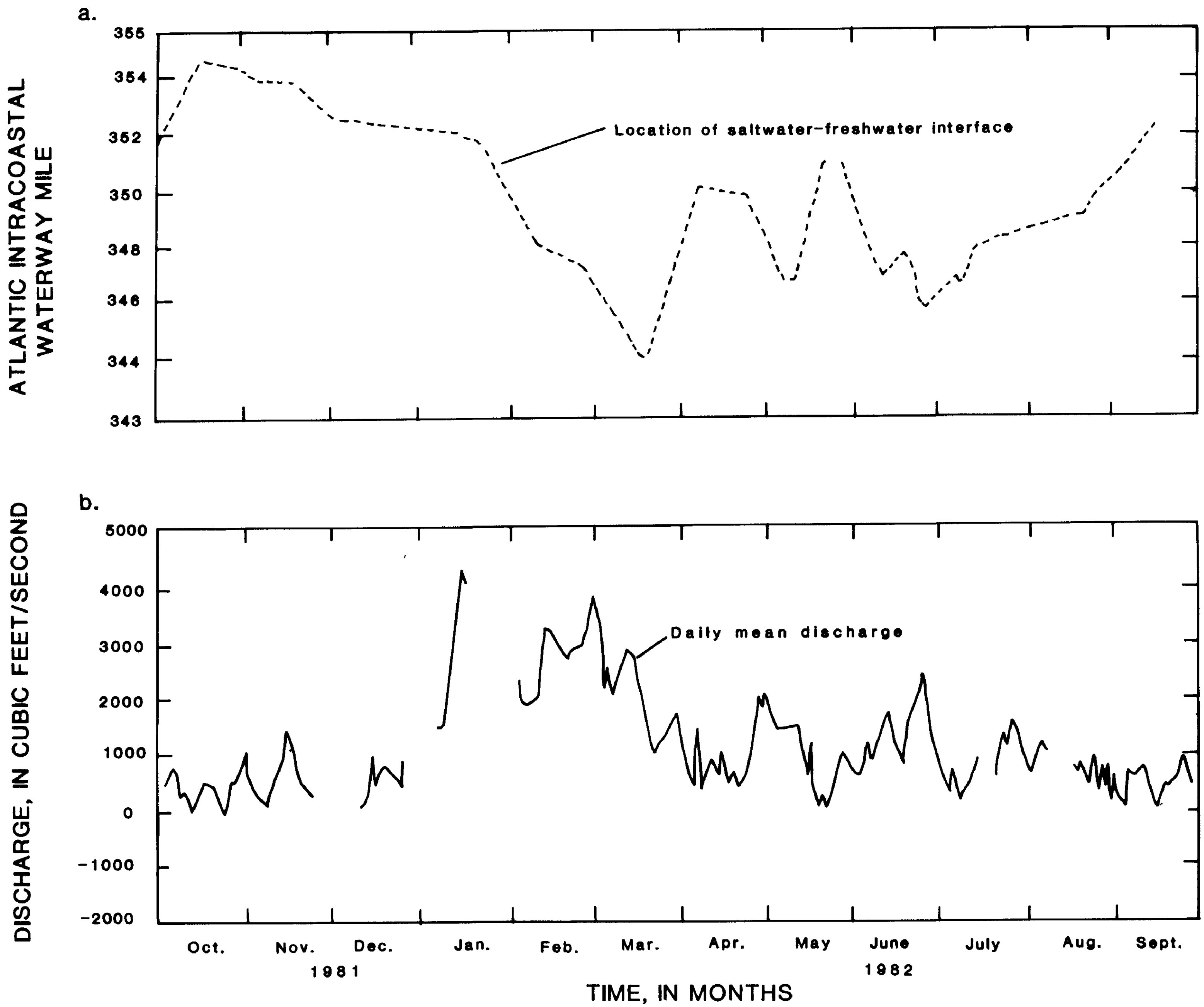


Figure 16.--Location of saltwater-freshwater interface and daily mean discharge in the Atlantic Intracoastal Waterway for the 1982 water year.

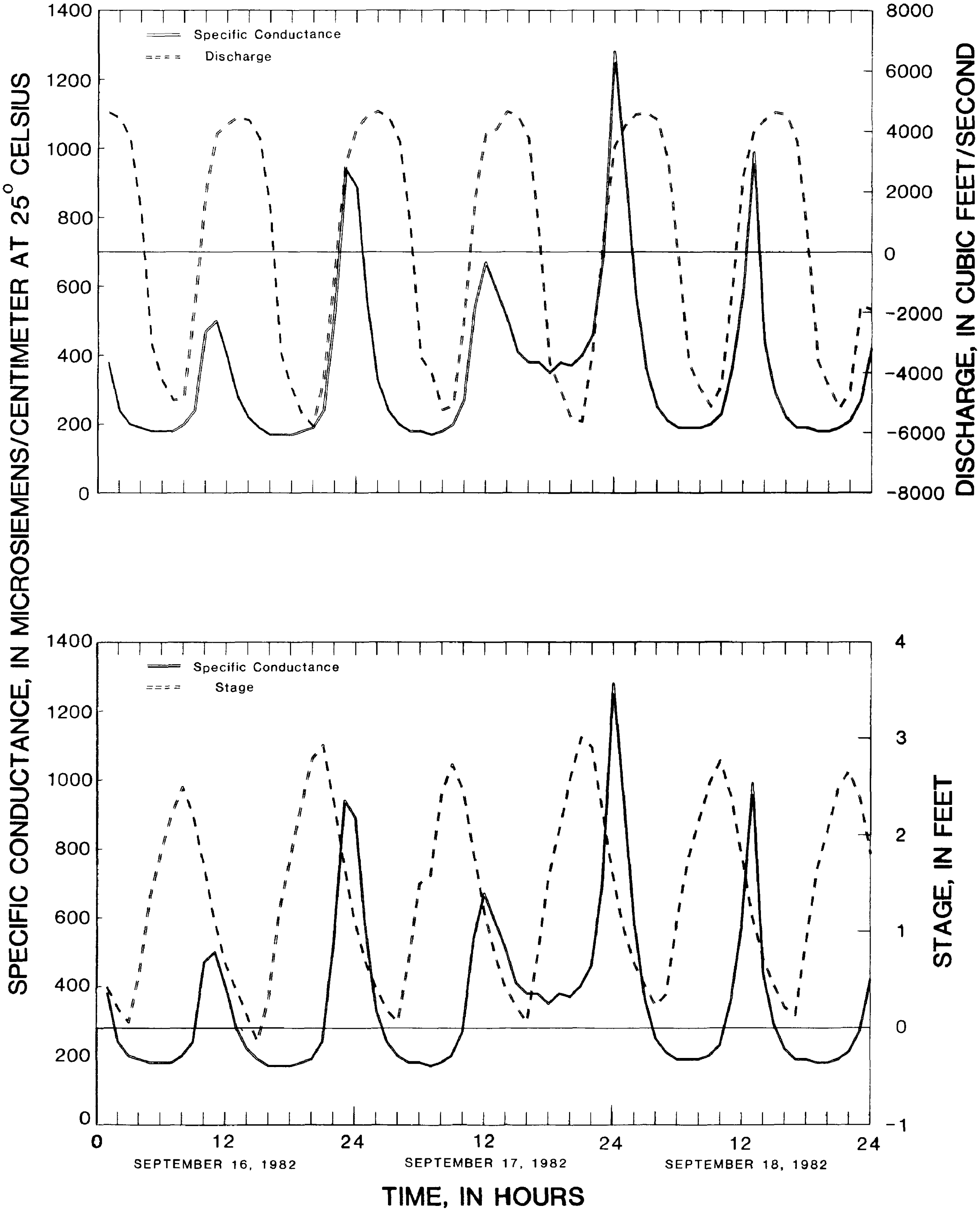


Figure 17.--Comparisons of specific conductance with water discharge and stage, September 16-18, 1982.

The location (X) in AICW mileage of the saltwater-freshwater interface at high slack water was related to specific conductance (C) in µs/cm at Vereen's Marina (02110730) as shown in figure 18 and by the least squares linear regression equation:

$$X = 0.000154 \quad C + 349.0 \ . \qquad (11)$$

The standard error of the relation is 0.69 miles. The correlation coefficient is 0.94 and the coefficient of determination is 0.88. Limits of the input data from which the equation was derived are from mile 349.7 to mile 355.6. The interface location was determined from specific conductances obtained at high slack water by field measurements from boats.

Equation 11 was used with recorded specific conductances at Vereen's Marina to generate the mile position of the daily maximum incursion of the saltwater-freshwater interface for the 1982-86 period of record. From these daily maximum values, 7-day average positions of the interface were computed.

A relation between the 7-day average position ($X_7$) in AICW mileage of the saltwater-freshwater interface and the 7-day average discharge ($Q_7$) in $ft^3/s$ of the AICW was established using 1982-85 data as shown in figure 19, which can be summarized by the least squares linear regression equation:

$$X_7 = -6.06 \quad LOG_{10} \ (Q_7) + 369.3 \ . \qquad (12)$$

The best fit was obtained by lagging the 7-day average discharge by two days. The limits of the equation are from mile 350.6 to mile 355.7. The relation has a standard error of estimate of 0.76 mile, a correlation coefficient of 0.80, and a coefficient of determination of 0.64, as computed by least-squares linear regression.

Because equation 12 was developed using equation 11, which had a standard error of 0.69 miles, the standard error of $X_7$ in equation 12 was adjusted to account for the standard error of equation 11. The adjusted standard error of estimate of $X_7$ equals the square root of the sum of the squares of the standard errors of estimate of the two equations, or 1.03 miles.

The correlation coefficient of 0.80 for equation 12 shows that the interface location is not completely defined by 7-day average discharges in the AICW, probably because of lack of consideration of wind effects in simulations of discharge, tides passing through the study reach from opposite directions at the same time, and storage between tributary gages and the AICW.

Location of the 7-day average of the position of the maximum daily incursions of the interface computed by equation 12 for the 1986 water year were compared with positions computed by equation 11 in figure 20.

For the 1986 water year, equation 12 computed interface positions an average of 0.47 mile further south than were computed using equation 11. A T-test showed that this difference did represent a bias. Therefore, equation 12 may tend to over-compute the mile of the interface. The standard deviation of the differences in the two equations was 0.66 miles.

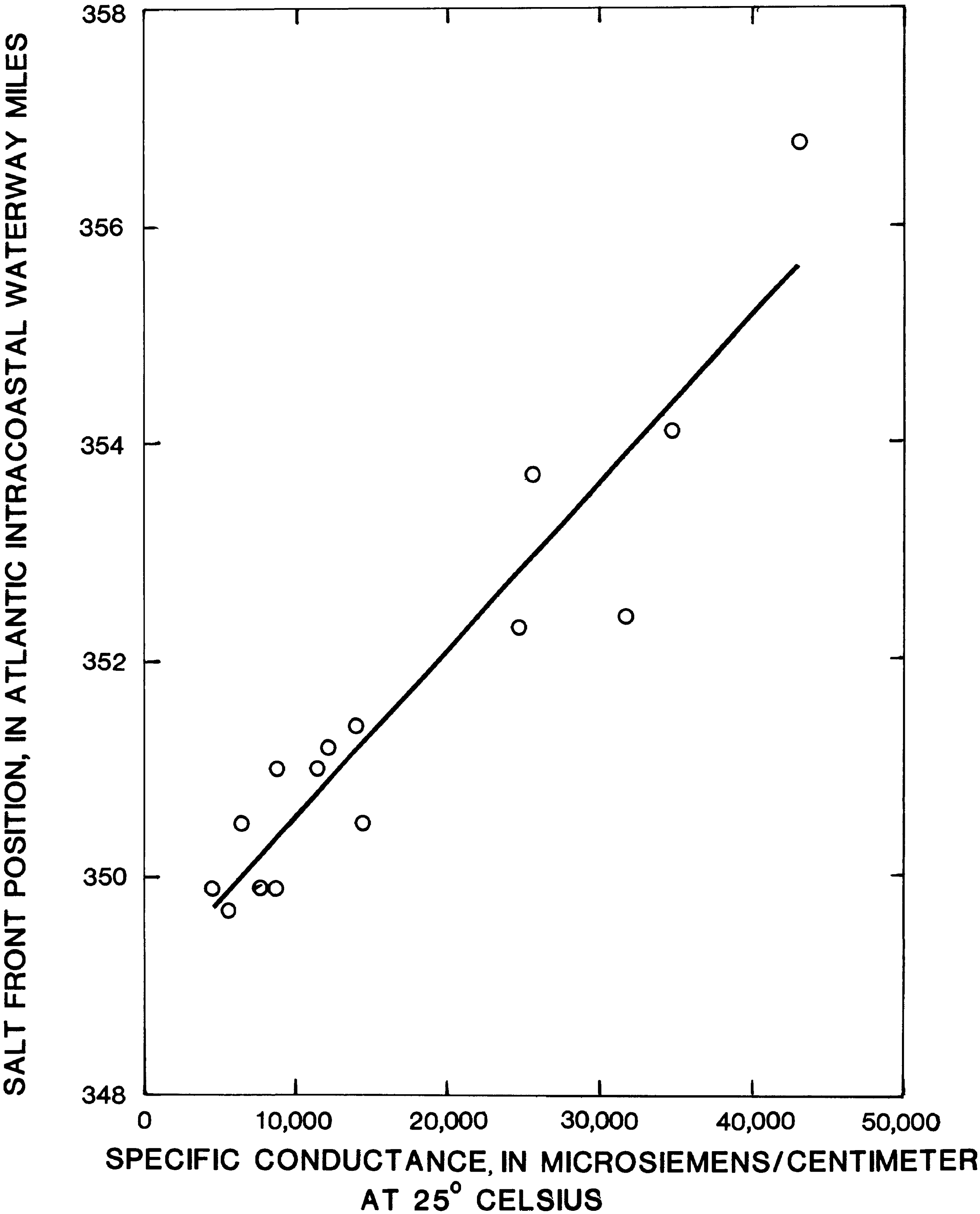


Figure 18.--Relation of the location of the saltwater-freshwater interface to specific conductance at Vereen's Marina (02110730).

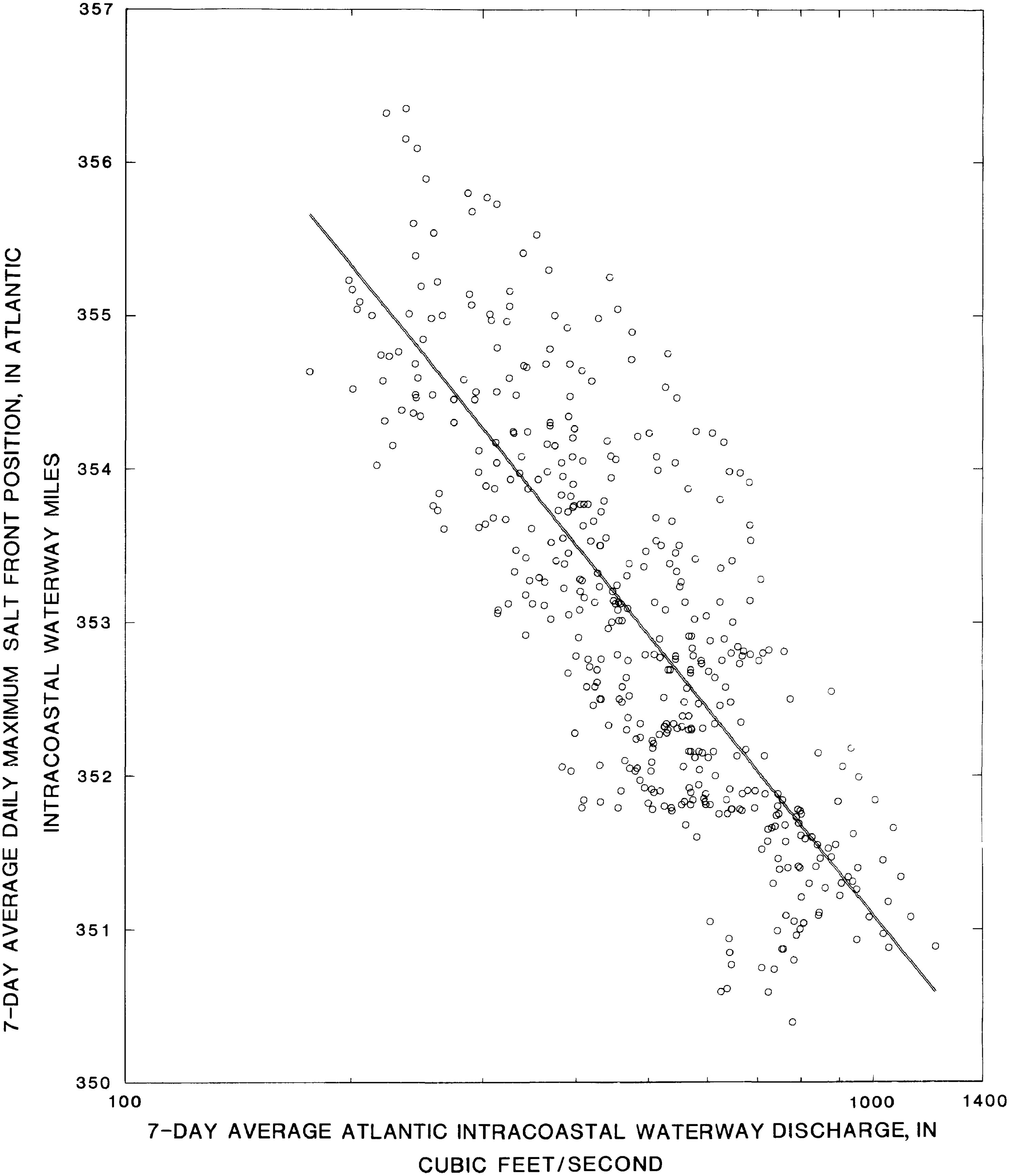


Figure 19.--Relation of the 7-day average mile position of the saltwater-freshwater interface to the 7-day average discharge of the Atlantic Intracoastal Waterway for 1982-85 water years near Myrtle Beach, South Carolina.

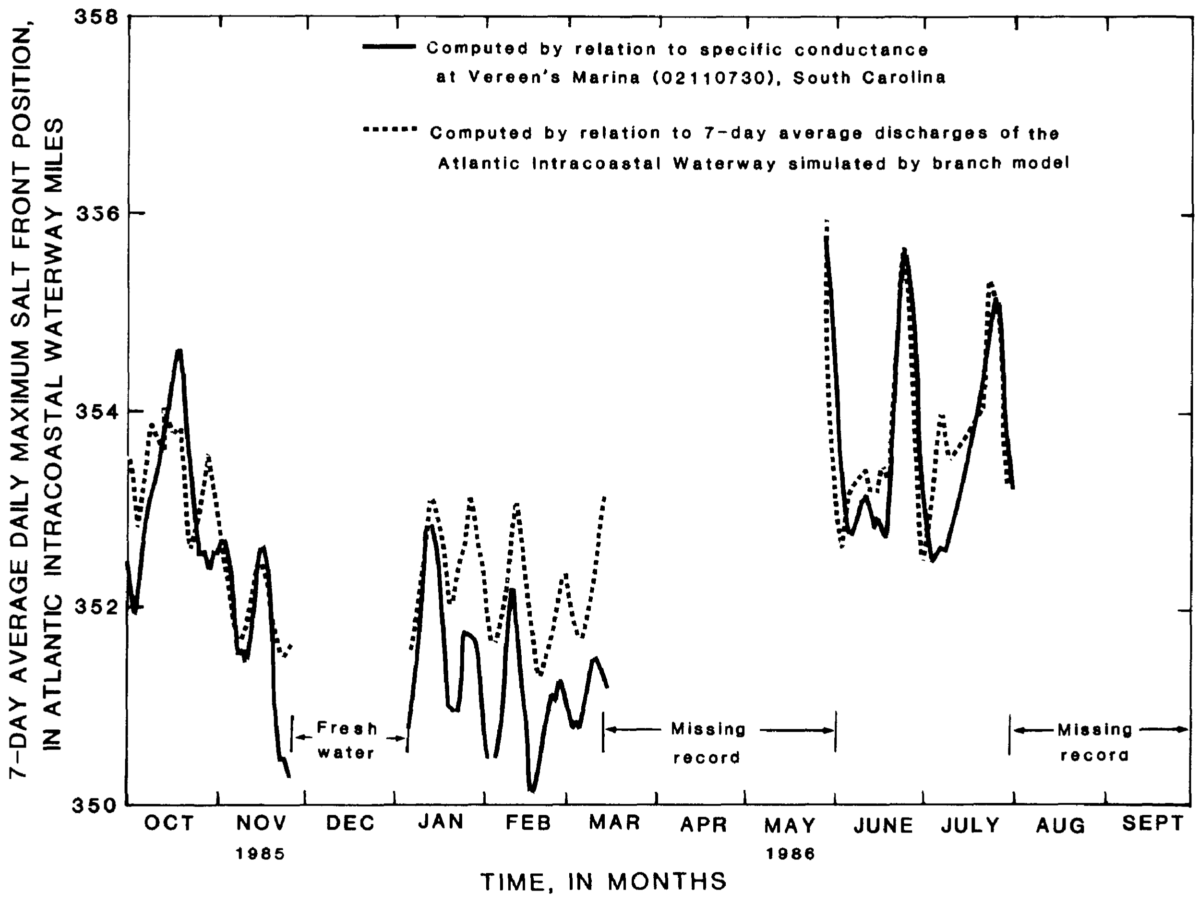


Figure 20.--Comparison of the 7-day average maximum daily mile of the saltwater-freshwater interface computed by a relation to discharge with the position computed by a relation to specific conductance at Vereen's Marina (02110730), South Carolina for the 1986 water year.

## WATER SUPPLY POTENTIAL

The long-term record generated using equation 5 for the period 1953-86 was used to develop flow-duration hydrographs using running 7-day average discharges. Figure 21 presents the duration hydrograph associated with the maximum 7-day and minimum 7-day running averages and 7-day running averages that were less than 90-, 50- and 10-percent of the values shown. The 1983 calendar year daily mean discharges are also shown on figure 21 to provide a comparison of discharges experienced in 1983 to those that can be expected for a longer period of record. It is evident from the information presented in figure 21 that periods of lower water-supply can be expected in some years during the months of August through October.

The relation between 7-day average discharge and 7-day average maximum incursion position of the interface shown in figure 19 can be used to determine the location of the saltwater-freshwater interface. The relation shown in figure 19 can be used in conjunction with the 7-day low-flow frequency curve in figure 12 to estimate the 7-day average maximum incursion position of the interface. As an example, the $7Q_{10}$ discharge, 192 ft$^3$/s, from figure 11 can be entered on figure 19, which shows the corresponding 7-day average location of the interface to be at mile 355.5.

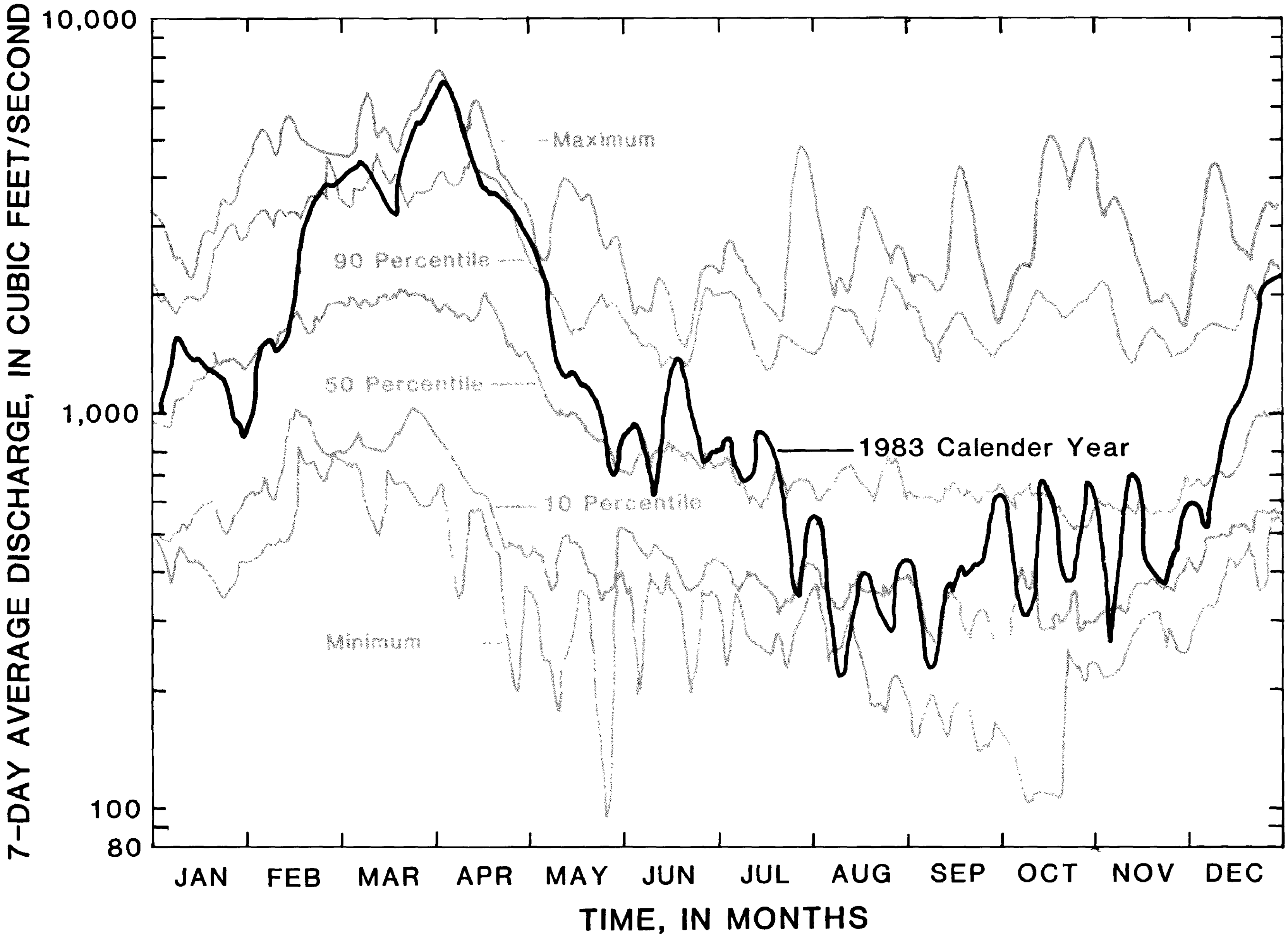


Figure 21.--Flow-duration hydrographs of computed running 7-day average discharges for indicated percentiles for the 1953-1986 water years and the running 7-day average discharge hydrograph for the 1983 calendar year for the Atlantic Intracoastal Waterway.

The $7Q_{10}$ of 192 $ft^3/s$ was determined using equation 5, which may tend to average a 15-day tidal cycle, short-term local impacts of wind and tides, and the unknown effects of storage between the tributary streams and the AICW. If the $7Q_{10}$ is decreased by the standard error of estimate of equation 5 as an approximation of the lower limits of variability not described by equation 5, the $7Q_{10}$ would be 139 $ft^3/s$. The corresponding 7-day average mile position of the saltwater-freshwater interface would be at mile 356.3, by extrapolation of equation 12.

The relation shown in figure 19 or equation 12 can also be used to estimate the movement of the saltwater-freshwater interface as a result of withdrawing water from the AICW. If a 7-day average of 30 Mgal/d (45 $ft^3/s$) was withdrawn from the AICW, the $7Q_{10}$ discharge would be reduced from 192 $ft^3/s$ to 147 $ft^3/s$. The location of the interface for a 7-day average discharge of 147 $ft^3/s$ is at mile 356.2 $\pm$1.0 miles. Therefore, removal of 30 Mgal/d during a period in which the $7Q_{10}$ discharge was experienced will cause a 0.7 mile southern migration of the interface at high-slack water. If flows were decreased from the lower limit of 139 $ft^3/s$ by 45 $ft^3/s$ to 94 $ft^3/s$, the corresponding interface would be at mile 357.3.

A relation of daily maximum intrusion ($X_m$) in AICW mileage of the saltwater-freshwater interface during the 7-day averaging period to the 7-day average of the maximum daily mile position ($X_7$) using 1982-86 data is shown in figure 22 and by the least-squares regression equation:

$$X_m = 1.01 \; X_7 - 2.71 \tag{13}$$

Equation 13 has a standard error of estimate of 0.44 miles, a correlation coefficient of 0.95, and a coefficient of determination of 0.90. Figure 22 also shows that the daily maximum intrusion can also be obtained by simply adding one mile to $X_7$.

The city of Myrtle Beach has proposed locating a water treatment plant and intake in the vicinity of mile 363.3. Equations 12 and 13 can be used to test several scenarios of the location of the maximum intrusions of the interface during the $7Q_{10}$. The maximum daily intrusion of the interface during a $7Q_{10}$ of 192 $ft^3/s$ (fig.12) would be at mile 356.3, 7.0 miles downstream (north) of the withdrawal point. If the $7Q_{10}$ were reduced by a withdrawal of 45 $ft^3/s$ (30 Mgal/d) to 147 $ft^3/s$, the maximum daily intrusion would be at mile 357.0, 6.3 miles downstream from the withdrawal point. If the lower bound of the standard error of estimate in figure 12 was used as a "worst case" estimate of the $7Q_{10}$, the $7Q_{10}$ would be 139 $ft^3/s$ and the maximum daily intrusion of the interface would be at mile 357.2, 6.1 miles downstream of the withdrawal point. If 45 $ft^3/s$ were withdrawn during the "worst case" $7Q_{10}$, the maximum daily intrusion of the interface would be at mile 358.2, 5.1 miles downstream of the withdrawal point.

The freshwater supply potential and location of the saltwater-freshwater interface is based on the assumption that the tributary streams and the AICW will continue to respond as they have during the period 1954-86. Changes in withdrawal or reservoir release patterns in the tributary streams or additional withdrawals from the AICW will alter the relations that have been developed based on historic data.

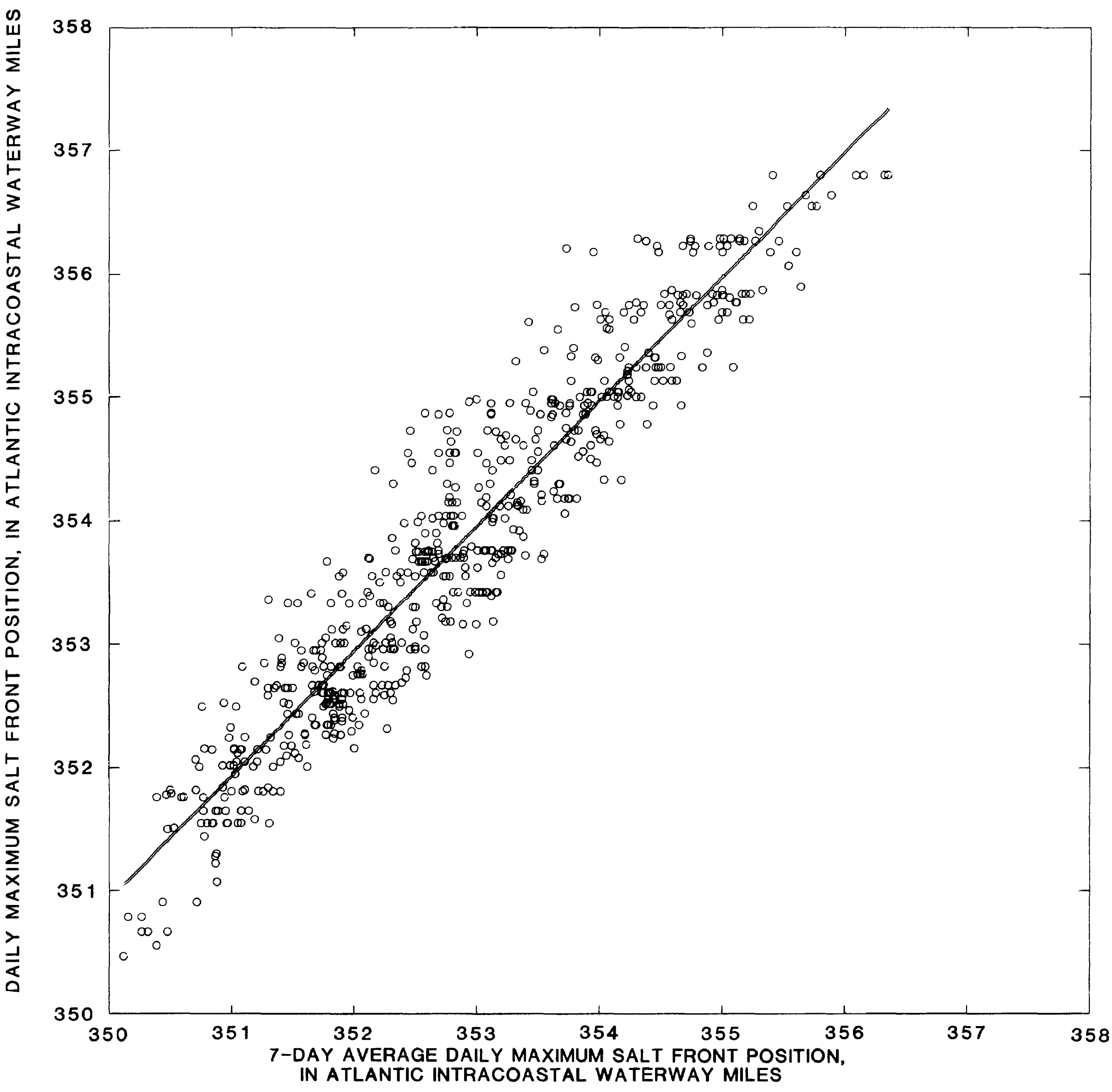


Figure 22.--Relation of the maximum daily mile position of the freshwater-saltwater interface to the 7-day average of the maximum daily mile position for 1982-86 water years for the Atlantic Intracoastal Waterway.

## SUMMARY

The demand for freshwater in Horry and Georgetown Counties in northeastern South Carolina has been increasing steadily and is expected to continue to increase as population growth and development continues. In general, most water-supply development has been from ground water. In some parts of the Myrtle Beach area, ground-water levels in production wells have been lowered to depths greater than 150 feet below sea level. As part of an investigation to find alternative sources of freshwater, the Atlantic Intracoastal Waterway (AICW) in the vicinity of Myrtle Beach was evaluated as a potential water supply of 45 $ft^3/s$ at mile 363.3. Freshwater entering the AICW from the major tributaries is adequate for drinking water purposes.

The AICW is a tidal-affected waterway excavated to a minimum of 12 feet below low tide. Stage recorders were used to monitor water levels in the AICW at four locations, and the location of the saltwater-freshwater interface was determined periodically during the 1982-86 period of record. A one-dimensional unsteady-flow model was used to simulate the daily discharge for the 1982-86 water years to aid in evaluating the use of the AICW as a freshwater supply in the Myrtle Beach area.

A linear least-squares regression equation was developed to relate the running 7-day average discharge in the AICW to the summed running 7-day average discharges of the major tributary streams using data for the period 1982-85. The regression equation was verified using 1986 data. The concurrent streamflow record of the tributary streams and the relation of 7-day average of the summed flows of the tributary streams to the 7-day average flows of the AICW were used to simulate the climatic year minimum 7-day average flows of the AICW for the climatic-year period 1954-86. The 1954-1986 minimum flows were then used to develop a 7-day low-flow frequency curve for the AICW. The estimate of $_7Q_{10}$ in the AICW is 192 $ft^3/s$.

Seven-day average flows of the AICW were also simulated for each day of the 1954-86 period of record using the same methods as above. A flow-duration hydrograph of these simulated discharges indicated that periods of lower water supply can be expected in some years during the months of August through October.

A relation of the mile position of the saltwater-freshwater interface to specific conductances of water recorded in the AICW at Vereen's Marina (02110730) was established. The relation was applied to maximum daily specific conductances recorded in the AICW at Vereen's Marina to simulate the daily maximum position of the interface for the 1982-86 period of record. The 7-day average maximum mile position of the interface was then related to the 7-day average discharges using the 1982-85 data and verified using 1986 data. Also, the position of the daily maximum intrusion of the saltwater-freshwater interface during the 7-day averaging period was related to the 7-day average maximum mile position of the interface. The last two relations show that the maximum daily position of the interface would be at mile 356.3 for the $7Q_{10}$ discharge. If a constant discharge of 45 $ft^3/s$ is withdrawn from the AICW during the period the $7Q_{10}$ is experienced, the relations show that the maximum daily location of the saltwater-freshwater interface would move upstream to mile 357.0. Thus, the investigation of the AICW in the vicinity of Myrtle Beach indicates that the AICW can provide a significant supply of freshwater at the proposed withdrawal at mile 363.3.

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# GLOSSARY

7-DAY AVERAGE DISCHARGE--The average of seven consecutive daily mean discharges.

$7Q_{10}$--The 7-day average discharge having a non-exceedance recurrence interval of 10 years.

CLIMATIC YEAR--A year of data collection ending on March 31 to span the summer-fall dry season.

EBB TIDE--A tidal current returning to the sea.

FLOOD TIDE --A tidal current moving inland from the sea.

HIGH WATER--The maximum height reached by a rising tide. The height may be due solely to the periodic tidal forces or it may have superimposed upon it the effects of prevailing meteorological conditions.

HIGH-SLACK WATER--The maximum height reached by a rising tide at the time of slack water.

SALT FRONT POSITION--Position of the saltwater-freshwater interface.

SLACK WATER--The state of a tidal current when its speed is near zero, especially the moment when a reversing current changes direction and its speed is zero.

SPECIFIC CONDUCTANCE--The ability of water to conduct an electrical current at a standard temperature of 25 degrees Celsius.

TIDAL CYCLE--The period from high water to the next high water, which on average is 12.42 hours.

WATER YEAR--A year of data collection ending on September 30 to span the winter-spring high flow season.