Chapter 3C: Status of Phosphorus and Nitrogen in the Everglades Protection Area

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SUMMARY

The Everglades ecosystem evolved as a highly nutrient-poor, phosphorus-limited system, with the native flora and fauna being adapted to successfully exist under these harsh conditions. Research has shown that relatively small additions of nutrients, especially phosphorus, can have dramatic effects on the biological conditions of the ecosystem. The primary purpose of this chapter is to provide an overview of the status of phosphorus and nitrogen levels in the surface water within the Everglades Protection Area during Water Year 2007 (May 1, 2006 through April 30, 2007). The chapter also presents the results of a preliminary total phosphorus criterion assessment conducted in accordance with the protocol provided in the *2007 South Florida Environmental Report – Volume I*, which was created to conform with the approved total phosphorus criterion rule [Section 62-302.540, Florida Administrative Code (F.A.C.)].

TOTAL PHOSPHORUS STATUS WITHIN THE EVERGLADES PROTECTION AREA

To provide a comprehensive overview of the current nutrient status in the Everglades, and to evaluate temporal and spatial patterns, total phosphorus (TP) concentrations measured during WY2007 are summarized and compared to levels obtained during previous monitoring periods as well as the limits set forth in the four-part TP criterion compliance test specified in the TP criterion rule (see **Table 3C-4**).

Since TP levels have shown marked changes in response to various restoration activities, the whole period of record was divided into three distinct timeframes for more meaningful comparison with Water Year 2007 (WY2007). These periods are (1) the Baseline period, which spans WY1979 through WY1993 [before Best Management Practices (BMPs) were instituted and the Stormwater Treatment Areas (STAs) constructed]; (2) the Phase I BMP/STA implementation period, from WY1994 through WY2004; and, (3) the Phase II BMP/STA implementation period, which began in WY2005 and is currently assessed through WY2007. Phase II will likely continue until 2016, or until phosphorus discharges to the Everglades Protection Area (EPA) meet the optimum criteria, whichever comes first.

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During WY1979–WY1993 (Baseline period), annual geometric mean TP concentrations at inflow and interior marsh sites across the EPA reached peak historic levels and were highly variable. As the agricultural BMPs and stormwater treatment programs were initiated and became operational during the WY1994–WY2004 BMP/STA implementation period (Phase I), annual mean TP concentrations at inflow and interior sites within all portions of the EPA were reduced markedly and became less variable compared to levels observed during the Baseline period. As the performance of the BMPs and STAs continue to be optimized and enhanced during the ongoing Phase II BMP/STA implementation period, the TP concentrations for the inflow and interior sites within the EPA have shown mixed results. TP levels during the first three years of Phase II have been dramatically influenced by climatic extremes, especially during WY2005.

As documented for earlier water years, TP concentrations measured during WY2007 exhibited a decreasing north-to-south gradient, with the highest levels present in the inflow to the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge) and Water Conservation Area 2 (WCA-2), and with concentrations decreasing to a minimum within the Everglades National Park (ENP or Park). The gradient indicates that as water entering the EPA from the north flows southward, biogeochemical processes (e.g., settling, sorption, and biological assimilation) help to decrease TP concentrations in the discharges (primarily phosphorus-rich agricultural runoff) from the Everglades Agricultural Area (EAA) and Lake Okeechobee.

Total phosphorus concentrations in the northern portions of the EPA (i.e., the Refuge and WCA-2) during WY2007 generally continued to decrease following the elevated concentrations observed in WY2005 that were associated with climatic extremes including multiple hurricanes and periods of marsh dry-out. During WY2007, both inflow and interior sites in the Refuge exhibited geometric mean TP concentrations well below the means observed during the Baseline period, with the mean TP concentration for the interior sites of 9.3 micrograms per liter (µg/L) being less than the lowest mean TP concentration (13.3 µg/L) among the Baseline period years, the Phase I period (mean TP concentration of 9.6 µg/L), and the WY2005–WY2007 period (mean TP concentration of 11.1 µg/L), see **Table 3C-1**. The lower TP concentrations observed in the Refuge are likely the result of multiple causes including lower levels of phosphorus-enriched discharges from the EAA and Lake Okeechobee, greater treatment by STA-1E, and recovery from the climatic extremes experienced during WY2005.

Similar to the Refuge, the geometric mean TP concentrations exhibited by both the inflow and interior sites in WCA-2 during WY2007 were lower than those determined for the Baseline, Phase I, and Phase II periods. During WY2007, the mean TP concentrations at WCA-2 inflow sites was 25.4 µg/L compared to levels of 69.8 µg/L, 45.0 µg/L, and 26.2 µg/L observed during the Baseline, Phase I, and WY2005–WY2007 periods, respectively. Likewise, the 13.3 µg/L geometric mean TP concentration for the WCA-2 interior sites during WY2007 was below the 16.2 µg/L, 16.9 µg/L, and 14.8 µg/L mean concentrations reported for the Baseline, Phase I, and Phase II periods, respectively.

In contrast, certain TP concentrations in the more southerly portions of the system (i.e., WCA-3 and the Park) during WY2007 reflect increasing influence from recent dry conditions and low water levels. The interior sites in both the Park and WCA-3 had geometric mean TP concentrations below the levels reported for the baseline period, but above those reported for both the Phase I and WY2005–WY2007 periods. It should be noted that elevated concentrations measured in the Park during two months of WY2007 (i.e., May 2006, and March 2007) when water levels were low and portions of the marsh dried out resulted in the higher overall means determined for WY2007.

Unlike inflow concentrations to the Park, the annual geometric mean TP concentrations at WCA-3 inflow sites during WY2007 were the lowest among the four monitoring periods. The mean Park inflow TP level of 11.1 µg/L during WY2007 is above the Baseline, Phase I, and WY2005–WY2007 values of 10.6 µg/L, 8.0 µg/L, and 9.8 µg/L, respectively.

Overall, interior marsh geometric mean TP concentrations for WY2007 ranged from 6.3 µg/L in the Park to 13.3 µg/L in WCA-2 as compared to ranges from 7.0–16.2 µg/L for Baseline, 4.7–16.9 µg/L for Phase I, and from 5.8 µg/L to 14.8 µg/L for the most recent phase. The annual geometric mean TP concentration across interior marsh sites in the Refuge, WCA-3, and the Park for WY2007 were below the 10.0 µg/L five-year limit. Although TP levels at interior sites in WCA-2 have improved in recent years, the geometric mean for WY2007 (13.3 µg/L) remains slightly above the annual 11.0 µg/L annual limit for assessing achievement with the TP criterion rule.

During WY2007, orthophosphate (OP) concentrations in the inflows to all areas within the EPA were the lowest among the four monitoring periods. The greatest decreases in OP concentrations were observed for inflow and rim canal sites in the Refuge and the inflows to WCA-2.

Annual geometric mean TP concentrations for individual interior marsh monitoring stations during WY2007 ranged from less than 4.0 µg/L in some unimpacted portions of the marsh to 45.8 µg/L at a WCA-2A site highly influenced by canal inputs. Across the entire EPA, 67.6 percent of the interior marsh sites exhibited annual geometric mean TP concentrations of 10.0 µg/L or less during WY2007, and 82.4 percent of the sites had annual geometric mean TP concentrations of 15.0 µg/L or less. For comparison, 40.5 percent, 67 percent, and 55.8 percent of the interior marsh sites exhibited geometric mean TP concentrations less than or equal to 10.0 µg/L during the Baseline, Phase I, and Phase II periods, respectively, and 64.7 percent, 80.2 percent, and 72.6 percent of the interior sites, respectively, had geometric mean concentrations of 15.0 µg/L or less.

PHOSPHORUS LOADS TO THE EVERGLADES PROTECTION AREA

During WY2007, TP loads from surface sources to the EPA totaled approximately 93.8 metric tons (mt), with a flow-weighted mean concentration of 56.0 µg/L; another 193 mt of TP is estimated to have entered the EPA through atmospheric deposition. The 93.8 mt TP load in the surface inflows to the EPA represents a decrease of approximately 46 percent compared to the previous year (WY2006 = 172.6 mt). The lower TP loads to the EPA observed during WY2007 primarily resulted from reduced flow volumes associated with the 2007 drought. The 1,361,269 acre-feet (ac-ft) of surface water flow to the EPA determined for WY2007 is approximately 46 percent lower than the 2,525,311 ac-ft reported for WY2006.

The effectiveness of the BMP and STA phosphorus removal efforts is demonstrated by the decreased TP loading to the Refuge, WCA-2, and WCA-3 during the Phase I and WY2005–WY2007 periods as compared to the Baseline period (despite increased flows to the EPA). The effect of the phosphorus removal efforts is less apparent in the Park where inflow concentrations have remained near background levels and the TP loading responds more directly to changes in flow and climatic conditions.

The average flow and TP load for the more recent WY2005–WY2007 period were influenced by the effects of climatic extremes including both multiple hurricanes and prolonged periods of

drought, especially during WY2005. Additional years of monitoring are needed before the effects of the current Phase II BMP/STA optimization projects can be seen in the Refuge.

PHOSPHORUS CRITERION ACHIEVEMENT ASSESSMENT

Only 30 of the 58 TP criterion monitoring network sites had sufficient data (i.e., ≥ 6 samples specified by the screening protocol referenced by the TP criterion rule (Section 62-302.540, F.A.C.), to be included in the TP criterion assessment during WY2007. The results of this WY2003–WY2007 TP criterion assessment indicate that the unimpacted (non-phosphorus-enriched) portions of each conservation area passed all four parts of the compliance test as expected and therefore are in compliance with the 10 µg/L TP criterion. Occasionally, individual sites within the unimpacted portions of the conservation areas exhibited an annual site geometric mean TP concentration above 10 µg/L, but in no case did the values for the individual unimpacted sites cause an overall exceedance of the annual or long-term network limits.

During WY2007, none of the annual geometric mean TP concentrations for the individual sites exceeded the 15 µg/L annual site limit, and during the WY2003–WY2007 period, only one exceedance of the 15 µg/L annual site limit occurred at an unimpacted site. The single exceedance, 19.8 µg/L, occurred at station X4 in the Refuge during WY2005 when TP levels throughout the EPA were elevated due to climatic extremes.

In contrast, the impacted (phosphorus-enriched) portions of each water body failed one or more parts of the test and therefore exceeded the criteria. The impacted portions of the water conservation areas consistently exceeded the annual and five-year network TP concentration limits of 11 µg/L and 10 µg/L, respectively. Occasionally, selected individual sites within the impacted areas exhibited annual geometric mean TP concentrations below the 15 µg/L annual site limit. Rarely, the annual mean for individual impacted sites was below 10 µg/L; however, none of the impacted sites was consistently below the 10 µg/L long-term limit.

Future TP criterion achievement assessments conducted with more robust datasets are expected to provide a better understanding of phosphorus concentrations in the EPA.

TOTAL NITROGEN CONCENTRATIONS WITHIN THE EVERGLADES PROTECTION AREA

As in previous years, total nitrogen (TN) concentrations in the EPA also exhibited a north-to-south gradient during WY2007. Similar to phosphorus, the TN gradient likely reflects the higher concentrations associated with agricultural discharges to the northern portions of the system, with a gradual reduction in levels southward as a result of assimilative processes in the marshes. The highest average TN concentrations were observed in the inflows to the Refuge with levels decreasing to a minimum at sites within the Park.

Geometric mean TN concentrations measured during WY2007 at both inflow and interior sites in all areas of the EPA were generally comparable to (or slightly lower than) the values for the WY2006 and WY1996–WY2005 periods and well below the levels observed for the pre-STA/BMP period. These results demonstrate the continued effectiveness of agricultural BMPs and nutrient removal by the STAs.

During WY2007, geometric mean TN concentrations at inflow stations ranged from 1.06 milligrams per liter (mg/L) in the Park to 2.14 mg/L in the Refuge. Similarly, mean TN

concentrations at the interior marsh stations during WY2007 ranged from 1.00 mg/L in the Park to 2.25 mg/L in WCA-2.

The geometric mean TN concentration for the inflows and interior of the Refuge during WY2007 were considerably lower than the levels for any of the preceding periods. The lower concentrations observed during WY2007 may have been caused by several factors including (1) the recovery of the nutrient-removal effectiveness of STA-1W since the vegetative communities were damaged by storm activity during the 2005 hurricane season, (2) further treatment resulting from operation of STA-1E, (3) and lower amounts of nutrient-enriched inflow from the EAA and Lake Okeechobee during dry periods.

PURPOSE

The primary purpose of this chapter is to provide an overview of the status of phosphorus and nitrogen levels in the surface water within the EPA during WY2007. The water quality evaluations presented in this section update previous analyses presented in earlier consolidated reports. More specifically, this chapter and its associated appendices are intended to (1) summarize phosphorus and nitrogen concentrations measured in surface waters within different portions of the EPA and describe spatial and temporal trends observed, (2) discuss factors contributing to any spatial and temporal trends observed, and (3) present preliminary phosphorus criterion achievement assessments for different areas within the EPA.

Following the final approval of the TP criterion rule for the EPA by the United States Environmental Protection Agency (USEPA) in July 2005, a protocol for assessing achievement of the TP criterion was developed and provided in the *2007 South Florida Environmental Report – Volume I* (SFER). This year's chapter includes a preliminary assessment of TP criterion achievement utilizing the protocol and also provides an annual update of the comprehensive overview of nitrogen and phosphorus levels throughout the EPA. It is anticipated that future SFERs will continue to include more detailed evaluation to assess achievement of the TP criterion within the different portions of the EPA, and continue to provide updated overviews.

METHODS

OVERVIEW OF EVERGLADES PROTECTION AREA NITROGEN AND PHOSPHORUS LEVELS

A regional synoptic approach used for water quality evaluations in previous SFERs was applied to phosphorus and nitrogen data for WY2007 to provide an overview of nutrient status within the EPA. The consolidation of regional water quality data provides for analysis over time, but limits spatial analysis within each region. However, spatial analysis can be performed between regions, because the majority of inflow and pollutants enter the northern one-third of the EPA, and the net water flow is from north to south.

As described in Chapter 3A of this volume, for the evaluation of other water quality constituents, the majority of the water quality data evaluated in this chapter was retrieved from the DBHYDRO database maintained by the South Florida Water Management District (SFWMD or District). Water quality data from the nutrient gradient sampling stations (monitored by the District's Everglades Regulation Division, Environmental Resource Regulation Department) in

the northern part of Water Conservation Area 2A (WCA-2A), the southwestern part of the Refuge, the west-central portion of WCA-3A, and Taylor Slough in the ENP were obtained from the SFWMD Everglades research database.

The phosphorus and nitrogen data summarized in this chapter were collected at the same monitoring stations shown in Chapter 3A, Figure 3A-1, of this volume. Likewise, the water quality sampling stations located throughout the Park and WCAs were categorized as inflow, rim canal, interior, or outflow sites within each region based on each's location and function (see Chapter 3A, Figures 3A-2 through 3A-5 of this volume). Due to the addition of a small amount of data unavailable during the preparation of the 2007 SFER, some statistics for phosphorus and nitrogen presented may differ slightly from those presented in earlier reports.

The current SFWMD monitoring programs are described by Germain (1998). The frequency of nutrient sampling varies by site depending on site classification and hydrologic conditions (water depth and flow). Additionally, the District has created a web site describing its water quality monitoring projects, including project descriptions and objectives. This web site currently provides limited site-specific information. Generally, interior monitoring stations were sampled monthly, with water control structures (inflows and outflows) typically sampled biweekly when flowing and monthly when not flowing. More information can be found on the District's web site at www.sfwmd.gov, under the *What We Do, Environmental Monitoring, Water Quality Monitoring* section.

As previously stated, the primary objectives of this chapter include summarizing the status of nitrogen and phosphorus levels observed during WY2007 and to describe trends or changes in nutrient concentrations over time. Previous Everglades Consolidated Reports (ECRs) and SFERs accomplished this task by comparing levels observed during the most recent water year (e.g., WY2007) to those during the previous water year (e.g., WY2006) and a historic period using all proceeding water years going back to WY1979 (e.g., WY1979–WY2005). The problem with this approach was that the historic period was expanding, and thus changing, with each subsequent report so that there was never a constant baseline against which to assess progress.

To address this shifting baseline, and in direct response to previous SFER Panel comments, this report and all future reports, makes comparisons across discrete multiple periods corresponding to major restoration activities occurring within the EPA. The periods utilized are the WY1979 through WY1993 period (Baseline), which corresponds to the timeframe prior to implementation of the Everglades Agricultural Area BMP program and Everglades Construction Project (i.e., the STAs); WY1994 through WY2004 (Phase I), which represents the time in which there was increasing implementation of the BMP program and all of the initial STAs became operational; and the period after WY2004 (i.e., WY2005–WY2007) that corresponds to the period in which the performance of the BMPs and STAs are being optimized and enhanced and various long-term plan and CERP restoration projects are being implemented (the Phase II BMP/STA implementation period). Since the optimization and enhancement of the STAs and BMP programs as well as other restoration activities are expected to continue for a number of years, the Phase II period will be expanded in future SFERs. In addition, data for the current individual water year (in this case, WY2007) will be used to make comparisons with the historic periods.

The quality assurance/quality control (QA/QC) procedures followed during data collection, as well as the data screening performed on the nutrient data presented in this chapter, are the same as those described in Chapter 3A of this volume. For purposes of summary statistics presented in this chapter, data reported as less than the Method Detection Limit (MDL) were assigned a value of one-half the MDL. All data presented in this chapter, including historical results, were handled consistently with regard to screening and MDL replacement.

PHOSPHORUS CRITERION ACHIEVEMENT ASSESSMENT

A preliminary evaluation to determine achievement of the TP criterion was performed in accordance with the protocol provided in the *2007 South Florida Environmental Report* (SFER) Chapter 3C, and the four-part test specified in the TP criterion rule (**Table 3C-4**). The available data from the 58 sites comprising the TP criterion monitoring network for the most recent five-year period (i.e., WY2003–WY2007) were utilized in the evaluation. It should be noted that not all sites have data available for the full five-year assessment period and that due to the extremely dry conditions that have prevailed, data for WY2007 are especially sparse in certain portions of the EPA. Because the results of the TP criterion compliance assessment presented in this chapter could be affected by this data limitation, this evaluation should be considered preliminary and the results interpreted with caution.

The TP criterion rule requires that a network be established for the purpose of evaluating compliance with the TP criterion. In establishing this network, existing sites being monitored for different purposes were selected wherever possible. However, to get the required spatial coverage new sites were added. The location of the TP criterion network monitoring sites used in this assessment and their classification as impacted or unimpacted are provided in **Figure 3C-1**. Collection of data from the complete TP criterion monitoring network, which includes the new site, was initiated in January 2007. It should be noted, again, that not all sites have data available for the full five-year assessment period and that due to extremely dry conditions that have prevailed, data for WY2007 are especially sparse in certain portions of the EPA. Because the results of the TP criterion compliance assessment presented in this chapter could be affected by this data limitation, this evaluation should be considered preliminary and the results cautiously interpreted. It is expected that future assessments will improve as additional datasets for all sites within the monitoring network are added.

The QA/QC procedures followed during data collection are the same as those described in Chapter 3A of this volume. Collected data were screened as specified in the protocol presented at the Florida Department of Environmental Protection (FDEP) web site at http://www.dep.state.fl.us/water/wqssp/everglades/docs/DataQualityScreeningProtocol.pdf.

For purposes of this assessment, data reported as less than the MDL were assigned a value of one-half the MDL. All data presented in this chapter, including historical results, were handled consistently with regard to screening and MDL replacement.

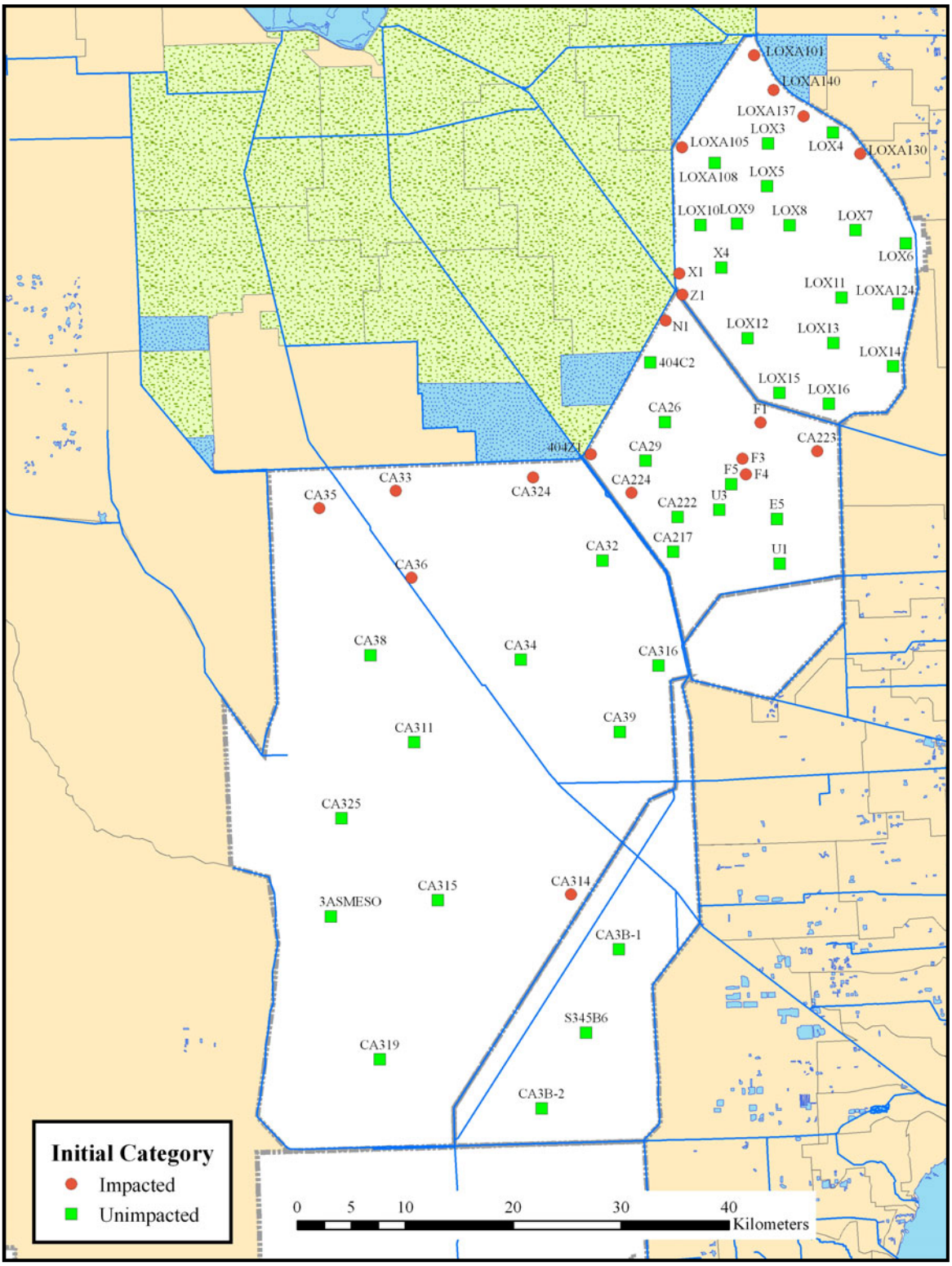

Figure 3C-1. Location of TP criterion assessment monitoring network sites used in the WY2003–WY2007 evaluation.

PHOSPHORUS AND NITROGEN IN THE EVERGLADES PROTECTION AREA

As primary nutrients, phosphorus and nitrogen are essential to the existence and growth of aquatic organisms in surface waters. The native flora and fauna in the Everglades, though, are adapted to successfully exist under nutrient-poor conditions. Because of their unique ability to thrive with lower levels of nutrients, relatively small additions, especially of phosphorus, have dramatic effects on the ecosystem.

Until recently, phosphorus and nitrogen concentrations in EPA surface water were only regulated by the Class III narrative criterion. The narrative criterion specifies that nutrient concentrations in a water body cannot be altered to cause an imbalance in the natural populations of aquatic flora or fauna. Because of the importance of phosphorus in controlling the natural biological communities, the FDEP has numerically interpreted the narrative criterion, as directed by the Everglades Forever Act (EFA), to establish a 10.0 µg/L TP criterion for the EPA.

In addition to analyses of individual levels of TP and TN, this chapter provides an evaluation of spatial and temporal trends in nutrient levels within the EPA as measured during WY2007 and compares the results to those from previous monitoring periods to achieve an overview.

TOTAL PHOSPHORUS

PHOSPHORUS STATUS IN THE EVERGLADES PROTECTION AREA

Table 3C-1 provides a summary of the TP concentrations measured within different portions of the EPA during WY2007, and the Baseline, Phase I, and WY2005–WY2007 periods using both geometric mean and median values. In addition, **Figures 3C-2** through **3C-5** illustrate the temporal changes in annual geometric mean TP concentrations during the whole period of record from WY1978 through WY2007 at inflow and interior sites for the Refuge, WCA-2, WCA-3, and the Park, respectively. The figures also provide the geometric mean TP concentrations for the Baseline, Phase I, and WY2005–WY2007 periods for comparison. Geometric means were used to summarize and compare TP concentrations based on the Everglades Forever Act (EFA) and TP criterion rule requirements that achievement of the TP criterion is based on the long-term, geometric mean. Given that the EFA and TP criterion were designed to provide long-term conditions that are ecologically protective, they require the use of geometric means. This methodology accounts for short-term variability in water quality data to provide a more reliable, long-term value for assessing and comparing the status of phosphorus.

One of the primary objectives of this chapter is to document temporal changes in TP concentrations across the EPA. The annual geometric mean TP concentrations for the inflow and interior sites in each portion of the EPA along with the mean concentrations for each of the periods specified above are provided in **Figures 3C-2** through **3C-5**.

Table 3C-1. Summary of total phosphorus (TP) concentrations (µg/L) in the Everglades Protection Area (EPA) for the WY1979–WY1993, WY1994–WY2004, WY2005–WY2007, and WY2007 periods.

Region	Class	Period	Sample Size (N)	Geometric Mean (µg/L)	Std. Deviation (Geometric Mean)	Median (µg/L)	Min. (µg/L)	Max. (µg/L)
REFUGE	Inflow	1979-1993	1213	90.7	2.3	97.5	6	1415
		1994-2004	1975	53.8	2.2	54.0	<4	722
		2005-2007	505	65.9	1.8	63.0	21	503
		2007	184	57.6	1.7	51.8	21	253
	Interior	1979-1993	364	13.3	2.6	12.0	<2	494
		1994-2004	2430	9.6	1.9	9.0	<4	200
		2005-2007	881	11.1	2.0	9.0	2	238
		2007	237	9.3	1.9	8.0	2	230
	Outflow	1979-1993	613	65.0	2.1	63.0	8	3435
		1994-2004	702	45.4	1.9	43.0	10	495
		2005-2007	163	42.2	2.1	36.0	11	515
		2007	54	33.4	1.8	29.0	14	127
	Rim	1979-1993	118	75.7	1.9	81.0	12	473
		1994-2004	632	60.7	1.7	57.0	17	290
		2005-2007	118	63.1	2.1	67.5	4	653
		2007	26	35.8	2.5	43.5	4	130
WCA-2	Inflow	1979-1993	789	69.8	2.0	68.0	10	3435
		1994-2004	1383	45.0	2.1	49.0	7	493
		2005-2007	468	26.2	2.0	23.0	4	245
		2007	149	25.4	1.8	24.0	4	130
	Interior	1979-1993	1698	16.2	3.4	13.0	<2	3189
		1994-2004	3599	16.9	2.8	14.0	<2	2400
		2005-2007	756	14.8	2.5	13.0	2	530
		2007	222	13.3	2.6	12.0	2	194
	Outflow	1979-1993	893	23.2	2.6	23.0	<2	556
		1994-2004	682	17.6	2.2	17.0	<4	199
		2005-2007	248	15.9	1.8	15.0	6	179
		2007	76	17.1	1.8	15.5	7	64
WCA-3	Inflow	1979-1993	2537	37.4	2.6	37.0	<2	933
		1994-2004	3325	31.5	2.3	30.0	<4	1286
		2005-2007	1256	24.0	2.0	22.0	6	289
		2007	419	23.8	1.9	22.0	7	289
	Interior	1979-1993	628	10.2	3.2	10.0	<2	438
		1994-2004	2097	8.1	2.2	7.0	<2	310
		2005-2007	804	9.4	2.4	8.0	2	560
		2007	231	9.7	2.4	8.0	2	560
	Outflow	1979-1993	1971	12.1	2.3	11.0	<2	593
		1994-2004	2412	10.1	2.0	10.0	<4	171
		2005-2007	575	14.8	1.9	13.0	5	189
		2007	204	16.6	1.8	15.0	6	88

Table 3C-1. Continued.

Region	Class	Period	Sample Size (N)	Geometric Mean (µg/L)	Std. Deviation (Geometric Mean)	Median (µg/L)	Min. (µg/L)	Max. (µg/L)
PARK	Inflow	1979-1993	2172	10.6	2.3	10.0	<2	593
		1994-2004	3053	8.0	1.9	8.0	<4	145
		2005-2007	826	9.8	1.9	9.0	2	189
		2007	289	11.1	1.9	9.5	3	70
	Interior	1979-1993	564	7.0	2.9	6.0	0.5	1137
		1994-2004	1199	4.7	2.1	5.0	<2	117
		2005-2007	242	5.8	2.3	5.0	<2	291
		2007	79	6.3	2.0	6.0	<2	122

During the Baseline period, annual geometric mean TP concentrations at inflow and interior marsh sites across the EPA reached peak historic levels and were highly variable as shown in **Figures 3C-2** through **3C-5**. As the agricultural BMP and stormwater treatment programs were initiated and became operational during the Phase I period, annual mean TP concentrations at inflow and interior sites within all portions of the EPA were reduced markedly and became less variable compared to levels observed during the Baseline period. As the performance of the BMPs and STAs continue to be optimized and enhanced during the Phase II period, the TP concentrations for the inflow and interior sites within the EPA have shown mixed results.

TP levels during the WY2005–WY2007 period have been dramatically influenced by climatic extremes. These extremes include the influence of both hurricane-season activity with its intense rainfall and periods of little or no rainfall and subsequent marsh dry-out. In general, the greatest effect from the climatic extremes was experienced during WY2005 when tropical activity (e.g, Hurricane Wilma) resulted in elevated inflow concentrations in concert with storm damage to STA vegetative communities that resulted in decreased STA nutrient removal for many months. WY2005 was also effected by prolonged periods of marsh dry-out because of sharply decreased rainfall that resulted in increased oxidation of the organic sediment and the subsequent release of phosphorus into the water column, resulting in elevated TP concentrations observed at marsh sites across the EPA.

During WY2006, much of the EPA experienced varying levels of recovery from the WY2005 climatic effects, but TP levels in portions of the EPA were again influenced by extended periods of marsh dry-out experienced during much of WY2007 (**Figures 3C-2** through **3C-5)**. Since the Phase II BMP/STA optimization and enhancement and the implementation of other restoration projects will all continue for a number of years, the Phase II historical period used in future reports will be expanded from the WY2005–WY2007 period used in this year's 2008 SFER. As the Phase II period is expanded, the results will be influenced less by single atypical years (e.g., WY2005) and the long-term effects of the continuing restoration efforts will be seen more clearly.

As documented for previous years, TP concentrations measured during WY2007 exhibited a decreasing north-to-south gradient, with the highest levels present in the inflow to the Refuge and concentrations decreasing to a minimum within the Park. This gradient results from the phosphorus-rich canal discharges, composed primarily of agricultural runoff originating in the EAA, entering the northern portions of the EPA. Settling, sorption (both adsorption and absorption), biological assimilation, and other biogeochemical processes result in decreasing concentrations as the water flows southward through the marsh.

Total phosphorus concentrations in the northern portions of the EPA (i.e., Refuge and WCA-2) during WY2007 generally continued to decrease following the elevated concentrations observed in WY2005. During WY2007, both inflow and interior sites in the Refuge exhibited a geometric mean TP concentration well below the mean observed during the Baseline period with the mean TP concentration for the interior sites being the lowest of the four periods (see **Table 3C-1** and **Figure 3C-2**). During WY2007, the interior sites in the Refuge had a geometric mean TP concentration of 9.3 µg/L compared to levels of 13.3 µg/L, 9.6 µg/L, and 11.1 µg/L found for the Baseline, Phase I, and WY2005–WY2007 periods, respectively (**Table 3C-1**). The lower TP concentrations observed in the Refuge are likely the result of multiple causes including lower levels of phosphorus-enriched discharges from the EAA and Lake Okeechobee, greater treatment by STA-1E, and general recovery from the climatic extremes experienced during WY2005. Also potentially influencing the results were the dry conditions experienced during much of WY2007 that caused fewer samples to be collected in the Refuge, especially in the impacted portions which tend to be shallower areas that dry out more quickly when there is little or no rainfall.

Similar to the Refuge, the geometric mean TP concentrations exhibited by both the inflow and interior sites in WCA-2 during WY2007 were lower than those determined for the Baseline, Phase I, and (current) Phase II periods (**Figure 3C-3**). During WY2007, the mean TP concentrations at WCA-2 inflow sites was 25.4 µg/L compared to levels of 69.8 µg/L, 45.0 µg/L, and 26.2 µg/L observed during the Baseline, Phase I, and WY2005–WY2007 periods, respectively (**Table 3C-1**). Likewise, the 13.3 µg/L geometric mean TP concentration for the WCA-2 interior sites during WY2007 was below the 16.2 µg/L, 16.9 µg/L, and 14.8 µg/L mean concentrations reported for the three historical periods, respectively (**Table 3C-1**). The continued decreases observed in WCA-2 likely reflect both the recovery from the climatic extremes experienced during WY2005 and improved conditions in the impacted portions of the marsh downstream of the S-10 structures where the quantity of discharge has been significantly reduced and the quality of the discharge has improved since STA-2 began operation.

In contrast, the TP concentrations in the more southerly portions of the system (i.e., WCA-3 and the Park) during WY2007 reflect increasing influence from recent dry conditions and low water levels. The interior sites in both the Park and WCA-3 had geometric mean TP concentrations below the levels reported for the Baseline period, but above those reported for both the Phase I and WY2005–WY2007 periods. It should be noted that elevated concentrations measured in the Park during two months during WY2007 (i.e., May 2006, and March 2007) when water levels were low and portions of the marsh dried out resulted in the higher overall geometric means determined for WY2007 **(Figure 3C-6)**. In addition, the inflow concentrations observed in WY2007 to the Park were the highest among the four periods, which probably reflects dry conditions in upstream areas. **Figures 3C-4** and **3C-5** illustrate the temporal changes in annual geometric mean TP concentrations during the period of record at inflow and interior sites for WCA-3, and the Park, respectively. The figures also provide the geometric mean TP concentrations during the three monitoring periods for comparison.

Annual geometric mean TP concentrations at inflow WCA-3 sites during WY2007 were the lowest among the four monitoring periods. In contrast, the mean Park inflow TP level of 11.1 µg/L during WY2007 is above the Baseline, Phase I, and WY2005–WY2007 values of 10.6 µg/L, 8.0 µg/L, and 9.8 µg/L, respectively (**Table 3C-1**). The likely cause of the elevated inflow TP concentrations observed during 2007 is the dry conditions in upstream areas resulting in oxidation of the sediment and subsequent release of phosphorus. This hypothesis is supported by the higher outflow TP concentrations determined for WCA-3 during WY2007.

Overall, interior marsh geometric mean TP concentrations for WY2007 ranged from a 6.3 µg/L in the Park to 13.3 µg/L in WCA-2 as compared to ranges from 7.0 µg/L to 16.2 µg/L for WY1979–WY1993 4.7 to 16.9 µg/L for WY1994-WY2004, and from 5.8 to 14.8 µg/L for WY2005–WY2007 (**Table 3C-1**). The annual geometric mean TP concentration across interior marsh sites in the Refuge, WCA-3, and the Park for WY2007 were below the 10.0 µg/L five-year limit and 11.0 µg/L annual limit for assessing achievement with the TP criterion rule. Although TP levels at interior sites in WCA-2 have improved in recent years, the geometric mean for WY2007 (13.3 µg/L) remains slightly above the annual 11.0 µg/L annual limit.

Orthophosphate (OP) is an inorganic, soluble form of phosphorus readily utilized by biological organisms, and therefore has the greatest and most rapid effect on the ecosystem. During WY2007, OP concentrations in the inflows to all areas within the EPA were the lowest among the four monitoring periods (**Table 3C-2**). The greatest decreases in OP concentrations were observed for inflow and rim canal sites in the Refuge and the inflows to WCA-2. The large decreases observed for the northern portions of the EPA likely result from multiple factors including the recovery of the STAs following the damage resulting from the 2005 hurricanes, and less inflow from Lake Okeechobee and the EAA. In addition, the Refuge and WCA-2, which historically received the highest levels of OP, now receive most of their inflow from the STAs, which preferentially remove OP.

Annual geometric mean TP concentrations for individual interior marsh monitoring stations having four or more samples during WY2007 ranged from less than 4.0 µg/L in some unimpacted portions of the marsh to 45.8 µg/L at a WCA-2A site highly influenced by canal inputs. Across the entire EPA, 67.6 percent of the interior marsh sites exhibited annual geometric mean TP concentrations of 10.0 µg/L or less with 82.4 percent of the interior sites in the EPA having annual geometric mean TP concentrations of 15.0 µg/L or below during WY2007. For comparison, 40.5 percent, 67.0 percent, and 55.8 percent of the interior marsh sites exhibited geometric mean TP concentrations less than or equal to 10.0 µg/L during Baseline, Phase I, and WY2005–WY2007 periods, respectively. During the three historical periods, 64.7 percent , 80.2 percent, and 72.6 percent of the interior sites, respectively, had annual geometric mean concentrations of 15.0 µg/L or less. Given that the location of interior monitoring sites has remained relatively constant in recent years, the temporal comparison of statistics from individual sites can be used to distinguish changes in measured concentrations. However, it should be noted that since the existing monitoring network was not designed to allow the results to accurately estimate the percentage of the marsh exceeding a TP concentration of 10.0 µg/L (or other threshold), it is not appropriate to use the results for that purpose.

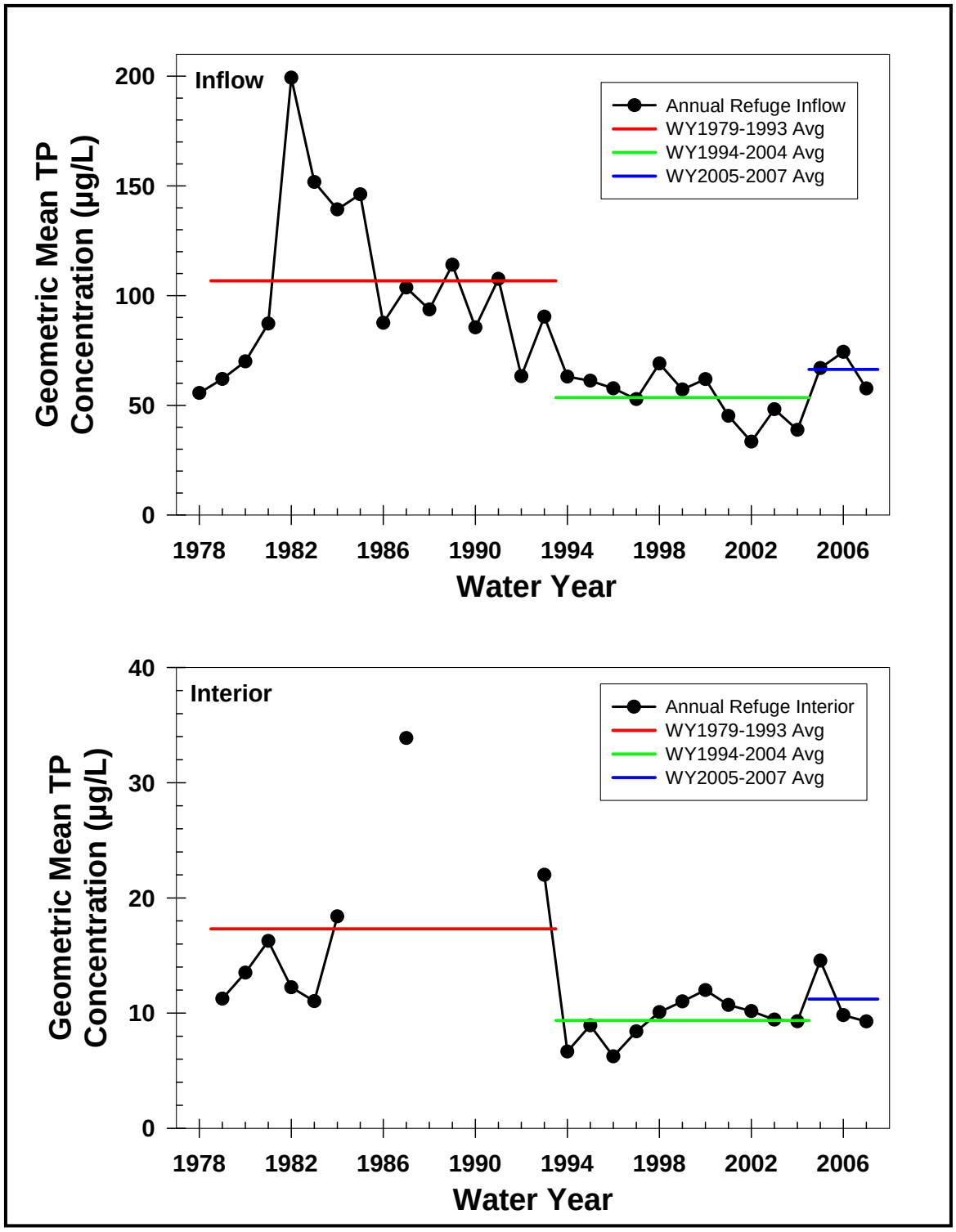

Figure 3C-2. Annual geometric mean TP concentrations (µg/L) for inflow (upper graph) and interior (lower graph) areas of the Refuge from WY1978 through WY2007. The horizontal lines indicate the average annual geometric mean TP concentrations for the WY1979–WY1993, WY1994–WY2004, and WY2005–WY2007 periods, respectively.

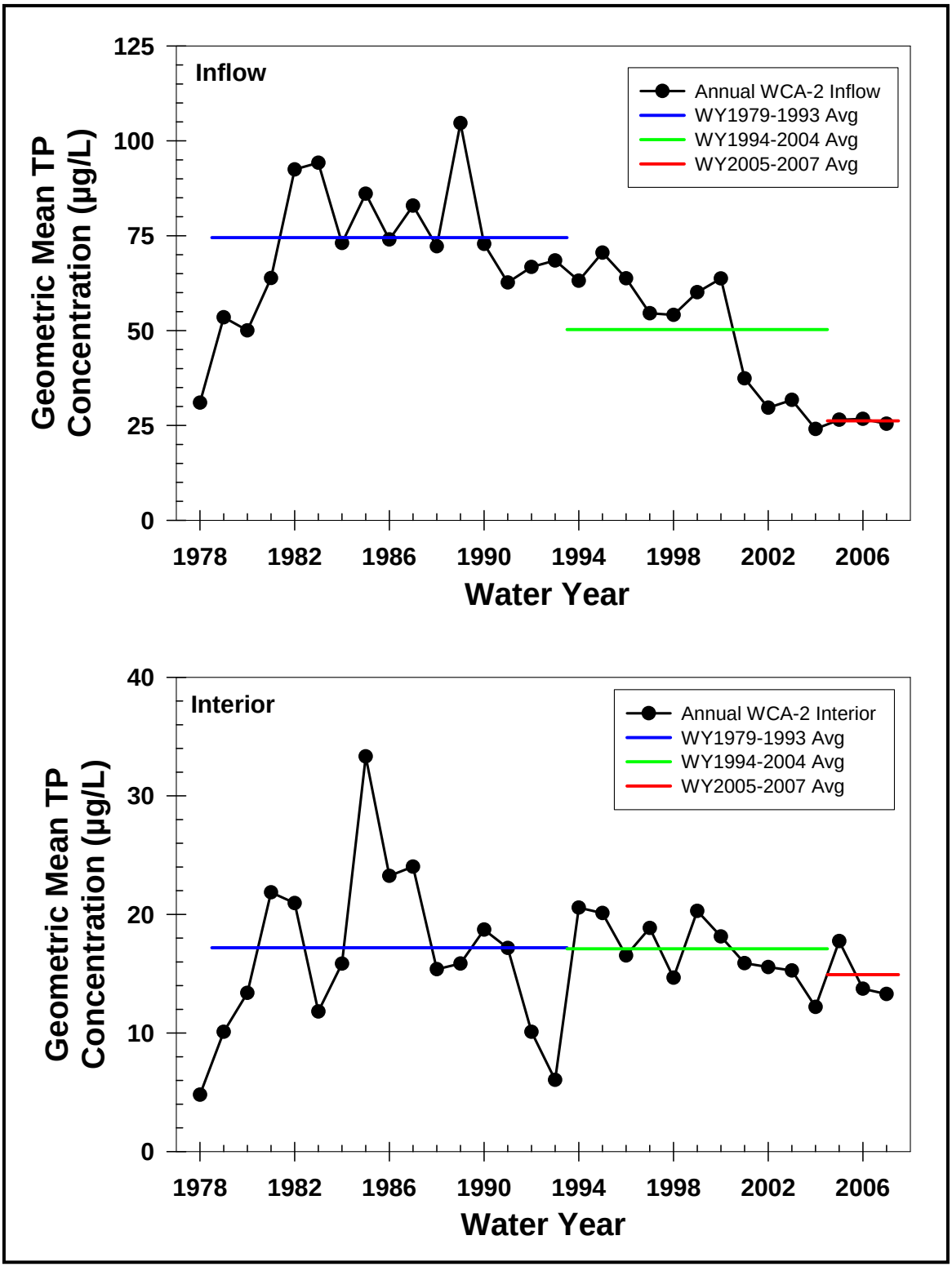

Figure 3C-3. Annual geometric mean TP concentrations (µg/L) for inflow (upper graph) and interior (lower graph) areas of WCA-2 from WY1978 through WY2007. The horizontal lines indicate the average annual geometric mean TP concentrations for the WY1979–WY1993, WY1994–WY2004, and WY2005–WY2007 periods, respectively.

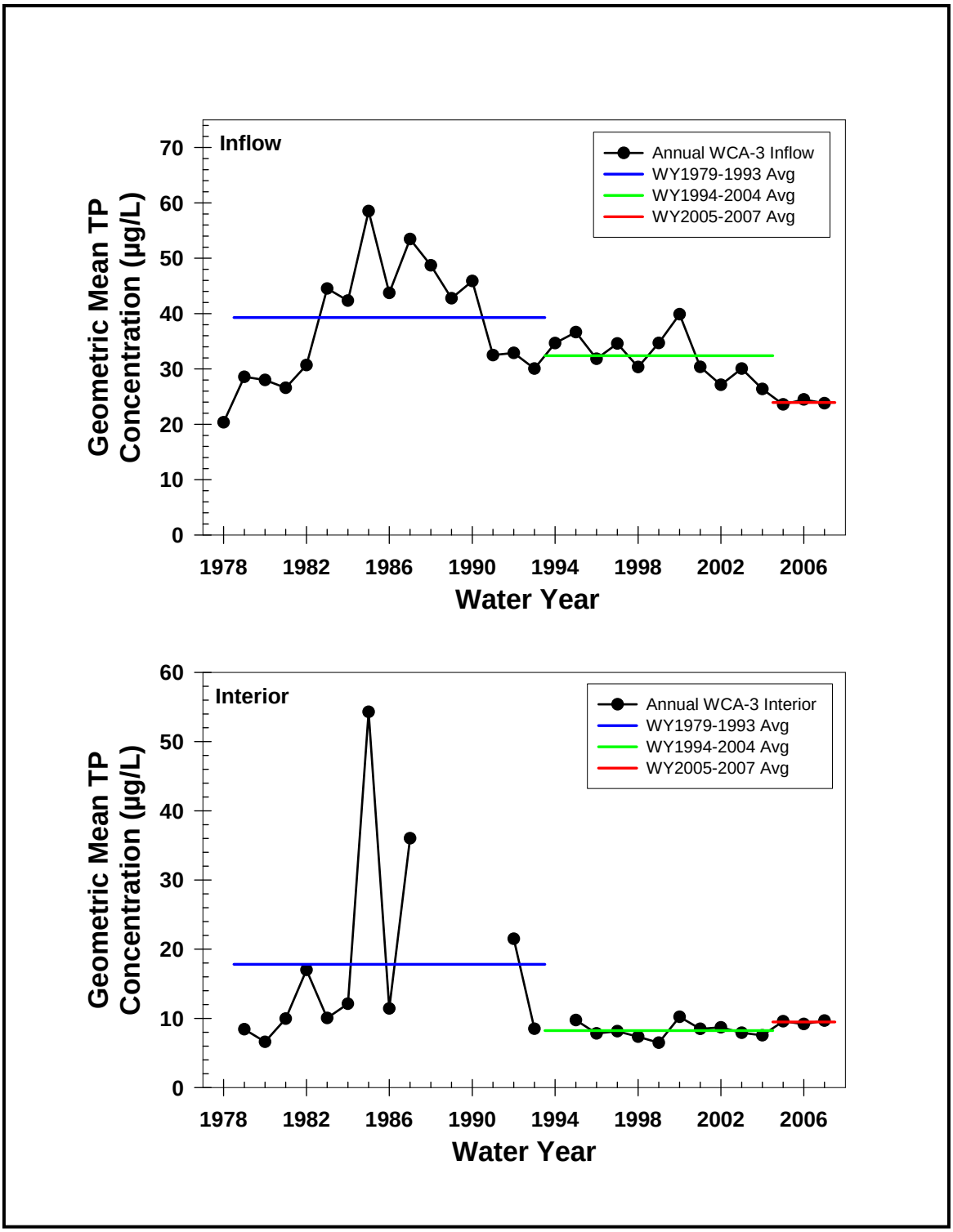

Figure 3C-4. Annual geometric mean TP concentrations (µg/L) for inflow (upper graph) and interior (lower graph) areas of WCA-3 from WY1978 through WY2007. The horizontal lines indicate the average annual geometric mean TP concentrations for the WY1979–WY1993, WY1994–WY2004, and WY2005–WY2007 periods, respectively.

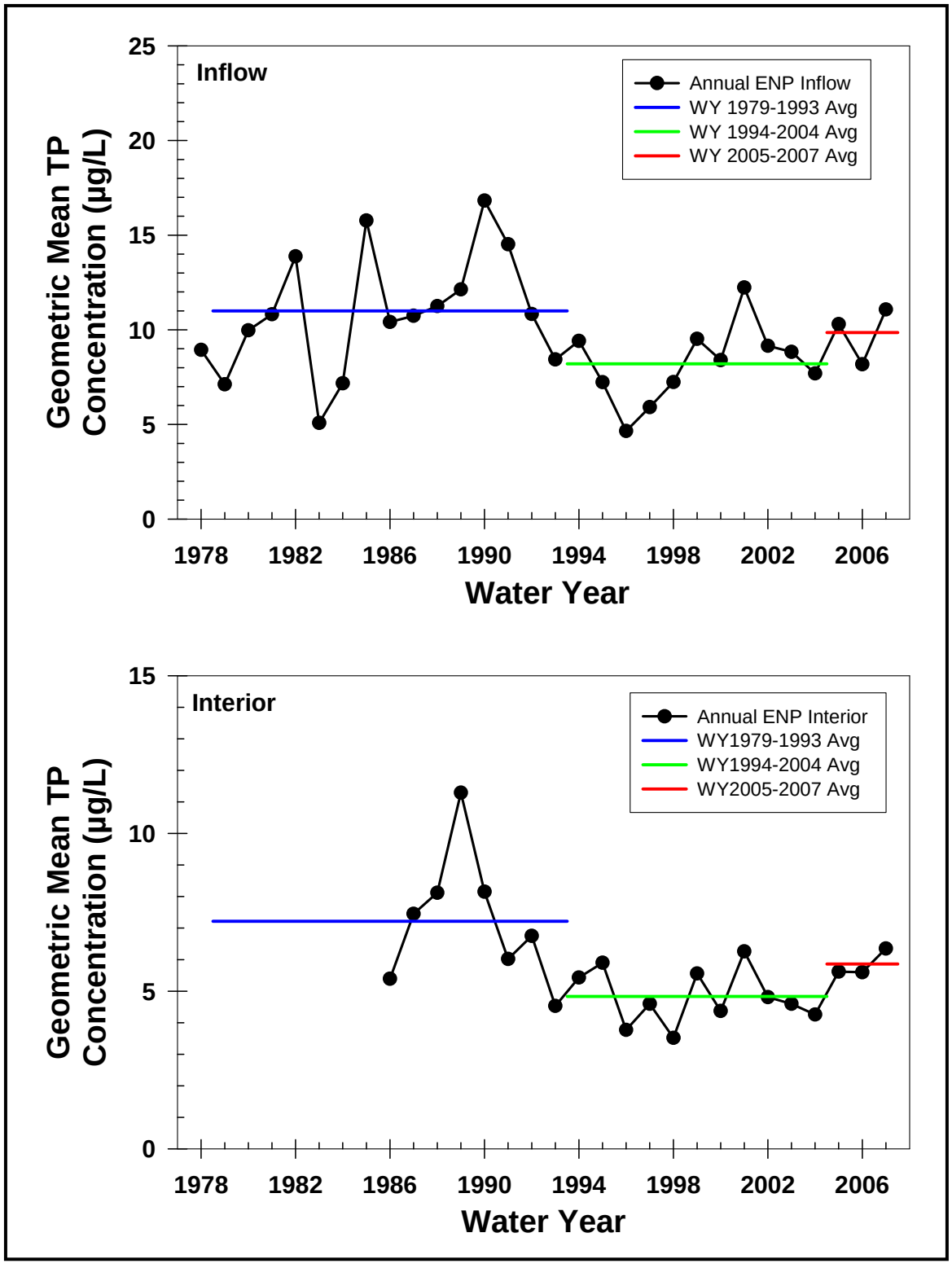

Figure 3C-5. Annual geometric mean TP concentrations (µg/L) for inflow (upper graph) and interior (lower graph) areas of the ENP from WY1978 through WY2007. The horizontal lines indicate the average annual geometric mean TP concentrations for the WY1979–WY1993, WY1994–WY2004, and WY2005–WY2007 periods, respectively.

Table 3C-2. Summary of orthophosphate (OP) concentrations (µg/L) in the Everglades Protection Area (EPA) for the WY1979–WY1993, WY1994–WY2004, WY2005–WY2007, and WY2007 periods.

Region	Class	Period	Sample Size (N)	Geometric Mean (µg/L)	Std. Deviation (Geometric Mean)	Median (µg/L)	Min. (µg/L)	Max. (µg/L)
REFUGE	Inflow	1979-1993	1175	32.1	4.4	44.0	<2.0	1106
		1994-2004	1231	15.8	3.0	14.0	2.0	294
		2005-2007	449	14.7	4.2	18.0	<2.0	249
		2007	185	8.4	4.6	8.0	<2.0	176
	Interior	1979-1993	370	1.5	2.1	1.0	<2.0	72
		1994-2004	1610	1.8	2.3	2.0	<2.0	380
		2005-2007	641	3.1	2.1	2.0	<2.0	193
		2007	161	2.4	1.8	2.0	<2.0	75
	Outflow	1979-1993	605	20.0	4.3	25.0	<2.0	1290
		1994-2004	691	14.7	3.0	13.0	2.0	383
		2005-2007	164	8.8	4.1	7.0	<2.0	461
		2007	54	4.8	3.6	2.0	<2.0	92
	Rim	1979-1993	118	28.9	3.2	35.0	<2.0	408
		1994-2004	408	20.4	3.2	24.0	<2.0	190
		2005-2007	98	20.4	4.1	27.0	2.0	544
		2007	20	9.6	4.5	8.5	2.0	99
WCA-2	Inflow	1979-1993	759	25.2	3.8	31.0	<2.0	1290
		1994-2004	836	11.6	3.0	9.0	2.0	352
		2005-2007	349	5.7	3.3	5.0	<2.0	190
		2007	112	3.9	3.2	2.0	<2.0	92
	Interior	1979-1993	1689	3.3	4.2	2.0	<2.0	2398
		1994-2004	2079	4.4	3.8	4.0	<2.0	2790
		2005-2007	595	4.0	2.6	2.0	<2.0	405
		2007	157	3.1	2.1	2.0	<2.0	47
	Outflow	1979-1993	882	5.0	3.8	4.0	<2.0	396
		1994-2004	684	5.9	2.5	6.0	2.0	156
		2005-2007	252	3.4	2.3	2.0	<2.0	153
		2007	76	2.3	2.1	2.0	<2.0	30
WCA-3	Inflow	1979-1993	2349	9.1	4.4	9.0	<2.0	586
		1994-2004	2084	8.8	3.2	7.0	2.0	297
		2005-2007	614	4.8	2.8	4.0	<2.0	180
		2007	178	3.3	2.8	2.0	<2.0	153
	Interior	1979-1993	617	1.9	2.8	1.0	<2.0	152
		1994-2004	1878	1.8	2.5	2.0	<2.0	190
		2005-2007	642	2.7	2.1	2.0	<2.0	180
		2007	160	2.6	2.6	2.0	<2.0	180
	Outflow	1979-1993	1704	2.7	2.3	2.0	<2.0	149
		1994-2004	1603	2.9	1.7	2.0	2.0	97
		2005-2007	402	2.3	1.5	2.0	<2.0	70
		2007	107	2.0	1.4	2.0	<2.0	10

Table 3C-2. Continued.

Region	Class	Period	Sample Size (N)	Geometric Mean (µg/L)	Std. Deviation (Geometric Mean)	Median (µg/L)	Min. (µg/L)	Max. (µg/L)
PARK	Inflow	1979-1993	1902	2.6	2.2	2.0	<2.0	77
		1994-2004	1914	2.8	1.7	2.0	2.0	97
		2005-2007	467	2.2	1.5	2.0	<2.0	20
		2007	132	2.0	1.4	2.0	<2.0	10
	Interior	1979-1993	546	2.9	1.9	2.0	2.0	63
		1994-2004	1059	2.7	1.6	2.0	2.0	45
		2005-2007	199	2.4	1.6	2.0	<2.0	19
		2007	59	1.9	1.3	2.0	<2.0	7

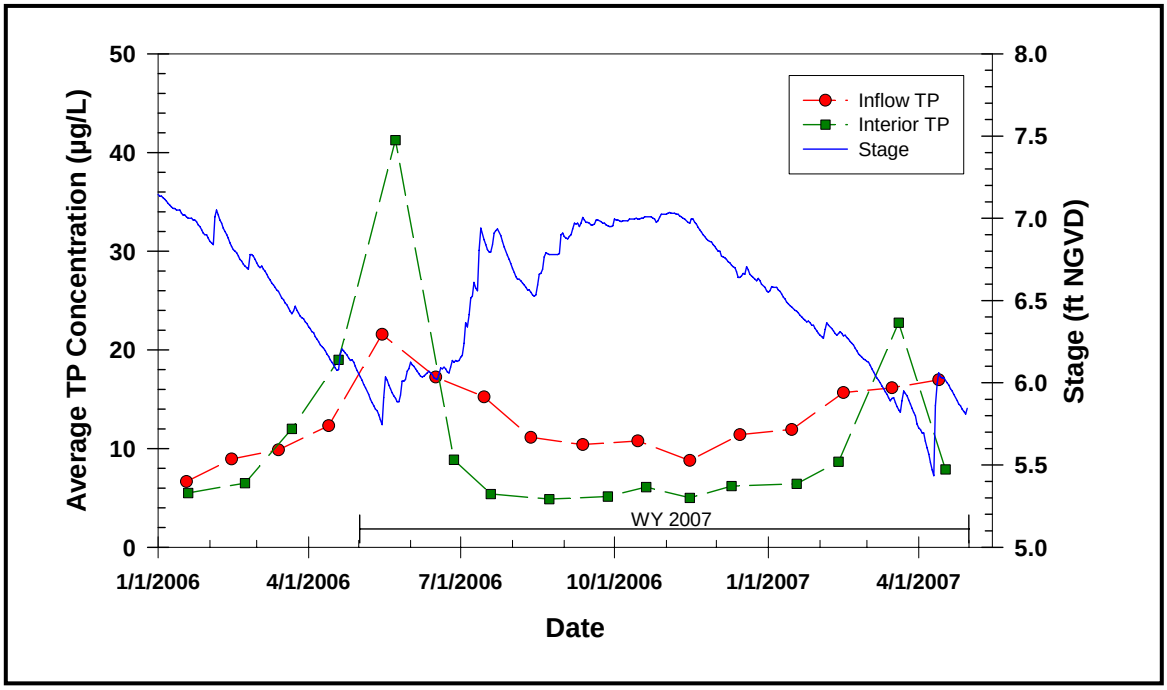

Figure 3C-6. Comparison of average monthly TP concentrations at inflow and interior sites with stage in Everglades National Park (ENP or Park).

Spatially, interior marsh TP concentrations measured during WY2007 exhibited the same north-to-south gradient observed during previous periods (Bechtel et al., 1999, 2000; Weaver et al., 2001, 2002, 2003; Payne and Weaver, 2004, Payne et al., 2006 and 2007). Typically, the highest TP concentrations obtained during WY2007 were collected from the northern WCAs and declined throughout WCA-3 and the Park. During WY2007, 38.9 percent of the monitoring sites in WCA-2 had annual geometric mean TP concentrations of 10.0 µg/L or less, with an increase to 88.9 percent in the Park (**Figure 3C-7**). Likewise, 61.1 percent of interior sites within WCA-2 had annual geometric mean TP concentrations of 15.0 µg/L or less for WY2007, with an increase to 100 percent in the Park.

As observed in WY2006, the only site in the Park exhibiting an annual geometric mean TP concentration above 10.0 µg/L for WY2007 was station P36, where exceptionally high measurements of 122.0 µg/L and 55.0 µg/L were collected in May 2006 and March 2007 during dry periods with low water levels. Since site P36 appears to be highly influenced by dry conditions, these high data may not be representative of typical ambient conditions. Without these two abnormally high measurements, the site geometric mean is well below 10.0 µg/L.

During WY2007, geometric mean TP concentrations exceeded 10.0 µg/L (with a range from 10.4–11.6 µg/L) at only three sites (CA34, LOX3, and P36) located in areas relatively uninfluenced by canal inflows (**Figure 3C-4,** and see also Figure 3A-5, in Chapter 3A of this volume). None of the sites located in the relatively unimpacted portions of the EPA exhibited a geometric mean TP concentration above the 15.0 µg/L annual site limit specified in the TP criterion for individual sites. A more detailed, site-specific summary of the TP concentrations for WY2007 is provided in **Appendix 3C-1** of this volume.

Over the entire EPA (all areas and site classifications), approximately 86.6 percent of the TP measurements collected during WY2007 were below 50.0 µg/L, 50.9 percent were below 15.0 µg/L, and 35.1 percent were at or below 10.0 µg/L. In comparison, TP concentrations in 85.4 percent of the samples were less than 50.0 µg/L, with 57 percent being at or below 15.0 µg/L, and 41.5 percent of the measured concentrations were at or below 10.0 µg/L during WY2006.

The distribution of TP concentrations in samples collected at inflow, interior, and outflow stations from each EPA region for WY2007 is presented in **Figure 3C-8**. By far, inflow stations to the Refuge had the highest percentage of measurements above 50.0 µg/L (51.6 percent) during WY2007. In contrast, only 2 percent of the TP measurements at the Park inflow sites were above 50.0 µg/L, with 71.6 percent below 15.0 µg/L. Likewise, WCA-2, the most highly phosphorus-enriched area, exhibited the lowest percentage of samples from interior sites at or below 10.0 µg/L (44.1 percent), while 72.2 percent and 69.3 percent of samples collected from the interior of the Refuge and WCA-3, respectively, had TP concentrations of 10.0 µg/L or below. Additionally, 82.3 percent of the samples collected in the interior of the Park had TP concentrations of 10.0 µg/L or less.

Figure 3C-8 also provides a comparison of the concentrations measured in samples collected during WY2007 to the levels reported for the Baseline, Phase I, and WY2005–WY2007 periods. In general, TP levels for WY2007 across all areas and classes of sites, except for inflows to the Park, were similar to or lower than those for the WY2005–WY2007 period and were within the range exhibited during the earlier periods. Future SFERs are expected to continue to track long-term trends in phosphorus levels throughout the EPA.

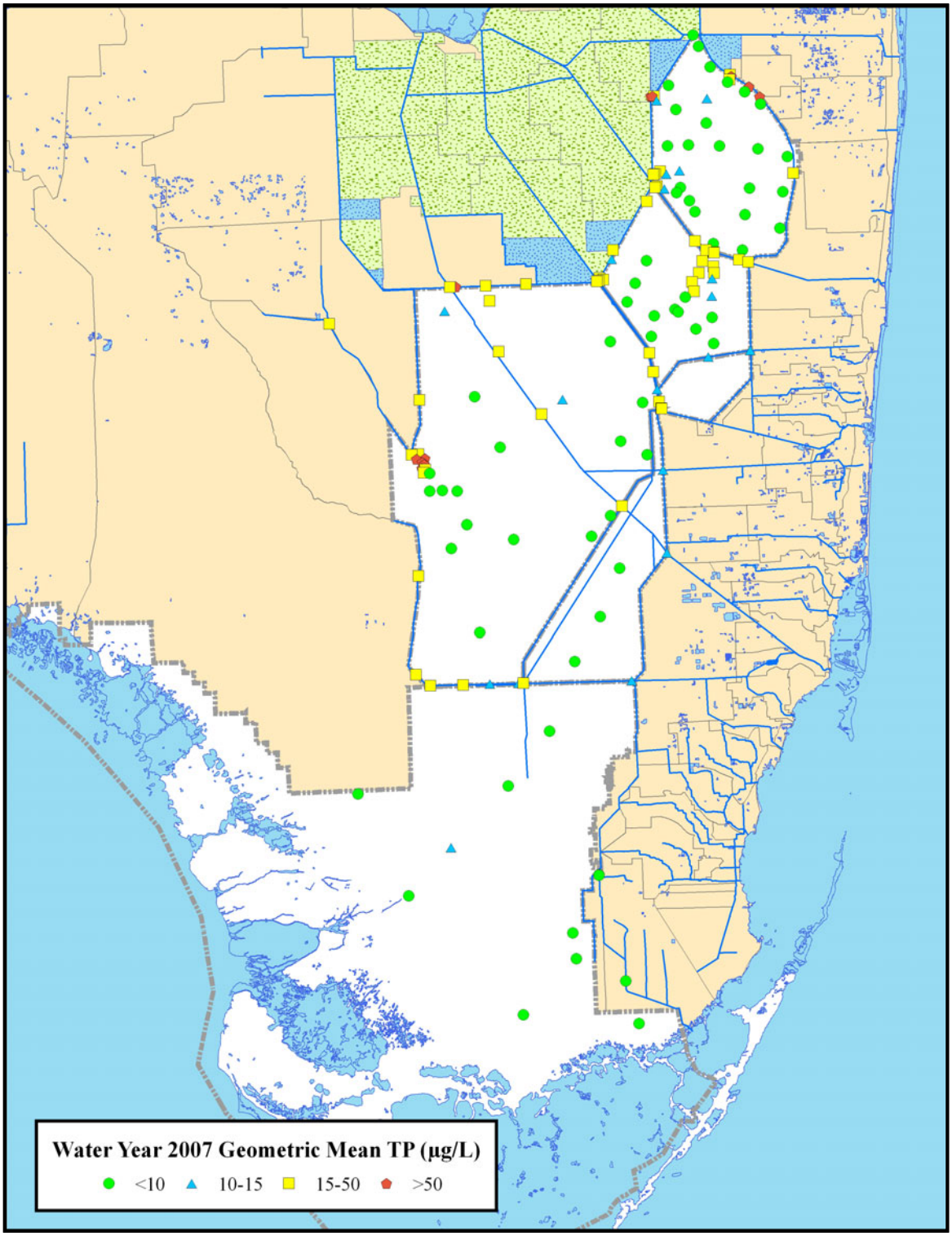

Figure 3C-7. Summary of geometric mean TP concentrations (µg/L) for WY2007 at stations across the EPA. Geometric mean TP concentrations are classified utilizing four levels: ≤ 10 µg/L, 10–15 µg/L, 15–50 µg/L, and > 50 µg/L.

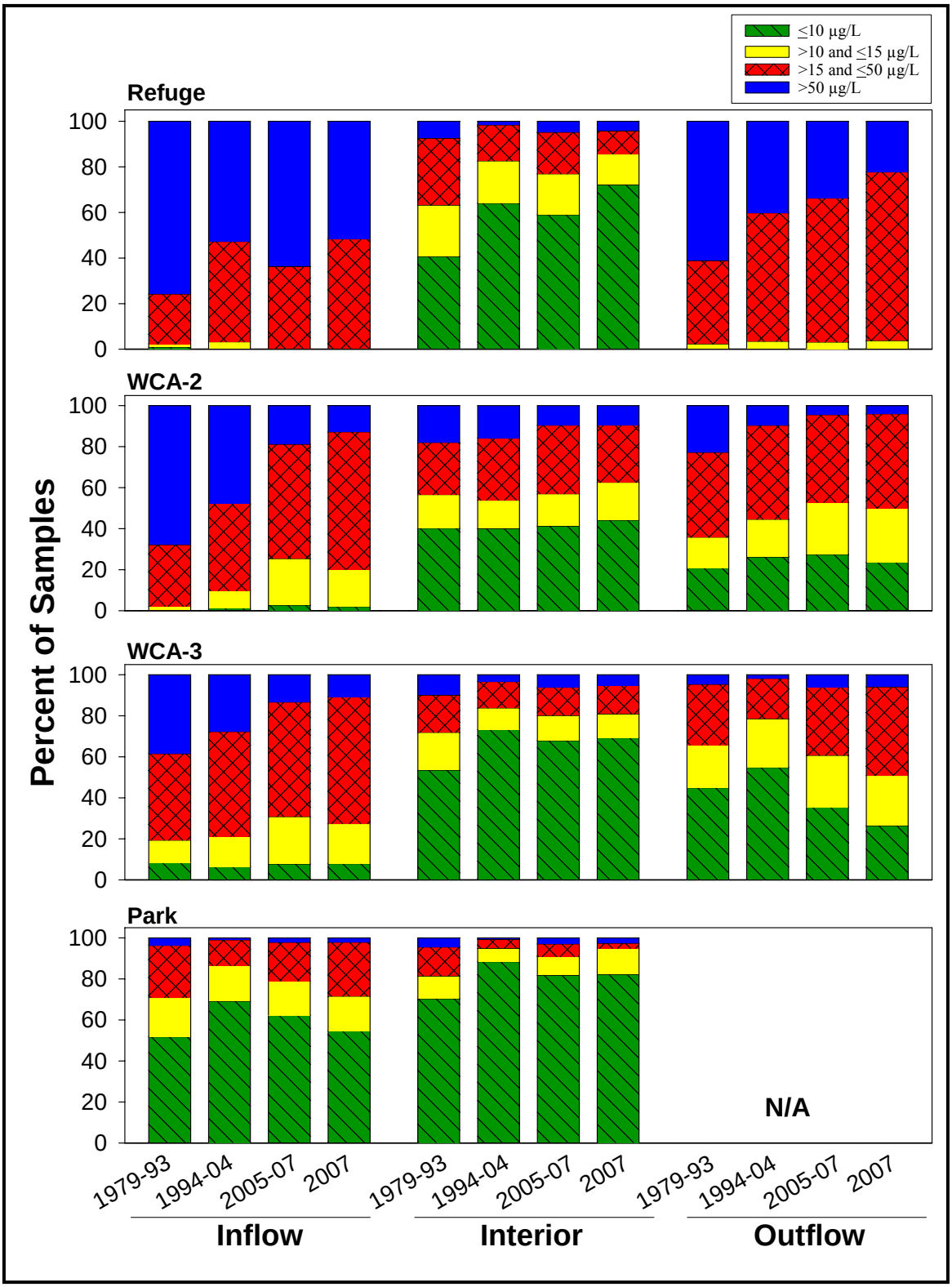

Figure 3C-8. Comparison of TP concentrations (µg/L) measured in samples collected in the EPA during the WY1979–WY1993, WY1994–WY2004, WY2005–WY2007, and WY2007 periods.
N/A = Not available. Outflow is not monitored for the Park.

PHOSPHORUS LOADS TO THE EVERGLADES PROTECTION AREA

The EPA is a complex system of marsh areas, canals, levees, and inflow and outflow water control structures covering almost 2.5 million acres. In addition to rainfall inputs, surface water inflows regulated by water control structures from agricultural tributaries, such as the EAA and the C-139 basin, feed the EPA from the northern and western boundaries. The EPA also receives surface water inflows originating from Lake Okeechobee to the north and from predominantly urbanized areas to the east. The timing and distribution of the surface inflows from the tributaries to the EPA are based on a complex set of operational decisions that account for natural and environmental system requirements, water supply for urbanized and natural areas, aquifer recharge, and flood control. It is also recognized that a certain amount of TP loading to the EPA emanates from atmospheric deposition. The long-term average range of atmospheric deposition of TP is between 107 mt and 143 mt per year as the total contribution to the WCAs. Atmospheric TP deposition rates are highly variable, very expensive to monitor and, as such, are not routinely monitored. The range (expressed spatially as 20–35 $mg/m^2/yr$) is based on data obtained from long-term monitoring that was evaluated by the District, as reported in Redfield (2002).

Each year, the EPA receives variable amounts of surface water inflows based on the hydrologic variability within the upstream basins. These inflows, regulated according to previously mentioned operational decisions, also contribute a certain amount of TP loading to the EPA system. **Appendix 3C-2**, Table 1 provides estimates of the flow and TP load to each portion of the EPA for WY2007. Flows and TP loads are also provided for the Baseline, Phase I, and WY2005–WY2007 periods for comparison.

Detailed estimates of TP loads by structure for WY2007 are presented in **Appendix 3C-2** of this volume. This appendix summarizes contributions from all connecting tributaries to the EPA: Lake Okeechobee, the EAA, the C-139 basin, other agricultural and urbanized areas, and the STAs. In some cases, surface water inflows represent a mixture of water from several sources as the water passes from one area to another before finally arriving in the EPA. For example, water discharged from Lake Okeechobee can pass through the EAA and then through an STA before arriving in the EPA. Similarly, runoff from the C-139 basin can pass through STA-5 and then into the EAA before ultimately arriving in the EPA.

As detailed in **Appendix 3C-2** of this volume, TP loads from surface sources to the EPA totaled approximately 93.8 mt, with a flow-weighted mean concentration of 56.0 µg/L. Another 193 mt of TP is estimated to have entered the EPA through atmospheric deposition. Surface discharges from the EPA account for approximately 9.5 mt. The 93.8 mt TP load in the surface inflows to the EPA represents a decrease of approximately 46 percent compared to the previous year (WY2006 = 172.6 mt). The lower TP loads to the EPA observed during WY2007 primarily resulted from reduced flow volumes associated with the 2007 drought. The 1,361,296 ac-ft of surface water flow to the EPA determined for WY2007 is approximately 46 percent lower than the 2,525,311 ac-ft reported for WY2006 (Payne et al, 2007).

Figures 3C-9 through **3C-12** provide a summary of the annual flows and TP loads to each portion of the EPA for the period from WY1979 through WY2007 along with the annual averages for the Baseline, Phase I, and WY2005–WY2007 (Phase II) periods. The effectiveness of the BMP and STA phosphorus removal efforts is demonstrated by the decreased TP loading to WCA-2 and WCA-3 during the WY1994–WY2004 and WY2005–WY2007 periods compared to the WY1979–WY1993 baseline period despite increased flows (**Figures 3C-9** through **3C-11**). The effect of the phosphorus removal efforts is less apparent in the Park where inflow

concentrations have remained near background levels and the TP loading responds more directly to changes in flow and climatic conditions (**Figure 3C-12**).

It should be noted that the average flow and TP loads to the EPA, especially the Refuge, during the recent WY2005–WY2007 period have been highly influenced by the effects of climatic extremes, including both hurricanes and prolonged drought, especially over the course of WY2005, as previously discussed. For example, the total TP load from all sources to the Refuge was approximately 31.3 mt during WY2007, which represents an approximate 29 percent reduction from the previous year (43.8 mt). The reduction reflects the continued recovery of the STAs following the WY2005 hurricane damage and the initiation of STA-1W operation and lower flows. More than half (approximately 54 percent) of the load entering the Refuge during WY2007 was discharged through various structures prior to entering the marsh. Additional years of monitoring are needed before the effects of the Phase II BMP/STA optimization projects can be seen.

Table 3C-3. Summary of annual average flow, flow-weighted mean TP concentrations, and TP loads in the Everglades Protection Area for the WY1979–WY1993, WY1994–WY2004, WY2005–WY2007, and WY2007 periods.

Area	Period	Average Annual Flow (1,000 ac-ft)	Average Annual Flow-Weighted Mean TP (µg/L)	Average Annual Load (kg)
REFUGE	WY1979-1993	506	186	111436
	WY1994-2004	647	100	83977
	WY2005-2007	332	128	53887
	WY2007	250	101	31298
WCA-2	WY1979-1993	581	119	78670
	WY1994-2004	704	65	57391
	WY2005-2007	821	37	36835
	WY2007	584	39	28310
WCA-3	WY1979-1993	1181	72	108357
	WY1994-2004	1396	49	84335
	WY2005-2007	1498	41	75944
	WY2007	900	44	49094
PARK	WY1979-1993	815	12	11450
	WY1994-2004	1477	9	15912
	WY2005-2007	1005	10	12273
	WY2007	533	11	7376

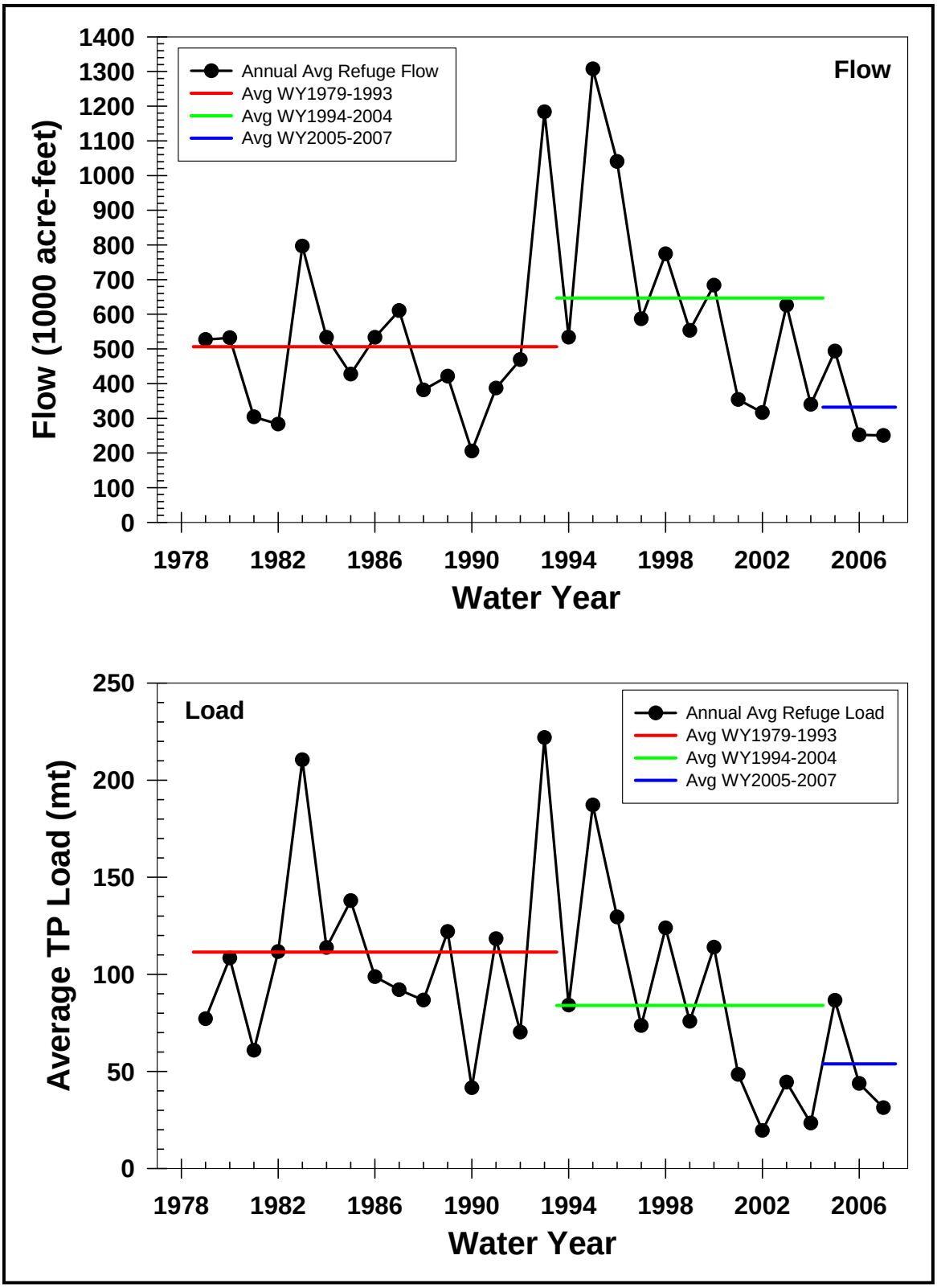

Figure 3C-9. Annual flow (upper graph) and TP load (lower graph) to the Refuge from WY1978 through WY2007. The horizontal lines indicate the average annual flows and loads for the WY1979–WY1993, WY1994–WY2004, and WY2005–WY2007 periods, respectively.

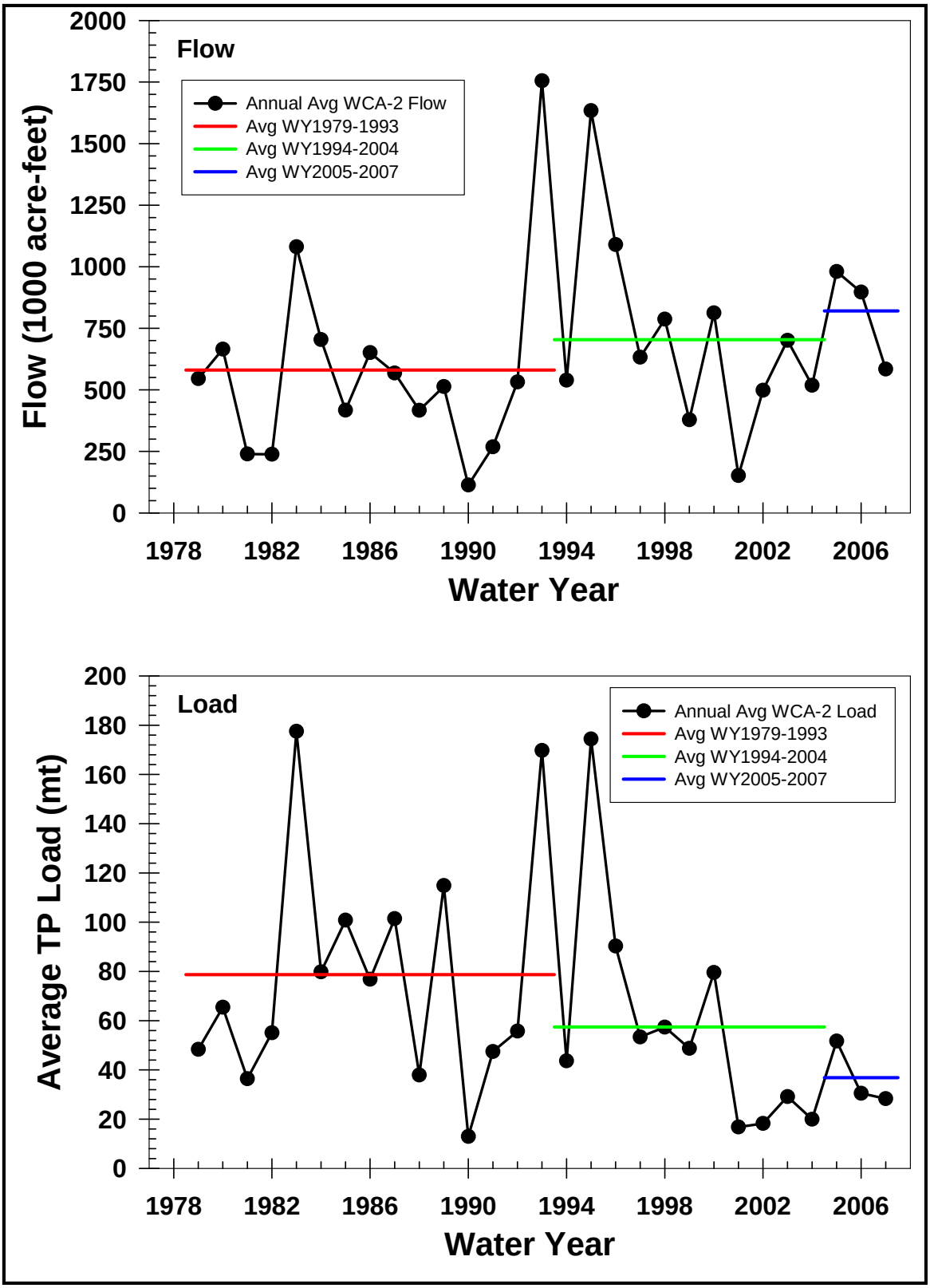

Figure 3C-10. Annual flow (upper graph) and TP load (lower graph) to WCA-2 from WY1978 through WY2007. The horizontal lines indicate the average annual flows and loads for the WY1979–WY1993, WY1994–WY2004, and WY2005–WY2007 periods, respectively.

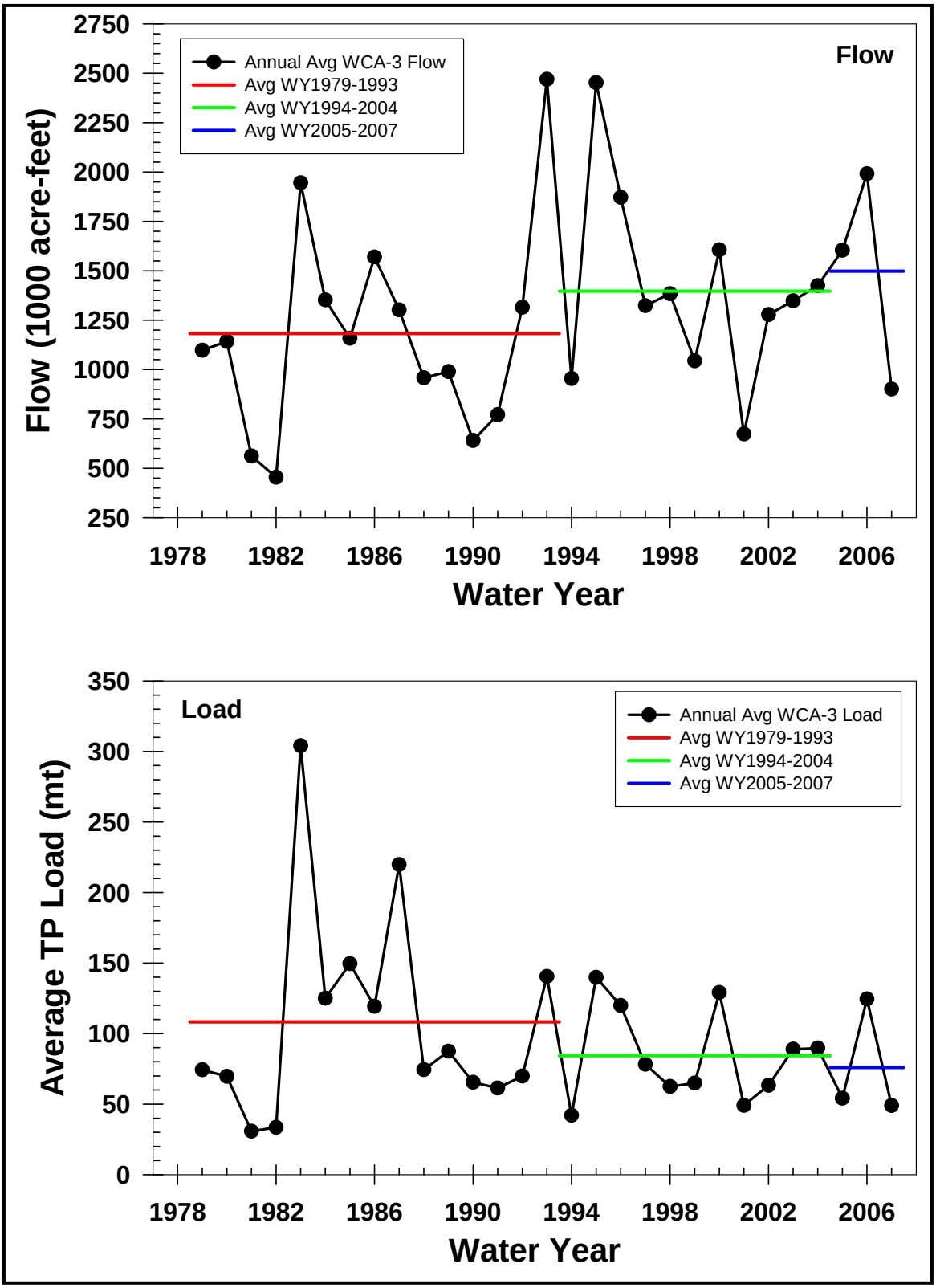

Figure 3C-11. Annual flow (upper graph) and TP load (lower graph) to WCA-3 from WY1978 through WY2007. The horizontal lines indicate the average annual flows and loads for the WY1979–WY1993, WY1994–WY2004, and WY2005–WY2007 periods, respectively.

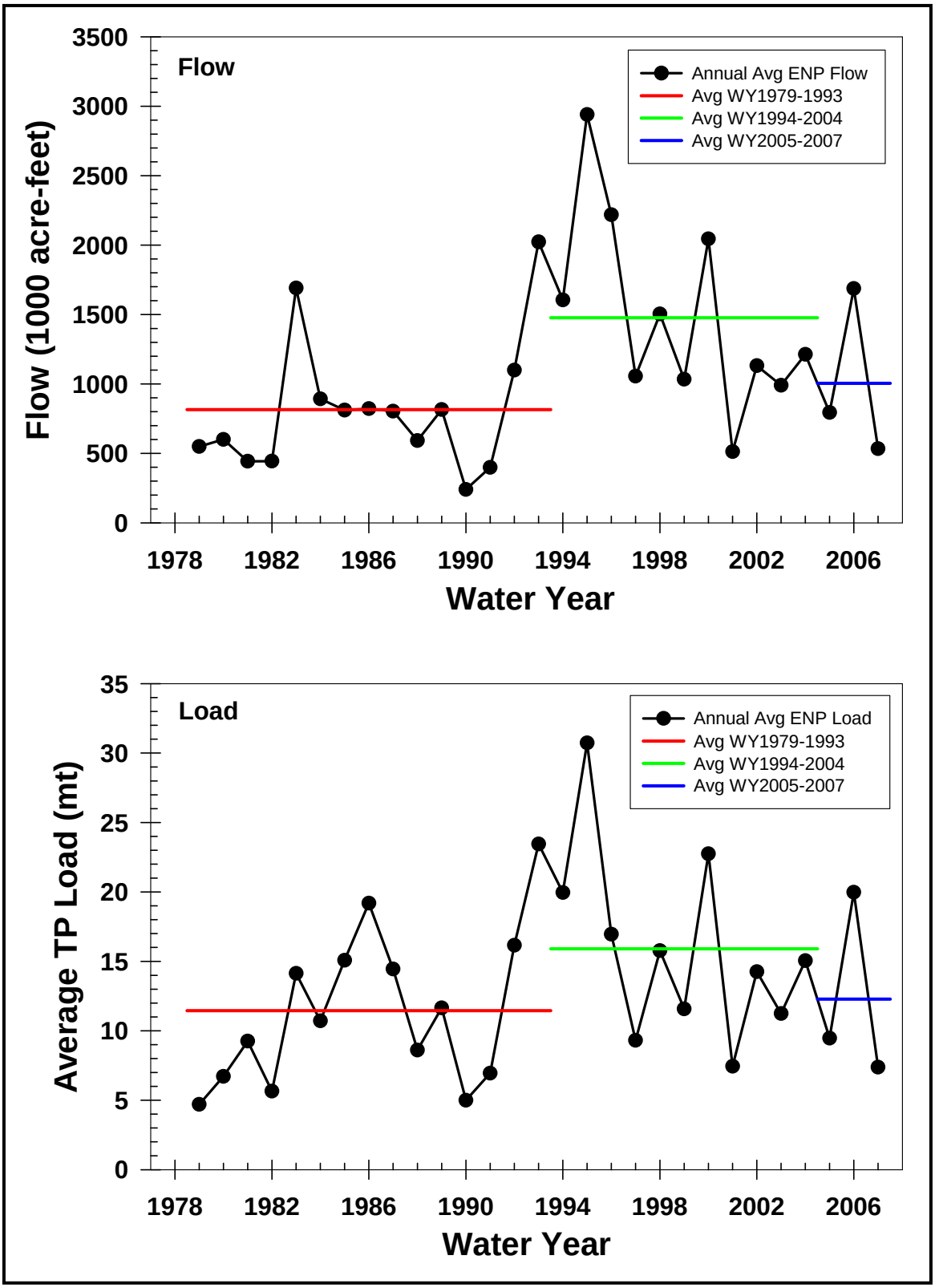

Figure 3C-12. Annual flow (upper graph) and TP load (lower graph) to Everglades National Park from WY1978 through WY2007. The horizontal lines indicate the average annual flows and loads for the WY1979–WY1993, WY1994–WY2004, and WY2005–WY2007 periods, respectively.

Everglades Protection Area Phosphorus Criterion Achievement Assessment

The TP criterion rule specifies that while the Settlement Agreement is in effect, compliance with the criterion in the Park will be assessed in accordance with the methodology specified in Appendix A of the Settlement Agreement using flow-weighted mean TP concentrations at inflow sites instead of ambient marsh TP concentrations, as done in the other portions of the EPA. The Settlement Agreement assessments for the Park are conducted by the SFWMD and reported on a quarterly basis to satisfy other mandates, and therefore are not replicated here. The quarterly Settlement Agreement reports prepared by the SFWMD can be found at the District's web site at www.sfwmd.gov under the *What We Do, Environmental Monitoring, Reports* section.

In addition to establishing the numeric TP criterion for the EPA, the TP criterion rule [Section 62-302.540 (F.A.C.)] also provides a four-part test to be used to determine achievement of the numeric TP criterion. The following four components of the assessment test must be achieved for a water body to be considered to comply with the TP criterion:

Table 3C-4. Summary of the four-part test as required by Section 62-302.540, (F.A.C.)

COMPONENT	TP CRITERION ACHIEVEMENT VALUE	NOTED HEREIN AS
Five-year geometric mean TP concentration averaged across the monitoring network	10 µg/L or less	five-year network limit
Annual geometric mean TP concentration averaged across all stations	10 µg/L or less for three out of each five years	multi-year network limit
Annual geometric mean TP concentration averaged across all stations	11 µg/L or less	annual network limit
Annual geometric mean TP concentration at all individual monitoring stations	15 µg/L or less	annual site limit

The detailed results of the preliminary evaluation to assess achievement of the TP criterion using available data for the five-year period WY2003–WY2007 are provided in **Appendix 3C-3** of this volume. As described previously, the results of this assessment were affected by data limitations in many parts of the EPA caused in part by the extremely dry conditions that have prevailed throughout the area. Additionally, monitoring at nine new sites which were added to the existing sites to form the TP criterion monitoring network was not initiated until January 2007. During WY2007, only 30 of the 58 TP criterion monitoring network sites had sufficient data [i.e., $\geq$ 6 samples specified by the screening protocol referenced by the TP criterion rule, per Section 62-302.540 (F.A.C.)] to be included in the TP criterion assessment. Less than 50 percent of the monitoring sites in the impacted portions of the Refuge and both the impacted and unimpacted portions of WCA-3 exhibited the minimum number of samples required for inclusion in the criterion assessment.

The results of the WY2003–WY2007 TP criterion assessment indicate that, even with the data limitations, the unimpacted portions of each WCA passed all four parts of the compliance test (as expected) and therefore are in compliance with the 10 µg/L TP criterion. Occasionally, individual sites within the unimpacted portions of the conservation areas exhibited an annual site geometric mean TP concentration above 10 µg/L; but in no case did the values for the individual unimpacted sites cause an exceedance of the annual or long-term network limits. During WY2007, none of the annual geometric mean TP concentrations for the individual sites exceeded the 15 µg/L annual site limit and during the entire WY2003–WY2007 period, only one exceedance of the 15 µg/L annual site limit occurred at an unimpacted site. The single exceedance (19.8 µg/L) occurred at station X4 in the Refuge during WY2005 when TP levels throughout the EPA were elevated due to climatic extremes as discussed in detail in the 2006 SFER (Payne et al., 2006). Of the more than 140 TP measurements collected at station X4 since it was established in 1996, the highest value (130 µg/L) was observed on March 10, 2005, when water levels were increasing following a dry period with low water stage in the marsh. This highly elevated value is nearly nine times the five-year average for this site, and much higher than the TP concentration in the inflows and surrounding sites during this period. Because this site is not located near any anthropogenic inputs, the high measurement likely reflects the effects of the low water levels during this period and/or the difficulty in collecting a representative sample during periods of low water level. During WY2006 and WY2007, the TP concentrations measured for station X4 returned to more typical levels, with annual geometric site means of 9.1 µg/L and 11.4 µg/L, respectively. It is expected that changes in TP concentrations at station X4 and other sites throughout the marsh will continue to be tracked in future SFERs.

In contrast, the impacted portions of each water body failed one or more parts of the test and therefore exceeded the criteria. The impacted portions of the WCAs consistently exceeded the annual and five-year network TP concentration limits of 11 µg/L and 10 µg/L, respectively. Occasionally, selected individual sites within the impacted areas exhibited annual geometric mean TP concentrations below the 15 µg/L annual site limit. Rarely, the annual mean for individual impacted sites was below 10 µg/L; however, none of the impacted sites was consistently below the 10 µg/L long-term limit.

Future TP criterion achievement assessments conducted with more robust datasets are expected to provide a better understanding of phosphorus concentrations in the EPA.

TOTAL NITROGEN

The concentration of total nitrogen (TN) in surface waters is not measured directly, but is calculated as the sum of total Kjeldahl nitrogen (TKN; organic nitrogen plus ammonia) and nitrite plus nitrate (NO_3+NO_2). The TN values for the 2008 SFER were calculated only for samples for which both TKN and NO_3+NO_2 results were available.

Table 3C-5 provides a summary of the TN concentrations measured in the different portions of the EPA during the Baseline period, the Phase I period, the WY2005–WY2007 period, and the WY2007 period. As in previous years, TN concentrations during WY2007 exhibited a general north-to-south spatial gradient across the EPA. This gradient likely reflects the higher concentrations associated with discharges to the northern portions of the system from agricultural areas and Lake Okeechobee. A gradual reduction in TN levels results from assimilative processes in the marsh as water flows southward. The highest geometric mean TN concentrations were observed in the inflows to the Refuge and WCA-2, and decreased to a minimum concentration in the Park.

Geometric mean TN concentrations measured during WY2007 at both inflow and interior sites in all areas of the EPA were generally comparable to or slightly lower than the values for the Phase I and WY2005–WY2007 periods, and well below the levels observed for the Baseline period. These results demonstrate the continued effectiveness of agricultural BMPs and nutrient removal by the STAs.

During WY2007, geometric mean TN concentrations at inflow stations ranged from 1.06 mg/L in the Park to 2.14 mg/L in the Refuge, and median TN concentrations ranged from 1.11 mg/L to 2.23 mg/L. Similarly, mean TN concentrations at the interior marsh stations during WY2007 ranged from 1.00 mg/L in Park to 2.25 mg/L in WCA-2, with median concentrations ranging from 0.91 mg/L to 2.20 mg/L.

The geometric mean TN concentration for the inflow and interior sites for the Refuge during WY2007 were considerably lower than the levels for any of the preceding periods. The lower concentrations observed during WY2007 may have been caused by several factors, including restoration of nutrient-removal effectiveness of STA-1W following damage to the vegetative communities resulting from the 2005 hurricane season, further nutrient removal resulting from operation of STA-1E, and lower amounts of nutrient-enriched inflow from the EAA and Lake Okeechobee during dry periods observed during much of WY2007. As described for TP, due to the dry conditions experienced during WY2007, there were fewer samples collected in the drier impacted portions of the Refuge marsh that are influenced by nutrient-enriched canal inflows. This phenomenon may also contribute to the differences observed among periods.

Table 3C-5. Summary of total nitrogen (TN) concentrations (mg/L) in the Everglades Protection Area (EPA) for the WY1979–WY1993, WY1994–WY2004, WY2005–WY2007, and WY2007 periods.

Region	Class	Period	Sample Size (N)	Geometric Mean (mg/L)	Std. Deviation (Geometric Mean)	Median (mg/L)	Min. (mg/L)	Max. (mg/L)
REFUGE	Inflow	1979-1993	1206	3.68	1.79	3.83	0.25	18.68
		1994-2004	1601	2.42	1.59	2.33	0.25	48.23
		2005-2007	267	2.19	1.33	2.25	0.63	5.17
		2007	102	2.14	1.36	2.23	0.63	3.72
	Interior	1979-1993	359	2.41	1.63	2.32	0.72	36.71
		1994-2004	1887	1.28	1.47	1.22	0.45	9.50
		2005-2007	622	1.28	1.41	1.22	0.54	6.41
		2007	166	1.16	1.37	1.12	0.64	4.01
	Outflow	1979-1993	602	2.65	1.69	2.58	0.25	22.84
		1994-2004	696	2.00	1.53	1.89	0.25	7.91
		2005-2007	148	1.79	1.42	1.77	0.78	5.52
		2007	49	1.52	1.40	1.59	0.78	2.63
	Rim	1979-1993	118	2.76	1.65	2.64	0.80	10.91
		1994-2004	592	2.38	1.51	2.26	0.68	9.66
		2005-2007	104	2.19	1.37	2.26	0.87	5.22
		2007	24	1.74	1.43	1.97	0.87	2.73
WCA-2	Inflow	1979-1993	784	2.91	1.66	2.91	0.25	22.84
		1994-2004	1192	2.40	1.49	2.42	0.67	7.91
		2005-2007	311	2.16	1.39	2.17	0.70	5.48
		2007	93	1.94	1.34	2.08	0.70	2.82
	Interior	1979-1993	1669	2.62	1.56	2.50	0.25	37.17
		1994-2004	2914	2.03	1.42	2.10	0.25	37.10
		2005-2007	604	2.21	1.29	2.18	1.08	6.27
		2007	169	2.25	1.27	2.20	1.32	6.10
	Outflow	1979-1993	894	2.25	1.41	2.18	0.75	7.65
		1994-2004	675	1.66	1.35	1.65	0.25	4.44
		2005-2007	235	1.82	1.25	1.88	0.94	3.93
		2007	71	1.81	1.24	1.88	1.13	3.04
WCA-3	Inflow	1979-1993	2401	2.02	1.57	1.95	0.25	10.80
		1994-2004	2561	1.67	1.44	1.59	0.54	7.79
		2005-2007	739	1.61	1.30	1.63	0.73	6.11
		2007	208	1.68	1.30	1.72	0.73	4.03
	Interior	1979-1993	590	1.91	1.55	1.87	0.43	10.01
		1994-2004	1686	1.18	1.39	1.15	0.25	9.00
		2005-2007	650	1.31	1.40	1.30	0.49	4.50
		2007	154	1.38	1.40	1.38	0.70	3.61
	Outflow	1979-1993	1721	1.51	1.47	1.51	0.25	14.86
		1994-2004	1534	1.05	1.44	1.09	0.25	4.10
		2005-2007	407	1.18	1.31	1.20	0.53	2.70
		2007	175	1.21	1.29	1.26	0.64	2.01

Table 3C-5. Continued.

Region	Class	Period	Sample Size (N)	Geometric Mean (mg/L)	Std. Deviation (Geometric Mean)	Median (mg/L)	Min. (mg/L)	Max. (mg/L)
PARK	Inflow	1979-1993	1929	1.37	1.63	1.45	0.25	14.86
		1994-2004	1828	0.88	1.59	0.93	0.25	3.60
		2005-2007	518	1.03	1.39	1.05	0.49	2.70
		2007	227	1.06	1.37	1.11	0.57	2.03
	Interior	1979-1993	565	1.28	1.90	1.37	0.25	40.84
		1994-2004	1007	1.03	1.64	1.06	0.25	5.70
		2005-2007	192	1.09	1.68	1.02	0.47	7.68
		2007	55	1.00	1.62	0.91	0.49	3.51

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