Project 2.2
C2130

# LITTLE MANATEE RIVER STUDY

## A Characterization of Watershed Hydrology and Investigation of Water Quality and Nutrient/Solids Transport

## FINAL REPORT


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## EXECUTIVE SUMMARY

The Little Manatee watershed is located in southern Hillsborough and northern Manatee Counties. The river generally flows in a westerly direction discharging to Tampa Bay near Ruskin.

Land use in the watershed was analyzed using a geographic information system. The entire watershed comprises 57,364 hectares (224 square miles). Upland plant communities comprise 13% of the watershed and consist of pinelands to hardwood forests. Wetland plant communities constitute 9% of the watershed ranging from saltmarsh to hardwood swamp. Water bodies comprise 3% of the watershed, not including the river and its tributaries.

The largest category under GIS land use is agriculture/pasture/barren, which constitutes 75% of the watershed. This category is very general, and includes urban areas. Urban areas represent a small portion of this percentage. This category is representative for subwatersheds except for the Cypress Creek subwatershed which includes the urbanized Sun City center area.

Streamflow and water quality in Carlton Branch, Dug Creek, Cypress Creek, the Little Manatee near Fort Lonesome, South Fork, and the Little Manatee near Wimauma were monitored during the study period from January 1988 through January 1989.

Bi-weekly water quality sampling during the study year found pronounced differences in water chemistry between the seven stream stations. DOC and nitrate concentrations were highly variable during the study period. Concentrations of ammonia and phosphate were somewhat less variable and reached maximum values between July and September. This was the approximate time of the highest discharge.

Particulate carbon, nitrogen and phosphorus vary, in general, with total suspended solids. The maximum or spike in particulate substances for the Cypress Creek, Carlton Creek, Wimauma and Ft. Lonesome chemographs occur at the same time but are not present in the Dug Creek and South Prong chemographs.

The Fort Lonesome station was the most upstream site monitored on the main channel of the Little Manatee River. Generally, water quality at this site can be characterized as highly colored, slightly acidic, with low levels of suspended matter and moderate levels of nutrients. Mean values of color and total dissolved carbon were highest at this station, probably reflecting the input of humic compounds leached from vegetation and litter in the drainage basin.

The site most similar to Fort Lonesome was the South Fork, which was the only station on that branch of the river. Mean values of alkalinity and chloride were ranked lowest for this station, and a number of parameters were ranked second lowest only to Fort Lonesome (conductivity, turbidity, total suspended solids, particulate carbon, particulate nitrogen, calcium and sulfate). For some other parameters (total dissolved carbon, ammonia, nitrate/nitrite, ortho-phosphate, and silica), the South Fork was ranked near the middle of the seven stations.

Of the remaining five stream sampling stations, two sites (LMR near Wimauma and LMR North Fork) were on the main channel of the river while three stations were on three tributary creeks to the main channel. These three tributaries, Carlton Branch, Dug Creek and Cypress Creek, all flow from north to south and enter the Little Manatee on its northern bank. In general, water in these tributaries was lower in color and more highly mineralized than water in the main river or the South Fork. Cypress Creek was notable for the high levels of turbidity, total suspended solids, particulate carbon and particulate nitrogen, probably reflecting the soil disturbance and resulting suspended load that was generated in the sub-basin during the study. Dug Creek and Carlton Branch had the lowest mean color values found in the study but had the highest levels of nitrate-nitrite and silica. It is believed that the high degree of mineralization and dissolved constituents in these three tributaries are the result of irrigation runoff.

The three stations on the main channel of the Little Manatee River are Fort Lonesome, LMR North Fork, and the LMR near Wimauma. Examination of mean water quality values for these three stations demonstrates the increasing mineral and nutrient content of the Little Manatee as it flows to Tampa Bay. Some constituents, such as nitrate, silica, TSS and sulfate show significant levels of enrichment proceeding downstream while both particulate and dissolved phosphorus show little or no enrichment.

Salinity distributions in the estuary showed distinct changes in response to these changes in flow. Mean water column salinity was measured at four fixed locations in the river. Salinity at the mouth of the river remained above 20 ppt until early September, when flood flows briefly reduced salinity to near 5 ppt. For the remainder of the year, salinities fluctuated between 18 and 23 ppt salinity, with slight decreases in November and January due to storm events. Maximum observed salt penetration was in June, near the end of the dry season. Salinity in the river decreased through July and August, and the river was completely fresh except for a small salt lens at the mouth during a flood in early September. By late September and through the fall, salinity distributions had returned to more typical profiles, although a significant storm event in January 1989 freshened the river above mile five.

Dissolved oxygen concentrations in the Little Manatee River were at high levels during most of the year but reduced to values below 4 mg/l during much of the summer, indicating potentially stressful concentrations for aquatic biota in the summer. Differences in dissolved oxygen between surface and bottom waters were small, however, and it does not appear that oxygen stress occurs in bottom waters due to limited mixing. Generally, with regard to temperature and salinity effects on water density and stratification, the Little Manatee tends to be well mixed. There are areas of the river, however, that appear to be sensitive to factors that could reduce dissolved oxygen concentrations.

A progression from the upper reaches of the Little Manatee estuary to Tampa Bay showed chemical differences indicative of a change from nutrient-rich, low-salinity waters to phytoplankton dominated, high-salinity waters. Nitrate-nitrite, silica, particulate carbon, turbidity, and total dissolved carbon showed distinct declines in concentrations from the upper reaches of the estuary to Tampa Bay. With the exception of phosphorus, the bay has much lower levels of dissolved nutrients (N, Si) due presumably to phytoplankton uptake. Dissolved phosphorus concentrations were distributed very evenly along the salinity gradient indicating this nutrient is not limiting and is in excess supply in the estuary. Total suspended solids were highest in Tampa Bay, and increased with salinity in the river due to the influence of bay water.

The Ruskin Inlet station was located in an urbanized tributary to the Little Manatee that receives considerable amounts of urban runoff. Of course, salinity fluctuated much more at this station than at the stations located on specific salinity concentrations. Nutrient concentrations showed large seasonal variation at this station due to stormwater inputs and the rapid change from a mesohaline (medium salinity) to a low salinity environment.

## ACKNOWLEDGEMENTS

Watershed management has been an elusive concept to apply in protecting estuaries and their tributaries. One of the reasons for this is the difficulty in obtaining physical, chemical and biological information on a scale needed to determine system-wide resource protection strategies.

The Little Manatee River Project demonstrates that skilled people will go beyond their routine responsibilities in contributing to a team effort to make a large-scale study work. In particular, the complex field and laboratory activities of this project could not have been conducted without the personal interest and professional help from: Quincy Wylupek, Phillip Rhinesmith and Mark Rials of the Southwest Florida Water Management District.

Of considerable importance to watershed studies are good descriptions of hydrological processes and upland features. For assistance in providing these, special thanks are due to Dr. Bruce Taylor, P.E. (Taylor Engineering, Inc.), and Harry Downing (Southwest Florida Water Management District). We especially appreciate the help of Ken Butcher (United States Geological Survey) for his promptness in collecting stream flow information and establishing stream discharge statistics.

Funded by NOAA through the Coastal Zone Management Act, as amended .

# I. INTRODUCTION

This is a report on water chemistry and hydrology in the Little Manatee River, its tributaries, and estuary. The results presented in this report deal mainly with characterizations of the movement of nutrients, solids and major ions through the system. The report also includes a brief physiographical description, including vegetative cover, land use, soils, and climate to support findings on the origin, transport and removal of chemical constituents and solids carried by the river.

This document, along with separate biological reports-(Peebles,1989),(Rast, 1989),(Vargo, 1989)-are the result of efforts by the Southwest Florida Water Management District (SWFWMD), Florida Department of Environmental Regulation (FDER), and Florida Department of Natural Resources (FDNR) to develop a system-wide understanding of resource management needs for the Little Manatee River basin. These reports are basic information sources to be used in identifying man's influences on the river, estimating possible degradation of the aquatic system, and understanding the susceptibility of the system to future problems.

SWFWMD, FDER and FDNR initiated this project in response to agency and public concern over protection of the last major river in a relatively natural condition in the Tampa Bay system. The protection of the Little Manatee River and estuary is a state priority. The river, in addition to its own resource values influences water quality and habitat in Tampa Bay including the adjacent Cockroach Bay Aquatic Preserve. Because of the lack of urbanization in the basin, there is opportunity to develop a comprehensive strategy to anticipate and prevent problems as the basin is developed.

Activities to protect and re-establish living resources in Tampa Bay cannot be fully effective without protecting the Bay's tributaries and their associated wetlands. Drainage basins with natural systems relatively intact, such as the Little Manatee River basin should be managed as ecological and hydrological units. This comprehensive approach is the only effective way to ensure that proper freshwater flows and nutrient inputs are maintained in the estuarine part of the system.

As in many coastal systems the existing information on the Little Manatee River and estuary was not on system-wide processes. While localized data is useful for individual regulatory decisions, larger-scale studies that integrate physical and chemical information are essential for judging the susceptibility of the river to development pressures, establishing sound management objectives and plans, and providing development criteria for maintaining conditions that support estuarine productivity.

# OVERVIEW OF THE LITTLE MANATEE RIVER WATERSHED PROJECT

Prior to initiating the study, we consulted with local, state and federal agency representatives to determine the extent of existing information on the system and to help establish a master plan and detailed sampling and analytical methods. During discussions between the project team and persons with local knowledge of the river, the following concerns were expressed:

1. Upstream impoundments and water diversions have decreased the estuary's value as a fishery nursery;

2. Nutrient enrichment has resulted from agriculture and aquaculture operations in the watershed;

3. Future development in the watershed may increase erosion and contribute to increased sedimentation and nutrient enrichment;

4. Land use planning agencies do not have sufficient information to adequately protect watershed features and natural processes; and

5. Finfish and shellfish yields have decreased.

During the preliminary stage, the U.S. Geological Survey, under contract with DER installed stream flow recorders on subwatersheds in preparation for chemical and hydrological measurements on the major system compartments.

After initial testing of field and laboratory methods, formal work began in January 1988. The last field measurements included in this report were taken January 1989, although monitoring will continue on a less intensive basis.

The SWFWMD conducted the field program, the majority of the laboratory work, and assisted in interpretation of the data. Supplemental laboratory analyses were done by commercial laboratory. The Department of Natural Resources Marine Research Institute provided mapping and descriptions of land features, land usage and drainage patterns. The Department of Environmental Regulation provided technical assistance on establishing methodology and interpreting chemical and physical measurements.

## II. DESCRIPTION OF THE WATERSHED

### SIZE AND TRIBUTARIES

The Little Manatee watershed is located in southern Hillsborough and northern Manatee Counties. The Little Manatee River is about 40 miles in length with a contributing drainage basin of about 221 square miles (Figure 2.1). Headwaters for the river are in a swampy area of southeastern Hillsborough County. The river generally flows in a westerly direction discharging to Tampa Bay near Ruskin. The river channel is usually well defined except in the most upstream areas. The lower 10 to 15 mile reach of the river is tidally influenced.

Major tributaries to the Little Manatee River include Cypress and Dug Creeks located in the northwestern portion of the basin; Gully, Carlton, and Pierce Branch located in the north-central portion; Howard Prairie Branch and Alderman Creek in the eastern portion; South Fork in the south-central portion; and Wildcat and Curiosity Creeks in the western portion of the basin. Streamflow and water quality in Carlton Branch, Dug Creek, Cypress Creek, the Little Manatee near Fort Lonesome, South Fork, and the Little Manatee near Wimauma were monitored during the study period from January 1988 through January 1989. Details

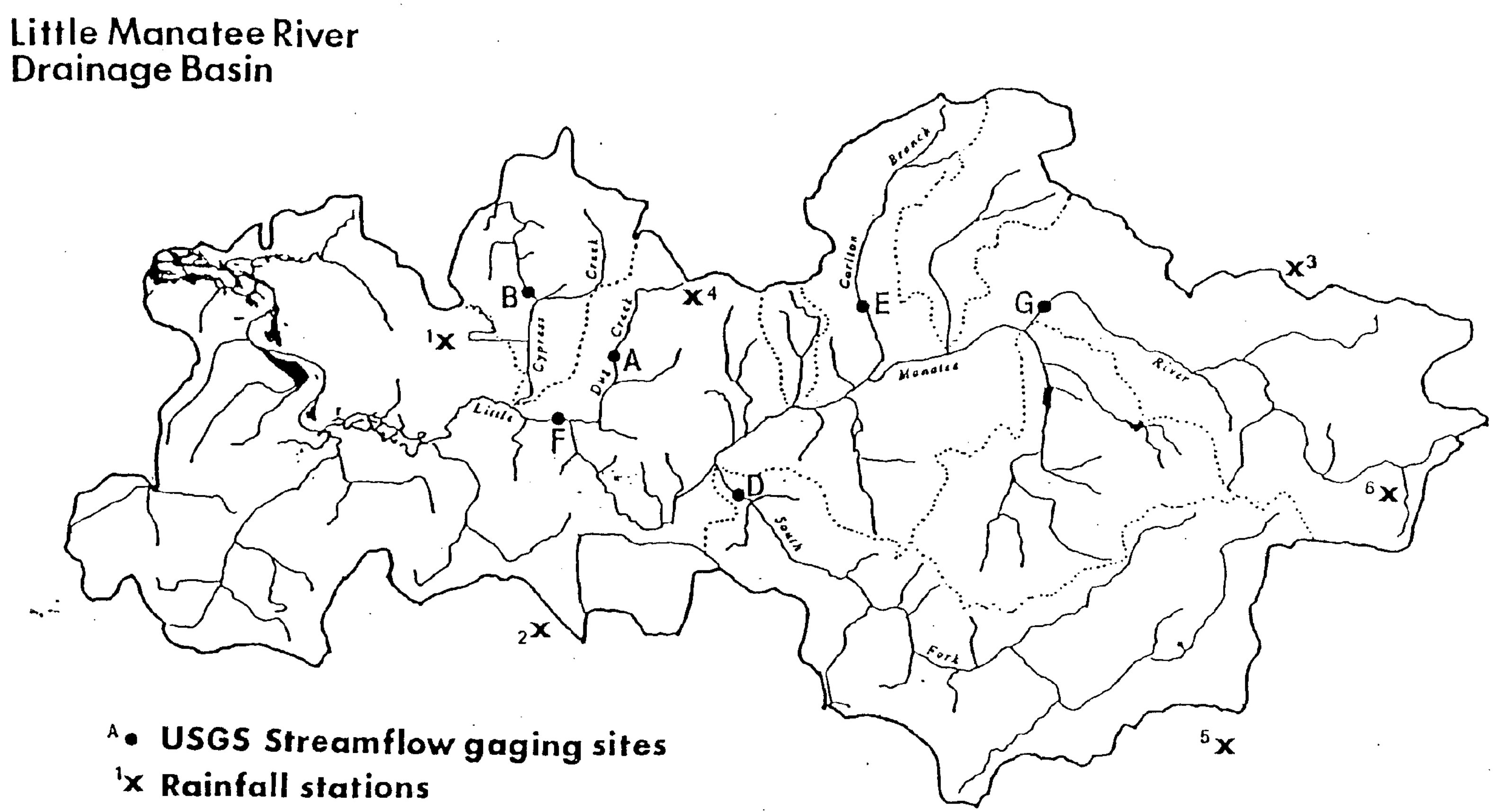


Figure 2.1. The Little Manatee River Drainage basin.

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presented in Figure 2.2. Most of the rainfall occurs during the summer months. Tropical storms and convective thunderstorms are the main reason for the higher precipitation rates in the summer months.

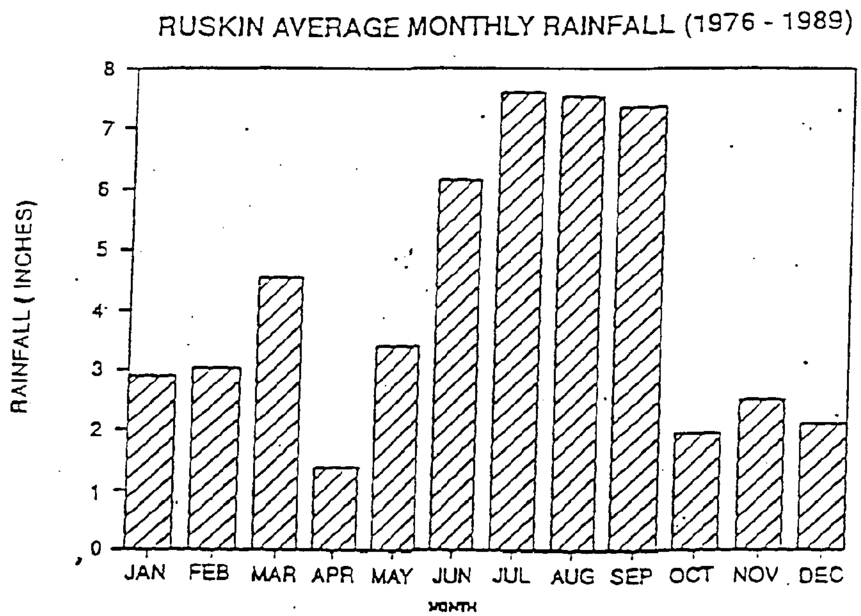


**Figure 2.2. Distribution of the monthly average annual rainfall for the Ruskin station (1976-1989).**

Another important aspect of the climate that effects runoff is evapotranspiration. Evapotranspiration is the process whereby incoming energy from solar radiation transforms water from a liquid to a gaseous state. The processes involve direct evaporation of water from moist surfaces and transpiration during plant respiratory processes. There are two types of evapotranspiration (ET) estimates: potential and actual. Potential ET is the maximum ET expected under prevailing climatic conditions assuming non-limited water availability. One of the most accurate methods for estimating potential ET is the Penman method. The method considers cloud cover, temperature, vapor pressure deficits and incoming solar radiation. For the Tampa area, the 50 percent probable potential ET is 54 inches (Smajstrla, 1984), which is close to the average annual precipitation for the area.

Actual ET, on the other hand, is the amount of water transformed based upon prevailing climatic conditions and the amount of available moisture. Actual ET is very difficult to estimate because of its dependency on numerous factors. Such factors include land cover, distribution of rainfall, surface water storage, and soil percolation. Since the basin exhibits very little ground water recharge or discharge into the aquifer system (Aucott, 1988), the actual ET rate can be approximated by rainfall minus runoff. If the average annual rainfall is taken as 50.5 inches/year and the average annual runoff depth at 15.6 inches/year, the actual ET estimate is 34.9 inches/year. This estimate is probably low because of the irrigation runoff within the basin. The USGS has estimated actual ET in the region at 39 inches/year.

## GENERAL RUNOFF CHARACTERISTICS

A one-hundred forty-nine square mile area of the Little Manatee River watershed has been monitored for runoff at a USGS gaging station since 1939. This USGS stream gaging station (#02300500) is located on the Hwy. 301 bridge near Wimauma 15 miles upstream from the river's mouth. Daily records for this site are available for a period of about 50 years which provide a good statistical base for establishing characteristic flow patterns for the watershed.

Average monthly discharges for the period of record available for the Wimauma station are presented on Figure 2.3. July through September represent the highest runoff months with average discharges between 300 and 400 cubic feet per second (cfs).

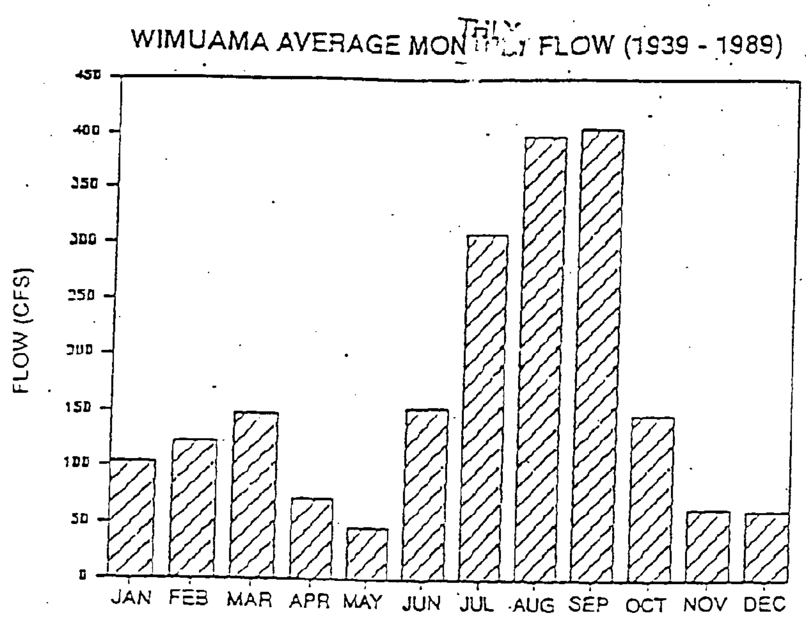


Figure 2.3. **Average monthly flows for Wimauma station (1939-1989).**

The remaining months of the year averaged 150 cfs or less. Pronounced low flow periods usually occur in the late spring (May) or the late fall and early winter (November and December). The average discharge for the 149 square mile area is 171 cfs. In terms of depth of water over the contributing watershed, this flow represents 15.6 inches of runoff per year. Along with the Alafia basin, the Little Manatee basin has the largest runoff depth of any basin located within west-central Florida (15 to 20 inches/year)(USGS, 1981).

A review of historical flow records for the Wimauma site reveals extreme seasonal and yearly variations in discharge. The largest instantaneous flow of record is about 14,000 cfs which occurred in June 1960. The lowest flow of record is about 0.8 cfs which occurred in December 1976. Table 2.1 represents a duration analysis of discharges at the Wimauma monitoring station. Between the 95 and 5 percent exceedance probabilities flows varied between 10.0 and 708 cfs, with a median of 54 cfs. This median flow is less than the average flow for this station by more than a factor of three, indicating that the average statistic is heavily influenced by brief periods of high runoff.

Based on a review of historical runoff events and the duration analysis, it appears that the runoff hydrographs are very peaked or ephemeral. This type of runoff pattern indicates the absence of significant surface water storage areas that can moderate discharges by attenuating flows. For example, the Withlacoochee River system drains an area greater than 2000

Table 2.1. Wimauna Flow Duration Table.

Wimauma Flow Duration Table

| Exceedance Probability | Flow | Exceedance Probability | Flow |
|---|---|---|---|
| 95.0 | 10.5 | 45.0 | 67.5 |
| 90.0 | 15.6 | 40.0 | 75.3 |
| 85.0 | 20.0 | 35.0 | 89.3 |
| 80.0 | 23.6 | 30.0 | 109.7 |
| 75.0 | 27.2 | 25.0 | 140.3 |
| 70.0 | 31.9 | 20.0 | 185.2 |
| 65.0 | 36.6 | 15.0 | 257.2 |
| 60.0 | 42.0 | 10.0 | 400.6 |
| 55.0 | 47.4 | 5.0 | 708.3 |
| 50.0 | 55.3 | | |

square miles; however, the highest recorded discharge near the mouth of that basin has been less than 10,000 cfs. This is because the associated lakes, sloughs, and swamps in the Withlacoochee basin provide significant attenuation of peak flows. This is in contrast to the Little Manatee River at the Wimauma USGS gaging station which has a drainage area of 149 square miles but a recorded peak discharge of 14,000 cfs.

During the study period several days of significant rainfall occurred over the basin yielding a peak discharge of 9700 cfs. This represents a discharge event with a probability of occurrence between one-in-10 to 25 years. As previously indicated, the largest instantaneous flow of record for the Wimauma station was 14,000 cfs. This represents a discharge event with a return frequency of one-in 50 years. Table 2.2 represents expected high discharges for various return intervals.

Table 2.2. Flood Flow Return Frequencies (D&M, 1975)

| Return Interval Years | Flow @ Wimauma |
|---|---|
| 100 | 18,550 |
| 50 | 14,800 |
| 25 | 11,560 |
| 10 | 7,930 |
| 2.33 | 3,300 |

Results of low flow frequency analysis for the Little Manatee River near Wimauma are presented in Table 2.3. This table shows that the river has prolonged periods of low flows. For instance, a thirty-day period of average flow less than 13 cfs has a return frequency of every two years. The lowest daily flow of record (0.8 cfs) has a return interval greater than one-in 20 years. Florida Power and Light (FP&L) has a large pumping station on the Little Manatee River that is used for make up water for their power generating facility which went into operation in 1976. It is expected that this withdrawal will have little impact on extreme low flows because of withdrawal limitations by agreement.

Table 2.3. Low-Flow Frequency Wimauma

| Consecutive | Return Frequency in Years | | | |
|---|---|---|---|---|
| Day | 2 | 5 | 10 | 20 |
| 1 | 7.9 | 4.1 | 2.7 | 1.9 |
| 3 | 8.3 | 4.4 | 3.0 | 2.1 |
| 7 | 9.1 | 4.8 | 3.2 | 2.3 |
| 14 | 10 | 5.7 | 4.1 | 3.1 |
| 30 | 13 | 7.6 | 5.8 | 4.7 |

The next longest term gaging station (#02300100) within the basin is the Little Manatee River near Fort Lonesome. The station monitors discharge from a 31.4 square mile basin located in the northeast section of the Little Manatee watershed which is within the 149 square mile area monitored by the Wimauma station. The monitoring station is located near the Hwy. 674 bridge 31 miles upstream from the Little Manatee River mouth. The station was installed in 1963 and has been continually operated since that time, providing about 25 years of daily discharge data.

A review of the historical flow records reveal the same extreme variations in flow as noted at the Wimauma station. The largest instantaneous flow of record is 3100 cfs which occurred in September 1979. The minimum flow is zero and it occurs quite often. Average monthly discharges for the period of record at Fort Lonesome are presented on Figure 2.4. July through September represent the highest runoff months with average discharges between 50 and 80 cfs. The remaining months of the year average from 30 to slightly below 10 cfs. Similar to the Wimauma station, the lowest average monthly flows are observed in the late spring and late fall. The average discharge for the basin is 29.6 cfs. In terms of depth of water over the contributing basin, this flow represents 12.80 inches of runoff per year. This is significantly less than the Wimauma runoff depth by about 20 percent. This difference in runoff depth would indicate that the hydrologic conditions within the basins are differences in irrigation runoff, may be affecting discharge volumes in certain tributaries represented by the Wimauma station.

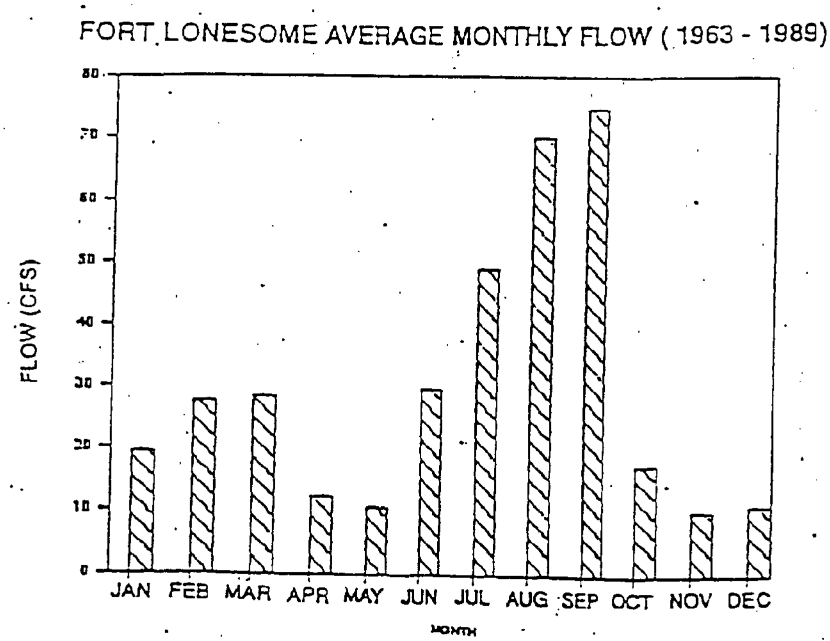


**Figure 2.4.** **Average monthly flow for Fort Lonesome station (1963-1989).**

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GEOGRAPHIC INFORMATION SYSTEMS DEVELOPMENT

The development of a GIS database is complex, dynamic and requires data acquisition from many sources. Since the future analyses to be conducted with the GIS will be quantitative, it is imperative that cartographic integrity be maintained. This constraint has inhibited data entry, but results of maintaining this approach will have long-term benefits.

Figure 2.5 depicts some of the layers of data being input to the Marine Resources Geographic System (MRGIS). These layers represent data identified as available in map form, or that can be generated from areal photography or satellite imagery.

The base map (data layer to which all other layers are referenced) consists of an April 1988 SPOT satellite panchromatic image geo-referenced to 7.5 minute U.S.G.S. quadrangles in a Universal Transverse Mercator(UTM) projection. The MRGIS data layers are currently in raster format, although we can accept vector data or convert raster data to vector for various analyses or for data distribution.

## Data Acquisition and Quality Control

Data Layers. Numerous problems have been encountered generating appropriate overlays. Some data sources, problems and solutions are depicted in Table 2.4. It should be understood that many of these databases were not created with GIS entry in mind and do not have the cartographic integrity of a photogrammetrically developed map. Problems have been compounded

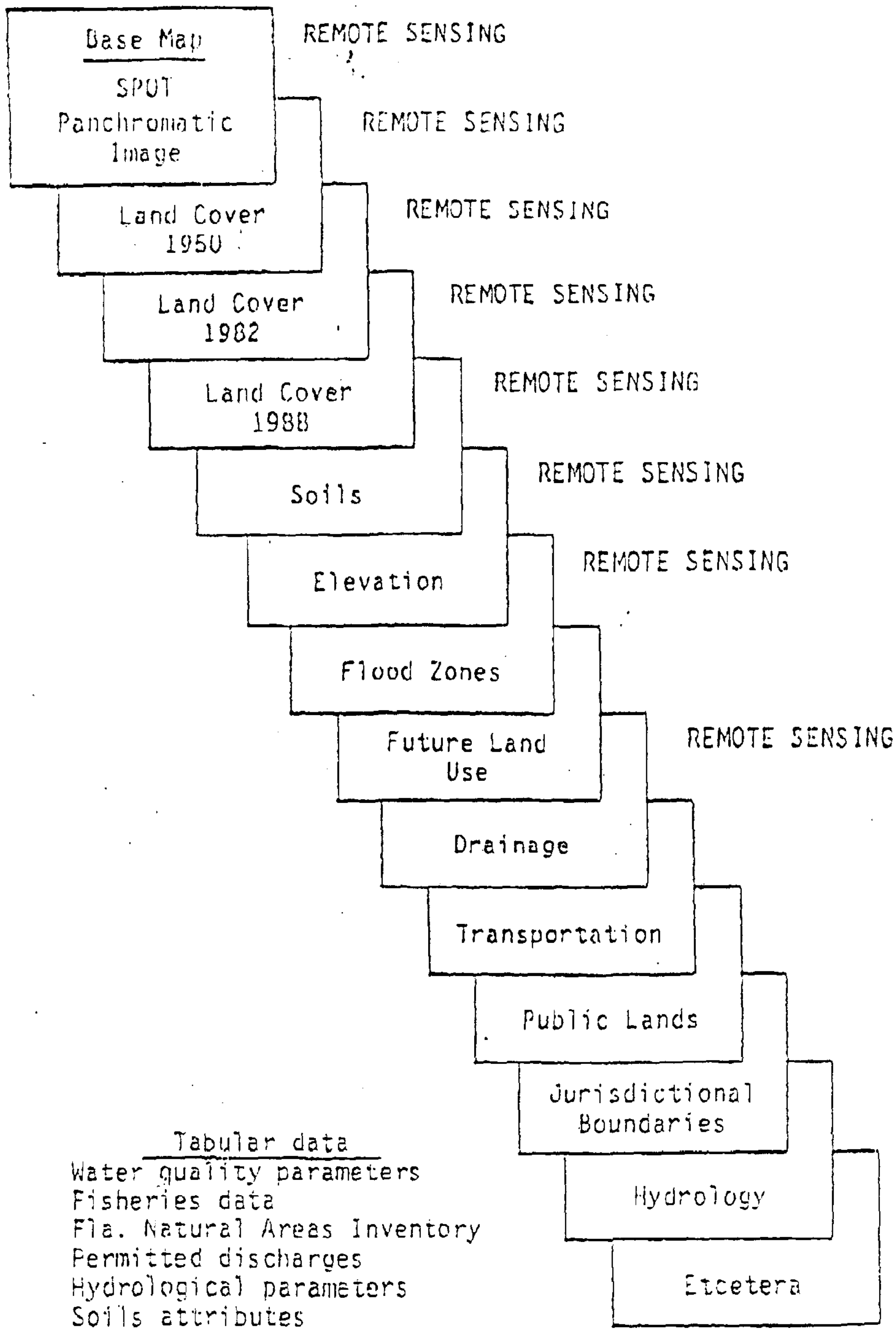



Figure 2.5 Some of the data layers being implemented on the MRCIS for the LMR watershed. Those layers dependent on remote sensing are noted. Tabular data to be linked to the data layers are also noted.

| Data Type | Source | Problems | Solutions |
|---|---|---|---|
| Base Map | SPOT Pancromatic satellite data | Geo-referencing to 1:24,000 USGS Quads. | Careful selection of control points to reduce spatial errors found on USGS quads |
| 1950/1980 Land cover | FDNR & USFWS aerial photography | 30 meter data | resampled to 10 meter data |
| 1988 Land cover | SPOT Multi-spectral satellite imagery. | Statistical analyses difficult at 10 meter spatial resolution | Incorporate TM satellite data in both the statistical analyses phase and interpretation phase. Use NHAP color-IR aerial photography. |
| Soils | Soil Conservation Service & Manatee County, Fl. | Soils delineated on photo-based separates are not cartographically accurate. | Soils scientist re-compile soils maps onto 1:24,000 USGS Quads. Scan digitize. |
| Elevation | USGS Quads and Southwest Fla. Water Managment District (SWFWMD) | 5 ft. contours from USGS Quads are not adequate in a low relief watershed. SWFWMD has undigitized 1 & 2 ft. contours | Accept resolution of USGS data or digitize SWFWMD maps |
| Flood Maps | Federal Emergency Management Agency | Cartographically inaccurate and very general spatially | Use 3 point triangulation to digitize. |
| Future land-use plans | Hillsborough and Manatee Counties | Cartographically inaccurate and different classification schemes | Use 3 point triangulation. Cross-reference classification system |
| Drainage | Aerial photography | Time consuming interpretation | None |

Table 2.4 Sources, problems, and solutions for some of the data layers being entered on the MRGIS for the LMR.

by the fact that rectified SPOT data were more spatially resolved than National Map Accuracy Standards for 1:24,000 maps, making geo-referencing difficult and creating overlay problems at common borders (for example, shorelines defined by soils vs. land-use vs. flood zones). Furthermore, many data are in scales smaller than 1:24,000, compounding overlay difficulties. This does not present a problem if the limitations of the analyses are understood. For example, the future land-use data, if originally developed by the county at a 1:100,000 scale, cannot be applied to individual zoning issues at a parcel level, but could be used to project land-use changes over larger portions of the watershed.

Complete watershed coverage has been built for flood zones, future land use, and general land cover for 1988. The estuarine portion of the watershed has land cover for 1950 and 1982 completed. The status and specific problems with several remaining data layers are as follows:

1. Soils: Soils data have been compiled by the Soil Conservation Service, and scan digitized for the LMR portion of Hillsborough County. Those data are in the MRGIS and being corrected and quality checked. Data are currently grouped by U.S.G.S. quad. Joining the quads (edge matching) to provide a continuous watershed coverage has proven difficult due to the complexity of soils polygons. Soils quads for the Manatee county portion of the watershed have been joined to form a continuous coverage. Based on preliminary observations, it appears that

merging soils data from Manatee and Hillsborough Counties will be challenging.

2. Elevation: The Southwest Florida Water Management District is providing this data layer. We are currently developing methods and formats for data transfer.

3. Drainage: This data layer is the most tedious effort for compilation, National High Altitude Program (NHAP) photos (1:50,000 scale) have been enlarged to 1:24,000 scale and detailed drainage line work is being interpreted. This type of interpretation has not been done for many areas in the U.S., particularly at the resolution being attempted for this program. For example, individual drainage ditches within agricultural fields are being identified, along with their connection to tributaries of the watershed. This will allow better analysis of sources of waterborne constituents and will allow network analyses.

4. Land cover/Land use: A land cover layer has been developed for the entire watershed by the Florida Game and Freshwater Fish Commission in cooperation with the Florida Marine Research Institute (FRMI). These data are for 1987 (from Landsat Thematic Mapper) and provide a first look at land cover from a habitat and runoff potential. A 1988 SPOT image is being used to complete a detailed land use coverage. The land use data are being compiled at a 0.1 hectare resolution.

5. Watershed and Subbasins: This data layer has been digitized from maps provided from the SWFWMD. The boundaries are

inaccurate in some areas because the basins were originally delineated in the 1970's. Substantial changes have occurred in the drainage characteristics of the watershed since then.

Tabular attribute data. Tabular data, such as soils definitions, bald eagle nesting locations, station locations and all associated water quality or fish distribution data, permitted effluent charges, and other digital data that represent a singular geographic location are also required for analyses. The biggest problem in working with these data are positional in accuracies and data exchange formats.

Quality Control and Assessment. Data quality control and assessment are extremely important in the generation of the GIS layers and their tabular attributes. The two components of concern are cartographic integrity and data accuracy (is it where it should be and is it being called the right thing?). When accessing databases outside the control of FMRI, these issues are often difficult to assess prior to data entry. When we have control, such as in the soils digitization, we have taken extreme measures to insure cartographic integrity but can only accept the SCS's ability to properly identify soils. In most cases accuracy assessment of the information has nor been completed by the parent organization. For data being developed at FRMI, such as land use, statistical analyses of classification errors are being conducted.

Data analyses. Numerous test analyses have been conducted on portions of the watershed with many data layers. Only results of analyses specific to water quality data will be presented. The specific analyses addressed the issue of what land covers comprise the drainage area (subwatersheds) of each seven water quality stations. This type of information, in conjunction with other data layer information, can be used to assess the contribution of runoff to water quality findings. Table 2.5 summarizes the general coverage, in hectares, for each of the water quality stations depicted in Figure 2.1. It should be noted that subwatersheds are defined by U.S.G.S. Criteria.

The entire watershed comprises 57,364 hectares (224 square miles). Upland plant communities comprise 13% of the watershed and consist of pinelands to hardwood forests. Wetland plant communities constitute 9% of the watershed ranging from saltmarsh to hardwood swamp. Water bodies comprise 3% of the watershed, not including the river and its tributaries.

Agriculture/pasture/barren constitute 75% of the watershed. This category is very general, and includes urban areas. Urban areas represent a small portion of this percentage, and will be well defined in the detailed land use layer. In Table 2.5 this category is representative for subwatersheds except at ST7 which is the urbanized suncity center area.

Within each of the subwatersheds, the dominant land cover is agriculture/pasture/barren with a high of 90% at ST2 and a low of

63% at ST4. Most of the areas are in agriculture with a small percentage of pasture. At ST1 the coverage is dominated by barren, representing urban land use.

| Station | Upland Plant Communities | Wetland Plant Communities | Water | Agriculture Pasture Barren | Total |
|---|---|---|---|---|---|
| ST1 | 624 | 718 | 208 | 6,577 | 8,127 |
| ST2 | 151 | 61 | 1 | 1,848 | 2,061 |
| ST3 | 4,281 | 1,527 | 226 | 17,169 | 23,203 |
| ST4 | 2,531 | 1,060 | 47 | 6,249 | 9,887 |
| ST5 | 77 | 79 | 26 | 862 | 1,044 |
| ST6 | 6,515 | 3,115 | 1,684 | 27,989 | 39,303 |
| ST7 | 127 | 341 | 42 | 1,636 (urban) | 2,146 |

TABLE 2.5 ~~Figure~~ - Distribution, in hectares, of major land cover types ~~in the~~ for the subwatersheds drainage areas defined by the location of water quality stations. Note ST7 is urban rather than agriculture.

## III. WATER RESOURCES

Local water resources in the Little Manatee River basin are used extensively for agriculture and other consumptive purposes. A brief summary of factors pertaining to water resource utilization in the basin is presented below.

### HYDROGEOLOGY

Most of the Little Manatee River watershed is overlain with a deposit of undifferentiated sands that vary in thickness from less than 25 feet along the coast to greater than 50 feet in the eastern portions. The Bone Valley Formation, which is comprised of a mixture of phosphatically enriched clays, limestone and sands, underlies these sands in certain areas. The undifferentiated sands also overlay the Hawthorn Formation which varies in thickness from less than 200 feet to more than 350 feet. Below the Hawthorn Formation are the water bearing limestone formations of the Floridan aquifer system. Vertical movement of water through the Hawthorn Formation to the Floridan aquifer, termed recharge, is slow. The estimated recharge for the area is 0-1 inches/year (Aucott, USGS 1988).

Due to impeded vertical movement of water in the Little Manatee watershed, the area has characteristic high water tables and runoff potentials. Agriculturalists in the area have maximized the utilization of the high water table condition for some of their farming operations. For example, vegetables are irrigated by managing the water table within close proximity of the root zone. Soil capillarity will then pull the water into the root zone of the crop providing a stabilized environment. Large quantities of groundwater are required to raise and maintain the water table due to irrigation inefficiencies.

## WATER USE PERMITS

The Southwest Florida Water Management District (SWFWMD) permits water use within a 16 county area which includes the Little Manatee River watershed. Most of the water used within the watershed is withdrawn from the Floridan aquifer. Figure 3.1 indicates the location of 200-plus production centers that each withdraw 100,000 gallons per day or more. Most of the water withdrawn is used for irrigation. As demonstrated by the density of squares, most of the withdrawals are concentrated in the northeastern and north-central portions of the watershed.

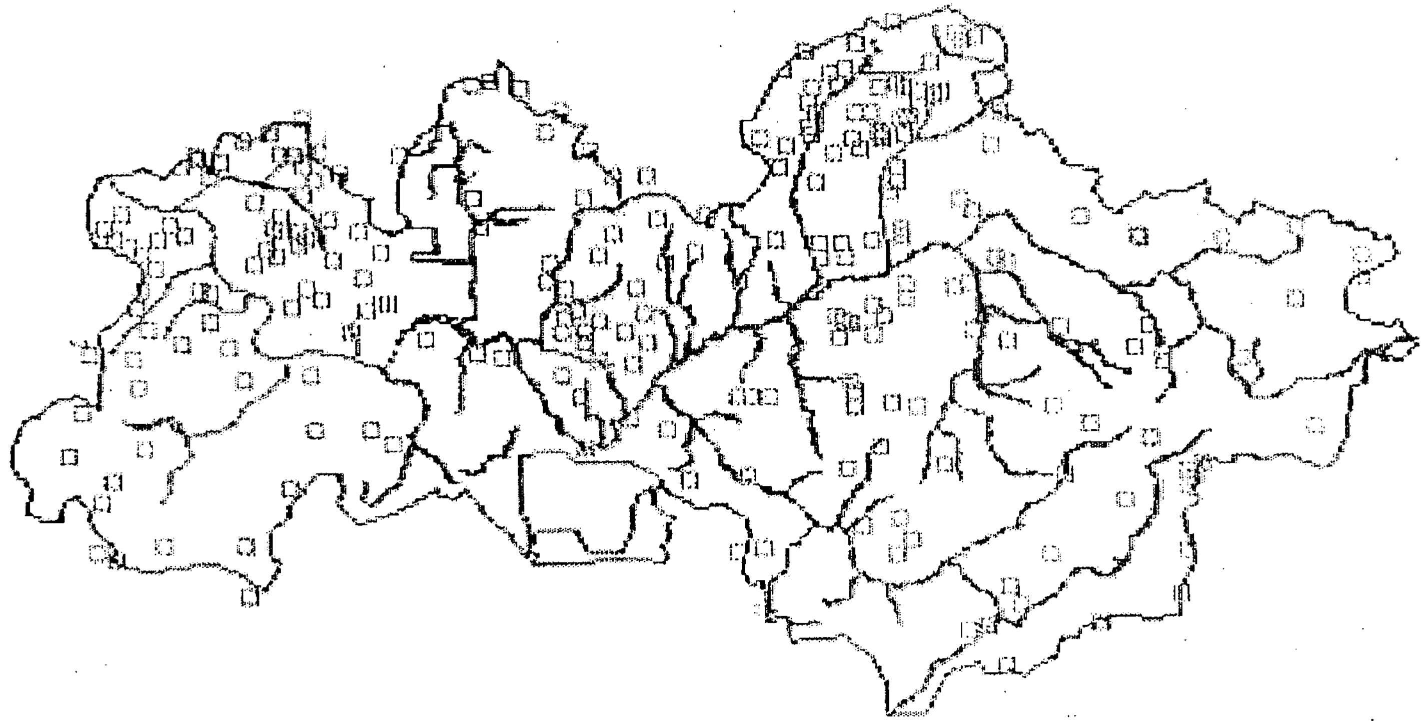


Figure 3.1. Location of water use permits in the Little Manatee River basin.

FLORIDA POWER AND LIGHT WITHDRAWALS

Lake Parrish is a man-made, off-stream reservoir adjacent to the Little Manatee River in Manatee County that was constructed by FP&L in 1975. The reservoir is located in the south-central portion of the basin and occupies about 4,000 acres. The storage capacity of the reservoir is 48,000 acre-feet or 15.7 billion gallons. The reservoir is used as a cooling source for the FP&L electric power generating facility. A diversion channel transports water from the Little Manatee river to pumps that discharge into the reservoir. A Southwest Florida Water Management agreement allows up to a 47 percent diversion of river flows that are above 40 cfs except during the months of August and September. During August and September, flows above 112 and 97 cfs may be diverted, respectively.

Make-up water is required to counteract losses from the reservoir from groundwater seepage and evaporation as the result of heat addition from the power plant and sun. The average pumpage rate into the reservoir since construction has been 11.5 cfs or 7.4 million gallons per day. Pumping at this rate for a year yields 17.2% of the total volumetric capacity of the reservoir. The largest withdrawal amount for any year has been 4,468 millions gallons during 1987, which represents 28.5% of the total reservoir capacity. During the 1988 study period, 2,407 million gallons of water were pumped to the reservoir.

The average pumping rate of 11.5 cfs represents 6.5 percent of the average flow at Wimauma during the period of operation.

Monthly values of pumping to the reservoir and streamflow at the Wimauma station are plotted for the period January 1979 to October 1989 in Figure 3.2.a. Diversion rates during this period are summarized by month in Table 3.1. Actual diversion quantities are greatest in July and August while percentage flow reductions are greatest in January and May through July.

Table 3.1. Average pumpage from the Little Manatee River (cfs) and the percentage of flow at the LMR near Wimauma gaging station, 1979 to 1989.

| | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | J | F | M | A | M | J | Jy | A | S | O | N | D |
| Pumpage (cfs) | 10.9 | 8.2 | 13.1 | 5.0 | 11.3 | 11.1 | 22.9 | 22.3 | 12.9 | 4.7 | 4.8 | 9.1 |
| Per cent of Flow | 10.2 | 6.8 | 9.2 | 4.6 | 9.5 | 9.0 | 14.7 | 7.7 | 5.7 | 9.9 | 5.1 | 8.4 |
| | J | F | M | A | M | J | Jy | A | S | O | N | D |

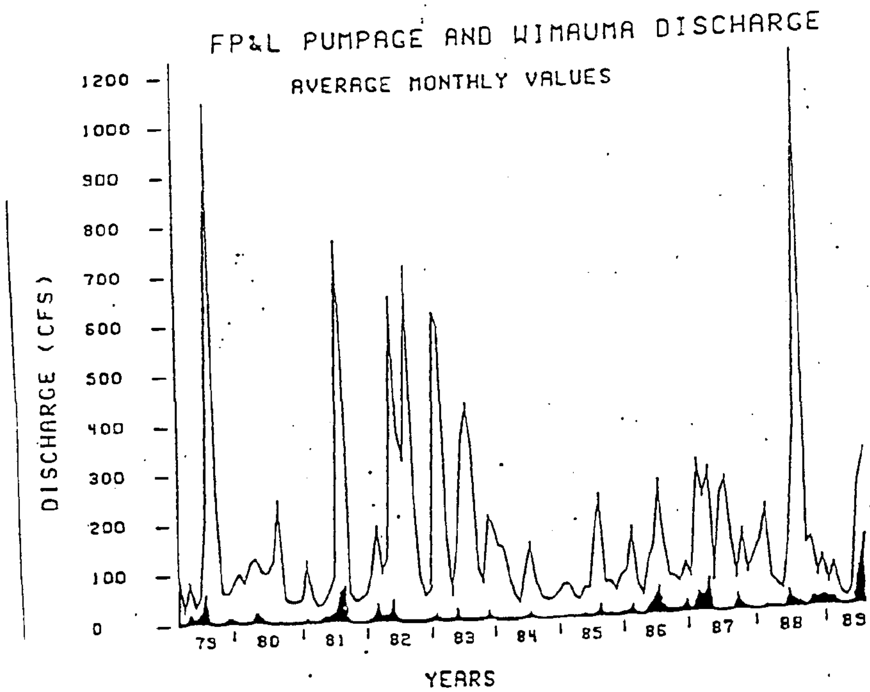
Daily pumpage to the reservoir and daily flow rates at the Wimauma gaging station are shown for the study year in Figure 3.2.b. Pumpage from the river was very small from January through June 1988. Then, significant quantities were pumped from the river from July to early September. Pumpage ceased from mid-September through October, but resumed for a period of frequent pumping from November 1988 through January 1989.

Since operation, FP&L's withdrawals from the river have been characterized by intermittent withdrawals with a high degree of short-term variation in quantities. For instance, during a 28-day period from December 12, 1988 to January 8, 1989, pumpage

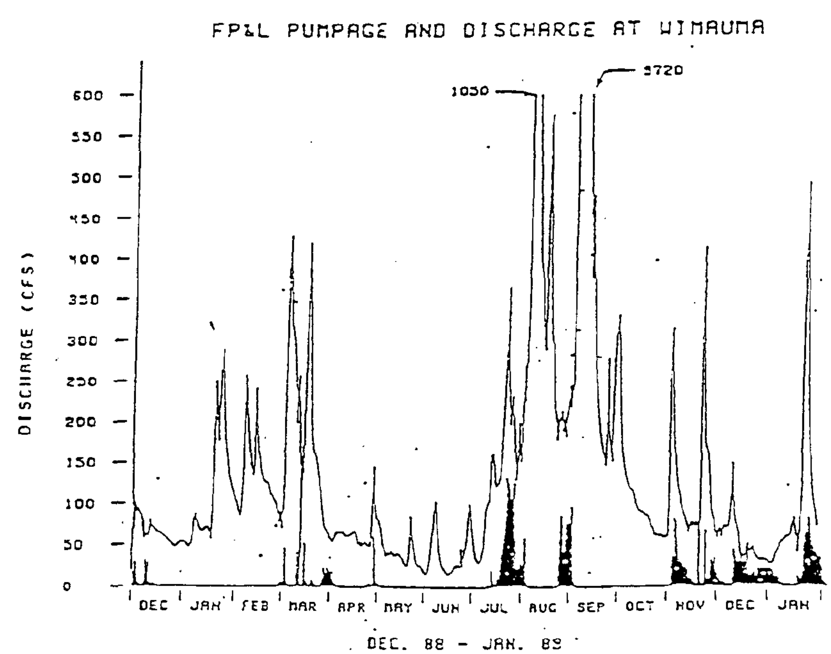
5 4

Figure 3.2. Daily (a) and monthly (b) pumpage of water from the Little Manatee River and corresponding flows at the LMR near Wimauma gaging station.

A




B





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averaged 22.6 cfs or about 48 percent of the average daily flow near Wimauma for that same period. By contrast, during the previous twenty-six day period when average daily flows in the river were more than twice as high, pumpage averaged only 10.3 cfs or 9 percent of average flow. It is not known why these differences in pumping rates were done by the Utility over this short-term period. One objective of the Little Manatee River Project is to recommend a withdrawal schedule based on probability analysis that meets the Utility's need for make-up water while better interacting with the inflow needs of the downstream riverine and estuarine ecosystems.

## IV. HYDROLOGIC CONDITIONS DURING THE STUDY

### DATA COLLECTION NETWORK

The collection of hydrologic data is essential for understanding the relationships of land use to runoff and water quality in the Little Manatee River basin. For this project, existing USGS stream gaging stations and District rainfall sites were utilized in addition to new data collection sites established for the study. Figure 4.1 is a map showing the location of streamflow gaging and rainfall data collection sites used during study year (January 1988 to January 1989). A continuous water level was also installed at the mouth of the river to record tide stage fluctuations.

The most downstream stream gaging station on the main stem of the Little Manatee River (LMR) is LMR near Wimauma (station F, Figure 4.1). The USGS has collected continuous streamflow data at this station since 1939, giving 50 years of daily record. Two other gaging sites in the basin, LMR near Fort Lonesome and Cypress Creek, are part of the regular USGS stream gaging network. The Fort Lonesome gage, with a corresponding drainage area of 31.4 square miles, measures flow from the upper-most reaches of the Little Manatee River basin. Data collection at this site began in 1963, giving 26 years of record. The Cypress Creek station, with a drainage area of 8.1 square miles, measures

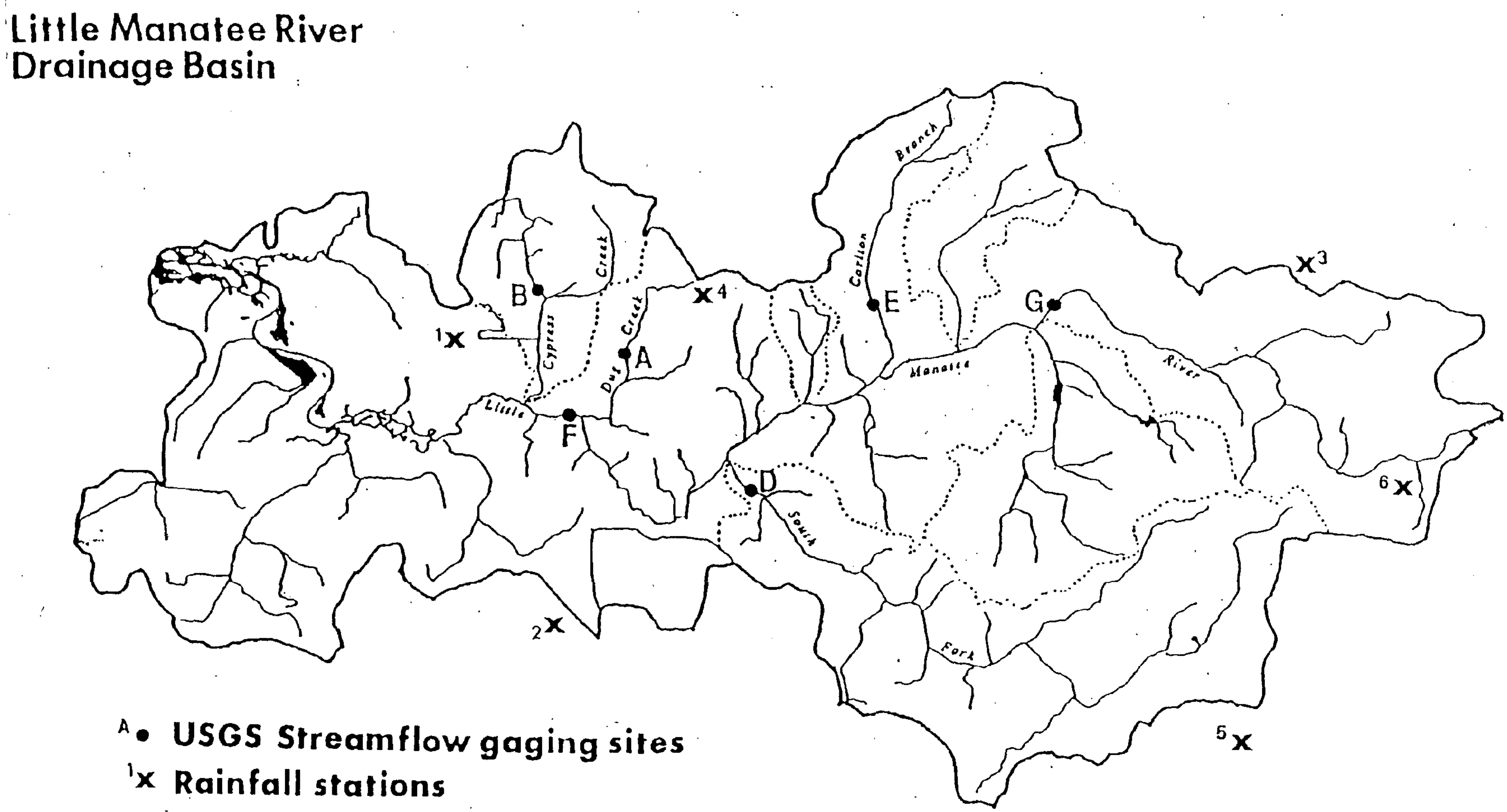



Figure 4.1. Location of stream gaging and rainfall data collection sites in the Little Manatee River basin during the study year (January 1988 to January 1989).

**Figure 4.1. (Key)**

Stream gaging sites

A. Dug Creek
B. Cypress Creek
D. LMR South Fork
E. Carlton Branch
F. LMR near Wimauma
G. LMR near Fort Lonesome

Rainfall sites

1. Ruskin
2. Florida Power and Light
3. Fort Lonesome
4. Wimauma
5. Fort Green
6. Four Corners

flow from the small sub-basin that includes the residential development of Sun City Center.

Three new streamflow sites, LMR South Fork, Dug Creek and Carlton Branch, were established for the duration of the project. Continuous streamflow at all sites was monitored by personnel of the USGS Tampa office. These sites were established to examine rainfall-runoff relationships in discrete sub-basins of the Little Manatee River basin. Data collection at these three sites began in either December 1987 or January 1988, and concluded after the last water quality sampling trip on January 24, 1989. The South Fork station, with a drainage area of 38.4 square miles, measured virtually all flow from the South Fork of the river. Carlton Branch, with a drainage area of 7.9 miles, measured flow from a small sub-basin dominated by agriculture. The Dug Creek site, with a drainage area of 3.6 square miles, measured flow from a very small basin with mixed land use.

The rainfall data collection network for the study included five stations in the existing District network (Figure 4.1). Periods of record for these stations range from eight years (Wimauma - 1981) to thirty-four years (Fort Green - 1955). An additional station at the FP&L power plant was established to measure rainfall in the southwestern portion of the drainage basin. Daily rainfall records were available from all the stations during the study year. At two of these stations (Wimauma and FP&L), recording rain gages make the examination of hourly rainfall data for the study year possible.

RAINFALL

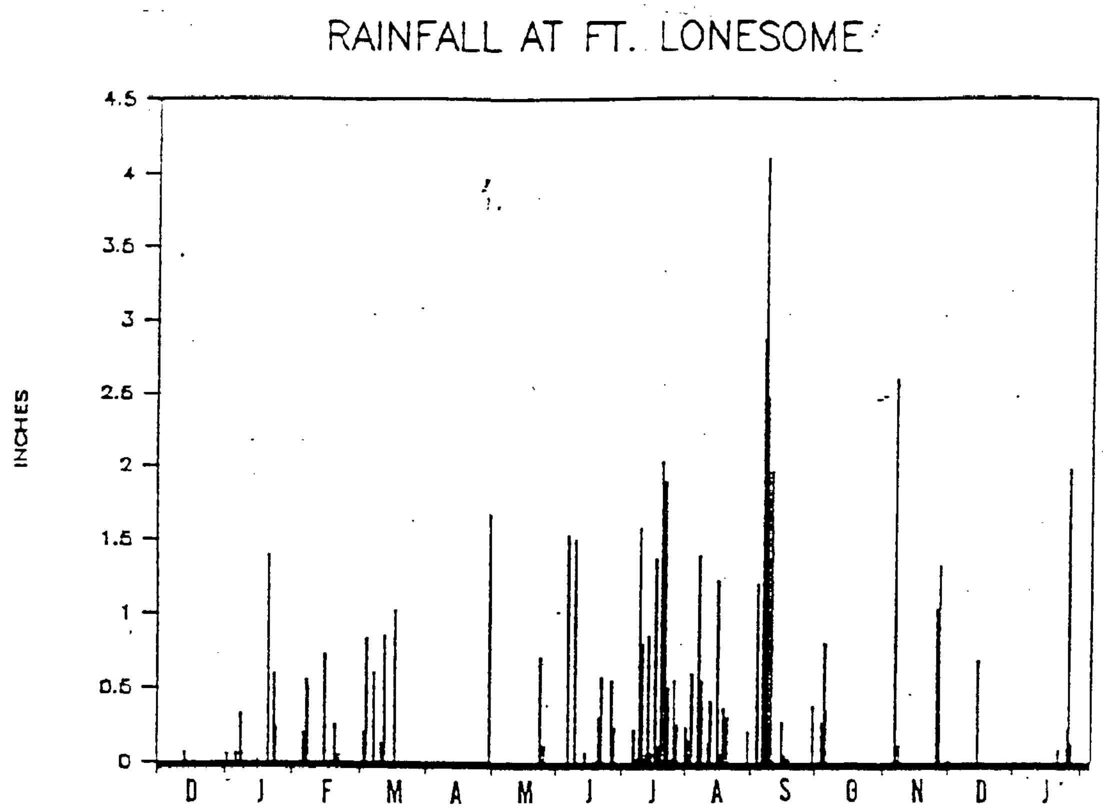
Monthly and total yearly rainfall amounts for the six stations in the project area are listed in Table 4.1. Total yearly rainfall for these stations averaged 52.6 inches, which is near normal for the region. The yearly total of 46.6 inches for the FP&L station in the southwestern area was somewhat lower than totals for the other five stations which ranged from 51.2 to 56.5 inches.

Seasonal rainfall distribution in the basin during the study period found the spring dry season and the summer rainy season to both be somewhat exaggerated. A comparison of the bar chart of average monthly flows for Ruskin (Figure 2.2) and the monthly values presented in Table 4.1 shows that rainfall was near normal at most of the stations from January through April, with a sharp drop in rainfall occurring in late March at the beginning of the dry season. This transition can be seen in greater detail in Figure 4.2, where daily rainfall amounts during the study year are shown for three of the stations (Ruskin, Fort Lonesome, FP&L). Rainfall from mid-March to early June was particularly low, with only 2 or 3 rainfall events of over 0.2 inches occurring in the basin. When the summer rains began in June they were well below normal for the remainder of that month at four of the six rainfall stations. As a result, from late March through June the basin experienced a pronounced dry season during which rainfall was below normal.

Table 4.1. Monthly and total yearly rainfall (inches) at stations shown in Figure 4.1 during January 1988 to January 1989. Listed yearly totals are for 1988 only.

Rainfall (Inches)

| Date | FP&L | Ft. Green | Four Corners | Ft. Lonesome | Ruskin | Wimauma | Average |
|---|---|---|---|---|---|---|---|
| 1/88 | 3.1 | 2.0 | 2.6 | 2.7 | 2.9 | 2.6 | 2.7 |
| 2/88 | 2.3 | 2.5 | 2.2 | 2.3 | 2.5 | 2.0 | 2.3 |
| 3/88 | 3.8 | 6.2 | 5.4 | 3.6 | 5.1 | 4.4 | 4.8 |
| 4/88 | 2.0 | 1.7 | 0.4 | 1.7 | 2.1 | 1.5 | 1.6 |
| 5/88 | 0.9 | 1.0 | 1.2 | 0.8 | 1.6 | 2.0 | 1.3 |
| 6/88 | 1.8 | 1.8 | 5.5 | 4.8 | 2.8 | 1.9 | 3.1 |
| 7/88 | 3.7 | 10.4 | 6.7 | 10.9 | 6.7 | 5.9 | 7.4 |
| 8/88 | 9.8 | 15.2 | 10.5 | 5.3 | 9.8 | 9.6 | 10.0 |
| 9/88 | 13.6 | 10.3 | 9.4 | 13.6 | 13.2 | 15.8 | 12.7 |
| 10/88 | 1.0 | 0.8 | 0.8 | 1.4 | 0.5 | 1.5 | 1.0 |
| 11/88 | 3.5 | 3.5 | 5.0 | 5.1 | 5.8 | 3.5 | 4.4 |
| 12/88 | 1.1 | 1.2 | 0.6 | 0.7 | 0.9 | 0.9 | 0.9 |
| 1/89 | 2.3 | 2.7 | 2.9 | 2.4 | 3.1 | 1.6 | 2.5 |
| 1988 TOTAL | 46.6 | 56.5 | 51.2 | 52.9 | 56.7 | 51.5 | 52.6 |



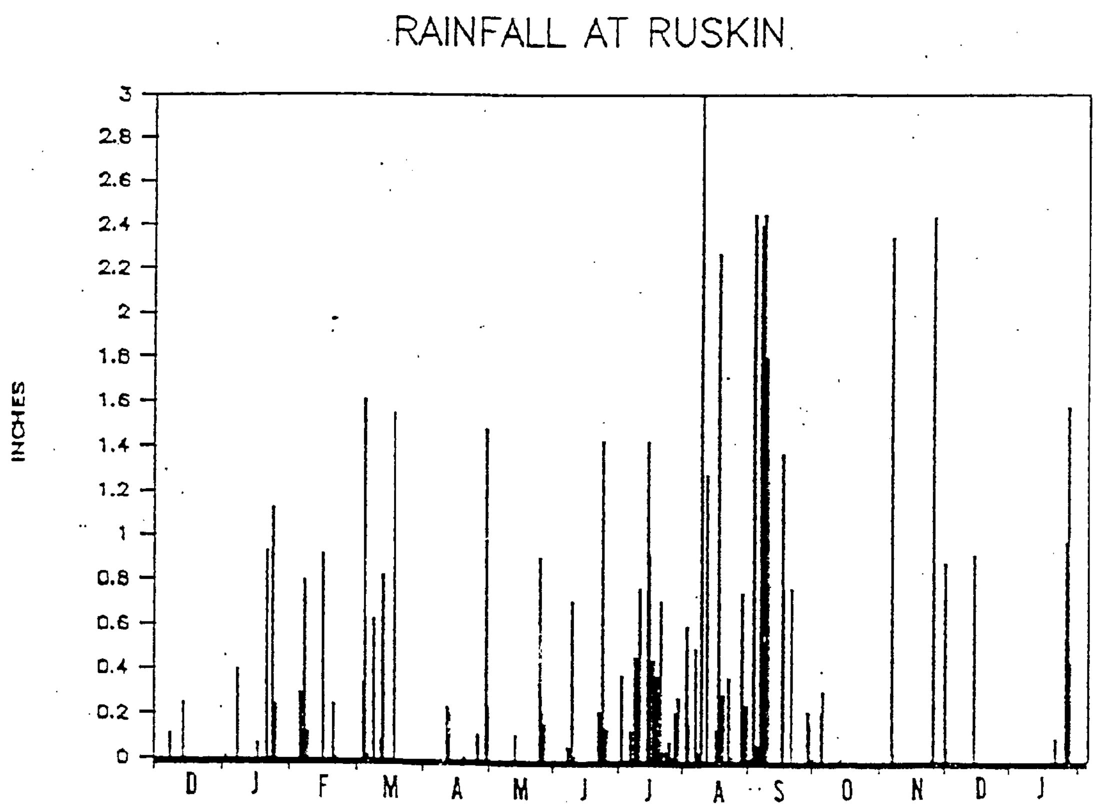




Figure 4.2. Daily rainfall at three stations in or near the Little Manatee River basin from December 1987 through January 1989.

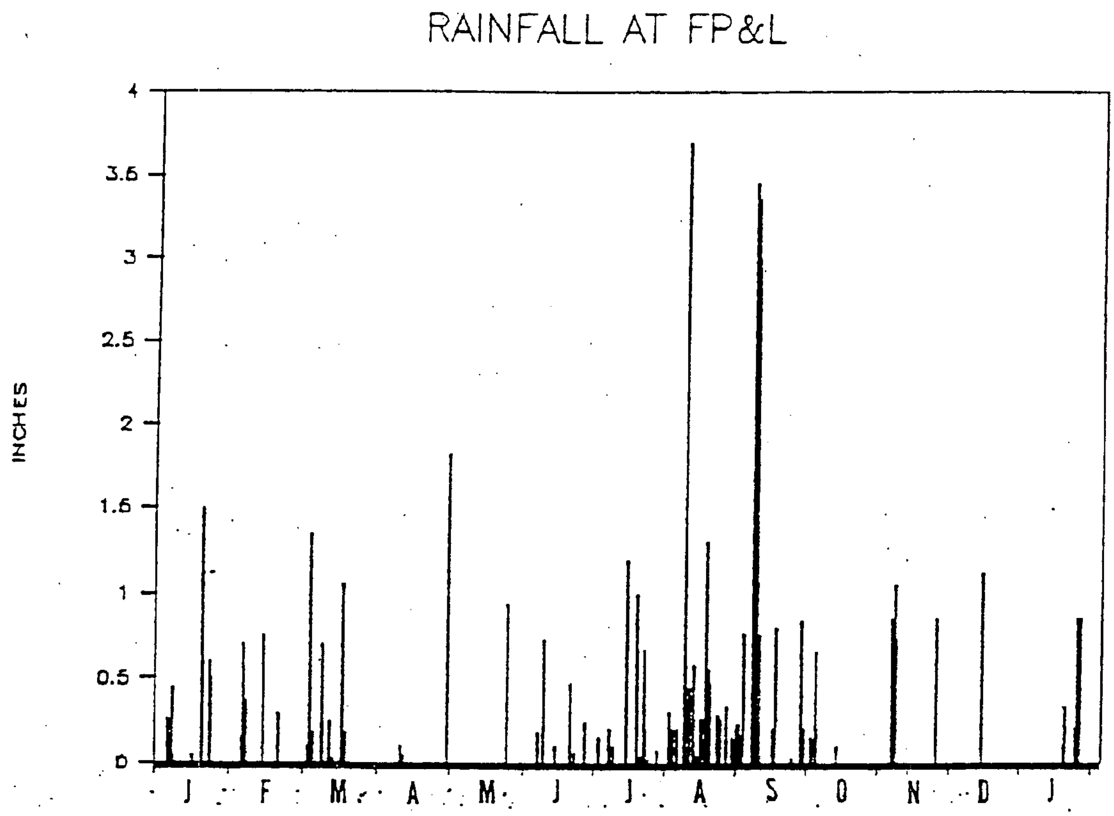



Figure 4.2. (Continued)

In contrast to the prolonged dry season, rainfall was abundant in the late summer. Rainfall totals were near normal for July and above normal for August and September. Of particular significance were a three-inch rainfall that occurred in early August and a four-day rainfall event in early September when a stalled frontal system dumped over ten inches of rain in the basin. Rainfall was greatly reduced in late September, however, and October received below normal amounts. The passage of two frontal systems in November resulted in a basin average of 4.4 inches for that month. During December and early January rainfall was again low, but another winter front in late January caused two days of rain at the end of the study period.

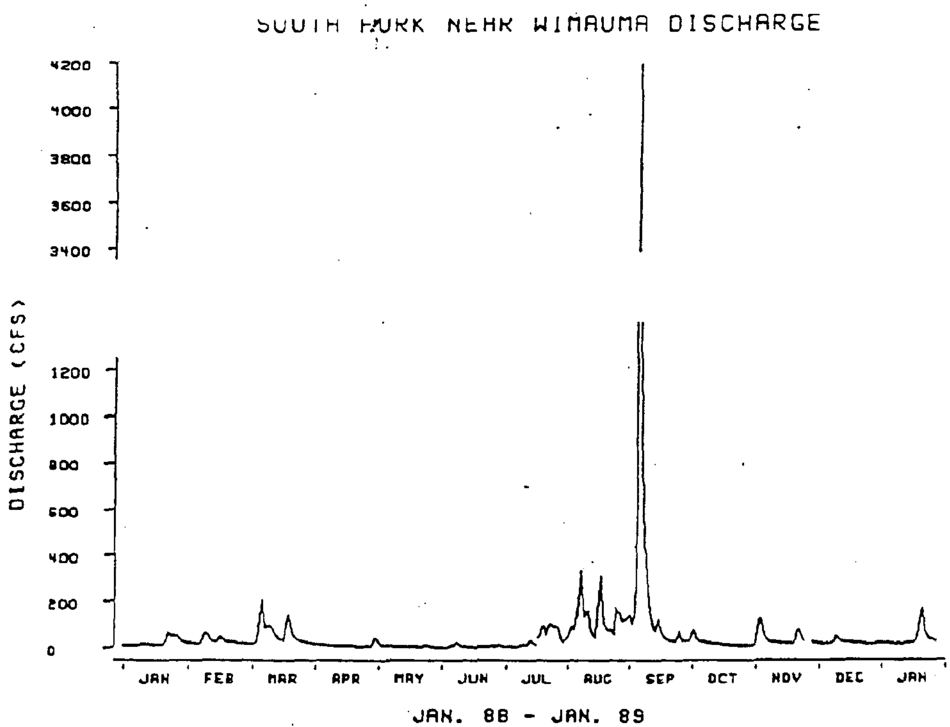
In sum, total rainfall during the study year was near normal but showed extreme fluctuations in short-term and seasonal quantities, which is not unusual for west-central Florida. With regard to the water quality aspect of the project, this pattern was fortuitous for it allowed monitoring of the basin under a wide range of hydrologic conditions.

## STREAMFLOW

Streamflow measured at the six stream gaging sites shown in Figure 4.1 closely followed the seasonal rainfall pattern described above. Average monthly flows and average flows for the study period for the six streamflow sites are listed in Table 4.2, while hydrographs of daily flows for these same stations are shown in Figure 4.3.

Table 4.2. Average monthly and study period streamflow (cfs) at stream gaging sites shown in Figure 4.1 during January 1988 to January 1989.

| Date | LMR Wimauma | South Fork | LMR Ft. Lonesome | Carlton Branch | Cypress Creek | Dug Creek |
|---|---|---|---|---|---|---|
| 1/88 | 112.9 | 27.6 | 18.1 | 8.6 | 8.7 | 3.7 |
| 2/88 | 140.1 | 33.2 | 23.8 | 9.7 | 10.3 | 3.2 |
| 3/88 | 209.3 | 64.3 | 47.8 | 16.3 | 19.5 | 5.9 |
| 4/88 | 61.3 | 13.4 | 11.4 | 9.3 | 1.4 | 2.1 |
| 5/88 | 50.2 | 12.6 | 5.6 | 6.9 | 2.7 | 1.7 |
| 6/88 | 35.4 | 9.5 | 2.2 | 3.5 | 1.0 | 0.5 |
| 7/89 | 133.1 | 40.3 | 46.0 | 5.3 | 2.2 | 1.0 |
| 8/88 | 372.2 | 125.7 | 103.6 | 20.6 | 31.1 | 7.8 |
| 9/88 | 1120.1 | 325.93 | 254.9 | 59.4 | 89.4 | 29.3 |
| 10/88 | 125.4 | 24.3 | 12.9 | 12.8 | 3.0 | 2.6 |
| 11/88 | 139.4 | 40.3 | 25.25 | 20.4 | 15.2 | 7.1 |
| 12/88 | 59.0 | 23.26 | 10.1 | 11.5 | 3.9 | 2.2 |
| 1/89 | 102.4 | 36.8 | 21.2 | 17.1 | 7.0 | 4.9 |
| Ave. | 209.7 | 61.4 | 46.2 | 15.9 | 15.5 | 5.6 |



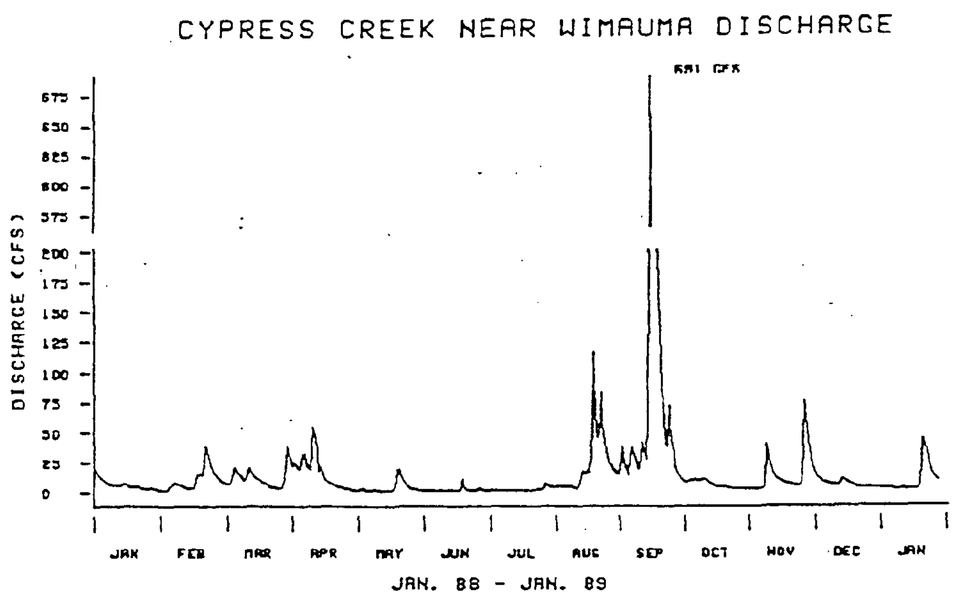
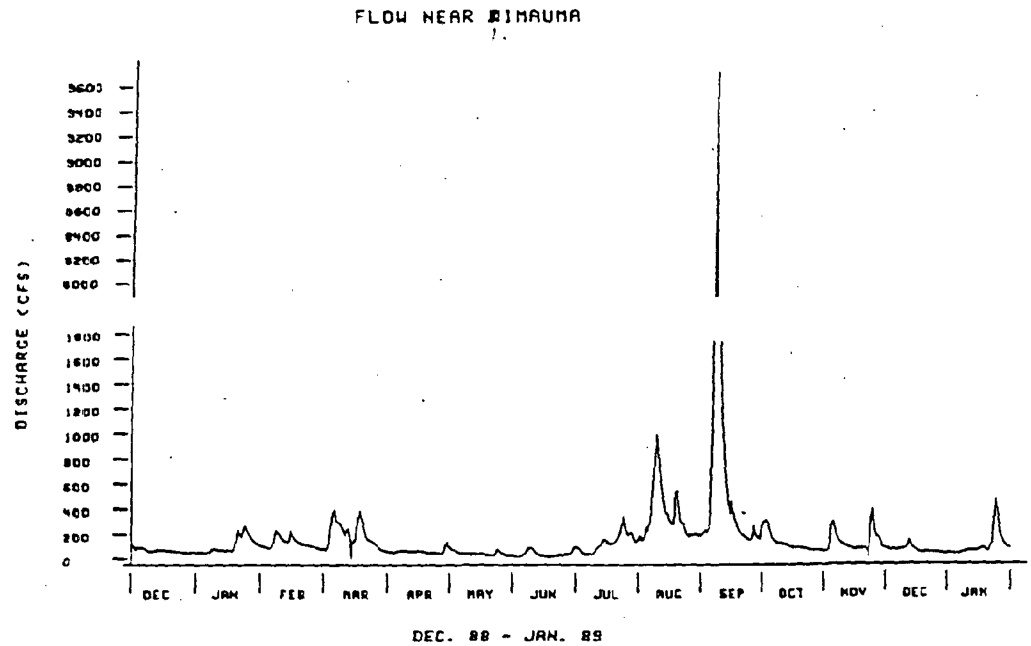




Figure 4.3. Hydrographs of daily streamflow at the stream gaging sites shown in Figure 4.1 for the period January 1988 to January 1989.



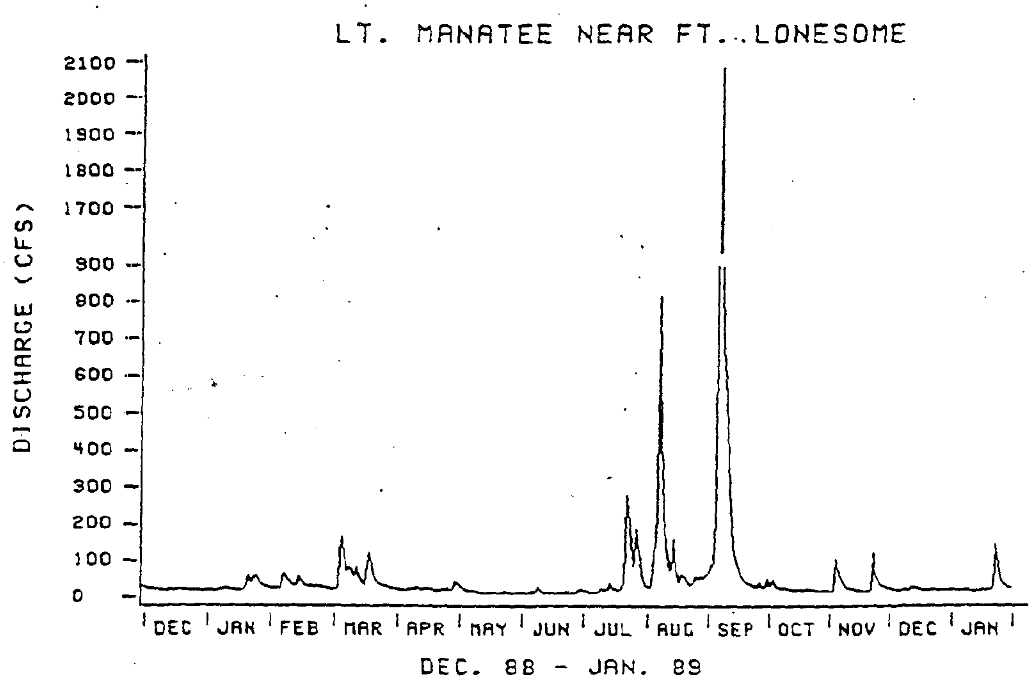
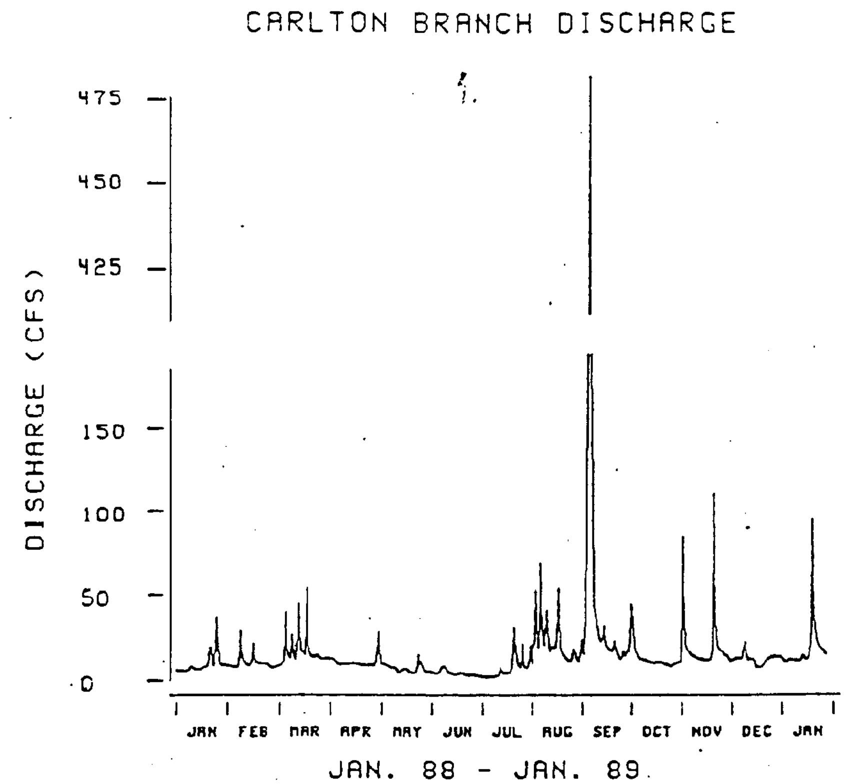




Figure 4.3. (Continued)



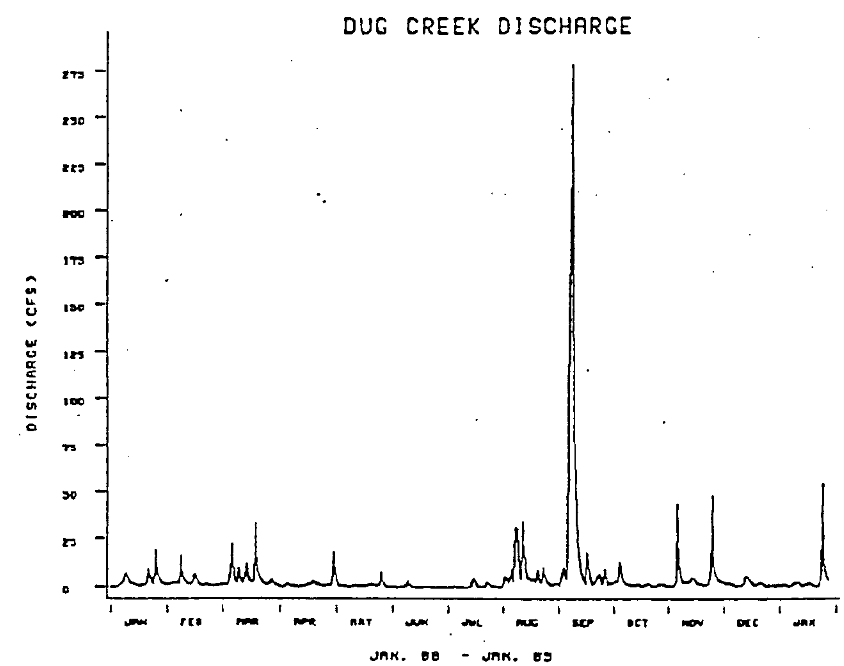




Figure 4.3. (Continued)

A comparison of average flows for the study period gives a grouping of the stations that corresponds to their ranking based on drainage basin sizes. The Wimauma site had by far the highest average flow at 209.7 cfs, which is approximately 22 percent greater than the long-term average for this site. The South Fork and Fort Lonesome sites, with average flows of 61.4 and 46.2 cfs, comprise a middle group with intermediate drainage basin sizes (38.4 and 31.4 square miles, respectively). The average study period flow for the Fort Lonesome site was 56 percent greater than the long-term average flow for this site, which is based on 25 years of record. This period of record, however, has been characterized by a trend in below average rainfall.

Average study period flows for Carlton Branch and Cypress Creek were nearly equal (15.5 and 15.9 cfs, respectively) reflecting their nearly equal drainage basin sizes (7.9 and 8.1 square miles). The small 3.6 square mile basin corresponding to the Dug Creek gage yielded the smallest average flow (5.6 cfs) for the study period.

A comparison of the hydrographs of daily streamflow values (Figures 4.3) with the plot of daily rainfall amounts (Figure 4.2) indicates close correlation between these two variables. Rainfall events in January, February, and March resulted in moderate flows for all the streamflow sites. Declining flows from April through June occurred with small peaks in flow observed after brief rainfall events. Rainfall was somewhat variable in the basin during July (Table 4.1) with amounts over ten inches falling in the eastern part of the basin. Pronounced increases in streamflow were observed in July at all stations except Dug and Cypress Creeks in the north-central part of the basin where rainfall was lower. All stations exhibited high flows in early August and particularly in early September, when maximum flows were observed for all stations. The peak flow of 9780 cfs at the Wimauma station was over 50 times greater than the average flow for this site and corresponded to a 10- to 25-year flood event. Although some homes and other structures were inundated during this September flood, economic damages in the basin were minor due to the undeveloped character of the river corridor. For the remainder of the study period, flows at all sites returned to low to moderate levels with brief peaks occurring during November and January in response to rainfall associated with the passage of cold fronts.

One interesting phenomenon that was observed during the study was a clear difference in base-flow levels between the sub-basins. For instance, the Fort Lonesome gage measures flow from an area almost four times greater than the Carlton Branch site. During wet months, average monthly flows at Fort Lonesome were significantly greater than at the Carlton Branch site. For the dry months (April, May, June, October, and December), however, average flows at Fort Lonesome and Carlton Branch were nearly equal. These results and the water chemistry data presented in Chapter V indicate that dry season flows in Carlton Branch are heavily supplemented by runoff from farms which originate as pumpage from groundwater sources.

## TIDES

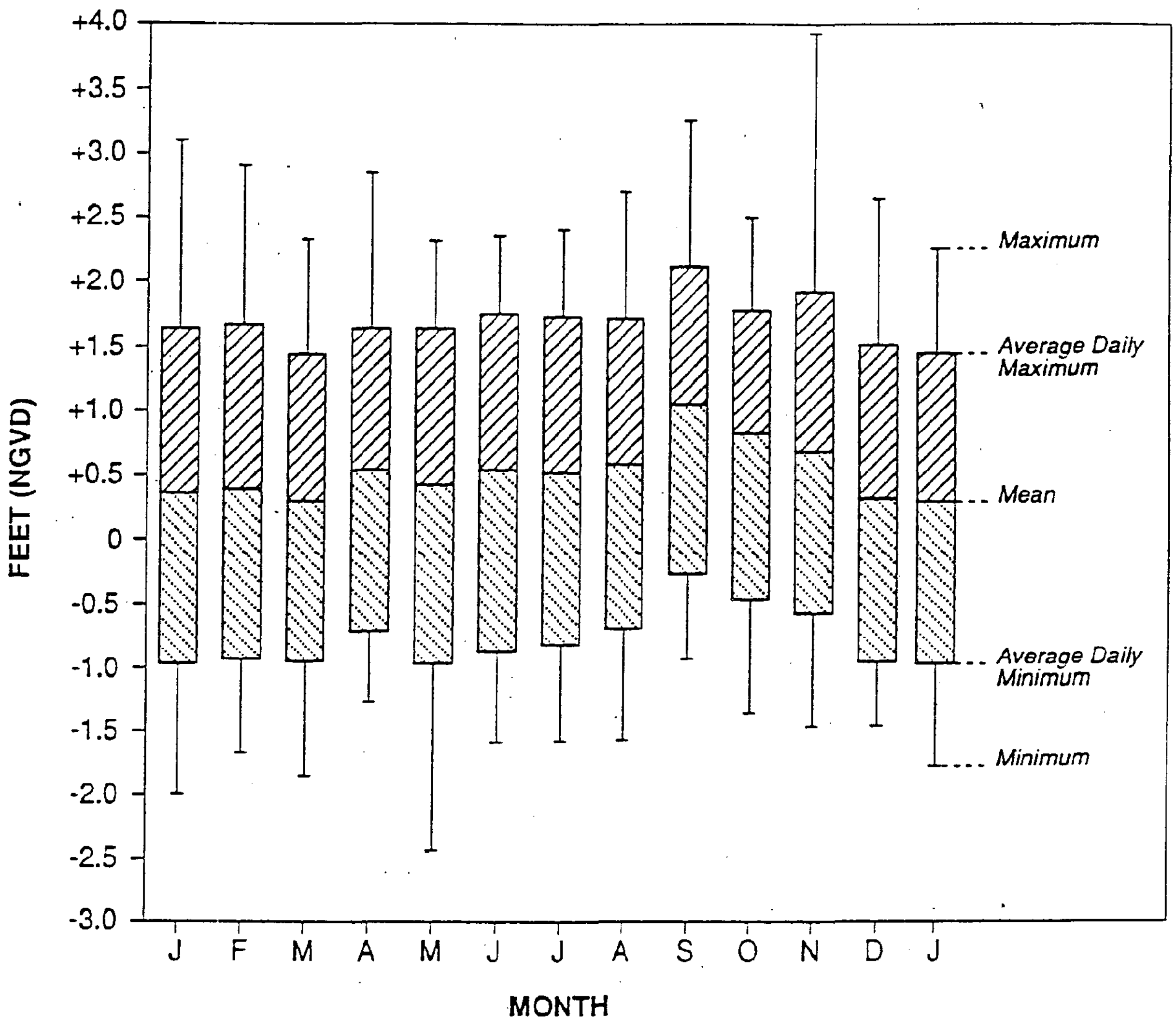
Water levels in the lower fifteen miles of the Little Manatee River are affected by tidal fluctuations in Tampa Bay. At the most upstream extent, this effect is very small and restricted to periods of extremely high tides in the bay. Water levels at the mouth of the river are largely controlled by tidal fluctuations in the bay, but periodically can be significantly affected by high river flows.

The recording of tide stage during the study is very important for interpreting the estuarine water chemistry and salinity results. Therefore, a water level recorder was installed at the mouth of the river at Shell Point and operated by the USGS for the duration of the study. This instrument recorded water level measurements every 15 minutes with retrieval of these measurements plus daily mean, minimum, and maximum values possible.

Tides at the mouth of the Little Manatee River contain a mixture of diurnal and semi-diurnal components. On most days, there are two high and two low tides. The high tides are of unequal height consisting of a high-high and a low-high tide. Low tides are similarly of unequal heights. During some periods of the year, depending on astronomical forces, there is only one high and one low tide daily at the mouth of the river. Water levels and tidal fluctuations in the lower Little Manatee River can also be affected by the action of prevailing winds on the waters of Tampa Bay.

Based on data collected between January 1988 and January 1989, the average daily tidal range at the mouth of the Little Manatee River was 2.47 feet. Average monthly values for daily mean tide, daily maximum, daily minimum, plus the absolute maximum and minimum tides for each month are illustrated in Figure 4.4. Monthly mean water levels were highest in the fall (September through November), but the September value was affected by the extremely high river stages during the flood in the early part of that month. The differences between monthly values for average daily maximum tide and average daily minimum tide range only from 2.25 to 2.60 feet, demonstrating the small seasonal fluctuations in daily tidal ranges at this station.

Figure 4.4. Average monthly values for daily mean tide, daily minimum and maximum tide plus monthly maximum and minimum tide at the mouth of the Little Manatee River from January 1988 to January 1989.



# V. FRESH WATER CHEMISTRY

## OBJECTIVES

The water chemistry program had three objectives:

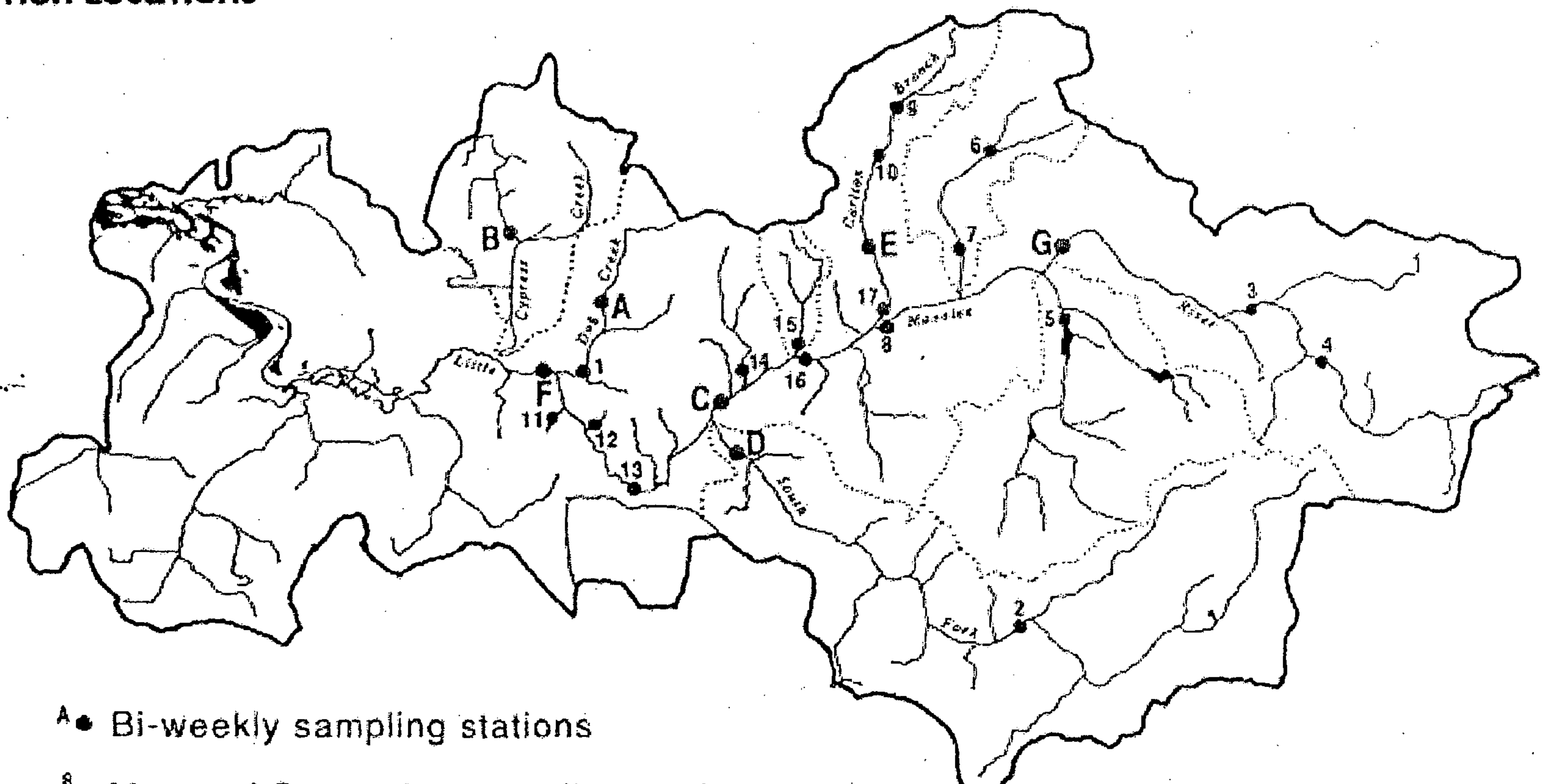
1) to determine the flux of nutrients and suspended solids contributed by each of the sub-basins of the Little Manatee Watershed,
2) to determine seasonal variations in concentrations of these substances in each sub-basin,
3) to evaluate the movement of these materials through the Little Manatee estuary.

The first two objectives required an examination of water quality in the freshwater streams of the basin. Water quality data will be compared to land use and soils in the respective sub-basins to document the effects of various land uses on water quality. The third objective is addressed in the following chapter on Estuarine Water Chemistry.

## SAMPLING AND ANALYTICAL METHODS

This report on stream water quality is based primarily on data collected between January 1988 and January 1989. During the study year, water chemistry and physical parameters were measured at seven freshwater stations in the Little Manatee basin (Figure 5.1). Six of these stations were located at USGS stream gaging sites, while the seventh station was located at a site on the

## Little Manatee River Freshwater Station Locations




A● Bi-weekly sampling stations

8● May and September sampling stations

Figure 5.1. Locations of freshwater stream sampling stations in the Little Manatee River basin.

**Figure 5.1. (Key)**

1. Bi-weekly sampling stations and continuous USGS streamflow gaging sites
   - A. Dug Creek
   - B. Cypress Creek
   - C. LMR (North Fork)
   - D. South Fork
   - E. Carlton Branch
   - F. LMR near Wimauma
   - G. LMR near Ft. Lonesome

2. May 17, and September 21, 1988 dissolved constituents sampling
   1. Dug Creek at Saffold Road
   2. South Fork at Bunker Hill Road
   3. Alderman Creek at S.R. 39
   4. Alderman Creek at Taylor-Gill Road
   5. Howard Prairie Branch at Grange Hall Road
   6. Pierce Branch at Owens Road
   7. Pierce Branch at C.R. 674
   8. LMR Grange Hall Road
   9. Carlton Branch at Sweet Loop Road
   10. Carlton Branch at Colden Loop Road
   11. Unnamed Creek near U.S. 301
   12. Unnamed Creek near railroad bridge
   13. LMR near FP&L intake
   14. Unnamed Creek near C.R. 579
   15. Gully Branch
   16. LMR main channel above Gully Branch
   17. Carlton Branch at confluence with LMR

river ("C", North Fork) where streamflow can be estimated by station differences. Sampling at these stations was done approximately every two weeks, so 26 regular samples were collected during the study year. At each stream sampling station, duplicate water samples were taken at .5 m depth or at mid-depth if total depth was less than one meter. Filtration for separation of particulate (C, N, P) and dissolved nutrients (PO4, $NO_3$ & $NO_2$, Organic Carbon) was done in the field with filters and filtrates kept in iced coolers for transport. Water samples for chlorophyll analysis were kept chilled and transported to the Department of Natural Resources Laboratory in St. Petersburg where filtration for pigment removal was done the same afternoon. Samples (filters) for particulate phosphorus determinations were periodically shipped to Savannah Laboratories and Environmental Services, Inc. (SL&ES) in Savannah, Georgia where digestion and measurement was done. Remaining water chemistry parameters were determined at the District Laboratory in Brooksville. Parameters measured and the analytical methods employed are listed in Table 5.1. Also, at each sampling station, in situ measurements of temperature, dissolved oxygen, pH, and specific conductance were made with a Hydrolab meter at .5 m or mid-depth, depending on water depth.

At the same stations as the bi-weekly sampling, major ion species (Ca, Mg, K, Na, Fl, Cl, and $HCO_3^{-}$) were measured on duplicate samples on a monthly basis for a total of twelve regular sampling events. In addition to regular bi-weekly and

Table 5.1. Water quality parameters measured and analytical methods for freshwater and estuarine sampling stations during January 1988 to January 1989.

| Parameter | Units | Method | Reference |
|---|---|---|---|
| Temperature | °C | Hydrolab | Hydrolab Instruments |
| Specific Conductance | umhos/cm | Hydrolab | Hydrolab Instruments |
| pH (field) | pH units | Hydrolab | Hydrolab Instruments |
| Dissolved Oxygen | mg/l | Hydrolab | Hydrolab Instruments |
| Turbidity | NTU | Nephelometric | APHA, 1985 |
| Color | PCU | Nessler tubes | APHA, 1985 |
| Total Suspended Solids | mg/l | filtration/gravimetric | APHA, 1985 |
| TSS-volatile fraction | mg/l | gravimetric/ignition | APHA, 1985 |
| Particulate carbon | mg/l | C-H-N analyzer | Perkin-Elmer Instruments |
| Particulate nitrogen | mg/l | C-H-N analyzer | Perkin-Elmer Instruments |
| Particulate phosphorous | mg/l | acid digestion/ colorimetric | EPA, 1979; APHA, 1985 |
| $NH_3$ | mg/l | colorimetric | APHA, 1985 |
| $NO_3$-$NO_2$ | mg/l | colorimetric | APHA, 1985 |
| $PO_4$ | mg/l | colorimetric | APHA, 1985 |
| Silica | mg/l | colorimetric | APHA, 1985 |

Table 5.1 continued

| Parameter | Units | Method | Reference |
|---|---|---|---|
| Chlorophyll a | $mg/m^3$ | Spectrophotometric | APHA, 1985 |
| *Calcium | mg/l | Atomic Absorption | APHA, 1985 |
| *Magnesium | mg/l | Atomic Absorption | APHA, 1985 |
| *Potassium | mg/l | Atomic Absorption | APHA, 1985 |
| *Sodium | mg/l | Atomic Absorption | APHA, 1985 |
| *Sulfate | mg/l | turbidimetric | APHA, 1985 |
| *Chloride | mg/l | titration | APHA, 1985 |
| *Fluoride | mg/l | electrode | APHA, 1985 |
| *Alkalinity | mg/l | titration | APHA, 1985 |

* Fresh water stations only

monthly sampling, two additional sampling trips on May 17, 1988 and September 21, 1988 were performed when major ions, dissolved nutrients and physical parameters were measured at an additional 17 water quality stations (Figure 5.1). Duplicate samples were not collected during these two additional sampling events except for duplicate analyses performed as routine quality assurance.

## OTHER DATA SOURCES

Other surface water quality data for the Little Manatee River basin are available from the U. S. Geological Survey (USGS) and the Hillsborough Environmental Protection Commission (HEPC). Mean values for several parameters measured by these two agencies during 1986 to 1988 are listed in Table 5.2. Station locations for these data are the same as three of the stations shown in Figure 5.1 and follow the same nomenclature.

Table 5.2. Mean values for selected water chemistry parameters in the Little Manatee River Basin recorded by the Hillsborough County Environmental Protection Commission, 1986 and 1987. Mean values recorded for Ft. Lonesome by the USGS during 1986 to 1988 are also shown.

| Parameter | Units | LMR near Wimauma | LMR (North Fork) | LMR near Ft.Lonesome (HEPC) | LMR near Ft.Lonesome (USGS) |
|---|---|---|---|---|---|
| Specific Conductance | umhos/cm | 345 | 371 | 220 | 187 |
| pH | pH units | 7.5 | 7.4 | 7.4 | 6.8 |
| Turbidity | NTU | 8 | 7 | 3 | --- |
| Color | PCU | 58 | 65 | 82 | 98 |
| Organic nitrogen | mg/l | .96 | .90 | 1.06 | .86 |
| $NH_3$ (as N) | mg/l | .16 | -- | .10 | --- |
| $NO_3$-$NO_2$ (as N) | mg/l | .57 | -- | .13 | .10 |
| Total Phosphorus | mg/l | .45 | .55 | .60 | .54 |
| Chlorophyll *a* | $mg/m^3$ | -- | 2.7 | 1.0 | -- |
| Calcium | mg/l | 26 | 30 | 17 | 14 |
| Sulfate | mg/l | 128 | 97 | 55 | 48 |

DATA REDUCTION

The data were first examined to ascertain similarities and differences in water quality among stations and seasons. All statistical analyses and presentations of bi-weekly data in this report are based on the means of duplicate samples. Then, the data were evaluated to determine the relative importance of fluxes of materials (nutrients and solids) from the major sub-basins of the Little Manatee River (Ft. Lonesome, Carlton

Branch, South Prong, Dug Creek, Cypress Creek and Wimauma) and to elucidate processes influencing the transport of these materials through the Little Manatee estuary.

Estimates of Annual Material Flux from Sub-Basins

The sum of the discharges recorded at the Cypress Creek (CYPR) and Wimauma (WIMA) gaging stations represent the approximate total fresh water and material fluxes to the Little Manatee estuary. Thus they, along with Tampa Bay, are the major sources of materials, such as nutrients, supplied to the estuary.

For the purpose of evaluating the relative importance of each sub-basin, the discharges and fluxes determined from data collected at the Cypress Creek, Dug Creek, Carlton Branch, Ft. Lonesome and South Prong gaging stations are assumed to represent the transports from their respective watersheds. The discharge and flux determined from the data collected at the Wimauma gaging station represents the influence of the intervening watershed below the upper sub-basins (all except Cypress Creek) when the sum of the fluxes and discharges from these are subtracted. This part of the watershed is referred to as the Inner sub-basin (IB).

The flux or load of a chemical substance transported from each sub-basin is simply the product of the chemical concentration and water discharge observed at the gaging station. Instantaneous values of flux are relatively simple to derive for each gaging station using measured substance concentrations and instantaneous or daily mean discharge at the time of sampling. It is, however, much more difficult to estimate, with a high degree of accuracy, fluxes over longer periods of time such as a year or more since this requires long term records of concentration (C) and discharge (Q), so that flux (F) can be calculated by integration using the equation:

$$F = \int_{0}^{t} C\,Q\,dt \qquad (1)$$

It would still be easy to calculate fluxes if concentrations of substances were constant over all variations in discharge. This, however, is not the case since the concentrations of virtually all substances, both particulate and soluble, vary with discharge. Nonetheless, several approaches have been used to calculate fluxes with limited data collected over various flow conditions of a watershed. Generally the approaches used involve either extrapolation or interpolation of the data. Both approaches were used in this study and are discussed below.

<u>Extrapolation method for estimating material flux.</u> These procedures attempt to extrapolate the available database by developing rating relationships which link chemical concentrations measured at infrequent intervals to river discharge at the time of sampling. Rating relationships are normally developed for sites with discharge monitoring facilities

so that the rating function may be applied to a continuous flow record thus allowing for extrapolation of chemical concentration (and flux) between periods of sample collection. Simple power functions of the form:

$$\text{Concentration} = aQ^b \qquad (2)$$

are used to relate the concentration of a substance and river flow, Q. Such relationships have been routinely documented by many studies. For example, suspended sediments generally show increased concentration with discharge following a relationship similar to that described in equation (2) with b being a positive number. In the case of total dissolved solids a similar relationship is observed, but b is often negative (Figure 5.2). Rating relationships or rating curves have been demonstrated for many specific substances, for both natural and anthropogenically disturbed (e.g., agricultural areas) watersheds (Nilsson, 1971; Turvey, 1975; Walling and Webb, 1983; Walling and Kane, 1984).

Although rating relationships for total dissolved solids often exhibit decreasing concentrations with increasing discharge, specific dissolved substances such as nutrients often show increases with discharge (Walling and Webb, 1984; Webb and Walling, 1985).

Rating curves are developed by obtaining concentration data over seasonal variations in discharge for a given watershed. Fitting concentration data to discharge is usually accomplished by least-squares regression techniques. This approach was employed in this study using the individual bimonthly concentrations of constituents and mean discharge for the station on the day of sample collection using a log transformation of equation (2).

Other authors (e.g., Jansson, 1985) have argued that other methods of curve fitting are more appropriate, and in some cases (e.g., Hall, 1970; Davis and Zobrist, 1978; Foster, 1980), the relationship between concentration and discharge will not be described by a simple power function. Nonetheless, we felt that the approach used in this study was more appropriate given the limited data set for each station.

Many investigators have stressed the complexity and variability of storm-period sediment and solute responses to discharge (Walling and Foster, 1978; Miller and Drever, 1977; Foster, 1978a,b; Reid et al., 1981; Dupraz et al., 1982; Webb and Walling, 1983; Walling and Webb 1986a,b). Thus it is important to determine concentration relationships to storm related variations in flow. In practice, for a given watershed, separate rating curves are developed for seasonal flow and storm related flow. For this study data collected during storm event campaigns are related to discharge averaged over hourly intervals also using the least squares regression approach.

Once the rating curves were developed annual flux of a given material by each river was calculated using the following equation,

$$\text{Flux} = \sum_{i=1}^{n} aQ_i^{b+1}\, t \qquad (3)$$

where $Q_i$ is the mean daily (hourly from storm event) discharge recorded at the specific stream gage, n = 365 (or the number of 15 minute intervals represented by the storm event), a and b are constants derived from the least square regression analysis of concentration on discharge, and t is the time over which $Q_i$ is averaged.

Interpolation method for estimating material flux. Several interpolation procedures have been used for estimating total loads or fluxes of materials. Five representative numerical procedures are listed in Table 5.3. These procedures make the assumption that the chemical concentration of a water sample is representative of conditions in the river for the period between sampling. These approaches essentially attempt to weight the concentration to discharge. Because of the sometimes considerable differences in flux values generated by the different procedures, two were used: Methods 3 and 5. In each case the calculations were carried out using the results from the 26 weekly samples collected between January 1988 and February 1989. Thus n = 26 and the conversion factor K was adjusted for a discharge record of 13 months.

Table 5.3. Interpolation methods for flux calculations.

| Method | Numerical Procedure |
|---|---|
| 1 | $\text{Total Load} = K\left(\sum_{i=1}^{n}\frac{C_i}{n}\right)\left(\sum_{i=1}^{n}\frac{Q_i}{n}\right)$ |
| 2 | $\text{Total Load} = KQ_r\left(\sum_{i=1}^{n}\frac{C_i}{n}\right)$ |
| 3 | $\text{Total Load} = K\sum_{i=1}^{n}\left(\frac{C_iQ_i}{n}\right)$ |
| 4 | $\text{Total Load} = K\sum_{i=1}^{n}(C_iQ_p)$ |
| 5 | $\text{Total Load} = \frac{K\sum_{i=1}^{n}(C_iQ_p)}{\sum_{i=1}^{n}Q_i}Q_r$ |

$K$ = Conversion Factor To Take Account Of Period Of Record

$C_i$ = Instantaneous Concentration Associated With Individual Samples

$Q_i$ = Instantaneous Discharge At Time Of Sampling

$Q_r$ = Mean Discharge For Period Of Record

$Q_p$ = Mean Discharge For Interval Between Samples

$n$ = Number Of Samples

RESULTS

Water Quality Characteristics

Hydrographs and chemographs for the six gaging stations during the period of study are shown in Figures 5.2, A through F. Dates of routine sample collection are indicated by data points along the time axis. Time is in days starting with 1 January 1988. Compared to historical streamflow data, the sampling appeared to capture a fairly wide range of discharge conditions.

The base flow recorded at all gaging stations is quite low. Superimposed on this pattern are short period storm spikes. Only one storm event, occurring during September, appears particularly significant.

Bi-weekly water quality sampling during the study year found pronounced differences in water chemistry between the seven stream stations. DOC and nitrate concentrations were highly variable during the study period. Concentrations of ammonia and phosphate were somewhat less variable and reached maximum values between July and September, although this varied between sub-basins. This was the approximate time of the highest discharge.

Particulate carbon, nitrogen and phosphorus vary, in general, with total suspended solids. The maximum or spike in particulate substances for the Cypress Creek, Carlton Creek,

# Hydrograph and Chemographs for Ft. Lonesome Gauging Station

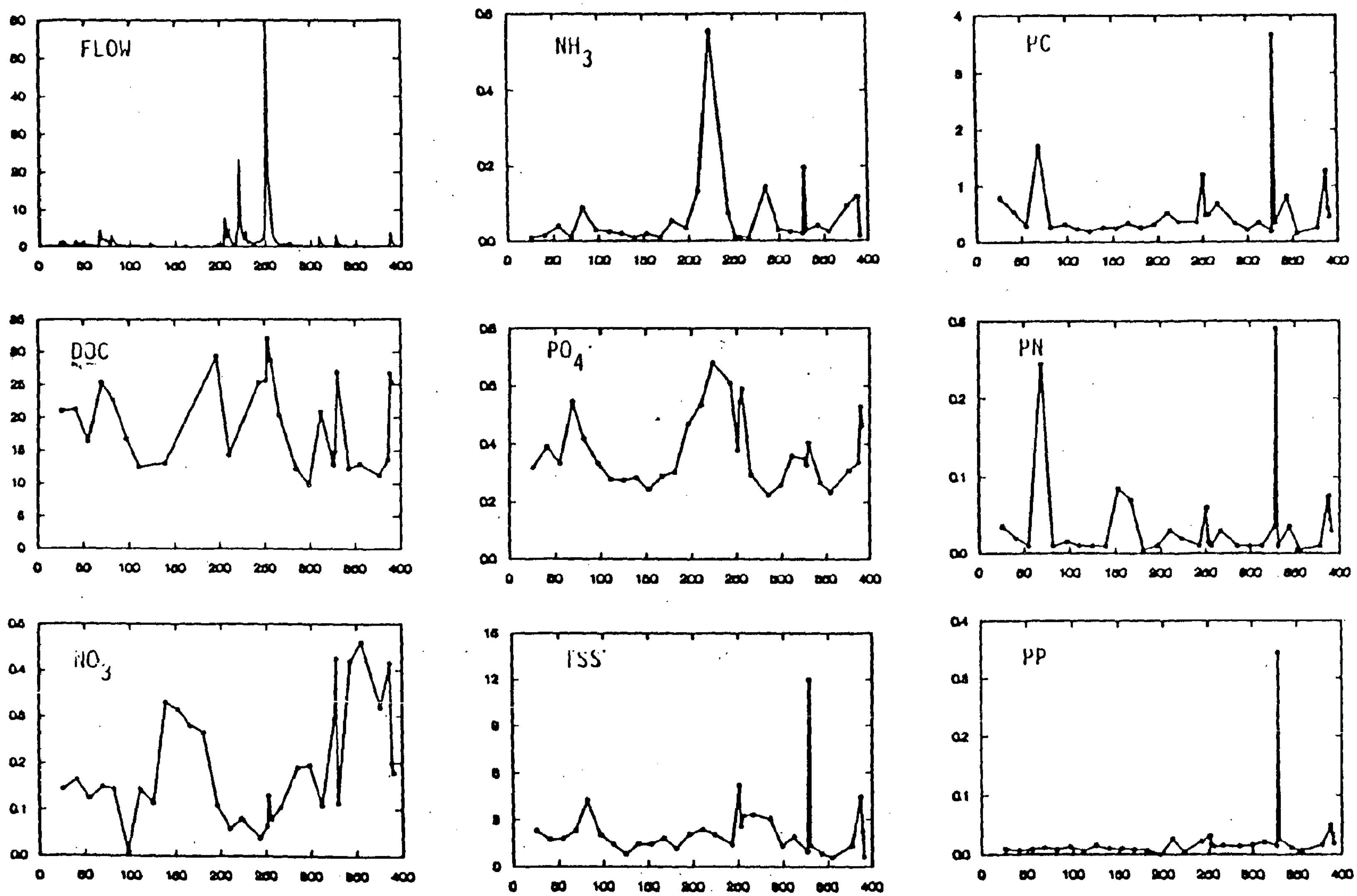
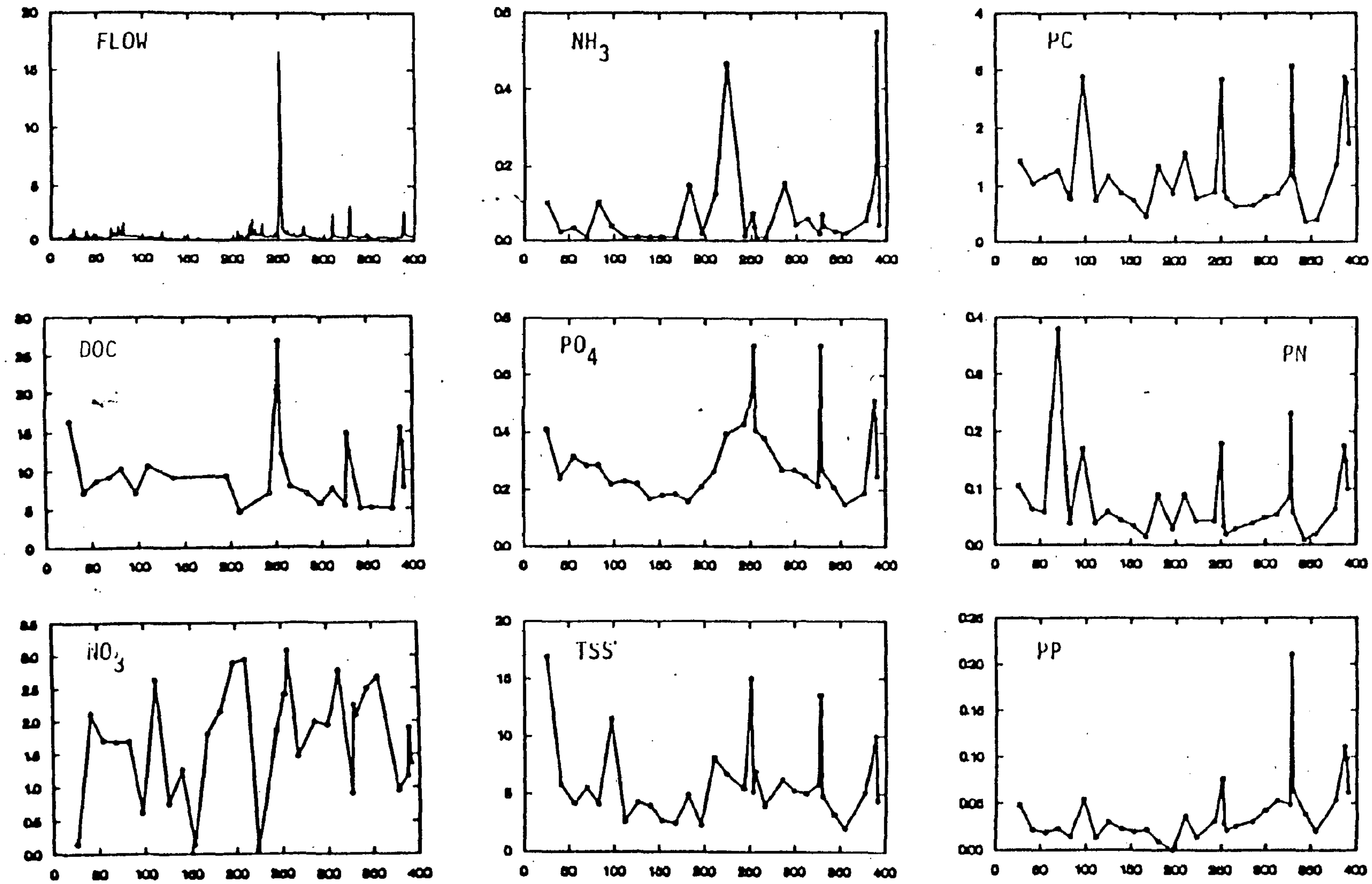
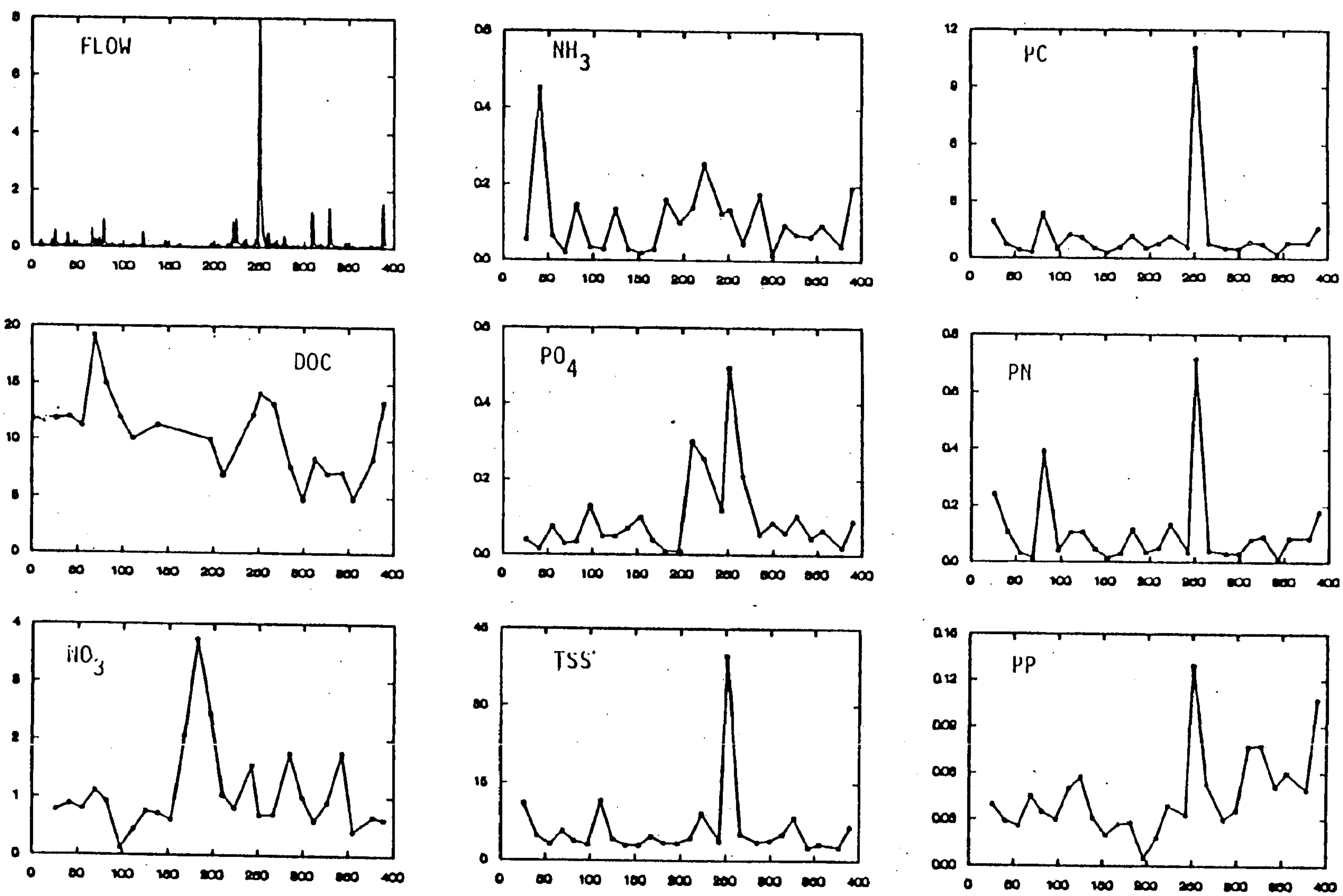



Figure E.2 A

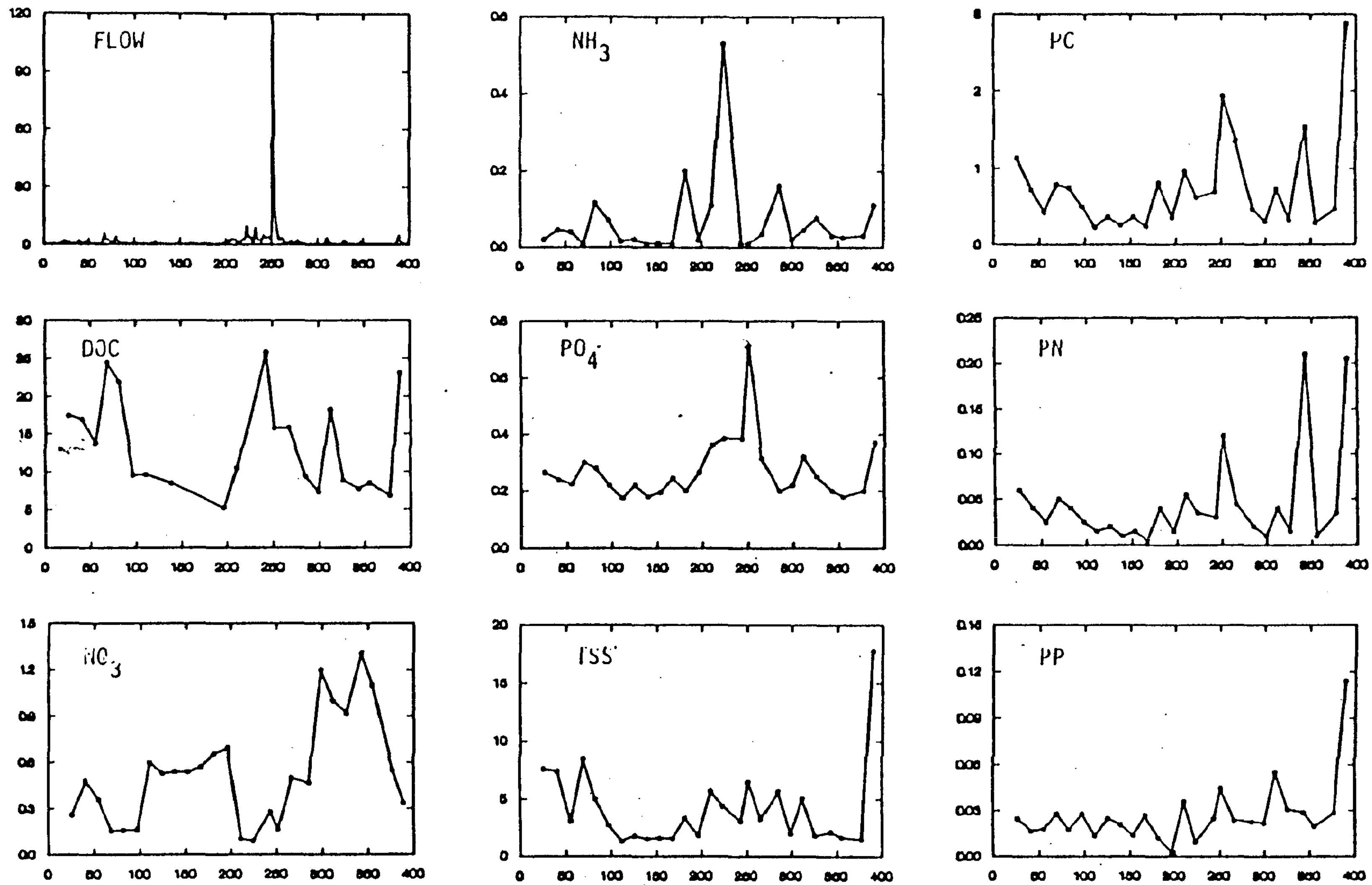
Hydrograph and Chemographs for Carlton Branch Station



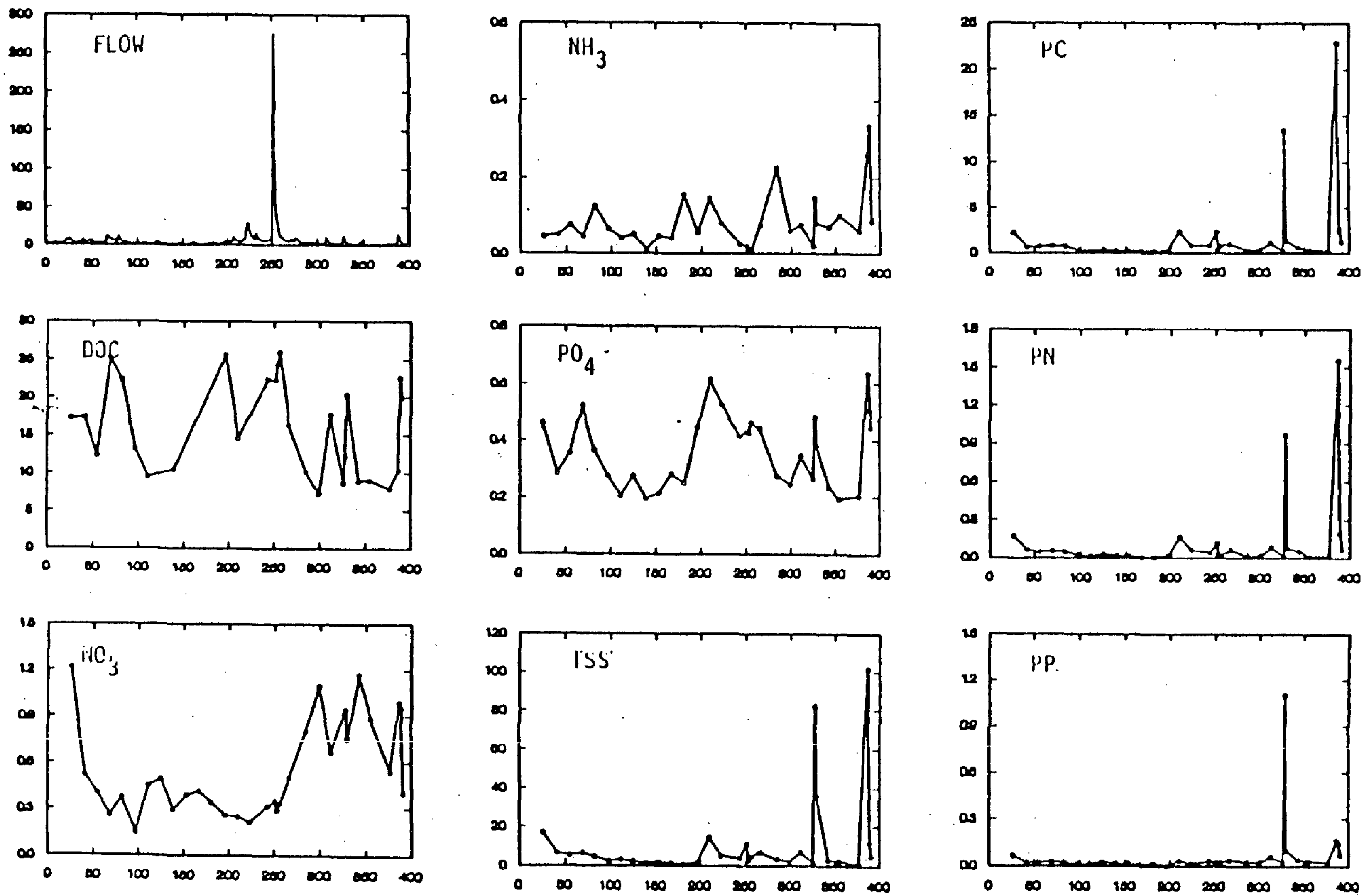
## Hydrograph and Chemographs for Dug Creek Station



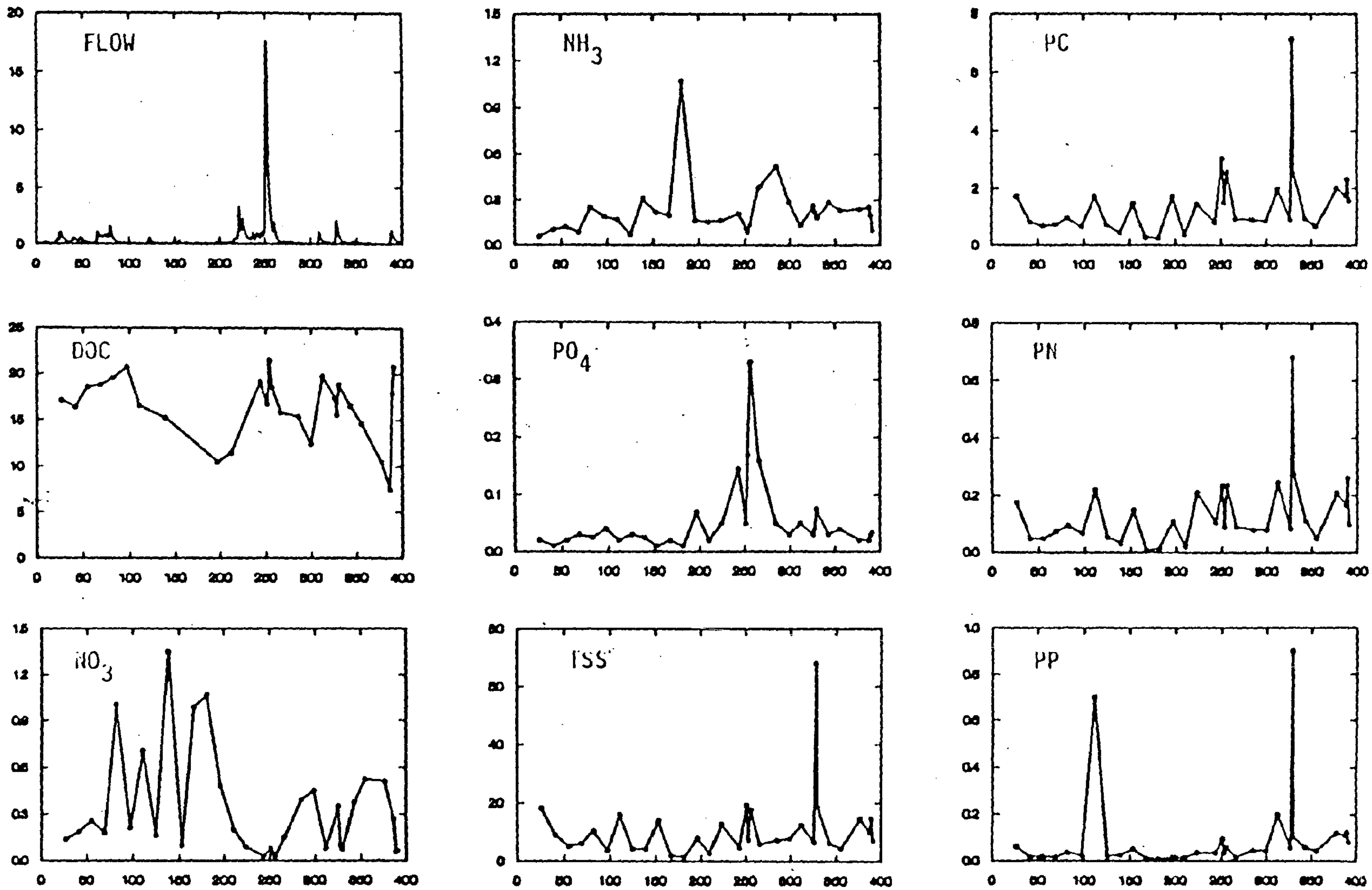
## Hydrograph and Chemographs for South Prong Station



Hydrograph and Chemographs for Wimahma Station



Hydrograph and Chemographs for Cypress Creek Station



Wimauma and Ft. Lonesome chemographs occur at the same time but are not present in the Dug Creek and South Prong chemographs.

Mean values for selected water quality parameters at these sites during the study year are listed in Table 5.4. For a few parameters (pH, turbidity, ortho-phosphorus), variation between the stations was not large and comparison of station means for these parameters with Duncan's multiple range test found no significant differences ($p < .05$) between stations. For the majority of the measured parameters, however, variation between stations was large and water quality in the different sub-basins showed clearly different characteristics. A general discussion of water quality at these sites based on mean values is presented below with general reference to land use and possible cause/effect relationships.

Table 5.4. Mean values for water chemistry parameters at regular bi-weekly freshwater stations - Little Manatee River Basin.

| Parameter | Units | Wimauma | Cypress Creek | Dug Creek | North Fork | Carlton Branch | South Fork | Ft. Lonesome |
|---|---|---|---|---|---|---|---|---|
| Specific Conduct. | umhos /cm | 271 | 429 | 528 | 288 | 322 | 204 | 155 |
| pH | pH units | 6.8 | 6.4 | 6.9 | 6.8 | 6.9 | 6.5 | 6.5 |
| Turbidity | NTU | 4.5 | 7.1 | 5.6 | 4.3 | 3.7 | 3.2 | 2.3 |
| Color | PCU | 113 | 78 | 39 | 121 | 38 | 116 | 142 |
| TSS | mg/l | 5.1 | 8.6 | 6.2 | 6.9 | 5.9 | 4.1 | 2.0 |
| Particulate Carbon | mg/l | .80 | 1.1 | 1.25 | .93 | 1.15 | .74 | .45 |
| Total Dissolved Carbon | mg/l | 15.7 | 16.7 | 11.0 | 14.9 | 9.3 | 13.8 | 18.5 |
| Particulate Nitrogen | mg/l | .05 | .11 | .11 | .08 | .08 | .04 | .03 |
| $NH_3$ (as N) | mg/l | .08 | .24 | .11 | .07 | .08 | .07 | .06 |
| $NO_3$-$NO_2$ (N) | mg/l | .55 | .39 | 1.1 | .60 | 1.70 | .53 | .19 |
| Particulate Phosphorus | mg/l | .03 | .07 | .04 | .04 | .03 | .03 | .01 |
| PO4 (as P) | mg/l | .34 | .04 | 1.0 | .37 | .27 | .34 | .37 |
| Silica | mg/l | 6.0 | 3.9 | 7.4 | 6.4 | 7.0 | 6.4 | 4.4 |
| Chlor. a | $mg/m^3$ | 2.7 | --- | --- | 2.9 | --- | 1.3 | --- |
| *Calcium | mg/l | 28.7 | 44.9 | 66.5 | 32.6 | 35.6 | 22.3 | 14.1 |
| *Alkalinity (as $CaCO_3$) | mg/l | 38.9 | 59.7 | 60.6 | 47.5 | 57.2 | 28.6 | 29.3 |
| *Chloride | mg/l | 17.1 | 29.6 | 22.4 | 16.8 | 22.8 | 13.9 | 17.9 |
| *Sulfate | mg/l | 60.7 | 93.5 | 166.5 | 63.6 | 56.0 | 38.0 | 15.7 |

* Sampled monthly

The Fort Lonesome station was the most upstream site monitored on the main channel of the Little Manatee River. Land use in the drainage basin for this station is different from other monitored sub-basins in that the primary land uses are open space and pasture. The other sub-basins have much higher densities of either citrus, row crops, or residential development. In accordance with this difference in land use, water quality at the Fort Lonesome site was distinct from the other stations and more similar to an unimpacted, central Florida stream. Generally, water quality at this site can be characterized as highly colored, slightly acidic, with low levels of suspended matter and moderate levels of nutrients. Mean values of color and total dissolved carbon were highest at this station, probably reflecting the input of humic compounds leached from vegetation and litter in the drainage basin. For a number of parameters, mean values were either ranked lowest or near lowest for this station, with Duncan's multiple range test grouping the station alone or with one or two other stations depending on the parameter (conductivity, turbidity, total suspended solids, particulate carbon, particulate phosphorus, nitrate-nitrite, calcium, alkalinity, and sulfate). Although further examination of soils distributions is necessary, it is suggested that the Fort Lonesome station can be viewed as a control, indicative of relatively unimpacted water quality in the basin.

The site most similar to Fort Lonesome was the South Fork, which was the only station on that branch of the river. Mean values of alkalinity and chloride were ranked lowest for this station, and a number of parameters were ranked second lowest only to Fort Lonesome (conductivity, turbidity, total suspended solids, particulate carbon, particulate nitrogen, calcium and sulfate). For some other parameters (total dissolved carbon, ammonia, nitrate/nitrite, ortho-phosphate, and silica), the South Fork was ranked near the middle of the seven stations.

Of the remaining five stream sampling stations, two sites (LMR near Wimauma and LMR North Fork) were on the main channel of the river while three stations were on three tributary creeks to the main channel. These three tributaries, Carlton Branch, Dug Creek and Cypress Creek, all flow from north to south and enter the Little Manatee on its northern bank. Land use in Carlton Branch is primarily agricultural with extensive citrus groves and row crops. Land use in the small basin (3.6 square miles) upstream of the Dug Creek sampling site is mixed with low density residential, citrus and fish farms. Cypress Creek drains an area of residential development where there was extensive highway construction during the study year. Water quality for these three tributaries to the Little Manatee were grouped together by the multiple range test, and with a few exceptions, were ranked 1, 2, and 3 with regard to mean values for specific conductance, alkalinity, calcium, ammonia, particulate nitrogen and particulate carbon.

In general, water in these tributaries was lower in color and more highly mineralized than water in the main river or the South Fork. This degree of mineralization was particularly reflected in high mean values for specific conductance (322 to 528 mg/l), calcium (35.6 to 66.5 mg/l) and sulfate (38.0 to 166.5 mg/l). Cypress Creek was notable for the high levels of turbidity, total suspended solids, particulate carbon and particulate nitrogen, probably reflecting the soil disturbance and resulting suspended load that was generated in the sub-basin during the study. Dug Creek and Carlton Branch had the lowest mean color values found in the study (39 and 38 mg/l), but had the highest levels of nitrate-nitrite and silica. It is believed that the high degree of mineralization and dissolved constituents in these three tributaries are the result of irrigation runoff. High levels of silica, calcium, and sulfate are characteristic of ground waters in the region.

As discussed in Chapter III, substantial groundwater pumping occurs in the Little Manatee basin for agricultural irrigation. Also, the USGS reports that runoff to Cypress Creek is supplemented by spray irrigation in the basin. High levels of nitrate-nitrite and ammonia in these tributaries may also result from runoff transport of fertilizer. Upcoming investigations are to confirm the occurrence of irrigation runoff in these tributaries. Runoff-rainfall relationships discussed elsewhere in this report show that baseflow levels in these creeks are higher than the other basins and likely supplemented by irrigation runoff.

The three stations on the main channel of the Little Manatee River are Fort Lonesome, LMR North Fork, and the LMR near Wimauma. Examination of mean water quality values for these three stations demonstrates the increasing mineral and nutrient content of the Little Manatee as it flows to Tampa Bay. Some constituents, such as nitrate, silica, TSS and sulfate show significant levels of enrichment proceeding downstream while both particulate and dissolved phosphorus show little or no enrichment. Although Cypress Creek flows into the Little Manatee below the LMR near Wimauma site, data from near Wimauma can be considered as indicative of the net water quality flowing to the estuary.

Mineral and nutrient enrichment of the Little Manatee River is also seen in the additional water quality samples that were taken on May 17 and September 21, 1989 (see Figure 5.1). Average values for selected water quality parameters at ten of these stations plus average values for four of the regular stations on the same two dates are listed in Table 5.5. The stations are grouped according to which region of the Little Manatee drainage basin they occur. Group A stations in Table 5.5 are located in upper part of the drainage basin near the Fort Lonesome site. These stations are characterized by relatively high color and low values of specific conductance, sulfate, and at three of the four sites, silica. Silica values were high at station 5 in Hurrah

Table 5.5. Average values for water quality parameters sampled on May 17 and September 21, 1988 at selected stations in Figure 5.1.

| | | Group A Stations | | | | Group B Stations | |
|---|---|---|---|---|---|---|---|
| Station | Units | 3 | 4 | 5 | 6 | 2 | D |
| Specific Conduct. | umhos/cm | 182 | 184 | 186 | 165 | 143 | 284 |
| pH | pH units | 7.0 | 7.0 | 6.2 | 6.9 | 6.9 | 6.8 |
| Color | PCU | 140 | 115 | 222 | 102 | 115 | 82 |
| $NH_3$ (N) | mg/l | .05 | .02 | .05 | .01 | .02 | .02 |
| $NO_3$-$NO_2$ (N) | mg/l | .62 | .60 | .02 | .22 | .14 | .52 |
| PO4 (P) | mg/l | .31 | .30 | .44 | .30 | .41 | .25 |
| Silica | mg/l | 2.9 | 2.5 | 7.4 | 5.2 | 7.4 | 8.5 |
| Ca | mg/l | 19 | 13 | 7 | 14 | 15 | 26 |
| Alkalinity | mg/l | 46 | 46 | 51 | 44 | 40 | 43 |
| Chloride | mg/l | 13 | 12 | 13 | 11 | 8 | 11 |
| Sulfate | mg/l | 15 | 16 | 18 | 13 | 14 | 75 |
| Total Dissolved Carbon | mg/l | 17 | 18 | 24 | 17 | 14 | 12.3 |

Table 5.5. (Continued)

| | | Group C Stations | | | Group D Stations | | Group E Stations | | |
|---|---|---|---|---|---|---|---|---|---|
| Station | Units | 7 | 9 | E | 15 | 14 | 8 | 16 | C |
| Specific Conduct. | umhos/cm | 193 | 178 | 375 | 810 | 690 | 181 | 290 | 376 |
| pH | pH units | 7.2 | 6.8 | 7.2 | 7.2 | 7.4 | 6.9 | --- | 7.2 |
| Color | PCU | 87 | 37 | 27 | 40 | 64 | 137 | 117 | 92 |
| $NH_3$ (N) | mg/l | .01 | .03 | .01 | .1 | .01 | .02 | .03 | .02 |
| $NO_3$-$NO_2$ (N) | mg/l | 1.7 | 1.3 | 1.4 | .25 | .14 | .36 | .71 | .47 |
| PO4 (P) | mg/l | .22 | .11 | .28 | .18 | .19 | .30 | .17 | .35 |
| Silica | mg/l | 4.0 | 4.7 | 9.2 | 12.8 | 13.8 | 4.2 | 7.0 | 7.9 |
| Ca | mg/l | 18 | 18 | 41 | 97 | 87 | 24 | 40 | 38 |
| Alkalinity | mg/l | 26 | 20 | 76 | 75 | 92 | 44 | 59 | 68 |
| Chloride | mg/l | 21 | 17 | 21 | 17 | 16 | 16 | 15 | 15 |
| Sulfate | mg/l | 16 | 22 | 200 | 260 | 208 | 17 | 60 | 90 |
| Total Dissolved Carbon | mg/l | 11 | 6.7 | 9.0 | 9.6 | 9.9 | 16 | 14 | 13.2 |

Creek, and moderate nitrate-nitrite concentrations were found at stations 3 and 4 in Aldermans Creek.

Group B stations are in the South Fork of the river, which as previously discussed, has water quality most similar to the Fort Lonesome area. There appears to be considerable enrichment of the South Fork for several constituents (conductivity, nitrate-nitrite, calcium and sulfate) progressing from upstream station 2 to the regular South Fork station which is just above the north fork confluence.

Group C stations are located on Pierce Branch and Carlton Branch which both flow into the Little Manatee North Fork. Station 7, on the lower reaches of Pierce Branch, has water quality similar to the upper station (#9) on Carlton Branch. Station E, the regular sampling station on Carlton Branch, however, has markedly higher concentrations for a number of parameters (conductivity, silica, calcium and sulfate) probably due to irrigation runoff to this stream. Closer investigation of land-use in the Pierce and Carlton Branch sub-basis should establish the water quality effects of various agricultural practices. Group D stations are two small tributaries which drain into the river downstream from the Carlton Branch confluence. These stations had some of the highest levels of specific conductance, silica, calcium and sulfate concentrations of any sites monitored during the study, presumably due to runoff from groundwater pumping. Interestingly, however, neither nitrate-nitrite nor dissolved phosphorus concentrations were high for these streams.

Group E stations are listed to show the increasing mineral content of the north fork of the Little Manatee as it progresses downstream between the confluences of Carlton Branch and the south fork. In a distance of approximately four river miles, increases are seen in conductivity and silica by near a factor of 2 and sulfate by a factor of 5. This small geographic region will be examined in detail with regard to land-use to investigate the causes of these water quality changes.

Chemical Transport from Sub-basins

As was discussed in the Data Reduction section, the annual flux of dissolved and particulate nitrogen, phosphorus, and carbon and total suspended solids were calculated using two different approaches: extrapolation and interpolation. The first approach is accomplished by developing rating curves and integrating these over the annual hydrographs. Two interpolation procedures were used to calculate annual fluxes.

Because the rating curves potentially provide information from which other conclusions can be drawn these results will be discussed in the next section. Following that, annual flux estimates based on both the extrapolation and interpolation approaches will be presented, compared and discussed.

Rating curves. The results of the least square regression fit of the data for the various parameters to discharge are given in Table 5.6 for each gaging station. For dissolved constituents, significant rating curves could be established for DOC, phosphate, total suspended solids and particulate carbon for all of the gaging stations. Nitrate and particulate nitrogen rating curves were significant for all gaging stations except Carlton Branch and Ft. Lonesome, respectively. These gaging stations had nonsignificant rating relationships for particulate

## TABLE 5.6

Rating Relationships for Gauging Stations*
($r^2$ values underlined represent non-significant relationships)

| | DOC | | | $NO_3$ | | | $NH_3$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | a | b | $r^2$ | a | b | $r^2$ | a | b | $r^2$ |
| LONE | 0.14 | 2.92 | 0.43 | -0.16 | -1.95 | 0.14 | 0.06 | -3.37 | $\underline{0.01}$ |
| CARL | 0.28 | 2.41 | 0.44 | 0.09 | 0.41 | $\underline{0.01}$ | 0.35 | -2.92 | $\underline{0.11}$ |
| SP | 0.22 | 2.47 | 0.42 | -0.32 | -0.87 | 0.36 | 0.12 | -3.34 | $\underline{0.02}$ |
| DUG | 0.12 | 2.60 | 0.19 | -0.15 | -0.54 | 0.11 | 0.13 | -2.25 | $\underline{0.04}$ |
| WIMA | 0.23 | 2.31 | 0.48 | -0.07 | -0.62 | $\underline{0.03}$ | -0.15 | -2.60 | $\underline{0.05}$ |
| CYPR | 0.06 | 2.85 | 0.22 | -0.42 | -2.19 | 0.56 | -0.18 | -1.95 | 0.32 |

| | $PO_4$ | | | TSS | | | PC | | |
|---|---|---|---|---|---|---|---|---|---|
| | a | b | $r^2$ | a | b | $r^2$ | a | b | $r^2$ |
| LONE | 0.10 | -0.97 | 0.40 | 0.16 | 0.70 | 0.22 | 0.19 | -0.79 | 0.24 |
| CARL | 0.31 | -0.98 | 0.67 | 0.32 | 1.97 | 0.45 | 0.26 | 0.31 | 0.26 |
| SP | 0.20 | -1.36 | 0.82 | 0.34 | 1.17 | 0.50 | 0.33 | -0.54 | 0.48 |
| DUG | 0.29 | -1.96 | 0.19 | 0.31 | 2.42 | 0.55 | 0.35 | 0.73 | 0.42 |
| WIMA | 0.18 | -1.34 | 0.44 | 0.38 | 1.00 | 0.20 | 0.40 | -0.93 | 0.23 |
| CYPR | 0.24 | -2.98 | 0.30 | 0.21 | 2.42 | 0.28 | 0.23 | 0.46 | 0.36 |

| | PN | | | PP | | |
|---|---|---|---|---|---|---|
| | a | b | $r^2$ | a | b | $r^2$ |
| LONE | 0.13 | -3.87 | $\underline{0.06}$ | 0.17 | -4.20 | $\underline{0.10}$ |
| CARL | 0.29 | -2.56 | 0.16 | 0.56 | -3.01 | 0.35 |
| SP | 0.41 | -3.51 | 0.41 | 0.18 | -3.79 | 0.16 |
| DUG | 0.38 | -1.70 | 0.30 | 0.21 | -2.70 | 0.22 |
| WIMA | 0.37 | -3.71 | 0.15 | 0.14 | -3.68 | $\underline{0.03}$ |
| CYPR | 0.26 | -1.95 | 0.28 | 0.13 | -2.83 | $\underline{0.06}$ |

*Parameters listed are for the general equation: ln C = alnQ + b phosphorous and all but two (Carlton Branch and Wimauma) had non-significant relationships for ammonia.

The lack of observed significant rating relationships for ammonia for most of the gaging stations is not surprising given the variability of nitrification and denitrification in the watershed.

In general, the significant rating curves for a given parameter are similar for all gaging stations.

Fluxes from Sub-basins. The annual fluxes of dissolved organic carbon nitrate, ammonia, phosphate; particulate carbon, nitrogen and phosphorous; and total suspended solids from the six sub-basins of the Little Manatee Watershed were estimated using the three methods described in the water chemistry data reduction section. Results of the two methods which gave the best agreement are presented in Table 5.7. These estimates of fluxes for each constituent for each gaging station were used to calculate mean annual fluxes. The poorest agreement was observed generally for the smaller sub-basins.

The total fluxes of the various constituents due to discharges from all sub-basins are presented in Table 5.8. The relative contributions to these fluxes from each sub-basin are also given in this table. Fluxes of dissolved nitrogen and particulates from Carlton Branch, Dug Creek appear disproportionately high on the basis of comparison to watershed size or discharge.

**TABLE**

Annual Flux of Dissolved and Particulate Nutrients
and Total Suspended Solids From Sub-Basins of
The Little Manatee River

Kilograms Per Year

| Sub-Basins | | DOC $\times 10^5$ | $NO_3$ $\times 10^3$ | $NH_3$ $\times 10^3$ | $PO_4$ $\times 10^3$ | PC $\times 10^3$ | PN $\times 10^3$ | PP $\times 10^3$ | TSS $\times 10^4$ |
|---|---|---|---|---|---|---|---|---|---|
| Ft. Lonesome (LONE) | 1 | 10.3 | 4.72 | 1.62 | 19.4 | 27.7 | 1.12 | 0.87 | 0.4 |
| | 2 | 10.8 | 4.30 | 2.34 | 18.9 | 39.4 | 2.11 | 1.36 | 17.2 |
| | Mean | 10.5 | 4.51 | 1.98 | 19.2 | 33.5 | 1.61 | 1.12 | 8.8 |
| | S.D | 0.4 | 0.30 | 0.51 | 0.3 | 8.3 | 0.70 | 0.35 | 11.9 |
| Carlton Branch (CARL) | 1 | 1.70 | 21.5 | 0.86 | 5.82 | 20.5 | 1.18 | 0.97 | 11.2 |
| | 2 | 2.46 | 30.9 | 1.26 | 7.07 | 31.5 | 2.01 | 1.06 | 16.1 |
| | Mean | 2.08 | 26.2 | 1.06 | 6.44 | 26.0 | 1.59 | 1.02 | 13.6 |
| | S.D | 0.53 | 6.7 | 0.28 | 0.88 | 7.8 | 0.58 | 0.06 | 3.5 |
| South Prong (SP) | 1 | 10.69 | 15.4 | 2.49 | 22.4 | 72.3 | 4.66 | 1.84 | 41.0 |
| | 2 | 9.05 | 11.6 | 2.41 | 34.6 | 96.0 | 5.96 | 2.39 | 3.61 |
| | Mean | 9.87 | 13.5 | 2.45 | 28.5 | 84.2 | 5.31 | 2.12 | 38.6 |
| | S.D | 1.16 | 2.7 | 0.06 | 8.6 | 16.8 | 0.92 | 0.38 | 3.5 |
| Dug Creek (DUG) | 1 | 0.65 | 3.29 | 0.51 | 0.71 | 10.7 | 0.96 | 0.33 | 5.7 |
| | 2 | 0.69 | 3.73 | 0.67 | 2.08 | 45.2 | 2.99 | 0.58 | 16.5 |
| | Mean | 0.67 | 3.51 | 0.59 | 1.39 | 27.9 | 1.97 | 0.45 | 11.1 |
| | S.D | 0.03 | 0.31 | 0.11 | 0.97 | 24.4 | 1.44 | 0.17 | 7.7 |
| Wimanma (WIMA) | 1 | 40.6 | 85.0 | 9.57 | 87.4 | 319 | 17.1 | 7.36 | 197 |
| | 2 | 41.8 | 75.3 | 8.10 | 82.4 | 349 | 19.4 | 9.25 | 191 |
| | Mean | 41.2 | 80.1 | 8.84 | 84.9 | 334 | 18.2 | 8.31 | 194 |
| | S.D | 0.8 | 6.9 | 1.04 | 3.5 | 21 | 1.7 | 1.34 | 4 |
| Cypress Creek (CYPR) | 1 | 2.54 | 1.57 | 1.88 | 0.88 | 26.9 | 2.51 | 0.92 | 18.7 |
| | 2 | 2.54 | 1.35 | 1.75 | 1.30 | 35.3 | 2.92 | 1.61 | 24.2 |
| | Mean | 2.54 | 1.46 | 1.82 | 1.09 | 31.1 | 2.72 | 1.27 | 21.5 |
| | S.D | 0.00 | 0.15 | 0.10 | 0.30 | 6.0 | 0.30 | 0.49 | 3.9 |

## TABLE

Annual Material Fluxes to the Little Manatee Estuary
and Relative Contributions from Sub-Basins

| | Total[1] (tons/yr.) | LONE | CARL | SP | DUG (Percent) | WIMA | CYPR | IB[2] |
|---|---|---|---|---|---|---|---|---|
| DOC | 4370 | 24 | 5 | 23 | 2 | 94 | 6 | 41 |
| $NO_3$ | 81.6 | 6 | 32 | 17 | 4 | 98 | 2 | 40 |
| $NH_3$ | 10.6 | 19 | 10 | 23 | 6 | 83 | 17 | 26 |
| $PO_4$ | 86.0 | 22 | 7 | 33 | 2 | 99 | 1 | 34 |
| PC | 365 | 9 | 7 | 23 | 8 | 92 | 8 | 44 |
| PN | 20.9 | 8 | 8 | 25 | 9 | 87 | 13 | 37 |
| PP | 9.58 | 12 | 11 | 22 | 5 | 87 | 13 | 38 |
| TSS | 2160 | 4 | 6 | 18 | 5 | 90 | 10 | 56 |
| Watershed | 451[3] | 19 | 4 | 27 | 2 | 95 | 5 | 52 |

1. Total is calculated as the sum of the fluxes measured at the Wimanma and Cypress Creek gauging stations.

2. IB refers to the inner basin. Fluxes are calculated as the difference between the flux at Wimanma and the sum of the fluxes at Dug Creek, Carlton Branch, Ft. Lonsome and South Prong.

3. Watershed area is in $km^2$.

Total fluxes given in Table 5.8 are conservative estimates of the amount of material delivered to the Little Manatee estuary because we have not considered smaller sources of materials such as direct surface runoff and contributions downstream of the gaging stations. We also have not considered removal processes that may be occurring downstream of the gaging stations.

The efficiency of material mobilization from each sub-basin is compared in Figures 5.3 A and B. Figure 5.3 A compares the flux of dissolved substance per unit area and Figure 5.3 B does the same for particulate substances. These comparisons can be used to distinguish similar watersheds and perhaps identify the influence of different land use practices.

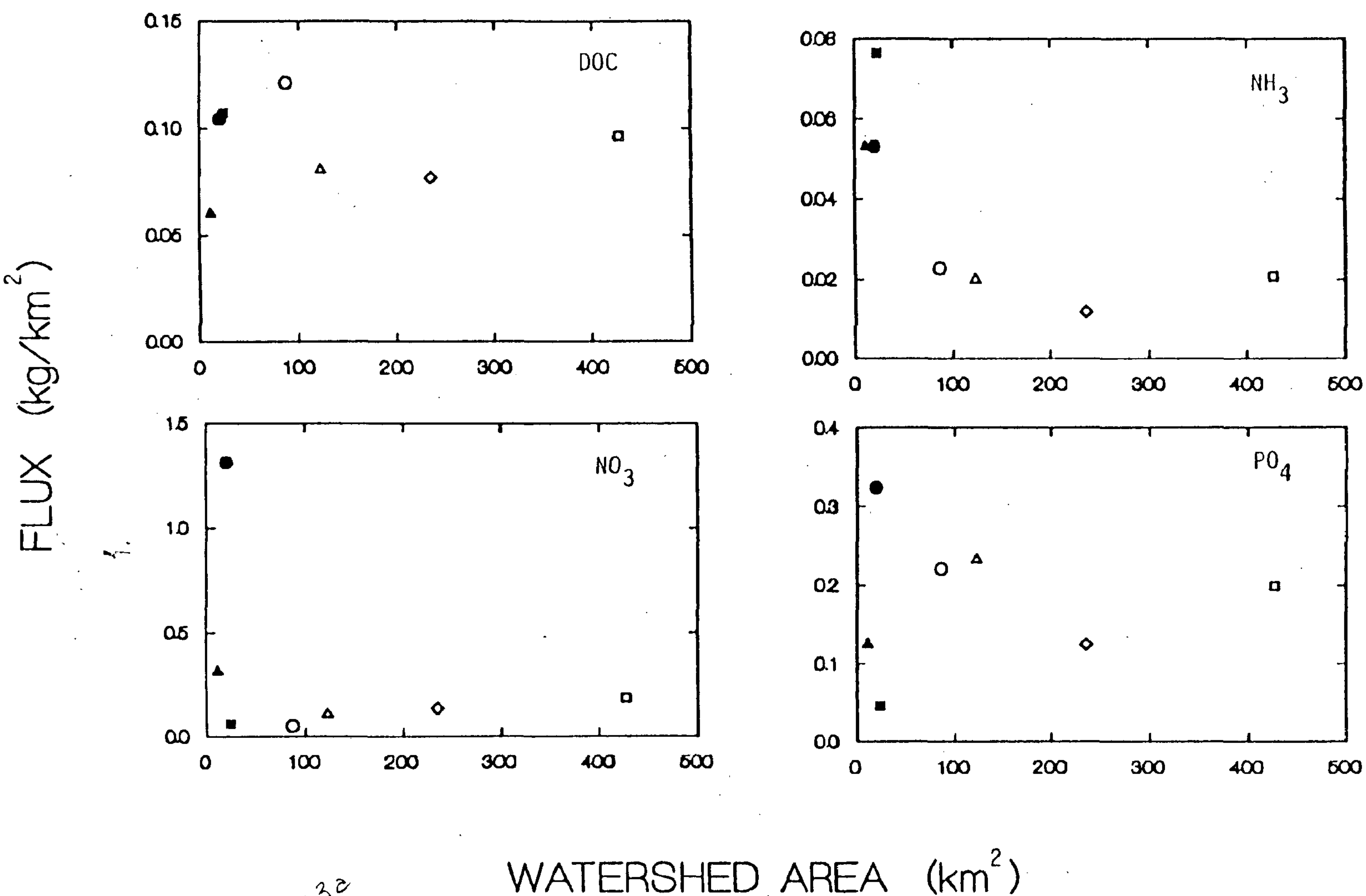



Figure 53e - Flux per unit area of dissolved nutrients for sub-basins of the Little Manatee River Watershed plotted against sub-basin area. Symbols are defined below.

LONE ○ CARL ● SP △ DUG ▲ WIMA □ CYPR ■ NP ◇

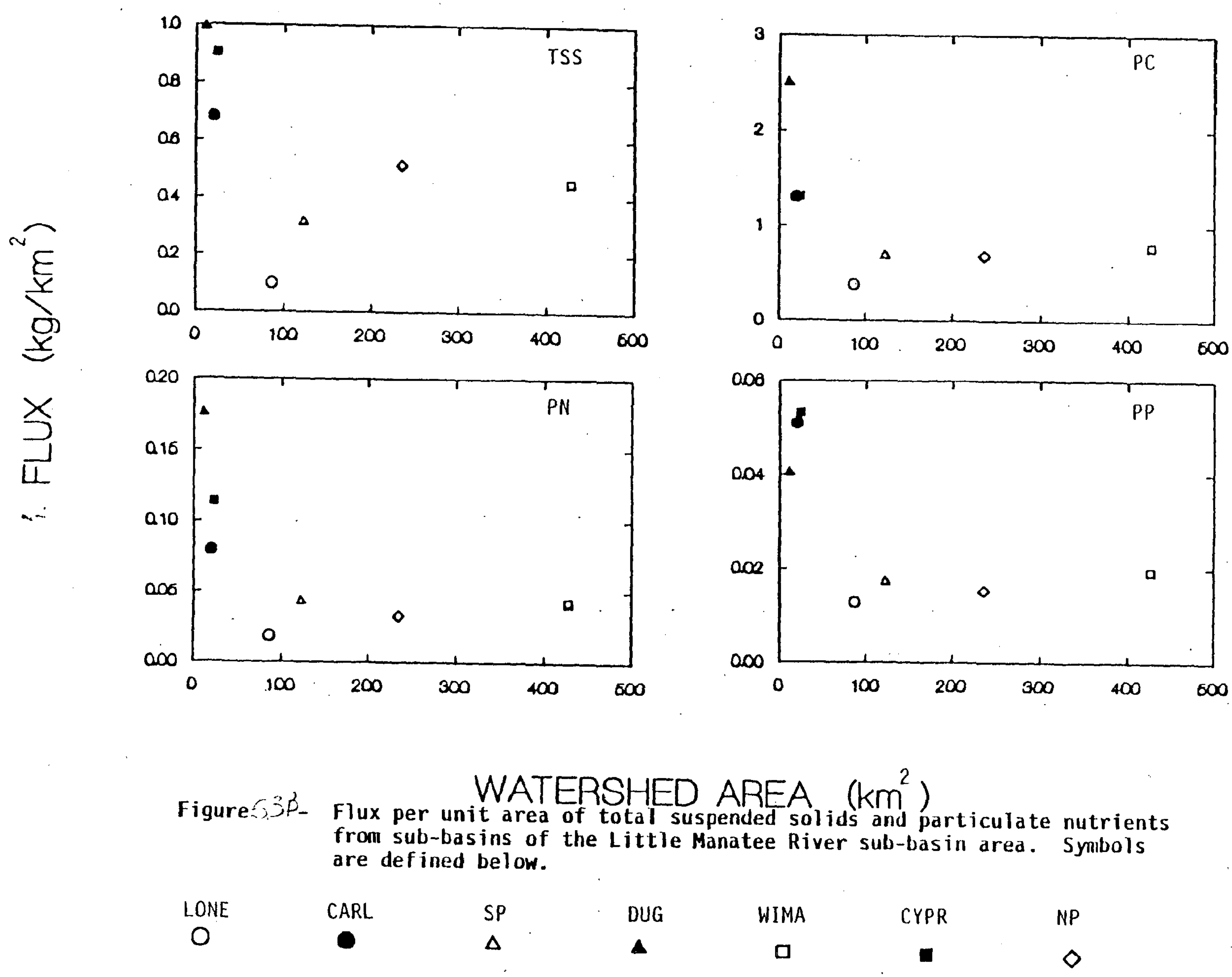



Figure 53B- Flux per unit area of total suspended solids and particulate nutrients from sub-basins of the Little Manatee River sub-basin area. Symbols are defined below.

LONE ○ CARL ● SP △ DUG ▲ WIMA □ CYPR ■ NP ◇

# VI. ESTUARINE WATER CHEMISTRY

## OBJECTIVES

An overall goal of the Little Manatee River Project was to examine the relationships of the quality and quantity of freshwater inflows to the ecological characteristics of the Little Manatee River estuary. A central component of this investigation was the monitoring of salinity and water quality conditions in the estuary during the study year. Data collected within the estuary were synoptic with the freshwater stream sampling so the effects in the estuary from short term changes in freshwater inflows could be examined.

## SAMPLING AND ANALYTICAL METHODS

Estuarine water quality sampling was conducted on a bi-weekly basis with 26 sampling events occurring during the study year (January 24, 1988 to January 24, 1989). Sampling in the estuary was coordinated with the freshwater sampling regime and on 24 dates estuarine and freshwater samples were collected on the same day. On two dates, freshwater samples were collected the day before the estuarine sampling.

Estuarine field sampling included a combination of two fixed location stations and several stations which were located on specific surface salinity concentrations (Figure 6.1). The first fixed location station was located in Tampa Bay northwest of marker #1, approximately 2.3 miles from the river mouth

# River miles - Little Manatee River Estuary

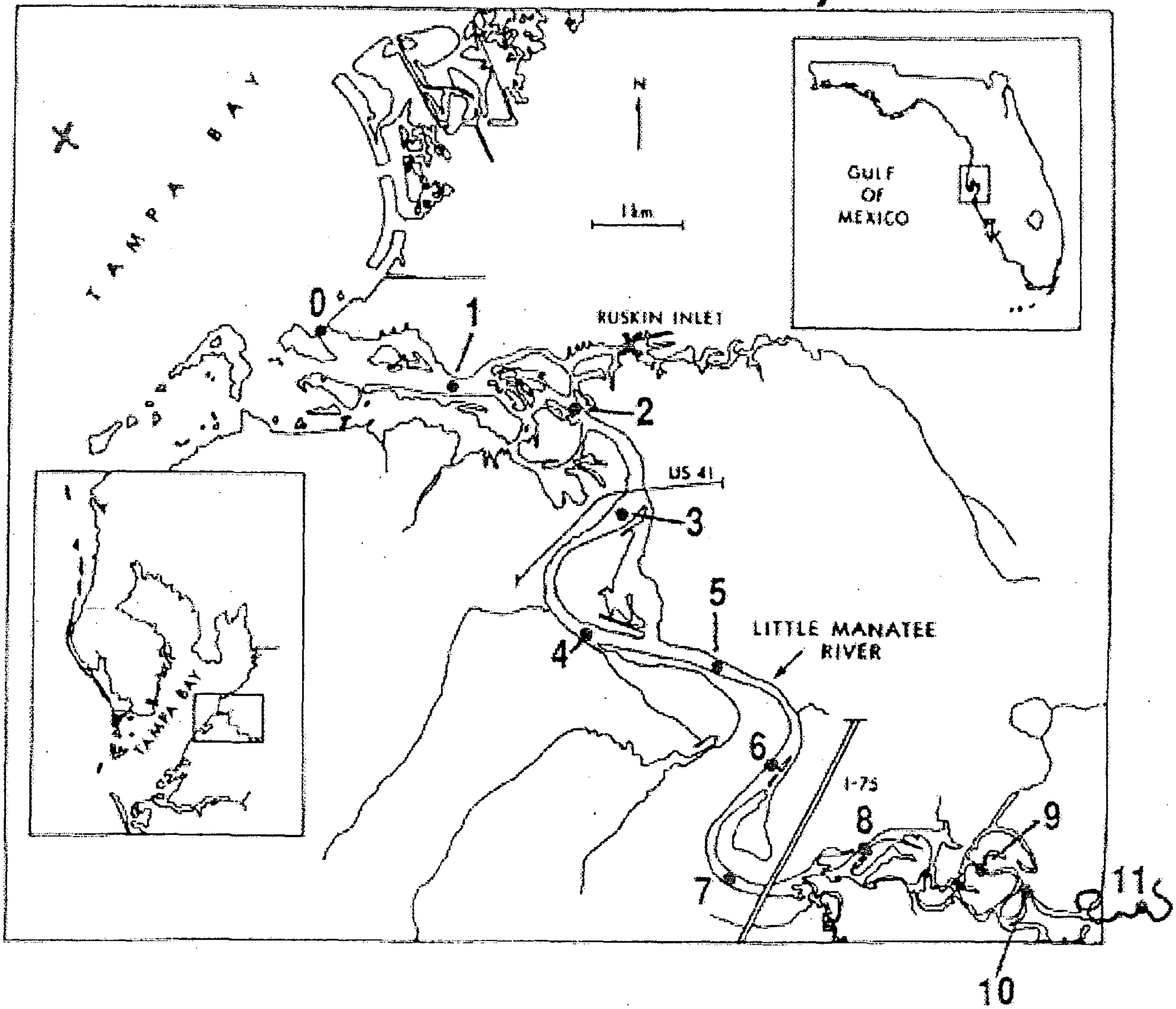



Figure 6.1. Reference locations of estuarine sampling stations in Little Manatee River and Tampa Bay. Fixed locations are shown by an X in Tampa Bay and Ruskin Inlet. Mileages shown provide reference for values listed in Table 6.1 for stations based on salinity concentrations.

following the boat channel[1]. The second fixed station was located in Ruskin Inlet, a channelized tributary to the Little Manatee River approximately 2.5 miles upstream of the river mouth. The locations of the remaining sampling stations were flexible and based on the location of selected surface water salinity concentrations on the that sampling day. For the entire study year samples were collected at 18 ppt and 0 ppt salinity concentrations. The 0 ppt salinity station was determined by the location of surface water near 1000 umhos/cm specific conductance. For the first two sampling trips, samples were taken at the 9 ppt salinity concentration, but this station was discontinued and for the remaining 24 trips samples were taken at the 12 ppt and 6 ppt salinities. River mile locations were recorded for all samples collected on salinities. The locations of these stations during the study year are listed by rivermile in Table 6.1, while a map of the estuary showing river mileages is illustrated in Figure 6.1.

All estuarine water quality sampling was conducted in the morning or early afternoon on an incoming tide. At each station, duplicate water samples were taken from both surface and bottom waters. Water samples for chlorophyll analyses were kept chilled and transported to the Florida Department of Natural Resources Laboratory in St. Petersburg where filtration of the sample for pigment removal was done the same afternoon. As with the fresh water samples, filtration for the separation of particulate (C, N, and P) and dissolved nutrients ($PO_4$, $NO_2$ & $NO_3$, Organic

Table 6.1. Location of Little Manatee River salinity stations and the Tampa Bay station by rivermile. Rivermiles were measured as distance from the mouth. Negative numbers indicate distance into Tampa Bay measured in the channel from navigation marker #1. Positive numbers are distances from the mouth toward the head of the river.

| Date | Tampa Bay | 18ppt | 12ppt | 6ppt | 0ppt | Ruskin Inlet |
|---|---|---|---|---|---|---|
| 01/26/88 | -2.27* | -0.22 | N.D. | N.D. | 5.7 | 2.50* |
| 02/10 | | -0.31 | N.D. | N.D. | 6.1 | |
| 02/24 | | 0.44 | 1.95 | 3.40 | 6.5 | |
| 03/09 | | 0.00 | 0.83 | 3.00 | 4.65 | |
| 03/22 | | -1.82 | -0.18 | 1.53 | 4.15 | |
| 04/06 | | 0.00 | 2.55 | 6.00 | 7.2 | |
| 04/20 | | 1.30 | 3.60 | 6.25 | 8.45 | |
| 05/04 | | 1.85 | 3.70 | 6.15 | 8.35 | |
| 05/18 | | 2.55 | 6.10 | 7.23 | 10.23 | |
| 06/01 | | 3.70 | 5.65 | 8.30 | 10.46 | |
| 06/15 | | 4.80 | 6.60 | 8.60 | 10.45 | |
| 06/29 | | 5.10 | 6.16 | 9.60 | 10.63 | |
| 07/14 | | 3.50 | 5.19 | 8.34 | 9.85 | |
| 07/28 | | 1.40 | 3.50 | 5.30 | 7.19 | |
| 08/10 | | 0.00 | 0.34 | 1.15 | 4.24 | |
| 08/30 | | -1.23 | -0.91 | 0.00 | 3.40 | |
| 09/08 | | -2.10 | T.Bay** | 0.81 | 0.0 | |
| 09/22 | | T.Bay** | 1.53 | 4.10 | 6.25 | |
| 10/11 | | T.Bay** | -0.45 | 4.20 | 6.25 | |
| 10/25 | | -0.19 | 1.00 | 2.72 | 7.10 | |
| 11/07 | | -1.45 | -1.18 | 1.40 | 4.55 | |
| 11/21 | | -0.37 | 0.95 | 4.70 | 7.83 | |
| 12/08 | | -1.46 | 0.80 | 3.80 | 7.19 | |
| 12/20 | | 0.00 | 1.51 | 4.65 | 7.19 | |
| 01/11/89 | | 0.00 | 2.70 | 4.44 | 7.6 | |
| 01/24 | | T.Bay** | -1.55 | 0.91 | 4.24 | |
| Average | -2.27 | +0.65 | +2.19 | +4.37 | +6.7 | +2.50 |
| Range | 0.0 | -2.10 to 5.10 | -1.55 to 6.60 | -0.81 to 9.6 | 0.0 to 10.63 | 0.0 |

*fixed location
**salinity concentration found at Tampa Bay station

Carbon) was done in the field with resulting filters and filtrates put immediately on ice. Samples (filters) for particulate phosphorus analysis were periodically shipped to SL&ES for digestion and measurement. Remaining water chemistry parameters were analyzed at the District Laboratory in Brooksville. Water samples were analyzed for the parameters listed in Table 5.1, using the methods indicated. All statistical analyses and presentations of these data are based on the means of duplicate samples.

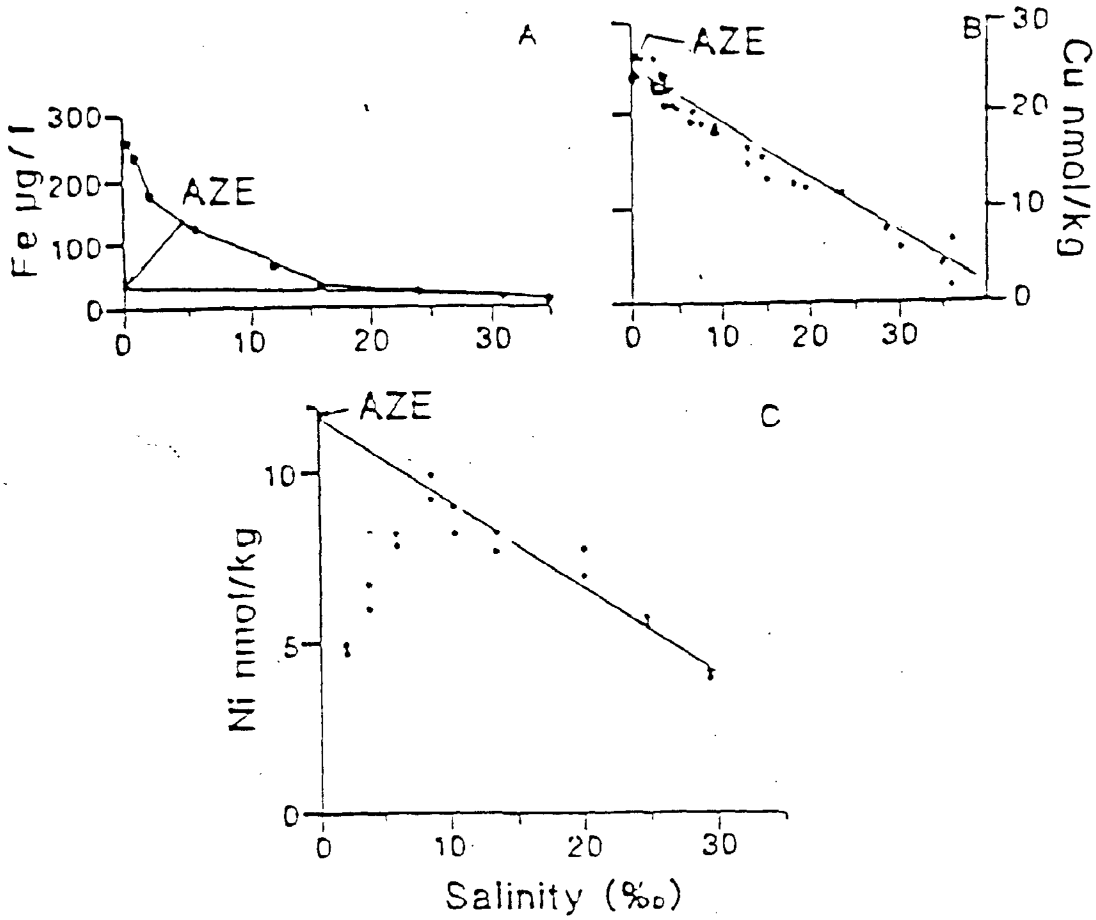
At each water quality station, vertical profiles of temperature, dissolved oxygen, pH, specific conductance and salinity were made at 1 meter intervals plus bottom with a Hydrolab Surveyor II water quality meter. Also, at each station, a light penetration profile was taken with a Li-Corr photometer by measuring ambient (deck) and in-water light intensities at .5 meter intervals plus bottom.

Beginning with the third sampling trip (February 24, 1989), additional measurements were made throughout the estuary for vertical profiles of temperature, dissolved oxygen, pH, specific conductance and salinity. These measurements were performed during what is termed a "Hydrolab run", where numerous fixed locations in the river were sampled within a one hour period. After water chemistry samples were collected on an incoming tide, Hydrolab runs were performed in the mid-afternoon on a slack, high-tide condition. Stations for the Hydrolab run were at fixed locations extending from the river mouth to 9.5 miles upstream, with extra measurements taken further upstream during two sampling events. The Hydrolab run was initiated to measure in situ physical parameters throughout the estuary on as similar conditions as possible. Similar sampling had been done in the Little Manatee River by the District between 1985 and 1987. Much of the analyses regarding salinity distributions and dissolved oxygen relationships in the river are based on the "Hydrolab runs" made from 1985 to 1987 plus the study year.

## DATA REDUCTION

Advection-diffusion models have been used by many investigators to interpret estuarine chemical data (e.g., Li and Chan, 1979; Kaul and Froelich, 1984). These models use salinity as a tracer. The distribution of a constituent in estuarine waters can be compared to salinity to determine whether a substance is: 1) conservatively transported through the estuary, (2) removed from the water column or (3) added to the water column due to local input (e.g. anthropogenic, release from sediments, etc.). These types of estuarine behaviors are demonstrated in Figure 6.2.

From the advection-diffusion models using salinity as a conservative tracer, the intercept of the extrapolation (or tangent) of the constituent-salinity curve at the high salinity end of the curve where change in constituent concentration with change in salinity is constant, is defined as the apparent zero salinity end-member (AZE). It can be demonstrated mathematically




6.2

Figure [redacted]. Examples of different estuarine behavior of trace metals: (a) removal (after Figueres et al., 1978); (b) conservative; and (c) release (Windom, unpublished data).

that river discharge multiplied by the difference in the observed zero salinity concentration and the AZE value gives the rate of removal, or release, of the constituent, per unit time, necessary to produce the observed concentration distribution. The only assumption required is that the concentration of the constituent in the freshwater input is constant over the residence time of the estuary. For the Little Manatee estuary, this assumption is satisfied sufficiently to draw the conclusions that will be made.

Following the approach described above bimonthly data for concentrations of dissolved nitrate + nitrite ($NO_3$), ammonia ($NH_4$) orthophosphate ($PO_4$), organic carbon (DOC); total suspended solids (TSS); and particulate carbon (PC), nitrogen (PN) and phosphorus (PP) were plotted against salinity. The zero salinity concentration was taken to be the mean value of the bimonthly concentrations observed at the Wimauma and Cypress Creek gaging stations weighted by their mean daily discharge at the time of sampling. This value was then plotted on the constituent vs. salinity curves for each month.

## RESULTS

### Salinity Distributions

Streamflow levels in the Little Manatee River typically have large seasonal variation with resulting effects on salinity distributions in the estuary. Streamflow characteristics for the Little Manatee River near Wimauma based on over 50 years of record were presented in Chapter II. In sum, the river experiences prolonged low-flow periods, usually in the spring or fall, when daily flows average less than 50 cfs. Conversely, brief periods of heavy rainfall rapidly increase streamflow in the basin and short-term flows over 1000 cfs are not uncommon.

As described in Chapter IV, an unusually wide range of streamflow levels occurred during the study year. Estuarine water quality and salinity sampling during January through March corresponded to medium to medium-high flow levels for the river (71 to 429 cfs daily flows). Beginning in April, a prolonged period of generally diminishing flows occurred which were lowest in mid-June (15 to 20 cfs) and extended into early July. Summer rains began in mid-July and flows were at moderate levels for the remainder of that month. The first high flow levels (1050 cfs) occurred during the August 10 sampling event, and extremely high flood flows (9720 cfs) were recorded in early September after four days of heavy rain. Flows generally returned to low to moderate levels for the study year, although storm events raised flows to 414 and 493 cfs in November 1988 and January 1989, respectively.

Salinity distributions in the estuary showed distinct changes in response to these changes in flow. Mean water column salinity for four fixed locations in the river are plotted by date in Figure 6.3. Salinity at the mouth of the river remained above 20 ppt until early September, when flood flows briefly reduced salinity to near 5 ppt. For the remainder of the year, salinities fluctuated between 18 and 28 ppt salinity, with slight

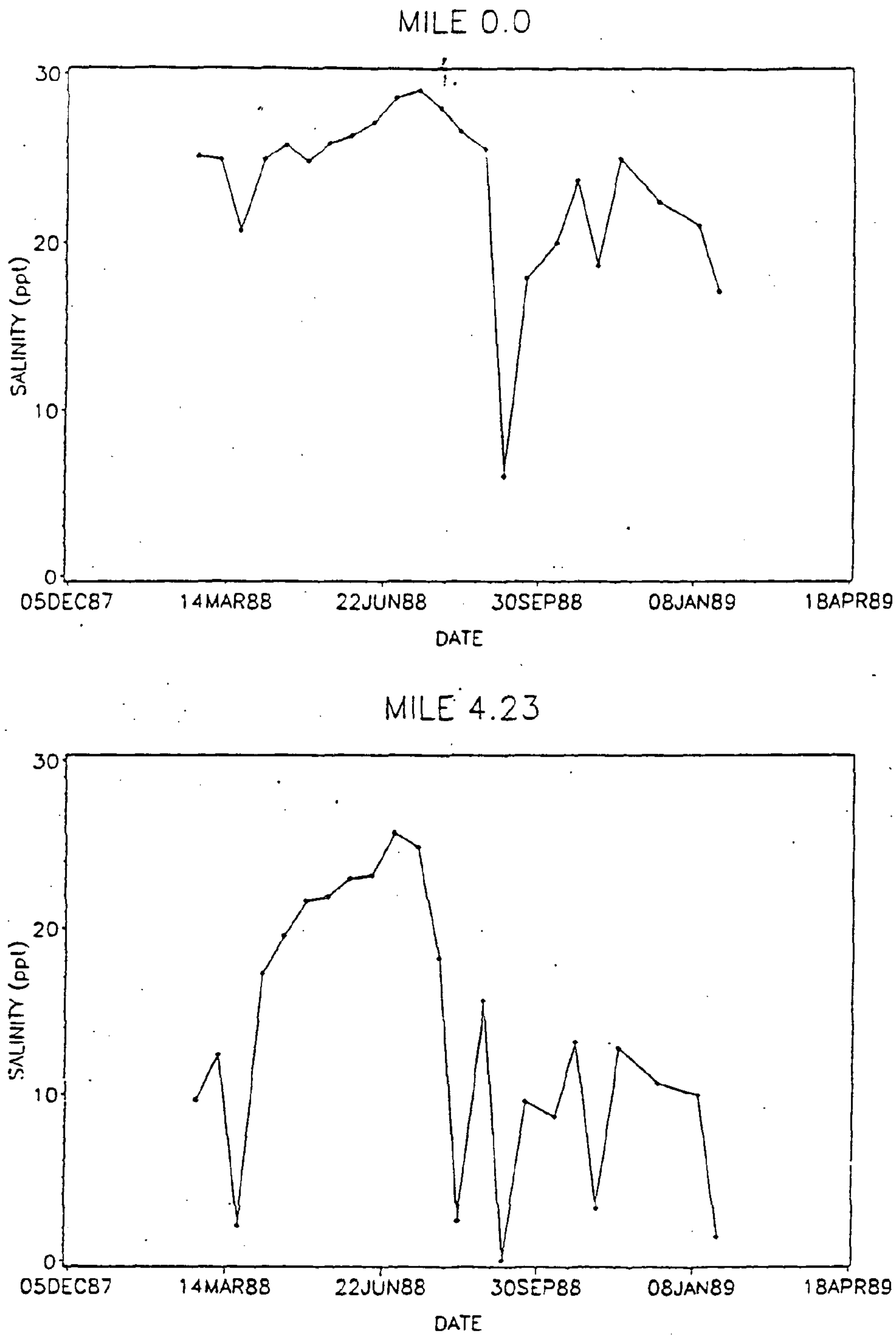
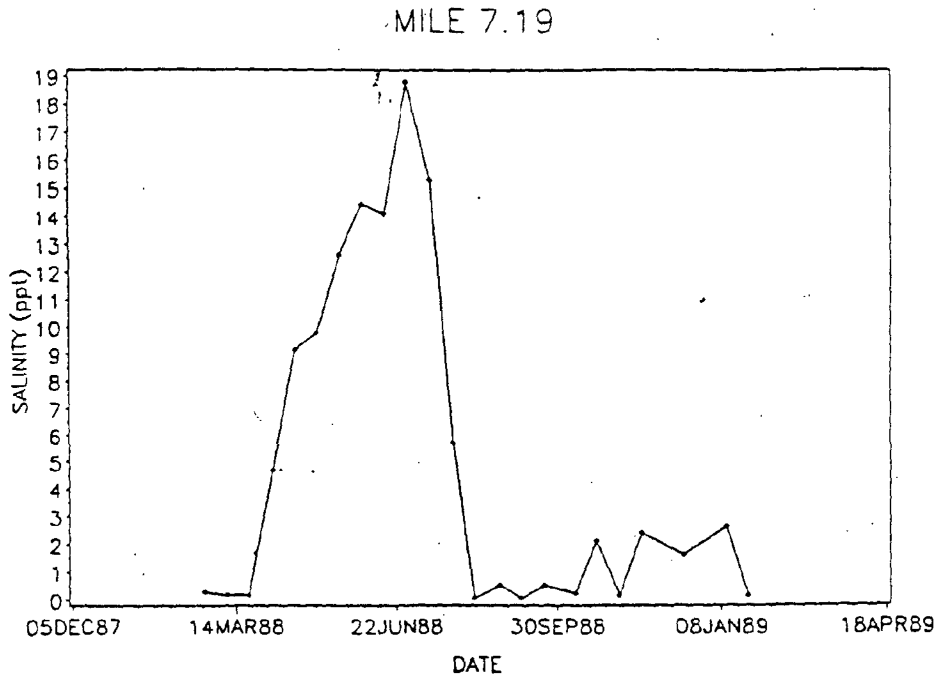



Figure 6.2. Mean water column salinities at four locations in the Little Manatee River, February 24, 1988 to January 24, 1989.



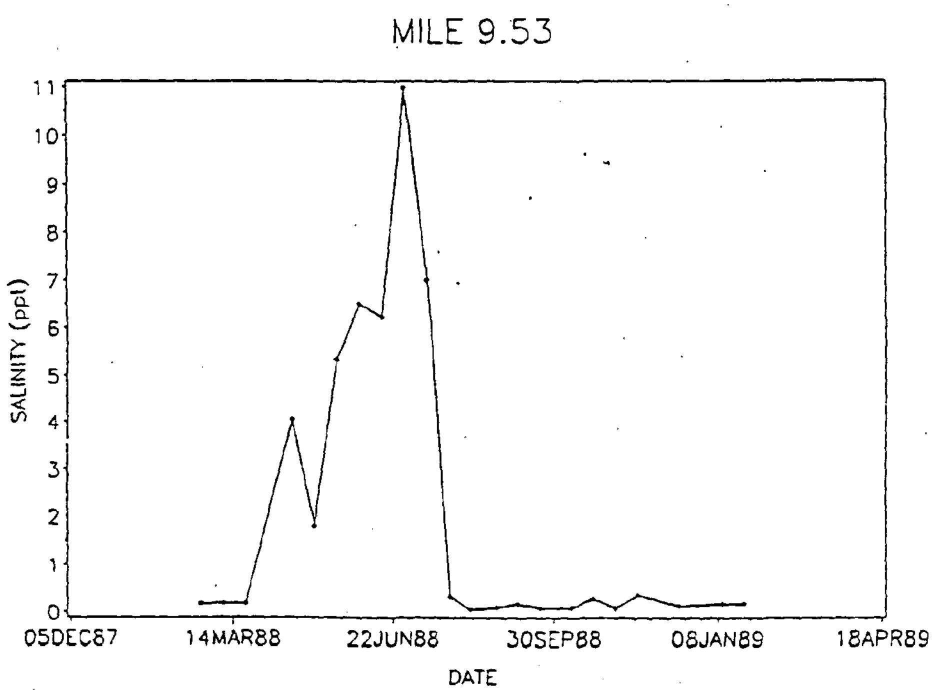



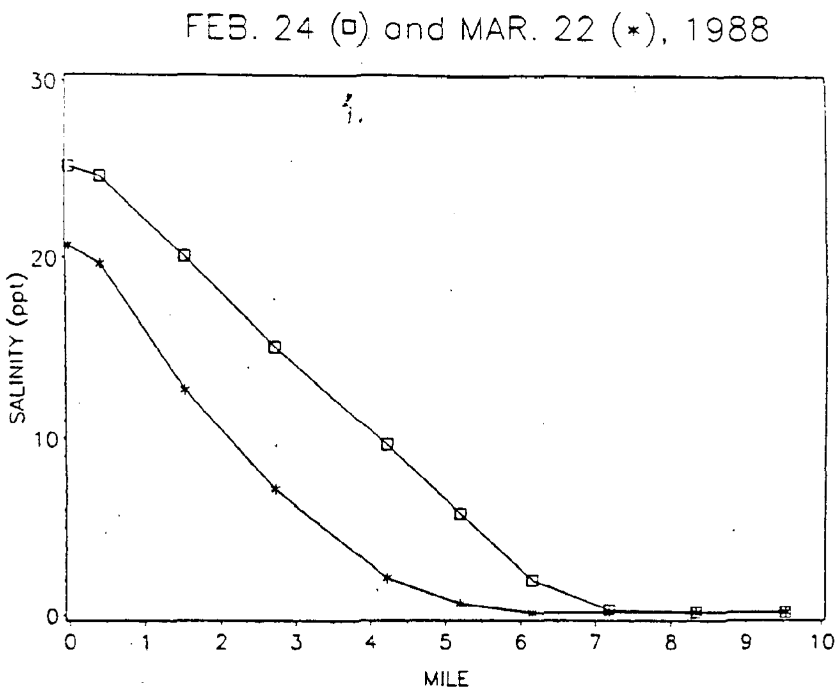

Figure 6.7. (Continued)

decreases in November and January due to storm events.

Salinity at mile 4.23 (Figure 6.3b) displayed a much wider degree of fluctuation. Salinity steadily increased in the spring and early summer in response to the continuing dry season. Salinity was highly variable the rest of the study year, ranging from 0 to 3 ppt after four storm events to values above 10 ppt during a dry spell during December and early January.

The other two stations (mile 7.19 and mile 9.53) presented in Figure 6.3 show a similar trend with regard to salinity. Both stations were essentially fresh in the early part of the study, but salinity increased beginning in April and continued with the dry season until early July. Increases in flow during the summer rainy season reduced salinities to low levels, and for the remainder of the year, they remained near fresh at mile 9.53 and below 3 ppt at 7.19.

Seasonal changes in salinity distributions are also described by longitudinal profiles of mean water column salinities on selected dates which are presented in Figure 6.4(a-f). As shown, salinity in the river below mile 7.19 were reduced from February to March due to an increase in flow. The maximum observed salt penetration is shown for June 29, near the end of the dry season, when salinities above 20 ppt were found six miles upstream and salinity at mile 10 was near 8 ppt. Salinity in the river decreased through July and August, and the river was completely fresh except for a small salt lens at the mouth during the flood in early September. By late September and



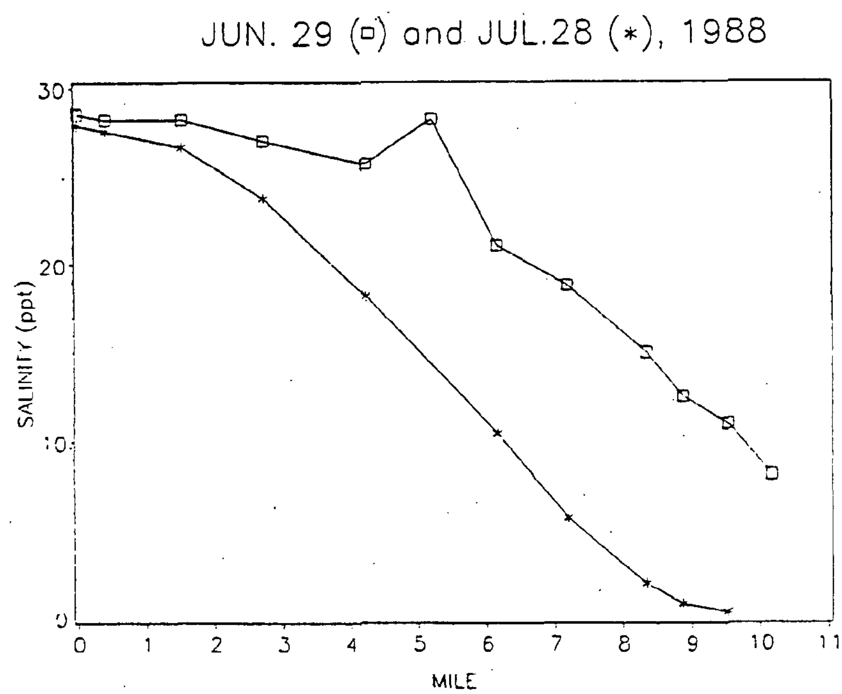
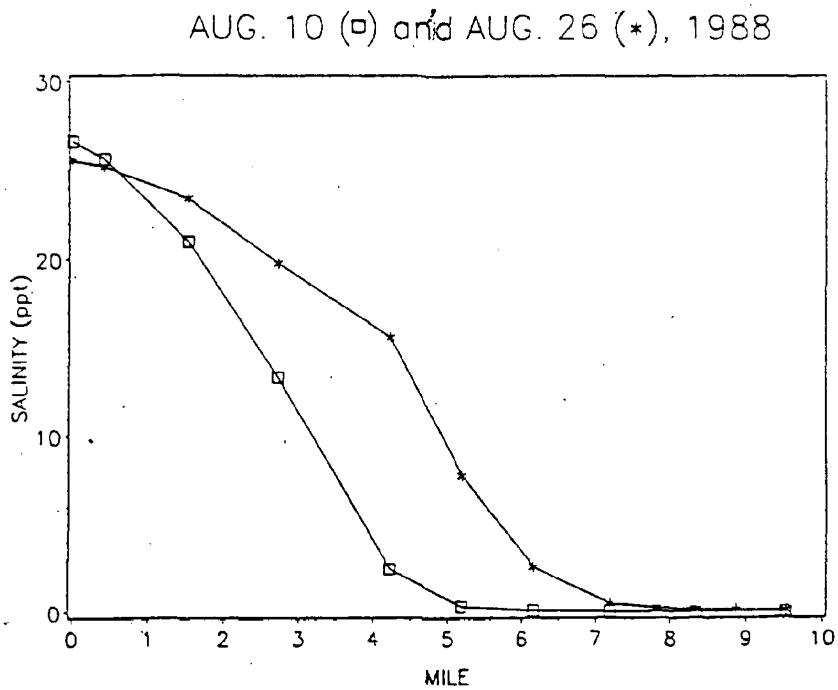




Figure 6.3. Longitudinal salinity profiles for the Little Manatee River estuary on selected dates from February 24, 1988 to January 1989.

c

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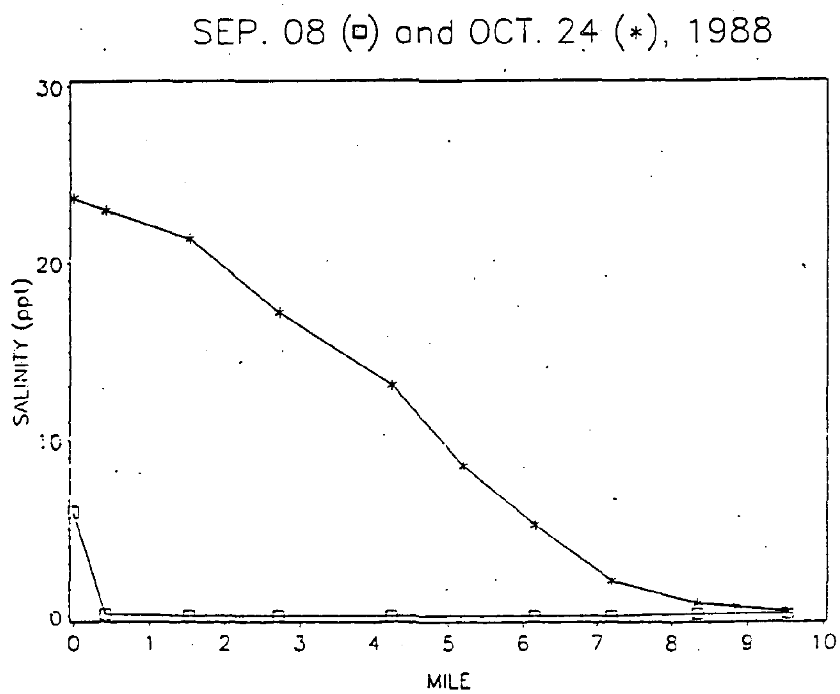
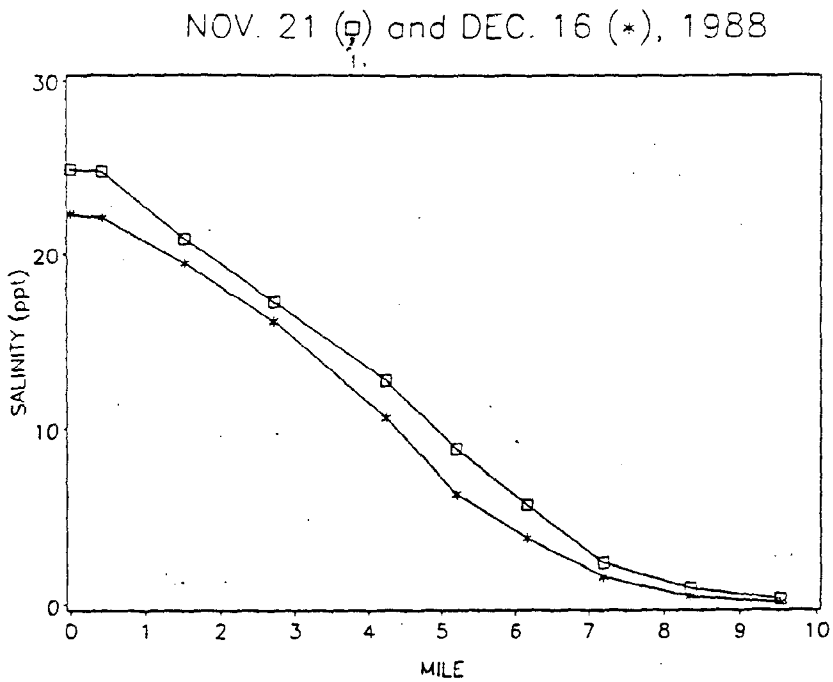



**Figure 6.3.** (Continued)



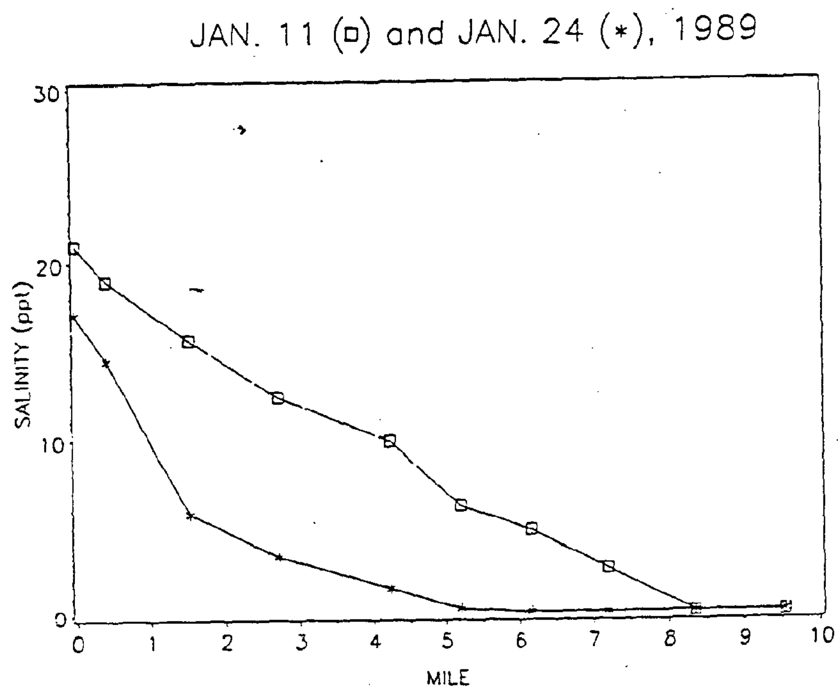
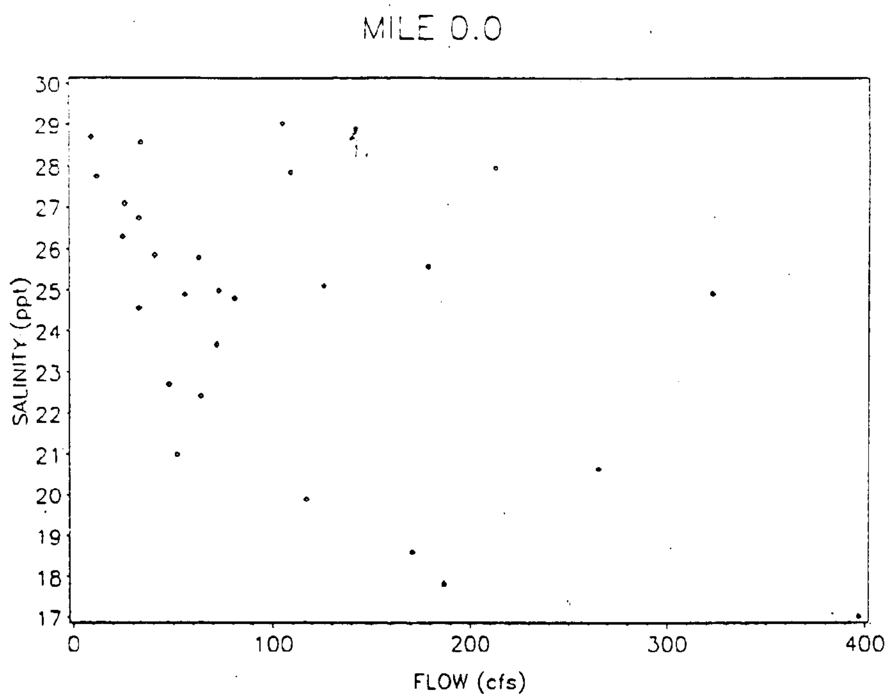




Figure 6.3. (Continued)

through the fall, salinity distributions had retained to more typical profiles, although a significant storm event in January 1989 freshened the river above mile five.

The salinity data presented graphically above show that salinity distribution in the Little Manatee River is highly variable and responds to relatively small changes in streamflow. This phenomenon is common in estuaries and much of the estuarine biota are tolerant of widely fluctuating salinity. One approach for describing estuarine ecological structure, however, is to estimate the frequency that various salinities are encountered at different parts of the river.

For the Little Manatee River Project, salinity measurements recorded between 1985 and 1989 allow the statistical examination of salinity-flow relationships in the estuary. In Figure 6.5, salinity at various points in the river are plotted versus average daily flow when the respective measurements were taken. Predictive equations for salinity as a function of flow for these locations are being established using linear regression analysis. Although the relationships presented in Figure 6.5 use average daily flow at the time of salinity measurement it is expected that some integrated flow value, such as the preceding 5 or 10 day average flow, will give a better fit. The inclusion of a tide stage variable corresponding to high-tide height at the time of sampling should also increase the fit of relationships. The development of equations using regression analysis will then be compared to the flow duration characteristics of the river to



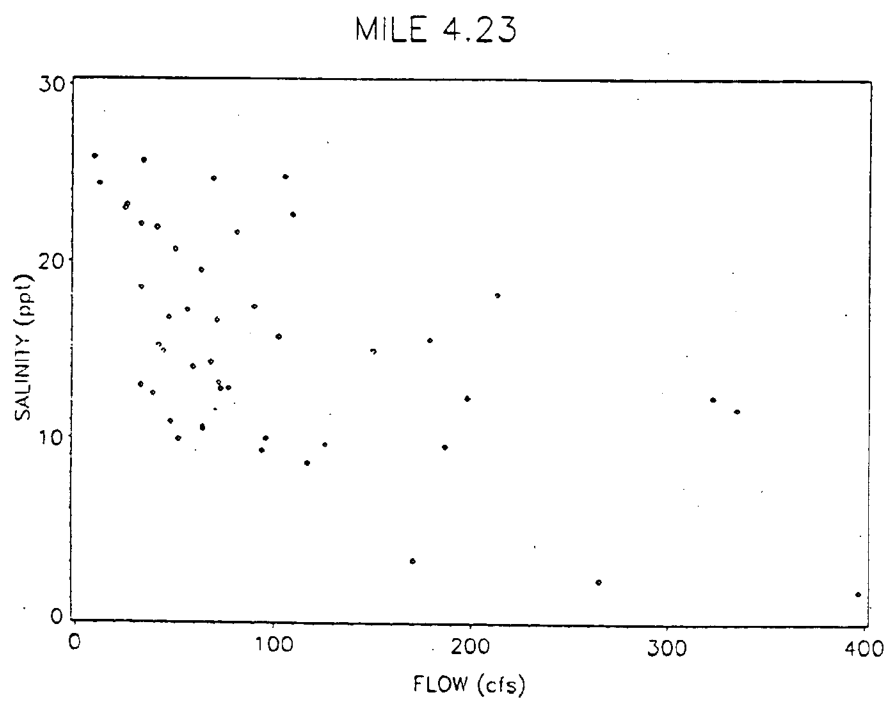
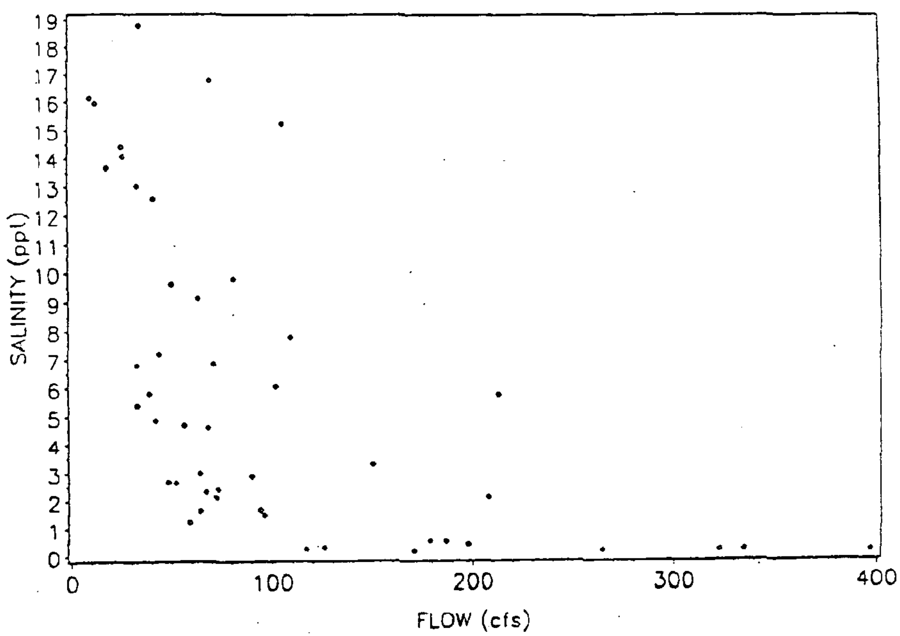
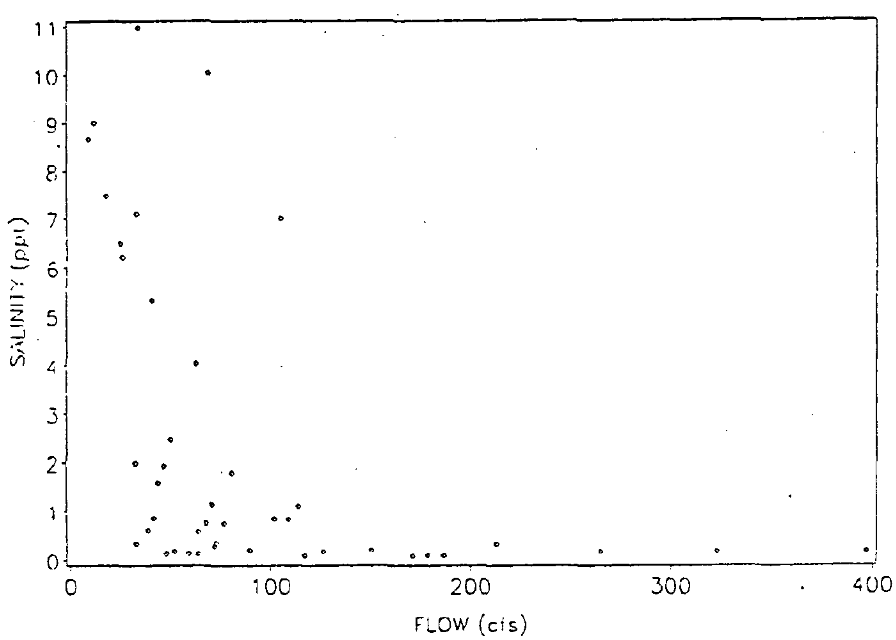




Figure 6.4. Relationships of mean water column salinity to same day average flow at four locations in the Little Manatee River estuary.

## MILE 7.19




## MILE 9.53



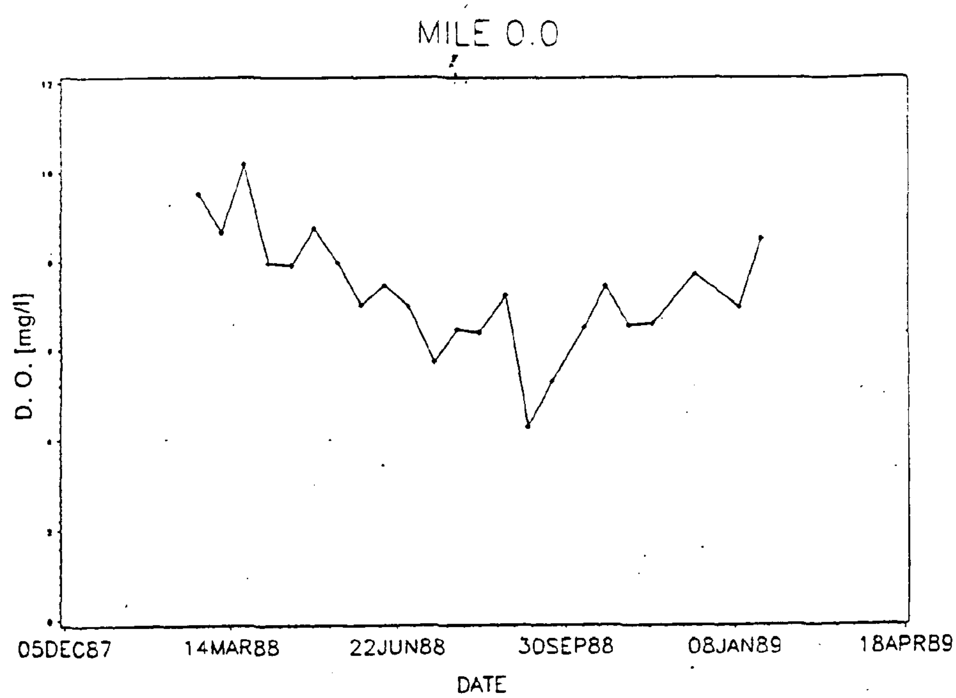
give estimates of what frequency various salinities are encountered at different locations on the river.

Dissolved Oxygen

Seasonal dissolved oxygen conditions in the Little Manatee River estuary are examined in this report primarily from data collected in the "Hydrolab runs" which were conducted on 24 sampling dates between February 24, 1988 and January 24, 1989. These data are particularly useful because they were collected throughout the estuary on similar conditions (mid-afternoon, slack high tide), thus reducing possible confounding effects from time of day or different tidal conditions. Other data which may be important for understanding dissolved oxygen concentrations in the estuary are the physical and chemical data collected each trip on the incoming tide before the Hydrolab run was performed.

Dissolved oxygen (D.O.) concentrations for four locations in the estuary during February 1988 to January 1989 are illustrated in Figure 6.6. D.O. concentrations were typically highest and had the least seasonal variation at the mouth of the river. D.O. did show the expected inverse relationship to water temperature, with highest D.O. concentrations found in the winter and lowest concentrations in the summer. The lowest instantaneous mean D.O. level measured at this site was near 4.0 mg/l during the early September flood.

D.O. concentrations at mile 4.23 (Figure 6.6.) were generally lower than at the mouth, particularly during the summer



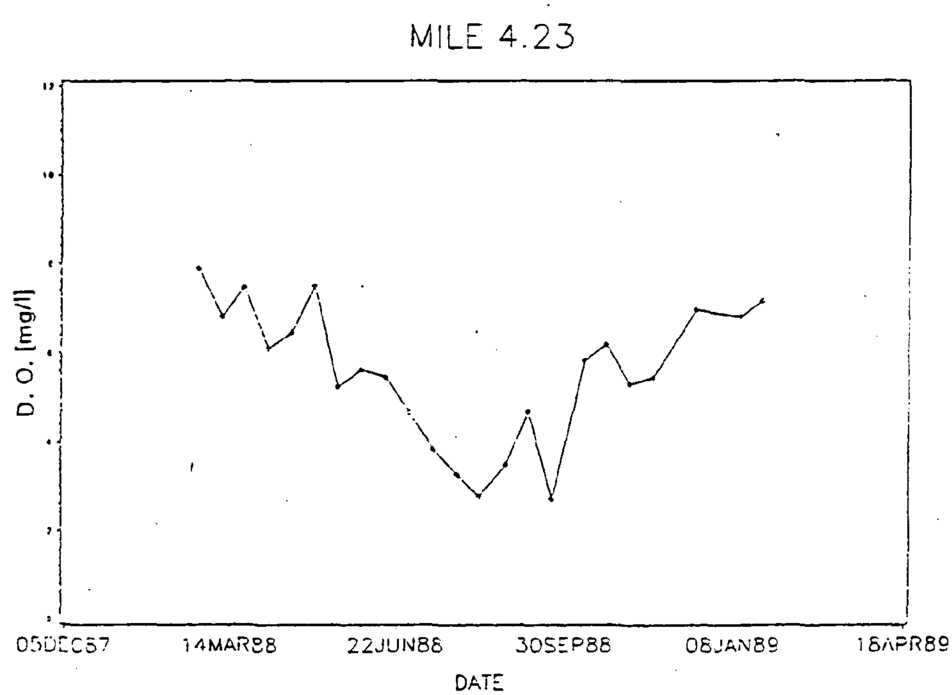
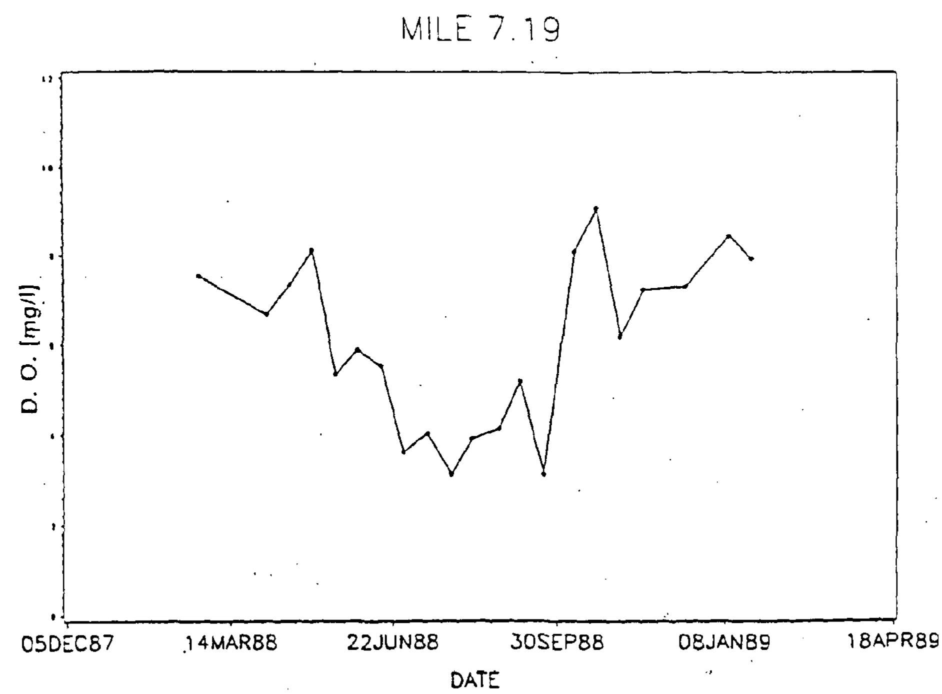




Figure 6.6 Mean water column dissolved oxygen concentrations at four locations in the Little Manatee River estuary, February 24, 1988 to January 24, 1989.



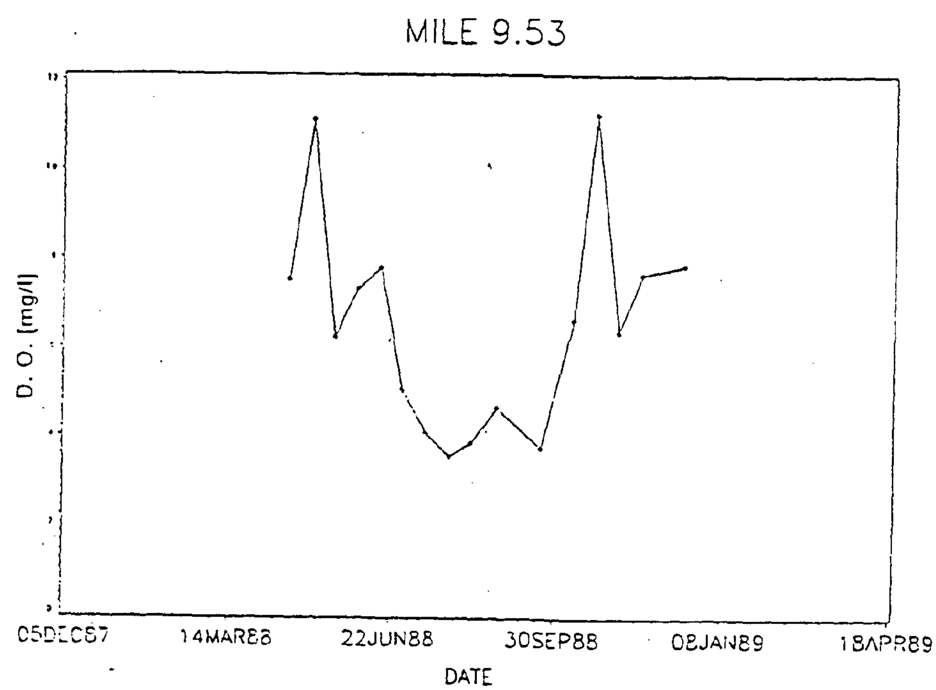




Figure 6.6 (Continued)

months. Mean D.O. concentrations below 4 mg/l were recorded on five dates between July 14 and September 22, 1988. The Septemberflood actually resulted in an increase in D.O. at this station. D.O. concentrations were more erratic at mile 7.19, but followed a similar seasonal pattern to mile 4.23. Low D.O. levels were observed during the summer, but D.O. concentrations increased from the September to October samples and remained high for the remainder of the year. D.O. concentrations showed the most seasonal variations at mile 9.53 where levels above 10 mg/l were recorded during May and October, 1988, but levels below 4 mg/l were recorded between June and September.

In sum, D.O. concentrations in the Little Manatee River were at high levels during most of the year but reduced to values below 4 mg/l during much of the summer, indicating potentially stressful concentrations for aquatic biota in the summer. Differences in D.O. between surface and bottom waters were small, however, and it does not appear that oxygen stress occurs in bottom waters due to limited mixing. Generally, with regard to temperature and salinity effects on water density and stratification, the Little Manatee tends to be well mixed. There are areas of the river, however, that appear to be sensitive to factors that could reduce D.O. concentrations. Longitudinal profiles of salinity and dissolved oxygen concentrations are plotted by rivermile in Figure 6.7. Profiles measured from June through August show consistent declines in D.O. from the mouth upstream to near miles 4.0 to 7.0, with minima often occurring

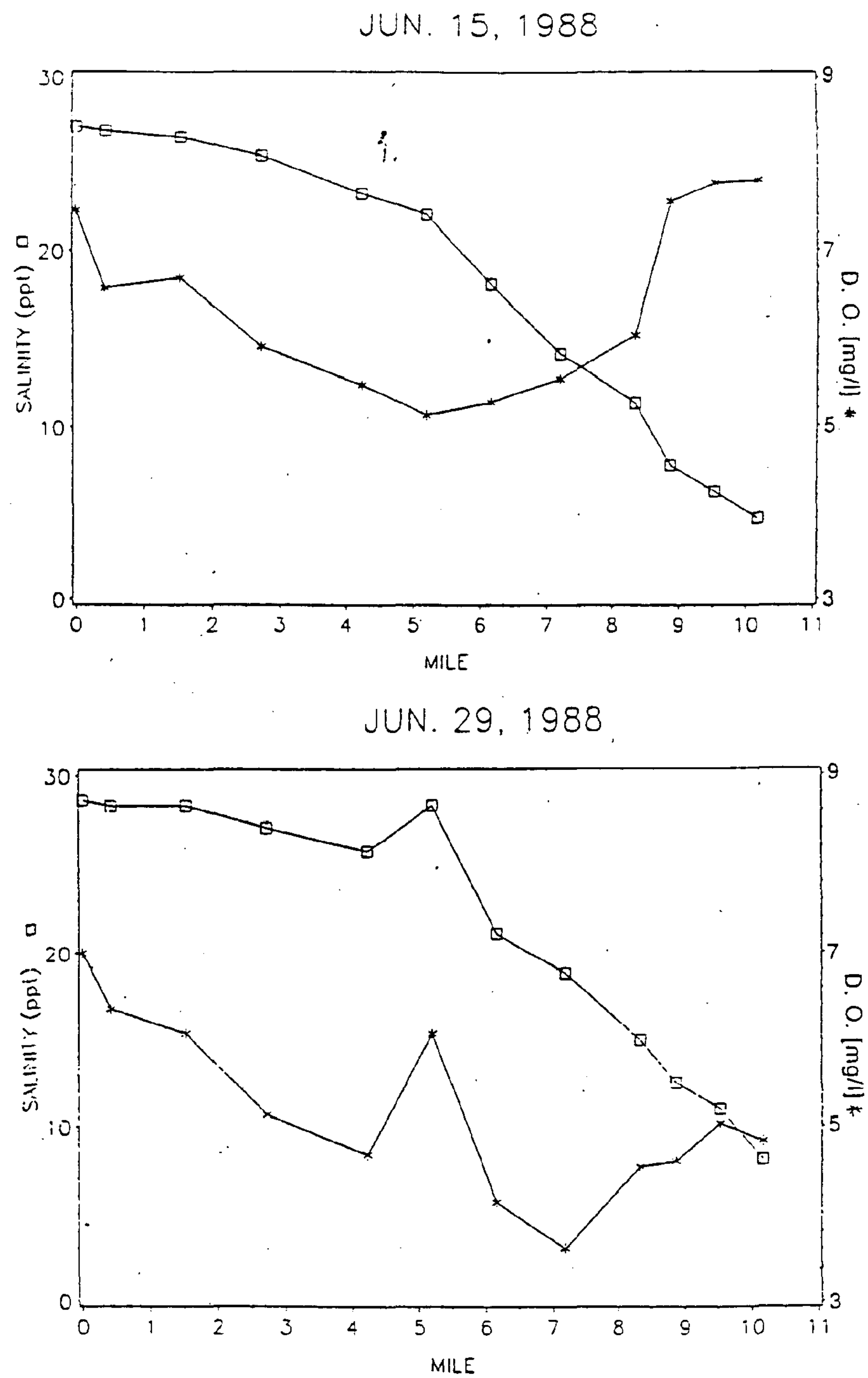
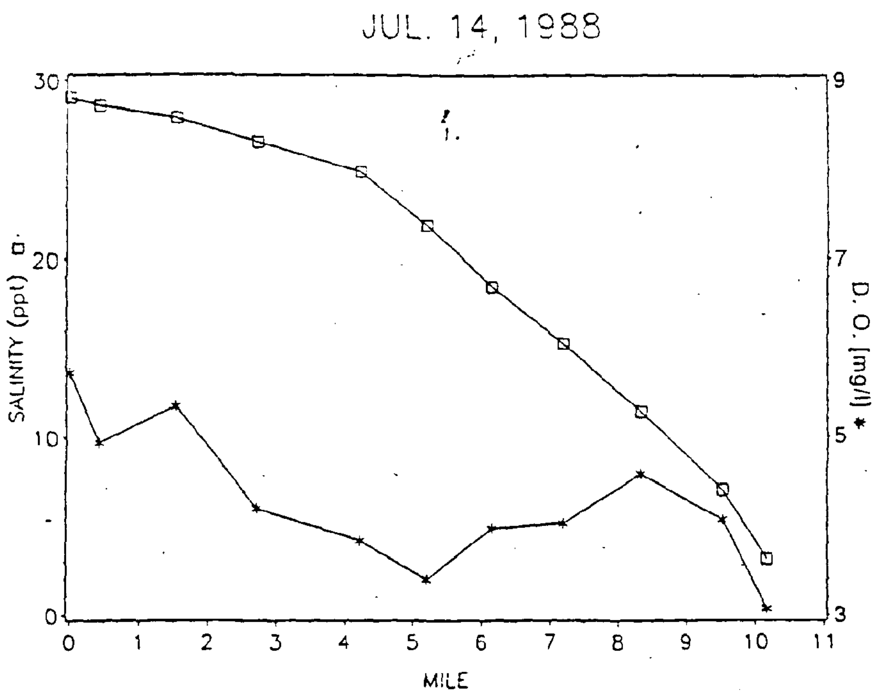



Figure 6.~~6~~7 Longitudinal profiles of mean water column salinity and dissolved oxygen profiles in the Little Manatee River estuary, February 24, 1988 to January 24, 1989.



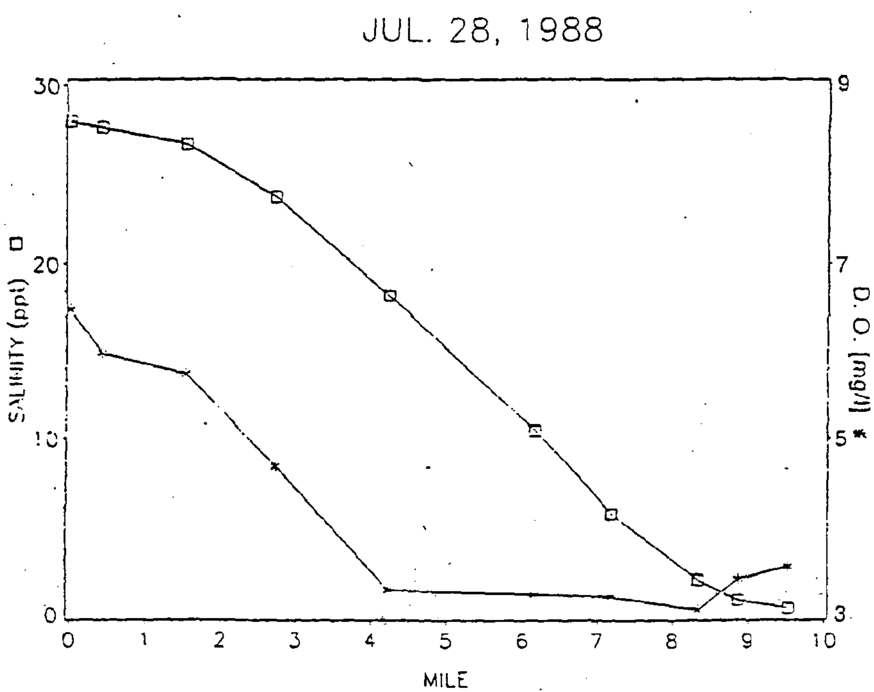
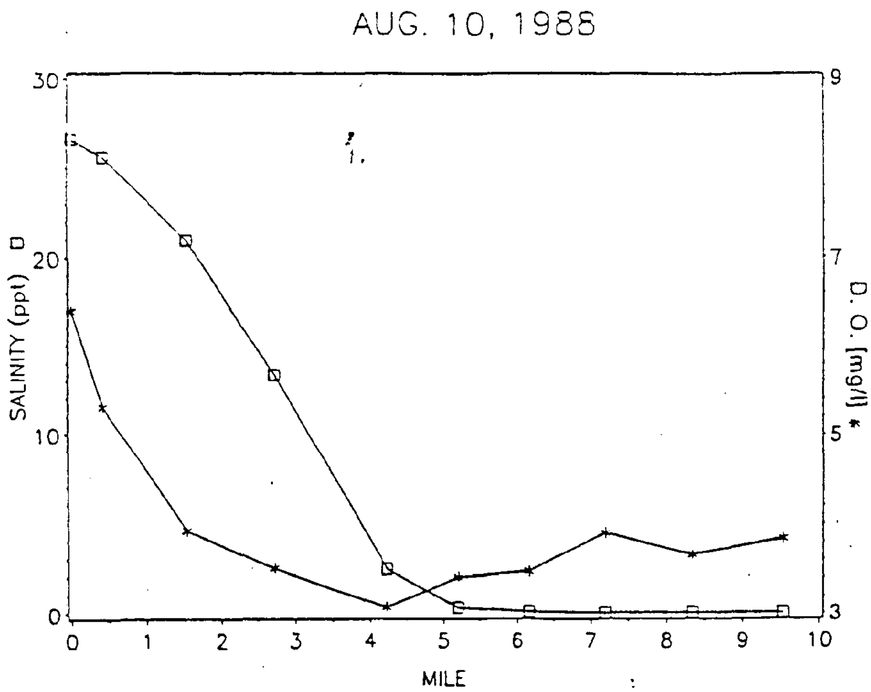




**Figure 6.6.** (Continued)



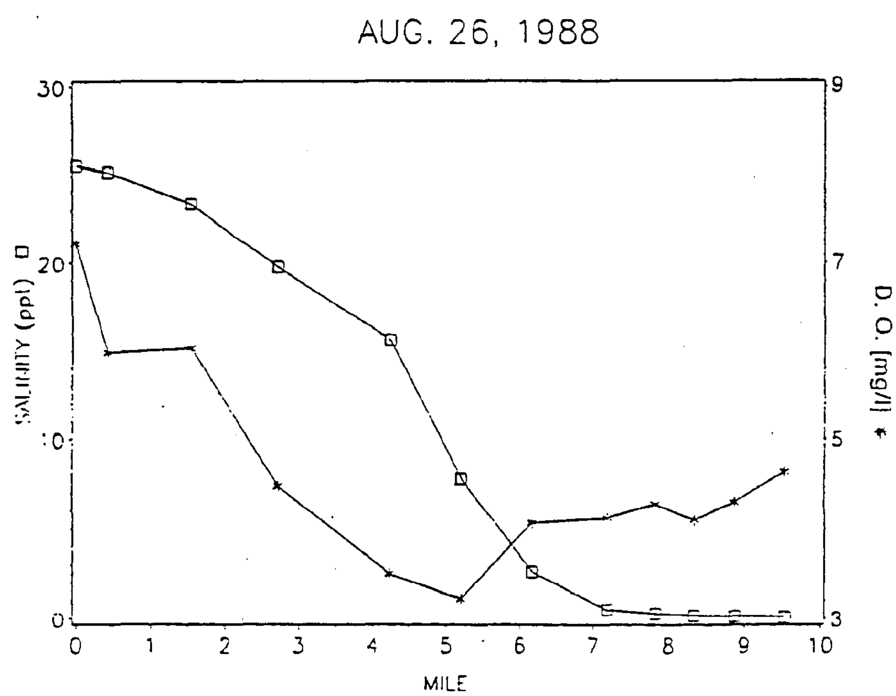
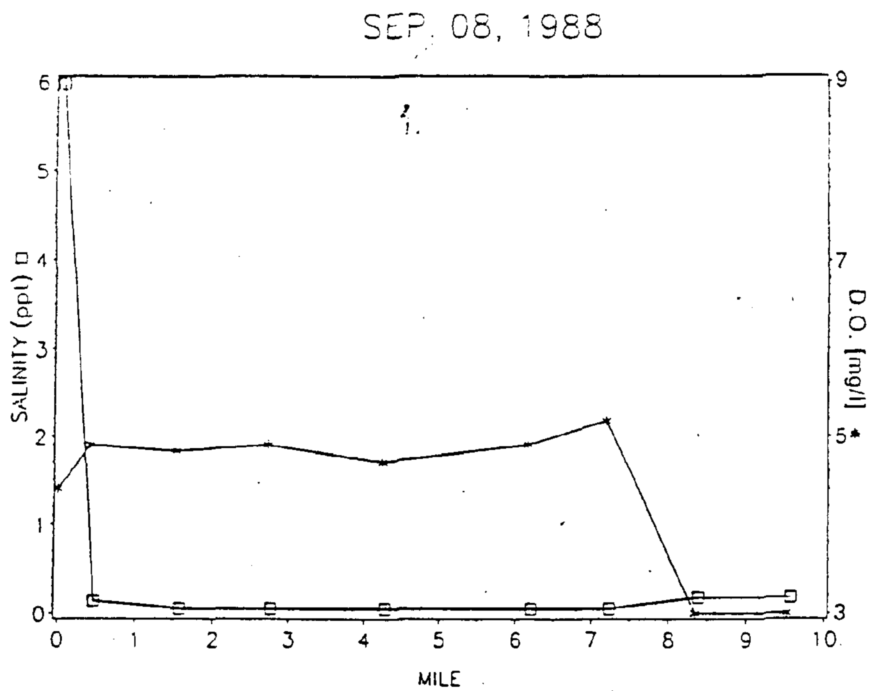




**Figure 6.6.** **(Continued)**



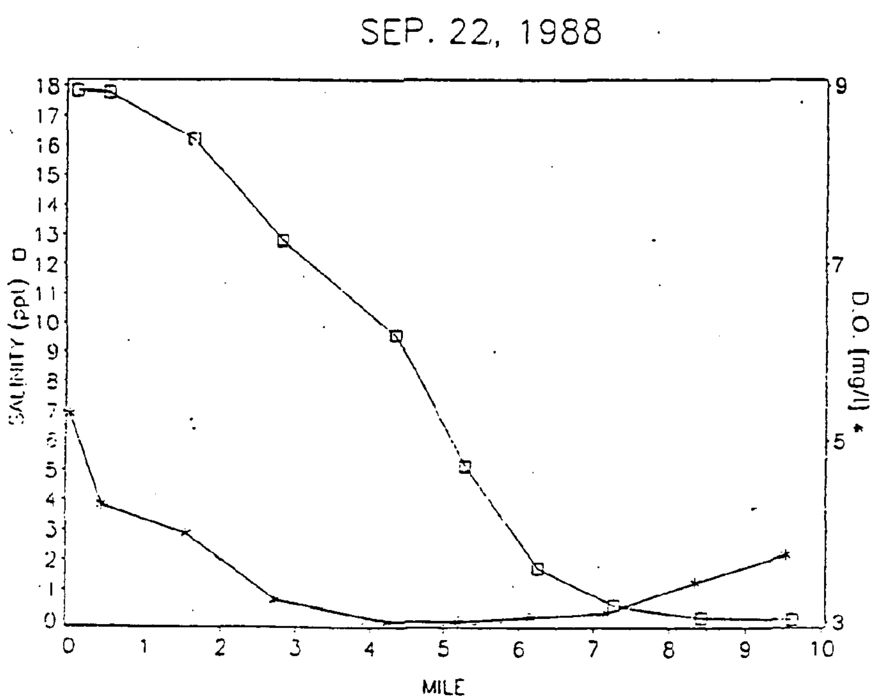




**Figure 6.6.** (Continued)

between mile 4.0 to 6.0. These minima were found over a wide range of salinity concentrations ranging from 3 to 22 ppt. On several dates, D.O. increased upstream in low salinity and freshwater reaches.

Although not shown, D.O. concentrations at the nearest freshwater stream site (near Wimauma) did not reach the low (<4 mg/l) concentrations observed in the estuary. Estuaries, because of their tendency to retain suspended and organic matter, are often sites of D.O. depression. Data to date indicate that the Little Manatee River estuary does not currently have a serious problem with low dissolved oxygen concentrations, but in many areas of the river, conditions are borderline and further perturbations could result in significant reductions in water quality.

General Water Chemistry

Mean values for nutrients and other water quality parameters for the estuarine sampling stations are listed in Table 6.2. All the stations, except Ruskin Inlet, are arranged with salinity reducing from left to right (from Tampa Bay to 0 ppt) so changes along the salinity gradient can be easily visualized. The general water quality characteristics of the estuary are summarized in the discussion below. Greater detail regarding the behavior of nutrients and suspended matter in the estuary is provided in the subsequent section.

Table 6.2. Mean values for water chemistry parameters at estuarine sampling stations - Little Manatee River.

| Parameter | Units | Tampa Bay | 18 ppt | 12 ppt | 6 ppt | 0 ppt | Ruskin Inlet |
|---|---|---|---|---|---|---|---|
| Mile | miles | -2.27 | 0.67 | 2.19 | 4.37 | 6.76 | 2.5 |
| Salinity | ppt | 23.4 | 18.6 | 12.4 | 6.4 | 0.6 | 10.6 |
| Temperature | °C | 22.6 | 23.0 | 24.1 | 25.1 | 22.9 | 24.7 |
| pH | pH | 7.3 | 7.0 | 6.9 | 6.8 | 6.7 | 7.2 |
| Turbidity | NTU | 4.6 | 2.9 | 3.0 | 4.2 | 5.8 | 4.13 |
| Color | PCU | 14 | 25 | 44 | 70 | 106 | 57 |
| Total Suspended Solids | mg/l | 19.2 | 10.5 | 8.2 | 8.0 | 7.1 | 10.1 |
| Particulate Carbon | mg/l | 1.18 | 0.84 | 0.91 | 1.25 | 1.30 | 1.46 |
| Total Dissolved Carbon | mg/l | 6.9 | 7.9 | 9.8 | 11.8 | 14.6 | 11.7 |
| Particulate Nitrogen | mg/l | 0.13 | 0.10 | 0.11 | 0.13 | 0.14 | 0.17 |
| $NH_3$ (as N) | mg/l | 0.04 | 0.08 | 0.09 | 0.08 | 0.07 | 0.07 |
| $NO_3$-$NO_2$-N | mg/l | 0.02 | 0.05 | 0.09 | 0.16 | 0.43 | 0.15 |
| Particulate Phosphorus | mg/l | 0.06 | 0.03 | 0.04 | 0.05 | 0.05 | 0.05 |
| PO4 (as P) | mg/l | 0.34 | 0.32 | 0.32 | 0.31 | 0.30 | 0.35 |
| Silica | mg/l | 0.9 | 2.2 | 3.1 | 3.7 | 4.9 | 3.6 |
| Chlor a | $mg/m^3$ | 8.6 | 5.5 | 10.4 | 15.6 | 20.3 | 19.0 |

The Little Manatee River estuary is really a functional unit of a much larger estuary, Tampa Bay. The open waters of Tampa Bay, however, are much different than the waters of its brackish tributaries such as the Little Manatee River. The progression from the upper reaches of the Little Manatee estuary (0 ppt station) to the Tampa Bay station showed chemical differences indicative of a change from nutrient-rich, low-salinity waters to phytoplankton dominated, high-salinity waters. Nitrate-nitrite, silica, particulate carbon, turbidity, and total dissolved carbon showed distinct declines in concentrations from the upper reaches of the estuary to Tampa Bay. With the exception of phosphorus, the bay has much lower levels of dissolved nutrients (N, Si) due presumably to phytoplankton uptake. Dissolved phosphorus concentrations were distributed very evenly along the salinity gradient with mean values ranging between .30 and .34 mg/l, indicating this nutrient is not limiting and is in excess supply in the estuary. Total suspended solids were highest in Tampa Bay, and increased with salinity in the river due to the influence of bay water.

The Ruskin Inlet station, listed on the far right of Table 6.2, was located in an urbanized tributary to the Little Manatee that receives considerable amounts of urban runoff. Of course, salinity fluctuated much more at this station than at the stations located on specific salinity concentrations. Surface water salinity at Ruskin Inlet ranged from 0.0 to 22.0 ppt during the course of the study and averaged 10.6 ppt. Nutrient concentrations showed large seasonal variation at this station due to stormwater inputs and the rapid change from a mesohaline (medium salinity) to a low salinity environment.

Nutrient and Suspended Solids Distribution

The results of the analyses of dissolved and particulate nutrients in estuarine samples are plotted against salinity in Appendices IA (dissolved) and IB (particulate). Comparing the weighted freshwater concentration of a substance to its concentrations at higher salinities provides a basis for judging estuarine behavior of the substance as discussed in the data reduction section. For this purpose, the trend in the data for concentration versus salinity connecting weighted mean freshwater concentration to concentration at highest salinity is interpreted as discussed earlier. The following discussion summarizes the behavior of the nutrients based on their estuarine distributions.

Dissolved Nutrients. DOC is observed to behave approximately conservatively throughout the year. Results suggest that the relatively high DOC associated with fresh water is diluted as fresh water mixes with seawater in the estuary.

Most of the year nitrate appears to be removed in the estuary, perhaps due to uptake by microorganisms, ammonia concentrations, however, show mid estuarine maxima indicating its production within the estuary.

Phosphate concentrations in the estuary suggest conservative mixing throughout most of the year. During May and June, phosphate appears to be removed in the estuary. Although phosphate concentrations are mostly conservative in the Little Manatee estuary, the relative value of the fresh water and high salinity end-members varies. January to March fresh water concentrations are higher than the high salinity (i.e, ocean end-member) concentrations. This is true during July and August as well, but during the rest of the year the high salinity mixing end member has greater concentrations of phosphate than does the fresh water end-member.

Total Suspended Sediments and Particulate Nutrients. Total suspended solids increase virtually conservatively from zero to higher salinities. This suggests that the greatest source of sediment to the Little Manatee estuary is Tampa Bay.

Particulate carbon, nitrogen and phosphorous are significantly correlated ($p<0.01$) throughout the estuary, throughout the year. While it is apparent that a large fraction of the particulate nutrients is derived from Tampa Bay, there is some indication that particle production, due to primary production, may influence mid-estuarine concentrations during June.

Chlorophyll, Phytoplankton and Primary Productivity

An important component of the Little Manatee River study was an investigation of spatial and temporal patterns of primary productivity in the estuary. Water quality parameters related to primary production, i.e. nutrients, chlorophyll *a* and light penetration profiles, were measured at each water quality station. In addition, researchers from the University of South Florida accompanied field crews on each trip and collected surface-water samples for analyses of phytoplankton composition, primary production (photosynthesis) and nutrient limitation. A brief summary of the year one results for chlorophyll concentrations and phytoplankton abundance and composition is presented below. Much greater detail regarding these data, plus the results for the primary production and nutrient limitation analyses, are contained in the report submitted by Dr. Vargo of the University of South Florida (Vargo, 1989).

Mean annual values for chlorophyll *a*, primary production and total phytoplankton cells are listed in Table 6.3. Chlorophyll *a* and phytoplankton cells were measured at all stations, while primary production measurements were performed at all stations except 6 ppt salinity and Ruskin Inlet. Because all stations except Ruskin Inlet were consistently collected along the salinity gradient, the results for Ruskin Inlet are examined separately.

Table 6.3. Annual mean values, for several parameters related to primary production in the LMR and Tampa Bay, arranged in rank order.

| | Total Phytoplankton | | Chlorophyll a | | Primary Production | |
|---|---|---|---|---|---|---|
| Rank | Station | Cells ml$^{-1}$ | Station | ug/l$^{-1}$ | Station | mgCm$^{-3}$ hr$^{-1}$ |
| 1 | R.Inlet | 9391.1 | 0% | 20.3 | 0% | 122.25 |
| 2 | T.Bay | 6007.0 | R.Inlet | 19.3 | T.Bay | 89.38 |
| 3 | 0% | 4712.1 | 6% | 15.6 | 12% | 84.85 |
| 4 | 6% | 4314.0 | 12% | 10.2 | 18% | 50.89 |
| 5 | 12% | 3260.8 | T.Bay | 9.4 | | |
| 6 | 18% | 2808.8 | 18% | 7.3 | | |

The ranking of mean values for chlorophyll a, primary production, and total phytoplankton cells sh the moveable salinity stations which were located in either the river or boat channel outside the river mouth. All three parameters were highest at the 0 ppt station, and steadily decreased with salinity, being lowest at the 18 ppt station. Generally, variation in these parameters was much greater at the low salinity stations, with frequent high values indicative of periodic algae blooms. Near the mouth of the river in higher salinity waters, seasonal variations in phytoplankton cells, chlorophyll a, and primary production were much reduced. A more detailed discussion of seasonal trends for these parameters is presented in a following section.

The results for the Tampa Bay station showed an inconsistent ranking with regard to the moveable salinity stations. This may reflect that the fixed-location bay station was always the most seaward, and represented a much different physical environment from the moveable stations which were located within or near the mouth of the river. The bay represents a high salinity (>18 ppt), wind mixed, open-water environment where substantial phytoplankton populations are present year-round and waters are generally low in dissolved nutrients, particularly silica and nitrogen. Total phytoplankton cells were highest at the bay compared to the other stations except Ruskin Inlet. Chlorophyll concentrations, however, were comparatively low and ranked only above the 18 ppt station. This difference in ranking for phytoplankton cells and chlorophyll concentrations is probably due to phytoplankton species composition in the bay, which was usually dominated by diatoms with low concentrations of chlorophytes and blue-green algae. Primary production at this site was at a moderate level, similar to the 12 ppt station.

In sum, although the bay was ranked differently for the various parameters, a consistent pattern was observed for the bay and river system. Phytoplankton production was high in the low-salinity upper reaches of the estuary and generally declined, with reduced seasonal variation, toward the mouth of the river. Phytoplankton production did increase, however, from the 18 ppt salinity station to the bay reflecting a transition from the river mouth to the open-bay environment. On some dates, usually when there were high flows in the river, there were exceptions to this pattern and these are described in a following section.

The Ruskin Inlet station, the only other fixed-location used in the study, was located in a channelized tributary to the Little Manatee approximately 2.5 miles upstream from the river mouth. Ruskin Inlet receives considerable stormwater runoff after rains, but residence times in the Inlet are probably relatively long because tidal and river currents appear to be much reduced there compared to the main channel of the river. Phytoplankton cell counts were highest for this station due to an abundance of microflagellates. Although the mean number of phytoplankton cells was twice as great for Ruskin Inlet compared to the 0 ppt station, these stations had similar chlorophyll means of approximately 20 ug/l.

<u>Seasonal Trends for Chlorophyll Concentrations and Phytoplankton Composition.</u> Surface water chlorophyll concentrations for the estuarine stations are plotted by date in Figure 6.8. These results are qualitatively compared to phytoplankton abundance and species composition in the estuary. However, the report by Vargo (1989) should be consulted for detailed information regarding phytoplankton communities.

Chlorophyll concentrations in Tampa Bay were low (less than 10 ug/l) for the period January through May. Diatoms were the most abundant phytoplankton group during this time, and were particularly numerous in January and February although this was

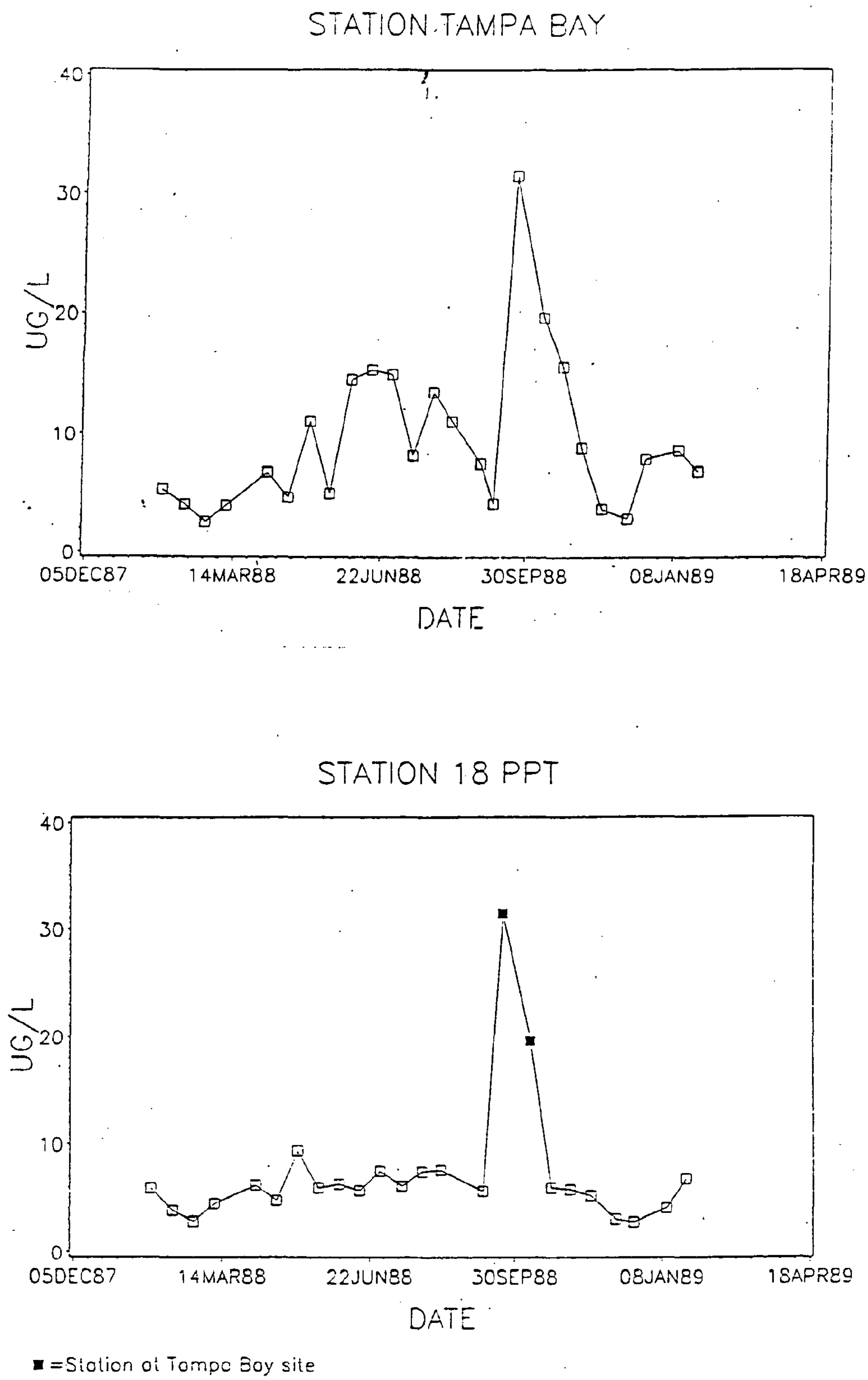
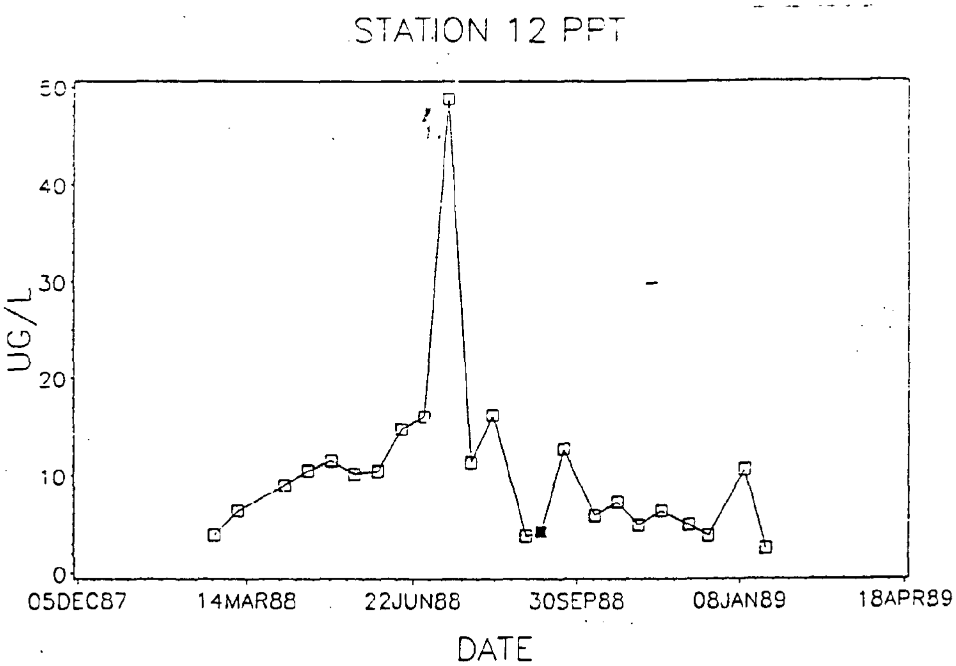



Figure 6.8. Mean values for surface water chlorophyll a concentrations at six stations in the Little Manatee River estuary.




■ =Station at Tampa Bay site

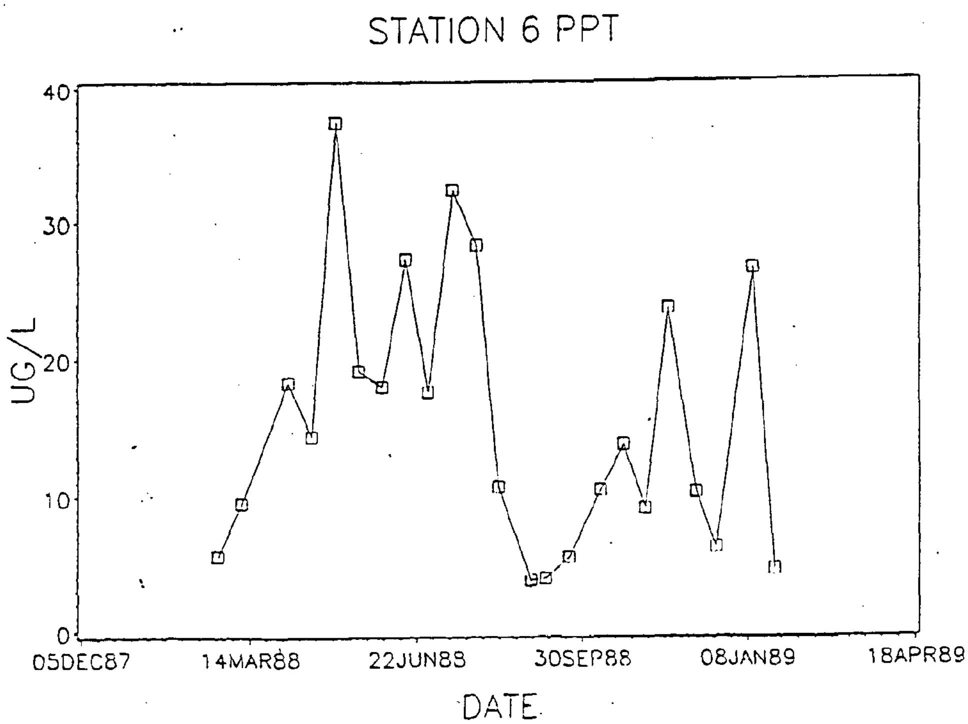
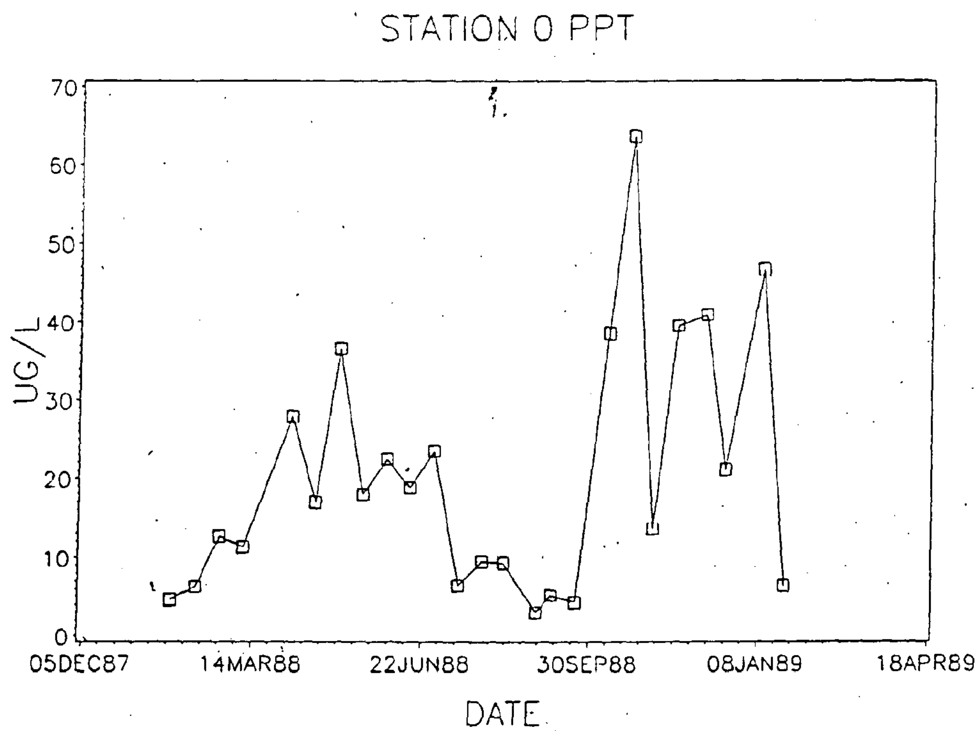



Figure 6.8. (Continued)



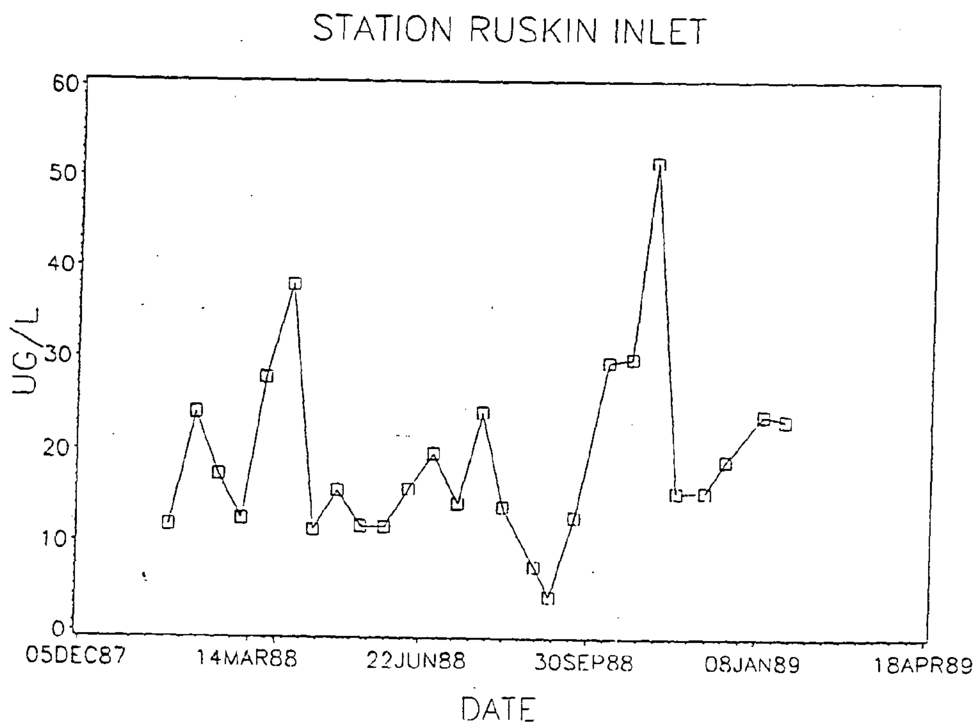




Figure 6.8. (Continued)

not reflected by the chlorophyll data. Chlorophyll concentrations were at increased levels in the early summer, but were low during the September flood. Peak chlorophyll concentrations occurred in late September and early October, when the blue-green alga *Schizothrix* sp. reached high densities. It is believed this blue-green algal bloom was associated with the increased nutrients and reduced salinities in the bay following the September flood. Chlorophyll levels returned to low values in the following winter period.

Chlorophyll concentrations were remarkably stable at the 18 ppt station, being less than 10 ug/l except during the October *Schizothrix* bloom when this station was located at the Tampa Bay site. With the exception of this bloom, microflagellates and diatoms were the dominant phytoplankton groups at this station.

Chlorophyll concentrations at the 12 ppt station showed a steady increase from winter to spring and were maximal in early July. This July peak was due to a bloom of an unknown, naked dinoflagellate which burst upon preservation. Chlorophyll concentrations and phytoplankton cells were low during the September flood and remained below 10 mg/l for the remainder of the study. After the flood, large numbers of the blue-green alga *Schizothrix* were not found at this station as the bloom was confined primarily to the waters of the bay.

The largest spatial differences between chlorophyll concentrations occurred between the 12 ppt and 6 ppt salinity stations. Chlorophyll concentrations increased at the 6 ppt station through the spring, and fluctuated between 15 and 40 ug/l from April through July. Microflagellates became relatively more important as water temperatures increased. Decreases in chlorophyll levels and phytoplankton abundance were observed during August and September when river flows were at high seasonal levels. It is suggested that low residence times in the upper estuary during high flow periods inhibited the development of large phytoplankton populations. Values for both parameters increased during October, and showed pronounced short-term variations, occasionally reaching high values, during the following fall and winter. Diatoms and microflagellates were the dominant phytoplankton groups at this station with diatoms at their greatest abundance during the fall and early winter. Also, several typical freshwater species were periodically found at this station.

Chlorophyll concentrations at the 0 ppt salinity station showed large seasonal variation, ranging between 3.1 ug/l and 63.8 ug/l. Chlorophyll concentrations were low in the winter of 1988, but increased to values between 15 and 40 ug/l during April through June. Chlorophyll returned to low values from July through September. Phytoplankton numbers followed this same trend and were low during the winter (January and February) and summer, separated by high spring counts. Although temperature effects could have been important for the winter minima, both chlorophyll and phytoplankton were clearly lowest at this station during periods of moderate to high streamflow, indicating that phytoplankton populations are flushed from the upper estuary by moderate to high flows. Chlorophyll and phytoplankton both showed pronounced peaks when flows returned to normal in October. The first peak was due to a bloom of *Skelotemema costatum*, a ubiquitous estuarine diatom that was distributed throughout the river and bay. The second bloom was comprised of large numbers of *Cyclotella* sp., a species that was restricted to low salinity waters. Chlorophyll and phytoplankton showed large variations for the remainder of the year with periodic blooms due primarily to diatoms or microflagellates. Freshwater chlorophytes (green algae) were most abundant at this station but never averaged more than 7 percent of the total phytoplankton cells. High chlorophyll and phytoplankton values at this station were the result of rapid algal growth in the estuary, and not importation from upstream, since chlorophyll values at the most downstream freshwater stream station averaged 2.7 ug/l and never exceeded 8.6 ug/l.

Chlorophyll values at Ruskin Inlet showed a seasonal pattern distinct from other stations. In contrast to the other sites, chlorophyll concentrations were high in the winter of 1988. Chlorophyll concentrations remained between 10 and 30 ug/l during the summer, generally being the highest values found in the estuary during that period. Peak chlorophyll values occurred in November due to a bloom of *Skelotemema costatum*. The most notable characteristic of the phytoplankton community in Ruskin Inlet was the almost continuous presence of chlorophytes, particularly Euglenoid flagellates, and dinoflagellates.

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