Annual Report on Water Quality Status and Trends in the Peace and Myakka River Basins

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Many individuals and organizations made substantial contributions to this report. Alton Cheatham (CHEC), Tiffany Lutterman (CHNEP), David Moldal (CHNEP), and Samuel Stone (PR/MRWSA) provided project oversight, logistical support and technical information regarding the Peace River watershed. Terri Williamson (SWFWMD) coordinated the retrieval of discharge data for the 1998 and 1999 water years, and water quality data for the years 1970-1998, from USGS databases. Chris Anastasiou, Fran Flores, Jan Geraldi, Pam Green, Jill Hood, Jason Hood, Ralph Meder, Keith Morrison, Nita Ostermann, Kelly Permenter, Brandy Steed, Chris Tomlinson, and Chris Zajac (SWFWMD) collected the water samples and *in situ* hydrographic data. Roberta Starks (SWFWMD) coordinated the monthly monitoring effort, supervised data entry and data management, and served as the project's quality assurance officer. Chemical analyses were performed by laboratory staff at FDEP, SWFWMD, and the Environmental Quality Laboratory, Inc. The report text and figures were prepared by Gerold Morrison (CHEC) and Roberta Starks (SWFWMD)

Executive Summary

Background

During the 1980's and 1990's a number of federal, state and regional resource management initiatives — including the U.S. EPA National Estuary Program (NEP), the Florida Surface Water Improvement and Management (SWIM) Program, and the Southwest Florida Water Management District Comprehensive Watershed Management (CWM) Program — designated the Charlotte Harbor watershed as a priority management area. Protection of water quality is a fundamental goal of these watershed management efforts, and successful management of water quality requires adequate information, knowledge, and understanding of water quality conditions and trends at a watershed-wide geographic scale.

In 1996 a watershed assessment project funded by the Charlotte Harbor SWIM program raised questions regarding the adequacy of the currently-available water quality data to support sound management decisions, and recommended that more frequent (e.g., biweekly or monthly) water quality monitoring be initiated at selected stream gaging stations in the Peace and Myakka River basins (Squires et al. 1996). That recommendation, and other concerns regarding the adequacy of available information to characterize water quality conditions and pollutant loadings in the Charlotte Harbor watershed, motivated the Charlotte Harbor National Estuary Program (CHNEP) and a number of partners to fund and undertake the water quality monitoring and assessment project reported here.

Using funds provided by the CHNEP and the Peace River/Manasota Regional Water Supply Authority (PR/MRWSA), and in-kind services provided by the Southwest Florida Water Management District (SWFWMD), the Florida Department of Environmental Protection (FDEP), and the City of Punta Gorda, the cooperating organizations carried out a monthly water quality monitoring program at 10 stations in the Peace River basin from October 1997 through September 1999 and at 5 stations in the Myakka River basin from October 1998 through September 1999. This report provides a summary of water quality conditions and estimated pollutant loads occurring during those periods. As background information, the report also includes an overview of long-term water quality and stream flow trends occurring at selected locations in the Peace and Myakka River basins between 1970 and 1998.

Sampling Methods

Hydrographic parameters (specific conductance, salinity, pH, temperature, and DO) were measured at each monitoring station using Hydrolab™ or YSI™ multi-probe datasondes. Water samples were collected at mid-depth at each station and transported on ice to the analytical laboratory. Laboratory analytes included total organic carbon (TOC), nitrate+nitrite nitrogen (NO_{2+3}–N), ammonium nitrogen (NH_4-N), total Kjeldahl nitrogen (TKN), total nitrogen (TN), dissolved ortho-phosphate (PO_4), total phosphorus (TP), chlorophyll *a*, color, total suspended solids (TSS), turbidity, and water column transparency (Secchi disk depth). All sampling activities were performed by SWFWMD staff, and all sample collection, preservation, transport, and chain of custody procedures were carried out in accordance with EPA, FDEP, and SWFWMD quality assurance guidelines.

Ambient Water Quality

A water quality index (WQI) developed for Florida streams by FDEP was used to characterize existing water quality conditions at the stations monitored during the 1997-1999 study period. The WQI was developed by Hand et al. (1994, 1996), based on sampling data collected in 1987 from 2,000 stream reaches throughout the state. Those data were used to determine percentile distributions for several groups of water quality indicators (e.g., nutrients, water clarity, DO and oxygen-demanding substances) on a statewide basis (Hand et al. 1994, 1996). The calculation of WQI values is based on these percentile distributions: for example, a station exhibiting an average annual TN concentration of 1.2 mg N/L (the median value observed in the 1987 data set) would receive an index score of 50 for that indicator. Scores are averaged across indicator categories to obtain an average WQI value per site. FDEP guidelines suggest that average index values of 0-44 indicate “good,” 45-60 indicate “fair,” and >60 indicate “poor” water quality conditions in Florida streams (Hand et al. 1994, 1996).

For this study, average WQI values were calculated using four parameters (turbidity, total suspended solids, total organic carbon, and total nitrogen) to characterize water quality conditions observed during the 1997-1999 monitoring period (Table ES-1). The Saddle Creek at Structure P-11 station, which is located immediately downstream from Lake Hancock in the upper Peace River basin, exhibited the poorest water quality among the sites sampled, falling in the 75th to 95th percentiles of Florida streams for the indicators assessed. Overall, six sites (all located in the Peace River basin) produced WQI values >60, indicative of “poor” water quality conditions. Only four sites (Horse Creek near Myakka Head, Shell Creek near Punta Gorda, Myakka River at Myakka City, and Myakka River near Sarasota) exhibited average WQI values that would be characterized as “good” (average WQI < 45) based on the FDEP classification system. The remaining sites were characterized as “fair” based on the WQI.

Stream Discharge and Pollutant Loads

U.S. Geological Survey (USGS) long-term stream gaging sites were used as monitoring stations in this project. At each site the USGS collects continuous records of stream stage (elevation of the water surface), makes periodic measurements of stream discharge (flow volume per unit time) throughout a range of stages, and computes an estimate of daily mean stream discharge based on the continuous stage records and the measured stage-discharge relationship. The long-term gaging sites are operated and maintained by the USGS as part of the agency’s national surface water monitoring network.

For this study, daily mean discharge estimates for the Peace and Myakka River monitoring sites were obtained from the USGS for the 1998 and 1999 "water years." (By convention, the USGS and other water-resource organizations define a "water year" as the 12-month period extending from October 1 through September 30. Each water year is numbered based on the calendar year in which it ends. Thus, the year ending September 30, 1999, is called the "1999 water year.") Records for the 1999 water year have not yet been published by the USGS, and must therefore be treated as provisional estimates that are potentially subject to revision.

Above-average rainfall associated with the 1997-1998 El Niño event produced increased stormwater runoff and elevated stream discharge during the 1998 water year. At the Peace River-Arcadia gaging site, for example, annual average discharge during that water year was more than two times higher than the site's long-term (1932-1998) average.

Estimated annual loads of selected water quality constituents (nitrogen forms, phosphorus forms, and TSS) were calculated for 14 of the gaging stations for the 1998 and 1999 water years. (Gaps in the available discharge data prevented calculation of loading estimates for USGS gage 02299455, located on Big Slough Canal north of the City of North Port.) Monthly loads for each constituent were calculated using estimated daily values, and were obtained by multiplying monthly average constituent concentration (milligrams per liter) and daily average stream discharge (liters per day). Annual loads were estimated by summing the monthly values. Estimated annual loads for the 1998 and 1999 water years are summarized in Table ES-2.

Table ES-1. Florida stream water quality index (WQI) values, based on October 1997 - September 1999 monitoring data. FDEP guidelines suggest that average index values of 0-44 indicate “good,” 45-60 indicate “fair,” and >60 indicate “poor” water quality conditions.

STATION	Turbidity	TSS	TOC	TN	TP	Avg. WQI	Water Quality Characterization
Peace Creek Canal near Wahneta	58	48	72	74	79	64	“poor”
Saddle Creek at Structure P-11	>95	>95	75	>95	78	87	“poor”
Peace River at Bartow	75	87	67	82	94	81	“poor”
Peace River at Ft. Meade	59	66	54	75	90	67	“poor”
Peace River at Zolfo Springs	52	52	53	71	94	63	“poor”
Peace River at Arcadia	51	53	56	69	90	64	“poor”
Charlie Creek near Gardner	27	28	74	63	83	55	“fair”
Horse Creek near Myakka Head	17	11	71	41	79	44	“good”
Horse Creek near Arcadia	19	23	65	56	80	47	“fair”
Shell Creek near Punta Gorda	17	11	62	50	59	37	“good”
Myakka River at Myakka City	7	3	70	--	74	38	“good”
Myakka River near Sarasota	15	8	74	58	78	44	“good”
Deer Prairie Slough near North Port	54	15	72	--	70	53	“fair”
Big Slough Canal near Myakka City	49	28	73	--	76	57	“fair”
Big Slough Canal near North Port Charlotte	41	32	61	--	75	55	“fair”

Table ES-2. Estimated annual loads (metric tons/year) of selected water quality constituents (TN, inorganic N, TP, PO_4-P and TSS) during water year 1998 (WY98) and water year 1999 (WY99).

	TN		Inorganic N		TP		PO_4-P		TSS	
Station	WY 98	WY 99 [a]	WY 98	WY 99	WY 98	WY 99	WY 98	WY 99	WY 98	WY 99
Peace Creek Canal near Wahneta	278	--	38	9	37	12	24	10	542	141
Saddle Creek at Structure P-11	771	--	4	1	114	12	24	3	10,719	2,643
Peace River at Bartow	781	--	86	18	214	68	132	49	6,039	2,632
Peace River at Ft`. Meade	963	--	178	28	540	112	384	86	5,562	1,232
Peace River at Zolfo Springs	1,811	--	548	130	1,038	303	850	253	7,757	1,800
Peace River at Arcadia	2,997	900	1,027	295	1,617	551	1,167	485	10,925	4,021
Charlie Creek near Gardner	1,057	182	278	25	331	72	270	61	3,183	647
Horse Creek near Myakka Head	78	--	7	1	23	7	21	6	207	44
Horse Creek near Arcadia	555	--	142	41	197	62	167	53	4,203	101
Shell Creek near Punta Gorda	624	471	76	56	68	76	48	58	1,041	851
Myakka River at Myakka City	--	--	--	20	--	69	--	65	--	64
Myakka River near Sarasota	--	226	--	12	--	116	--	100	--	261
Deer Prairie Slough near North Port	--	--	--	1	--	2	--	2	--	78
Big Slough Canal near Myakka City	--	--	--	10	--	10	--	8	--	140
Big Slough Canal near North Port Charlotte	--	--	--	--	--	--	--	--	--	--

[a] Data quality concerns prevented calculation of estimated TN load at several stations (see text).

In addition to the constituent loads observed at individual gaging stations in the Peace and Myakka River basins, the CHNEP and other stakeholders are also interested in quantifying the annual mass loads of nutrients and TSS that are discharged from the watershed to Charlotte Harbor. For the Peace River basin, estimates of these values can be obtained by summing the estimated loads from three gaging stations (Peace River at Arcadia, Horse Creek near Arcadia, and Shell Creek near Punta Gorda), which are located immediately upstream from the Harbor on the Peace River and its southernmost tributaries. These three stations have a cumulative drainage area of 1,958 mi^2 (USGS 1997), representing 83% of the Peace River watershed (Hammett 1987). Assuming that the portion of the watershed lying downstream from the gages generates loads of each constituent that are comparable (on a per-unit-area basis) to the upstream portion, loads observed at these stations should represent (as a first approximation) about 83% of the watershed totals. Estimated annual loads calculated using these assumptions are shown in Table ES-3. (Similar estimates were not calculated for the Myakka River basin, because <50% of the surface area of that basin is currently gaged.) Previous loading estimates, prepared by Coastal Environmental, Inc., as part of a SWIM-funded watershed assessment project, are also shown in Table ES-3.

Table ES-3. Estimated constituent loads (metric tons/year) from the Peace River watershed to Charlotte Harbor.

Constituent	1985-1991[a]	1998 water year[b]	1999 water year[b,c]
TN	1,633	5,012	--
Inorganic N	--	1,494	470
TP	580	2,260	826
PO_4-P	--	1,659	715
TSS	13,061	19,407	5,969

[a] Data source = Coastal Environmental, Inc. 1995
[b] Data source = this study
[c] Data quality concerns prevented calculation of TN load (see text)

Long-Term Trends in Streamflow and Water Quality

When interpreting the water quality conditions observed during the 1998-1999 water years, it is helpful to evaluate them in the context of long-term trends in stream discharge and water quality that have occurred in the Peace and Myakka River basins in recent decades.

To assist in that effort, daily streamflow records from a number of USGS gaging stations in the two river basins, and periodic measurements of selected water quality indicators made at those stations by the USGS, were obtained from the USGS database for the period 1970-1998. These data were examined for the presence of long-term trends using the nonparametric Mann-Kendall test (Gilbert 1987). Tests for trend were performed on annual minimum, annual mean, and annual maximum values of each water quality indicator. Trend tests were also performed on dry season ("lowest monthly mean") and wet season ("highest monthly mean") discharge, and on annual runoff (serving as a proxy for annual mean discharge). Trend tests were not performed for water quality constituents for which the available period of record was <10 years.

Streamflow Trends

Statistically significant declining trends in dry-season discharge were observed at two Peace River gaging stations (Bartow and Zolfo Springs) over the 1970-1998 period. Significant increasing trends in dry season flows occurred on two Peace River tributaries (Charlie Creek and Joshua Creek) and at the Myakka River-Sarasota gage. Increasing trends in annual runoff occurred at four stations (Saddle Creek at Structure P-11, Peace River-Ft. Meade, Joshua Creek-Nocatee, and Horse Creek-Arcadia). No statistically significant trends in dry season, wet season, or annual mean discharge were observed at the Peace River-Arcadia gage over the 1970-1998 period.

Long-term trends in discharge and runoff in the Peace River watershed are a topic of considerable interest to resource managers in the west-central Florida region. Several investigators have documented long-term declines in annual mean discharge, particularly at gaging stations on the river's main stem in the northern portion of the watershed, that occurred between the 1930's and 1990's (e.g., Hammett 1987, Coastal Environmental Services 1995). These declining trends appear to have been caused by a combination of natural (e.g., reduced frequency of tropical cyclones) and anthropogenic factors (e.g., increased groundwater pumpage; surface strip mining)(Hammett 1987, Coastal Environmental Services 1995). Because these declines occurred prior to 1970 (Hammett 1987), they were not detected in the analyses reported here.

Water quality trends

During the 1970-1998 period, specific conductance — a potential indicator of the magnitude of groundwater discharges to surface waters — exhibited significant increasing trends at four stations (Charlie Creek-Gardner, Joshua Creek-Nocatee, Horse Creek-Myakka Head, and Myakka River-Sarasota). Declining trends in specific conductance occurred at three stations (Saddle Creek at Structure P-11, Peace River at Bartow and Zolfo Springs), all located in the northern portion of the Peace River basin. In central Florida increasing trends in specific conductance in inland surface waters are often associated with increasing groundwater discharges, frequently due to agricultural or residential irrigation or industrial discharges. The declining specific conductance trends observed at some upper Peace River stations were presumably caused by declines in groundwater discharge, which enters the river from a variety of man-made sources and from natural springs and seeps located in the riverbed.

Concentrations of NO_{2+3} -N (nitrite plus nitrate nitrogen) increased significantly at the Horse Creek-Arcadia and Charlie Creek-Gardner gage sites during the 1970-1998 period. Significant declines in NO_{2+3} -N concentrations occurred at the Bartow, Ft. Meade, and Zolfo Springs gages on the main stem of the Peace River. Changes in NO_{2+3} –N concentrations in surface water bodies are frequently used by watershed managers as indicators of changing inorganic nitrogen loads from manmade sources.

Concentrations of ammonia nitrogen also declined significantly at several stations on the main stem of the Peace River (Bartow, Ft. Meade, Zolfo Springs and Arcadia), presumably reflecting long-term reductions in discharges of ammonia-N via domestic and industrial wastewaters in the upper Peace River basin.

Phosphorus (PO_4 and TP) concentrations declined significantly at several sites in the Peace River basin (Horse Creek-Arcadia, and Peace River at Bartow, Ft. Meade, Zolfo Springs, and Arcadia), but increased significantly at a Peace River tributary site (Charlie Creek-Gardner) and at a long-term monitoring station located on the Myakka River (Myakka River-Sarasota). The increasing trend observed at the Myakka River site, which is located between the Upper and Lower Myakka Lakes within Myakka River State Park, may be an item of interest to state and regional water resource managers because of its potential implications for trophic state conditions within the park.

1.0 INTRODUCTION

1.1 Background

During the 1980's and 1990's a number of federal, state and regional resource management initiatives — including the U.S. EPA National Estuary Program (NEP), the Florida Surface Water Improvement and Management (SWIM) Program, and the Southwest Florida Water Management District Comprehensive Watershed Management (CWM) Program — designated the Charlotte Harbor watershed as a priority management area. Protection of water quality is a fundamental goal of these watershed management efforts, and successful management of water quality requires adequate information, knowledge and understanding of water quality conditions and trends at a watershed-wide geographic scale.

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Using funds provided by the CHNEP and the Peace River/Manasota Regional Water Supply Authority (PR/MRWSA), and in-kind services provided by the Southwest Florida Water Management District (SWFWMD), the Florida Department of Environmental Protection (FDEP), the Charlotte Harbor Environmental Center (CHEC), and the City of Punta Gorda, the cooperating organizations carried out a monthly water quality monitoring program at 10 stations in the Peace River basin from October 1997 through September 1999 and at 5 stations in the Myakka River basin from October 1998 through September 1999. This report provides a summary of water quality conditions and estimated pollutant loads occurring during those periods. As background information, the report also includes an overview of long-term water quality and stream flow trends occurring at selected locations in the Peace and Myakka River basins between 1970 and 1998.

1.2 Water Quality Management Issues

The Peace and Myakka River basins lie in a naturally fertile area that contains extensive phosphate-bearing geological deposits (the Bone Valley formation of the Hawthorn group) and experiences abundant seasonal rainfall and a humid subtropical climate. Phosphate is an important nutrient supporting the growth of terrestrial and aquatic organisms, and many lakes and streams that drain the Bone Valley region are "eutrophic" (exhibit high rates of biological productivity) as a result of naturally elevated phosphate inputs (Odum 1953, Canfield and Hoyer 1988). These naturally eutrophic waterbodies have the potential to become hypereutrophic — exhibiting undesirably high levels of biological productivity — if human activities cause nutrient loads to increase to excessive levels. Several historically-eutrophic lakes located in the headwaters region of the Peace River basin (e.g., Lake Parker, Lake Hancock, Banana Lake) appear to have shifted to hypereutrophic productivity levels in recent decades as a result of additional, manmade nutrient loads.

Eutrophication is a process in which increasing nutrient loads cause changes in the water chemistry and ecological structure of surface water bodies. These changes, which are currently affecting many Florida waters, often include:

- increasing rates of biological production, and increasing biomass of algae or rooted aquatic plants;
- increasing deposition of unutilized organic material to the sediment zone (with associated increases in sediment oxygen demand);
- reduced water clarity, due to increased algal densities and resuspension of unconsolidated bottom sediments; and
- shifts in the composition of plant and animal communities, with increasing abundance of species more highly adapted to nutrient-enriched conditions

(Day et al. 1989). In addition to ecological and esthetic impacts, excessive nutrient loads can also affect human uses of surface waters by increasing the frequency of nuisance algal blooms, causing taste and odor problems in potable water sources and contributing to oxygen-related stress or mortality in economically important fish and shellfish species.

From a regulatory perspective the Federal Water Pollution Control Act ("Clean Water Act"), as amended, provides the underlying legal framework for water quality management throughout the United States. The Clean Water Act requires that the chemical, physical and biological integrity of the Nation's waters be maintained at levels that provide "fishable and swimmable" conditions for all citizens. Regulations developed by the U.S. EPA and other agencies to implement the Act have therefore focused on maintaining water quality at levels necessary to support viable populations of fish and wildlife and protect human health.

Water quality standards — which include designated uses, numeric and narrative water quality criteria, and an anti-degradation policy — have been the primary tools used in the national management effort. *Designated uses*, such as potable water supply, shellfish harvesting, wildlife propagation and recreational contact, are identified by each state through its rulemaking process and are established for all waterbodies within a state's jurisdiction (e.g., Ch. 62-302.400, Florida Administrative Code). *Water quality criteria*, which describe the specific water quality conditions needed to achieve designated uses, are also established by rulemaking at the state level (e.g., Ch. 62-

302.530, F.A.C.). *Anti-degradation policy*, which is implemented through the permitting process, holds that all existing uses of a waterbody (including those that may exceed the designated uses) should also be maintained. If existing water quality is higher than is strictly necessary to support designated uses, for example, regulatory agencies will seek to maintain that quality unless important economic and social goals require otherwise.

In order to prevent or correct water quality degradation caused by manmade nutrient discharges, state criteria typically include provisions intended to prevent excessive loads from anthropogenic sources (e.g., stormwater runoff; wastewater discharges from municipal, industrial, and agricultural facilities). State policies and programs also support the restoration of water bodies degraded by historical anthropogenic discharges. Like many states, however, Florida has not established numerical criteria for regulating nutrient loads and eutrophication, relying instead on a narrative guideline which states that "in no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna" (Chap. 62-302.530, F.A.C.).

In areas such as the Peace and Myakka River basins, where many surface water bodies receive naturally-elevated phosphorus loads as well as manmade nutrient discharges from a variety of point and nonpoint sources, regular monitoring and reporting of water quality conditions are helpful to ensure that watershed stakeholders and managers have access to the information needed to assess compliance with these state and national water quality goals.

1.3 Report Objectives and Structure

This report provides a summary of water quality status and trends at a number of USGS gaging stations located in the Peace and Myakka River basins. The report is organized as follows:

- **Sect. 2.0 Existing Water Quality Conditions** – summarizes the monthly water quality monitoring data collected at 10 gaging stations during the 1998 water year and 15 stations during the 1999 water year, and pollutant loading estimates calculated using those data.

- **Sect. 3.0 Long-term Trends in Stream Flow and Water Quality** – summarizes stream discharge and water quality trends observed at 11 Peace River gaging stations and 1 Myakka River gaging station over the period 1970 through 1998.

- **Sect. 4.0 References Cited**

- **Appendix: Quarterly QA reports**

2.0 Existing Water Quality Conditions

2.1 Methods

U.S. Geological Survey (USGS) stream gaging sites (locations shown in Fig. 1) were used as monitoring stations during the 1998 and 1999 water years. At each site the USGS collects continuous records of stream stage, makes periodic measurements of stream discharge throughout a range of stages, and computes an estimate of daily mean stream discharge based on the continuous stage records and the measured stage-discharge relationship.

Co-location of water quality monitoring and stream gaging stations is important for at least three reasons (NRC 1999):

- Concentrations of many water quality constituents vary with stream stage, and adequate information on both concentration and stage is needed to allow these dynamic relationships to be documented and understood;

- Records of stream discharge (volume/time) and constituent concentrations (mass/volume) are necessary for the calculation of constituent loadings (mass/time), which are important indicators of the effectiveness of water quality management efforts;

- Watershed management efforts are more likely to succeed if managers have an adequate understanding of relationships between the quantity and quality of surface water flows within the watershed, and relationships between these variables and other ecosystem components.

Monthly water quality monitoring was initiated at the Peace River watershed in October 1997, and at the Myakka River stations in October 1998. Water samples were collected by SWFWMD field staff over a three-day period during the first week of each month. Stations located in the northern portion of the Peace River basin were normally sampled on the initial day of field work; the remaining stations were sampled over the following two days.

Water quality parameters monitored included: specific conductance, pH, temperature, dissolved oxygen (DO), total organic carbon (TOC), nitrate+nitrite nitrogen, ammonia nitrogen, total ammonia+organic nitrogen (TKN), total nitrogen (TN), dissolved ortho-phosphate (PO_4), total phosphorus (TP), chlorophyll *a*, color (PCU), total suspended solids (TSS), and turbidity (NTU).

Hydrographic parameters (specific conductance, salinity, pH, temperature, and DO) were measured in the field using a multi-probe (Hydrolab ™ or YSI ™) datasonde that was calibrated at the beginning and end of each field day. Water samples were collected at mid-depth at each gaging station and transported on ice to the analytical laboratory. Concentrations of dissolved ortho-phosphate were determined using

Figure 1
(locations of monthly monitoring stations used in WY98 and WY99)
on this page

samples that were field-filtered, immediately following collection, through 0.45 *u*m membrane filters and stored on ice until analysis. Samples used for chlorophyll analysis were filtered in the laboratory immediately following sample delivery, using Gellman A/E (1 *u*m) glass fiber filters, and the filters and attached algal cells were stored frozen prior to chlorophyll extraction. All sampling, sample preservation and transport, and chain of custody procedures were performed in accordance with federal (US EPA), state (FDEP), and regional (SWFWMD) quality assurance requirements. Chemical analyses were performed by three laboratories (SWFWMD, FDEP, and EQL, Inc.) during the 1997-1999 study period, using EPA-approved analytical methods.

Data quality was assessed and reported on a quarterly basis by SWFWMD staff (see Appendix). The most significant quality assurance issues noted involved exceedances of laboratory holding times (primarily affecting samples collected in December, 1997), and questions concerning the accuracy and precision of TN determinations reported by the SWFWMD laboratory during 1999. Data points affected by currently-unresolved QA concerns have been omitted from the analyses performed for this report. The greatest impact of these omissions has been the creation of several data gaps in our estimates of water quality index values (Table 2) and TN loads (Tables 3-4) for the 1999 water year.

In addition to the CHNEP-sponsored monitoring effort, the USGS also conducts periodic water quality monitoring at the gaging stations used in this study, following methods that are summarized in annual Water Resource Data reports (e.g., USGS 1999). Where available, the USGS monitoring data have been incorporated in the analyses reported here.

2.2 Constituent concentrations and water quality index (WQI) values

Concentrations of major water quality constituents observed during the 1998 and 1999 water years are listed in Table 1. Relative to median values observed in Florida streams (e.g., Hand et al. 1994), many of the Peace and Myakka River stations exhibited elevated concentrations of total phosphorus, total nitrogen, total organic carbon, turbidity, TSS, color, and chlorophyll *a* during the October 1997-September 1998 time period (Table 1).

The State of Florida has developed a stream water quality index (WQI) — based on observed concentrations of nutrients, water clarity, DO, and oxygen demanding substances — that provides a helpful tool for summarizing water quality monitoring data (Hand et al. 1994, 1996). Sampling data collected in 1987 from 2,000 Florida stream reaches were used to determine percentile distributions for each indicator on a statewide basis (Hand et al. 1994, 1996). Index scores are calculated based on these percentile distributions: for example, a site exhibiting an average TN concentration of 1.2 mg N/L (the median value observed in the 1987 data set) would receive an index score of 50 for that indicator. Scores are averaged across indicator categories to obtain an average WQI value per site (Hand et al. 1994, 1996). State guidelines suggest that average index values of 0-44 indicate “good,” 45-60 indicate “fair,” and >60 indicate “poor” water quality conditions in Florida streams.

Hand et al. (1996) provides the following summary of the WQI: “The Florida Water Quality Index has several advantages over previous measures. First, since it is based on the percentile distribution of Florida stream data, it is tailored to Florida. Second, the index uses the most important measures of water quality in Florida: clarity, dissolved oxygen, oxygen-demanding substances, nutrients, bacteria, and biological diversity. Third, it is simple to understand and calculate and does not require a mainframe computer or any complex data transformations or averaging schemes. Finally, the index nicely identifies areas of good, fair, and poor water quality that correspond to professional and public opinion.”

An application of the WQI to the 1997-1999 Peace and Myakka River sampling data is shown in Table 2. (In recognition of the naturally-elevated phosphate concentrations that can occur in these basins, the average WQI values shown in Table 2 were calculated in two ways — one including and the other omitting TP concentrations.) Based on these data the Saddle Creek at Structure P-11 gaging station, which is located immediately downstream from Lake Hancock, appears to have the poorest water quality of the 15 sites monitored, falling in the 75th to 90th percentiles of Florida streams for all indicators assessed. Several sites — primarily located in the northern portion of the Peace River basin — exhibited WQI values >60, indicative of “poor” water quality conditions (Table 2). Five sites (Horse Creek near Myakka Head, Horse Creek near Arcadia, Shell Creek near Punta Gorda, Myakka River at Myakka City, and Myakka River near Sarasota) exhibited average WQI values that would be characterized as “good” (average WQI < 45) based on the State classification system. The remaining sites exhibited “fair” conditions based on the WQI.

Because they are based on only two years of monitoring data, these results represent a relatively short-term “snapshot” of water quality conditions in the Peace and Myakka River basins. In general, however, they appear consistent with previous water quality information collected from the basin (e.g., Fraser 1991, Hand et al. 1994, Lowrey et al.1990).

Table 1. Constituent concentrations (average and range) observed in October 1997 - September 1999 sampling events. ("BDL" indicates value below detection limit of analytical method.)

STATION	Turbidity (NTU)	TSS (mg/L)	Color	pH	Conduct (umhos)	DO (mg/L)	Chl *a* (ug/L)
Peace Creek Canal near Wahneta	8.0 (3.8 – 25.0)	6.1 (BDL – 34.1)	228 (125 – 350)	6.8 (5.9 – 7.5)	268 (125 – 563)	4.6 (0.8 – 8.0)	2.8 (BDL – 20.4)
Saddle Creek at Structure P-11	32.5 (14.7 – 59.0)	60.8 (7.2 – 211.0)	74 (40 – 156)	8.3 (6.9 – 9.6)	188 (147 – 246)	5.9 (1.7 – 10.9)	150.6 (43.0 – 333.0)
Peace River at Bartow	14.2 (5.8 – 55.0)	22.1 (BDL – 151.2)	183 (100 – 300)	6.8 (6.0 – 7.4)	265 (129 – 683)	4.3 (2.0 – 8.5)	26.1 (BDL – 155)
Peace River at Ft. Meade	8.4 (2.8 – 29.0)	11.4 (BDL – 54.0)	109 (30 – 225)	7.2 (6.5 – 8.0)	350 (172 – 597)	6.2 (4.4 – 9.0)	15.3 (BDL – 64.2)
Peace River at Zolfo Springs	5.9 (1.2 – 15.3)	7.1 (BDL – 30.0)	106 (30 – 200)	7.4 (6.8 – 8.1)	361 (194 – 563)	7.1 (4.8 – 9.7)	8.9 (BDL – 79.8)
Peace River at Arcadia	5.6 (2.3 – 15.8)	7.3 (BDL – 26.0)	140 (40 – 300)	7.4 (6.8 – 8.0)	338 (143 – 537)	7.1 (4.1 – 9.6)	4.2 (BDL – 26.7)
Charlie Creek near Gardner	3.7 (1.0 – 14.1)	3.8 (BDL – 10.0)	248 (60 – 500)	6.7 (5.9 – 7.4)	224 (117 – 428)	6.4 (3.9 – 9.1)	0.7 (BDL – 2.6)
Horse Creek near Myakka Head	2.5 (0.8 – 8.4)	2.1 (BDL – 10.9	257 (60 – 580)	6.7 (5.8 – 7.6)	140 (73 – 248)	7.3 (4.7 – 9.8)	0.9 (BDL – 3.6)
Horse Creek near Arcadia	2.9 (0.5 – 8.6)	2.9 (BDL – 32.0)	195 (30 – 500)	6.6 (4.4 – 7.4)	354 (86 – 795)	6.8 (4.7 – 8.6)	2.2 (BDL – 31.5)
Shell Creek near Punta Gorda	2.5 (1.6 – 4.7)	2.1 (BDL – 6.0	138.3 (46 – 218)	7.4 (6.8 – 8.0)	672 (394 – 1003)	4.7 (1.4 – 8.0)	7.8 (BDL – 24.2)
Myakka River at Myakka City	1.1 (0.2 – 2.1)	0.5 (BDL – 1.9)	141 (70 – 250)	7.0 (6.4 – 7.8)	353 (164 – 595)	5.8 (3.3 – 8.8)	1.7 (BDL – 3.8)
Myakka River near Sarasota	2.3 (1.0 – 4.8)	1.6 (BDL – 6.7	161 (65 – 300)	6.9 (6.2 – 7.8)	342 (133 – 690)	4.0 (0.2 – 8.2)	6.1 (BDL – 23.3)
Deer Prairie Slough near North Port	6.5 (2.5 – 23.0)	2.5 (BDL – 7.3)	201 (25 – 300)	6.9 (6.1 – 8.0)	223 (58 – 533)	6.6 (3.8 – 10.1)	2.6 (BDL – 5.6)
Big Slough Canal near Myakka City	5.0 (1.1 – 10.5)	3.8 (BDL – 13.8	180.5 (30 – 500)	7.2 (6.5 – 7.8)	701 (324 – 1419)	6.1 (3.2 – 8.7)	4.6 (BDL – 19.2)
Big Slough Canal near North Port Charlotte	5.2 (1.8 – 14.1)	4.3 (BDL – 12.1)	169 (30 – 350)	7.3 (6.9 – 7.9)	621 (255 – 1276)	6.6 (3.4 – 9.2	3.2 (BDL – 9.3)
Median Fla. Stream	5.2	6.5	70	7.2	366	5.8	12 [1]

[1] Median Florida lake concentration (Chl *a*)

Table 1 (cont.)

STATION	NH4 (mg N/L)	NO2+3 (mg N/L)	TKN (mg N/L)	TN (mg N/L)	PO4 (mg P/L)	TP (mg P/L)	TOC (mg C/L)
Peace Creek Canal near Wahneta	0.09 (BDL – 0.22)	0.33 (BDL – 0.79)	1.45 (1.17 – 2.12)	1.75 (1.21 – 2.84)	0.36 (0.67 – 1.05)	0.43 (0.11 – 10.6)	22.3 (13.0 – 31.0)
Saddle Creek at Structure P-11	0.02 (BDL – 0.07)	0.03 (BDL – 0.41)	4.54 (2.88 – 6.54)	4.55 (2.93 – 6.54)	0.06 (BDL – 0.24)	0.42 (0.15 – 0.71)	24.2 (11.8 – 35.4)
Peace River at Bartow	0.09 (BDL – 0.27)	0.26 (BDL – 0.90)	1.94 (0.54 – 5.10)	2.16 (0.61 – 5.11)	0.86 (0.02 – 2.97)	1.08 (0.25 – 3.11)	20.1 (12.6 – 30.0)
Peace River at Ft. Meade	0.04 (BDL – 0.08)	0.43 (0.02 – 1.17)	1.42 (0.71 – 3.10)	1.79 (1.21 – 3.16)	0.66 (0.22 – 0.94)	0.90 (0.55 – 1.27)	15.2 (8.0 – 25.0)
Peace River at Zolfo Springs	0.04 (BDL – 0.09)	0.64 (0.02 – 1.38)	1.00 (0.55 – 1.70)	1.65 (1.32 – 2.27)	0.88 (0.32 – 1.23)	1.05 (0.70 – 1.54)	15.1 (8.7 – 30.6)
Peace River at Arcadia	0.04 (BDL – 0.12)	0.59 (0.28 – 0.98)	0.97 (0.58 – 1.40)	1.55 (1.16 – 1.88)	0.73 (0.23 – 1.00)	0.91 (0.66 – 1.15)	16.2 (8.7 – 31.0)
Charlie Creek near Gardner	0.05 (BDL – 0.16)	0.28 (BDL – 0.88)	1.19 (0.59 – 2.00)	1.47 (0.61 – 2.18)	0.53 (0.26 – 0.91)	0.60 (0.30 – 1.00)	23.4 (5.0 – 47.0)
Horse Creek near Myakka Head	0.02 (BDL – 0.04)	0.08 (BDL – 0.15)	0.94 (0.41 – 1.46)	1.03 (0.51 – 1.54)	0.38 (0.18 – 0.93)	0.43 (0.23 – 0.99)	21.4 (9.5 – 35.0)
Horse Creek near Arcadia	0.03 (BDL – 0.09)	0.40 (BDL – 1.06)	0.92 (0.37 – 1.60)	1.31 (0.42 – 2.00)	0.40 (0.29 – 0.74)	0.46 (0.31 – 0.79)	19.2 (8.1 – 37.6)
Shell Creek near Punta Gorda	0.04 (BDL – 0.10)	0.09 (BDL – 0.21)	1.11 (BDL – 1.78)	1.20 (0.01 – 1.91)	0.11 (0.03 – 0.30)	0.15 (0.53 – 0.36)	18.2 (11.8 – 30.8)
Myakka River at Myakka City	0.07 (BDL – 0.30)	0.05 (BDL – 0.16)	--	--	0.30 (0.10 – 0.46)	0.32 (0.13 – 0.53)	21.0 (16.8 – 28.5)
Myakka River near Sarasota	0.04 (BDL – 0.18)	0.02 (BDL – 0.05)	1.35 (0.90 – 2.60)	1.37 (0.93 – 1.91)	0.37 (0.21 – 0.54)	0.43 (0.24 – 0.66)	23.5 (18.0 – 32.0)
Deer Prairie Slough near North Port	0.04 (BDL – 0.09)	0.02 (BDL – 0.07)	--	--	0.14 (0.04 – 0.40)	0.25 (0.07 – 0.85)	22.4 (11.6 – 33.5)
Big Slough Canal near Myakka City	0.09 (BDL – 0.24)	0.12 (BDL – 0.62)	--	--	0.28 (0.10 – 0.52)	0.36 (0.13 – 0.68)	21.9 (7.8 – 38.2)
Big Slough Canal near North Port Charlotte	0.06 (BDL – 0.20)	0.07 (BDL – 0.24)	--	--	0.29 (0.14 – 0.54)	0.36 (0.18 – 0.61)	21.4 (9.4 – 35.9)
Median Florida Stream	N/A	N/A	N/A	1.2	N/A	0.09	14

Table 2 Florida Stream Water Quality Index values (Hand et al. 1994, 1996), based on October 1997 - September 1999 sampling events. FDEP guidelines suggest that average index values of 0-44 indicate “good,” 45-60 indicate “fair,” and >60 indicate “poor” water quality conditions.

STATION	Turbidity	TSS	TOC	TN	TP	Avg. WQI (incl. TP)	Avg. WQI (w/o TP)
Peace Creek Canal near Wahneta	58	48	72	74	79	64	59
Saddle Creek at Structure P-11	>95	>95	75	>95	78	87	90
Peace River at Bartow	75	87	67	82	94	81	76
Peace River at Ft. Meade	59	66	54	75	90	67	60
Peace River at Zolfo Springs	52	52	53	71	94	63	52
Peace River at Arcadia	51	53	56	69	90	64	57
Charlie Creek near Gardner	27	28	74	63	83	55	48
Horse Creek near Myakka Head	17	11	71	41	79	44	33
Horse Creek near Arcadia	19	23	65	56	80	47	35
Shell Creek near Punta Gorda	17	11	62	50	59	37	30
Myakka River at Myakka City	7	3	70	--	74	38	27
Myakka River near Sarasota	15	8	74	58	78	44	32
Deer Prairie Slough near North Port	54	15	72	--	70	53	47
Big Slough Canal near Myakka City	49	28	73	--	76	57	50
Big Slough Canal near North Port Charlotte	41	32	61	--	75	55	48

2.3 Stream Discharge and Estimated Constituent Loads

Daily mean discharge records for the Peace and Myakka River gaging stations were provided by the USGS for water years 1998 and 1999. (Values from the 1999 water year have not yet been published by the USGS, and should therefore be viewed as provisional estimates that are potentially subject to revision.)

Above-average rainfall, primarily associated with the 1997-1998 El Niño event, produced elevated stream discharge during the initial portion of the project. At the Peace River-Arcadia gage, for example, annual average discharge during the 1998 water year was more than two times higher than the station's long term (1932-1998) annual mean.

Estimated loads of selected water quality constituents (nitrogen forms, phosphorus forms, and TSS) were calculated at each monitoring station for each month of the 1998 and 1999 water years, using the following equation:

$$L_{ijk} = C_{ijk} * Flow_{jk} * f_1 * f_2$$

where:

L_{ijk} = estimated load of constituent *i* during month *j* at station *k* (in units of metric tons/month)

C_{jk} = measured concentration of constituent *i* during month *j* at station *k* (inunits of mg/L)

$Flow_{jk}$ = cumulative flow during month *j* at station *k* (in units of ft^3), and

f_1, f_2 = conversions factors (used to convert mg to metric tons and l to ft^3).

Missing data points were eliminated by averaging the preceding and succeeding observations (e.g., missing nutrient and TSS concentrations from the December 1997 sampling event were replaced by the averages of the November 1997 and January 1998 values.) Annual (water year) loads were estimated by summing the estimated monthly loads for the period October 1997 - September 1999. The annual loading estimates are summarized in Table 3.

2.4 Loadings to Charlotte Harbor

In addition to the estimated constituent loads passing individual gaging stations each year, the CHNEP and other stakeholders are also interested in quantifying the nutrient and TSS loads that are discharged from the river basins to Charlotte Harbor. For the Peace River basin, estimates of these values can be obtained by summing the loads from three gaging stations (Peace River at Arcadia, Horse Creek near Arcadia, and Shell Creek near Punta Gorda) that are located immediately upstream from the Harbor on the river and its southernmost tributaries. These three stations have a cumulative drainage area of 1,958 mi^2 (USGS 1997), representing 83% of the Peace River

Table 3. Estimated constituent loads (metric tons/yr) during the 1998 and 1999 water years.

STATION	TN		Inorganic N		TP		PO_4-P		TSS	
	WY 98	WY 99	WY 98	WY 99	WY 98	WY 99	WY 98	WY 99	WY 98	WY 99
Peace Creek Canal near Wahneta	278	--	38	9	37	12	24	10	542	141
Saddle Creek at Structure P-11	771	--	4	1	114	12	24	3	10,719	2,643
Peace River at Bartow	781	--	86	18	214	68	132	49	6,039	2,632
Peace River at Ft. Meade	963	--	178	28	540	112	384	86	5,562	1,232
Peace River at Zolfo Springs	1,811	--	548	130	1,038	303	850	253	7,757	1,800
Peace River at Arcadia	2,997	900	1,027	295	1,617	551	1,167	485	10,925	4,021
Charlie Creek near Gardner	1,057	182	278	25	331	72	270	61	3,183	647
Horse Creek near Myakka Head	78	--	7	1	23	7	21	6	207	44
Horse Creek near Arcadia	555	--	142	41	197	62	167	53	4,203	101
Shell Creek near Punta Gorda	624	471	76	56	68	76	48	58	1,041	851
Myakka River at Myakka City	--	--	--	20	--	69	--	65	--	64
Myakka River near Sarasota	--	226	--	12	--	116	--	100	--	261
Deer Prairie Slough near North Port	--	--	--	1	--	2	--	2	--	78
Big Slough Canal near Myakka City	--	--	--	10	--	10	--	8	--	140
Big Slough Canal near North Port Charlotte	--	--	--	--	--	--	--	--	--	--

watershed (Hammett 1987). Assuming that the portion of the watershed lying downstream from the gages generates loads of each constituent that are comparable (on a per-acre basis) to the upstream portion, loads observed at these stations should represent (as a first approximation) about 83% of the watershed totals. Estimated annual loads calculated using these assumptions are shown in Table 4.

In an earlier study, annual average loads of TN, TP, and TSS from the Peace River watershed to Charlotte Harbor for the years 1985-1991 were estimated by Coastal Environmental, Inc. (1995), as part of a watershed assessment project funded by the SWFWMD Surface Water Improvement and Management (SWIM) program. For each constituent, the estimated annual loads calculated by Coastal Environmental, Inc. for the 1985-1991 period are substantially lower than the values we have calculated for the 1998 water year (Table 4). These differences are presumably due, at least in part, to the different amounts of rainfall and stormwater runoff that occurred in the watershed during the two periods. Over the years 1985-1991, for example, mean discharge at the Peace River-Arcadia gage was <60% of the site's long-term annual average. As noted previously, however, annual average discharge during the 1998 water year was more than two times higher than the long-term mean.

During the 1999 water year, annual average discharge in the lower Peace River basin fell once again to levels below the long-term mean. At the Peace River-Arcadia gage, annual average discharge during the 1999 water year was about 72% lower than in 1998. Estimated loads showed similar declines, ranging from 57% (PO_4-P) to 69% (inorganic N and TSS) between the two years.

Table 4. Estimated constituent loads (metric tons/year) from the Peace River watershed to Charlotte Harbor.

Constituent	1985-1991[a]	1998 water year[b]	1999 water year[b]
TN	1,633	5,012	--
Inorganic N	--	1,494	470
TP	580	2,260	826
PO_4-P	--	1,659	715
TSS	13,061	19,407	5,969

[a] Data source = Coastal Environmental, Inc. 1995
[b] Data source = this study

2.5 Unit area loads

Additional insight into water quality conditions within a watershed can often be obtained by examining the constituent "yields" or "unit area loads" (expressed as mass per unit area per unit time) observed in different portions of a river basin. Estimated yields (in kilograms per hectare per year) for the gaged sub-basins included in this project during the 1998 and 1999 water years are summarized in Table 5.

In general, higher per-hectare yields of nutrients and TSS occurred in both basins during the 1998 water year, presumably due to the elevated rainfall and runoff that occurred in that year. Six gaging stations (Saddle Creek at Structure P-11, Charlie Creek near Gardner, and the Peace River gages at Bartow, Ft. Meade , Zolfo Springs, and Arcadia), located in the upper and middle portions of the Peace River watershed, exhibited per-hectare nutrient yields that appear elevated relative to other sub-basins monitored in this project.

The highest estimated yields of TN (22 kg/ha/yr) occurred at the Saddle Creek gaging station during the 1998 water year, presumably reflecting the impact of discharges from Lake Hancock, a hypereutrophic waterbody that lies immediately upstream from the station. Interestingly, estimated yields of "inorganic" (nitrate, nitrite, and ammonia) nitrogen at the Saddle Creek gage were low relative to other sites in the Peace River basin. Concentrations of inorganic N were frequently below detection limits at the Saddle Creek gage, suggesting that the abundant algal populations in Lake Hancock had effectively removed much of the inorganic N from the water column and converted it to organic forms. (Nitrogen fixation by blue-green algae in Lake Hancock may also provide a significant proportion of the organic N measured at the Saddle Creek gage.)

The Saddle Creek station also exhibited the highest yields of TSS (307 kg/ha/yr and 75 kg/ha/yr, respectively) during the 1998 and 1999 water years, perhaps due to episodic discharges of algal cells and unconsolidated sediments resuspended from the bottom of Lake Hancock during storm events. Much lower TSS yields were calculated for the Peace River-Bartow gaging station, which is located less than 5 miles downstream from the Saddle Creek station, in both years.

Elevated TP yields were observed at the gages located on the main stem of the Peace River (at Ft. Meade, Zolfo Springs and Arcadia) and on the main stem of the Myakka River (at Myakka City and Sarasota) presumably reflecting the abundance of phosphate-bearing geological deposits and the active mining and processing of phosphate products that occur in both basins.

Substantial increases in the estimated yields of TN, inorganic N, TP, and PO_4-P occurred between the upstream and downstream stations located on Horse Creek, suggesting the potential presence of anthropogenic sources of those constituents at one or more locations between the two stations.

Table 5. Estimated sub-basin yields (kilograms/hectare/year) during the 1998 and 1999 water years.

STATION	TN WY 98	TN WY 99	Inorganic N WY 98	Inorganic N WY 99	TP WY 98	TP WY 99	PO_4-P WY 98	PO_4-P WY 99	TSS WY 98	TSS WY 99
Peace Creek Canal near Wahneta	6.6	--	0.9	0.2	0.9	0.3	0.6	0.2	12.9	3.4
Saddle Creek at Structure P-11	22.1	--	0.1	0.04	3.3	0.3	0.7	0.1	306.6	75.6
Peace River at Bartow	7.7	--	0.8	0.2	2.1	0.7	1.3	0.5	59.8	26.1
Peace River at Ft. Meade	8.0	--	1.5	0.2	4.5	0.9	3.2	0.7	46.2	10.2
Peace River at Zolfo Springs	8.5	--	2.6	0.6	4.9	1.4	4.0	1.2	36.3	8.4
Peace River at Arcadia	8.5	2.5	2.9	0.8	4.6	1.6	3.3	1.4	30.9	11.4
Charlie Creek near Gardner	12.4	2.1	3.3	0.3	3.9	0.8	3.2	0.7	37.2	7.6
Horse Creek near Myakka Head	7.4	--	0.7	0.1	2.2	0.6	1.9	0.6	19.5	4.1
Horse Creek near Arcadia	9.8	--	2.5	0.7	3.5	1.1	3.0	0.9	74.5	1.8
Shell Creek near Punta Gorda	6.6	4.9	0.8	0.6	0.7	0.8	0.5	0.6	10.8	8.8
Myakka River at Myakka City	--	--	--	0.6	--	2.1	--	2.0	--	2.0
Myakka River near Sarasota	--	--	--	0.2	--	2.0	--	1.7	--	4.4
Deer Prairie Slough near North Port										
Big Slough Canal near Myakka City	--	--	--	1.0	--	1.1	--	0.9	--	14.8
Big Slough Canal near North Port Charlotte	--	--	--	--	--	--	--	--	--	--

3.0 Long-term Trends in Stream Flow and Water Quality

In addition to the monthly water quality monitoring data collected during the 1998 and 1999 water years, stream discharge and water quality records for the years 1970-1998 were also obtained, in digital form from a USGS database, for a number of long-term gaging stations located in the Peace and Myakka River basins. The locations of these stations are shown in Fig. 2. Summaries of the methods used to collect, analyze and disseminate these records are provided in Water Resources Data Reports (e.g., USGS 1999), which are published annually by the agency.

The years for which daily mean discharge records were available varied between stations (summarized in Table 6). Eight stations in the Peace River basin and 1 station in the Myakka River basin had complete daily records covering the entire (1970-1998) period of interest. Continuous daily records were also available from the remaining stations for a number of years, but monitoring at those sites was either initiated or terminated at some point within the 1970-1998 period (Table 6).

The number of water quality records present in the USGS data set also varied between stations, years, and water quality constituents. For a given constituent and station, all years in which <4 records were available were omitted from the analyses reported here, due to a concern that "infrequent" (e.g., less than quarterly) sampling might produce data that are not representative of the full range of water quality conditions occurring in those years.

For cases meeting these minimum data requirements, summary statistics (e.g., minimum, mean and maximum values) were calculated for stream discharge and constituent concentrations, on monthly and annual time steps. Concentration data flagged as "<" by the USGS — indicating that the actual value was known to be less than the reported value — were reduced to 0.5x the reported values prior to analysis.

The statistical significance of multi-year trends was assessed using the nonparametric Mann-Kendall test (Gilbert 1987). Tests for trend were performed on annual minimum, annual mean, and annual maximum values of each water quality indicator. Trend tests were also performed on annual minimum ("lowest monthly mean") and annual maximum ("highest monthly mean") discharge, and on annual runoff (serving as a proxy for annual mean discharge). Trend tests were not performed for water quality constituents for which the available period of record was <10 years.

3.1 Peace River Stations

Levels and trends in minimum and maximum monthly discharge and annual runoff at the Peace River gaging stations are summarized in Table 6. Monthly mean discharge was extremely variable, ranging from zero in headwater areas and tributary streams following periods of low rainfall to >6,000 cubic feet per second (cfs) on the river's main stem during periods of high flow. Trend analyses suggest that stream flow patterns underwent changes at several stations during the 1970-1998 period. The magnitude or

Insert Fig. 2
(locations of USGS gages used in long-term analyses)
on this page

duration of low-flow periods apparently intensified at the Bartow and Zolfo Springs stations, as evidenced by significant ($p<0.05$) downward trends in “lowest monthly mean” discharges over the 29-year period. A marginally significant ($p<0.10$) downward trend in lowest monthly mean flow also occurred at the Ft. Meade station. In contrast, low-flow episodes became less pronounced at two tributary sites (Charlie Creek-Gardner and Joshua Creek-Nocatee). At these stations, lowest monthly mean discharges increased significantly between 1970 and 1998 (Table 6). Marginally significant increasing trends in dry-season flows also occurred at the Horse Creek-Arcadia and Shell Creek-Punta Gorda stations (Table 6).

Wet-season flows — as measured by the “highest monthly mean” discharges recorded each year — exhibited significant increasing trends at several stations (Saddle Creek-P11, Peace River-Bartow, Peace River-Ft. Meade, and Peace River-Zolfo Springs) during the 1970-1998 period. Each of these stations is located in the northern portion of the basin.

Total annual runoff exhibited increasing trends at one station on the river’s main stem (Peace River-Ft. Meade), and at four tributary stations (Saddle Creek-P11, Joshua Creek-Nocatee, and Horse Creek-Arcadia) over the 1970-1998 period.

Long-term trends in discharge and runoff in the Peace River watershed are a topic of considerable interest to resource managers in the west-central Florida region. Several investigators have documented long-term declines in annual mean discharge, particularly at gaging stations on the river’s main stem in the northern portion of the watershed, that occurred between the 1930’s and 1990’s (e.g., Hammett 1987, Coastal Environmental Services 1995). These declining trends appear to have been caused by a combination of natural (e.g., reduced frequency of tropical cyclones) and anthropogenic factors (e.g., increased groundwater pumpage; surface strip mining)(Hammett 1987, Coastal Environmental Services 1995). Because the declines occurred prior to 1970 (Hammett 1987), they were not detected in the analyses shown in Table 6.

Human activities can also produce increasing trends in dry-season stream discharge, through the pumpage and subsequent release of groundwater at the land surface, and in wet-season discharge by increasing the amount of impervious material (e..g., paved roadways) present on the land surface.

The variety of discharge and runoff trends observed at different gaging stations over the 1970-1998 period appear to reflect the full range of these natural and manmade effects.

3.1.1 Specific Conductance

Specific conductance records for the 1970-1998 period are summarized in Table 7. Statistically significant ($p<0.05$) trends in annual mean specific conductance occurred at three tributary stations (Charlie Creek-Gardner, Joshua Creek-Nocatee, and Horse Creek-Myakka Head), and a marginally significant ($p<0.10$) increasing trends occurred at one station (Shell Creek-Punta Gorda). Significant downward trends in annual mean specific conductance occurred at three stations (Saddle Creek-P11, Peace River-Bartow, and Peace River-Zolfo Springs), all located in the northern half of the watershed. A marginally significant downard trend in annual mean values occurred at the Peace River-Ft. Meade station, which is also located in the northern half of the watershed.

The upward trends in specific conductance most likely reflect increased discharges of groundwater (e.g., via spring discharges or return flows from industrial or agricultural facilities) into surface waters in the sub-basins in which the trends were observed. The downward trends presumably reflect declining inputs of groundwater to surface waters in the areas where those trends occurred, perhaps in response to regional declines in the potentiometric surface of the Upper Floridan aquifer in the northern portion of the Peace River basin (e.g., Hammett 1987).

3.1.2 pH

Higher-than-normal pH levels (>10 standard units) were observed at the Saddle Creek-P11 and Peace River-Bartow gaging stations, presumably in response to discharges from Lake Hancock and other hypereutrophic lakes and impoundments located upstream from these stations (Table 8). The high rates of algal photosynthesis occurring in hypereutrophic lakes tend to reduce CO_2 concentrations in the water column, affecting the equilibrium point of the CO_2-H_2CO_3 buffering system and increasing ambient pH values.

More acidic pH values (e.g., <6.0 standard units) were also recorded occasionally at all stations during the 1970-1998 period (Table 8), perhaps reflecting episodic inputs of low-pH water from natural (e.g., cypress swamps or the surficial aquifer) or manmade sources (e.g., mine discharges).

A significant downward trend in annual mean pH occurred at the Charlie Creek-Gardner site, and a marginally significant downward trend occurred at the Horse Creek-Arcadia site over the period 1970 - 1998. No stations exhibited significant increasing trends in annual mean pH during the period.

3.1.3 Dissolved oxygen

Substantially elevated (>10 mg/L) and depressed (<3 mg/L) DO concentrations were recorded at most stations during the 1970-1998 period (Table 9). A significant upward trend in annual mean DO occurred at the Peace River-Ft. Meade station, and a marginally significant increase was observed at the Peace River-Zolfo Springs stations. Significant downward trends occurred at the Charlie Creek-Gardner and Peace River-Arcadia stations.

3.1.4 Nitrogen forms

3.1.4.1 Nitrite+Nitrate N

Average concentrations of NO_{2+3} –N during 1970-1998 ranged from <0.05 mg N/L at the Saddle Creek-P11 station to >0.5 mg N/L at several stations in other portions of the watershed (Table 10). Significant upward trends in annual mean NO_{2+3}-N concentration occurred at the Horse Creek-Arcadia and Charlie Creek-Gardner stations, both located on tributary streams in the southern half of the watershed. Significant downward trends in annual mean NO_{2+3}-N concentration occurred at the Peace River-Bartow, Peace River-Ft. Meade, and Peace River-Zolfo Springs stations, all located on the river's main stem in the northern portion of the watershed.

Substantial changes in concentrations of NO_{2+3} –N in surface water bodies are frequently caused by land use changes and other anthropogenic activities occurring within their watersheds. Such activities could be examined as potential causes underlying the trends in NO_{2+3} –N concentrations observed at gaging stations in the Peace River basin during the 1970-1998 period.

3.1.4.2 NH_4-N

Average NH_4-N concentrations ranged from below detection limit (observed periodically at most stations) to >10 mg N/L (the maximum value recorded at the Saddle Creek-P11 station, located immediately downstream from Lake Hancock)(Table 11). No significant upward trends in annual mean ammonium concentrations were observed at any station. Significant downward trends in annual mean concentrations occurred at the four stations located on the river's main stem (Peace River-Bartow, Ft. Meade, Zolfo Springs, and Arcadia), presumably reflecting reductions in NH_4 loads from one or more manmade sources discharging in the northern portion of the watershed.

3.1.4.3 TKN

Average concentrations of total Kjeldahl (combined organic + ammonia) nitrogen at the Saddle Creek-P11 and Peace River-Bartow stations exceeded 2 mg N/L over the 1970-1998 period. Average concentrations in other portions of the watershed ranged between 0.7 and 1.7 mg/L (Table 12). Significant downward trends in annual mean concentrations occurred at the Peace River-Bartow and Charlie Creek-Gardner stations, and a marginally significant downward trend occurred at the Peace River-Arcadia station. A marginally significant upward trend occurred at the Peace River-Zolfo Springs station (Table 12).

3.1.4.4 Total Nitrogen

Average TN concentrations ranged from ca. 1 mg/L at the two Horse Creek stations to >5 mg/L at the Saddle Creek station located immediately downstream from Lake Hancock (Table 13). Average concentrations at or above the FDEP "screening level"

(Hand et al. 1988) of 2.0 mg/L occurred at the Saddle Creek, Peace River-Bartow, Peace River-Ft. Meade, and Peace River-Zolfo Springs stations. (The FDEP screening level is intended to serve as an indicator of potential water quality impacts.)

Significant declining trends in annual mean TN concentrations were recorded at the Peace River-Bartow and Peace River-Ft. Meade gaging stations (Table 13), presumably reflecting the significant downward trends in concentrations of NO_{2+3} and other nitrogen forms also observed at those stations.

3.1.4.5 Phosphorus Forms (PO_4 and TP)

Average TP concentrations ranged from <0.2 mg P/L (at the Shell Creek-Punta Gorda station) to >1 mg P/L (at the Arcadia, Zolfo Springs, Ft. Meade, and Bartow stations on the river's main stem)(Table 15). PO_4 concentrations were of similar magnitude and showed similar spatial patterns (Table 14). The FDEP "screening level" for TP in streams is 0.46 mg P/L (Hand et al. 1988).

Long-term declining trends in phosphorus concentrations in surface waters within the Peace River basin, apparently associated with the activity levels and production processes used by the phosphate mining and fertilizer processing industries, have been noted by several investigators (e.g., Fraser 1986, Hammett 1987). Those trends are also evident in the 1970-1998 USGS data (Tables 14-15). Highly significant downward trends in PO_4 and TP concentrations occurred at the Peace River-Bartow, Peace River-Ft. Meade, Peace River-Zolfo Springs, Peace River-Arcadia, and Horse Creek-Arcadia gaging stations. Only the Charlie Creek-Gardner station exhibited significant upward trends, suggesting that an increase in anthropogenic phosphorus discharges may have occurred in the Charlie Creek sub-basin during the years 1970-1988.

Table 6. Reported levels and trends in stream discharge and annual runoff, 1970-1998. (ρ or ο indicate highly significant [p<0.05] trend; ω or ξ indicate marginally significant [0.10>p>0.05] trend; n.t. indicates non-significant [p>0.10] trend. Values in parentheses = significance levels.)

		Discharge (cfs)			Trends in Discharge and Runoff (Mann-Kendall significance level)		
Station	Period (years)	Lowest Monthly Mean	Overall Mean	Highest Monthly Mean	Lowest Monthly Mean Discharge (cfs)	Annual Runoff	Highest Monthly Mean Discharge (cfs)
Saddle Creek Structure P-11	1970 – 1998	0	60.3	693.4	n.t. (>0.10)	ρ (0.02)	ρ (0.04)
Peace River Bartow	1970 – 1998	6.1	162.1	1536.1	ο (0.01)	ω (0.06)	ρ (0.04)
Peace River Ft. Meade	1975 – 1998	2.2	198.9	1849.7	ξ (0.09)	ρ (0.04)	ρ (0.01)
Peace River Zolfo Springs	1970 – 1998	42.4	499.1	3860	ο (0.04)	n.t. (>0.10)	ρ (0.04)
Charlie Creek Gardner	1970 – 1998	0.3	220.2	2274.9	ρ (0.02)	n.t. (>0.10)	n.t. (>0.10)
Peace River Arcadia	1970 – 1998	51.6	857.9	6410	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)
Joshua Creek Nocatee	1970 – 1998	1.2	98.9	1133.2	ρ (0.001)	ρ (0.04)	n.t. (>0.10)
Horse Creek Myakka Head	1978 – 1998	<0.1	30.3	297.0	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)
Horse Creek Arcadia	1970 – 1998	0.3	165.7	1854	ω (0.07)	ρ (0.05)	ω (0.08)
Shell Creek Punta Gorda	1970 – 1998	0	323.8	2485.2	ω (0.10)	n.t. (>0.10)	n.t. (>0.10)
Myakka River Sarasota	1970 – 1998	0	241.2	1853.6	ρ (0.013)	ω (0.07)	n.t. (>0.10)

Table 7. Reported levels and trends in specific conductance, 1970-1998.

Station	Period (years)	n (years)	n (obs)	Specific Conductance (uS/cm)			Specific ConductanceTrends (Mann-Kendall significance level)		
				Minimum	Mean	Maximum	Annual Minimum	Annual Mean	Annual Maximum
Saddle Creek Structure P-11	1973 – 1994	17	100	198	317	595	n.t. (>0.10)	ο (0.05)	ο (0.01)
Peace River Bartow	1971 – 1998	28	195	125	323	790	ξ (0.07)	ο (0.001)	ο (0.001)
Peace River Ft. Meade	1973 – 1998	26	180	175	405	715	n.t. (>0.10)	ξ (0.09)	ξ (0.07)
Peace River Zolfo Springs	1970 – 1998	28	201	130	395	742	n.t. (>0.10)	ο (0.04)	ο (0.02)
Charlie Creek Gardner	1970 – 1998	20	127	70	207	410	ρ (0.03)	ρ (0.002)	ρ (0.004)
Peace River Arcadia	1970 – 1998	28	266	81	342	635	n.t. (>0.10)	n.t. (>0.10)	ο (0.05)
Joshua Creek Nocatee	1973 – 1998	21	132	125	533	1040	ρ (0.001)	ρ (0.002)	ω (0.098)
Horse Creek Myakka Head	1979 – 1998	11	67	46	132	340	ρ (0.03)	ρ (0.01)	ρ (0.03)
Horse Creek Arcadia	1971 – 1998	28	187	64	297	945	ω (0.07)	n.t. (>0.10)	n.t. (>0.10)
Shell Creek Punta Gorda	1972 – 1998	23	146	130	640	1200	ρ (0.009)	ω (0.08)	n.t. (>0.10)
Myakka River Sarasota	1971 – 1998	28	134	70	217	678	ρ (0.001)	ρ (0.001)	ρ (0.004)

Table 8. Reported levels and trends in pH, 1970-1998.

Station	Period (years)	n (years)	N (obs)	pH			pH Trends (Mann-Kendall significance level)		
				Minimum	Mean	Maximum	Annual Minimum	Annual Mean	Annual Maximum
Saddle Creek Structure P-11	1978 – 1994	17	102	5.8	8.4	10.4	n.t. (>0.10)	n.t. (>0.10)	ο (0.02)
Peace River Bartow	1971 – 1998	25	168	5.3	6.9	10.1	n.t. (>0.10)	n.t. (>0.10)	ξ (0.065)
Peace River Ft. Meade	1978 – 1998	21	144	5.7	7.1	9.1	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)
Peace River Zolfo Springs	1970 – 1998	26	168	4.2	7.2	9.2	n.t. (>0.10)	n.t. (>0.10)	ρ (0.05)
Charlie Creek Gardner	1978 – 1998	14	90	5.1	6.8	9.3	ο (0.01)	ο (0.045)	n.t. (>0.10)
Peace River Arcadia	1970 – 1998	27	239	4.5	7.2	9.1	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)
Joshua Creek Nocatee	1978 – 1998	16	96	4.7	7.0	8.8	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)
Horse Creek Myakka Head	1979 – 1998	11	68	4.7	6.4	7.9	n.t. (>0.10)	n.t. (>0.10)	ξ (0.07)
Horse Creek Arcadia	1978 – 1998	21	142	4.4	6.7	9.0	ξ (0.08)	ξ (0.06)	ο (0.003)
Shell Creek Punta Gorda	1978 – 1998	17	103	5.9	7.2	9.0	ω (0.08)	n.t. (>0.10)	n.t. (>0.10)
Myakka River Sarasota	1978 – 1998	14	116	4.6	6.6	8.4	ξ (0.08)	ο (0.02)	ο (0.02)

Table 9. Reported levels and trends in DO, 1970-1998.

Station	Period (years)	n (years)	n (obs)	Dissolved Oxygen (mg/L)			D.O.Trends (Mann-Kendall significance level)		
				Minimum	Mean	Maximum	Annual Minimum	Annual Mean	Annual Maximum
Saddle Creek Structure P-11	1973 – 1993	16	92	0.1	7.5	16.7	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)
Peace River Bartow	1971 – 1998	27	193	1.1	5.0	11.1	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)
Peace River Ft. Meade	1973 – 1998	25	168	1.0	6.1	11.2	ρ (<0.001)	ρ (0.02)	n.t. (>0.10)
Peace River Zolfo Springs	1971 – 1998	25	190	3.8	7.3	12.9	n.t. (>0.10)	ω (0.09)	n.t. (>0.10)
Charlie Creek Gardner	1970 – 1998	20	128	3.5	6.8	16.8	n.t. (>0.10)	ο (0.01)	n.t. (>0.10)
Peace River Arcadia	1971 – 1998	28	235	3.5	7.2	12.4	n.t. (>0.10)	ο (0.03)	ο (0.04)
Joshua Creek Nocatee	1972 – 1998	21	124	3.2	6.9	11.6	ω (0.08)	n.t. (>0.10)	n.t. (>0.10)
Horse Creek Myakka Head	1979 – 1998	11	67	1.0	7.2	11.0	n.t. (>0.10)	ξ (0.06)	n.t. (>0.10)
Horse Creek Arcadia	1971 – 1998	27	173	1.9	7.1	11.7	ρ (0.02)	n.t. (>0.10)	n.t. (>0.10)
Shell Creek Punta Gorda	1972 – 1998	23	144	0.2	4.6	9.6	ρ (0.001)	n.t. (>0.10)	n.t. (>0.10)
Myakka River Sarasota	1978 - 1998	14	106	0.1	4.4	9.0	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)

Table 10. Reported levels and trends in nitrite + nitrate nitrogen, 1970-1998.

				NO_{2+3} – N (mg/L)			NO_{2+3} Trend (Mann-Kendall significance level)		
Station	Period (years)	n (years)	n (obs)	Minimum	Mean	Maximum	Annual Minimum	Annual Mean	Annual Maximum
Saddle Creek Structure P-11	1983 – 1994	9	44	<0.01	0.023	0.3			
Peace River Bartow	1975 – 1998	24	147	0.01	0.29	2.6	n.t. (>0.10)	ο (0.001)	ο (0.001)
Peace River Ft. Meade	1982 – 1998	17	101	<0.001	0.59	4.0	n.t. (>0.10)	ο (0.004)	ο (0.003)
Peace River Zolfo Springs	1975 – 1998	23	139	0.09	0.93	2.7	ο (0.02)	ο (0.001)	ο (0.001)
Charlie Creek Gardner	1980 – 1998	12	67	<0.001	0.28	1.7	n.t. (>0.10)	ρ (0.004)	ρ (0.009)
Peace River Arcadia	1974 – 1998	13	96	0.01	0.74	2.6	n.t. (>0.10)	ρ (0.05)	ρ (0.02)
Joshua Creek Nocatee	1984 – 1998	9	51	0.01	0.88	2.1			
Horse Creek Myakka Head	1992 – 1998	6	35	0.01	0.10	0.4			
Horse Creek Arcadia	1980 – 1998	19	108	<0.001	0.48	4.0	n.t. (>0.10)	ρ (0.01)	ρ (0.001)
Shell Creek Punta Gorda	1984 – 1998	7	44	<0.01	0.08	0.2			
Myakka River Sarasota	1978 - 1998	8	86	<0.001	0.01	0.04			

Table 11. Reported levels and trends in NH_4-N 1970-1998.

				NH_4 – N (mg/L)			NH_4 – N Trend (Mann-Kendall significance level)		
Station	Period (years)	n (years)	n (obs)	Minimum	Mean	Maximum	Annual Minimum	Annual Mean	Annual Maximum
Saddle Creek Structure P-11	1983 - 1994	9	44	<0.01	0.43	15			
Peace River Bartow	1971 - 1998	28	170	<0.01	0.22	2.9	n.t. (>0.10)	ο (0.045)	ξ (0.065)
Peace River Ft. Meade	1982 - 1998	17	102	<0.01	0.14	1.4	n.t. (>0.10)	ο (0.01)	ο (0.02)
Peace River Zolfo Springs	1972 - 1998	26	156	<0.01	0.08	0.88	ο (0.04)	ο (<0.001)	ο (<0.001)
Charlie Creek Gardner	1980 - 1998	12	68	<0.001	0.05	0.15	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)
Peace River Arcadia	1971 - 1998	22	167	<0.01	0.07	0.37	n.t. (>0.10)	ο (<0.001)	ο (<0.001)
Joshua Creek Nocatee	1984 - 1998	9	51	0.02	0.05	0.15			
Horse Creek Myakka Head	1992 – 1998	6	36	<0.01	0.03	0.07			
Horse Creek Arcadia	1980 - 1998	19	108	<0.001	0.04	0.27	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)
Shell Creek Punta Gorda	1984 - 1998	7	44	0.01	0.05	0.11			
Myakka River Sarasota	1970 - 1998	10	98	<0.005	0.08	0.70	ρ (0.03)	n.t. (>0.10)	n.t. (>0.10)

Table 12. Reported levels and trends in total Kjeldahl nitrogen (TKN), 1970-1998.

				TKN (mg/L)			TKN Trend (Mann-Kendall significance level)		
Station	Period (years)	n (years)	n (obs)	Minimum	Mean	Maximum	Annual Minimum	Annual Mean	Annual Maximum
Saddle Creek Structure P-11	1983 – 1994	9	44	1.3	5.9	26			
Peace RiverBartow	1975 – 1998	24	147	0.1	2.5	11.0	ξ (0.075)	ξ (0.054)	ο (0.01)
Peace RiverFt. Meade	1982 – 1998	17	97	0.4	1.7	8.4	n.t. (>0.10)	n.t. (>0.10)	ο (0.01)
Peace RiverZolfo Springs	1975 – 1998	23	139	0.4	1.1	4.9	ρ (0.01)	ω (0.09)	n.t. (>0.10)
Charlie CreekGardner	1980 – 1998	12	67	0.1	1.2	3.1	n.t. (>0.10)	ο (0.03)	n.t. (>0.10)
Peace RiverArcadia	1974 – 1998	24	189	0.1	1.1	5.3	n.t. (>0.10)	ξ (0.095)	ο (0.04)
Joshua CreekNocatee	1984 – 1998	9	51	0.3	1.0	1.7			
Horse CreekMyakka Head	1992 – 1998	6	36	0.4	0.9	2.4			
Horse CreekArcadia	1980 – 1998	19	108	0.3	1.0	1.9	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)
Shell CreekPunta Gorda	1984 – 1998	7	44	0.2	1.0	1.5			
Myakka RiverSarasota	1979 – 1998	13	95	0.6	1.3	9.0	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)

Table 13. Reported levels and trends in total nitrogen, 1970-1998.

				Total Nitrogen (mg/L)			TN Trend (Mann-Kendall significance level)		
Station	Period (years)	n (years)	n (obs)	Minimum	Mean	Maximum	Annual Minimum	Annual Mean	Annual Maximum
Saddle Creek Structure P-11	1983 - 1994	9	44	1.3	5.9	26.0			
Peace River Bartow	1975 - 1998	24	147	0.1	2.8	11.0	n.t. (>0.10)	ο (0.048)	ο (0.01)
Peace RiverFt. Meade	1982 - 1998	17	101	0.7	2.3	8.4	ξ (0.10)	ο (0.02)	ο (0.04)
Peace RiverZolfo Springs	1975 - 1998	23	139	0.9	2.0	5.3	n.t. (>0.10)	ξ (0.06)	n.t. (>0.10)
Charlie Creek Gardner	1980 - 1998	12	67	0.1	1.5	3.2	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)
Peace River Arcadia	1974 - 1998	13	93	0.4	1.9	3.8	n.t. (>0.10)	n.t. (>0.10)	ο (0.03)
Joshua Creek Nocatee	1984 - 1998	9	51	0.4	1.9	3.4			
Horse Creek Myakka Head	1992 - 1998	6	35	0.4	1.0	2.5			
Horse Creek Arcadia	1980 - 1998	19	108	0.5	1.4	4.9	n.t. (>0.10)	ω (0.09)	ω (0.07)
Shell Creek Punta Gorda	1984 - 1998	7	44	0.2	1.1	1.7			
Myakka River Sarasota	1978 - 1998	8	73	0.7	1.5	9.1			

Table 14. Reported levels and trends in ortho-phosphorus, 1970-1998.

				PO_4 – P (mg/L)			PO_4 – P trend (Mann-Kendall significance level)		
Station	Period (years)	n (years)	n (obs)	Minimum	Mean	Maximum	Annual Minimum	Annual Mean	Annual Maximum
Saddle Creek Structure P-11	1983 – 1994	9	44	0.02	0.20	0.90			
Peace River Bartow	1972 – 1998	27	169	<0.01	3.80	52.00	o (0.005)	o (0.001)	o (0.001)
Peace River Ft. Meade	1982 – 1998	17	103	0.40	1.20	4.90	o (0.001)	o (0.001)	o (0.001)
Peace River Zolfo Springs	1972 – 1998	26	157	0.03	2.10	21.00	o (0.001)	o (0.001)	o (0.001)
Charlie Creek Gardner	1980 – 1998	12	68	<0.01	0.50	1.00	ρ (0.10)	ρ (0.02)	n.t. (>0.10)
Peace River Arcadia	1971 – 1995	15	121	0.10	2.00	9.70	o (0.001)	o (0.001)	o (0.001)
Joshua Creek Nocatee	1984 – 1995	9	51	0.06	0.20	0.40			
Horse Creek Myakka Head	1992 – 1998	6	36	0.08	0.40	0.80			
Horse Creek Arcadia	1971 – 1998	20	113	0.05	0.40	1.00	o (0.017)	o (0.009)	o (0.032)
Shell Creek Punta Gorda	1984 – 1998	7	44	<0.01	0.12	0.66			
Myakka River Sarasota	1971 - 1998	9	89	0.02	0.32	0.77			

Table 15. Reported levels and trends in total phosphorus, 1970-1998.

				Total Phosphorus (mg/L)			TP Trend (Mann-Kendall significance level)		
Station	Period (years)	n (years)	n (obs)	Minimum	Mean	Maximum	Annual Minimum	Annual Mean	Annual Maximum
Saddle Creek Structure P-11	1983 – 1994	9	44	0.2	0.7	4.4			
Peace RiverBartow	1972 – 1998	27	167	<0.01	4.1	52	ξ (0.07)	ο (0.001)	ο (0.001)
Peace RiverFt. Meade	1982 – 1998	17	103	0.4	1.4	4.9	ο (0.001)	ο (0.001)	ο (0.001)
Peace RiverZolfo Springs	1972 – 1998	26	157	0.07	2.3	21	ο (0.001)	ο (0.001)	ο (0.001)
Charlie CreekGardner	1980 – 1998	12	67	0.01	0.6	1.0	ω (0.08)	ρ (0.04)	n.t. (>0.10)
Peace RiverArcadia	1971 – 1998	28	227	0.1	1.8	10	ο (0.001)	ο (0.001)	ο (0.001)
Joshua CreekNocatee	1984 – 1998	9	50	0.7	0.2	0.5			
Horse CreekMyakka Head	1992 – 1998	6	36	0.1	0.4	0.9			
Horse CreekArcadia	1971 – 1998	20	112	0.3	0.5	1.2	ο (0.001)	ο (0.001)	ο (0.001)
Shell CreekPunta Gorda	1984 – 1998	7	44	0.04	0.16	0.9			
Myakka RiverSarasota	1971 – 1998	15	121	0.03	0.39	1.10	ρ (0.03)	ω (0.06)	n.t. (>0.10)

3.2 Myakka River Station

In contrast to the Peace River system, long-term water quality and stream discharge data were available from only one USGS monitoring station (Myakka River near Sarasota) in the Myakka River basin. Trends occurring at that station over the years 1970-1998 are also summarized in Tables 6-15.

Minimum monthly stream discharge exhibited a highly significant increasing trend, and average annual discharge showed a marginally significant increase, over the 29-year period (Table 6). Specific conductance also showed highly significant increasing trends (Table 7). Taken together, these trends in discharge and conductance imply that surface waters at one or more locations upstream from the Myakka River-Sarasota gaging station received increasing groundwater inputs during the years 1970 – 1998.

Annual average and annual minimum total phosphorus concentrations also showed significant increasing trends over the period (Table 15), as did annual NH_4-N concentrations (Table11). Because these nutrients are important in the eutrophication process, and the increasing trends are occurring at a site that is located within the Myakka River State Park, this finding may be of interest to State and regional water quality managers.

Studies funded by the SWFWMD (e.g., Coastal Environmental/PBS&J 1998, PBS&J 1999) have explored a variety of hydrologic modifications and related habitat changes that have occurred in the upper Myakka River basin in recent decades. Increases in seasonal high water elevations, and more extended seasonal hydroperiods in wetlands, have been documented in portions of the upper basin and have been implicated in the extensive tree mortality that has occurred in the area in recent years (Coastal Environmental/ PBS&J 1998, PBS&J 1999). A combination of anthropogenic (e.g., agricultural irrigation practices) and natural factors (e.g., El Nino rain events) are thought to have contributed to the hydrologic, water quality, and ecological changes observed in the area (Coastal Environmental/PBS&J 1998, PBS&J 1999).

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