ESTIMATES OF TOTAL NITROGEN, TOTAL PHOSPHORUS, TOTAL SUSPENDED SOLIDS, AND BIOCHEMICAL OXYGEN DEMAND LOADINGS TO TAMPA BAY, FLORIDA: 1999-2003

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FOREWORD

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1. INTRODUCTION

The Tampa Bay Estuary Program (TBEP) has previously developed pollutant loading estimates for 1985-1991,1992-1994 and 1995-1998 (Zarbock et al., 1994; 1996, Pribble et al., 2001). These estimates were developed for total nitrogen, total phosphorus, and total suspended solids loadings to the bay. This report is the fourth in the series of loading estimates, for the period 1999-2003.

The 1985-1994 loading estimates were used in the development of empirical relationships between total nitrogen loadings and observed chlorophyll concentrations in three mainstem segments of the bay: Old Tampa Bay, Hillsborough Bay, and Middle Tampa Bay (Janicki and Wade, 1996). These relationships were part of the empirical model relating total nitrogen loadings to chlorophyll concentrations, chlorophyll concentrations to light availability, and light availability to seagrass restoration acreage.

1.1 Objectives

The objective of this report is to provide annual average loading estimates for total nitrogen, total phosphorus, total suspended solids, and total biochemical oxygen demand for 1999-2003. These annual average estimates are derived from monthly loading estimates, using methods similar to those used previously (Pribble et al. 2001, Zarbock et al., 1994; 1996).

The estimated 1992-1994 mean annual total nitrogen loadings represent those identified by the TBEP expected to result in light availability sufficient to meet the TBEP's seagrass restoration goals. The empirical model relating total nitrogen loadings to seagrass restoration goals (Janicki and Wade, 1996) and observed increases in seagrass coverage through 1992 suggested that light availability necessary for obtaining seagrass restoration goals could be met by establishing a “hold the line” strategy for nitrogen loadings. This strategy would hold nitrogen loadings to each segment of the bay to the average levels of 1992-1994. The TBEP adopted this strategy in 1996, and local government partners agreed to preclude increases in future nitrogen loadings to the bay to aid in this effort.

Comparison of annual TN loadings for 1999-2003 to the loadings from 1992-1994 allows identification of the sources responsible for changes in loadings during 1999-2003. It also allows comparison of 1999-2003 nitrogen loadings to the “hold the line” loadings of 1992-1994 and extends the annual TN, TP, BOD and TSS loading estimates through 2003.

Estimated pollutant loadings are reported for each bay segment (Figure 1-1) and from each major drainage basin to Tampa Bay (Figure 1-2). These loadings were developed by estimating loadings from each previously identified source in the watershed of the bay (Figure 1-2). The following sections present the methods and results of the 1999-2003 loading estimates. These sections include:

- descriptions of the methods used and data summaries for the estimated loadings from each loading source for the 1999-2003 period;

- descriptions of the estimated hydrologic loadings for the 1999-2003 period, with comparison of 1999-2003 estimated annual hydrologic loadings to the mean annual 1992-1994 and 1995-1998 hydrologic loadings;

- a summary of the estimated total bay pollutant loadings, the estimated pollutant loadings from each bay segment, the estimated pollutant loadings from each major drainage basin, and a discussion of the differences in estimated total pollutant loadings of the 1999-2003 period from those of 1992-1994, and their causes; and

- conclusions concerning the results of this update

- appendices I-N were taken from the Zarbock et al. 1994 report titled Estimates of Total Nitrogen, Total Phosphorus, and Total Suspended Solids Loadings to Tampa Bay, Florida in order to provide a complete discription of the methods necessary to calculate the 1999-2003 loadings.

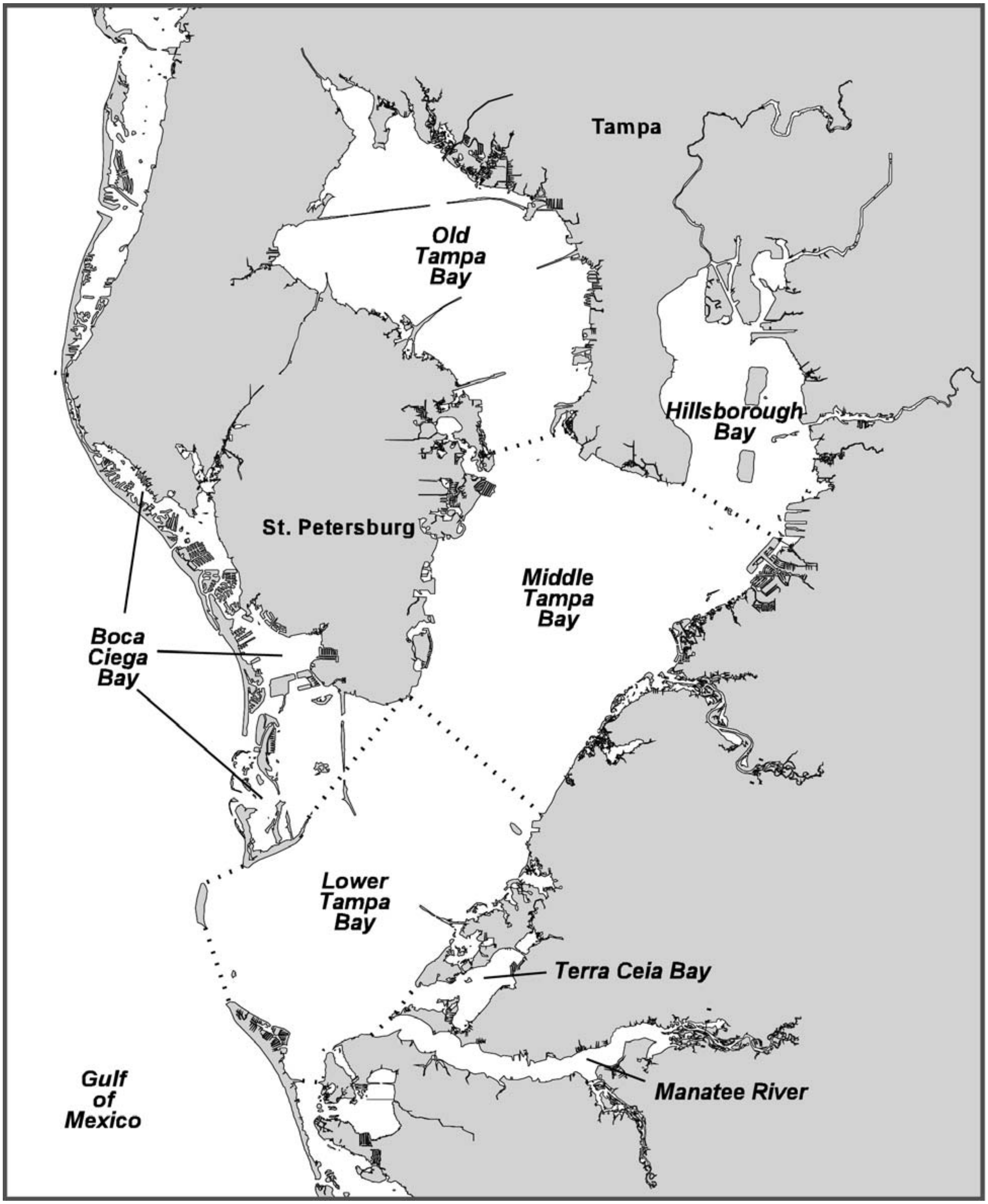

Figure 1-1. Bay segments of Tampa Bay.

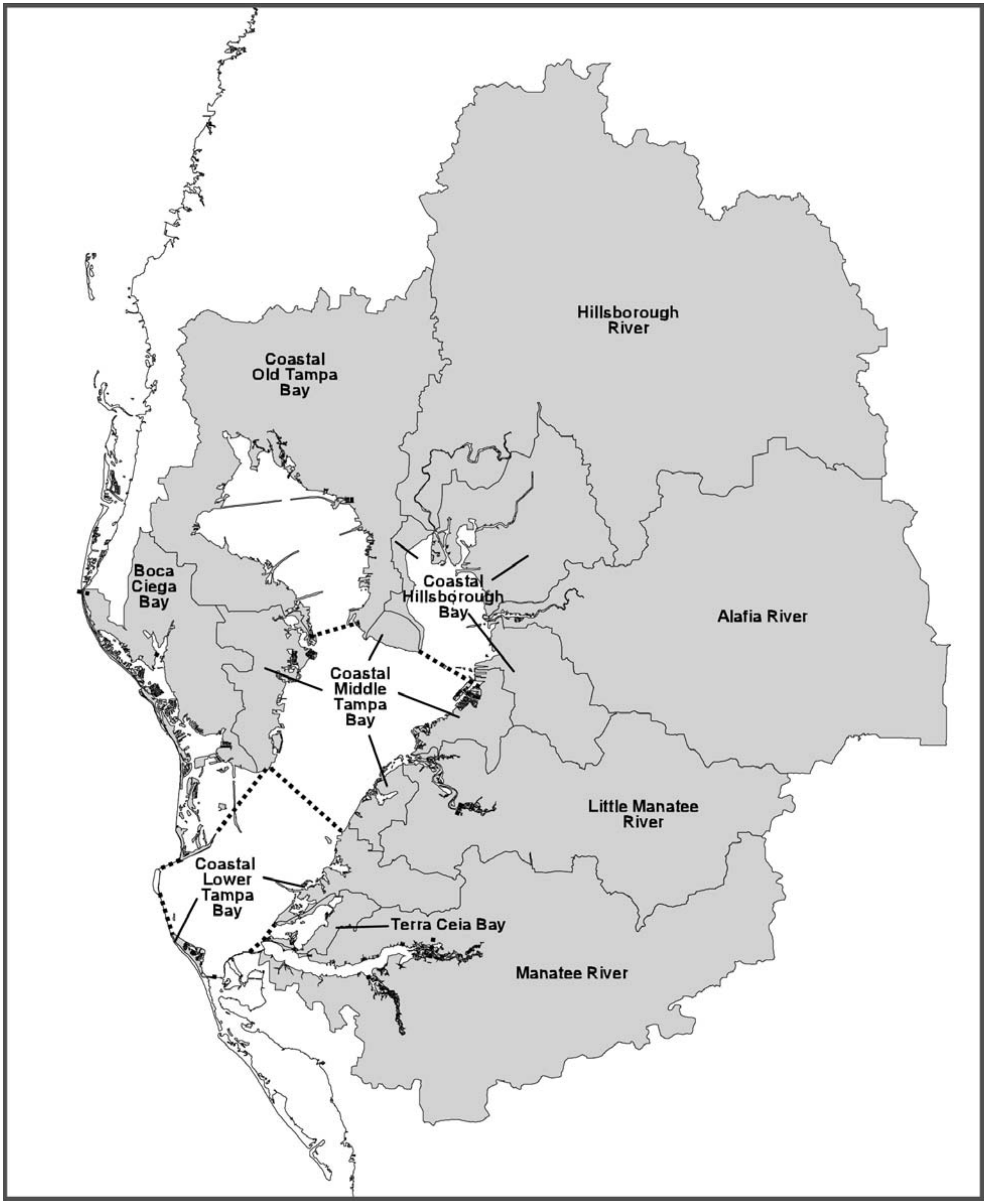

Figure 1-2. Major basins of the Tampa Bay watershed.

2. LOADING SOURCES

As in previous loading estimates (Pribble et al. 2001, Zarbock et al., 1994; 1996), seven categories of sources were examined for their contributions to loadings of total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS) to the bay. Loading estimates of biochemical oxygen demand (BOD) were also developed for the 1999-2003 period. The loading sources examined were:

- atmospheric deposition,
- domestic point sources,
- industrial point sources,
- springs,
- groundwater,
- material losses from fertilizer handling facilities, and
- nonpoint sources.

The methods used to develop the loading estimates and summaries of the results for each loading source are given in the following subsections. Modifications to the methods used for developing estimates from each source are described in each of the subsections.

2.1 Atmospheric Deposition

Total atmospheric deposition is defined as the sum of wet deposition (rainfall) and dry deposition (gaseous constituent interaction and dust fallout) directly to the surface of the bay. Deposition of pollutants to the watershed of the bay is incorporated into nonpoint source loading estimates.

There are three data types needed to estimate total atmospheric deposition. First, an estimate of the hydrologic load to the bay via precipitation is needed. Secondly, an estimate of the pollutant concentration in that precipitation is also needed. Lastly, an estimate of dry deposition is needed, either from empirical data or model-based estimates.

2.1.1 Methods

The hydrologic load to the bay via precipitation was estimated in the same manner as in the previous loading estimates (Zarbock et al., 1994; 1996). An inverse distance-squared method was applied to data from 22 National

Weather Service (NWS) rainfall monitoring sites in or near the Tampa Bay watershed to provide bay segment-specific monthly hydrologic loads from rainfall inputs.

For the previous loading estimates, TN concentration data in precipitation were obtained from the National Atmospheric Deposition Program (NADP) Verna Wellfield site (Zarbock et al., 1994; 1996). This site is near the southern boundary of the Tampa Bay watershed in Sarasota County, and represented the nearest site measuring precipitation concentration data. Concentrations of TP in precipitation were estimated based on data collected by the Tampa National Urban Runoff Study (NURP) (Metcalf & Eddy, 1983), and the mean TP concentration of 0.195 mg/L from the study was used for all rainfall events (Zarbock et al., 1994). The TN loadings from precipitation were estimated by multiplying the monthly precipitation-weighted mean TN concentrations from the Verna site and the monthly segment-specific hydrologic loads to estimate monthly wet TN loads to each bay segment. Similarly, the constant TP concentration derived from the NURP study was multiplied by the monthly segment-specific hydrologic loads to estimate monthly wet TP loads to each bay segment.

The previous loading estimates derived dry deposition of TN and TP using a ratio of dryfall to wetfall from the Florida Acid Deposition Study (FADS). Results of the study suggested that the dry:wet deposition ratio in Hillsborough County was 2.04:1 (ES&E, 1987). Thus, the monthly wet deposition was multiplied by 3.04 to estimate the total monthly TN and TP loading attributable to atmospheric deposition directly to the surface of the bay (Zarbock et al., 1994; 1996).

For the 1995-1998 period, more site-specific data were available for the atmospheric deposition loading estimate. In August 1996, the TBEP initiated monitoring as part of the Tampa Bay Atmospheric Deposition Study (TBADS). This program includes sampling elements for both wet and dry deposition at an intensive monitoring site located on the Gandy Bridge Causeway. The data available from TBADS that can be used to estimate atmospheric deposition to Tampa Bay include precipitation pollutant (nitrogen and phosphorous) concentration data, wet and dry deposition rates, and an estimate of the ratio of dry:wet deposition.

Four methods of estimating atmospheric deposition of TN were evaluated to arrive at the most defensible approach for providing these estimates. The data used were for the time period August 1996 through July 1998. The methods evaluated are described below.

Method 1. This method was the same as that employed in previous loading estimates for Tampa Bay (Zarbock et al., 1994; 1996). Estimates of wet deposition of TN were calculated by multiplying precipitation-weighted mean monthly TN concentrations in rainfall by the total monthly hydrologic loading via rainfall to each bay segment. The TN (nitrate and ammonia nitrogen) concentration data were from the monitoring done at the NADP Verna Wellfield site. The hydrologic loads were estimated using rainfall data obtained from the NWS. The dry:wet deposition ratio was 2.04:1, as used for the previous estimates.

The equation for wet deposition of nitrogen was as follows:

$$Nwet_{m,s} = [N]_m * H_{m,s},$$

where:

$Nwet_{m,s}$ = wet deposition of nitrogen (kg/month) for each month *m* and bay segment *s*,

$[N]_m$ = monthly mean precipitation-weighted nitrogen concentration (kg/m^3) in the rainfall measured at the NADP Verna site for each month *m*, and

$H_{m,s}$ = estimated hydrologic load (m^3/month) from rainfall for each month *m* and bay segment *s*.

The dry:wet deposition ratio of 2.04:1 was used to estimate dry deposition to each segment of the bay, as follows:

$$Ndry_{m,s} = 2.04 * Nwet_{m,s},$$

where:

$Ndry_{m,s}$ = dry deposition of nitrogen (kg/month) for each month *m* and bay segment *s*, and

$Nwet_{m,s}$ = wet deposition of nitrogen (kg/month) for each month *m* and bay segment *s*.

The total atmospheric deposition to a bay segment was given as the sum of the wet and dry deposition, as follows:

$$Ntot_{m,s} = Nwet_{m,s} + Ndry_{m,s},$$

where:

$Ntot_{m,s}$ = total atmospheric deposition of nitrogen (kg/month) for each month *m* and bay segment *s*.

Method 2. This method utilized the same equations for estimating atmospheric deposition as used in Method 1. However, the dry:wet deposition ratio used was derived from data gathered at the TBADS Gandy sampling site. The estimated ratio of dry:wet deposition from the TBADS was 1.003:1. It was assumed that this ratio was constant across all bay segments and time.

Method 3. This method utilized the mean monthly wet and dry deposition rates obtained from TBADS. It was assumed that these rates were constant across all bay segments.

The equation for the wet deposition of nitrogen was:

$$Nwet_{m,s} = NWETRATE_m * A_s,$$

where:

$Nwet_{m,s}$ = wet deposition of nitrogen (kg/month) for each month *m* and bay segment *s*,

$NWETRATE_m$ = mean wet deposition rate (kg/m^2/month) for each month *m*, and

A_s = surface area (m^2) of each segment *s*.

The dry deposition rate for nitrogen was estimated using the following equation:

$$Ndry_{m,s} = NDRYRATE_m * A_s,$$

where:

$Ndry_{m,s}$ = dry deposition of nitrogen (kg/month) for each month *m* and bay segment *s*,

$NDRYRATE_m$ = mean dry deposition rate ($kg/m^2/month$) for each month *m*, and

A_s = surface area (m^2) of each segment *s*.

The total atmospheric deposition was estimated as the sum of the dry and wet deposition, as in Methods 1 and 2.

Method 4. This method utilized a combination of several methods described above. Method 4 utilized the most site-specific data for both concentrations and hydrologic loads to the bay segments, as opposed to Method 2, for example, in which the wet deposition rate was held constant over all bay segments. Method 4 allowed for segment-specific differences in monthly wet deposition rates as a function of the segment-specific hydrologic loads. The wet nitrogen concentration data from the TBADS site, as in Method 3, and the segment-specific hydrologic loads, as in Method 1, were used to estimate wet nitrogen deposition. Dry deposition was estimated using the TBADS-derived seasonal dry:wet deposition ratio, which was 1.05 for the dry season (months 1-6, 11, and 12) and 0.66 for the wet season (months 7-10).

Estimates of dry deposition of nitrogen from monitoring performed at the TBADS site were used only to derive the seasonal dry:wet deposition ratio. Estimates of dry deposition of nitrogen at the TBADS site were not summed with estimated wet deposition of nitrogen at the site to arrive at a total deposition estimate applicable to the entire bay. Rather, spatial variations in segment-specific wet deposition, driven by differences in estimated rainfall to the various segments, were expected to result in spatial variations in segment-specific dry deposition as well. Thus, the seasonal dry:wet deposition ratios, as estimated from the TBADS data, were applied to estimate total deposition on a segment-specific basis.

The equation for estimation of wet deposition of nitrogen was as follows:

$$Nwet_{m,s}=[N]_m * H_{m,s},$$

where:

$Nwet_{m,s}$ = wet deposition of nitrogen (g/month) for each month *m* and bay segment *s*,

$[N]_m$ = mean precipitation-weighted nitrogen concentration (g/m^3) in the rainfall measured at the Verna Wellfield for January 1995 through July 1996, and at the TBADS site for August 1996 through December 1998, for each month *m*, and

$H_{m,s}$ = estimated hydrologic load (m^3/month) from rainfall for each month *m* and bay segment *s*.

The dry deposition of nitrogen to each bay segment was estimated as follows:

Dry season: $Ndry_{m,s}$=1.05 * $Nwet_{m,s}$, for months 1-6, 11, and 12, and
Wet season: $Ndry_{m,s}$=0.66 * $Nwet_{m,s}$, for months 7-10,

where

$Ndry_{m,s}$ = dry deposition of nitrogen (g/month) for each month *m* and bay segment *s*, and

$Nwet_{m,s}$ = wet deposition of nitrogen (g/month), for each month *m* and bay segment *s*.

The total atmospheric deposition to each segment for each month was the sum of the segment- and monthly-specific wet and dry deposition, as follows:

$Ntot_{m,s}$= $Nwet_{m,s}$ + $Ndry_{m,s}$,

where:

$Ntot_{m,s}$ = total atmospheric deposition of nitrogen (kg/month) for each month *m* and bay segment *s*.

Evaluation of Methods. A comparison of the average monthly atmospheric deposition resulting from each of the methods evaluated for the August 1996 – July 1998 period is shown in Table 2-1. Total nitrogen deposition resulting from Methods 2 and 3 was less than that from Method 1. This follows from the utilization in Methods 2 and 3 of a lower dry:wet ratio (1.003:1) than in Method 1 (2.04:1), yielding lower dry and total deposition. Method 3 resulted in higher wet deposition than did Methods 1 and 2, primarily because of the higher wet nitrogen concentrations at the Gandy site than at the Verna site (Pribble and Janicki, 1999). Relative to Method 1, Methods 2 and 3 significantly underestimated total deposition. Method 4 resulted in the highest total deposition, and most closely estimated the loadings from the original method (Method 1). The dry deposition resulting from Method 4 was lower than that from Method 1, but Method 4 wet deposition was higher.

Table 2-1. Average monthly total atmospheric deposition of nitrogen to Tampa Bay derived by the four methods, August 1996 – July 1998.

METHOD	Wet Deposition (tons/month)	Dry Deposition (tons/month)	Total Deposition (tons/month)
Method 1	31	63	94
Method 2	31	31	62
Method 3	36	36	72
Method 4	55	55	110

Based on the results of this evaluation and consultation with the Tampa Bay Atmospheric Deposition Group, the TBEP selected Method 4 as the most appropriate for estimation of atmospheric deposition for the 1995-1998 period. This method utilizes the most site-specific data for both concentrations and hydrologic loads to the bay segments. This method includes segment-specific differences in monthly wet deposition rates as a function of the segment-specific hydrologic loads. The data used for estimation of the 1995-1998 loadings are described in the following.

The precipitation nitrogen (nitrate and ammonia) concentration data for January 1995-July 1996 used for estimating wet deposition were from the monitoring done at the NADP Verna Wellfield site. Concentration data for the same two nitrogen species for August 1996-December 1998 were taken from wet deposition monitoring at the TBADS site (Pribble and Janicki, 1999; Poor, 2000). As for previous loading estimates, segment-specific hydrologic loads derived from 22 NWS rainfall monitoring sites were used to estimate wet nitrogen deposition. For the 1995-1998 estimates, dry deposition of nitrogen was estimated using the seasonal dry:wet deposition ratio derived from the TBADS data, also constant across all bay segments but varying in time.

The estimation of phosphorus deposition utilized the same equations, with wet phosphorus concentrations for January 1995-July 1996 set to a constant value of 0.195 mg/L, as in previous loading estimates (Zarbock et al., 1994), and wet concentrations for August 1996-December 1998 obtained from monitoring at the TBADS site. No atmospheric concentration data for phosphorus were measured at the TBADS site, so that estimates of dry deposition of phosphorus were obtained using the same seasonal dry:wet ratios as utilized for estimation of nitrogen deposition.

For the 1999-2003 loading estimates, more site-specific data were available for the atmospheric deposition loading estimate. In August 1996, the USF College of Public Health and EPCHC initiated monitoring as part of the Tampa Bay Atmospheric Deposition Study (TBADS). This program includes sampling elements for both wet and dry deposition at an intensive monitoring site located on the Gandy Bridge Causeway. The data available from TBADS that can be used to estimate atmospheric deposition to Tampa Bay include precipitation pollutant (nitrogen and phosphorous) concentration data, wet and dry deposition rates, and an estimate of the ratio of dry:wet deposition.

This method allowed for segment-specific differences in monthly wet deposition rates as a function of the segment-specific hydrologic loads. The wet nitrogen concentration data from the TBADS site and the segment-specific hydrologic loads were used to estimate wet nitrogen deposition. Dry deposition was estimated using the TBADS-derived seasonal dry:wet deposition ratio, which was 1.20 for the dry season (November to June) and 0.55 for the wet season (July to October).

Estimates of dry deposition of nitrogen from monitoring performed at the TBADS site were used only to derive the seasonal dry:wet deposition ratio. Estimates of dry deposition of nitrogen at the TBADS site were not summed with estimated wet deposition of nitrogen at the site to arrive at a total deposition estimate applicable to the entire bay. Rather, spatial variations in segment-specific wet deposition, driven by differences in estimated rainfall to the various segments, were expected to result in spatial variations in segment-specific dry deposition. Thus, the seasonal dry:wet deposition ratios, as estimated from the TBADS data, were applied to estimate total deposition on a segment-specific basis.

The equation for estimation of wet deposition of nitrogen was as follows:

$$Nwet_{m,s} = [N]_m * H_{m,s}$$

where:

$Nwet_{m,s}$ = wet deposition of nitrogen (g/month) for each month *m* and bay segment *s*,

$[N]_m$ = mean precipitation-weighted nitrogen concentration (g/m^3) in the rainfall measured at the TBADS site for January 1999 through December 2003, for each month *m*, and

$H_{m,s}$ = estimated hydrologic load (m^3/month) from rainfall for each month *m* and bay segment *s*.

The dry deposition of nitrogen to each bay segment was estimated as follows:

Dry season: $Ndry_{m,s} = 1.20 * Nwet_{m,s}$, for November to June, and
Wet season: $Ndry_{m,s} = 0.55 * Nwet_{m,s}$, for July to October,

where

$Ndry_{m,s}$ = dry deposition of nitrogen (g/month) for each month *m* and bay segment *s*, and

$Nwet_{m,s}$ = wet deposition of nitrogen (g/month), for each month *m* and bay segment *s*.

The total atmospheric deposition to each segment for each month was the sum of the segment- and monthly-specific wet and dry deposition, as follows:

$$Ntot_{m,s} = Nwet_{m,s} + Ndry_{m,s}$$

where:

$Ntot_{m,s}$ = total atmospheric deposition of nitrogen (kg/month) for each month *m* and bay segment *s*.

The precipitation nitrogen (nitrate and ammonia) concentration data for January 1999-December 2003 were taken from wet deposition monitoring at the TBADS site (Poor, 2004). As for previous loading estimates, segment-specific hydrologic loads derived from 22 NWS rainfall monitoring sites were used to estimate wet nitrogen deposition. For the 1999-2003 estimates, dry deposition of nitrogen was estimated using the seasonal dry:wet deposition ratio derived from the TBADS data, also constant across all bay segments but varying in time.

The estimation of phosphorus deposition utilized the same equations, with wet phosphorus concentrations for January 1999 - December 2003 obtained from monitoring at the TBADS site. No atmospheric concentration data for phosphorus were measured at the TBADS site, so that estimates of dry deposition of phosphorus were obtained using the same seasonal dry:wet ratios as utilized for estimation of nitrogen deposition.

A database containing the data used for estimation of the wet and dry deposition of TN and TP for 1999-2003 can be found on the accompanying CD. This database contains monthly data for TN and TP concentrations in rainfall at the TBADS site, estimates of monthly dry deposition of TN at the TBADS site, and estimates of monthly rainfall volumes to each bay segment.

2.2 Domestic Point Sources

Point sources of flow and pollutant loadings are defined as discharges that originate at a discrete location, such as from a pipe or a small, definable land area (such as for land application of treated wastewater effluent). Domestic sources include publicly and privately owned wastewater treatment plants.

2.2.1 Methods

The estimated pollutant loadings from domestic point sources were derived using the same methods as used in previous loading estimates (Pribble et al. 2001, Zarbock et al., 1994; 1998). Domestic point sources identified for use in estimation of 1999-2003 loadings are shown in Table 2-2, and include all direct surface discharges and all land application discharges with an annual average daily flow (ADF) of 0.1 mgd or greater.

Domestic point sources were identified by reviewing FDEP point source discharge locations in relation to the Tampa Bay watershed. These locations were used to create an ArcGIS coverage, and then mapped for FDEP Tampa office staff review. The domestic point sources in the Tampa Bay watershed with ADF of 0.1 mgd or greater were identified with the assistance of FDEP Tampa office staff.

Data sources used to estimate domestic point source discharge and concentration data to Tampa Bay for 1999-2003 are as follows:

- Monthly Operating Reports (MOR) and Discharge Monitoring Reports (DMR) obtained from the EPCHC and the Tampa office of the FDEP; and

- MOR and DMR data obtained directly from the domestic wastewater treatment facilities for those data not obtained from the EPCHC and FDEP.

A database of domestic point source discharge information was developed, listing monthly discharge rates and TN, TP, TSS, and BOD concentration data.

Both surface water dischargers and facilities with land application of effluent were included. Monthly data from a total of 35 major domestic point source dischargers (Table 2-2) were included. Four facilities that were included in the 1995-1998 estimates are not included in the 1999-2003 list because discharges were below the 0.1 mgd limit. There are no new facilities in the 1999-2003 list.

The database was subjected to quality control measures to ensure that the most accurate flows and concentrations obtainable were used in the loading estimates. The entries were scanned for incongruous data points. Obvious outliers (such as flows of two or three orders of magnitude higher than the design capacity of the facility) were removed from the record. Complete records existed for most domestic wastewater treatment plants, with facilities reporting flow rate and concentrations for TN, TP, TSS, and BOD on a monthly basis. Attempts were made to locate sources of valid data to replace missing or invalid values, often by contacting facility personnel directly.

Table 2-2. Domestic point sources in the Tampa Bay watershed (1999-2003).

Facility Name	Bay Segment	Major Basin
City of Bradenton	Manatee River	Manatee River
City of Clearwater East	Old Tampa Bay	Coastal OTB
City of Clearwater Northeast	Old Tampa Bay	Coastal OTB
Hillsborough County Dale Mabry	Old Tampa Bay	Coastal OTB
Hillsborough County Eagles	Old Tampa Bay	Coastal OTB
Hillsborough County Falkenburg	Hillsborough Bay	Coastal HB
City of Tampa H.F. Curren	Hillsborough Bay	Coastal HB
City of Lakeland	Hillsborough Bay	Alafia River
City of Largo	Old Tampa Bay	Coastal OTB
Manatee County North County Regional	Lower Tampa Bay	Coastal LTB
Manatee County Southeast Subregional	Manatee River	Manatee River
MacDill A.F.B.	Middle Tampa Bay	Coastal MTB
Meadowlands	Hillsborough Bay	Hillsborough River
City of Mulberry	Hillsborough Bay	Hillsborough River
Hillsborough County Northwest Regional	Old Tampa Bay	Coastal OTB
City of Oldsmar	Old Tampa Bay	Coastal OTB
On Top of the World	Old Tampa Bay	Coastal OTB
City of Palmetto	Terra Ceia Bay	Terra Ceia Bay
Pasco County Southeast Subregional	Hillsborough Bay	Hillsborough River
Pebble Creek	Hillsborough Bay	Hillsborough River
City of Plant City	Hillsborough Bay	Hillsborough River
Polk County Southwest Regional	Hillsborough Bay	Alafia River
Hillsborough County River Oaks	Old Tampa Bay	Coastal OTB
Hillsborough County South County Regional	Middle Tampa Bay	Little Manatee River
City of St. Petersburg Albert Whitted	Old Tampa Bay, Middle Tampa Bay, and Boca Ciega	Coastal OTB, Coastal MTB, Boca Ciega Bay
City of St. Petersburg Northeast		
City of St. Petersburg Northwest		

City of St. Petersburg Southwest	Bay	
Hillsborough County Summerfield Subregional	Hillsborough Bay	Coastal HB
Hillsborough County Valrico	Hillsborough Bay	Alafia River
Hillsborough County Van Dyke	Old Tampa Bay	Coastal OTB
Wesley Chapel	Hillsborough Bay	Hillsborough River
City of Zephyrhills	Hillsborough Bay	Hillsborough River
Pinellas County South Cross Bayou	Boca Ciega Bay	Boca Ciega Bay
Pinellas County Northwest	Old Tampa Bay	Coastal OTB

For those data gaps that could not be filled with actual recorded data, two methods were used to complete the record, depending upon the amount of data missing, as follows.

- If 1-3 consecutive months of data were missing, discharge and/or pollutant concentrations were set to those of the last month for which values existed.

- If data from more than 3 consecutive months were missing, discharge and/or pollutant concentrations were set to the monthly averages of the 1999-2003 record.

In some cases, a form of nutrient other than total nitrogen was reported. For example, if both total nitrogen and nitrate nitrogen were recorded for some months at a facility, but only nitrate nitrogen was recorded for most months, the average ratio of nitrate to total nitrogen was calculated for those months with both values. The resulting ratio was applied to the other months, resulting in an estimate of total nitrogen for those months. If only nitrate nitrogen data existed, then total nitrogen concentration was set to the reported concentration of nitrate nitrogen.

If no data for a certain parameter were available for a facility and it was known or suspected that loadings of that chemical did occur, then other similar facilities were examined. Typical or averaged data from these facilities were used to fill data gaps if no other source of information was available. This method was chosen as an alternative to showing missing data for loads from major point sources.

The proportions of data records for which data were estimated based on previous months records:

- approximately 26% of the records were filled using interpolated data;

- approximately 16% of the records were filled using facility mean values.

<u>Surface Discharge</u>

Many of the inventoried domestic facilities utilize direct surface discharge for effluent disposal. Surface water inputs from domestic point sources were estimated for both the gaged and ungaged basins of the watershed, expressed as a volume per unit time, such as million gallons per day (mgd). The flows from each point source were assigned to the subbasin that receives the discharge, allowing the aggregation of point source flows for each major drainage basin and each bay segment. All of the effluent released via surface discharge was assumed to reach Tampa Bay. Domestic point source loadings were subtracted from the total gaged nonpoint source loads, discussed later, to avoid double counting of point source loadings originating upstream of gages.

Estimates of point source pollutant loading for surface water discharges were obtained by multiplying the reported mean monthly concentration of the pollutant of concern and the mean monthly discharge volume. With appropriate conversion factors, this calculation yields a mass per unit time, such as tons per year of pollutant (TN, TP, TSS, BOD).

Land Application

Treated effluent from domestic facilities is frequently discharged onto the land, most commonly for reuse by spray irrigation or into percolation ponds. The applied effluent evaporates, is taken up by vegetation, becomes surface runoff (generally a very small component of the total volume), or infiltrates to the water table. Therefore, pollutant loadings from this source that reach the bay generally do so via groundwater. In this loading analysis, land application effluent loads are calculated separately from groundwater loads.

Land application loadings were estimated using recorded effluent quality data from specific facilities, with "typical" reduction rates applied to the nitrogen and phosphorus once in the environment. These reduction rates are the same as those used previously for loading estimations for the 1984-1998 period (Pribble et al. 2001, Zarbock et al., 1994; 1996), and account for attenuation of pollutants in the environment prior to the effluent flow reaching the receiving water of Tampa Bay. Pollutant loading reductions applied to loads discharged to land were as follows:

TN (spray irrigation) : 95% reduction for City of St. Petersburg facilities,
: 90% reduction for all other facilities,
TN (percolation pond) : 70% reduction,
TP (all) : 95% reduction,

TSS (all) : 95% reduction, and
BOD (all) : 95% reduction.

These rates were the same as those used previously for TN, TP, and TSS (Pribble et al., 2001; Zarbock et al., 1994; 1996), with the attenuation of BOD loads set to the same rate as that for TP and TSS. A complete description of loading calculations from land application from the Zarbock et al. 1994 report can be found in Appendices J and K.

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2.3 Industrial Point Sources

Industrial point sources include dischargers of process water and other effluent not categorized as domestic sewage.

2.3.1 Methods

The estimated pollutant loadings from industrial point sources were derived using the same methods as used in previous loading estimates (Pribble et al., 2001; Zarbock et al., 1994; 1998). Industrial point sources identified for use in estimation of 1999-2003 loadings are shown in Table 2-3, and include all direct surface discharges and all land application discharges with an average daily flow of 0.1 mgd or greater.

Table 2-3. Industrial point sources in the Tampa Bay watershed (1999-2003).

Facility Name	Bay Segment
Agrifos Nichols Mine (fka Mobil)	Hillsborough Bay
Agrifos Nichols Prep Plant (fka Mobil)	Hillsborough Bay
Alpha/Owens-Corning	Hillsborough Bay
Bridgeway Acres Landfill	Old Tampa Bay
Cargill East Tampa	Hillsborough Bay
Coronet Industries	Hillsborough Bay
CSX Transportation Winston Yard	Hillsborough Bay
Crystals International	Hillsborough Bay
Florida Power and Light Manatee Steam	Middle Tampa Bay
FDEP Stock Enhancement Program	Middle Tampa Bay
Estech Inc. Silver City Mine	Hillsborough Bay
Farmland Hydro Green Bay Plant	Hillsborough Bay
Farmland Hydro Port Sutton	Hillsborough Bay

Florida Juice (WBRK Property)	Hillsborough Bay
IMC Agrico Four Corners Mine	Middle Tampa Bay
IMC Agrico Haynesworth/Kingsford Mine	Hillsborough Bay
IMC Agrico Lonesome Mine	Hillsborough Bay
IMC Agrico Port Sutton	Hillsborough Bay
Mulberry Phosphates	Hillsborough Bay
Nitram Chemical	Hillsborough Bay
Pakhoed Dry Bulk Terminals	Hillsborough Bay
Piney Point Phosphates	Lower Tampa Bay
TECO Big Bend Station	Middle Tampa Bay
TECO Gannon Station	Hillsborough Bay
Trademark Nitrogen	Hillsborough Bay
Tropicana North America	Manatee River

Industrial point source identification was initiated using those sources identified for the 1995-1998 loading estimates (Zarbock et al., 1996). These sources were first checked to identify which sources were operational during the 1999-2003 period, with those that were no longer discharging removed from the list. Additional industrial point sources in the Tampa Bay watershed not included in the 1995-1998 list and meeting the 0.1 MGD discharge criterion were then identified with the assistance of FDEP staff. The locations of these sources were obtained from FDEP. These locations were used to create an ArcGIS coverage, and then mapped for FDEP Tampa office staff review.

Data sources used to estimate industrial point source discharges and loadings to Tampa Bay for 1999-2003 are as follows:

- MORs and DMRs obtained from the Environmental Protection Commission of Hillsborough County (EPCHC) and the Tampa office of the FDEP; and

- MOR and DMR data obtained directly from the industrial wastewater treatment facilities for those data not obtained from the EPCHC and FDEP.

A database of industrial point source discharge information was developed, listing monthly discharge rates and TN, TP, TSS, and BOD concentration data. Both surface water dischargers and facilities with land application of effluent were included. Monthly data from a total of 26 major industrial point sources (Table 2-3) were included. Two facilities that were included in the 1995-1998 estimates are not included in the 1999-2003 list. There were no new facilities added to the list for 1999-2003.

The database was subjected to quality control measures to ensure that the most accurate flows and concentrations obtainable were used in the loading estimates. The entries were scanned for incongruous data points. Obvious outliers (such as flows of two or three orders of magnitude higher than the design capacity of the facility) were removed from the record. Attempts were made to locate sources of valid data to replace missing or invalid values, often by contacting facility personnel directly.

For those data gaps that could not be filled with actual recorded data, two methods were used to complete the record, depending upon the amount of data missing, as follows.

- If 1-3 consecutive months of data were missing, discharge and/or pollutant concentrations were set to those of the last month's for which values existed.

- If data from more than 3 consecutive months were missing, discharge and/or pollutant concentrations were set to the monthly averages of the 1999-2003 record.

In some cases, a form of nutrient other than total nitrogen was reported. For example, if both total nitrogen and nitrate-nitrogen were recorded for some months at a facility, but only nitrate-nitrogen was recorded for most months, the average ratio of nitrate to total nitrogen was calculated for those months with both values. The resulting ratio was applied to the other months, resulting in an estimate of total nitrogen for those months. If only nitrate-nitrogen data existed, then total nitrogen concentration was set to the reported concentration of nitrate-nitrogen.

If no data for a certain parameter were available for a facility and it was known or suspected that loadings of that chemical did occur, then other similar facilities were examined. Typical or averaged data from these facilities were used to fill data gaps if no other source of information was available. This method was chosen as an alternative to showing missing data for loads from major point sources.

The proportions of data records for which data were estimated based on previous months' records:

- approximately 43% of the records were filled using interpolated data;

- approximately 9% of the records were filled using facility mean values.

Surface Discharge

Most of the inventoried industrial facilities utilize direct surface discharge for effluent disposal. Surface water inputs from industrial point sources were estimated for both the gaged and ungaged basins of the watershed, expressed as a volume per unit time, such as mgd. The flows from each point source were assigned to the subbasin that receives the discharge, allowing the aggregation of point source flows for each major drainage basin and each bay segment. All of the effluent released via surface discharge was assumed to reach the Tampa Bay system. As for domestic point source loadings, industrial point source loadings were subtracted from the total gaged nonpoint source loads, discussed later, to avoid double counting of point source loadings originating upstream of gages.

Estimates of industrial point source pollutant loading for surface water discharges were calculated by multiplying the reported concentration of the pollutant of concern and the discharge volume. With appropriate conversion factors, this calculation yields a mass per unit time, such as tons of pollutant per year (TN, TP, TSS, BOD).

Land Application

Treated effluent from industrial facilities is sometimes discharged onto the land, most commonly into percolation ponds. The applied effluent evaporates, is taken up by vegetation, becomes surface runoff (generally a very small component of the total volume), or infiltrates to the water table. Therefore, pollutant loadings from this source that reach the bay generally do so via groundwater. In this loading analysis, land application effluent loads are calculated separately from groundwater loads.

Land application loadings were estimated using recorded effluent quality data from specific facilities, with "typical" reduction rates applied to the nitrogen and phosphorus once in the environment. These reduction rates are the same as those used previously for loading estimations for the 1985-1998 period (Pribble et al., 2003; Zarbock et al., 1994; 1996), and account for attenuation of pollutants in the environment prior to the effluent flow reaching the receiving water of Tampa Bay. The reduction rates are listed above in the description of the domestic point source loading estimate methods.

Accidental Spills

If large spills occur during the time period under study they are accounted for in the loading report. For example the Mulberry Phosphate spill was incorporated into the 1995-1998 loadings report. No large spills occurred during the 1999-2003. The Piney Point Phosphate facility was accounted for in this report and was treated as discharge.

2.4 Springs

Springs are also a source of pollutant loadings to Tampa Bay. Previous loading estimates have been developed for Sulphur Springs, Lithia Springs, and Crystal Springs, which were identified as significant discharges in the Tampa Bay watershed (Zarbock et al., 1994; 1996). Smaller springs do exist in the watershed, but have relatively small discharges and were not considered in this loading analysis or the previous estimates. Lithia Springs and Sulphur Springs are not in gaged portions of the Tampa Bay watershed, but are themselves gaged, therefore loading estimates were derived for these springs.

2.4.1 Methods

Pollutant loadings from Sulphur Springs and Lithia Springs were estimated. Spring discharge loadings were estimated based on measured discharge and water quality data obtained from USGS and FDEP (Coffin and Fletcher, 1996; Coffin and Fletcher, 1997a; Coffin and Fletcher, 1997b; Coffin and Fletcher, 1999). Only periodic data were available. The pollutant concentrations were obtained by averaging measured data for each spring over the 1999-2003 period. Revised pollutant concentrations were received from the FDEP Monitoring Program. Discharge estimates for months with no measured flow data were made by interpolating between preceding and succeeding months that did have measured data. For each spring, the monthly measured or estimated pollutant concentrations were multiplied by the monthly estimated or measured discharge to obtain monthly loads. Monthly loads were summed to produce annual loads for the 1999-2003 period.

2.5 Groundwater

Groundwater is a source of freshwater and nutrient loadings to many coastal areas. The surficial (water table), intermediate, and Floridan aquifers all contribute flows and loads to Tampa Bay. Estimates of groundwater pollutant loadings for the 1999-2003 period were derived using the same methods as in previous estimates (Pribble et al., 2001; Zarbock et al., 1994; 1996).

2.5.1 Methods

Data sources used to estimate groundwater flows and loadings to Tampa Bay for 1999-2003 are as follows:

- Floridan and intermediate aquifer potentiometric surfaces for May (representing the dry season) and September (representing the wet season) for calendar years 1999 through 2003 were obtained from USGS Open File Reports

- Topography data for the Tampa Bay watershed and shoreline lengths of the bay were obtained from USGS quadrangle (7.5-minute) maps.

- TN and TP concentration data for the surficial, intermediate, and Floridan aquifers were obtained from the SWFWMD Ambient Ground Water Monitoring Program (AGWMP) (DeHaven, personal communications, 2001). Reported concentrations from monitor wells in the groundwater flow areas tributary to each bay segment were averaged to yield a representative groundwater concentration. If only a few monitor wells were present in an area, concentrations from several adjoining flow areas were averaged. It was desired to obtain a representative regional set of concentration values. Thus, the data set was reviewed and monitor wells deemed to not be representative of regional conditions (such as wells located adjacent to known groundwater pollution sources), were not used. Additionally, individual concentration values that were noted in the data set as being outside the normal range of concentrations for that station (potential outliers) were censored. Nitrate+nitrite (as N) concentrations were used to estimate nitrogen loads, as these species are most often cited as groundwater pollution threats. Few ammonia concentration data were available, and ammonia nitrogen concentrations were typically less than 10% of those of nitrate+nitrite nitrogen. Total phosphorus (as P) was used to estimate phosphorus loads due to the general lack of significant concentrations of organic phosphorus in groundwater.

- Surficial aquifer elevation data used by Brooks et al. (1993) were the most recent available information suitable for bay-wide loading calculations, and were used for this analysis.

Groundwater flows were estimated for each of the bay segments. Only groundwater inflow that entered the bay directly from the shoreline or bay bottom was considered. Groundwater and septic tank leachate inflow to streams was accounted for through measured or modeled surface water flow and was attributed as nonpoint source loading, and was not included in these groundwater loading estimates.

Existing estimates of wet and dry season groundwater inflow to Tampa Bay were completed using the methods of Hutchinson (1983) and Brooks et al. (1993). Flow estimates were calculated using a flow net analysis and Darcy's equation (Freeze and Cherry, 1979), a well-recognized analytical method for estimating groundwater flow. The flow net analysis is a graphical procedure used to identify groundwater flow paths based on water surface profiles. Darcy's Equation is:

$$Q = (7.48 \times 10^{-6})\ T \times I \times L$$

where:

- Q = flow rate, in million gallons per day (MGD),
- T = aquifer transmissivity, in ft^2/day,
- I = hydraulic gradient (head difference/length of flow path),
- L = width of flow path, in feet,

and

1 cubic foot = 7.48×10^{-6} million gallons.

Average wet season and dry season flows and loadings from the Floridan and intermediate aquifers, and annual flows and loadings from the surficial aquifer, were estimated using the following methods:

1) Values for transmissivity (T) for the Floridan and intermediate aquifers were taken from USGS and SWFWMD groundwater modeling reports for the Tampa Bay area (Ryder et al., 1980; Wolansky and Corral, 1985; Jones, 1990). “T” values for different areas of the watershed were used as available. A single watershed-wide value for “T” for the surficial aquifer was taken from Brooks et al. (1993). These aquifer characteristic values are generally stable over time and did

not change from previous loading estimates (Pribble et al., 2001; Zarbock et al., 1994; 1996).

2) For all three aquifers, the regions of groundwater flow to each bay segment were identified as discrete flow zones. Flow zones were delineated using USGS potentiometric surface maps and a flow net analysis. Groundwater flow path lines were drawn perpendicular to the lines of equipotential (constant head). Flow paths leading to each bay segment were identified, and the associated flow zones were then delineated.

3) Values for "I" and "L" for the Floridan and intermediate aquifers were determined using USGS potentiometric surface maps as referenced above. Seasonal values for "I", the hydraulic gradient of the aquifer, were estimated by measuring the change in potentiometric surface elevation and the length of the groundwater flow path over the distance from the inland boundary of the groundwater flow area to the bay shoreline, for each bay segment tributary area. An average annual value of "I" for the surficial aquifer was estimated by measuring the change in land surface elevation over the horizontal distance from an inland topographic depression to the bay shoreline, and measuring the length of the groundwater flow path from the topographic depression to the bay shoreline, for each bay segment tributary area. It was assumed that the gradient of the surficial aquifer would follow the general gradient of the land surface. This value did not change from previous estimates.

4) "L," the width of the flow path, was estimated by measuring the length of the bay segment shoreline, expressed as a plane perpendicular to the groundwater flow path for each bay segment.

5) Using the above data and Darcy's equation, flow estimates were made for the Floridan and intermediate aquifers for wet and dry seasons using the appropriate potentiometric surface maps.

6) Because surficial aquifer gradients can change greatly over relatively small distances and time frames, it was not feasible to estimate surficial aquifer inflows on a seasonal basis. Therefore, surficial aquifer flow rates were estimated for average annual conditions only, also using Darcy's equation.

Monthly groundwater TN, TP, and freshwater loadings to each bay segment from each aquifer for the period 1999 through 2003 were then estimated as follows:

1) Wet and dry season Floridan and intermediate aquifer flow rates (expressed as million gallons per day) were multiplied by the average TN and TP concentrations (mg/L) for each bay segment flow zone. The resulting bay segment loading rates were converted to kg/month.

2) Surficial aquifer loading rates were estimated in the same manner, but with a constant monthly flow rate throughout the year, not seasonal rates.

3) Pollutant loads and flows from the Floridan, intermediate, and surficial aquifers were then summed on a monthly basis to yield total monthly pollutant loads (kg/month) and inflows (cubic meters/month) to each bay segment.

2.6 Material Losses

Fertilizer losses from loading docks at port facilities constitute a source of nutrient loading classified as material losses. In particular, bulk phosphate fertilizer is subject to product losses during its transfer from land carrier to storage facility, and onto vessels for shipping. Product is lost both through spilled product washing into the bay with stormwater runoff, and via fugitive dust. Material losses occur at facilities at the Port of Tampa, in the Coastal Hillsborough Bay basin, and at Port Manatee, in the Coastal Lower Tampa Bay basin.

2.6.1 Methods

Estimates of total nitrogen and total phosphorus loadings due to material losses were developed for handling facilities listed in Table 2-4. For previous loading estimates, facility personnel provided shipping tonnage estimates, to which were applied multipliers to represent loss fractions (Pribble et al., 2001; Zarbock et al., 1994; 1996). For the 1999-2003 estimates, all facilities provided spreadsheets containing loss estimates due to handling losses and airborne (fugitive) losses on an annual basis. These estimates were requested and obtained through the assistance of Mr. Craig Kovach, QuietEarth Consultants, Inc., and provided to the TBEP in electronic format. The letter accompanying these electronic files is provided in Appendix A.

The estimates for the 1999-2003 period represent the best estimates by facility personnel of actual losses. These estimates reflect both actual reductions in nutrient losses from improved handling practices implemented by all facilities over the past several years, and improved loss estimation techniques for both ship loading losses and air borne losses.

Table 2-4. Fertilizer handling facilities 1999-2003.

Facility Name	Bay Segment
CF Industries	Hillsborough Bay
CSX	Hillsborough Bay
Cargill	Hillsborough Bay
Eastern	Hillsborough Bay
IMC-Agrico Big Bend	Hillsborough Bay
Kinder Morgan Port Sutton	Hillsborough Bay
Kinder Morgan Port Manatee	Lower Tampa Bay

2.7 Nonpoint Sources

Nonpoint source pollutant loadings result from stormwater runoff from the Tampa Bay watershed and base flow from the rivers draining to the bay. The estimated nonpoint source loadings for the 1999-2003 period were derived using the same methods as those for the previous loadings estimates (Pribble et al., 2001; Zarbock et al., 1994; 1996). The SWFWMD 1999 land use was utilized for the 1999-2003 nonpoint source loadings estimates, whereas previous estimates used the SWFWMD landuse for 1995 and 1990.

2.7.1 Methods

Nonpoint source TN, TP, TSS, and BOD loadings for the gaged and ungaged portions of the watershed were estimated for the period 1999-2003. The methods for estimating loadings from gaged basins and ungaged basins are described below. A map showing the location of the gaged and ungaged basins is shown in Figure 2-1.

The methods for estimating pollutant loadings from the watershed are presented in Figure 2-2 below. It should be noted that the watershed pollutant loadings include loadings from nonpoint sources, domestic point sources, industrial point sources, and springs. The first method shown in Figure 2-2 is used for those gaged basins for which both measured flow and water quality data exist. The second method is used for those gaged basins for which measured flow data exist, but for which no measured water quality data exist. The third method is used for ungaged basins, for which neither flow nor water quality data are measured. Each of these methods is described below.

Streamflow data were obtained from USGS, SWFWMD, Manatee County, and the City of Bradenton. Water quality data were obtained from the USGS, EPCHC, Pinellas County Department of Environmental Management, and Manatee County.

Gaged Basins with Measured Streamflow and Water Quality Data. Measured streamflow data and measured water quality data were used to estimate nonpoint source loadings from the gaged basins where both data types existed. As shown in Figure 2-2, pollutant loadings from these basins were estimated by multiplying measured monthly flows (Q) at stream gage sites by pollutant concentrations (WQ) measured at or very near the same site, yielding monthly pollutant loads at each gaged point. The pollutant concentration for any missing month at a stream gage was estimated by interpolating between the nearest preceding and succeeding months. Pollutant loads for the most downstream gage in each gaged river and stream were estimated on a monthly basis. Data from the sites in Table 2-5 were used to estimate gaged area loadings.

To derive the nonpoint source loading estimates using this method, the contributions of domestic and industrial point sources in the gaged basins were subtracted from the total watershed loadings estimates. This provided estimates of the loadings from nonpoint sources only.

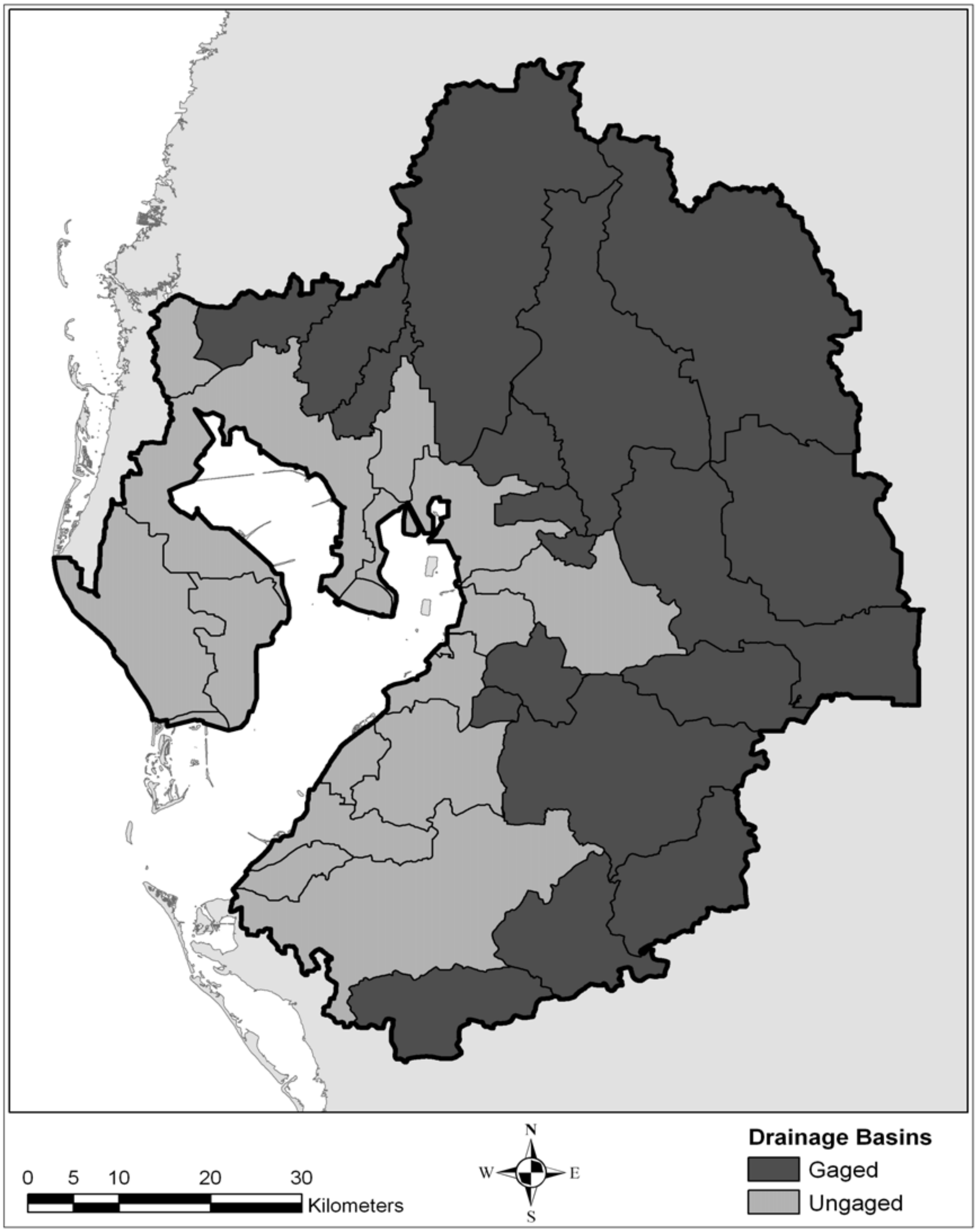

Figure 2-1. Map showing gaged and ungaged basins.

Gaged Basins with Measured Streamflow but no Water Quality Data. Measured streamflow and estimated water quality data were used to estimate nonpoint source loadings from the gaged basins for which measured water quality data did not exist.

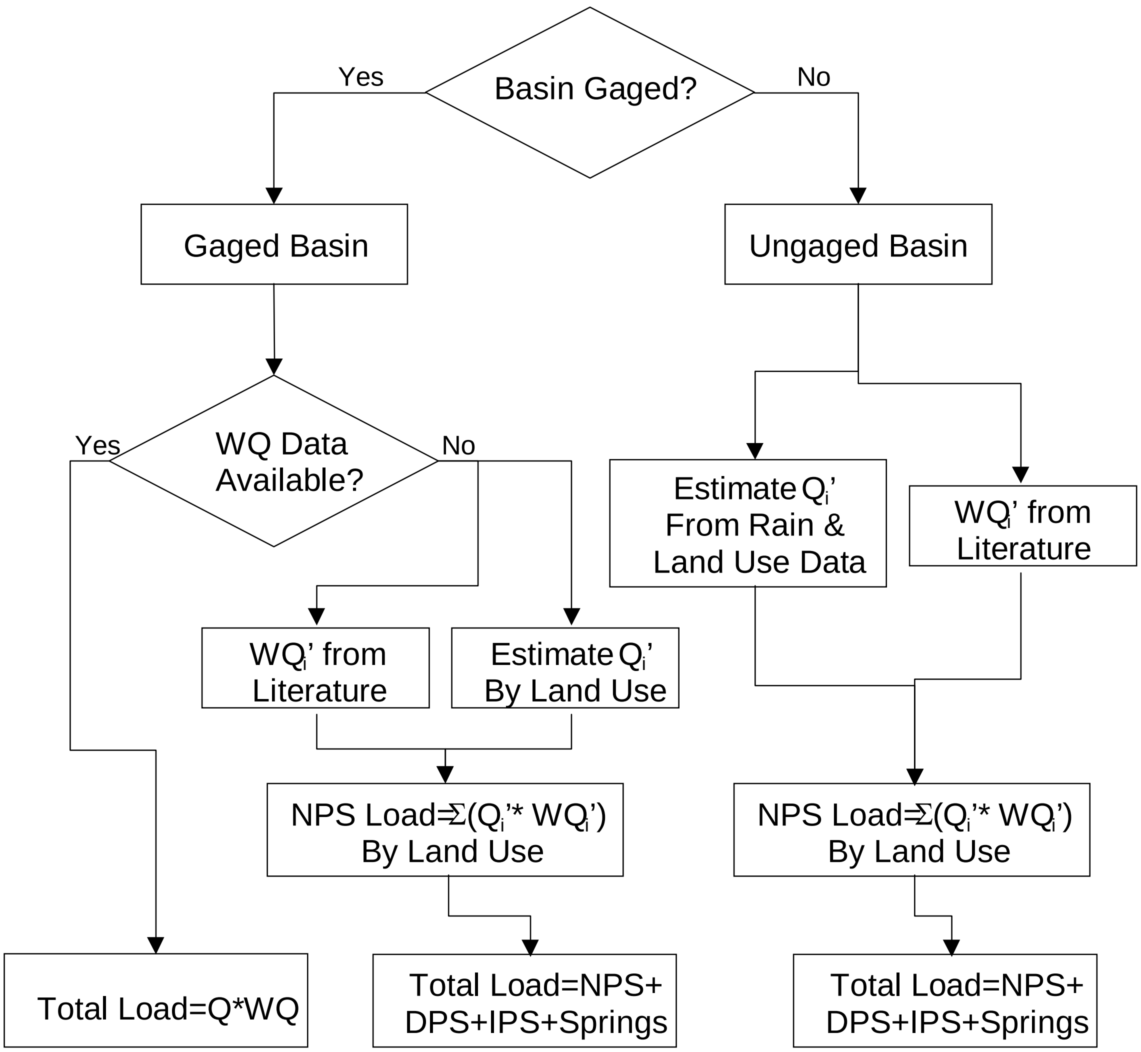

Figure 2-2. Process for estimated total watershed loadings from gaged and ungaged basins.

As in previous loading estimates, derivation of pollutant loadings from these basins involved utilization of streamflow data and data from GIS coverages for land use and subbasin boundaries, wet and dry season land use-specific runoff coefficients, and land use-specific water quality concentrations. Land use information was obtained from the SWFWMD GIS coverages based on 1999 aerial photographs and classified according to the Florida Land Use and Cover

Classification System (FDOT, 1985). Land uses were aggregated into 21 categories (Appendix B) for loading calculations. Subbasin delineations were also obtained from SWFWMD, and were based on USGS subbasin boundaries (Foose, 1993). The land use categories and subbasin boundaries are the same as those used in the previous loading estimates (Pribble et al., 2001; Zarbock et al., 1994; 1996).

Table 2-5. Downstream Stream Gage Stations

Stream Gage Site Name	Streamflow (Agency/Site Number)	Water Quality (Agency/Site Number)
Lake Tarpon Outfall Canal	SWFWMD/FLO12 (S-551)	PCDEM/3-9
Rocky Creek	USGS/02307000	EPCHC/103
Sweetwater Creek	USGS/02306647	EPCHC/104
Hillsborough River at Dam	USGS/02304500	EPCHC/105
Tampa Bypass Canal	SWFWMD/FLO13 (S-160)	EPCHC/147
Delaney Creek	USGS/02301750	EPCHC/138
Alafia River at Lithia	USGS/02301500	EPCHC/114
Bullfrog Creek	USGS/02300700	EPCHC/132
Little Manatee River at Wimauma	USGS/02300500	EPCHC/113
Manatee River at Lake Manatee Dam	Manatee County/Lake Manatee Dam	Manatee County/Lake Manatee Dam

As shown in Figure 2-2, for each land use category (i), specific water quality concentrations (WQ_i') were obtained from the literature (Appendix C). Runoff from each land use category was estimated by apportioning the nonpoint source streamflow among the constituent land use categories in the basin. The nonpoint source streamflow was derived from the gaged basin flow by subtracting domestic point source, industrial point source, and spring contributions from the gaged flow. The apportionment of the nonpoint source flows to each land use category was accomplished as follows:

$$Q_i' = \frac{Q_n A_i R_i}{\sum_i A_i R_i}$$

where:

Q_i'= total nonpoint source flow (m^3/month) from land use category *i*,

Q_n= total nonpoint source flow (m3/month) from the gaged basin,

A_i = area of land use category *i* in gaged basin, and

R_i = runoff coefficient for land use category *i* for the month, representing fraction of rainfall that runs off of the land (Appendix D).

As shown in Figure 2-2, nonpoint source pollutant loadings from these basins were estimated by multiplying the monthly nonpoint source flows apportioned to each land use category (Q_i') by the land use-specific pollutant concentrations (WQ_i'), yielding monthly pollutant loadings from each land use category in the basin. The monthly pollutant loadings from all land use categories were then summed over the basin to provide an estimate of the total nonpoint source pollutant loadings from the basin.

Loadings for the gaged portion of the Alafia River were adjusted for the reduction of loading due the permanent withdrawal for potable water supply by Tampa Bay Water. The withdrawal point is located on the Alafia River between the Lithia and Bell Shoals Road Crossing. The permitted withdrawal schedule is shown in Appendix H . The reduction in load was calculated by multiplying the rate of the actual water withdrawals by ambient EPC observed concentrations of pollutants at Bell Shoals Road. The numbers throughout the report reflect this correction.

Ungaged Basins. The empirical model was used with NWS rainfall data, GIS coverages for 1999 land use, soils, and subbasin boundaries, seasonal land use-specific runoff coefficients (Appendix D), and land use-specific water quality concentrations (Appendix C) to estimate pollutant loads from ungaged areas of the watershed. Land use information was taken from the SWFWMD GIS coverages based on 1999 aerial photographs and classified according to the Florida Land Use and Cover Classification System (FDOT, 1985). Land uses were aggregated into 21 categories for loading calculations. Soils data were taken from the SWFWMD GIS coverages that included soil series and hydrologic soils group information from the Natural Resources Conservation Service Soil Surveys. Subbasin delineations were also obtained from SWFWMD, and were based on USGS subbasin boundaries (Foose, 1993).

The empirical model provides estimates of runoff from ungaged portions of the watershed. The empirical model was validated by comparison with measured flows from ten gaged basins in the watershed, as described in Zarbock et al (1994). A complete description of the model is provided in Appendix I. A summary of the model is provided here.

The empirical model predicts runoff as a function of rainfall and land use categories, using a log-linear relationship. Rainfall amounts for the current month and the two previous months were included in the formulation. The 21 land use categories were aggregated into four land use types: urban, agricultural, wetlands, and forests. The total monthly nonpoint source flow from each ungaged basin is estimated using the log-linear relationship. The nonpoint source flow is then apportioned to each of the 21 land use categories as a function of the area of the land use category in the basin and the seasonal land use-specific runoff coefficients, as described previously.

As shown in Figure 2-2, for each land use category (i), specific water quality concentrations (WQ_i') were obtained from the literature (Appendix C). Runoff (Q_i') from each land use category was estimated by the empirical model. The product of the literature-based land use-specific water quality concentrations and the estimated runoff from each land use category is summed over each basin to provide the pollutant loadings from each basin.

3. DATA SUMMARY

3.1 Atmospheric Deposition Data Summary

Annual average pollutant loads from atmospheric deposition directly to the surface of Tampa Bay for the 1999-2003 period were estimated at:

- TN - 892 tons/year, and
- TP - 19 tons/year.

Annual average bay segment loads for TN ranged from 15 tons/year in Terra Ceia Bay to 258 tons/year in Middle Tampa Bay. The largest bay segments received the greatest TN loads from atmospheric deposition, with Lower Tampa Bay receiving 224 tons/year and Old Tampa Bay receiving 186 tons/year. Lowest annual average bay segment loads for TP were approximately 0.3 tons/year in Terra Ceia Bay and 0.8 tons/year in Manatee River. Atmospheric deposition of TP was greatest at approximately 5 tons/year in both Middle and Lower Tampa Bay, and 4 tons/year in Old Tampa Bay.

The 1999-2003 average annual TN loads due to atmospheric deposition to Tampa Bay (892 tons/year) were slightly lower than those of the 1992-1994 period (1,101 tons/year) and the 1995-1998 period (1,094 tons/year).

Average annual TP loads to the bay for 1999-2003 (19 tons/year) were much less than those of 1992-1994 (807 tons/year) and 1995-1998 (259 tons/year). The large reduction in TP loading for 1999-2003 in relation to 1992-1994 was largely a function of the precipitation phosphorus concentrations used. For TP loading estimates for 1992-1994, the total phosphorus concentration used was a constant 0.195 mg/L (Zarbock et al., 1996). This constant concentration was only used for 19 months of the 1995-1998 period, with the total phosphorus concentration data obtained from the TBADS site used for the remaining 29 months. For 1999-2003 total phosphorus concentration data was obtained from the TBADS site.

3.2 Domestic Point Source Data Summary

Annual average pollutant loads from domestic point sources to Tampa Bay for 1999-2003 were estimated at:

- TN - 393 tons/year,
- TP - 392 tons/year,
- TSS - 204 tons/year, and
- BOD - 353 tons/year.

Annual average bay segment loads for TN ranged from 0.7 tons/year in Lower Tampa Bay to 242 tons/year in Hillsborough Bay. Annual average bay segment loads for TP ranged from 0.1 tons/year in Lower Tampa Bay to 302 tons/year in Hillsborough Bay. Average bay segment loads for TSS ranged from 0.15 tons/year in Lower Tampa Bay to 119 tons/year in Hillsborough Bay. Annual average bay segment loads for BOD ranged from 0.3 tons/year in Lower Tampa Bay to 220 tons/year in Hillsborough Bay.

The 1999-2003 average annual TN loads to Tampa Bay (393 tons/year) are higher than those of 1992-1994 (362 tons/year) and lower than those of 1995-1998 (426 tons/year). Average annual TP loads to the bay for 1999-2003 (392 tons/year) were higher than those during 1992-1994 (385 tons/year) and 1995-1998 (356 tons/year). Average annual TSS loads to the bay for 1999-2003 (204 tons/year) were lower than 1992-1994 (253 tons/year) and 1995-1998 (255 tons/year).

3.3 Industrial Point Source Data Summary

Annual average pollutant loads from industrial point sources to Tampa Bay for 1999-2003 were estimated at:

- TN - 135 tons/year,
- TP - 220 tons/year,
- TSS - 650 tons/year, and
- BOD - 771 tons/year.

Annual average bay segment loads for TN ranged from 1.6 tons/year in Old Tampa Bay to 88 tons/year in Hillsborough Bay, with no industrial point source TN loadings to Boca Ciega Bay or Terra Ceia Bay. Annual average bay segment loads for TP ranged from 0.3 tons/year in Old Tampa Bay to 203 tons/year in Hillsborough Bay. Several bay segments had no industrial point source TP loadings: Boca Ciega Bay, Terra Ceia Bay and Manatee River. Annual average bay segment loads for TSS ranged from 9 tons/year to Lower Tampa Bay to 512 tons/year to Hillsborough Bay, with no industrial point source TSS loadings to Old Tampa Bay, Boca Ciega Bay, Terra Ceia Bay or Manatee River. Annual average

BOD bay segment loads ranged from 8 tons/year in Old Tampa Bay to 583 tons/year in Hillsborough Bay, with no industrial point source BOD loadings to Lower Tampa Bay, Boca Ciega Bay or Terra Ceia Bay.

The 1999-2003 average annual TN loads to Tampa Bay (135 tons/year) were much lower than the 1995-1998 average annual TN loads to Tampa Bay (208 tons/year) and slightly lower than 1992-1994 (149 tons/year). Average annual TP loads to the bay were higher for 1999-2003 (220 tons/year) as compared to 1995-1998 (177 tons/year) and 1992-1994 (108 tons/year) as well. Average annual TSS loads to the bay for 1999-2003 (650 tons/year) were lower than 1995-1998 (798 tons/year) and 1992-1994 (909 tons/year).

3.4 Spring Loads Data Summary

All estimated 1999-2003 spring loads were to Hillsborough Bay. Annual average pollutant loads from springs for 1999-2003 were estimated at:

- TN - 125 tons/year,
- TP - 26 tons/year, and
- TSS - 295 tons/year.

The estimated TN loadings for 1999-2003 (125 tons/year) were lower than those during 1992-1994 (192 tons/year) and 1995-1998 (205 tons/year) (Zarbock et al., 1996). Estimated loadings of TP were much higher than during 1992-1994 (3.8 tons/year) and 1995-1998 (3 tons/year). TSS during 1999-2003 were much higher than during 1992-1994 (0.9 tons/year) and 1995-1998 (1 ton/year). Changes in loadings from the previous years were the result of updated data from the Department of Environmental Protection. Spring sampling was done on April 18, 2002 at Sulphur, Buckhorn and Lithia Springs.

3.5 Ground Water Data Summary

Annual average pollutant loads from groundwater to Tampa Bay for the 1999-2003 period were estimated at:

- TN - 2 tons/year, and
- TP - 12 tons/year.

Annual average bay segment loads for TN ranged from 0.01 tons/year in Boca Ciega Bay to 1.4 tons/year in Hillsborough Bay. Annual average bay segment loads for TP ranged from 0.1 tons/year in Boca Ciega Bay to 6.3 tons/year in Hillsborough Bay.

The 1999-2003 annual average TN loading values (2 tons/year) were similar to those for 1992-1994 (1.9 tons/year) and 1995-1998 (2.1 tons/year). TP loads for 1999-2003 (12.2 tons/year) were lower than during 1992-1994 (27.9 tons/year) and the similar to 1995-1998 (12.1 tons/year).

3.6 Material Losses

Annual average pollutant loads from material losses to Tampa Bay for the 1999-2003 period were estimated at:

- TN - 28 tons/year, and
- TP - 91 tons/year.

Annual average bay segment loads for TN were 27 tons/year to Hillsborough Bay and <1 ton/year to Lower Tampa Bay. Annual average bay segment loads for TP were 90 tons/year to Hillsborough Bay and 1 ton/year to Lower Tampa Bay.

Table 3-1. Fertilizer handling facilities 1999-2003.

Facility Name	**Bay Segment**
CF Industries	Hillsborough Bay
CSX	Hillsborough Bay
Cargill	Hillsborough Bay
Eastern	Hillsborough Bay
IMC-Agrico Big Bend	Hillsborough Bay
IMC-Agrico Port Sutton	Hillsborough Bay
Pakhoed Port Manatee	Lower Tampa Bay
Pakhoed Port Sutton	Hillsborough Bay

The 1999-2003 estimated average annual TN loads to Tampa Bay (28 tons/year) are much lower than those of 1992-1994 (251 tons/year) and similar to 1995-1998 (33 tons/year). Average annual TP loads to the bay for 1999-2003 are likewise much lower than those of 1992-1994 (368 tons/year) and lower than 1995-1998 (106 tons/year). The lower loadings for 1999-2003, as described above, are the result of improved handling practices at the facilities compared to the 1992-1994 loss estimates.

3.7 Non Point Source Data Summary

Annual average pollutant loads from nonpoint sources to Tampa Bay for the 1999-2003 period were estimated at:

- TN - 2,559 tons/year,
- TP - 823 tons/year,
- TSS - 40,880 tons/year, and
- BOD - 7,247 tons/year.

Annual average bay segment loadings for TN ranged from 18 tons/year in Terra Ceia Bay to 919 tons/year in Hillsborough Bay. Annual average bay segment loadings for TP ranged from 4 tons/year in Terra Ceia Bay to 444 tons/year in Hillsborough Bay. Annual average bay segment loadings for TSS ranged from 382 tons/year in Terra Ceia Bay to 14,831 tons/year in Hillsborough Bay. Annual average bay segment loadings for BOD ranged from 81 tons/year in Terra Ceia Bay to 2,058 tons/year in Manatee River.

The 1999-2003 average annual TN loadings to Tampa Bay (2,559 tons/year) are greater than those of 1992-1994 (1,723 tons/year) and less than 1995-1998 (3,151 tons/year). Average annual TP loadings to the bay for 1999-2003 (823 tons/year) are greater than those of 1992-1994 (581 tons/year) and less than 1995-1998 (1,686 tons/year). Average annual TSS loadings to the bay for 1999-2003 (40,880 tons/year) are also higher than those for the 1992-1994 (26,707 tons/year) but lower than the 1995-1998 (54,077 tons/year).

In comparison to 1992-1994, the large increases in pollutant loadings in the bay in 1995-1998 and subsequent decreases in 1999-2003 were primarily attributable to increased and subsequent decreased rainfall, respectively. Annual average rainfall during 1999-2003 was 44 inches compared to 57 inches during 1995-1998 and 40 inches during 1992-1994 as measured at Tampa International Airport.

Annual average hydrologic loads to each bay segment during 1999-2003 were higher than those during 1992-1994 and generally lower than during 1995-1998 except in the Manatee River. The annual average hydrologic loadings to each bay segment are shown in Table 3-2, with the annual average hydrologic loadings from 1992-1994 and 1995-1998 shown for comparison. The increase in hydrologic load to the Manatee River is tied to the higher rainfall to the segments watershed during 1999-2003 as compared to 1995-1998.

Table 3-2. Average annual nonpoint source hydrologic loading estimates (10^6 m^3/year).			
Bay Segment	**1992-1994**	**1995-1998**	**1999-2003**
Old Tampa Bay	119	262	202
Hillsborough Bay	512	948	691
MiddleTampa Bay	250	306	325
Lower Tampa Bay	34	58	56
Boca Ciega Bay	36	95	103
Terra Ceia Bay	8	13	14
Manatee River	202	401	524
Total	1161	2083	1915

The increase in nonpoint source TN loadings for most bay segments generally follows the increase in hydrologic loading. The average annual nonpoint source TN loadings for 1992-1994, 1995-1998 and 1999-2003 are shown in Table 3-3 for each bay segment.

Table 3-3. Average annual nonpoint source TN loading estimates (tons/year).			
Bay Segment	**1992-1994**	**1995-1998**	**1999-2003**
Old Tampa Bay	174	340	261
Hillsborough Bay	596	1422	919
MiddleTampa Bay	415	467	465
Lower Tampa Bay	36	57	56
Boca Ciega Bay	69	169	178
Terra Ceia Bay	11	16	18
Manatee River	422	680	662
Total	1723	3151	2559

Average annual nonpoint source TN loading estimates decreased for all bay segments except for a slight increase in Boca Ciega Bay and Terra Ceia Bay. Overall TN loading from nonpoint sources stayed relatively consistent or decreased from the 1995-1998 period as shown in Table 3-3.

Table 3-4. Estimated nonpoint source TN loadings per unit area (kg/ha/year), mean annual 1992-1994, 1995-1998, and annual 1999-2003.

Segment	1992-1994	1995-1998	1999	2000	2001	2002	2003
Old Tampa Bay	2.5	4.9	1.7	1.8	2.4	2.9	4.9
Hillsborough Bay	1.7	4	1.6	0.8	2.5	2.9	6.1
Middle Tampa Bay	3.0	5.7	2.5	2.1	5.8	2.8	7.5
Lower Tampa Bay	4.4	7.0	0.9	0.8	2.2	2.2	2.9
Boca Ciega Bay	3.1	8.1	3.6	4.9	8.0	4.0	7.1
Terra Ceia Bay	4.0	6.0	2.1	1.7	5.2	1.9	7.5
Manatee River	4.3	7.0	5.0	2.6	10.0	5.4	16.0
Totals	23	42.7	17.4	14.7	36.1	22.1	52

Estimated annual TN loadings per unit area from nonpoint sources were typically less than during 1995-1998 and were comparable to those during 1992-1994 (Table 3-4). Lower hydrologic loadings during 1999-2003 as compared to the 1995-1998 accounted for lower TN loading.

4. HYDROLOGIC LOADINGS

Changes in hydrologic loadings were examined to evaluate whether increases in pollutant loadings were due to increased hydrologic loadings, the results of higher rainfall totals, or to anthropogenic activities. If higher than expected pollutant loadings result, then anthropogenic activities may be suspected as a causative factor. For this reason, annual variations in hydrologic loadings were examined with respect to annual rainfall totals.

This section presents the estimated hydrologic loads from each loading source for each bay segment, as well as total hydrologic loads to the segments. Annual mean rainfall to each Bay Segments is shown below in Table 4-1. Average rainfall from 1999-2003 ranged from 46-55 inches, much lower than the 1995-1998 range of 57-60 inches that resulted from the El Nino event of 1997-1998. Rainfall between years was variable during the period, with 1999 and 2000 being dry years and 2002 and 2003 wetter years.

Table 4-1. Total rainfall (inches) to the watersheds draining to each bay segment, mean annual 1992-1994, 1995-1998, 1999-2003, and annual 1999-2003.

Year	Bay Segment						
	Old Tampa Bay	Hillsborough Bay	Middle Tampa Bay	Lower Tampa Bay	Boca Ciega Bay	Terra Ceia Bay	Manatee River
1992-1994	44.9	51.6	53.3	55.4	44.0	56.4	58.2
1995-1998	57.5	57.2	59.4	60.2	58.4	60.8	60.9
1999-2003	46.8	51.7	55	54.3	52.6	54.6	55.9
1999	39.7	43.9	44.5	45.6	44.7	46.1	46.5
2000	36.5	36.8	39.7	39.9	43.4	39.0	40.3
2001	45.8	55.2	56.3	56.4	52.9	57.4	57.6
2002	61.5	63.9	61.2	58.5	61.3	56.7	59.1
2003	50.9	58.5	73.2	71.3	60.7	73.6	75.8

The estimated hydrologic loadings from each source to the seven bay segments are shown in Tables 4-2 through 4-8. During 1999-2003 hydrologic loading contributions from atmospheric deposition and nonpoint sources generally accounted for lower proportions of the total hydrologic loading than during 1995-1998. Because rainfall drives the atmospheric and nonpoint source contributions to hydrologic loadings, the hydrologic loadings were typically lower during 1999-2003 than during 1995-1998. Higher loadings during 2002, 2003 in comparison to 1999 and 2000 were the result of higher rainfall in five of the seven bay segments including, Middle Tampa Bay, Lower Tampa Bay, Boca Ciega Bay, Terra Ceia Bay and Manatee River.

Table 4-2. Estimated hydrologic loadings (10^6 m^3/year) to Old Tampa Bay, mean annual 1992-1994, 1995-1998 and annual 1999-2003.								
Source	**1992-1994**	**1995-1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**1999-2003**
Atmospheric Deposition	254	341	214	214	272	366	320	277
Domestic Point Sources	46	51	53	53	50	53	61	54
Industrial Point Sources	<1	0	2.3	1	<1	<1	2	1.4
Springs	0	<1	0	0	0	0	0	0
Groundwater	28	39	41	34	36	35	35	36
Nonpoint Sources	102	262	113	123	161	203	320	184
TOTAL	430	693	454	424	518	658	738	558

Table 4-3. Estimated hydrologic loadings (10^6 m^3/year) to Hillsborough Bay, mean annual 1992-1994, 1995-1998 and annual 1999-2003.								
Source	**1992-1994**	**1995-1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**1999-2003**
Atmospheric Deposition	127	158	111	99	135	168	162	135
Domestic Point Sources	91	104	81	79	82	95	90	85
Industrial Point Sources	63	77	64	19	55	48	130	63
Springs	62	0	0	0	0	0	0	0
Groundwater	93	56	58	62	55	54	56	57
Nonpoint Sources	512	949	361	175	560	701	1339	627
TOTAL	948	1413	675	434	861	1066	1783	964

Table 4-4. Estimated hydrologic loadings (10^6 m^3/year) to Middle Tampa Bay, mean annual 1992-1994, 1995-1998 and annual 1999-2003.								
Source	**1992-1994**	**1995-1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**1999-2003**
Atmospheric Deposition	345	434	329	310	400	451	478	393
Domestic Point Sources	15	16	44	41	42	36	30	39
Industrial Point Sources	32	30	10	7	16	12	39	17
Springs	0	0	0	0	0	0	0	0
Groundwater	4	5	4	3	4	4	9	5
Nonpoint Sources	252	306	174	147	407	206	541	295
TOTAL	648	791	560	508	868	708	1096	748

Table 4-5. Estimated hydrologic loadings (10^6 m^3/year) to Lower Tampa Bay, mean annual 1992-1994, 1995-1998 and mean annual 1999-2003.								
Source	**1992-1994**	**1995-1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**1999-2003**
Atmospheric Deposition	324	378	286	255	354	369	439	341
Domestic Point Sources	2	2	1	2	1	2	1	1
Industrial Point Sources	<1	<1	0	0	0	<1	2	<1
Springs	0	0	0	0	0	0	0	0
Groundwater	2	2	1	4	4	4	6	3.8
Nonpoint Sources	31	58	28	25	70	32	100	51
TOTAL	359	440	317	286	428	406	547	397

Table 4-6. Estimated hydrologic loadings (10^6 m^3/year) to Boca Ciega Bay, mean annual 1992-1994, 1995-1998 and mean annual 1999-2003.								
Source	**1992-1994**	**1995-1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**1999-2003**
Atmospheric Deposition	106	136	104	100	125	140	148	123
Domestic Point Sources	3	7	9	9	10	18	37	17
Industrial Point Sources	0	0	0	0	0	0	0	0
Springs	0	0	0	0	0	0	0	0
Groundwater	2	1	1	1	1	1	1	1
Nonpoint Sources	36	95	62	83	136	68	121	94
TOTAL	147	239	175	192	271	227	305	234

Table 4-7. Estimated hydrologic loadings (10^6 m^3/year) to Terra Ceia Bay, mean annual 1992-1994, 1995-1998 and mean annual 1999-2003.								
Source	**1992-1994**	**1995-1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**1999-2003**
Atmospheric Deposition	23	25	19	16	24	23	30	22
Domestic Point Sources	2	2	1	1	3.4	12	5	4
Industrial Point Sources	0	0	0	0	0	0	0	0
Springs	0	0	0	0	0	0	0	0
Groundwater	1	1	1	1	1	1	1	1
Nonpoint Sources	8	13	7	6	18	7	26	13
TOTAL	33	40	28	24	46	33	63	39

Table 4-8. Estimated hydrologic loadings (10^6 m^3/year) to the Manatee River, mean annual 1992-1994, 1995-1998 and mean annual 1999-2003.

Source	1992-1994	1995-1998	1999	2000	2001	2002	2003	1999-2003
Atmospheric Deposition	60	65	50	42	61	59	77	58
Domestic Point Sources	10	11	11	10	11	8	11	10
Industrial Point Sources	2	2	2	2	2	<1	<1	2
Springs	0	0	0	0	0	0	0	0
Groundwater	5	3	3	2	3	4	3	3
Nonpoint Sources	296	400	306	161	590	353	974	477
TOTAL	372	580	371	216	666	423	1065	548

5. POLLUTANT LOADINGS BY BAY SEGMENT

This section examines the variation in annual TN loadings by bay segment for the 1999-2003 period. The focus is on the TN loadings because these loads are of most interest given the concerns of the Nitrogen Management Consortium. The TBEP adopted the "hold the line" strategy, aimed at keeping TN loadings to each bay segment at mean 1992-1994 levels, to aid in reaching the seagrass restoration goals of the program.

Rainfall and anthropogenic activities in the watershed and airshed are the major determinants of the TN loadings to Tampa Bay. Therefore, it is important to examine the relationship between the resultant hydrologic loadings and TN loadings on an annual basis. It is also important to examine the contributions of the different sources to arrive at explanations of the observed variations in TN loadings.

Figures 5-1 through 5-7 present the annual TN loadings to each bay segment for the 1985-2003 period. Similar presentations for TP, TSS, and BOD are provided in Appendix E.

Table 5-1. Total annual rainfall (inches) to the watersheds draining to each bay segment watersheds.

Year	Bay Segment						
	Old Tampa Bay	Hillsborough Bay	Middle Tampa Bay	Lower Tampa Bay	Boca Ciega Bay	Terra Ceia Bay	Manatee River
1985	47.6	49.7	48.8	51.3	48.7	50.0	46.3
1986	49.4	54.3	53.8	54.1	58.0	53.9	53.1
1987	54.7	56.6	54.5	55.1	57.2	55.8	55.8
1988	58.0	58.3	62.7	65.0	66.1	64.4	61.9
1989	43.2	45.4	48.8	52.2	43.5	53.0	52.5
1990	38.5	41.0	38.7	41.0	38.1	42.1	41.3
1991	48.3	49.8	48.2	46.6	48.4	47.3	49.6
1992	45.2	52.2	55.4	59.8	46.1	61.5	62.6
1993	41.8	44.7	48.3	50.0	41.5	50.5	52.3
1994	47.8	57.8	56.2	56.4	44.5	57.2	59.8
1995	57.2	56.0	62.5	64.1	63.1	64.3	63.7
1996	49.6	49.7	45.3	47.0	44.0	47.7	47.0
1997	67.7	65.0	71.3	73.3	71.7	74.1	73.5
1998	55.4	58.2	58.3	56.4	54.8	57.2	59.6
1999	39.7	43.9	44.5	45.6	44.7	46.1	46.5

2000	36.5	36.8	39.7	39.9	43.4	39.0	40.3
2001	45.8	55.2	56.3	56.4	52.9	57.4	57.6
2002	61.5	63.9	61.2	58.5	61.3	56.7	59.1
2003	50.9	58.5	73.2	71.3	60.7	73.6	75.8

To further examine the influence of rainfall on TN loading to Tampa Bay, the relationship between annual TN loadings to each bay segment for the 1985-2003 period and the annual hydrologic loadings were examined, as shown in Figures 5-8 through 5-14. Assuming the relationships between TN loadings and hydrologic loadings are linear within each bay segment, there should be no changes in the ratios within each bay segment. If there were no major changes in anthropogenic activities between the 1985-1998 and 1999-2003 periods, the 1999-2003 TN loadings should fall along the same lines as those from 1985-1998. Deviations from the linear relationships suggest changes in the anthropogenic impacts on TN loadings. As shown in Figures 5-8 through 5-14, the relationship of TN loadings to hydrologic loadings was similar during both periods in all bay segments.

Examination of the loadings by source provides important information concerning which sources have contributed to the loadings changes observed during the 1999-2003 period. Mean annual TN loadings during the 1999-2003 period were higher than those of the 1992-1994 period. The 1999-2003 TN loadings are presented in Figure 5-15. The greatest contributions were from nonpoint source loadings, which accounted for 64% of the TN loadings. During the 1992-1994 period, nonpoint source contributions were 45% and during the 1995-1998 period contributions were 62%. Atmospheric deposition contributions during 1999-2003 accounted for 22% of the TN loadings, compared to 29% during the 1992-1994 period and 21% during the 1995-1998 period. There was a slight increase in domestic point source from 8% during 1995-1998 to 10% during 1999-2003.

Estimated annual TN loadings from each pollutant source for each year of the 1999-2003 period are presented by bay segment in Tables 5-4 through 5-10, along with the mean annual TN loadings from each source for the 1992-1994 and 1995-1998 period. Graphical presentations of annual TN, TP, TSS, and BOD loadings by source for the 1985-2003 period are shown in Appendix F. Tabular and graphical summaries of the mean annual 1992-1994 and 1999-2003 estimated TN loadings are provided in Appendix G for comparison purposes.

Clearly, the most obvious difference between the two periods is the much higher TN loadings to Hillsborough Bay in the 1999-2003 period, particularly from nonpoint sources. As discussed previously, the large increases in nonpoint source TN loadings during 1997 and 1998 were a function of the increased rainfall and the process water release in December of 1997. A portion of the nonpoint source increase during 1999-2003 may have resulted from changes in landuse. The increases in nonpoint source loadings may also have been partially the result of land use changes between 1990 and 1999. The 1992-1994 loadings estimates utilized 1990 land use data, whereas the 1999-2003 loadings were developed using 1999 land use data. Land use changes from 1990 to 1999 resulted in increases in urban, agricultural, and mining land uses in the watershed, with associated decreases in pasture, rangeland, forest, and wetlands. The changes in land use within the watershed draining to each bay segment are shown in Table 5-11, represented as the percentage of the watershed.

Atmospheric deposition contributions to TN loadings were also higher in each bay segment during the 2003 period than those of 1995-1998 as a result of higher rainfall. The relative contributions to TN loading due to atmospheric deposition were less during the 1999-2003 period than during 1992-1994, however.

Domestic point source contributions to TN loadings in Hillsborough Bay also increased during the 1999-2003 period. Increased domestic loading to Boca Ciega Bay during 2003 resulted from discharge from the South Cross Bayou Waste Water Treatment Facility. Industrial contributions to TN loadings in Lower Tampa Bay in 2003 accounted for approximately 10% of the loading to the segment as a result of Piney Point discharge.

Table 5-4. Estimated TN loadings (tons/year and percentage of total) by source to Old Tampa Bay, mean annual 1992-1994 and annual 1999-2003.

Source	1992-94	1995-98	1999	2000	2001	2002	2003	1999-03
Atmospheric Deposition	227 (47%)	245 (36%)	148 (38%)	162 (41%)	157 (35%)	220 (39%)	243 (30%)	186 (33%)
Domestic Point Sources	85 (18%)	87 (13%)	83 (21%)	60 (15%)	59 (13%)	71 (12%)	94 (12%)	74 (14%)
Industrial Point Sources	0 (0%)	2 (0%)	3 (1%)	1 (0%)	0 (0%)	2 (0%)	2 (0%)	0 (0%)
Springs	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Groundwater	<1	<1	<1	<1	<1	<1	<1	<1

	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)
Material Losses	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Nonpoint Sources	174 (36%)	340 (51%)	157 (40%)	175 (44%)	230 (52%)	277 (49%)	466 (58%)	261 (50%)
TOTAL	486	674	392	398	446	570	806	522

Table 5-5. Estimated TN loadings (tons/year and percentage of total by source to Hillsborough Bay, mean annual 1992-1994 and annual 1999-2003.

Source	1992-94	1995-98	1999	2000	2001	2002	2003	1999-03
Atmospheric Deposition	115 (8%)	113 (5%)	74 (7%)	76 (10%)	77 (6%)	103 (6%)	125 (5%)	91 (6%)
Domestic Point Sources	220 (15%)	270 (12%)	240 (22%)	212 (29%)	238 (17%)	268 (17%)	252 (9%)	242 (16%)
Industrial Point Sources	80 (6%)	120 (6%)	101 (9%)	27 (4%)	56 (4%)	97 (6%)	160 (6%)	88 (6%)
Springs	205 (14%)	206 (10%)	158 (15%)	94 (13%)	102 (7%)	121 (8%)	152 (5%)	125 (8%)
Groundwater	1 (0%)	1 (0%)	1 (0%)	2 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)
Material Losses	233 (16%)	33 (2%)	32 (3%)	28 (4%)	26 (2%)	26 (2%)	26 (1%)	14 (1%)
Nonpoint Sources	596 (41%)	1422 (65%)	479 (44%)	302 (41%)	890 (64%)	965 (61%)	2024 (74%)	952 (62%)
TOTAL	1451	2165	1086	741	1391	1581	2740	1508

Table 5-6. Estimated TN loadings (tons/year and percentage of total) by source to Middle Tampa Bay, mean annual 1992-1994 and annual 1999-2003.

Source	1992-1994	1995-98	1999	2000	2001	2002	2003	1999-03
Atmospheric Deposition	306 (38%)	310 (37%)	213 (41%)	236 (47%)	215 (24%)	259 (40%)	368 (29%)	258 (34%)
Domestic Point Sources	20 (3%)	26 (3%)	39 (8%)	28 (6%)	45 (5%)	24 (4%)	11 (1%)	29 (4%)
Industrial Point Sources	58 (7%)	35 (4%)	9 (2%)	7 (1%)	17 (2%)	16 (2%)	20 (2%)	14 (2%)

Springs	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Groundwater	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)
Material Losses	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Nonpoint Sources	415 (52%)	467 (56%)	254 (49%)	229 (46%)	627 (69%)	354 (54%)	860 (68%)	465 (61%)
TOTAL	799	838	516	500	904	654	1259	766

Table 5-7. Estimated TN loadings (tons/year and percentage of total) by source to Lower Tampa Bay, mean annual 1992-1994 and annual 1999-2003.

Source	1992-1994	1995-98	1999	2000	2001	2002	2003	1999-03
Atmospheric Deposition	288 (83%)	267 (74%)	190 (86%)	187 (86%)	191 (70%)	213 (86%)	338 (69%)	224 (77%)
Domestic Point Sources	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)
Industrial Point Sources	<1 (0%)	35 (10%)	0 (0%)	0 (0%)	0 (0%)	<1 (0%)	47 (10%)	10 (3%)
Springs	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Groundwater	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)	<1 0
Material Losses	24 (7%)	<1 (1%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	<1 (0%)	<1 (0%)
Nonpoint Sources	36 (10%)	57 (16%)	31 (14%)	28 (13%)	79 (29%)	33 (13%)	107 (22%)	56 (20%)
TOTAL	349	360	222	217	271	247	494	290

Table 5-8. Estimated TN loadings (tons/year and percentage of total) by source to Boca Ciega Bay, mean annual 1992-1994 and annual 1999-2003.

Source	1992-1994	1995-98	1999	2000	2001	2002	2003	1999-03
Atmospheric Deposition	93 (53%)	97 (33%)	66 (35%)	76 (32%)	67 (20%)	79 (35%)	113 (28%)	80 (29%)
Domestic Point Sources	15 (9%)	16 (5%)	5 (2%)	5 (2%)	5 (2%)	18 (8%)	61 (15%)	19 (7%)

Industrial Point Sources	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Springs	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Groundwater	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)
Material Losses	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Nonpoint Sources	69 (39%)	179 (61%)	117 (62%)	158 (66%)	258 (78%)	128 (57%)	227 (57%)	178 (64%)
TOTAL	177	292	188	238	330	226	401	277

Table 5-9. Estimated TN loadings (tons/year and percentage of total) by source to Terra Ceia Bay, mean annual 1992-1994 and annual 1999-2003.

Source	1992-1994	1995-98	1999	2000	2001	2002	2003	1999-03
Atmospheric Deposition	20 (57%)	18 (46%)	13 (52%)	12 (58%)	13 (30%)	14 (53%)	23 (32%)	15 (40%)
Domestic Point Sources	4 (11%)	5 (12%)	2 (8%)	<1 (1%)	5 (11%)	3 (11%)	14 (19%)	6 (16%)
Industrial Point Sources	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Springs	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Groundwater	<1 (0%)	<1 (0%)	<1 (<1%)	<1 (<1%)	<1 (<1%)	<1 (<1%)	<1 (<1%)	<1 (1%)
Material Losses	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Nonpoint Sources	11 (31%)	16 (42%)	10 (40%)	8 (41%)	25 (59%)	9 (35%)	36 (49%)	18 (46%)
TOTAL	35	38	25	20	43	26	74	38

Table 5-10. Estimated TN loadings (tons/year and percentage of total) by source to the Manatee River, mean annual 1992-1994 and annual 1999-2003.

Source	1992-1994	1995-98	1999	2000	2001	2002	2003	1999-2003
Atmospheric Deposition	54 (11%)	45 (6%)	34 (7%)	30 (10%)	34 (4%)	35 (8%)	60 (4%)	39 (5%)
Domestic Point Sources	16	23	54	21	14	5	22	23

	(3%)	(3%)	(11%)	(7%)	(1%)	(6%)	(2%)	(3%)
Industrial Point Sources	11 (2%)	14 (2%)	11 (2%)	11 (4%)	13 (1%)	1 (0%)	1 (0%)	0 (0%)
Springs	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Groundwater	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)	<1 (0%)
Material Losses	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Nonpoint Sources	422 (84%)	680 (89%)	411 (80%)	232 (79%)	899 (94%)	429 (91%)	1339 (94%)	662 (90%)
TOTAL	503	761	511	295	960	471	1421	732

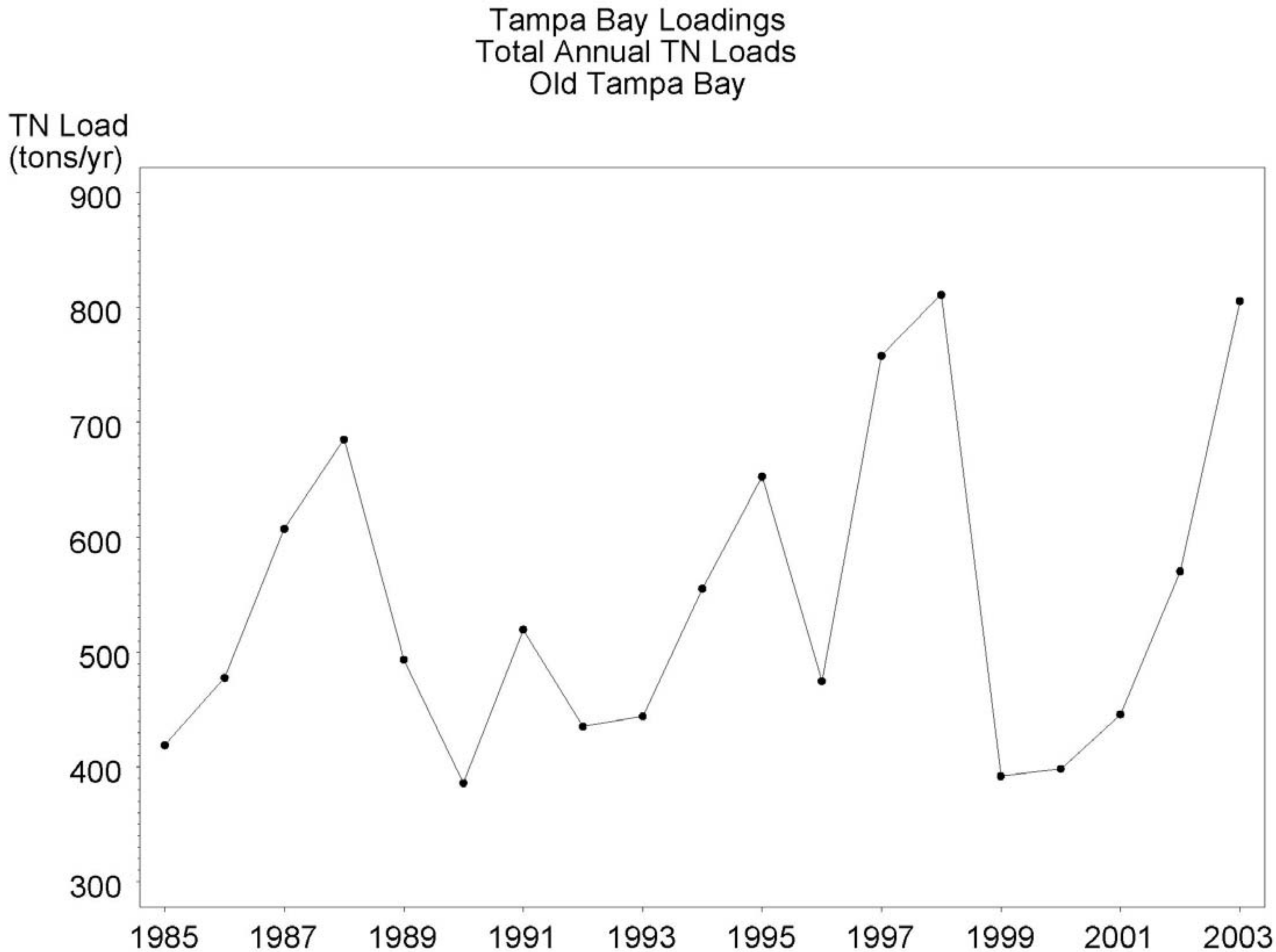

Figure 5-1. Estimated annual TN loadings to Old Tampa Bay, 1985-2003.

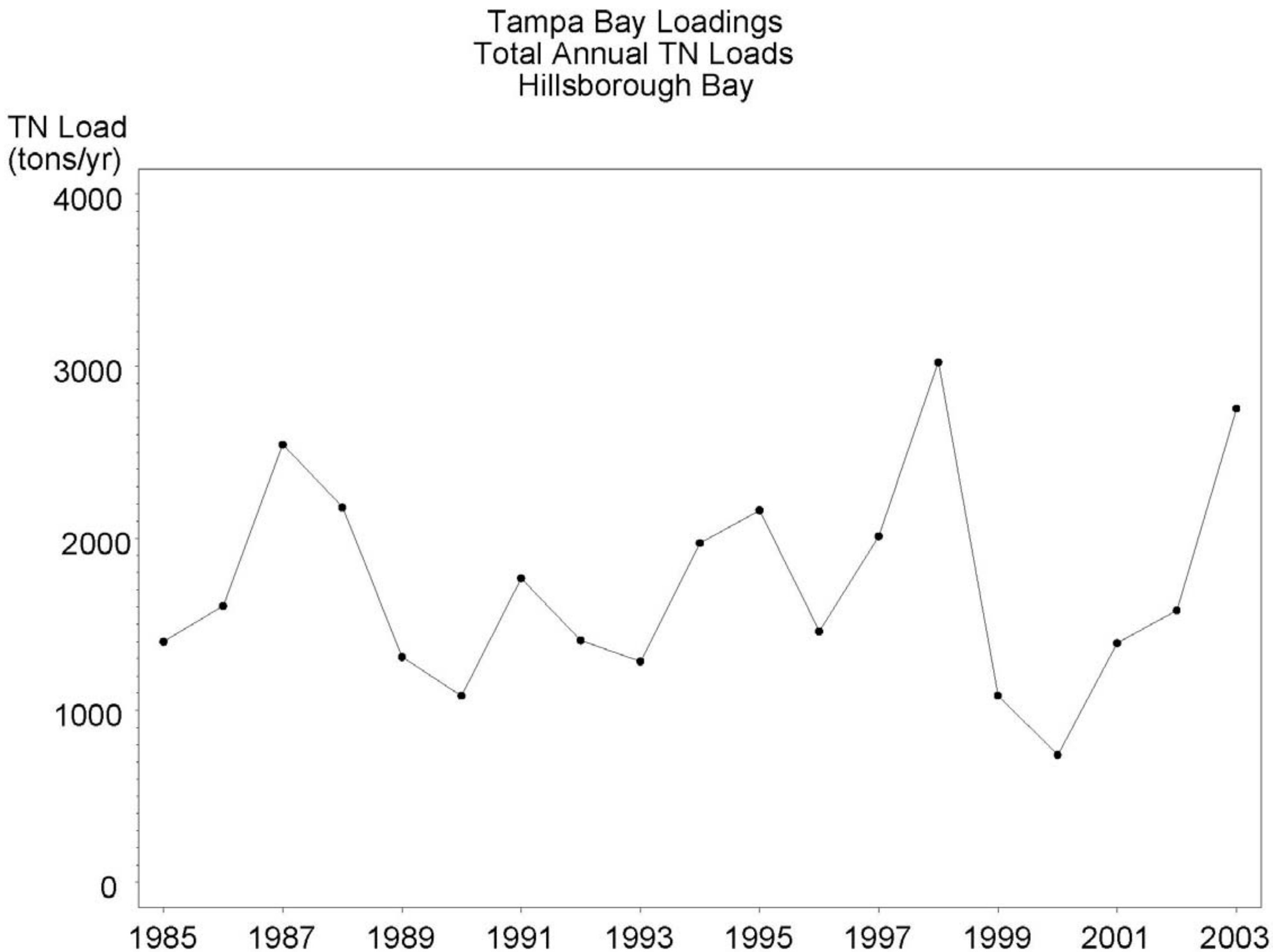

Figure 5-2. Estimated annual TN loadings to Hillsborough Bay, 1985-2003.

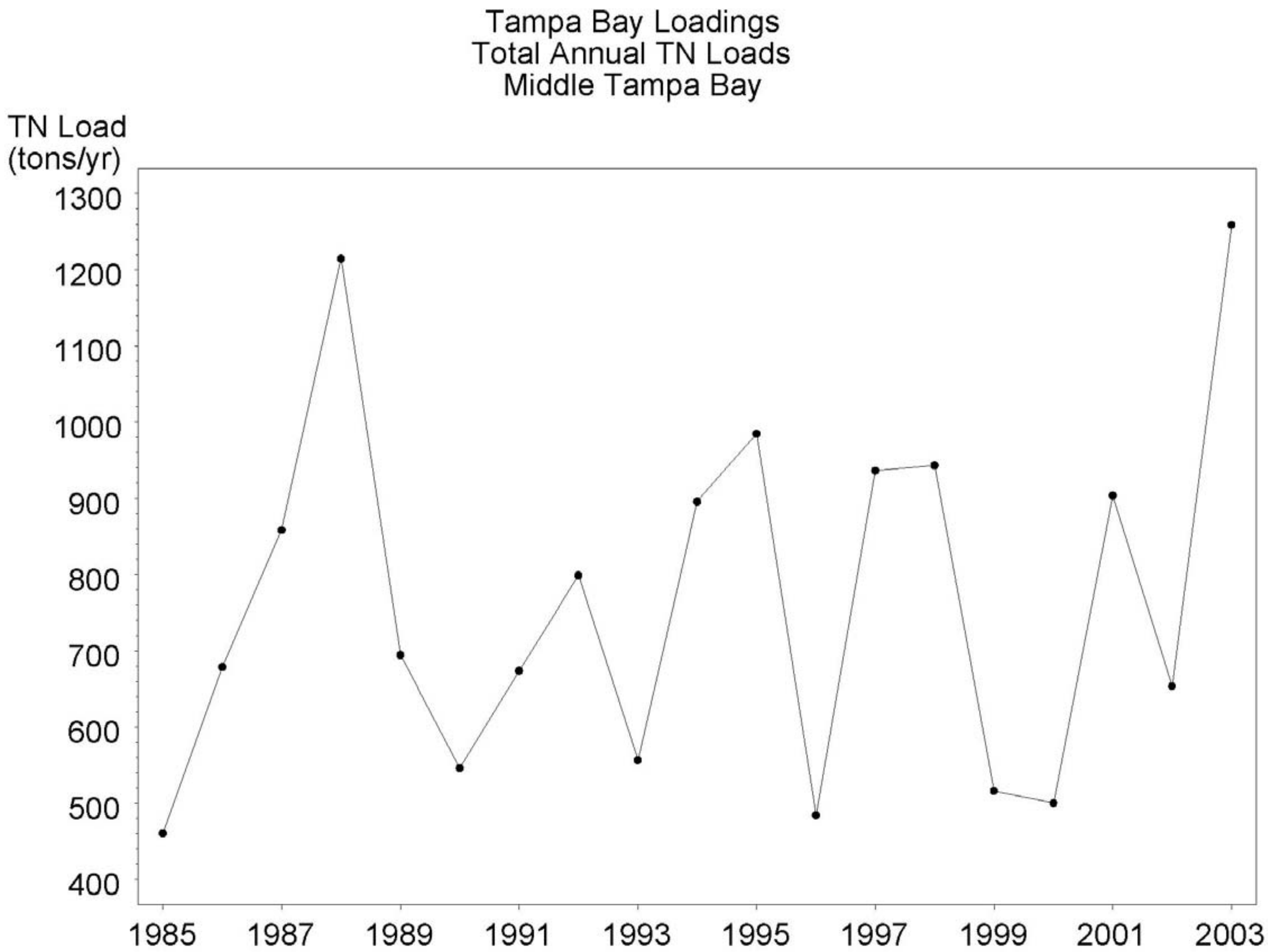

Figure 5-3. Estimated annual TN loadings to Middle Tampa Bay, 1985-2003.

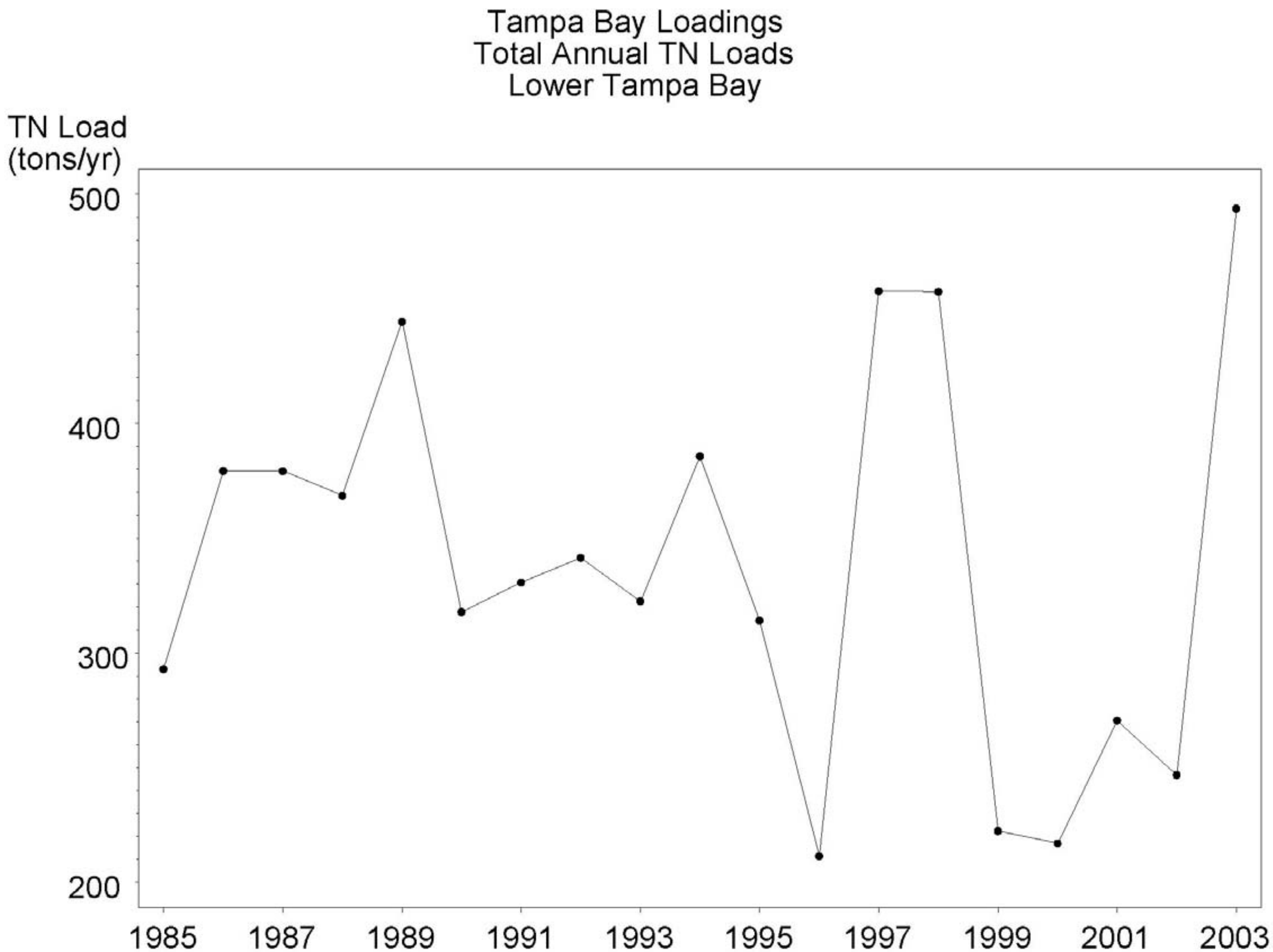

Figure 5-4. Estimated annual TN loadings to Lower Tampa Bay, 1985-2003.

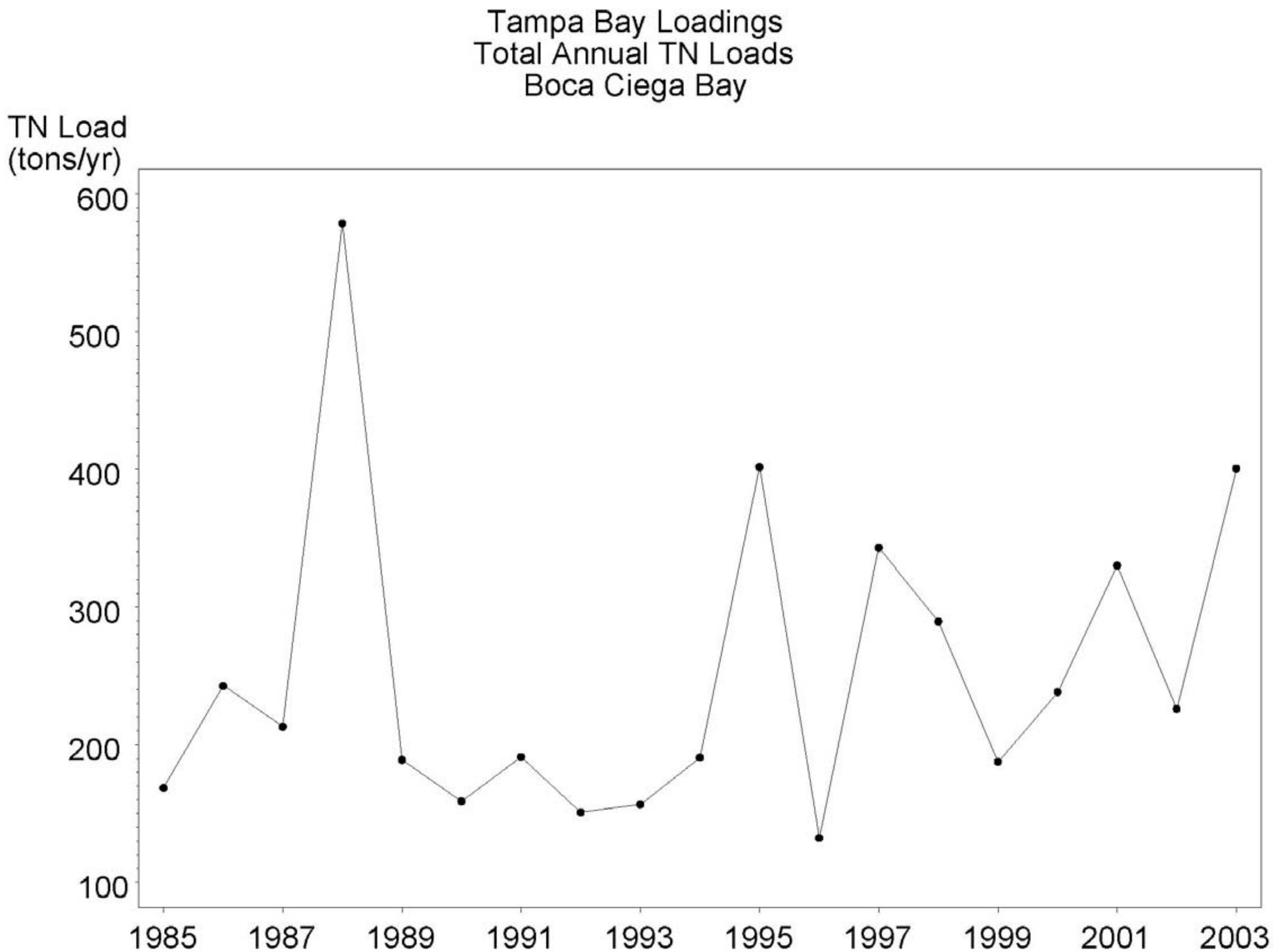

Figure 5-5. Estimated annual TN loadings to Boca Ciega Bay, 1985-2003.

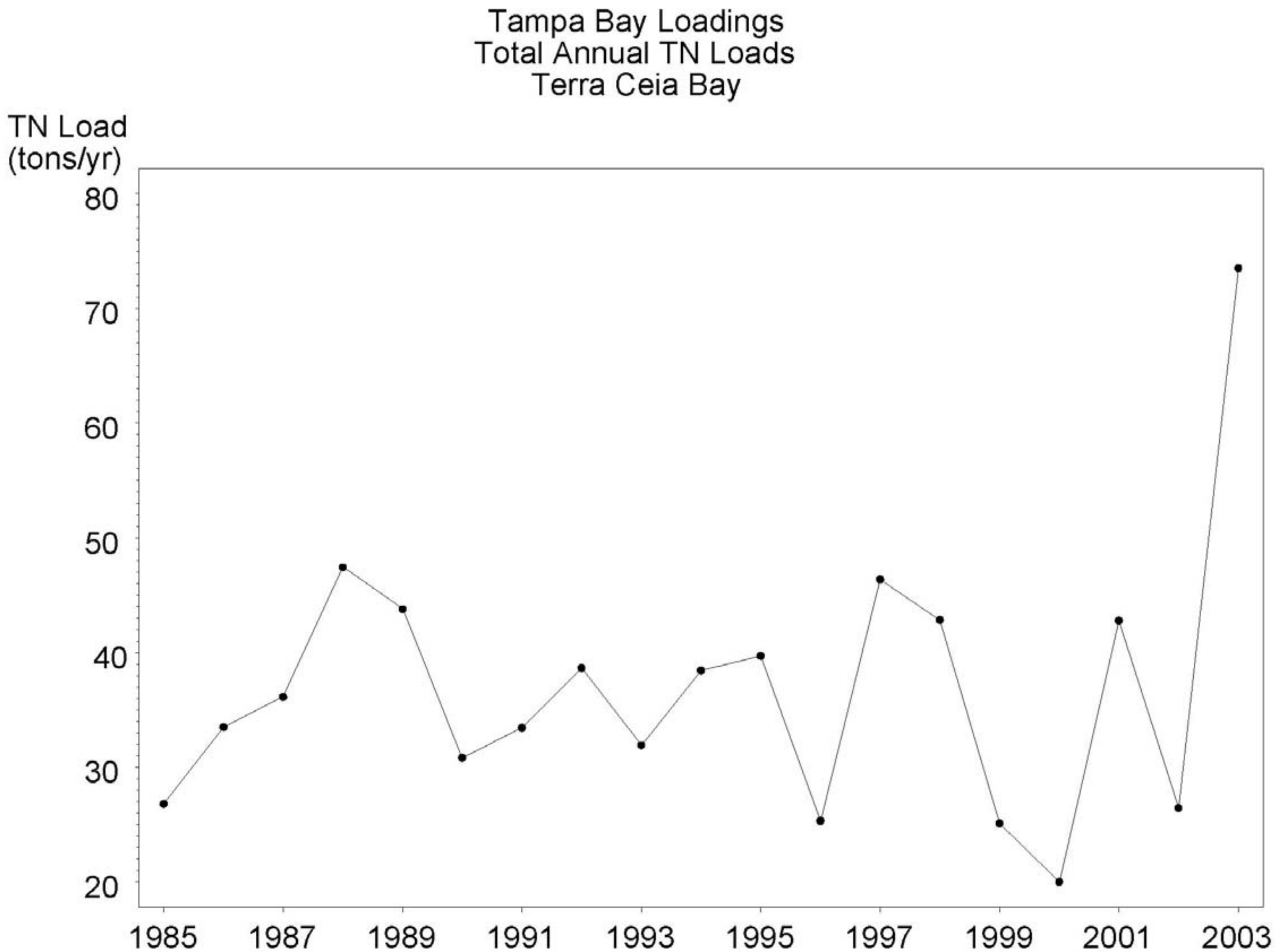

Figure 5-6. Estimated annual TN loadings to Terra Ceia Bay, 1985-2003.

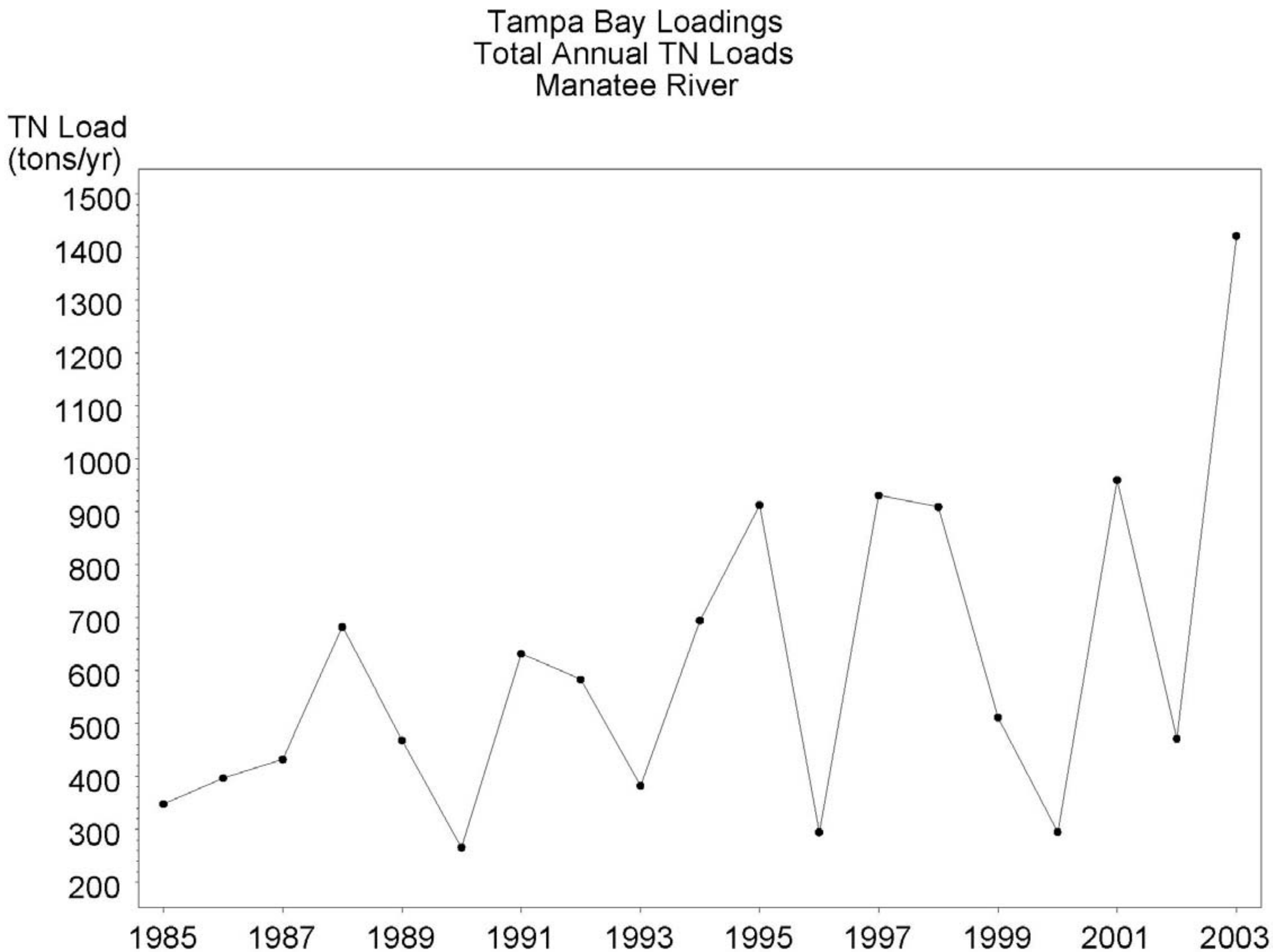

Figure 5-7. Estimated annual TN loadings to the Manatee River, 1985-2003.

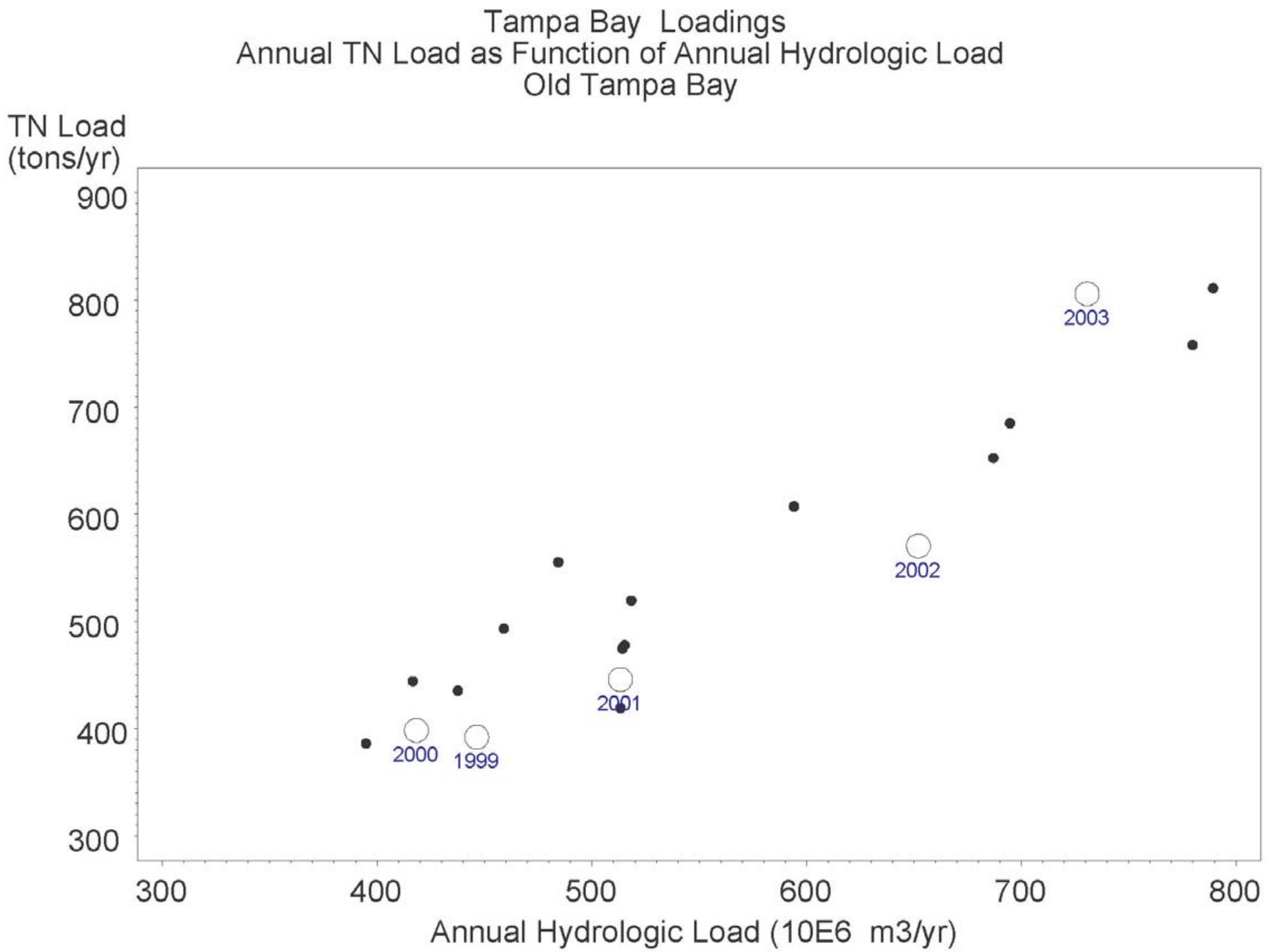

Figure 5-8. Relationship between TN and hydrologic loadings, Old Tampa Bay, 1985-2003.

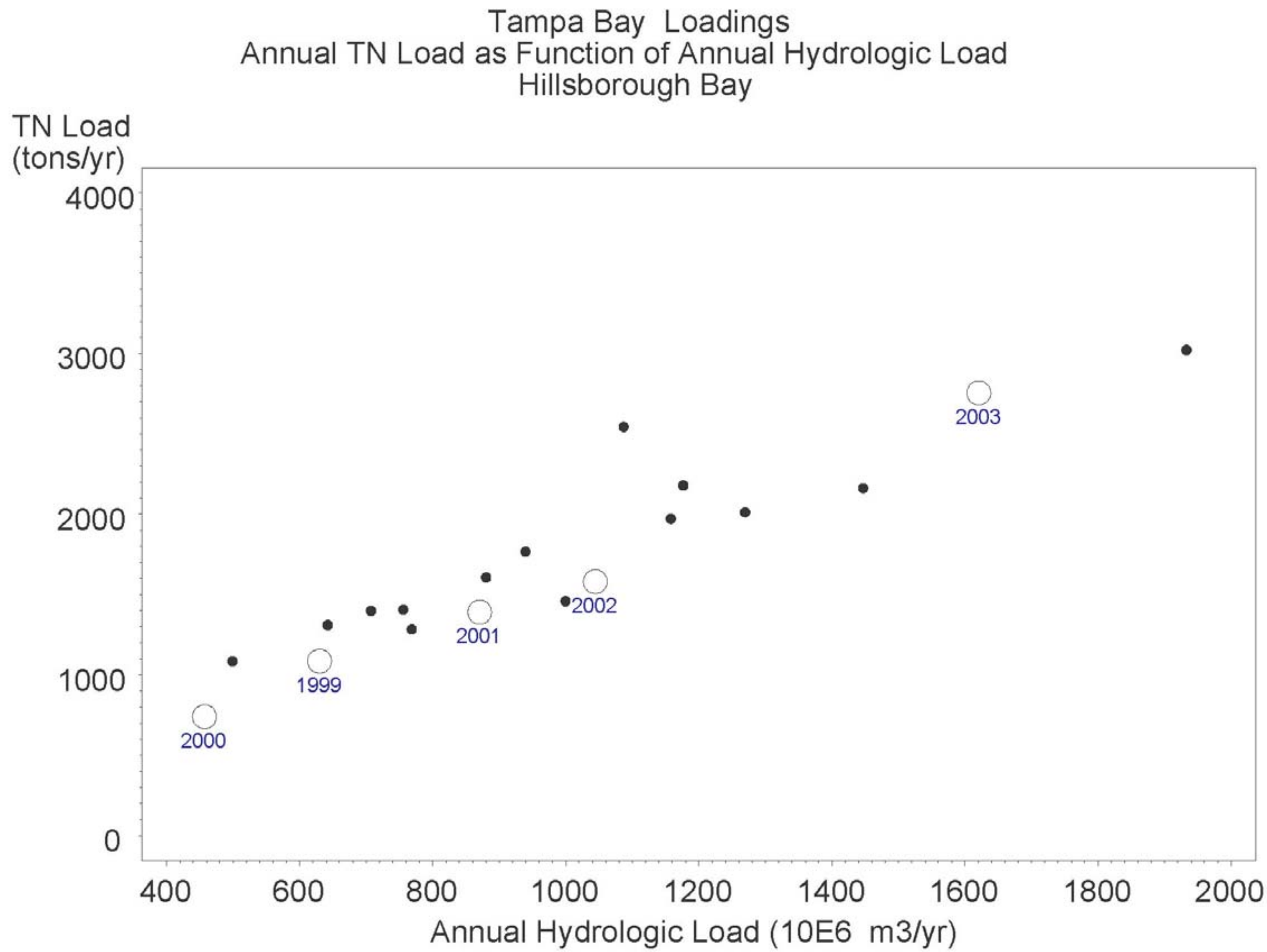

Figure 5-9. Relationship between TN and hydrologic loadings, Hillsborough Bay, 1985-2003.

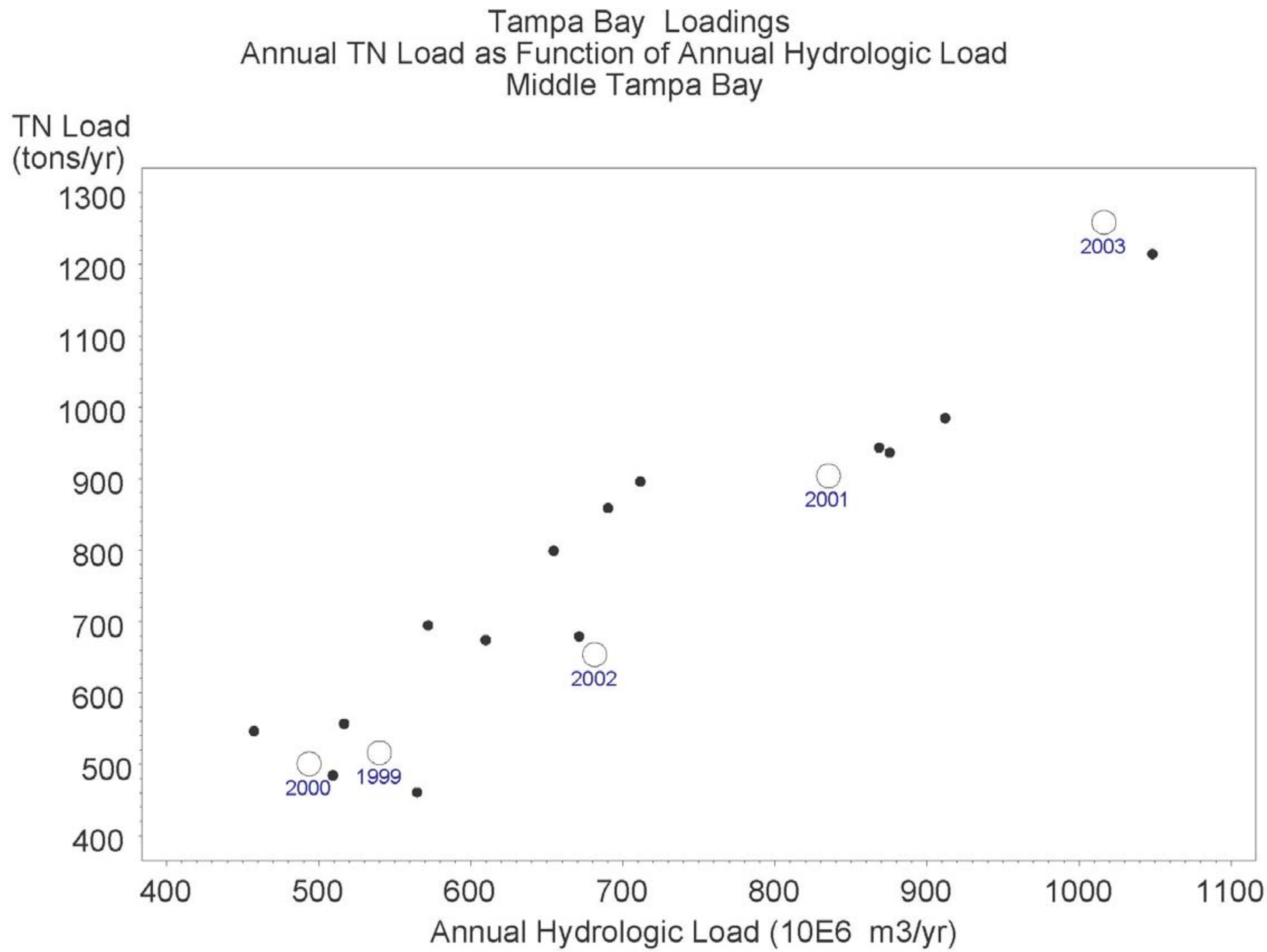

Figure 5-10. Relationship between TN and hydrologic loadings, Middle Tampa Bay, 1985-2003.

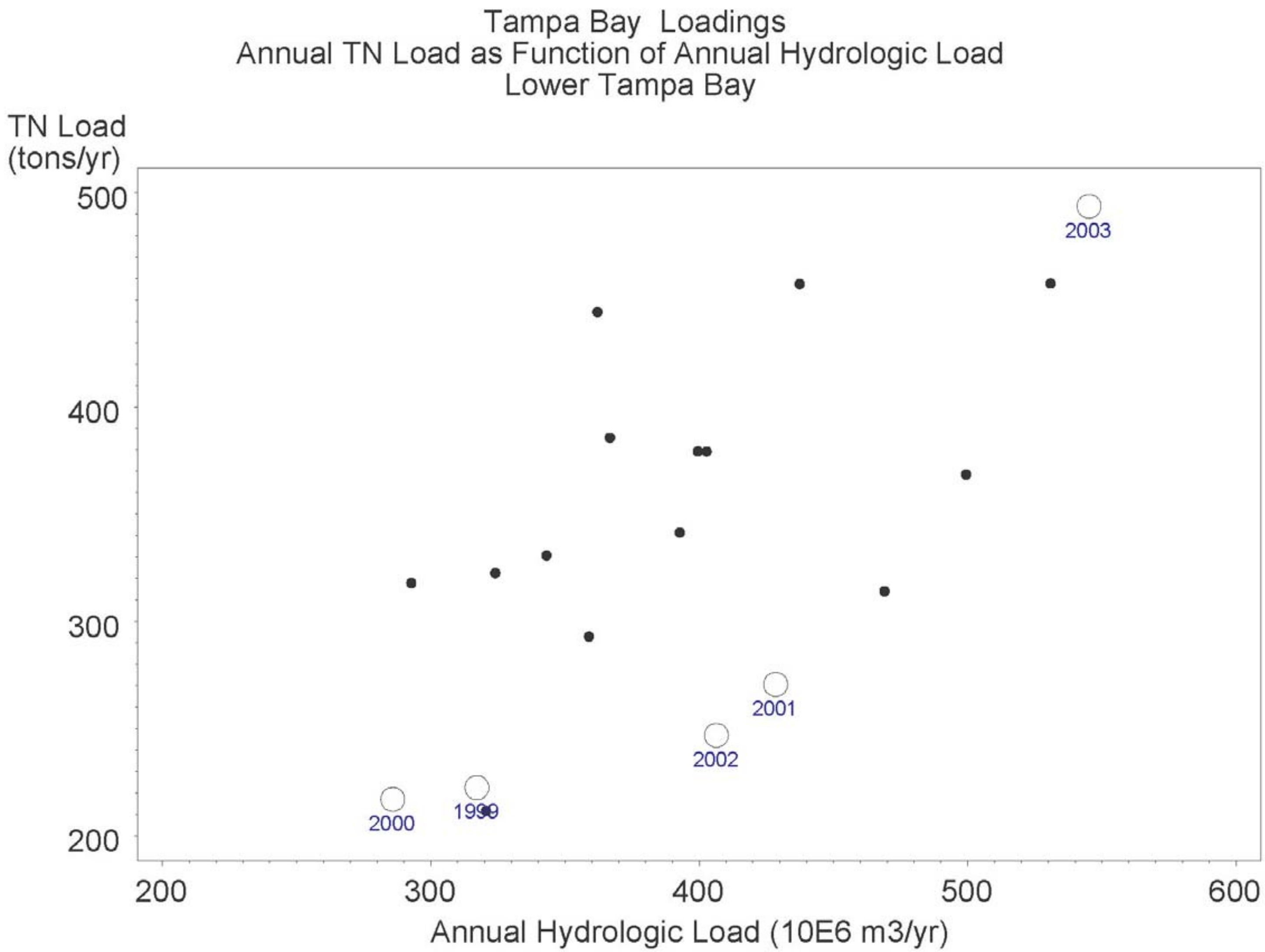

Figure 5-11. Relationship between TN and hydrologic loadings, Lower Tampa Bay, 1985-2003.

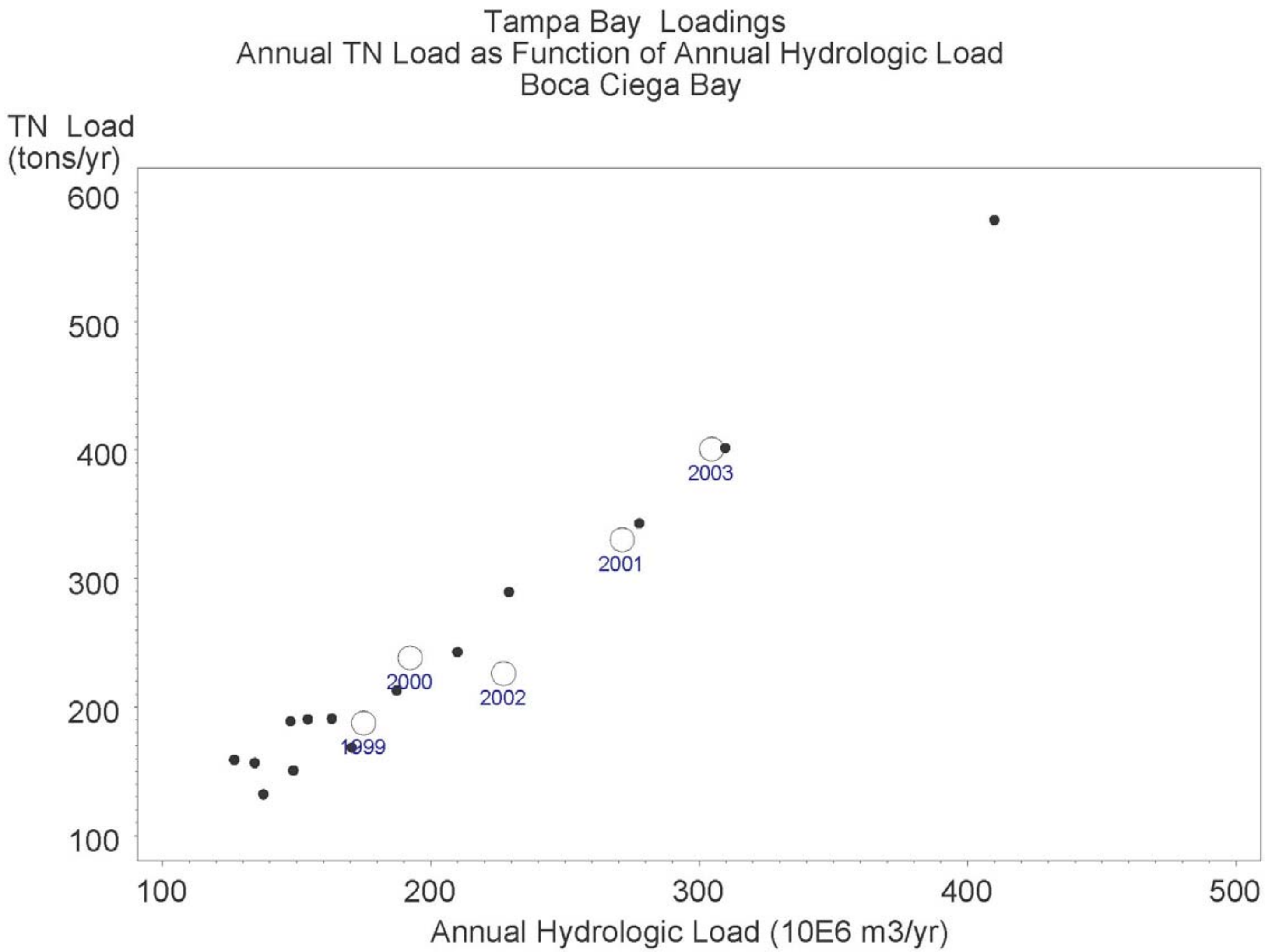

Figure 5-12. Relationship between TN and hydrologic loadings, Boca Ciega Bay, 1985-2003.

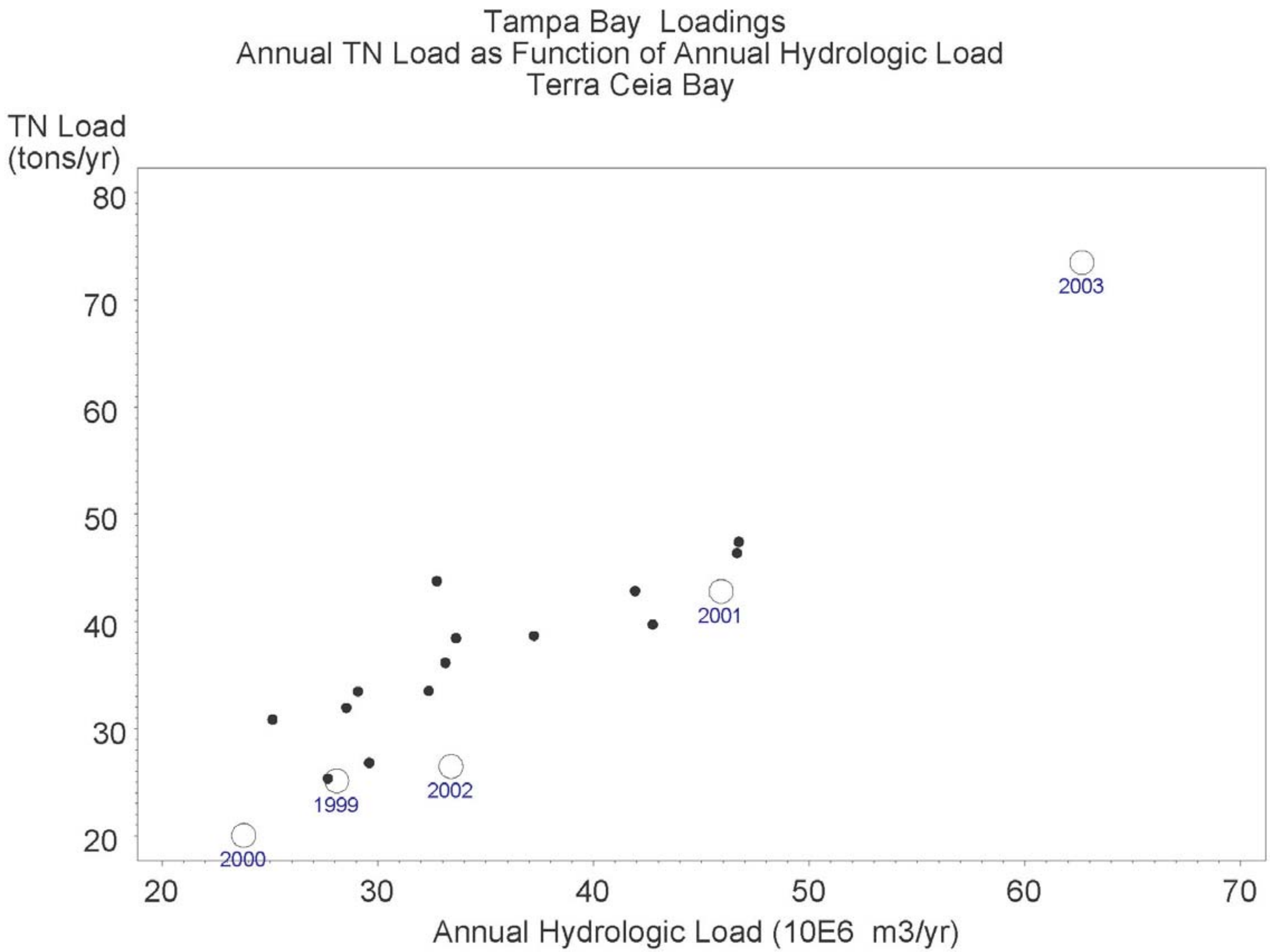

Figure 5-13. Relationship between TN and hydrologic loadings, Terra Ceia Bay, 1985-2003.

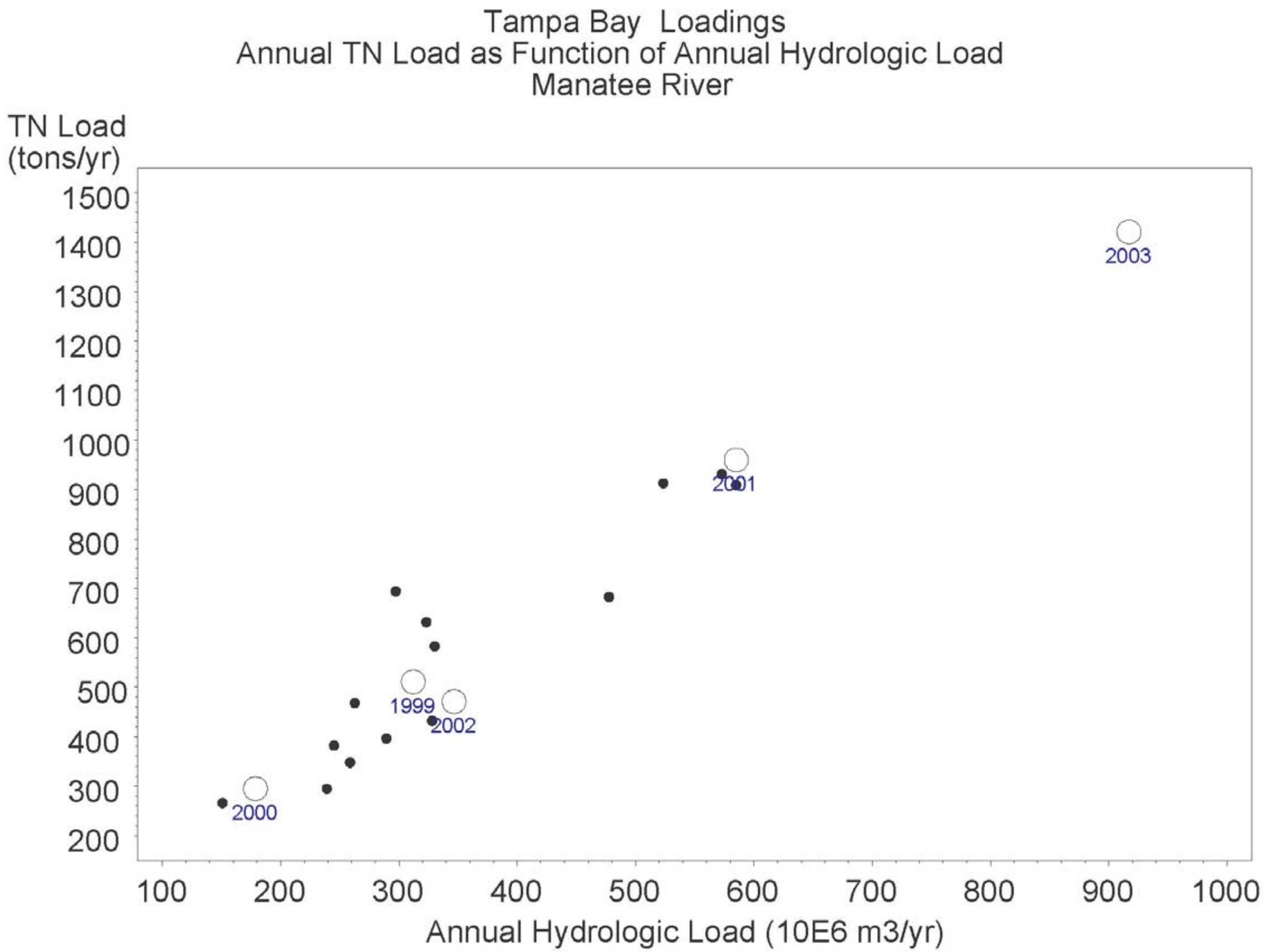

Figure 5-14. Relationship between TN and hydrologic loadings, Manatee River, 1985-2003.

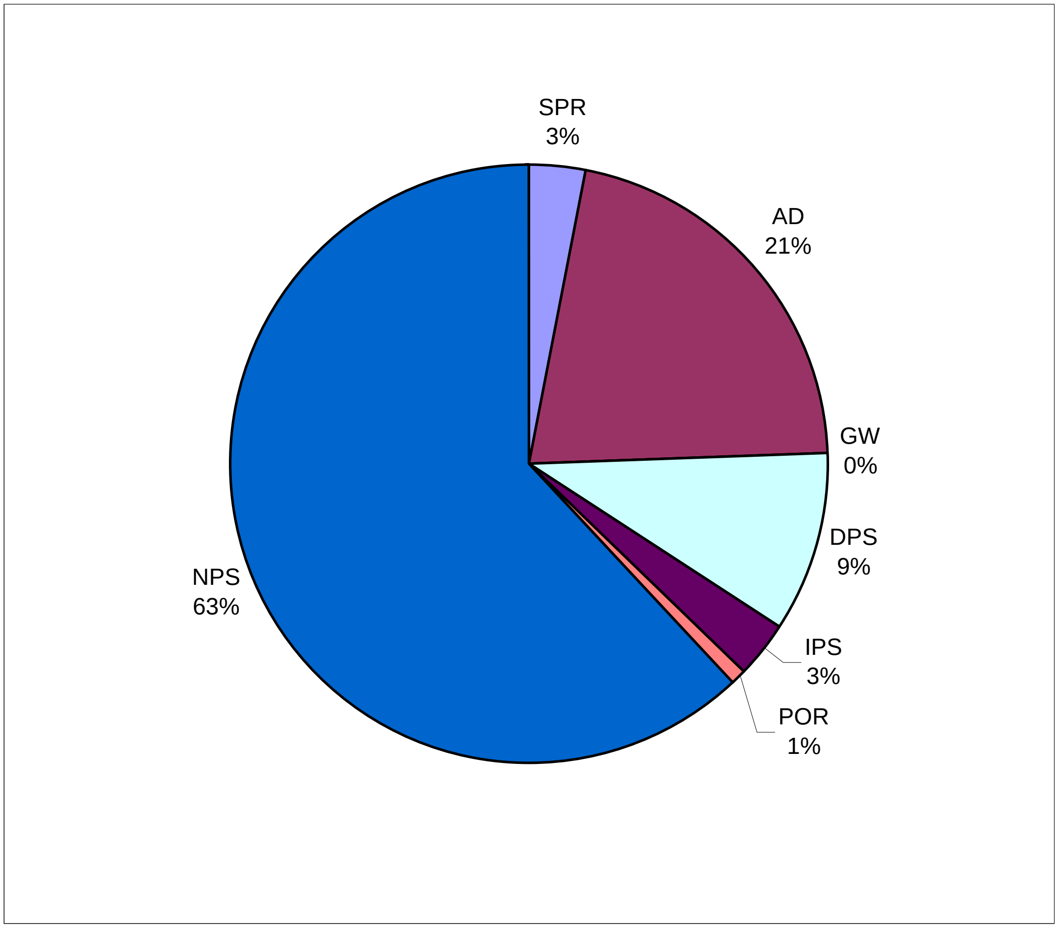

Figure 5-15. Percentage contributions from sources to mean annual TN loadings for the 1999-2003 period.

6. POLLUTANT LOADINGS BY MAJOR BASIN

This section examines the variation in annual TN loadings by major basin for the years 1999-2003. The Florida Department of Environmental Protection (FDEP) has adopted a watershed management approach to manage water resources in Florida. This approach is based on naturally occurring hydrologic features such as river basins, as opposed to political or regulatory boundaries, thus promoting the management of entire natural systems. In addition, this approach strives to increase cooperation among programs and provide consistent environmental management while maintaining the flexibility to address local and regional issues and implement Total Maximum Daily Loads (TMDLs). In order to better address the FDEP's watershed management approach to water resource management, the Tampa Bay Estuary Program is currently examining loading estimates at the major basin level. The major basins are shown in Figure 2-1.

Figures 6-1 through 6-10 present estimated TN loadings (tons/year and percentage of total by source) to each major basin.

Table 6-1. Estimated TN loadings (tons/year and percentage of total) by source to Coastal Old Tampa Bay 1999-2003.

Source	1999	2000	2001	2002	2003	AVG 99-03
Domestic Point Sources	83 21%	60 15%	59 13%	71 12%	94 12%	73 14%
Industrial Point Sources	3 1%	1 0%	0 0%	2 0%	2 0%	2 0%
Springs	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
Ground Water	<1 0%	<1 0%	<1 0%	<1 0%	<1 0%	<1 0%
Atmospheric Deposition	148 38%	162 41%	157 35%	220 39%	243 30%	186 36%
Material Losses	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
Nonpoint Sources	157 40%	175 44%	230 52%	277 49%	467 58%	261 50%
TOTAL	391	398	446	570	806	522

Table 6-2. Estimated TN loadings (tons/year and percentage of total) by source to Hillsborough River 1999-2003.

Source	1999	2000	2001	2002	2003	AVG 99-03
Domestic Point Sources	12 6%	13 12%	25 9%	20 5%	27 3%	19 4%
Industrial Point Sources	0 0%	0 0%	0 0%	4 1%	10 1%	3 1%
Springs	116 56%	58 55%	62 23%	79 20%	104 10%	84 19%
Ground Water	1 0%	1 1%	1 0%	1 0%	1 0%	1 0%
Atmospheric Deposition	39 19%	40 28%	41 13%	55 12%	66 6%	48 11%
Material Losses	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
Nonpoint Sources	38 18%	33 31%	177 67%	301 74%	901 86%	290 65%
TOTAL	206	145	305	459	1109	445

Table 6-3. Estimated TN loadings (tons/year and percentage of total) by source to Coastal Hillsborough Bay 1999-2003.

Source	1999	2000	2001	2002	2003	AVG 99-03
Domestic Point Sources	211 44%	183 55%	193 35%	230 39%	201 30%	204 39%
Industrial Point Sources	12 3%	11 3%	11 2%	13 2%	11 2%	12 2%
Springs	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
Ground Water	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
Atmospheric Deposition	10 2%	11 3%	11 2%	14 2%	18 3%	13 2%
Material Losses	32 7%	28 9%	26 5%	26 5%	26 4%	28 5%
Nonpoint Sources	210 44%	102 31%	308 57%	306 53%	422 64%	270 51%
TOTAL	476	335	549	590	678	525

Table 6-4. Estimated TN loadings (tons/year and percentage of total) by source to Alafia River 1999-2003.

Source	1999	2000	2001	2002	2003	AVG 99-03
Domestic Point Sources	17 4%	15 6%	20 4%	18 3%	24 3%	19 4%
Industrial Point Sources	89 22%	16 6%	45 8%	81 15%	139 15%	74 14%
Springs	42 10%	37 14%	41 8%	41 8%	48 5%	42 8%
Ground Water	0 0%	1 0%	0 0%	0 0%	0 0%	0 0%
Atmospheric Deposition	24 6%	25 10%	25 5%	34 6%	41 4%	30 6%
Material Losses	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
Nonpoint Sources	231 57%	167 64%	404 75%	357 67%	701 74%	372 69%
TOTAL	404	261	536	531	954	537

Table 6-5. Estimated TN loadings (tons/year and percentage of total) by source to Coastal Middle Tampa Bay 1999-2003.

Source	1999	2000	2001	2002	2003	AVG 99-03
Domestic Point Sources	38 18%	27 11%	44 13%	23 10%	8 2%	28 10%
Industrial Point Sources	3 1%	2 1%	2 1%	0 0%	0 0%	1 1%
Springs	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
Ground Water	<1 0%	<1 0%	<1 0%	<1 0%	<1 0%	<1 0%
Atmospheric Deposition	98 46%	109 44%	99 30%	119 54%	169 51%	119 44%
Material Losses	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
Nonpoint Sources	76 35%	110 44%	185 56%	77 35%	153 46%	120 45%
TOTAL	215	248	330	219	330	268

Table 6-6. Estimated TN loadings (tons/year and percentage of total) by source to Little Manatee River 1999-2003.

Source	1999	2000	2001	2002	2003	AVG 99-03
Domestic Point Sources	0 0%	0 0%	0 0%	1 0%	2 0%	1 0%
Industrial Point Sources	6 2%	5 2%	16 3%	16 4%	20 2%	13 3%
Springs	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
Ground Water	<1 0%	<1 0%	<1 0%	<1 0%	<1 0%	<1 0%
Atmospheric Deposition	115 38%	127 51%	116 20%	140 32%	199 21%	139 28%
Material Losses	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
Nonpoint Sources	179 60%	119 47%	442 77%	277 64%	707 76%	345 69%
TOTAL	300	251	574	434	928	497

Table 6-7. Estimated TN loadings (tons/year and percentage of total) by source to Boca Ciega Bay 1999-2003.

Source	1999	2000	2001	2002	2003	AVG 99-03
Domestic Point Sources	5 3%	5 2%	5 2%	18 8%	61 15%	19 7%
Industrial Point Sources	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
Springs	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
Ground Water	<1 0%	<1 0%	<1 0%	<1 0%	<1 0%	<1 0%
Atmospheric Deposition	66 35%	76 32%	67 20%	79 35%	113 28%	80 29%
Material Losses	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
Nonpoint Sources	117 62%	158 66%	258 78%	128 57%	227 57%	178 64%
TOTAL	188	239	330	225	401	277

Table 6-8. Estimated TN loadings (tons/year and percentage of total) by source to Terra Ceia Bay 1999-2003.

Source	1999	2000	2001	2002	2003	AVG 99-03
Domestic Point Sources	2 8%	0 0%	5 12%	3 12%	14 19%	5 13%
Industrial Point Sources	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
Springs	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
Ground Water	<1 0%	<1 0%	<1 0%	<1 0%	<1 0%	<1 0%
Atmospheric Deposition	13 52%	12 60%	13 30%	14 54%	23 32%	15 40%
Material Losses	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
Nonpoint Sources	10 40%	8 40%	25 58%	9 35%	36 49%	18 47%
TOTAL	25	20	43	26	73	37

Table 6-9. Estimated TN loadings (tons/year and percentage of total) by source to Coastal Lower Tampa Bay 1999-2003.

Source	1999	2000	2001	2002	2003	AVG 99-03
Domestic Point Sources	1 0%	1 0%	1 0%	1 0%	1 0%	1 0%
Industrial Point Sources	0 0%	0 0%	0 0%	0 0%	47 10%	9 3%
Springs	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
Ground Water	<1 0%	<1 0%	<1 0%	<1 0%	<1 0%	<1 0%
Atmospheric Deposition	190 86%	187 86%	191 70%	213 86%	338 69%	224 77%
Material Losses	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
Nonpoint Sources	31 14%	29 13%	79 29%	33 13%	107 22%	56 19%
TOTAL	222	217	271	247	493	290

Table 6-10. Estimated TN loadings (tons/year and percentage of total) by source to the Manatee River 1999-2003.

Source	1999	2000	2001	2002	2003	AVG 99-03
Domestic Point Sources	54 11%	21 7%	14 1%	5 1%	22 2%	23 3%
Industrial Point Sources	11 2%	11 4%	13 1%	1 0%	1 0%	7 1%
Springs	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
Ground Water	<1 0%	<1 0%	<1 0%	<1 0%	<1 0%	<1 0%
Atmospheric Deposition	34 7%	30 10%	34 4%	35 7%	60 4%	39 5%
Material Losses	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
Nonpoint Sources	411 81%	232 79%	899 94%	429 91%	1339 94%	662 91%
TOTAL	510	294	960	470	1422	731

7. CONCLUSIONS

This loading update was performed to provide recent information on loadings to Tampa Bay for two purposes:

- To provide a comparison to baseline TN loadings established by the Nitrogen Management Consortium; and

- To provide additional data to assess the chlorophyll-loading empirical model.

The following provides the conclusions from this update.

- Annual loadings from 1999-2003 were generally lower or equal to those observed during the 1992-1994 period. During 2001 and 2002 higher rainfall contributed to higher loadings.

- Examination of the TN loadings data suggests that much of the increase in TN loadings could be explained by the higher rainfall and resultant hydrologic loadings observed in 2002 and 2003.

- Increases in nonpoint source loadings were the primary contributions to the increased annual loadings.

- Changes in loadings from each source were as follows:

  - Atmospheric deposition loadings were lower in most bay segments during 1999-2001 and higher during 2002 and 2003 in comparison to 1992-1994.

  - Estimated domestic point source loadings were relatively consistent as compared to 1992-1994 with the exception of Boca Ceiga Bay during 2003. Increased loading in Boca Ceiga Bay resulted from discharge from South Cross Bayou treatment facility.

  - Industrial point sources loads during 1999-2003 were variable across bay segments as compared to 1992-1994. A loading increase of 10% in Lower Tampa Bay resulted from Piney Point Discharge in 2003.

- Loading contributions from groundwater remained relatively unchanged compared to 1992-1994.

- Loading contributions from Springs in Hillsborough Bay decreased from 1999-2003 as a result of lower nitrogen concentration data provided by EPC.

- Material losses declined during 1999-2003 to both Hillsborough Bay and Lower Tampa Bay due to improvements in handling processes by several facilities.

- Contributions from nonpoint sources varied in direct proportion to differences in hydrologic loadings.

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APPENDIX A

Letter from Mr. Craig Kovach, CF Industries Inc.,
Accompanying Material Handling Loss Estimates from
Industrial Stormwater Discussion Group for 1999-2003

APPENDIX B

Aggregated Florida Land Use, Cover and
Form Classification System Categories

URBAN LAND USE CATEGORIES

Coastal Land Use Code	FLUCCS Code
1 - Low Density Residential	1100
2 - Medium Density Residential	1200
3 - High Density Residential	1300
4 - Commercial	1400
5 - Industrial	1500
7 - Institutional, Transportation, Utilities	1700 8100 8200 8300

AGRICULTURAL LAND USE CATEGORIES

Coastal Land Use Code	FLUCCS Code
6 - Mining	1600
11 - Groves	2200 2210 2220 2230
12 - Feedlots	2300
13 - Nursery	2400
14 - Row and Field Crops	2100 2140 2150 2440

UPLAND FORESTED LAND USE CATEGORIES

Coastal Land Use Categories	FLUCCS Code
8 - Range Lands	1480 1800 1900 2420 2600 3100 3200 3300
9 - Barren Lands	7100 7200 7300 7400
10 - Pasture	2110 2120 2130
15 - Upland Forests	4100 4110 4120 4200 4300 4340 4400

WATER AND WETLANDS LAND USE CATEGORIES

Coastal Land Use Categories	FLUCCS Code
16 - Freshwater	2500 2540 2550 5100 5200 5210 5220 5230 5240 5300 5310 5320 5330 5340 5500 5600 6440 6450
17 - Saltwater	5400 9113 9116 9121
18 - Forested Freshwater Wetlands	6100 6110 6150 6200 6210 6240 6300
19 - Saltwater Wetlands	6120 6420
20 - Non-forested Freshwater Wetlands	6400, 6410, 6411, 6430 6530
21 - Tidal Flats	6500, 6510 6520

APPENDIX C

Land Use-specific Water Quality Concentrations

Land Use-Specific Nonpoint Source Water Quality Concentrations

URBAN LAND USES						
Land Use Classification			Land Use-Specific Water Quality Concentrations			
Coastal Land Use Classification	Land Use Description	Reference	TN (mg/L)	TP (mg/L)	TSS (mg/L)	BOD (mg/L)
1 (LDR)	Low Density Single Family Residential (SFR)	(1)	2.31	0.40	33.0	-
		(1)	2.14	0.32	28.0	-
		(1)	0.605	0.073	7.2	-
		(1)	1.18	0.307	3.5	-
		(1)	3.0	0.45	-	-
		(1)	2.2	0.25	-	-
		(4)	1.87	0.39	-	-
		(8)	1.46	0.401	19.0	-
		(9)	1.56	0.27	20.8	-
		(10)	2.04	0.593	49.7	-
		(11)	2.88	0.72	56.8	-
		(13)	-	-	-	4.4
		min	0.605	0.073	3.5	-
		mean	1.93	0.380	27.3	4.4
		max	2.88	0.598	56.8	-
2 (MDR)	Medium Density (See notes)	mean	2.04	0.44	33.5	- 7.4 -
3 (HDR)	Multifamily Residential	(1)	1.61	0.33	53.0	-
		(1)	2.57	0.45	36.8	-
		(1)	4.68	0.72	95.6	-
		(1)	1.91	0.73	-	-
		(1)	1.02	0.033	67.6	-
		(1)	1.91	0.51	14.3	-
		(4)	1.65	0.33	-	-
		(8)	2.05	1.34	29.0	-
		(9)	2.04	0.282	10.7	-
		(10)	2.05	0.150	8.3	-
		(11)	2.00	0.56	41	-
		(13)	-	-	-	11.0
		min	1.02	0.033	8.3	-
		mean	2.14	0.49	39.6	11.0
		max	4.68	1.34	95.6	-

Coastal Land Use Classification	Land Use Description	Reference	TN (mg/L)	TP (mg/L)	TSS (mg/L)	BOD (mg/L)
4	Low Intensity Commercial	(1)	1.19	0.15	22.0	-
		(1)	1.10	0.10	45.0	-
	High Intensity Commercial	(1)	2.81	0.31	94.3	-
		(1)	3.53	0.82	-	-
		(1)	2.15	0.15	-	-
	Commercial (Office)	(8)	2.38	0.305	36.5	-
		(9)	1.08	0.495	50.6	-
		(10)	1.40	0.113	6.2	-
		(11)	1.05	0.145	13.8	-
	Commercial (Retail)	(8)	1.69	0.253	9.3	-
		(10)	1.28	0.177	14.5	-
		(11)	2.12	0.22	36.3	-
	Combined Commercial	min	1.05	0.100	6.2	-
		mean	1.82	0.270	32.9	17.2
		max	3.53	0.495	94.3	-
5	Industrial	(1)	1.42	0.19	71.8	-
		(1)	1.42	0.31	102.0	-
		(4)	1.18	0.15	-	-
		(8)	2.28	0.332	18.2	-
		(9)	1.77	0.465	28.3	-
		(10)	1.92	0.490	84.3	-
		(11)	3.00	0.503	70.0	-
		(13)	-	-	-	9.6
6	Mining	(4)	1.18	0.15	35 (e)	-
		(13)	-	-	-	9.6
7	Institutional	(4)	1.18	0.15	35 (e)	-
		(13)	-	-	-	8.2

AGRICULTURAL LAND USES						
Land Use Classification			Land Use-Specific Water Quality Concentrations			
Coastal Land Use Classification	Land Use Description	Reference	TN (mg/L)	TP (mg/L)	TSS (mg/L)	BOD (mg/L)
10	Pasture	(1)	2.37	0.697	-	-
		(1)	2.48	0.27	8.6	-
		(2)	2.0	0.3	-	-
		(3)	3.0	0.25	-	-
		(4)	1.02	0.16	-	-
		(5)	5.1	3.2	-	-
		(13)	-	-	-	5.1
11	Grove	(7)	2.31	0.10	-	-
		(13)	-	-	-	2.55
11,13	Grove, Nursery	(4)	0.92	0.41	-	-
		(13)	-	-	-	2.55
12	Feed Lot	(3)	29.3	5.1	-	-
		(3)	3.74	1.13	-	-
		(5)	26.0	5.1	-	-
		(13)	-	-	-	5.1
14	Field Crop	(2)	2.5	0.25	-	-
		(3)	2.5	2.5	-	-
		(4)	3.75	1.13	-	-
		(13)	-	-	-	5.1
Mixed Agricultural						
10,11	Citrus+ Pasture	(1)	1.57	0.09	-	-
		(1)	1.33	0.09	4.6	-
		(1)	2.58	0.046	180	-
		(1)	2.68	0.562	-	-
		(1)	3.26	0.24	28.0	-
11,14	Citrus+ Row Crops	(6)	1.78	0.3	5.6	-

(See following page for summarized agricultural water quality concentrations.)

WATER/WETLAND AND FOREST/UNDEVELOPED LAND USES						
Land Use Classification			Land Use-Specific Water Quality Concentrations			
Coastal Land Use Classification	Land Use Description	Reference	TN (mg/L)	TP (mg/L)	TSS (mg/L)	BOD (mg/L)
8	Open Space/ Non-forested	(1) (1) (1) (4) (13)	1.38 0.90 1.47 1.02 -	0.07 0.02 0.07 0.16 -	17.3 4.8 - - -	- - - - 1.45
15	Upland Forest	(2) (3) (4) (13)	0.1 0.2 1.02 -	0.007 0.007 0.16 -	- - - -	- - - 1.45
16,17	Open Water	(1) (1) (1) (13)	0.79 0.73 2.22 -	0.17 0.04 - -	- 0.00 6.2 -	- - - 0.00
18,20	Freshwater Wetland	(1) (1) (1) (1) (4) (13)	2.26 1.02 1.24 1.88 0.79 -	0.09 0.16 0.018 0.33 0.17 -	13.4 - 4.6 12.7 - -	- - - - - 4.63
17	Saltwater		NA	NA	NA	NA
19	Saltwater Wetlands		NA	NA	NA	NA
21	Tidal Flats		NA	NA	NA	NA

Notes:

- Concentrations for CLUCCS code 2 (MDR) are an average of CLUCCS codes 1 (LDR) and 3 (HDR).
- Concentrations for CLUCCS code 4 (Commercial) are an average of reported values for "low intensity" and "high intensity" commercial.
- Estimated (e) agricultural values were based on similar land uses data when no land use specific data were identified.
- Row crop data were often reported with other agricultural uses.
- Saltwater and salwater wetlands were assigned zero loads.

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APPENDIX D

Land Use-specific Seasonal Runoff Coefficients

Land Use-Specific Seasonal Runoff Coefficients

Coastal Land Use Classification and Land Use Type	Hydrologic Soil Group	Dry Season Runoff Coeff.	Wet Season Runoff Coeff.
1) Single Family Residential	A	0.15	0.25
	B	0.18	0.28
	C	0.21	0.31
	D	0.24	0.34
2) Medium Density Residential	A	0.25	0.35
	B	0.30	0.40
	C	0.35	0.45
	D	0.40	0.50
3) Multifamily Residential	A	0.35	0.50
	B	0.42	0.57
	C	0.50	0.65
	D	0.58	0.75
4) Commercial	A	0.70	0.79
	B	0.74	0.83
	C	0.78	0.97
	D	0.82	0.91
5) Industrial	A	0.65	0.75
	B	0.70	0.80
	C	0.75	0.85
	D	0.80	0.90

Land Use-Specific Seasonal Runoff Coefficients (cont)

Land Use	Hydrologic Soil Group	Dry Season Runoff Coeff.	Wet Season Runoff Coeff.
6) Mining	A	0.20	0.20
	B	0.30	0.30
	C	0.40	0.40
	D	0.50	0.50
7) Institutional, Transportation Utils.	A	0.40	0.50
	B	0.45	0.55
	C	0.50	0.60
	D	0.55	0.65
8) Range Lands	A	0.10	0.18
	B	0.14	0.22
	C	0.18	0.26
	D	0.22	0.30
9) Barren Lands	A	0.45	0.55
	B	0.50	0.60
	C	0.55	0.65
	D	0.60	0.70
10) Agricultural - Pasture	A	0.10	0.18
	B	0.14	0.22
	C	0.18	0.26
	D	0.22	0.30

Land Use-Specific Seasonal Runoff Coefficients (cont)

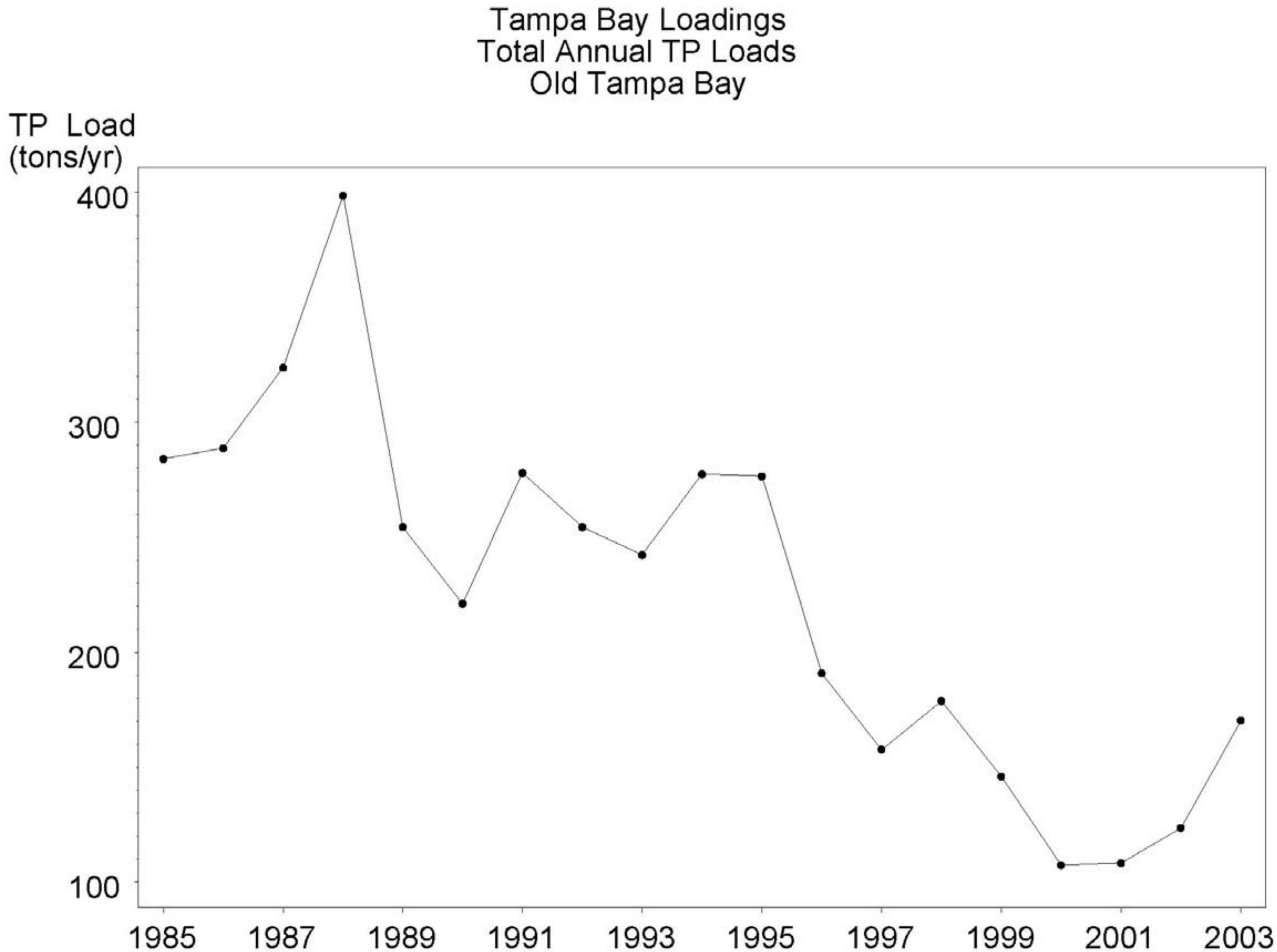
Land Use	Hydrologic Soil Group	Dry Season Runoff Coeff.	Wet Season Runoff Coeff.
11) Agricultural - Groves	A	0.20	0.26
	B	0.23	0.29
	C	0.26	0.32
	D	0.29	0.33
12) Agricultural - Feedlots	A	0.35	0.45
	B	0.40	0.50
	C	0.45	0.55
	D	0.50	0.60
13) Agricultural - Nursery	A	0.20	0.30
	B	0.25	0.35
	C	0.30	0.40
	D	0.35	0.45
14) Agricultural - Row and Field Crops	A	0.20	0.30
	B	0.25	0.35
	C	0.30	0.40
	D	0.35	0.45
15) Upland Forested	A	0.10	0.15
	B	0.13	0.18
	C	0.16	0.21
	D	0.19	0.24

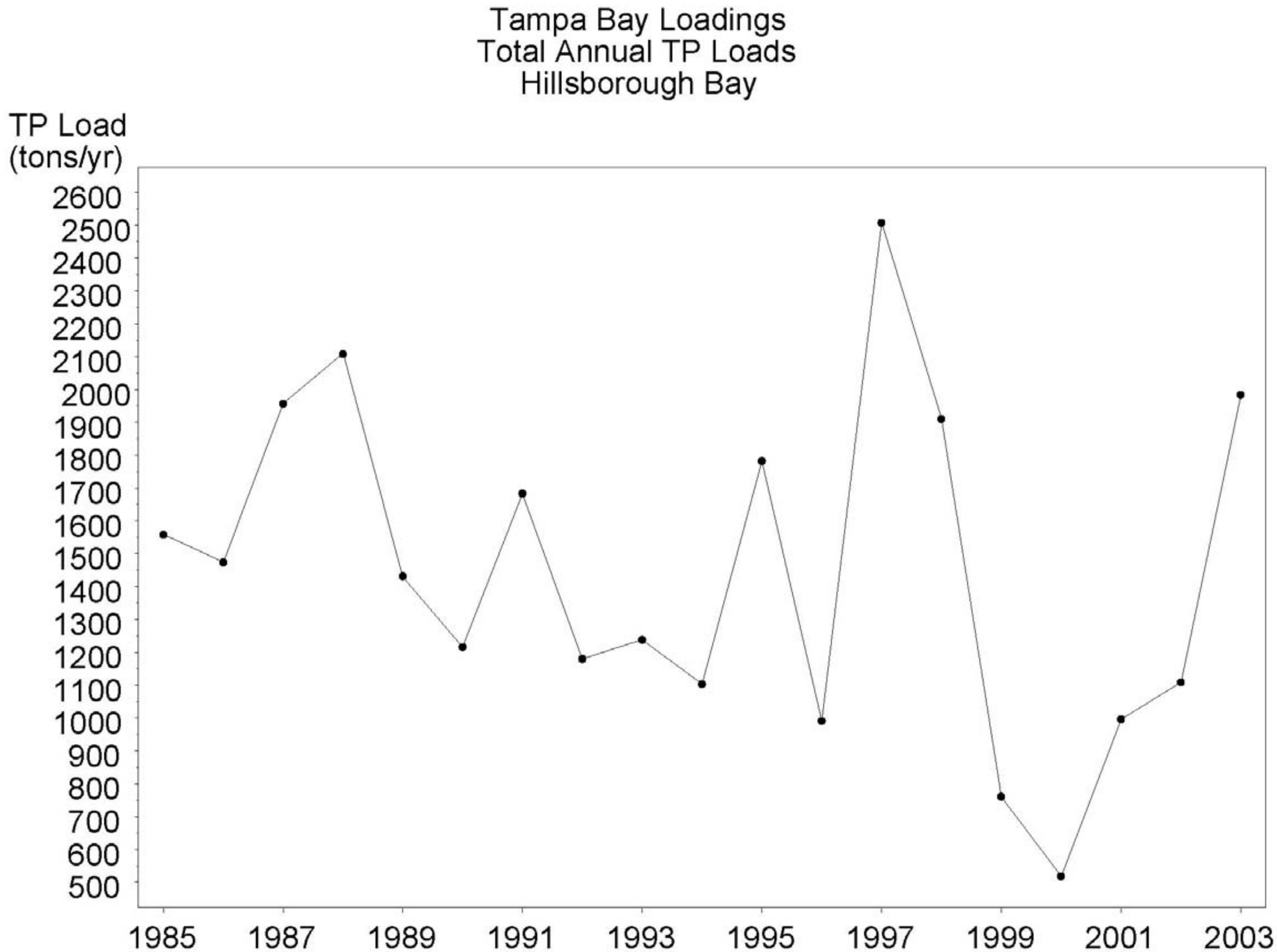
Land Use-Specific Seasonal Runoff Coefficients (cont)

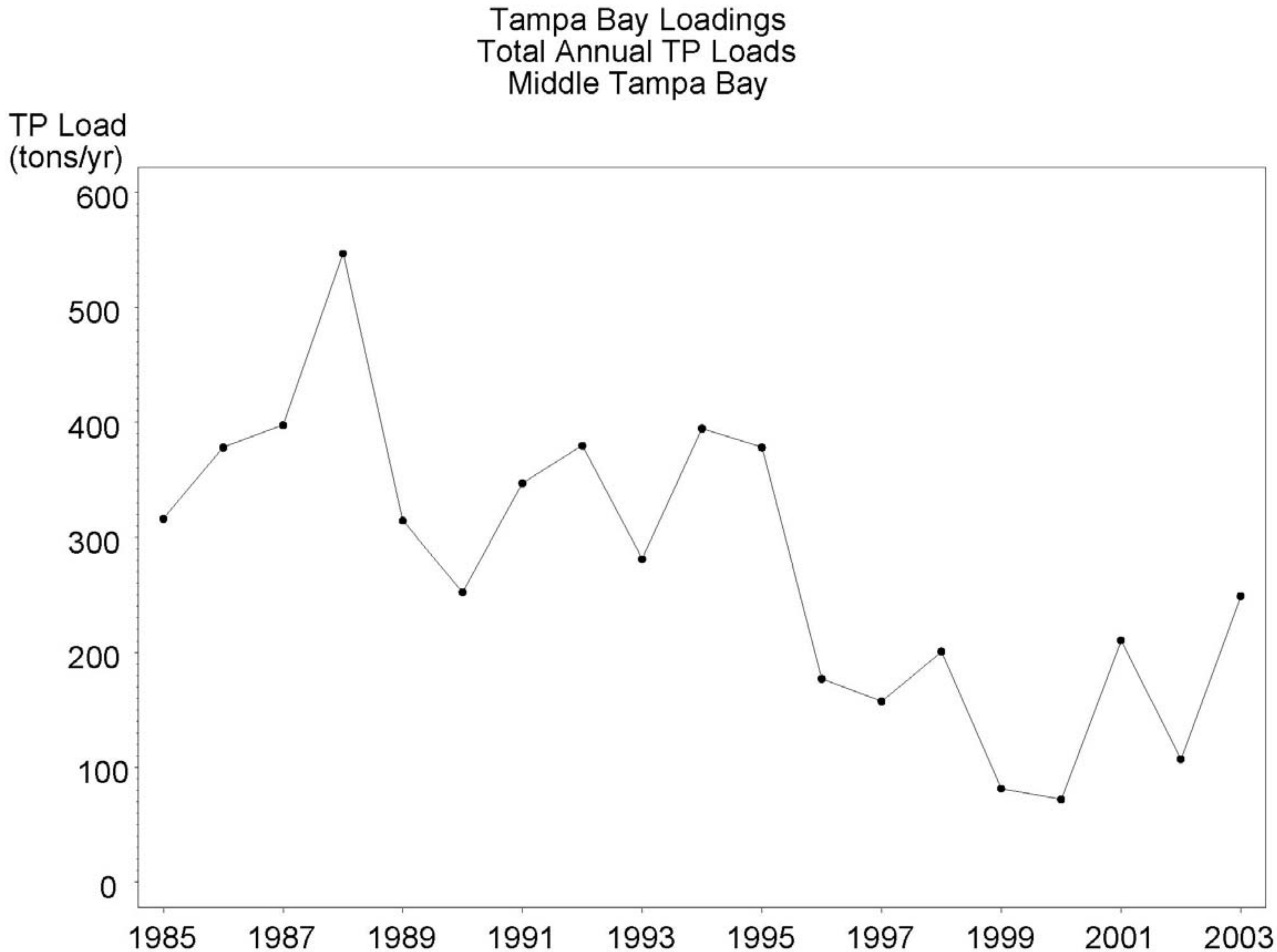
Land Use	Hydrologic Soil Group	Dry Season Runoff Coeff.	Wet Season Runoff Coeff.
16) Freshwater - Open Water	A	0.80	0.90
	B	0.80	0.90
	C	0.80	0.90
	D	0.80	0.90
17) Saltwater - Open Water	A	1.0	1.0
	B	1.0	1.0
	C	1.0	1.0
	D	1.0	1.0
18) Forested Freshwater Wetlands	A	0.50	.60
	B	0.55	0.65
	C	0.60	0.70
	D	0.65	0.75
19) Saltwater Wetlands	A	0.95	0.95
	B	0.95	0.95
	C	0.95	0.95
	D	0.95	0.95
20) Non-forested Freshwater Wetlands	A	0.45	0.55
	B	0.50	0.60
	C	0.55	0.65
	D	0.60	0.70
21) Tidal Flats	A	1.0	1.0
	B	1.0	1.0
	C	1.0	1.0
	D	1.0	1.0

APPENDIX E

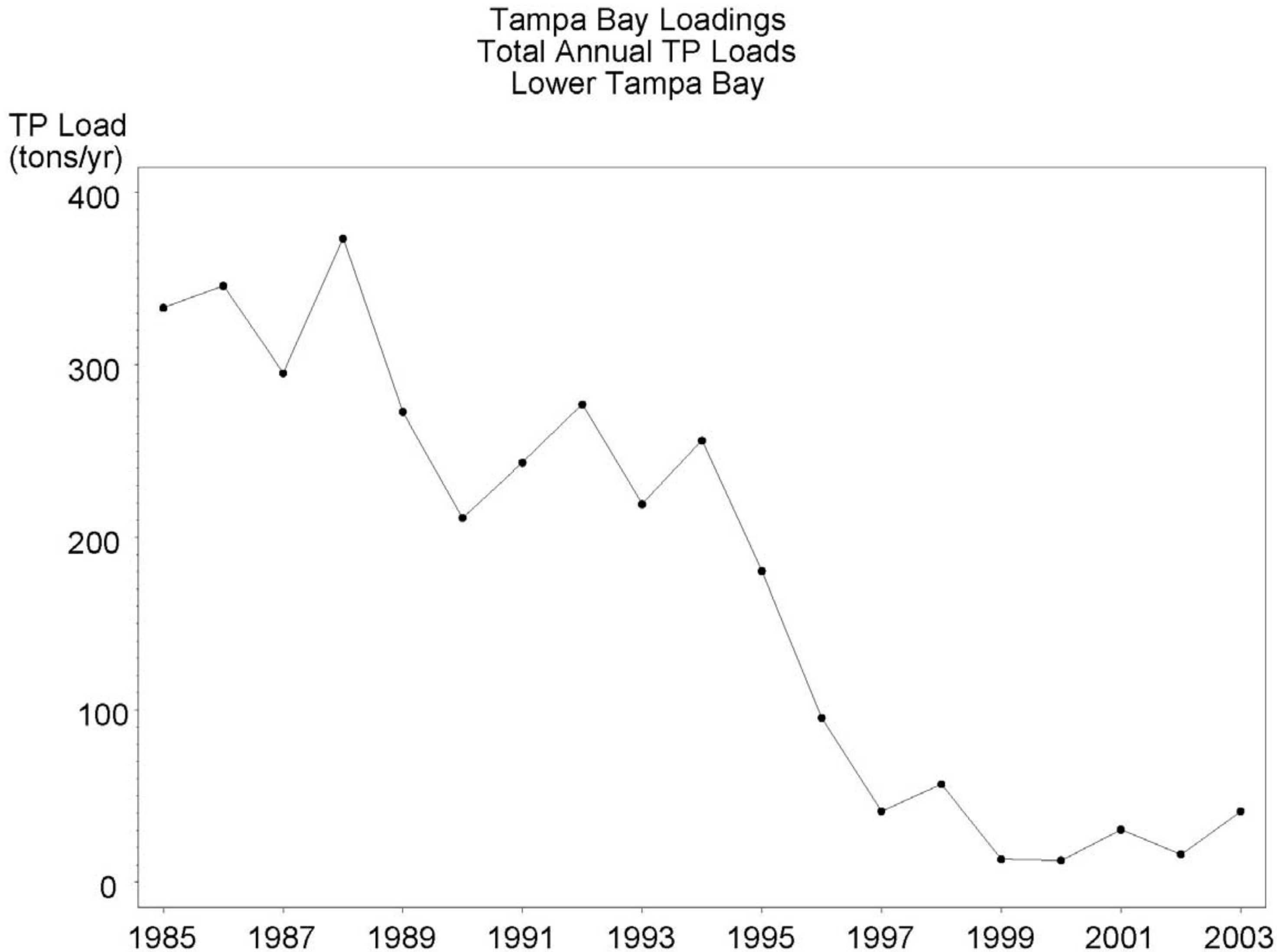
Annual Loadings of TP, TSS, and BOD
to each Bay Segment, 1985-2003

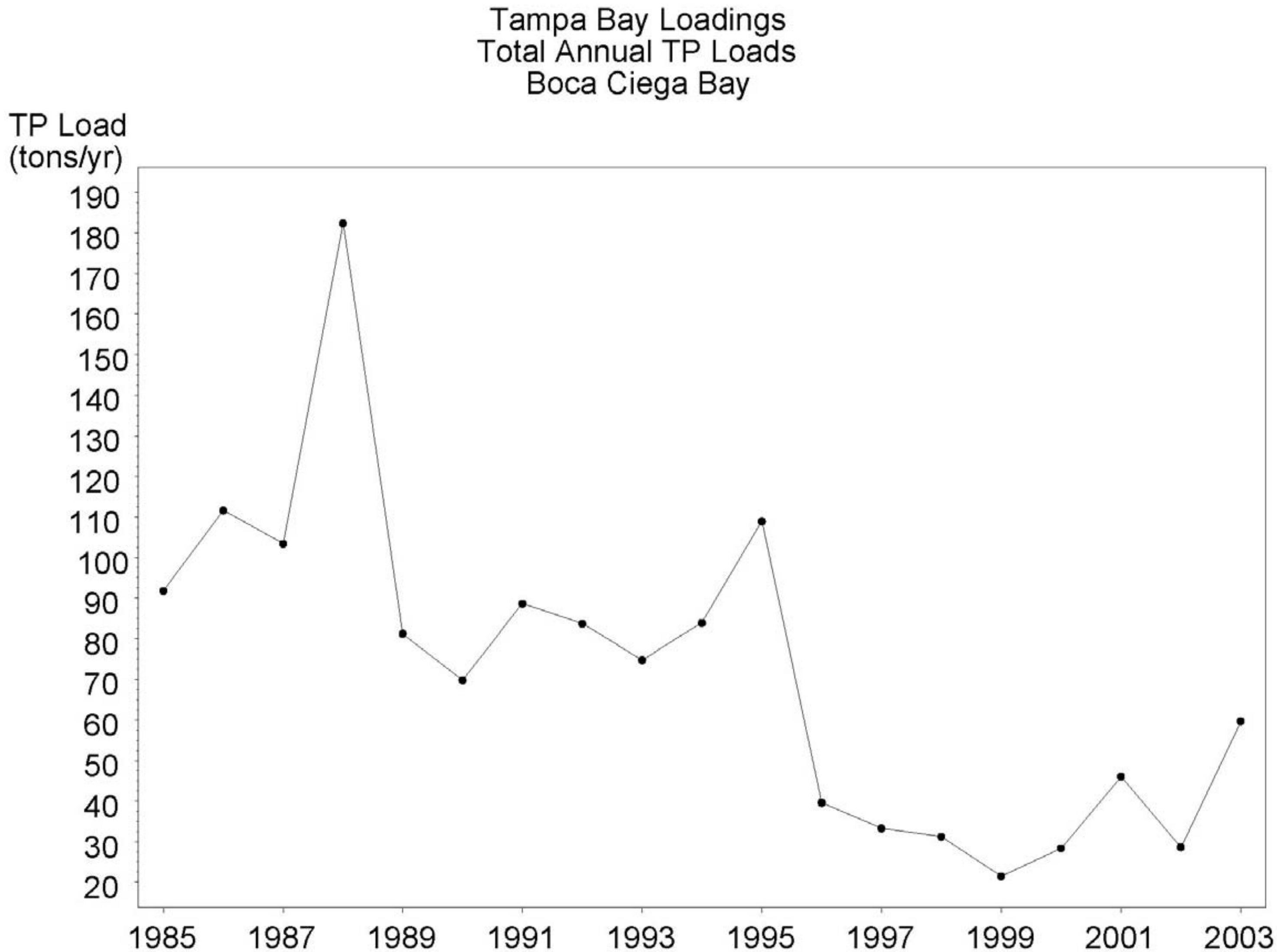

Tampa Bay Loadings
Total Annual TP Loads
Old Tampa Bay
TP Load
(tons/yr)
400
300
200
100
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003


Tampa Bay Loadings
Total Annual TP Loads
Hillsborough Bay
TP Load
(tons/yr)
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003

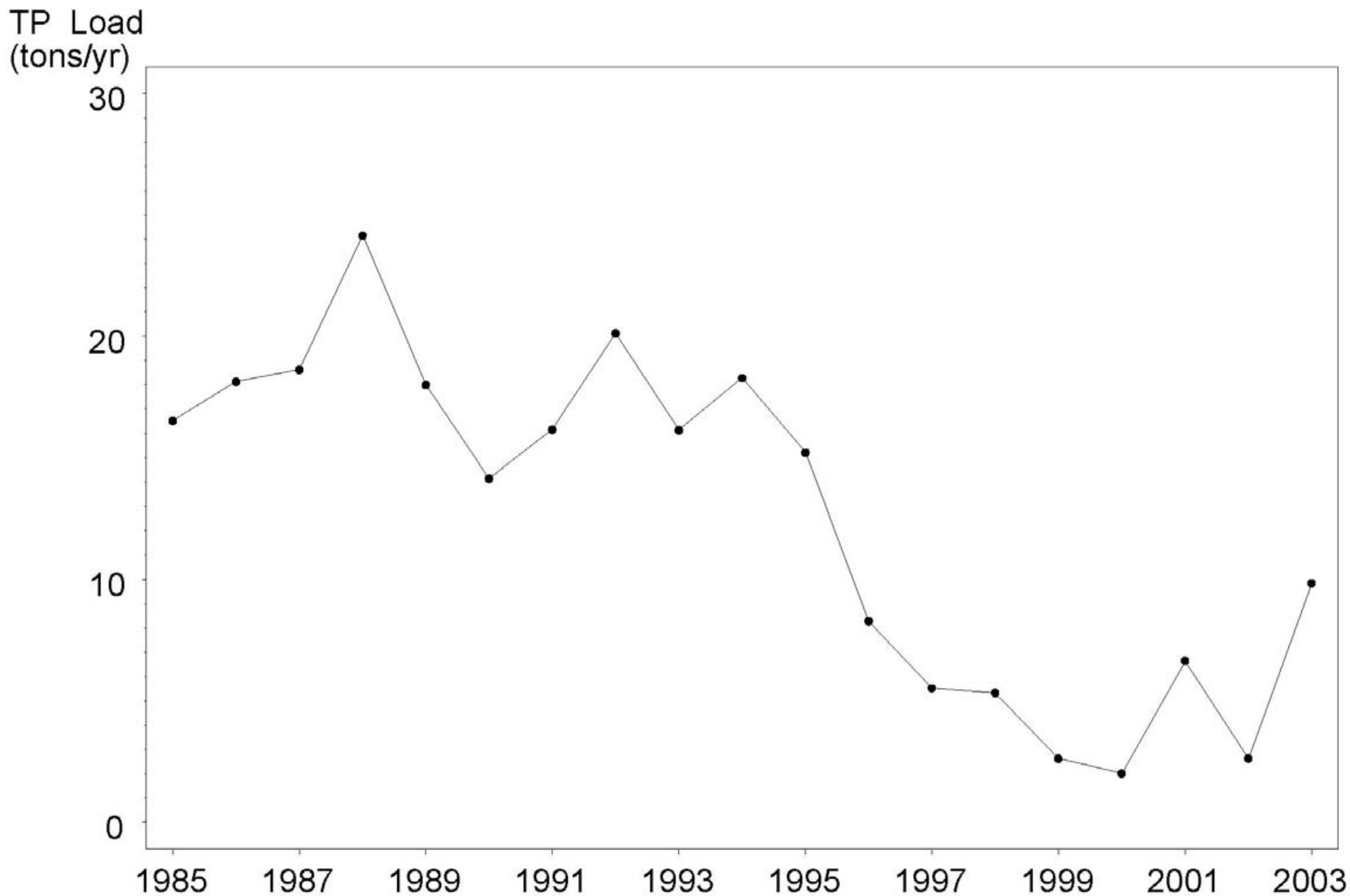


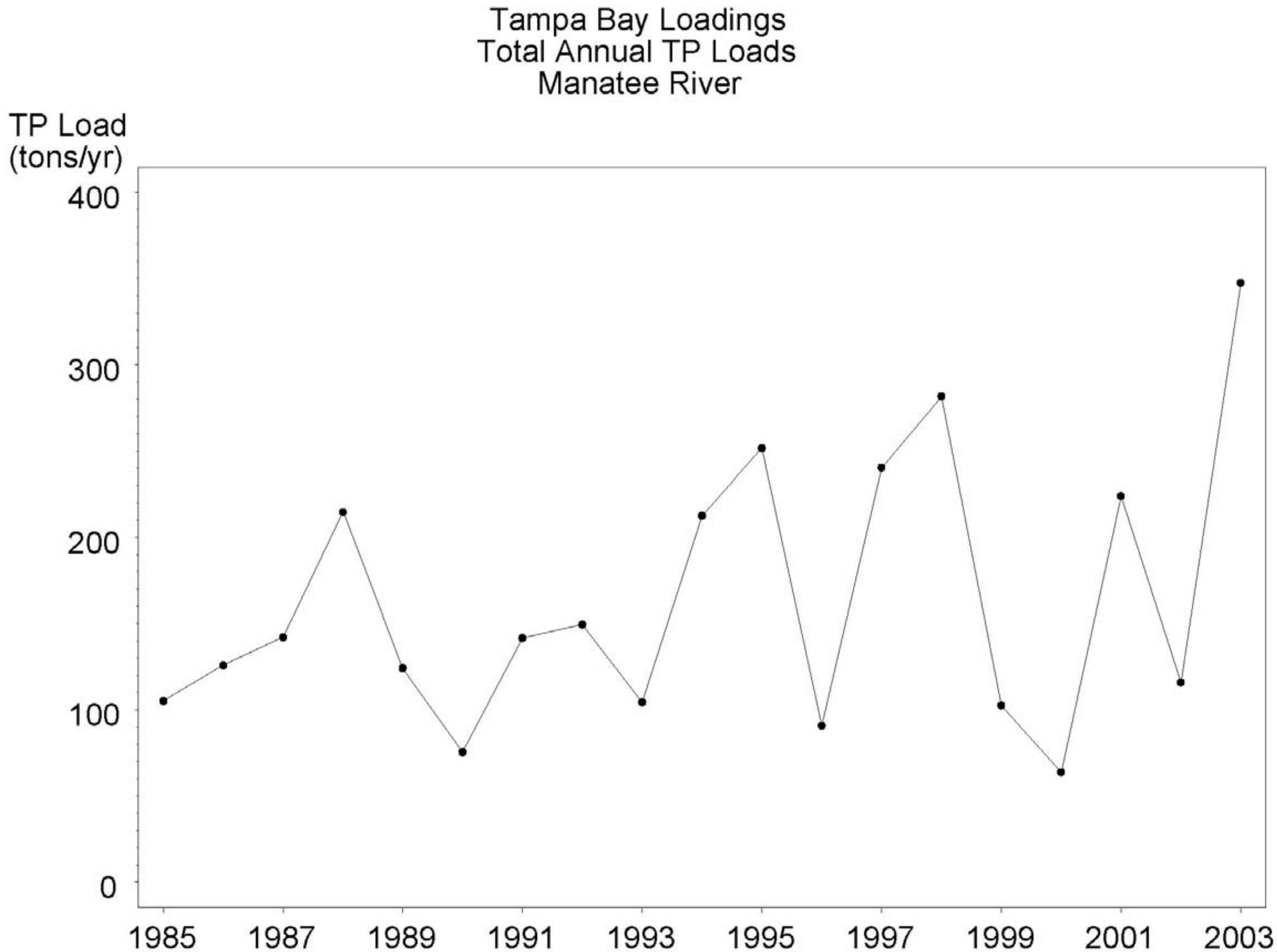
Tampa Bay Loadings
Total Annual TP Loads
Middle Tampa Bay
TP Load
(tons/yr)
600
500
400
300
200
100
0
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003

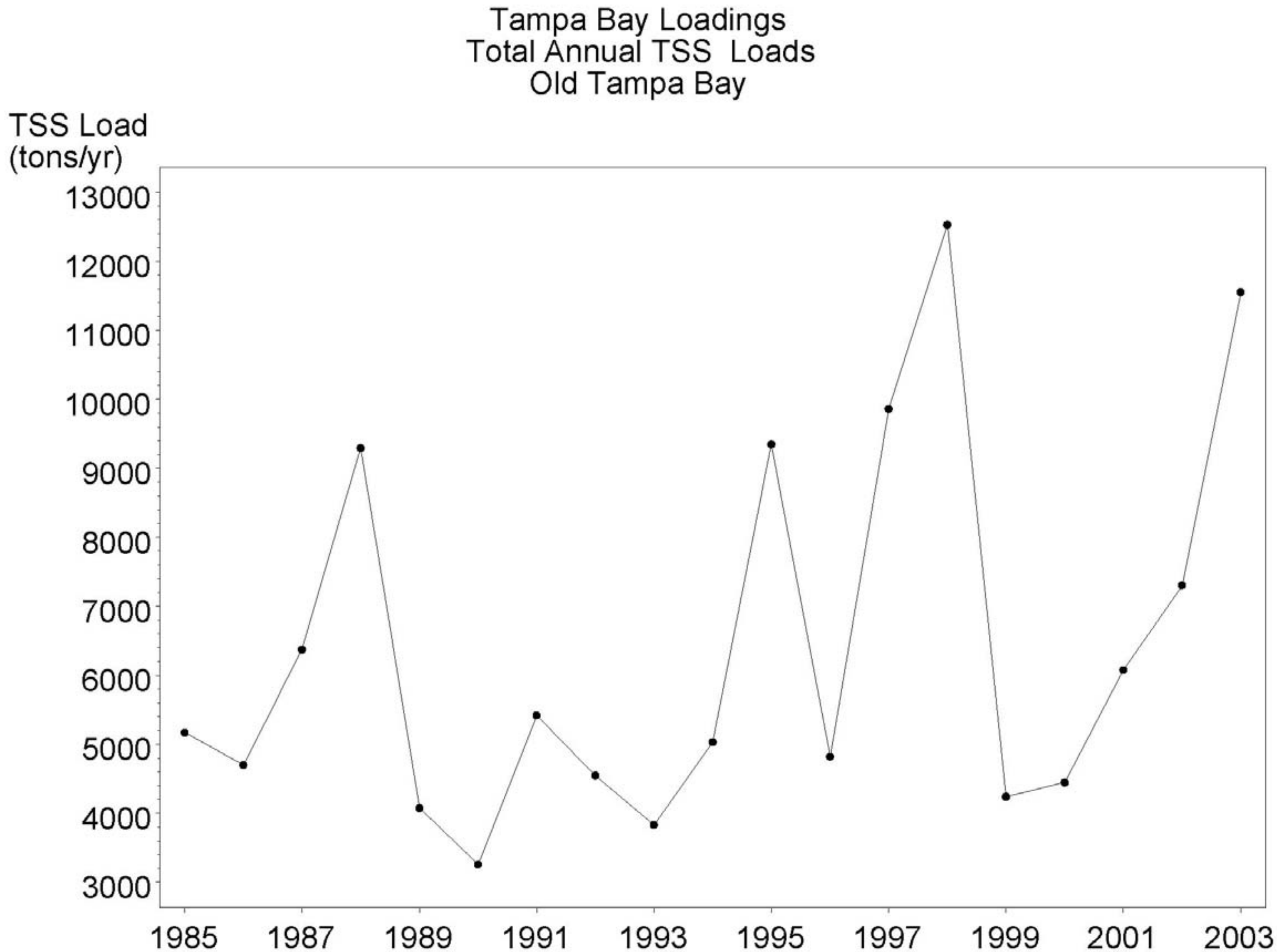

Tampa Bay Loadings
Total Annual TP Loads
Lower Tampa Bay
TP Load
(tons/yr)
400
300
200
100
0
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003

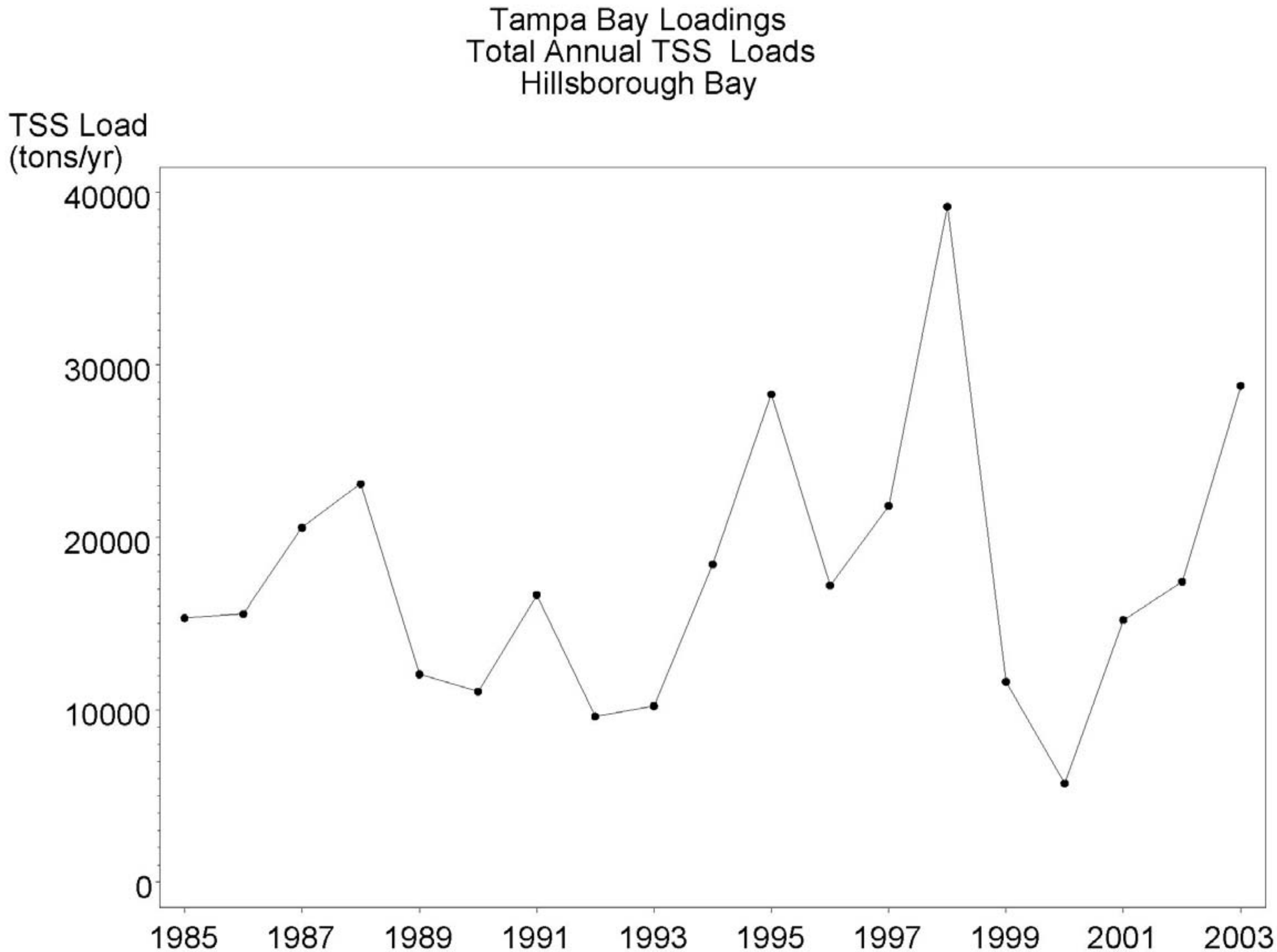

Tampa Bay Loadings
Total Annual TP Loads
Boca Ciega Bay
TP Load
(tons/yr)
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003

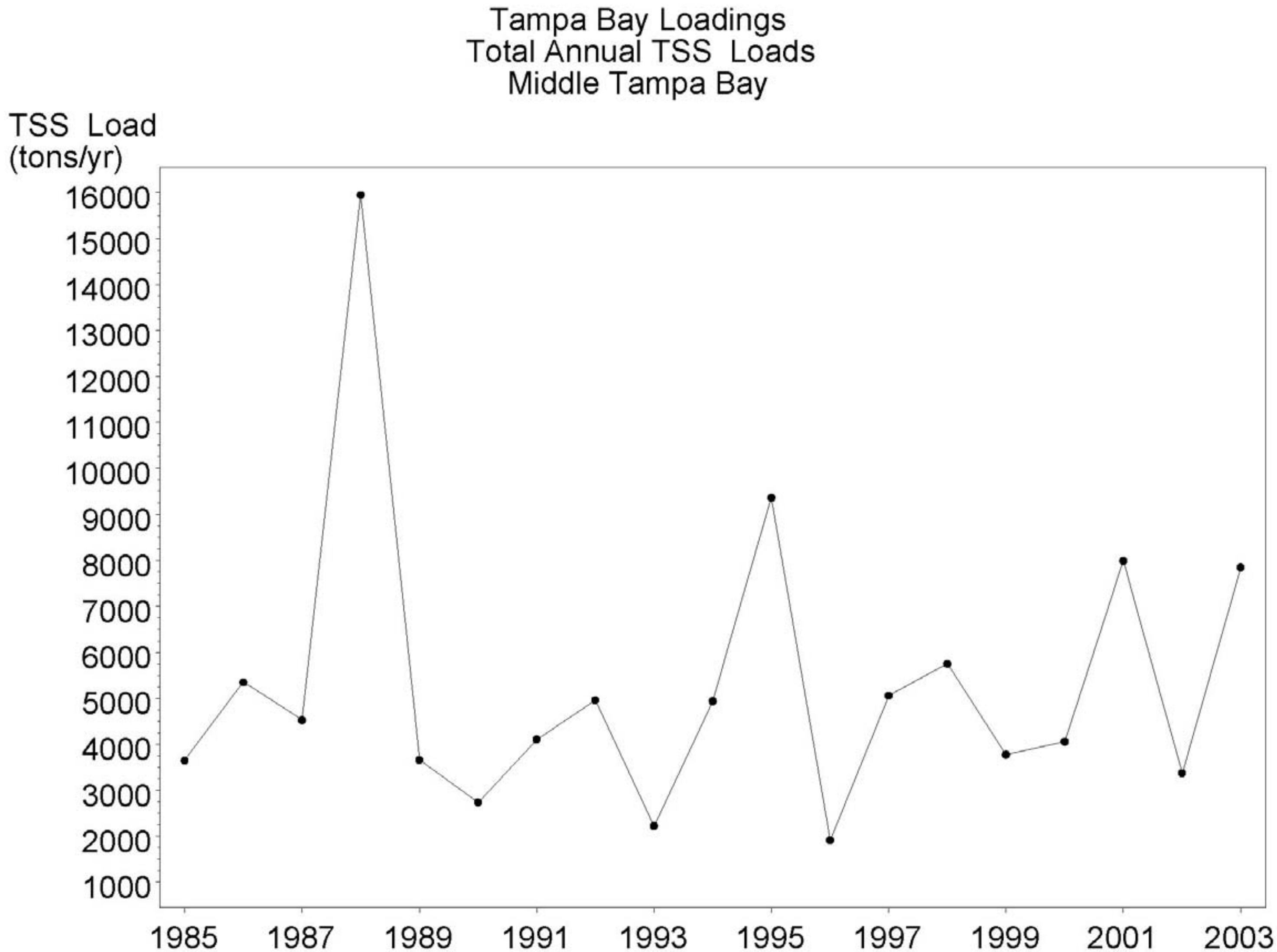
Tampa Bay Loadings
Total Annual TP Loads
Terra Ceia Bay

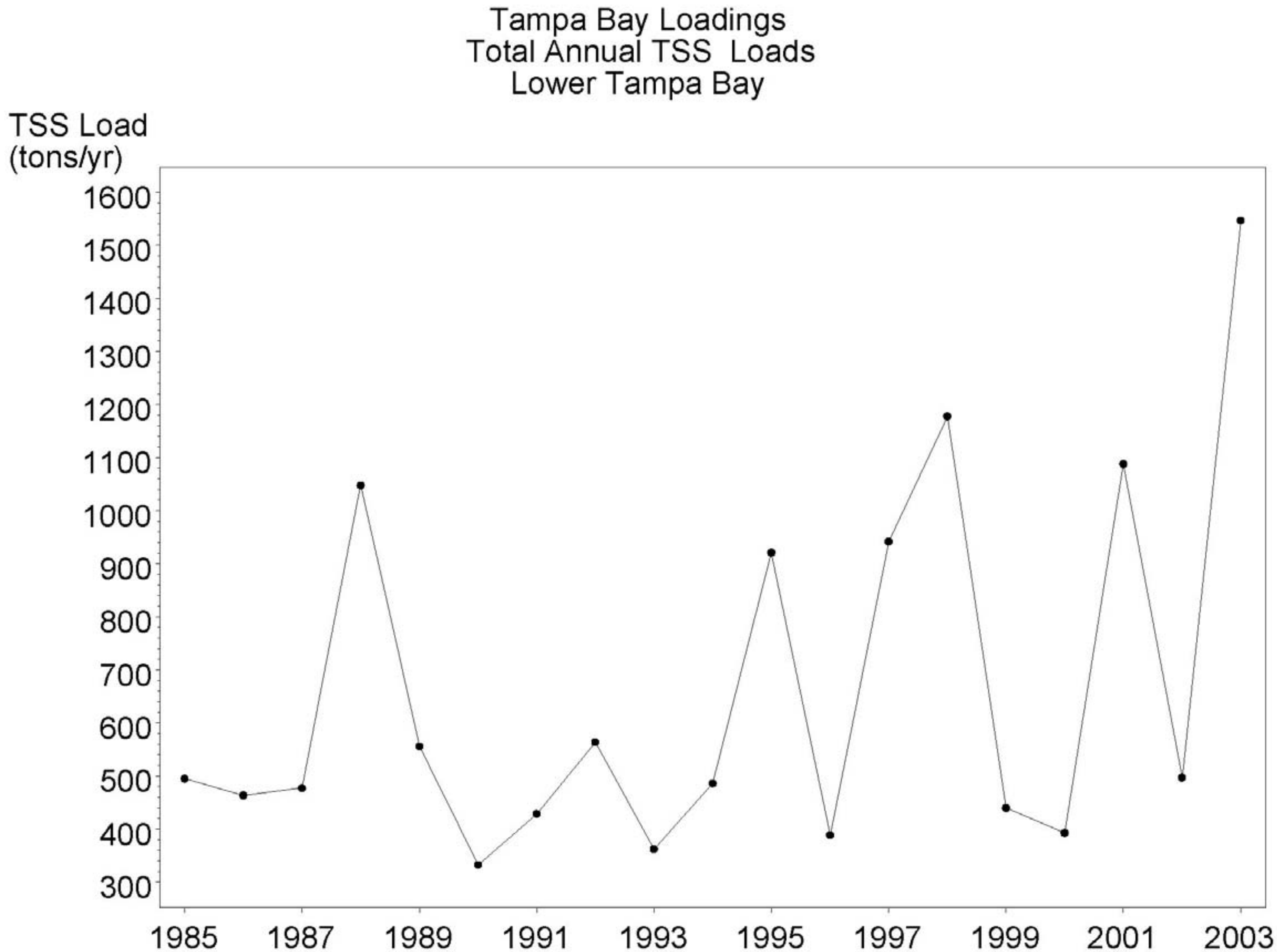



Tampa Bay Loadings
Total Annual TP Loads
Manatee River
TP Load
(tons/yr)
400
300
200
100
0
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003

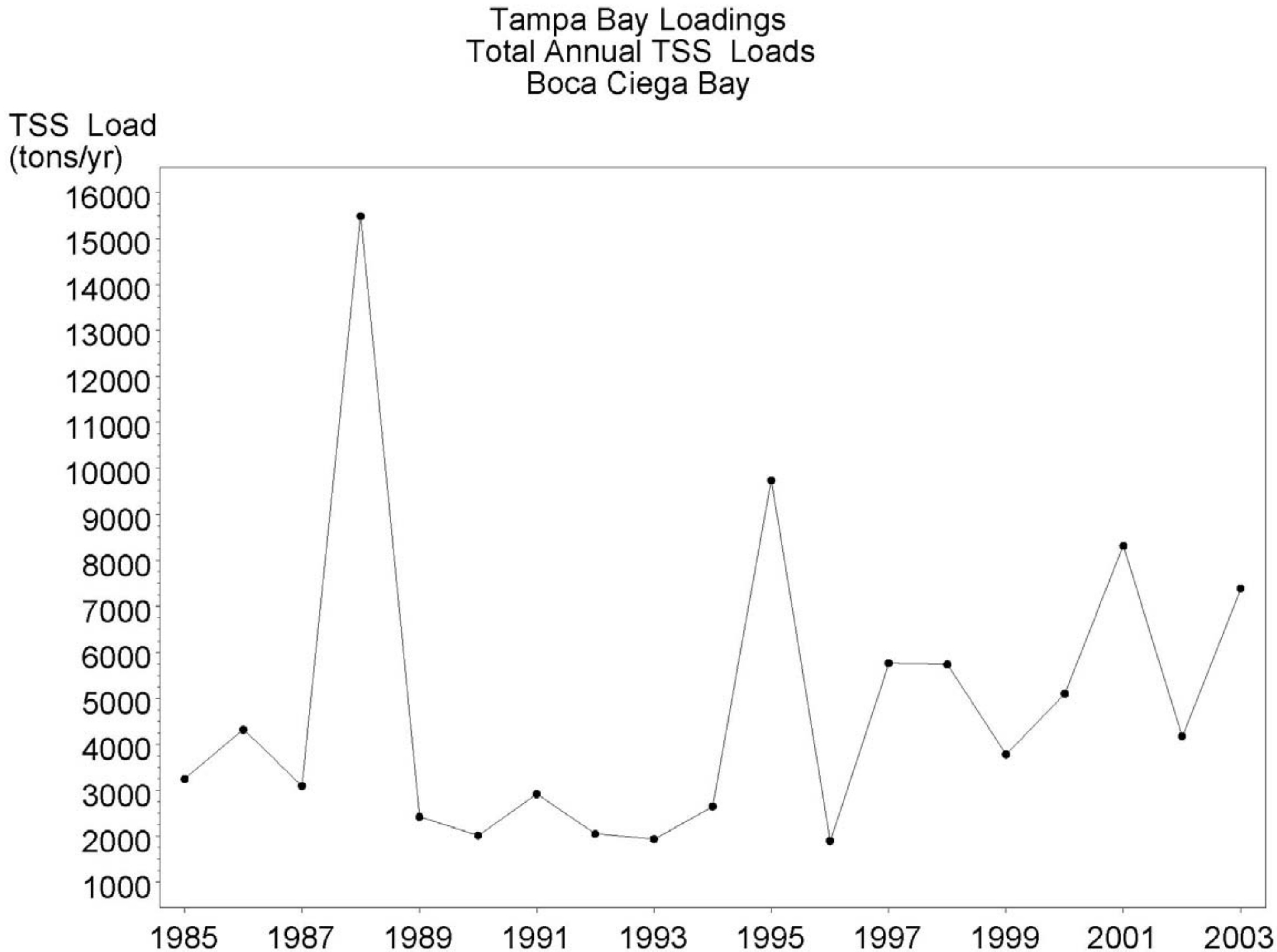

Tampa Bay Loadings
Total Annual TSS Loads
Old Tampa Bay
TSS Load
(tons/yr)
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003

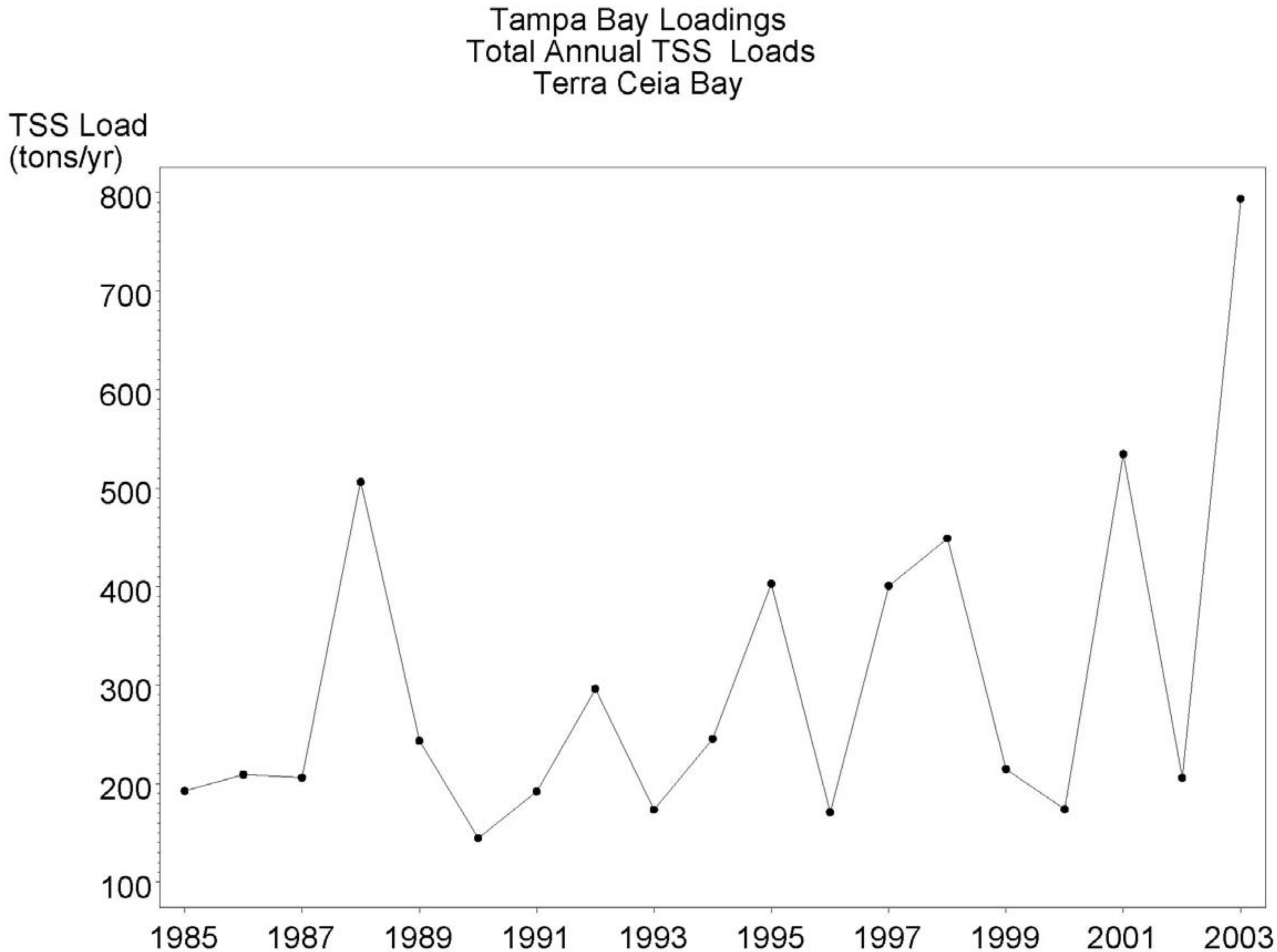

Tampa Bay Loadings
Total Annual TSS Loads
Hillsborough Bay
TSS Load
(tons/yr)
40000
30000
20000
10000
0
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003


Tampa Bay Loadings
Total Annual TSS Loads
Middle Tampa Bay
TSS Load
(tons/yr)
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003

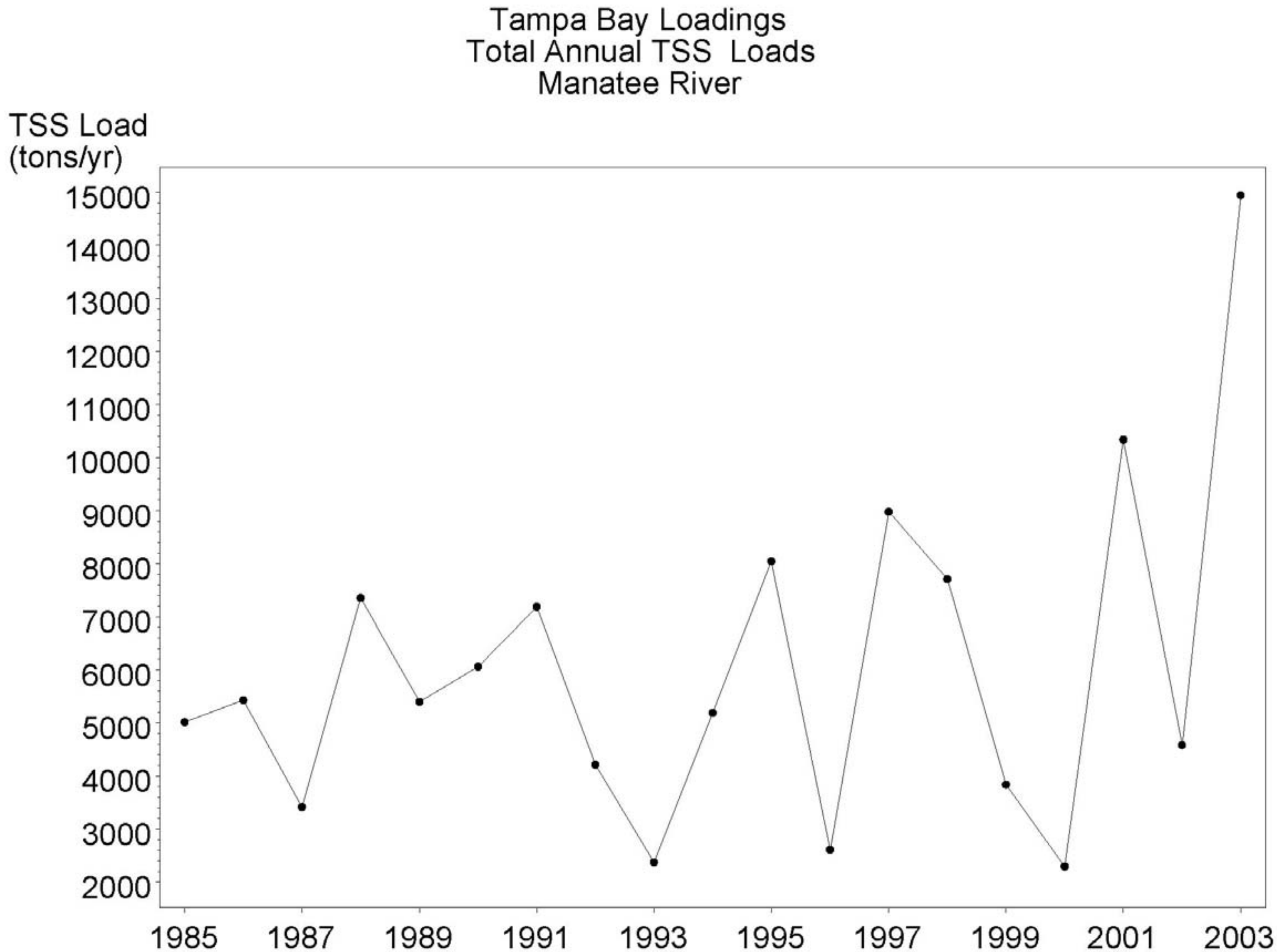


Tampa Bay Loadings
Total Annual TSS Loads
Lower Tampa Bay
TSS Load
(tons/yr)
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003

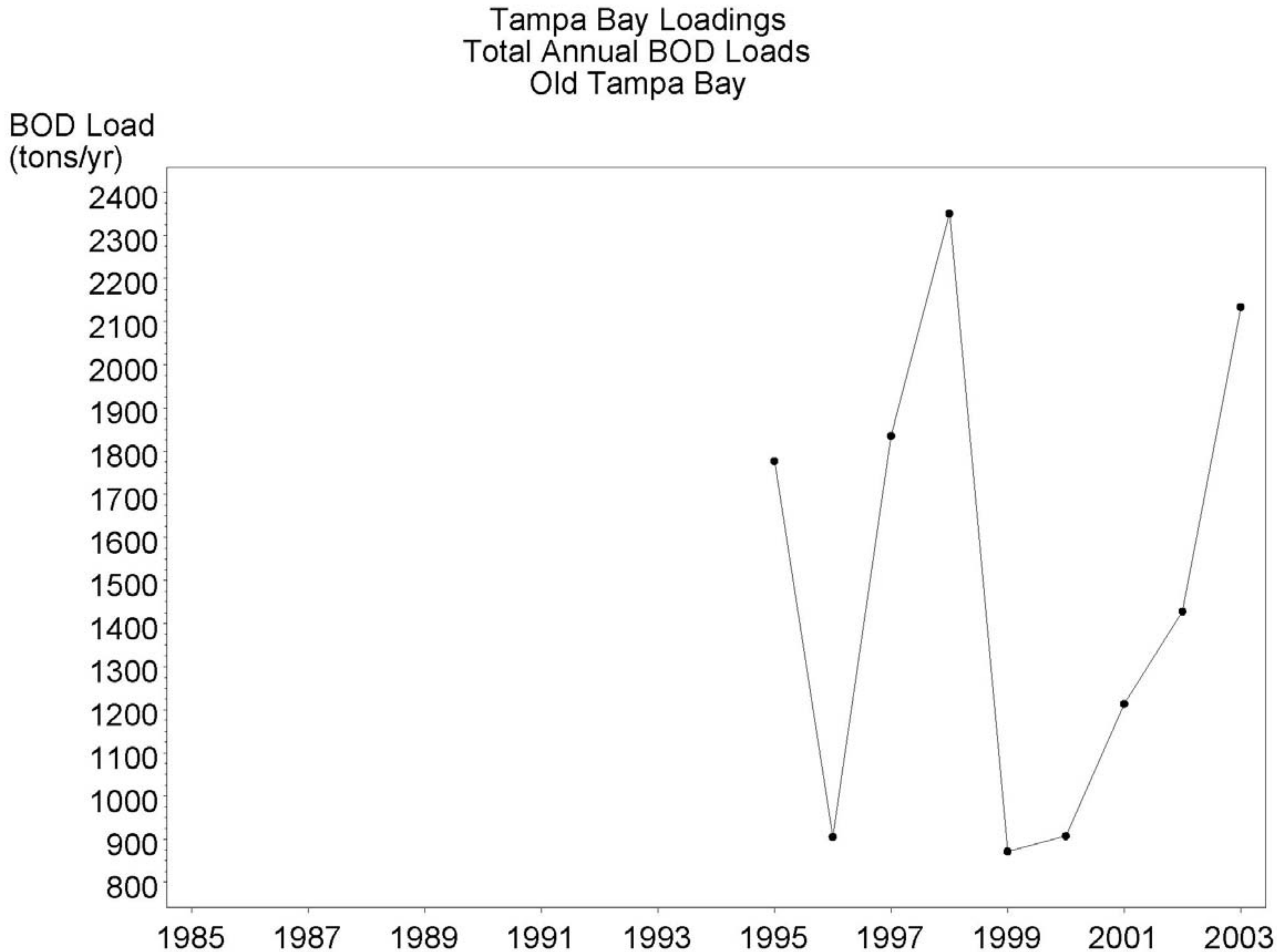

Tampa Bay Loadings
Total Annual TSS Loads
Boca Ciega Bay
TSS Load
(tons/yr)
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003



Tampa Bay Loadings
Total Annual TSS Loads
Terra Ceia Bay
TSS Load
(tons/yr)
800
700
600
500
400
300
200
100
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003



Tampa Bay Loadings
Total Annual TSS Loads
Manatee River
TSS Load
(tons/yr)
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003


Tampa Bay Loadings
Total Annual BOD Loads
Old Tampa Bay
BOD Load
(tons/yr)
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
1985
1987
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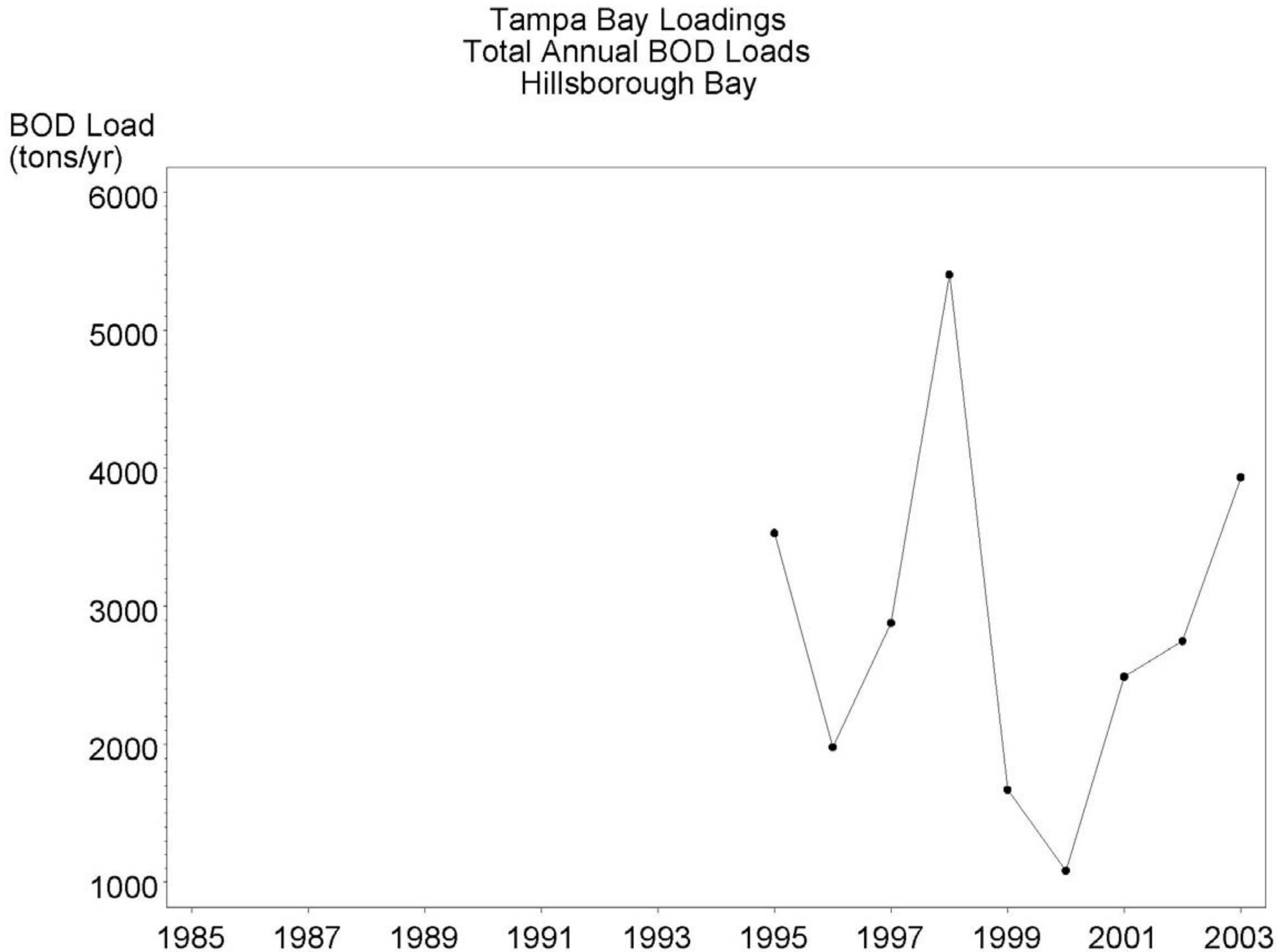
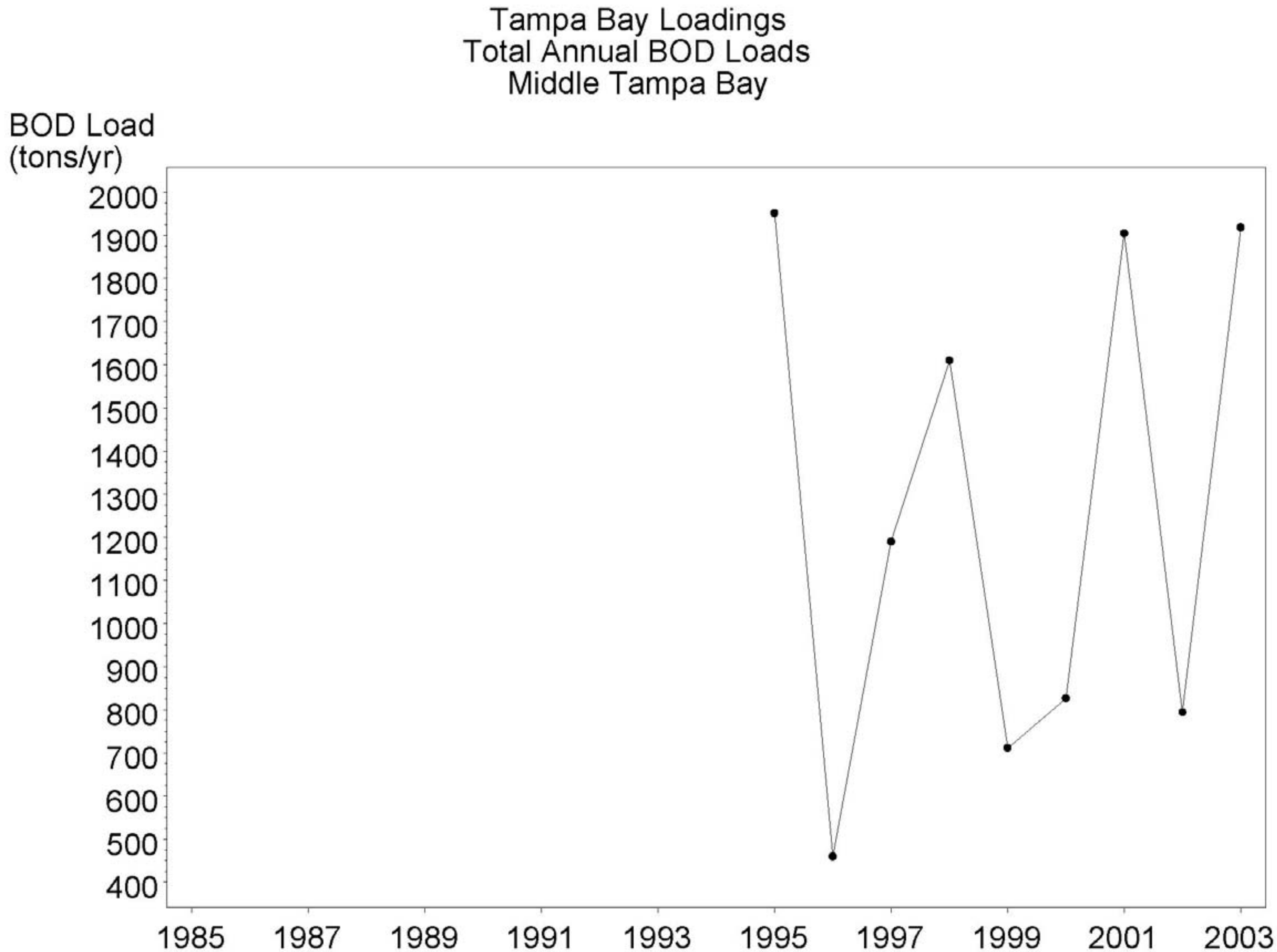
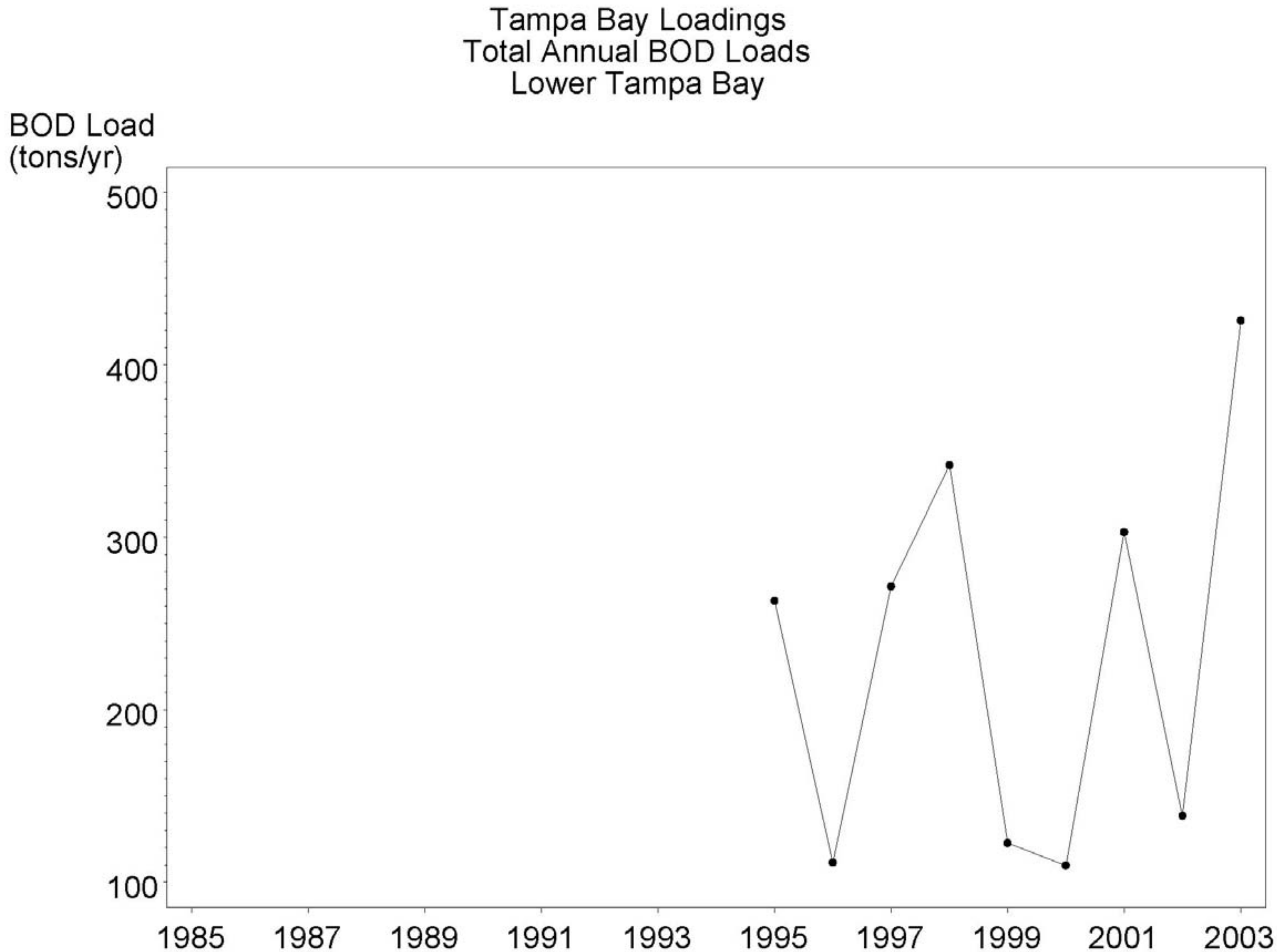
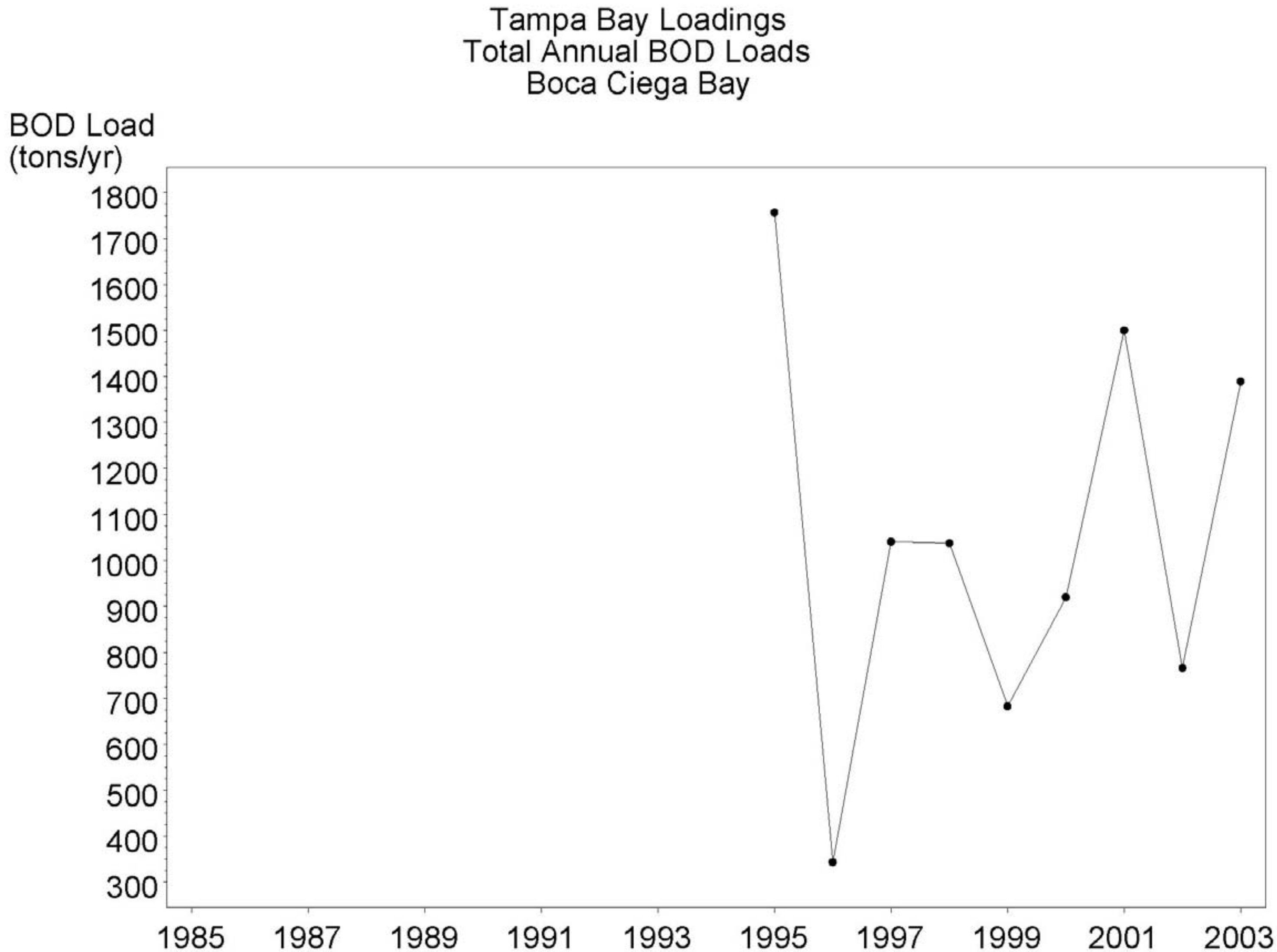
1993
1995
1997
1999
2001
2003


Tampa Bay Loadings
Total Annual BOD Loads
Hillsborough Bay
BOD Load
(tons/yr)
6000
5000
4000
3000
2000
1000
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003

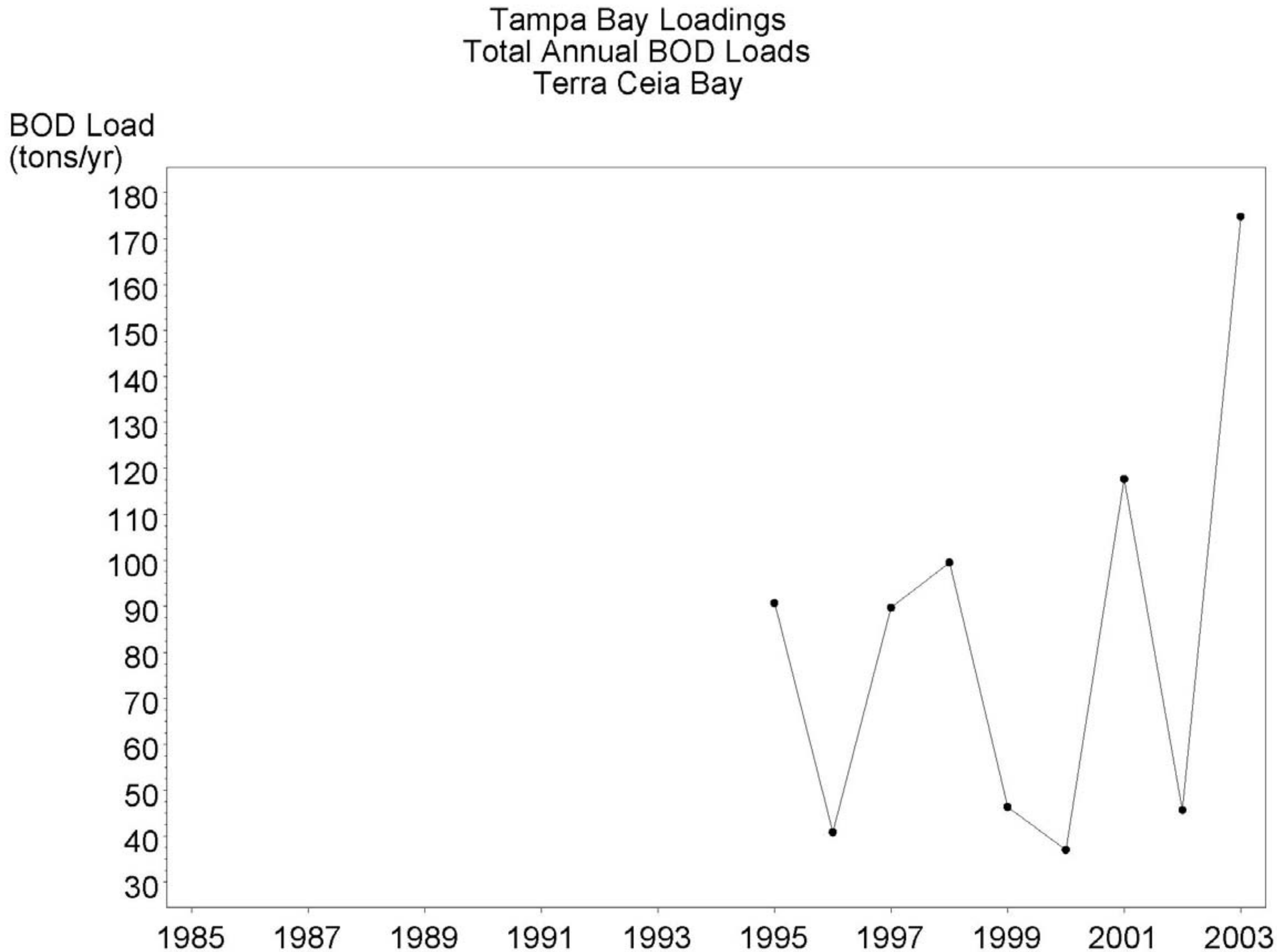

Tampa Bay Loadings
Total Annual BOD Loads
Middle Tampa Bay
BOD Load
(tons/yr)
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003



Tampa Bay Loadings
Total Annual BOD Loads
Lower Tampa Bay
BOD Load
(tons/yr)
500
400
300
200
100
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003



Tampa Bay Loadings
Total Annual BOD Loads
Boca Ciega Bay
BOD Load
(tons/yr)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003


Tampa Bay Loadings
Total Annual BOD Loads
Terra Ceia Bay
BOD Load
(tons/yr)
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
1985
1987
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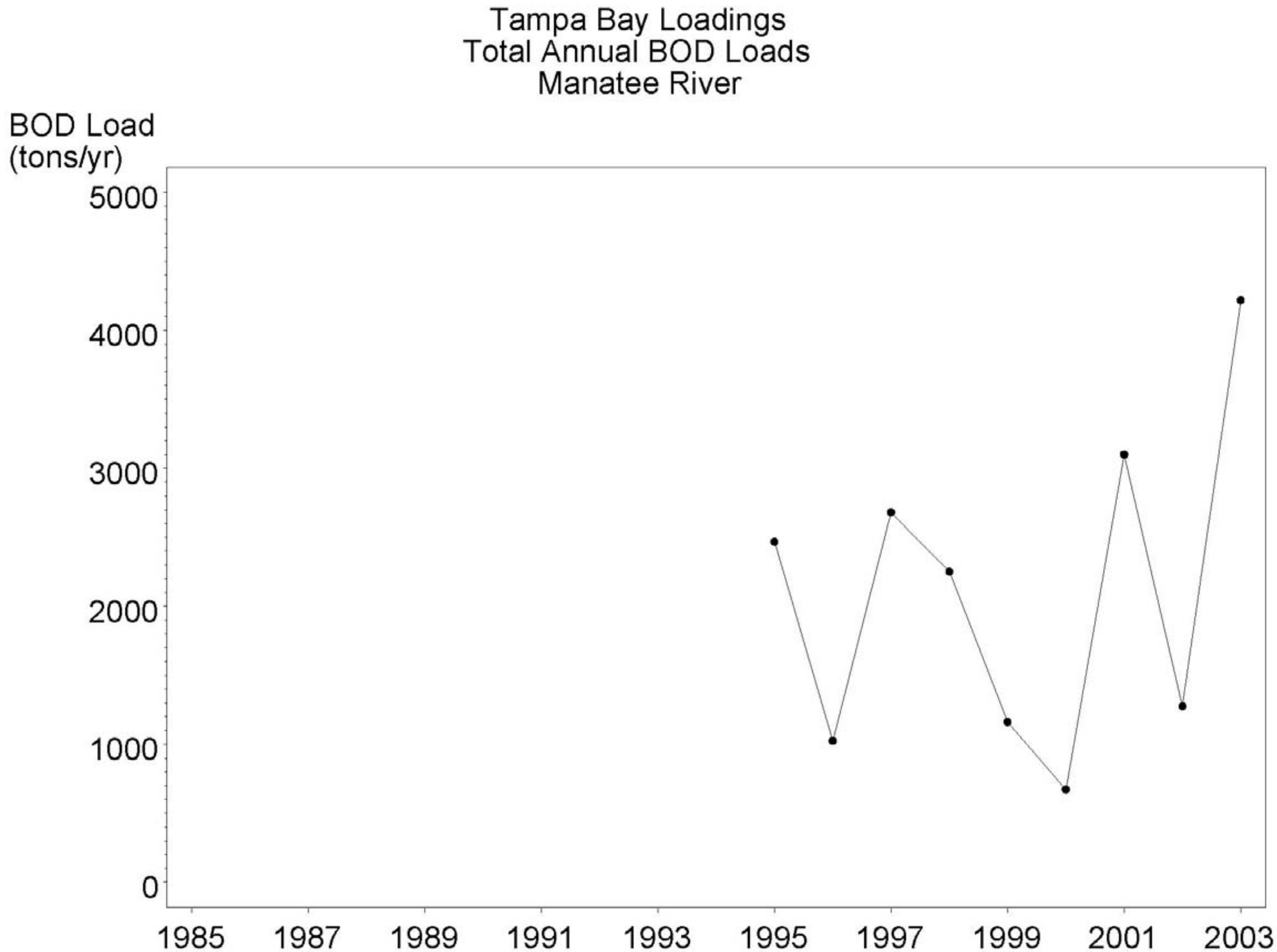
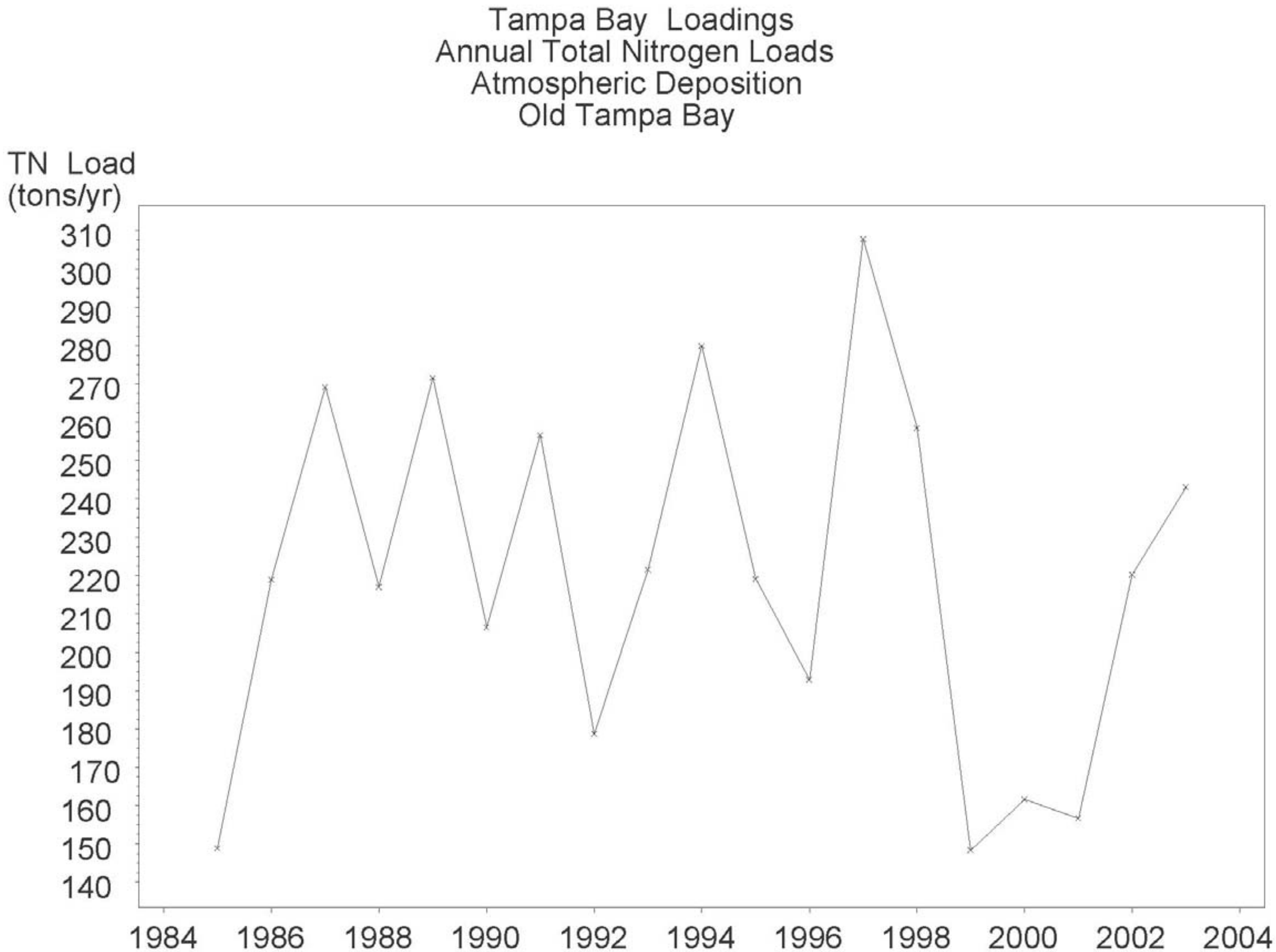
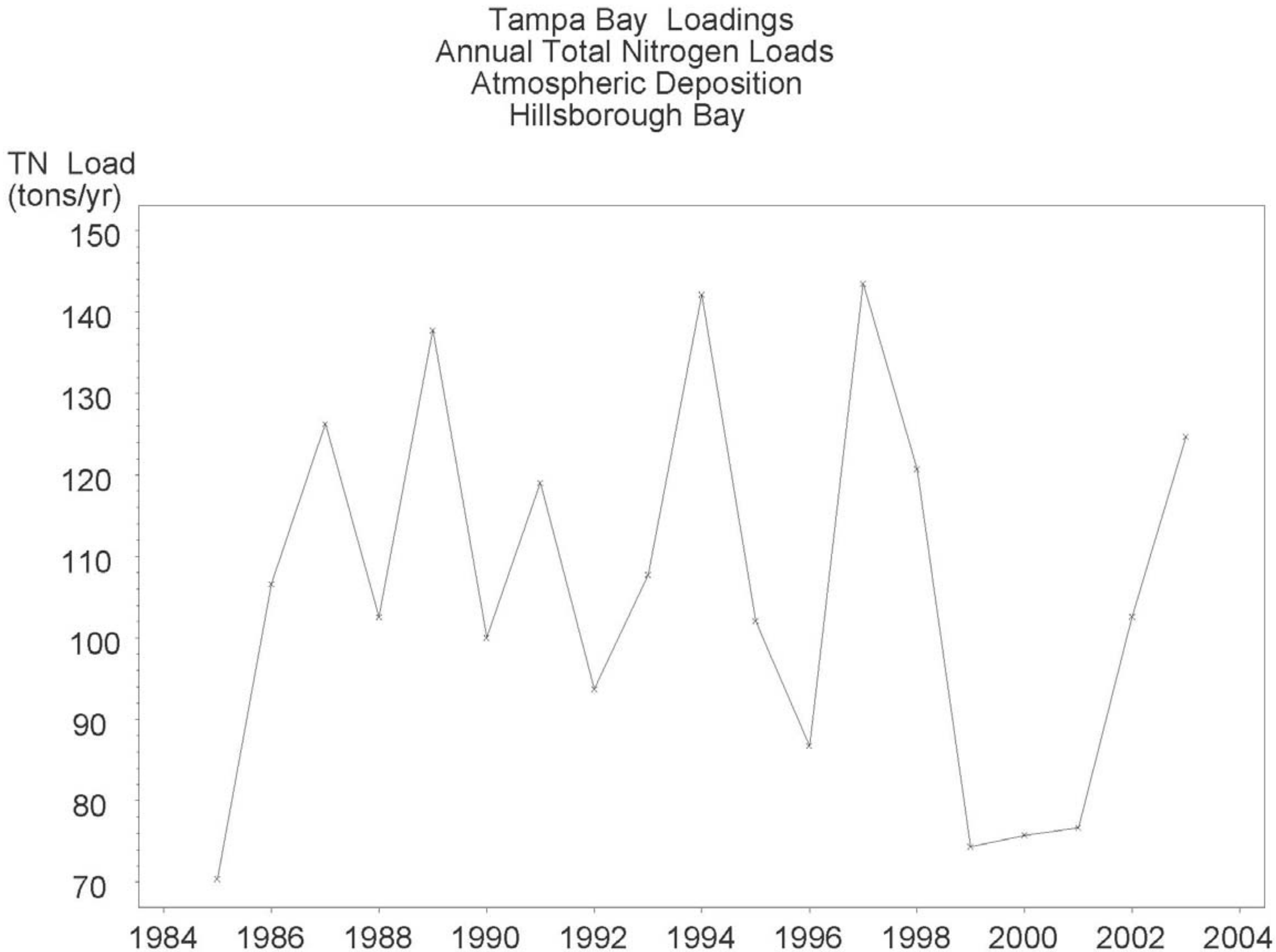
1991
1993
1995
1997
1999
2001
2003

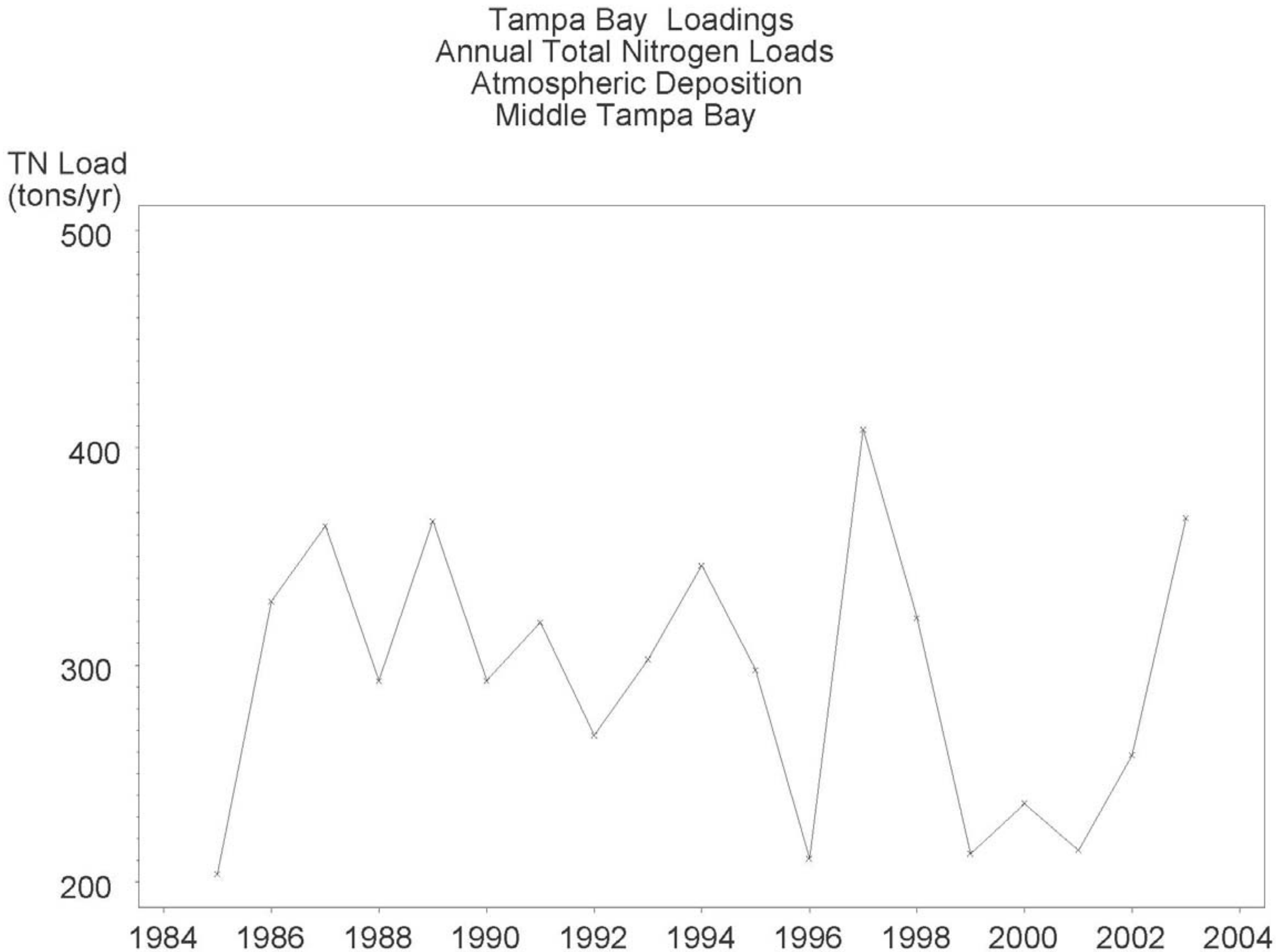

Tampa Bay Loadings
Total Annual BOD Loads
Manatee River
BOD Load
(tons/yr)
5000
4000
3000
2000
1000
0
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003

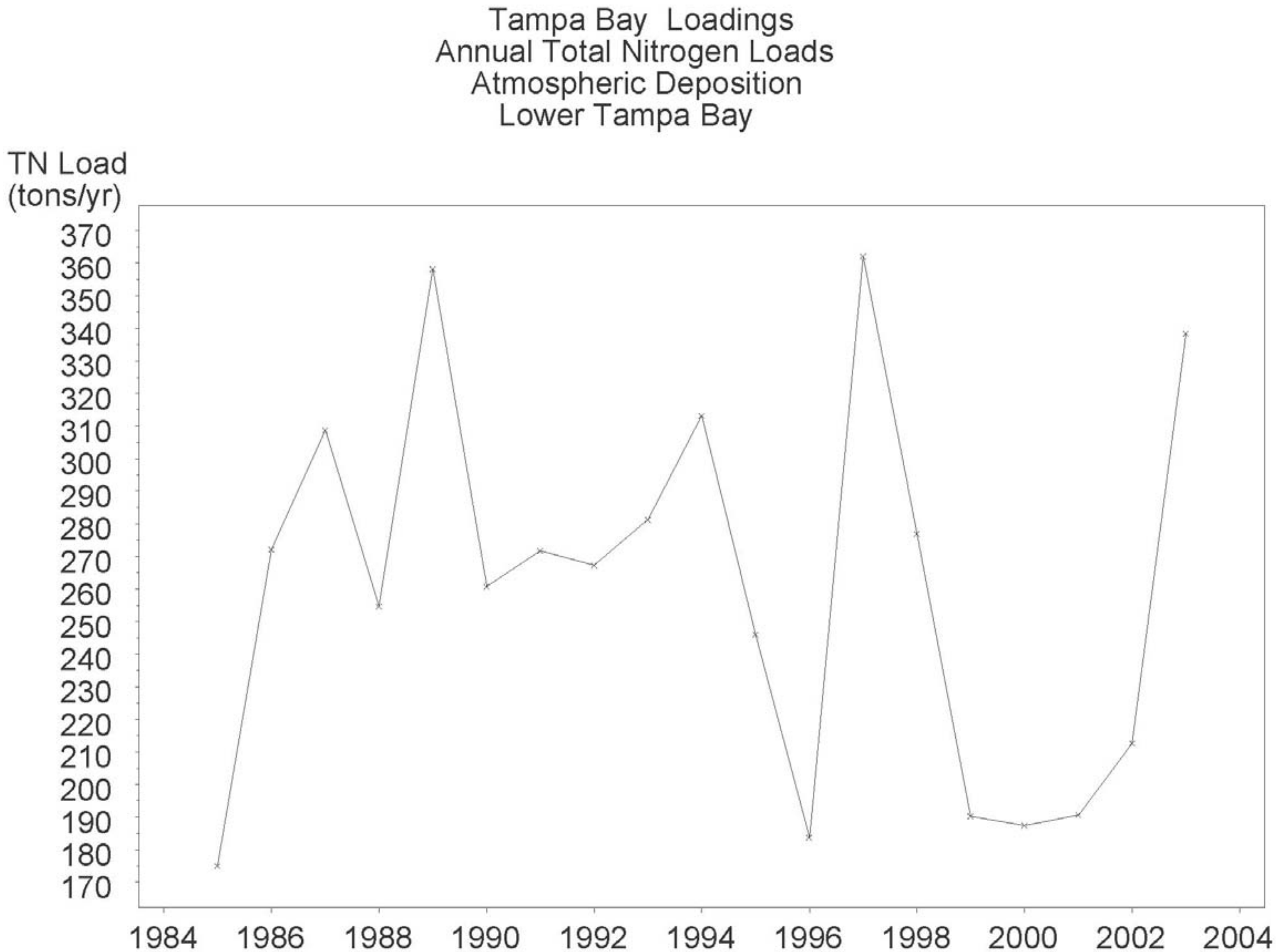
APPENDIX F

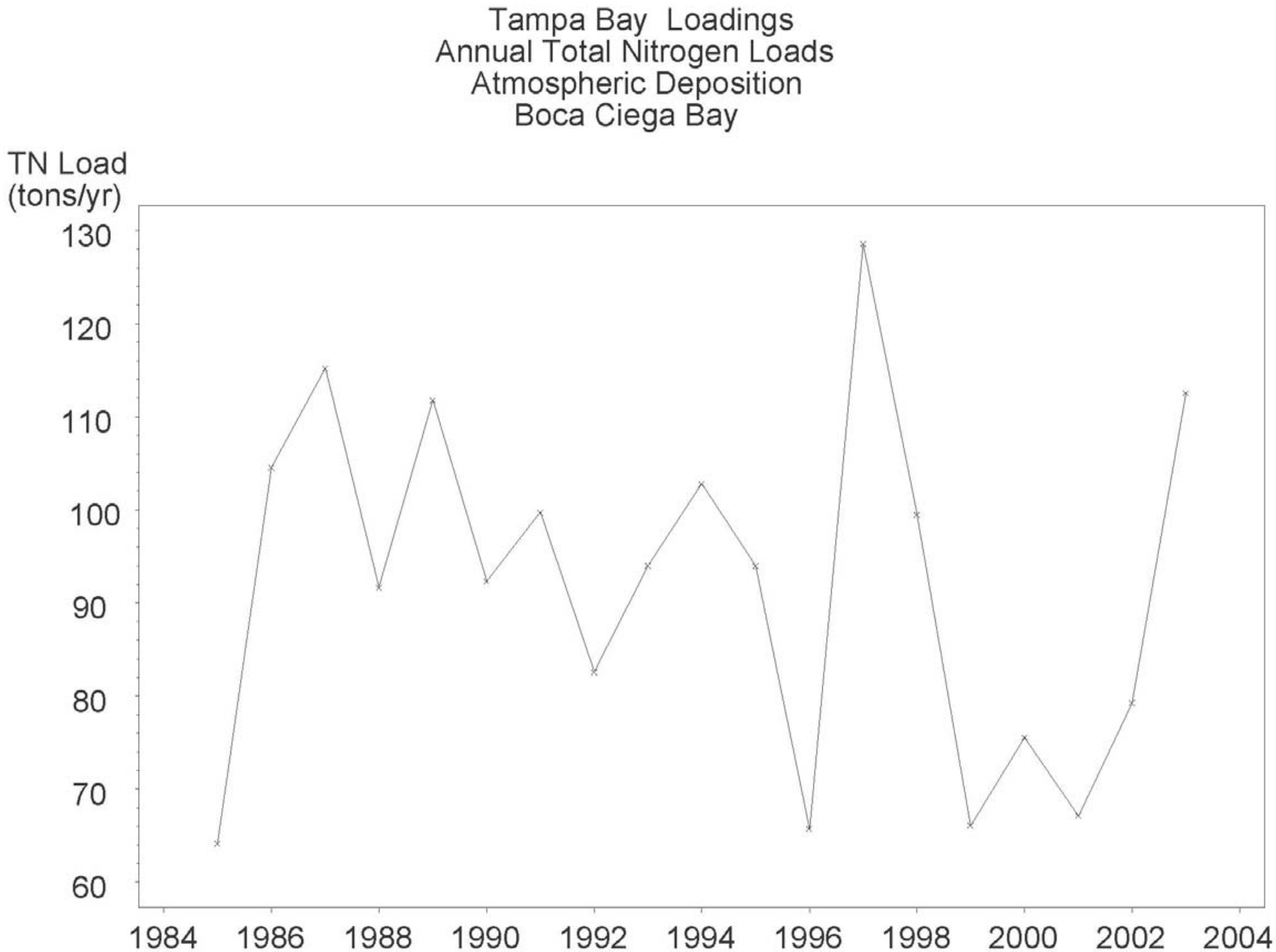
Annual Loadings of TN, TP, TSS, and BOD
to Each Bay Segment by Source, 1985-2003

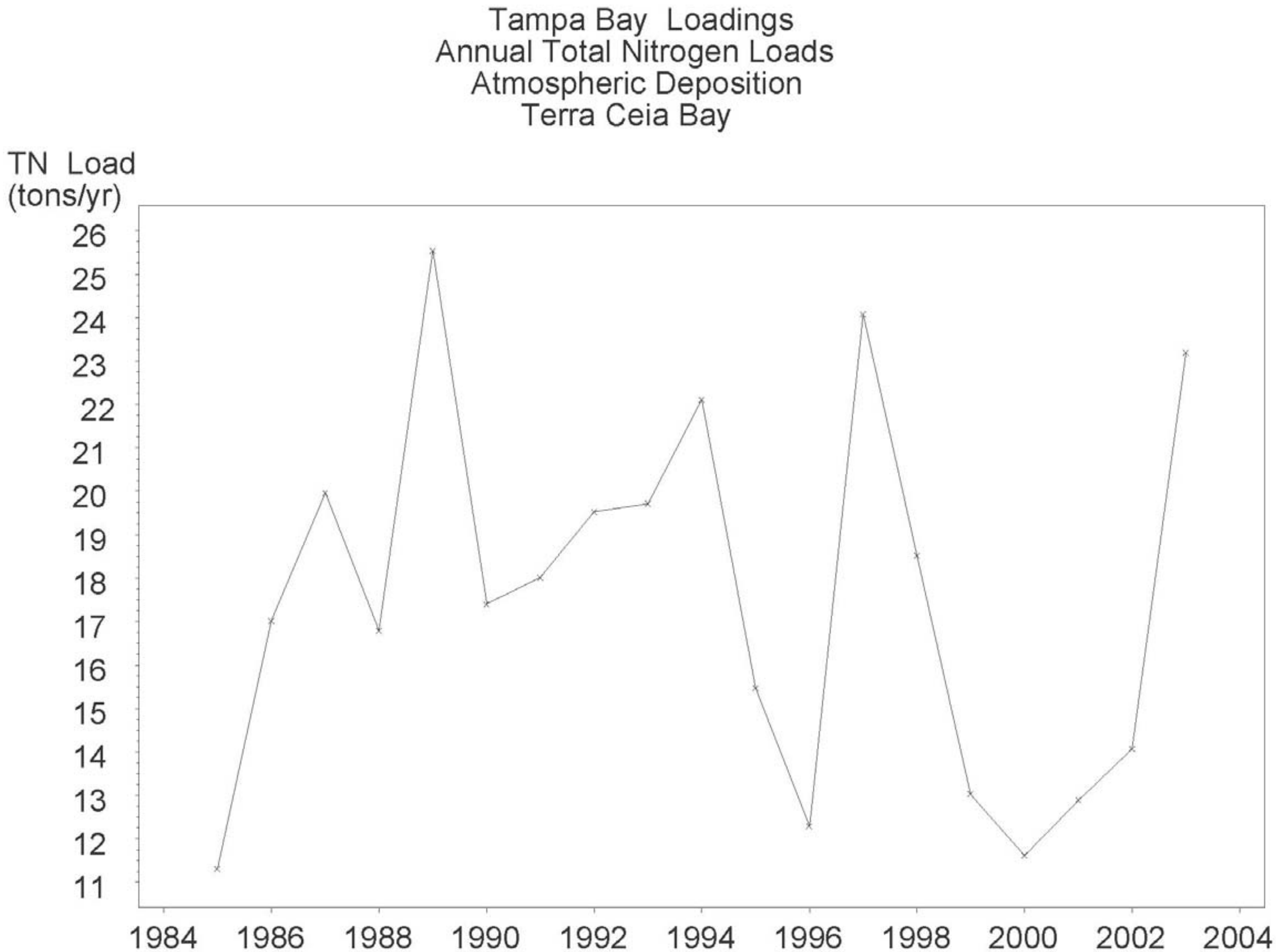

Tampa Bay Loadings
Annual Total Nitrogen Loads
Atmospheric Deposition
Old Tampa Bay
TN Load
(tons/yr)
310
300
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual Total Nitrogen Loads
Atmospheric Deposition
Hillsborough Bay
TN Load
(tons/yr)
150
140
130
120
110
100
90
80
70
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

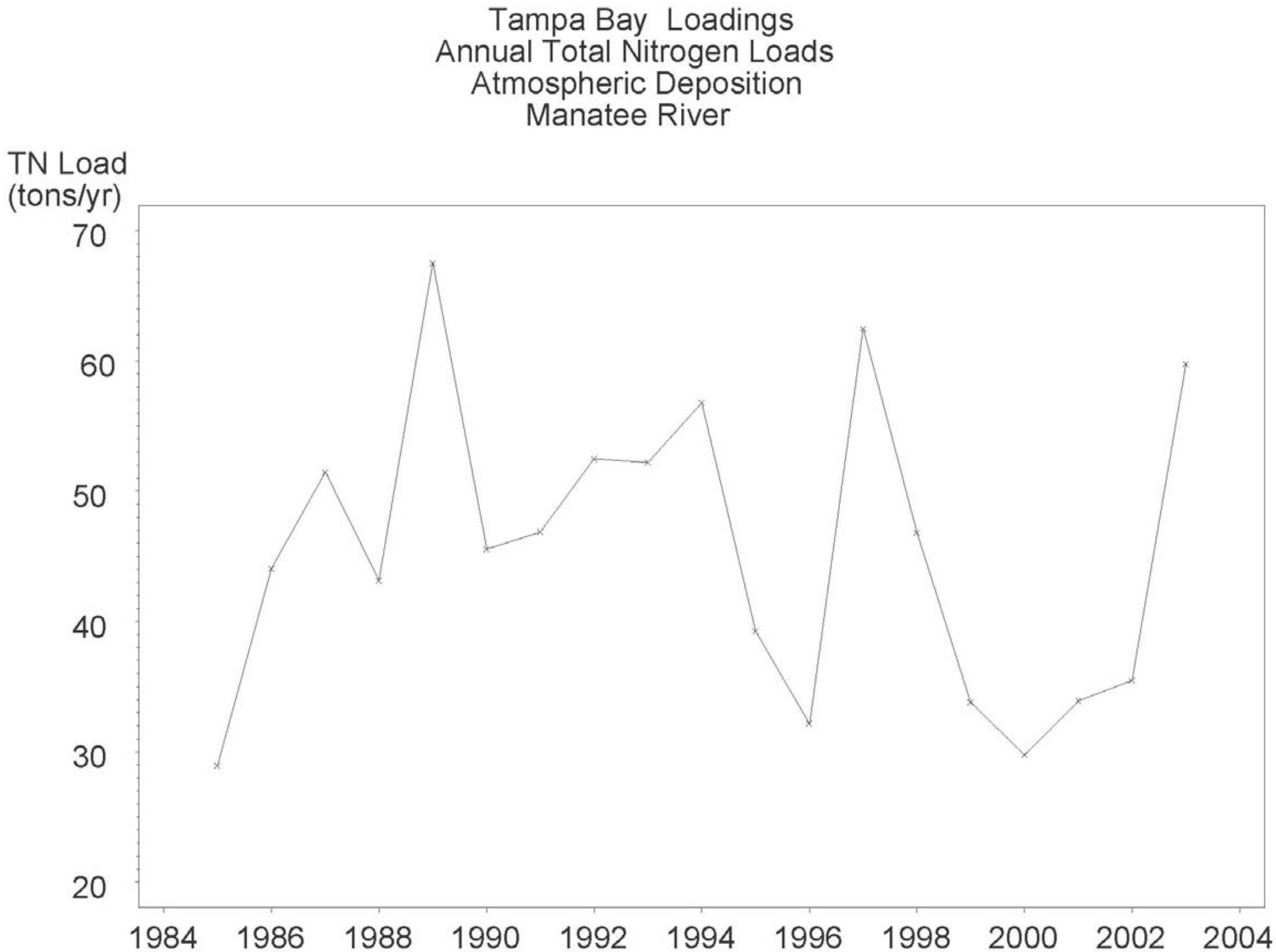

Tampa Bay Loadings
Annual Total Nitrogen Loads
Atmospheric Deposition
Middle Tampa Bay
TN Load
(tons/yr)
500
400
300
200
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

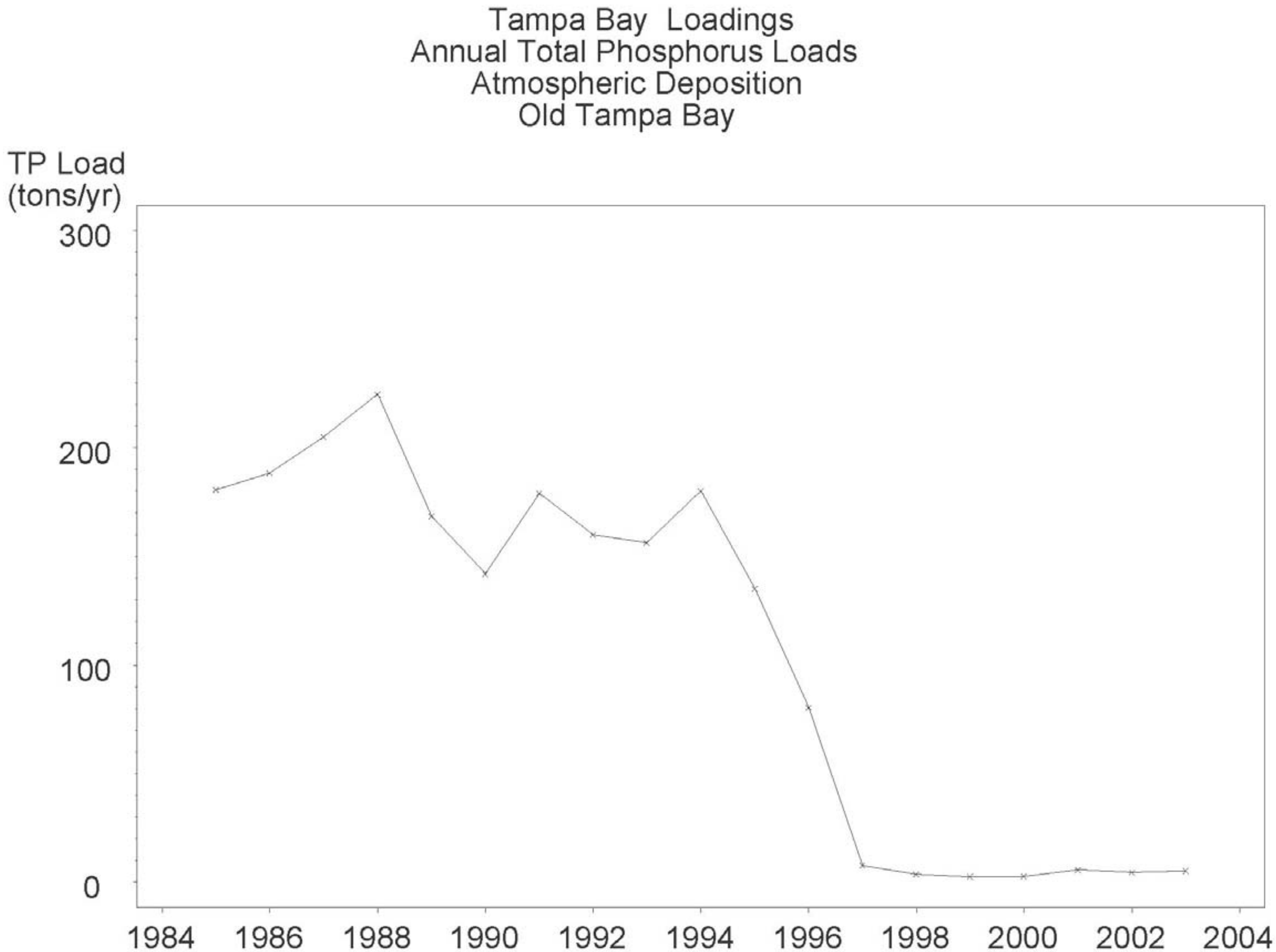

Tampa Bay Loadings
Annual Total Nitrogen Loads
Atmospheric Deposition
Lower Tampa Bay
TN Load
(tons/yr)
370
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
190
180
170
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

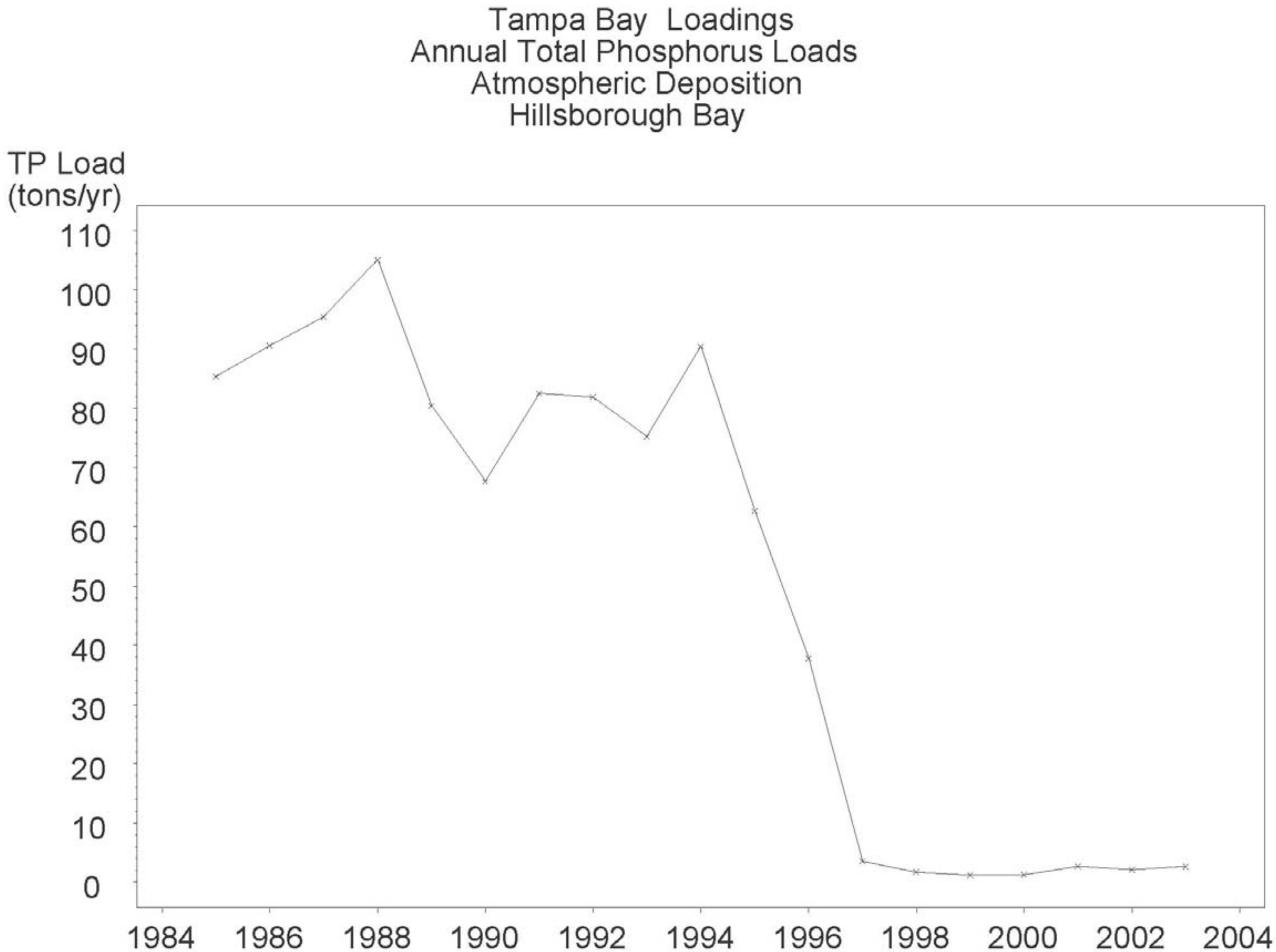

Tampa Bay Loadings
Annual Total Nitrogen Loads
Atmospheric Deposition
Boca Ciega Bay
TN Load
(tons/yr)
130
120
110
100
90
80
70
60
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

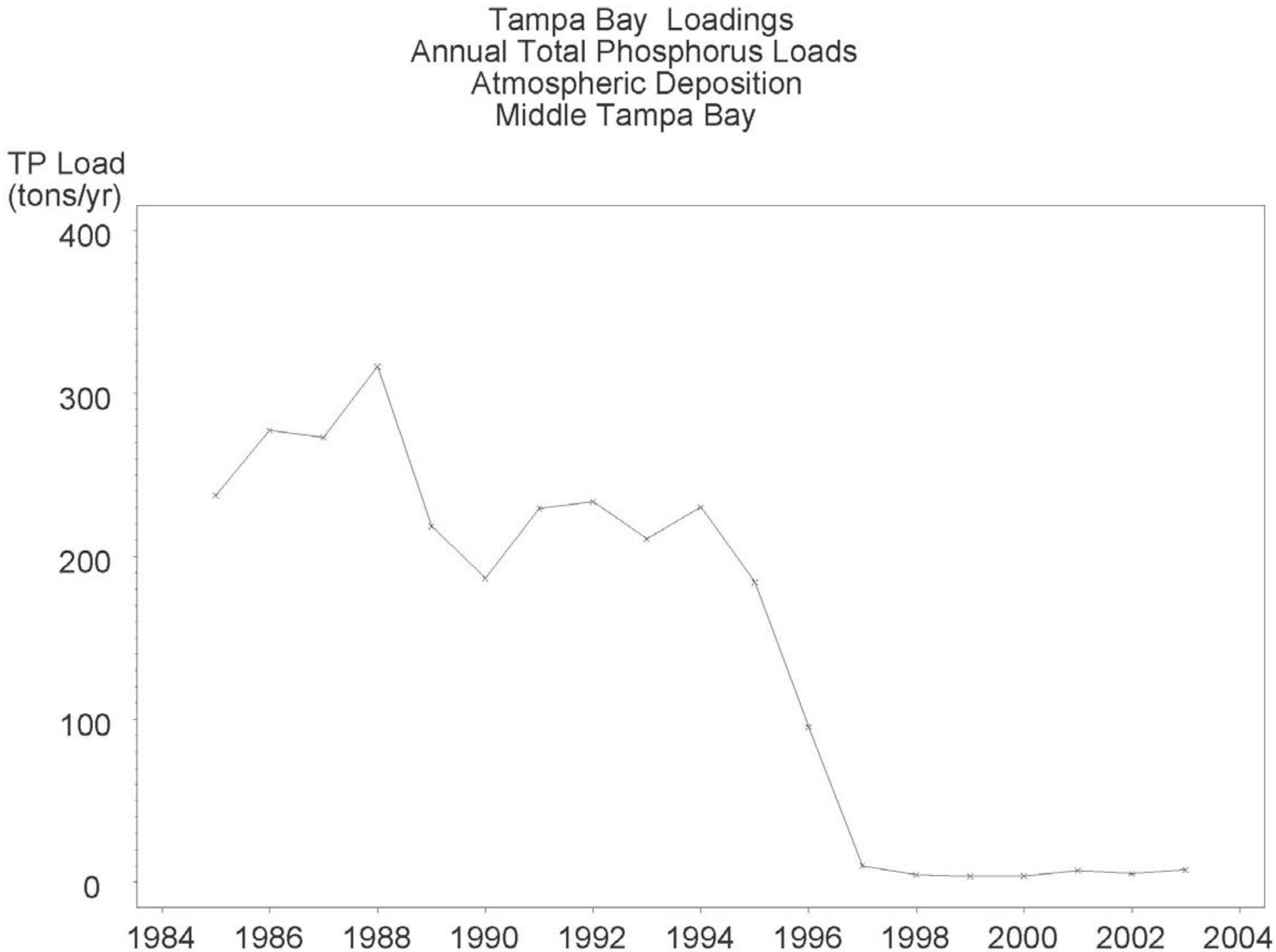


Tampa Bay Loadings
Annual Total Nitrogen Loads
Atmospheric Deposition
Terra Ceia Bay
TN Load
(tons/yr)
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

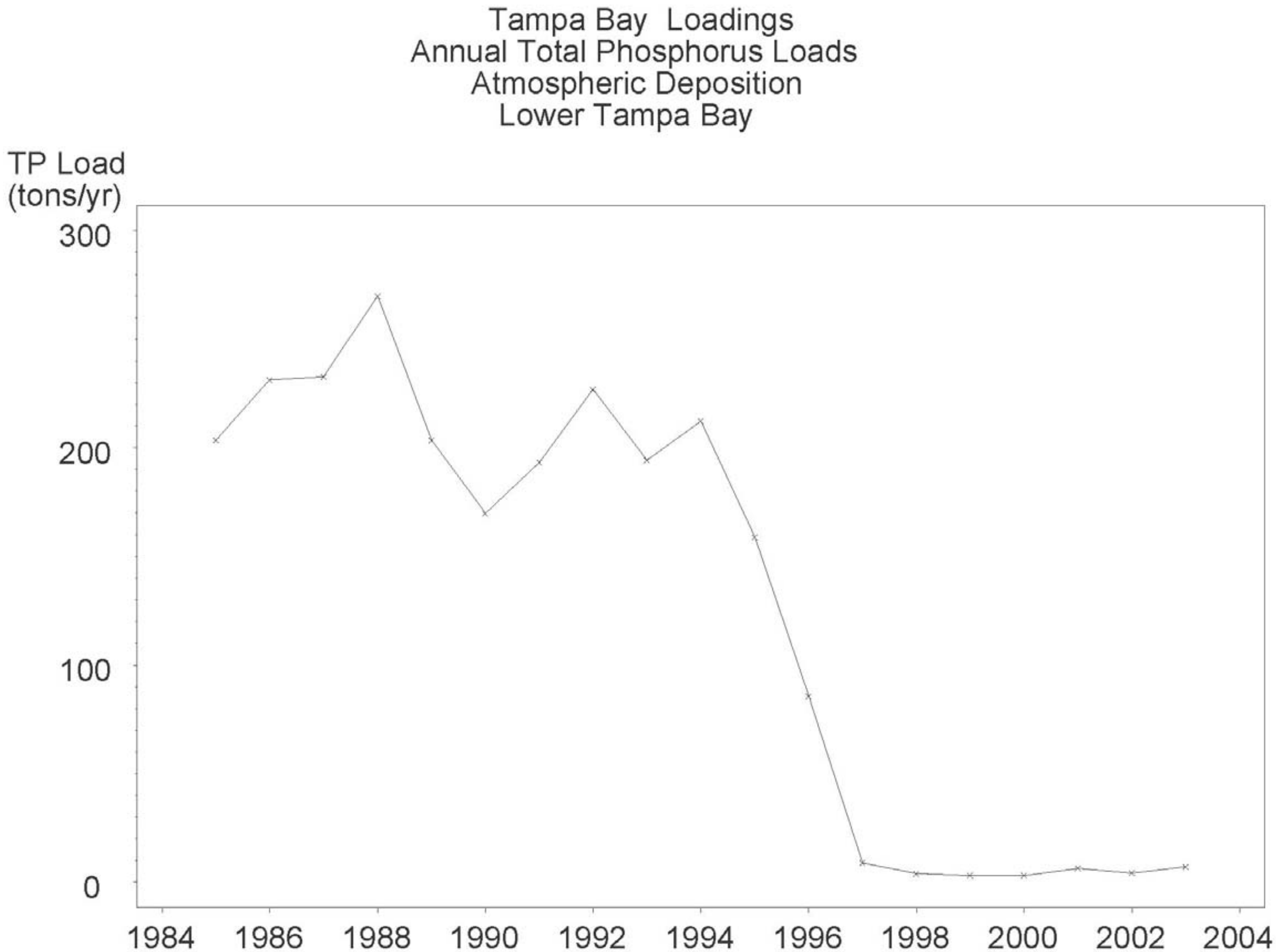

Tampa Bay Loadings
Annual Total Nitrogen Loads
Atmospheric Deposition
Manatee River
TN Load
(tons/yr)
70
60
50
40
30
20
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

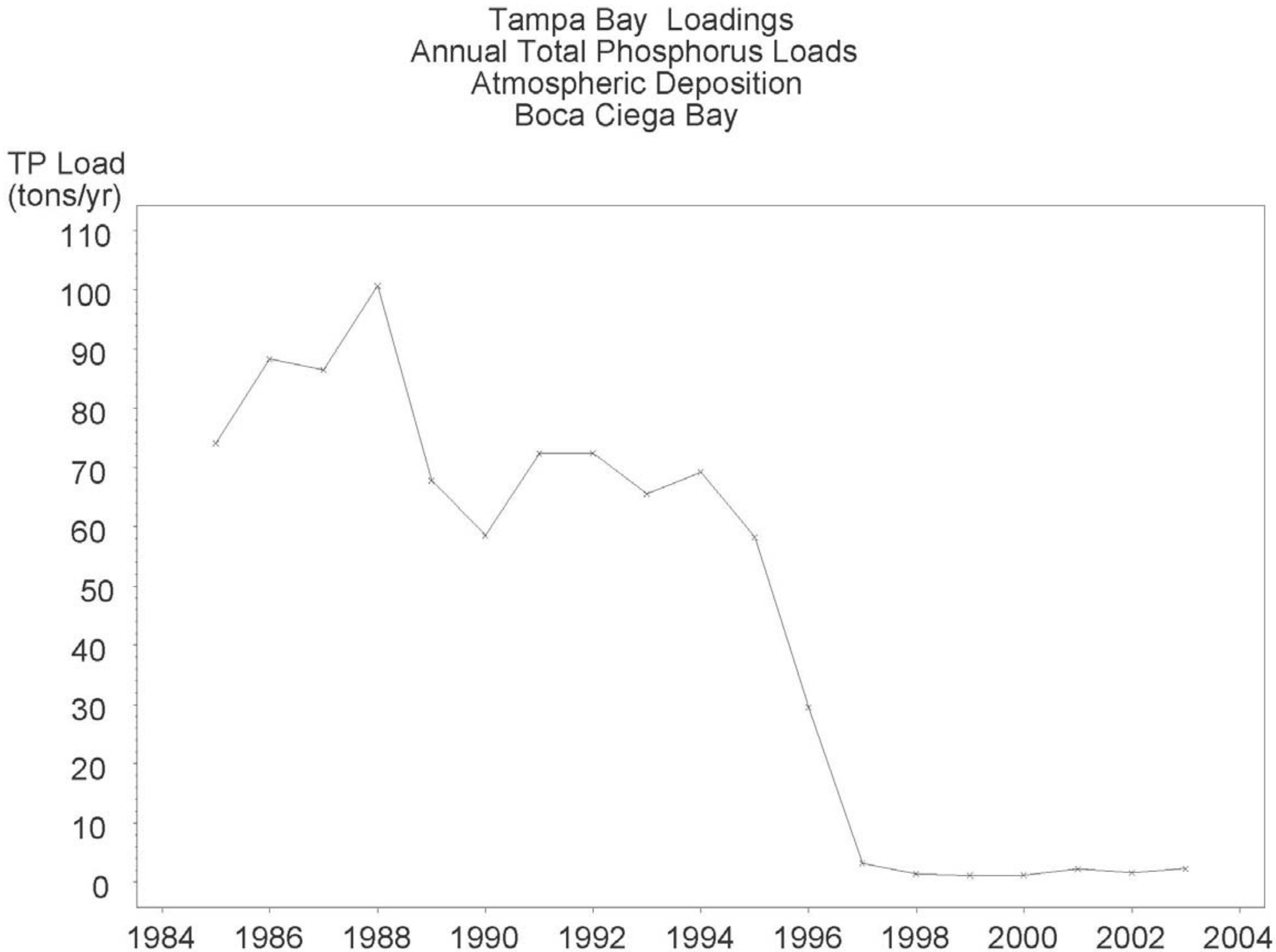

Tampa Bay Loadings
Annual Total Phosphorus Loads
Atmospheric Deposition
Old Tampa Bay
TP Load
(tons/yr)
300
200
100
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

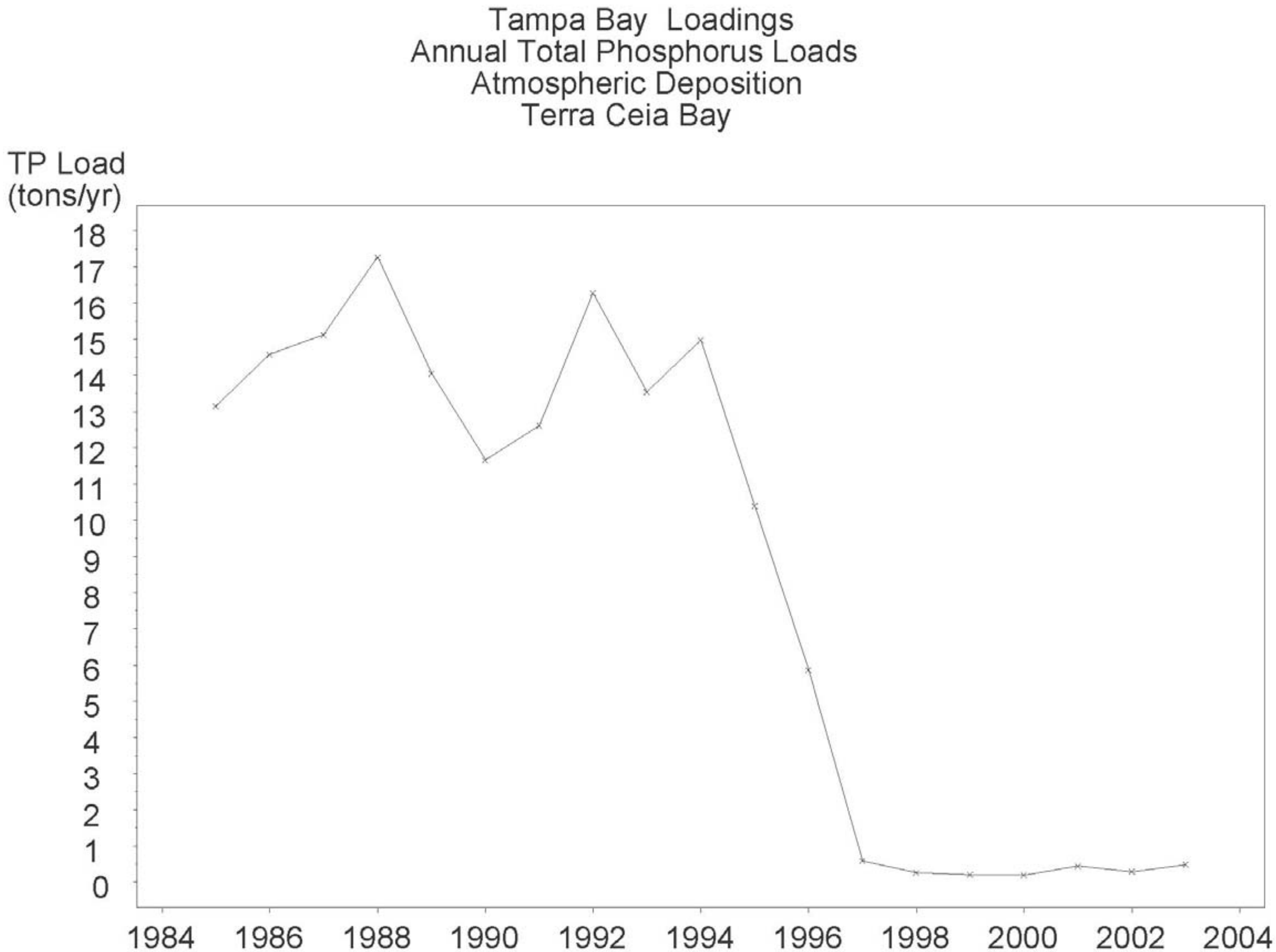

Tampa Bay Loadings
Annual Total Phosphorus Loads
Atmospheric Deposition
Hillsborough Bay
TP Load
(tons/yr)
110
100
90
80
70
60
50
40
30
20
10
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

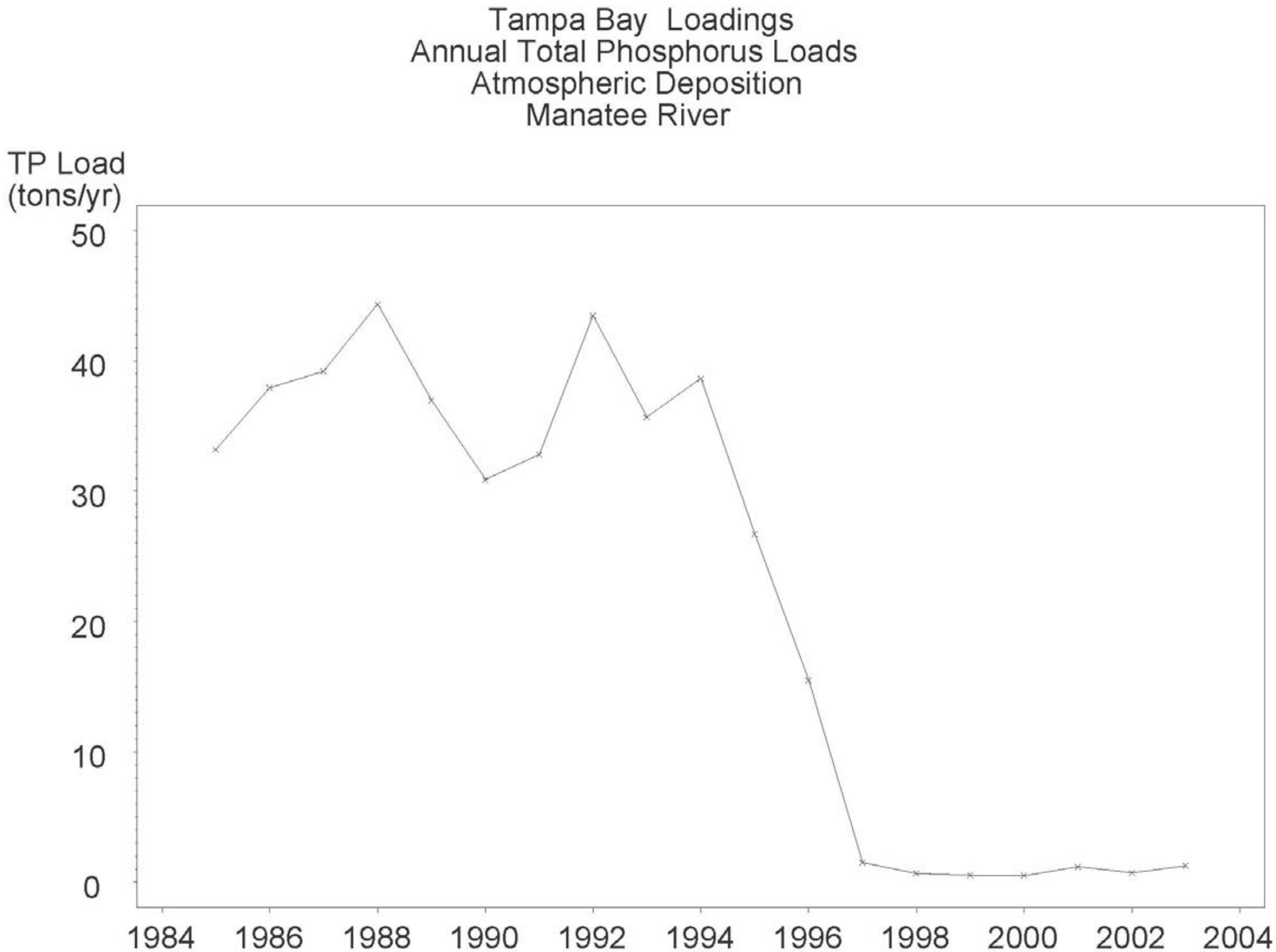


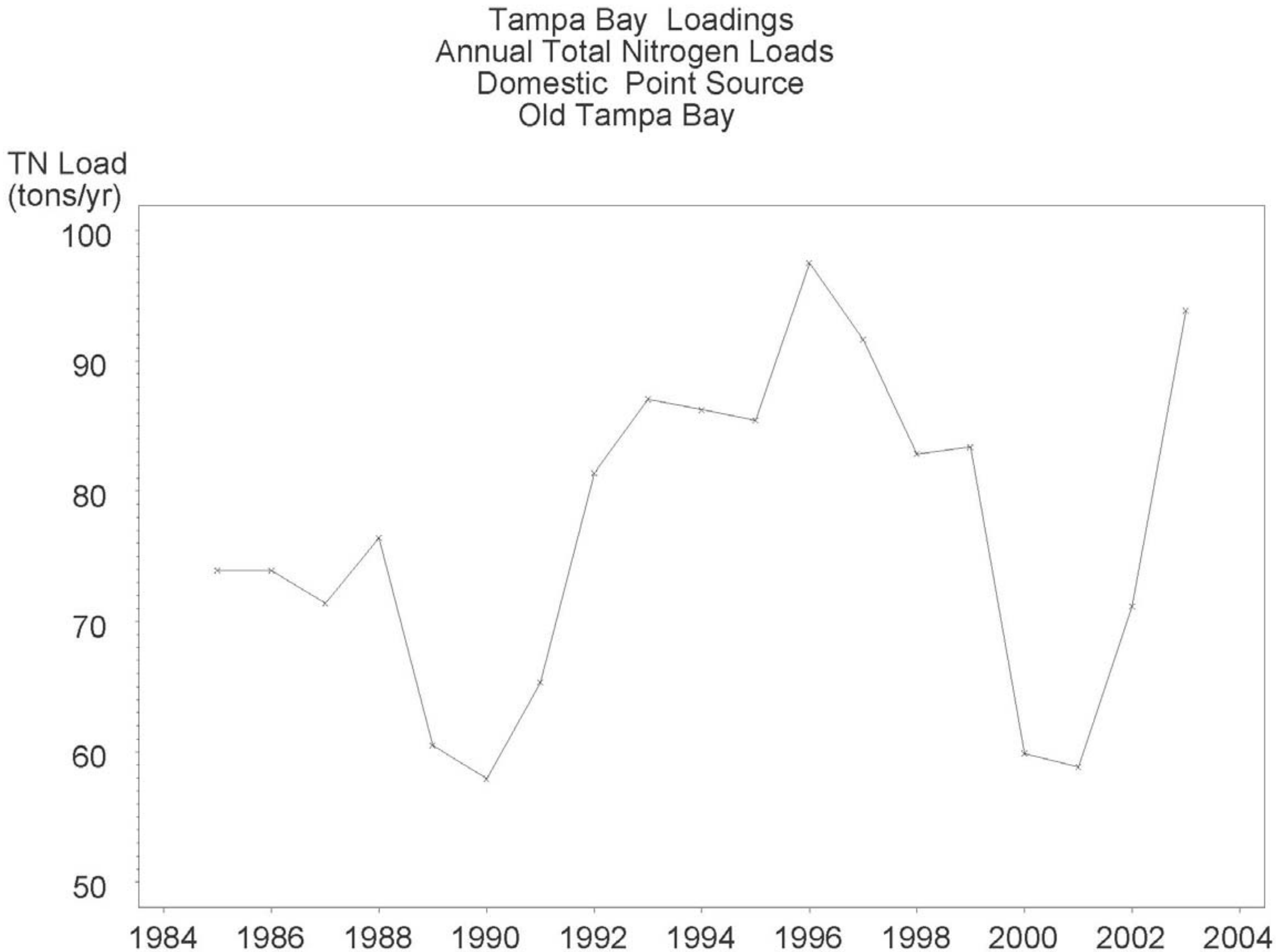
Tampa Bay Loadings
Annual Total Phosphorus Loads
Atmospheric Deposition
Middle Tampa Bay
TP Load
(tons/yr)
400
300
200
100
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

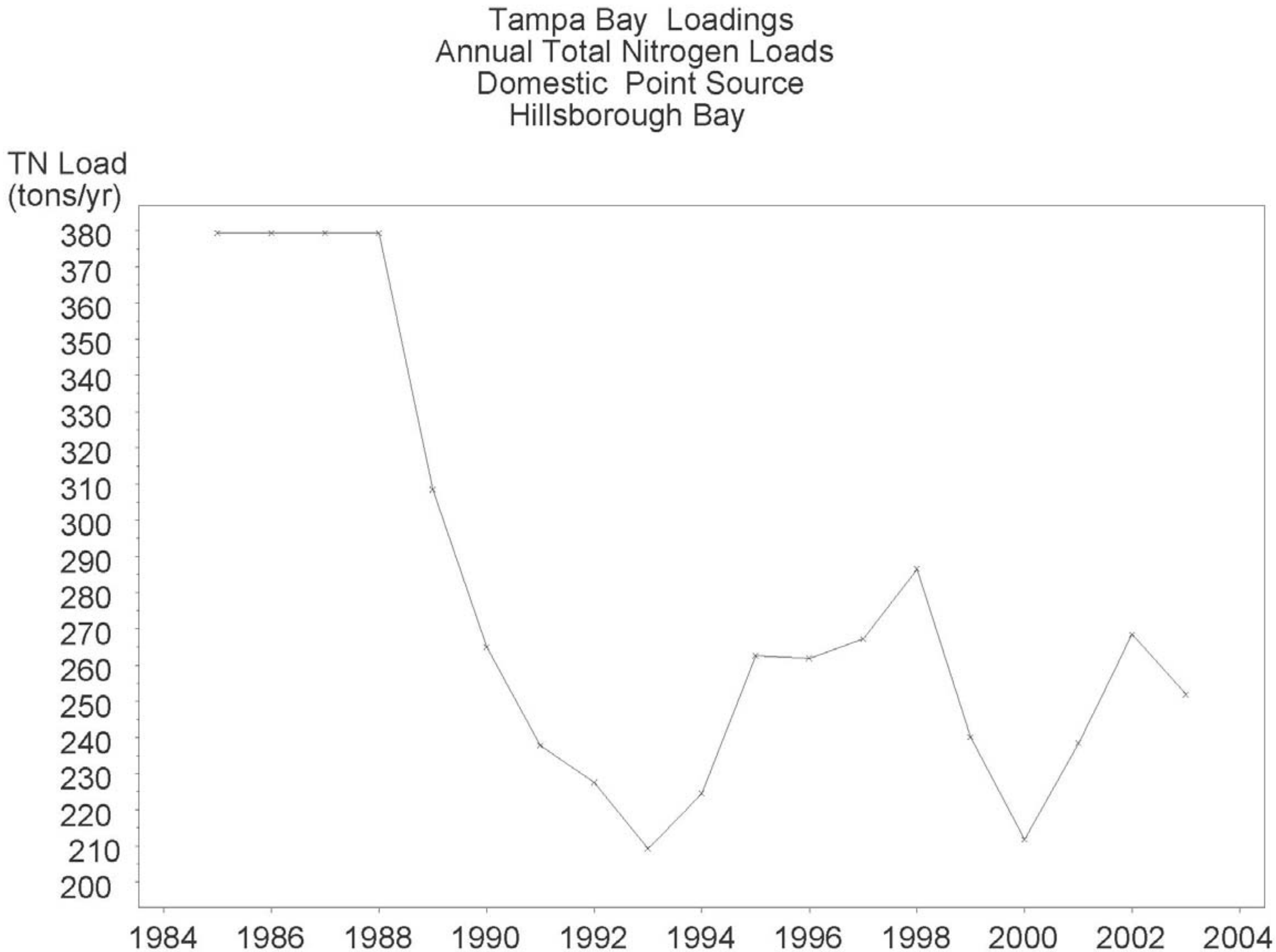

Tampa Bay Loadings
Annual Total Phosphorus Loads
Atmospheric Deposition
Lower Tampa Bay
TP Load
(tons/yr)
300
200
100
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual Total Phosphorus Loads
Atmospheric Deposition
Boca Ciega Bay
TP Load
(tons/yr)
110
100
90
80
70
60
50
40
30
20
10
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

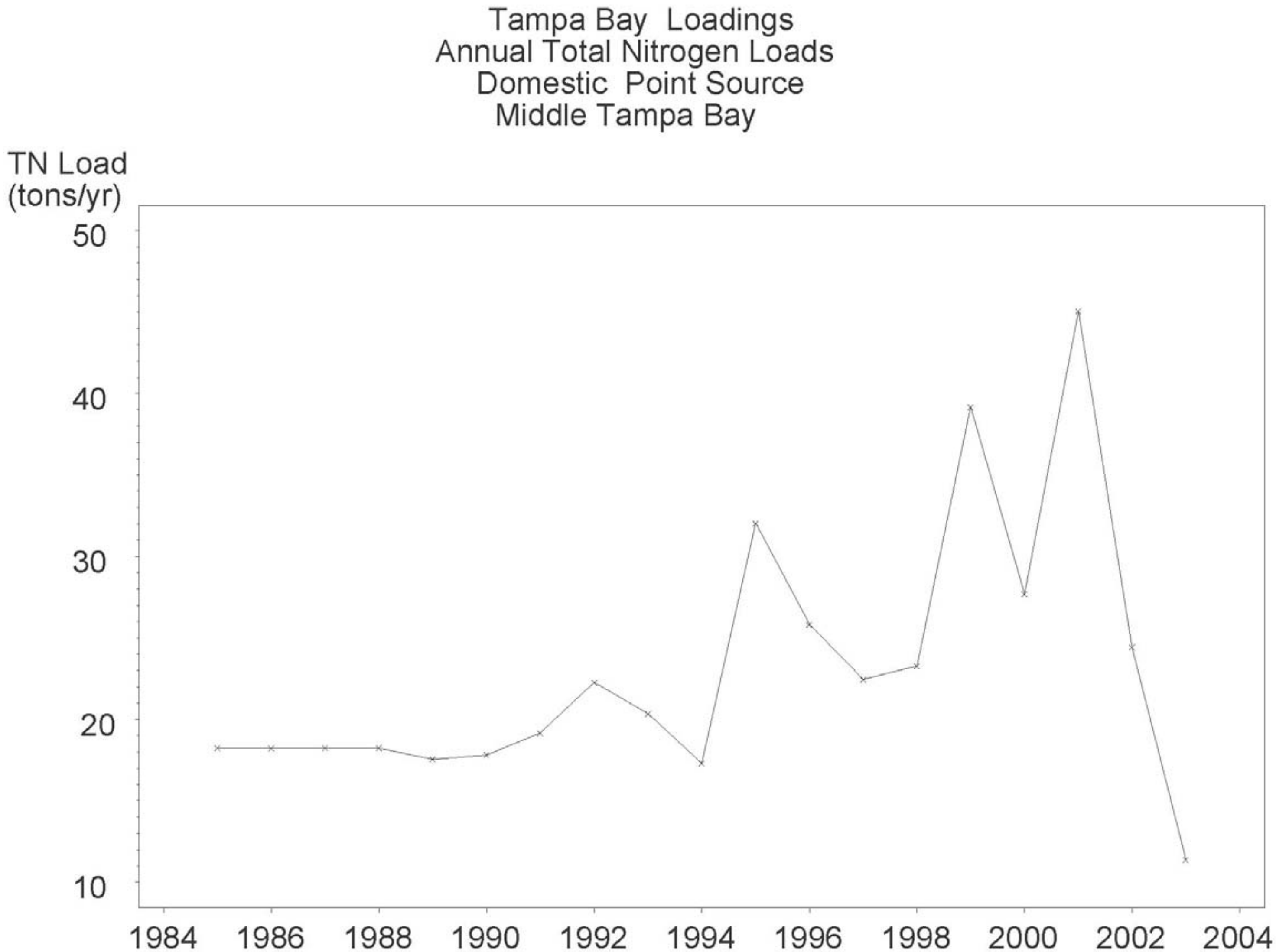

Tampa Bay Loadings
Annual Total Phosphorus Loads
Atmospheric Deposition
Terra Ceia Bay
TP Load
(tons/yr)
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

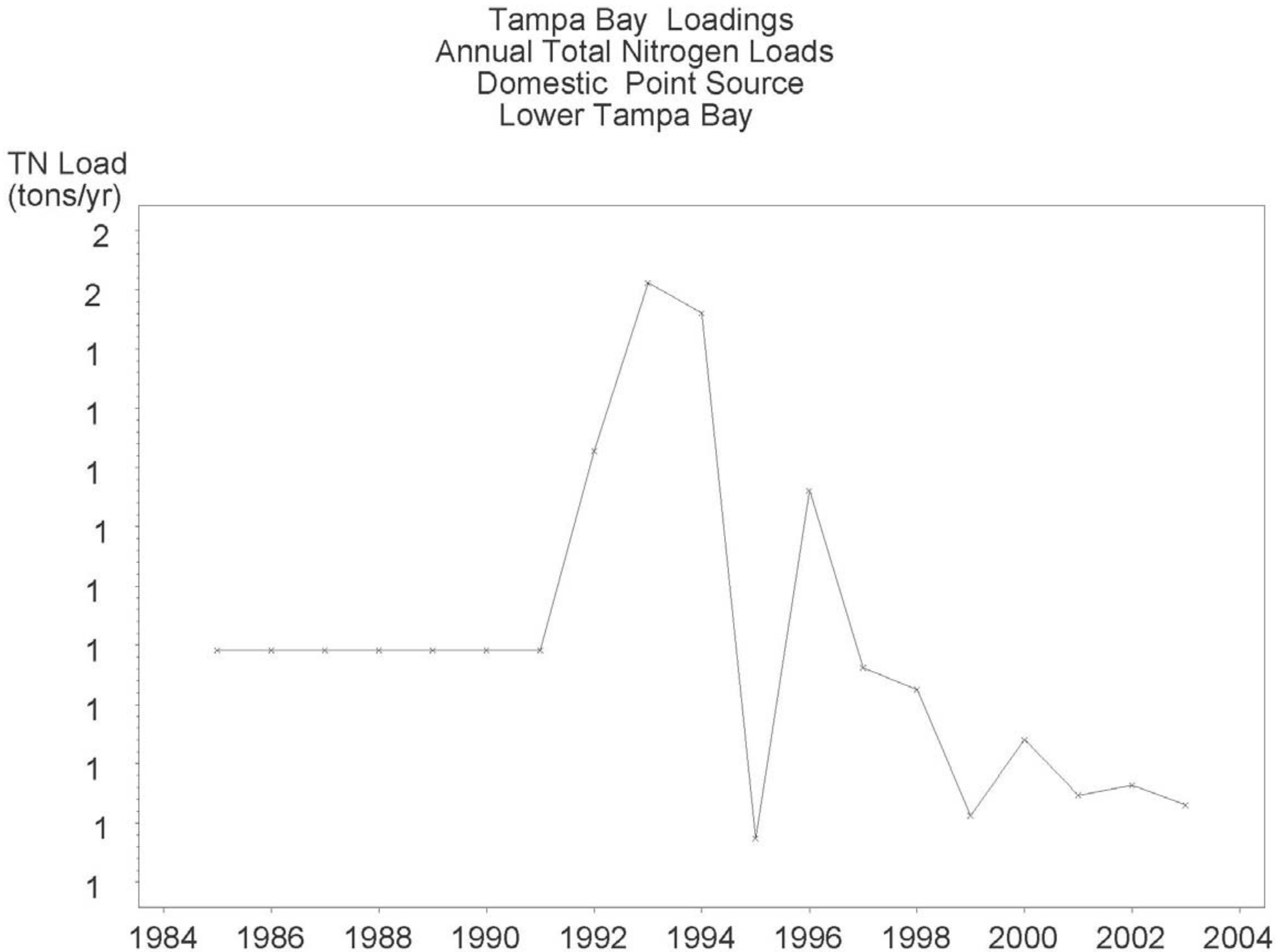

Tampa Bay Loadings
Annual Total Phosphorus Loads
Atmospheric Deposition
Manatee River
TP Load
(tons/yr)
50
40
30
20
10
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual Total Nitrogen Loads
Domestic Point Source
Old Tampa Bay
TN Load
(tons/yr)
100
90
80
70
60
50
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

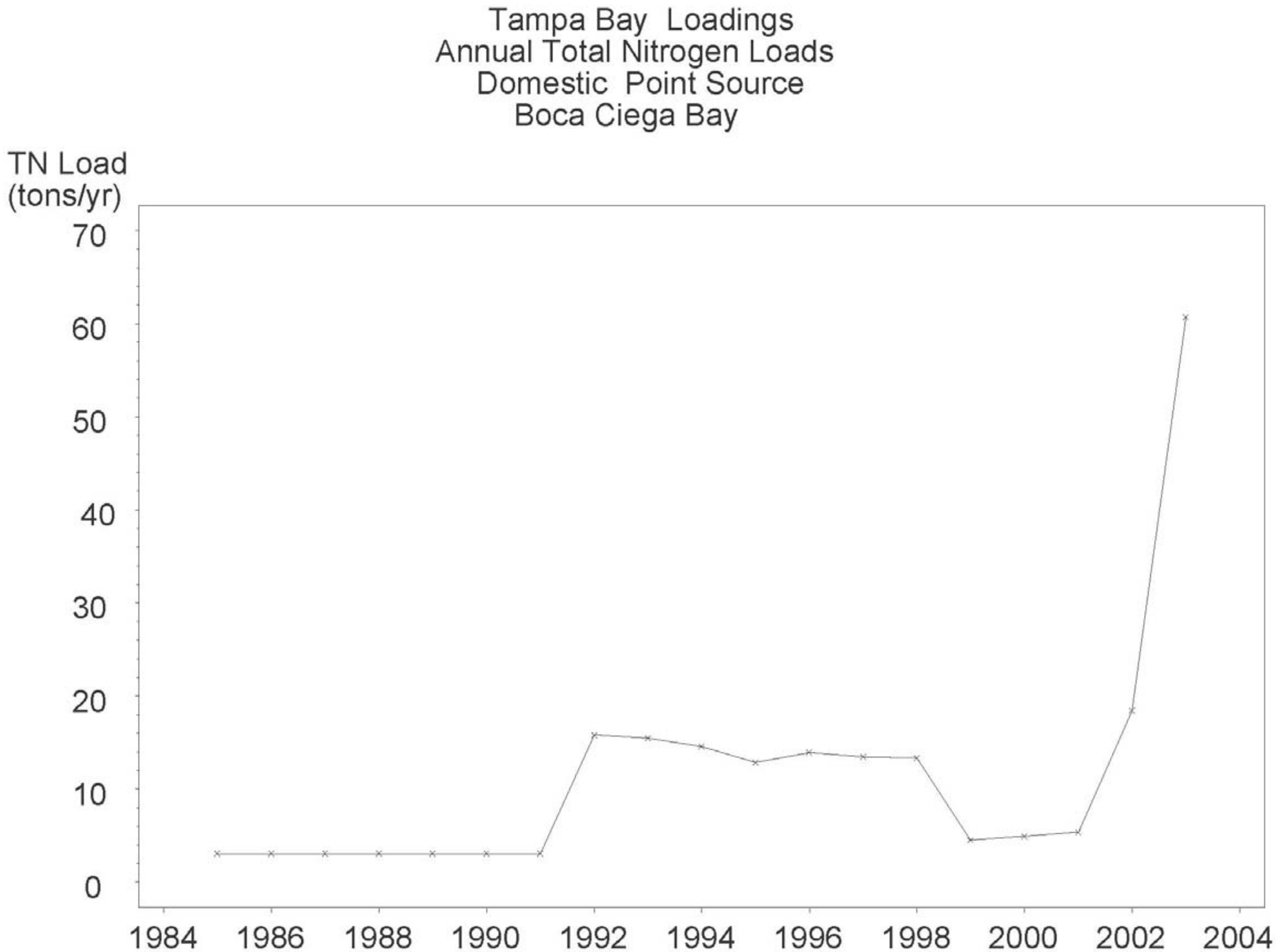


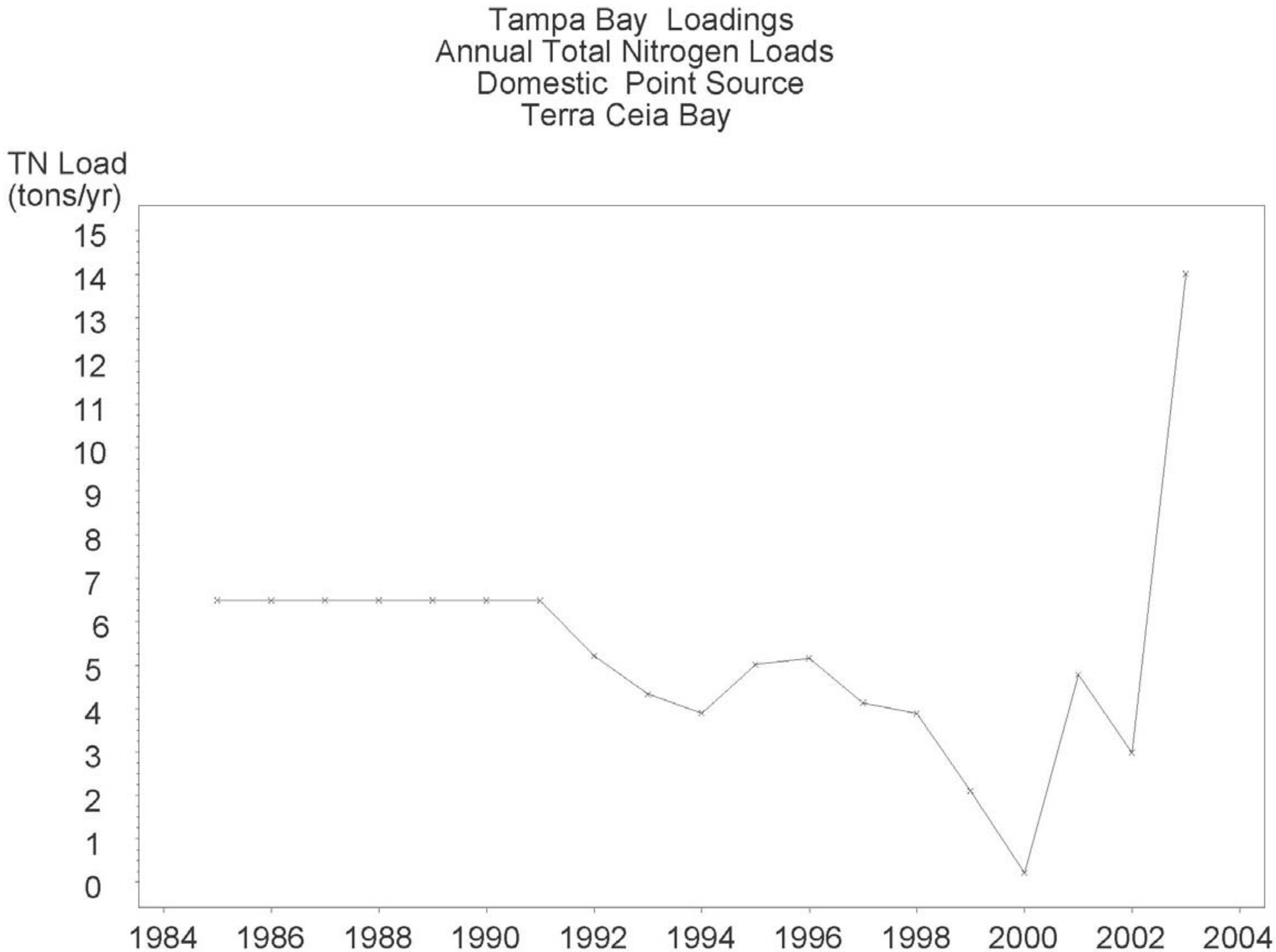
Tampa Bay Loadings
Annual Total Nitrogen Loads
Domestic Point Source
Hillsborough Bay
TN Load
(tons/yr)
380
370
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

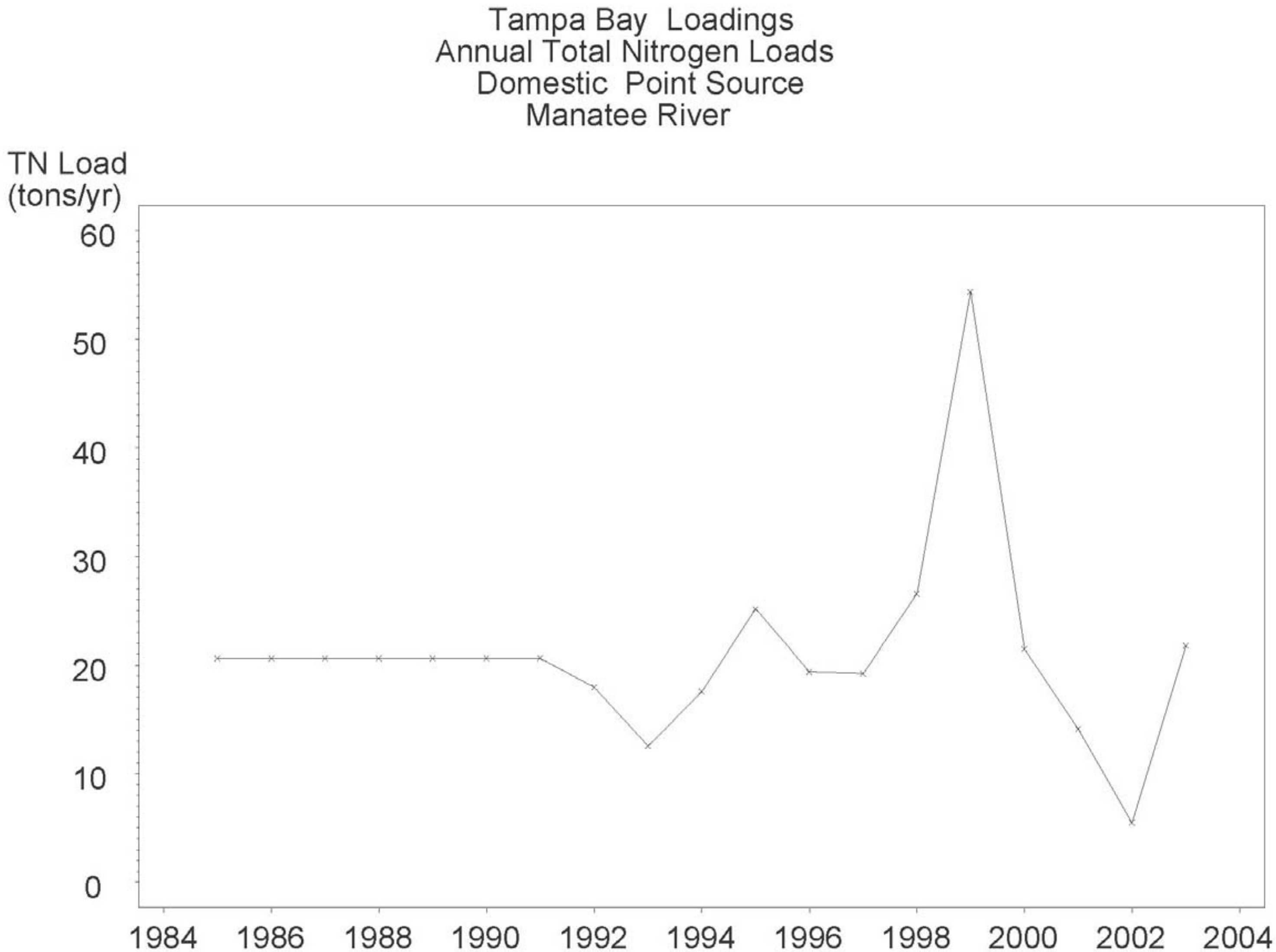

Tampa Bay Loadings
Annual Total Nitrogen Loads
Domestic Point Source
Middle Tampa Bay
TN Load
(tons/yr)
50
40
30
20
10
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

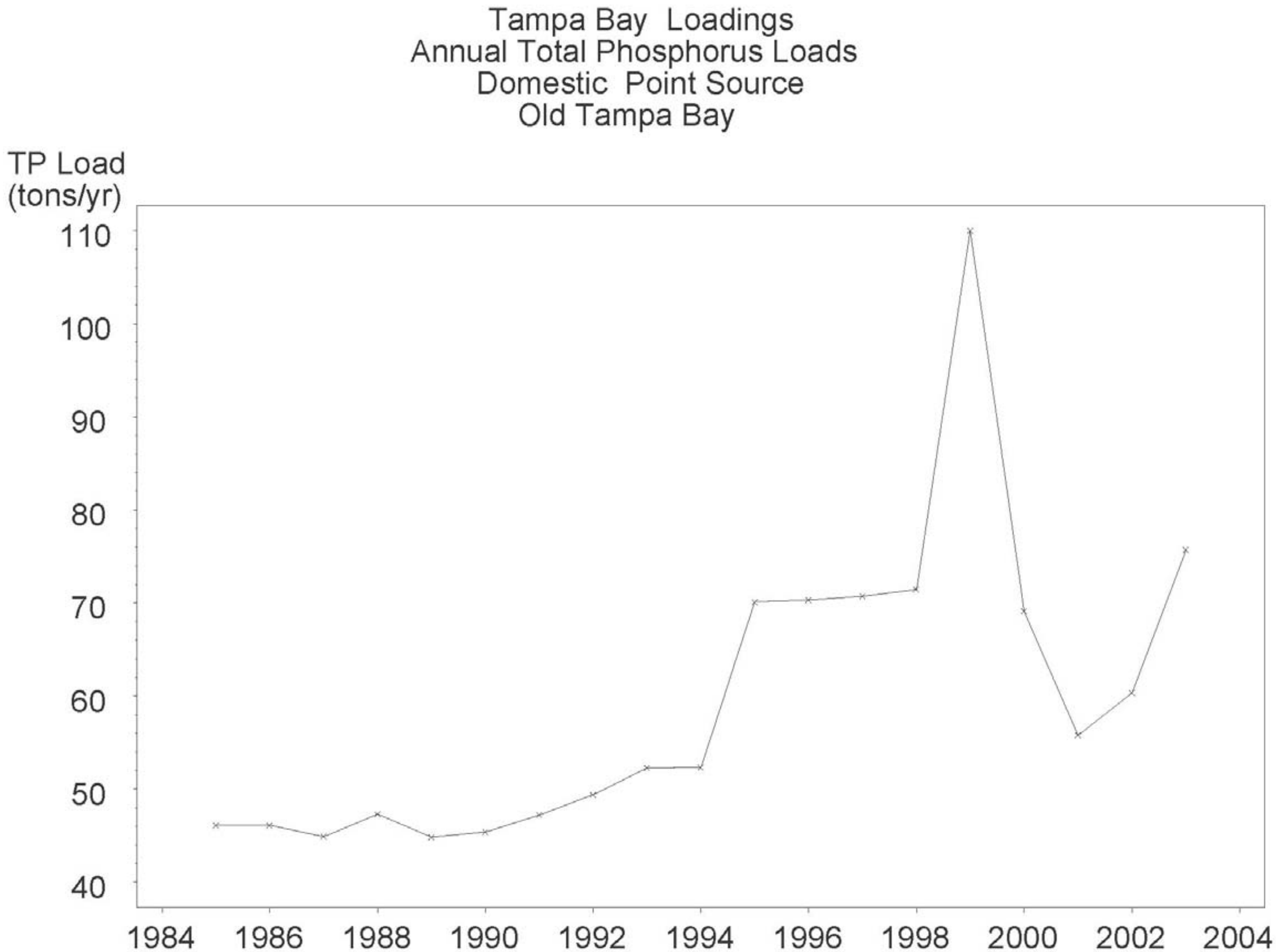


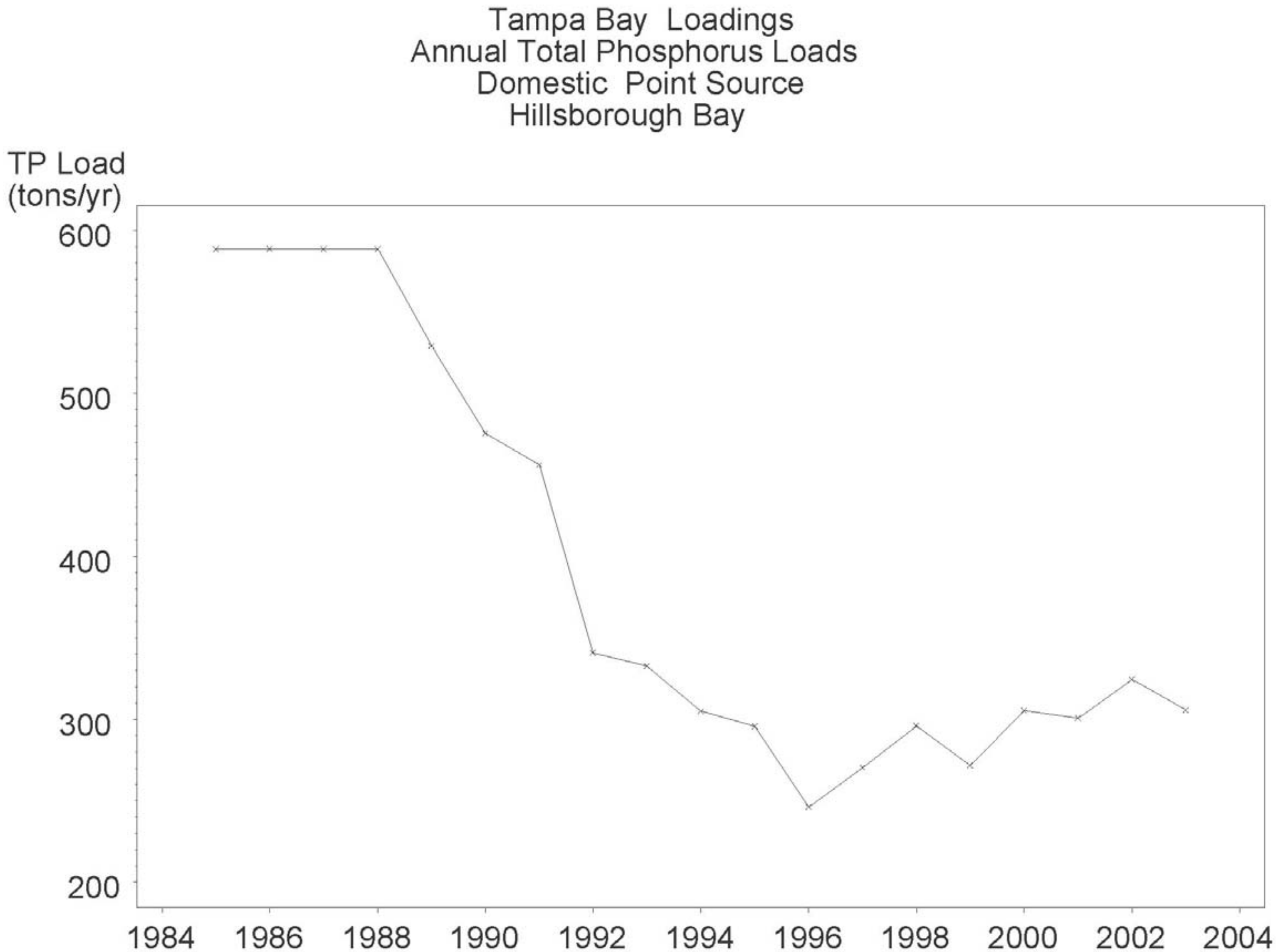
Tampa Bay Loadings
Annual Total Nitrogen Loads
Domestic Point Source
Lower Tampa Bay
TN Load
(tons/yr)
2
2
1
1
1
1
1
1
1
1
1
1
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual Total Nitrogen Loads
Domestic Point Source
Boca Ciega Bay
TN Load
(tons/yr)
70
60
50
40
30
20
10
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

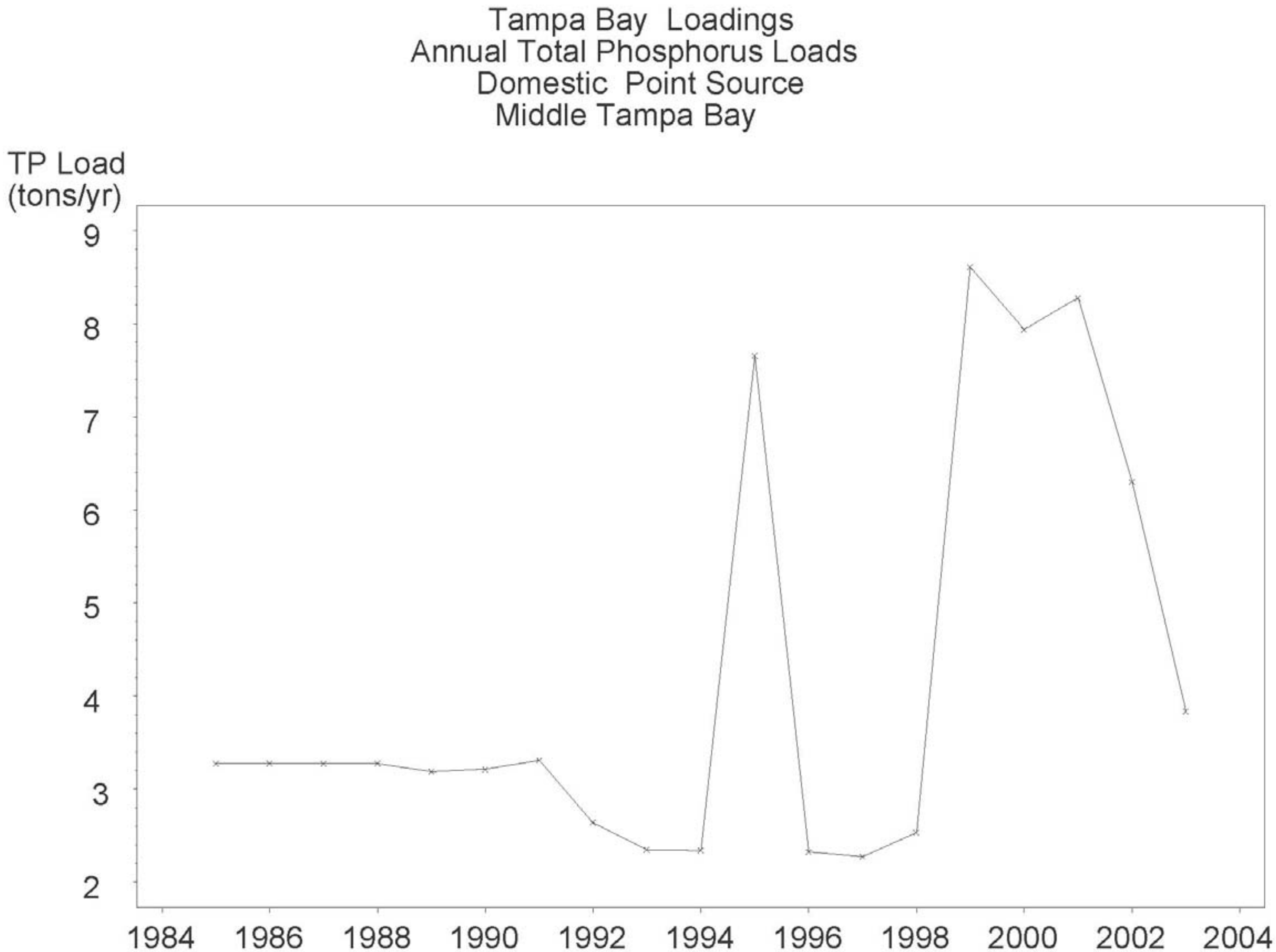

Tampa Bay Loadings
Annual Total Nitrogen Loads
Domestic Point Source
Terra Ceia Bay
TN Load
(tons/yr)
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

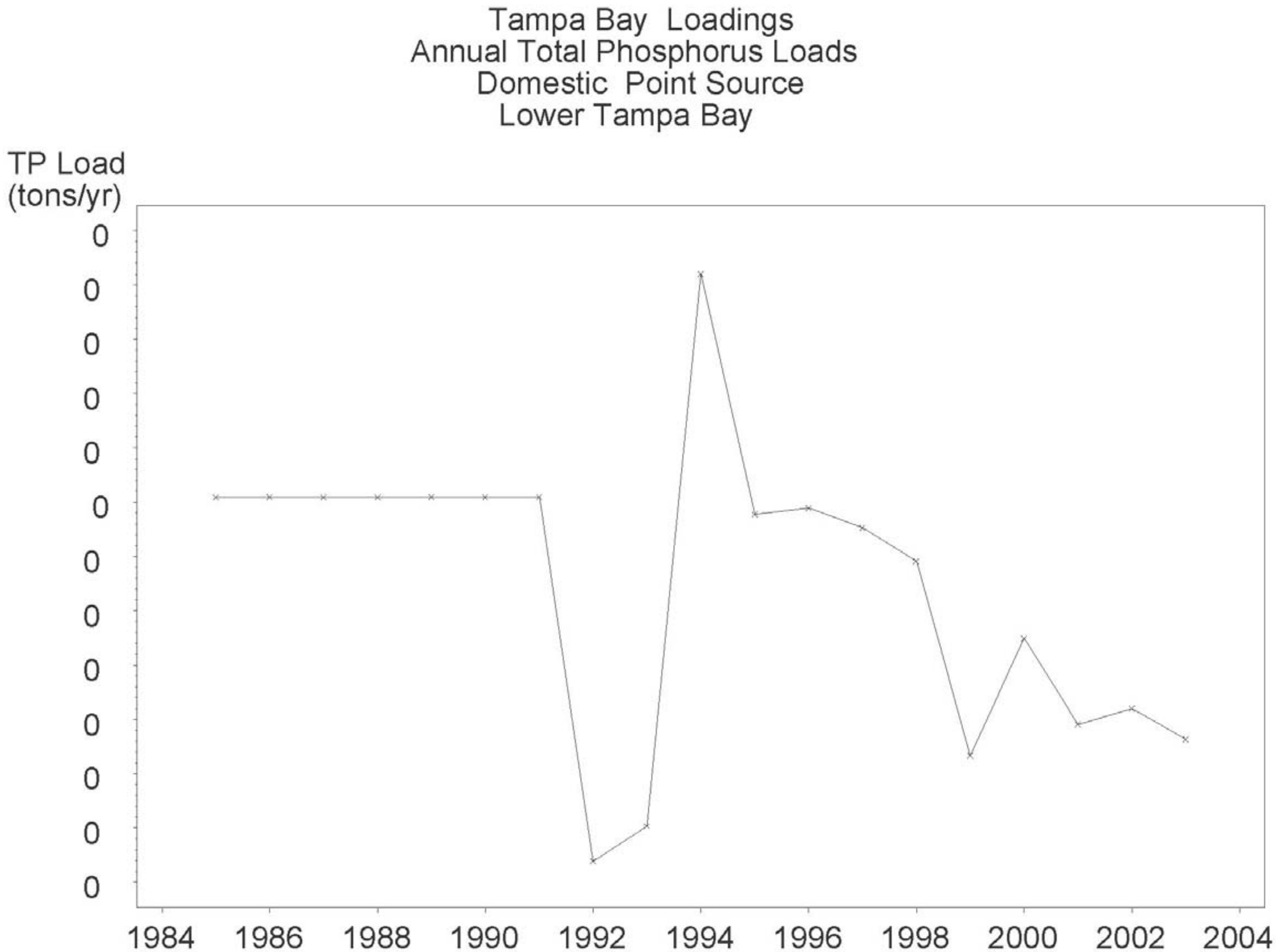

Tampa Bay Loadings
Annual Total Nitrogen Loads
Domestic Point Source
Manatee River
TN Load
(tons/yr)
60
50
40
30
20
10
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

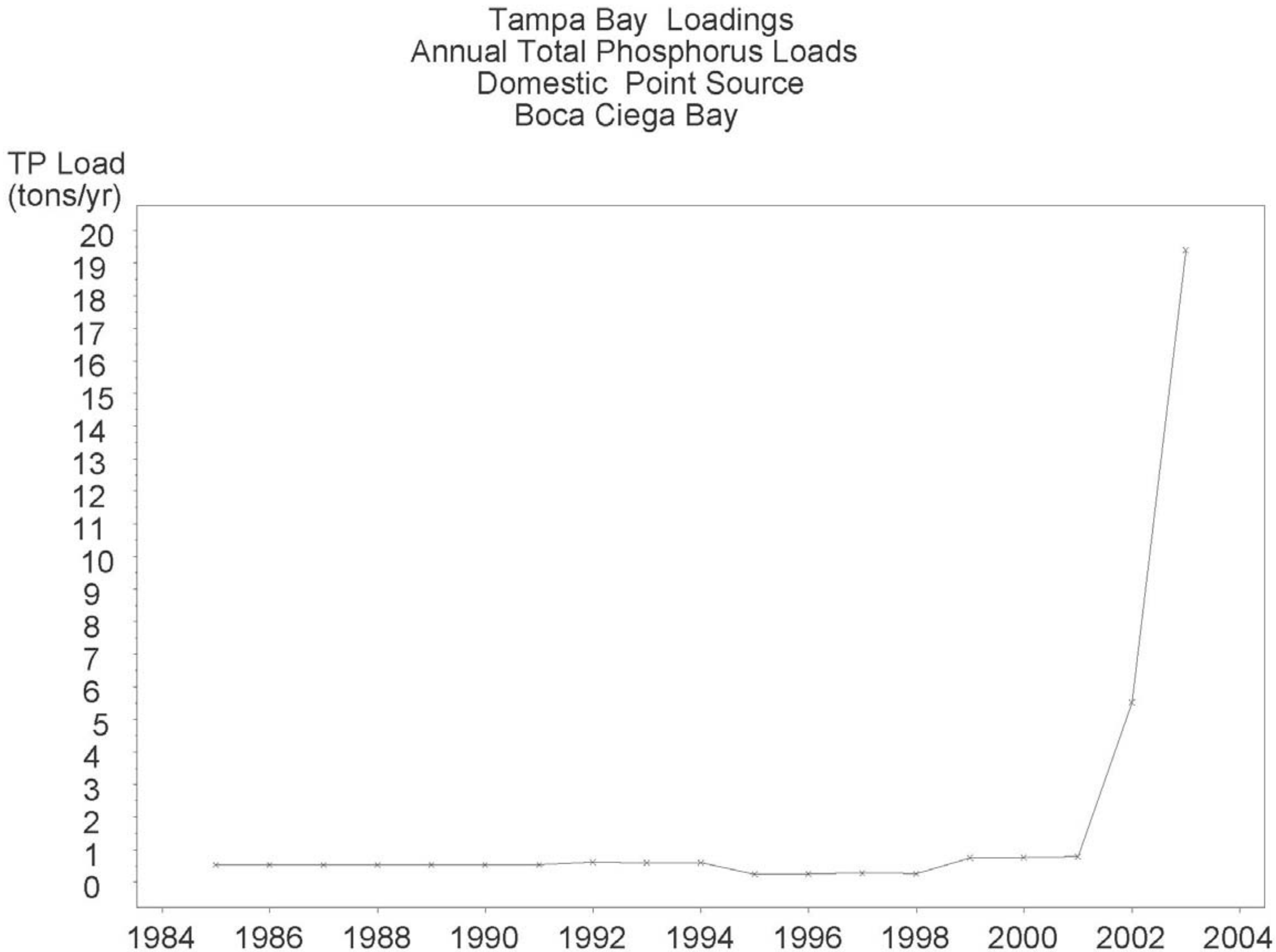

Tampa Bay Loadings
Annual Total Phosphorus Loads
Domestic Point Source
Old Tampa Bay
TP Load
(tons/yr)
110
100
90
80
70
60
50
40
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

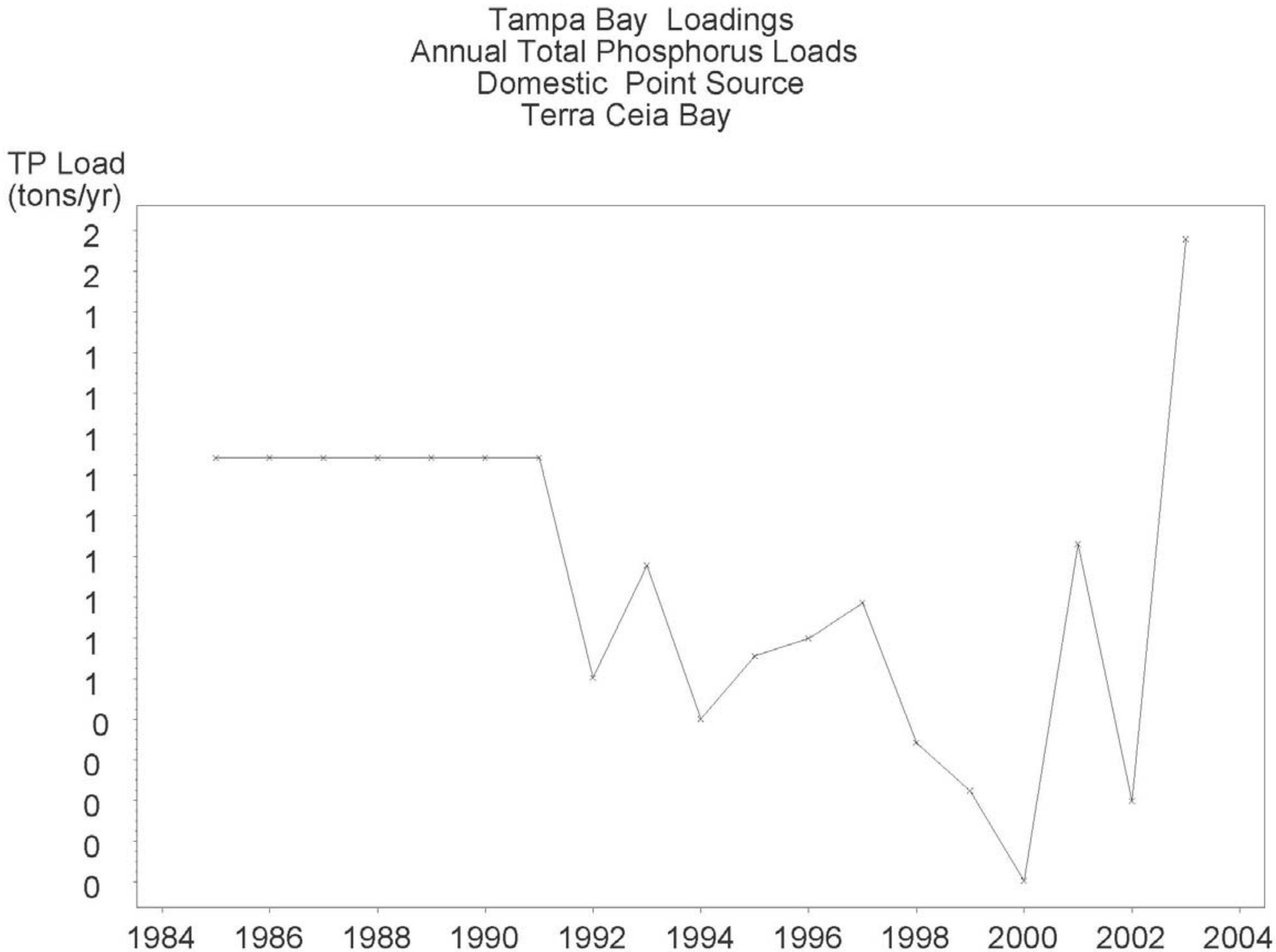


Tampa Bay Loadings
Annual Total Phosphorus Loads
Domestic Point Source
Hillsborough Bay
TP Load
(tons/yr)
600
500
400
300
200
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

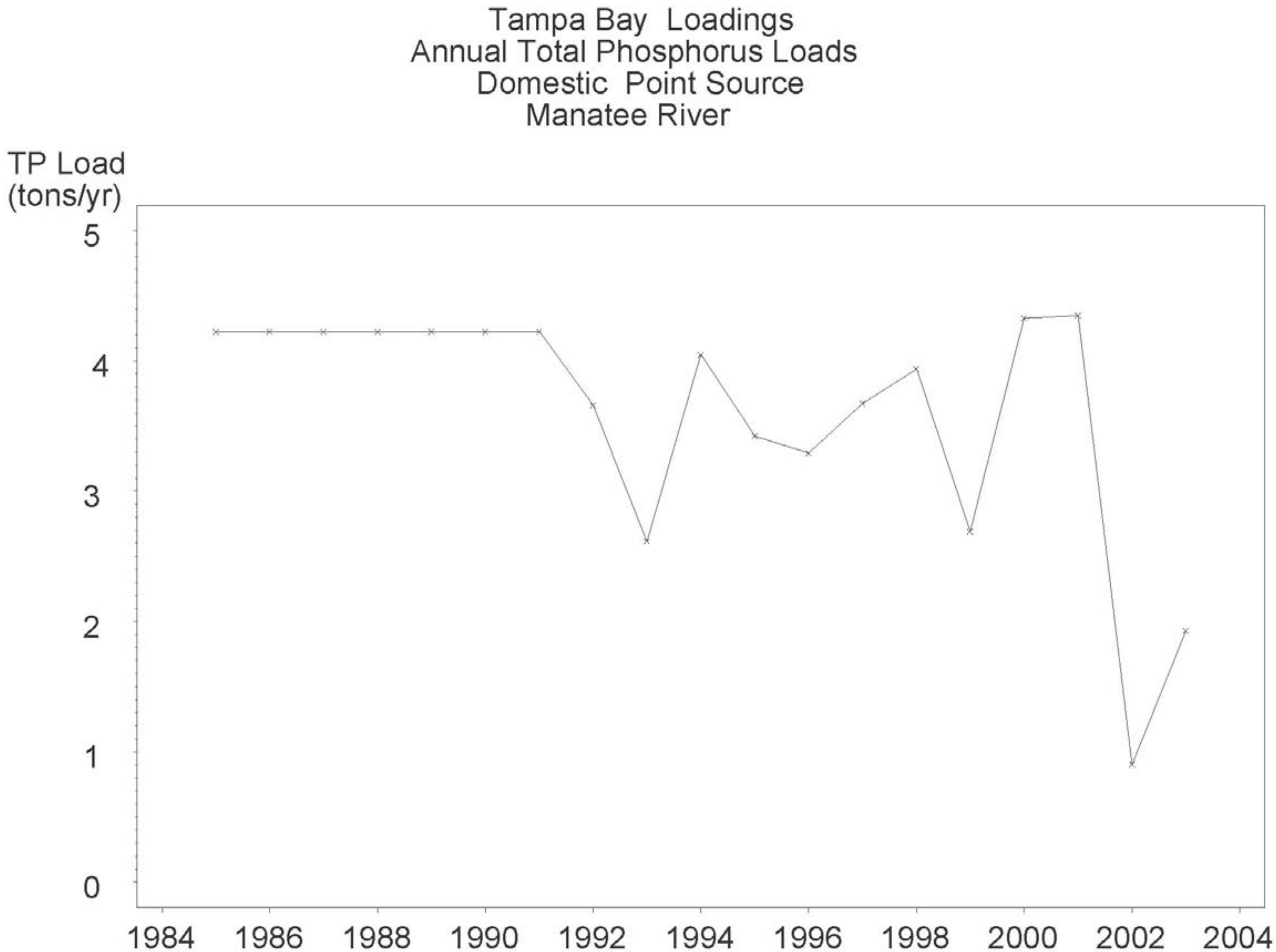

Tampa Bay Loadings
Annual Total Phosphorus Loads
Domestic Point Source
Middle Tampa Bay
TP Load
(tons/yr)
9
8
7
6
5
4
3
2
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

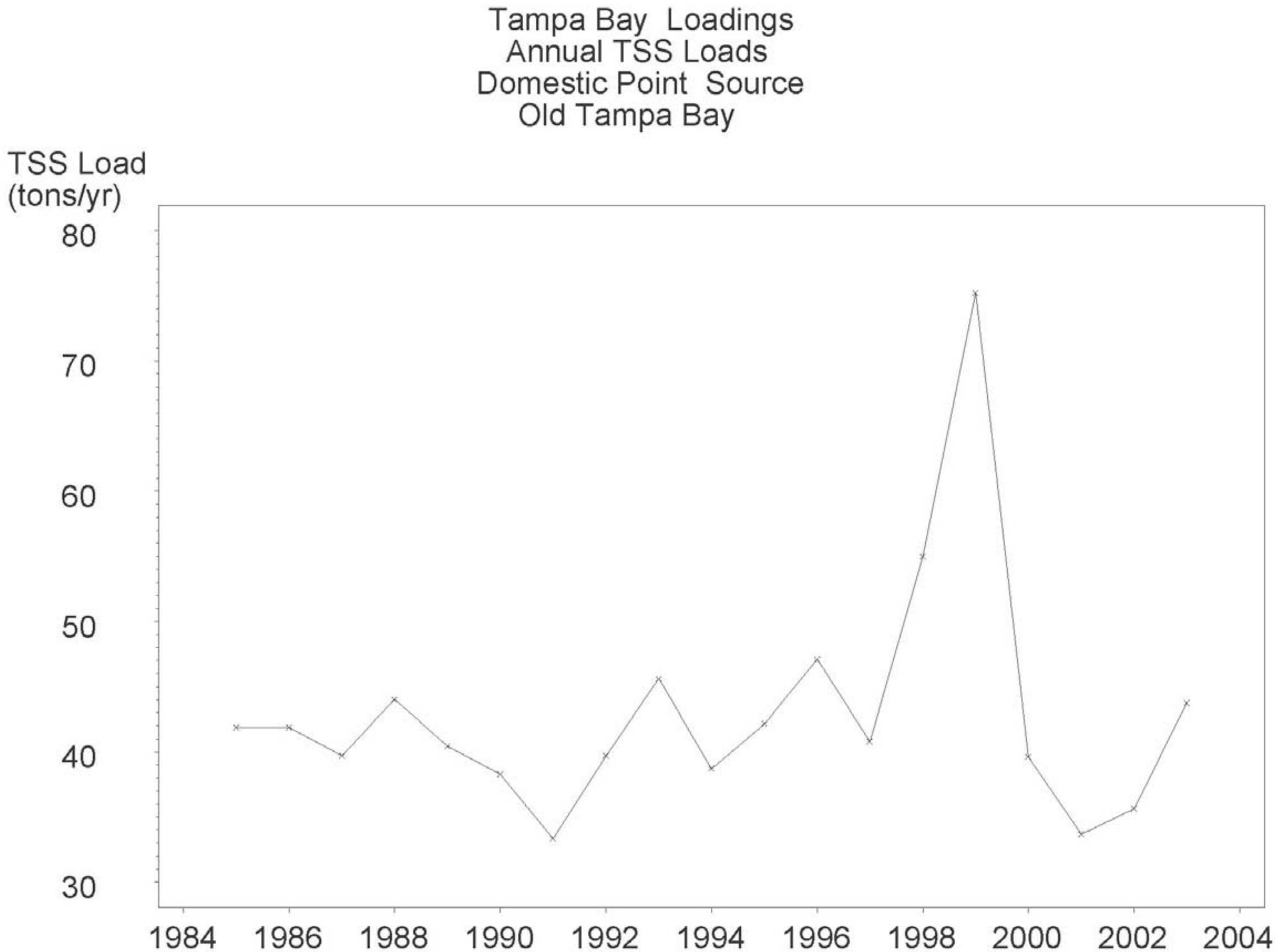

Tampa Bay Loadings
Annual Total Phosphorus Loads
Domestic Point Source
Lower Tampa Bay
TP Load
(tons/yr)
0
0
0
0
0
0
0
0
0
0
0
0
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

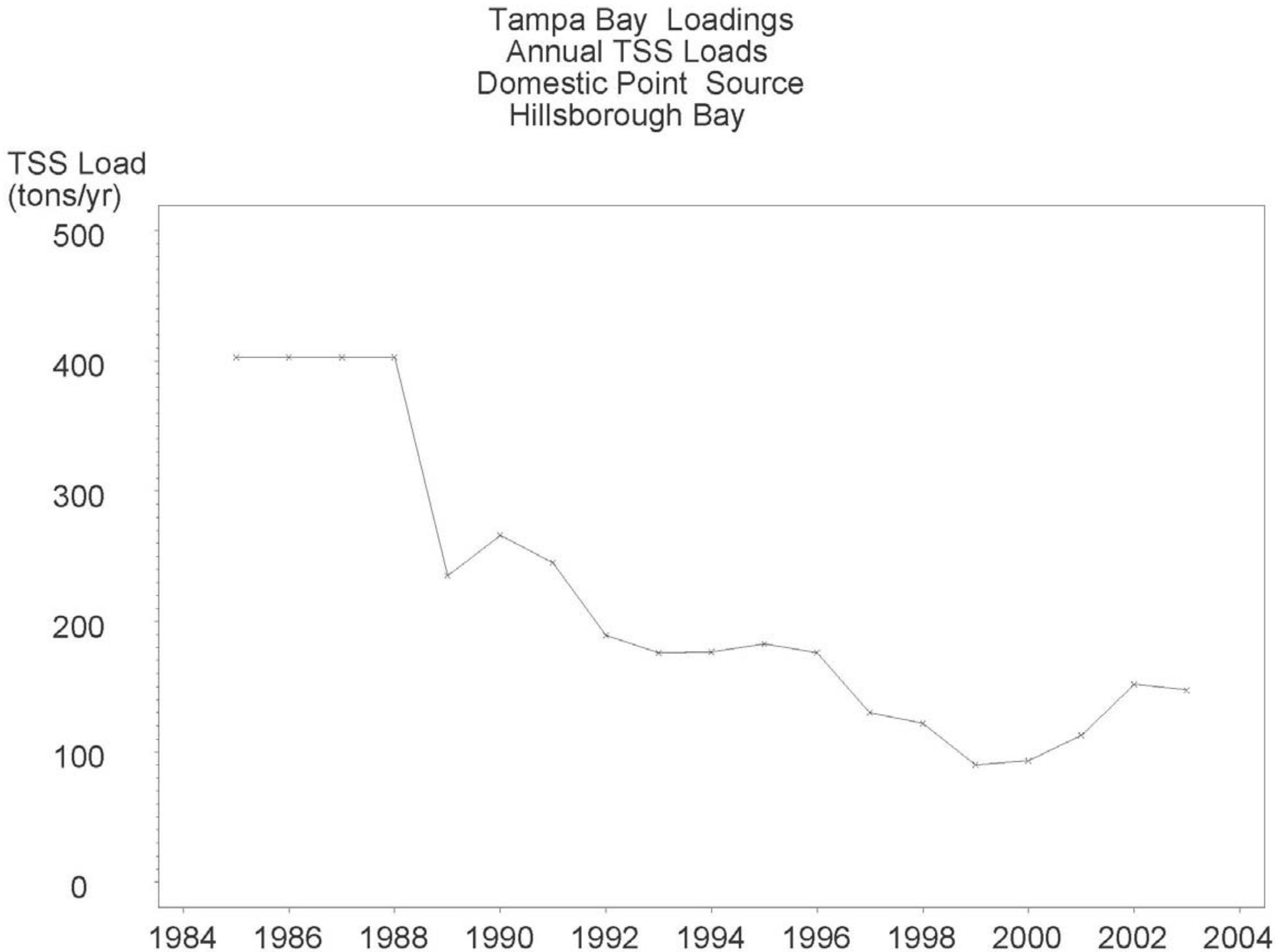

Tampa Bay Loadings
Annual Total Phosphorus Loads
Domestic Point Source
Boca Ciega Bay
TP Load
(tons/yr)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004



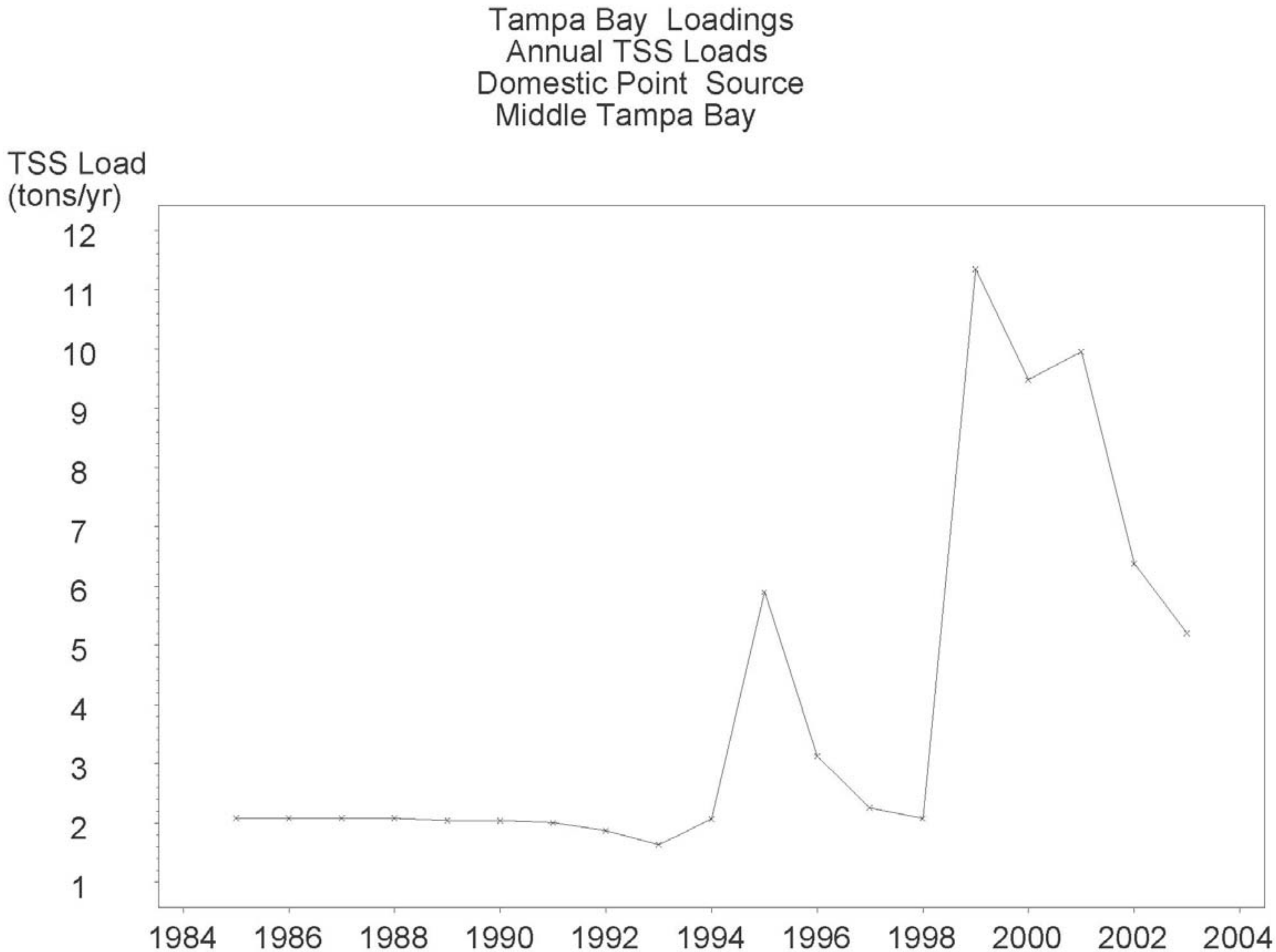
Tampa Bay Loadings
Annual Total Phosphorus Loads
Domestic Point Source
Terra Ceia Bay
TP Load
(tons/yr)
2
2
1
1
1
1
1
1
1
1
1
1
0
0
0
0
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual Total Phosphorus Loads
Domestic Point Source
Manatee River
TP Load
(tons/yr)
5
4
3
2
1
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

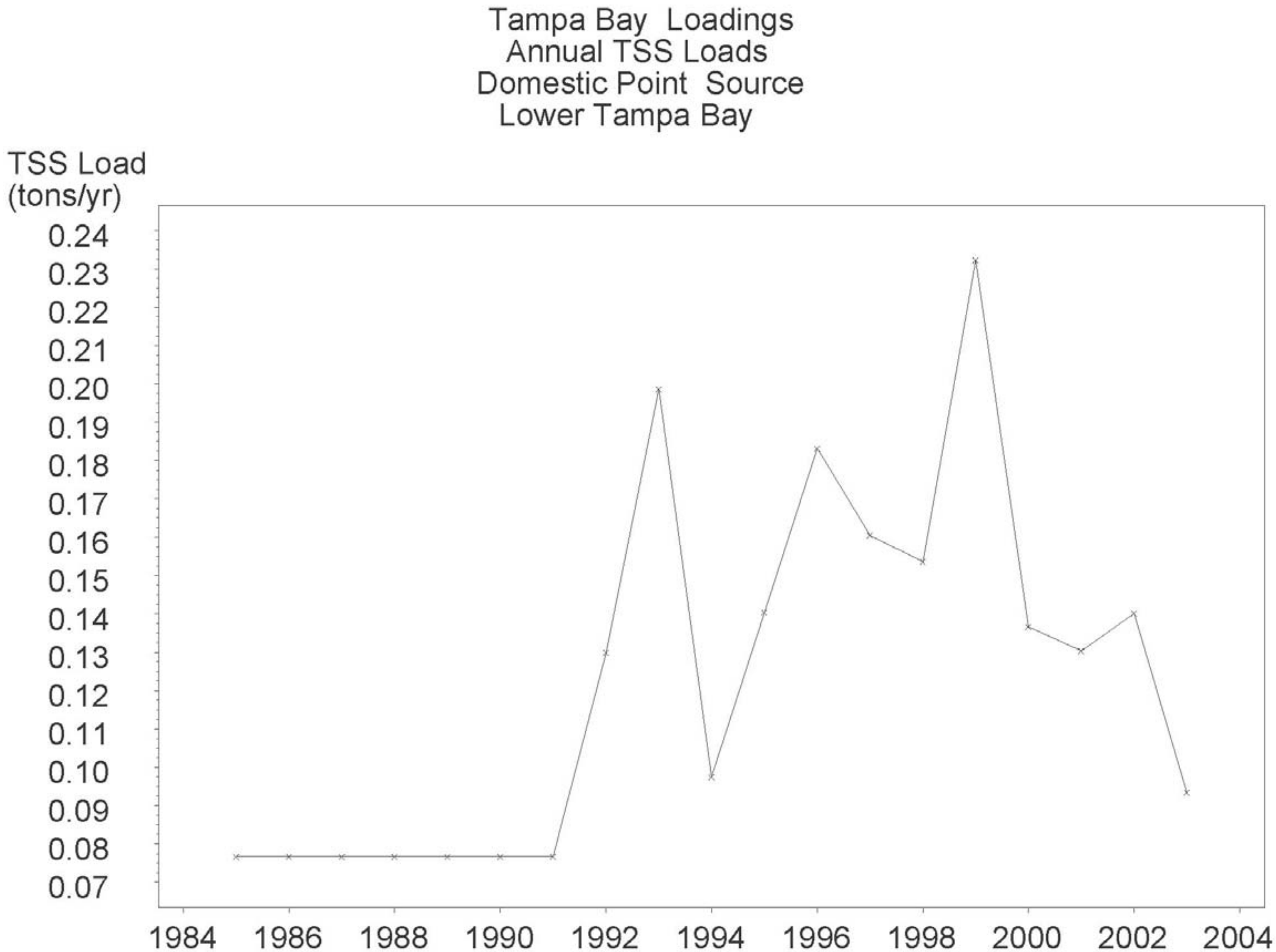

Tampa Bay Loadings
Annual TSS Loads
Domestic Point Source
Old Tampa Bay
TSS Load
(tons/yr)
80
70
60
50
40
30
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

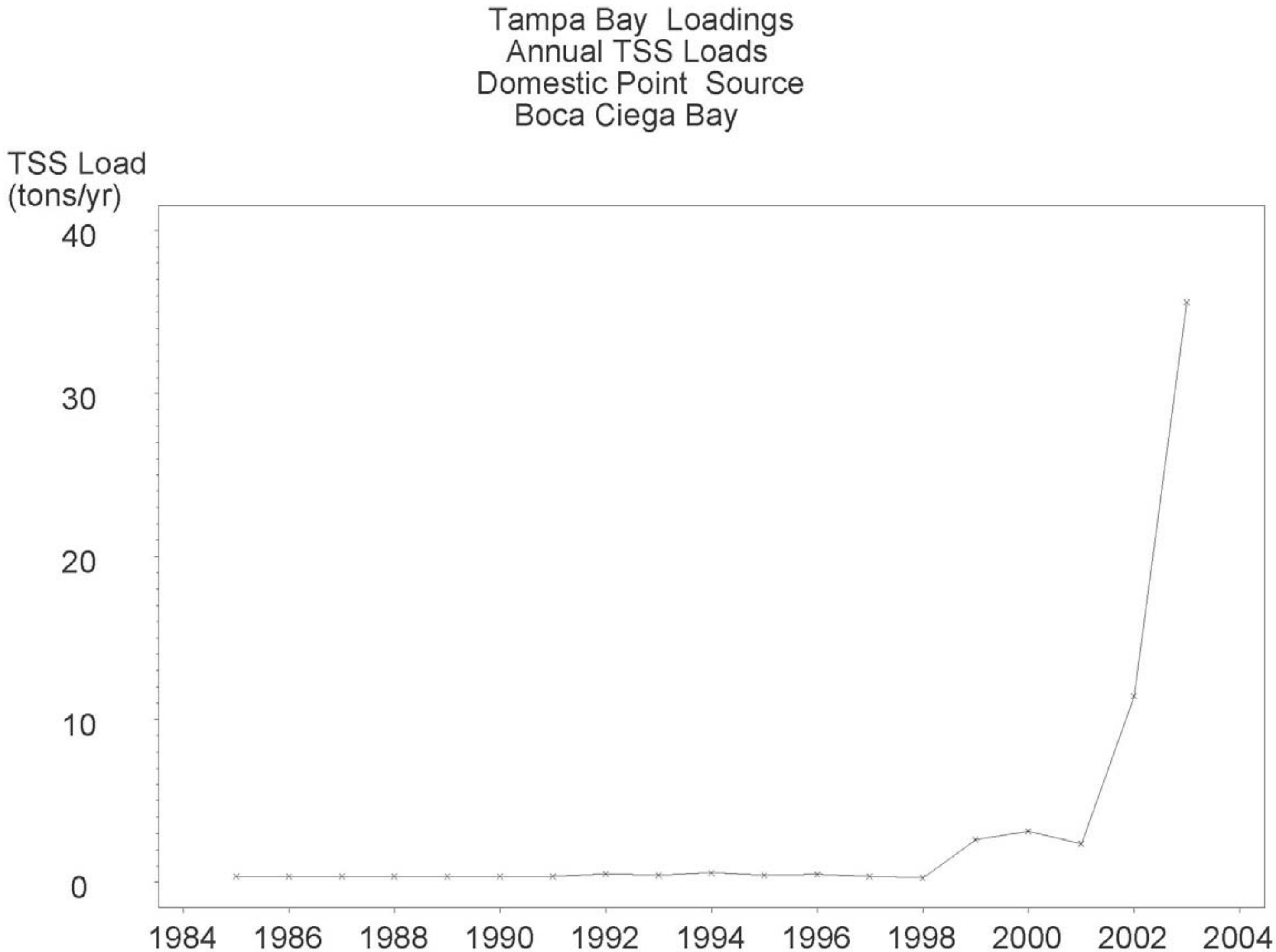


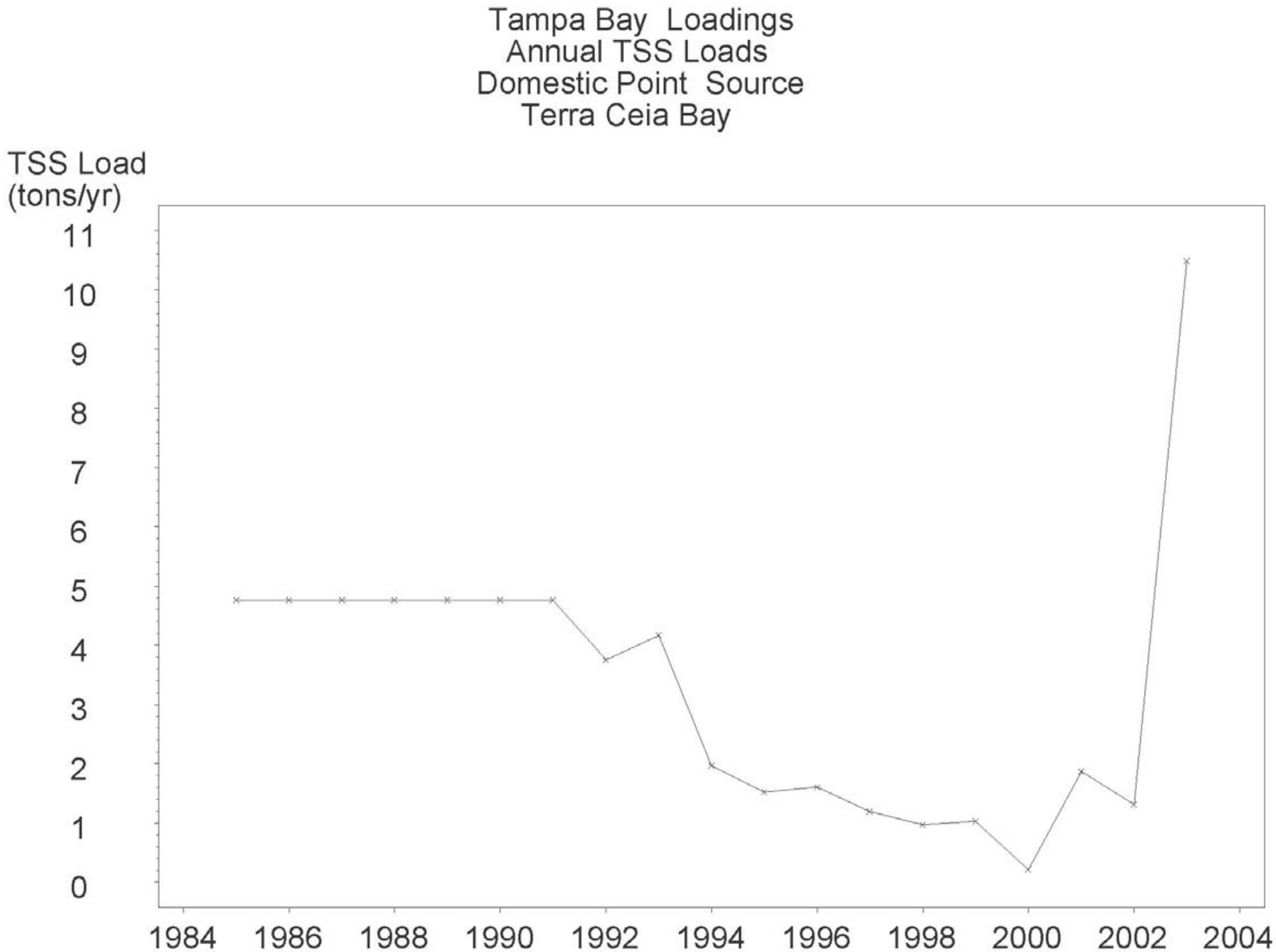
Tampa Bay Loadings
Annual TSS Loads
Domestic Point Source
Hillsborough Bay
TSS Load
(tons/yr)
500
400
300
200
100
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

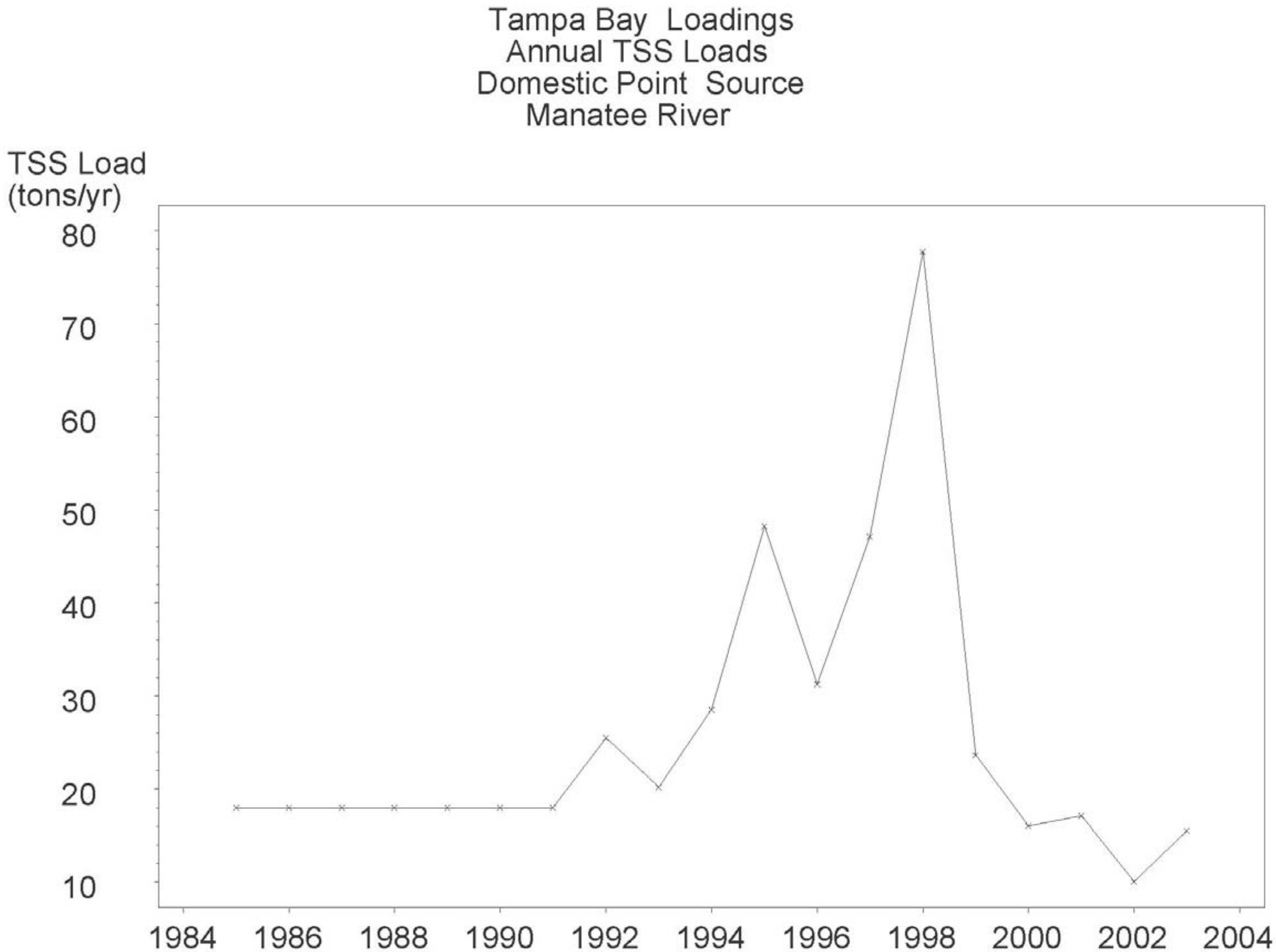


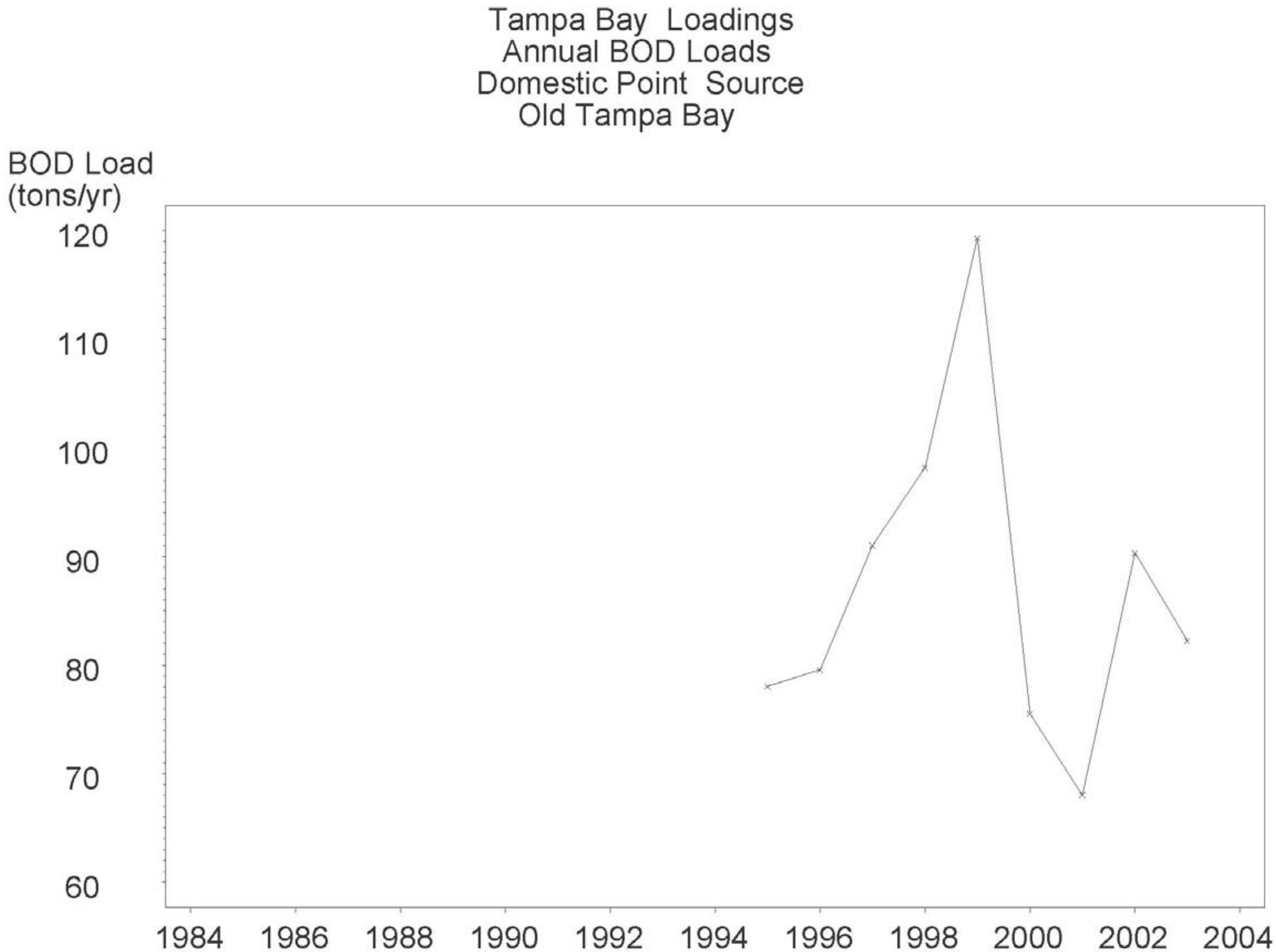
Tampa Bay Loadings
Annual TSS Loads
Domestic Point Source
Middle Tampa Bay
TSS Load
(tons/yr)
12
11
10
9
8
7
6
5
4
3
2
1
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual TSS Loads
Domestic Point Source
Lower Tampa Bay
TSS Load
(tons/yr)
0.24
0.23
0.22
0.21
0.20
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual TSS Loads
Domestic Point Source
Boca Ciega Bay
TSS Load
(tons/yr)
40
30
20
10
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual TSS Loads
Domestic Point Source
Terra Ceia Bay
TSS Load
(tons/yr)
11
10
9
8
7
6
5
4
3
2
1
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual TSS Loads
Domestic Point Source
Manatee River
TSS Load
(tons/yr)
80
70
60
50
40
30
20
10
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual BOD Loads
Domestic Point Source
Old Tampa Bay
BOD Load
(tons/yr)
120
110
100
90
80
70
60
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual BOD Loads
Domestic Point Source
Hillsborough Bay
BOD Load
(tons/yr)
260
250
240
230
220
210
200
190
180
170
160
150
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

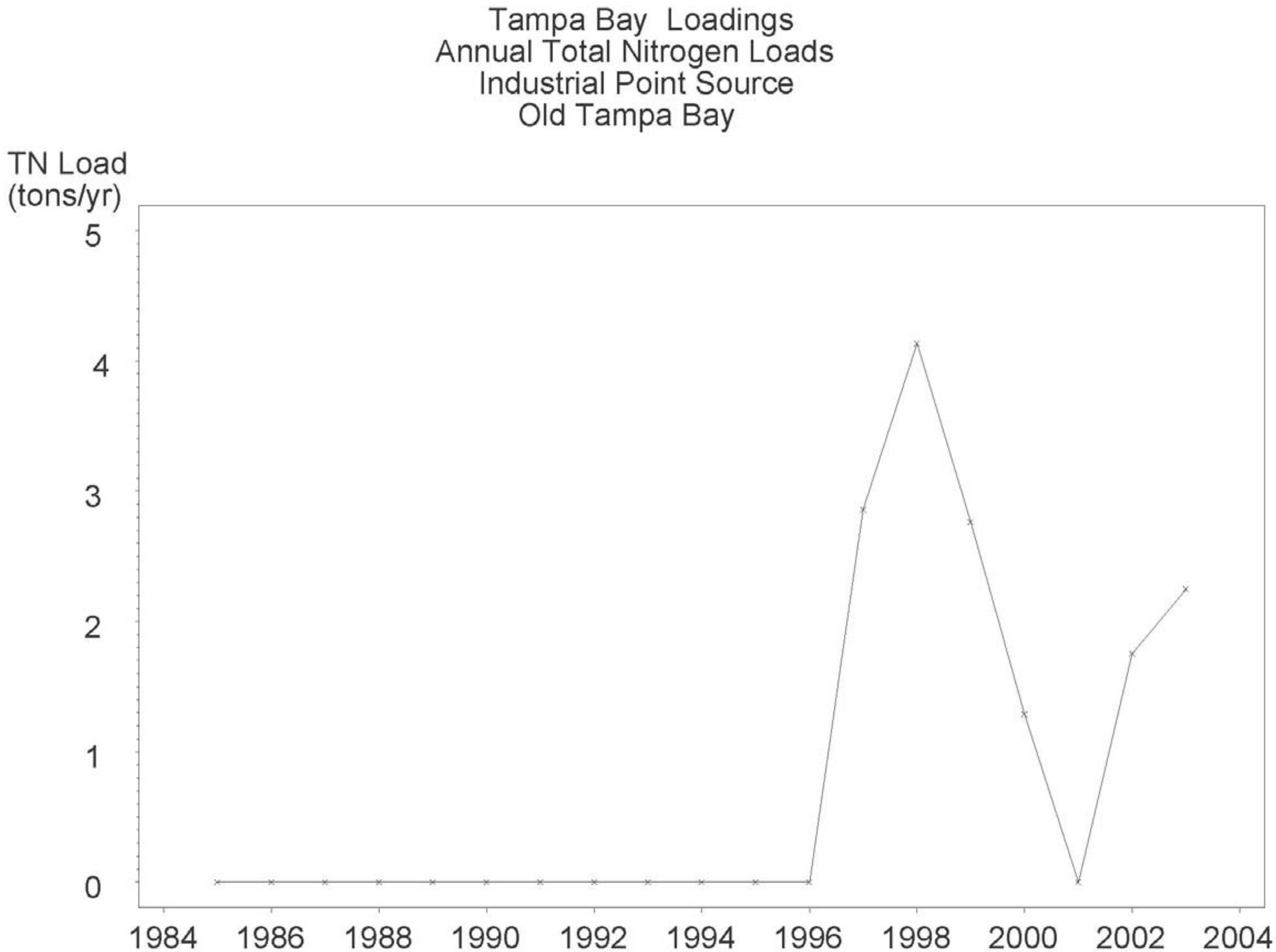

Tampa Bay Loadings
Annual BOD Loads
Domestic Point Source
Middle Tampa Bay
BOD Load
(tons/yr)
12
11
10
9
8
7
6
5
4
3
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

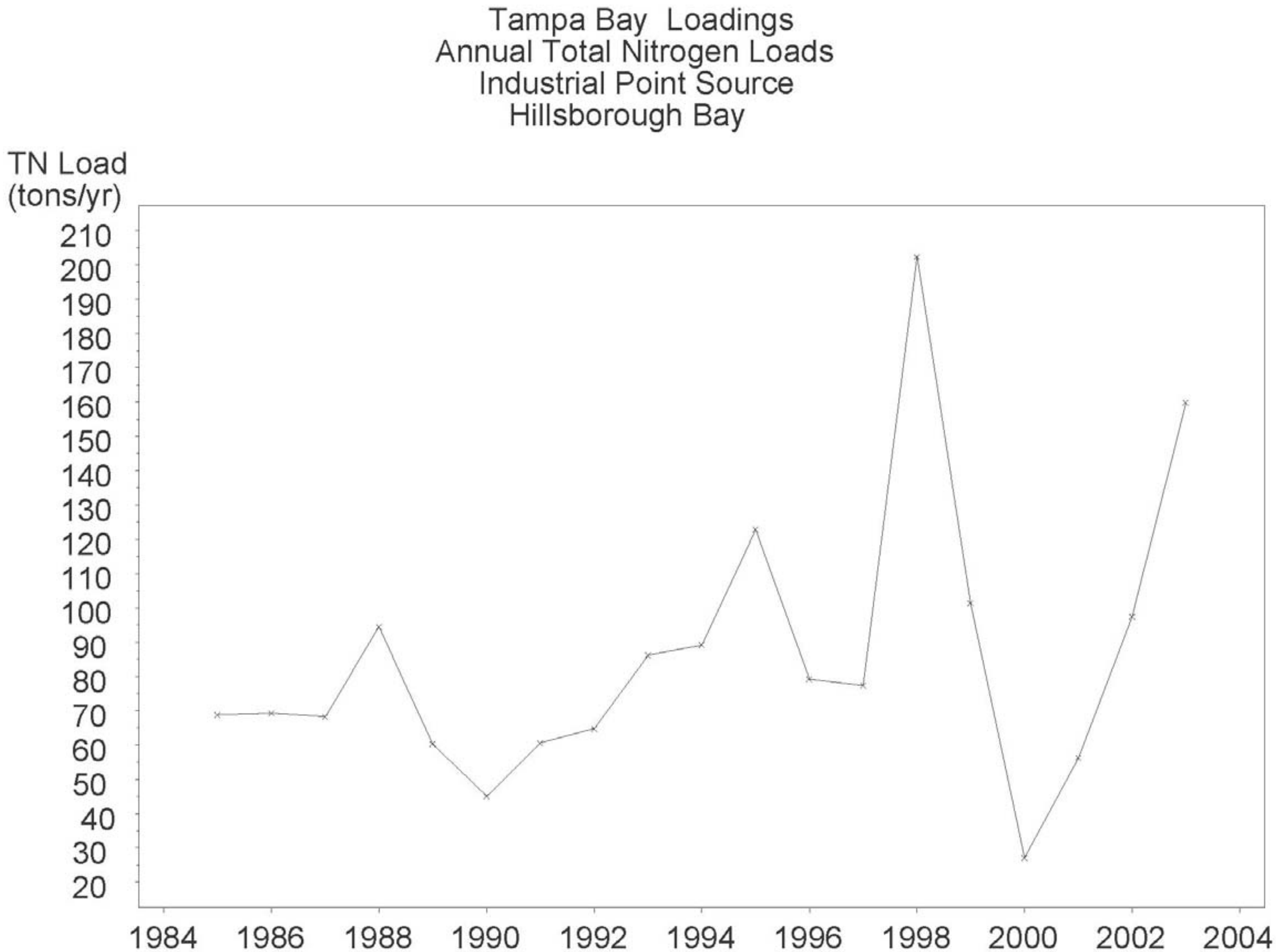

Tampa Bay Loadings
Annual BOD Loads
Domestic Point Source
Lower Tampa Bay
BOD Load
(tons/yr)
0.56
0.54
0.52
0.50
0.48
0.46
0.44
0.42
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual BOD Loads
Domestic Point Source
Boca Ciega Bay
BOD Load
(tons/yr)
70
60
50
40
30
20
10
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

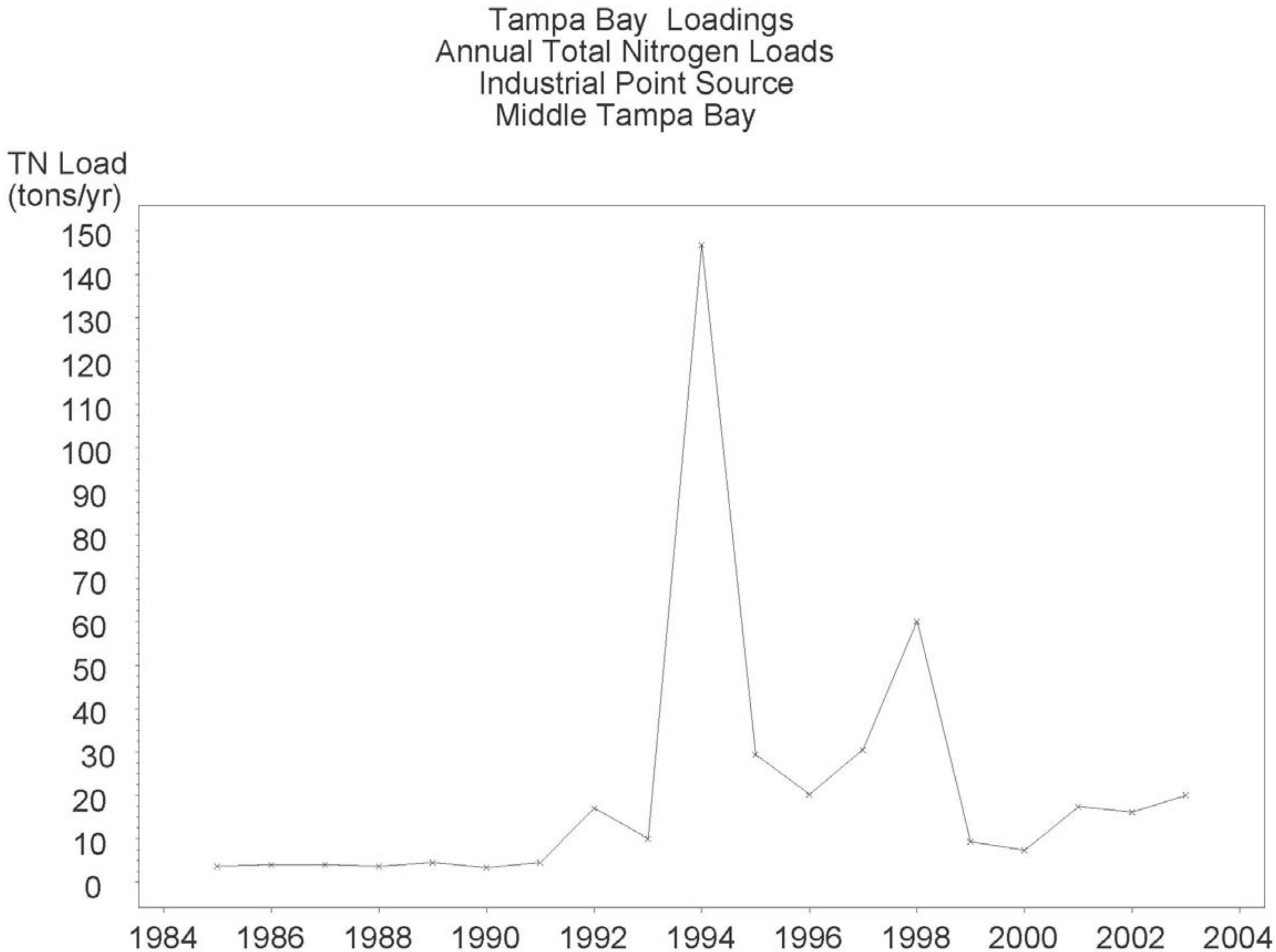
Tampa Bay Loadings
Annual BOD Loads
Domestic Point Source
Terra Ceia Bay


Tampa Bay Loadings
Annual BOD Loads
Domestic Point Source
Manatee River
BOD Load
(tons/yr)
30
20
10
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

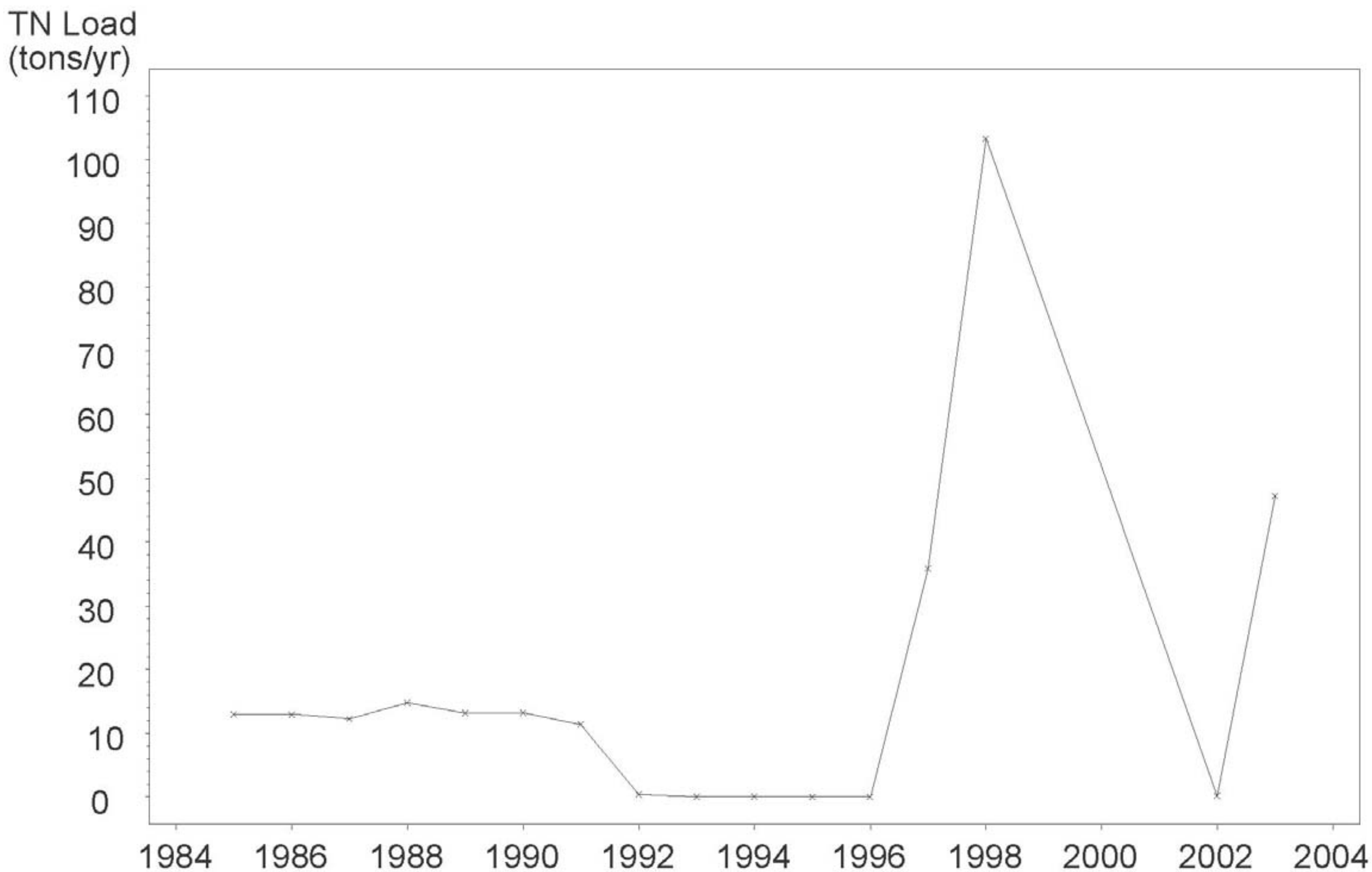

Tampa Bay Loadings
Annual Total Nitrogen Loads
Industrial Point Source
Old Tampa Bay
TN Load
(tons/yr)
5
4
3
2
1
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

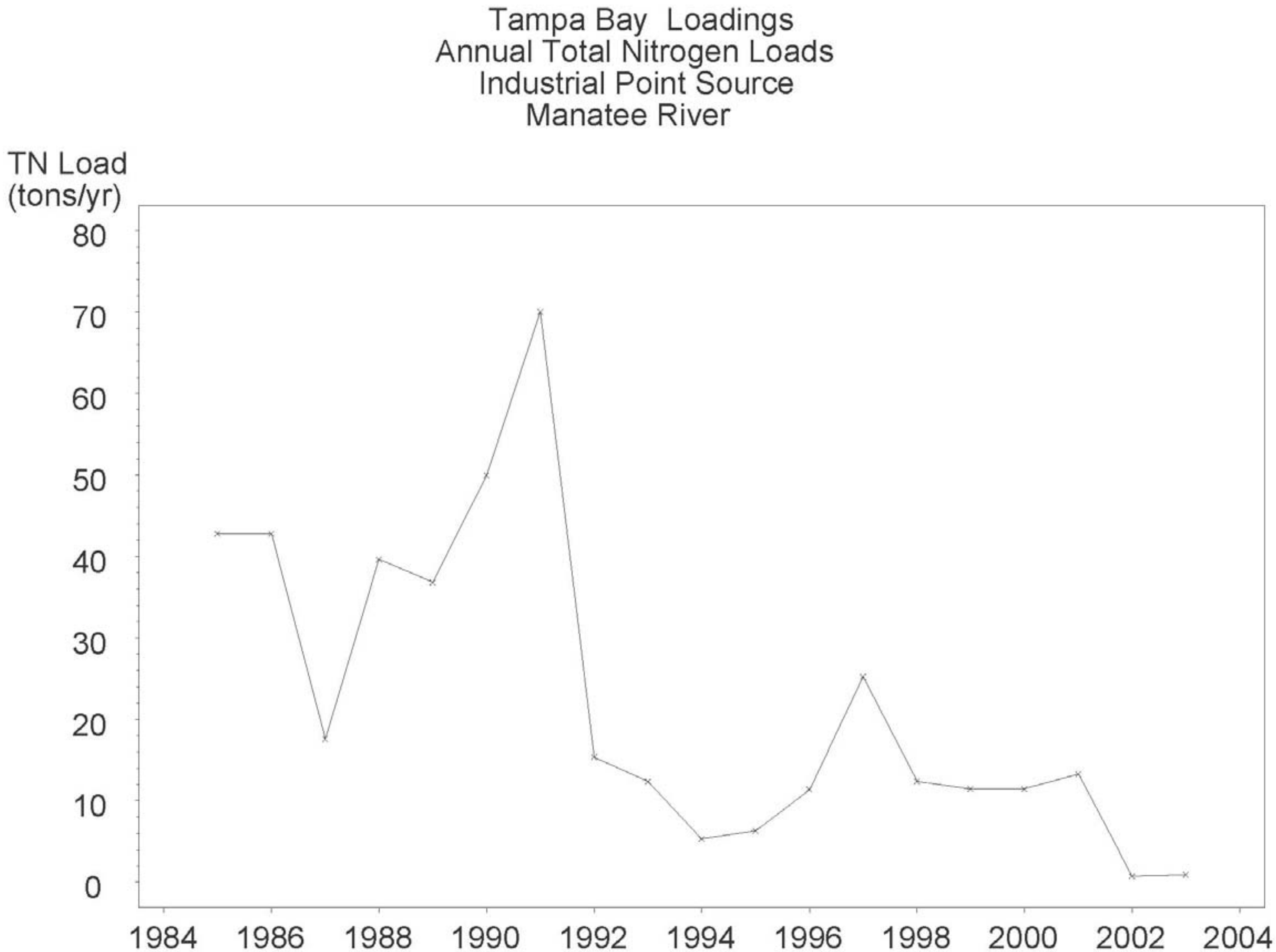


Tampa Bay Loadings
Annual Total Nitrogen Loads
Industrial Point Source
Hillsborough Bay
TN Load
(tons/yr)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

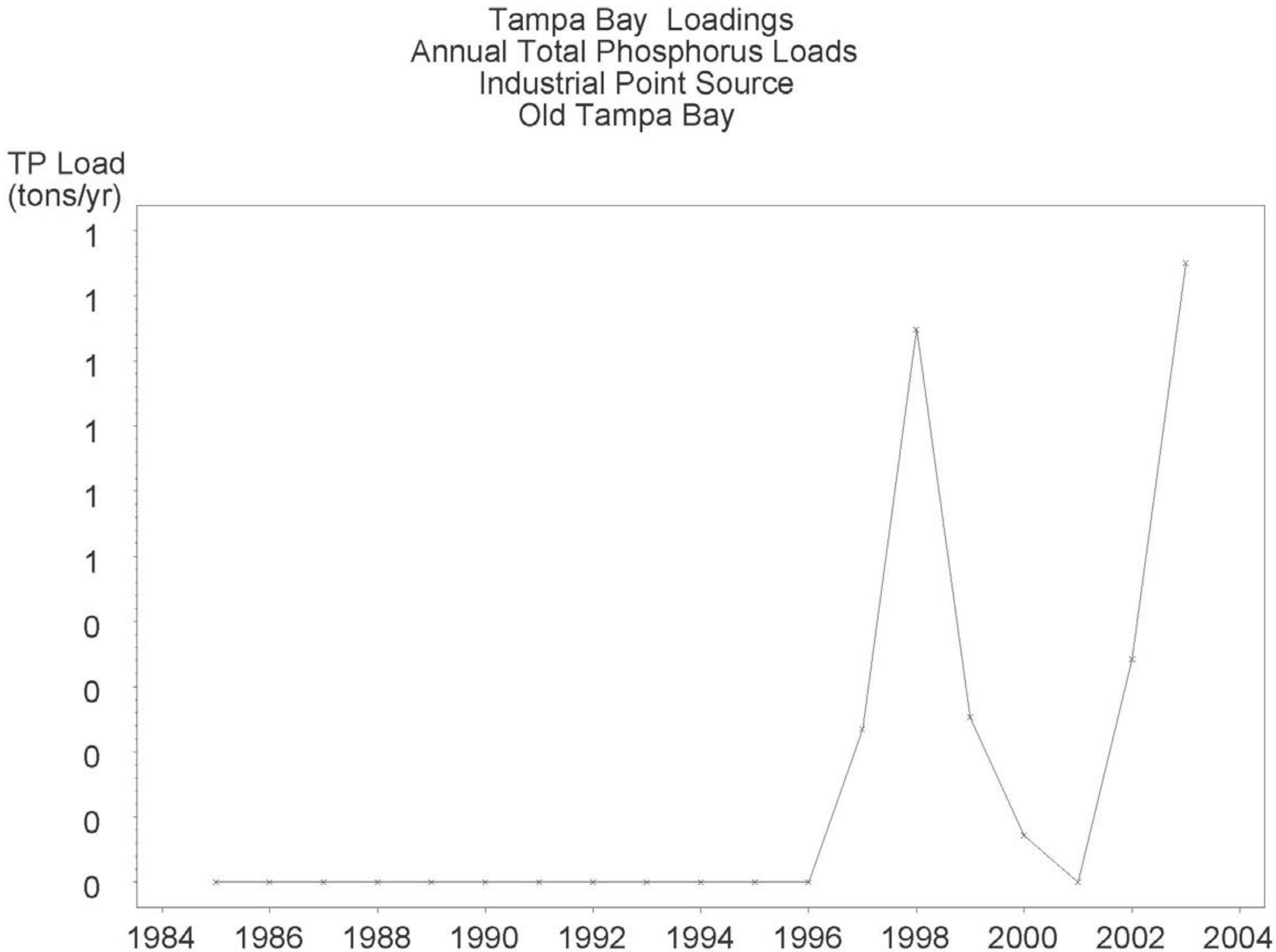

Tampa Bay Loadings
Annual Total Nitrogen Loads
Industrial Point Source
Middle Tampa Bay
TN Load
(tons/yr)
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

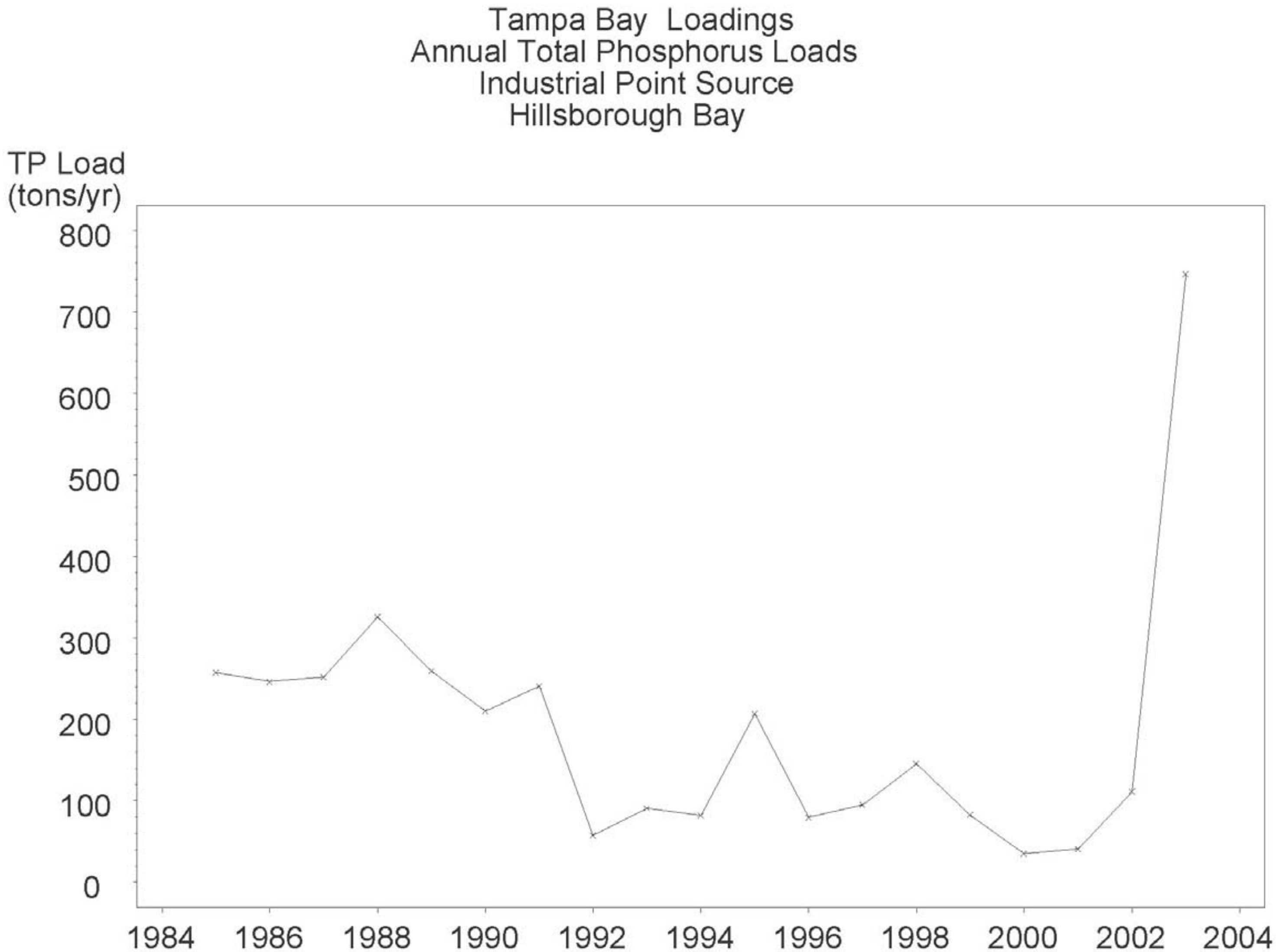
Tampa Bay Loadings
Annual Total Nitrogen Loads
Industrial Point Source
Lower Tampa Bay

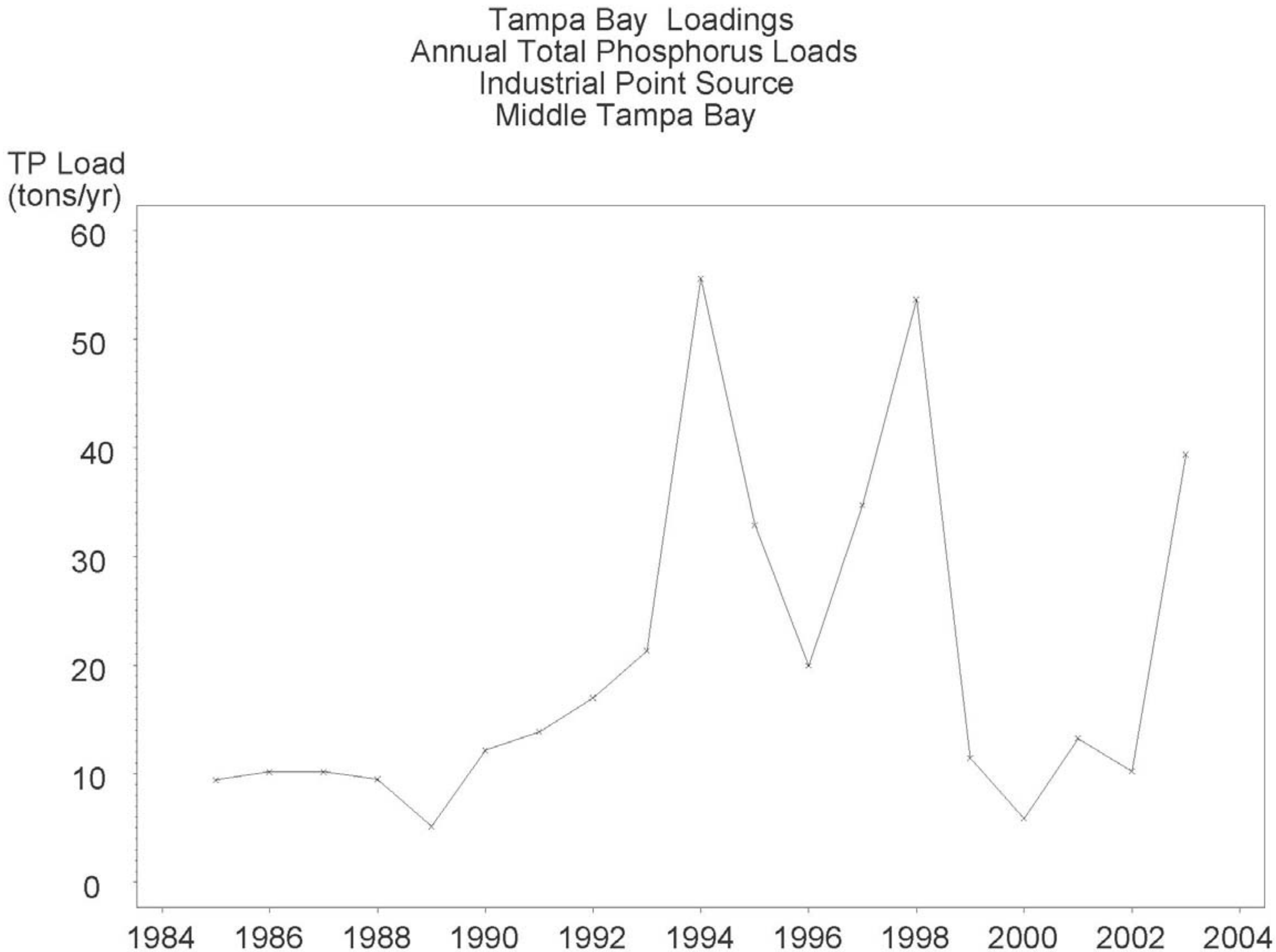




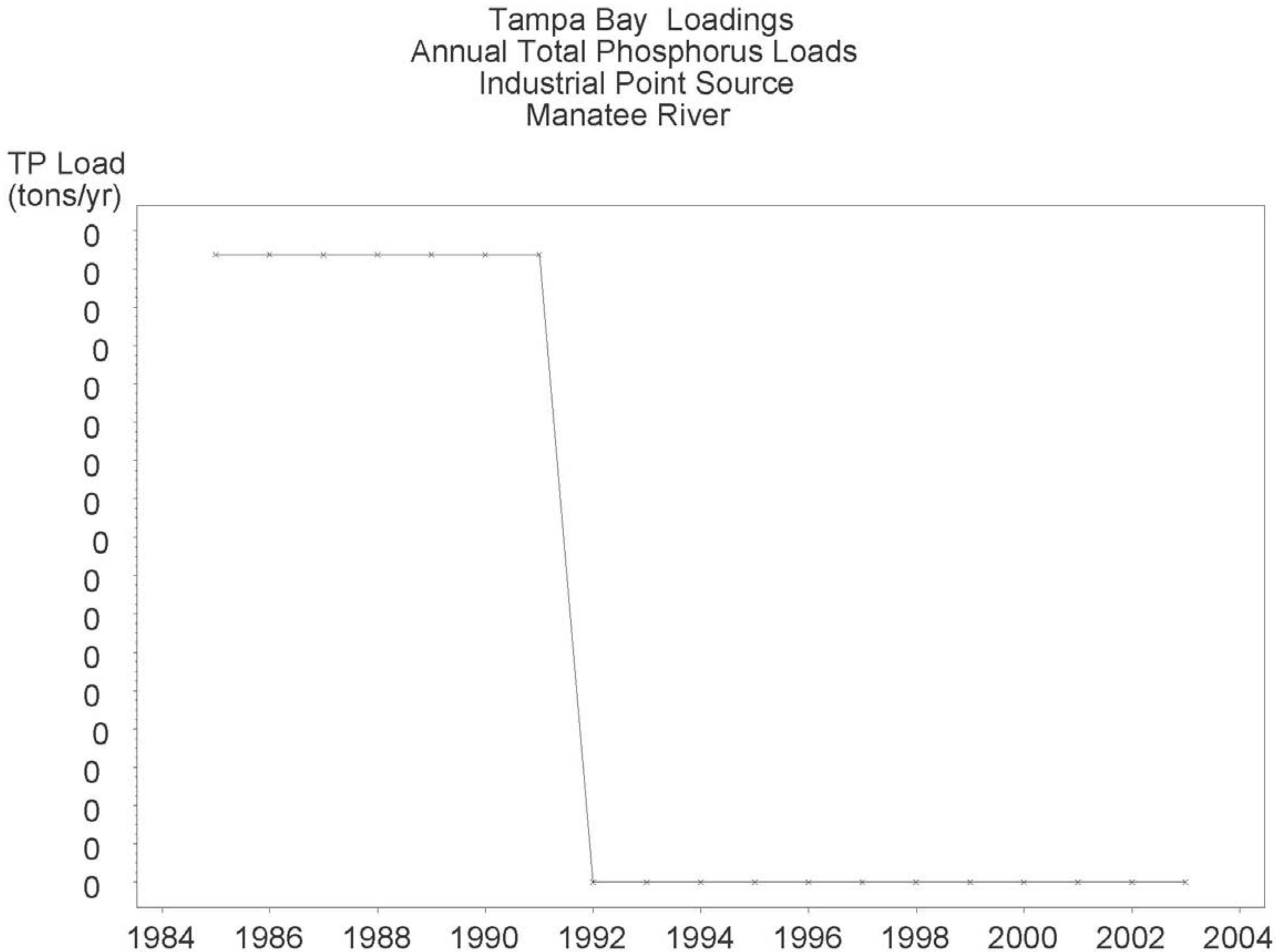
Tampa Bay Loadings
Annual Total Nitrogen Loads
Industrial Point Source
Manatee River
TN Load
(tons/yr)
80
70
60
50
40
30
20
10
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

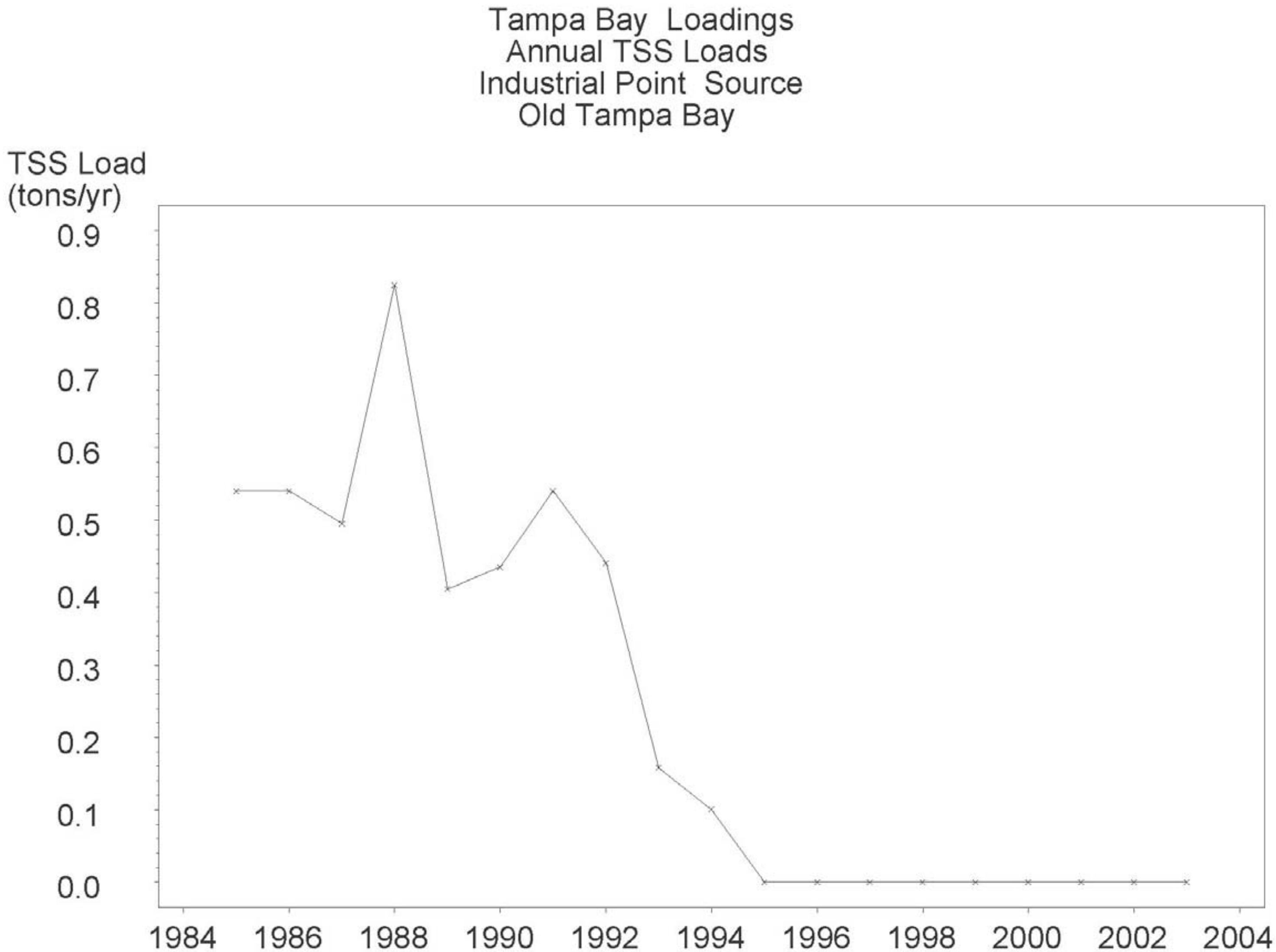

Tampa Bay Loadings
Annual Total Phosphorus Loads
Industrial Point Source
Old Tampa Bay
TP Load
(tons/yr)
1
1
1
1
1
1
0
0
0
0
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

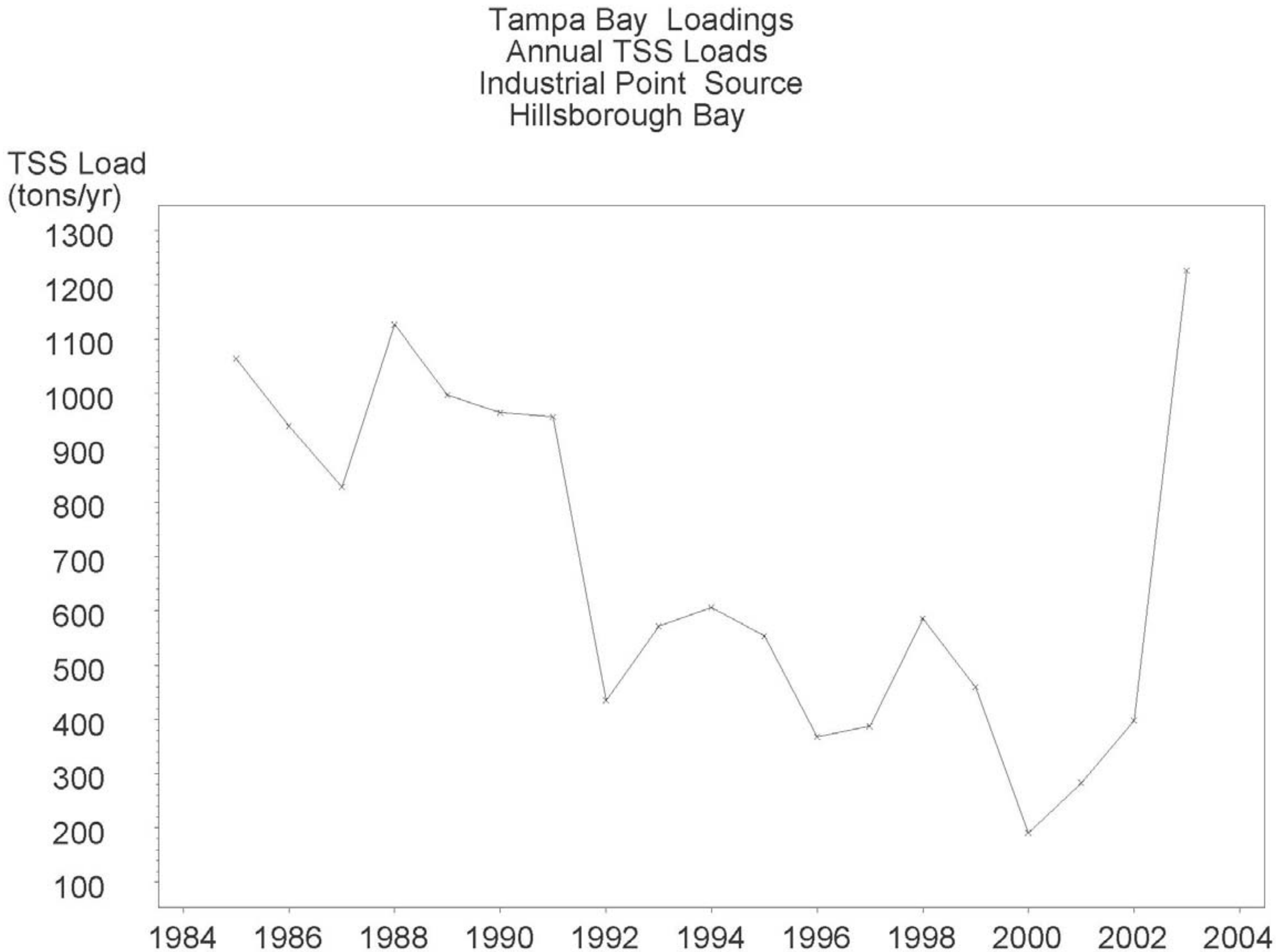

Tampa Bay Loadings
Annual Total Phosphorus Loads
Industrial Point Source
Hillsborough Bay
TP Load
(tons/yr)
800
700
600
500
400
300
200
100
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

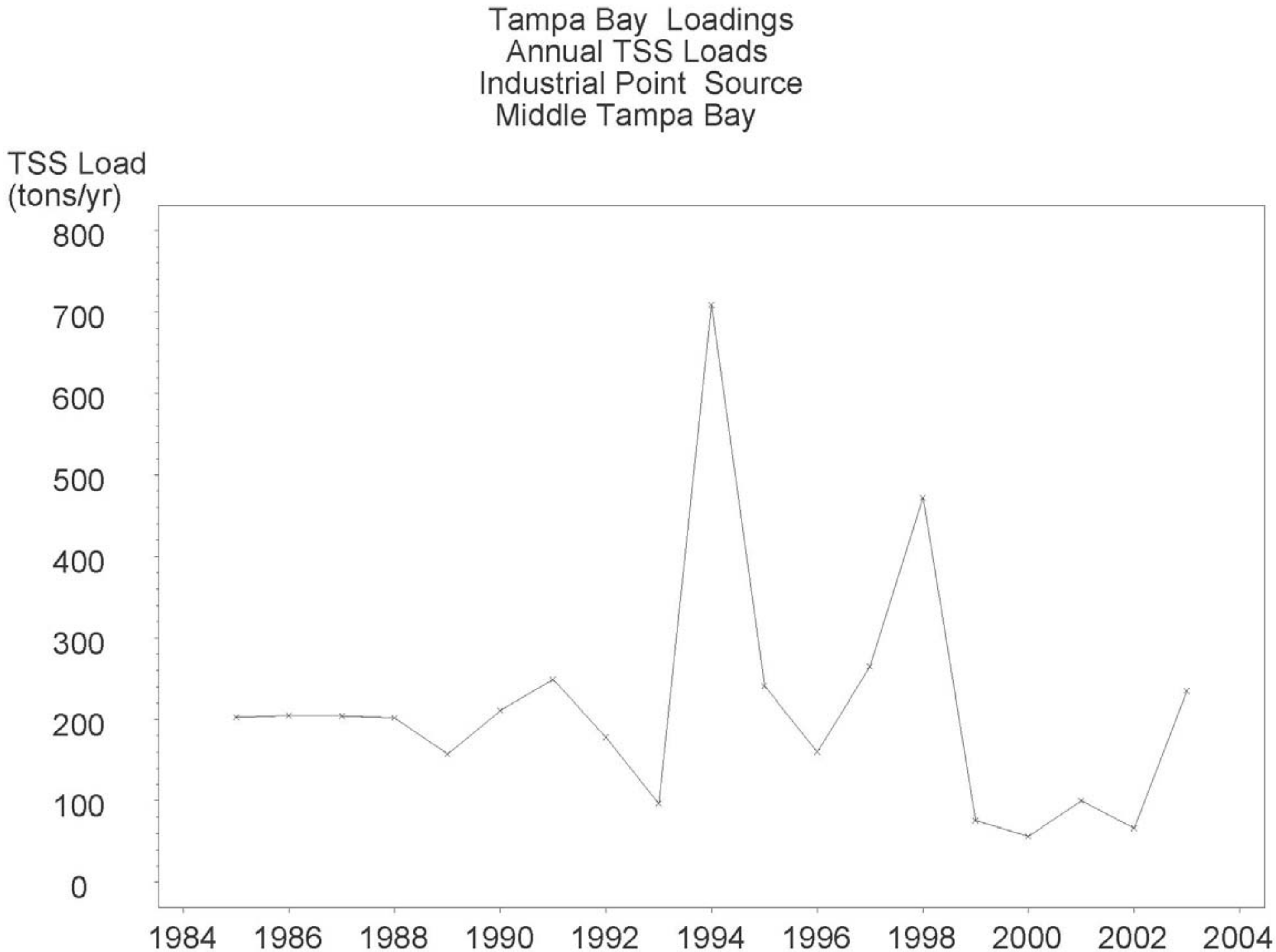

Tampa Bay Loadings
Annual Total Phosphorus Loads
Industrial Point Source
Middle Tampa Bay
TP Load
(tons/yr)
60
50
40
30
20
10
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

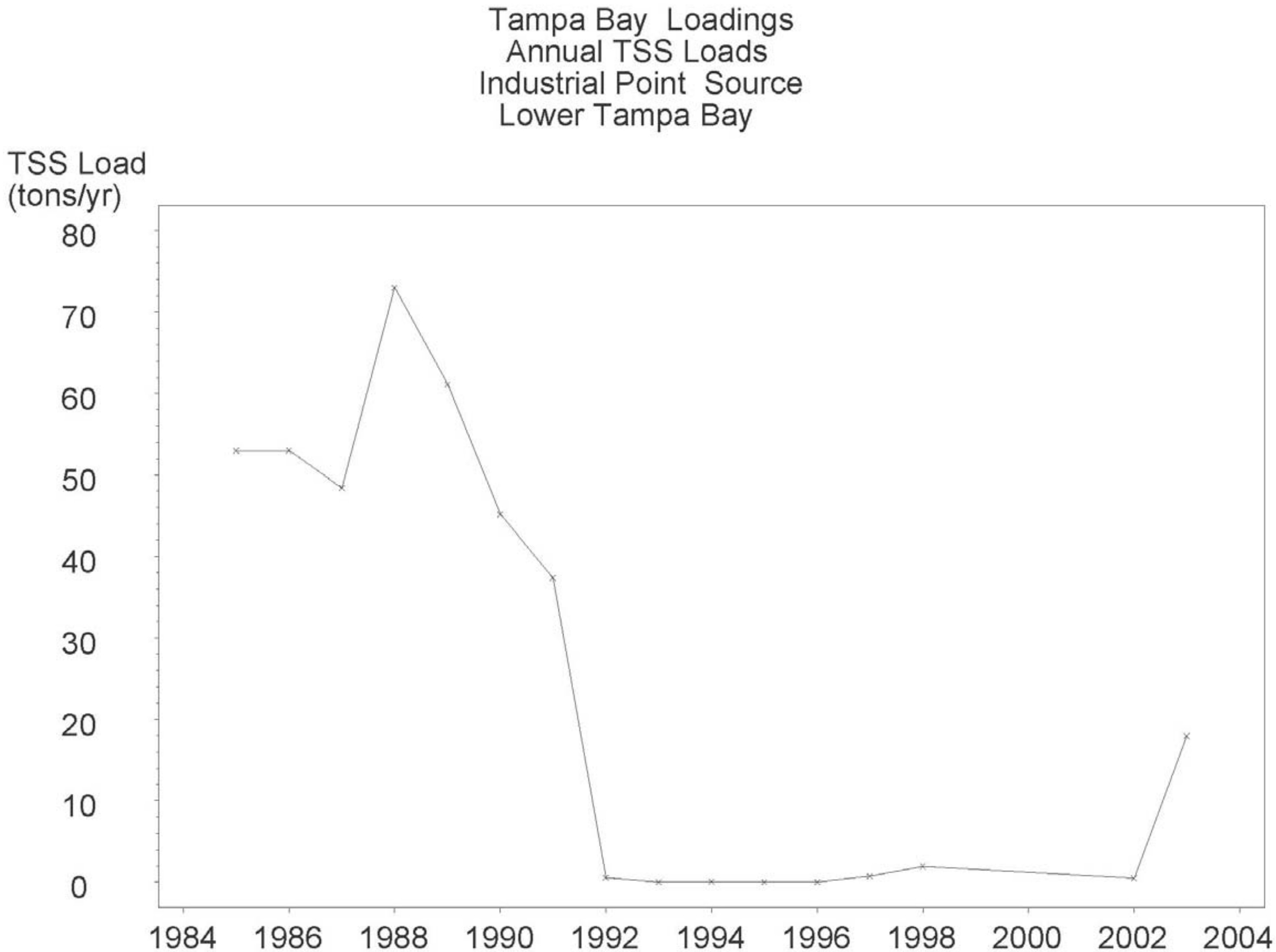
Tampa Bay Loadings
Annual Total Phosphorus Loads
Industrial Point Source
Lower Tampa Bay

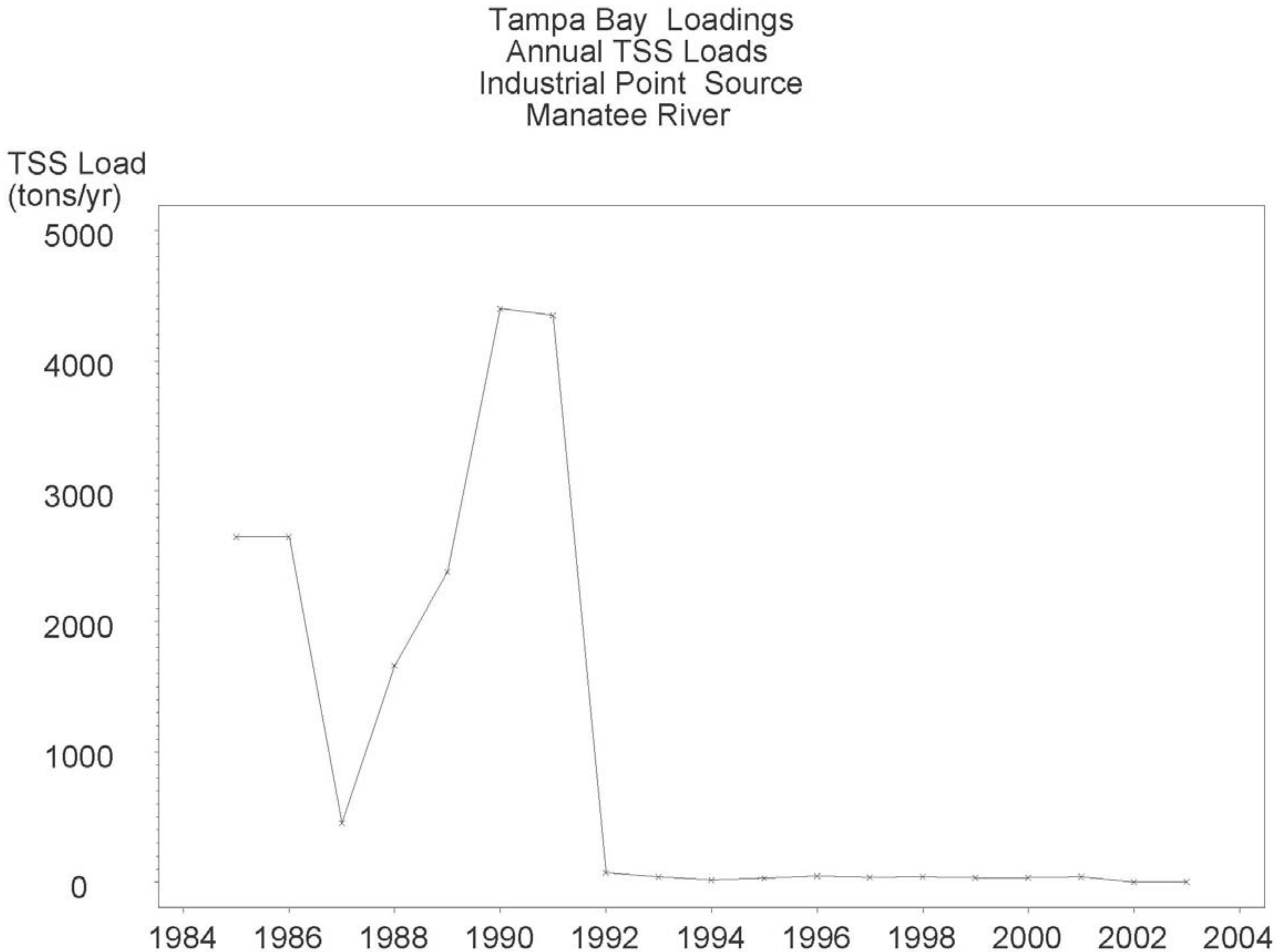

Tampa Bay Loadings
Annual Total Phosphorus Loads
Industrial Point Source
Manatee River
TP Load
(tons/yr)
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

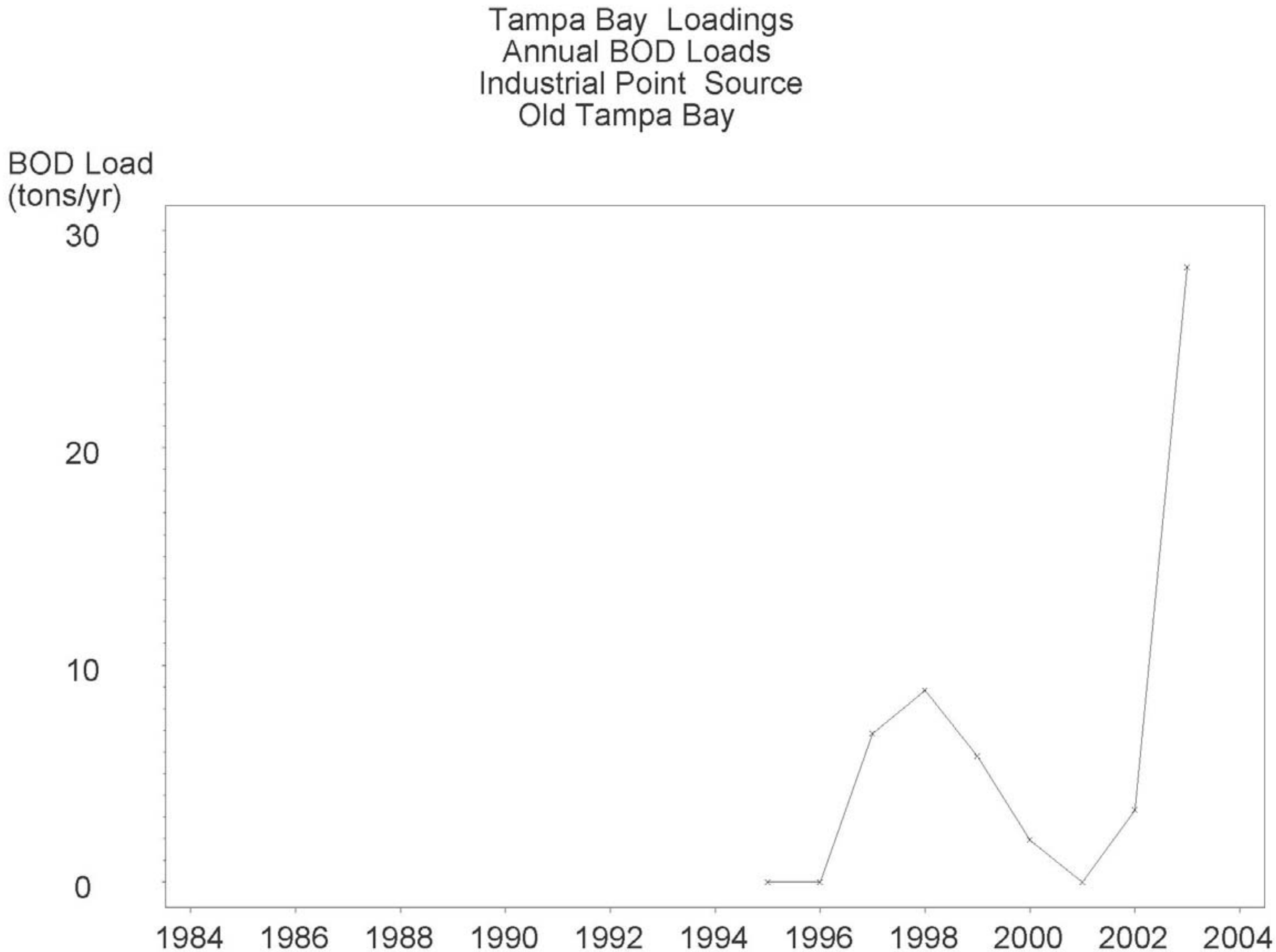

Tampa Bay Loadings
Annual TSS Loads
Industrial Point Source
Old Tampa Bay
TSS Load
(tons/yr)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

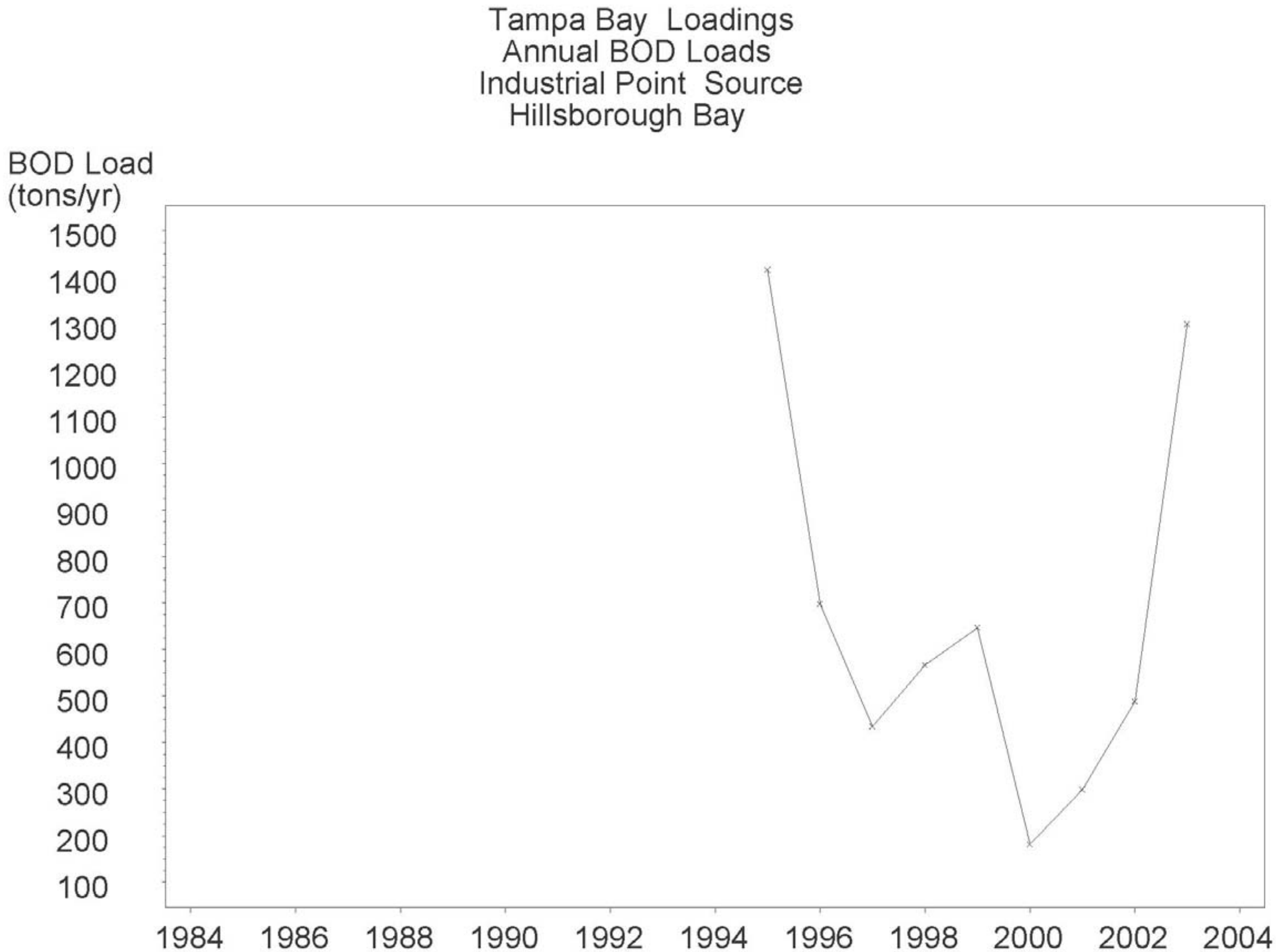

Tampa Bay Loadings
Annual TSS Loads
Industrial Point Source
Hillsborough Bay
TSS Load
(tons/yr)
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual TSS Loads
Industrial Point Source
Middle Tampa Bay
TSS Load
(tons/yr)
800
700
600
500
400
300
200
100
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

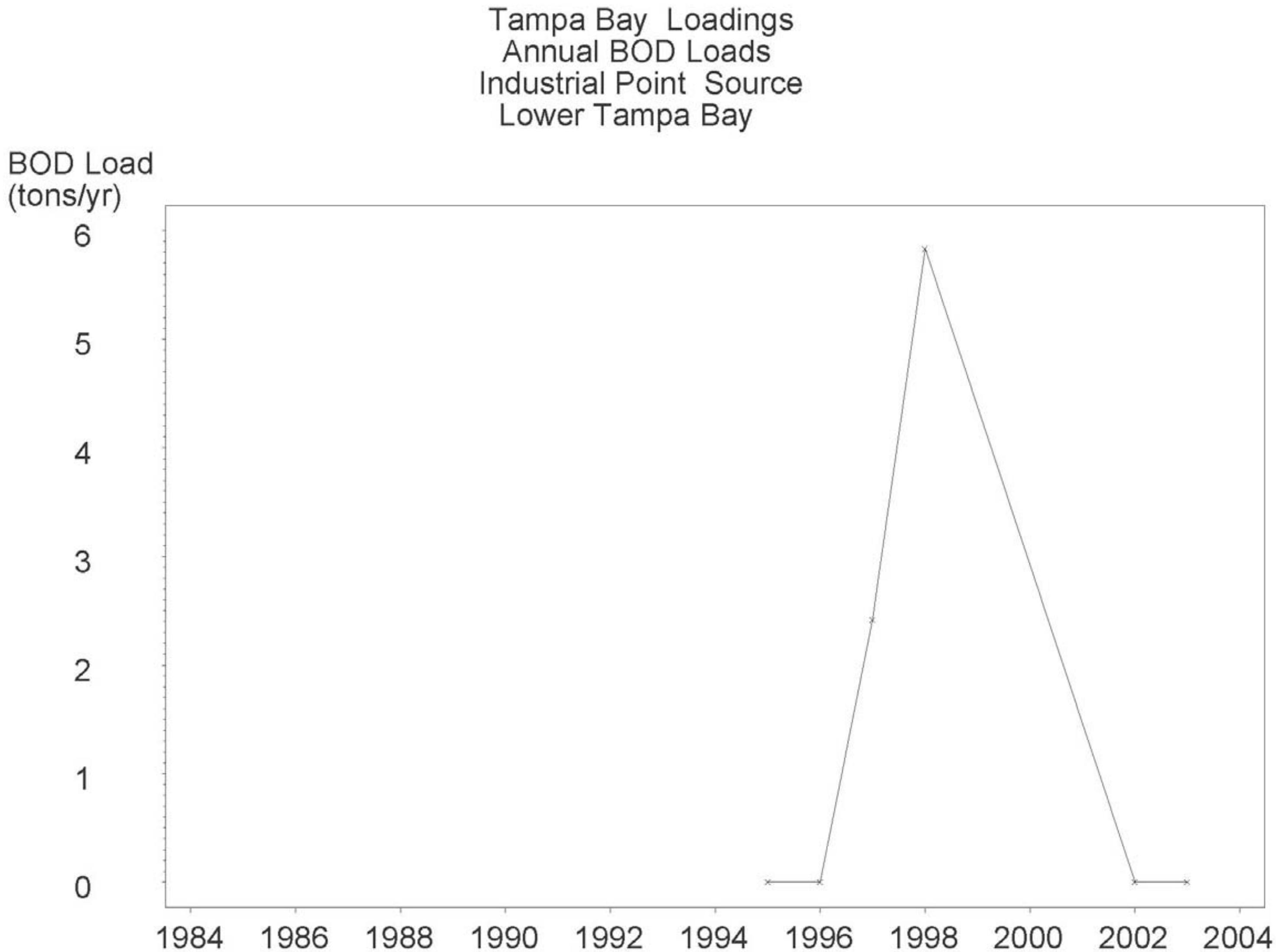

Tampa Bay Loadings
Annual TSS Loads
Industrial Point Source
Lower Tampa Bay
TSS Load
(tons/yr)
80
70
60
50
40
30
20
10
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

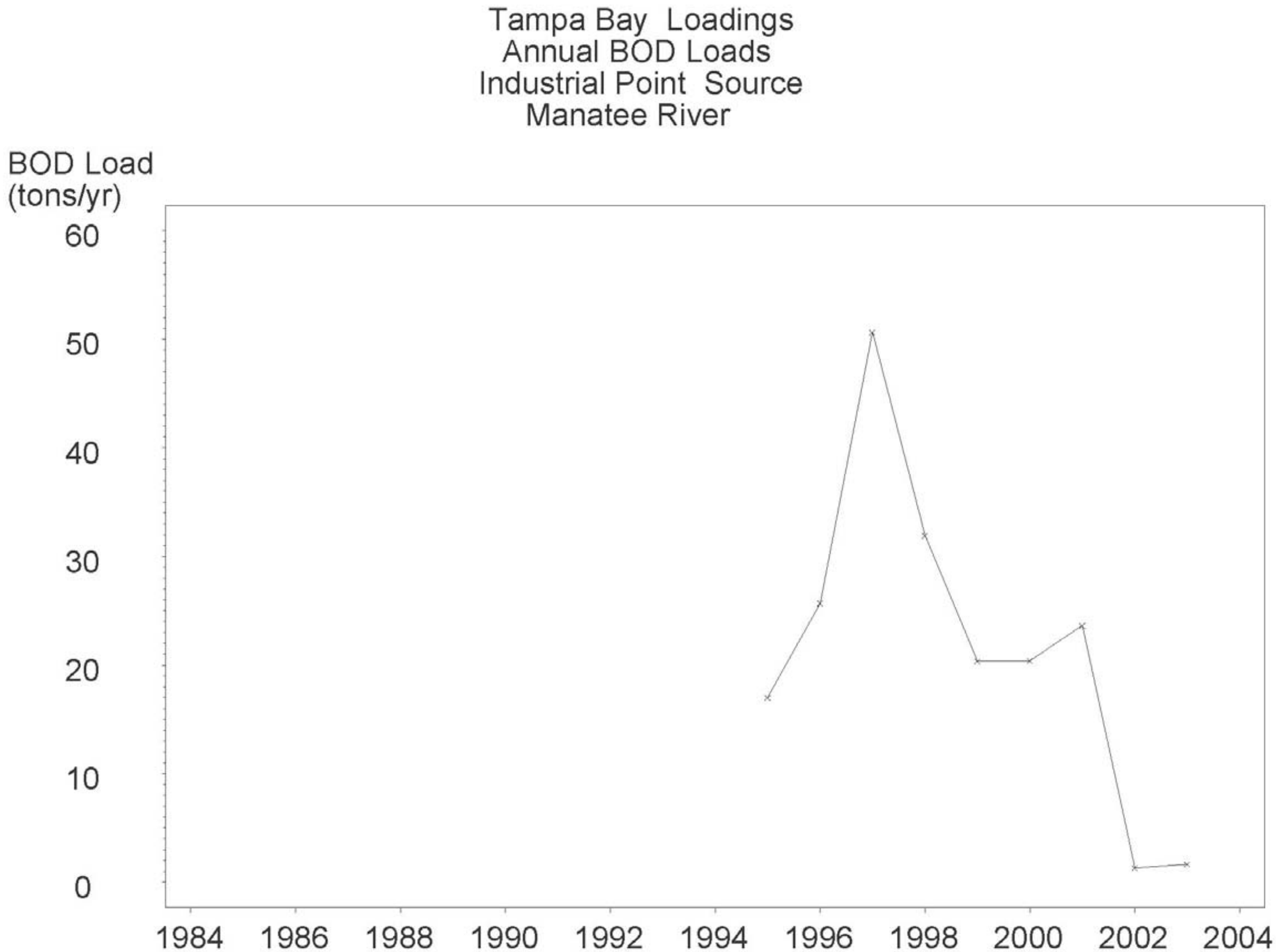

Tampa Bay Loadings
Annual TSS Loads
Industrial Point Source
Manatee River
TSS Load
(tons/yr)
5000
4000
3000
2000
1000
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

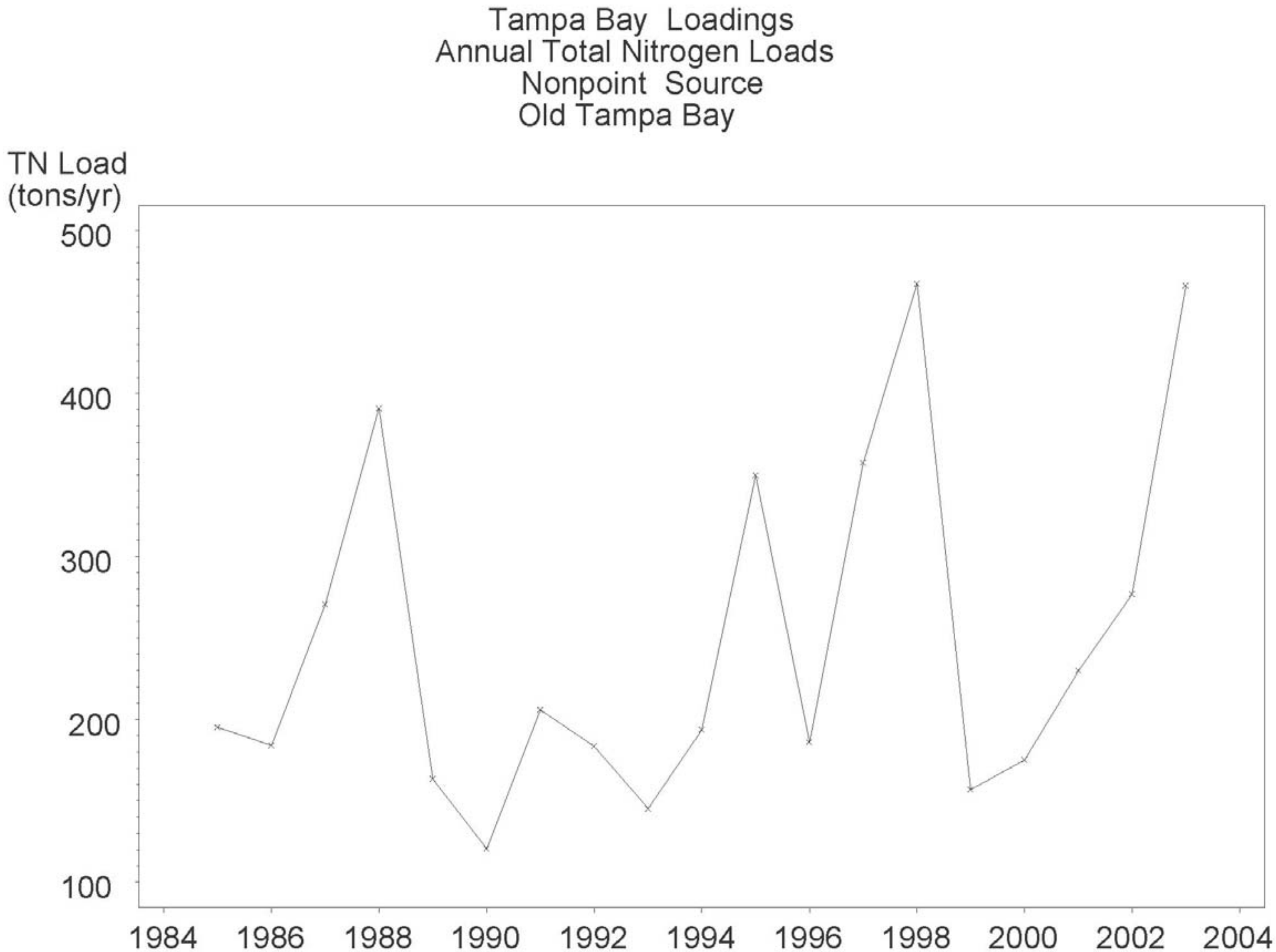

Tampa Bay Loadings
Annual BOD Loads
Industrial Point Source
Old Tampa Bay
BOD Load
(tons/yr)
30
20
10
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

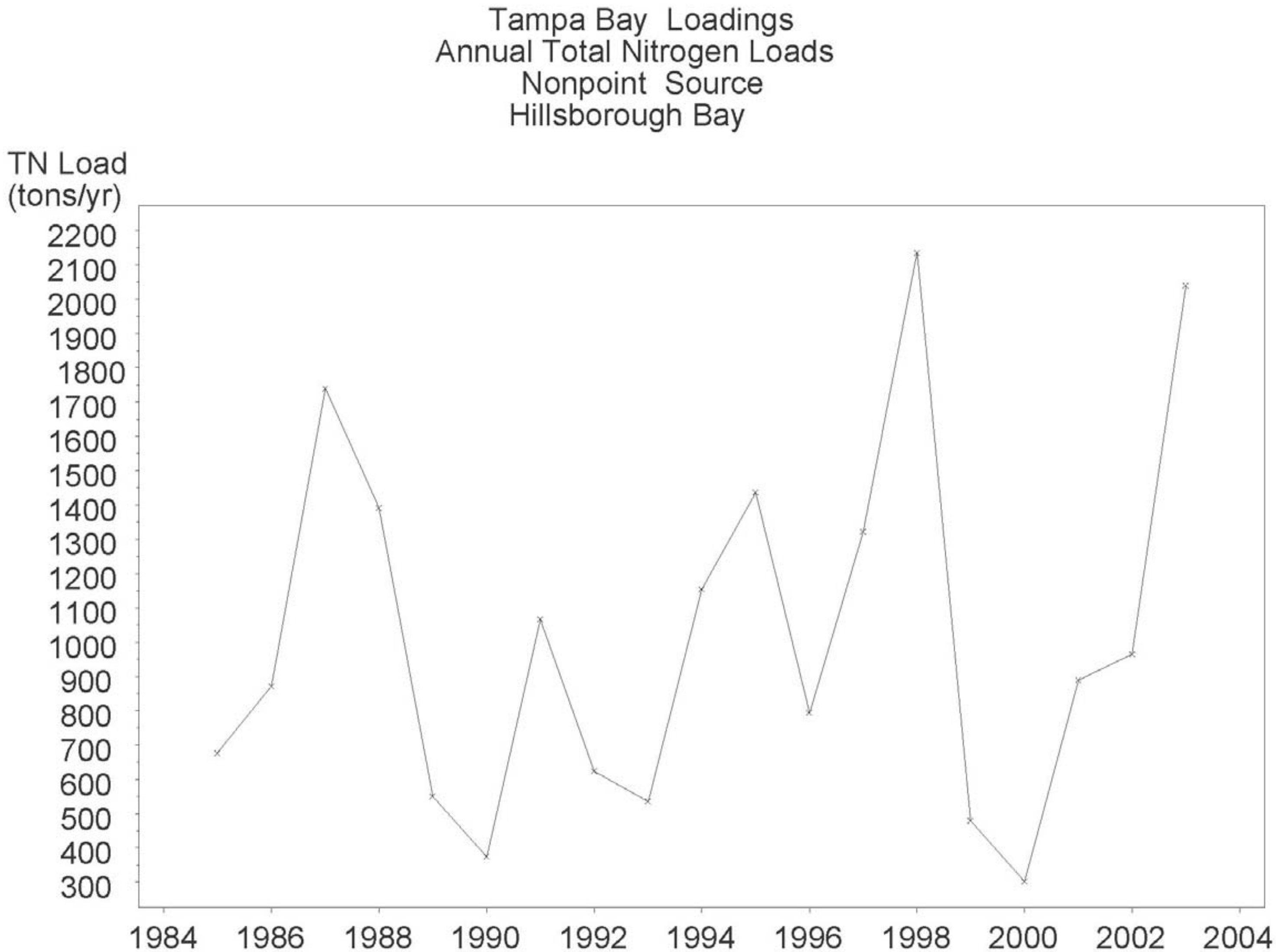

Tampa Bay Loadings
Annual BOD Loads
Industrial Point Source
Hillsborough Bay
BOD Load
(tons/yr)
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

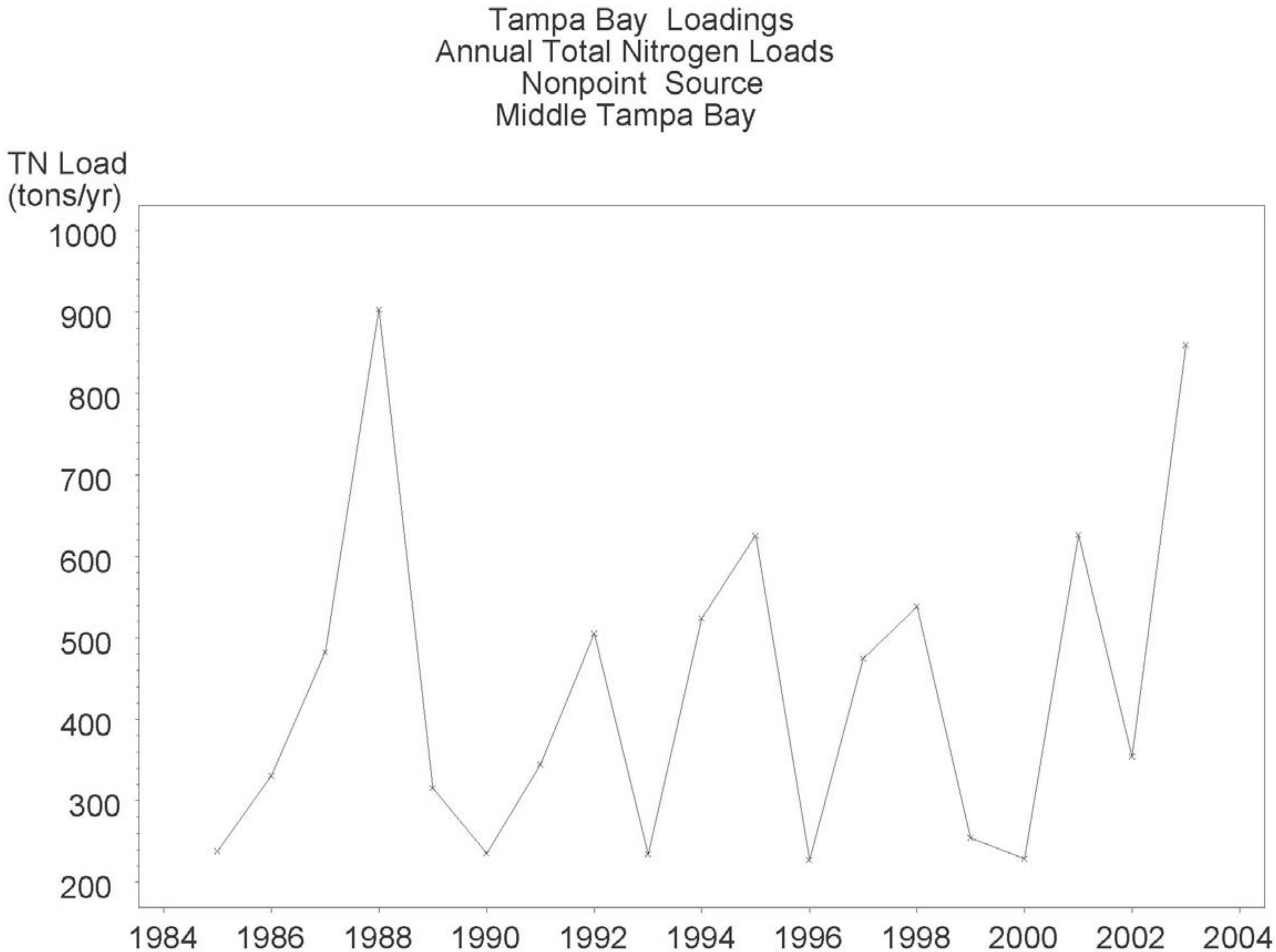

Tampa Bay Loadings
Annual BOD Loads
Industrial Point Source
Middle Tampa Bay
BOD Load
(tons/yr)
500
400
300
200
100
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual BOD Loads
Industrial Point Source
Lower Tampa Bay
BOD Load
(tons/yr)
6
5
4
3
2
1
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

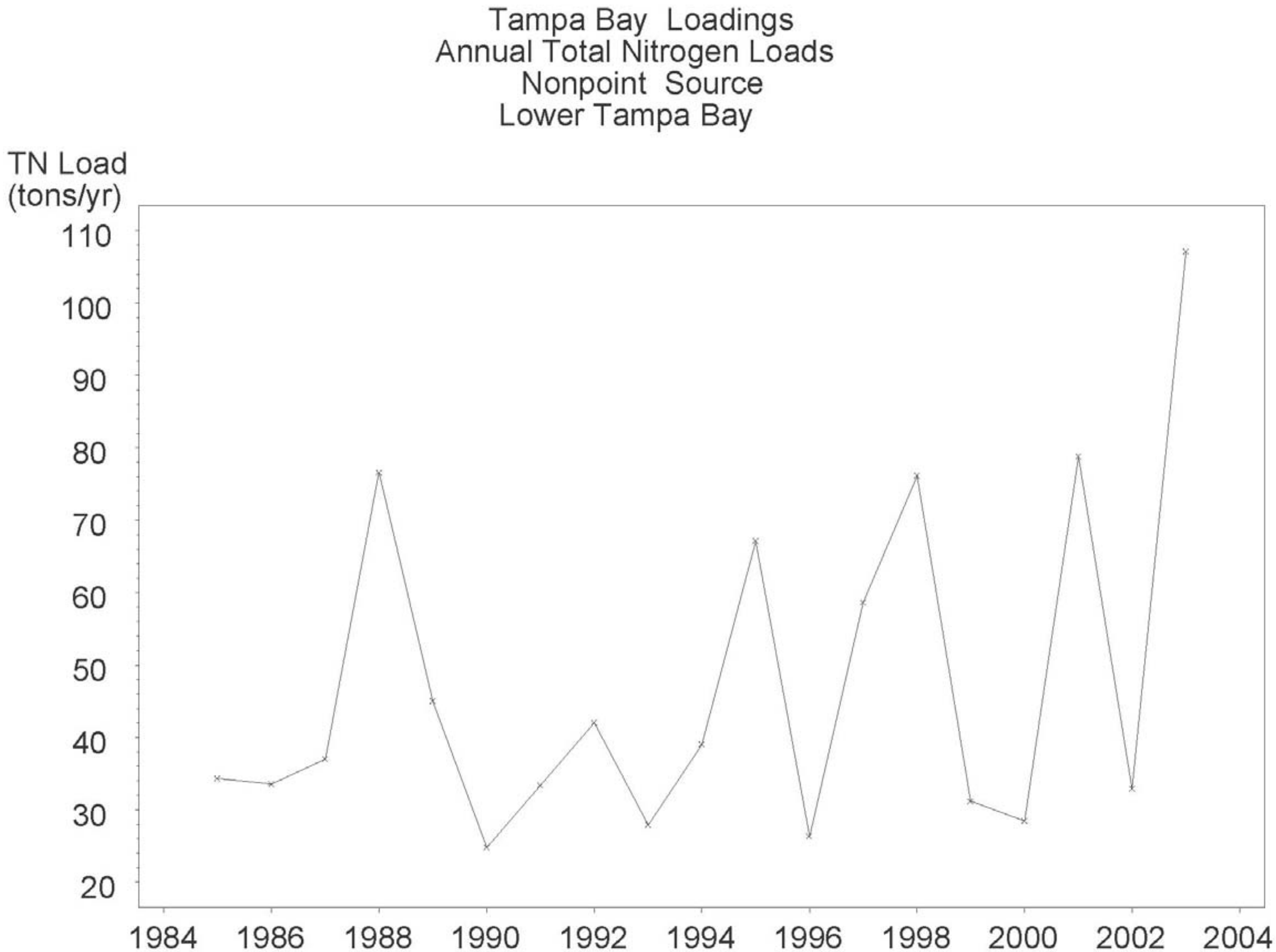

Tampa Bay Loadings
Annual BOD Loads
Industrial Point Source
Manatee River
BOD Load
(tons/yr)
60
50
40
30
20
10
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

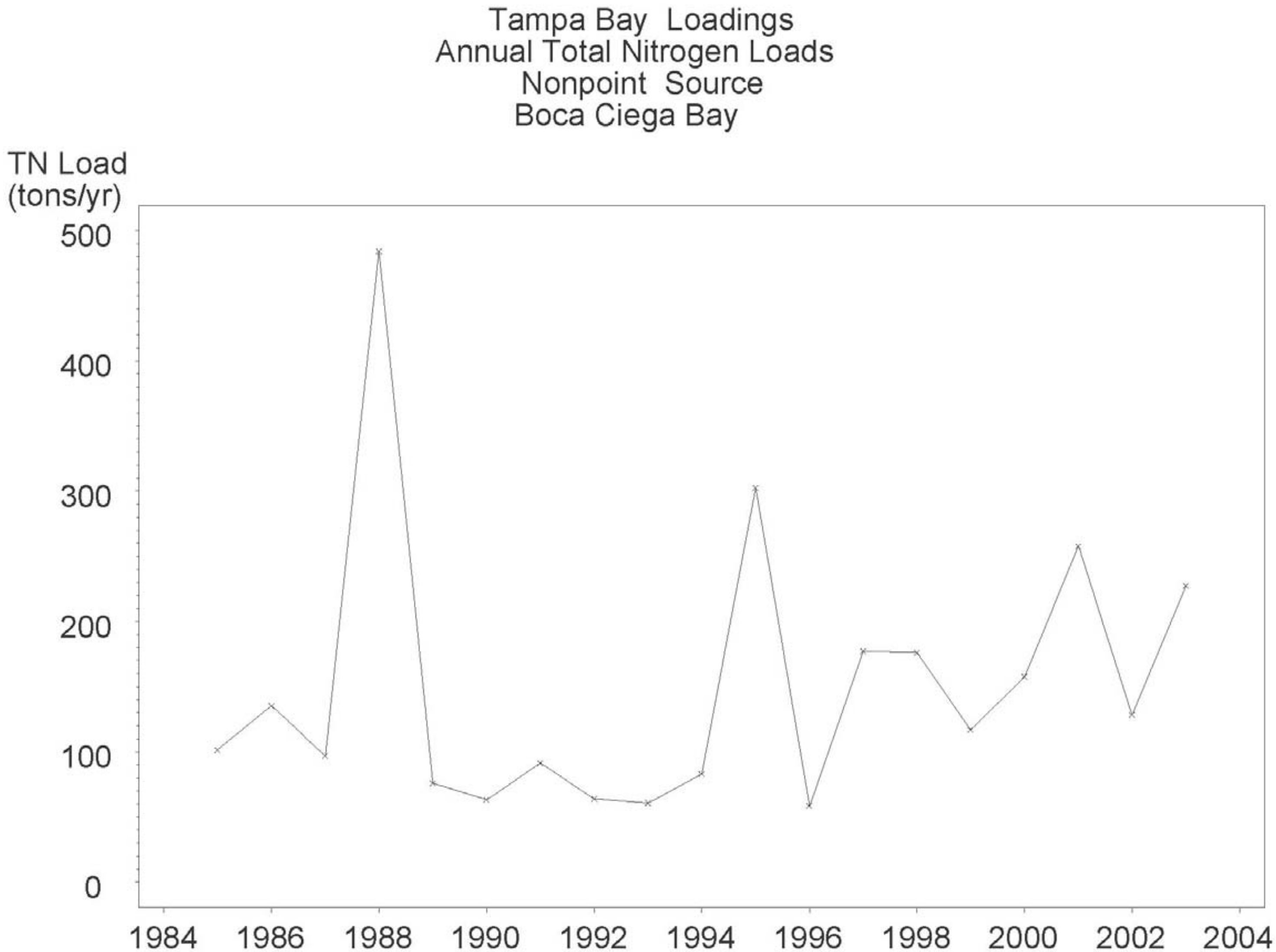

Tampa Bay Loadings
Annual Total Nitrogen Loads
Nonpoint Source
Old Tampa Bay
TN Load
(tons/yr)
500
400
300
200
100
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

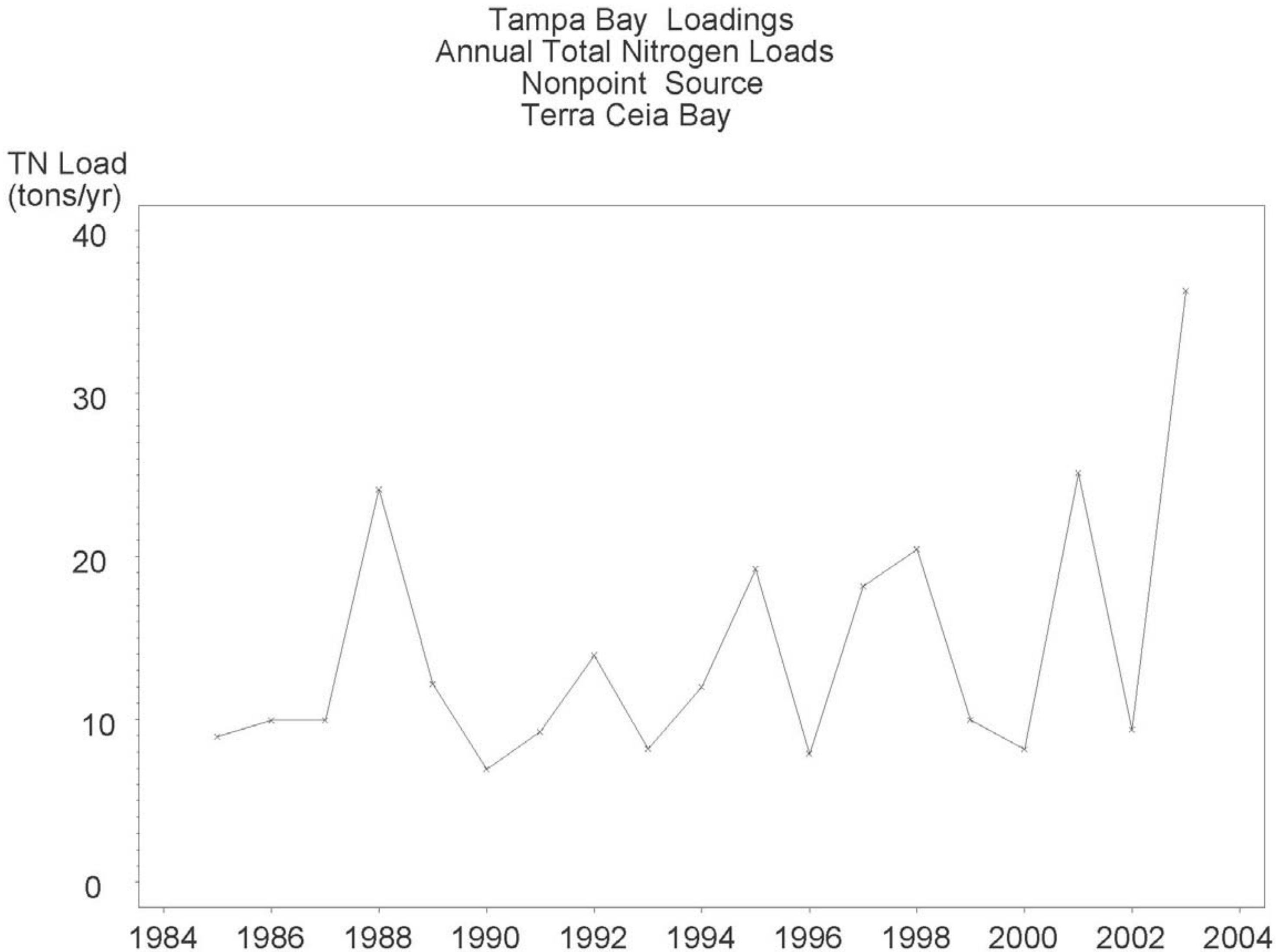

Tampa Bay Loadings
Annual Total Nitrogen Loads
Nonpoint Source
Hillsborough Bay
TN Load
(tons/yr)
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

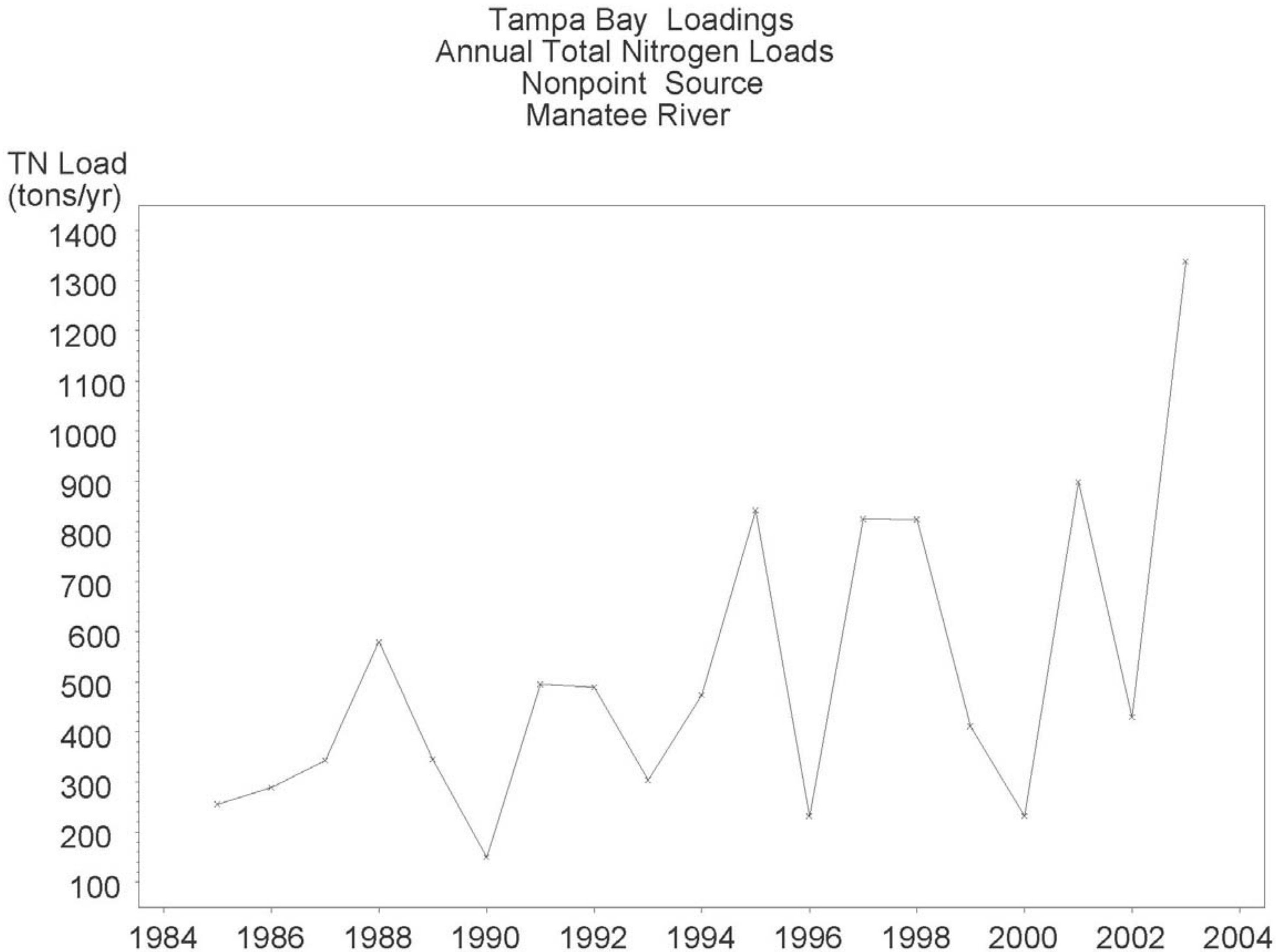


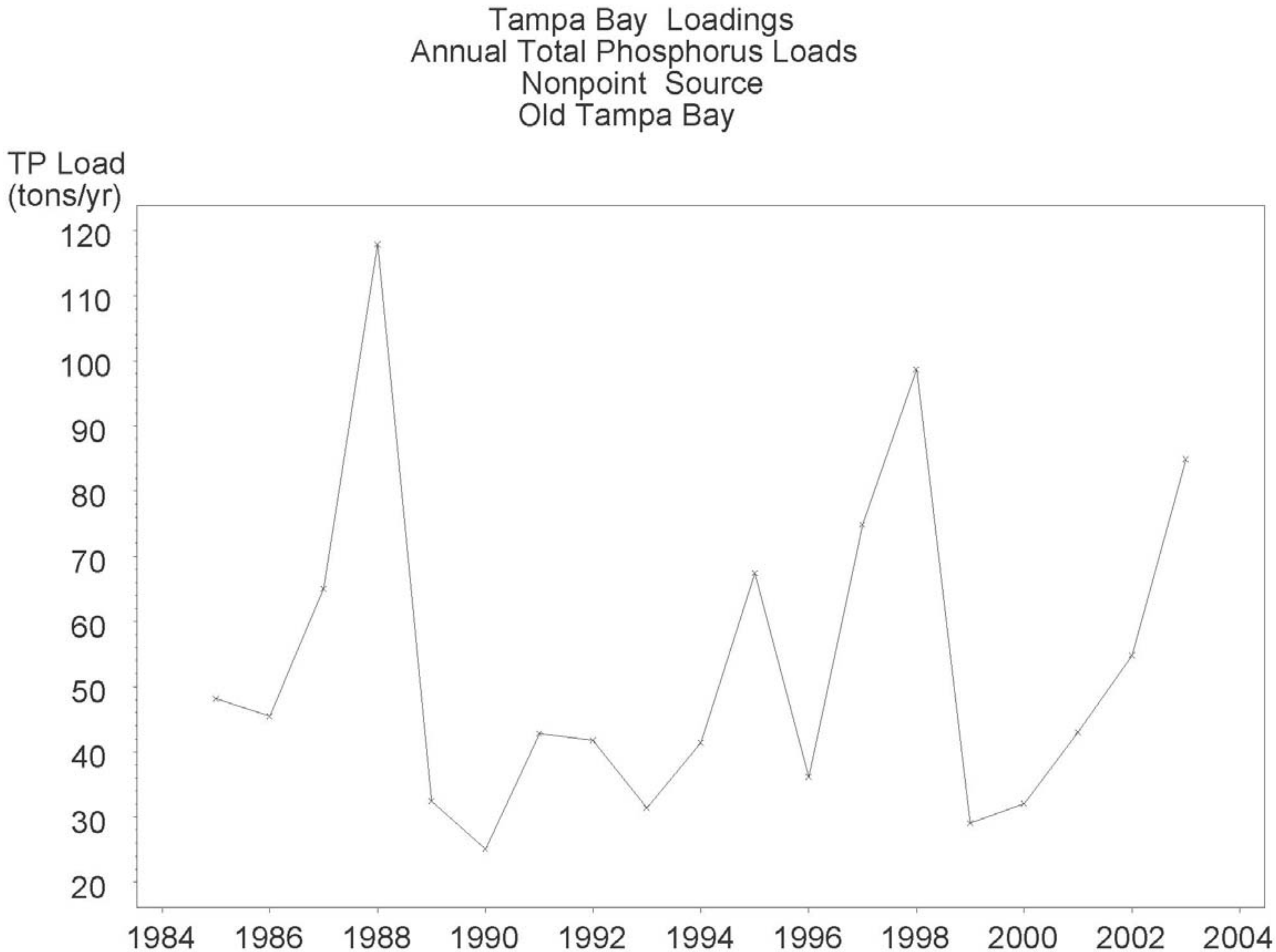
Tampa Bay Loadings
Annual Total Nitrogen Loads
Nonpoint Source
Middle Tampa Bay
TN Load
(tons/yr)
1000
900
800
700
600
500
400
300
200
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

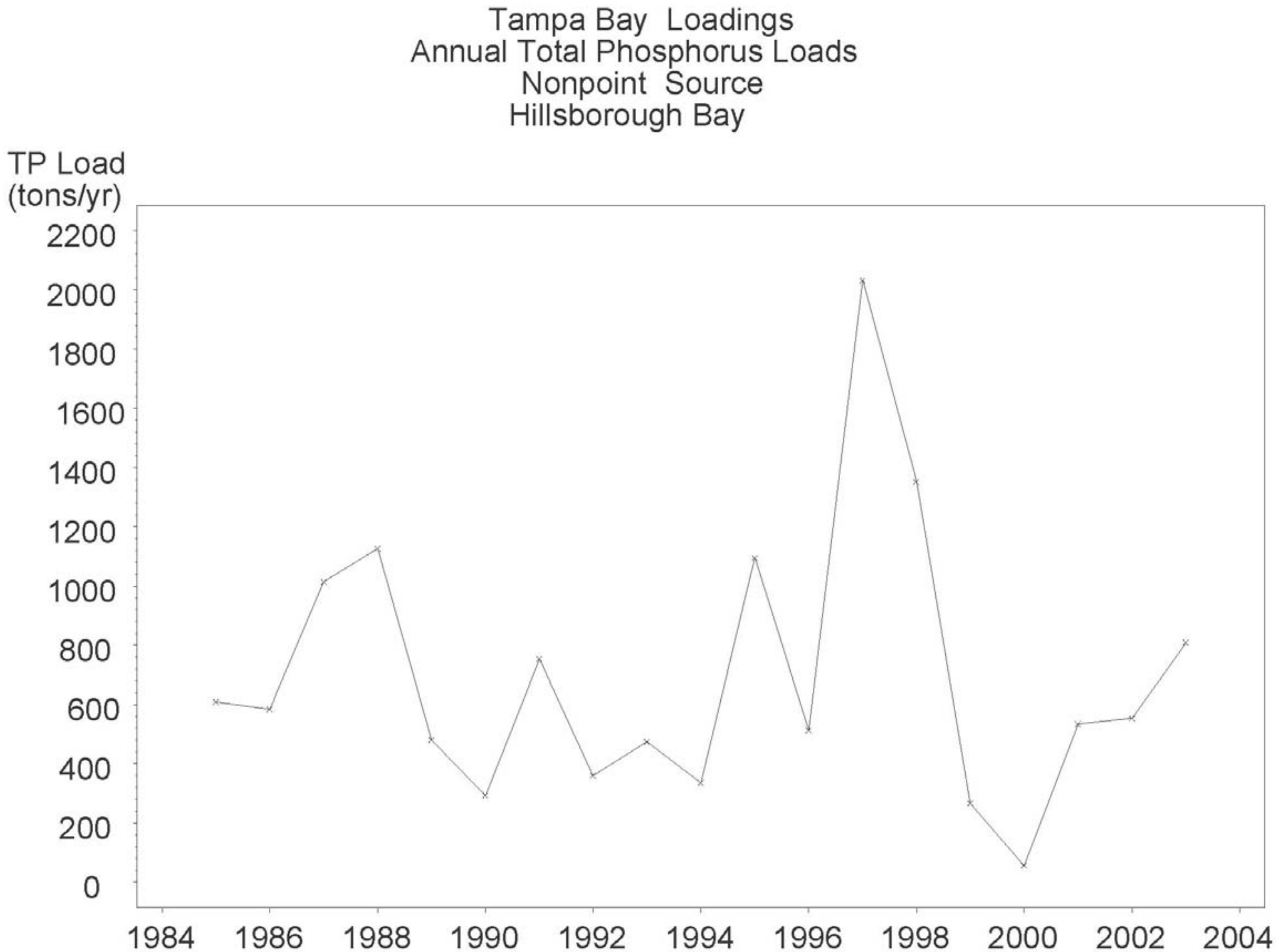

Tampa Bay Loadings
Annual Total Nitrogen Loads
Nonpoint Source
Lower Tampa Bay
TN Load
(tons/yr)
110
100
90
80
70
60
50
40
30
20
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual Total Nitrogen Loads
Nonpoint Source
Boca Ciega Bay
TN Load
(tons/yr)
500
400
300
200
100
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

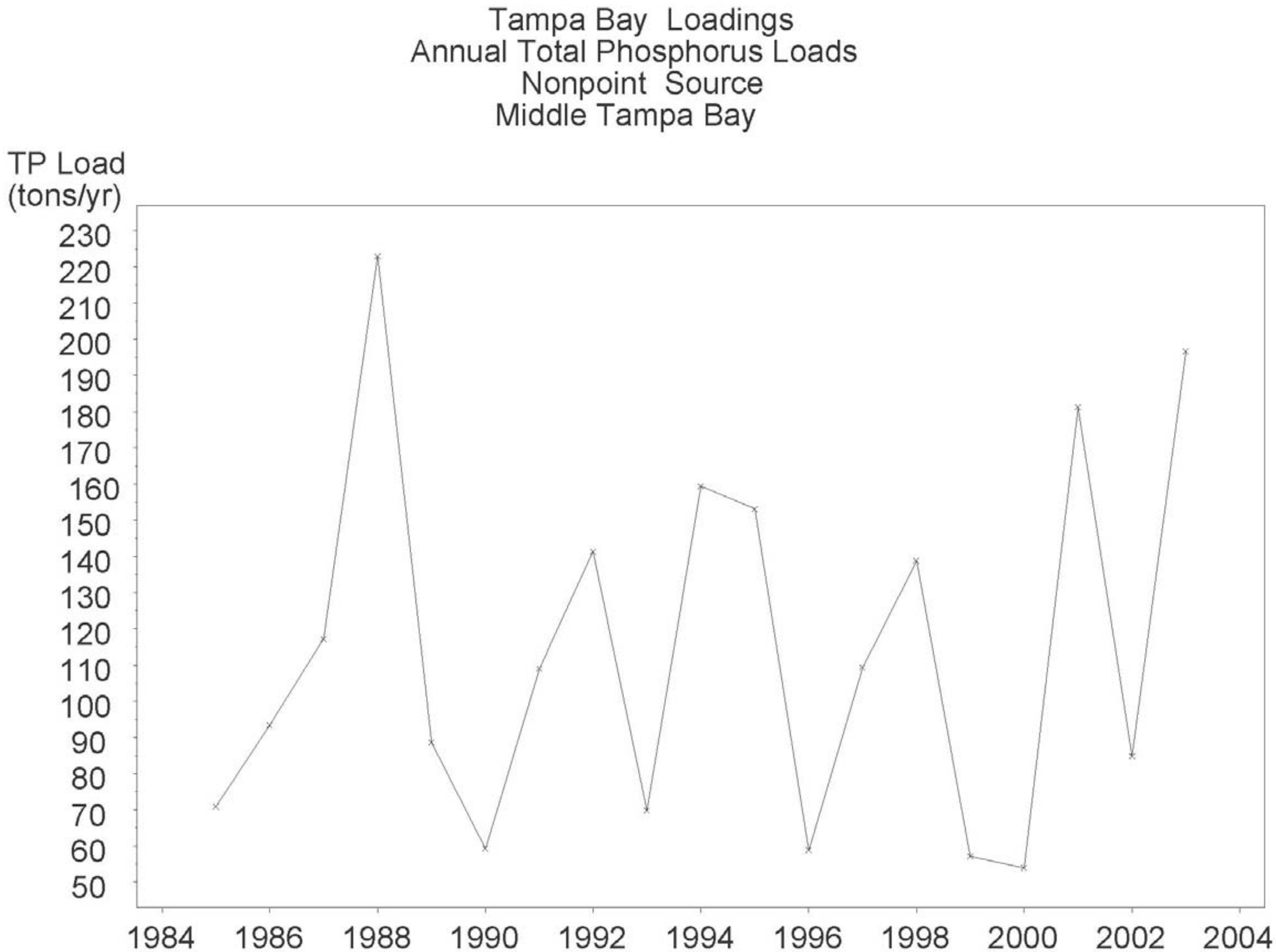

Tampa Bay Loadings
Annual Total Nitrogen Loads
Nonpoint Source
Terra Ceia Bay
TN Load
(tons/yr)
40
30
20
10
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

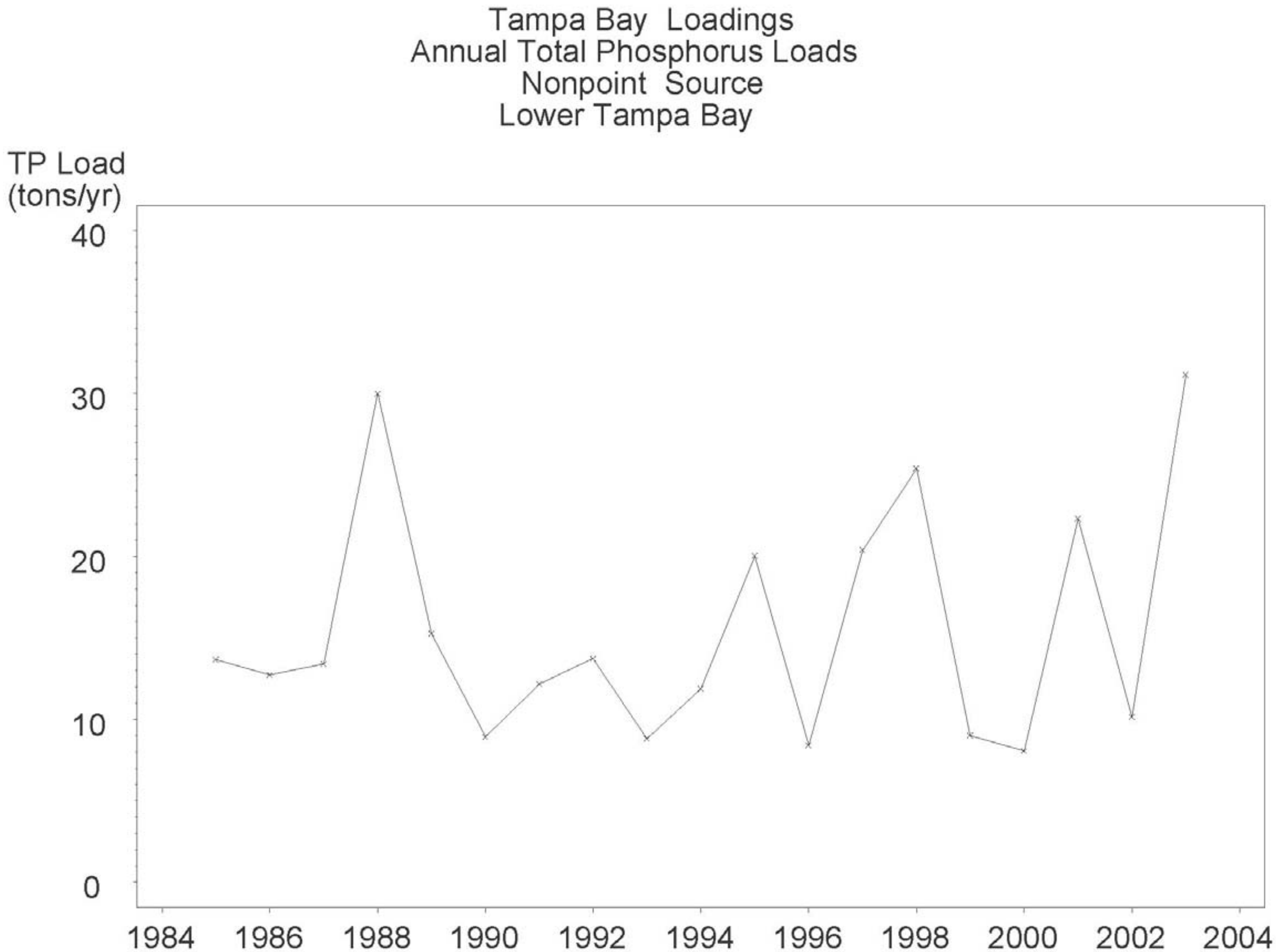

Tampa Bay Loadings
Annual Total Nitrogen Loads
Nonpoint Source
Manatee River
TN Load
(tons/yr)
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

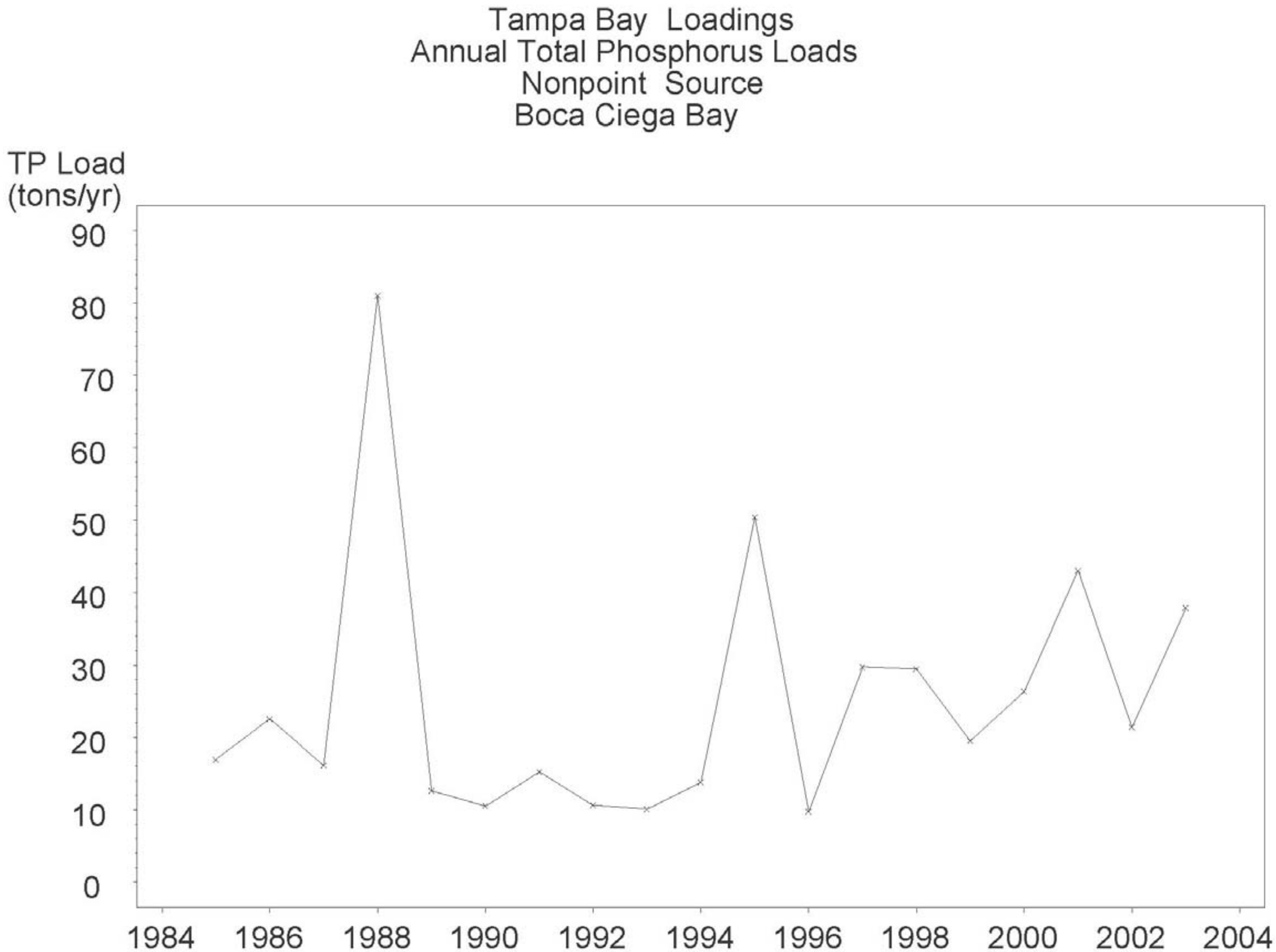

Tampa Bay Loadings
Annual Total Phosphorus Loads
Nonpoint Source
Old Tampa Bay
TP Load
(tons/yr)
120
110
100
90
80
70
60
50
40
30
20
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

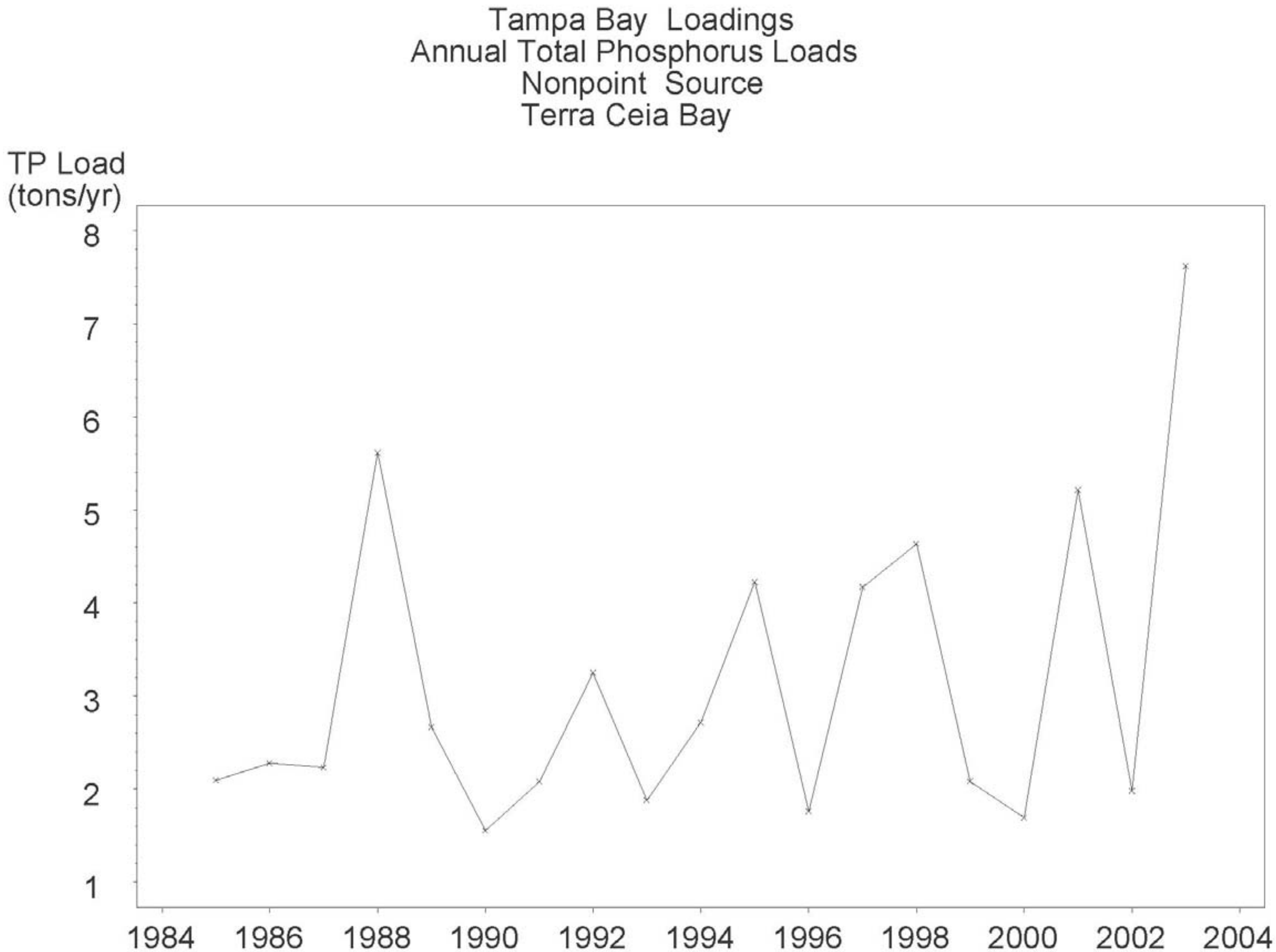


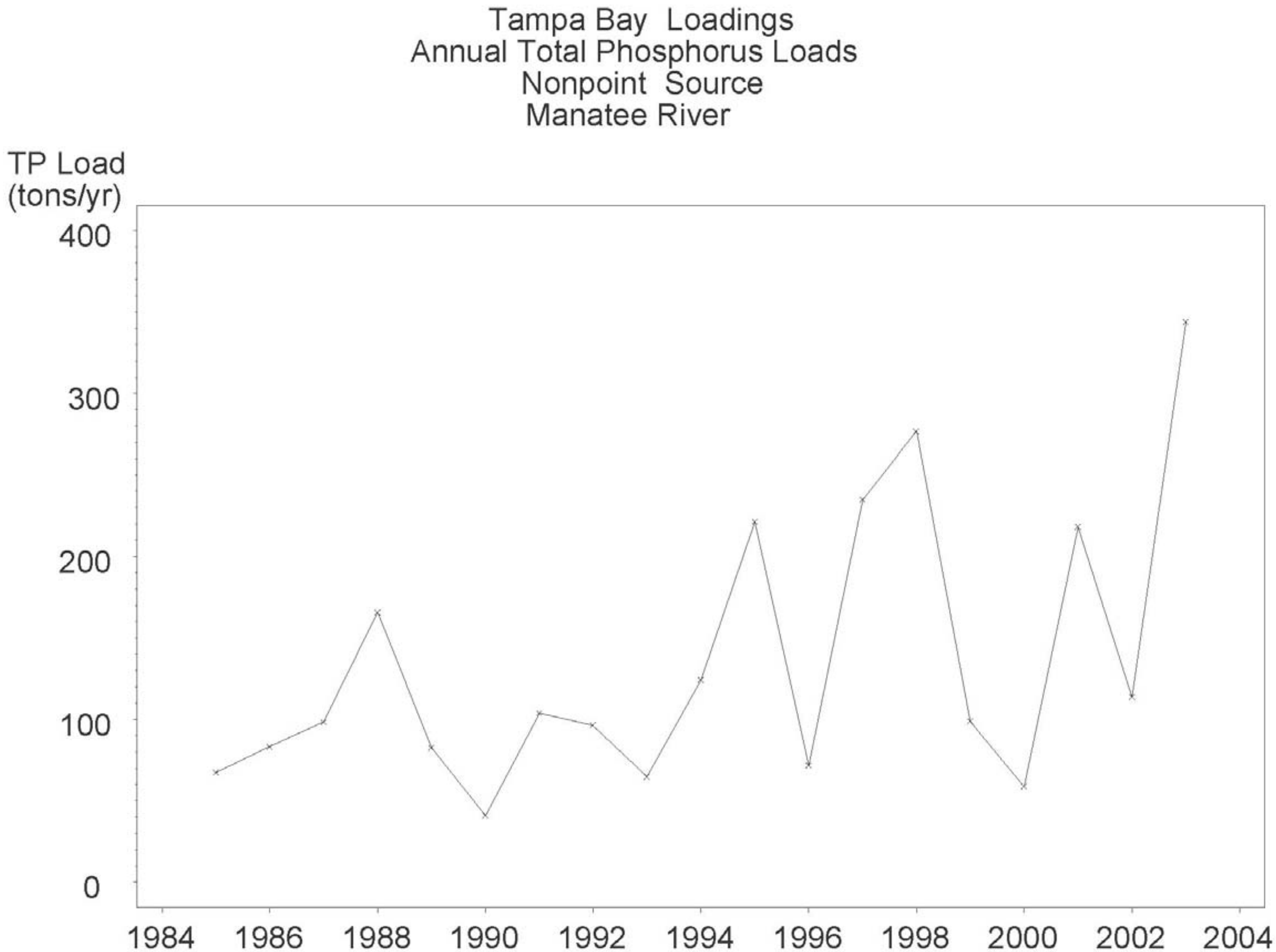
Tampa Bay Loadings
Annual Total Phosphorus Loads
Nonpoint Source
Hillsborough Bay
TP Load
(tons/yr)
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

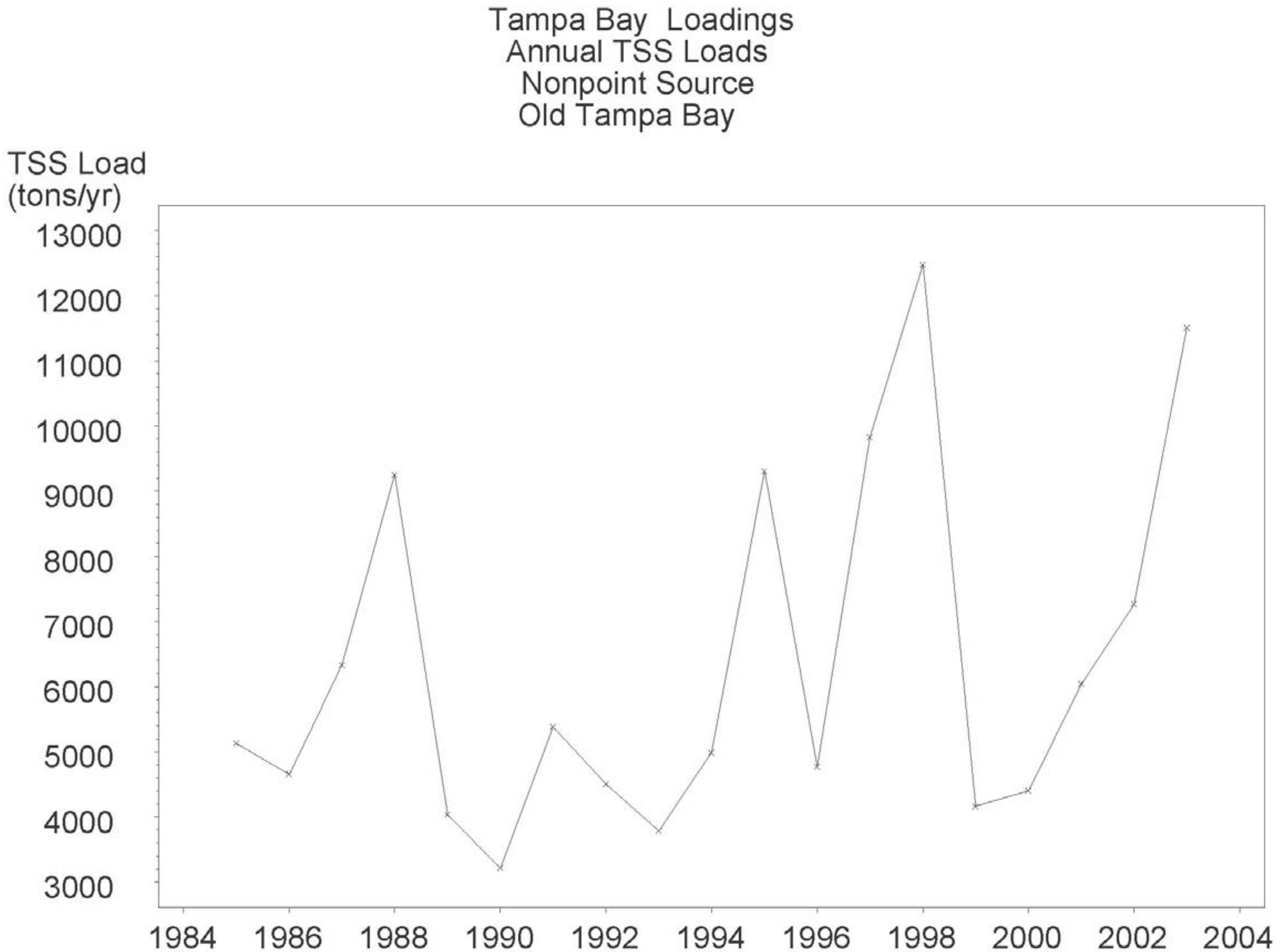

Tampa Bay Loadings
Annual Total Phosphorus Loads
Nonpoint Source
Middle Tampa Bay
TP Load
(tons/yr)
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual Total Phosphorus Loads
Nonpoint Source
Lower Tampa Bay
TP Load
(tons/yr)
40
30
20
10
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

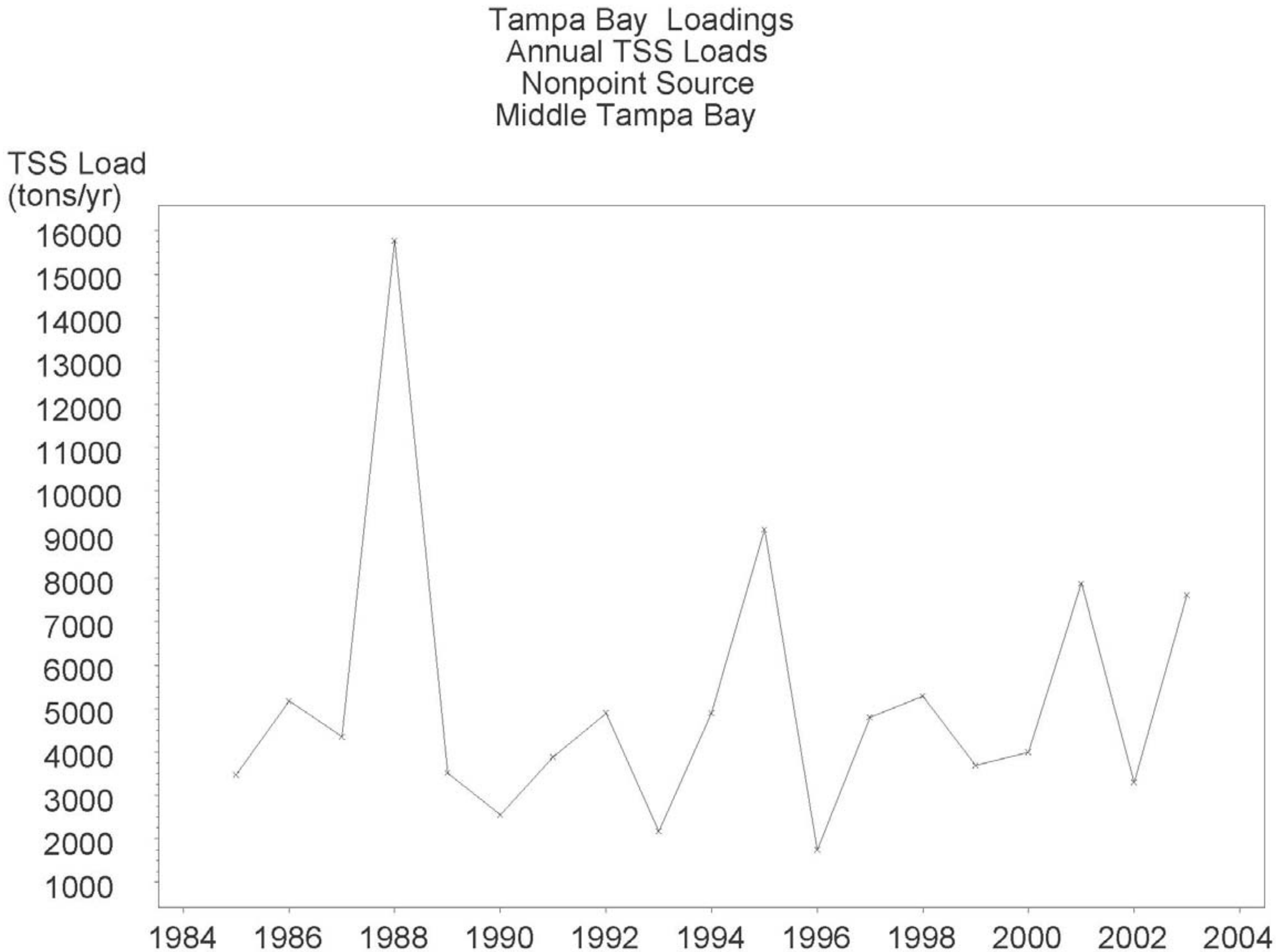

Tampa Bay Loadings
Annual Total Phosphorus Loads
Nonpoint Source
Boca Ciega Bay
TP Load
(tons/yr)
90
80
70
60
50
40
30
20
10
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

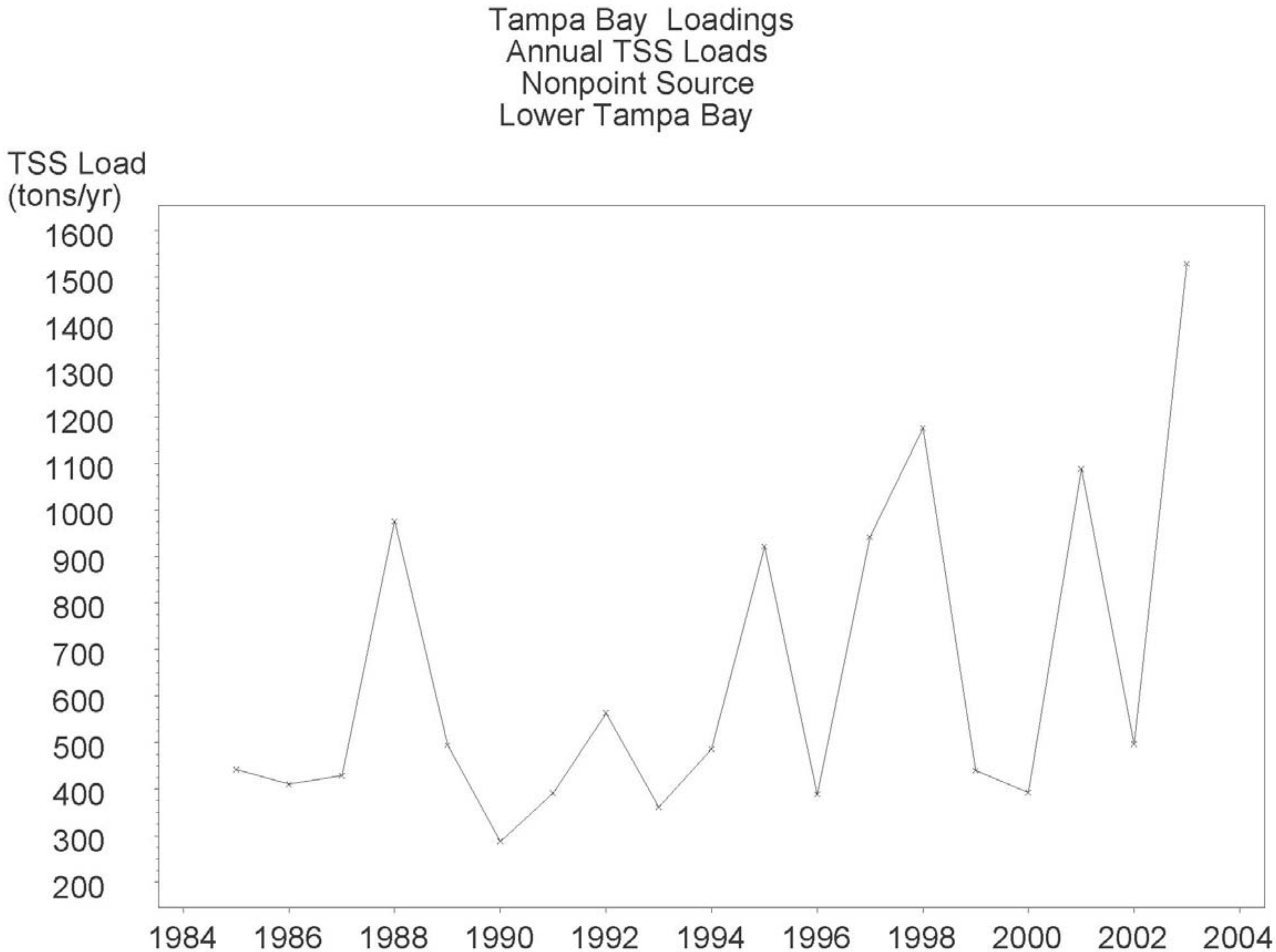

Tampa Bay Loadings
Annual Total Phosphorus Loads
Nonpoint Source
Terra Ceia Bay
TP Load
(tons/yr)
8
7
6
5
4
3
2
1
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

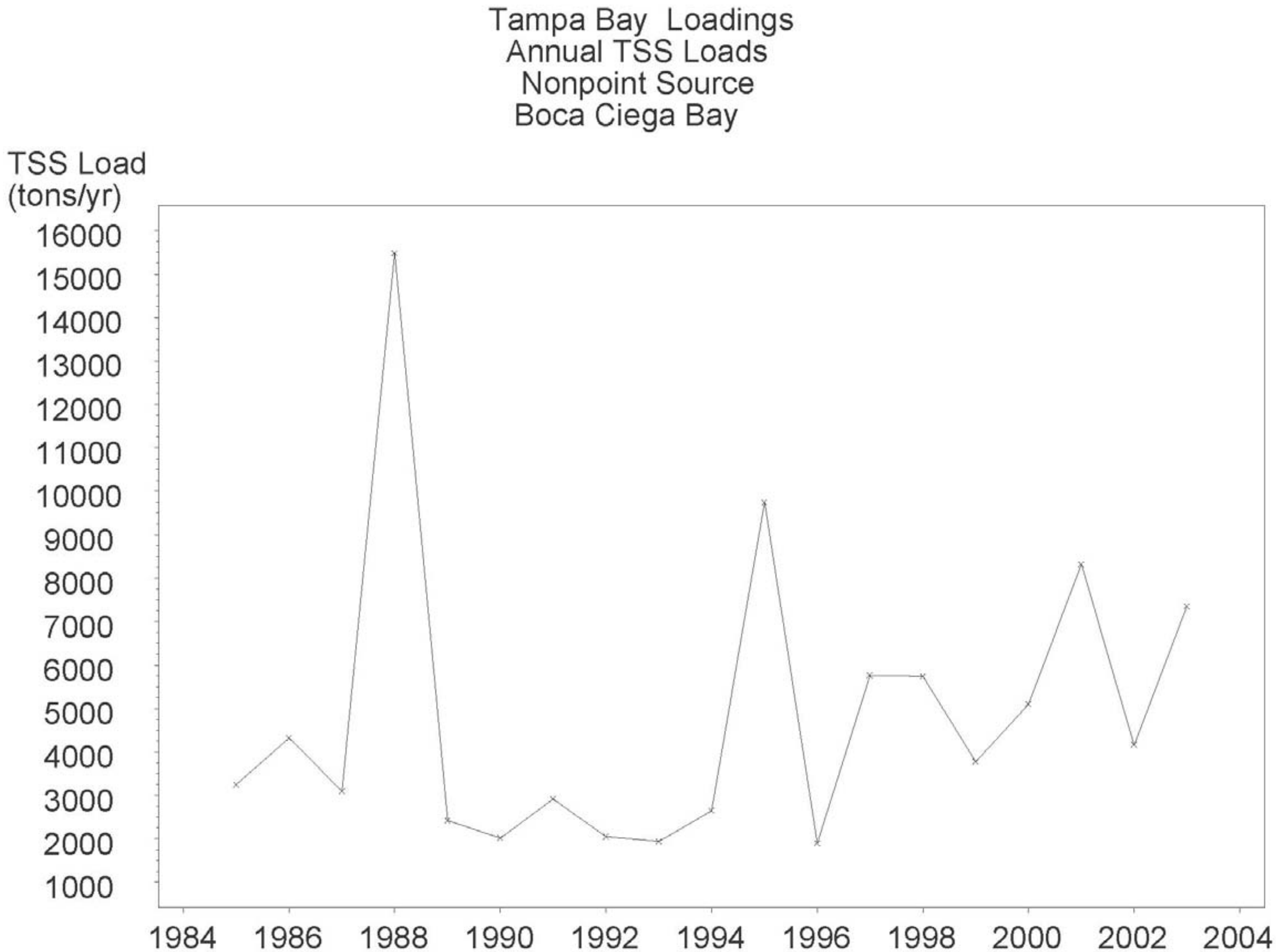

Tampa Bay Loadings
Annual Total Phosphorus Loads
Nonpoint Source
Manatee River
TP Load
(tons/yr)
400
300
200
100
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

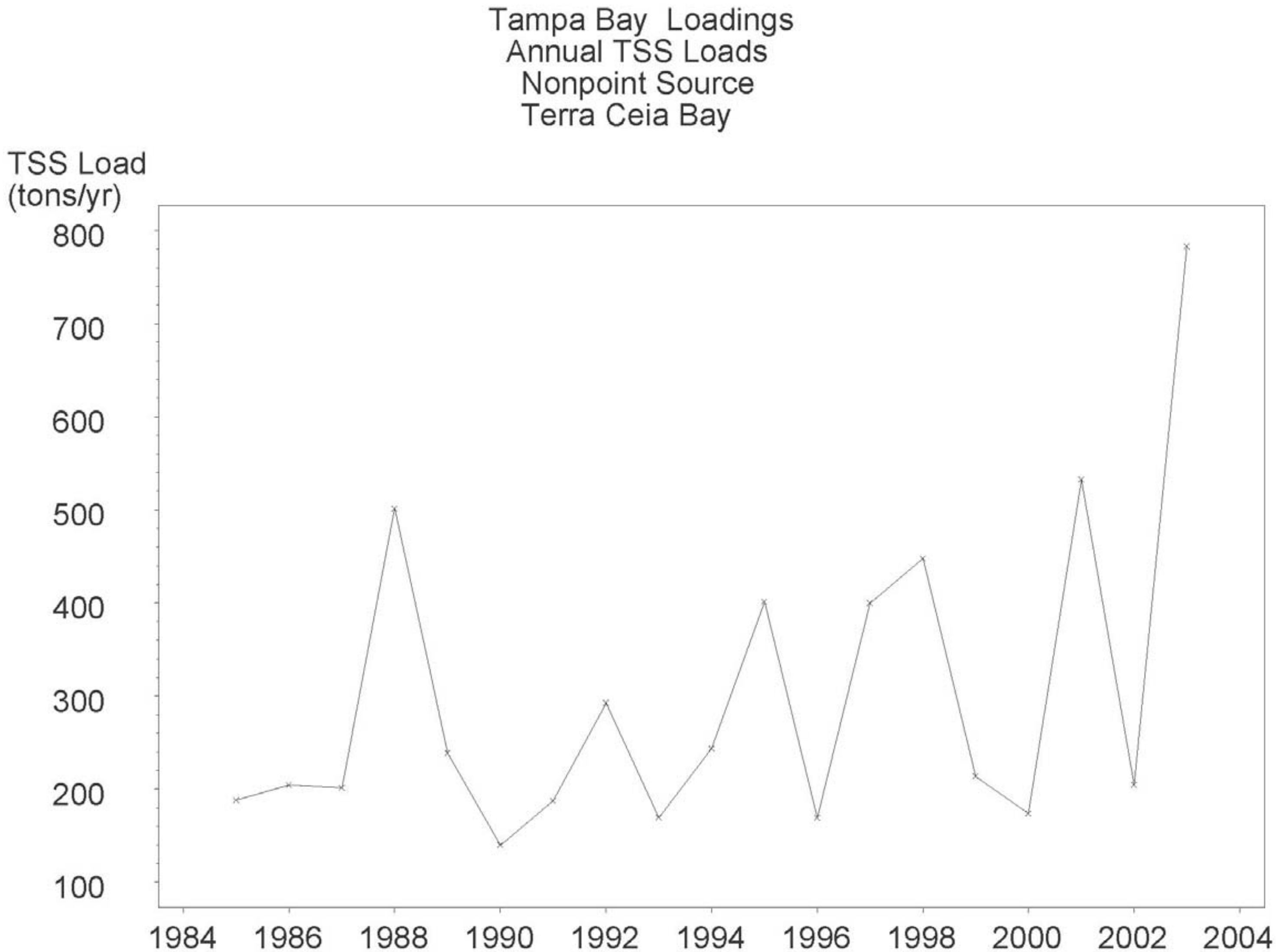

Tampa Bay Loadings
Annual TSS Loads
Nonpoint Source
Old Tampa Bay
TSS Load (tons/yr)
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

Tampa Bay Loadings
Annual TSS Loads
Nonpoint Source
Hillsborough Bay

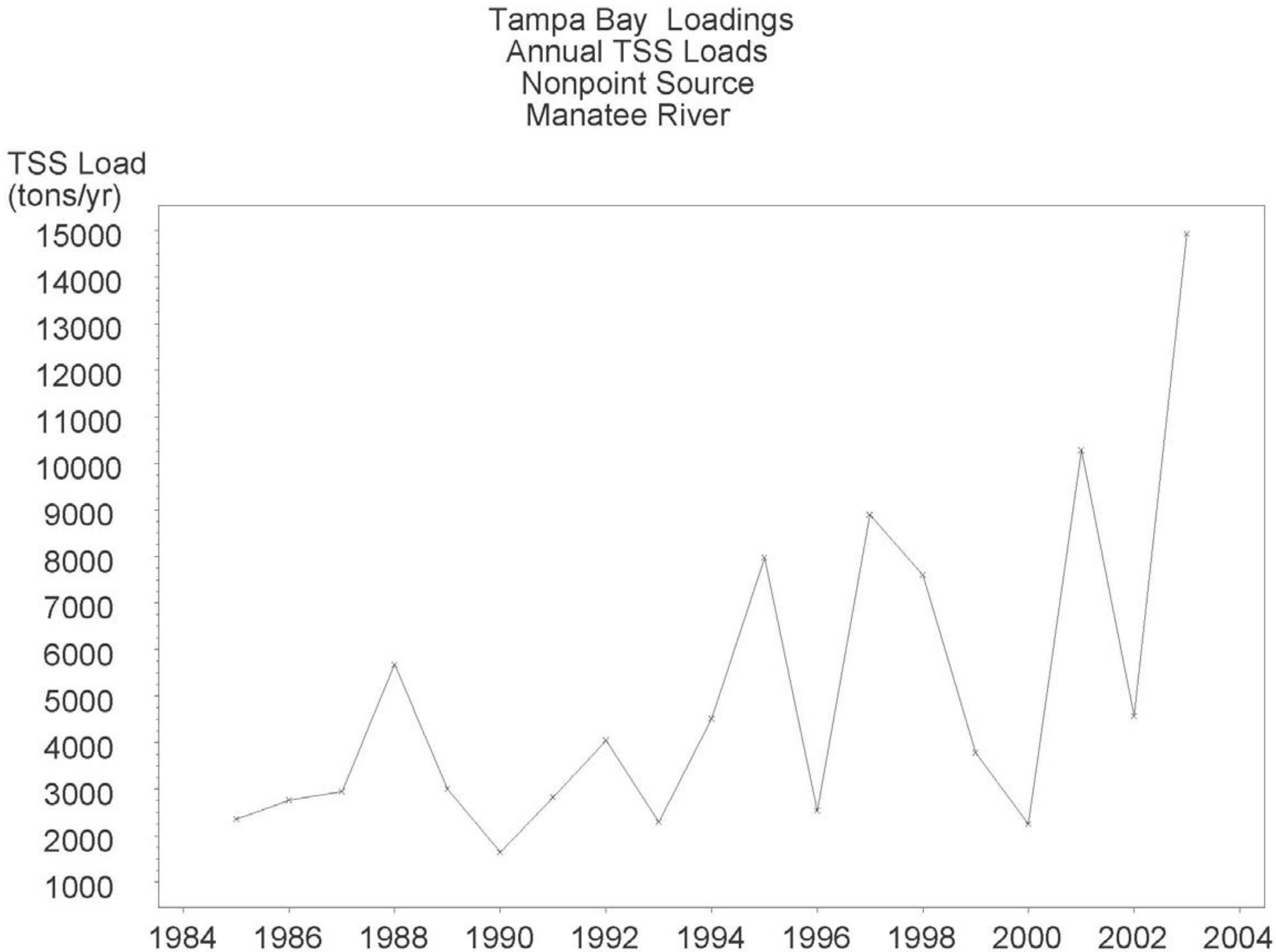

Tampa Bay Loadings
Annual TSS Loads
Nonpoint Source
Middle Tampa Bay
TSS Load
(tons/yr)
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual TSS Loads
Nonpoint Source
Lower Tampa Bay
TSS Load
(tons/yr)
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual TSS Loads
Nonpoint Source
Boca Ciega Bay
TSS Load
(tons/yr)
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004



Tampa Bay Loadings
Annual TSS Loads
Nonpoint Source
Terra Ceia Bay
TSS Load
(tons/yr)
800
700
600
500
400
300
200
100
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004



Tampa Bay Loadings
Annual TSS Loads
Nonpoint Source
Manatee River
TSS Load
(tons/yr)
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual BOD Loads
Nonpoint Source
Old Tampa Bay
BOD Load
(tons/yr)
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual BOD Loads
Nonpoint Source
Hillsborough Bay
BOD Load
(tons/yr)
5000
4000
3000
2000
1000
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

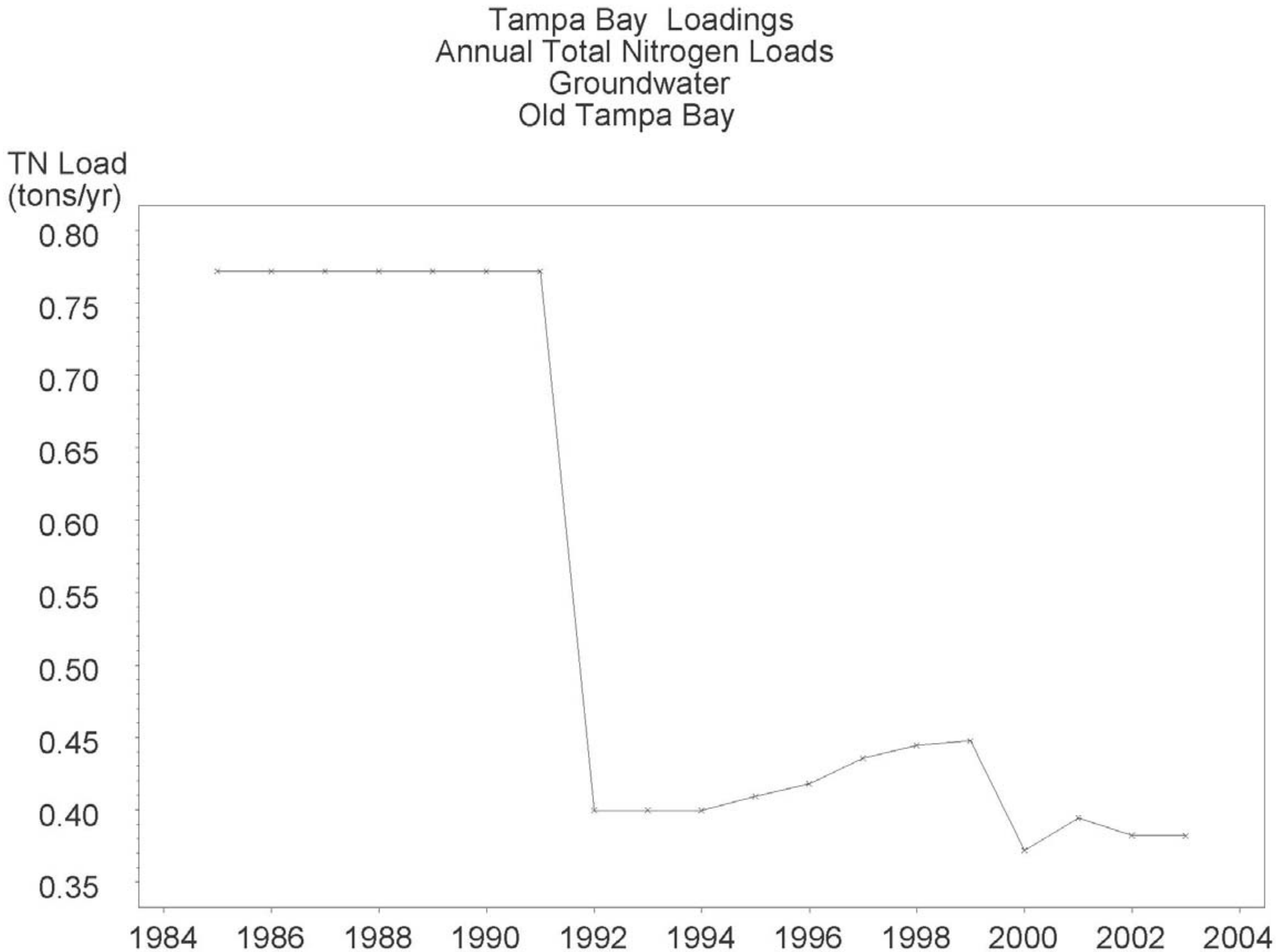
Tampa Bay Loadings
Annual BOD Loads
Nonpoint Source
Middle Tampa Bay
BOD Load
(tons/yr)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

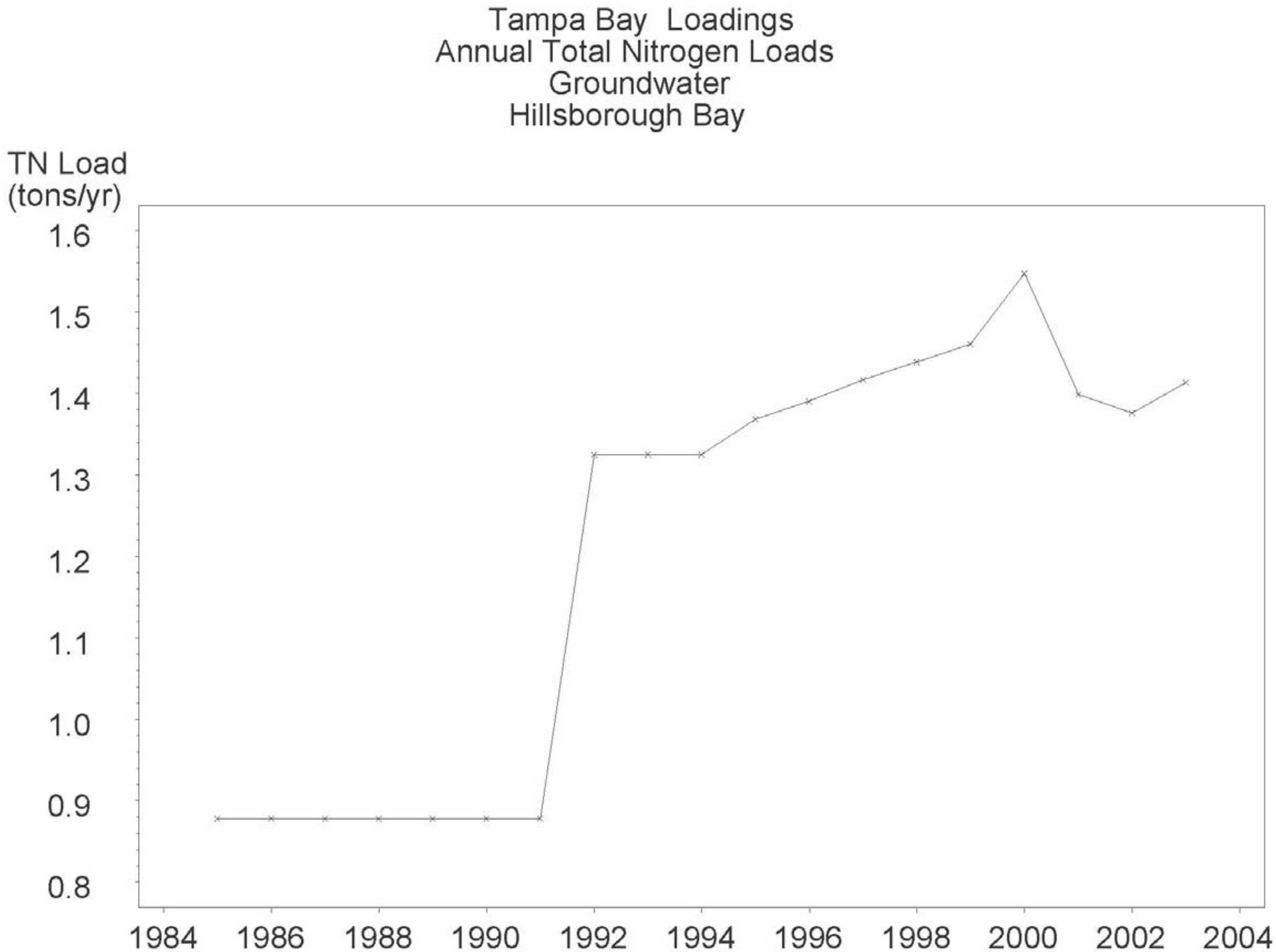

Tampa Bay Loadings
Annual BOD Loads
Nonpoint Source
Lower Tampa Bay
BOD Load
(tons/yr)
500
400
300
200
100
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

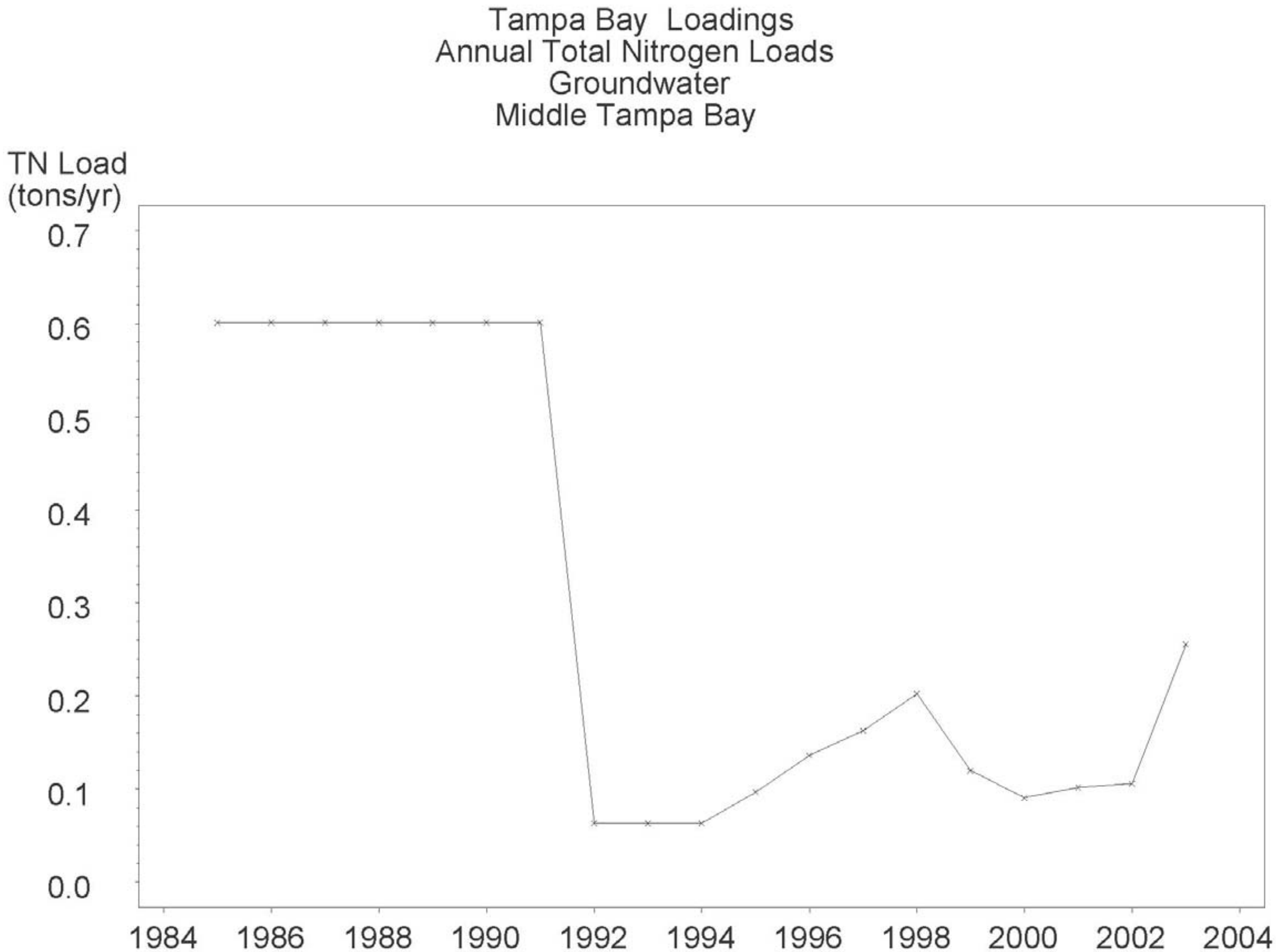

Tampa Bay Loadings
Annual BOD Loads
Nonpoint Source
Boca Ciega Bay
BOD Load
(tons/yr)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

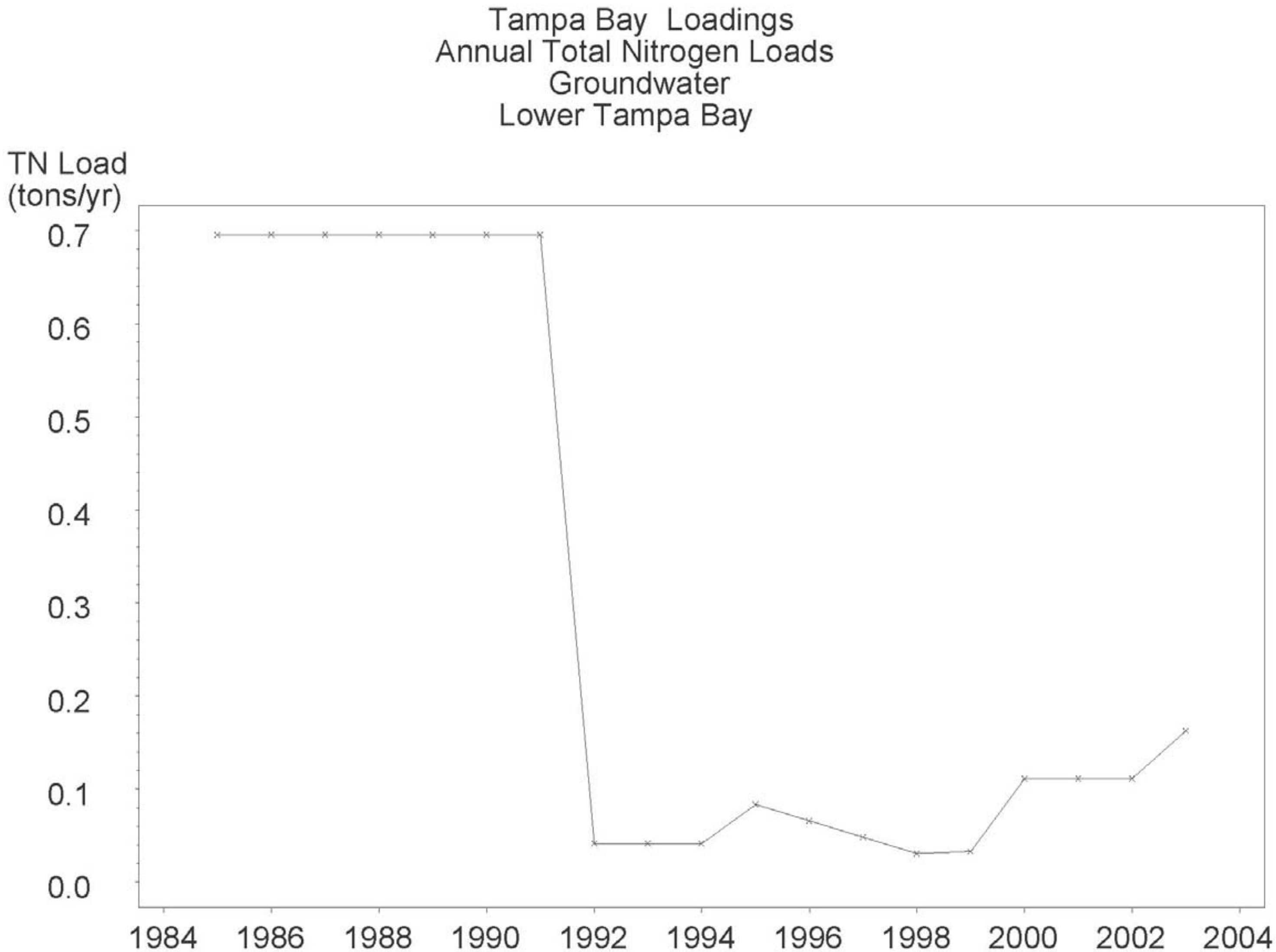

Tampa Bay Loadings
Annual BOD Loads
Nonpoint Source
Terra Ceia Bay
BOD Load
(tons/yr)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

Tampa Bay Loadings
Annual BOD Loads
Nonpoint Source
Manatee River
BOD Load
(tons/yr)
5000
4000
3000
2000
1000
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

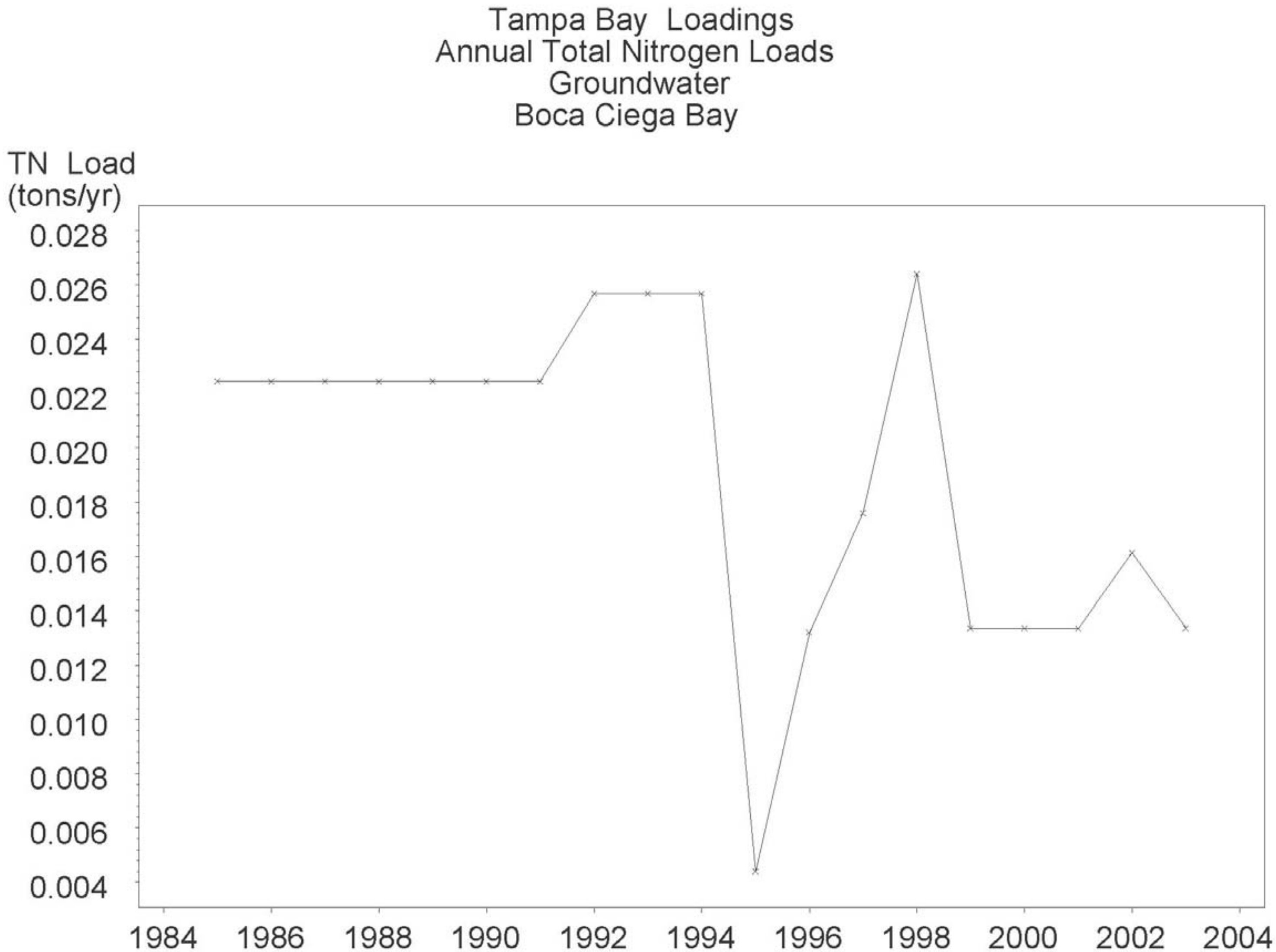

Tampa Bay Loadings
Annual Total Nitrogen Loads
Groundwater
Old Tampa Bay
TN Load
(tons/yr)
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual Total Nitrogen Loads
Groundwater
Hillsborough Bay
TN Load
(tons/yr)
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

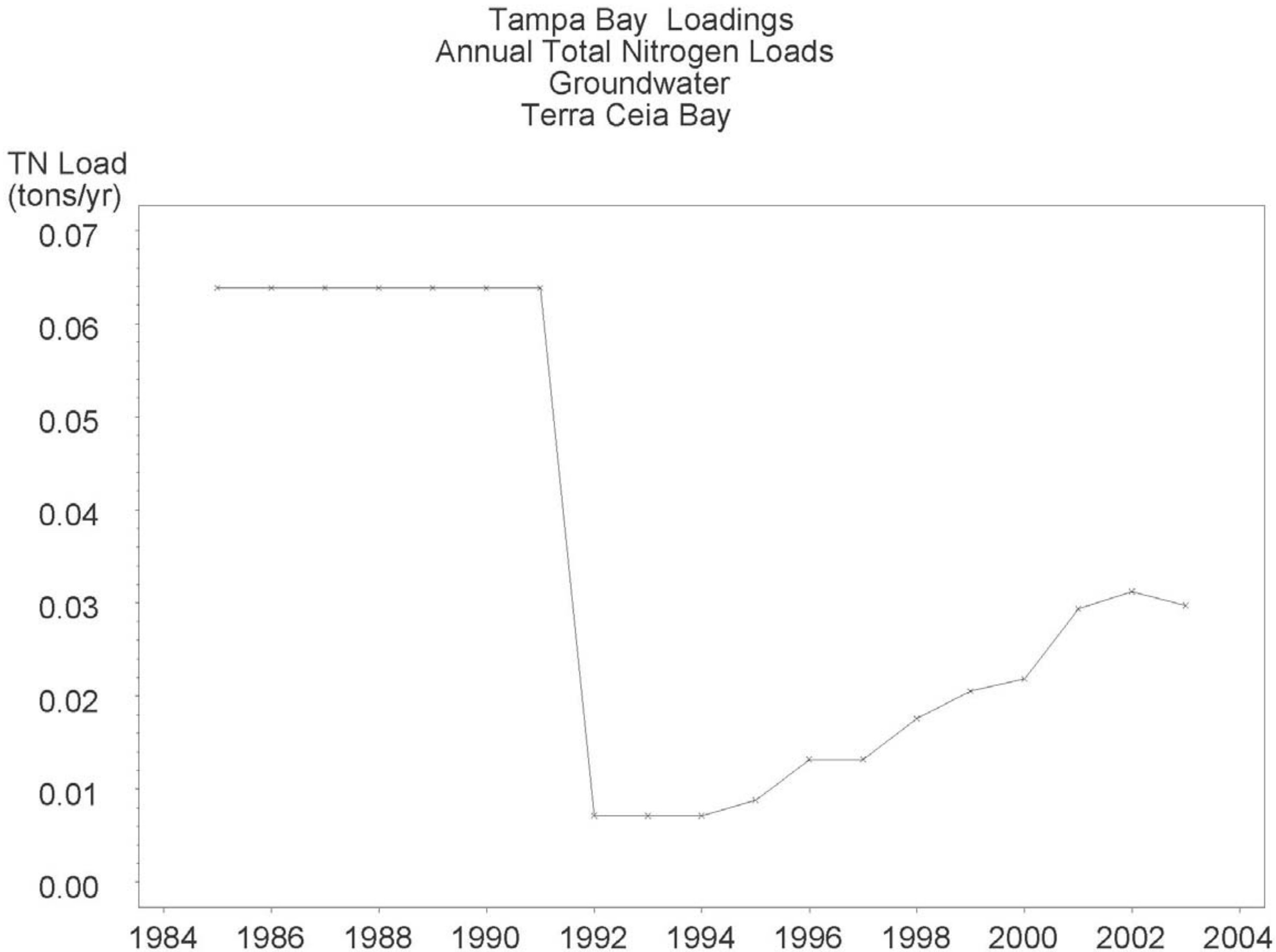

Tampa Bay Loadings
Annual Total Nitrogen Loads
Groundwater
Middle Tampa Bay
TN Load
(tons/yr)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

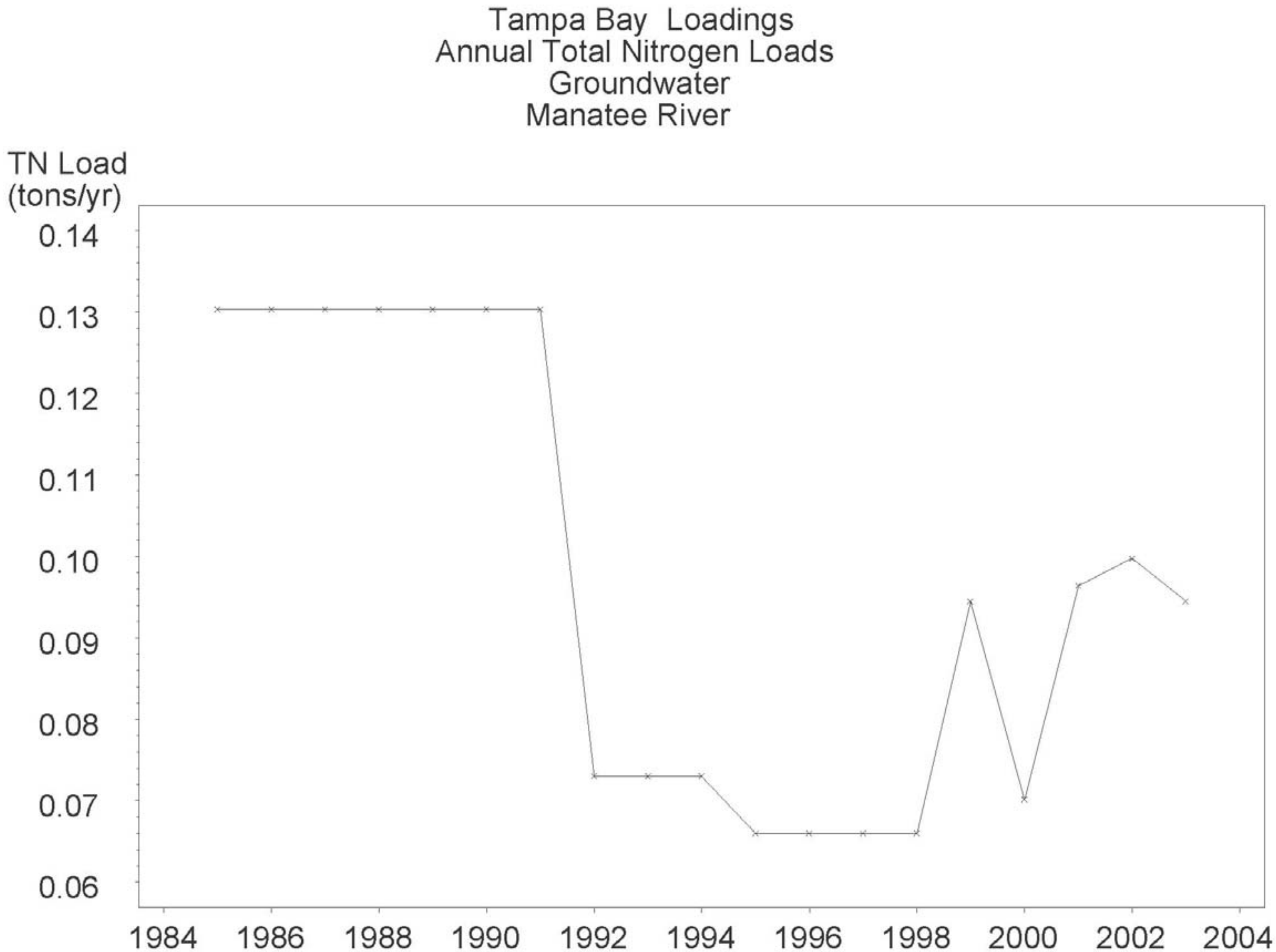


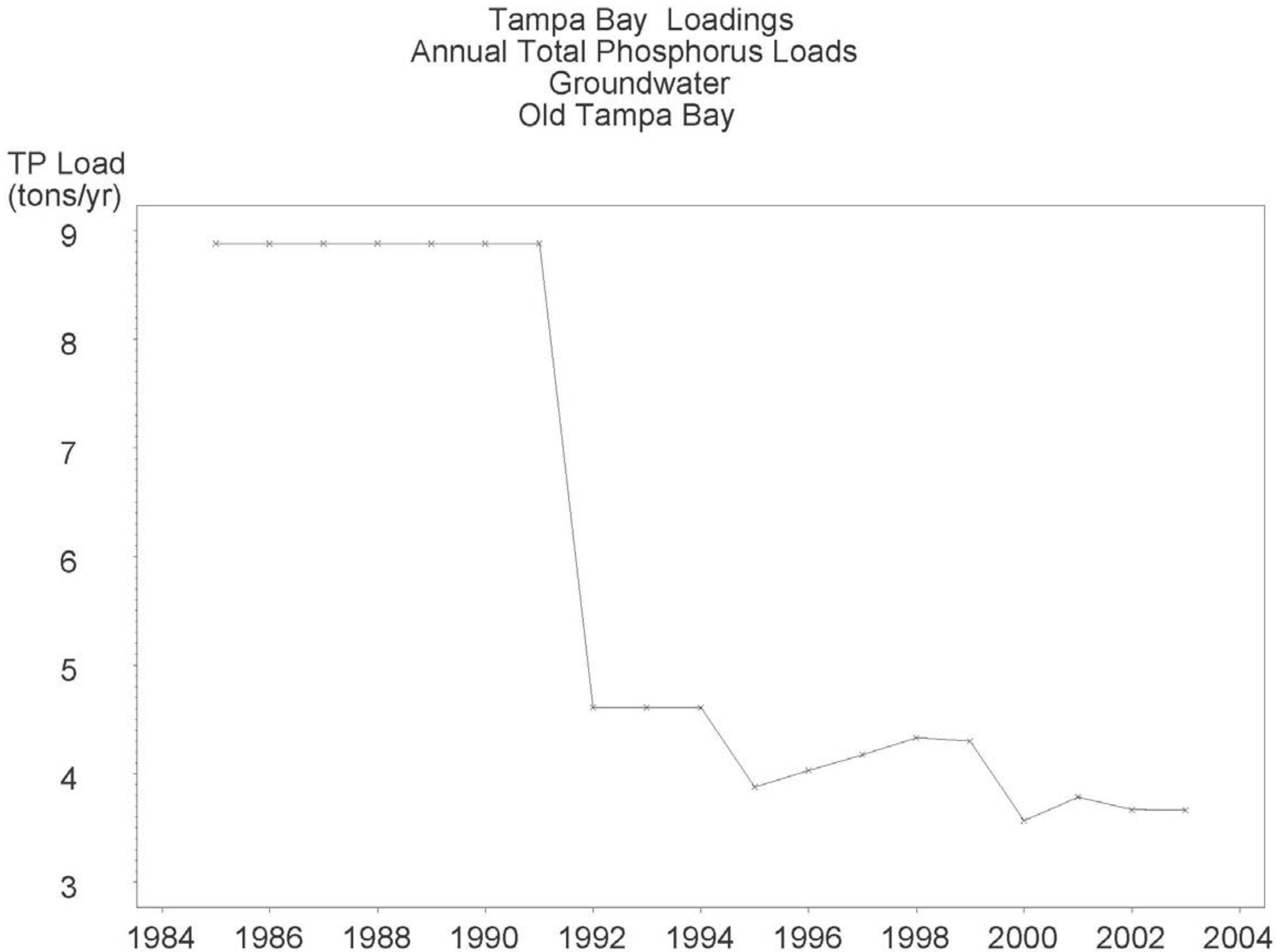
Tampa Bay Loadings
Annual Total Nitrogen Loads
Groundwater
Lower Tampa Bay
TN Load
(tons/yr)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

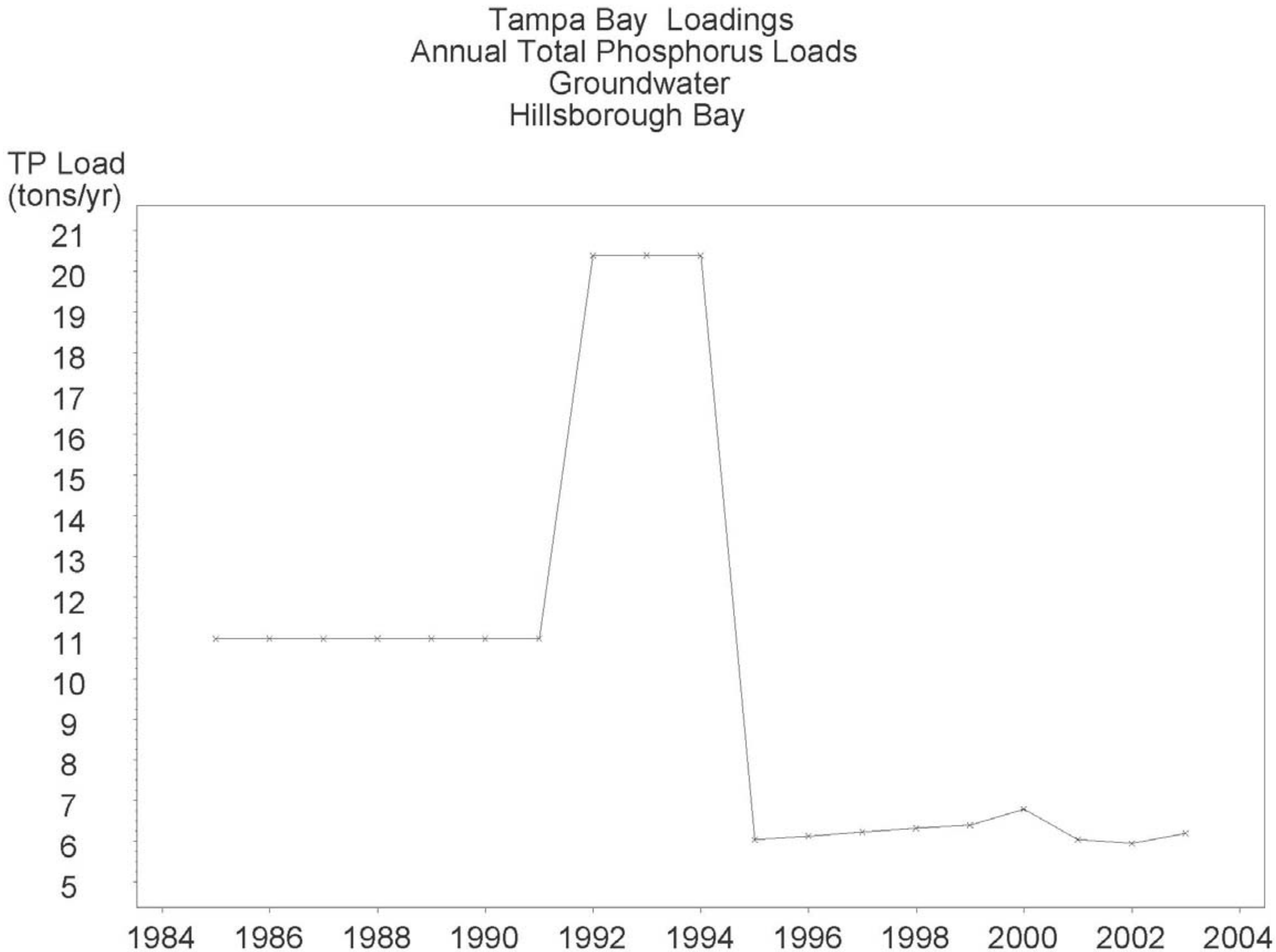


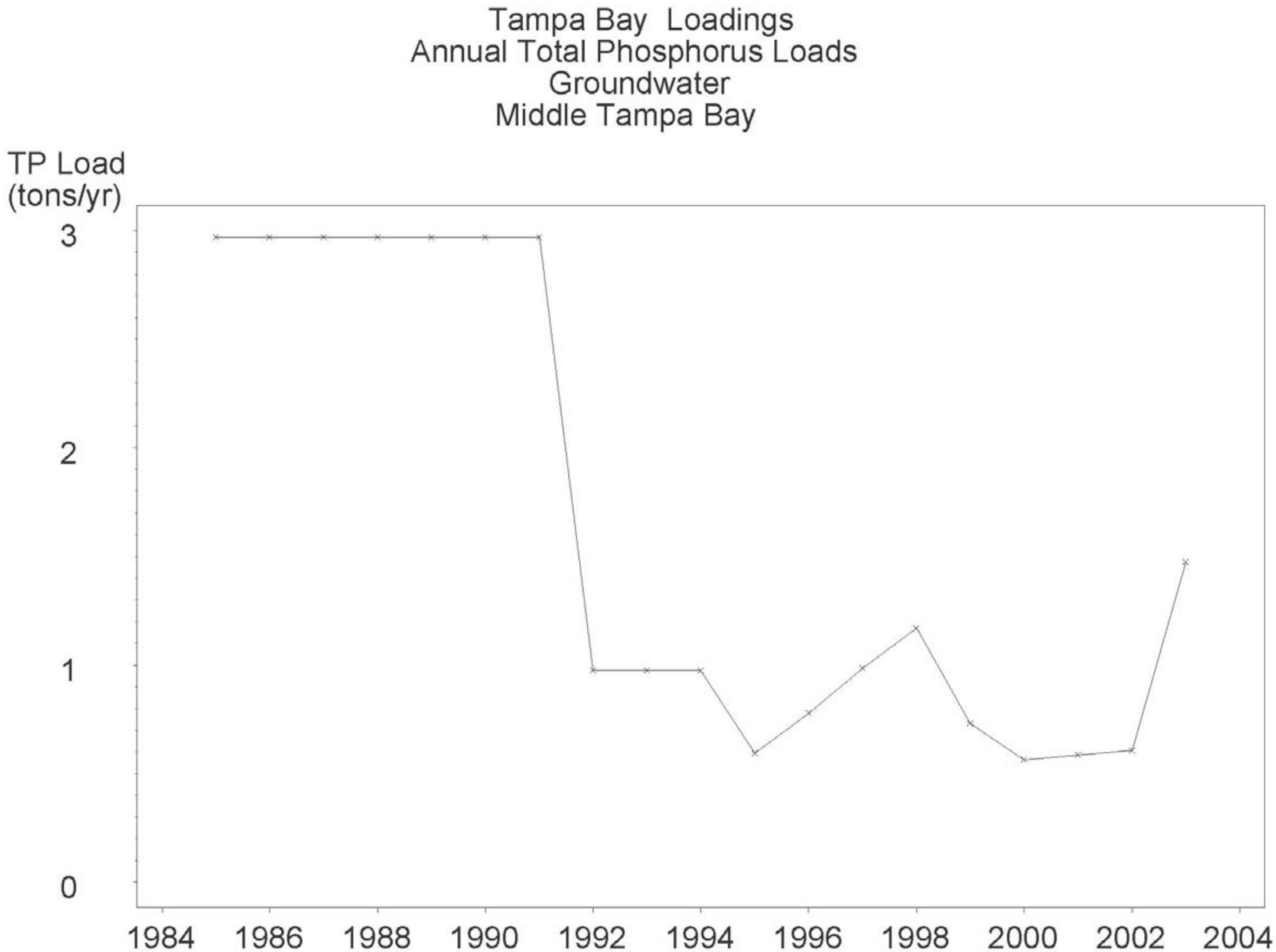
Tampa Bay Loadings
Annual Total Nitrogen Loads
Groundwater
Boca Ciega Bay
TN Load
(tons/yr)
0.028
0.026
0.024
0.022
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

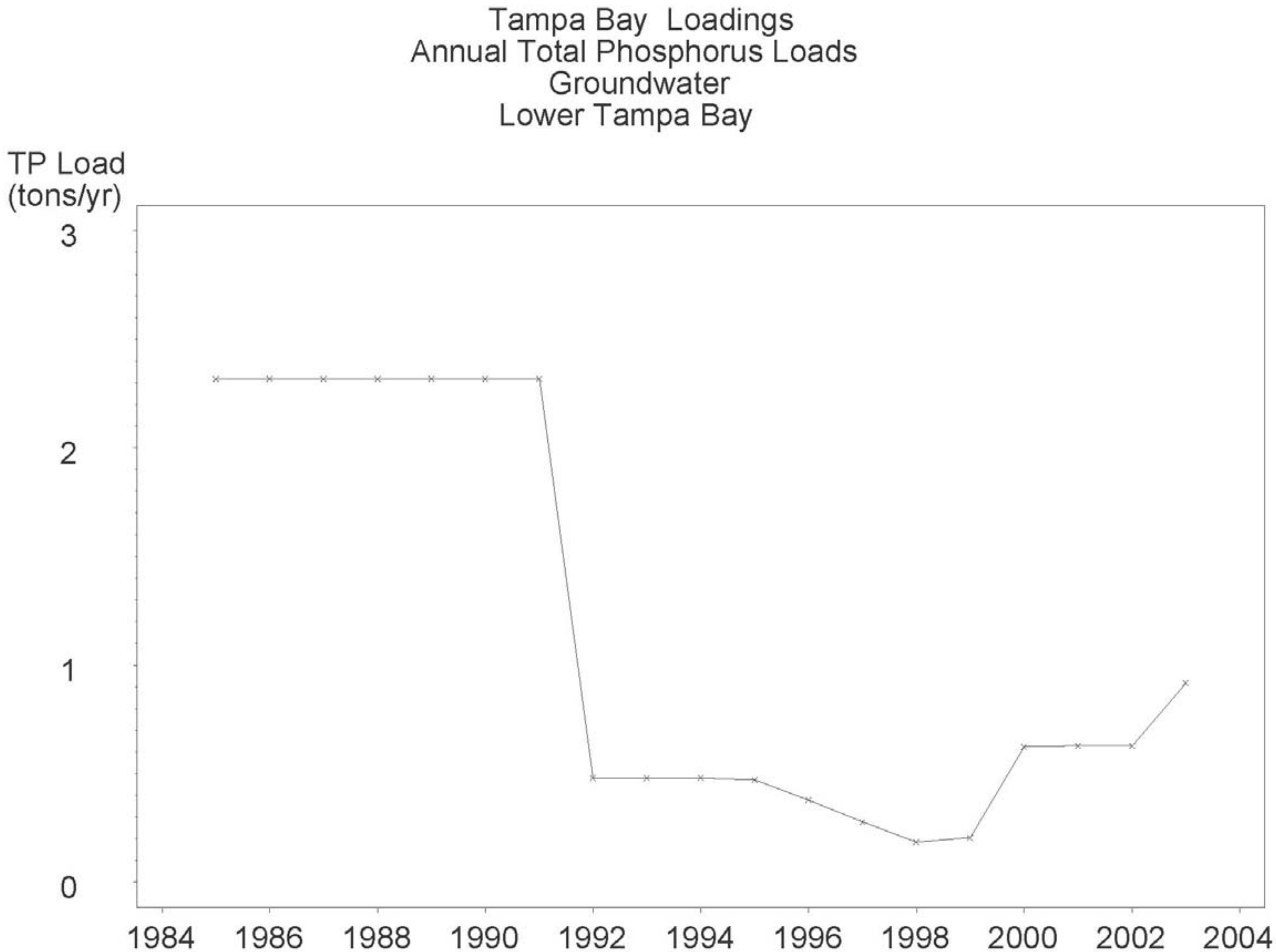

Tampa Bay Loadings
Annual Total Nitrogen Loads
Groundwater
Terra Ceia Bay
TN Load
(tons/yr)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

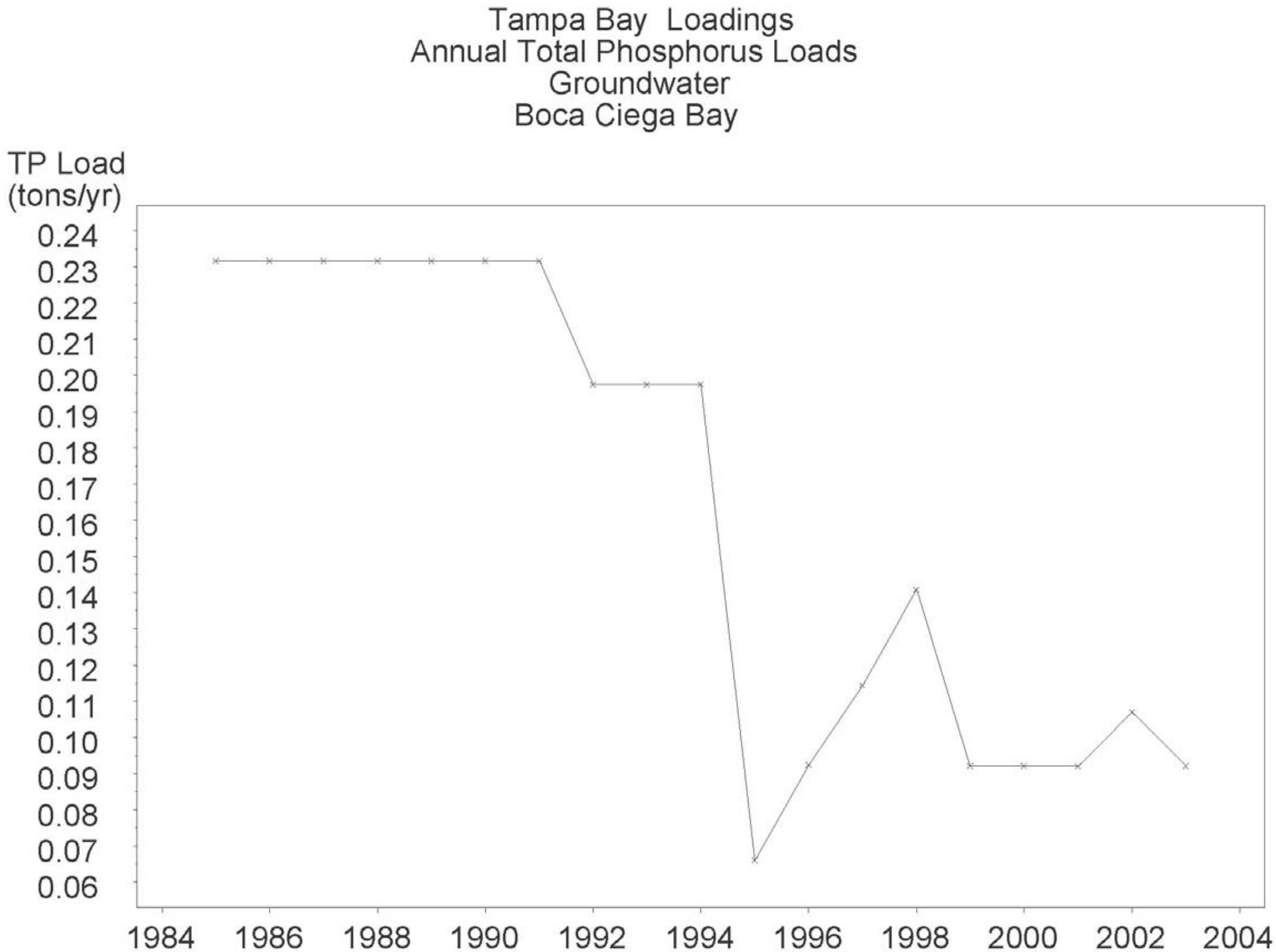

Tampa Bay Loadings
Annual Total Nitrogen Loads
Groundwater
Manatee River
TN Load
(tons/yr)
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

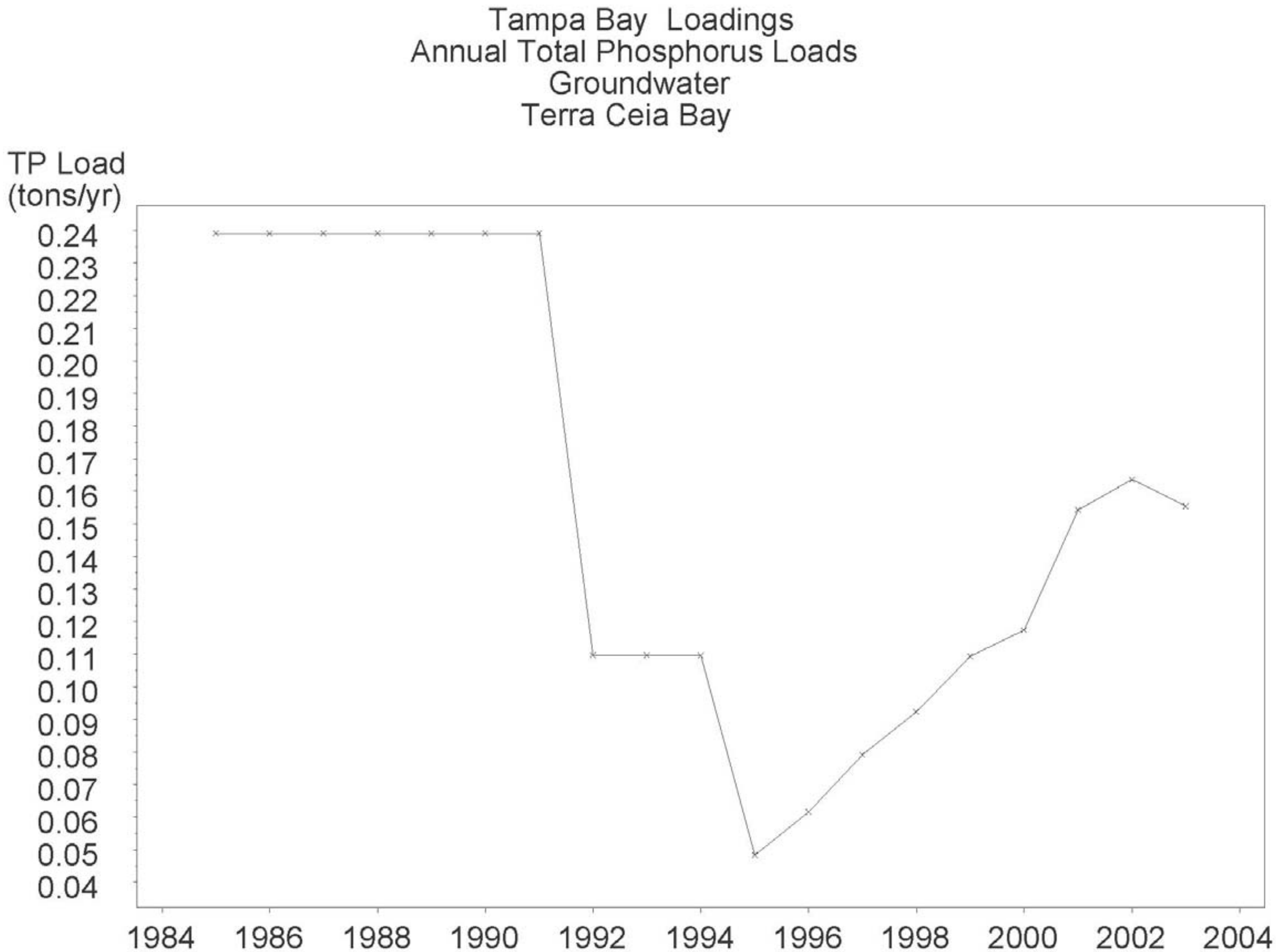

Tampa Bay Loadings
Annual Total Phosphorus Loads
Groundwater
Old Tampa Bay
TP Load
(tons/yr)
9
8
7
6
5
4
3
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual Total Phosphorus Loads
Groundwater
Hillsborough Bay
TP Load
(tons/yr)
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

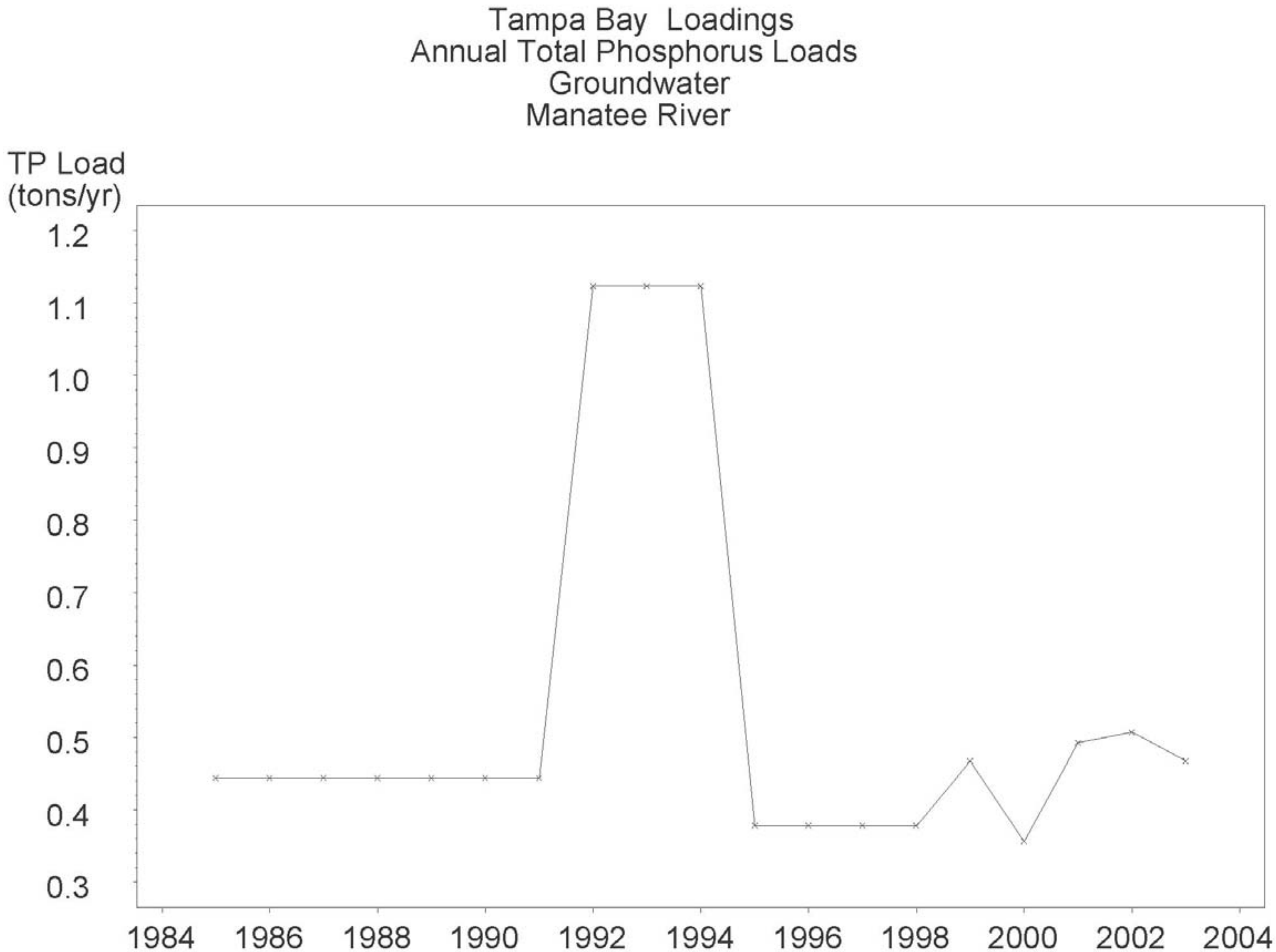

Tampa Bay Loadings
Annual Total Phosphorus Loads
Groundwater
Middle Tampa Bay
TP Load
(tons/yr)
3
2
1
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

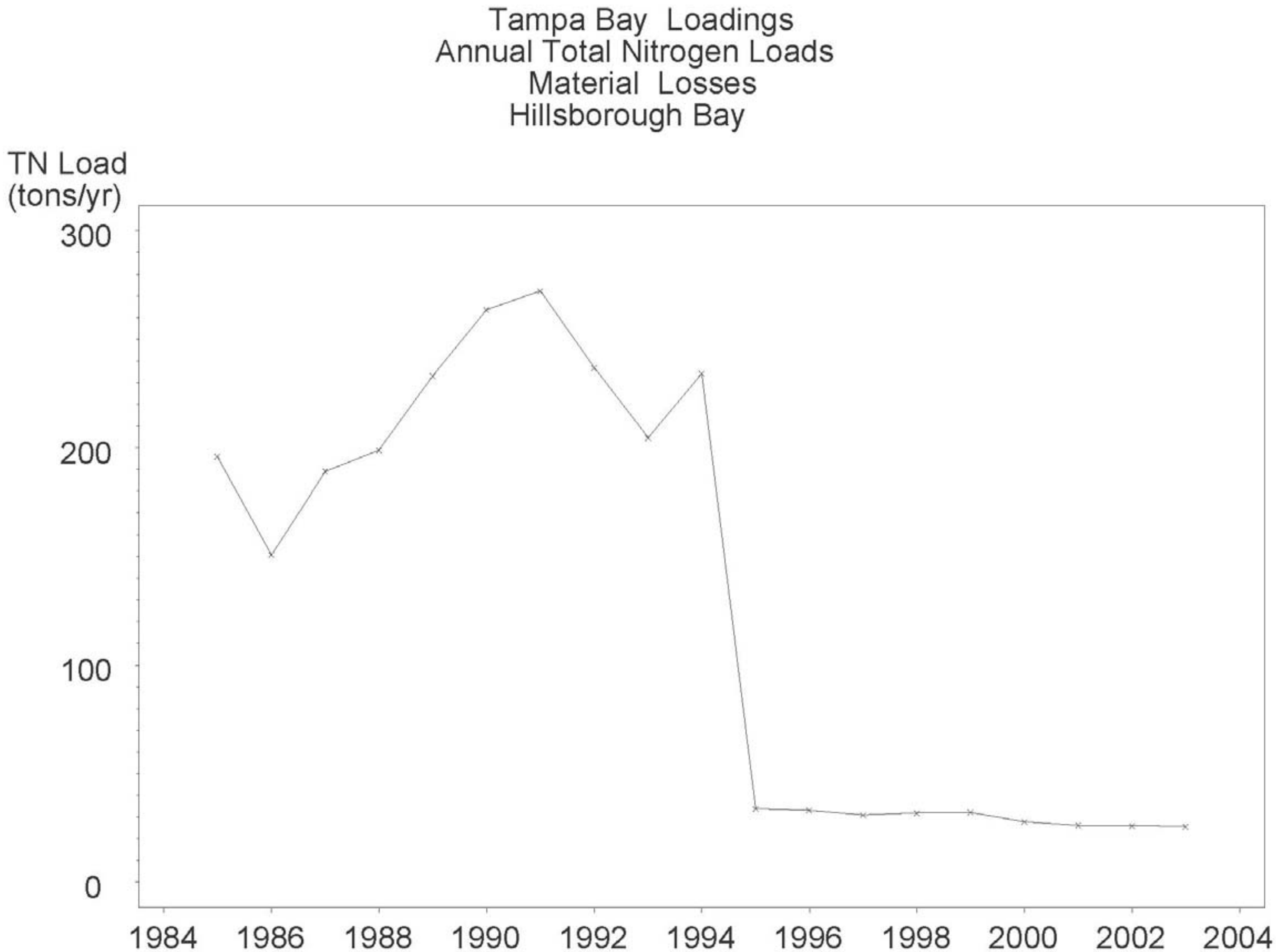

Tampa Bay Loadings
Annual Total Phosphorus Loads
Groundwater
Lower Tampa Bay
TP Load
(tons/yr)
3
2
1
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

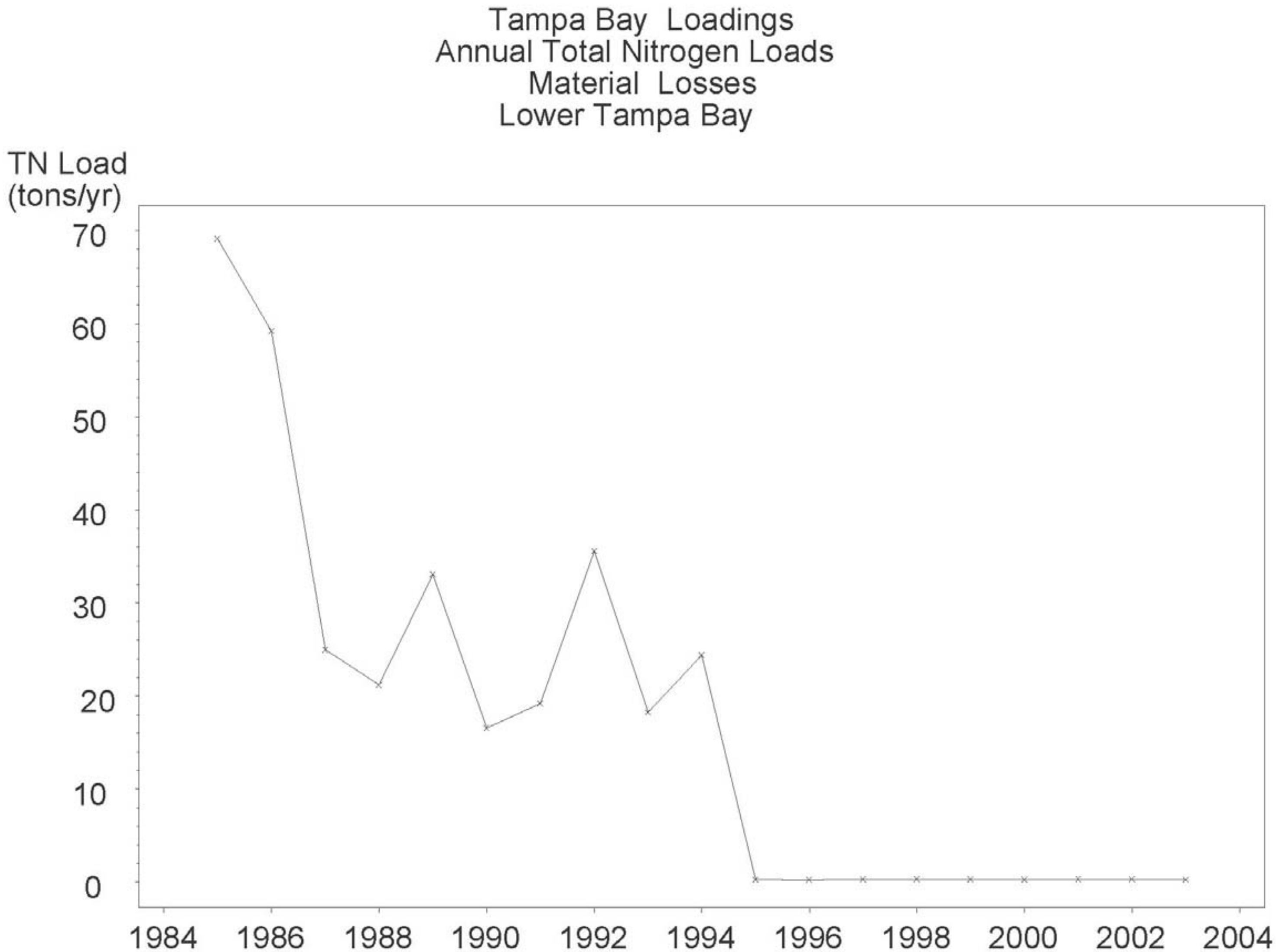

Tampa Bay Loadings
Annual Total Phosphorus Loads
Groundwater
Boca Ciega Bay
TP Load (tons/yr)
0.24
0.23
0.22
0.21
0.20
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

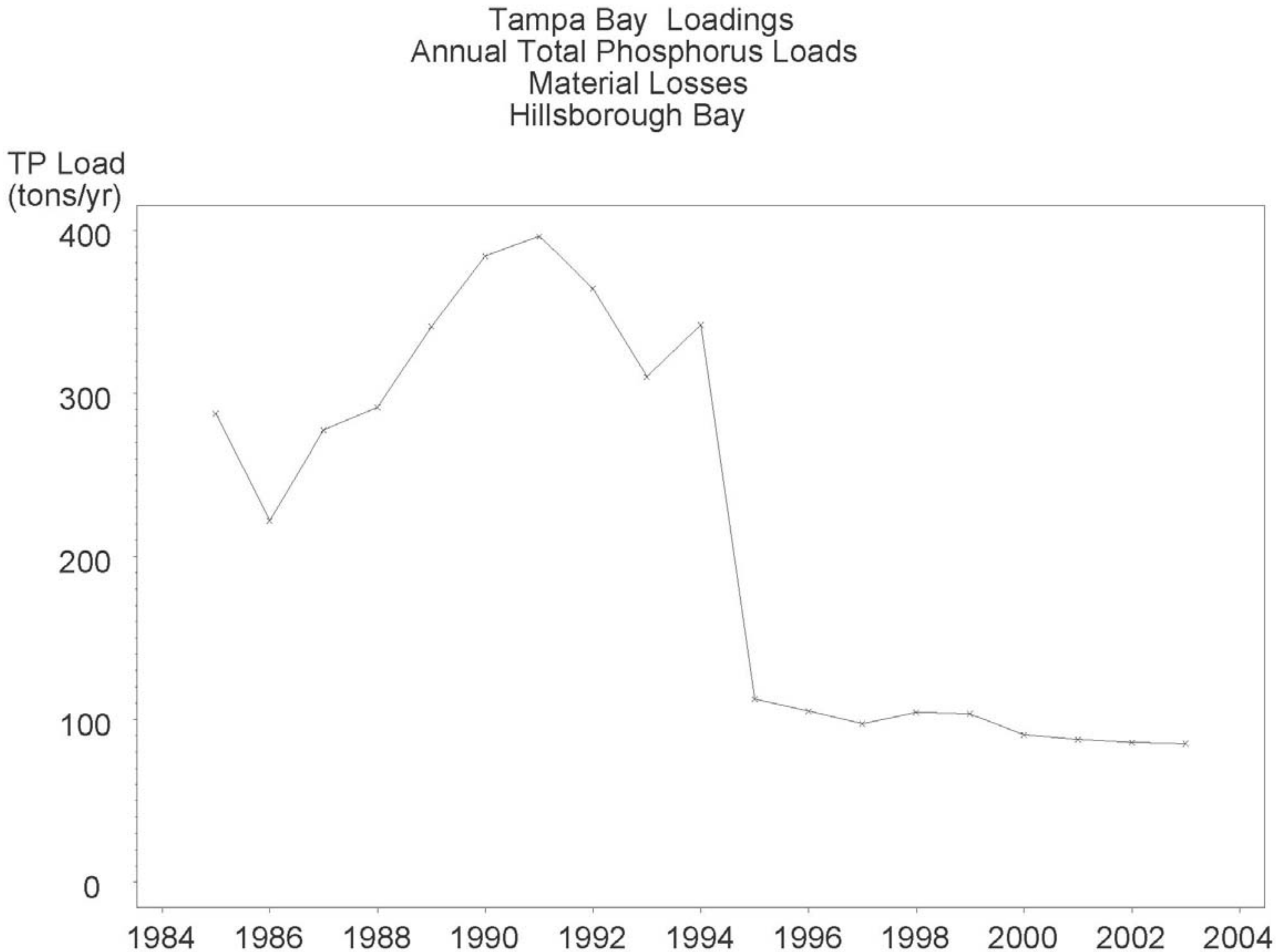


Tampa Bay Loadings
Annual Total Phosphorus Loads
Groundwater
Terra Ceia Bay
TP Load
(tons/yr)
0.24
0.23
0.22
0.21
0.20
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

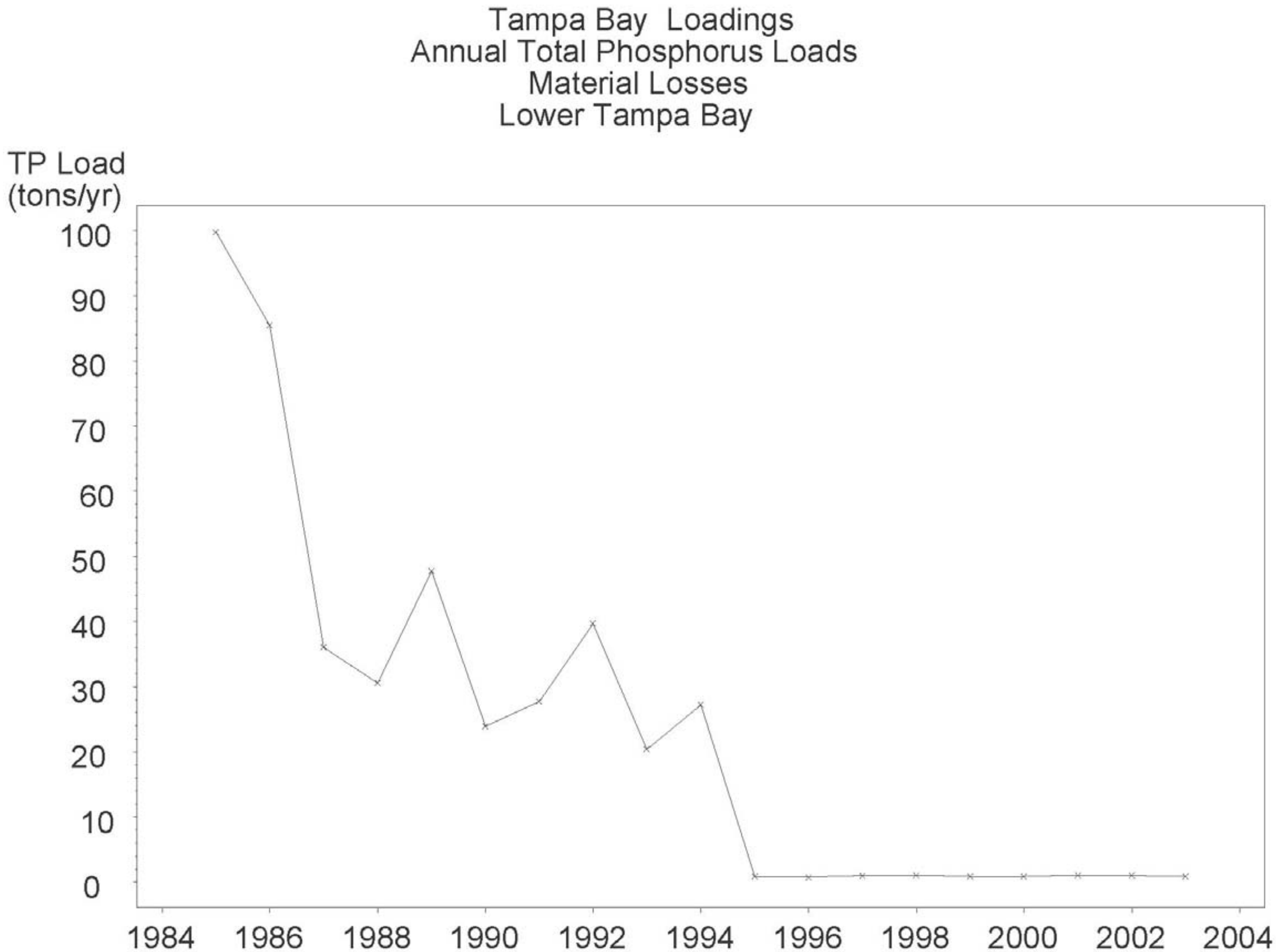

Tampa Bay Loadings
Annual Total Phosphorus Loads
Groundwater
Manatee River
TP Load
(tons/yr)
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

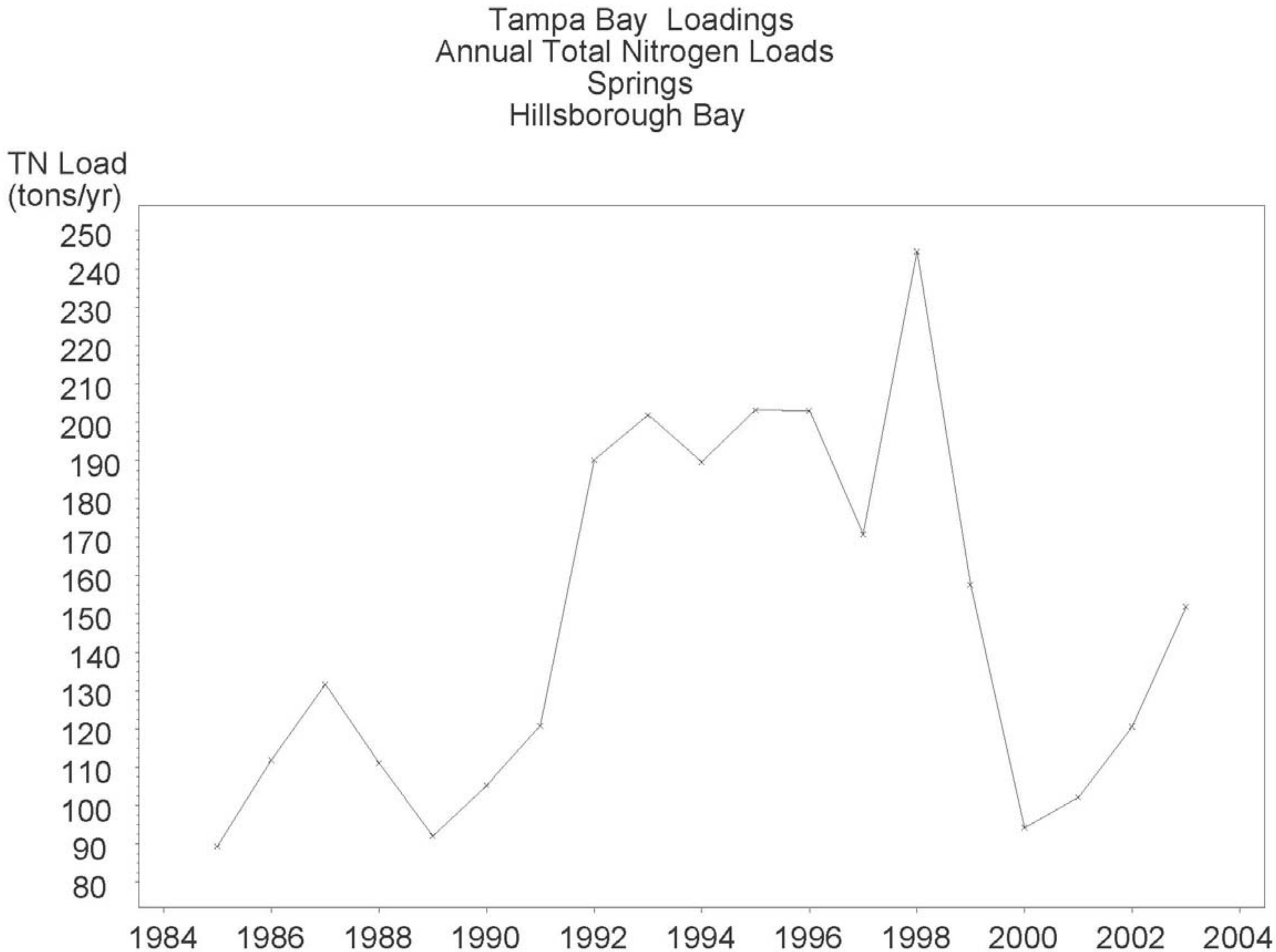

Tampa Bay Loadings
Annual Total Nitrogen Loads
Material Losses
Hillsborough Bay
TN Load
(tons/yr)
300
200
100
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

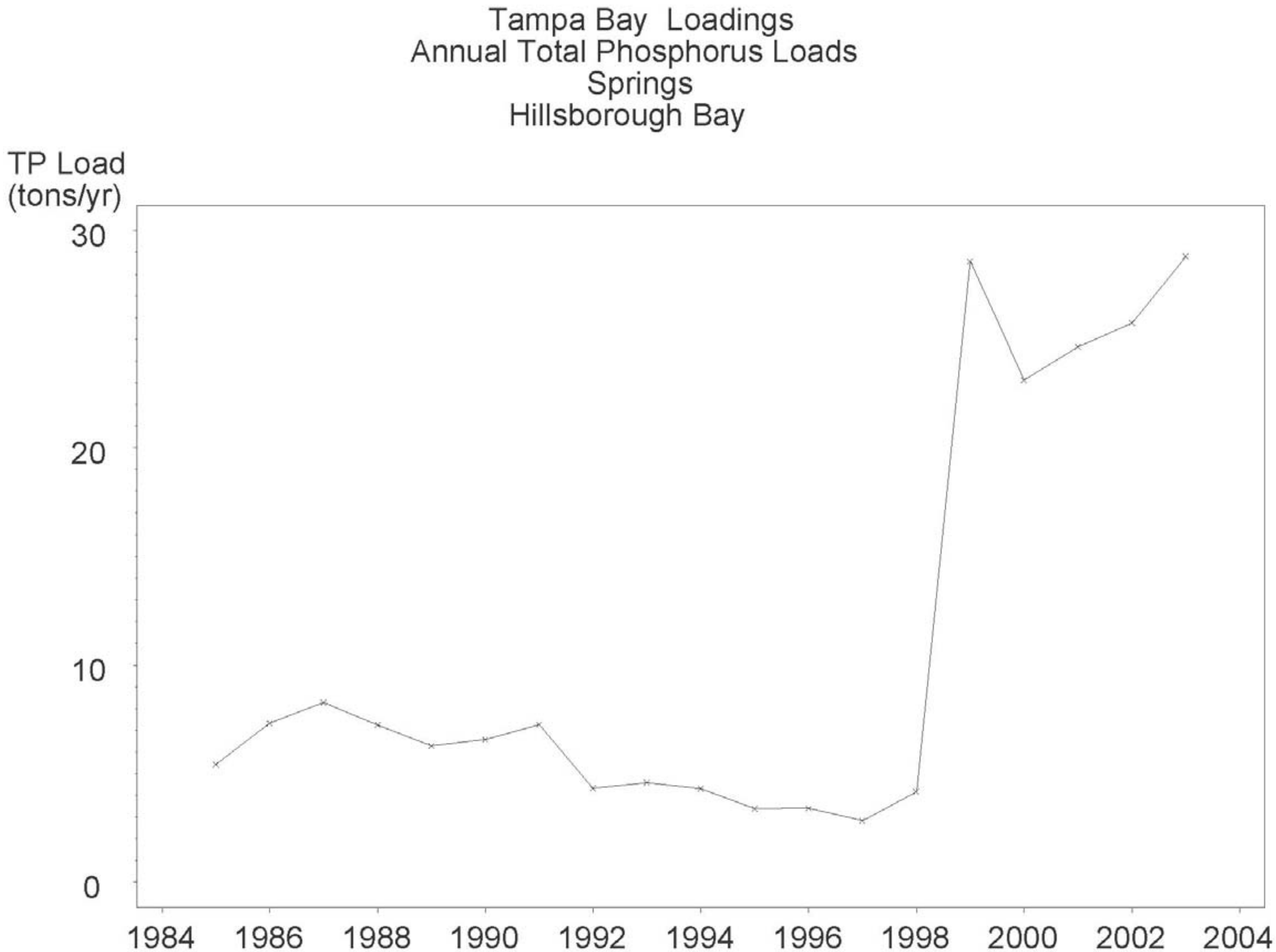

Tampa Bay Loadings
Annual Total Nitrogen Loads
Material Losses
Lower Tampa Bay
TN Load
(tons/yr)
70
60
50
40
30
20
10
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004



Tampa Bay Loadings
Annual Total Phosphorus Loads
Material Losses
Hillsborough Bay
TP Load
(tons/yr)
400
300
200
100
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual Total Phosphorus Loads
Material Losses
Lower Tampa Bay
TP Load
(tons/yr)
100
90
80
70
60
50
40
30
20
10
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual Total Nitrogen Loads
Springs
Hillsborough Bay
TN Load
(tons/yr)
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004


Tampa Bay Loadings
Annual Total Phosphorus Loads
Springs
Hillsborough Bay
TP Load
(tons/yr)
30
20
10
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

APPENDIX G

Comparisons of Mean Annual TN Loadings by Source
for 1992-1994 and 1999-2003,
and
Comparison of Annual TN, TP, and TSS Loadings
for 1999-2003 to Mean Annual 1992-1994 Loadings

Table G-1. Best estimate mean annual total nitrogen loadings to Tampa Bay for 1999-2003 (tons/year).

Bay Segment	Loading Sources						
	Nonpoint Source	Domestic Point Source	Industrial Point Source	Atmospheric Deposition	Groundwater and Springs	Material Losses	Total
Old Tampa Bay	261	73	2	186	<1	0	522
Hillsborough Bay	935	242	88	91	127	27	1,510
Middle Tampa Bay	465	30	13	258	<1	0	766
Lower Tampa Bay	56	1	24	223	<1	<1	304
Boca Ciega Bay	178	19	0	80	<1	0	277
Terra Ceia Bay	18	5	0	15	<1	0	38
Manatee River	662	23	8	39	<1	0	732
Total	2,574	393	135	892	127	28	4,149

Table G-2. Best estimate mean annual total nitrogen loadings to Tampa Bay for 1992-1994 (tons/year) (after Zarbock et al., 1996).

Bay Segment	Loading Sources						
	Nonpoint Source	Domestic Point Source	Industrial Point Source	Atmospheric Deposition	Groundwater and Springs	Material Losses	Total
Old Tampa Bay	174	85	0	227	<1	0	486
Hillsborough Bay	596	220	80	115	206	233	1,451
Middle Tampa Bay	415	20	58	306	<1	0	799
Lower Tampa Bay	36	1	<1	288	<1	24	349
Boca Ciega Bay	69	15	0	93	<1	0	177
Terra Ceia Bay	11	4	0	20	<1	0	35
Manatee River	422	16	11	54	<1	0	503
Total	1,723	361	149	1,103	206	257	3,800

APPENDIX H

Overview of Tampa Bay Water's Withdrawal Schedules From the TBC, Hillsborough River, And Alafia River (source: Tampa Bay Water)

Table H-1. OVERVIEW OF TAMPA BAY WATER'S WITHDRAWAL SCHEDULES FROM THE TBC, HILLSBOROUGH RIVER, AND ALAFIA RIVER (source: Tampa Bay Water).

TBC/Hills R WUP 2011796.00 (MGD)					TBC/Hills R WUP 2011796.00 (CFS)				
Discharge at HR Dam		Diversion		Note	Discharge at HR Dam		Diversion		Note
Min	Max	Min	Max		Min	Max	Min	Max	
--	65	--	0	no diversion if flow <65	--	100	--	0	no diversion if flow <100
65	97	6.5	9.7	10% if flow >65	100	150	10	15	10% if flow >100
97	141	9.7	42.3	10-30% if flow >97	150	215	15	65	10-30% if low >150
141	647	42	194	30% if flow >141, to 194 max divert	215	1001	65	300	30% if flow >215, to 300 max divert
Discharge at S-160		Withdrawal		Note	Discharge at S-160		Withdrawal		Note
Min	Max	Min	Max		Min	Max	Min	Max	
0	7	--	0	no withdrawal if flow <7	0	11	--	0	no withdrawal if flow <11
7	81	0	65	80% if flow >7, to 65 max withdraw	11	125	0	100	80% if flow >11, to 100 max withdraw

APPENDIX I

Section 2.0-: Development and Testing of Hydrologic Model, From: The Estimates of Total Nitrogen, Phosphorus, and Total Suspended Solids Loadings To Tampa Bay, Florida, May 1994.
Prepared For:
Tampa Bay Estuary Program
Prepared By: Coastal Environmental, Inc.

2.0 DEVELOPMENT AND TESTING OF HYDROLOGIC MODEL

Estimates of total streamflow and TN, TP, and TSS loads for the Tampa Bay watershed cannot be completed without modeling surface water hydrology. Although measured data were used in this investigation to the fullest extent possible, it was necessary to use modeling methods to estimate streamflow inputs and water quality loadings for that portion of the watershed that was not gaged.

2.1 Selection of Modeling Approach

It was desired to use a relatively simple model that could yield acceptably accurate results using only existing data, but that was flexible enough to be used over the entire watershed. A balance must be reached between providing enough variables in the model construction to adequately simulate existing conditions, and not including excess variables that may improve model performance for one area, but reduce its ability to mimic conditions on a broader scale (Draper and Smith, 1981).

To this end, three models were evaluated - two deterministic models of spreadsheet construction, and a statistical regression model. This section describes the evaluated alternatives to the selection of a hydrologic model to predict streamflow.

<u>Computations Based on Literature Values of Runoff Coefficients and Watershed Characteristics</u>

An existing spreadsheet model - Nonpoint Source Load Analysis Model (NPSLAM) (Dames & Moore, 1991; Dames & Moore, 1992) - was previously developed to model stormwater runoff using literature values for runoff coefficients and watershed characteristics. The original version of this model was similar in construct to other spreadsheet models previously used in west-central Florida, such as the Sarasota Bay watershed assessment model (Camp, Dresser & McKee, 1992) in that they assume a linear relationship between rainfall and stormwater runoff.

The NPSLAM model had been used to predict relative levels of nonpoint source pollutant loading to Tampa Bay for eight parameters, including TN, TP, TSS, BOD, metals, and bacteria (Dames & Moore, 1991). This application was uncalibrated, and was intended to provide estimates of relative pollutant loadings of individual subbasins in the watershed. Land use-specific runoff coefficients were used, to estimate stormwater runoff in amounts proportional to the size of the subbasin, its land use and soils composition, and rainfall amounts. When the model was used in an application requiring an accurate simulation of measured data, results were unacceptable. Subsequently, modifications were made to improve its performance.

<u>NPSLAM Modified Version</u>

2.1.1 Existing Alternatives

In an effort to improve the spreadsheet model performance, modifications were made to NPSLAM. The first was a seasonal adjustment that was developed using measured rainfall and runoff data from the Little Manatee River. This factor allowed a unique monthly rainfall/runoff relationship to be used, depending on the long term seasonal and monthly rainfall/runoff characteristics of the basin, and improved the model fit.

A second adjustment factor was developed to account for short-term antecedent soil moisture conditions. Using soil moisture characteristics from Chow (1964), a set of multiplication factors was developed to apply to the initial runoff volume, based on preceding rainfall conditions. Validation results showed that model fit was improved. However, when a review of the ability of the modified NPSLAM model to predict flows in seven basins other than those used for the initial validation work was completed, the overall goodness of fit of modeled values to measured flows was only marginally acceptable. Resulting r^2 values ranged from 0.39 to 0.80. The r^2 of 0.80 was obtained for the Little Manatee River. This relatively good fit may be partially attributable to the fact that long-term streamflow data from this water body was used to develop the seasonal adjustment factor incorporated into the model.

Figure 2-1 shows the overall fit of modeled values versus observed data for monthly flows estimated by the spreadsheet model, and Figure 2-2 presents comparisons between predicted and observed monthly flows using the modified NPSLAM model for monthly flows between zero and four inches (the 95th percentile for observed flows). A generally limited agreement was observed between the model predictions and the observed flows for the tested subbasins. Overall, the model predictions showed a positive bias - that is, it tended to overpredict flow for a given rainfall amount, especially for low flow conditions.

2.1.2 Need for Further Refinement of Hydrologic Model

To improve upon the spreadsheet modeling methodology, an alternative to this model formulation was investigated. The methods focused on the use of available measured flow data from the Tampa Bay watershed. Initially, the relationship between measured monthly flow and rainfall was examined. Nonlinear relationships between rainfall and streamflow are often suggested by measured data, as shown in Figure 2-3. This characteristic appears to contribute to the bias (i.e., overprediction of low flows) in the original version of the NPSLAM model. Figure 2-4 illustrates how, if a linear model (straight diagonal line) is used to fit what is actually a nonlinear relationship (curved line), the predicted values in the lower range of values will be overestimated.

There also appeared to be a relationship between the existing month's streamflow and the previous month's rain, as suggested from earlier work by Dames & Moore (1992). This relationship may be due to the lag in release of rainfall stored in wetlands and surface water bodies, groundwater interflow, or other factors. As has been pointed out in the Dames & Moore work, flows are often observed during months with little or no rainfall. Thus, it was concluded that a non-zero intercept for a model which relates flow to rainfall was appropriate. Based on these data analyses, a modeling approach using available empirical data was developed as described below.

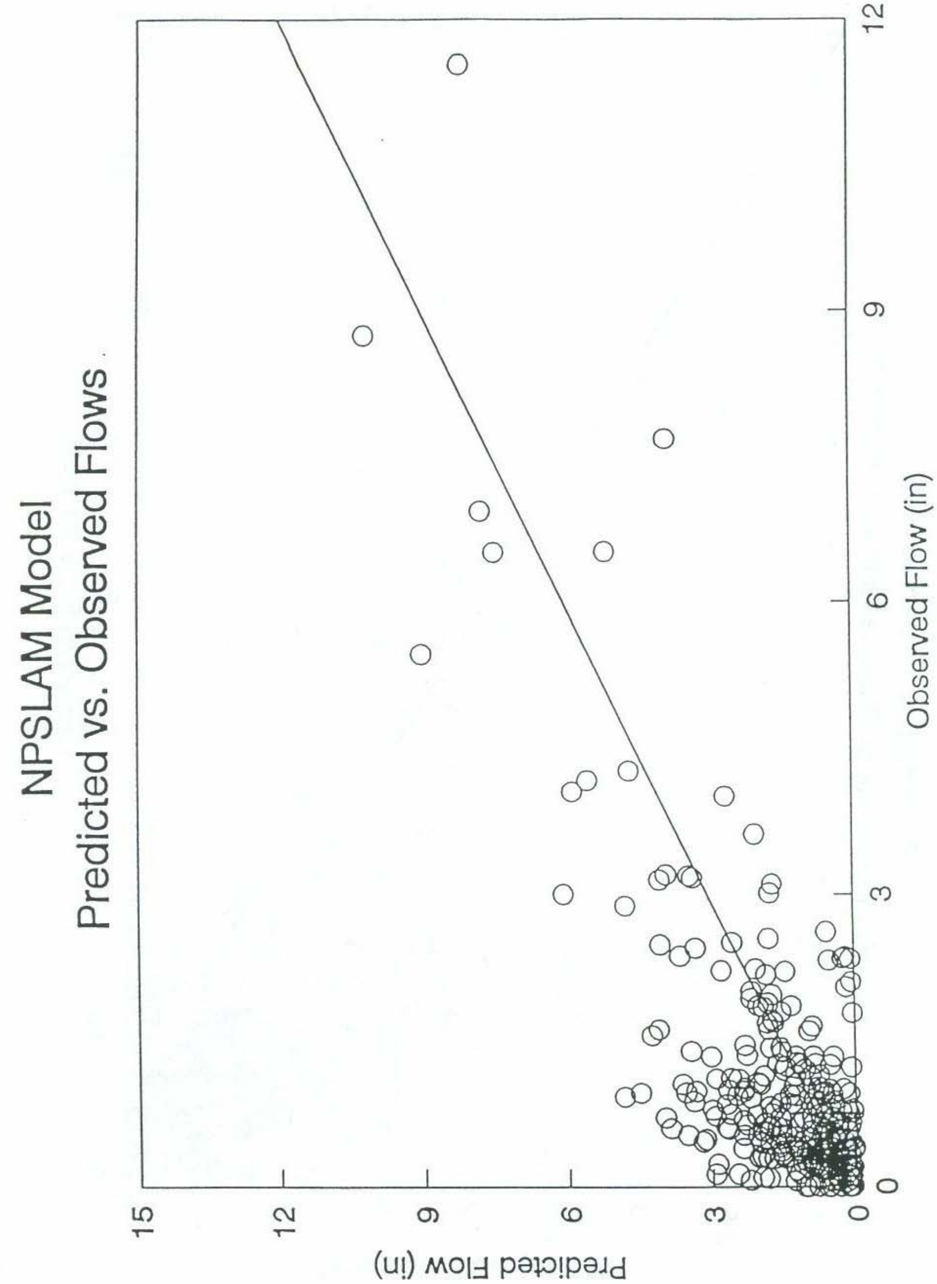


Figure 2-1 Modified NPSLAM Model - overall fit.

Figure 2-1 Modified NPSLAM Model - overall fit.

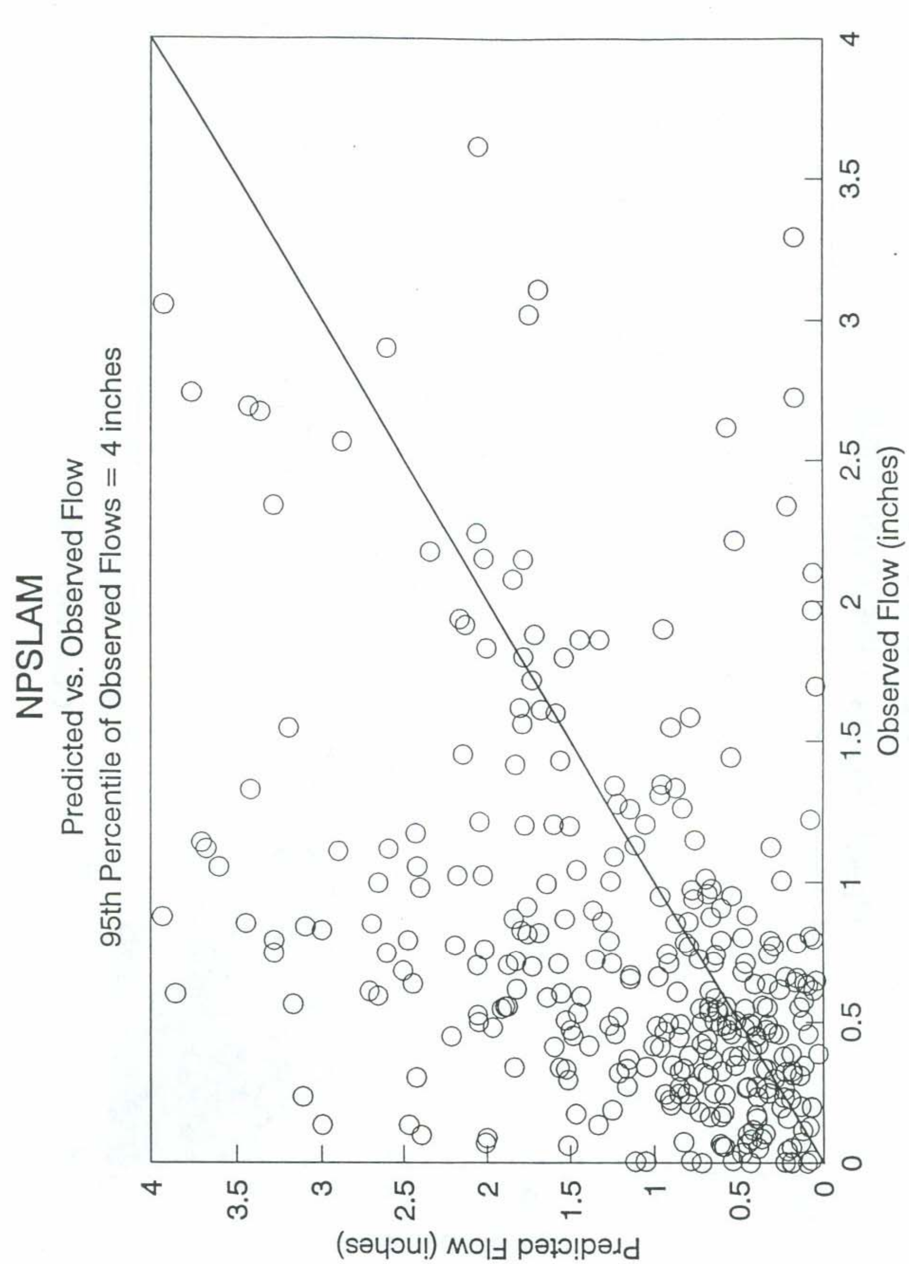


Figure 2-2 Modified NPSLAM Model - 95th percentile fit.

2-4

Figure 2-2 Modified NPSLAM Model - 95th percentile fit.

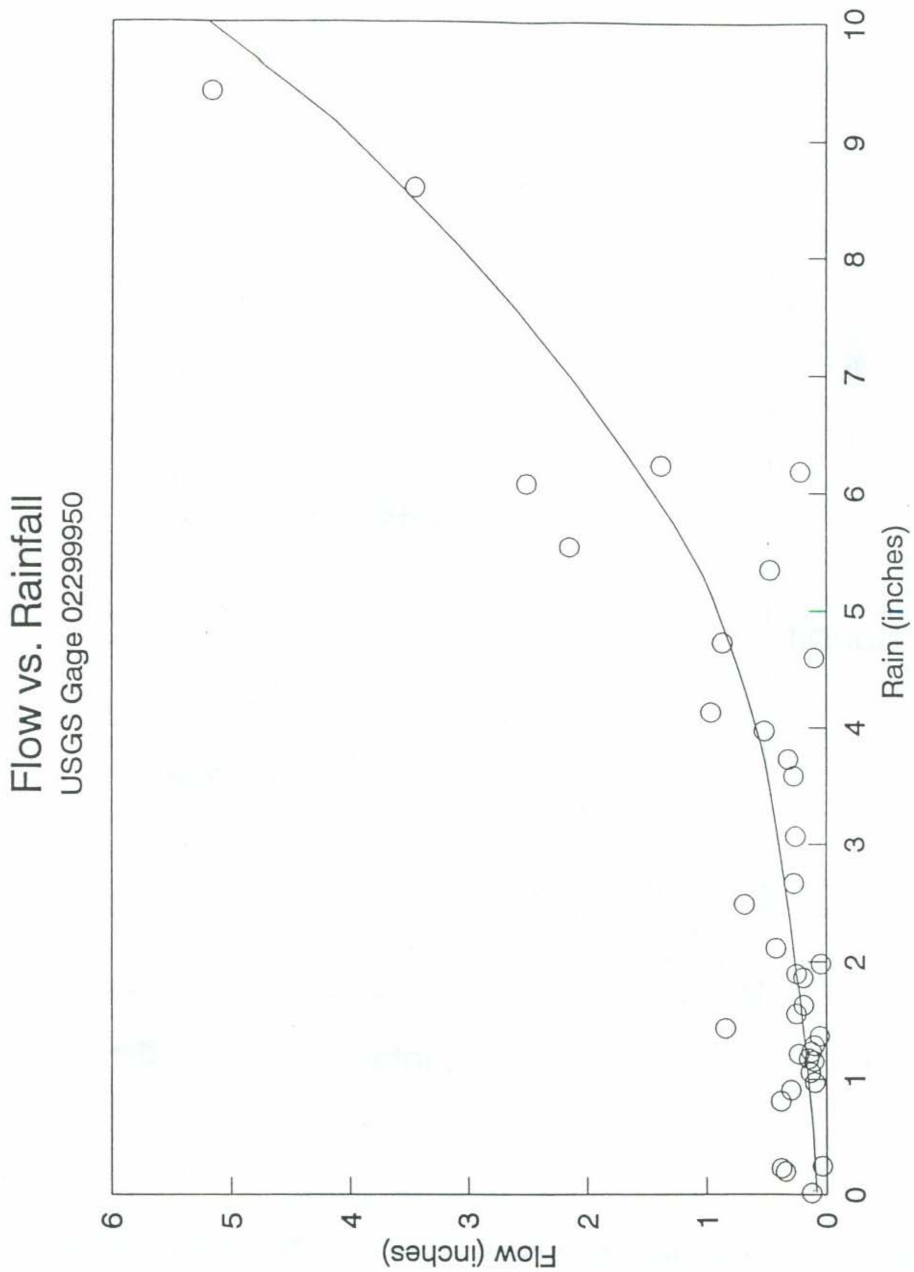


Figure 2-3 Nonlinear rainfall/runoff data

Figure 2-3 Nonlinear rainfall/runoff data

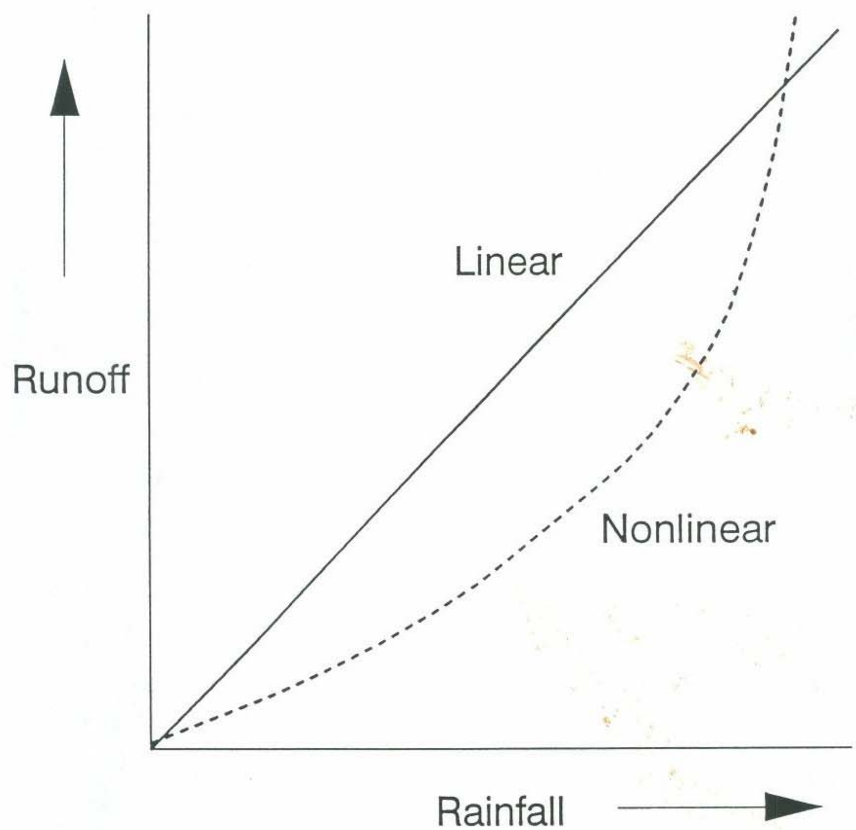


Figure 2-4 Consequences of fitting a linear model to data having a nonlinear relationship.

Figure 2-4 Consequences of fitting a linear model to data having a nonlinear relationship.

2.1.3 Selected Modeling Approach

As previously discussed, a minimum number of parameters was used in model construction to ensure that it would be capable of adequately predicting flows in all ungaged areas in the watershed. Initial testing of the alternative modeling approach indicated the need to predict total monthly runoff magnitudes for a basin as a nonlinear function of 1) rainfall for the present month and two previous months, and 2) the percent coverage in a basin of each of four major land use groups. The four classes were urban, agricultural, forest/undisturbed, and wetland/water. The distribution of these four classes is presented below in Section 2.3.4. The use of the percent coverage of these four classes in the hydrology model was found to improve the fit of the rainfall/runoff relationships without compromising the predictive capacity of the model.

Model development resulted in the definition of four separate rainfall/runoff relationships, varying with season and basin land use characteristics. The four cases were 1) wet season, more urban basin; 2) dry season, more urban basin; 3) wet season, less urban basin; and 4) dry season, less urban basin.

Based on long-term rainfall records for the watershed, the wet season was defined as July through October, and the dry season was November through June. Although long-term rainfall data from Tampa International Airport suggests a June-September wet season, the July-October period accounted for approximately 55% of the annual precipitation on a watershed-wide basis.

"More urban" basins were defined as having greater than 19% urban land use, and "less urban" basins had less than 19% urban land use. The selection of the 19% level was based on an investigation of the distribution of urban land cover and the goodness of fit of the rainfall/runoff relationships.

Another objective of this modeling was to apportion total estimated runoff in a basin to constituent land uses, based on their relative frequency of occurrence in the basin. This was accomplished through the use of land use-specific runoff coefficients that allocated fractions of total streamflow to the individual land uses based on the extent of their coverage and the literature values of land use-specific runoff coefficients.

2.2 Model Formulation

As described in the previous section, empirical data analyses indicated that the preferred model for predicting runoff was based on a log-linear relationship with rainfall and land use categories as independent variables. Rainfall for two previous months was included in the model in addition to that for the present month. The land use composition of each basin was included through an adjustment factor **(a).** The model used is:

$$\mathbf{FLOW = exp\ [a + (b_0 * RAIN_0 + b_1 * RAIN_1 + b_2 * RAIN_2)]} \qquad \text{(Equation 1)}$$

and,

$$\mathbf{A = (c_1 * L_1) + (C_2 * L_2) + (C_3 * L_3) + (C_4 * L_4)}$$

Where

FLOW = nonpoint source flow (meters per month) for a given basin, year and month,

RAIN = rainfall (meters per month) in the month,

$RAIN_1$ = rainfall (meters per month) in the month before the present month,

$RAIN_2$ =rainfall (meters per month) two months before the present month,

L_1 = the fraction of the basin acreage in the URBAN land use category,

L_2 = the fraction of the basin acreage in the AGRICULTURAL land use category,

L_3= the fraction of the basin acreage in the WETLANDS land use category, and

L_4= the fraction of the basin acreage in the FOREST land use category, and

c_1, c_2, c_3, c_4, b_0, b_1, and **b_2** are parameters to be estimated.

expressed as a volume of water with an area equal to the land area, and the depth in meters. Although the unit is listed as depth, the volume is implicitly accounted for in the land area. For rainfall, m/mo represents the depth of rainfall over the land area during the time period (month), although it may also be expressed as a volume, such as cubic meters/month, acre-feet/month, etc.

A least squares regression with no intercept was used to estimate the seven parameters in Equation (1) after taking the natural logarithm of both sides of the equation:

$$\text{Log (FLOW)}= (c_1*L_1) + (c_2+L_2) + (c_3*L_3) + (C_4*L_4) + (b_0*RAIN0 + b_1*RAIN_1+ b_2*RAIN_2) \quad \text{(Equation 2)}$$

Basins were classified into two categories based on land use category: greater than 19% urban or less than 19% urban. The distribution of subbasins through this category is shown in Figure 2-6. Months were classified into two categories based on rainfall: dry (November through June) or wet (July through October). The model was run for each combination of these categories, resulting in four complete sets of parameter estimates:

! 19% urban, dry season
! 19% urban, wet season
! > 19% urban, dry season
! > 19% urban, wet season

Total monthly flow was estimated for each basin using Equation (1) with the appropriate parameter estimates. Flow was then apportioned among the constituent land use categories within each basin as follows:

$$\mathbf{FLOW} = \frac{\mathbf{FLOW^{*}\ A_i{*}R_i}}{\sum_i \mathbf{A_i{*}R_i}} \qquad \text{(Equation 3)}$$

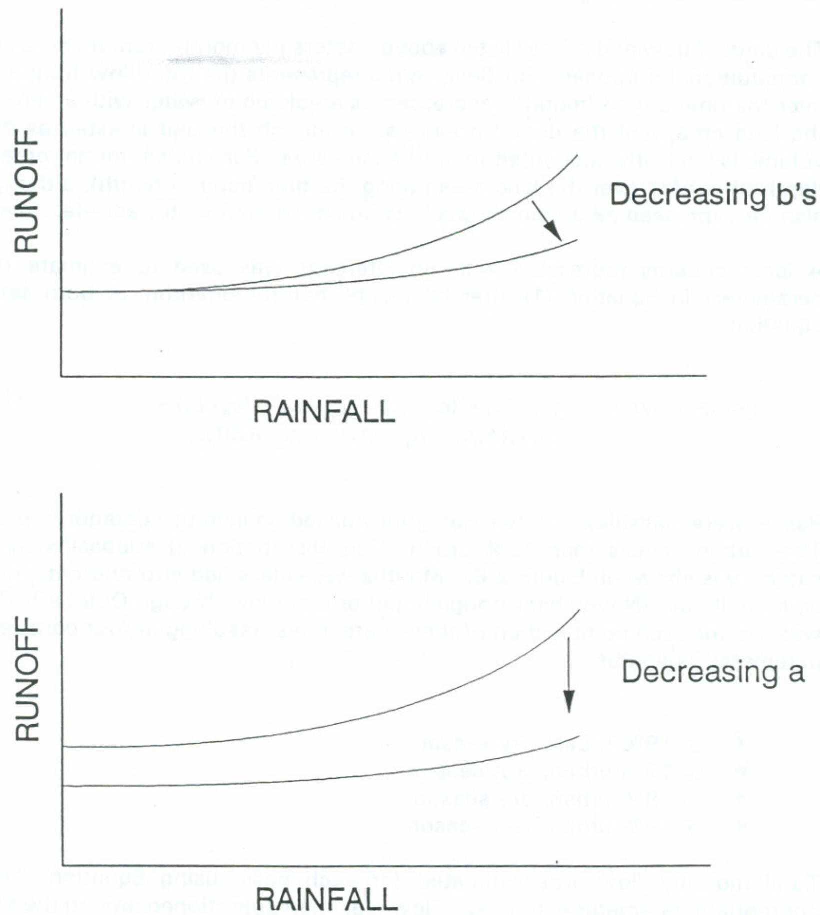
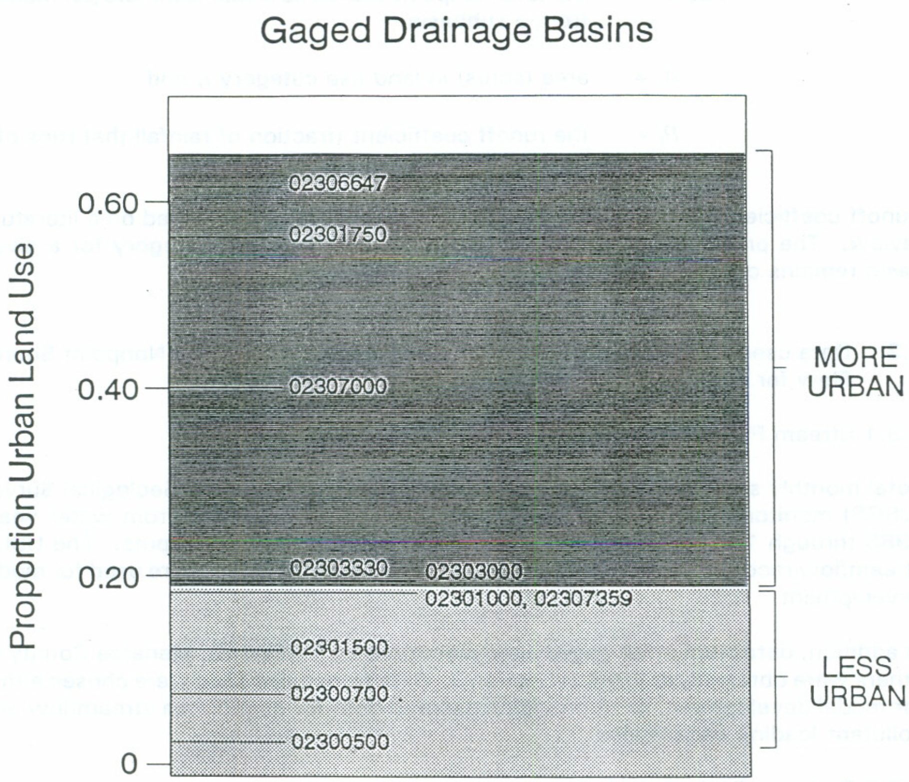


Figure 2-5 (a and b) Effects of varying model parameters.

Figure 2-5 (a and b) Effects of varying model parameters.



NOTE: Basins are identified by USGS gaging station numbers.

Figure 2-6 More urban and less urban basins.

2-11

NOTE: Basins are identified by USGS gaging station numbers.

Figure 2-6 More urban and less urban basins.

Where

$FLOW_i$ = the total nonpoint source flow (cubic meters per month) from Land use category i,

FLOW = the total nonpoint source flow (cubic meters per month) from a subbasin,

A_i = area (acres) in land use category I, and

Ri = the runoff coefficient (fraction of rainfall that runs off) for land use Category I.

Runoff coefficients for each land use category were developed based on a literature review. The proportion of runoff attributed to each land use category for a given basin remains constant as total runoff increases (Figure 2-7).

2.3 Data used for Parameter Estimation and Distribution of Total Nonpoint Source Flow for Land Use Groups

2.3.1 Stream Flow Measurements

Total monthly streamflow data were obtained from United States Geological Survey (USGS) monitoring records for the Tampa Bay watershed. Data from water years 1985 through 1991 were used to calculate existing streamflow inputs. The USGS streamflow recording stations shown in Figure 2-8 and Table 2-1 were used for model development.

In addition, data from other gaged sites monitored by SWFWMD, Manatee County or others were obtained, as listed in Section 3. Data from these sites were chosen either for model development, or to provide measured data for gaged area streamflow and pollutant loading calculations.

2.3.2 Drainage Basin Boundaries

Drainage basin boundaries were incorporated into all geographically-based data used for this project (e.g., land use data, precipitation data, drainage areas, point source locations). The drainage area boundaries were based on data obtained from SWFWMD (1992(a)). Modifications were made to the basin boundaries for the development of the surface water hydrology model. These modifications include the correction of minor coding errors, the subdivision of coastal basins following the bay segmentation scheme used by TBNEP, and the subdivision of gaged and ungaged portions of the watershed.

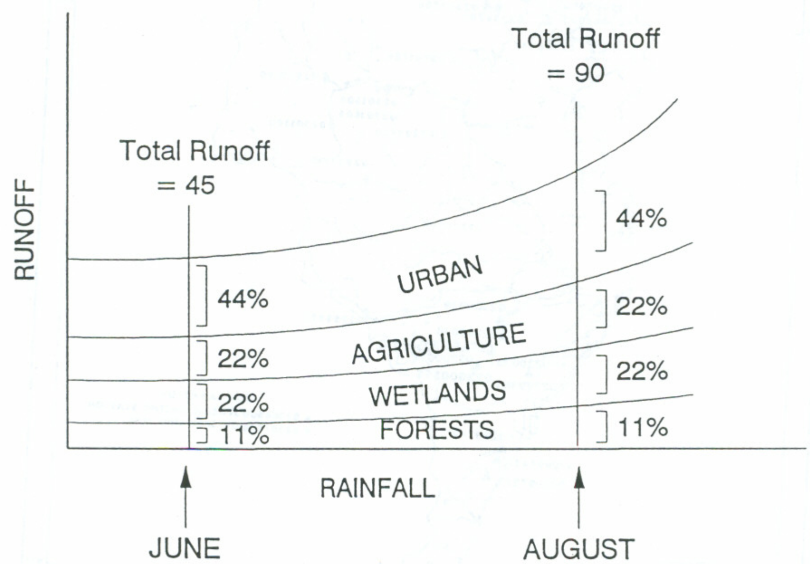


Figure 2-7 Effect of increasing total runoff on proportion of runoff attributed to each land use category.

Figure 2-7 Effect of increasing total runoff on proportion of runoff attributed to each land use category.

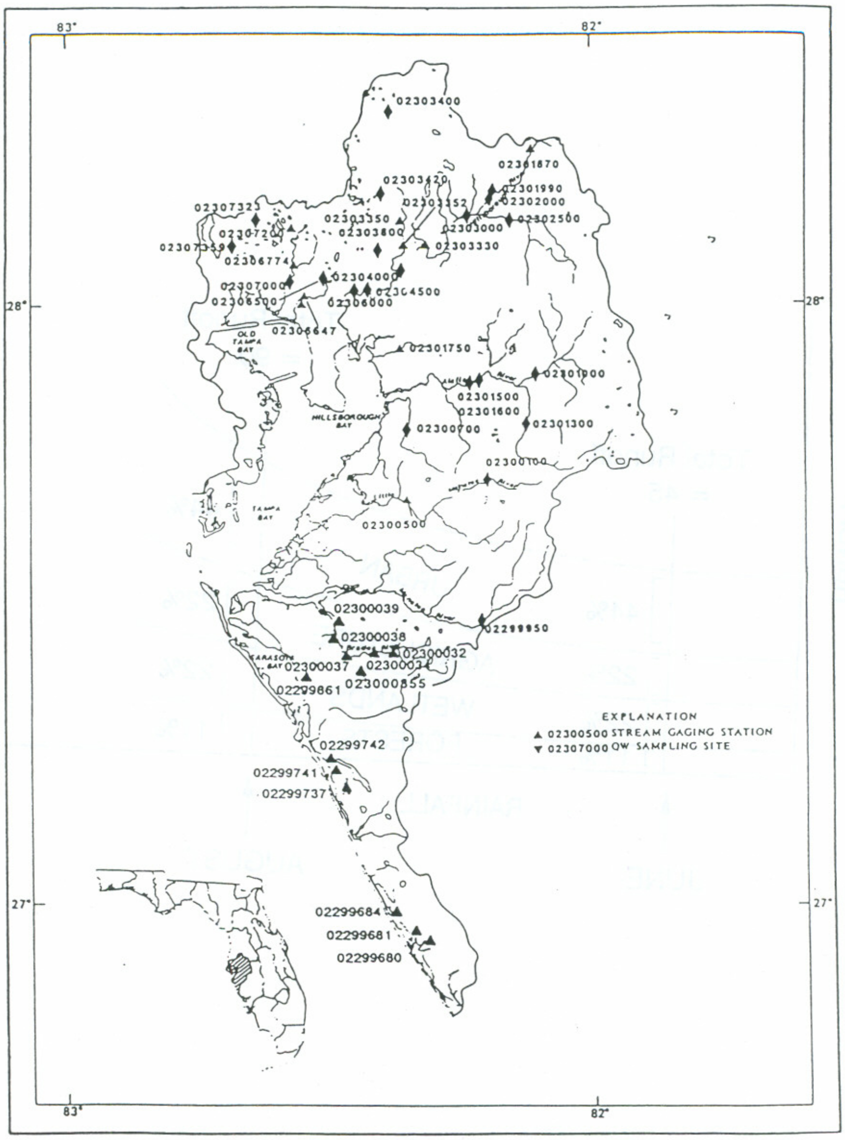


Figure 2-8 Location of USGS gaging stations.

(Refer to Table 2-1 for identification of stations used in hydrologic model development. - from USGS, 1992)

Figure 2-8 Location of USGS gaging stations.

(Refer to Table 2-1 for identification of stations used in hydrologic model development. - from USGS, 1992)

Table 2-1 Streamflow Monitoring Stations Used for Hydrologic Model Development	
USGS Gage Number	Site Name
02300500	Little Manatee River near Wimauma
02300700	Bullfrog Creek
02301000	North Prong Alafia River
02301500	Alafia River at Lithia
02301750	Delaney Creek
02303000	Hillsborough River near Zephyrhills
02303330	Hillsborough River at Morris Bridge
02306647	Sweetwater Creek near Tampa
02307000	Rocky Creek near Sulphur Springs
02307359	Brooker Creek near Tarpon Springs

A total of 435 subbasins, including ten subbasins comprising open water areas of Tampa Bay, have been delineated, encompassing an area of approximately 2,646 square miles (sq. mi.), or 6,835 square kilometers (sq. km.). Excluding open waters of the bay, the watershed includes 425 subbasins covering approximately 2,276 sq. mi. (5,895 sq. km.).

These subbasins were delineated by USGS (Foose, 1993), however, some of the subbasins were further subdivided to break out gaged and ungaged areas. For example, if a streamflow gage was located in the midpoint of a USGS subbasin, that subbasin was divided into two parts. The upstream portion of the original subbasin included the gaged area, and the downstream portion would be ungaged. This was necessary for streamflow estimate computation, which used a different method of calculation for gaged and ungaged areas.

Each of the 425 individual subbasins that comprise the 2,276 sq. mi. watershed has been assigned an extended Hydrologic Unit Code (HUC) by USGS. This eight-digit code indicates hydrologic linkage between catchments, making it possible to trace upstream subbasins to their ultimate outfall at the estuary. In addition, internally drained ("hydraulically noncontributing") areas have been delineated by USGS. These internally drained lands, which include 22 subbasins, encompass 125 sq. mi., or slightly more than 5% of the watershed area. These areas may be expected to retain initial rainfall volumes, and provide surface discharge only after internal storage areas are filled. For nonpoint source load modeling, these noncontributing subbasins were removed from the land area that generated stormwater runoff.

2.3.3 Rainfall Records

The precipitation data used for modeling surface water hydrology were obtained from the National Climatic Data Center of the National Weather Service (NWS) (National Weather Service, 1993).

Total monthly precipitation data were obtained for the existing period (1985-91) for 22 long-term stations within and near the Tampa Bay watershed. The names and locations of these stations are presented in Table 2-2 and Figure 2-9, respectively.

Total monthly precipitation values were estimated for each subbasin, month, and year of the existing period. Subbasin estimates were interpolated from a precipitation response surface which was fit to the entire watershed for each month and year of the existing period. The response surface was fit by computing an inverse-distance-squared, weighted-average of precipitation measurements within a search radius of 50 kilometers for each subbasin. This method of estimating rainfall for a subbasin accounts for regional patterns, but gives more emphasis to local conditions. Using this method the total monthly precipitation for each subbasin was computed as follows:

$$\frac{\sum_{k=1}^{K_j} p_k \left(\frac{1}{D_k^2} \right)}{\sum_{k=1}^{K_j} \left(\frac{1}{D_k^2} \right)}$$

where $\mathbf{p_j}$ = estimated total monthly precipitation for the jth subbasin

$\mathbf{K_j}$= the number of NWS stations within 50 kilometers of the geographic center of the jth subbasin,

$\mathbf{p_k}$ = the total monthly precipitation recorded at the kth NWS station, and

$\mathbf{D_k}$ = the distance (meters) between the geographic center of the jth subbasin and the kth NWS station.

Table 2-2 Long-Term National Weather Service Precipitation Stations

Precipitation Site Number	Site Name
228	Arcadia
478	Bartow
520	Bay Lake
940	Bradenton

945	Bradenton 5ESE
1046	Brooksville
1163	Bushnell
1632	Clearwater
1641	Clermont
3153	Ft. Green
3986	Hillsborough
4707	Lake Alfred
5973	Mountain Lake
6065	Myakka
6880	Parrish
7205	Plant City
7851	St. Leo
7886	St. Petersburg
8788	Tampa International Airport
8824	Tarpon Springs
9176	Venice
9401	Wauchula

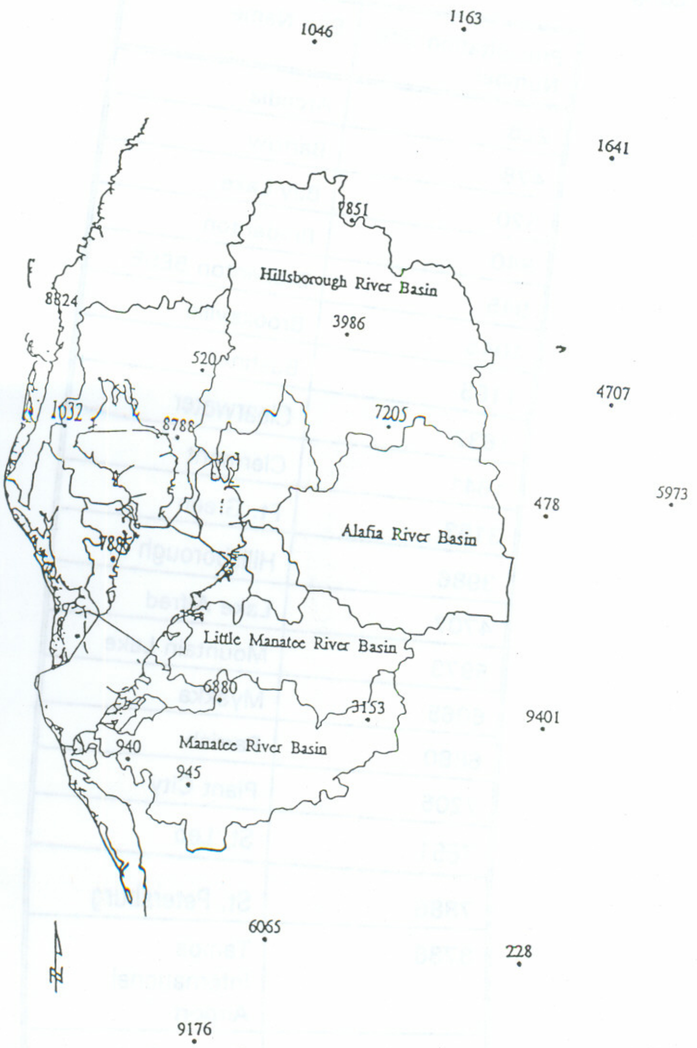


Figure 2-9 Location of National Weather Service precipitation monitoring stations.

Figure 2-9 Location of National Weather Service precipitation monitoring stations.

2.3.4 Land Use/Land Cover Data

Land use/land cover GIS data were obtained from SWFWMD (1992(b)), and incorporated into the surface water hydrology model. The SWFWMD data were interpreted from 1:24,000 and 1:40,000 scale, color infrared aerial photographs. The photographs were made during December of 1989 and January of 1990. The land use data were recorded following the Florida Land Use Cover Classification System (FLUCCS) level 3 developed by the Florida Department of Transportation Thematic Mapping Section (FDOT, 1985).

For the purpose of assigning land use-specific runoff and pollutant loading factors, the land use data were aggregated into 21 classes as shown in Appendix 1 and described in Section 3. This classification system was developed by examining the source literature for the FLUCCS land use classification scheme, land use specific runoff factors, and land use specific pollutant loading factors, as referenced in Section 3.

In order to compute parameters for the surface water hydrology model, the land use data were further aggregated into four major classes as described in Section 3. The classes were urban, agricultural/mining, forest/undisturbed, and wetland/water. The areal extent of each of the four aggregated land use classes for each of the basins used to fit the surface water hydrology model is listed in Table 2-3. For pollutant loadings estimates, these land use categories were disaggregated into 21 classes.

As described in the previous section, the areal percent of urban land use was used to divide the basins into a less urban group (group A) and a more urban group (group B). The classification of basins into these two groups is summarized above in Figure 2-6.

2.3.5 Land Use-Specific Runoff Coefficients

Land use-specific runoff coefficients were obtained from published literature, including references for the west-central and south Florida geographic area (Chow, 1964; USDA, 1975; Harper, 1991). A range of coefficient values for each land use was developed to account for seasonal changes in rainfall/runoff relationships, and for local soils conditions, as shown in Appendix 2. These coefficient ranges reflect higher rates of runoff during the wet season when soils are more saturated, water table elevations are higher, and depressional storage availability is lower.

The soils coverage includes discrete polygons of individual soil series (types) as identified by the USDA SCS in the county soil surveys. This coverage was obtained from SWFWMD in ARC/INFO format. Each discrete polygon represents a soil series, which was aggregated by hydrologic soil groups (A - D). The SCS has assigned a hydrologic group identification to each soil series to indicate runoff generating

Table 2-3 Distribution of Land Use Categories in Gaged Basins

USGS Gaged Basin	Percent Urban	Percent Agri.	Percent Forest/ Open Space	Percent Water/ Wetland
02300500	2	57	26	15
02300700	7	54	25	14
02301000	19	52	15	14
02301500	12	56	16	16
02301750	55	12	25	8
02303000	19	35	24	22
02303330	20	33	24	23
02306647	61	05	13	21
02307000	40	12	20	28
02307359	19	19	27	35

characteristics. "A" soils, in general, generate the least, and "D" soils the most amount of runoff for a given rainfall. The soils coverage was intersected with the land use coverage to provide the GIS layer used to estimate runoff coefficients. Each unique combination of land use type, soil series, and season has been assigned an associated runoff coefficient value.

2.4 Parameter Estimates for Tampa Bay Watershed

The hydrologic model includes seven parameters associated with three rainfall categories and four land use categories. The values of these parameters were estimated using least squares regressions after log transforming the log-linear model (Equation 2). Parameter estimates were made for each of four categories of basin type, defined by land use (19% urban or >19% urban) and season (wet or dry).

<u>Results from Regression Analyses</u>

Least squares regressions were highly significant for each category of basin type, with the model accounting for 52-66% of the variance in the data (Table 2-4). The parameter estimates used in predicting runoff are presented in Table 2-5, with their

Table 2-4 Results of least squares regression analyses for the model predicting runoff from rainfall and land use

Basin Land Use	Season	F Value	Prob > F	r^2
19% Urban	Dry	588.42	0.0001	0.60

19% Urban	Wet	378.14	0.0001	0.64
> 19% Urban	Dry	1608.33	0.0001	0.52
> 19% Urban	Wet	806.56	0.0001	0.66

standard errors. When viewed as weighting factors, the parameters associated with rainfall (b_0-b_2) generally placed greatest weight on the present month, as expected. The preceding two months do contribute significantly to the model, however, especially during dry season months.

2.5 Hydrologic Model Validation

The predicted flows from the hydrologic model described above were compared to measured flows in ten basins in the Tampa Bay watershed. These model predictions compare more favorably to the observed flows than did the modified NPSLAM Model predictions discussed above. Therefore, it appears that the empirical model provides better estimates of flows in the range of typical flows for these basins. The bias in the NPSLAM predictions averaged approximately 1500%, due in great part to extreme overprediction of flows in Brooker Creek. Exclusion of the Brooker Creek data from the NPSLAM model results in an average bias of approximately 300%. The average bias in the predictions of the empirical hydrologic model prepared for this project was 33%. Figure 2-10 shows the overall relationship between the predicted and observed flows. Figure 2-11 compares predicted and observed flows in the range of 0-4 inches (the 95th percentile of observed flows). Plots of observed versus predicted flows are shown in Appendix 3. The correlation coefficient (r^2) for these relationships ranged from 0.5 to 0.89, with an average r^2 of approximately 0.7, with the poorest fit observed for Brooker Creek. The r^2 for the relationship between NPSLAM predictions and observed flows ranged from 0.39 to 0.8, with an average of 0.54.

Table 2-5 Parameter estimates and standard errors (in parentheses) for hydrologic model

Parameter	≤19% Urban Dry	≤19% Urban Wet	> 19% Urban Dry	> 19% Urban Wet
b_0	4.59 (1.04)	7.22 (1.09)	5.93 (1.07)	7.60 (1.05)
b_1	6.27 (1.23)	3.59 (1.16)	6.17 (1.19)	1.71 (1.19)
b_2	4.30 (0.85)	2.25 (1.25)	3.58 (0.85)	2.79 (1.33)
c_1	-4.86 (1.51)	-5.63 (2.10)	-5.98 (0.58)	-4.67 (0.85)
c_2	-2.97 (0.49)	-3.85 (0.74)	-5.49 (1.29)	-5.39 (1.78)
c_3	-16.91 (1.97)	-11.77 (2.77)	-1.45 (0.72)	-2.79 (1.04)
c_4	-3.04 (1.95)	-5.00 (2.75)	-10.15 (1.92)	-10.22 (2.67)

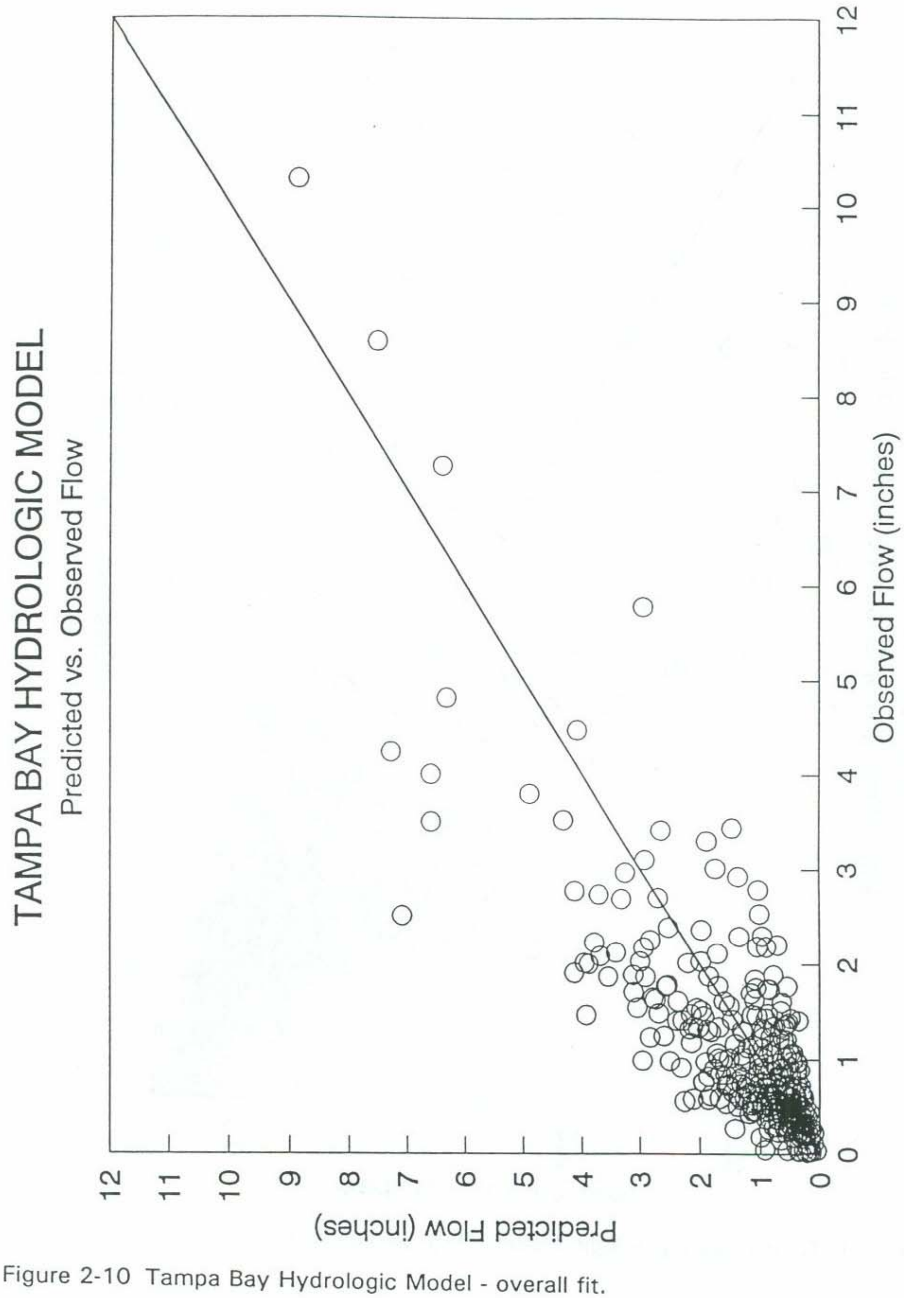


Figure 2-10 Tampa Bay Hydrologic Model - overall fit.

Figure 2-10 Tampa Bay Hydrologic Model - overall fit.

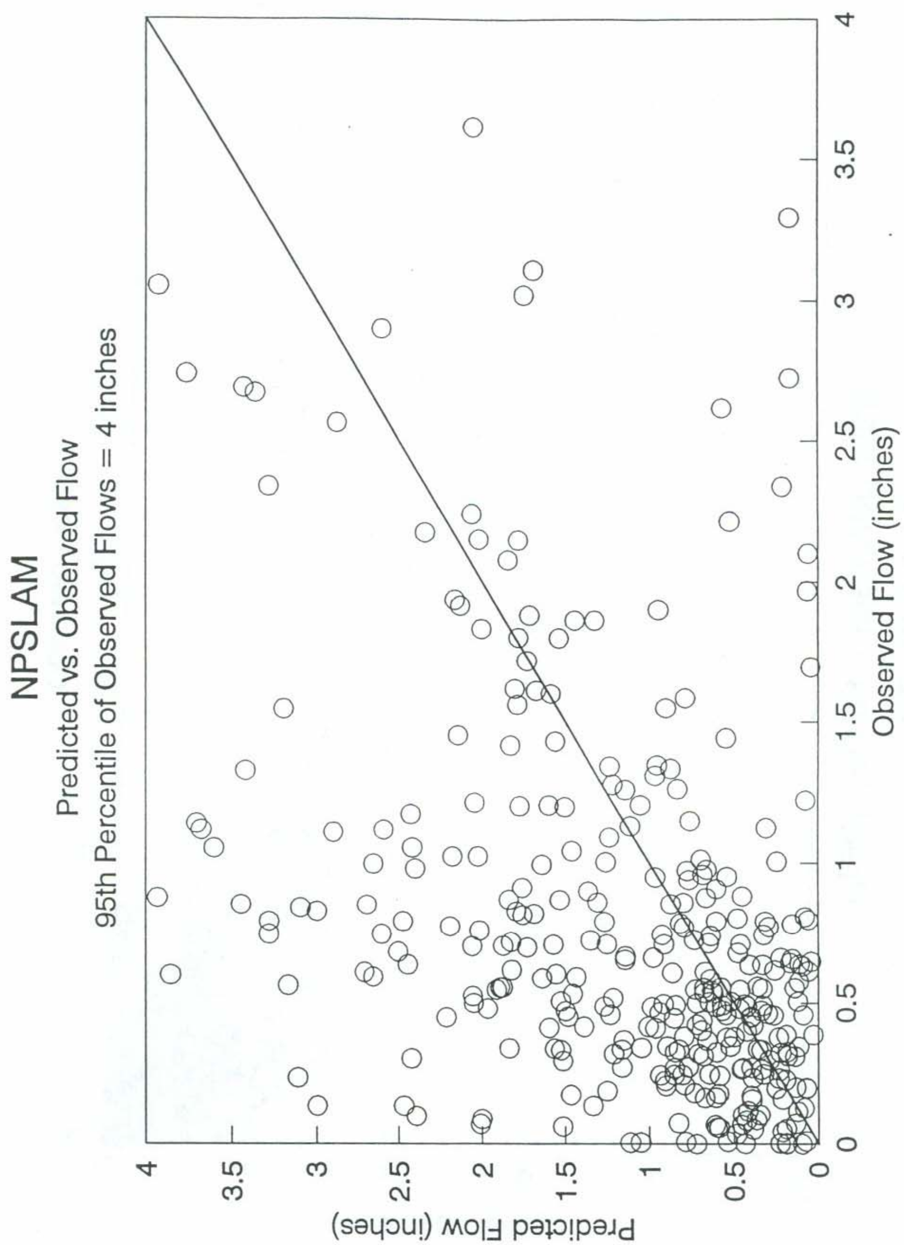


Figure 2-2 Modified NPSLAM Model - 95th percentile fit.

2-4

Figure 2-11 Tampa Bay Hydrologic Model - 95th percentile fit

APPENDIX J

SECTION 3.2.1.2-: Estimation of Point Source Loadings From: The Estimates of Total Nitrogen, Phosphorus, and Total Suspended Solids Loadings to Tampa Bay, Florida

Prepared For:

Tampa Bay Estuary Program

Prepared By: Coastal Environmental, Inc.

Tampa Bay, Florida

3.2.1.2 Estimation of Point Source Loadings

Existing condition point source loading estimates were developed as overall average monthly loads, to reflect the most recent upgrades to treatment facilities and disposal methods and are summarized in Section 5. Point source loads were also estimated as a time series of monthly values for the period January 1985 through December 1991. These time series will provide input to the TBNEP statistical nutrient-chlorophyll model and the SWIM box model, as discussed in Section 1.

Surface Discharge

Many of the inventoried facilities utilize direct surface discharge for effluent disposal. Surface water inputs from point sources were estimated for both the gaged and ungaged basins of the watershed, expressed as a volume per unit time, such as millions of gallons per day (mgd). The flows from each point source were assigned to the subbasin that receives the discharge, allowing the aggregation of point source flows for each major drainage basin and each bay segment. All of the effluent released via surface discharge was assumed to reach the Tampa Bay system.

Estimates of point source pollutant loading for surface water discharges were calculated by multiplying the flow (expressed as volume per unit time, such as mgd), by the reported concentration (mg/L) for the pollutant of concern. With appropriate conversion factors, this calculation yields a mass per unit time, such as pounds per month of pollutant (TN, TP, TSS).

Land Application

Treated effluent from domestic wastewater treatment plants is frequently discharged onto the land, most commonly by either spray irrigation or in percolation ponds. The applied effluent either evaporates, is taken up by vegetation, becomes surface runoff (generally a very small component of the total volume), or infiltrates to the water table. Therefore, pollutant loadings that reach the bay generally do so via groundwater. In this loading analysis, effluent loads are calculated separately from groundwater loads. Different water quality information was used in the calculation
of both of these inflow pathways. Measured groundwater quality data from wells not located adjacent to a known pollution source were used for the groundwater loadings.
Land application loadings were estimated using recorded effluent quality data from specific facilities, with "typical" reduction rates applied to the nitrogen and phosphorus once in the environment. These reduction rates, discussed below, account for uptake of nitrogen and phosphorus in the environment prior to the effluent flow reaching the receiving water of Tampa Bay.

Calculation of Loadings from Land Application

The determination of the amount of land-applied effluent that is delivered to the Tampa Bay system was not as straightforward as for surface discharge loadings (Anderson et al., 1991; 1993; Cherry et al., 1973). Both the hydraulic inflow and the pollutant loadings from the effluent that reaches Tampa Bay are reduced from the amount that leaves the treatment plant because of a variety of natural processes. Because potential nutrient loadings from land application (reuse) is quantifiable, and attributable to a definable area, this source of nitrogen and phosphorus is accounted for separately from overall groundwater loadings, as discussed below.

Because a portion of the point source effluent discharged as land application is lost due to evaporation, transpiration, and infiltration, inflow estimates were corrected for this loss. Casseaux (1985) estimates that approximately one-quarter (26%) of rainfall falling in Pinellas County reaches Tampa Bay - either as streamflow, direct runoff, or groundwater flow. Based on these findings, it was assumed that 26% of the hydraulic load of treated wastewater effluent from land application facilities reached the bay. To account for variability within the watershed, a range was estimated of 15% and 35% of the total discharged land application flow to be delivered to the bay.

In addition, TN, TP, and TSS concentrations were assumed to be reduced through assimilation, uptake, and filtering of the effluent during its path from the point of discharge to the receiving water. These values were developed as a result of the review of numerous references on the behavior of nitrogen and phosphorus in the environment.

- Nitrogen

Land application of wastewater effluent can utilize percolation ponds or spray irrigation facilities. Percolation ponds behave much like septic tank systems, (on-site wastewater treatment systems, or OWTS) in that the effluent from the pond is discharged directly to the unsaturated zone above the water table. Sprayed effluent has the benefit of increased evaporation, volatilization of ammonia nitrogen, vegetative uptake, and chemical conversion from bacteria in the soil. These processes can greatly reduce the amount of nitrogen remaining in the effluent when it reaches the shallow groundwater.

In the infiltration system, effluent-borne nitrogen travels downward through the unsaturated zone towards the water table. Volatilization, adsorption, mineralization, biological uptake, and denitrification occur at the land surface and in the root zone. However, the major transformation process in the unsaturated soil zone is nitrification. During this process, aerobic bacteria transform organic and ammonia nitrogen into nitrate. The nitrate ion is very soluble, and moves freely with the groundwater flow (Otis et al., 1993; Cantor et al., 1986). These processes are illustrated in Figure 3-5. Although nitrification does change the form of nitrogen, it does remain in solution. If conditions favorable for denitrification are present, up to 20% of the nitrate can be volatilized to elemental nitrogen gas during the infiltration period (Otis et al., 1993). Volatilization and biological uptake rates are generally higher for sprayed effluent because of prolonged exposure to the atmosphere and vegetation. Because of its solubility and anionic nature, nitrate is very stable in the aqueous environment and can migrate great distances in groundwater with little transformation or attenuation.

- Phosphorus

In contrast, phosphorus is usually effectively retained in soils, with only low concentrations typically reaching the water table (Cantor et al., 1986). Many monitoring programs have documented only minimal migration of phosphorus through the subsurface media. In the unsaturated zone, phosphorus is found in proportions of approximately 85% ortho-P and 15% organic-P. As shown in Figure 3-6, at low concentrations phosphorus is subject to sorption to carbonate minerals. At high concentrations, phosphorus may precipitate, forming a variety of relatively insoluble compounds. This constrains the migration of phosphorus in groundwater under most circumstances. However, under low-term or high application rates, the retention capacity of the soils may become exceeded. Under these conditions, phosphorus may migrate within the groundwater environment (Otis et al., 1993).

FATE AND TRANSPORT OF WASTEWATER CONSTITUENTS IN SOIL AND GROUNDWATER

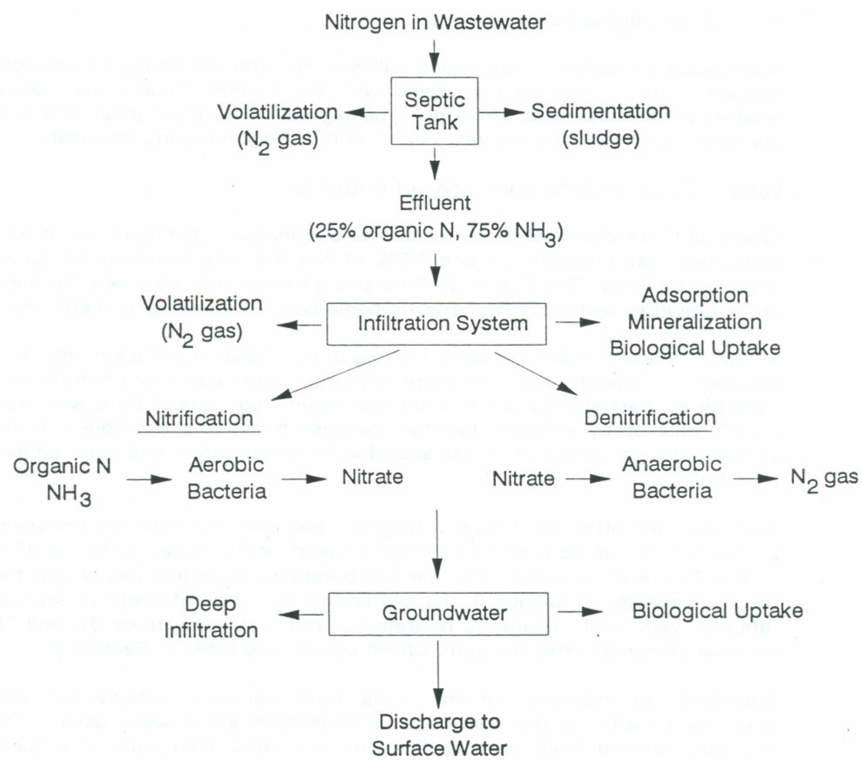


Figure 3-5 Fate and transport of wastewater constituents in soil and groundwater - nitrogen.

3-16

Figure 3-5 Fate and transport of wastewater constituents in soil and groundwater - nitrogen.

- Suspended Solids

Subsurface migration of suspended solids is constrained mainly by physical process. Solids that are discharged with the treated effluent are mainly retained at the soil surface, although some migration may occur under high flow conditions or if the soils are very coarse and lacking in organic material.

Loading Rates for Land Application of Nutrients

Based on these chemical characteristics and a review of the literature, it was estimated that between 70 and 95% of the TN was removed for spray irrigation facilities. The City of St. Petersburg wastewater treatment facilities are operated so as to maximize the ammonia content of nitrogen in effluent.

A high ammonia content increases the rate of volatilization and plant uptake of nitrogen from the effluent. Therefore, a nitrogen attenuation rate of 95% was used for St. Petersburg plants. A nitrogen attenuation rate of 90% was used for all other spray irrigation facilities because much of the nitrogen in the sprayed effluent is in a form less available for volatilization and plant uptake (nitrate).

Also, between 50% and 70% of nitrogen in percolation ponds was removed, between 70% and 95% of the TP was removed, and between 70% and 95% of the TSS was removed. For the computations described below and the results presented in Section 5, the low end of the range of loadings (highest removal) was used. Literature references used to develop these TN and TP removal efficiency rates are summarized below, and listed in Section 6.

Therefore, to estimate nutrient loads from domestic wastewater land application facilities, the following computational steps were used. The hydraulic loading from land application, (the total flow rate of effluent discharged from a treatment plant) was multiplied by 0.26 based on the findings of Casseaux (1985). The concentrations of TN, TP, and TSS, were multiplied by the higher estimates of chemical removal. The removed fraction was subtracted from the total. For computational purposes, this is the equivalent of multiplying the "end of the pipe" monthly average concentrations of TN by the attenuation factor (0.9 to 0.95 for spray irrigation, 0.7 for percolation ponds), TP by 0.95, and TSS by 0.95. The point source loading results shown in Section 5 include only 1991 data for surface discharges, to account for improvements to treatment or disposal components of the point sources made during the 1980's, as discussed above.

One pollutant source that may be included with point source loading estimates is septic tank (OWTS) loadings. OWTS are regulated to minimize the potential for groundwater and surface water contamination, but site specific conditions or lack of maintenance leading to failure of the OWTS may produce locally significant pollutant loadings. Although domestic waste loads for the benchmark period were estimated as originating from septic tanks as described in Section 4, no explicit accounting for septic tank loads from the existing period was completed. However, it is assumed that septic tank effects are implicitly accounted for in the gaged portion of the watershed by use on measured streamflow and water quality data.

As described above, the separation of nonpoint and point sources of water in the measured flow data were necessary whenever estimates of the nonpoint source component of streamflow were desired. In these cases, the point source flow estimate was subtracted from the measured flow. Whenever the regression model was used to estimate flows for either gaged or ungaged areas, the point source flow was added to the model estimates of nonpoint source flow to provide estimates of total streamflow.

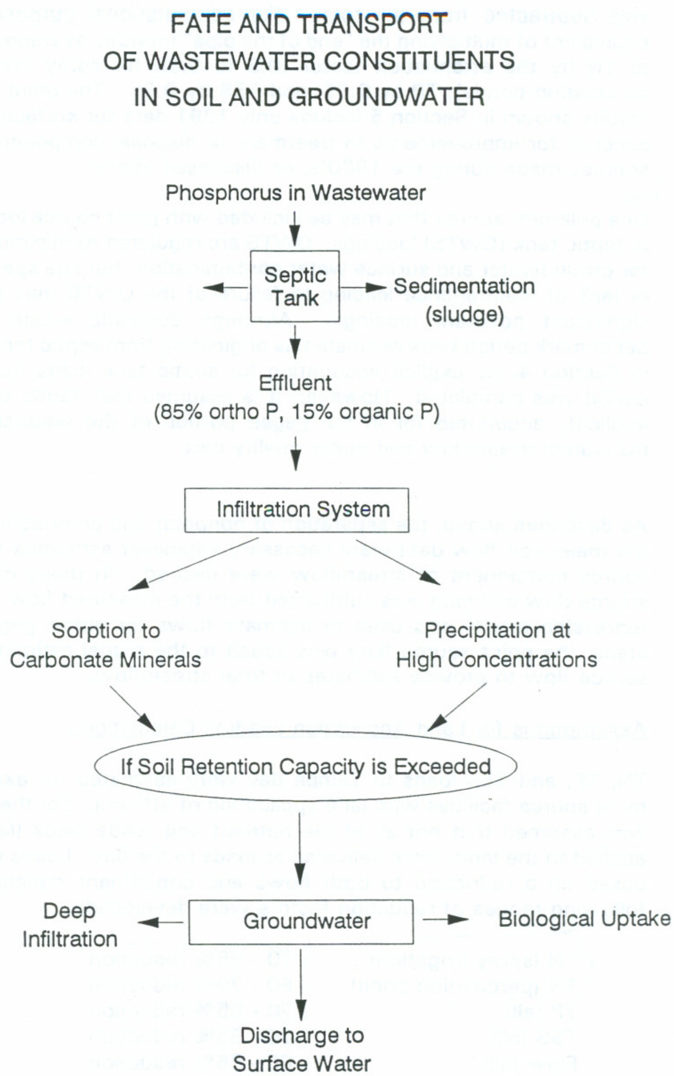


Figure 3-6 Fate and transport of wastewater constituents in soil and groundwater - phosphorus

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Figure 3-6 Fate and transport of wastewater constituents in soil and groundwater - phosphorus

Assumptions for Land Application Loading Calculations

TN, TP, and TSS loads to Tampa Bay were estimated for existing condition point source facilities with land application of effluent. For these estimates, it was assumed that not all of the nutrient and solids loads (loads) that were applied to the land, were delivered as loads to the bay. Loads were calculated based on a reduction to both flows and constituent concentrations. The following ranges of reduction factors were developed:

TN (spray irrigation) : 70 - 95% reduction
TN (percolation pond): 50 - 70% reduction
TP (all) : 70 - 95% reduction
TSS (all) : 70 - 95% reduction
Flow (all) : 65 - 85% reduction

TN, TP, and TSS reductions were based on literature values for nutrient behavior in the subsurface environment and local groundwater monitoring data. General assumptions include:

- Recorded monthly values for domestic effluent for facilities with land application were used as the influent value.

- Initial concentration reductions result from above-ground and root zone processes, followed by downward migration through the unsaturated zone, to the water table.

- Some additional removal of TN, TP, and TSS may occur during waste stream movement towards the receiving water (surface water), through the surficial aquifer. However, this additional removal is thought to be relatively small, so there was no accounting for varying distances of effluent travel among individual sources.

- Removal rates for nitrogen in effluent are higher for spray irrigation than for percolation ponds because of enhanced volatilization and plant uptake that occurs with spray facilities. The City of St. Petersburg wastewater treatment plants operate to maximize the ammonia proportion of nitrogen in the effluent. This enhances plant uptake and volatilization of nitrogen, and supports the estimated 95% removal rate calculated using monitor well data, as discussed in Appendix 6.

Literature References

Several references were reviewed to determine a range of TN, TP, and TSS removal rates and efficiencies for domestic waste effluent. Summaries of findings or excerpts of these studies listed below:

Reichenbaugh et al. (1979) - TN concentrations were shown to be reduced by 50 to 100%, and TP by 15 to 93% in samples from some monitoring wells downgradient from a domestic spray irrigation site in St. Petersburg, Florida. Other monitor wells at the site yielded samples showing no increase in TN concentrations.

Yurewicz & Rosenau (1986) - Sampling monitoring wells downgradient from a domestic spray irrigation site in Tallahassee, Florida found TN concentrations were reduced by 33 to 80%, and TP by 100% in samples from wells downgradient from the application site.

Franks (1981) - A review of spray irrigation sites in Florida found that at a spray irrigation site in Tarpon Springs, both TN and TP had 90% removal after 900 feet of travel. A site in Lakeland showed TN concentrations reduced to background levels after 8 feet of travel, and TP reduced to background levels after 4 feet of travel. A site in Eustis showed 0% TN removal after 4 feet of travel, and TP removal of 50% after 4 feet of travel.

Martin (1990) - This model septic tank ordinance, produced for SWFWMD/SWIM states that typical TP removal rates can vary from 85 to 95%, and that TSS reduction is typically 50 to 60%.

Cantor et al. (1986) - Reports 20 - 35% as typical removal rates for TN in the soil unsaturated zone, on a nationwide basis. This removal rate does not account for above-ground processes such as volatilization and biological uptake by plants.

Otis et al. (1993) - States that nitrification is the major process that transforms nitrogen in the subsurface environment. Because the resulting nitrate is very soluble and chemically stable, very little transformation occurs once the water table is reached. He states that (for OWTS), "...it is usually assumed that all the nitrogen applied to subsurface wastewater infiltration systems ultimately reaches the groundwater." However, denitrification can be a significant process if anaerobic conditions exist, resulting in up to 20% reduction in nitrate levels within the soil layers, especially in fine-grained systems of clays and silts.

Postma et al. (1992) - Lists OWTS TN reduction rates as low, typically 10%, again on a national scale and not accounting for above-ground and root zone processes.

Camp, Dresser & McKee (1992) - Assumes 90% reduction in both TN and TP concentrations for land application of effluent in Sarasota Bay watershed.

Analysis of City of St. Petersburg Reuse Monitor Wells

The City of St. Petersburg Public Utilities Department maintains and monitors a network of monitor wells located at selected spray irrigation reuse sites. Water quality samples from these wells provide data that are used to determine what, if any, impact the reuse water has on local groundwater quality. An analysis of monitoring results was completed to determine if any increase in nitrogen or phosphorus in groundwater should be attributed to the application of reuse water. This is an empirical means of estimating nitrogen removal rates for nutrients introduced into the environment through the application of reuse water. A summarization of the analysis and results of the monitor well data is presented in Appendix 6. The nutrient removal rates obtained from that analysis are used in this loading analysis, as described above

Appendix K

Appendix 6 Analysis of City of St. Petersburg Reuse Water Monitoring Well Data
From: The Estimates of Total Nitrogen, Phosphorus, and Total Suspended Solids
Loadings to Tampa Bay, Florida
Prepared For:
Tampa Bay Estuary Program
Prepared By: Coastal Environmental, Inc.

APPENDIX 6

ANALYSIS OF CITY OF ST.PETERSBURG

REUSE WATER MONITORING WELL DATA

1) Background

The determination of transport and assimilation rates of chemicals in the natural environment, including groundwater, is the subject of widespread research. However, the behavior of many chemicals, in particular nitrogen and phosphorus, appear to vary greatly with site-specific characteristics. Therefore, it is sometimes difficult to predict these phenomena based on data collected under a variety of site conditions.

Because primary production in Tampa Bay is widely believed to be limited by nitrogen, it was desired to determine the most technically-defensible estimates of nitrogen loading rates from all potentially important sources. Land application of treated wastewater is a common method of effluent disposal in the Tampa Bay watershed. The practice of spray application of effluent (reuse water) for landscape irrigation provides many benefits, such as introducing vital nutrients to vegetation, and greatly reducing the use of potable water for irrigation purposes. However, because eutrophication can occur if excess nutrients reach an estuarine system such as Tampa Bay, it is very important to obtain as accurate an estimate as possible of the retention and delivery rates of nitrogen that enters the environment through reuse. The following discussion summarizes an analysis of local groundwater monitoring data that were used to aid in this process (see Section 3.B.1). The City of St. Petersburg has been instrumental in obtaining and providing these local groundwater monitoring data.

2) City of St. Petersburg Reuse Monitor Well System

The City of St. Petersburg Public Utilities Department maintains and samples groundwater from a network of shallow monitor wells located at selected reuse application sites (see location map). Results of the sampling data were obtained and analyzed to estimate potential impacts to groundwater quality from the application of reuse water. Two sets of data exist. The earlier monitor wells (numbered 770 - 778) were constructed to screened depths of 19 to 21 feet below land surface. These wells were sampled from April, 1979 to February, 1992. In 1992 new wells (numbered (770A, 772A, 775A, and 777A) were constructed to much shallower depths, and their screens intersect the water table surface, These shallower wells have been sampled from April of 1992 to present.

These wells are constructed within or adjacent to areas receiving secondary treated effluent from St. Petersburg municipal wastewater treatment plants. As discussed below, some of the well sites are thought to be influenced by other sources of nutrients, such as supplemental landscape fertilization. Groundwater quality data from the wells were examined to determine what, if any, impacts the reuse water had on local groundwater quality. Chemicals of interest include ammonia (NH_3), nitrate (NO_3), and chloride (Cl). Ammonia is the most prevalent nitrogen species in St. Petersburg's reuse water, and is not otherwise commonly found in high concentrations in an urban setting. Nitrate is also present in effluent, but is also a common form of nitrogen found in fertilizer. Chloride is used as a conservative tracer to indicate the presence and strength of effluent present. Cl concentrations in the effluent averages about 400 mg/L, and background groundwater concentrations are 50 mg/L or less. The location of the monitor wells discussed below is shown and described following this text. Graphs showing results of monitoring data also follows.

3) Analysis of NH_3, NO_3 and Cl concentrations in deeper discontinued wells:

Well #771

Total Kjeldahl Nitrogen (TKN) ranges from 0.50 to 3.0 mg/L during first two years (1979 - 1981) with an average of approximately 0.8. No TKN data were collected after 1981. Highest TKN value may be due to lab error, as all wells showed a peak at the same time.

Background (well 776) NH_3 ranged from 0.2 to 0.5 mg/L. Background nitrite appears negligible (generally less than 0.01 mg/L). Effects of effluent first were first picked up in samples in 1986, seven years after sampling began, as evidenced by a rise in CL from a background of about 30 mg/L to 400mg/L. After 1986, NH_3 increased to an average of about 1.8 mg/L, with a peak concentration of 2.8 mg/L. Nitrate remained low.

Conclusion: NH_3 was not reduced to background before reaching the water table at this site. Seven year delay for impacts to reach the monitor well may be a result of the deep sampling.

Well #773

Cl concentrations did not show a significant increase until 1990, ten years after sampling began. No clear trend in NH_3 concentration is evident, but may be slightly increased over a background of 0.5 mg/L. No NH_3 data exist for 1990 and beyond. No change was observed in NO_3 which remains negligible small.

Well # 774

NH_3 and NO_3 was greater than 150 mg/L for first two (2) years (1979-1989) of monitoring. This site is near an old landfill. Cl is highly variable, and ranges from near zero to 1700 mg/L. The variability reduces after 1985 when a declining trend begins. Cl concentration gradually falls from 1600 to about 700 between 1985-1992.

NH_3 and NO_3 concentrations fell to about 40 mg/L in 1988 and 1989, down from a pre-1981 average of about 150 mg/l.

Conclusion: Effluent from the spray operation apparently diluted high Cl and NO_3 in leachate from the old landfill. This well is of no value for reporting impact of spray irrigation but does raise a flag regarding potential landfill impacts.

Well #776

This is a control well, with no reuse of other identified nitrogen source nearby. NH_3 concentrations averaged about 0.6 mg/L for first two (2) years of monitoring (1979-1981). Sampling was discontinued from 1981-1986. NH_3 appeared to be at about the same level when sampling resumed in 1987. NO_3 showed low concentrations (less than 0.1 mg/L) at all times.

No discernable change in Cl was observed between 1979 and 1992, although Cl did rise from below 10 mg/L to above 20 mg/L from 1986 - 1992. Low concentrations indicate little reuse exist at the site, or that dilution is active.

Conclusion: This site appears to be a valid control.

Well #778

Cl concentrations were very low (less than 15 mg/L) in first two (2) years of monitoring (1979 - 1981). Sampling was discontinued during 1981 -1985. Cl concentrations increased to an average of about 250 mg/L (ranging from 100 to 400) between 1985 and 1992.

NH_3 averaged about 0.6 mg/L during 1979 - 1981. Samples taken from 1987 - 1990 show higher NH_3 concentrations, averaging about 1.0 mg/L, with high values over 1.5 mg/L. The coincident rise in Cl and NH_3 concentrations suggest that effluent has impacted water quality at this site.

Well #770

Cl concentrations are low (less than 20mg/L) for first two (2) years (1979 - 1981) with one peak near 100 mg/L. Cl begins a gradually increasing trend in 1988 and climbing to peak of 500 in 1991.

NH_3 concentrations range from 0.7 to 1.4 from 1979 - 1981. Monitoring of NH_3 was discontinued at #770 in 1982. NO_3 had a spike in 1979 of 0.65 mg/L, but was negligible at all other times.

Conclusions: No conclusions can be made regarding potential impacts of spray irrigation because of lack of NH_3 data.

Well #772

No discernable influence of reuse water. NH_3, Cl and NO_3 all remained low from April 1979 to 1992.

Well #775

Cl concentrations were low (less than 50mg/L) from 1979 until 1990, and sharply rose, peaking at about 400 mg/L in 1991 and dropping back to 175 mg/l by 1992.

NH_3 concentrations were low (approximately 0.3 mg/L) for 1979 - 1981. No NH_3 measurements were made after that date. NO_3 was low through 1990, and then rose to 1.75 mg/L in August, 1991 before dropping to 0.7 in February, 1992.

Conclusions:

Strong influence of reuse water was evident in early 1991, followed in about six months by high NO_3 peak, by far the largest of any noticed in deeper wells.

Well #777

Cl was low for the period 1979 through 1980. Sampling of Cl was discontinued until 1985 by which time the Cl concentration was up to an average of about 250 mg/L, and as high as 600 mg/L in August 1986.

NH_3 average was about 0.3 - 0.4 for first two (2) years (1979 - 1980). No information thereafter. NO_3 was very low throughout.

Conclusions:

Reuse water reaches this well (high Cl) but impact of NH_3 cannot be determined due to lack of data after October, 1980.

4) Analysis of NH_3, NO_3 and Cl concentrations in new, shallower wells:

<u>Well #770A</u>

CL averaging 80-100 mg/L over the last two years (1992-1993). No background from this well to compare, but at the deeper well, background was 15 to 20 mg/l. Cl had peaked at about 500 mg/L at the deeper well just before it was discontinued.

The low chloride concentration at the shallow well compared to the levels detected at the deeper wells suggests a high degree of dilution in the last several years or a substantial reduction in Cl in the applied effluent.

<u>Well #772A</u>

This well may be impacted by other nitrogen sources according to St. Petersburg.
The Cl concentration rose from 200 to 300 mg/L since April, 1992 during which time NH_3 oscillated around 2 mg/l. The fact that the ratio of NH_3 to Cl is quite variable suggesting factors other than simple dilation of the effluent are influencing these concentrations. NO_3 has remained very low except for one value of 0.3 corresponding to drop in NH_3 of 0.5.

<u>Well #775A</u>:

St. Petersburg believes that fertilizer application to a landscaped area adjacent to the well has influenced the water quality. NO_3 averages 2.3 mg/l and peaked at 4.5 mg/l. NH_3 average 0.03 with a peak at 0.08.

CL has averaged about 225 mg/l at the new well but peaked around 400 in the deeper well.

Possible explanations:

1) Fertilizer application results in high NO_3. Low NH_3 suggests no significant reuse water impact.

2) Applied fertilizer contains NH_3 and NO_3, and reuse water is high in NH_3. Soil nitrifying bacteria may have converted all nitrogen in the fertilizer and the reuse water to NO_3.

Problem with that hypothesis: Why hasn't the conversion of NH_3 to NO_3 occurred at the other shallow sites and the deeper sites? High levels of NH_3 have not been measured at any of the other site (except the ones presumably receiving fertilizer loads.

3) High NO_3 levels in the reuse water. This is not likely, as all operating reports for municipal plants show very high ration of NH_3 to NO_3.

Well #777A:

Same conclusions and questions apply here as to #772.

Further Notes on #775:

The high NO_3 measured at #775 (deeper well) in 1991 and 1992 (4 values of 0.6 and above) were probably accurate values. The fact that they peaked almost in phase with the Cl concentration suggests that they were following a similar diffusion pattern. The NO_3 concentrations lag the Cl by about four months but is very similar.

5) Estimation of background nitrogen concentrations

St. Petersburg reuse monitor well data

WELL	Nitrogen concentrations			COMMENTS
	NH3	NO_3	DIN	
#771	0.66	0.04	0.70	Based on St. Petersburg monitoring results 4/79 - 8/80
#773	0.27	0.03	0.30	Same
#778	0.58	0.04	0.62	Based on St. Petersburg data 4/79 - 8/80
#770	1.14	0.05	1.19	Same
#772	0.39	0.01	0.40	Same
#775	0.24	0.01	0.25	Same
#777	0.46	0.01	0.47	Same
AVE	0.53	0.03	0.56	

Other monitoring data of nitrogen concentrations in unimpacted shallow groundwater

WELL	BACKGROUND NH_3	NO_3	DIN	COMMENTS
USGS (Reichenhaugh) #CB-1 & CB-2	1.70	0.00	1.70	From St. Petersburg reuse test site. Average of 6 samples prior to irrigation with effluent. Sampling depth 5-20 ft.
SWFWMD - various reports	0.0	0.001 to 0.1	0.001 to 0.1	From unimpacted sites in Tampa Bay watershed. Summary of SWFWMD monitoring data - see cited literature.

Assume: Organic nitrogen is not included in the computation of background and potentially impacted concentrations. This may underestimate the impact of reuse water, because although there is virtually no organic nitrogen in the effluent, some portion of the NH_3 may be converted to organic nitrogen in the biologically active layers of soil. Ammonia and nitrate are combined as dissolved inorganic nitrogen (DIN).

Estimated average background DIN for St. Petersburg water table is:

((7 x 0.56)+(2 x 1.7))/9 = 0.81 mg/L

where:

- 7 St. Petersburg wells average 0.56 mg/L
- USGS wells averaged 1.7 mg/L at reuse test site
- to be conservative, watershed-wide unimpacted well data not used.

Monitoring data of nitrogen concentrations in impacted shallow groundwater

WELL	Nitrogen concentrations NH_3	NO_3	DIN	COMMENT
771	2.00	0.00	2.00	Ave. of three samples during period with high Cl concentration
778	1.50	0.03	1.53	Average of most recent samples

772A	1.90	0.04	1.94	This site may be influenced by other sources.
AVE	1.80	0.02	1.82	

ASSUMPTION: Well #770 was not included in the estimate since low Cl concentrations suggest that the well was not apparently showing the full influence of reclaimed water. Average Cl levels were only 100 mg/L or less. Cl would be expected to be higher (300 - 400 mg/L) if reuse water had full influence on samples. If NH_3 (DIN) levels were increased in proportion to that required to raise the Cl concentration to "full impact" (300/100, or a factor of 3), the DIN concentration for that well would be 0.62 x 3 = 1.86 mg/L, or virtually the same as the average for the other wells.

6) Estimation of percent nitrogen removal

Using the results from City of St. Petersburg monitor wells and USGS test wells, the application of reclaimed water is estimated to raise groundwater inorganic nitrogen (DIN) concentrations by about:

1.82 - 0.81 = 1.01 mg/L.

where:

- background DIN concentration is 0.81 mg/L
- impacted DIN concentration is 1.82 mg/L

Concentration of ammonia and nitrate-nitrogen in secondary treated effluent from municipal plants averaged 17.2 mg/L for the period 1985 - 1991 (from FDEP files of domestic wastewater monthly operating records). The fraction of nitrogen remaining in groundwater resulting from spray application of reuse water is:

1.01/17.2 = 0.059, or about 6%

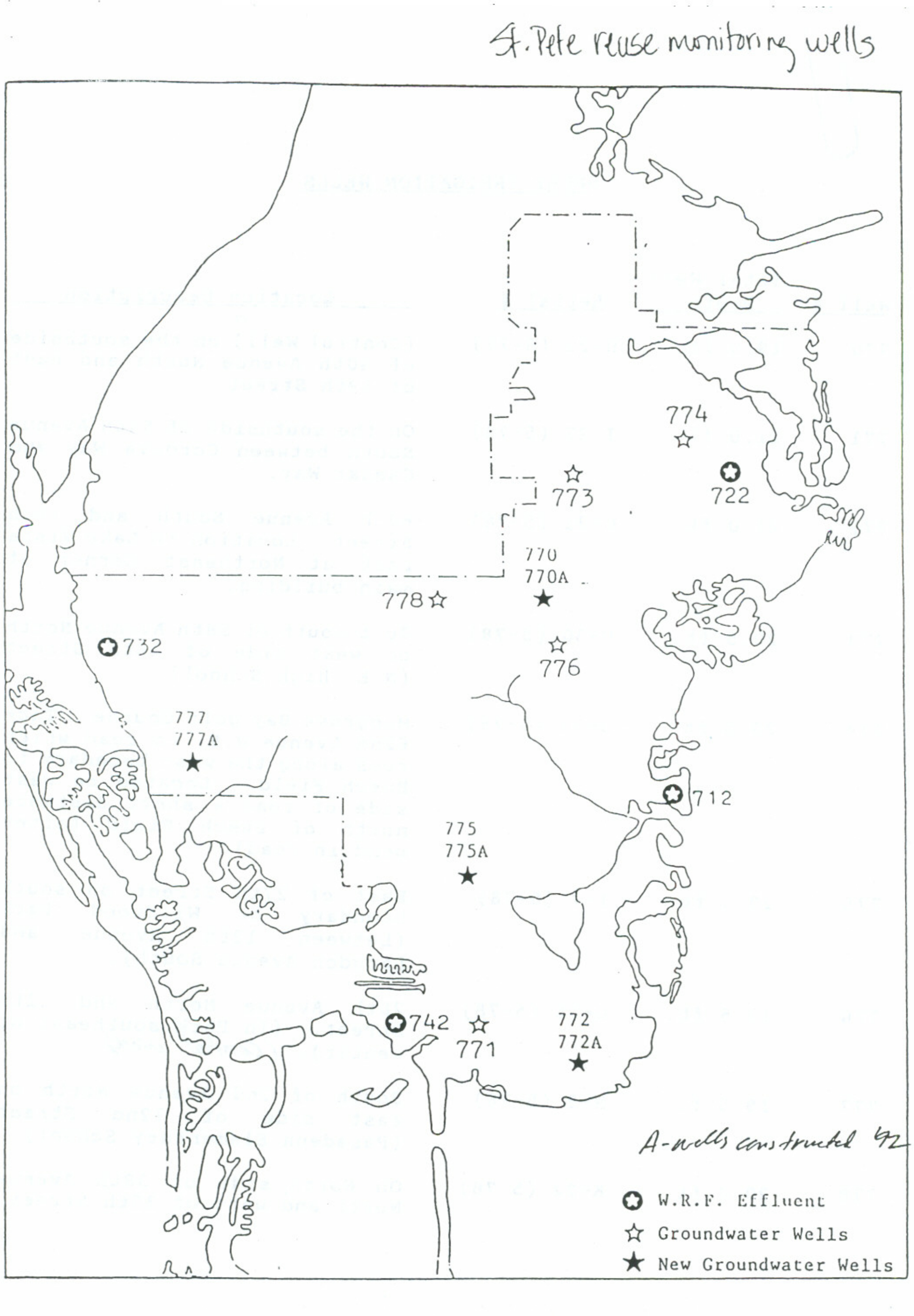
where:

- concentration increase in groundwater DIN attributed to reuse water is 1.01 mg/L
- effluent TN concentration (NH_3 + NO_3) is 17.2 mg/L

Therefore, the removal rate of nitrogen from the effluent is approximately:

(1-0.06) x 100 = 94%

The 94% (rounded to the nearest 5%, or 95%) removal rate is applied to the total volume of effluent, with no further reduction in load based on flow reductions.



GROUNDWATER MONITORING SYSTEM

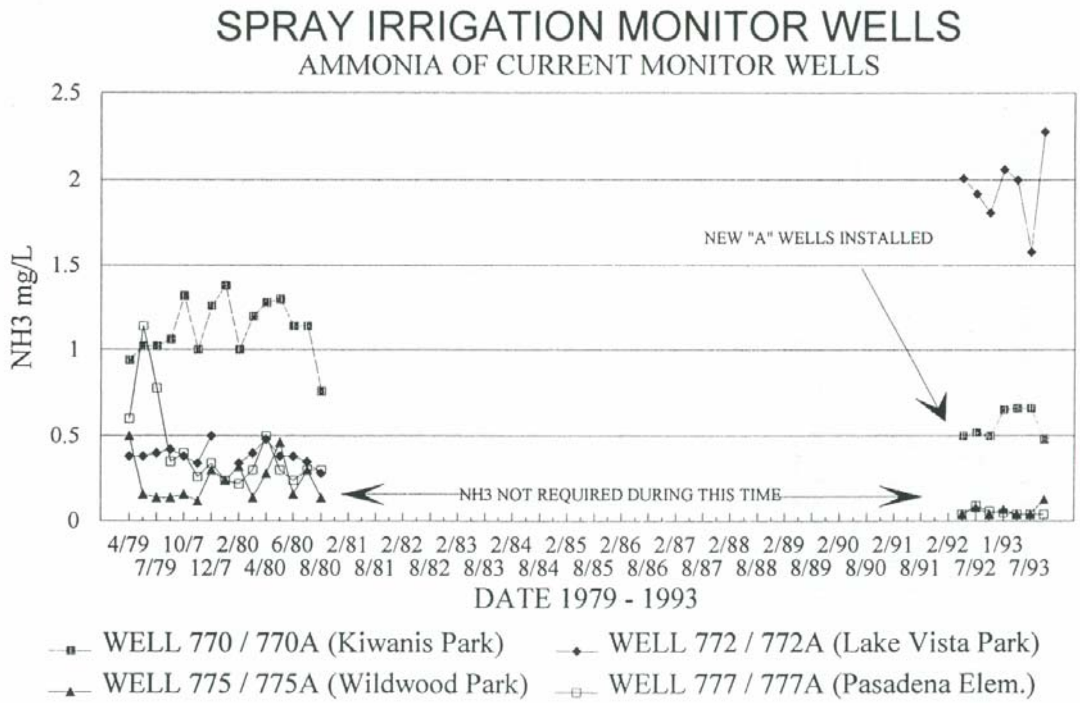
21

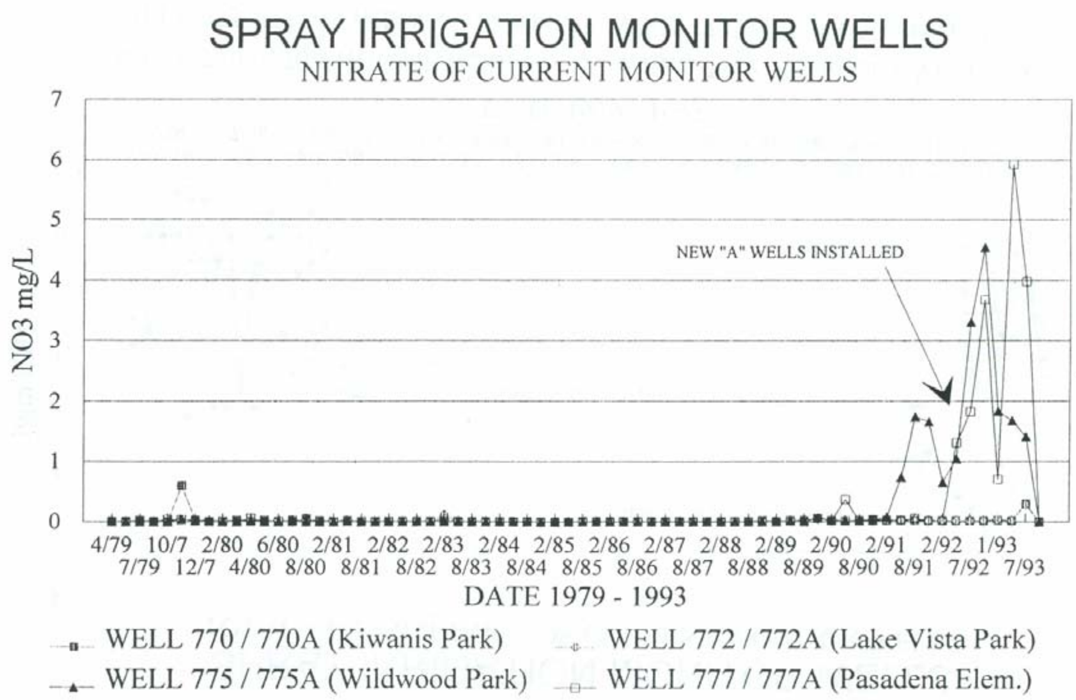
SPRAY IRRIGATION WELLS

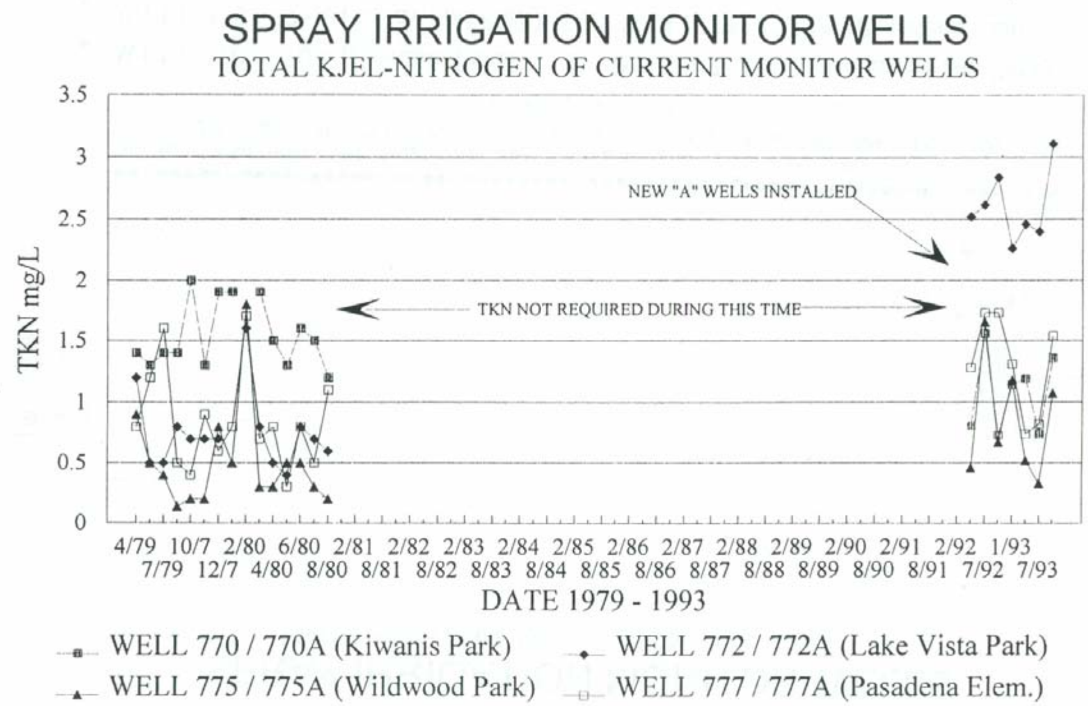
Well #	Total Well Depth	Aerial #	Location Description
770	19.0 ft.	H-22 (5-78)	(Control Well) on the southside of 40th Avenue North and east of 19th Street.
771	21.0 ft.	I-27 (5-78)	On the southside of 54th Avenue South between Cordova Way and Caesar Way.
772	21.0 ft.	G-31 (5-78)	60th Avenue South and 16th Street. Location in Lake Vista Park at Northeast Corner of main building.
773	20.5 ft.	H-30 (5-78)	Just south of 58th Avenue North on west side of 16th Street (N.E. High School).
774	20.5 ft.	D-34 (5-78)	Mangrove Bay golf Course. Take 62nd Avenue N.E. to road which runs along the west boundary to Busch Field. Located on west side of road a short distance north of Busch Field (after bend in road).
775	20.5 ft.	I-7 (5-78)	East of 27th Street on south boundary of Wildwood Park (between 12th Avenue and Langdon Avenue South).
776	19.5 ft.	G-16 (5-78)	28th Avenue North and 11th Street. (In Park southeast of center). (Control well)
777	19.5 ft.	R-2 (5-78)	South of 2nd Avenue North on east side of 72nd Street (Pasadena Elementary School).
778	20.0 ft.	K-22 (5-78)	On North side of 38th Avenue North and west of 35th Street.

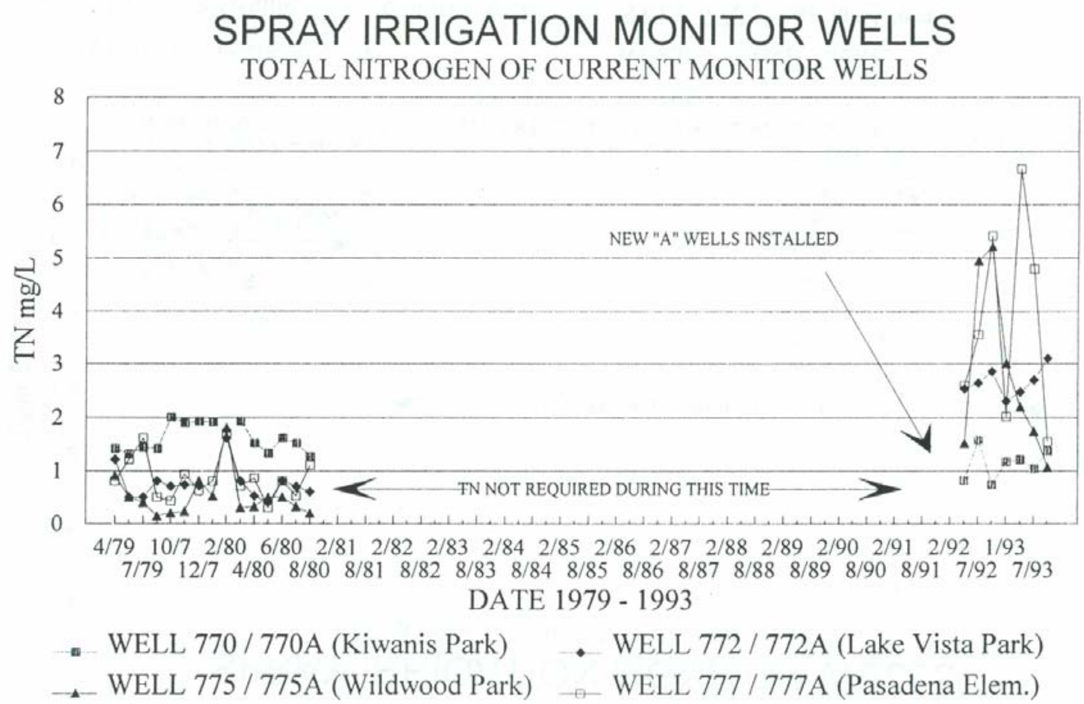
NEW SPRAY IRRIGATION MONITOR WELL LOCATIONS

WELL #	LOCATION
770A	Kiwanis Park - East of old well 770 along parkway by picnic area.
772A	Lake Vista - Move north northeast about 100-150 feet from old 772 well over by sprinkler controls.
775A	Wildwood Park - Just east of old 775 well along sidewalk.
777A	Pasadena Elementary School - Move north about 100 feet along parkway from old 777 well.

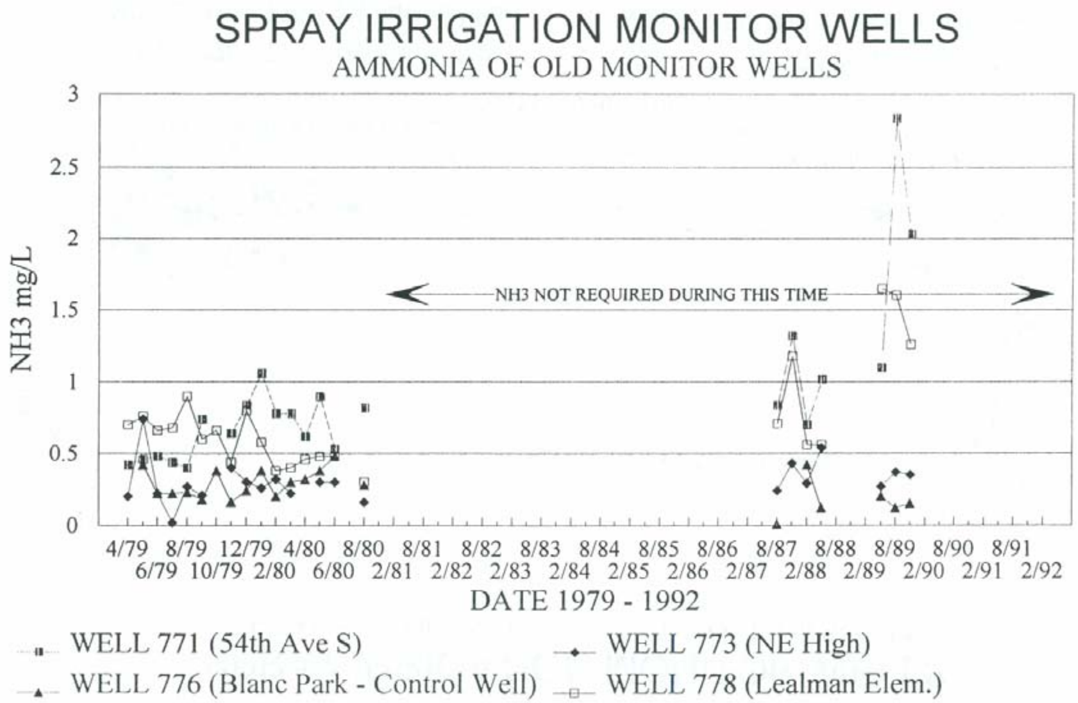

SPRAY IRRIGATION MONITOR WELLS
AMMONIA OF CURRENT MONITOR WELLS
NH3 mg/L
2.5
2
1.5
1
0.5
0
NEW "A" WELLS INSTALLED
NH3 NOT REQUIRED DURING THIS TIME
4/79 10/7 2/80 6/80 2/81 2/82 2/83 2/84 2/85 2/86 2/87 2/88 2/89 2/90 2/91 2/92 1/93
7/79 12/7 4/80 8/80 8/81 8/82 8/83 8/84 8/85 8/86 8/87 8/88 8/89 8/90 8/91 7/92 7/93
DATE 1979 - 1993
WELL 770 / 770A (Kiwanis Park)
WELL 772 / 772A (Lake Vista Park)
WELL 775 / 775A (Wildwood Park)
WELL 777 / 777A (Pasadena Elem.)

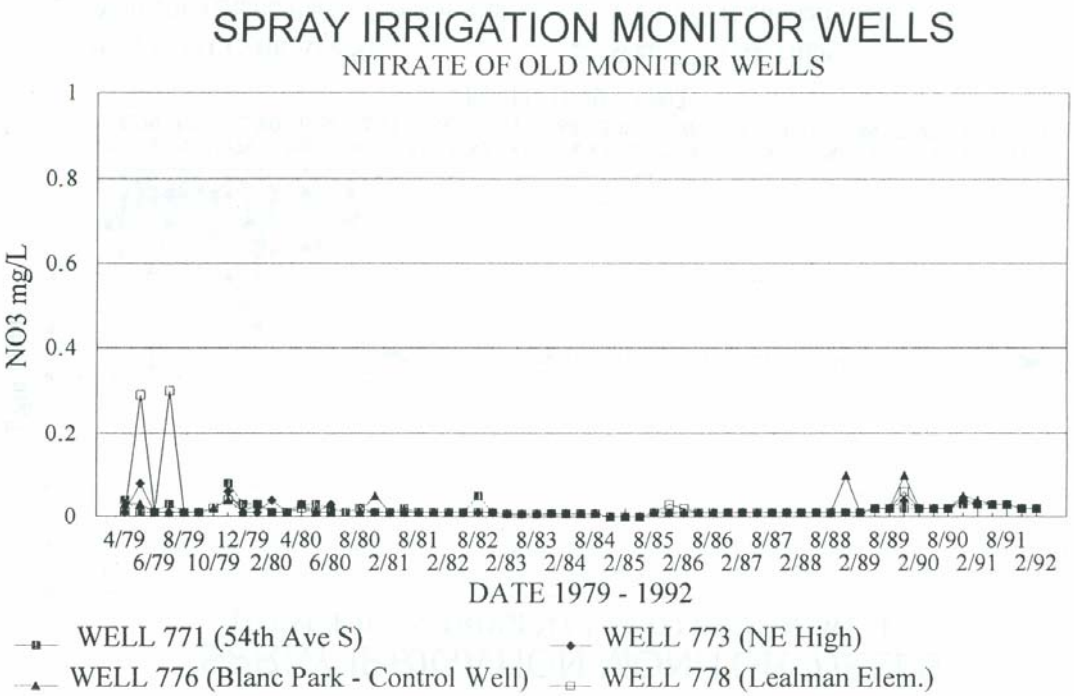

SPRAY IRRIGATION MONITOR WELLS
NITRATE OF CURRENT MONITOR WELLS
NEW "A" WELLS INSTALLED
NO3 mg/L
7
6
5
4
3
2
1
0
4/79 10/7 2/80 6/80 2/81 2/82 2/83 2/84 2/85 2/86 2/87 2/88 2/89 2/90 2/91 2/92 1/93
7/79 12/7 4/80 8/80 8/81 8/82 8/83 8/84 8/85 8/86 8/87 8/88 8/89 8/90 8/91 7/92 7/93
DATE 1979 - 1993
WELL 770 / 770A (Kiwanis Park)
WELL 772 / 772A (Lake Vista Park)
WELL 775 / 775A (Wildwood Park)
WELL 777 / 777A (Pasadena Elem.)

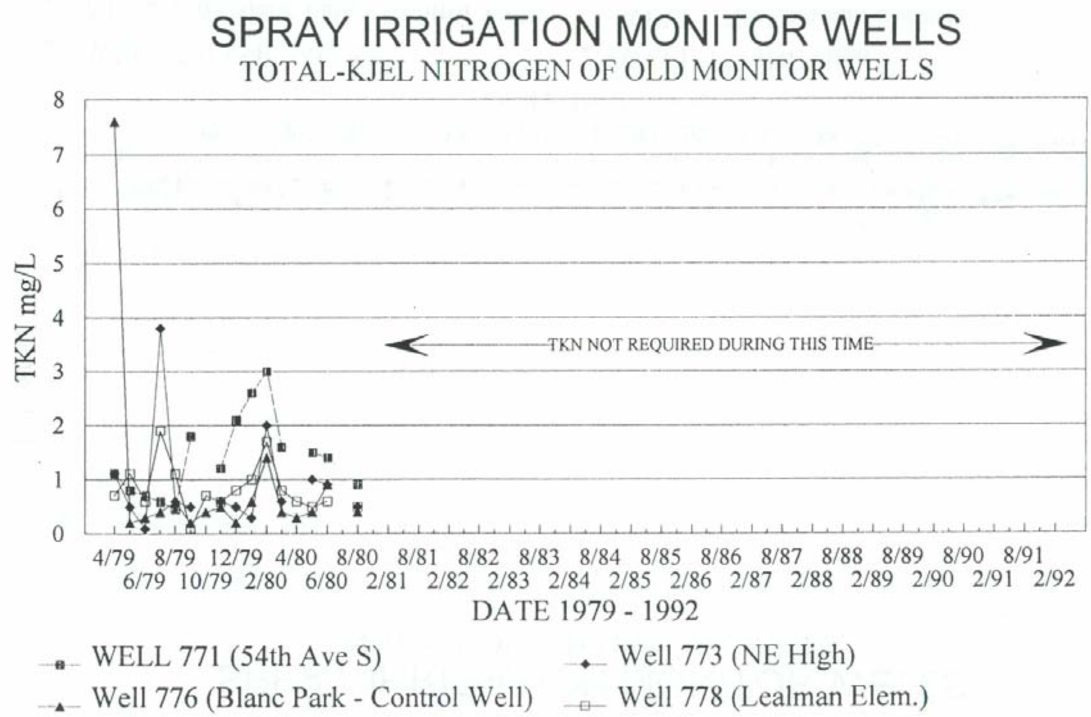

SPRAY IRRIGATION MONITOR WELLS
TOTAL KJEL-NITROGEN OF CURRENT MONITOR WELLS
TKN mg/L
NEW "A" WELLS INSTALLED
TKN NOT REQUIRED DURING THIS TIME
DATE 1979 - 1993
WELL 770 / 770A (Kiwanis Park)
WELL 772 / 772A (Lake Vista Park)
WELL 775 / 775A (Wildwood Park)
WELL 777 / 777A (Pasadena Elem.)

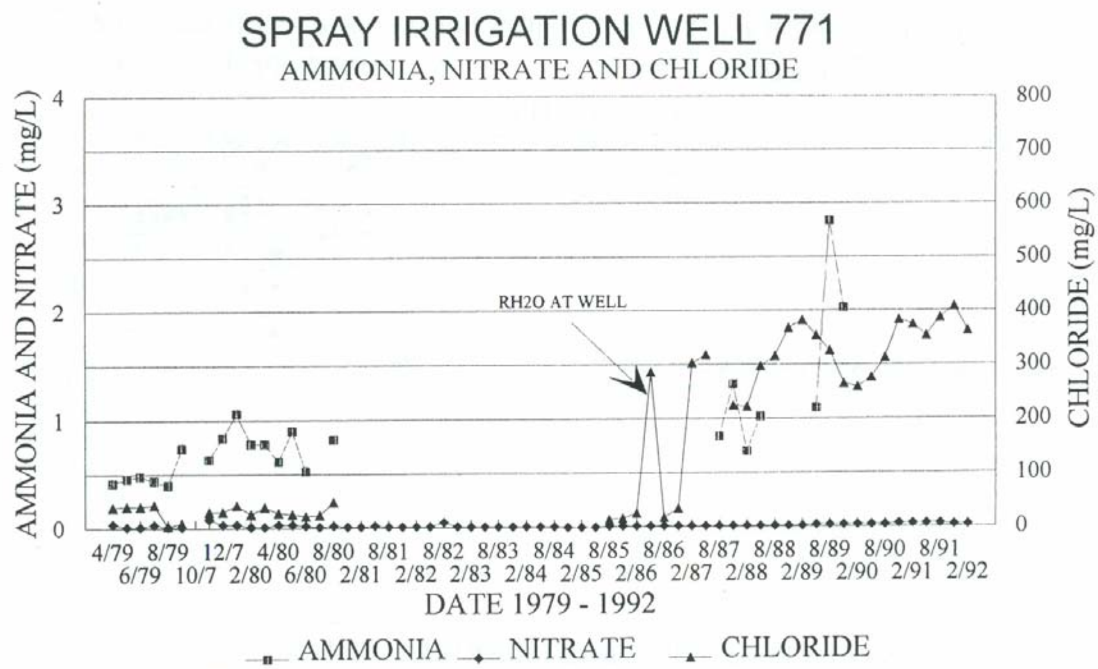


SPRAY IRRIGATION MONITOR WELLS
TOTAL NITROGEN OF CURRENT MONITOR WELLS
TN mg/L
NEW "A" WELLS INSTALLED
TN NOT REQUIRED DURING THIS TIME
4/79 10/7 2/80 6/80 2/81 2/82 2/83 2/84 2/85 2/86 2/87 2/88 2/89 2/90 2/91 2/92 1/93
7/79 12/7 4/80 8/80 8/81 8/82 8/83 8/84 8/85 8/86 8/87 8/88 8/89 8/90 8/91 7/92 7/93
DATE 1979 - 1993
WELL 770 / 770A (Kiwanis Park)
WELL 772 / 772A (Lake Vista Park)
WELL 775 / 775A (Wildwood Park)
WELL 777 / 777A (Pasadena Elem.)

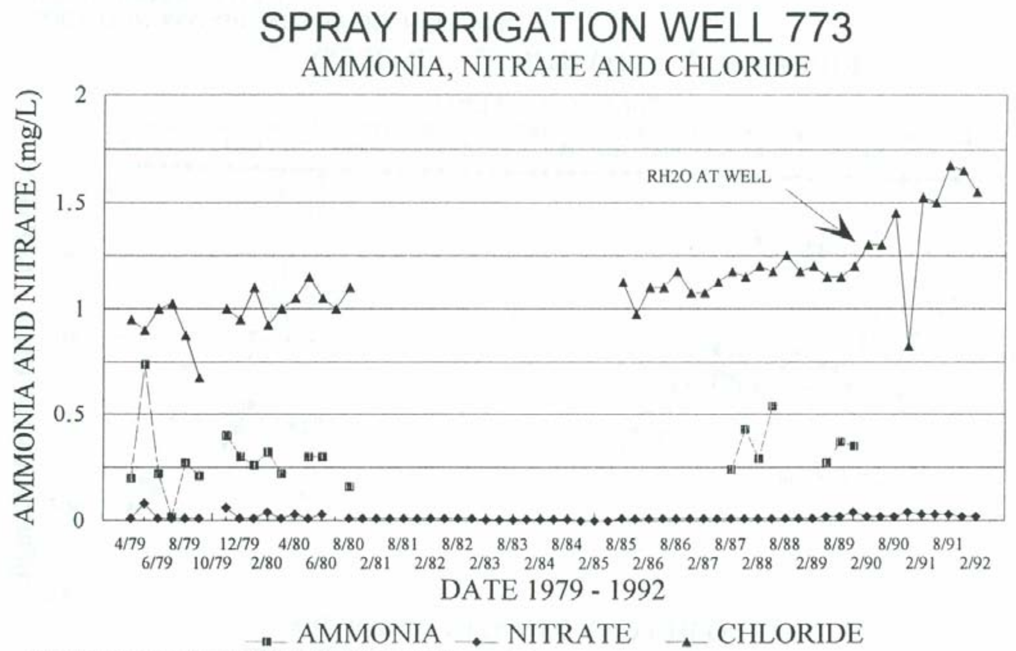

SPRAY IRRIGATION MONITOR WELLS
AMMONIA OF OLD MONITOR WELLS
NH3 mg/L
3
2.5
2
1.5
1
0.5
0
NH3 NOT REQUIRED DURING THIS TIME
4/79 8/79 12/79 4/80 8/80 8/81 8/82 8/83 8/84 8/85 8/86 8/87 8/88 8/89 8/90 8/91
6/79 10/79 2/80 6/80 2/81 2/82 2/83 2/84 2/85 2/86 2/87 2/88 2/89 2/90 2/91 2/92
DATE 1979 - 1992
WELL 771 (54th Ave S)
WELL 773 (NE High)
WELL 776 (Blanc Park - Control Well)
WELL 778 (Lealman Elem.)


SPRAY IRRIGATION MONITOR WELLS
NITRATE OF OLD MONITOR WELLS
NO3 mg/L
1
0.8
0.6
0.4
0.2
0
4/79 8/79 12/79 4/80 8/80 8/81 8/82 8/83 8/84 8/85 8/86 8/87 8/88 8/89 8/90 8/91
6/79 10/79 2/80 6/80 2/81 2/82 2/83 2/84 2/85 2/86 2/87 2/88 2/89 2/90 2/91 2/92
DATE 1979 - 1992
WELL 771 (54th Ave S)
WELL 773 (NE High)
WELL 776 (Blanc Park - Control Well)
WELL 778 (Lealman Elem.)

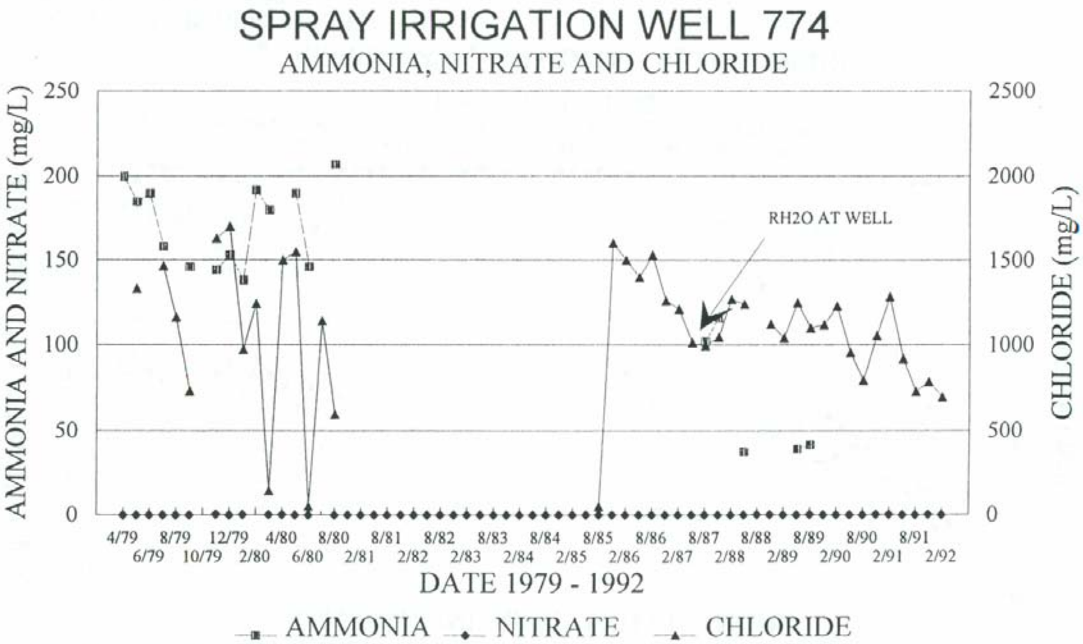

SPRAY IRRIGATION MONITOR WELLS
TOTAL-KJEL NITROGEN OF OLD MONITOR WELLS
TKN mg/L
8
7
6
5
4
3
2
1
0
TKN NOT REQUIRED DURING THIS TIME
4/79 8/79 12/79 4/80 8/80 8/81 8/82 8/83 8/84 8/85 8/86 8/87 8/88 8/89 8/90 8/91
6/79 10/79 2/80 6/80 2/81 2/82 2/83 2/84 2/85 2/86 2/87 2/88 2/89 2/90 2/91 2/92
DATE 1979 - 1992
WELL 771 (54th Ave S)
Well 773 (NE High)
Well 776 (Blanc Park - Control Well)
Well 778 (Lealman Elem.)



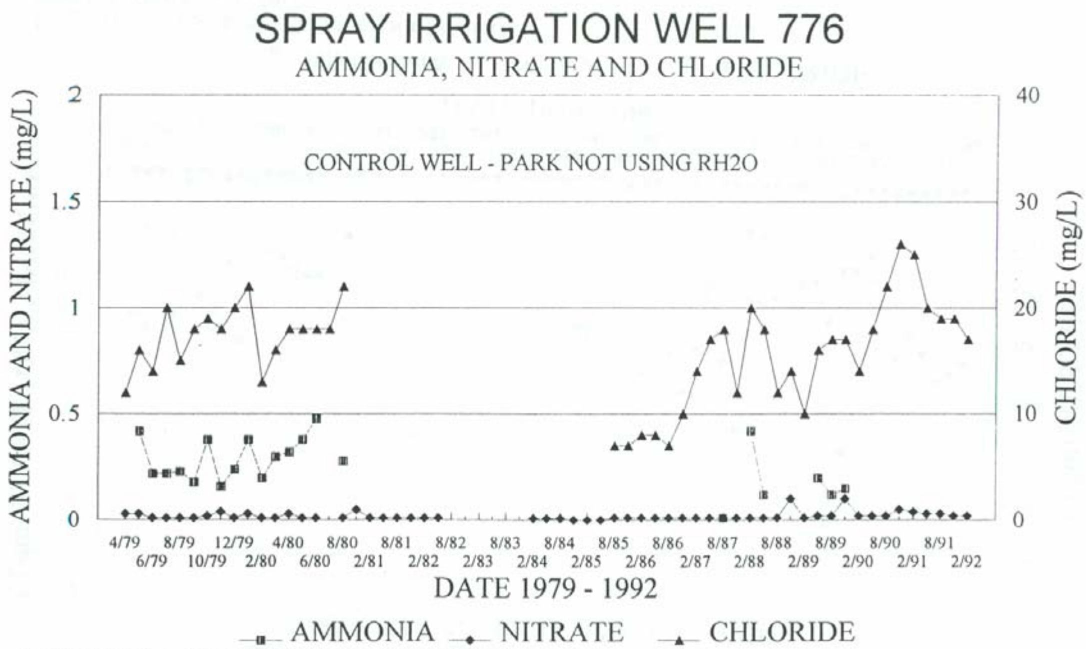
LOCATION: 54TH AVE SO PARKWAY
WELL ABANDONED 4/92



LOCATION: NORTHEAST HIGH SCHOOL
WELL ABANDONED 4/92



LOCATION: MANGROVE BAY GOLF COURSE
WELL ABANDONED 4/92



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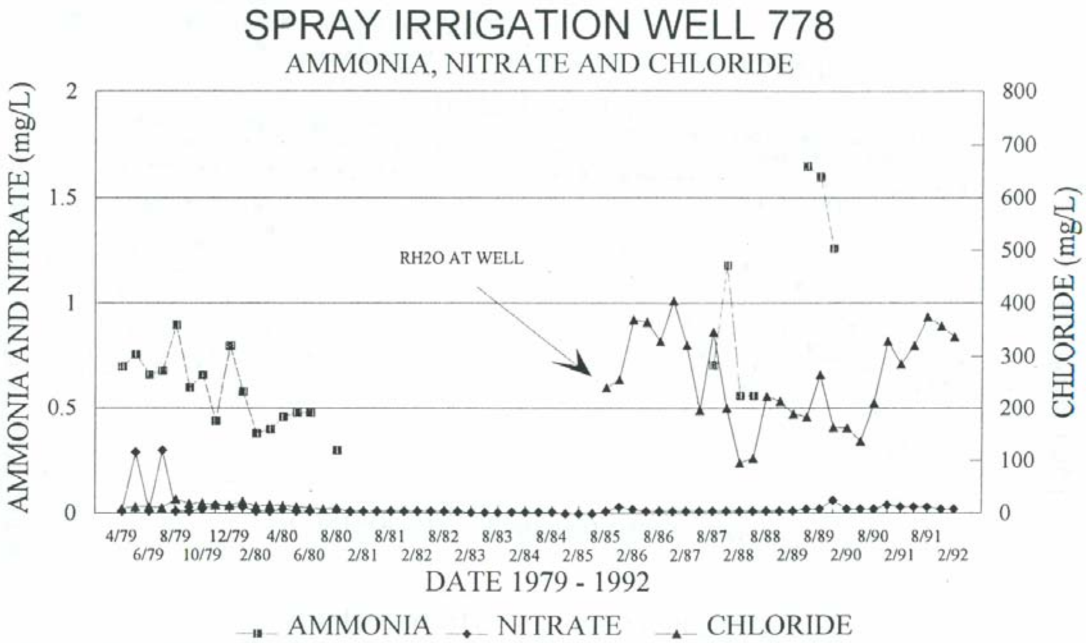

LOCATION: LEALMAN ELEMENTRY SCHOOL
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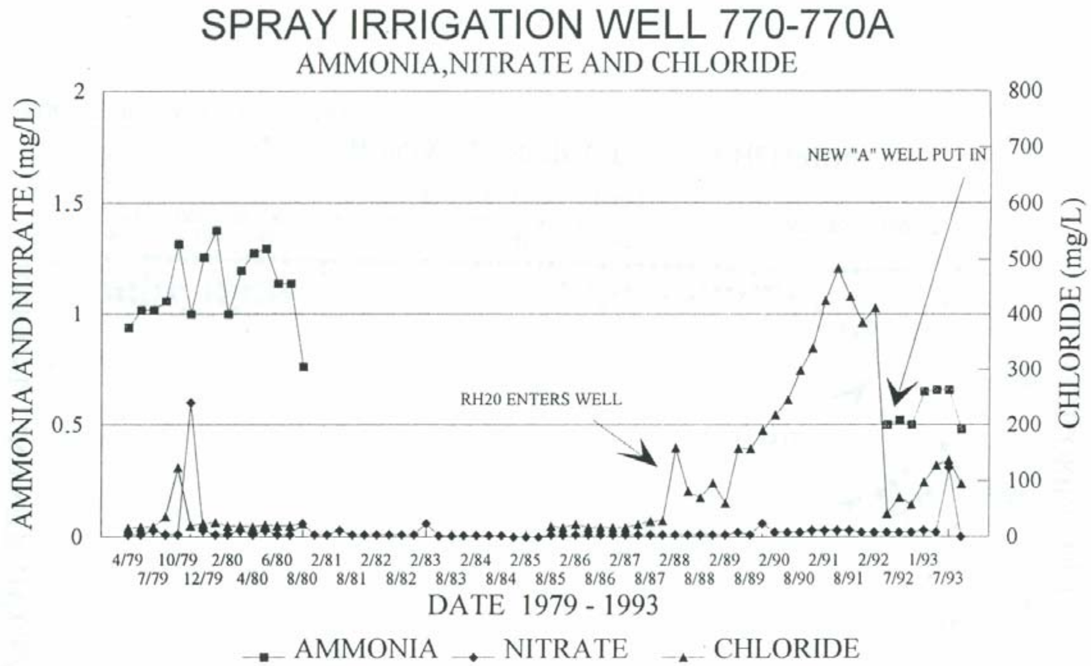
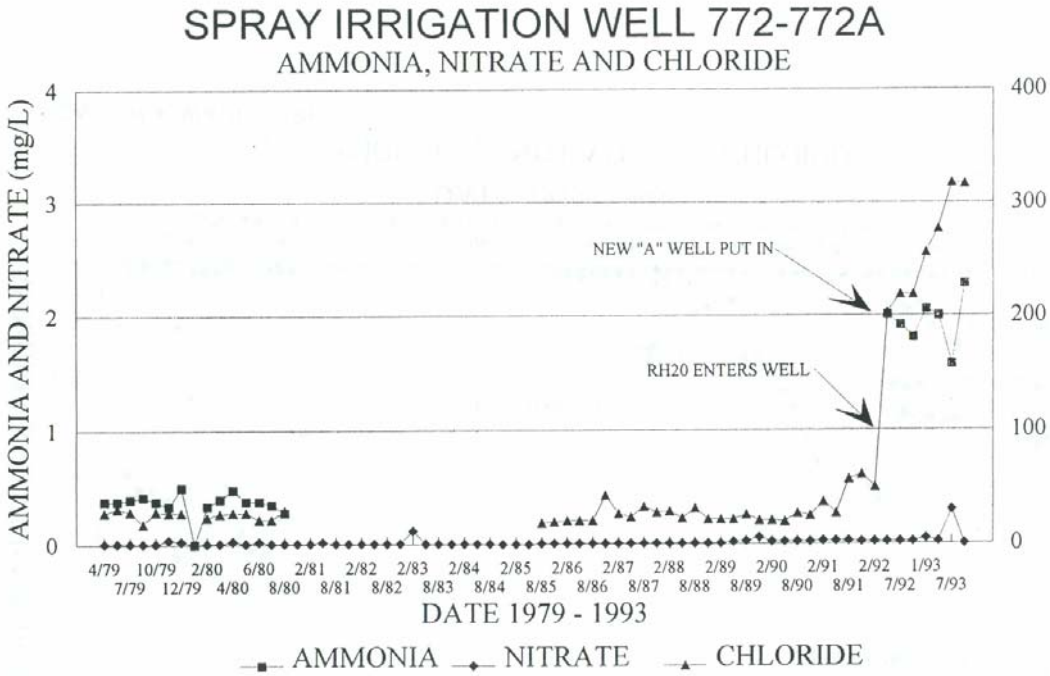
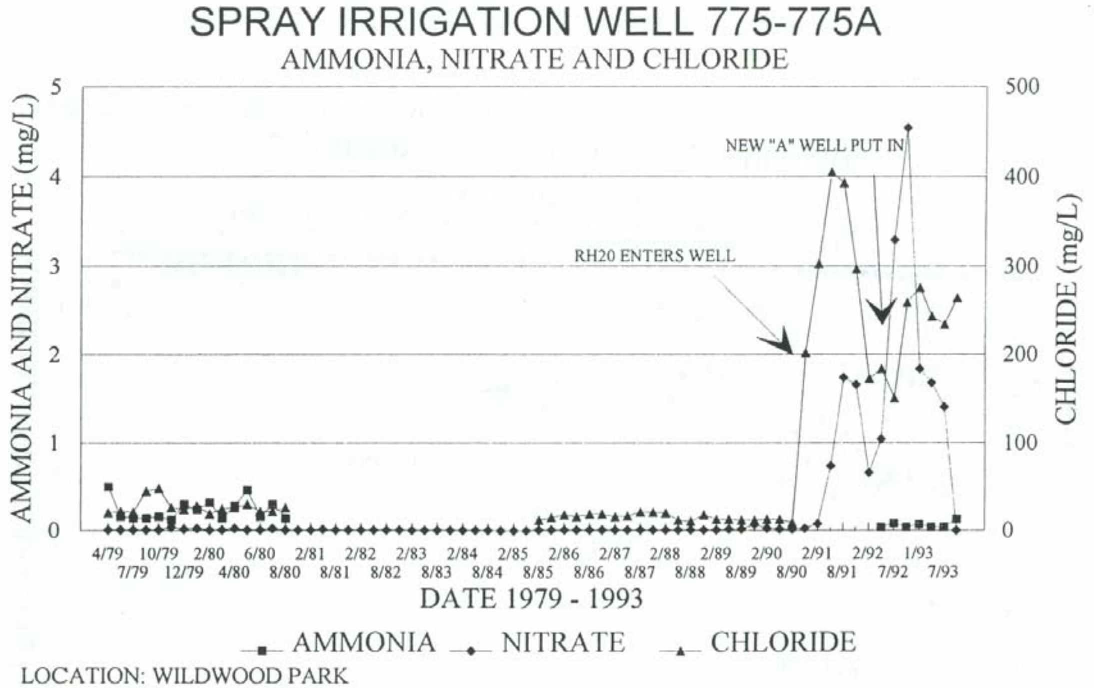
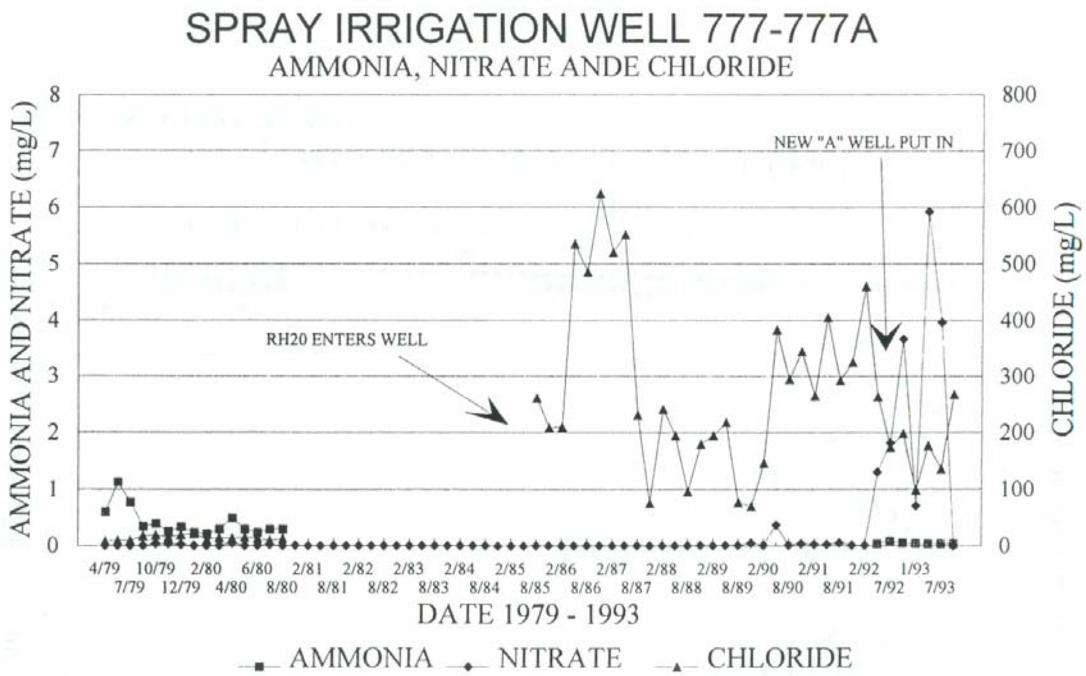


LOCATION: KIWANIS PARK



LOCATION: LAKE VISTA PARK


SPRAY IRRIGATION WELL 775-775A
AMMONIA, NITRATE AND CHLORIDE
AMMONIA AND NITRATE (mg/L)
CHLORIDE (mg/L)
NEW "A" WELL PUT IN
RH20 ENTERS WELL
DATE 1979 - 1993
AMMONIA
NITRATE
CHLORIDE
LOCATION: WILDWOOD PARK



LOCATION: PASADENA ELEMENTARY SCHOOL

APPENDIX L

Appendix 13 Estimated Nutrient and Suspended Solids Loading
to Tampa Bay for "Worst Case" Conditions

From: The Estimates of Total Nitrogen, Phosphorus, and Total Suspended Solids
Loadings to Tampa Bay, Florida
Prepared For:
Tampa Bay Estuary Program
Prepared By: Coastal Environmental, Inc.

ESTIMATED NUTRIENT AND SUSPENDED SOLIDS LOADING
TO TAMPA BAY FOR "WORST CASE" CONDITIONS
APPENDIX 13

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1.0 INTRODUCTION

Nutrient loading estimates for the Tampa Bay watershed were made for the mid-1970's period, as a "worst case" condition. This time period is thought to represent the period of maximum nutrient loading to Tampa Bay, and subsequently, overall water quality was at perhaps its lowest level, on a bay-wide basis. Urbanization was at relatively high levels, but several water quality improvement programs now in practice had not yet been implemented. During this period, major publically-owned domestic wastewater treatment facilities discharged large volumes of poorly treated effluent directly to the bay, and numerous privately-operated small treatment plants operated without adequate oversight and treatment of sewage. Stormwater runoff generated by new development was not managed until the passage of the Henderson Act. In addition, the phosphate industry was very active, but without the environmental controls currently in place. Several activities occurred shortly after that period that resulted in reduced nutrient loadings and improved bay water quality:

- major improvements were made upgrading the level of treatment provided by several large domestic wastewater treatment plants (such as the City of Tampa's Hookers Point facility),
- many of the small wastewater treatment plants (package plants) were taken out of use,
- enhanced phosphate mining regulations for surface water quality improvement were implemented,
- surface water management permitting programs to improve nonpoint source water quality were developed,
- effluent treatment and discharge facilities for several significant industrial point sources were improved, and
- the phosphate industry experienced a general decline in activities.

It was desired to document the estimated total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS) loadings to Tampa Bay for the mid-1970's period to compare, in a relative sense, the reduction in loadings that has occurred during the past 15 to 20 years. This analysis was not intended to develop loading estimates with the level of accuracy and detail as for existing condition loads. Rather, it was desired to make a general estimate of these loads from the mid-1970's to allow a "first order" comparison to be made between this time period and existing conditions. Sources of information reviewed included various reports on Tampa Bay including studies conducted by state agencies, private firms and summary proceedings.

The objective of this investigation was to identify and evaluate existing summary information of TN, TP, and TSS loading estimates for Tampa Bay as a whole, and for bay segments, for the mid-1970's period. Existing documents with summaries of point and nonpoint source loadings were examined for technical merit and accuracy. The best existing summaries of TN, TP, and TSS loadings were synthesized to develop an overall estimate of these loads during the mid-1970's.

In the literature cited, data were presented in various formats including information from individual point sources, summarized loadings from all point sources to a bay segment, or estimates combining point and nonpoint sources. Loading estimates were obtained via different methods such as the summarization of previous information or actual field studies. Loading estimates were presented in numerous formats including daily, weekly, monthly, wet/dry season or annually. Because of the variations in data presentation and the fact that each publication focused on different objectives, few direct comparisons could be made.

2.0 METHODS

Although this investigation required the evaluation of several existing loading model studies, it was not within this scope of work to develop new estimates of point and nonpoint loadings for the mid-1970's. Additionally, flow and quality data for individual point source facilities were not obtained from the FDEP permit files. Rather, existing documents with estimates of TN, TP, and TSS loadings were reviewed and summarized to develop a best estimate of point and nonpoint contributions to nutrient loadings to Tampa Bay based on previous work. Several documents that addressed aspects of point and/or nonpoint nutrient loading to Tampa Bay for the mid-1970's were reviewed, including:

- Surface Flows to Tampa Bay: Quantity and Quality Aspects (Dooris and Dooris, 1985)
- Nonpoint Assessment for the Wilson-Grizzle Area (FDER, 1982)
- Tributary Streamflows and Pollutant Loadings Delivered to Tampa Bay (Hartigan and Hanson-Walton, 1984)
- Long-Term Trends of Nitrogen Loading, Water Quality and Biological Indicators in Hillsborough Bay, Florida (Johansson, 1991)
- Point Source Discharge in the Tampa Bay Area (Moon, 1985)
- Central Florida Phosphate Industry Areawide Impact Assessment Program Volume V: Water (Texas Instruments, 1978)
- Waste Load Allocation for Tampa Bay Tributaries (Yousef, 1976)
- Nonpoint Source Effects (Wanielista, 1976)

Several of these references were not appropriate for use for a variety of reasons, including incomplete coverage, inadequate documentation of methods, suspect methods or results, or other factors. However, data from the documents that were believed to be most accurate and representative were summarized and compared, as described below. The following discussion describes the synthesis of these data and methods that were used to develop estimates of TN, TP, and TSS loads.

2.1 Nonpoint Sources

Initially, existing literature values were used to develop estimates of "worst case" TN, TP, and TSS loading. Several studies previously estimated these nutrient inputs for the mid to late 1970's, including those listed above. Of those reports, "Nonpoint Assessment for the Wilson-Grizzle Area" (FDER, 1982) provided the only available consistent, basin-wide estimate of nonpoint source TN and TP loads, and was closely scrutinized. This investigation used a land use coverage for 1975, projected to 1980 conditions. Using a delineation for the Tampa Bay watershed that included 33 subbasins, TN and TP loadings were estimated on an average annual basis for the seven bay segments.

Despite the consistent coverage of nonpoint source loadings, no detailed discussion of methods was included in the FDER (1982) report. However, the development of the nonpoint source loadings used in this study are described in the report "Wasteloads and Wasteload Allocation for Priority and Non-Priority Areas of the Tampa Bay Region" (ESE, 1977). Several potential shortcomings of that nonpoint source analysis are pointed out in the 1982 FDER report, and should be noted. These include incompatibility of the land use data used by ESE with other existing land use classifications, use of 1975 land use data to project 1980 land use, and the categorization of mining lands into one of three generalized rural land use classifications. The quality of input data as well as the predictive capabilities of the models used (USEPA model SWMM-Level 1 and EPARRB-Model B), is also questioned in the FDER (1982) report.

Another potential weakness in the ESE (1977) report includes the approach that was used, which was to model nutrient loads from the entire watershed, instead of using measured streamflow and water quality concentration data where available. In addition, modeling nonpoint source loads in the mid 1970's was hampered by the relative scarcity of land use specific water quality data for stormwater runoff.

Because of these weaknesses, the nonpoint source loads presented in the FDER (1982) report were not thought to be of sufficient accuracy to be used for compare to existing conditions loadings as developed for this report. Additionally, nonpoint source TN and TP loads as estimated by FDER (1982) were compared to existing condition loads. Both TN and TP nonpoint source loads from FDER (1982) were about 2.0 times existing loads, and were substantially higher than loads for test basins that were estimated using measured data. These comparisons suggest that the nonpoint source loadings from FDER (1982) are unrealistically high, and were not used.

During the past fifteen years, advances in nonpoint source modeling, stormwater characterization, and land use mapping capabilities have reduced many of these uncertainties. However, it was beyond the purpose of this investigation to attempt to refine the mid-1970's nonpoint source loadings, based on current knowledge. Because none of the identified nonpoint source loading estimates appeared to be sufficiently accurate, it was necessary to determine an alternative method of estimating nonpoint TN, TP, and TSS loads to Tampa Bay for the mid-1970's period. The following steps were used to develop a suitable estimate:

1) It was assumed that, on a watershed-wide basis, 20% of the urban land that is shown on the 1990 GIS land use coverage (used for the existing condition analysis) that now receives stormwater treatment had no treatment during the mid-1970's. This represents

urban land that existed in the mid-1970's that had no form of stormwater treatment, either intentional or inadvertent (e.g. from drainage ponds or overland flow).

2) It was assumed that treatment efficiencies for stormwater facilities was 50% removal for TN, TP, and TSS. This assumption is based on using treatment efficiency rates that are similar to, but slightly lower than treatment efficiencies for modern, well-functioning stormwater BMP's.

3) Therefore, 20% of the 1990 urban land area was assigned an increased loading rate for the mid-1970's period, based on a 50% treatment efficiency.

It is recognized that land use development patterns vary significantly in different portions of the watershed, and that stormwater facilities' treatment efficiencies vary based on design and parameter. However, this methodology was determined to be an adequate means of estimating nonpoint source loadings for the mid-1970's period in lieu of acceptable existing data. Moreover, the primary focus on this loading scenario was to document the level of reduction of point source loads to Tampa Bay. The nonpoint source loadings shown in Section 3 reflect these assumptions.

2.2 Point Sources

2.2.1 Domestic and Industrial Facilities

TN, TP, and TSS loads from domestic and industrial point sources were obtained from three main information sources. The primary source of information was the document entitled "Nonpoint Assessment for the Wilson-Grizzle Area" (FDER, 1982). This report summarizes domestic and industrial point source discharges of TN and TP to Tampa Bay with adequate spatial resolution. These data were originally obtained from a review of FDER monthly operating records of facilities with surface water discharges to Tampa Bay and adjacent waters.

The FDER (1982) assessment report partitions the Tampa Bay watershed into 33 subbasins, which are assigned to four major study areas - Old Tampa Bay, Hillsborough Bay, Tampa Bay (which includes the areas tributary to Middle Tampa Bay, Lower Tampa Bay, and the Manatee River), and Boca Ciega Bay. The subbasins in the report were generally delineated matching existing conditions major basin boundaries, and thus allowed the assignment of point source loads to the respective bay segments. However, in some cases it was necessary to make assumptions about splitting subbasin loads between two adjacent bay segments. For example, some point source loads in the eastern Pinellas County peninsula had to be partitioned between Old Tampa Bay and Middle Tampa Bay (Figure 1).

Using the data provided, point source loads were assigned to the seven current bay segments. Although the loading data were from 1980 - several years after the target period of the mid 1970's - it was assumed that they would be adequate to represent point source loadings during that time, with a few exceptions, as described below. One major exception was the City of Tampa's Hookers Point facility. This wastewater treatment plant was converted to a higher level of treatment (advanced secondary - AWT) in 1978, so loadings from 1980 would not reflect the conditions during the mid 1970's. In addition, some of the other point sources, specifically industrial facilities in the phosphate industry, had made improvements to their discharge systems by 1980.

To obtain point source data for the "pre-improvement" condition at these facilities, a second reference document was used. The "Central Florida Phosphate Industry Areawide Impact Assessment Program, Volume V: Water" (Texas Instruments, 1978) was originally published to support an evaluation of cumulative impacts from phosphate industry activities in the Tampa Bay and Charlotte Harbor watersheds.

These drainage areas include the Alafia River and Peace River basins, which have historically supported the most intensive levels of phosphate mining and processing activities. Average daily point source loads for TN, TP, and TSS, based on 1976 FDER records, are listed for individual facilities in all portions of the Tampa Bay watershed except Pinellas County. Because it was desired to obtain the most consistent, watershed-wide loading estimates, these data were not used as the primary source of loadings, but were used to supplement the information obtained from the Wilson-Grizzle evaluation. Data obtained from this reference includes TN, TP, and TSS average daily loads for major dischargers in the Hillsborough Bay drainage area, which includes Hookers Point and almost all the phosphate industry facilities in the watershed. Additionally, "worst case" TSS loads for point source facilities in the watershed were not available from any other source, and were obtained from this document.

The third reference used to estimate surface discharge point source loads was the document "Tributary Streamflows and Pollutant Loadings Delivered to Tampa Bay" (Hartigan and Hanson-Walton, 1984). This report provides a description of data to be used for input to the University of South Florida (USF) Tampa Bay Model, which was designated by FDER as the primary planning tool for the FDER Tampa Bay Wasteload Allocation Study. Individual domestic and industrial facilities are listed with mean flow (mgd), and TN and TP concentrations obtained from FDER data for 1982-3. Although these data were also from several years after the period of interest, in some

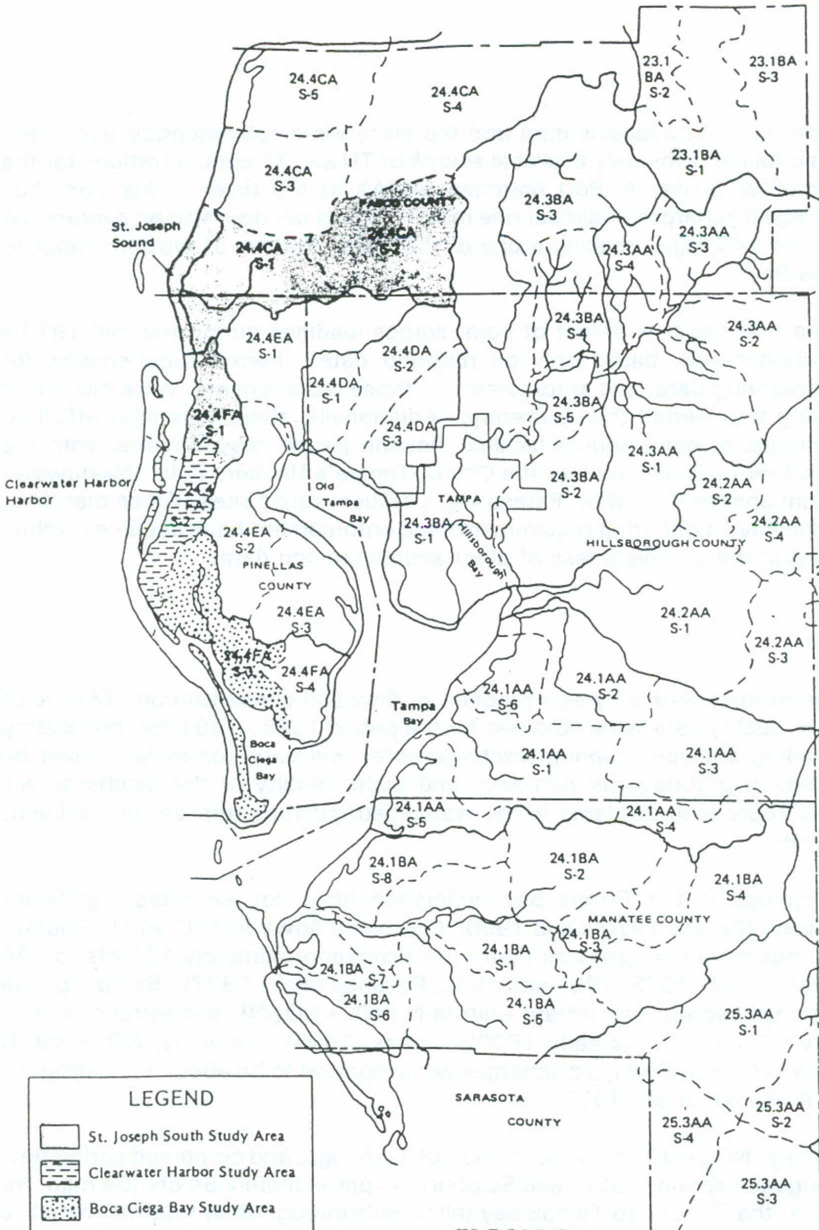

FIGURE 2
SURVEY AREA I BOUNDARY

SOURCE: Tampa Bay Regional Planning Council, Wasteloads and Wasteload Allocations For Priority and Non-Priority Areas of the Tampa Bay Region. September 1977.

Figure 1 Survey Area Boundaries (FDER, 1982)

Figure 1 Survey Area Boundaries (FDER, 1982)

cases they are the best available data and therefore were subsequently used. For example, this data set is the only available source of TN and TP concentrations for the phosphate fertilizer facility at Port Manatee (AMAX at the time). This plant had recorded average discharges of almost one million gallons per day with an average TN concentration of 145 mg/L, making it one of the major sources of nitrogen input to Middle Tampa Bay.

It is suspected that the true extent of point source loadings during the mid 1970's may be underestimated, based only on reported data. Permit requirements for reporting of operating data, and enforcement of those requirements, were much less stringent during that period than currently. Additionally, there was little effort to monitor conditions at point source facilities beyond permit requirements, with the exception of a few facilities, such as the City of Tampa's Hookers Point Wastewater Treatment Plant and the City of St. Petersburg's effluent reuse sites. Since that time, more comprehensive monitoring requirements and enforcement have become routine, greatly improving the completeness of point source loading data.

2.2.2 Springs

Nutrient loads from springs vary as a function of flow and concentration. Measured flow and water quality data were obtained for the period 1985 - 1991 for the existing conditions loading analysis. Spring discharge rates will vary somewhat based on rainfall and nearby groundwater pumping, and water quality of the discharge will reflect various sources of nutrients in the watershed (such as fertilizer and effluent land application).

Flows from springs in the Tampa Bay watershed have not exhibited significant changes between the late 1970's and 1990. Combined flows from Crystal, Sulphur, and Lithia springs have changed less than 10% (from approximately 132 cfs to 126 cfs) during that period (USGS, 1991 and 1992; Rosenau et al., 1977). Sampling data from Lithia Springs suggest that nitrate+nitrite-N (NO_2+NO_3-N) concentrations were approximately 1.3 mg/L in the early 1970's (Jones and Upchurch, 1993). Similarly, NO_2+NO_3-N concentrations in Crystal Springs discharges were reported to be about 1.2 during the same period (Rosenau et al., 1977).

Taking an average NO_2+NO_3-N concentration of 1.25 mg/L and combined spring flow for the two ungaged springs (Lithia and Sulphur) of approximately 84 cfs (54 mgd) for the mid 1970's, the TN load to Tampa Bay (all to Hillsborough Bay) was estimated to be about 103 tons/year. The current (1985-91) spring loading for Lithia and Sulphur springs is approximately 106 tons/year (from Appendix 12). Because spring TN loading estimates for the two periods varied by only 3% it was assumed that existing conditions average nutrient and solids loadings from springs would be appropriate for the mid-1970's loading analysis.

2.3 Fugitive Losses of Fertilizer

Fugitive emission loadings of nitrogen and phosphorus result from spillage and dust releases of phosphate rock and fertilizer products shipped from the loading terminals at East Bay, in upper Hillsborough Bay. Because fugitive emissions were not widely recognized as a significant source of nutrient loadings during the mid 1970's, no measured data from this period exist. This load can be expressed as a percent of product shipped, and is thought to be a significant source of nutrients to the upper bay. Estimates of fugitive emissions in Hillsborough Bay for the periods 1966-67 and 1987-90 have been made by Johansson (1991) based on a 0.05% loss rate of fertilizer product shipped. These values - 120 tons/year for 1967-69 and 770 tons/year for 1987-90 - were averaged to estimate a fugitive loss rate for the mid-1970's period for Hillsborough Bay of 450 tons/year.

Port Manatee shipped almost 200,000 tons/year of phosphate rock and fertilizer products during the period 1975-76 (Highland, 1993). Based on an estimated ratio of nitrogen-containing fertilizer products to total fertilizer material shipments of 40% (Highland, 1993) and the 0.05% loss rate, a fugitive loss rate of 39 tons/year was estimated for Lower Tampa Bay.

2.4 Atmospheric Deposition

Data from the National Atmospheric Deposition Program (NADP) and National Urban Runoff Program (NURP) were used to estimate atmospheric deposition of nitrogen and phosphorus for existing conditions. Neither of these programs were in existence in the time period of worst case loadings (mid-1970's). In addition, there was a general lack of measured precipitation chemistry data, and the characteristics of this nutrient source, especially dryfall, were much less understood than currently. Therefore, it was necessary to identify either 1) precipitation chemistry data collected from that period, or 2) a trend analysis to relate either emissions or deposition from that period to existing conditions levels.

No representative, reliable precipitation chemistry data from the mid-1970's were identified. However, the document "National Air Pollutant Emission Trends, 1900-1992" (EPA, 1993) contains a trend analysis for NO_x emissions from 1900 to 1992. Based on this report, nation-wide NO_x emissions increased steadily from the turn of the century until the early 1970's, and have remained at about the same levels since then. This finding is also documented in other nation-wide trend analysis reports (USEPA, 1991; U.S. Congress Office of Technology Assessment, 1984).

The assumption was made that 1) changes in NO_x emissions are proportional to total atmospheric deposition, and that 2) the national trend is representative of conditions in the Tampa Bay watershed. These assumptions were made because of the lack of regional data, and because atmospheric deposition is thought to be much more responsive to large scale transport processes, and not local conditions. Based on these factors, atmospheric deposition for the mid-1970's scenario was made equal to existing conditions levels.

2.5 Groundwater

Groundwater nutrient loads are a function of flow rate and concentration. Groundwater flows were estimated and measured nutrient concentrations were obtained for the existing conditions analysis. No data were identified that suggested that nutrient loading from groundwater was significantly different from existing conditions, and that would justify changing either flows or concentrations for future conditions. Monitoring data at some locations, such as springs, shows an increase in spring discharge concentrations of nitrogen (Jones, 1993). However, it must be noted that springs are geologically unusual, and, in the Tampa Bay watershed, are usually located in areas where the geology allows significant surface water infiltration into the ground. The geology of most of the watershed is such that the potential for surface water infiltration to groundwater is much less. In addition, groundwater loading of nutrients is estimated to be less than one-tenth of one percent of the total bay-wide TN loading for mid-1970's conditions. Therefore, it was assumed that existing condition groundwater loads would be appropriate, and were used for this analysis.

3.0 RESULTS

3.1 Bay-wide Loadings

Estimated bay-wide loadings of TN, TP,and TSS are shown in Figures 2, 3, and 4. Comparisons of estimated current (1985-91) to mid-1970's loadings are shown in Figures 5, 6, and 7. On a bay-wide basis, "worst case" (ie. mid-1970's) total nitrogen (TN) loading was estimated to be approximately 9,900 tons/year from all sources (Figure 2). In contrast, current (1985 - 1991) TN loads are estimated to be about 3,900 tons/year, a significant reduction. Similarly, mid-1970's TP loads are estimated to be approximately 4,000 tons/year, while current conditions loads are approximately 2,800 tons/year (Figure 3), and mid-1970's TSS loads are about 73,700 tons/year, to current conditions loads of approximately 40,500 tons/year (Figure 4). This represents a relative reduction from worst case conditions in bay-wide TN, TP, and TSS loadings of approximately 60%, 30%, and 45%, respectively. These load reductions are thought to be mainly the result of reduced point source loadings and lower fugitive emission loadings from phosphate handling facilities.

Point sources were estimated to contribute ten times (6,000 tons/year) the existing conditions TN load (600 tons/year) to Tampa Bay during the mid-1970's (Figure 5). Loadings from both domestic and industrial point sources were higher, based on the available data. However, it is believed that the point source loads, while much higher than for existing conditions, may have been underestimated in the cited literature for the mid-1970's period. This would be primarily a result of monitoring and reporting techniques and requirements, which were much less stringent than for subsequent time periods. Nonpoint source loadings were also estimated to be higher during that period, based on available information.

Fugitive emission TN loadings were also estimated to be higher during the mid-1970's (500 tons/year), than the existing conditions estimate of 300 tons/year. These external loads enter the bay at the East Bay (Hillsborough Bay) and Port Manatee (Lower Tampa Bay) phosphate shipping terminals. It should be noted that the data for the existing condition period covers the years 1985 - 1991. Significant reductions to several phosphate handling and loading facilities have occurred since 1991, most notably the IMC-Agrico Port Sutton facility, and additional reductions to this source are anticipated during the next several years.

Atmospheric deposition was assumed to be the same for both time periods (Section 2.4. Spring discharges and groundwater loadings are much smaller than other major sources of TN loading that were evaluated. Although these inputs can be expected to change with time, the expected variation in these loads is not significant with respect to the other sources (Section 2.5). Therefore, these loads were set to equal existing conditions for this analysis.

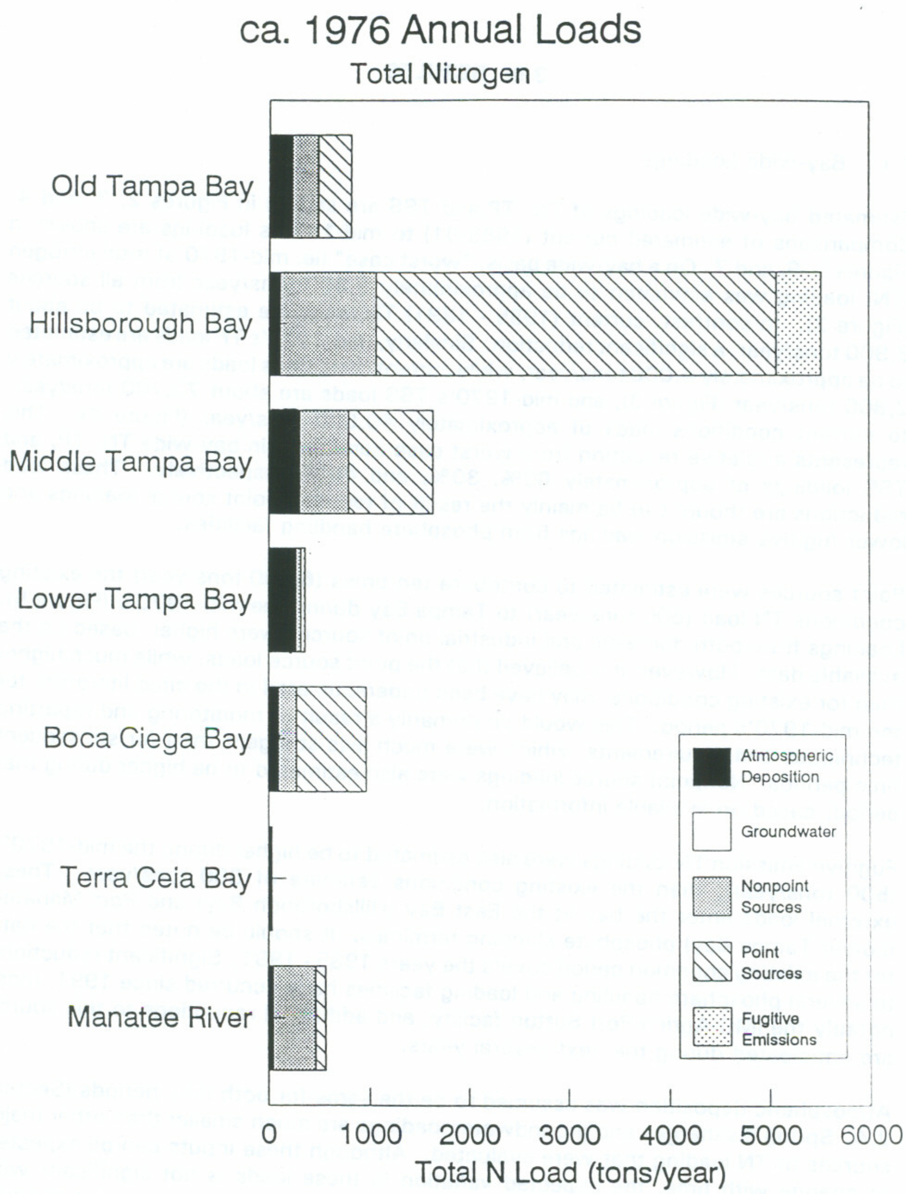

Figure 2 Circa 1976 Annual Loads - Total Nitrogen

A13-12

Figure 2 Circa 1976 Annual Loads - Total Nitrogen

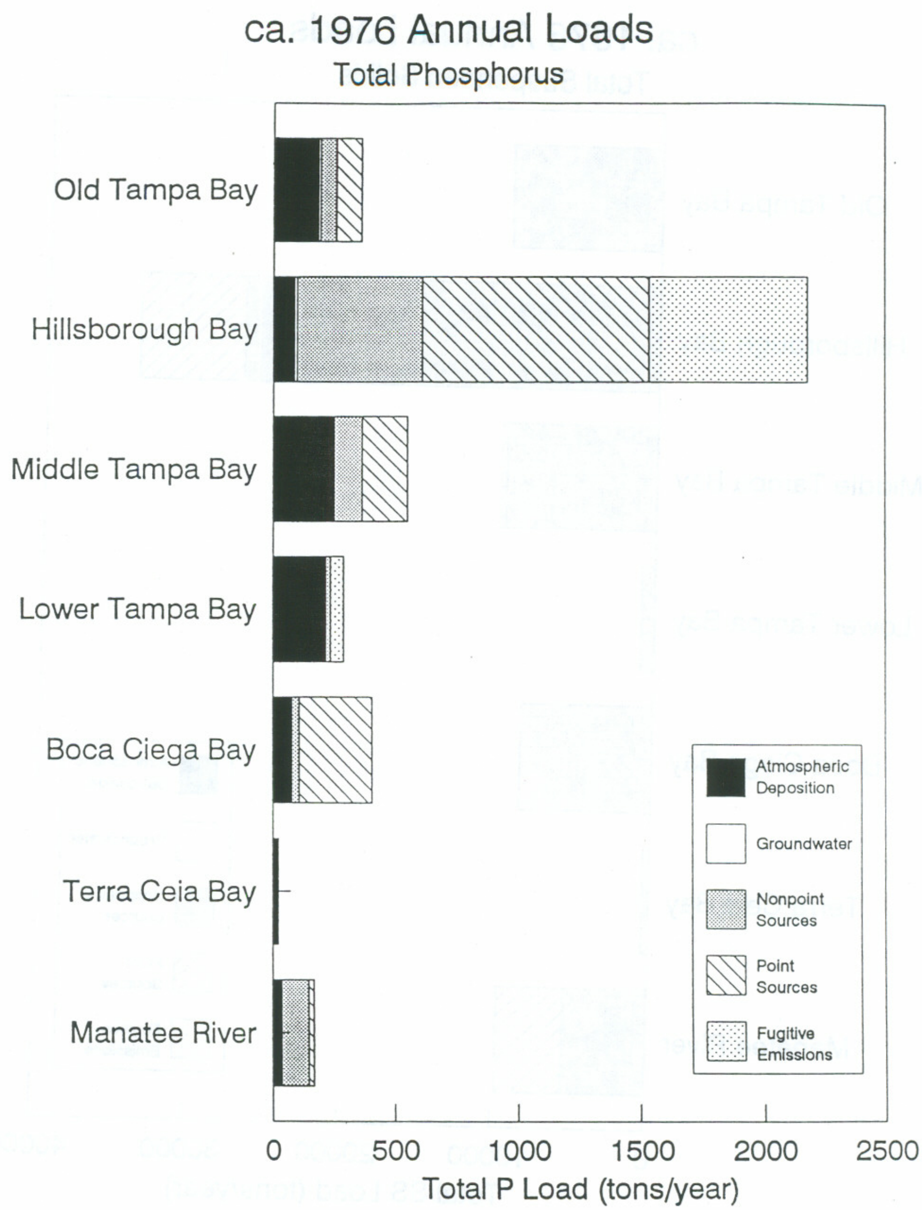

Figure 3 Circa 1976 Annual Loads - Total Phosphorus

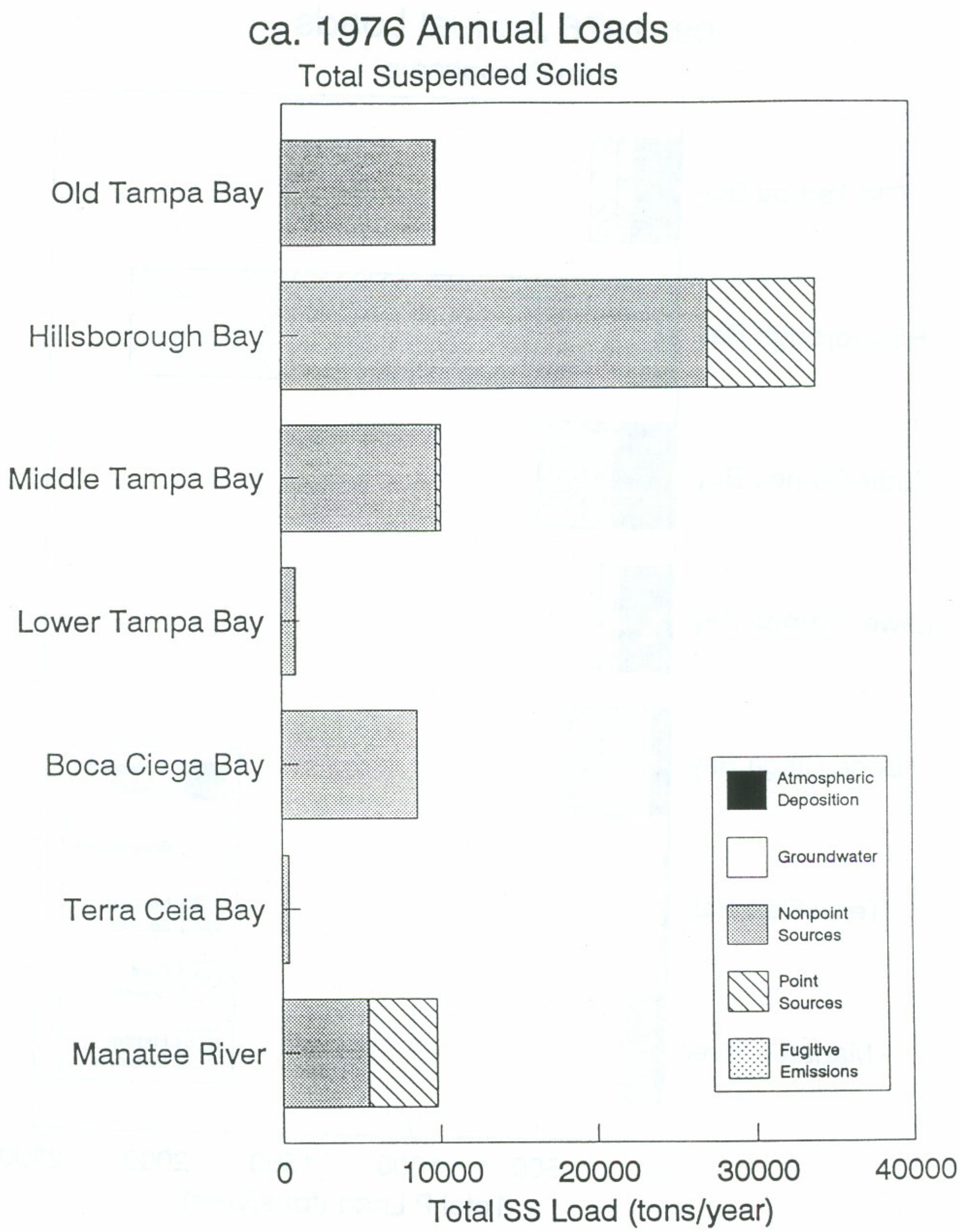

Figure 4 Circa 1976 Annual Loads - Total Suspended Solids

A13-14

Figure 4 Circa 1976 Annual Loads - Total Suspended Solids

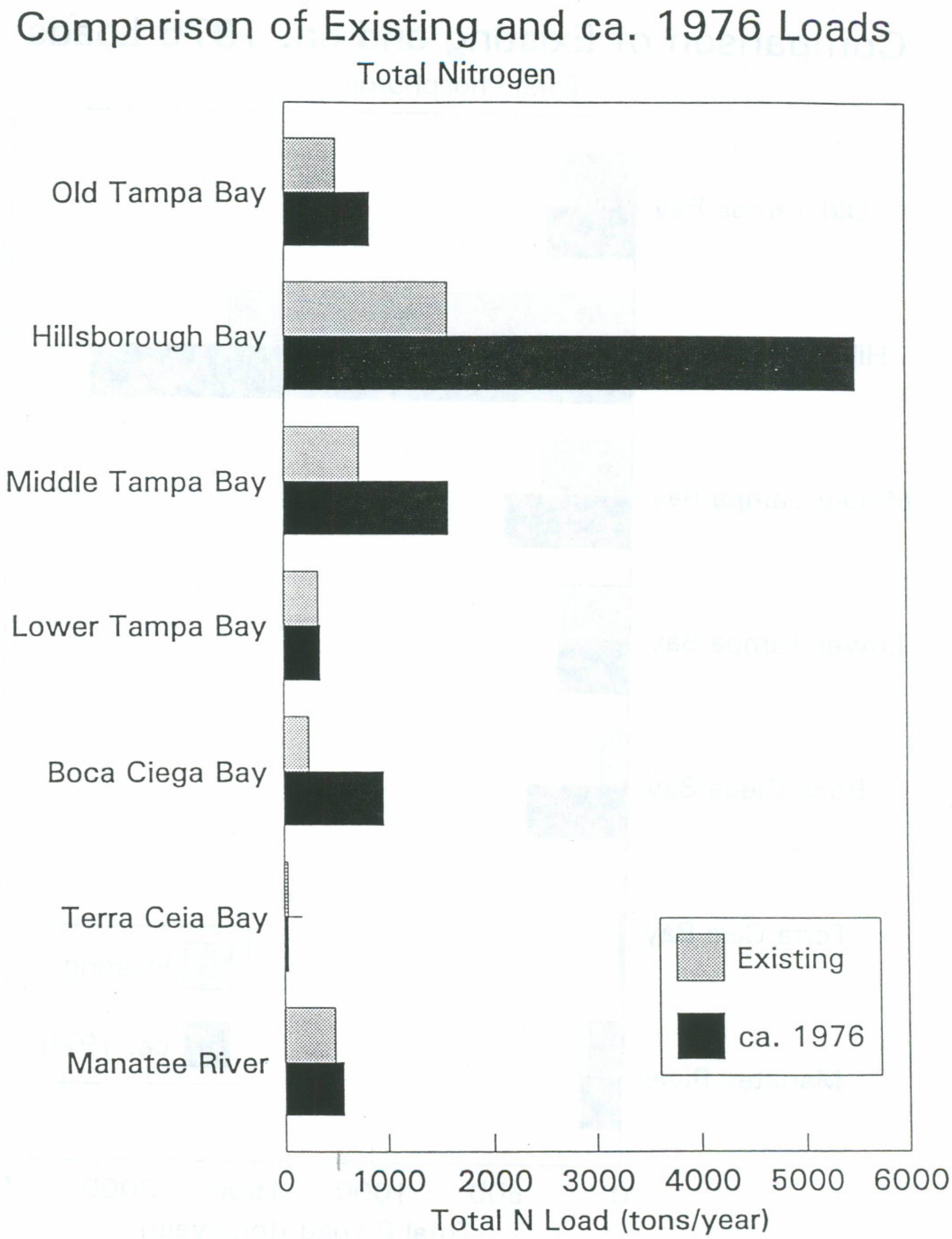

Figure 5 Comparison of Existing and circa 1976 Loads - Total Nitrogen

A13-15

Figure 5 Comparison of Existing and circa 1976 Loads - Total Nitrogen

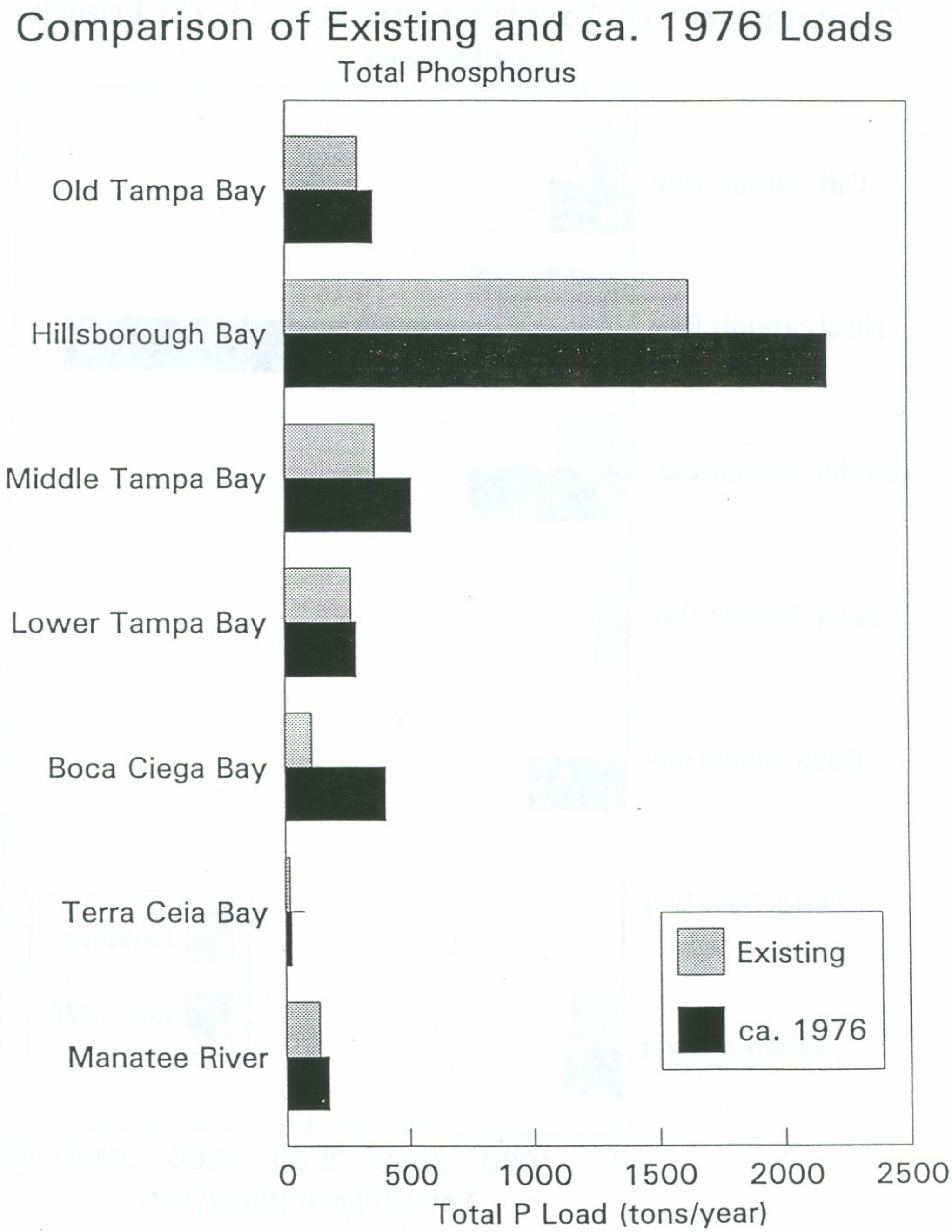

Figure 6 Comparison of Existing and circa 1976 Loads - Total Phosphorus

A13-16

Figure 6 Comparison of Existing and circa 1976 Loads - Total Phosphorus

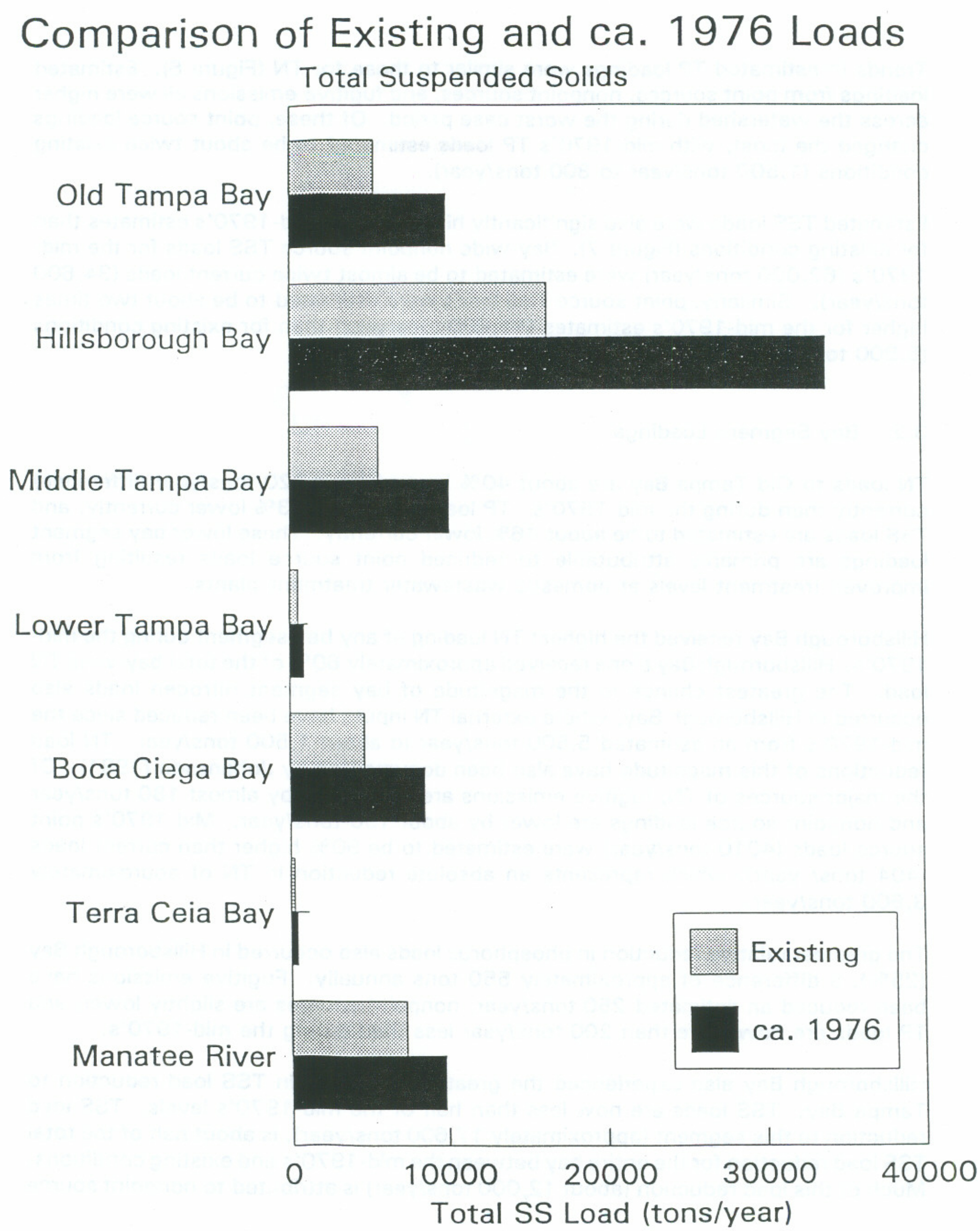

Figure 7 Comparison of Existing and circa 1976 Loads - Total Suspended Solids

A13-17

Figure 7 Comparison of Existing and circa 1976 Loads - Total Suspended Solids

Trends in estimated TP loadings were similar to those for TN (Figure 6). Estimated loadings from point sources, nonpoint sources, and fugitive emissions all were higher across the watershed during the worst case period. Of these, point source loadings changed the most, with mid-1970's TP loads estimated to be about twice existing conditions (1,500 tons/year to 800 tons/year).

Estimated TSS loads were also significantly higher for the mid-1970's estimates than for existing conditions (Figure 7). Bay-wide nonpoint source TSS loads for the mid-1970's (62,000 tons/year) were estimated to be almost twice current loads (34,600 tons/year). Similarly, point source TSS loads were estimated to be about two times higher for the mid-1970's estimates (11,600 tons/year) than for existing conditions (5,900 tons/year).

3.2 Bay Segment Loadings

TN loads to Old Tampa Bay are about 40% lower (about 320 tons/year difference) currently than during the mid-1970's. TP loads are about 13% lower currently, and TSS loads are estimated to be about 46% lower currently. These lower bay segment loadings are primarily attributable to reduced point source loads resulting from improved treatment levels at domestic wastewater treatment plants.

Hillsborough Bay received the highest TN loading of any bay segment during the mid-1970's. Hillsborough Bay alone received approximately 60% of the total bay-wide TN load. The greatest change in the magnitude of bay segment nitrogen loads also occurred in Hillsborough Bay, where external TN inputs have been reduced since the mid-1970's from an estimated 5,500 tons/year to about 1,500 tons/year. TN load reductions of this magnitude have also been documented by Johansson (1991). Of the major sources of TN, fugitive emissions are now lower by almost 180 tons/year and nonpoint source loadings are lower by about 150 tons/year. Mid-1970's point source loads (4010 tons/year) were estimated to be 90% higher than current loads (404 tons/ year), which represents an absolute reduction in TN of approximately 3,600 tons/year.

The greatest relative reduction in phosphorus loads also occurred in Hillsborough Bay (25%), a difference of approximately 550 tons annually. Fugitive emissions have been reduced an estimated 250 tons/year, nonpoint sources are slightly lower, and TP loads are now more than 200 tons/year less than during the mid-1970's.

Hillsborough Bay also experienced the greatest reduction in TSS load reduction to Tampa Bay. TSS loads are now less than half of the mid-1970's levels. TSS load reduction to this segment (approximately 17,600 tons/year), is about half of the total TSS load reduction for the entire bay between the mid-1970's and existing conditions. Much of this load reduction (about 12,000 tons/year) is attributed to nonpoint source loads. It is possible that the cited loading estimates for the mid-1970's overestimated nonpoint source loads (Section 2.1), and the comparison between periods therefore may not be strictly valid.

Middle Tampa Bay has experienced a large relative reduction in TN loadings, with mid-1970's loadings reported at approximately 1,630 tons/year and current loadings at 730 tons/year - a 55% decrease. Point sources contributed about half (800 tons/year) of the total nitrogen load to Middle Tampa Bay in the mid-1970's, mainly from surface discharge of domestic wastewater and phosphate facilities. However, as a result of wastewater reuse programs and improvements to industrial permitting, that contribution is now under 5% (less than 25 tons/year). TP also has been significantly reduced, and TSS loads are now about 44% lower than during the mid-1970's.

TN loads to Lower Tampa Bay are estimated to have experienced virtually no change. TP loads are now slightly lower, and TSS loads are estimated to be approximately 45% lower. During the mid-1970's, Lower Tampa Bay received approximately 7% of the TN load, about 13% of the TP load, and less than 3% of the TSS load of Hillsborough Bay.

Boca Ciega Bay has had its TN load reduced from an estimated 970 tons/year during the mid-1970's to almost 250 tons/year (a reduction of almost 75%). Although the relative reduction in TN loading for Boca Ciega Bay is greater than Hillsborough Bay's, Hillsborough Bay accounts for a much greater absolute reduction in tonnage of nitrogen - almost 4,000 tons/year versus about 500 tons/year for Boca Ciega Bay.
TN, TP, and TSS loads to Terra Ceia Bay were all estimated to have been higher during the mid-1970's. TN and TP loads show little change between the two periods (36 versus 37 tons/year, and 18 versus 23 tons/year, respectively). TSS loading for mid-1970's conditions (450 tons/year) was almost double existing conditions (250 tons/year).

The Manatee River bay segment is also estimated to have experienced reductions in TN, TP, and TSS loads since the mid-1970's. TN loads are estimated to have been reduced by about 80 tons/year, TP loads are estimated to be approximately 35 tons/year less currently than during that time period, and TSS loads are approximated to be about 2,500 tons/year less under existing conditions.

4.0 LITERATURE CITED

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APPENDIX M

Sections 5.2 and 5.3 and Appendix 8-11 From:
The Estimates of Total Nitrogen, Phosphorus, and Total Suspended Solids Loadings to Tampa Bay, Florida
Prepared For:
Tampa Bay Estuary Program
Prepared By: Coastal Environmental, Inc.

Section 5.2 Benchmark Loads
Section 5.3 Comparison of Benchmark and Existing Loads
Appendix 8 Benchmark Land-use Specific Water Quality
Appendix 9 Benchmark Wastewater Treatment Plants
Appendix 10 Benchmark Domestic Loading Estimates
Appendix11 Benchmark Groundwater Flow and Nutrient Loading Estimates

5.2 Benchmark Loads

The estimated pollutant loads for the benchmark period (ca. 1938-40) were completed as described in Section 4. Figures 5-17 through 5-19 present the benchmark annual loads by bay segment for TN, TP, and TSS, respectively. Estimated loads by source, including nonpoint source, point source, atmospheric deposition, groundwater, and fugitive emissions, are shown. Hillsborough Bay had the highest estimated benchmark TN load - about 800 tons/year.

The major contributions to benchmark TN loads for all bay segments were from nonpoint sources and atmospheric deposition (Figure 5-17). The estimated point source TN loads to Hillsborough Bay were also significant, and were estimated to contribute a little over 20% (180 tons/year) of the total benchmark TN load to that segment. No TN load resulted from fugitive emissions during the benchmark period, because nitrogen was not a component of fertilizer until the late 1940's.

The largest contributors of benchmark TP loads were estimated to be atmospheric deposition and point sources. As has been estimated for existing conditions, fugitive emissions were a relatively important source of TP loading to Hillsborough Bay and Middle Tampa Bay during the benchmark period (Figure 5-18). The relative contribution of benchmark nonpoint source TP loading was generally lower than for TN loads. Atmospheric deposition, point sources, and fugitive emissions all contributed major fractions of benchmark TP loads.

The major contribution to the TSS loads to all bay segments in the benchmark period was from nonpoint sources (Figure 5-19). Point source loads are the only other source, and contribute only an estimated 5% of the total benchmark TSS load.

5.3 Comparison of Benchmark and Existing Loads

The estimated loads to each bay segment for benchmark and existing conditions can be compared to estimate increases in pollutant loading to Tampa Bay during the past 50 years. Figures 5-20 through 5-22 present the comparison of TN, TP, and TSS loads under benchmark and existing conditions, respectively. Overall, benchmark TN, TP, and TSS loads were estimated to be approximately 50%, 35%, and 25% of existing conditions loads, respectively.

In all bay segments except Terra Ceia Bay, the TN load under existing conditions is considerably greater than that estimated for benchmark conditions (Figure 5-20). The greatest relative differences are estimated for Hillsborough Bay, Boca Ciega Bay, and Middle Tampa Bay. On a bay-wide basis, existing TN loading are estimated to exceed benchmark loads by about 2,000 tons/year. Of that amount, the absolute difference in both estimated TN loads under benchmark and existing conditions is clearly greatest

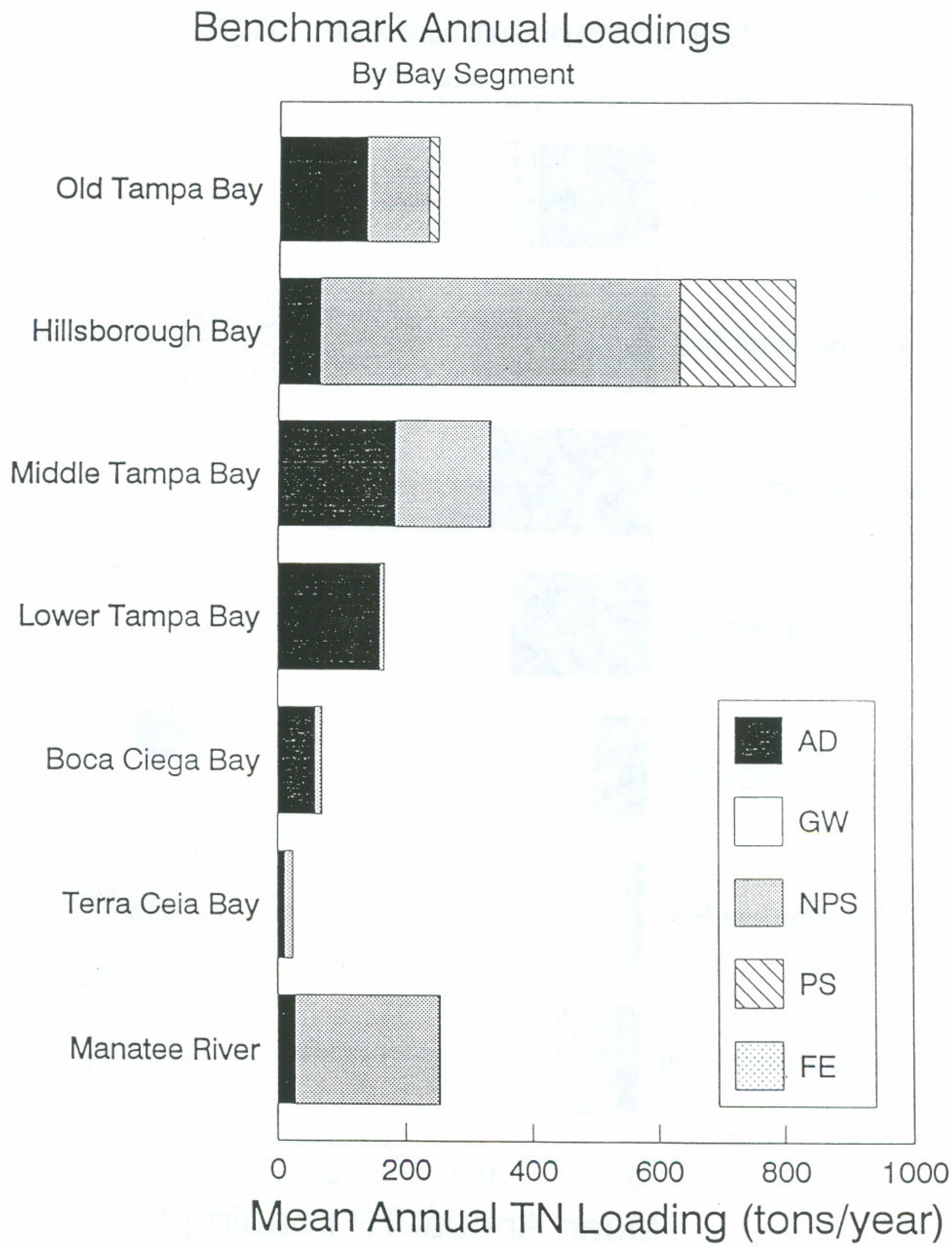


Figure 5-17 Benchmark annual loads of TN by bay segment

5-23

Figure 5-17 Comparison of benchmark and existing loads of TN by bay segment

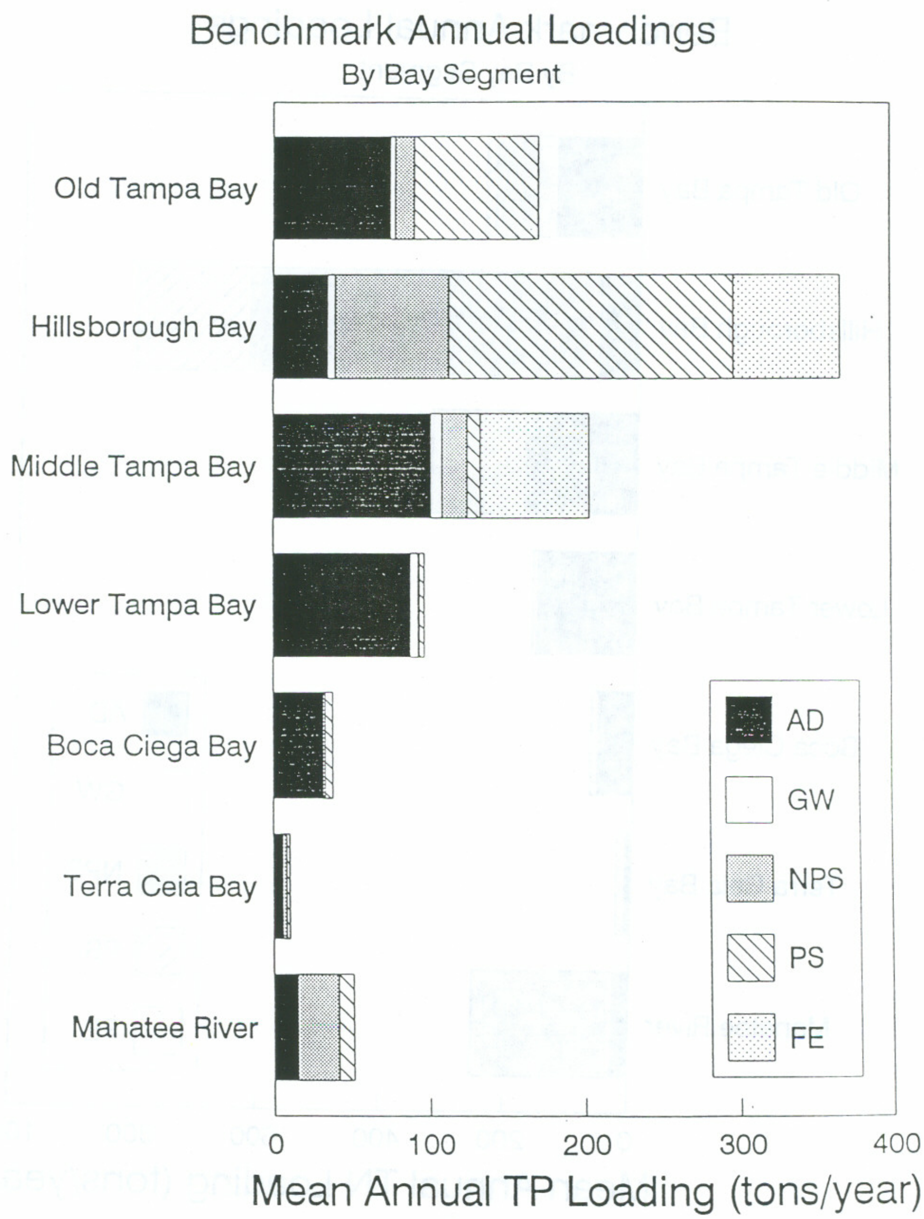


Figure 5-18 Benchmark annual loads of TP by bay segment

5-24

Figure 5-18 Comparison of benchmark and existing loads of TP by bay segment

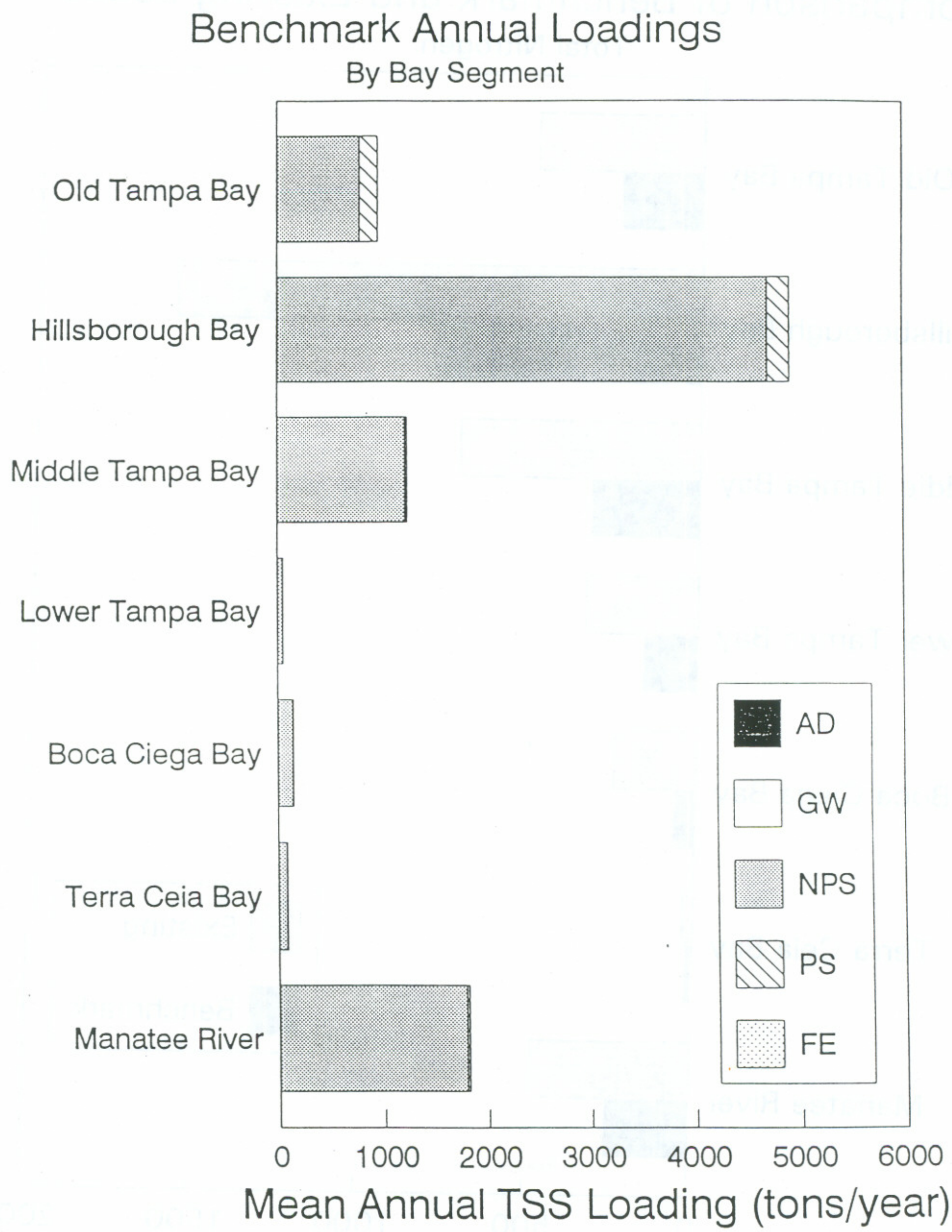


Figure 5-19 Benchmark annual loads of TSS by bay segment

5-25

Figure 5-19 Comparison of benchmark and existing loads of TSS by bay segment

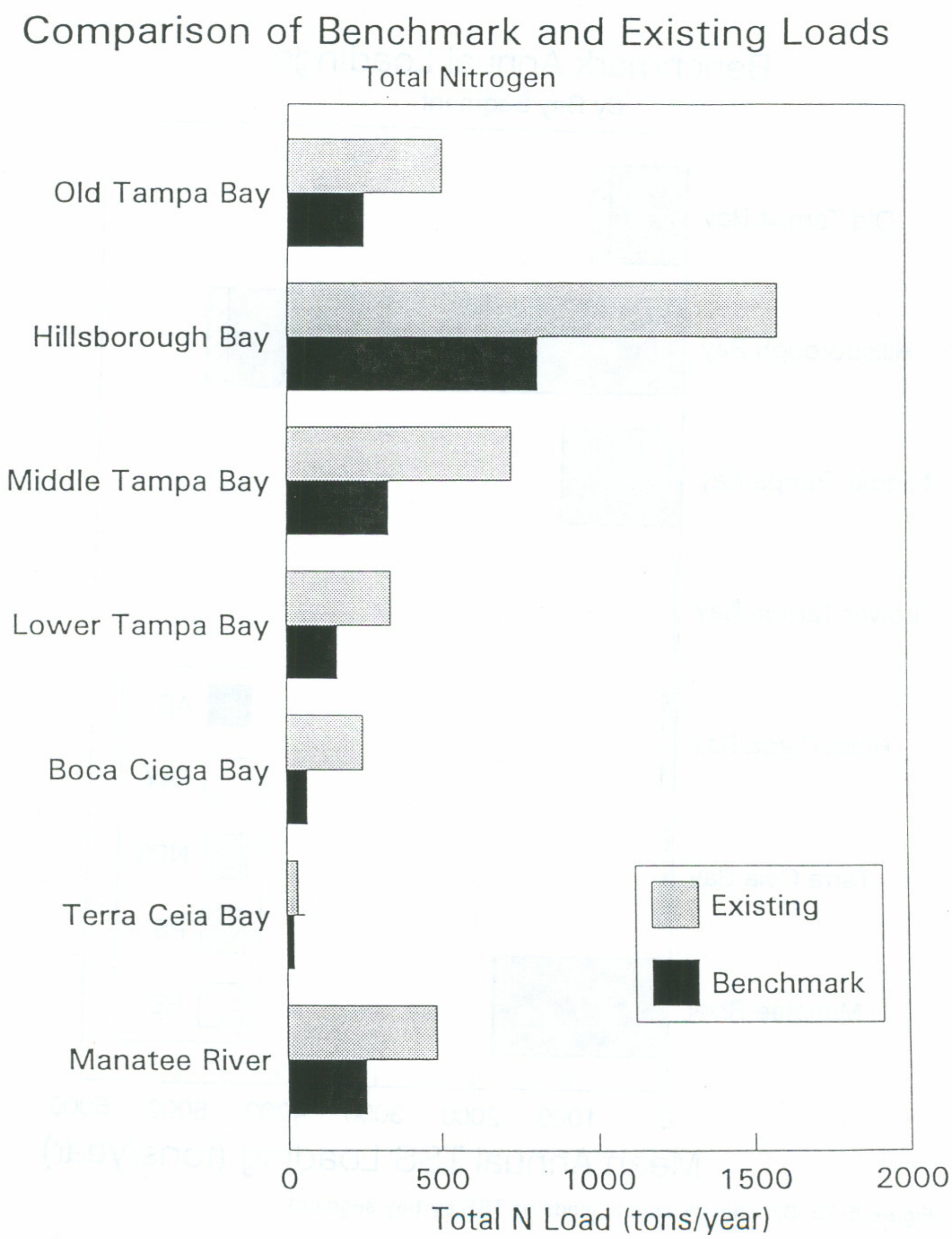
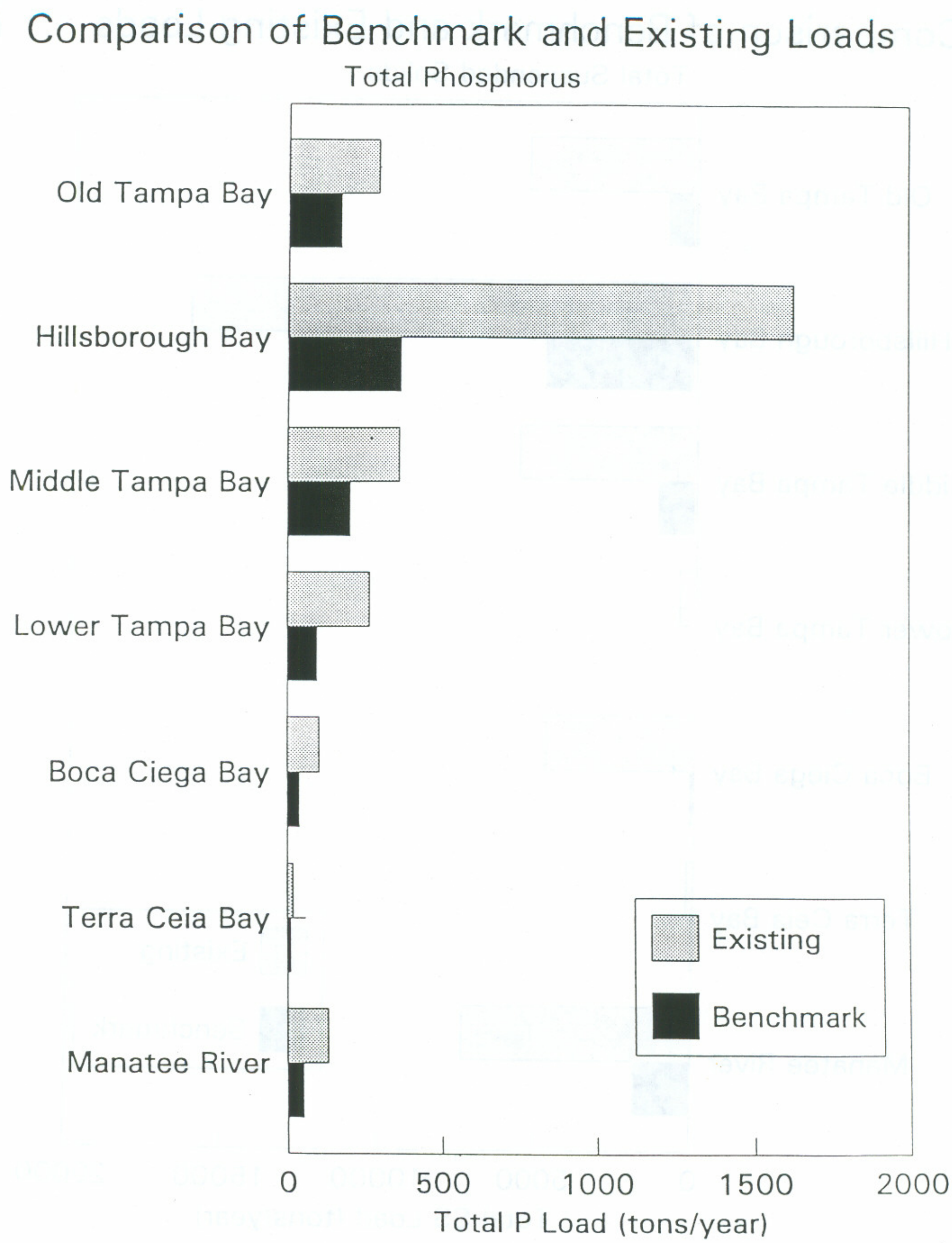


Figure 5-20 Comparison of benchmark and existing TN loads by bay segment

5-26

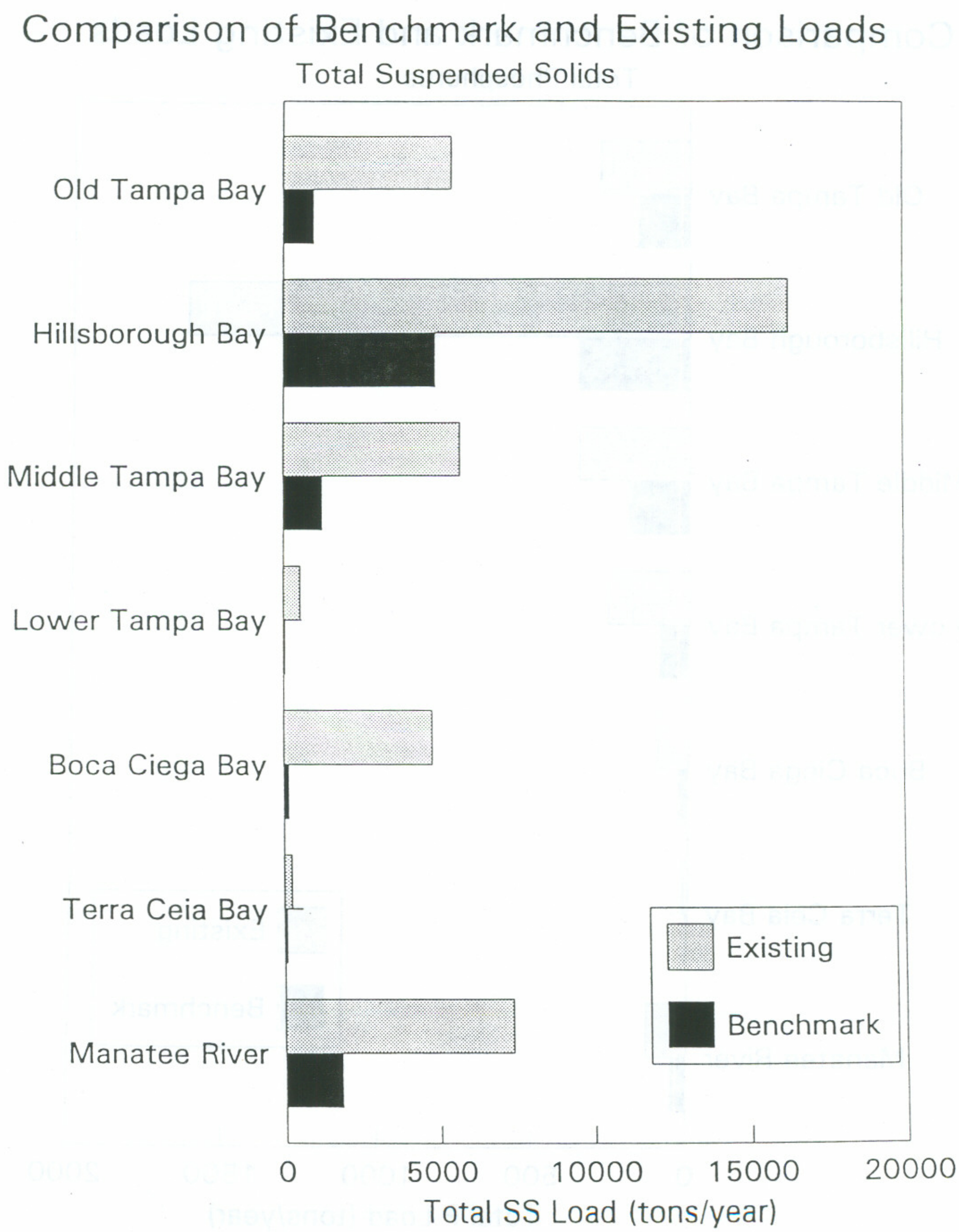
Figure 5-20 Comparison of benchmark and existing TN loads by bay segment



5-21 Comparison of benchmark and existing TP loads by bay segment

5-27

5-21 Comparison of benchmark and existing TP loads by bay segment



5-22 Comparison of benchmark and existing TSS loads by bay segment

5-28

5-22 Comparison of benchmark and existing TSS loads by bay segment

(780 tons/year and 400 tons/year, respectively), for Hillsborough Bay and Middle Tampa Bay. There is less difference between the TP load estimates for these two time periods for Old Tampa Bay, Middle Tampa Bay, Boca Ciega Bay, and Terra Ceia Bay. With the exception of Terra Ceia Bay and the Manatee River, the TSS loads to all bay segments under existing conditions are estimated to be appreciably greater (more than twice as large) than under the benchmark conditions.

A comparison of loadings under the two conditions can be further examined by comparing the loads by source for existing conditions to the total estimated loads under the benchmark conditions (Figures 5-23 through 5-25). This approach to loading comparisons for these two conditions is very interesting, especially with regard to potential management strategies that would be necessary if it were desired to reduce pollutant loads to near levels similar to those estimated under benchmark conditions. For example, Figure 5-23 presents the comparison of the benchmark TN loads to each bay segment to the TN loads by source under existing conditions. It is clear from this comparison that current TN loads from atmospheric deposition alone generally equal or exceed the estimated TN loads under the benchmark conditions for several bay segments. This is also true for nonpoint source loads of TN to Hillsborough Bay, Middle Tampa Bay, Boca Ciega Bay and the Manatee River. The estimated current TP loads from atmospheric deposition and nonpoint sources also exceed the total estimated TP loads for several segments under the benchmark conditions (Figure 5-24). Similar results can be seen for TSS loads in Figure 5-25.

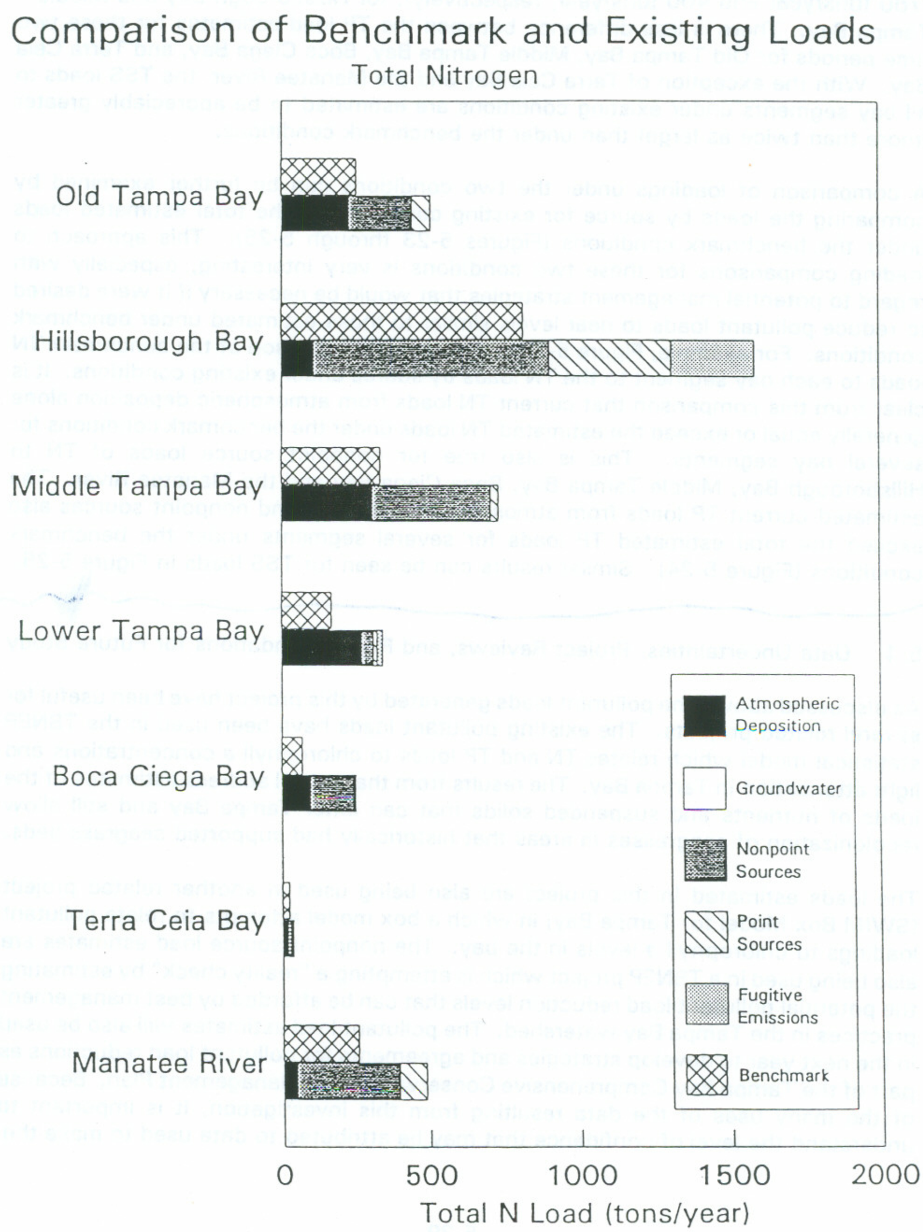


Figure 5-23 Comparison of benchmark and existing TN loads by source and bay segment

Figure 5-23 Comparison of benchmark and existing TN loads by source and bay segment

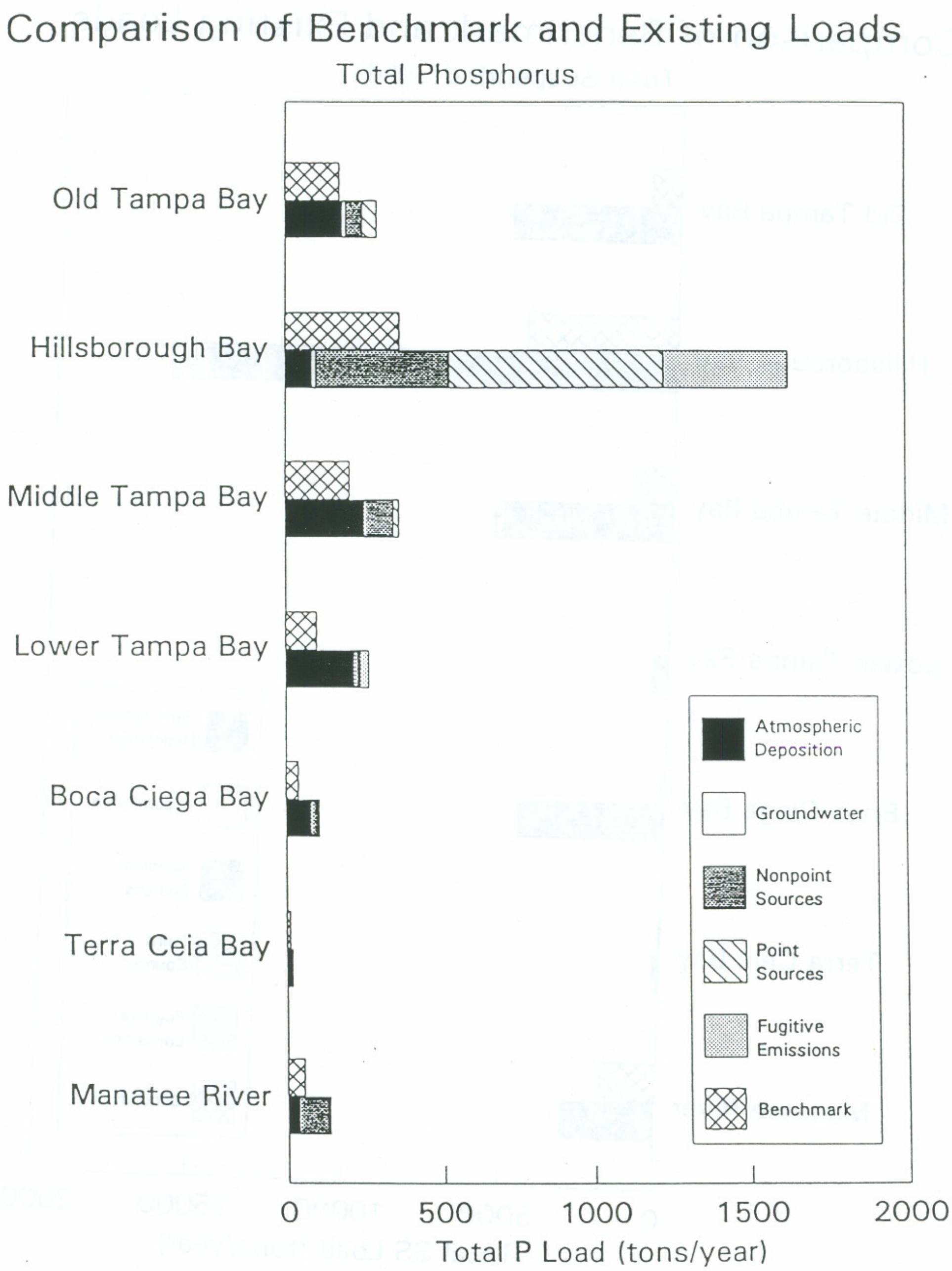


Figure 5-24 Comparison of benchmark and existing TP loads by source and bay segment

5-31

Figure 5-24 Comparison of benchmark and existing TP loads by source and bay segment

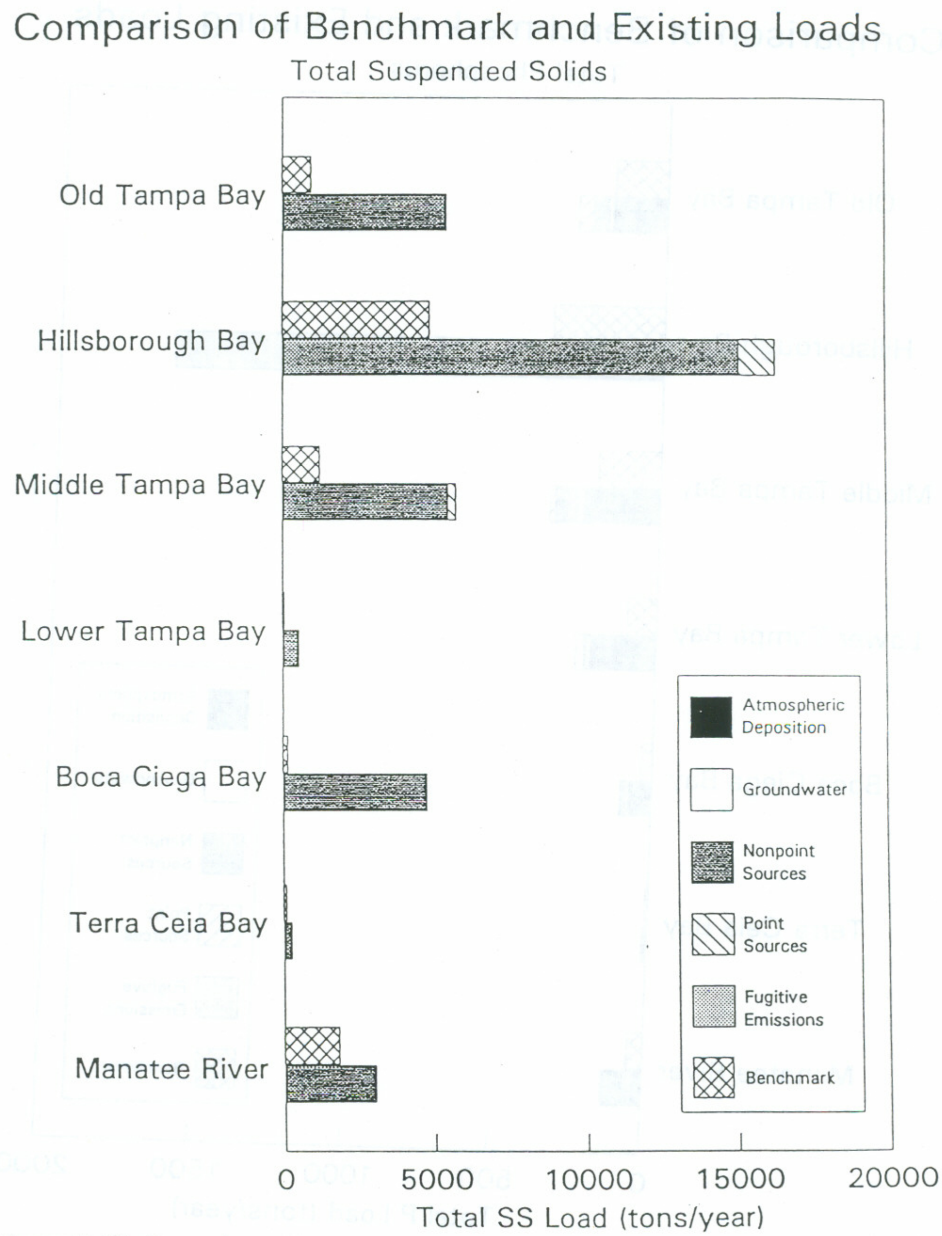


Figure 5-25 Comparison of benchmark and existing TSS loads by source and bay segment

5-32

Figure 5-25 Comparison of benchmark and existing TSS loads by source and bay segment

APPENDIX 8

BENCHMARK LAND USE-SPECIFIC
WATER QUALITY CONCENTRATIONS

HISTORICAL NONPOINT SOURCE

LAND USE-SPECIFIC WATER QUALITY CONCENTRATIONS

1) URBAN

	(w/ estimated relative area coverage)			
	0.7	0.2	0.1	Estimated Area-weighted
	Residential	Commercial	Industrial	Average
TN				
Min.	0.41	0.76	0.59	0.50
Mean	1.02	0.61	0.82	0.92
Max.	1.91	1.18	1.26	1.70
TP				
Min.	0.025	0.06	0.08	0.04
Mean	0.19	0.14	0.14	0.18
Max.	0.29	0.44	0.21	0.31
TSS				
Mean	36	42	94	43

2) AGRICULTURAL

	(w/ estimated relative area coverage)			
	0.3	0.05	0.65	Estimated Area-weighted
	Grove	Nursery Feed lot	Row & Field Crop	Average
TN				
Min.	0.75	2.70	1.00	1.01
Mean	1.00	15.0	1.16	1.80
Max.	1.50	21.0	1.50	2.48
TP				
Min.	0.075	0.85	0.10	0.13
Mean	0.10	2.80	0.27	0.35
Max.	0.3	3.80	1.06	0.97
TSS				
Mean	5	50	10	10.5

3) UNDEVELOPED ("FOREST")

	(w/ estimated relative area coverage)				Estimated
	0.4	0.125	0.4	0.075	Area-
			Open space/	Upland	weighted
	Range	Pasture	non-forested	forest	Average
TN					
Min.	0.68	0:50	0.90	0.10	0.70
Mean	0.93	1.30	1.21	0.50	1.06
Max.	1.10	2.50	1.47	1.02	1.38
TP					
Min.	0.008	0.02	0.08	0.007	0.022
Mean	0.016	0.09	0.40	0.05	0.096
Max.0.16	0.16	0.21	1.50	0.16	0.35
TSS					
Mean	8.2	11	5	2	8.5

4) OPEN WATER/WETLAND

	(Assume no load) 0.50 Open water	0.50 FW wetland	Estimated Area-weighted Average
TN			
Min.		0.79	0.40
Mean	0	1.43	0.72
Max.		2.26	1.13
TP			
Min.		0.09	0.05
Mean	0	0.19	0.10
Max.		0.33	0.16
TSS			
Min.		4.6	2.3
Mean	0	10.23	5.12
Max.		13.4	6.7

APPENDIX 9

BENCHMARK WASTEWATER TREATMENT PLANTS

Historical WWTP Information
(compiled by Andy Squires)

Dave Pickard, Plant Manager, City of Tampa AWT Plant (Hookers Point), Interviewed at AWT Plant, 3-30-93

Hookers Point primary plant went on-line about 1950-51. An Imhoff Tank, located near 22nd Street and McKay Bay, may have been in use prior to that time.

The "rule of thumb" flow expected from a typical domestic population is 100 gallons per person. Hookers Point was primary from 1951 through December 1977. During that time frame, the percent TKN and TP removed was very small. Expected TN and TP influent concentrations for a domestic WWTP is generally around 30mg/l and 8-10mg/l, respectively. Due to recent changes in detergents low in phosphates, influent TP levels are presently around 4 mg/l. Ten years ago it was twice as high.

Around 1967-68, the Breweries went on-line an affected TN (TKN) influent significantly. The Breweries discharge very high concentrations of TN in their effluent which then becomes part of the COT plant influent.

In Section 8, page 15, of the Hagan report, they found that about 7000 lbs TKN was going out into the bay. Dave suggested that this may be same that was going into the plant.

Records of building permits for Davis Island may give indication as to how sewage was treated prior to 1950.

Dave also suggested calling Cliff Courson (former plant manager of Drew Park WWTP in mid to late 1940's, 685-7254). He has good knowledge of domestic wastewater practices prior to 1950. Ralph Metcalf and his father may also prove to be good sources of information.

Cliff Courson, currently retired, but former manager of Drew Park WWTP, phone conversation 3-30-93.

Mr. Courson operated the first WWTP in Florida at Drew Park (current site of TIA) about 1948 through 1951.

Tampa's primary plant (Hookers Point) was constructed in 1950-51, on-line by 1951. Prior to that time an Imhoff tank located just off 22nd Street near McKay Bay was in use, but Mr. Courson did not know the population it served.

Prior to 1950, the COT dumped much of their sewage directly into the bay or river without any treatment whatsoever. He specifically recalls a discharge site near Marabell's Fish Company (current location of Convention Center) in downtown Tampa. In general, industrial and commercial entities dumped directly into surface waters without treatment, while single residences typically had septic tank systems.

Dave Shulmister (sp?), City of St. Petersburg, manager of all WWTPs, phone conversation on 3-31-93.

1893-1894 - First sanitary sewer system (gravity sewer) covered 100 acres.

1925 - sewer system served 1200 acres.
1925 - Albert Whitted was put on-line and performed screening and chlorination. Its service area included N to 9th Av N, S to 7th Av S, and W to 16th St., and E to the bay.
1931 - Plant expanded, but exact nature unknown.
1953 - Service area extended N to 54 Av N & 16th St.
1954 - A 14 million dollar bond issued resulted in Plant expansion.
1956 - Two primary plants went on-line: 1) NE (2mgd capacity), and 2) NW (4mgd capacity).
1957 - SW plant went on-line (6mgd)
1968 - Albert Whitted expanded to 20mgd capacity and upgraded to secondary treatment (contact stabilization).
1976-77 - SW expanded to advanced secondary.
1977 - SW plant started reclaimed water discharge, and deep well injection.
1979 - NE plant to adv. secondary (16mgd)
1980 - NE started reclaimed discharge
1980 - SW stops all surface water discharges to Boca Ciega Bay.
1982 - NW on-line, 20 mgd adv. secondary.
1984 - NW stops all discharges to Boca Ciega Bay.
1988 - Albert Whitted stopped all discharge to Tampa Bay.

Old STP records may be at Central Records, but they may have cleaned those files out in 1988 or 1989.

Tim Forgue (893-7377), the Chief operator at Albert Whitted, may have some old records on plant flows and concentrations. Also Fred Krafa (892-5693), Central Lab supervisor, may know if any old records are available at the lab.

Typical St. Pete TP influent at present is 4 mg/l TP and 20-30 TN. TP effluent is about 3.5-4.0 mg/l TP.

Old population information may be obtained at Planning (893-7153).

Bill Washburn, FDER Tampa, Manatee Co. Domestic WWTP coordinator, phone conversation on 3-29-93.

Information on STPs out of service in archives and difficult at best to obtain. The old plants operated by County public utilities no longer exists. They consisted of several small package plants.

Current Co. plants include:
- North - new plant
- Southeast - new plant
- Southwest - relatively old

Port Manatee had 3 plants serving County at one time.
City of Palmetto - old plant at current plant site.
City of Bradenton - old plant at current plant site.

Ed Snipes, FDER Tampa, Pinellas Co. Domestic WWTP coordinator, phone conversation on 3-29-93.

Status of WWTP is described in document published in mid 60's (perhaps he is referring to Hagan report) by HRS, Wayne Wyatt, Pinellas Co. Health Dept.

To get handle on historical WWTPs, check EPA records and perhaps 201 Plans.

Bill Dunn, of the Pinellas County Sewer System, may have working knowledge of pre-development WWTP situation in County (462-4721).

Bill Dunn, Pinellas Co. Sewer, phone conversation on 3-29-93.

STPs in general not constructed until 1950's, with the following exceptions:
- Clearwater - Marshall Street STP in 1930's
- St. Pete - Albert Whitted in 1920's
- Largo - Centralized Septic Tank system in 1920's
- Safety Hbr - Septic Tank serving small area of City (pre 1940's

Major population centers in 20's-30's were in St. Pete & Clearwater.

Pinellas County's first plant was South Cross Bayou in 1961-62.

Municipal plant history:

St. Pete	- plants in 1950's
Pinellas Park	- STP came on-line in 1960's, but has been abandoned since early 1970's.
Long Key Sewer District	- served southwestern Pinellas beach communities in late 1950's.
Treasure Is.	- small plants in 1950's
Madeira Beach	- STPs in 1950's
Largo	- STPs in 1950's
Clearwater	- STP's 1950's
Dunedin	- STP's 1950's
Oldsmar	- STP in late 50's or early 60's.
Tarpon Springs	- STP in 50's

In general, several small package plants operated prior to the 1950's.

Ralph Metcalf, Director, COT Dept. of Sanitary Sewers phone conversation 3-31-93.

Ralph concurred with my summary of what Cliff Courson's described, but suggested I call his farther, Ralph Metcalf Senior (831-2591).

Ralph Metcalf (Senior, 831-2591), phone conversation on 4-7-93, Former Head of the Wastewater Treatment Division for the State Board of Health in Jacksonville (1940's) and sold wastewater treatment plant equipment for the private sector from the early 50's through the 1970's. During his tenure at the Bd. of Health, he traveled around the state in order to promote the implementation of primary wastewater treatment plants.

Prior to the 1950's, only a small percentage of the population in most areas (certainly less than 20%) was on any type of primary treatment system. The most common system was primary treatment by an Imhoff tank (or some facsimile thereof) which provided both settling and digestion in the same structure. These tanks typically served small subdivisions and were purchased by the developers. Mr. Metcalf recalls an Imhoff tank near Bay-to-Bay and Manhattan, and near Gandy and Dale Mabry, both of which were purchased by the developers of the subdivision being served. The majority of residential households were served by separate septic tanks. In urban areas, including the City of Tampa, commercial and industrial buildings were usually outfitted to discharge raw sewage directly to the nearest surface water, due to lack of space for septic tanks operation.

Starting from the 1950's and continuing through to the 1970's, increasingly larger percentages of the population were served by a regional sanitary sewer system. However, from the 1950's into the 1960's, many subdivision developers provided their own wastewater treatment in the form of Imhoff tank type systems. Some of these Imhoff tanks were modified with trickling filters, and thus, were considered to achieve secondary treatment capabilities.

APPENDIX 10

BENCHMARK DOMESTIC LOADING ESTIMATES

Benchmark (circa 1940) Domestic Waste Loading
Tampa Bay Watershed

Bay Segment	Parameter Name	(A) 1940 Populatio	(B) Flow per Capita (gal/d)	(C) Net Flow (Less ET Recharge Loss) (gal/d)	(D) Effluent Quality (mg/L)	(E) In-ground Reduction High %	(E) In-ground Reduction Low %	(F) Total Benchmark Domestic Load Low (kg/yr)	(F) Total Benchmark Domestic Load High (kg/yr)
Old TB									
	TN	98702	50	37.5	40	0.525	0.225	97156	158518
	TP	98702	50	37.5	6	0.713	0.525	8805	14573
	TSS	98702	50	37.5	50	0.713	0.375	73378	159796
	Qtotal	98702	4935100	3701325				3701325	
Hills	TN	128706	50	30	40	0.525	0.225	101352	165364
	TP	128706	50	30	6	0.713	0.525	9186	15203
	TSS	128706	50	30	50	0.713	0.375	76547	166697
	Qtotal	128706	6435300	3861180				3861180	
Middle TB									
	TN	11201	50	35	40	0.525	0.225	10291	16790
	TP	11201	50	35	6	0.713	0.525	933	1544
	TSS	11201	50	35	50	0.713	0.375	7772	16925
	Qtotal	11201	560050	336030				336030	
Lower TB									
	TN	3991	50	35	40	0.525	0.225	3667	5982
	TP	3991	50	35	6	0.713	0.525	332	550
	TSS	3991	50	35	50	0.713	0.375	2769	6031
	Qtotal	3991	199550	119730				119730	
Boca Ciega									
	TN	5581	50	40	40	0.525	0.225	5860	9561
	TP	5581	50	40	6	0.713	0.525	531	879
	TSS	5581	50	40	50	0.713	0.375	4426	9638
	Qtotal	5581	279050	167430				167430	
Terra Ceia									
	TN	2500	50	40	40	0.525	0.225	2625	4283
	TP	2500	50	40	6	0.713	0.525	238	394
	TSS	2500	50	40	50	0.713	0.375	1982	4317
	Qtotal	2500	125000	75000				75000	
Manatee River									
	TN	12722	50	35	40	0.525	0.225	11688	19070
	TP	12722	50	35	6	0.713	0.525	1059	1753
	TSS	12722	50	35	50	0.713	0.375	8827	19223
	Qtotal	12722	636100	381660				381660	
TOTAL									
	TN	(kg/yr)						232638	379567
	TP	(kg/yr)						21084	34896
	TSS	(kg/yr)						175703	382628
	Qtotal	(gal/yr)						8642355	
	Qtotal	(gal/mo)						720196	
	Populatio	(people)						263403	

(A) 1940 population from Florida Statistical Abstracts, 1967.
(B) 1940 domestic waste stream of 50 gpd/cap is less than current rate of 75-100.
(C) ET+Recharge varies from 0.2 - 0.4 oif total 1940 domestic waste by bay segment drainage ar
(D) 1940 TP concentrations in domestic effluent are less than typical current values.
(E) Assume no WWTP, 75% on-site facilities, 25% have direct discharge.
(E) In ground reduction efficiencies are: TN(30-70%), TP(70-95%), TSS(50-95%). Reduction acts on effluent leaving drain field, final concentration is in water table plume.
(F) kg/yr=(gal/day)*(mg/L)*(3.785L/gal)*(kg/10E6mg)*(365day/yr)*(1-treatment efficiency)

APPENDIX 11

BENCHMARK GROUNDWATER FLOW AND NUTRIENT LOADINGS

Historical Groundwater and Nutrient Inflow to Tampa Bay

-based on (1) (Hutchinson, 1983) and (2) (Brooks et al, 1992)

Bay Segment	Aquifer	Wet Season Flow (mgd) (1) 9/78	(2) 9/85	(2) 9/90	x bar	Nitrate Load (kg/mo)	Phos. Load (kg/mo)	Nitrate Conc. (mg/l)	Phos. Conc. (mg/l)
Old TB									
	Fla	35	38	35	36.0	8.28	207.00	0.002	0.05
	Int	0	0	0	0.0	0.00	0.00	0.001	0.26
	WT	0.1	0.1	0.1	0.1	0.78	2.30	0.068	0.2
	total	35.1	38.1	35.1	36.1	9.06	209.30		
Hill.Bay									
19.5	Fla	63	29	35	61.8	14.22	355.54	0.002	0.05
	Int	0	1.4	1.6	1.5	0.17	44.85	0.001	0.26
	WT	0.05	0.05	0.05	0.1	0.01	0.69	0.0013	0.12
	total	63.05	30.45	36.65	63.4	14.40	401.08		
MTB									
74.5	Fla	14	10	12	86.5	19.90	497.38	0.002	0.05
	Int	0	1.8	3.6	2.7	0.31	80.73	0.001	0.26
	WT	0.1	0.1	0.1	0.1	0.15	0.81	0.013	0.07
	total	14.1	11.9	15.7	89.3	20.36	578.91		
LTB									
41.5	Fla	5	6	5	46.8	10.77	269.29	0.002	0.05
	Int	0	1.65	6.8	4.2	0.49	126.33	0.001	0.26
	WT	0.1	0.1	0.1	0.1	0.15	0.12	0.013	0.01
	total	5.1	7.75	11.9	51.2	11.41	395.73		
BCB									
2	Fla	0	2	2	3.3	0.77	19.17	0.002	0.05
	Int	0	0	0	0.0	0.00	0.00	0.001	0.26
	WT	0.01	0.01	0.01	0.0	0.00	0.01	0.002	0.01
	total	0.01	2.01	2.01	3.3	0.77	19.18		
TCB									
2	Fla	0	0	0	2.0	0.46	11.50	0.002	0.05
	Int	0	0.35	0.5	0.4	0.05	12.71	0.001	0.26
	WT	0.002	0.002	0.002	0.0	0.00	0.00	0.002	0.01
	total	0.002	0.352	0.502	2.4	0.51	24.21		
Wet Season Totals									
	Fla	117	85	89	236.50	54.40	1359.88		
	Int	0	5.2	12.5	8.85	1.02	264.62		
	WT	0.362	0.362	0.362	0.362	1.09	3.92		
	total	117.36	90.56	101.86	103.3	56.50	1628.41		

Conversion: (mg/l)*(mgd)*(30.5d/mo)*(10e6gal/1mgal)*(kg/10e6mg)*(3.79liter/gal)=kg/mo
:(mg/l)*(mgd)*(115)=kg/mo

Bay Seg.	Aquifer	Historical (1) 5/78	Dry Season Flow (mgd) (2) 5/86	(2) 5/91	x bar	Nitrate Load (kg/mo)	Phos. Load (kg/mo)	Nitrate Conc. (mg/l)	Phos. Conc. (mg/l)
Old TB									
	Fla	34	43	44	40.3	9.28	231.92	0.002	0.05
	Int		0	0	0.0	0.00	0.00	0.001	0.26
	WT	0.05	0.05	0.05	0.1	0.39	1.15	0.068	0.2
	total	34.05	43.05	44.05	40.4	9.67	233.07		
Hill.Bay									
19.5	Fla	45	16	31	50.2	11.54	288.46	0.002	0.05
	Int		0.8	1.2	1.0	0.12	29.90	0.001	0.26
	WT	0.05	0.05	0.05	0.1	0.01	0.69	0.0013	0.12
	total	45.05	16.85	32.25	51.2	11.66	319.05		
MTB									
74.5	Fla	3	8	2	78.8	18.13	453.29	0.002	0.05
	Int		1.3	2.4	1.9	0.21	55.32	0.001	0.26
	WT	0.05	0.05	0.05	0.1	0.07	0.40	0.013	0.07
	total	3.05	9.35	4.45	80.7	18.42	509.01		
LTB									
41.5	Fla	2	9	5	46.8	10.77	269.29	0.002	0.05
	Int		0.5	4.4	2.5	0.28	73.26	0.001	0.26
	WT	0.05	0.05	0.05	0.1	0.07	0.06	0.013	0.01
	total	2.05	9.55	9.45	49.3	11.13	342.60		
BCB									
2	Fla		2	1	3.0	0.69	17.25	0.002	0.05
	Int		0	0	0.0	0.00	0.00	0.001	0.26
	WT	0.005	0.005	0.005	0.0	0.00	0.01	0.002	0.01
	total	0.005	2.005	1.005	0.5	0.69	17.26		
TCB									
2	Fla		1	1	2.7	0.61	15.33	0.002	0.05
	Int		0.25	0.5	0.4	0.04	11.21	0.001	0.26
	WT	0.001	0.001	0.001	0.0	0.00	0.00	0.002	0.01
	total	0.001	1.251	9	0.5	0.66	26.55		
Dry Season Totals									
	Fla	84	79	84	221.83	51.02	1275.54		
	Int	0	2.85	8.5	5.675	0.65	169.68		
	WT	0.206	0.206	0.206	0.206	0.55	2.31		
	total	84.206	82.056	92.706	222.2	52.22	1447.53		
						52.22	1447.53		

Conversion: (mg/l)*(mgd)*(30.5d/mo)*(10e6gal/1mgal)*(kg/10e6mg)*(3.79liter/gal)=kg/mo

APPENDIX N

Appendix 15 Summary of Reported Chemical Spills of Nitrogen and Phosphorus in Tampa Bay, 1985-1991 From: The Estimates of Total Nitrogen, Phosphorus, and Total Suspended Solids Loadings to Tampa Bay, Florida
Prepared For:
Tampa Bay Estuary Program
Prepared By: Coastal Environmental, Inc