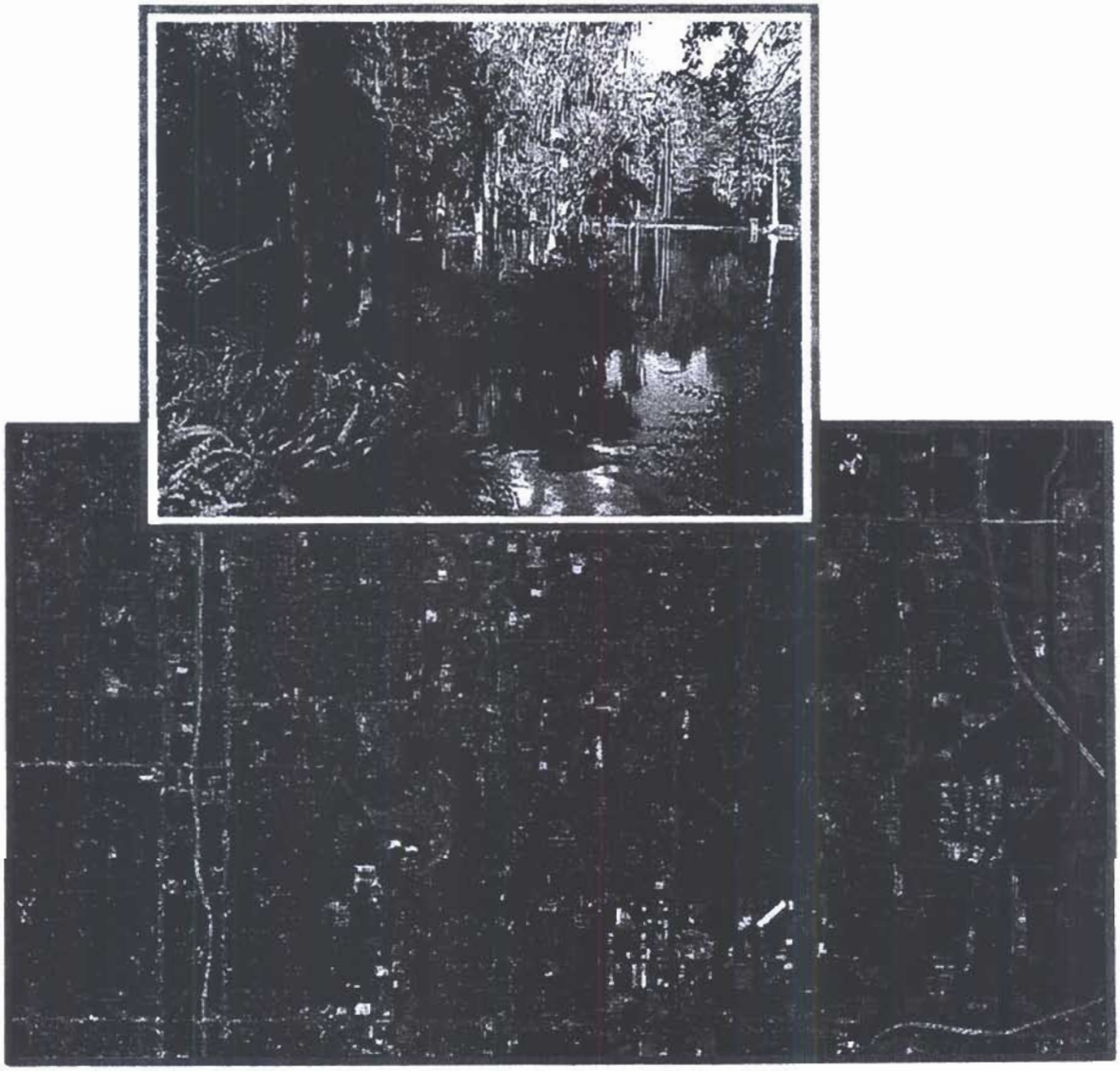
TAMPA BAY ESTUARY PROGRAM
Technical Report #10-00

Contribution of Total Nitrogen Loading to the Hillsborough River Reservoir from Crystal Springs



Prepared for the Tampa Bay Estuary Program

by the

Ambient Ground-Water Quality Monitoring Program
Southwest Florida Water Management District

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February, 1999

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INTRODUCTION

This report has been prepared for the Tampa Bay National Estuary Program (TBNEP) under a contract between the Tampa Bay Regional Planning Council (TBRPC) and the Southwest Florida Water Management District (SWFWMD). The contribution of total nitrogen (TN) discharged from Crystal Springs to the lower Hillsborough River was investigated.

Spring discharge from the Floridan aquifer has been identified as a significant source of nutrients to riverine and estuarine systems (Jones *et al.*, 1996, 1997, 1998). Nutrients (e.g. nitrate) have been shown to enhance the growth of nuisance aquatic vegetation which can inhibit light penetration to beneficial aquatic species. A recurring problem in the Hillsborough River Reservoir (HRR) is the accelerated growth of blue-green algae caused by the impoundment of nutrient-rich river water (SWFWMD, 1998). Discharge from Crystal Springs, reported by the U.S. Geological Survey from 1989 to 1998, averaged 44 cubic feet per second (cfs), or approximately 28 million gallons per day (mgd) into the Hillsborough River.

DESCRIPTION OF THE STUDY AREA

The Hillsborough River, originating in the Green Swamp of west-central Florida (Figure 1), flows southwesterly for approximately 54 miles through Polk, Pasco, and Hillsborough Counties, and discharges into Hillsborough Bay (SWFWMD, 1988). The Hillsborough River watershed is comprised of 63 sub-basins which drain a total area of approximately 675 square miles (Appendix I). In the upper portion of the basin, Crystal Springs, a second magnitude spring (discharges of 10-100 cubic feet per second), and three major tributaries, Blackwater Creek, Trout Creek, and Cypress Creek, contribute a significant amount of flow to the Hillsborough River (SWFWMD, 1988). Numerous smaller tributaries also contribute flow to the upper and central portions of the river.

Just north of Fletcher Avenue a flood-control structure can divert high flows from the Hillsborough River to Tampa Bay through the Tampa Bypass Canal (TBC). Approximately 1.5 miles below Fletcher at Fowler Avenue is the upper limit of the HRR from which the City of Tampa draws approximately 75% of its drinking water (FDEP, 305b, 1996). Four miles long and covering 328 acres (Richard Gant, pers. comm.), the reservoir is formed from a section of the river that has been impounded by a dam belonging to the City of Tampa. The TBC and Sulphur Springs, a second magnitude spring located on the Hillsborough River south of the dam, are used to augment the supply of water to the reservoir during periods of low-flow or drought. South of the reservoir dam the river flows approximately 10 miles through areas of urbanized Tampa before discharging into Hillsborough Bay.

Wetland forests are numerous in the northernmost segments of the Hillsborough River watershed. Major land use in the upper sub-basin regions include agriculture, rangeland, and urban development in Zephyrhills, Crystal Springs, and Plant City. In the central and lower portions of the river basin, land use is predominantly urban through the cities of Temple Terrace and Tampa. The river channel has been modified throughout the lower segment of the river by the construction of seawalls, riprap, and bridges (FDEP, 305b, 1996). A more detailed description of land use in the Hillsborough River Basin is discussed in *The Hillsborough River Comprehensive Watershed Management Draft Plan (*SWFWMD, 1998).

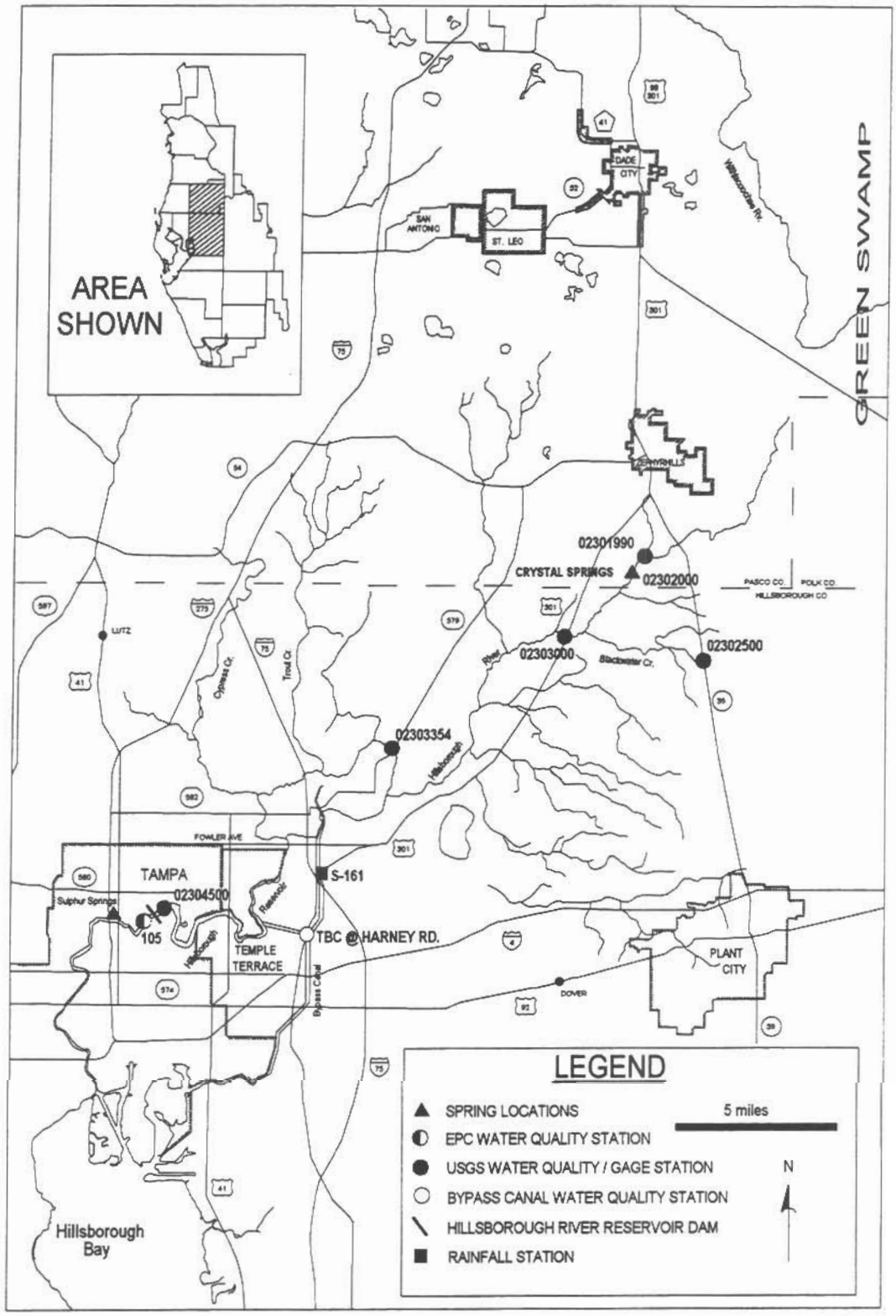

Figure 1. Study Area in the Upper Hillsborough River Watershed

PROBLEM STATEMENT

The TBNEP has concluded that, among the major drainage basins, the Hillsborough River watershed is a significant source of nitrogen and phosphorus loading to Tampa Bay (Coastal Environmental, 1994). The majority of the current nutrient loads ~~is~~ are due to surface runoff from various land uses in the watershed. To meet resource-based water-quality targets established for the Bay by the TBNEP, attention is being directed towards load reductions in the contributing basin (Limno-Tech, 1997).

Crystal Springs, located just north of the Pasco County line, discharges an average rate of 28 mgd to the upper Hillsborough River, and constitutes a major ground-water source of nitrogen to the river. Nitrate concentrations in Crystal Springs appear to have been increasing since the 1940's (Figure 2), with current average nitrate levels of 2.5 mg/l. A sharp upward trend in nitrate levels and nitrogen loading rates is evident from the late 1960's to the present (Figure 4).

Causes for this increasing nitrate trend are currently being evaluated by the SWFWMD for the Crystal Springs ground-water basin. Similar studies conducted on nutrient levels in springs (Jones *et al.* 1996, 1997, 1998) have focused on the use of inorganic fertilizers in both agricultural and urban residential land use practices as major contributors to ground-water nitrate concentrations. The contribution of nitrogen from Crystal Springs to the Hillsborough River, using the current average discharge and nitrate values, is estimated to be over 100 tons annually (Appendix III).

A significant decline in discharge at Crystal Springs has been documented over a 75 year period of record. A 30 percent decline in flow is reported from 1933 to 1993 through non-parametric slope estimator analysis of discharge data (SWFWMD, 1998). A generalized linear analysis of discharge data (Figure 3) indicates a 32 percent decline in flow over the period of record. More detailed analyses of historical spring discharge are presented in Tibbals et al. (1980), suggesting that increased ground-water withdrawls from the Floridan aquifer since the late 1960's caused the decline in discharge, and also in a recent consultants report (CH2MHILL, 1998) which correlates the discharge at Crystal Springs with regional declines in stream flow since 1970, presumably due to climatic variations. An analysis of rainfall over the last thirty years (SWFWMD, 1995) also indicates a decrease in rainfall across central Florida that coincides with both declining flows, and increasing nitrate concentrations, at Crystal Springs.

The apparent correlation of decreased discharge and increased nitrate levels from the spring may lead to the conclusion that the increasing trend in nitrate concentration is an artifact of declining flows. While there may be a minor seasonal response in ground-water nitrate concentrations in the Floridan aquifer due to climatic variations, a correlation between nitrate levels, rainfall or discharge over the past thirty years is not evident. The relation between discharge and nitrate loading (Figure 4), taking into account the decreased flow, clearly shows a rapid increase in loading between 1968 and 1983. This increase is followed by an apparent stabilization of loading rates that generally tracks discharge data from 1983 to the present. Continued increasing trends in both nitrate concentration and loading to the upper Hillsborough River are still apparent in recent water-quality data and are not an artifact of declining discharge from the springs.

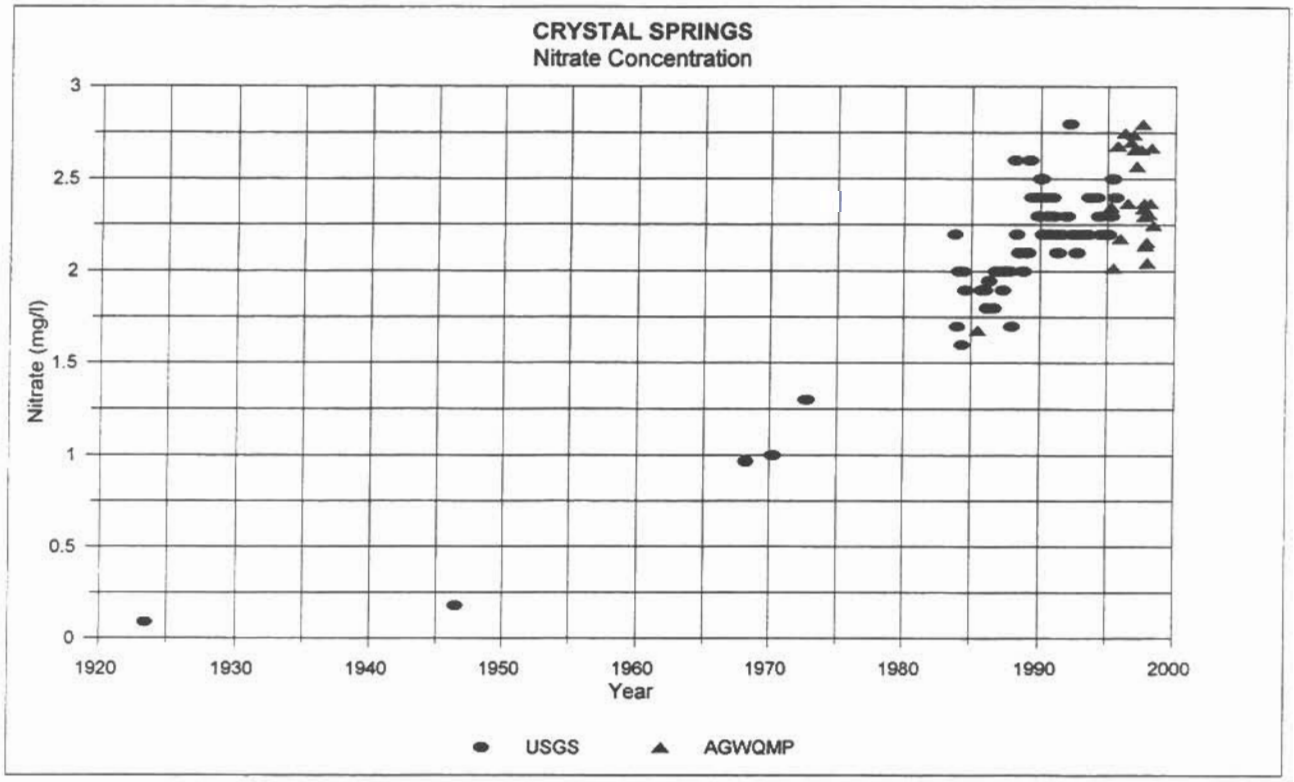

Figure 2. Increasing nitrate trend at Crystal Springs.

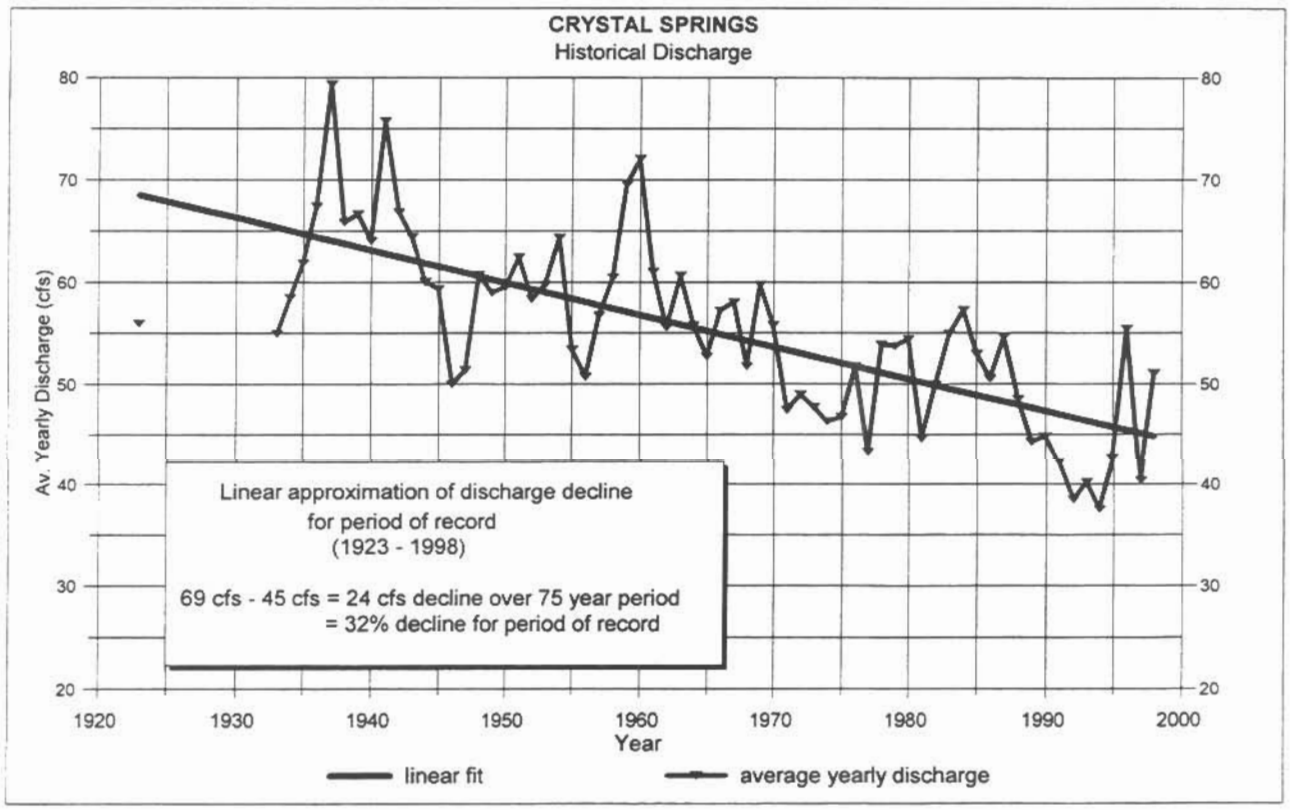

Figure 3. Decline in discharge at Crystal Springs for the period of record.

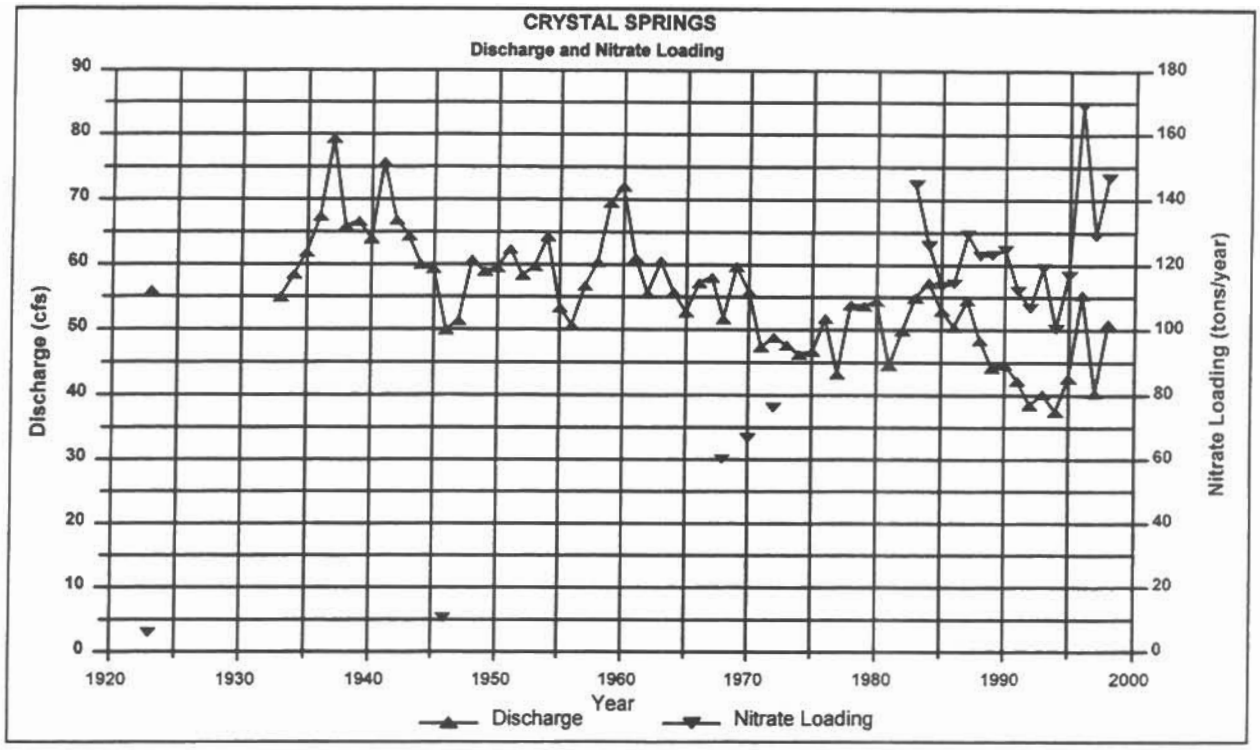

Figure 4. Relationship between nitrate loading and discharge at Crystal Springs.

PROJECT OBJECTIVE

The goal of this investigation was to estimate the amount of total nitrogen (TN) discharged from Crystal Spring that reaches the lower Hillsborough River immediately downstream of the HRR. To accomplish this, both water-quality and discharge data were analyzed for the calendar years of 1991, 1994, and 1997. These years were selected as representative data sets for the development of current TN loading estimates for the study area.

DATA COLLECTION AND STUDY METHODS

Stream Flow Data

All stream flow data were obtained from U.S. Geological Survey (USGS) Water Resources Data Reports (Volume 3A. Southwest Florida Surface Water) for the calendar years of 1991, 1994, and 1997. Data from six USGS gaging stations (Figure 1, Table 1) located directly on the Hillsborough River upstream of and including the HRR were used to calculate TN loading values (Appendix III). These gaging stations were chosen to represent loading values from different regions of the upper Hillsborough River watershed north of the reservoir. Other USGS gaging stations are located on tributaries in the upper portions of the watershed, but were considered to be too far from the river to determine actual TN loads to the river.

Table 1. USGS stream gaging stations located on the upper Hillsborough River.

Station Number	Station Name	Latitude	Longitude	County
02301990	Hillsborough River above Crystal Springs	28° 11' 07"	82° 11' 03"	Pasco
02302000	Crystal Springs	28° 10' 30"	82° 11' 20"	Pasco
02302500	Blackwater Creek near Knights, Fl.	28° 08' 25"	82° 09' 00"	Hillsborough
02303000	Hillsborough River near Zephyrhills	28° 08' 59"	82° 13' 57"	Hillsborough
02303354	Hillsborough River at Morris Bridge	28° 05' 50"	82° 18' 45"	Hillsborough
02304500	Hillsborough River near Tampa	28° 01' 25"	82° 25'40"	Hillsborough

Water-Quality Data

Water-quality data used in this report are shown in Appendix II and are available from the Ambient Ground Water Monitoring Program (AGWQMP) at the SWFWMD. The water-quality parameters of interest in this study included nitrate + nitrite ($NO_3 + NO_2$), ammonium (NH_4), total Kjeldahl nitrogen (TKN), and total nitrogen (TN). When TN values were not reported, a calculation was performed (i.e. TKN + NO_2 + NO_3) to determine TN. These parameters were used with stream gaging flow data for the calculation of TN loading values. Water-quality data in the Hillsborough River watershed north of the HRR and immediately below the reservoir dam were obtained from the five sources listed below.

U.S. Geological Survey (USGS)

Water-quality data were available from USGS Water Resource Data Reports for all parameters of interest at each of the six gaging stations listed in Table 1. Sampling frequencies varied from monthly to bimonthly at each station for the 1991, 1994, and 1997 study period. Average annual values were calculated for these parameters at each monitoring station using a minimum of six data points for each year. Data for year 1991 at the Hillsborough River at Morris Bridge station were not available so 1992 data were used.

Hillsborough County Environmental Protection Commission (HCEPC)

Water-quality data were available for $NO_3 + NO_2$, NH_4, TKN, and TN for the Hillsborough River at Rowlett Park Drive station (#105) which is located immediately downstream of the HRR dam. The HCEPC conducted water-quality monitoring at this station monthly for the 1991, 1994, and 1997 study period. Average annual values were calculated for these water-quality parameters using twelve data points for each year. These data were used to determine TN loading to the portion of the river below the reservoir dam.

Southwest Florida Water Management District (SWFWMD)

Water-quality data for all parameters of interest were available for Crystal Springs. The Ambient Ground Water Monitoring Program (AGWQMP) at the SWFWMD conducted water-quality monitoring at this station on a monthly basis during 1997. These data were available through the AGWQMP water-quality data base, and average annual values were calculated for these parameters using twelve data points for the 1997 study year. The AGWQMP also monitored this station on a quarterly basis through the years of 1995 and 1996. These data were used along with USGS historical water-quality data to show increasing nitrate trends at Crystal Spring over time (Figure 2).

Water-quality data were available for $NO_3 + NO_2$, NH_4, TKN, and TN for the TBC at Harney Road station. The AGWQMP at the SWFWMD conducted monthly water-quality monitoring at this station for the years of 1995, 1996, and 1997. The data were available through the SWFWMD LIMS data base, and average annual values were calculated for these parameters using twelve data points for each year. These data were used in conjunction with the City of Tampa withdrawal values from the TBC to determine TN loading values to the HRR from augmentation. Water-quality data were not available for 1991.

Water-quality data for all parameters of interest were available for Sulphur Springs for the 1991 study year through the SWFWMD Regulatory data base. To satisfy requirements under Water Use Permit (WUP) #2062, these data were reported by the City of Tampa to the SWFWMD. These data were used in conjunction with City of Tampa withdrawal data from Sulphur Springs to determine TN loading values to the HRR from augmentation. Average annual values were calculated for $NO_3 + NO_2$, NH_4, TKN, and TN using twelve data points for the 1991 year.

City of Tampa

Water-quality data for all parameters of interest were available for Sulphur Springs. To satisfy requirements under WUP #2062, the City of Tampa conducted water-quality monitoring at this station on a monthly basis for the 1994 and 1997 study period. These data were available through the City of Tampa Water Department, Water Production Division, Technical Services Section, and were used in conjunction with the City of Tampa withdrawal values from Sulphur Springs to determine TN loading values to the HRR from augmentation. Average annual values were calculated for $NO_3 + NO_2$, NH_4, TKN, and TN using twelve data points for each year.

TN LOADING ESTIMATES

Appendix III presents a summary of estimated TN loads for 1991, 1994, and 1997 to the Hillsborough River from gaged portions of the study area north of, and including the Morris Bridge site. The table also shows estimated TN loads to the portion of the river directly below the dam. These TN loads were used in conjunction with calculated loading estimates to the HRR to determine the contribution of TN loading to the reservoir from Crystal Springs.

Modeling results which represent nutrient loading to the upper Hillsborough River basin and the HRR for the years of 1983, 1987, and 1990 have been developed by Limno-Tech, Inc. These modeling results were also used to generate water-quality and nutrient reduction goals for the management of the reservoir and was presented in a report titled *Upper Hillsborough River Diagnostic Watershed Assessment, 1997.* These models were to be applied in determining the contribution of TN loading to the reservoir from Crystal Springs for 1991, 1994, and 1997. Due to the lack of current data for application of the models for these years, it was determined that it would be beyond the scope of this project to apply the models.

Calculations for Determining TN Loading Estimates to the Hillsborough River Reservoir

TN loading to the upper Hillsborough River watershed shows variations between gaging stations on the river, as well as yearly variations, for the 1991, 1994, and 1997 study years (Figure 5). For the purpose of this report it has been assumed that TN loading estimates, calculated at the Morris Bridge gaging/water-quality station, represent TN loads that are discharged to the reservoir from all sub-basins upstream of this gage station.

The Fowler Avenue station is located in the upper portion of the reservoir but was not used to estimate TN loads to the reservoir because only water-quality data are available from that site. The USGS does not operate a gaging station at this site due to operations at the HRR dam which cause fluctuations in water levels, and may cause back-flow at the Fowler site (Janice Todd, USGS, pers. comm.).

For sub-basins that drain to the river downstream of the Morris Bridge station (Table 2, Figure 6), the following calculations were used to estimate TN loads. Sub-basin #13 extends beyond the study area boundary at the reservoir dam and was not considered in the total acreage of gaged sub-basins. Therefore, half of this sub-basin's total acreage was not included in the TN loading calculations.

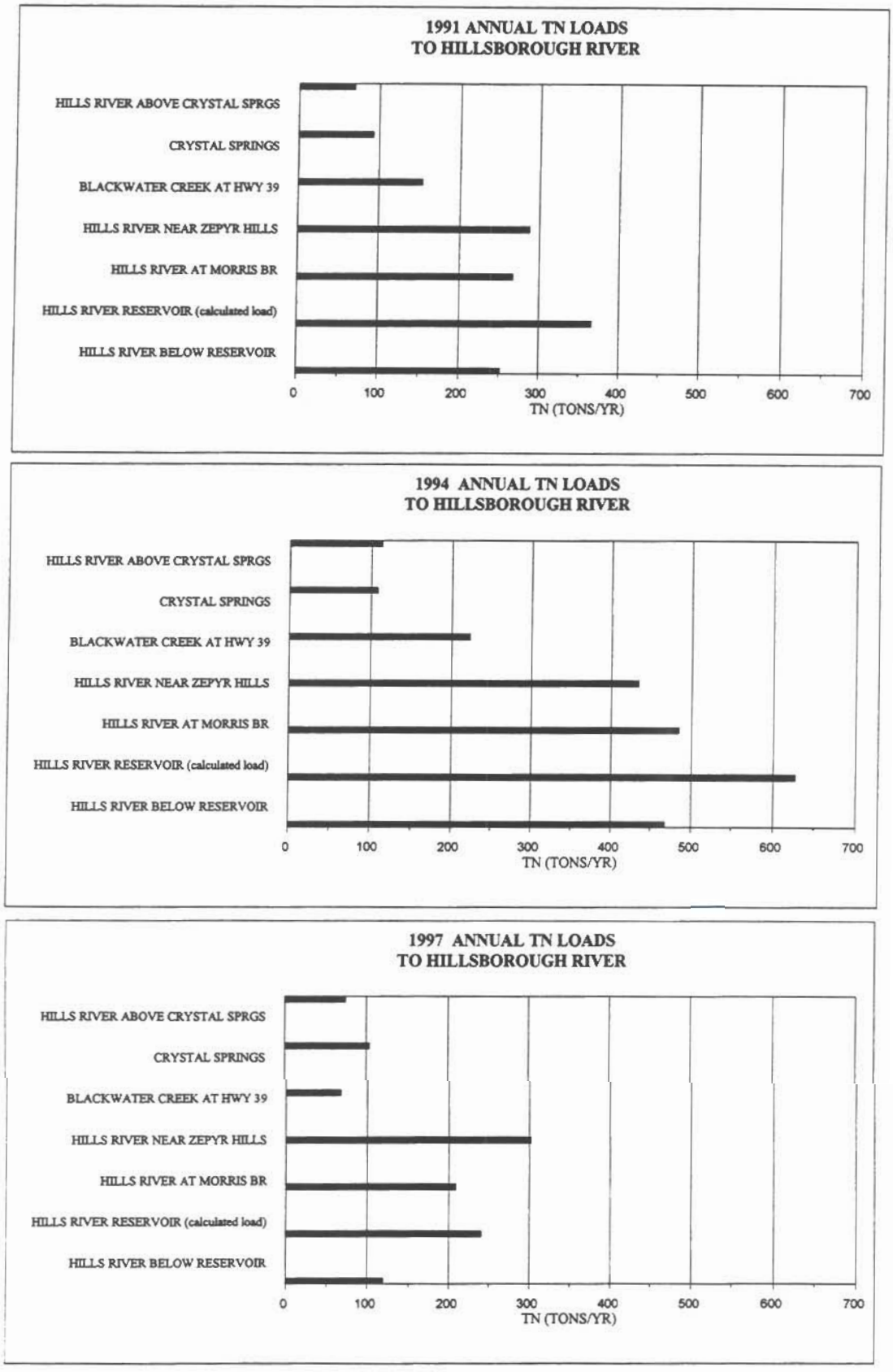

Figure 5. Yearly and spatial variations in TN loading to the upper Hillsborough River.

Table 2. Sub-basins where discharge and water-quality data are not included at Morris Bridge gage station.

1	Cypress Creek	49,220.31
2	Ponds Drainage Ditch	9,383.38
3	Stanley Branch	1,706.82
4	Bee Tree Branch	1,768.80
6	Drain	2,773.17
8	Slough	13,974.35
9	Drain	2,259.87
10	Drain	896.42
14	Drain	3,914.13
18	Lake Hanna Outlet	8,271.39
20	Trout Creek	14,958.61
24	Banjo Lake Outlet	546.01
25	Clay Gulley	6,048.40
33	Sherrys Brook	589.73
39	Thirteen Mile Creek	1,686.13
49	Cow House Creek	872.19
	Acres Not Represented in Study Area	37,463
	Acres Not Represented at Morris Bridge	118,869.71
	Total Acres Not Represented at Morris Bridge	156,332.71

The percentages of total acres represented at the Morris Bridge gage station, and acres not represented at the Morris Bridge station were calculated and are summarized below:

a. Acres in Hillsborough River Basin (from Appendix I)	432,156
b. Acres in Hillsborough River Basin Not Represented at Morris Bridge	- 118,869
c. Acres in Hillsborough River Basin Not Included in the Study Area	- 37,463
d. Acres in Hillsborough River Basin Represented at Morris Bridge	= **275,824**

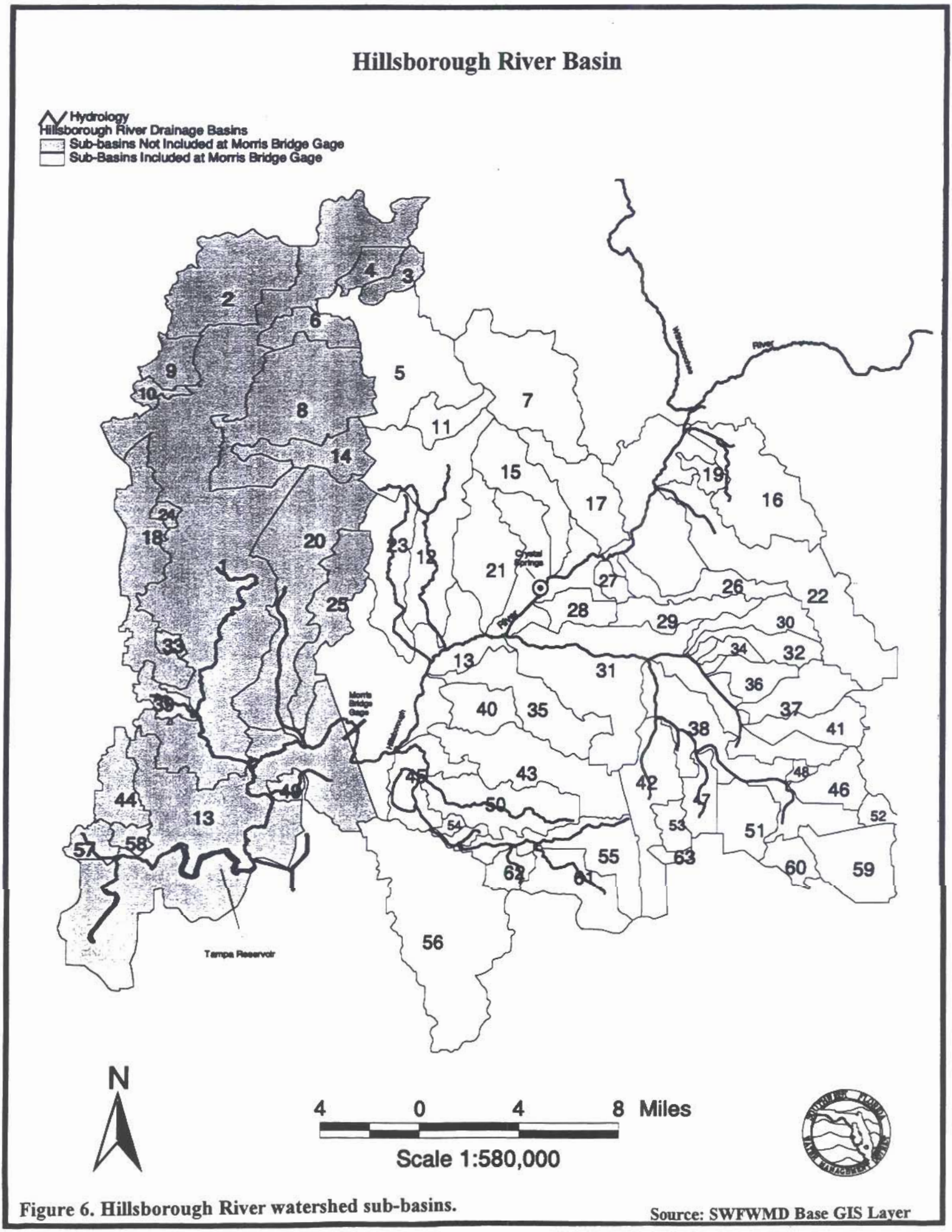

Figure 6. Hillsborough River watershed sub-basins.

Source: SWFWMD Base GIS Layer

$$\frac{\text{Acres Represented at Morris Br.(d)}}{\text{Total Acres in Basin (a)}} = 64\% \text{ of the Hillsborough River Basin is Represented at the Morris Bridge Station}$$

The remaining 36% of the Hillsborough River basin represents sub-basin drainage below the Morris Bridge gage station.

The above percentages and acreages were used in the following calculations to determine TN loads to the HRR from portions of the Hillsborough River basin not included at the Morris Bridge gage for 1991, 1994, and 1997. The results of these calculations for each year are summarized in Table 3.

1) X tons per year ÷ 275,824 acres = $\frac{\text{Y tons per year}}{\text{acre}}$

where X = TN loading values (for each year) at Morris Bridge Station (from Appendix III)

2) $\frac{\text{Y tons per year} * (b + c)}{\text{acre}}$ = Z tons per year from portion of basin not represented at Morris Bridge

where b = Acres not represented at Morris Bridge station
where c = Acres not included in study area

3) Therefore: X + Z = TN Load to the HRR from the Upper Hillsborough River Basin

Table 3. TN loads to the Hillsborough River Reservoir from the upper Hillsborough River basin.

Year	X = TN Load @ Morris Br. (tons/yr)	Z = TN Load From Basins Not Included @ Morris Br. (tons/yr)	TN Load to HRR (tons/yr)
1991	268	152	420
1994	485	275	760
1997	209	118	327

ADDITIONAL FACTORS AFFECTING TN LOADS AT THE HRR

TN loads in the reservoir can be affected by algicide applications, augmentation, withdrawals, and rainfall. Storage of TN in sediments and plant material also may have an effect on TN values. The following sections show estimated inputs and losses of TN to the HRR from these factors and the results are presented in Table 6.

TN Stored in Sediments and Plant Material in the Hillsborough River Reservoir

Storage of TN by sediments and plant material in the HRR was estimated for each of the study years. To determine this, the difference between estimated TN load values in the reservoir (Table 3) and estimated TN load values found immediately downstream of the dam (Appendix III) were calculated. The results are presented in Table 6.

TN Withdrawals from the Hillsborough River Reservoir

Raw water withdrawals from the HRR are recorded daily by the City of Tampa and reported to the SWFWMD under WUP #2062 requirements. Theses data were available for each of the study years and were available through the Regulatory data base at the SWFWMD (Table 4). Withdrawal values and water-quality data from the reservoir (from Appendix II) were used to calculate TN losses from the reservoir for each of the study years.

TN loads to the reservoir are also affected by operations of the Tampa Bypass Canal. Control structure #155 which is located upstream of Fowler Avenue is closed when water levels reach 28 feet, and flow is then diverted from the river to the canal through structure #159 (SWFWMD, 1998). The El Nino event in 1997 produced record amounts of rainfall over the Hillsborough River watershed. From the periods of September 28, 1997 through October 16, 1997, and again during December 12, 1997 through January 20, 1997 it was estimated that daily averages of 4,000 to 6,000 cubic feet per second were diverted from the river through the canal (Scott Stevens, Structures Operations Manager, SWFWMD, pers. comm.). Gage stations have not been established at these structures, therefore TN loads diverted from the reservoir due to TBC operations could not be established.

Additional TN Loads to the Hillsborough River Reservoir From Rainfall and Augmentation

Annual average withdrawals from Sulphur Springs and the TBC by the City of Tampa to augment the HRR were obtained from the SWFWMD (Figure 7). Discharge data for 1997 were not available for Sulphur Springs or the TBC so 1996 withdrawal values were used. These withdrawal values were used with TN concentrations from Appendix II to determine TN loads to the reservoir from Sulphur Springs and the TBC. All TN loading estimates were calculated by multiplying average yearly discharge values by average yearly TN concentrations measured at the same location (Table 5).

TN loading estimates to the HRR from rainfall for each of the study years were calculated using data collected at SWFWMD rain gage station # S-161 (Appendix IV). This station is located on the Harney Canal portion of the TBC and was chosen because of its location near the upper region of the reservoir. A mean nitrate concentration of 1 mg/l was used for determining TN load contributions from rainfall (Irwin and Kirkland, 1980).

Table 4. Withdrawals from HRR by the City of Tampa and TN losses.

Year	Withdrawal (mgd)	TN Loss (tons/yr)
1991	42	58
1994	59	146
1997	62	94

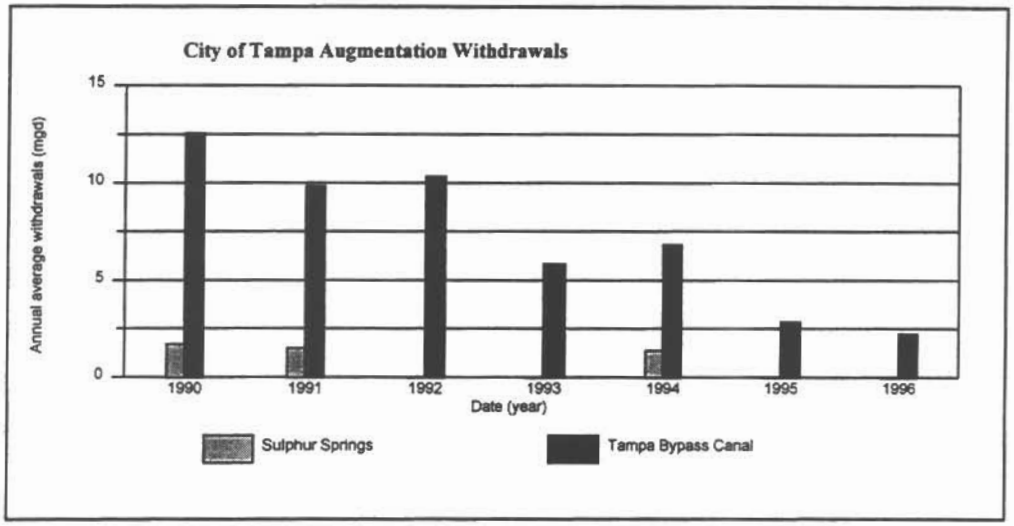

Figure 7. Annual average withdrawals by the City of Tampa from Sulphur Springs and the Tampa Bypass Canal for augmentation of the Hillsborough River Reservoir.

Table 5. Summary of TN loading values from Sulphur Springs and the Tampa Bypass Canal for augmentation of the Hillsborough River Reservoir.

Sulphur Springs	Year	Tot N (mg/l)	Discharge (mgd)	TN (lbs/gal)	TN Load(tons/yr)
SWFWMD (reg. database)	1991	0.96	1.26	7.90E-06	1.82
City of Tampa	1994	1.74	1.56	1.45E-05	4.13
No Discharge Data Available	1997	1.81	----	----	----
Bypass Canal @ Harney Rd.	**Year**	**Tot N (mg/l)**	**Discharge (mgd)**	**TN (lbs/gal)**	**TN Load(tons/yr)**
No Water Quality Data Available	1991	----	----	----	----
AGWQMP	1994	1.31	2.60	1.09E-05	5.19
AGWQMP	1997	0.63	2.20	5.30E-06	2.13

Table 6. Additional Factors Affecting TN Loads at The HRR

	1991	1994	1997
Storage of TN in HRR by Sediments and Plant Material (Table 3, Appendix III)	167	292	207
TN Loss (tons/yr) at HRR From Withdrawals by City of Tampa (Table 4)	58	146	94
Additional TN Load (tons/yr) to HRR From Rainfall (Appendix IV)	1.4	1.37	2.17
Additional TN Load (tons/yr) to HRR From Tampa Bypass Canal (Table 5)	---	5.19	2.13
Additional TN Load (tons/yr) to HRR From Sulphur Springs (Table 3)	1.8	4.13	---

CONTRIBUTION OF TN LOAD FROM CRYSTAL SPRINGS

In order to estimate the amount of TN discharged from Crystal Springs that reaches the lower Hillsborough River immediately downstream of the HRR dam for each of the study years, the product of the TN load discharged from the spring (Appendix III) was multiplied by the ratio of the TN load discharged from the reservoir (Rowlett Park station - Appendix III) to the TN load delivered to the reservoir from all sources (Table 3).

Application of the previous calculations yield the following results:

1991 $\quad 92 \text{ tons N/yr}_{\text{(crystal spring)}} \left[\frac{253 \text{ tons N/yr}_{\text{(below dam)}}}{420 \text{ tons N/yr}_{\text{(reservoir)}}} \right] = 55 \text{ tons N/yr}$

1994 $\quad 108 \text{ tons N/yr}_{\text{(crystal spring)}} \left[\frac{468 \text{ tons N/yr}_{\text{(below dam)}}}{760 \text{ tons N/yr}_{\text{(reservoir)}}} \right] = 67 \text{ tons N/yr}$

1997 $\quad 104 \text{ tons N/yr}_{\text{(crystal spring)}} \left[\frac{120 \text{ tons N/yr}_{\text{(below dam)}}}{327 \text{ tons N/yr}_{\text{(reservoir)}}} \right] = 38 \text{ tons N/yr}$

Approximately 253 tons of nitrogen from the upper Hillsborough River watershed were discharged over the Hillsborough Reservoir dam in 1991. Of this total nitrogen load, it was estimated that 55 tons were contributed by Crystal Springs. In 1994, 468 tons of nitrogen were discharged over the dam, and 67 tons was estimated to be contributed by Crystal Springs. An estimated 38 tons of nitrogen from Crystal Springs contributed to the total load of 120 tons which were discharged over the reservoir dam in 1997.

An average TN load of 101 tons/yr was discharged from Crystal Spring based on estimates from the three years studied. It was estimated that a maximum of 53 tons N/yr (52%) of the total nitrogen load from the spring contributed to the TN load discharged over the reservoir dam.

SUMMARY

The Hillsborough River watershed is a major contributor of nutrients to the Hillsborough River reservoir, and subsequently Tampa Bay. The majority of these nutrient loads have been linked to surface runoff from various land use activities, but ground-water discharging from Crystal Springs is a significant source of nutrients to the river. During the period of 1991, 1994, and 1997, Crystal Springs contributed an average annual total nitrogen load of 100 tons to the Hillsborough River. Although other tributaries that contribute flow to the river show variations in total nitrogen loads for these years, Crystal Springs values have remained relatively constant.

A significant decline in discharge at Crystal Springs has been documented over a 75 year period of record, with a 30 percent decline in flow reported from 1933 to 1993. Nitrate levels in Crystal Springs appear to have been increasing since 1960, with current average nitrate concentrations of 2.5 mg/l. The relation between discharge and nitrate loading shows a rapid increase in loading between 1968 and 1983, followed by an apparent stabilization of loading rates from 1983 to the present. Increasing trends in both nitrate concentration and loading rates appear to be continuing at Crystal Springs, contributing to the nutrient loads in the Hillsborough River.

The assimilation of nitrogen from Crystal Springs as it moves through the upper Hillsborough River system is undefinable without intense biological monitoring efforts and modeling applications. The impact of nitrogen loads discharged from Crystal Springs on the lower Hillsborough River immediately downstream of the Hillsborough River Reservoir was estimated with the assumption that no nitrogen losses occurred in the upper watershed. These following estimations represent the **maximum** amount of TN load from Crystal Spring to the HRR. The additional factors on TN loads in the HRR (withdrawals, augmentation, rainfall, storage of TN by sediments and plant material) were not included in this estimate, but are a significant factor when considering the TN load from Crystal Spring that discharges over the reservoir dam.

During the El Nino event in 1997, operation of the Tampa Bypass Canal was a significant factor concerning nitrogen loss from the reservoir. Due to the lack of discharge data from the Bypass Canal, these losses, which would have an impact on the estimations made for 1997 nitrogen loads in the reservoir, were unable to be established.

Approximately 253 tons of nitrogen from the upper Hillsborough River watershed were discharged over the Hillsborough Reservoir dam in 1991. Of this total nitrogen load, it was estimated that 55 tons (or 22% of the total load) were contributed by Crystal Springs. In 1994, 468 tons of nitrogen were discharged over the dam, and 67 tons (14% of the total load) were estimated to be contributed by Crystal Springs. An estimated 38 tons of nitrogen from Crystal Springs (or 32% of the total load) contributed to the total load of 120 tons which were discharged over the reservoir dam in 1997.

An average TN load of 101 tons/yr was discharged from Crystal Spring based on estimates from the three years studied. It was estimated that a **maximum** of 53 tons N/yr (52%) of the total nitrogen load from the spring contributed to the TN load discharged over the reservoir dam.

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APPENDICES

APPENDIX I

Sub-Basin Acreage and Total Acreage of the Hillsborough River Watershed

Appendix I. Sub-Basin Acreage and Total Acreage of the Hillsborough River Watershed.

Basin No.	Basin Name	Acres	Basin No.	Basin Name	Acres
1	Cypress Creek	49,220.31	33	Sherrys Brook	589.73
2	Ponds Drainage Ditch	9383.38	34	Channelized Stream	936.64
3	Stanley Branch	1706.82	35	Two Hole Branch	6,301.67
4	Bee Tree Branch	1768.80	36	Intermittent Ditch	2,317.25
5	Bayou Branch	11,769.43	37	Kathleen Drain	3,970.26
6	Drain	2,773.17	38	Itchepackasassa Creek	10,028.44
7	Noncontributing Area	11,271.12	39	Thirteen Mile creek	1,686.13
8	Slough	13,974.35	40	Clay Gulley	3,088.03
9	Drain	2.259.87	41	Channelized Stream	3,294.84
10	Drain	896.42	42	East Canal	6,693.38
11	Bayou Lake Outlet	2,439.09	43	Hollomans Branch	8,819.85
12	New River	13,359.53	44	Curiosity Creek	3,335.05
13	Hillsborough River	74,926.69	45	Flint Creek	5,355.63
14	Drain	3,914.13	46	Channelized Stream	2,896.03
15	Southside Branch	5,569.48	47	Midway Road Drain	2,404.10
16	Port Lonesome Ditches	9,2770.00	48	Channelized Stream	443.23
17	Zephyrhills Airport Run	5,416.48	49	Cow House Creek	872.19
18	Lake Hanna Outlet	8,271.39	50	Campbell Branch	6,774.59
19	Ditch	990.64	51	Wiggins Prairie Drain	3,946.47
20	Trout Creek	14,958.61	52	Lake Bonnet Outlet	947.90
21	Indian Creek	6,740.77	53	Intermittent Stream	1,432.31
22	Fish Hatchery Drain	13,241.53	54	Baker Creek Tributary	415.09
23	Basset Branch	6,174.16	55	Pemberton Creek	6,748.43
24	Banjo Lake Outlet	546.01	56	Selfer Canal	19,826.85
25	Clay Gulley	6,048.40	57	Twin Lake Outlet	1,649.44
26	Intermittent Stream	3,151.82	58	Sulphur Springs	980.10
27	Hawk Lake Drain	991.05	59	Trailer Park Drain	5,546.21
28	Big Ditch	2,274.02	60	Winston Drain	1,853.95
29	Big Ditch Noncont Area	3,415.88	61	Sparkman Branch	4,923.98
30	Channelized Stream	2,918.41	62	Moore Lake Drain	1,629.68
31	Blackwater Creek	19,718.66	63	Intermittent Stream	510.79
32	Channelized Stream	2,570.73		**Total Acres - All Sub-Basins**	**432,156.30**

APPENDIX II

Summary of Water-Quality Data in the Upper Hillsborough River Watershed

APPENDIX II. SUMMARY OF WATER QUALITY DATA IN THE UPPER HILLSBOROUGH RIVER WATERSHED					
Average annual concentrations in mg/l					
Hillsborough River above Crystal Springs	YEAR	NO2+NO3	NH3	TKN	TOTN
USGS	1991	1.10	0.02	0.20	1.30
USGS	1994	0.52	0.03	1.00	1.52
USGS	1997	1.08	0.02	1.40	2.48
Crystal Springs	YEAR	NO2+NO3	NH3	TKN	TOTN
USGS	1991	2.22	0.02	<0.20	2.22
USGS	1994	2.26	0.05	0.68	2.94
AGWQMP	1997	2.41	0.03	0.20	2.61
Blackwater Creek near Knights, Florida	YEAR	NO2+NO3	NH3	TKN	TOTN
USGS	1991	0.91	0.07	1.38	2.29
USGS	1994	0.58	0.17	1.44	2.02
USGS	1997	0.43	0.06	0.84	1.27
Hills Rv nr Zephyrhills (Hills Rv State Pk)	YEAR	NO2+NO3	NH3	TKN	TOTN
USGS	1991	1.40	0.01	0.34	1.74
USGS	1994	1.00	0.04	0.73	1.73
USGS	1997	1.63	0.02	0.34	1.97
Hillsborough River at Morris Bridge	YEAR	NO2+NO3	NH3	TKN	TOTN
USGS	1992	0.82	0.04	0.63	1.45
USGS	1994	0.43	0.04	0.99	1.42
USGS	1997	1.12	0.03	0.44	1.56
Hills Rv @ Rowlett Park Dr (below dam)	YEAR	NO2+NO3	NH3	TKN	TOTN
EPC	1991	0.15	0.15	0.88	1.03
EPC	1994	0.08	0.12	1.03	1.11
EPC	1997	0.10	0.09	1.74	1.10
Sulphur Springs	YEAR	NO2+NO3	NH3	TKN	TOTN
SWFWMD (reg. database)	1991	0.75	0.071	0.21	0.96
City of Tampa	1994	1.39	0.087	0.41	1.74
City of Tampa	1997	1.37	0.069	0.42	1.81
Bypass Canal @ Harney Road	YEAR	NO2+NO3	NH3	TKN	TOTN
No Water-Quality Data for 1991	-----	-----	-----	-----	-----
AGWQMP	1994	0.76	0.15	0.55	1.31
AGWQMP	1997	0.02	0.02	0.61	0.63

APPENDIX III

Summary of TN Loading Estimates in the Upper Hillsborough River Watershed

APPENDIX III. SUMMARY OF TN LOADING ESTIMATES IN THE UPPER HILLSBOROUGH RIVER WATERSHED						
Average annual concentrations and loading values						
Hillsborough River above Crystal Springs	YEAR	TOTN (mg/l)	DISCHARGE(cfs)	TN (lbs/gal)	DISCHARGE (gal/day)	TN LOADS(tons/yr)
USGS	1991	1.30	54	1.08E-05	3.49E+07	69.00
USGS	1994	1.52	76.5	1.27E-05	4.94E+07	114.00
USGS	1997	2.48	30.9	2.07E-05	2.00E+07	75.00
Crystal Springs	YEAR	TOTN (mg/l)	DISCHARGE(cfs)	TN (lbs/gal)	DISCHARGE (gal/day)	TN LOADS(tons/yr)
USGS	1991	2.22	42.3	1.85E-05	2.73E+07	92.00
USGS	1994	2.94	37.5	2.45E-05	2.42E+07	108.00
AGWQMP	1997	2.61	40.4	2.18E-05	2.61E+07	104.00
Blackwater Creek near Knights, Florida	YEAR	TOTN (mg/l)	DISCHARGE(cfs)	TN (lbs/gal)	DISCHARGE (gal/day)	TN LOADS(tons/yr)
USGS	1991	2.29	68.5	1.91E-05	4.43E+07	154.00
USGS	1994	2.02	112	1.68E-05	7.24E+07	222.00
USGS	1997	1.27	53.8	1.06E-05	3.48E+07	67.00
Hills Rv near Zephyrhills (Hills Rv State Pk)	YEAR	TOTN (mg/l)	DISCHARGE(cfs)	TN (lbs/gal)	DISCHARGE (gal/day)	TN LOADS(tons/yr)
USGS	1991	1.74	168	1.45E-05	1.09E+08	287.00
USGS	1994	1.73	256	1.44E-05	1.65E+08	435.00
USGS	1997	1.97	156	1.64E-05	1.01E+08	302.00
Hillsborough River at Morris Bridge	YEAR	TOTN (mg/l)	DISCHARGE(cfs)	TN (lbs/gal)	DISCHARGE (gal/day)	TN LOADS(tons/yr)
USGS	1992	1.45	188	1.21E-05	1.21E+08	268.00
USGS	1994	1.42	347	1.18E-05	2.24E+08	484.00
USGS	1997	1.56	136	1.30E-05	8.79E+07	208.00
Hillsborough River at Rowlett Park Dr (below dam)	YEAR	TOTN (mg/l)	**DISCHARGE(cfs)	TN (lbs/gal)	DISCHARGE (gal/day)	TN LOADS(tons/yr)
EPC	1991	1.03	250	8.59E-06	1.62E+08	253.00
EPC	1994	1.11	429	9.25E-06	2.77E+08	468.00
EPC	1997	1.10	111	9.17E-06	7.17E+07	120.00
**Discharge Data (cfs) From USGS Station #02304500 (Hillsborough River nr Tampa at dam) used to Determine TN Loads at Rowlett Pk.						

APPENDIX IV

Rainfall Data From the Hillsborough Reservoir Region

Appendix IV. Rainfall Data From the Hillsborough Reservoir Region

Station: S-161
Latitude: 28 01 06.06
Longitude: 82 22 14.31
Measuring Unit: Inches
Reporting Agency: SWFWMD

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1991	2.07	N/A	3.83	2.74	8.85	N/A	10.91	5.46	2.03	0.45	0.13	0.59	37.06
1994	N/A	0.56	0.62	3.79	1.07	N/A	8.99	7.46	8.05	3.95	0.41	2.10	37.00
1997	0.51	1.20	2.22	7.91	2.53	N/A	13.72	9.91	N/A	N/A	3.02	17.39	58.41

Calculation to Determine Yearly TN Loading to Reservoir From Rainfall

$$(A * B * C * D) / 2000 \text{ lbs/ton} = \text{TN Load Attributed to Rainfall in Tons/Year}$$

Where: A = 328 ac (acres in Reservoir)
B = rainfall in ft/year
C = 325,850 gal/ac ft
D = $8.3 * 10^{-6}$ lbs/gal (concentration of N in lbs/gal @ 1 mg/l)

Results From Rainfall Loading Calculations

	1991	1994	1997
TN Load to HRR From Rainfall (tons/yr)	**1.38**	**1.37**	**2.17**

THE AMERICANS WITH DISABILITIES ACT INFORMATION

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