Chapter 2C: Status of Phosphorus and Nitrogen in the Everglades Protection Area

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SUMMARY

The Everglades ecosystem evolved as a highly oligotrophic (nutrient-poor), phosphorus-limited system, with the natural 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 natural ecosystem. The primary purposes of this chapter are to provide an update regarding the development of a numeric phosphorus criterion for the Everglades Protection Area (EPA), and to present an overview of the status of phosphorus and nitrogen levels in the surface waters within the EPA during Water Year 2004 (WY2004) (May 1, 2003 through April 30, 2004).

TOTAL PHOSPHORUS CRITERION

Given the importance of phosphorus in controlling the natural biological communities, the Florida Department of Environmental Protection (FDEP) has used the results of extensive research to numerically interpret the existing narrative criterion, as directed by the Everglades Forever Act (EFA), and develop a TP criterion of 10 micrograms per liter (µg/L), or 10 parts per billion (ppb), for the EPA. The 10-µg/L TP criterion was approved by the Environmental Regulation Commission (ERC) during a hearing on July 8, 2003. Subsequent to the approval by ERC, both environmental and agricultural interest groups filed administrative challenges to the phosphorus criterion rule. Following discussions with the FDEP concerning the application of the rule, all parties except the Miccosukee Tribe of Indians and the Friends of the Everglades withdrew their challenges. To resolve the remaining challenges, an administrative hearing was held during the period from November 2003–January 2004. The final order filed by the Administrative Law Judge on June 17, 2004 upheld all parts of the proposed rule finding that the rule "is not an invalid exercise of delegated legislative authority" by the FDEP. Following the Administrative Law Judge's ruling, the proposed rule [Section 62-303.540, Florida Administrative Code (F.A.C.)] was filed with the Florida Secretary of State by the FDEP on June 25, 2004. Subsequent to this filing, the rule was submitted to the U.S. Environmental Protection Agency (USEPA) for approval. Once the rule has been approved by the EPA, the required monitoring networks will be established and achievement of the phosphorus criterion will be assessed in accordance with the rule.

The phosphorus criterion rule for the EPA filed to the Florida Secretary of State remains essentially unchanged, except for minor technical edits, from that included as Appendix 2C-1 of the 2004 Everglades Consolidated Report (Payne and Weaver, 2004). The current rule is composed of eight sections rather than the nine sections found in the previous version because one of the technical edits involved combining Sections (4) and (5) from the initial rule. The eight sections in the current rule are (1) purpose and scope, (2) findings, (3) definitions, (4) the numeric criterion for Class III waters in the EPA and methods for determining achievement of the criterion, (5) requirements for long-term compliance permits for phosphorus discharges into the EPA, (6) moderating provisions for discharges into the EPA that do not achieve the 10-ppb criterion, (7) documents incorporated by reference, and (8) contingencies.

TOTAL PHOSPHORUS CONCENTRATIONS WITHIN THE EVERGLADES PROTECTION AREA

Because the monitoring networks necessary to apply the phosphorus criterion have not been established and USEPA's review of the rule has not been completed, the achievement methodology associated with the phosphorus criterion was not fully applied to the current data provided in this chapter. However, some of the provisions for determining achievement of the criterion set forth in the rule are used to evaluate the status of phosphorus concentrations in the EPA presented in this chapter. It is anticipated that subsequent versions of this chapter in future South Florida Environmental Reports will evaluate achievement of the criterion consistent with the requirements of the final phosphorus criterion rule. To provide an overview of the current nutrient status in the Everglades and to evaluate temporal and spatial patterns, TP concentrations measured during WY2004 are compared to the limits set forth in the criterion and the levels found during previous monitoring periods.

As documented for previous years, TP concentrations measured during WY2004 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). This gradient is indicative of the phosphorus-rich canal discharges, composed primarily of agricultural runoff originating in the Everglades Agricultural Area (EAA), entering the northern portions of the EPA with biogeochemical processes (e.g., settling, sorption, and biological assimilation), and resulting in decreasing concentrations as the water flows southward through the marsh.

TP concentrations measured during WY2004 at inflows to all portions of the EPA were below the levels reported for WY2003 and the WY1978–WY2002 historical period. Monitoring results show a decreasing temporal trend in the annual geometric mean TP concentrations in the inflows to the Refuge and WCA-2. The magnitude of the decreasing trend is greatest for the WCA-2, where WY2004 inflow concentrations were 59 percent lower than the levels reported for the WY1978–WY2002 historical period, and 24 percent lower than WY2003 levels. Inflow TP concentrations for the Refuge during WY2004 were 43 percent lower than recorded during the historical period, and 20 percent lower than WY2003 levels. Inflow TP concentrations for WCA-3 and the Park were also the lowest recorded for any of the three reporting periods, with the inflows to the Park continuing to exhibit TP concentrations well below the 10-ppb criterion. The decreasing inflow concentrations are likely the result of the continued implementation of Best Management Practices (BMPs) in the upstream agricultural and urban watersheds, and the greater treatment afforded by the increasing number of operating Stormwater Treatment Areas (STAs). In addition to the reduction in the level of TP in the inflows, the concentration of soluble orthophosphate (OP) (the biologically active form of phosphorus) also decreased substantially in WY2004 compared to the previous periods with the inflows to all areas having an annual geometric mean concentration below 10 ppb for WY2004.

As observed for the inflows, the geometric mean TP concentrations measured across interior marsh stations in all portions of the EPA during WY2004 were the lowest recorded for any of the three reporting periods. During WY2004, interior marsh geometric mean TP concentrations ranged from a high of 11.6 µg/L in WCA-2, to a minimum of 4.3 µg/L in the ENP, compared to ranges from 14.8–4.5 µg/L and 16.9–5.5 µg/L for WY2003 and the WY1978–WY2002 historical period, respectively. The annual geometric mean TP concentration across interior marsh sites for all areas, except WCA-2, was below the respective 10-µg/L and 11-µg/L five-year and annual provisions for determining achievement of the criterion, as set forth in the current phosphorus criterion rule. The geometric mean for the interior marsh sites in WCA-2, the most phosphorus-enriched portion of the EPA, was slightly above the annual 11-µg/L limit (i.e., 11.6 µg/L). The lower marsh TP levels measured during WY2004 likely reflect the lower inflow concentrations, changes in water management practices, and a general improvement in nutrient conditions in the marsh.

TOTAL PHOSPHORUS LOADS TO THE EVERGLADES PROTECTION AREA

The lower phosphorus concentrations in the inflows to the EPA observed during WY2004 are also reflected in reduced phosphorus loads delivered to the EPA during the year. Phosphorus loads to the EPA during WY2004 were significantly lower than the 1979–1988 baseline period, due to better water management practices (reduction in the volume of Lake Okeechobee discharges to the EPA), and continued implementation and refinement of BMPs and STAs. The 112-ton load from the surface water discharges during WY2004 represents an almost 18-percent reduction from the previous year (136 metric tons, or mt). Phosphorus loads from all sources to the Refuge during WY2004 totaled approximately 22.3 mt, which is an almost 50-percent reduction from the previous year (43.4 mt).

Phosphorus loads to the WCAs from the EAA during WY2004 totaled about 41.5 mt, slightly lower than the previous year. Even though, STA-1E and STA-3/4 were not fully operational during WY2004, the three-year average load to the WCAs from the EAA is 38 mt, which is slightly lower than the expected 10-yr average of 40.2 mt. The flow-weighted mean phosphorus concentration entering the WCAs from the EAA, STA-1W, STA-2, STA-3/4, STA-6, and bypass flows during WY2004 was approximately 40 ppb, which is below the annual maximum of 76 ppb established by the Technical Oversight Committee (TOC) methodology.

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 WY2004. As for phosphorus, this 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 and WCA-2, with levels decreasing to a minimum in the Park.

Mean and median TN concentrations measured during WY2004 were similar to or slightly lower than those measured during WY2003 and the WY1978–WY2002 historical period across all portions of the EPA. During WY2004, mean TN concentrations at inflow stations ranged from 0.9–2.5 milligrams per liter (mg/L), with median TN concentrations ranging from

0.8–2.3 mg/L. Similarly, mean TN concentrations at the interior marsh stations during WY2004 ranged from 1.0–1.9 mg/L, with median concentrations ranging from 0.9–1.9 mg/L.

PURPOSE

The primary purpose of this chapter is to provide an overview of the status of phosphorus (P) and nitrogen (N) levels in the surface waters within the Everglades Protection Area (EPA) during Water Year 2004 (WY2004) (May 1, 2003 through April 30, 2004). The water quality evaluations presented in this section update previous analyses presented in the 1999 Everglades Interim Report and the 2000–2004 Everglades Consolidated Reports (ECRs). More specifically, this section and its associated appendices are intended to achieve the following objectives:

1. Summarize phosphorus and nitrogen concentrations measured in the 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
3. Present an update on the progress made towards the establishment of a phosphorus-specific criterion for the EPA

The following chapter represents a combination of the nutrient levels for total phosphorus (TP) and total nitrogen (TN) presented in the chapter evaluating the overall water quality status of the EPA (see Chapter 2A of the 2005 SFER – Volume I) and the information provided in previous Everglades Consolidated Reports (ECRs) detailing the development of the phosphorus-specific criterion for the EPA (Payne et al., 2002 and 2003).

Once the final TP criterion is approved by the USEPA and data becomes available from the monitoring network established in accordance with the rule, it is anticipated that future versions of this section will be expanded to include a more detailed evaluation of the EPA marsh phosphorus levels consistent with the requirements of the final phosphorus criterion.

METHODS

A regional synoptic approach used for water quality evaluations in previous ECRs was applied to phosphorus and nitrogen data for WY2004 to provide an overview of the 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 for the evaluation of other water quality constituents, the majority of the water quality data evaluated in this chapter were retrieved from the South Florida Water Management District's (SFWMD's or District's) DBHYDRO database. Water quality data from the nutrient gradient sampling stations monitored by the Everglades Systems Research Division in the northern part of Water Conservation Area 2A (WCA-2A), the southwestern part of the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge), the west-central portion of Water Conservation Area 3A (WCA-3A), and Taylor Slough in Everglades National Park (ENP or Park) were obtained from the SFWMD's Everglades research database.

The phosphorus and nitrogen data summarized in this chapter were collected at the same monitoring stations described in Chapter 2A of the *2005 South Florida Environmental Report–Volume I* (2005 SFER) (see Figure 2A-1). 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 their location and function, as previously described. Due to minor changes to the station classifications, and the addition of a small amount of data unavailable during the preparation of the previous report, some of the statistics for phosphorus and nitrogen presented in the *2005 South Florida Environmental Report* are slightly different from those presented in previous ECRs. For example, the *2004 Everglades Consolidated Report* reported a geometric mean TP concentration of 48.4 micrograms per liter (µg/L) for Refuge inflows during WY2003, whereas **Table 2C-1** of this chapter reports a concentration of 48.2 µg/L for WY2003. The location and categorization of the monitoring stations used for the analysis of the phosphorus and nitrogen data in this chapter are the same as those utilized for the evaluation of other water quality constituents, as described in Chapter 2A of this volume (see Figures 2A-2 through 2A-5).

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 Website describing its water quality monitoring projects, including project descriptions and objectives. This Website currently provides limited site-specific information. Generally, interior monitoring stations were sampled monthly, with water control structures (inflows and outflows) typically being sampled biweekly when flowing, and monthly when not flowing. More information can be found on the District's Website at http://www.sfwmd.gov/org/ema/envmon/wqm/index.html.

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 2A 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.

Table 2C-1. Summary of total phosphorus (TP) concentrations (µg/L) in the Everglades Protection Area (EPA) for WY2004, WY2003, and WY1978–WY2002.

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	1978–2002	2976	67.9	2.3	74	< 4	1415
		2003	131	48.2	1.7	45	20	315
		2004	136	38.8	1.7	33	16	172
	Interior	1978–2002	2320	10.1	2.0	9	< 2	494
		2003	222	9.4	1.8	9	< 4	45
		2004	243	9.3	1.8	9	< 4	63
	Outflow	1978–2002	1205	55.4	2.1	53	7	3435
		2003	69	39.8	1.6	40	12	143
		2004	65	31.7	2.1	29	10	381
	Rim	1978–2002	706	63.8	1.8	61	12	473
		2003	20	65.5	1.4	68	36	110
		2004	24	39.8	1.4	39	21	91.5
WCA-2	Inflow	1978–2002	1877	58.6	2.1	60	7	3435
		2003	154	31.7	1.8	34.5	10.5	128
		2004	162	24.0	1.9	23	9	91.5
	Interior	1978–2002	4692	16.9	3.1	13	< 4	3189
		2003	279	14.8	2.3	13	< 4	170
		2004	253	11.6	2.5	11	< 4	239
	Outflow	1978–2002	1460	20.4	2.5	19	< 2	556
		2003	61	21.5	1.8	22	6	93
		2004	75	19.4	1.8	20	6	86
WCA-3	Inflow	1978–2002	5125	34.7	2.5	34	< 2	1286
		2003	397	30.0	2.0	29	8	212.5
		2004	414	26.3	1.8	25	7	181
	Interior	1978–2002	2005	8.9	2.5	8	< 2	438
		2003	326	8.0	2.1	7	< 4	120
		2004	351	7.6	2.4	6	< 4	110
	Outflow	1978–2002	4025	10.9	2.2	10	< 2	593
		2003	210	12.2	1.7	11	5	63
		2004	217	10.5	1.5	10	3	38
Park	Inflow	1978–2002	4675	9.1	2.2	9	< 2	593
		2003	298	8.8	1.7	8	3	52
		2004	321	7.7	1.6	7	2	51
	Interior	1978–2002	1577	5.5	2.4	5	< 2	1137
		2003	83	4.6	1.8	5	< 4	20
		2004	103	4.3	1.7	4	< 2	22

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 Everglades, however, evolved as a highly oligotrophic (nutrient-poor), phosphorus-limited system, with the natural flora and fauna being adapted to successfully exist under these harsh conditions. Research has demonstrated that relatively small additions of these nutrients, especially phosphorus, can have dramatic effects on the biological conditions of the natural ecosystem.

Until recently, phosphorus and nitrogen concentrations in the EPA's surface waters were regulated by the Class III narrative criterion alone. The narrative criterion specifies that nutrient concentrations in a water body cannot be altered to cause an imbalance in the natural populations of flora or fauna. Because of the importance of phosphorus in controlling the natural biological communities, the Florida Department of Environmental Protection (FDEP) has numerically interpreted the narrative criterion, as directed by the Everglades Forever Act (EFA), to develop a TP criterion of 10 µg/L for the EPA. The status of the phosphorus criterion for the Everglades is further discussed below.

To evaluate spatial and temporal trends in nutrient levels within the EPA, phosphorus and nitrogen concentrations measured during WY2004 are further discussed in this chapter with a comparison to results from previous monitoring years. Once the TP criterion becomes effective and data are made available from the monitoring network, it is anticipated that future versions of this chapter will be expanded to include a more detailed evaluation of phosphorus levels in the EPA marshes, consistent with the requirements of the final criterion rule.

TOTAL PHOSPHORUS

STATUS OF PHOSPHORUS CRITERION RULEMAKING

The Everglades Forever Act [Section 373.4592, Florida Statutes (F.S.)] specifically states that waters flowing into a part of the remnant Everglades (also known as the EPA) contain excessive phosphorus levels, and a reduction in phosphorus levels will benefit the ecology of the EPA. The EFA further directs the FDEP to develop a numeric total phosphorus criterion by numerically interpreting the existing Class III narrative criterion as it applies to the EPA.

In response to the requirements of the EFA, the FDEP and the District conducted an extensive research program to provide the data necessary to establish a numeric TP criterion. The research program consisted of field transect monitoring along existing, man-made nutrient gradients; dosing experiments; and laboratory experiments. To derive an appropriate numeric TP criterion, the FDEP conducted extensive analyses of the data from the District's research with data from other sources also being incorporated, where appropriate. Details of the FDEP's analyses and the derivation of the TP criterion are provided in previous ECRs (McCormick et al., 1999; Payne et al., 2001a, 2002, and 2003), with additional detail provided in the FDEP's Everglades Phosphorus Criterion Development Technical Support Documents (Payne et al., 1999, 2000, and 2001b). Results of the FDEP's analyses indicate that the maintenance of a long-term (five-year) annual geometric mean TP concentration at or below 10 µg/L would be protective of the natural flora and fauna, without being overly protective or below the natural background levels. However, FDEP's analyses also indicate that, over shorter periods (less than or equal to one year), TP levels can naturally vary significantly above 10 µg/L without long-term biological impacts (Payne et al., 1999 and 2000).

As previously noted, following a series of hearings, the Environmental Regulation Commission (ERC) approved the 10-µg/L TP criterion for the EPA during a July 8, 2003 hearing. Subsequent to the ERC approval, both environmental and agricultural interest groups filed administrative challenges to the phosphorus criterion rule. Following discussions with the FDEP concerning the application of the rule, all parties, except the Miccosukee Tribe of Indians and the Friends of the Everglades, withdrew their challenges. To resolve these remaining challenges, an administrative hearing was held from November 2003 through January 2004. The Administrative Law Judge issued a final order in the cases on June 17, 2004 that upheld all parts of the proposed rule finding that the rule "is not an invalid exercise of delegated legislative authority" by the FDEP. The complete final order for Case No. 03-002872 can be found online at the Department of Administrative Hearings' Website at http://www.doah.state.fl.us/ros/2003/03-2872.PDF. Following the Administrative Law Judge's ruling, the proposed rule [Section 62-303.540, Florida Administrative Code (F.A.C.)] was filed with the Florida Secretary of State on June 25, 2004. Subsequent to the formal adoption by the FDEP, the rule was submitted to the U.S. Environmental Protection Agency (USEPA) for approval. Once the rule has been approved by the USEPA, the required monitoring networks will be established and evaluation of achievement will be assessed consistent with the requirement of the final phosphorus criterion rule.

Because final agency action by the FDEP did not occur prior to December 31, 2003 as a result of unresolved administrative challenges, a default TP criterion of 10 µg/L became effective, as specified by the EFA. The default criterion was superseded by the FDEP's criterion when it was filed with the Florida Secretary of State on June 25, 2004.

With the exception of minor edits, the final phosphorus criterion rule for the EPA remains essentially unchanged from that included as Appendix 2C-1 of the 2004 Everglades Consolidated Report (Payne and Weaver, 2004). The current rule is composed of eight sections rather than the nine sections found in the previous version of the rule, because one of the technical edits involved combining Sections (4) and (5) from the initial rule. The eight sections in the current rule include Sections (1), (2), and (3), which are the purpose and scope, findings, and definitions sections, respectively. Section (4) establishes the numeric criterion for Class III waters in the EPA as a long-term geometric mean of 10 µg/L, or parts per billion (ppb), and provides methods for determining achievement of the criterion, which take into account spatial and temporal variability, natural background conditions, and confidence in laboratory results. Section (5) establishes long-term compliance permit requirements for phosphorus discharges into the EPA. Section (6) establishes two new moderating provisions for discharges into the EPA that do not achieve the 10-ppb criterion. The two moderating provisions are a net improvement moderating provision for discharges into impacted areas of the EPA, and a hydropattern restoration moderating provision for discharges into unimpacted areas of the EPA. Sections (7) and (8) of the rule contain a list of documents incorporated by reference and contingencies. A copy of the current TP criterion rule for the EPA (Section 62-302.540, F.A.C.) is provided in Appendix 2C-1.

As specified above, in addition to establishing the numeric phosphorus criterion for the EPA, Section (4) of the rule also provides a methodology to determine achievement of the numeric TP criterion in an objective and scientifically reliable manner. The methodology, developed by the FDEP in cooperation with the SFWMD, is based on information obtained during the TP criterion development. The measurement methodology is designed to allow the TP criterion to be applied so that it protects the natural biological communities within the EPA without restricting the natural heterogeneity of the ecosystem, while taking into account natural spatial and temporal variability, including variability above 10 µg/L, as required by the EFA. Therefore, the FDEP's recommended measurement methodology consists of two major components: (1) the maintenance of a long-term (five-year) geometric mean TP concentration across a network of evenly distributed marsh sites, and (2) a series of three components intended to protect against localized or shorter-term imbalances in the natural flora and fauna, while allowing for natural temporal and spatial variability. The adopted methodology specifies the following:

> The water body will have achieved the criterion if the five-year geometric mean is less than or equal to 10 ppb. In order to provide protection against imbalances of aquatic flora or fauna, the following provisions must also be met:
>
> a. the annual geometric mean averaged across all stations is less than or equal to 10 ppb for three of five years; and
>
> b. the annual geometric mean averaged across all stations is less than or equal to 11 ppb; and
>
> c. the annual geometric mean at all individual stations is less than or equal to 15 ppb.

Achievement of the criterion in WCA-2 and WCA-3 shall be determined based upon the application of the above methodology to data collected monthly from stations that are evenly distributed and located in freshwater open-water sloughs within each water body (i.e., areas similar to those utilized during the derivation of the numeric TP criterion). Furthermore, achievement of the TP criterion in the impacted and unimpacted areas within each water body will be determined separately.

To ensure compatibility with the federal Settlement Agreement (i.e., Settlement Agreement dated July 26, 1991, entered in Case No. 88-1886-Civ-Hoeveler, U.S. District Court for the Southern District of Florida, as modified by the Omnibus Order entered in the case on April 27, 2001), the approved rule specifies that achievement of the TP criterion in the Park and the Refuge will be based on the methods set forth in Appendices A and B, respectively, of the Settlement Agreement until this agreement is rescinded or terminated. If the Settlement Agreement is no longer in effect, then achievement of the TP criterion will be determined based on the method provided for WCA-2 and WCA-3.

The measurement methodology contained in the adopted TP criterion is used to (1) provide for an objective and scientifically reliable assessment of the TP status at sampling stations representative of the EPA, (2) take into account natural spatial and temporal variability without being significantly biased by extreme events, and (3) allow the TP criterion to be applied so that it protects the natural biological communities present within the EPA without restricting the natural heterogeneity of the ecosystem or being below background levels.

PHOSPHORUS STATUS IN THE EVERGLADES PROTECTION AREA

Because the required monitoring networks have not been established and the sites have not been classified as impacted or unimpacted, the TP criterion achievement methodology set forth in the rule cannot be applied to the current data. However, some of the provisions set forth in the rule are used as the basis for the evaluation of the status of phosphorus concentrations in the EPA presented in this chapter. It is anticipated that subsequent versions of this chapter in future South Florida Environmental Reports (after the rule is approved by the USEPA and appropriate monitoring stations are established) will be expanded to include an assessment of achievement of the phosphorus criterion in EPA marshes consistent with methods set forth in the final phosphorus criterion rule. To provide an overview of the current nutrient status in the Everglades and to evaluate temporal and spatial patterns, TP concentrations measured during WY2004 are compared to the provisions set forth in the phosphorus criterion rule and the levels observed during previous monitoring periods.

In this chapter, TP concentrations measured during WY2004 are compared to the TP levels determined during WY2003, and the historical period from WY1978–WY2002. **Table 2C-1** provides a summary of the TP concentrations measured within different portions of the EPA during WY2004, WY2003, and the WY1978–WY2002 historical period using both geometric mean and median values. Geometric means were used to summarize and compare TP concentrations based on requirements in the EFA and the phosphorus criterion rule that specify that achievement of the TP criterion be based on the long-term geometric mean. Given that the EFA and phosphorus 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.

As documented during previous years, TP concentrations measured during WY2004 exhibited a decreasing north-to-south gradient, with the highest levels present in the inflow to the Refuge and WCA-2, and with 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.

TP concentrations (expressed either as median or geometric mean values) measured in the inflows to all portions of the EPA during WY2004 were below the levels reported for both WY2003 and the WY1978–WY2002 historical period (**Table 2C-1**). **Figure 2C-1** illustrates a decreasing temporal trend in the annual geometric mean TP concentrations in the inflows to the Refuge and WCA-2.

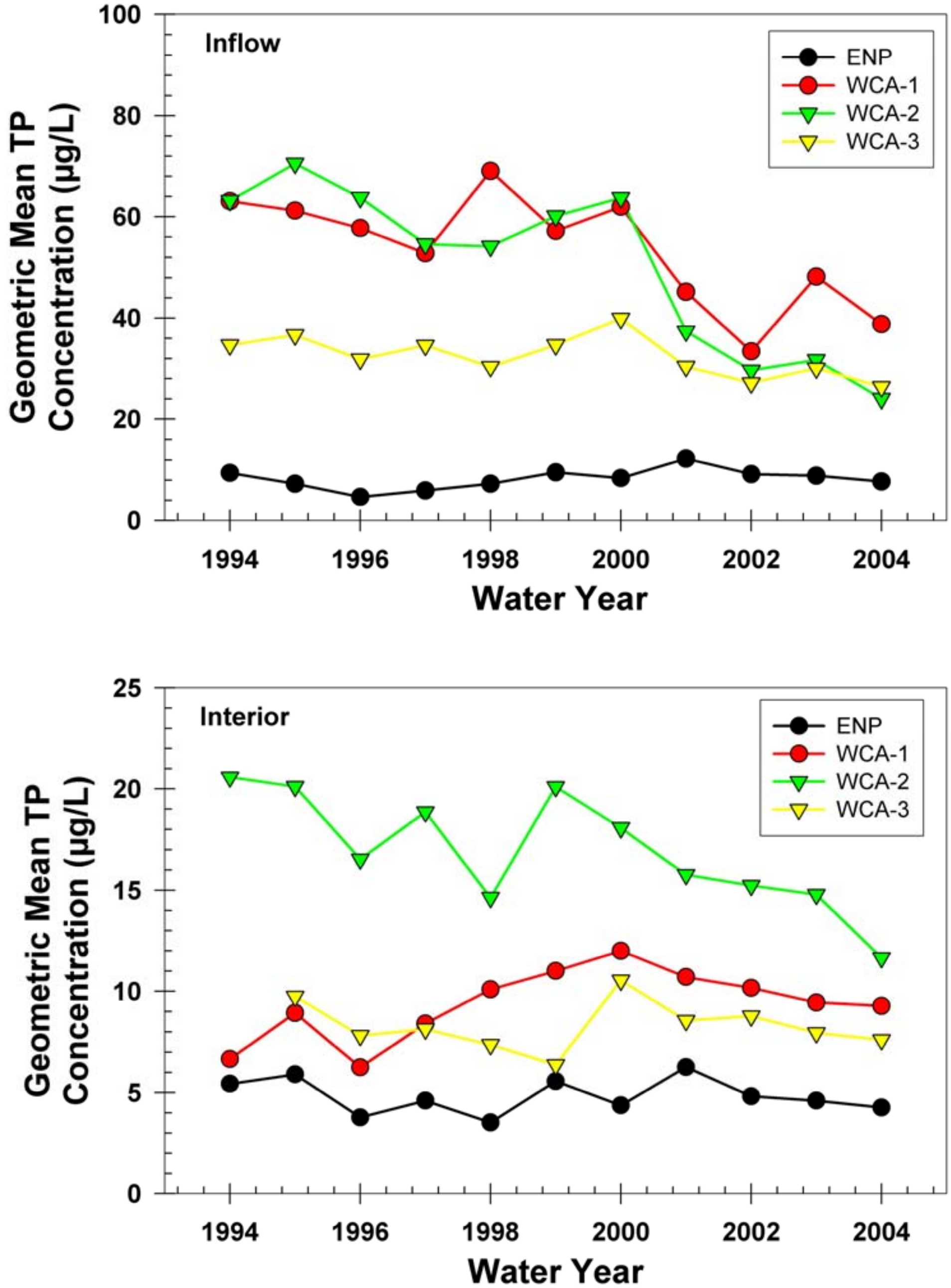

Figure 2C-1. Annual geometric mean total phosphorus (TP) concentrations (µg/L) for inflow (upper graph) and interior (lower graph) for each area within the EPA during the period from WY1978–WY2004.

The magnitude of the decreasing trend is greatest for the WCA-2, where the 2004 inflow concentrations were 59 percent lower than the levels reported for the WY1978–WY2002 historical period, and 24 percent lower than the WY2003 levels. Inflow TP concentrations for the Refuge during WY 2004 were 43 percent lower than recorded during the historical period, and 20 percent lower than WY2003 levels. Inflow TP concentrations for WCA-3 and the Park were also the lowest recorded for any of the three reporting periods with the inflows to the Park continuing to exhibit phosphorus concentrations well below the 10-ppb criterion. The low TP levels reported for the Park provide further support for the conclusion that the increased TP concentrations in the inflow to the Park observed during the WY2001 drought (Weaver et al., 2002) were a temporary, natural phenomenon associated with the low water levels and the increased release of phosphorus from oxidized sediments as portions of the system dried. The decreasing inflow concentrations observed during recent years throughout the EPA are likely the result of the continued implementation of BMPs in the upstream agricultural and urban watersheds, and the greater treatment afforded by the increasing number of operating STAs. As discussed later in this chapter, the reduced TP concentrations in the inflows have translated into significant reductions in the phosphorus loads delivered to the EPA during WY2004, compared to the historic baseline period and the previous year.

In addition to the reduction in the level of TP in the inflows, the concentration of orthophosphate (OP) also decreased substantially in WY2004, compared to the previous periods with the inflows to all areas having an annual geometric mean concentration below 10 ppb for WY2004 (**Table 2C-2**). OP is a fraction of TP that is soluble and readily utilized by biological organisms and therefore has the greatest and most rapid effect on the ecosystem. Similar to TP, the greatest decreases in OP concentrations were observed for inflow to WCA-2 and the Refuge, with WY2004 concentrations being from 59 to 65 percent lower than those for the WY1978–WY2002 historical period, and from 15 to 42 percent lower than WY2003 levels. Because the decreases in OP levels are relatively greater than those observed for TP, these results indicate that the concentrations of biologically active phosphorus decreased, and that the TP entering the EPA is comprised of a smaller percentage of readily available OP. Similar to TP, the decreasing inflow OP concentrations observed during recent years are likely the result of the continued implementation of BMPs in the upstream agricultural and urban watersheds, and the greater treatment afforded by the increasing number of operating STAs. The effectiveness of the STAs and BMPs is also illustrated by the greater decreases in OP concentrations relative to TP levels, as the biological treatment afforded by the upstream BMPs and STAs preferentially remove the soluble biologically available forms of phosphorus.

Table 2C-2. Summary of orthophosphate (OP) concentrations (µg/L) measured in the EPA during WY2004, WY2003, and WY1978–2002.

Region	Class	Period	Sample Size (N)	Geometric Mean (µg/L)	Std. Deviation	Median (µg/L)	Min. (µg/L)	Max. (µg/L)
Refuge	Inflow	1978–2002	2214	23.4	4.0	28.0	< 2.0	1106
		2003	116	16.3	2.3	15.0	4.0	109
		2004	131	9.5	2.1	8.0	4.0	122
	Interior	1978–2002	1544	1.4	2.2	1.0	< 2.0	380
		2003	212	3.6	1.7	4.0	< 4.0	18
		2004	222	3.0	1.8	2.0	< 4.0	42
	Outflow	1978–2002	1186	17.5	3.7	19.5	< 2.0	1290
		2003	70	13.0	2.4	12.0	< 4.0	75
		2004	65	8.1	3.0	7.0	< 4.0	297
	Rim	1978–2002	480	23.9	3.2	28.3	< 2.0	408
		2003	22	16.3	4.0	29.0	< 4.0	76
		2004	24	5.5	2.0	5.0	< 4.0	18
WCA-2	Inflow	1978–2002	1368	19.3	3.6	22.0	< 2.0	1290
		2003	123	8.3	2.7	6.0	< 4.0	91
		2004	126	6.6	2.3	6.0	< 4.0	121
	Interior	1978–2002	3222	3.7	4.3	2.0	< 2.0	2790
		2003	258	4.3	2.2	4.0	< 4.0	119
		2004	239	4.3	2.0	5.0	< 4.0	57
	Outflow	1978–2002	1448	5.1	3.4	4.0	< 2.0	396
		2003	62	8.2	2.1	7.0	< 4.0	69
		2004	77	6.9	1.7	6.0	< 4.0	43
WCA-3	Inflow	1978–2002	4096	9.0	4.0	8.0	< 2.0	586
		2003	203	8.5	2.7	7.0	< 4.0	145
		2004	208	7.3	2.4	6.0	< 4.0	116
	Interior	1978–2002	1879	1.6	2.7	1.0	< 2.0	190
		2003	296	2.8	1.8	2.0	< 4.0	83
		2004	317	2.8	2.0	2.0	< 4.0	67
	Outflow	1978–2002	3031	2.8	2.1	2.0	< 2.0	149
		2003	170	2.8	1.5	2.0	< 4.0	10
		2004	175	2.7	1.5	2.0	< 4.0	10
Park	Inflow	1978–2002	3499	2.7	2.0	2.0	< 2.0	97
		2003	186	2.6	1.5	2.0	< 4.0	10
		2004	199	2.5	1.5	2.0	< 4.0	10
	Interior	1978–2002	1426	2.8	1.8	2.0	2.0	63
		2003	79	2.5	1.4	2.0	< 4.0	6
		2004	100	2.5	1.5	2.0	< 4.0	8

As observed for the inflows, the geometric mean TP concentrations measured across interior marsh stations in all portions of the EPA during WY2004 were the lowest recorded for any of the three reporting periods. During WY2004, interior marsh geometric mean TP concentrations ranged from a high of 11.6 µg/L in WCA-2, to a minimum of 4.3 µg/L in the Park compared to ranges from 14.8–4.5 µg/L, and 16.9–5.5 µg/L for WY2003 and the WY1978–WY2002 historical period, respectively (**Table 2C-1**). The annual geometric mean TP concentration across interior marsh sites for all areas, except WCA-2, was below the respective 10 and 11 µg/L five-year and annual provisions, respectively, for assessing achievement set forth in the final phosphorus criterion rule. The geometric mean for the interior marsh sites in WCA-2, the most phosphorus-enriched portion of the EPA, was slightly above the annual 11 µg/L provision (i.e., 11.6 µg/L). The lower marsh TP levels measured during WY2004 likely reflect the lower inflow concentrations, changes in water management practices, and a general improvement in nutrient conditions in the marsh. **Figure 2C-1** provides the annual geometric mean TP concentrations across interior marsh sites within each area from WY1978–WY2004. Generally, TP levels have decreased during the past four to five years with the greatest improvements observed for WCA-2, which contains the largest phosphorus enriched area. Overall, the WY2004 results indicate that the average TP concentrations at interior marsh sites have decreased slightly during recent years. OP concentrations measured for interior marsh sites during WY2004 were comparable to those reported for WY2003 and the WY1978–WY2002 historical period. The less dramatic decreases in phosphorus concentrations observed at interior marsh sites are expected. This is because a large portion of the interior marsh remains relatively unenriched with phosphorus concentrations near background levels, and the improvements in enriched portions of the marsh are expected to occur at a slower pace due to the reflux of phosphorus from the enriched sediments in these areas. However, before more definitive conclusions can be drawn concerning the recovery of interior marsh sites, a more detailed evaluation needs to be conducted that evaluates the phosphorus loading to each portion of the EPA, as well as the reductions in inflow TP concentrations.

Annual geometric mean TP concentrations for individual interior marsh monitoring stations during WY2004 ranged from less than 4.0 to 55.5 µg/L, with 67.5 percent of the interior marsh sites across the EPA exhibiting annual geometric mean TP concentrations that were less than or equal to 10 µg/L. Additionally, 81.8 percent of the interior sites across the EPA had annual geometric mean TP concentrations of 15 µg/L or below during WY2004. For comparison, 63.6 and 47.1 percent of the sites monitored during WY2003 and the WY1978–WY2002 historical period, respectively, had annual geometric mean TP concentrations less than or equal to 10 µg/L. During WY2003 and the WY1978–WY2002 historical period, 79.2 and 65.9 percent of the interior sites, respectively, exhibited annual geometric mean concentrations of 15 µg/L or less. Given that the location of interior monitoring sites has remained relatively constant over the past several years, the temporal comparison of statistics from individual sites can be used to distinguish trends in measured concentrations. However, as the monitoring sites are not evenly distributed across the EPA, it is not possible to accurately estimate the percentage of the marsh exceeding a TP concentration of 10 µg/L, or any other specified level based on these results.

Spatially, interior marsh TP concentrations measured during WY2004 exhibited the same north-to-south gradient observed during previous periods (Bechtel et al., 1999 and 2000; Weaver et al., 2001a, 2002, and 2003; Payne and Weaver, 2004). Typically, the highest TP concentrations obtained during WY2004 were collected from the northern WCAs, and declined throughout WCA-3 and the Park. During WY2004, 50 percent of the monitoring sites in WCA-2 had annual geometric mean TP concentrations of 10 µg/L or less, with that percentage increasing to 100 percent in the Park (**Figure 2C-2**). Likewise, 66.7 percent of interior sites within WCA-2 were determined to have annual geometric mean TP concentrations of 15 µg/L or less for WY2004 with higher percentages in other areas of the EPA.

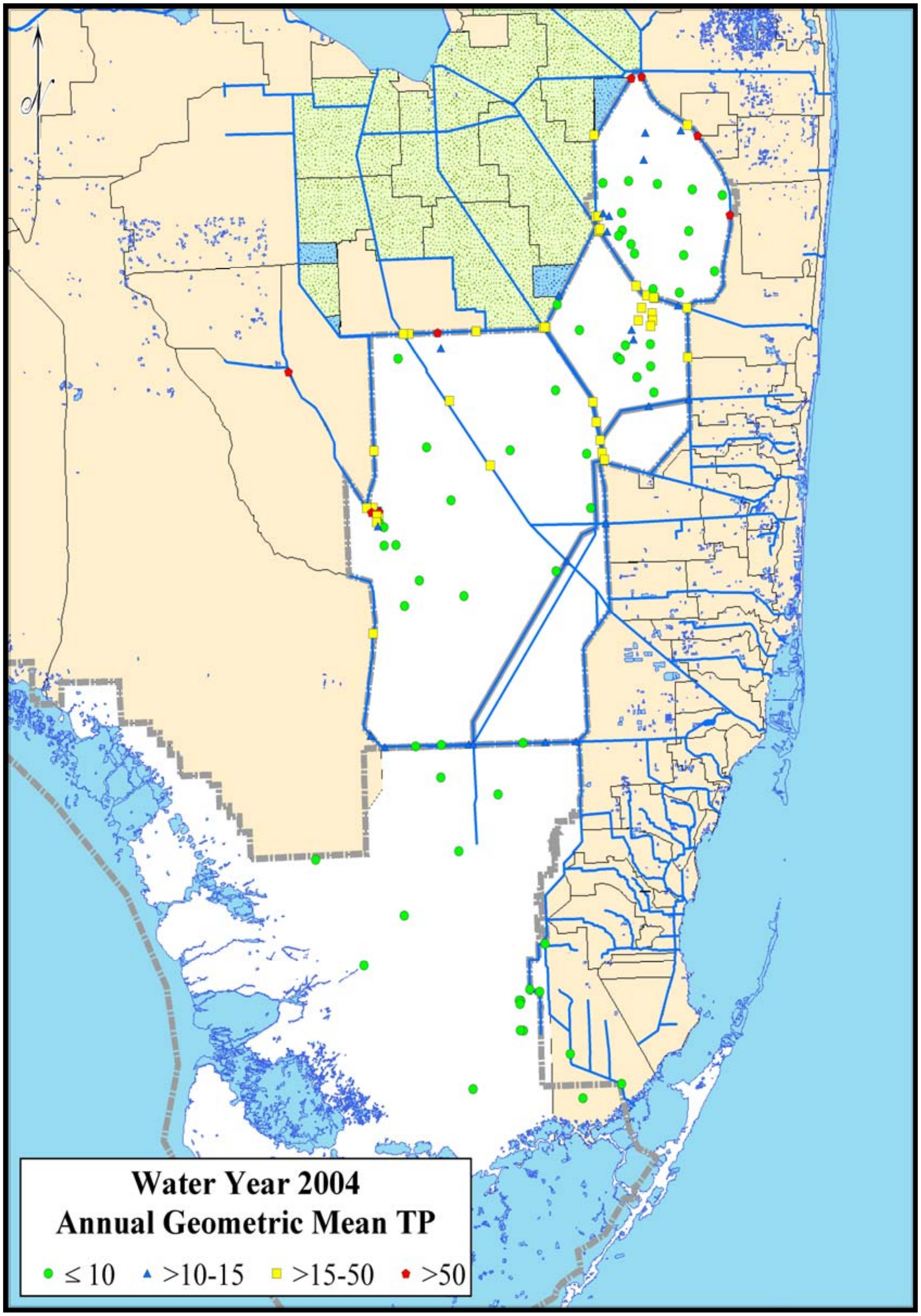

Figure 2C-2. Summary of geometric mean TP concentrations (µg/L) at stations across the EPA for WY2004. Geometric mean TP concentrations are classified utilizing four levels: ≤ 10 µg/L, 10–15 µg/L, 15–50 µg/L, and > 50 µg/L.

During WY2004, geometric mean TP concentrations at a few individual sites (LOX3, LOX4, LOX5, X3, and CA33) located in areas relatively uninfluenced by canal inflows slightly exceeded 10 µg/L (ranged from 10.4 to 12.1 µg/L). Sites LOX3, LOX4, and LOX5 are located in the northern portion of the Refuge, and were not sampled for several months in early WY2004 due to dry conditions. Likewise, site CA33 is located in the northern portion of WCA-3, where low water levels and dry conditions often result in elevated TP levels. None of the sites in the relatively unimpacted portion of the marsh exhibited a geometric mean TP concentration above the 15 µg/L annual limit specified in the phosphorus criterion for individual sites. A more detailed, site-specific summary of the TP concentrations for WY2004 is provided in Appendix 2C-2. Calculated TP loads for individual water control structures within the EPA (EAA and non-ECP sites) are presented in Chapter 3 of the 2005 SFER – Volume I.

Over the entire EPA (all areas and site classifications), 93 percent of the TP measurements collected during WY2004 were below 50 µg/L, with 58.8 percent being below 15 µg/L and 43.5 percent of the measurements being at or below 10 µg/L. These WY2004 results are slightly improved compared to the WY2003 results in which the TP concentrations in 89 percent of the samples were less than 50 µg/L, with 54 percent being at or below 15 µg/L, and 40 percent of the measured concentrations at or below 10 µg/L.

The distribution of TP concentrations in samples collected at inflow, interior, and outflow stations from each EPA region for WY2004 is presented in **Figure 2C-3**. Inflow stations to the Refuge and the WCAs had the highest percentage of measurements above 50 µg/L (11.6 to 26.5 percent) during WY2004. In contrast, less than 0.5 percent of the TP measurements at the Park inflow sites were above 50 µg/L, with 73.2 percent below 10 µg/L. Likewise, WCA-2, the most highly phosphorus-enriched area, exhibited the lowest percentage of samples from interior sites at or below 10 µg/L (47.4 percent), while 63.8 and 73.5 percent of samples collected from the interior of the Refuge and WCA-3, respectively, had TP concentrations of 10 µg/L or below. Additionally, more than 96 percent of the samples collected in the interior of the Park had TP concentrations of 10 µg/L or less.

Figure 2C-3 also provides a comparison of the concentrations measured in samples collected during WY2004 to the levels reported for WY2003 and the WY1978–WY2002 historical period. In general, decreased phosphorus levels were observed across all areas and classes of sites.

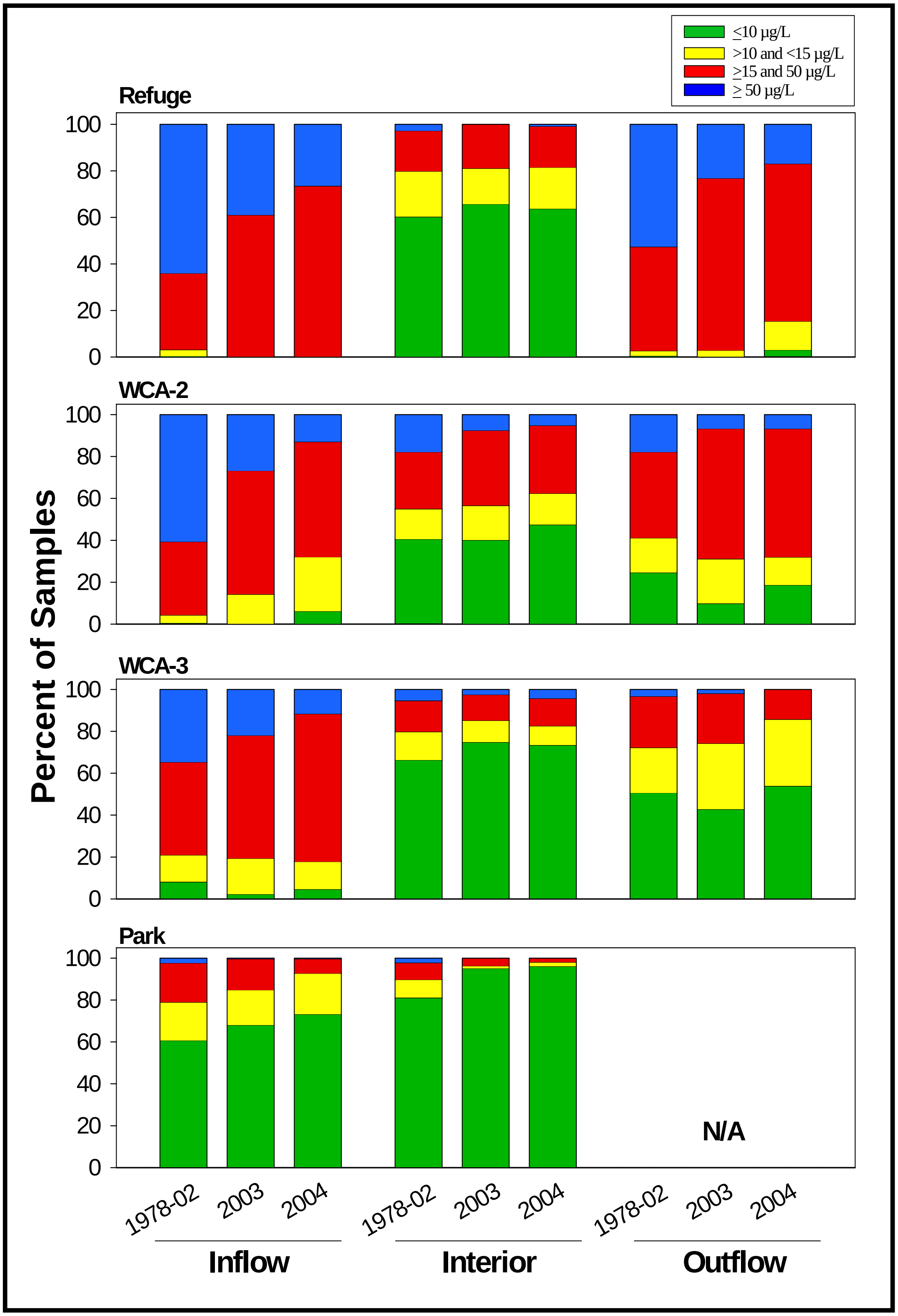

Figure 2C-3. Comparison of TP concentrations (µg/L) measured in samples collected in the EPA during WY2004, WY2003, and the WY1978–WY2002 historical period. "N/A" indicates that the outflow is not monitored for the ENP.

As stated previously, substantial improvement in the phosphorus levels in the inflows to the EPA, especially those to WCA-2 and the Refuge, were observed (with smaller improvements at the interior sites). The lower phosphorus levels observed in recent years are likely the result of the continued implementation of BMPs in the upstream watersheds and the greater phosphorus removal afforded by the increasing number of operating STAs. The improvements in the interior portions of the EPA are expected to occur at a slower pace than those in the inflows, as observed, due to the reflux of phosphorus from the enriched sediments in the impacted portions of the marsh.

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 from agricultural areas such as the EAA and the C-139 basin, regulated by water control structures, feed the EPA from the north and western boundaries. The EPA also receives surface water inflows originating from Lake Okeechobee to the north, and from highly 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.

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. The TP loads to the EPA for WY2004 are tabulated in **Table 2-3**. Detailed estimates of TP loads by structure are presented in **Table 2-4**. These tables summarize 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.

It is also recognized that a certain amount of TP loading to the EPA emanates from atmospheric deposition. It is estimated that the long-term average annual TP load delivered to the WCAs through atmospheric TP deposition ranges between 107 and 143 mt per year. Deposition rates are highly variable, and very expensive to monitor and as such, atmospheric inputs of TP are not routinely monitored. The range shown in **Table 2-3** (20 to 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).

Table 2C-3. WY2004 total phosphorus (TP) loads to the EPA and other waters.

Source Water	Receiving Water	TP Load (metric tons)	Portion of Surface Loading to EPA	Portion of Total Loading to EPA
Lake Okeechobee	**EPA (WCAs)**	**5.8**	5.2%	1.9%
	EAA	**40.3**	---	---
	STAs	**4.5**	---	---
	Total from Lake Okeechobee	**50.5**	---	---
Everglades Agricultural Area (EAA)	**EPA (WCAs)**	**21.5**	19.3%	7.1%
(includes Ch. 298 Districts)	**Lake Okeechobee**	**0.1**	---	---
	STAs	**66.7**	---	---
	Holey Land	**1.9**	---	---
	Total from EAA	**90.2**	---	---
Stormwater Treatment Areas (STAs)	**EPA (WCAs)**	**38.1**	34.3%	12.5%
	Lake Okeechobee	**0.0**	---	---
	Holey Land and Rotenberger	**1.0**	---	---
	Total from STAs	**39.0**	---	---
			---	---
Rotenberger	**EPA (WCAs)**	**0.02**	0.0%	0.0%
L-8 & C-51W	**STAs**	**1.1**	---	---
Acme Basin B	**EPA (WCAs)**	**2.1**	1.9%	0.7%
Boynton Farms	**EPA (WCAs)**	**0**	0.0%	0.0%
North Springs Improvement District	**EPA (WCAs)**	**0**	0.0%	0.0%
North New River Canal Basin	**EPA (WCAs)**	**0.05**	0.0%	0.0%
C-11 West Basin	**EPA (WCAs)**	**5.1**	4.6%	1.7%
C-111 Basin	**EPA (ENP)**	**2.8**	2.5%	0.9%
Feeder Canal Basin	**EPA (WCAs)**	**14.4**	12.9%	4.7%
L-28 Canal Basin	**EPA (WCAs)**	**7.0**	6.3%	2.3%
C-139 Basin	**EPA (WCAs)**	**14.1**	12.7%	4.7%
	STAs	**48.6**	---	---
	Lake Okeechobee	**0.0**	---	---
	Total from C-139 Basin	**62.8**	---	---
L-28 Gap Basin	**EPA (WCAs)**	**No data**	---	---
Total Surface Inflows	**EPA (WCAs)**	**110.9**	100%	36.5%
Atmospheric Deposition	**WCA-1 (35 mg/m2/yr)**	**20**	---	---
	WCA-2 (35 mg/m2/yr)	**18.8**	---	---
	WCA-3 (25 mg/m2/yr)	**70.4**	---	---
	ENP (20 mg/m2/yr)	**84.1**	---	---
	Total Atmospheric Deposition	**193**	---	63.5%
Total Load to the EPA	**EPA (WCAs)**	**304**	---	100%
Load from the EPA	**STAs**	**1.4**	---	---
	S-34, S-38 and S-39	**10.8**	---	---
	Total Loads from EPA	**12.2**	---	---

Table 2-4. WY2004 summary of flow and total phosphorus by structure.

Into WCA1

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
G300 & G301	17	3104	148
from EAA	*15.732*	*2629*	*135*
from Lake O	*0.025*	*16*	*526*
from East Beach	*1.219*	*449*	*299*
from inflow Basin	*0.025*	*11*	*361*
G251 (from STA-1W)	55	3000	44
G310 (from STA-1W)	243	14061	47
ACME1 (from Basin B)	10	890	72
ACME2 (from Basin B)	10	1227	101
Total	**335**	**22282**	**54**

From WCA1

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
S10A	9	665	57
S10C	8	436	42
S10D	60	5292	72
S10E	0	0	n/a
S39	136	4201	25
G300	1	110	89
G301	30	1463	39
G94C	26	3829	120
Total	**271**	**15996**	**48**

Into WCA2

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
G335 (from STA-2)	285	5031	14
S7	156	8578	44
From EAA	*149.440*	*7189*	*39*
from Lake O	*6.560*	*1389*	*172*
S10A (from WCA1)	9	665	57
S10C (from WCA1)	8	436	42
S10D (from WCA1)	60	5292	72
S10E (from WCA1)	0	0	n/a
N. Springs Improv. District	0	0	n/a
Total	**517**	**20002**	**31**

From WCA2

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
S7	2	80	32
S11A	47	1003	17
S11B	108	1983	15
S11C	122	4504	30
S38	144	2331	13
S34	151	4261	23
Total	**574**	**14162**	**20**

Into WCA3

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
S140 (from L28 Canal)	136	7018	42
S190 (from Feeder Canal)	118	14410	99
L3 Borrow Canal (from C139)	38	10827	233
STA6	35	512	12
S8	352	30862	71
From EAA	*210.001*	*10455*	*40*
From Lake O	*20.174*	*4355*	*175*
From C-139	*12.495*	*3156*	*205*
From STA-5	*109.482*	*12881*	*95*
From Rotenberger	*0.212*	*14*	*53*
G204 (from Holey Land)	*0*	*0*	*n/a*
S150 (from EAA)	10	454	36
G404 & G357	67.143	3479	42
From EAA	*44.478*	*735*	*13*
From C-139	*0.629*	*159*	*205*
From STA-5	*21.897*	*2576*	*95*
from Rotenberger	*0.140*	*9*	*53*
S11A (from WCA2)	47	1003	17
S11B (from WCA2)	108	1983	15
S11C (from WCA2)	122	4504	30
G123 (from N. New River)	2	46	16
S9 (from C-11 West)	150	3387	18
S9A (from C-11 West)	108	1735	13
Total	**1293**	**80220**	**50**

From WCA3

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
S150	0	0	n/a
S8	0	0	n/a
G204	0	0	n/a
S31	32	No data	No data
S337	2	No data	No data
S343A	6	68	9
S343B	8	90	9
S344	4	47	9
S12A	103	990	8
S12B	98	782	6
S12C	302	2767	7
S12D	335	4521	11
S333	175	2328	11
S14	0	0	n/a
Total	**1031**	**11593**	**9**

Into Everglades National Park

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
S12A (from WCA3)	103	990	8
S12B (from WCA3)	98	782	6
S12C (from WCA3)	302	2767	7
S12D (from WCA3)	335	4521	11
Tamiami Canal	79	927	11
S14 (from WCA3)	0	0	n/a
S174 (from L-31W)	5	42	6
S332D (from L-31W)	128	908	6
C-111 Canal	156	1832	9
Total	**1206**	**12769**	**9**

From ENP

Structure	Flow	Phosphorus	
	1000 ac-ft	Load (kg)	FWMC (ppb)
Total	**0**	**0**	**n/a**

FWMC = flow-weighted mean concentration

Note: Inflow to ENP from Tamiami Canal is calculated as the difference between S-333 and S-334, using the S-333 concentration.
Inflow to ENP from C-111 Canal is calculated as the difference between S-18C and S-197, using the S-18C concentration.

Comparison of WY2004 Phosphorus Loads to 1979–1988 Baseline

The following section provides an overview of phosphorus loading into the EPA for WY2004. The period from October 1978 through September 1988 has been identified as a comparative baseline period (known as the 1979–1988 baseline period) for various planning purposes, including the Surface Water Improvement and Management Act (SWIM) Plan for the Everglades (SFWMD, 1992a, 1992b, and 1992c), the design of the Everglades Construction Project, the federal Settlement Agreement, and the EFA, as amended.

During this 10-year period, annual phosphorus loads in surface inflows to the EPA ranged from approximately 100 mt to over 350 mt, with an average of 270 mt (1992 Everglades SWIM Plan). Included in this 270-metric ton annual average were approximately 205 mt to the WCAs from the EAA, Lake Okeechobee, and the L-8 and C-51W basins through the S-5A, S-6, S-7, S-150, and S-8 structures. This 205-metric ton annual average for this 10-year baseline period was the basis of design for the four original STAs of the federal Settlement Agreement. During the 1979–1988 baseline period, phosphorus loads in surface inflows to the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge) ranged from approximately 40 mt to over 150 mt per year, with a 10-year average of about 110 mt per year (SFWMD, 1992a and 1992b). Included in this 110-metric ton annual average were approximately 105 mt from the EAA, Lake Okeechobee, and the L-8 and C-51W basins through the S-5A and S-6 pump stations. This 105-metric ton annual average for the 10-year baseline period to the Refuge was the basis of design for the original STA-1 and STA-2 in the Settlement Agreement.

Appendix C of the Settlement Agreement identifies several assumptions which, when combined in series, are expected to yield approximately an 80-percent reduction of phosphorus loads from the EAA to the WCAs. These assumptions include the following:

- The EAA BMPs will achieve 25-percent load reduction.
- Water retention due to implementation of EAA BMPs will equal 20 percent of the 10-year base flow.
- The STAs will achieve 70-percent load reduction.
- A further load reduction of 6 percent was assumed by conversion of existing agricultural land to STAs.

Because no long-term performance results for BMPs and STAs at this scale were available, these assumptions were based on the best professional judgment at the time (1991) of the technical group developing the load reduction estimates. From 1994–2004, the actual BMP reduction was approximately 50 percent, or twice the assumed reduction. The water retention due to implementation of EAA BMPs has averaged about 5 percent, much less than assumed, while the STAs have achieved the assumed reduction of 70 percent. It is impossible to compare the actual load reduction attributable to conversion of lands to STAs; however, the 6 percent compares well with the percent of land taken out of production. For modeling purposes associated with Appendix C, the historical load and flow from each basin were reduced to account for low-flow water-supply deliveries from Lake Okeechobee, i.e., canal flows that do not impact WCA marshes. The STAs were then sized to achieve a long-term, annual flow-weighted mean concentration of 50 ppb at each inflow point. Accomplishment of the 50-ppb objective was assumed to provide the load reduction of approximately 80 percent from the EAA into the EPA. Using the loads that occurred during the baseline period (1979–1988) and the Appendix C assumptions, the anticipated 10-year average load equating to this 80-percent reduction is approximately 40.2 mt from the EAA to the WCAs.

Similarly, the Settlement Agreement also envisions an approximate 85-percent reduction of phosphorus loads from the EAA to the Refuge, if the STAs achieve a long-term annual flow-weighted mean concentration of 50 ppb. Using the loads that occurred during the baseline period (1979–1988) and the Appendix C assumptions, the anticipated 10-year average load equating to this 85-percent reduction is approximately 15.5 mt from the EAA to the Refuge.

In 2002, the Technical Oversight Committee (TOC) established, pursuant to the Settlement Agreement, a methodology developed by Walker (1996) for reviewing the load reductions based on annual phosphorus concentrations of water entering the WCAs and the Refuge. This methodology assumes compliance with the reduction requirements, unless the annual phosphorus inflow concentration to the WCAs (and the Refuge) from the EAA and bypassed flows is greater than 76 ppb in any water year, or is greater than 50 ppb in three or more consecutive water years (Walker, 1996). Compliance will not be tested in water years when the EAA adjusted annual rainfall is above 63.8 inches, as defined in the SFWMD's Rule 40E-63 (http://fac.dos.state.fl.us/faconline/chapter40.pdf). Compliance will also not be tested in water years when the EAA adjusted rainfall is below 35.1 inches, if sufficient water is not available to maintain wet conditions in the STAs. The following discussion of the water year loads does not substitute for the compliance review activities of the TOC, but is simply a public presentation of relevant data as requested by the TOC.

Phosphorus loads to the EPA during WY2004 were significantly lower than the 1979–1988 baseline period, due primarily to a reduction in the volume of Lake Okeechobee discharges sent to the Everglades during the year. Future years may have more or less Lake Okeechobee releases in response to stages in the lake. As shown in **Tables 2C-3** and **2C-4**, phosphorus loads from surface sources to the EPA totaled approximately 112 mt, with a flow-weighted mean concentration of 43 ppb. Another 193 tons of phosphorus is estimated to have entered the EPA through atmospheric deposition. Surface water discharges from the EPA account for approximately 12.2 tons. The 112-ton surface inflow is an almost 18-percent reduction from the previous year (136 mt). It should be recognized that not all of this load came from the EAA. Phosphorus loads to the WCAs from the EAA were calculated as:

- A proportion of STA-1W and STA-2 discharges, adjusted to reflect contributions from non-EAA sources [STA-1W (from EAA: 82 percent), STA-2 (from EAA: 97 percent)]
- STA-6 discharges
- Direct EAA discharges from the S-7, S-8, S-150, G-300, and G-301 structures

Phosphorus loads to the WCAs from the EAA during WY2004 totaled about 40.8 mt, slightly lower than the previous year. The three-year-average load to the WCAs from the EAA is approximately 38 mt, which is slightly lower than the expected 10-year average of 40.2 mt. This relatively low average load is significant considering that STA-1E and STA-3/4 were not fully operational during WY2004. The flow-weighted mean phosphorus concentration entering the WCAs from the EAA, STA-1W, STA-2, STA-3/4, STA-6, and bypass flows during WY2004 was approximately 38 ppb, which is below the annual maximum of 76 ppb established by the TOC methodology.

Phosphorus loads from all sources to the Refuge during WY2004 totaled approximately 22.3 mt, which is an almost 50-percent reduction from the previous year (43.4 mt). A portion of this load was recirculated into STA-1W from the Refuge during a two-week flow test. The phosphorus load to the Refuge from the EAA during WY2004 was approximately 17 mt, including more than 3 mt that were diverted directly into the Refuge because insufficient hydraulic capacity existed in the inflow structure to STA-1W; some of this load could have been captured and treated in STA-1E had it been in flow-through operation. The three-year average of loads from the EAA to the Refuge was 15.4 mt, slightly below the anticipated 10-year average load of 15.5 mt. The flow-weighted mean phosphorus concentration for WY2004 from STA-1W into the Refuge was 47 ppb; the 10-year (1994–2004) flow-weighted mean phosphorus concentration from STA-1W into the Refuge was 38 ppb, 24-percent lower than the 50-ppb objective in the Settlement Agreement. The flow-weighted mean phosphorus concentration entering the Refuge from the EAA, STA-1W, and bypass flows during WY2004 was approximately 52 ppb, which is below the annual maximum of 76 ppb established by the TOC methodology and slightly lower than the 54 ppb observed during the previous water year. If STA-1E had been in flow-through operation during this period, then the total TP load and concentration from the EAA to the Refuge would have been reduced.

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). For the *2005 South Florida Environmental Report*, TN values were calculated only for samples for which both TKN and NO_3+NO_2 results were available. **Table 2C-5** provides a summary of the TN concentrations measured in the different portions of the EPA during WY2004, WY2003, and the WY1978–WY2002 historical period. Mean and median TN concentrations measured across all portions of the EPA during WY2004 were similar to or slightly lower than those observed during WY2003 and the historical period from WY1978 through WY2001. During WY2004, mean TN concentrations at inflow stations ranged from 0.9–2.2 milligrams per liter (mg/L), and median TN concentrations ranged from 0.8–2.0 mg/L. Similarly, mean TN concentrations at the interior marsh stations during WY2003 ranged from 1.1–2.1 mg/L, and median TN concentrations ranged from 1.1–2.0 mg/L.

As in previous years, TN concentrations in the EPA exhibited a north-to-south gradient during WY2004. This gradient likely reflects the higher concentrations associated with agricultural discharges to the northern portions of the system. A gradual reduction in TN levels results from assimilative processes in the marsh as water flows southward. The highest average TN concentrations were observed in the inflows to the Refuge and WCA-2, and decreased to a minimum concentration in the Park.

Table 2C-5. Summary of TN concentrations (mg/L) measured in the EPA during WY2004, WY2003, and WY1978–WY2002.

Region	Class	Period	Sample Size (N)	Arithmetic Mean (mg/L)	Std. Deviation	Median (mg/L)	Min. (mg/L)	Max. (mg/L)
Refuge	Inflow	1978–2002	2710	3.5	2.3	2.9	0.3	48.2
		2003	75	1.8	0.5	1.7	1.2	3.3
		2004	77	2.2	0.5	2.2	1.2	3.4
	Interior	1978–2002	1833	1.6	1.3	1.3	0.5	36.7
		2003	203	1.4	0.4	1.4	0.7	2.6
		2004	204	1.4	0.5	1.3	0.6	3.2
	Outflow	1978–2002	1190	2.7	1.7	2.3	0.3	22.8
		2003	69	1.7	0.4	1.6	1.0	3.2
		2004	64	1.9	0.5	1.7	1.3	3.3
	Rim	1978–2002	668	2.7	1.4	2.3	0.7	10.9
		2003	20	1.8	0.4	1.7	1.5	2.7
		2004	22	2.6	0.5	2.7	1.9	3.3
WCA-2	Inflow	1978–2002	1779	2.9	1.5	2.6	0.3	22.8
		2003	110	2.2	0.9	2.0	1.0	5.7
		2004	109	2.5	0.9	2.3	1.3	5.2
	Interior	1978–2002	4063	2.5	1.7	2.2	0.3	37.2
		2003	241	2.1	0.6	2.0	1.1	4.6
		2004	219	1.9	0.7	1.9	0.8	5.6
	Outflow	1978–2002	1453	2.1	0.9	2.0	0.3	7.7
		2003	63	1.9	0.5	1.8	1.1	4.0
		2004	74	1.8	0.6	1.6	1.1	4.3
WCA-3	Inflow	1978–2002	4552	2.0	1.0	1.8	0.3	10.8
		2003	242	1.7	0.7	1.5	0.9	5.3
		2004	242	1.7	0.7	1.4	0.9	5.8
	Interior	1978–2002	1686	1.6	0.9	1.3	0.3	10.0
		2003	282	1.3	0.3	1.2	0.7	2.1
		2004	304	1.1	0.3	1.1	0.6	2.6
	Outflow	1978–2002	3016	1.4	0.7	1.4	0.3	14.9
		2003	155	1.0	0.3	1.0	0.6	2.1
		2004	155	1.0	0.3	0.9	0.5	2.0
Park	Inflow	1978–2002	3477	1.3	0.7	1.2	0.3	14.9
		2003	174	0.9	0.3	0.9	0.4	2.1
		2004	177	0.9	0.3	0.8	0.4	2.0
	Interior	1978–2002	1412	1.4	1.4	1.1	0.3	40.8
		2003	79	1.1	0.4	1.1	0.4	2.8
		2004	81	1.0	0.3	0.9	0.5	1.7

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