Chapter 3A: Water Quality in the Everglades Protection Area

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SUMMARY

This chapter is intended to (1) provide an assessment of water quality within the Everglades Protection Area (EPA) during Water Year 2013 (WY2013) (May 1, 2012–April 30, 2013), (2) fulfill numerous reporting requirements of the Everglades Forever Act (EFA), (3) provide a preliminary assessment of total phosphorus (TP) criterion achievement, and (4) provide an annual update of the comprehensive overview of nitrogen and phosphorus concentrations and loads throughout the EPA. The information provided in this chapter is an update to Chapter 3A of the *2013 South Florida Environmental Report* (SFER) – *Volume I*.

WATER QUALITY CRITERIA EXCURSION ANALYSIS

The analyses and summaries presented provide a synoptic view of water quality conditions in the EPA on a regional scale, including the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge, also known as WCA-1), Water Conservation Areas 2 and 3 (WCA-2 and WCA-3, respectively), and Everglades National Park (ENP or Park). For parameters with water quality criteria, regional analyses were conducted based on the frequency of exceedances of the applicable criteria, similar to the methods employed in the 1999 Everglades Interim Report, 2000–2004 Everglades Consolidated Reports, and 2005–2013 SFERs. For WY2013, water quality parameters that did not meet existing standards were classified based on excursion frequencies that were statistically tested using the binomial hypothesis test. These categories are (1) concern – any parameter with a criterion exceedance frequency statistically greater than 10 percent, (2) potential concern – any parameter with an exceedance frequency statistically greater than 5 percent but less than 10 percent, and (3) minimal concern – any parameter with an exceedance frequency less than 5 percent but greater than zero.

Similar to the last several years with a few exceptions, water quality was in compliance with existing state water quality criteria during WY2013. During WY2013 excursion of applicable Class III water quality criteria for four parameters were observed, these parameters include dissolved oxygen (DO), alkalinity, pH, and specific conductance. Similar to previous periods, these excursions were localized to specific areas of the EPA, and all of these parameters exhibited excursions in previous water years.

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For WY2013, a summary of the DO, alkalinity, pH, specific conductance, and un-ionized ammonia excursions, as well as the status of pesticides, phosphorus, and nitrogen within the EPA, is presented below.

- Due to excursions of the site-specific alternative criterion, DO was classified as a potential concern for interior portion of the Refuge, WCA-2 and WCA-3 interior. Inflow, outflow, and Rim Canal monitoring locations were assessed using the current Class III water quality standard, which states that DO shall not be below 5 milligrams per liter (mg/L). The inflow, outflow, and Rim Canal region for all areas were also classified as a concern for DO.
- Alkalinity and pH criteria exceedances were observed in the Refuge; however, the Florida Department of Environmental Protection (FDEP) considers the relatively low values to be representative of the range of natural conditions for this ecosystem. Therefore, they are not considered violations of state water quality standards. Exceedances of the pH criterion resulted in areas and regions being classified as minimal concern including the Refuge inflow and interior and WCA-3 inflow.
- Specific conductance was categorized as a concern for the Refuge inflows and minimal concern for WCA-2 inflow and interior regions.
- No exceedances of total iron, turbidity, or un-ionized ammonia were observed throughout the EPA during WY2013.
- No pesticides or pesticide breakdown products exceeded their respective toxicity guideline concentrations, and no parameters exceeded state water quality standards. However, several pesticides or pesticide breakdown products were detected at levels above their method detection limit (MDL), including 2,4-D, ametryn, atrazine, atrazine desethyl, metolachlor, metribuzin, and norflurazon.
- TP concentrations were highest in Refuge inflows and lowest within the Park. Annual geometric mean inflow[3] TP concentrations ranged from 30.7 micrograms per liter (µg/L) for the Refuge to 8.2 µg/L for the Park. Annual geometric mean TP concentrations at interior regions ranged from 8.5 µg/L in the Refuge to 3.7 µg/L in the Park. Annual geometric mean TP concentrations for individual interior marsh monitoring stations ranged from less than 3.0 µg/L in some unimpacted portions of the marsh to 29.0 µg/L at sites that are highly influenced by canal inputs. Of the interior marsh sites, 80.4 percent exhibited annual geometric mean TP concentrations of 10.0 µg/L or less and 92.4 percent of the marsh sites having annual geometric mean TP concentrations of 15.0 µg/L or less.
- Annual geometric mean inflow orthophosphate (OP) concentrations ranged from 4.6 µg/L for the Refuge to less than 2.0 µg/L for the Park. The annual geometric mean interior OP concentrations for all regions of the EPA were less than 2.0 µg/L during WY2013.
- Similar to previous years' reporting, the five-year (WY2009–WY2013) TP criterion assessment results indicate that unimpacted portions of each Water Conservation Area (WCA) passed all four parts of the compliance test. In contrast, impacted portions of each water body failed one or more parts of the test. The impacted portions of the WCAs routinely exceeded the annual and five-year network TP concentration limits of 11 µg/L and 10 µg/L, respectively.
- TP loads from surface sources, including internal transfers within the EPA, totaled approximately 88.4 metric tons (mt), with a flow-weighted mean concentration (FWM) of

[3] In most cases, geometric mean concentrations do not compare (i.e., 1:1 relationship) to flow-weighted mean concentrations.

18 µg/L. Another 193 mt of TP are estimated to have entered the EPA through atmospheric deposition. The 88.4 mt TP load in the surface inflows to the EPA represents an increase of approximately 92 percent compared to the previous year (46.2 mt in WY2012).

- Annual geometric mean inflow total nitrogen (TN) concentrations ranged from 2.16 mg/L for the Refuge to 0.96 mg/L for the Park. The annual geometric mean TN concentration at interior marsh regions ranged from 1.73 mg/L for WCA-2 to 0.97 mg/L for the Park during WY2013.
- TN loads from surface sources, including internal transfers within the EPA totaled approximately 6,795 mt, with a FWM concentration of 1.41 mg/L. Another 4,664 mt of TN are estimated to have entered the EPA through atmospheric deposition. The 6,795 mt TN load in the surface inflows to the EPA represent an increase of approximately 62 percent compared to the previous year (4,197 mt in WY2012).
- During WY2013, Tropical Storm Isaac contributed significant quantities of rainfall to South Florida, resulting in the operation of diversion structures flowing into the Refuge. Related water quality parameters, flow, TP load and TN load are summarized in this chapter.

PURPOSE

The primary purpose of this chapter is to provide an assessment of water quality within the Everglades Protection Area (EPA) during Water Year 2013 (WY2013) (May 1, 2012–April 30, 2013) and an update to the information provided in Chapter 3A of the *2013 South Florida Environmental Report* (SFER) – *Volume I*. Notably, in this year's reporting the assessment of sulfate (SO_4^{2-}) within the EPA is covered in Chapter 3B of this volume due to the link between SO_4^{2-} concentrations and mercury methylation.

The chapter is intended to fulfill the Everglades Forever Act (EFA) requirement for an annual report to "identify water quality parameters, in addition to phosphorus, which exceed state water quality standards or are causing or contributing to adverse impacts in the Everglades Protection Area." In addition, this chapter provides an annual update of the comprehensive overview of nitrogen and phosphorus concentrations and loads throughout the EPA along with an assessment of total phosphorus (TP) criterion achievement utilizing the protocol provided in the *2007 SFER – Volume I, Chapter 3C*.

More specifically, this chapter and its associated appendices use water quality data collected during WY2013 to achieve the following objectives:

1. Summarize areas and times where water quality criteria are not being met, and indicate trends in excursions over space and time.
2. Discuss factors contributing to excursions from water quality criteria, and provide an evaluation of natural background conditions where existing standards may not be appropriate.
3. Present an updated review of pesticide and priority pollutant data made available during WY2013.
4. Present a preliminary TP criterion achievement assessment for different areas within the EPA for the most recent five-year period (i.e., WY2009–WY2013).
5. Summarize phosphorus and nitrogen concentrations measured in surface waters within different portions of the EPA.
6. Summarize the flow and phosphorus loads entering different portions of the EPA during WY2013, and describe spatial and temporal trends observed.
7. Describe and discuss factors contributing to any spatial and temporal trends observed.

METHODS

A regional synoptic approach similar to that used for water quality evaluations in previous SFERs was applied to phosphorus and nitrogen data for WY2013 to provide an overview of water quality status within the EPA. Consolidating regional water quality data provides the ability to analyze data over time but limits spatial analyses within each region. However, spatial analyses can be made between regions because the majority of inflow and pollutants enter the northern third of the EPA, and the net water flow is from north to south.

AREA OF INTEREST

The EPA is a complex system of marsh areas, canals, levees with inflow and outflow water control structures that covers almost 2.5 million acres (1 acre = 0.405 hectare) of former Everglades marsh and currently is divided into large separate distinct shallow impoundments (Bancroft et al., 1992). In addition to rainfall inputs, surface water inflows regulated by water control structures from agricultural tributaries, such as the Everglades Agricultural Area (EAA) to the north and the C-139 basin to the west, feed the EPA. 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. The major features of the EPA and surrounding area are illustrated in Figure 1-1.

WATER QUALITY SAMPLING STATIONS IN THE EPA

To efficiently assess annual water quality standard violations and long-term trends, a network of water quality sampling sites has been identified (**Figures 3A-1** through **3A-4**). These sites are part of the South Florida Water Management District's (SFWMD or District) long-term monitoring projects and are monitored for different purposes. These stations were carefully selected to be representative of either the EPA boundary conditions (i.e., inflow or outflow) or ambient marsh conditions (interior). Furthermore, an effort has been made to utilize a consistent group of stations among previous annual consolidated reports to ensure consistent and comparable results. As the naming convention for monitoring stations within the EPA has changed throughout the progression of the monitoring periods, Appendix 3A-1, Table 2, provides cross-reference table for each stations identifier. Every attempt is made to maintain the same sampling frequency for the network of monitoring sites to ensure a consistent number of samples across years and the data available for each year undergo the same careful quality assurance/quality control (QA/QC) screening to assure accuracy.

Water quality sampling stations located throughout the Water Conservation Areas (WCAs) and Everglades National Park (ENP or Park) were categorized as inflow, interior, or outflow stations within each region based on their location and function (**Figures 3A-1** through **3A-4**). This organization of monitoring sites allows a more detailed analysis of the water quality status in each region of the EPA and assists in the evaluation of potential causes for observed excursions from Class III water quality criteria.

Several interior structures convey water between different regions in the EPA and therefore are designated as both inflow and outflow stations based on this categorization system. For example, the S-10 structures act as both outflow stations for the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge, also known as WCA-1) and inflow sites to Water Conservation Area 2 (WCA-2) (**Figures 3A-1** and **3A-2**). The interior sites of each region consist of marsh and canal stations as well as structures that convey water within the area.

In addition to inflow, outflow, and interior sites, the Refuge has a category for Rim Canal sites to account for water entering the Refuge interior from canals that border the east and west levees of the Refuge (**Figure 3A-1**). Waters discharged to the L-7 Rim Canal will either overflow into the Refuge interior when canal stages exceed the levee height or will bypass the marsh and be discharged to WCA-2A through the S-10 structures. The extent (distance) to which Rim Canal overflows penetrate the marsh depends on the relative stages of the L-7 and L-40 Rim Canal and the Refuge interior.

The current District monitoring programs were described by Germain (1998). Sampling frequency varies by site depending on site classification, parameter group, and hydrologic conditions (e.g., water depth and flow). Water control structures (inflows and outflows) were typically sampled biweekly when flowing; otherwise, sampling was performed monthly. Generally, interior monitoring stations were sampled monthly for most parameters reported in this chapter. Pesticide monitoring is conducted across the entire District at 15 sites on a biannual basis. An overview of the water quality monitoring projects, including project descriptions and objectives with limited site-specific information, is available on the District’s website at www.sfwmd.gov/environmentalmonitoring.

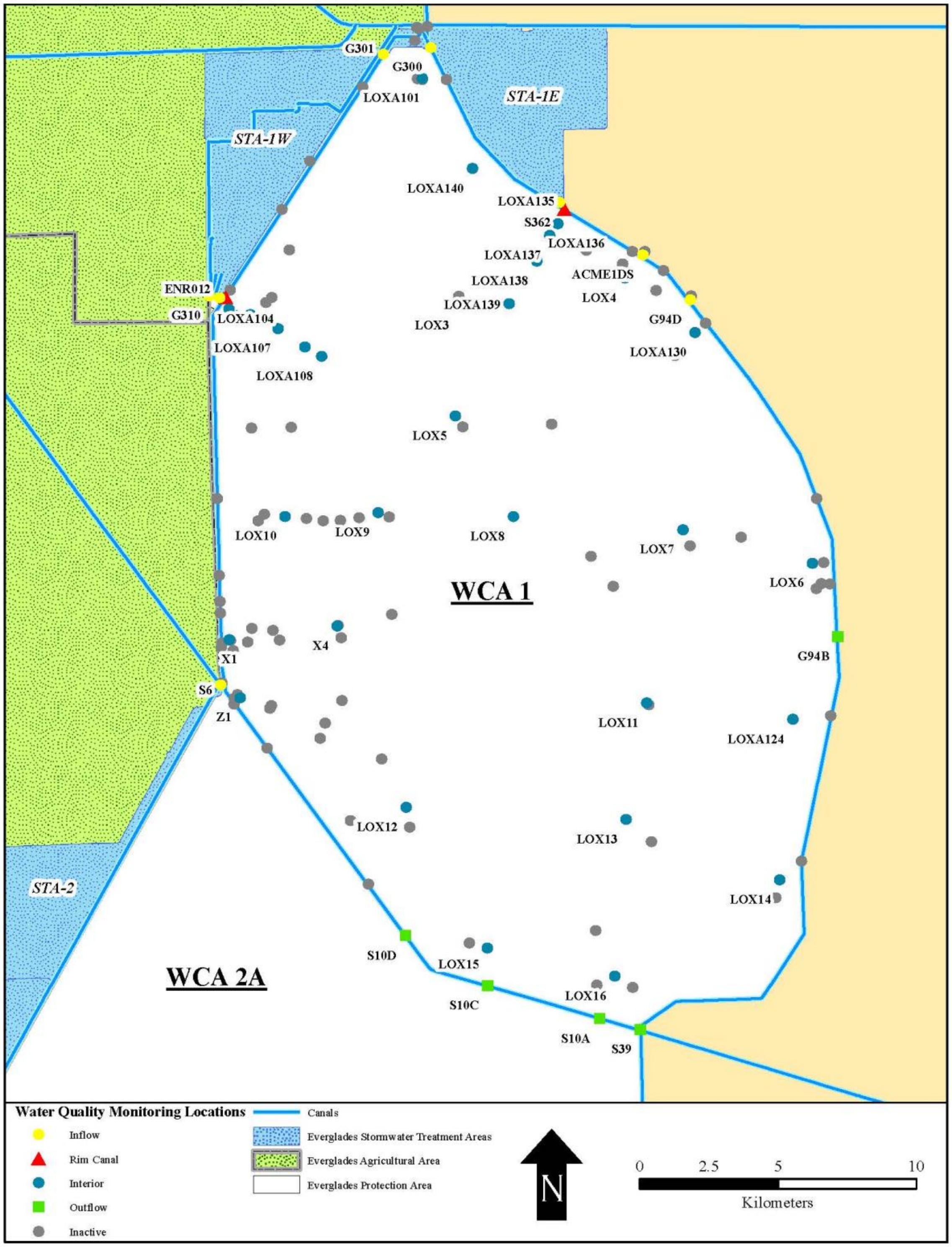

Figure 3A-1. Location and classification of water quality monitoring stations in the Water Conservation Area 1 (WCA-1)/Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge). [Note: Stations G300 and G301 located north of the Refuge are diversion structures and rarely exhibit flow into the Refuge.]

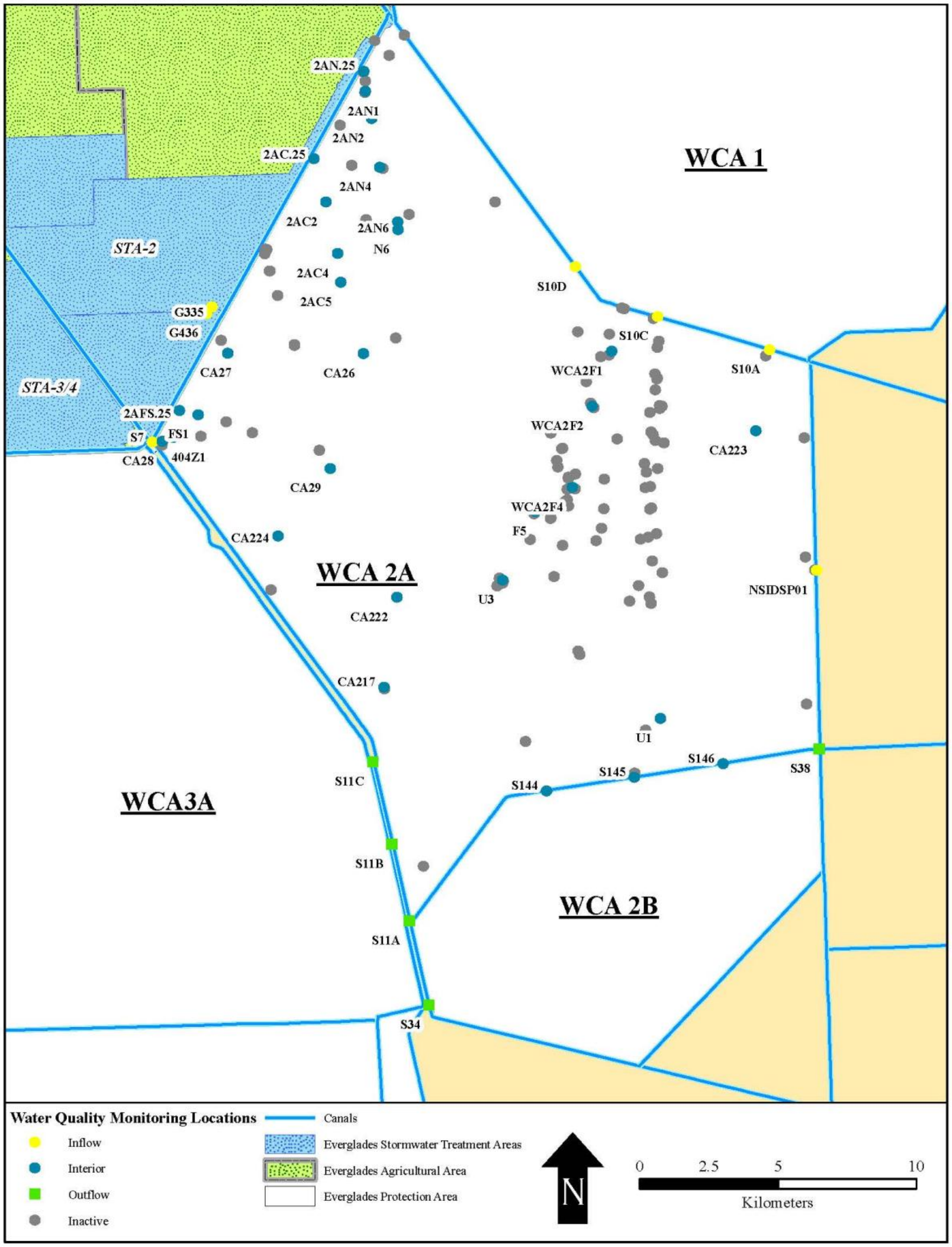

Figure 3A-2. Location and classification of water quality monitoring stations in Water Conservation Area 2 (WCA-2).

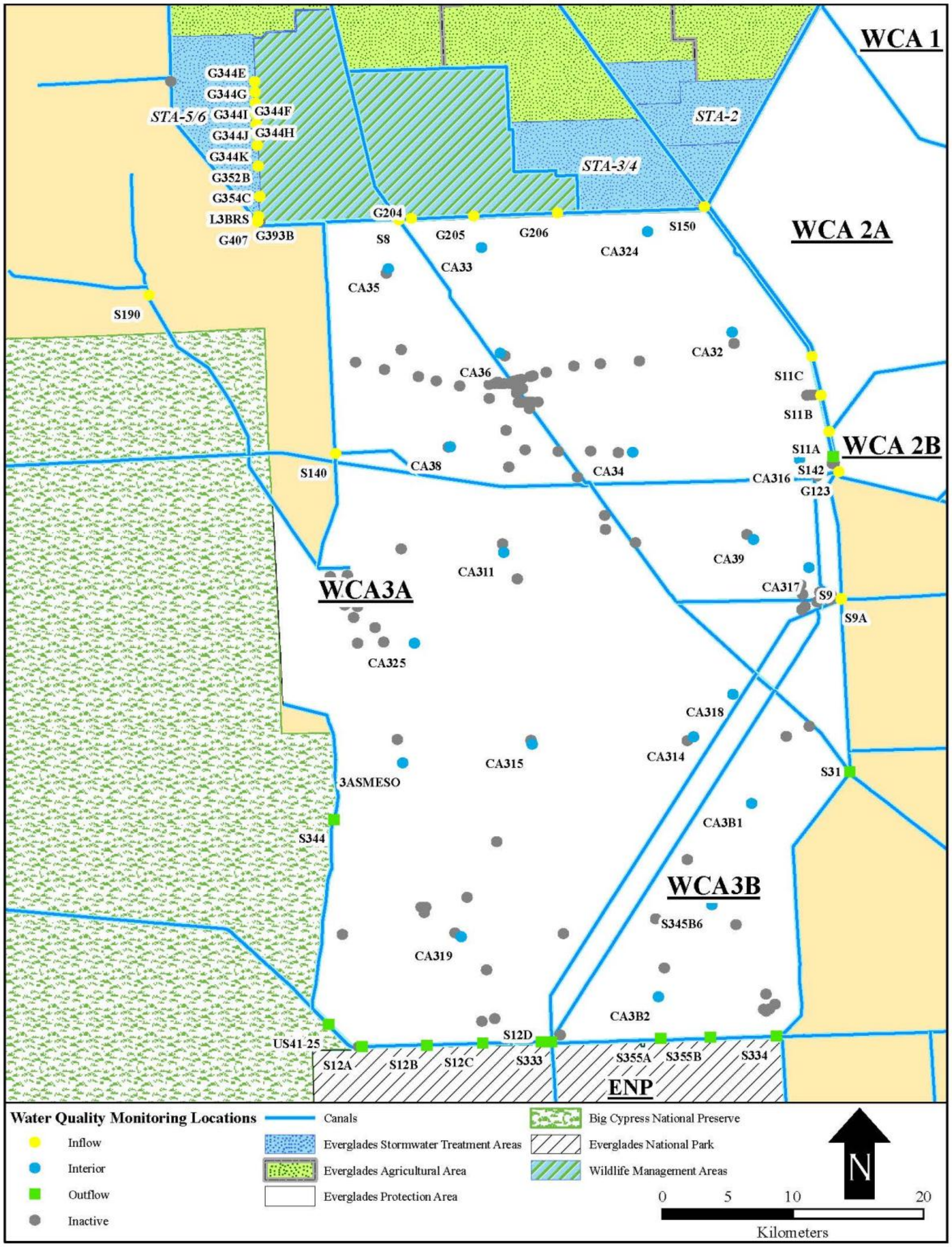

Figure 3A-3. Location and classification of water quality monitoring stations in Water Conservation Area 3 (WCA-3).

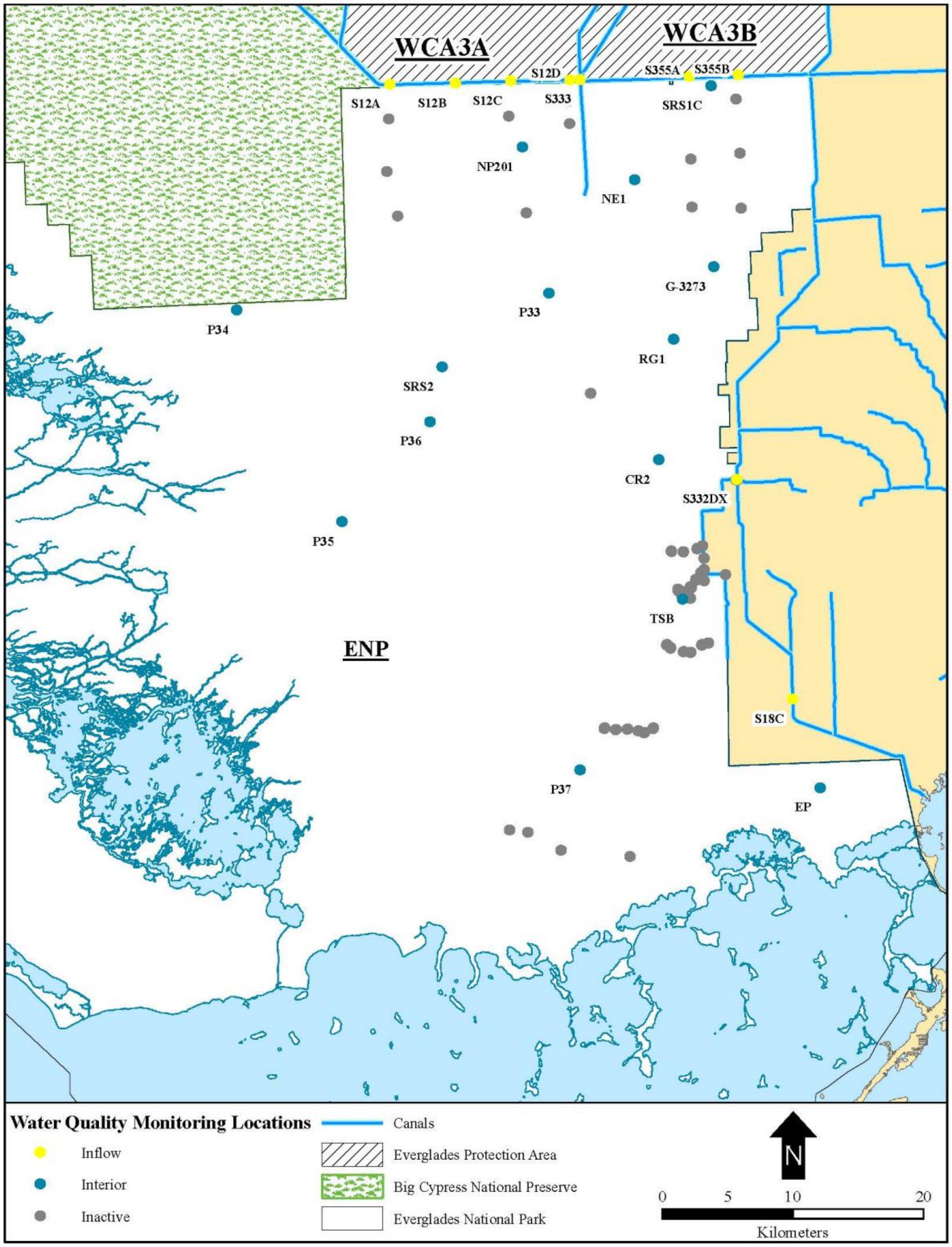

Figure 3A-4. Location and classification of water quality monitoring stations in Everglades National Park (ENP or Park).

ANALYSIS PERIODS

As previously noted, the primary focus of this chapter is to summarize the status of water quality within the EPA during WY2013 and to describe trends or changes in water quality conditions over time. To accomplish this objective, comparisons are made across discrete periods that correspond to major restoration activities occurring within the EPA. The four periods are (1) the historical WY1979–WY1993 period (Baseline), which corresponds to the timeframe prior to implementation of the EAA Best Management Practices (BMPs) Program and the Everglades Construction Project (i.e., the Stormwater Treatment Areas, or STAs), (2) the intermediate WY1994–WY2004 period (Phase I), (3) the Phase II BMP/STA implementation period after WY2004 (i.e., WY2005–WY2012), and (4) WY2013.

Phase I represents the period in which implementation of the EAA BMP Program was increasing, and all the initial STAs were constructed and became operational. The Phase II BMP/STA implementation period corresponds to when the performance of the BMPs and STAs were being optimized and enhanced. Additionally, during this period various restoration projects were being implemented under the Long-Term Plan for Achieving Water Quality Goals in the Everglades Protection Area (Long-Term Plan), Comprehensive Everglades Restoration Plan (CERP), and other state or federal restoration projects. Because optimization, enhancement, and other restoration activities are expected to continue for years, the Phase II period will continue to expand in future SFERs to incorporate additional years of sampling. In addition, data for the current water year (in this case, WY2013) will be used to make comparisons with the historical periods and will be analyzed independently as the fourth period. Individual station assessments and certain mandated reporting (e.g., TP criterion achievement) were based on the previous five water years (WY2009–WY2013) rather than on the single year used for regional analysis. Reporting periods are specified in each section of this chapter.

WATER QUALITY DATA SOURCES

The majority of the water quality data evaluated in this chapter were retrieved from the District's DBHYDRO database. Additionally, water quality data from the nutrient gradient sampling stations monitored by the District were obtained from the District's Water Resources Division database.

DATA SCREENING AND HANDLING

Water quality data were screened based on laboratory qualifier codes, consistent with the Florida Department of Environmental Protection (FDEP) Quality Assurance Rule [Chapter 62-160, Florida Administrative Code (F.A.C.)]. Any datum associated with a fatal qualifier (e.g., H, J, K, N, O, V, Q, Y, or ?) indicating a potential data quality problem was removed from the analysis (SFWMD, 2008). Values that exceeded possible physical or chemical measurement constraints (e.g., if resulting pH is greater than 14), had temperatures well outside seasonal norms (e.g., 6 degrees Celsius in July), or represented data transcription errors were excluded. Multiple samples collected at the same location on the same day were considered as one sample, with the arithmetic mean used to represent the sampling period.

Additional considerations in the handling of water quality data are the accuracy and sensitivity of the laboratory method used. 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 unless otherwise noted. All data presented in this chapter, including historical results, were handled consistently with regard to screening and MDL replacement.

WATER QUALITY DATA PARAMETERS

The District monitors 109 water quality parameters within the EPA (Payne and Xue, 2012). Given this chapter's focus on water quality criteria, the evaluation was primarily limited to parameters with Class III criteria pursuant to the FDEP's Surface Water Quality Standards Rule (Chapter 62-302, F.A.C.). The parameters evaluated in this chapter include 62 pesticides and the following water quality constituents:

- Alkalinity
- Dissolved oxygen (in situ)
- Specific conductance (in situ)
- pH (in situ)
- Total selenium*
- Total thallium*
- Total zinc*
- Turbidity
- Un-ionized ammonia
- Sulfate
- Total nitrogen [1]
- Total cadmium*
- Total iron
- Total lead*
- Total nickel*
- Total silver*
- Total antimony*
- Total arsenic*
- Total beryllium*
- Total copper*
- Total phosphorus
- Orthophosphate

[1] Total nitrogen as Total Kjeldahl Nitrogen + Nitrate/Nitrite

Parameters marked with asterisks (*) were not measured in WY2013. However, these have been analyzed and reported in previous SFERs and, if measured in the future, will be analyzed and reported in future SFERs.

WATER QUALITY CRITERIA EXCURSION ANALYSIS

The FDEP and the District have developed an excursion analysis protocol for use in the annual SFER (Weaver and Payne, 2005) to effectively provide a synoptic view of water quality criteria compliance on a regional scale [i.e., the Refuge, WCA-2, Water Conservation Area 3 (WCA-3), and the Park]. The protocol was developed to balance consistency with previous versions of the report, other State of Florida ambient water quality evaluation methodologies [e.g., Impaired Waters 303(d) designations], and the United States Environmental Protection Agency (USEPA) exceedance frequency recommendations, as well as provide a concise summary for decision makers and the public. This methodology ensures results will be compatible with information from other sources provided to water managers.

A multi-tiered categorical system was used in this chapter to rank the severity of excursions from state water quality criteria (see **Table 3A-2**). Categories were assigned based on sample excursion frequencies evaluated using a statistically valid assessment methodology (i.e., binomial hypothesis test) that accounted for uncertainty in monitoring data (Weaver and Payne, 2005). Parameters without excursions were categorized as no concern (NC) and are not discussed further in this chapter. Based on the results of the binomial test using a 90 percent confidence level, parameters with exceedance rates between 0 and 5 percent are classified as minimal concerns (MC), those with exceedance rates between 5 and 10 percent are classified as potential concerns (PC), and those with exceedance rates greater than 10 percent are classified as concerns (C).

Because exceedances of the pesticide criteria can result in more immediate and severe effects to aquatic organisms and human health, a 10 percent excursion frequency was not used in the assessment of pesticides as recommended by the USEPA (USEPA, 1997; 2002). Pesticides were evaluated under the assumption that the Class III criteria values represent instantaneous maximum concentrations for which any exceedance constitutes a non-attainment of designated use. Pesticides were categorized based on whether the parameter was detected at concentrations above the MDL (potential concern) or at concentrations exceeding Class III criteria or chronic toxicity values (concerns). Pesticides classified as concerns have a high likelihood of resulting in an impairment of the designated use of the water body. Classification of a pesticide as a potential concern signifies that the constituent is known to be present within the basin at concentrations reasonably known to be below levels that can result in adverse biologic effects but may result in a problem at some future date or in interaction with other compounds. The no concern category was used to designate pesticides that were not detected at sites within a given area.

The data sources as well as the data handling and evaluation methods employed in this chapter are identical to those used in previous SFERs. Greater detail concerning the methods used can be found in Weaver and Payne (2005) and Payne and Xue (2012).

PHOSPHORUS CRITERION ACHIEVEMENT ASSESSMENT

An evaluation to determine achievement of the TP criterion was performed in accordance with the protocol provided in Chapter 3C of the 2007 SFER – Volume I (Payne et al., 2007), and the four-part test specified in the FDEP's Water Quality Standards for Phosphorus within the Everglades Protection Area (Chapter 62-302.540, F.A.C.). The available data from the 58 sites comprising the TP criterion monitoring network for the most recent five-year period (i.e., WY2009–WY2013) were utilized in the evaluation. The location of the TP criterion network monitoring sites established pursuant to the TP criterion rule used for the TP criterion assessment along with their classification as "impacted" or "unimpacted" are provided in **Figure 3A-5**. Details concerning the selection of sites in the TP criterion monitoring networks and their classification can be found in Payne et al. (2007).

Data collection from the complete TP criterion monitoring network was initiated in January 2007. Due to the relatively recent inception of network monitoring, not all sites have data available for the full five-year assessment period. In addition, data availability is further limited for certain portions of the EPA due to extremely dry conditions that have prevailed during a number of years since WY2007. Because the results of the TP criterion compliance assessment presented in this chapter could be affected by these data limitations, this evaluation should be considered preliminary and the results cautiously interpreted. It is expected that future assessments will improve as additional datasets are added. Data were screened according to the QA/QC procedures described in the protocol on the FDEP's website at http://www.dep.state.fl.us/everglades/files/criterion_ScreeningProtocol.pdf or http://www.dep.state.fl.us/water/wqssp/docs/swqdocs/data-quality-screening-protocol.pdf

STATISTICAL ANALYSIS

Trend analysis was performed on annual geometric mean TP and total nitrogen (TN) concentrations for inflow and interior regions of the EPA using the Kendall's τ correlation analysis. Analysis of variance (ANOVA) was used to determine the difference of flow, TP and TN load between the analysis periods, for this analysis the current water year (WY 2013) was included in the Phase II period. To detect difference among means, Tukey-Kramer honestly significant difference (Tukey HSD) was used. Annual flow values for each region of the EPA were log-transformed; annual TP loads for WCA-2, WCA-3, and ENP were log-transformed, while annual load for the Refuge were square-root transformed. Annual TN inflow load for all areas were natural log transformed to fit the assumptions of the statistical test. All transformations were conducted to fit the assumptions of the statistical test. Linear regress was applied to WY2013 TN and total organic carbon (TOC) concentrations for interior portions of the EPA, all areas were aggregated for this analysis. TOC samples were not collected within ENP; therefore, this analysis is limited to the Refuge, WCA-2, and WCA-3. All statistical operations were performed with JMP® (Version 10.0.0, SAS, Cary, NC, USA). The critical level of significance was set at α=0.05.

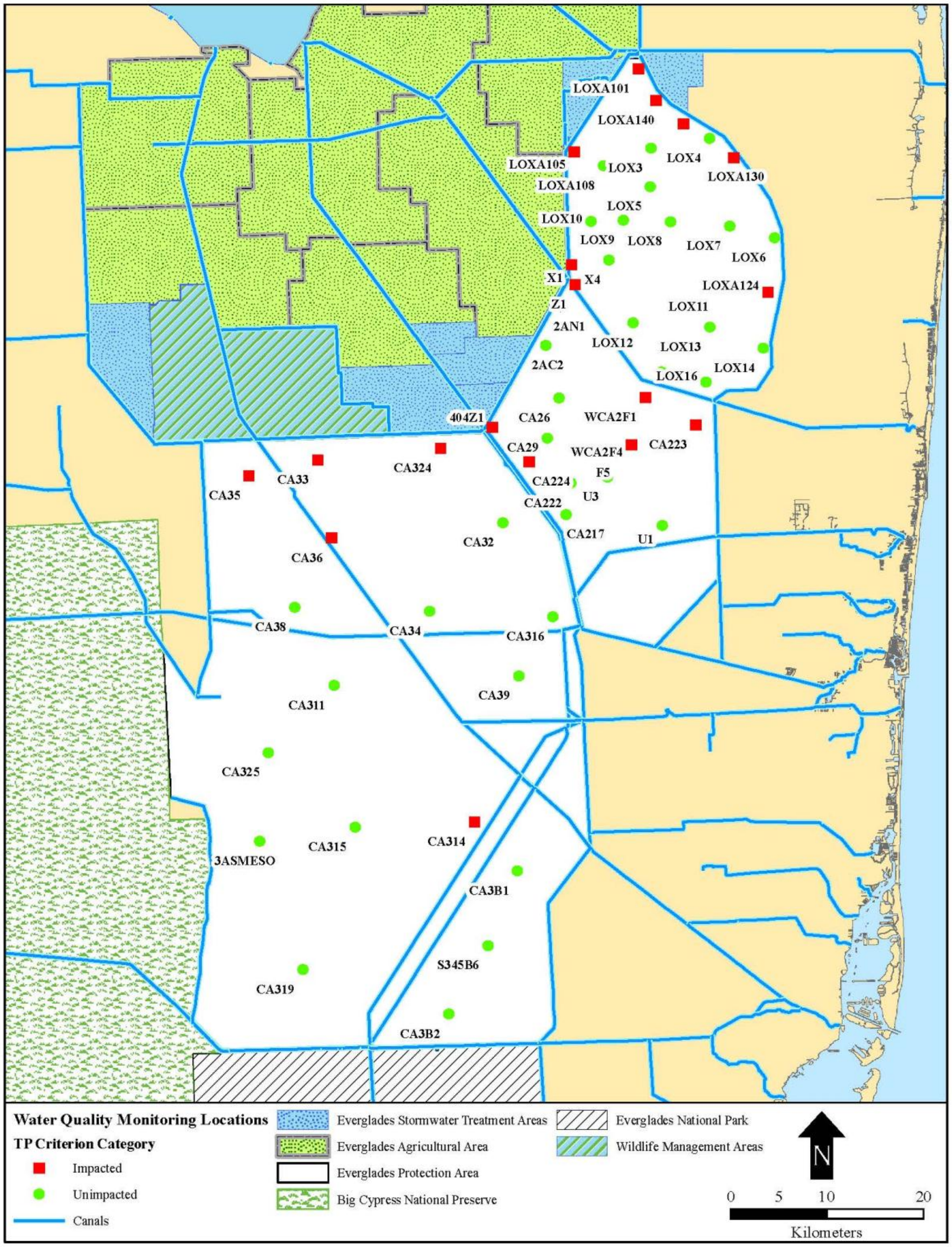

Figure 3A-5. Location of total phosphorus (TP) criterion assessment monitoring network sites used in the Water Year 2009–2013 (WY2009–WY2013) (May 1, 2008–April 30, 2013) evaluation.

WATER YEAR 2013 WATER QUALITY RESULTS

In WY2013, an average of 264 sampling days occurred throughout the EPA. The Refuge had the fewest number of sampling days with 163 sampling days; 164 sampling days occurred within WCA-2, and 365 sampling days occurred within WCA-3 and ENP. Due to the relatively wet start to the water year, monitoring at water control structures and interior marsh stations occurred at the start of the water year. Very few samples collected during WY2013 resulted in qualified data; 1.9 percent (836 qualified samples from a total of 43,883 samples collected) of the data collected was removed due to fatal qualifiers. The dominant qualifier was the J qualifier (estimated value).

DIVERSION EVENT – TROPICAL STORM ISAAC

Tropical Storm Isaac entered the southeastern Gulf of Mexico early on August 27, 2012, moving relatively slowly (Berg, 2013). Due to this slow movement, a nearly stationary rain band was established spanning southeastern Florida. This band produced 14.7 inches (37.3 centimeters) of rain between August 26 and 28 within the C-51 basin. The rainfall total for these three days was approximately a third of the District-wide average rainfall for WY2012 (see Chapter 2 of this volume). To maintain flood control, protect human health and safety in the S-5A and C-51 West basins, ensure safe operation of Stormwater Treatment Area 1 East (STA-1E) and Stormwater Treatment Area 1 West (STA-1W), and avoid conditions that would threaten the survival of STA vegetation and treatment efficiency, the District initiated diversions into the Refuge through the G-300 and G-301 structures (SFWMD, 2012).

From August 27–September 3, a total of 27.9 kacre-feet (1,000 acre-ft) passed through the G-300 and G-301 structures resulting in 13.1 metric tons (mt) of TP and 100.8 mt of TN entering the northern portion of the Refuge. Within this period, the flow-weighted mean (FWM) concentrations were 2.9 milligrams per liter (mg/L) and 382 micrograms per liter (µg/L) of TN and TP, respectively. None of the applicable water quality parameters exceed water quality standards with dissolved oxygen (DO) being the exception (**Table 3A-1**).

Table 3A-1. Descriptive statistics of water quality parameters collected at the G-300 and G-301 diversion structures during the Tropical Storm Isaac diversion event between August 27 and September 3, 2012.

Parameter	Units	Arithmetic Mean	Sample Size	Standard Deviation	Minimum	Maximum
Temperature	Degrees Celsius (°C)	26.6	6	1.8	24.9	28.9
Dissolved Oxygen	milligrams per liter (mg/L)	4.5	6	2.59	1.38	7.62
pH	standard units	7.4	6	0.34	7	7.8
Specific Conductivity	microsiemens per centimeter (µS/cm)	663.3	6	375.3	297	1173
Alkalinity	mg/L	97.5	2	19.1	84	111
Hardness	mg/L	143.6	2	57.42	103	184.2
Total Nitrogen	mg/L	4.9	2	5	1.4	8.4
Total Kjeldahl Nitrogen	mg/L	1.8	2	1.39	0.85	2.81
Nitrate + Nitrate (NOx)	mg/L	3.1	2	3.59	0.525	5.596
Ammonia	mg/L	0.2	2	0.07	0.11	0.21
Unionized Ammonia	mg/L	0.002	2	0.001	0.001	0.002
Dissolved Phosphorus	micrograms per liter (µg/L)	96	4	60	49	175
Ortho-Phosphorus	µg/L	86	4	60	38	166
Total Phosphorus	µg/L	302	6	150	109	480
Total Suspended Solids	mg/L	41.5	2	46	9	74

WATER QUALITY CRITERIA EXCURSION ANALYSIS

Summarized by region and classification, WY2013 data is included in Appendix 3A-1. Additionally data for the last five water years (WY2009–WY2013) summarized by region, class, and monitoring station is presented in Appendix 3A-2. Comparisons of WY2013 water quality data with applicable Florida Class III water quality criteria resulted in excursions for four water quality parameters: DO, alkalinity, pH, and specific conductance (**Table 3A-2**). Similar to previous periods, these excursions were generally isolated to specific areas of the EPA.

Water quality parameters with exceedances of applicable criteria are discussed in greater detail below with the excursion frequencies summarized for the Baseline through current water year periods (WY1979–WY1993, WY1994–WY2004, WY2005–WY2012, and WY2013) to evaluate the presence of any temporal trends (**Table 3A-2**). Meanwhile, sulfate summary statistics for the current water year summarized by region and classification is presented in Appendix 3A-1 and the last five water years summarized by monitoring station is provided in Appendix 3A-2. Historically, this chapter included a temporal and spatial trends analysis of SO_4^{2-} concentrations within the EPA; however, considering the link between SO_4^{2-} concentrations and mercury methylation, this information is now covered in Chapter 3B of this volume (see Table 3B-5).

Table 3A-2. Excursions from Florida Class III criteria in the Everglades Protection Area (EPA) for the Baseline period [Water Year (WY)1979–WY1993], Phase I (WY1994–WY2004), Phase II (WY2005–WY2012), and WY2013. [Note: A water year begins on May 1 and ends on April 30 of the following year.]

Area	Class	Parameter	Number of Excursions/Sample Size, Percent Excursions (Category)[1]			
			Baseline WY1979–WY1993	Phase I WY1994–WY2004	Phase II WY2005–WY2012	Current WY WY2013[4]
Refuge	Inflow	Alkalinity	3/1446, 0.2% (MC)	0/1153, 0% (NC)	0/961, 0% (NC)	0/112, 0% (NC)
		Dissolved Oxygen[3]	886/1129, 78.5% (C)	1768/2381, 74.3% (C)	1437/2436, 59% (C)	141/281, 50.2% (C)
		pH	8/1107, 0.7% (MC)	4/2155, 0.2% (MC)	6/1752, 0.3% (MC)	1/178, 0.6% (MC)
		Specific Conductance	481/1122, 42.9% (C)	371/2158, 17.2% (C)	232/1755, 13.2% (C)	24/178, 13.5% (C)
		Unionized Ammonia	25/1083, 2.3% (MC)	7/1640, 0.4% (MC)	6/863, 0.7% (MC)	0/63, 0% (NC)
	Interior	Alkalinity	103/387, 26.6% (C)	479/1156, 41.4% (C)	311/1213, 25.6% (C)	66/135, 48.9% (C)
		Dissolved Oxygen[2]	8/30, 26.7% (C)	21/140, 15% (C)	51/247, 20.6% (C)	4/28, 14.3% (PC)
		pH	59/253, 23.3% (C)	131/1394, 9.4% (PC)	69/2007, 3.4% (MC)	8/278, 2.9% (MC)
		Specific Conductance	6/153, 3.9% (MC)	1/1365, 0.1% (MC)	0/1927, 0% (NC)	0/296, 0% (NC)
		Unionized Ammonia	1/189, 0.5% (MC)	1/1115, 0.1% (MC)	0/1061, 0% (NC)	0/110, 0% (NC)
	Outflow	Alkalinity	1/591, 0.2% (MC)	0/709, 0% (NC)	0/352, 0% (NC)	0/64, 0% (NC)
		Dissolved Oxygen[3]	403/605, 66.6% (C)	443/697, 63.6% (C)	211/497, 42.5% (C)	41/82, 50% (C)
		pH	1/590, 0.2% (MC)	4/692, 0.6% (MC)	1/503, 0.2% (MC)	0/88, 0% (NC)
		Specific Conductance	128/607, 21.1% (C)	21/696, 3% (MC)	1/501, 0.2% (MC)	0/88, 0% (NC)
		Unionized Ammonia	8/587, 1.4% (MC)	4/670, 0.6% (MC)	0/346, 0% (NC)	0/64, 0% (NC)
	Rim	Dissolved Oxygen[3]	41/96, 42.7% (C)	350/455, 76.9% (C)	103/209, 49.3% (C)	13/28, 46.4% (C)
		Specific Conductance	27/96, 28.1% (C)	57/453, 12.6% (C)	9/221, 4.1% (MC)	0/32, 0% (NC)
		Unionized Ammonia	0/96, 0% (NC)	2/432, 0.5% (MC)	3/95, 3.2% (MC)	N/A
WCA2	Inflow	Dissolved Oxygen[3]	451/644, 70% (C)	573/951, 60.3% (C)	597/1230, 48.5% (C)	95/177, 53.7% (C)
		pH	2/630, 0.3% (MC)	5/949, 0.5% (MC)	2/1240, 0.2% (MC)	0/181, 0% (NC)
		Specific Conductance	161/649, 24.8% (C)	129/951, 13.6% (C)	105/1237, 8.5% (PC)	13/181, 7.2% (MC)
		Unionized Ammonia	5/625, 0.8% (MC)	4/770, 0.5% (MC)	0/613, 0% (NC)	0/123, 0% (NC)
	Interior	Dissolved Oxygen[2]	52/99, 52.5% (C)	45/115, 39.1% (C)	34/139, 24.5% (C)	3/20, 15% (PC)
		pH	17/867, 2% (MC)	3/1832, 0.2% (MC)	2/1322, 0.2% (MC)	0/209, 0% (NC)
		Specific Conductance	85/760, 11.2% (PC)	193/1870, 10.3% (PC)	102/1320, 7.7% (PC)	13/209, 6.2% (MC)
		Unionized Ammonia	8/776, 1% (MC)	6/1516, 0.4% (MC)	0/896, 0% (NC)	0/69, 0% (NC)
	Outflow	Dissolved Oxygen[3]	575/898, 64% (C)	452/673, 67.2% (C)	387/644, 60.1% (C)	66/102, 64.7% (C)
		pH	2/881, 0.2% (MC)	5/687, 0.7% (MC)	0/656, 0% (NC)	0/107, 0% (NC)
		Specific Conductance	26/896, 2.9% (MC)	1/683, 0.1% (MC)	0/660, 0% (NC)	0/107, 0% (NC)
		Unionized Ammonia	3/874, 0.3% (MC)	2/680, 0.3% (MC)	0/464, 0% (NC)	0/82, 0% (NC)

Table 3A-2. Continued.

Area	Class	Parameter	Number of Excursions/Sample Size, Percent Excursions (Category)[1]			
			Baseline WY1979–WY1993	Phase I WY1994–WY2004	Phase II WY2005–WY2012	Current WY WY2013[4]
WCA3	Inflow	Dissolved Oxygen[3]	1448/2140, 67.7% (C)	2067/3139, 65.8% (C)	2951/4392, 67.2% (C)	395/636, 62.1% (C)
		pH	19/2103, 0.9% (MC)	16/3166, 0.5% (MC)	5/4457, 0.1% (MC)	1/660, 0.2% (MC)
		Specific Conductance	58/2153, 2.7% (MC)	7/3152, 0.2% (MC)	13/4472, 0.3% (MC)	0/659, 0% (NC)
		Unionized Ammonia	3/1945, 0.2% (MC)	6/2395, 0.3% (MC)	5/1527, 0.3% (MC)	0/171, 0% (NC)
	Interior	Dissolved Oxygen[2]	22/67, 32.8% (C)	45/139, 32.4% (C)	17/113, 15% (C)	2/11, 18.2% (PC)
		pH	0/406, 0% (NC)	1/1943, 0.1% (MC)	1/1188, 0.1% (MC)	0/107, 0% (NC)
		Specific Conductance	4/296, 1.4% (MC)	0/1955, 0% (NC)	0/1197, 0% (NC)	0/107, 0% (NC)
		Unionized Ammonia	1/297, 0.3% (MC)	2/1494, 0.1% (MC)	0/919, 0% (NC)	0/83, 0% (NC)
	Outflow	Dissolved Oxygen[3]	1419/1943, 73% (C)	1867/2418, 77.2% (C)	1320/1855, 71.2% (C)	233/264, 88.3% (C)
		pH	27/1898, 1.4% (MC)	20/2415, 0.8% (MC)	2/1867, 0.1% (MC)	0/270, 0% (NC)
		Specific Conductance	0/1956, 0% (NC)	1/2428, 0% (MC)	0/1857, 0% (NC)	0/270, 0% (NC)
		Unionized Ammonia	0/1665, 0% (NC)	5/1649, 0.3% (MC)	0/599, 0% (NC)	0/1, 0% (NC)
ENP	Inflow	Dissolved Oxygen[3]	1600/2306, 69.4% (C)	2297/3040, 75.6% (C)	1501/2351, 63.8% (C)	255/315, 81% (C)
		pH	29/2260, 1.3% (MC)	33/3049, 1.1% (MC)	2/2377, 0.1% (MC)	0/322, 0% (NC)
		Specific Conductance	0/2319, 0% (NC)	1/3021, 0% (MC)	0/2358, 0% (NC)	0/322, 0% (NC)
		Unionized Ammonia	0/2026, 0% (NC)	23/1980, 1.2% (MC)	0/695, 0% (NC)	N/A
	Interior	Dissolved Oxygen[2]	1/69, 1.4% (MC)	3/105, 2.9% (MC)	5/83, 6% (MC)	0/9, 0% (NC)
		pH	9/459, 2% (MC)	27/1014, 2.7% (MC)	0/658, 0% (NC)	0/98, 0% (NC)
		Unionized Ammonia	15/458, 3.3% (MC)	4/975, 0.4% (MC)	1/500, 0.2% (MC)	0/59, 0% (NC)

[1] Excursion categories of concern, potential concern, minimal concern and no concern are denoted by "C," "PC," "MC," and "NC", respectively.

[2] Dissolved Oxygen (DO) site-specific alternative criterion was used to assess water quality excursions.

[3] DO for inflow, outflow, and Rim Canal sampling locations were assessed using the Florida Class III freshwater water quality standard, which states DO concentrations must not be below 5 mg/L.

[4] Due to low sample size, some of these estimates should be used with caution.

Dissolved Oxygen

Marsh DO conditions within the EPA were assessed utilizing the Everglades DO site-specific alternative criterion (SSAC) for all periods, even though the SSAC was developed and implemented during 2004. To be consistent among time periods, the DO SSAC was applied across all periods. Because a single-value criterion does not adequately account for the wide-ranging natural daily fluctuations observed in the Everglades marshes, the SSAC uses an algorithm that includes sample collection time and water temperature to model the observed natural sinusoidal diel cycle and seasonal variability (Weaver, 2004). The DO SSAC was originally developed to assess DO conditions within the EPA (i.e., marsh interior stations); therefore, for this analysis DO SSAC was applied to interior monitoring locations. Compliance with the DO water quality standard for inflow, outflow, and Rim Canal monitoring locations was assessed using the Class III standard (discussed below); however, for informational purposes only the DO SSAC was also applied to inflow, outflow, and Rim Canal monitoring locations and presented in Appendix 3A-3. The SSAC is assessed based on a comparison between the annual average measured DO concentration and the average of the corresponding DO limits. DO excursion results for WY2013 for individual stations are provided in Appendix 3A-3.

During WY2013, nine interior stations (LOXA104.5, LOXA136, Z1, Z2, 404Z1, WCA2F1, WCA2F2, CA318, and CA36) exceeded the DO SSAC. Interior marsh stations that failed to achieve the SSAC during WY2013 either reside within phosphorus-impacted areas or are heavily influenced by canal flow. Phosphorus impacted areas of the marsh have long-term surface water TP concentrations greater than 10 µg/L and sediment TP concentrations in excess of 500 milligrams per kilogram (mg/kg). The DO SSAC was originally developed to assess DO concentrations within the marsh and never intended to be applied to Rim Canal, inflow, and outflow monitoring locations. However, for comparison purposes only, the DO SSAC was applied to Rim Canal, inflow, and outflow monitoring locations (Appendix 3A-3).

DO for inflow, outflow, and Rim Canal monitoring stations were assessed using the Class III freshwater water quality standard, which states that DO concentration shall not fall below 5.0 mg/L. Inflow, outflow, and Rim Canal region for all areas were classified as a concern. The percent excursion for most areas remained relatively constant, with most areas having slight improvements in the percent of excursions but still within the concerned category (**Table 3A-2**). Many of the water bodies within Florida exhibit low DO concentration due to relatively high temperature, dense canopy, shading, low water velocities, stratification, and abundant natural organic input (leaf litter). Therefore, it is expected that DO concentrations often would be below 5 mg/L during sampling events. It is important to note that during the 2013 Florida legislative session, a revised DO water quality criterion was adopted and is based on bioregion and percent DO saturation rather than a single number. The associated rule was adopted and is effective beginning in WY2014. For the 2015 SFER and future reporting, DO for inflow, outflow, and Rim Canal monitoring stations will be assessed using the newly adopted standard.

Unlike most other parameters, DO is not a direct pollutant. Instead, it is a secondary response parameter that reflects changes in other pollutants or physical or hydrologic changes in the system. The FDEP recognizes that DO impairments in phosphorus-impacted areas are related to biological changes caused by phosphorus enrichment (Weaver, 2004). Phosphorus concentrations in excess of the numeric criterion produce a variety of system changes in the Everglades that ultimately depress the DO regime in the water column (Payne and Xue, 2012). The District is actively implementing a comprehensive restoration program to lower TP concentrations within the phosphorus-impacted portions of the EPA. Over time, DO concentrations at the nutrient impacted sites are expected to continue to improve as phosphorus concentrations in surface water and sediment are reduced and biological communities recover.

Compliance with the DO SSAC is based on the annual average of the instantaneous DO measurements for each site; sufficient annual average DO data is not available for a single year to confidently apply the binomial hypothesis test to the regional assessment units. Therefore, excursion categories for DO were assigned based on a five-year period of record (POR) (WY2008–WY2013). Interior portions of the Refuge and WCA-2 were categorized as a concern for the WY2008–WY2013 period. A summary of water quality monitoring data and excursions from applicable criteria for the five-year POR period is presented in Appendix 3A-2, and analysis of the WY2013 data is provided in Appendix 3A-3 for each individual monitoring location. No conclusions regarding differences in DO excursion rates between individual water years and the previous periods can be made given the large disparity in sample sizes among periods.

Alkalinity and pH

Alkalinity is the measure of water's acid neutralization capacity and provides a measure of the water's buffering capacity. In most surface water bodies, the buffering capacity is primarily the result of the equilibrium between carbon dioxide (CO_2), bicarbonate (HCO_3^-), and carbonate ions (CO_3^{2-}). The dissociation of calcium carbonate, magnesium carbonate, or other carbonate-containing compounds entering the surface water through weathering of carbonate-containing rocks and minerals (e.g., limestone and calcite) contributes to the water's buffering capacity. Therefore, in certain areas that are influenced by canal inflows primarily composed of mineral-rich agricultural runoff and groundwater (such as ENP, WCA-2, and WCA-3), alkalinity concentrations are relatively high (Payne and Xue, 2012). Conversely, areas such as the Refuge interior, which receive their hydrologic load primarily through rainfall, have very low alkalinities. Alkalinity [i.e., calcium carbonate ($CaCO_3$)] protects against dramatic pH changes, which can be lethal to sensitive organisms. The current Class III water quality criterion specifies that alkalinity shall not be lowered than 20 mg/L of alkalinity as calcium carbonate.

Excursions from the alkalinity water quality criterion have historically occurred in the Refuge interior (Payne and Xue, 2012). Alkalinity was designated as a concern for the Refuge interior during WY2013 due to an excursion rate of 48.9 percent (**Table 3A-2**). However, as discussed above and in previous SFERs (e.g., Payne and Xue, 2012; Julian et al., 2013), the Refuge interior is hydrologically dominated by rainfall, which is naturally low in alkalinity. As such, the FDEP considers the low alkalinity values to be representative of the range of natural conditions within the Refuge; therefore, these are not considered violations of state water quality standards. The excursion rate for alkalinity in the Refuge interior during WY2013 was higher than the rates of reported for the Baseline, Phase I, and Phase II periods (26.6, 24.3, and 21.0 percent, respectively) as well as the previous water year (WY2012; 21.8 percent). In WY2013, excursions occurred at numerous stations including the following sites (number of exceedances for each site in parentheses): LOX11 (12), LOX7 (12), LOX8 (12), LOX13 (9), LOX9 (7), LOX5 (5), LOX12 (2), LOX14 (2), LOX16 (2), LOX3 (2), and LOX10 (1).

pH is defined as the negative $\log_{(base10)}$ of the hydrogen (H^+) ion activity. Most organisms, especially aquatic life, function best in a pH ranging from 6.0 to 9.0, although individual species have specific ideal ranges. In WY2013, pH was considered a minimal concern for the Refuge, and WCA-3 inflows as well as the Refuge interior, which is an improvement from WY2012 that was categorized as a potential concern. For Refuge interior sites, pH levels occasionally fell slightly below the 6.0 minimum criteria at 6 of the monitoring locations. The excursions were recorded for the following sites (number of excursions for each site provided in parentheses): LOX8 (2), LOX11 (1), LOX13 (1), LOX3 (1), LOX5 (1), LOX7 (1), LOXA139 (1), and G206 (1). As pH excursions within the Refuge interior generally occur at sites distanced from the influence of inflows and have been linked to natural low background alkalinity conditions, the FDEP does not consider the pH excursions in this area to be a violation of state water quality standards.

Specific Conductance

Specific conductance (conductivity) is a measure of water's ability to conduct an electrical current and is an indirect measure of the total concentration of ionized substances (e.g., Ca^{2+}, Mg^{2+}, Na^+, Cl^-, HCO_3^-, and SO_4^{2-}) in the water. Conductivity varies with the quantity and type of ions present in solution. The current state water quality criteria for Class III freshwater allows for a 50 percent increase above background conditions in specific conductance or 1,275 microsiemens per centimeter (µS/cm), whichever is greater. This limit is meant to preserve natural background conditions and to protect aquatic organisms from stressful ion concentrations. Given that background conductivities are low within the EPA, excursions were calculated using the 1,275 µS/cm criterion (Payne and Xue, 2012).

For WY2013, specific conductance was categorized as a concern for Refuge inflows and minimal concern for WCA-2 inflow and interior regions (**Table 3A-2**). Specific conductance excursion category for Refuge remained the same between WY2012 and WY2013, which could be caused by increased inflow volumes and greater pumping of canal water. Exceedances in the Refuge occurred at the S-338 (15 excursions) and S-362 (9 excursions) inflow structures, which overall had 24 specific conductance measurements above 1,275 µS/cm. In WCA-2, the G436 (13 excursions) inflow station and WCA2F1 (3), 2AN6 (2), 2ANC2 (1), 2AN4 (1), CA27 (1), CA29 (1), FS0.25 (1), FS1 (1), WCA2C4 (1), and WCA2C5 (1) interior stations exhibited exceedances during WY2013. Elevated conductivity levels at water control structures and stations near canal inflows could be explained by groundwater intrusion into canal surface waters (Payne and Xue, 2012; Krest and Harvey, 2003). This groundwater intrusion can occur due to seepage into canals via pump station operation (which can pull additional groundwater into surface water) and as a result of agricultural dewatering practices.

Specific conductance excursion frequency in the Refuge inflows decreased from 42.9 to 17.2 percent during the Baseline and Phase I periods, respectively; a continued decrease to 13.2 percent during Phase II and increased to 13.5 percent in WY2013 was observed. Excursion rates in WCA-2 inflows declined from 24.8 and 13.6 percent during the Baseline and Phase I periods, respectively, to 8.5 percent in Phase II and decreased to 7.2 percent in WY2013. Excursion frequency in WCA-3 inflows steadily decreased throughout the Baseline, Phase I, and Phase II periods (2.7, 0.2, and 0.3 percent, respectively) and further decreased to no excursions during WY2013.

Overall, a steady long-term decrease in specific conductance within the Refuge, WCA-2, WCA-3, and ENP inflows has occurred since WY1979 (**Figure 3A-6**). Median annual specific conductance levels in the Refuge inflows have decreased approximately 306 µS/cm over the POR with a rate of approximately 11 µS/cm per year (across the entire POR). Similarly, across the sample period specific conductance has decreased 285 µS/cm and 123 µS/cm in WCA-2 inflows and WCA-3 inflow, respectively. The rate of decrease is slightly lower than the Refuge for WCA-2 and WCA-3 with a 5 µS/cm per year and 3 µS/cm per year, respectively. However, the ENP has experienced a slight increase of 104 µS/cm from WY1979 to WY2013 with a rate of <1 µS/cm per year, but is still well below the state water quality standard and throughout the POR has not exceeded 617 µS/cm.

Unionized Ammonia

Ammonia is the principal excretory product in aquatic animals and its mechanisms of toxicity are relatively well understood (Armstrong et al., 1978; Thurston and Russo, 1981; Neil et al., 2005). The toxic effects of ammonia to aquatic species are generally considered to be caused by the unionized fraction (NH_3), rather than the ionic components (NH_4^+), which exist in equilibrium. This equilibrium is highly dependent on pH, temperature, pressure and salinity (Hampson, 1977). The current Class III freshwater water quality standard states that the unionized ammonia concentration shall be less than or equal to 0.02 mg/L as ammonia (NH_3), this criterion has been adopted by the state to protection aquatic life from the toxic effects of unionized ammonia and is not a nutrient-related criterion.

During WY2013, there were no exceedances of the ammonia water quality standard. Calculated unionized ammonia concentrations were well below the FDEP-approved target MDL of 0.4 µg/L (Chapter 62-4.246(4), F.A.C.) for all areas and regions during WY2013. Historically, unionized ammonia was considered a minimal concern for most areas of the EPA during the Baseline, Phase I, and Phase II periods, with all areas improving to no concern as shown in **Table 3A-2**.

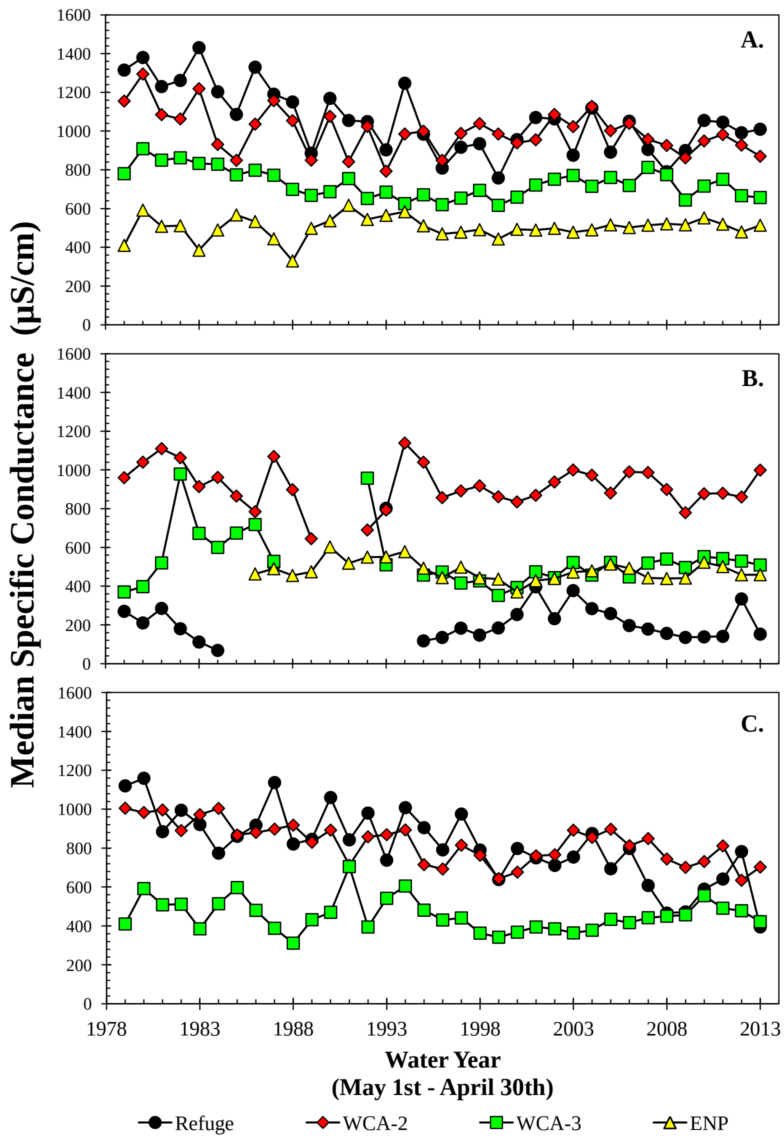

Figure 3A-6. Annual median specific conductance levels in microsiemens per centimeter (µS/cm) in the Everglades Protection Area (EPA) (A) inflows, (B) interior, and (C) outflows for WY1979–WY2013.

Pesticides

The District has been actively monitoring pesticides since 1976 (Pfeuffer, 1985), and since 1984 has established a routine pesticide monitoring program (Pfeuffer and Rand, 2004). The pesticide monitoring network includes sites designated in Memoranda of Agreement with the ENP and the Miccosukee Tribe and permits for Lake Okeechobee operations and non-Everglades Construction Projects (non-ECP). Results of monitoring conducted as part of these permits are provided in Volume III of the SFER. The current EPA monitoring program consists of 19 sites and is conducted on a biannual basis (**Figure 3A-7**). A subset of sampling stations from the entire pesticide monitoring network was used for analysis.

Surface water concentrations of pesticides are regulated under criteria presented in Chapter 62-302, F.A.C. Chemical-specific numeric criteria for a number of pesticides and herbicides (e.g., DDT, endosulphan, and malathion) are listed in Section 62-302.530, F.A.C. Compounds not specifically listed, including many contemporary pesticides (e.g., ametryn, atrazine, and diazinon), are evaluated based on acute and chronic toxicity. A set of toxicity-based guidelines for non-listed pesticides was presented by Weaver (2001). These guidelines were developed based on the requirement in Subsection 62-302.530(62), F.A.C., which calls for Florida's surface waters to be free from "substances in concentrations, which injure, are chronically toxic to, or produce adverse physiological or behavioral response in humans, plants, or animals."

Surface water pesticide data is typically collected biannually for most monitoring locations within the network. Compliance with pesticide water quality standard is assessed annually, therefore only WY2013 data is presented. During WY2013, seven pesticide or pesticide breakdown products were detected at concentrations above the MDL within the EPA. These compounds include 2,4-D, ametryn, atrazine, atrazine desethyl, metolachlor, metribuzin, and norflurazon. None of the compounds detected during WY2013 exceeded the toxicity guideline concentrations, therefore annual arithmetic mean, minimum, and maximum concentrations are presented (**Table 3A-3**). This is the second straight year in which pesticide or pesticide breakdown products were detected at concentrations above the MDL, but not exceeding the state water quality criteria.

Table 3A-3. Detected pesticide concentrations in micrograms per liter (µg/L) for WY2013[1].

Area	Parameter	Arithmetic Mean Concentration (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Total Detections	Total Samples	Criteria (µg/L)[2]
Refuge	Ametryn	0.063	0.040	0.080	4	4	6.2
	Atrazine	0.115	0.020	0.170	4	4	1.8
	Atrazine Desethyl	0.010	0.010	0.010	1	1	NG
	2, 4-D	0.410	0.410	0.410	1	1	80
	Metribuzin	0.070	0.070	0.070	1	1	64
WCA-2	Ametryn	0.030	0.020	0.040	4	4	6.2
	Atrazine	0.195	0.030	0.350	4	4	1.8
	Atrazine Desethyl	0.030	0.030	0.030	1	1	NG
	Metribuzin	0.030	0.030	0.030	1	1	64
WCA-3	Ametryn	0.025	0.020	0.030	2	2	6.2
	Atrazine	0.093	0.020	0.210	11	11	1.8
	Atrazine Desethyl	0.013	0.010	0.020	4	4	NG
	2, 4-D	0.400	0.400	0.400	1	1	80
	Diuron	0.480	0.480	0.480	1	1	8
	Hexazinone	0.445	0.200	0.690	2	2	1020
	Norflurazon	0.040	0.030	0.050	2	2	815
ENP	Ametryn	0.010	0.010	0.010	1	1	6.2
	Atrazine	0.050	0.020	0.110	3	3	1.8

[1] No detectable pesticide or breakdown by-product was detected above pesticide surface water criteria; therefore reporting of excursion criteria is not applicable.
[2] NG = No guidance, no water quality standard or limit exists

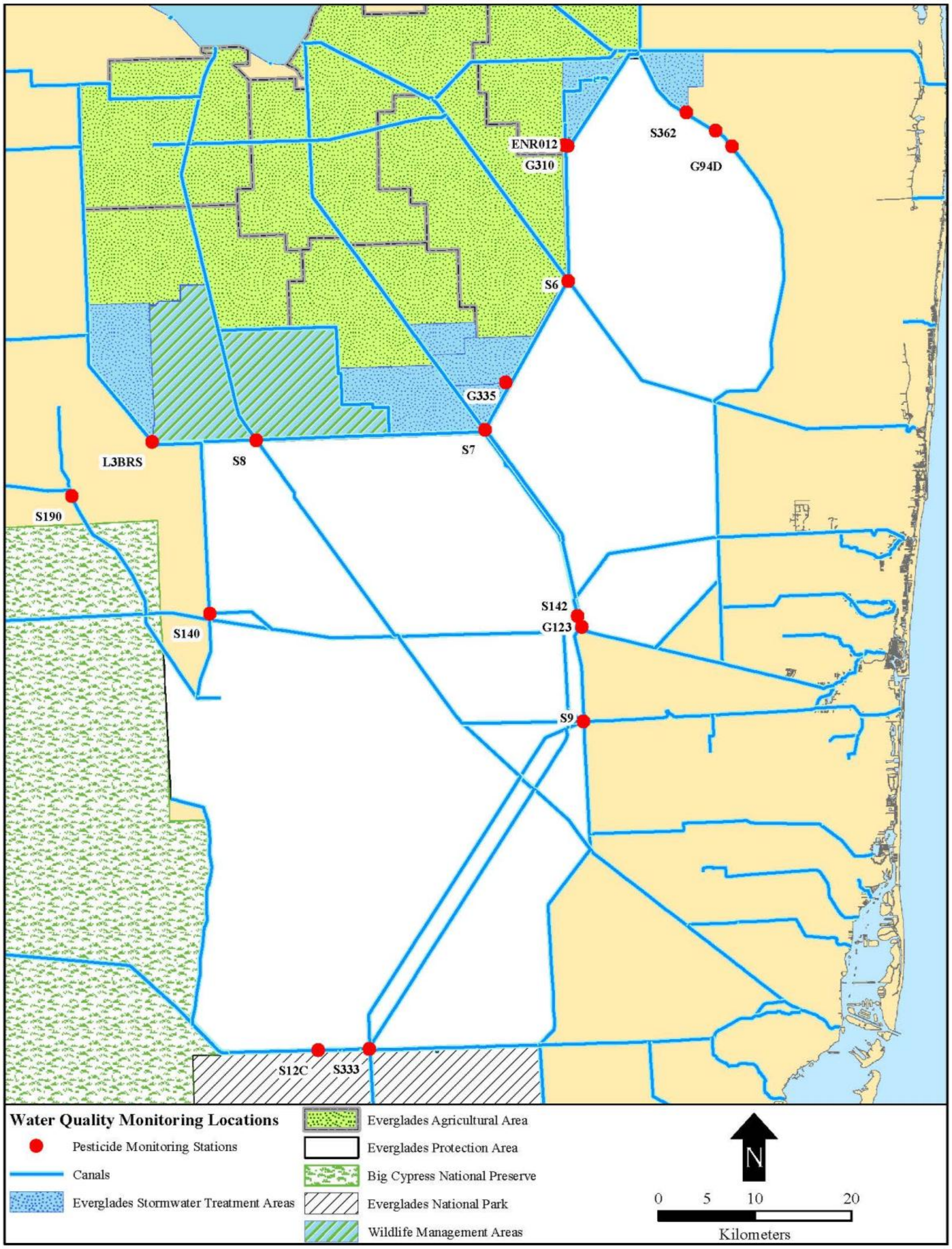

Figure 3A-7. The South Florida Water Management District's pesticide monitoring stations in proximity to the EPA.

PHOSPHORUS AND NITROGEN

Phosphorus and nitrogen are essential to the existence and growth of aquatic organisms in surface waters. The EPA and, to a larger extent, the Everglades ecosystem is a phosphorus-limited system (Noe et al. 2001). The native flora and fauna in the Everglades are adapted to nutrient-poor conditions; therefore relatively small additions of nutrients, especially phosphorus, have dramatic effects on the ecosystem.

Until the adoption of the numeric phosphorus criteria, both phosphorus and nitrogen concentrations in EPA surface waters were only regulated by 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 natural biological communities, the FDEP has numerically interpreted the narrative criterion, as directed by the EFA, to establish a long-term geometric mean of 10.0 µg/L TP for the EPA. Currently, nitrogen does not have a numeric criterion and is still regulated by only the narrative criteria.

In addition to presenting analyses of individual TP and TN concentration, this chapter provides an evaluation of spatial and temporal trends in nutrient levels within the EPA as measured during WY2013 and compares the results with previous monitoring periods to provide an overview of the changes in nutrient levels within the EPA.

Total Phosphorus Concentrations

One of the primary objectives of this chapter is to document temporal changes in TP concentrations across the EPA using long-term geometric means to summarize and compare TP concentrations in accordance with the EFA and TP criterion rule requirements. The EFA and TP criterion were designed to provide long-term, ecologically protective conditions and require the use of geometric means due to the log-normal distribution of natural TP concentrations in the environment. The geometric mean employed by the criterion and the methodology used in this chapter to assess the nutrient concentrations account for short-term variability in water quality data, while providing more reliable, long-term values for evaluation and comparison of nutrient status.

Temporal changes in annual geometric mean TP concentrations during the POR from WY1978 to WY2013 at both inflow and interior sites of the Refuge, WCA-2, WCA-3, and Park are shown in **Figure 3A-8**. Additionally average geometric mean TP concentrations for the Baseline, Phase I, Phase II, and WY2013 periods for comparison have been identified within **Figure 3A-8**. A descriptive statistics summary of TP concentrations measured within each portion of the EPA during the Baseline, Phase I, Phase II, and WY2013 periods is provided in **Table 3A-4**.

During the Baseline period, annual geometric mean TP concentrations at inflow and interior marsh sites across the EPA reached peak historic concentrations and were highly variable as shown in **Figure 3A-8**. As the agricultural BMP and STA programs were initiated and became operational during the Phase I period, annual mean TP concentrations were reduced markedly and became less variable compared to levels observed during the Baseline period. Additionally, due to extreme climatic events and low water elevations during the mid-1980s, TP concentrations remained relatively high, while the 1990s experienced higher water levels and lower TP concentrations (McCormick et al., 1998; also, see Appendix 2-3 of this volume). Effectiveness of continued optimization and enhancement of BMPs and STAs on phosphorus concentrations and loads during Phase II has been difficult to assess due to climatic extremes that have occurred during this period.

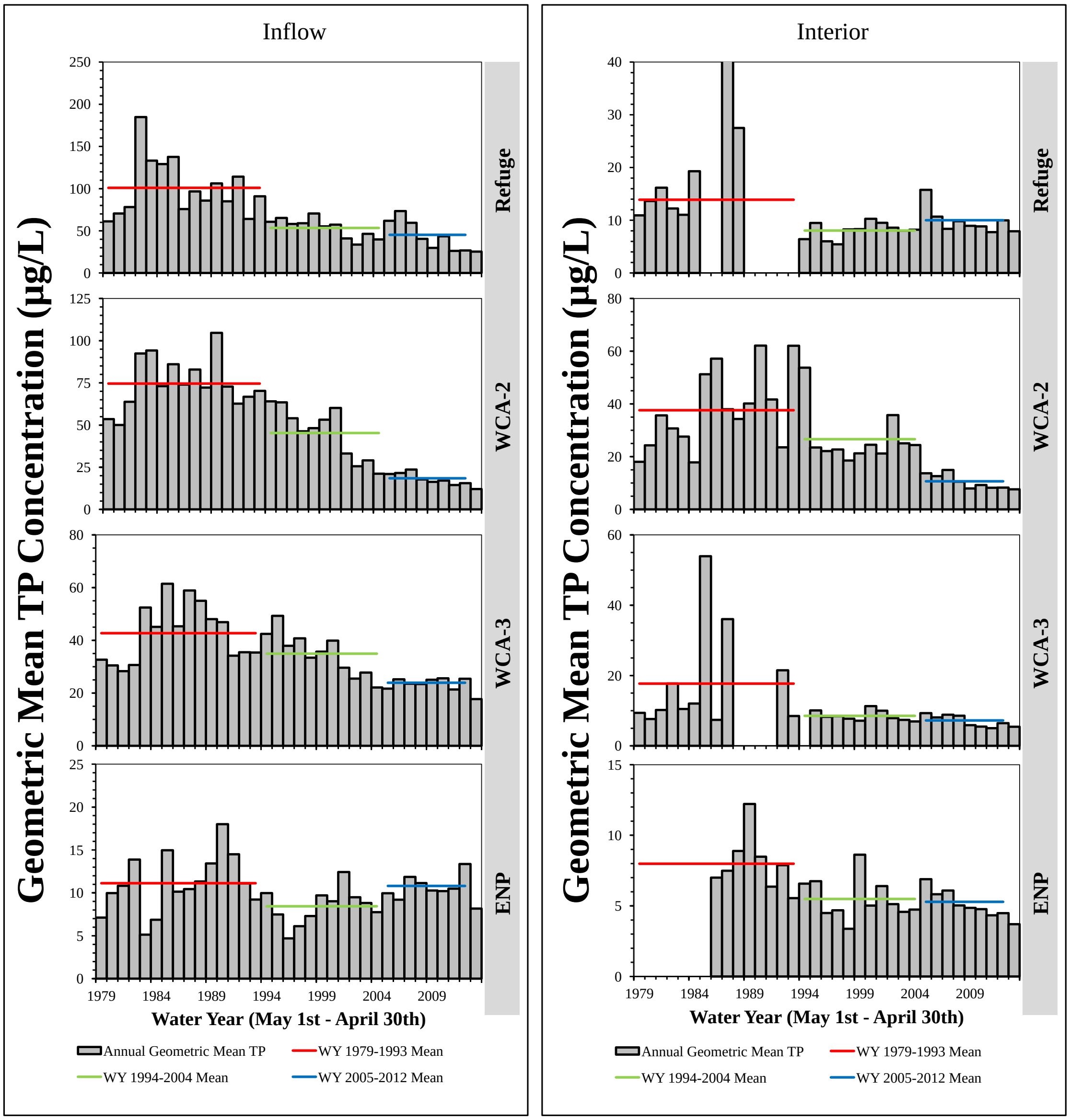

Figure 3A-8. Annual geometric mean TP concentrations in micrograms per liter (μg/L) for inflow (left panel) and interior (right panel) areas of the Refuge, WCA-2, WCA-3, ENP from WY1978–WY2013. The horizontal lines indicate the mean annual geometric mean TP concentrations for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), and Phase II (WY2005–WY2012) periods. [Note: Areas with no bars indicate data gaps. Additionally, for WY1987 the Refuge interior annual geometric mean TP concentrations reached 85 μg/L (outside the current scale).]

Table 3A-4. Summary statistics of TP concentrations (μg/L) for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), Phase II (WY2005–WY2012), and WY2013.

Region	Class	Period	Sample Size	Geometric Mean	Geometric Standard Deviation	Median	Minimum	Maximum
Refuge	Inflow	1979-1993	1557	87.7	6.7	92.0	6.0	1415.0
		1994-2004	2473	52.5	6.1	53.0	8.5	722.0
		2005-2012	2109	42.7	5.8	37.0	3.0	987.0
		2013	229	30.7	5.2	27.0	12.0	328.0
	Interior	1979-1993	381	13.7	5.3	12.0	< 2.0	494.0
		1994-2004	1503	8.0	3.7	8.0	2.0	80.0
		2005-2012	2373	10.4	4.4	9.0	2.0	574.0
		2013	364	8.8	3.9	8.0	4.0	219.0
	Outflow	1979-1993	625	65.0	6.3	63.0	8.0	3435.0
		1994-2004	700	45.5	5.7	43.5	10.0	495.0
		2005-2012	499	25.3	5.2	22.0	8.0	515.0
		2013	88	16.8	4.3	15.5	10.0	67.0
	Rim	1979-1993	96	84.5	6.3	89.0	22.0	473.0
		1994-2004	471	68.2	6.0	69.0	17.0	564.0
		2005-2012	228	57.2	6.3	55.0	11.0	817.0
		2013	30	25.2	4.6	25.0	10.0	72.0
WCA-2	Inflow	1979-1993	798	70.0	6.3	68.0	10.0	3435.0
		1994-2004	1111	38.7	5.7	40.0	7.0	493.0
		2005-2012	1430	18.3	4.6	17.0	< 2.0	245.0
		2013	214	15.6	4.1	15.0	8.0	52.5
	Interior	1979-1993	2002	20.2	6.6	16.0	< 2.0	3189.0
		1994-2004	1812	16.3	5.8	12.0	< 2.0	5652.0
		2005-2012	1776	10.8	4.5	9.0	< 2.0	278.0
		2013	295	9.2	4.2	8.0	3.0	269.0
	Outflow	1979-1993	901	23.4	5.7	23.0	< 2.0	556.0
		1994-2004	674	17.8	5.0	17.0	2.0	199.0
		2005-2012	637	13.9	4.4	13.0	3.0	179.0
		2013	102	11.0	4.0	11.0	5.0	90.0
WCA-3	Inflow	1979-1993	2324	41.1	6.3	42.5	< 2.0	933.0
		1994-2004	3666	31.5	5.8	30.0	2.0	1286.0
		2005-2012	4989	23.9	5.2	22.0	3.0	1378.5
		2013	711	21.5	5.0	21.0	5.0	589.0
	Interior	1979-1993	591	10.4	5.5	10.0	< 2.0	438.0
		1994-2004	1919	8.2	4.2	8.0	< 2.0	310.0
		2005-2012	1626	6.8	3.7	6.0	2.0	180.0
		2013	205	5.4	3.4	5.0	2.0	88.0
	Outflow	1979-1993	1962	12.4	4.8	12.0	< 2.0	593.0
		1994-2004	2479	10.7	4.3	10.0	2.0	217.0
		2005-2012	5499	13.9	4.4	13.0	< 2.0	8540.0
		2013	881	10.5	3.9	10.0	3.0	125.0
ENP	Inflow	1979-1993	2313	10.9	4.7	10.0	< 2.0	593.0
		1994-2004	3134	8.3	4.0	8.0	2.0	217.0
		2005-2012	7888	11.0	4.2	10.0	< 2.0	8540.0
		2013	1251	8.8	3.8	8.0	3.0	125.0
	Interior	1979-1993	509	7.9	4.9	7.0	2.0	1137.0
		1994-2004	934	5.3	3.8	5.0	< 2.0	117.0
		2005-2012	803	5.1	3.5	5.0	< 2.0	291.0
		2013	142	3.7	3.0	4.0	< 2.0	13.0

TP concentrations during the early and mid-portions of the Phase II period were dramatically influenced by climatic extremes, including active hurricane seasons with intense rainfall and periods of extended drought with little or no rainfall and subsequent marsh dryout. In general, the greatest effect from climatic extremes was experienced during WY2005 and WY2006 when tropical activity (e.g., Hurricane Wilma) resulted in elevated inflow concentrations, in concert with storm damage to STA vegetative communities, which resulted in decreased STA nutrient removal for many months. Decreased rainfall in WY2005 led to prolonged periods of marsh dryout, which resulted in increased oxidation of the organic sediment and the subsequent release of phosphorus into the water column. This release, in turn, resulted in elevated TP concentrations at marsh sites across the EPA.

During WY2006, much of the EPA experienced varying levels of recovery from the climatic events of WY2005. However, TP concentrations in portions of the EPA were again influenced by extended periods of limited rainfall and the subsequent marsh dryout experienced during WY2007, WY2008, and portions of WY2009 (**Figure 3A-8**). As the Phase II BMP and STA implementation period is expanded, results will most likely be influenced less by single atypical years (e.g., WY2005), and the long-term effects of continuing restoration efforts will become more clear.

As documented in previous years, annual geometric mean TP concentrations measured during WY2013 exhibited a general gradient from the highest concentrations present in Refuge inflows (30.7 µg/L) in the north and decreasing to a minimum within the Park (inflow: 8.8 µg/L and interior: 3.7 µg/L) to the south. This gradient results from the phosphorus-rich canal discharges, which are composed primarily of agricultural runoff originating in the EAA that enter 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 (**Figure 3A-9**). A detailed, site-specific summary of the TP concentrations for WY2013 is provided in **Appendix 3A-4** of this volume.

Annual geometric mean inflow TP concentrations during WY2013 were 30.7 µg/L for the Refuge, 15.6 µg/L for WCA-2, 21.5 µg/L for WCA-3, and 8.8 µg/L for ENP (**Table 3A-4** and **Figure 3A-8**). Geometric mean TP concentrations have continued to decrease with annual geometric mean concentrations during WY2013 being lower than values reported for WY2012. Inflow TP concentrations in the Refuge and WCA-2 generally continued to decrease following the elevated concentrations observed in WY2005 with the Refuge, WCA-2, and WCA-3 inflows having the lowest concentrations of the four monitoring periods.

During WY2013, Refuge inflow TP concentration was slightly higher than the previous water year (26.7 µg/L) with a geometric mean of 30.7 µg/L. Furthermore, the geometric mean TP concentration during WY2013 was reduced compared to concentrations of 87.7 µg/L, 52.5 µg/L, and 42.7 µg/L for the Baseline, Phase I, and Phase II periods, respectively (**Table 3A-4**). Likewise geometric mean TP concentrations in WCA-2 inflows have progressively decreased from 70.0 µg/L in the Baseline period to 38.7 µg/L in the Phase I, 18.3 µg/L in the Phase II period, and 15.6 µg/L in WY2013. WCA-3 inflow geometric mean TP concentrations have also exhibited a continual decrease, dropping from 41.1 µg/L in the Baseline period to 21.5 µg/L in WY2013. The lower TP concentrations in WCA-2 and WCA-3 inflows over the four monitoring periods are likely the result of multiple variables, including improved treatment by STAs, tighter BMP control, lower stormwater volumes resulting from periods of limited rainfall, and a general recovery from the damage resulting from the WY2005 hurricanes. Meanwhile, ENP inflow TP concentrations have remained low with a geometric mean concentration of 8.8 µg/L during WY2013, which is lower than 10.9 µg/L, 8.3 µg/L, and 11.0 µg/L geometric mean concentrations reported for the Baseline, Phase I and Phase II periods, respectively (**Table 3A-4**). Trends in inflow annual geometric mean TP concentration for the Refuge, WCA-2 and WCA-3 significantly declined throughout the POR (i.e., WY1979–WY2013). However, there was no significant trend in inflow annual geometric mean TP concentrations for ENP (**Table 3A-5**).

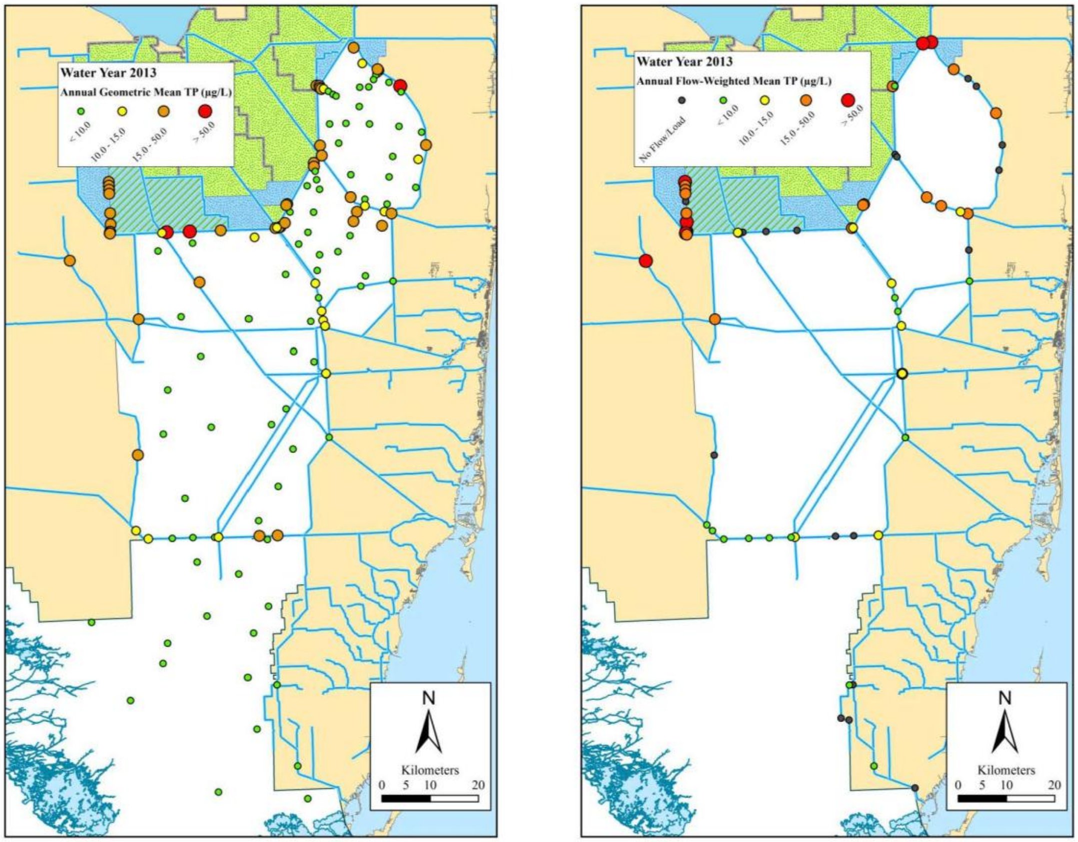

Figure 3A-9. Annual geometric mean TP concentrations for all classifications (left panel) and annual flow-weighted mean TP concentrations at water control structures (right panel) for WY2013 at stations across the EPA.

Table 3A-5. Kendall's τ annual geometric mean TP concentration trend analysis results for each region's inflow and interior classification within the EPA between WY1979 and WY2013. Statistically significant ρ-values are italicized.

Area	Class	Kendall's τ	ρ-value
Refuge	Inflow	-0.64	*<0.01*
	Interior	-0.29	*<0.05*
WCA-2	Inflow	-0.73	*<0.01*
	Interior	-0.52	*<0.01*
WCA-3	Inflow	-0.52	*<0.01*
	Interior	-0.48	*<0.01*
ENP	Inflow	-0.0017	0.99
	Interior	-0.49	*<0.01*

Interior marsh annual geometric mean TP concentrations observed across the EPA during WY2013 were lower relative to inflow structures. During WY2013, interior geometric mean TP concentrations ranged from 8.8 µg/L in the Refuge, 9.2 µg/L in WCA-2, 5.4 µg/L in WCA-3, and 3.7 µg/L in the Park. Overall during WY2013, geometric mean TP concentrations for interior sites in all areas of the EPA were below the 11.0 µg/L, which is the annual limit used to assess achievement of the TP criterion. Additionally the geometric mean TP concentrations for interior sites were also below the five-year TP criterion limit As reported for previous years, the geometric mean TP concentrations for most individual Park interior sites were below 10 µg/L with the lowest concentration being record at 6 µg/L. Please note that the data was assessed using the TP criterion assessment guidelines and presented only for informational purposes only. Marsh conditions are influenced significantly by marsh stage elevation, which is evident with high TP concentrations within the Refuge (WY1987: 85.4 µg/L and WY1988: 27.5 µg/L).

The most dramatic decreases in interior marsh TP concentrations in recent years have been observed for WCA-2 and WCA-3. The geometric mean TP concentrations in WCA-2 have for the Baseline and Phase I periods have remained relatively constant with geometric mean concentration for those period being 20.2 µg/L and 16.3 µg/L, respectively. Further decreases during Phase II and WY2013 have been observed with geometric mean concentrations decreasing to 10.8 µg/L and 9.2 µg/L, respectively. Likewise, interior geometric mean TP concentrations within WCA-3 has steadily decreased from 10.4 µg/L during the Baseline period to 8.2, 6.8, and 5.4 µg/L for the Phase I, Phase II, and WY2013 periods, respectively (**Table 3A-4** and **Figure 3A-8**). For WCA-2, the interior geometric mean TP concentration of 9.2 µg/L observed for WY2013 represents the fifth straight year that this areas mean TP concentration has been below 10 µg/L and is also the lowest concentration observed since WY1979 (**Figure 3A-9**). Annual geometric mean TP concentration trends throughout the interior portions of the EPA have significantly declined throughout the entire POR for all areas as indicated by the Kendall's τ trend analysis (**Table 3A-5**). The continued decreases in TP concentration observed in WCA-2 and WCA-3 likely reflect recovery from the recent climatic extremes, improved treatment of the inflows to these areas (which is supported by similar decreases in inflow concentrations), and improved conditions in the impacted portions of the marsh. This includes the area downstream of the S-10 structures, which is one of the areas most highly impacted by historical phosphorus enrichment, where the quantity of discharge has been significantly reduced and the quality of the discharge has improved since STA-2 began operation.

Annual geometric mean TP concentrations for individual interior marsh monitoring stations used in the assessment of the TP rule (i.e., Rule 62-302.540 F.A.C., as detailed in Appendix 3A-6 of this volume) and other ambient interior marsh monitoring stations sampled six or more times during WY2013 ranged from less than 3.0 µg/L in some unimpacted portions of the marsh to 32.8 µg/L at a WCA-2 site that is highly influenced by canal inputs (i.e., 404Z1). Across the entire EPA (Refuge, WCA-2, WCA-3, and ENP), 52.2 percent of the interior marsh sites exhibited annual geometric mean TP concentrations of 10.0 µg/L or less during WY2013. Interior marsh stations within the EPA experienced 13.6, 61.4, and 56.3 percent of samples with geometric mean TP concentrations less than or equal to 10 µg/L during the Baseline, Phase I, and Phase II periods, respectively. Additionally, 54.6 percent of the interior sites had annual geometric mean TP concentrations of 15.0 µg/L or less during WY2013. Interior marsh stations within the EPA experienced 20.2, 74.5, and 69.2 percent of samples with geometric mean TP concentrations less than or equal to 15 µg/L during the Baseline, Phase I, and Phase II periods, respectively.

The higher percent of interior monitoring stations meeting the 10 and 15 µg/L limits observed for WY2013 reflects the continued recovery from recent climatic extremes, improved treatment of the inflows, and overall improvement in phosphorus conditions within the interior marsh due to ongoing restoration activities. Furthermore, this trend of improvement is apparent for stations used to assess the TP rule. Given the relatively constant location of interior monitoring sites in recent years, 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 originally designed to allow results to accurately estimate the percentage of the marsh exceeding a TP concentration of 10.0 µg/L (or other thresholds), it is not appropriate to use the results for that purpose. Instead, a select group of stations have been established in recent years and identified so that comparison of TP concentrations to established threshold can be conducted.

Total Phosphorus Criterion Achievement Assessment

The TP criterion rule specifies that while the federal Settlement Agreement (Case No. 88-1886-CIV-MORENO) 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 FWM 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 District and reported on a quarterly basis to satisfy other mandates and are not replicated here. The quarterly Settlement Agreement reports prepared by the District are available online at www.sfwmd.gov/toc.

In addition to establishing numeric TP criterion, Rule 62-302.540, F.A.C., also provides a four-part test to be used to determine achievement of the criterion. Each component must be achieved for a water body to be considered in compliance. **Appendix 3A-6** provides results of the preliminary evaluation to assess TP criterion achievement using available data for the most recent five-year period, WY2009–WY2013. As described previously, the results of this assessment were affected by data limitations in many parts of the EPA during some years caused in part by the extremely dry conditions that have prevailed throughout the area. Additionally, monitoring at nine new sites (added to the existing sites to form the TP criterion monitoring network) was not initiated until January 2007. During WY2013, 55 of the 58 TP criterion monitoring network sites had sufficient data (i.e., six or more samples specified by the screening protocol referenced by the TP criterion rule, per Rule 62-302.540, F.A.C.) to be included in the TP criterion assessment. In contrast, only 30 of the 58 sites had a sufficient number of samples during WY2007, with less than 50 percent of the Refuge and WCA-3 monitoring sites having the minimum number of samples required for inclusion in the TP criterion assessment.

The results of the WY2009–WY2013 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 are therefore in compliance with the 10 µg/L TP criterion. Occasionally, individual sites within the unimpacted portions of the WCAs exhibited an annual site geometric mean TP concentration above 10 µg/L, as expected, but in no case did the values from any one unimpacted site influence that could result in an exceedance of the annual or long-term network limits. None of the annual geometric mean TP concentrations for the individual unimpacted sites during the WY2009–WY2013 period exceeded the 15 µg/L annual site limit.

In contrast, the impacted (i.e., 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 WCAs routinely exceeded the annual and five-year network TP concentration limits of 11 µg/L and 10 µg/L, respectively. During the WY2009–WY2013 period, numerous individual sites within the impacted areas exhibited annual geometric mean TP concentrations below the 15 µg/L annual site limit. In a few instances, the annual mean for individual impacted sites was below 10 µg/L; however, none of the impacted sites were consistently below the 10 µg/L long-term limit.

Total Phosphorus Loads

Each year, the EPA receives variable amounts of surface water inflows based on the hydrologic variability within the upstream basins. These regulated inflows contribute to the TP loading to the EPA system. **Figure 3A-10** shows five-year (WY2009–WY2013) average annual flows, TP loads, and FWM TP concentrations to STAs and diversions from inflow tributaries and across the EPA. Approximately 175 mt per year of phosphorus was delivered from upstream sources (Lake Okeechobee, EAA basin, C-139 basin, L-8, C-51W basin and other Water Conservation Districts) over the last five years. About 33 mt per year of phosphorus was delivered to the EPA after treatment by STAs and 5 mt per year of phosphorus was delivered to the EPA by diversion. Another 12 mt per year of phosphorus was delivered to the EPA from the Western Non-ECP Basins and 6 mt per year of phosphorus was delivered to the EPA from the Eastern Non-ECP Basins. **Figure 3A-11** shows five-year (WY2009–WY2013) average annual flows, TP loads, and FWM TP concentrations across the EPA. The data shows there is a concentration gradient from north (five-year average annual FWM TP concentration of 42 µg/L into WCA-1) to south (five-year average annual FWM TP concentration of 9 µg/L into ENP). Data for **Figures 3A-10** and **3A-11** are presented in Tables 6 through 11 of Appendix 3A-5. **Table 3A-6** provides estimates of the inflow and TP load to each portion of the EPA for WY2013. Flows and TP loads are also provided for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), and Phase II (WY2005–WY2012) periods for comparison.

In addition to inflow, atmospheric deposition contributes to the TP loading into the EPA. The long-term average range of TP atmospheric deposition to the WCAs is between 107 and 143 mt per year. Atmospheric TP deposition rates are highly variable and very expensive to monitor; therefore, they are not routinely monitored. The range [expressed spatially as 20 to 35 milligrams per square meter per year ($mg/m^2/yr$)] is based on data obtained from long-term monitoring evaluated by the District (Redfield, 2002).

Detailed estimates of TP loads by structure for WY2013 are presented in Appendix 3A-5 of this volume. This appendix summarizes contributions from all tributaries connecting to the EPA: Lake Okeechobee, EAA, C-139 basin, other agricultural and urbanized areas, and STAs. In some cases, surface water inflows represent a mixture of water from several sources as it passes from one area to another before 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 Stormwater Treatment Area 5/6 (STA-5/6) and Stormwater Treatment Area 3/4 (STA 3/4), then into the EAA before reaching the EPA.

As detailed in Appendix 3A-5, WY2013 annual TP loads from surface sources to the Refuge, WCA-2, and WCA-3 were 60.5 mt, with a FWM TP concentration of 25 µg/L. Another 193 mt of TP is estimated to have entered the EPA through atmospheric deposition (Redfield, 2002). Discharges from the EPA account for 9.5 mt of TP for water supply. The 60.5 mt TP load in EPA surface inflows represents an increase of approximately 65 percent compared to WY2012 (36.7 mt). The higher TP loads to the EPA during WY2013 resulted from increased flow volumes. The EPA received 1,945 kacre-feet of surface water flow, which is a 40 percent increase from WY2012 volumes (1,389 kacre-ft; Julian et al., 2013). Annual TP loads to ENP from surface water sources were 10.8 mt with a FWM TP concentration of 8 µg/L. ENP inflow loads increased 60 percent from the previous WY (WY2012: 6.7 mt), presumably due to the 84 percent increase in surface water flow from the previous water year (WY2012: 597 kacre-ft, WY2013: 1,096 kacre-ft).

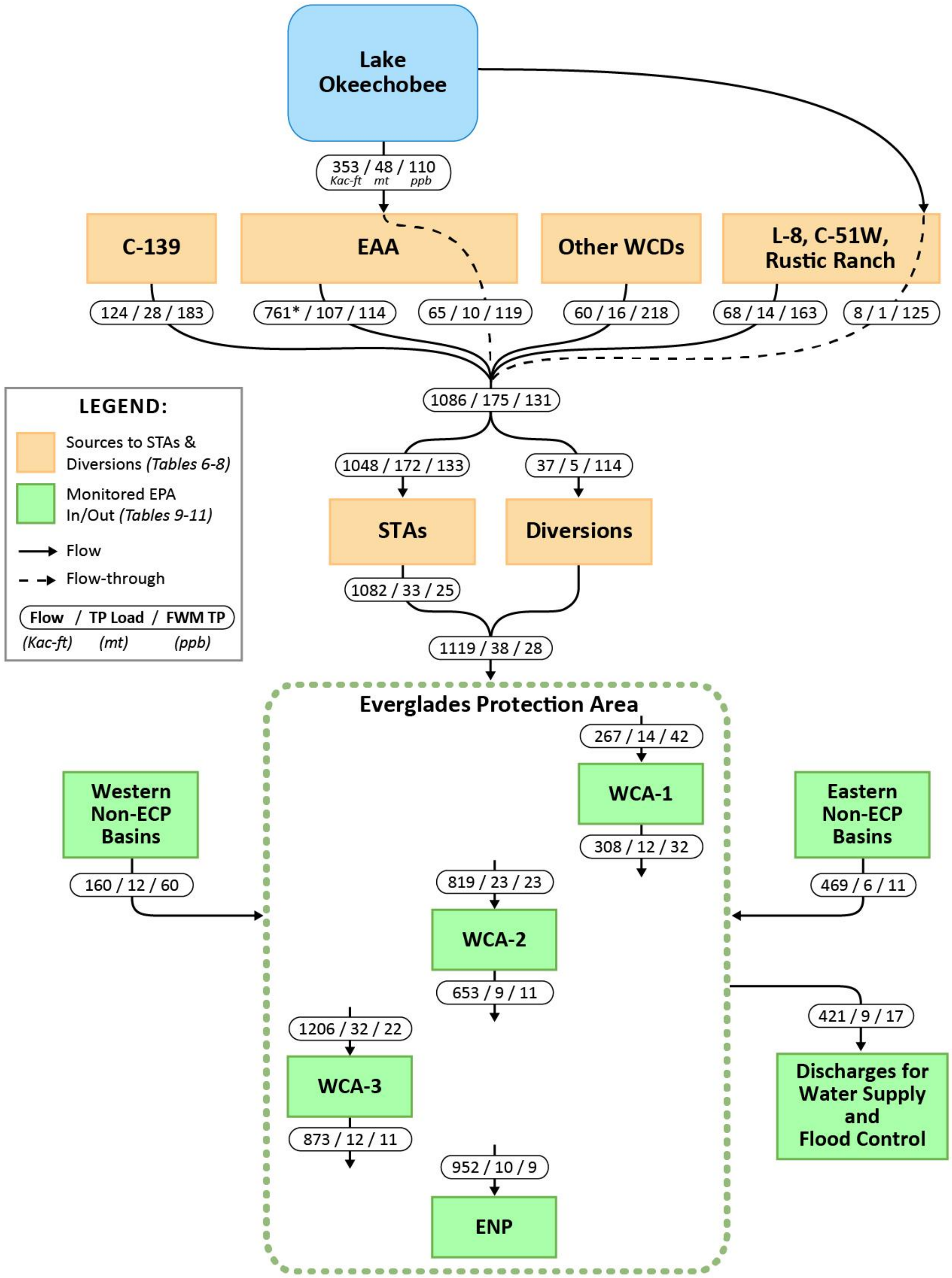

Figure 3A-10. Five-year (WY2009–WY2013) average annual flows [1,000 acre-feet (Kac-ft)], TP loads [metric tons (mt)], and flow-weighted mean (FWM) TP concentrations [µg/L or parts per billion (ppb)] to the STAs and diversions from inflow tributaries and across the EPA. [Note: WCD=water control district; ECP=Everglades Construction Project. *EAA to STAs and Diversions is a portion of the total EAA runoff reported in Chapter 4 of this volume. A small mass balance difference reflects measurement uncertainties.]

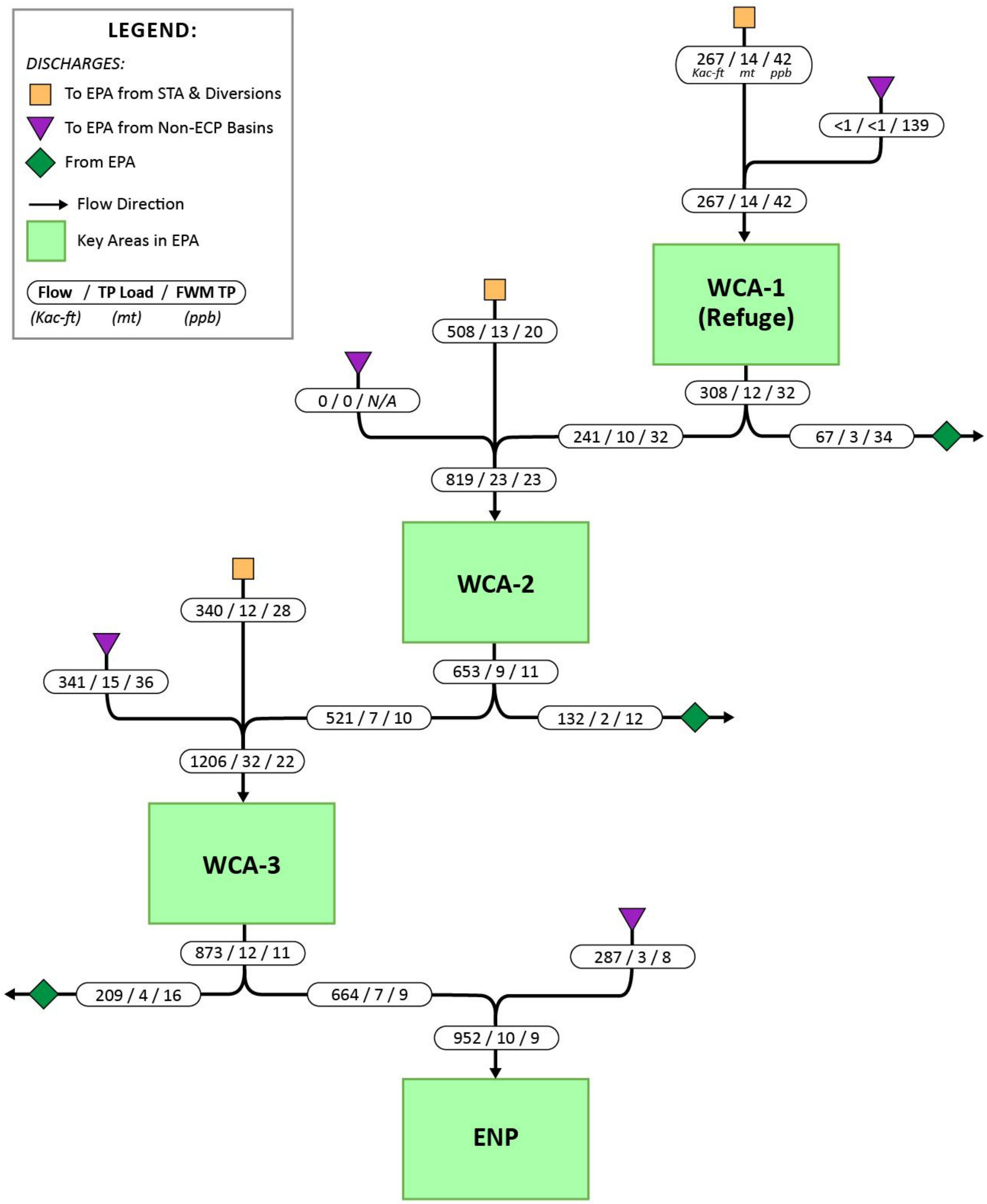

Figure 3A-11. Five-year (WY2009–WY2013) average annual flows (1,000 ac-ft), TP loads (mt), and FWM TP concentrations (μg/L or ppb) across the EPA. [Note: Values for each year are presented in this appendix and the 2010–2013 SFERs – Volume I, Appendix 3A-5. From EPA are discharges for water supply and flood control.]

Table 3A-6. Annual average flow, flow-weighted mean (FWM) total phosphorus (TP) concentrations, and TP loads in the EPA for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), Phase II (WY2005–WY2012), and WY2013 periods. Also included mean flow, FWM TP and TP loads for the previous five water years.

	Area	Period: Baseline WY1979-1993	Phase I WY1994-2004	Phase II WY2005-2012	Current WY2013	Last 5-year Mean 2009-2013
Mean Annual Flow (kacre-feet)[1]	Refuge	506	647	276	365	267
	WCA-2	581	704	747	1,069	819
	WCA-3	1,181	1,396	1,253	1,368	1206
	ENP	815	1,477	867	1,096	952
Mean Annual TP Load (kilograms)[2]	Refuge	111,436	83,977	26,885	26,372	13,807
	WCA-2	78,670	57,391	26,298	26,053	22,732
	WCA-3	108,357	84,335	48,021	25,169	32,094
	ENP	11,450	15,912	10,060	10,813	10,285
Mean Annual FWM TP (µg/L)	Refuge	186	100	79	59	42
	WCA-2	119	65	29	20	23
	WCA-3	72	49	31	15	22
	ENP	12	9	9	8	9

[1] 1 kacre-ft = 1,000 acre-feet; 1 acre-feet = 0.1233 hectare-meters

[2] 1 kilogram = 0.001 metric tons

A summary of the annual flows and TP loads to each portion of the EPA for WY1979–WY2013 along with the annual averages for the Baseline, Phase I, and Phase II periods can be found in **Figure 3A-12**. The effectiveness of the BMP and STA phosphorus removal efforts is demonstrated by decreased TP loading to WCA-2 and WCA-3 during the Phase I and Phase II periods compared to the Baseline period despite increased flows (**Figure 3A-12**). The effects are less apparent in the Park, where inflow concentrations have remained near background levels and TP loading responds more directly to changes in flow and climatic conditions (**Figure 3A-12**).

The mean flow and TP loads to the EPA, especially the Refuge, during the Phase II and WY2013 periods have been highly influenced by climatic extremes, as previously discussed. The annual TP load from all sources to the Refuge was approximately 26.4 mt during WY2013, which represents a 472 percent increase from WY2012 (4.6 mt). Surface water volume also increased 115 percent in WY2013 (365 kacre-ft) compared to WY2012 (170 kacre-ft). The FWM concentration increased from 22 µg/L in WY2012 to 59 µg/L in WY2013. Other areas of the EPA experienced similar increases in flow and TP load during WY2013, with WCA-3 being the exception. WCA-2 experienced an increase of 235 percent in TP inflow load during WY2013 (26.1 mt) relative to WY2012 (7.77 mt). WCA-3 experienced a decrease of 7 percent in TP inflow load during WY2013 (25.2 mt) relative to WY2012 (27.0 mt) even though surface water inflow increased 43 percent (WY2012: 960 kacre-ft, WY2013:1,368 kacre-ft). ENP experienced an increase of 60 percent in TP inflow load during WY2013 (10.8 mt) relative to WY2012 (6.7 mt). Dramatically increased TP loads and flows to the Refuge are primarily due to Tropical Storm Isaac. Tropical Storm Isaac resulted in increased annual inflows and TP loads, in comparison to WY2012, at STA-1E (from 86 kacre-ft in WY2012 to 135 kacre-ft in WY2013) and STA-1W (from 97 kacre-ft in WY2012 to 166 kacre-ft in WY2013) and likely contributed to increases in FWM TP concentrations. STA-1E increased from 21 µg/L in WY2012 to 26 µg/L in WY2013 and STA-1W increase from 22 µg/L in WY2012 to 36 µg/L in WY2013. Even though

TP loads and concentrations were reduced relative to the Baseline period, more monitoring is needed before the effects of Phase II BMP and STA optimization projects can be accurately assessed.

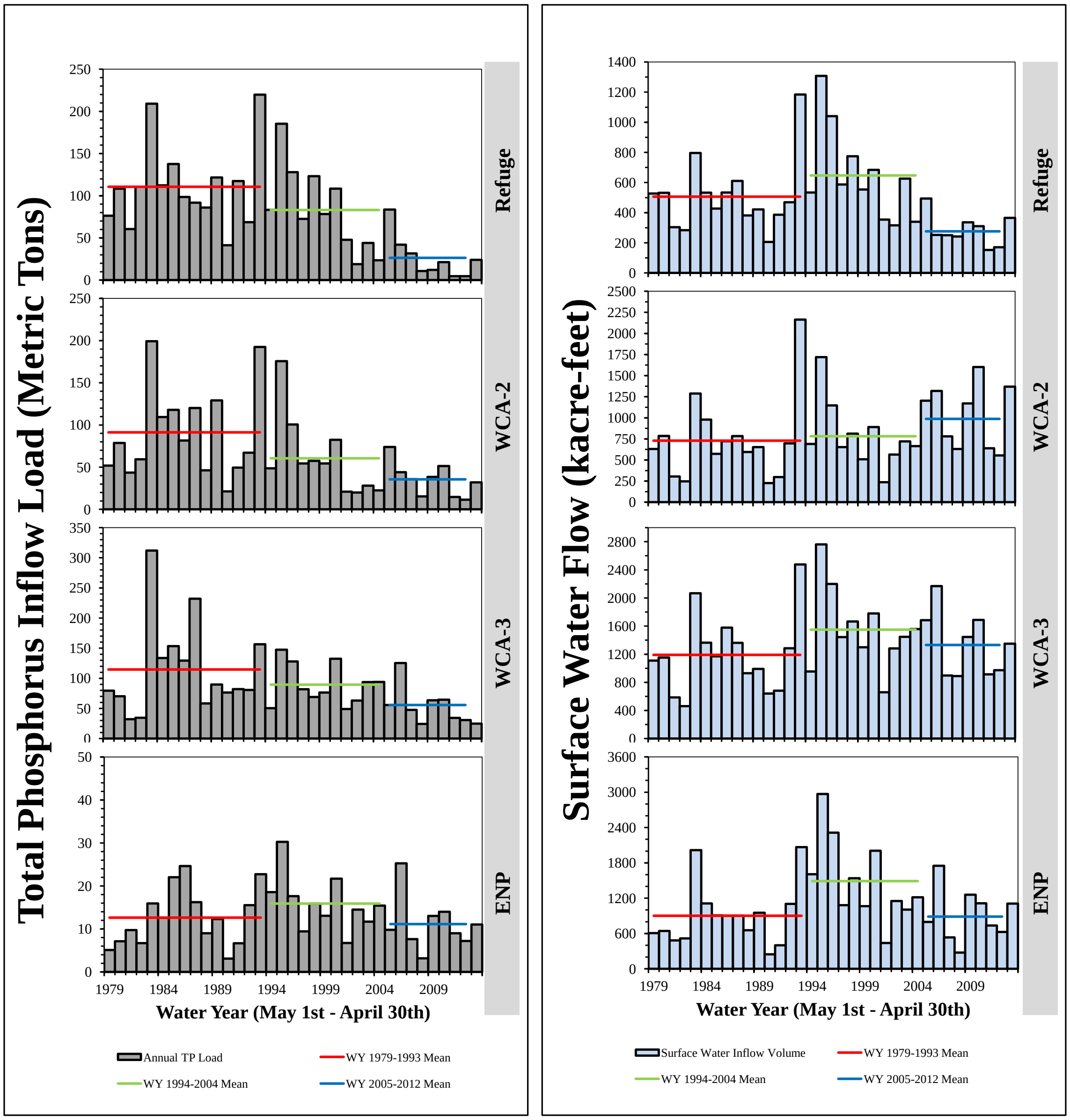

Figure 3A-12. Annual inflow TP load (left panel) and annual total flow (right panel) for the Refuge, WCA-2, WCA-3, and ENP from WY1979–WY2013. The horizontal lines indicate the mean annual loads and flows for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), and Phase II (WY2005–WY2012) periods.

Annual flow was significantly different between periods for the Refuge (Df 2, F Ratio 9.00, $\rho < 0.01$) and ENP (Df 2, F Ratio 3.55, $\rho < 0.05$) with Phase II being significantly lower than both baseline and Phase I periods for both areas. Meanwhile annual flow was not significantly different for WCA-2 (Df 2, F Ratio 2.07, ρ 0.14) and WCA-3 (Df 2, F Ratio 1.70, ρ 0.20). Annual TP load was not significantly different between periods for ENP (Df 2, F Ratio 1.72, ρ 0.20), however annual TP load was significantly different between each period for the Refuge (Df 2, F Ratio 15.16, $\rho<0.01$), WCA-2 (Df 2, F Ratio 6.27, $\rho < 0.01$), and WCA-3 (Df 2, F Ratio 5.56, $\rho < 0.01$). Annual TP loads to the Refuge, WCA-2, and WCA-3 were all significantly lower during the Phase II period, which is expected due to construction and optimization of the Everglades STAs, which treat a large portion of the water entering these areas of the EPA.

Orthophosphate Concentrations

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 Everglades ecosystem. During WY2013, geometric mean OP concentrations at inflow, interior, and outflow stations in all areas within the EPA were lower than concentrations observed during the Baseline, Phase I, and Phase II periods (**Figure 3A-13** and **Table 3A-7**).

Since WY1979, OP concentrations have drastically declined for inflows into the EPA (**Figure 3A-13**). During WY2013 geometric mean OP concentrations at inflow stations ranged from 4.6 µg/L in the Refuge to 1.1 µg/L in the Park. Inflow geometric mean OP concentrations have declined for all areas. The Refuge has experienced the greatest reduction in OP concentrations with Baseline and Phase I periods experiencing 30.8 µg/L and 15.8 µg/L. This trend has continued with geometric mean concentrations of 5.8 µg/L and 4.6 µg/L during the Phase II and WY2013 periods. Geometric mean OP concentrations at WCA-2 inflow regions during the Baseline, Phase I, Phase II and WY2013 were 25.5, 12.7, 2.4 and 1.4 µg/L, respectively. Geometric mean OP concentrations at WCA-3 inflow regions during the Baseline, Phase I, Phase II, and WY2013 were 10.7, 9.5, 3.0, and 1.7 µg/L, respectively. ENP has by far experienced the lowest geometric mean OP concentrations than all other areas of the EPA with inflow geometric mean OP concentrations during the Baseline, Phase I, Phase II, and WY2013 of 2.6, 2.7, 1.5, and 1.1 µg/L, respectively.

Geometric mean concentrations for interior regions of the EPA have fluctuated between periods for the Refuge and WCA-2. Geometric mean OP concentrations within the Refuge interior during the Baseline, Phase I, Phase II, and WY2013 were 1.5, 1.4, 2.1, and 1.0 µg/L, respectively. Geometric mean OP concentrations within WCA-2 interior during the Baseline, Phase I, Phase II, and WY2013 were 4.0, 4.3, 1.7, and 1.3 µg/L, respectively. WCA-3 and ENP have experienced an overall decline in geometric mean OP concentration throughout the periods of assessment. Geometric mean OP concentrations within WCA-3 interior during the Baseline, Phase I, Phase II, and WY2013 were 1.8, 1.7, 1.5 and 1.1 µg/L, respectively. Geometric mean OP concentrations within ENP interior during the Baseline, Phase I, Phase II, and WY2013 were 2.6, 2.5, 1.5, and 1.1 µg/L, respectively

Since WY2007, annual geometric mean OP concentrations for interior locations have been low, with concentrations being less than 2.0 µg/L for all areas (**Figure 3A-12**). Sustained reduction of OP concentrations for both inflow and interior sites over the past several water years shows the continued recovery from the recent extreme climatic events, the preferential removal of OP by the STAs, and the effects of restoration activities to improve the overall phosphorus conditions in the interior marsh areas.

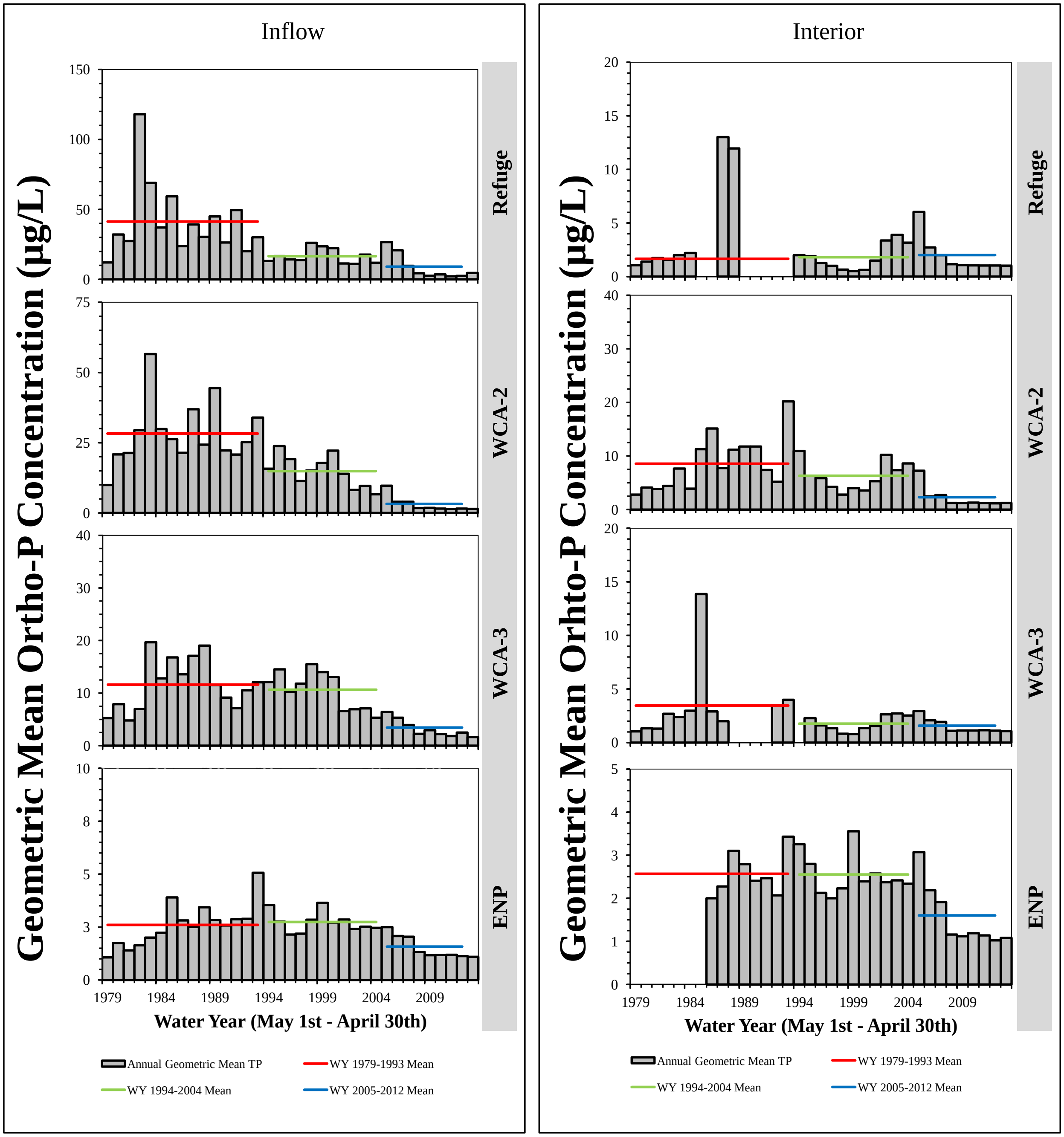

Figure 3A-13. Annual geometric mean OP concentrations (µg/L) for inflow (left panel) and interior (right panel) areas of the Refuge, WCA-2, WCA-3, and ENP from WY1978–WY2013. The horizontal lines indicate the mean annual geometric mean TP concentrations for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), and Phase II (WY2005–WY2012) periods. [Note: Areas with no bars indicate data gaps.]

Table 3A-7. Summary statistics of orthophosphate concentrations (μg/L) for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), Phase II (WY2005–WY2012), and WY2013 periods.

Region	Class	Period	Sample Size	Geometric Mean	Geometric Standard Deviation	Median	Minimum	Maximum
Refuge	Inflow	1979-1993	1500	30.8	7.8	42.0	< 2.0	1106.0
		1994-2004	1243	15.8	5.6	14.0	2.0	226.0
		2005-2012	1556	5.8	7.1	4.0	< 2.0	854.0
		2013	114	4.6	6.6	3.0	< 2.0	270.0
	Interior	1979-1993	381	1.5	2.8	1.0	< 2.0	278.0
		1994-2004	1192	1.4	2.6	1.0	< 2.0	10.0
		2005-2012	1135	2.1	3.4	2.0	< 2.0	506.0
		2013	135	1.0	1.2	1.0	< 2.0	2.0
	Outflow	1979-1993	616	20.3	7.3	25.0	< 2.0	1290.0
		1994-2004	676	15.0	5.6	13.5	2.0	383.0
		2005-2012	446	2.9	4.8	2.0	< 2.0	461.0
		2013	69	1.5	2.5	1.0	< 2.0	20.0
	Rim	1979-1993	96	33.5	6.7	39.5	< 2.0	408.0
		1994-2004	324	27.8	6.3	34.0	< 2.0	190.0
		2005-2012	100	38.2	7.2	46.5	2.0	544.0
		2013	0	---	---	---	---	---
WCA2	Inflow	1979-1993	765	25.5	7.0	31.0	< 2.0	1290.0
		1994-2004	741	12.7	5.5	10.0	2.0	352.0
		2005-2012	895	2.4	3.9	2.0	< 2.0	190.0
		2013	162	1.4	2.3	1.0	< 2.0	30.0
	Interior	1979-1993	1990	4.0	5.9	2.0	< 2.0	1967.0
		1994-2004	1535	4.3	5.5	4.0	< 2.0	960.0
		2005-2012	971	1.7	2.8	1.0	< 2.0	186.0
		2013	76	1.3	1.9	1.0	< 2.0	9.0
	Outflow	1979-1993	887	5.1	5.5	4.0	< 2.0	396.0
		1994-2004	656	5.9	4.3	6.0	2.0	156.0
		2005-2012	631	2.0	3.0	2.0	< 2.0	153.0
		2013	102	1.3	1.9	1.0	< 2.0	20.0
WCA3	Inflow	1979-1993	2133	10.7	6.8	11.0	< 2.0	586.0
		1994-2004	2157	9.5	5.9	7.0	2.0	431.0
		2005-2012	2633	3.0	4.6	2.0	< 2.0	337.0
		2013	335	1.7	3.0	1.0	< 2.0	80.0
	Interior	1979-1993	580	1.8	3.2	1.0	< 2.0	142.0
		1994-2004	1695	1.7	2.9	2.0	< 2.0	85.0
		2005-2012	932	1.5	2.1	2.0	< 2.0	39.0
		2013	88	1.1	1.3	1.0	< 2.0	3.0
	Outflow	1979-1993	1682	2.7	3.3	2.0	< 2.0	116.0
		1994-2004	1638	3.0	2.9	2.0	2.0	97.0
		2005-2012	1194	1.6	2.3	2.0	< 2.0	180.0
		2013	188	1.1	1.6	1.0	< 2.0	30.0
ENP	Inflow	1979-1993	2025	2.6	3.1	2.0	< 2.0	77.0
		1994-2004	1957	2.7	2.6	2.0	2.0	97.0
		2005-2012	1456	1.5	2.1	1.0	< 2.0	43.0
		2013	243	1.1	1.5	1.0	< 2.0	30.0
	Interior	1979-1993	488	2.6	2.7	2.0	2.0	63.0
		1994-2004	873	2.5	2.5	2.0	2.0	45.0
		2005-2012	497	1.5	2.1	1.0	< 2.0	19.0
		2013	78	1.1	1.3	1.0	< 2.0	3.0

Total Nitrogen Concentrations

Elevated concentrations of nitrogen in freshwater ecosystems are of concern due to the role of nitrogen in eutrophication of freshwater systems, the effect on the oxygen content of receiving waters, and its potential toxicity to aquatic invertebrate and vertebrate species (Kadlec and Wallace, 2009; Saunders and Kalff, 2001). However, the EPA and the greater Everglades ecosystem in general is a phosphorus-limited system. Which means the growth of algae and macrophytes are limited by the quantity of the phosphorus input into the system. When nitrogen is limited biota (i.e., algae and macrophytes) can offset this nitrogen limitation through fixation of atmospheric N_2 (Noe et al., 2001).

One of the primary objectives of this chapter is to document temporal changes in TN concentrations across the EPA using long-term geometric means concentrations. Unlike TP, the concentration of 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 this chapter were calculated only for those samples for which both TKN and NO_3 + NO_2 results were available. **Table 3A-8** provides a summary of the TN concentrations measured in the different portions of the EPA during the Baseline, Phase I, and Phase II periods, as well as WY2013.

As in previous years, TN concentrations during WY2013 exhibited a general north-to-south spatial gradient across the EPA (**Figure 3A-14**). 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 concentrations results from the assimilative processes in the marsh as water flows southward. The north-to-south gradient is apparent for inflow regions within the EPA with the highest geometric mean TN concentrations being observed in the Refuge (2.17 mg/L) followed by WCA-2 (1.58 mg/L), WCA-3 (1.60 mg/L) and ENP inflows (0.96 mg/L). Interior geometric mean TN concentrations were reduced relative to inflow concentration within each region of the EPA most likely due to marsh assimilation. During WY2013 interior concentrations generally followed the north-to-south gradient with WCA-2 experiencing the highest geometric mean TN concentration of 1.73 mg/L, followed by WCA-3 (1.21 mg/L), Refuge (1.06 mg/L) and ENP (0.97 mg/L). In interior portions of the EPA biota (i.e., bacteria, algae, macrophytes) are generally highly limited by phosphorus but may become nitrogen-limited in areas enriched with P, such as areas in close proximity to canals and impacted areas (Noe et al., 2001). Therefore, assimilation of TN within WCA-2 marsh could be limited due to the relatively large portion of impacted areas (i.e., high phosphorus concentration). Since the implementation and enforcement of BMPs, changes in water management and optimization of the STAs, the marsh condition within WCA-2 has improved. This is apparent as indicated by marsh phosphorus concentrations (see above) and the TP rule assessment (Appendix 3A-6) within WCA-2. Improvement of the marsh condition is also apparent in terms of interior geometric mean TN concentrations within WCA-2 with a steady decline in TN concentrations throughout the assessment periods (**Table 3A-8**). This improvement is not just isolated to WCA-2 but the entire EPA.

Table 3A-8. Summary statistics of total nitrogen (TN) concentrations in milligrams per liter (mg/L) for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), Phase II (WY2005–WY2012), and WY2013 periods.

Region	Class	Period	Sample Size	Geometric Mean	Geometric Standard Deviation	Median	Minimum	Maximum
Refuge	Inflow	1979-1993	1552	3.69	3.05	3.84	<0.50	18.68
		1994-2004	1995	2.58	2.57	2.52	<0.50	1303.45
		2005-2012	1110	2.38	2.29	2.37	0.63	11.98
		2013	124	2.17	2.23	2.16	0.66	4.52
	Interior	1979-1993	378	2.40	2.50	2.29	0.72	36.71
		1994-2004	1114	1.12	1.52	1.10	<0.50	9.50
		2005-2012	1086	1.24	1.61	1.20	0.64	8.69
		2013	198	1.06	1.36	1.07	0.56	1.95
	Outflow	1979-1993	614	2.63	2.65	2.56	<0.50	22.84
		1994-2004	700	2.01	2.22	1.91	<0.50	7.91
		2005-2012	477	1.56	1.81	1.52	0.78	6.33
		2013	88	1.11	1.35	1.11	0.69	1.89
	Rim	1979-1993	96	2.95	2.73	2.76	0.80	10.91
		1994-2004	443	2.43	2.42	2.27	0.84	9.66
		2005-2012	111	2.44	2.29	2.29	1.16	8.24
		2013	20	1.58	1.63	1.60	1.01	1.94
WCA-2	Inflow	1979-1993	793	2.90	2.72	2.90	<0.50	22.84
		1994-2004	938	2.23	2.27	2.25	0.52	7.91
		2005-2012	813	1.90	1.97	1.99	<0.50	6.33
		2013	138	1.58	1.78	1.70	0.73	2.63
	Interior	1979-1993	2708	2.72	2.66	2.55	<0.50	104.13
		1994-2004	2109	1.99	2.26	2.00	<0.50	19.61
		2005-2012	1058	1.95	1.94	2.00	0.75	4.77
		2013	166	1.73	1.79	1.79	0.86	2.86
	Outflow	1979-1993	906	2.24	2.22	2.17	<0.50	7.65
		1994-2004	679	1.67	1.86	1.66	<0.50	4.44
		2005-2012	615	1.68	1.79	1.69	0.90	3.93
		2013	102	1.44	1.70	1.53	0.70	2.87
WCA-3	Inflow	1979-1993	2194	2.02	2.28	1.94	<0.50	10.80
		1994-2004	2455	1.68	1.95	1.57	0.54	7.79
		2005-2012	2340	1.62	1.76	1.60	0.61	12.25
		2013	320	1.60	1.76	1.57	0.97	10.96
	Interior	1979-1993	729	1.94	2.21	1.88	<0.50	10.01
		1994-2004	2508	1.22	1.65	1.20	<0.50	100.60
		2005-2012	932	1.36	1.65	1.37	0.69	3.96
		2013	88	1.21	1.53	1.20	0.67	2.24
	Outflow	1979-1993	1738	1.51	1.88	1.52	<0.50	14.86
		1994-2004	1634	1.11	1.52	1.13	<0.50	4.10
		2005-2012	4908	1.23	1.53	1.23	<0.50	11.10
		2013	763	1.03	1.34	1.06	0.55	3.87
ENP	Inflow	1979-1993	2114	1.36	1.91	1.44	<0.50	14.86
		1994-2004	1952	0.91	1.44	0.95	<0.50	3.60
		2005-2012	7024	1.11	1.46	1.11	<0.50	11.10
		2013	1061	0.96	1.28	0.97	<0.50	3.87
	Interior	1979-1993	572	1.30	2.21	1.37	<0.50	80.93
		1994-2004	959	1.07	1.70	1.13	<0.50	5.70
		2005-2012	510	1.00	1.59	1.00	<0.50	7.68
		2013	79	0.97	1.35	0.97	<0.50	2.40

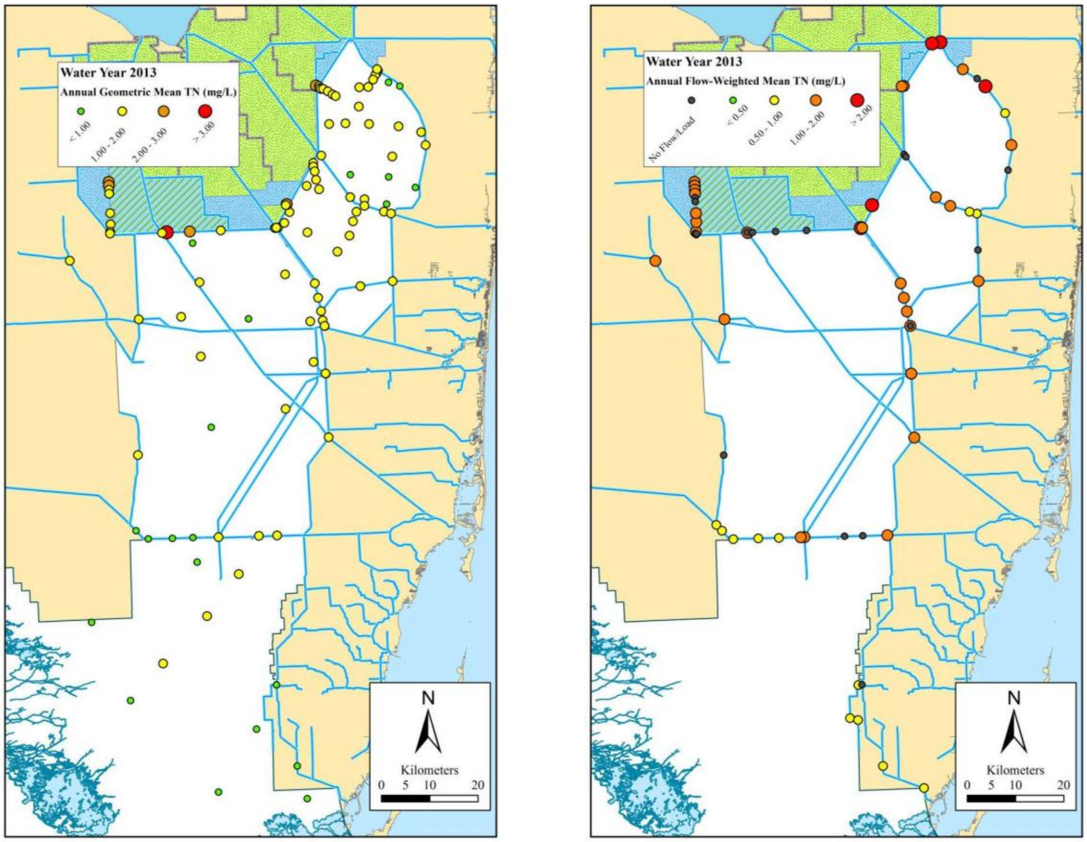

Figure 3A-14. Annual geometric mean total nitrogen (TN) concentrations for all classifications (left panel) and annual FWM TN concentrations at water control structures (right panel) for WY2013 at stations across the EPA.

Annual geometric mean TN concentrations have significantly declined since WY1979 for inflow and interior regions of the EPA as indicated by both **Table 3A-8** and **Figure 3A-15**. Further evidence of this decline is apparent as indicated by the trend analysis in which interior and inflow regions for all compartments of the EPA declined significantly (**Table 3A-9**). The low TN concentrations observed during WY2013 and the decreasing concentrations during the relatively recent history (i.e., WY2005–present) may be the result of improved nutrient removal effectiveness of the STAs, especially during low water conditions. As previously described (Payne et al., 2011; Julian et al. 2013), a strong relationship between interior station TN and TOC within the EPA is present (**Figure 3A-16).** This relationship indicates that the dominant source of the TN measured within the marsh is the organic material that naturally occurs in abundance in the wetland and enters the marsh from the oxidized sediments in the EPA. Additionally, relatively low observed NO_3 + NO_2 concentrations, provides support to this conclusion indicating that inorganic forms of nitrogen from anthropogenic sources to the EPA are relatively small and are not expected to pose a significant risk to the water quality and marsh condition within the EPA.

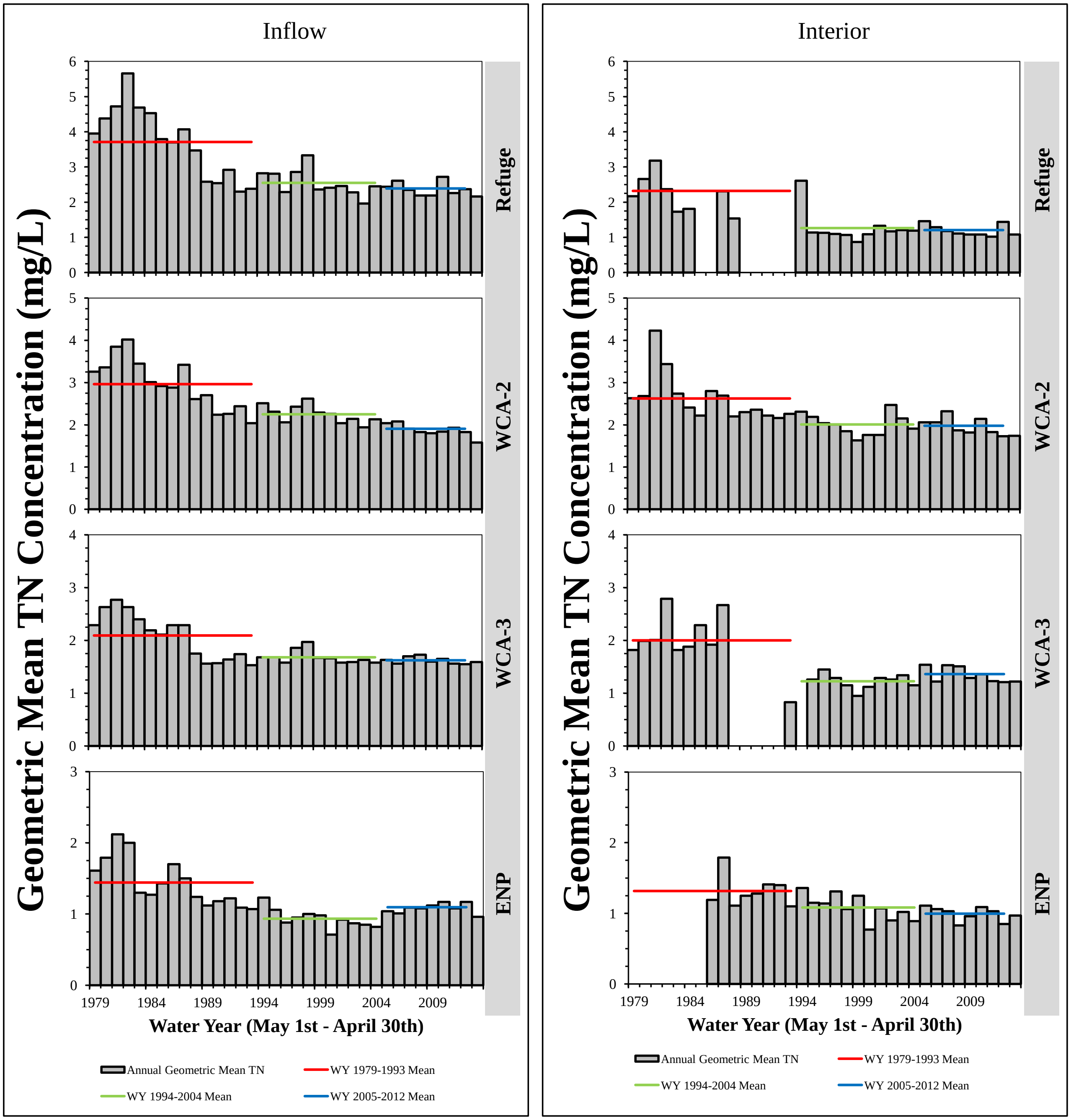

Figure 3A-15. Annual geometric mean TN concentrations (mg/L) for inflow (left) and interior (right) areas of the Refuge, WCA-2, WCA-3, ENP from WY1978 to WY2013. The horizontal lines indicate the mean annual geometric mean TP concentrations for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), and Phase II (WY2005–WY2012) periods. [Note: Areas with no bars indicate data gaps.]

Table 3A-9. Kendall's τ annual geometric mean TN concentration trend analysis results for each region's inflow and interior classification within the EPA. Statistically significant ρ-values are italicized.

Area	Class	Kendall's τ	ρ-value
Refuge	Inflow	-0.62	*<0.01*
	Interior	-0.49	*<0.01*
WCA-2	Inflow	-0.77	*<0.01*
	Interior	-0.60	*<0.01*
WCA-3	Inflow	-0.51	*<0.01*
	Interior	-0.35	*<0.01*
ENP	Inflow	-0.49	*<0.01*
	Interior	-0.54	*<0.01*

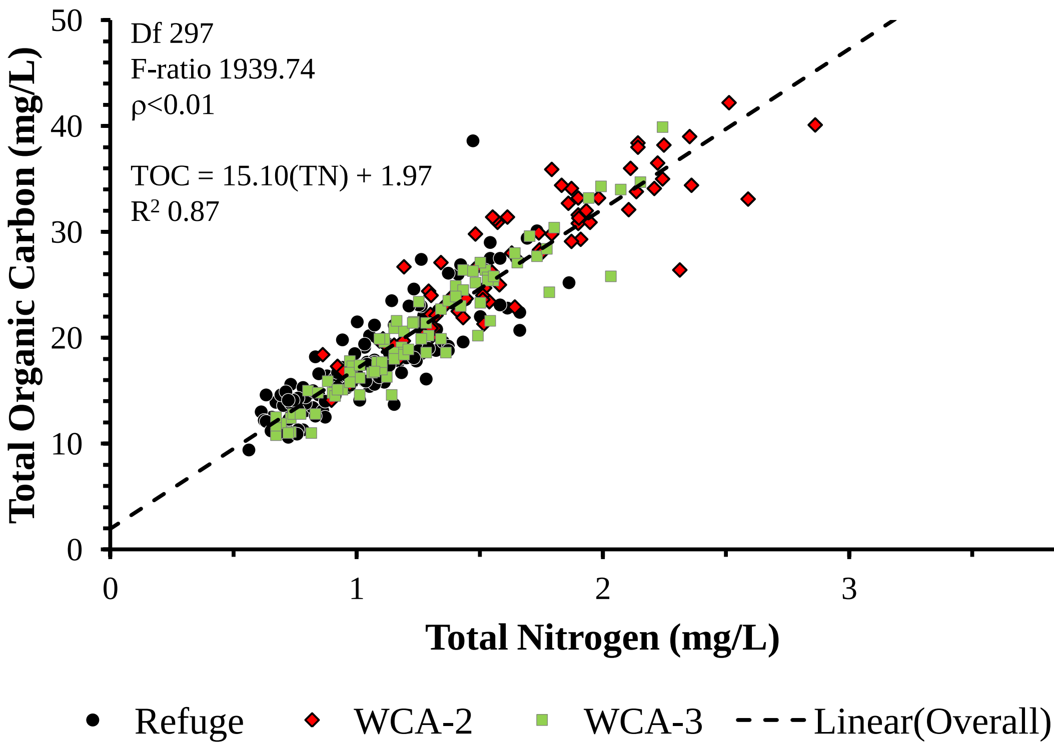

Figure 3A-16. Relationship between TN and total organic carbon concentrations at interior stations from the Refuge, WCA-2, and WCA-3 for WY2013 (n=298).

Total Nitrogen Loads

Regulated inflows significantly contribute to the loading of TN to the EPA system. Estimates of the TN load and FWM TN concentrations to each portion of the EPA for the Baseline, Phase I, and Phase II periods and WY2013 is presented in **Table 3A-10**.

Table 3A-10. Mean FWM TN concentrations and TN loads to the EPA for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), Phase II (WY2005–WY2012), and WY2013 periods.

	Area	Period			
		Baseline WY1979-1993	Phase I WY1994-2004	Phase II WY2005-2012	Current WY2013
Mean Annual TN Load (kilograms)[1]	Refuge	3,719,272	753,648	6,233,852	806,878
	WCA-2	2,710,058	2,275,882	2,296,335	1,950,291
	WCA-3	3,880,250	2,460,407	3,321,158	2,446,137
	ENP	1,450,915	1,305,352	1,799,873	1,150,260
Mean Annual TN FWM (mg/L)	Refuge	6.20	1.67	7.90	2.29
	WCA-2	4.13	1.73	2.67	2.10
	WCA-3	2.71	1.46	1.91	1.58
	ENP	1.35	0.96	0.97	1.06

[1] 1 kilogram = 0.001 metric tons

In addition to inflow, atmospheric deposition contributes to the TN loading into the EPA. Atmospheric deposition is an important source of nutrients to oligotrophic ecosystems, furthermore meteorological conditions of South Florida are ideal for atmospheric deposition in that rainfall can scavenge aerosolized nitrogen from the atmosphere (Sutula et al., 2001). Atmospheric deposition rates can be highly variable ranging from approximately 0.005 g/m^2/yr N in remote areas to > 2 g/m^2/yr N in urban areas (Galloway et al., 2004). Since atmosphere TN deposition is highly variable and very expensive to monitor, routine monitoring is not conducted. Inglett et al. (2011) reported a TN deposition rate to the Everglades of 0.48 g/m^2/yr N. This atmospheric deposition estimate does not address the influence of traffic density of the highways near or transecting the EPA (i.e., I-75, US-41, SR-27, etc.). Motor vehicle traffic is a very important source of atmospheric deposition of NOx and is influenced by traffic density (Jimenez et al., 2000). However with improved mileage mandated by the USEPA, the NOx emission rate will be potentially reduced.

Annual TN loads from surface water sources, including internal transfers within the EPA (i.e., Refuge to WCA-2 and WCA-2 to WCA-3) were 5,490 mt 5,489,937 kilograms per year (kg/yr)], with a FWM TN concentration of 1.59 mg/L during WY2013. Using the estimated TN deposition rate provided by Inglett et al. (2011), the northern portion of the EPA (i.e., Refuge, WCA-2, and WCA-3) can potentially receive up to 1,677 metric tons per year (mt/yr) of TN (1,676,922 kg/yr) from atmospheric deposition. Discharges from the northern EPA account for 3,643 mt/yr (3,642,962 kg/yr) of TN with a FWM TN concentration of 1.25 mg/L during WY2013. The difference between inflow and outflow load (1,847 mt TN) indicates that uptake and assimilation of nitrogen is occurring within the natural communities of the EPA even though the surface water load is greater than the atmospheric deposition load. In comparison to last water years TN load estimate, a 62 percent increase in TN inflow load was observed between WY2012 and WY2013. This increase most likely was due to an increase in surface water flow.

Annual TN loads from surface waters to ENP were 1,305 mt (1,305,351 kg/yr), with a FWM TN concentration of 0.96 mg/L during WY2013. Based on the atmospheric deposition rate provided by Inglett et al. (2011), ENP can potentially receive up to 2,987 mt/ yr of TN (2,986,506 kg/yr) from atmospheric deposition. Much like the EPA, ENP observed a 62 percent increase in TN surface water inflow load presumably due to increased flow.

As stated previously, mean flow and load to the EPA, especially the Refuge during the Phase II and current water year, have been highly influence by climates extremes. The annual TN load to the Refuge was 754 mt during WY2013, representing a 95 percent increase in TN inflow load during the previous water year (WY2012: 386 mt). This trend is consistent for WCA-2 but less drastic for WCA-3. WCA-2 received 2,276 mt during WY2013, representing a 114 percent increase in TN inflow load during the previous water year (WY2012: 1,062 mt). WCA-3 received 2,460 mt during WY2013, representing a 43 percent increase in TN inflow load during the previous water year (WY2012: 1,945 mt).

Annual TN inflow loads were only significantly different between periods for the Refuge (Df 2, F Ratio 16.38, ρ <0.01) and WCA-3 (Df 2, F Ratio 3.37, ρ <0.05) with TN loads being significantly reduced during Phase II relative to the Baseline and Phase I periods. TN inflow loads to the Refuge peaked during from WY1997 to WY1998 resulting in 32,838 mt and 12,207 mt, respectively, presumably due to high rainfall throughout South Florida resulting in increased stages in both Lake Okeechobee and the Refuge (see Appendix 2-3 of this volume). Mean TN loads during each respective period progressively dropped for WCA-3. However, annual TN inflow loads for WCA-2 (Df 2, F Ratio 0.63, ρ 0.54) and ENP (Df 2, F Ratio 1.34, ρ 0.28) were not significantly different between periods. These results are apparent when reviewing annual loads and the average across those periods (**Figure 3A-17**).

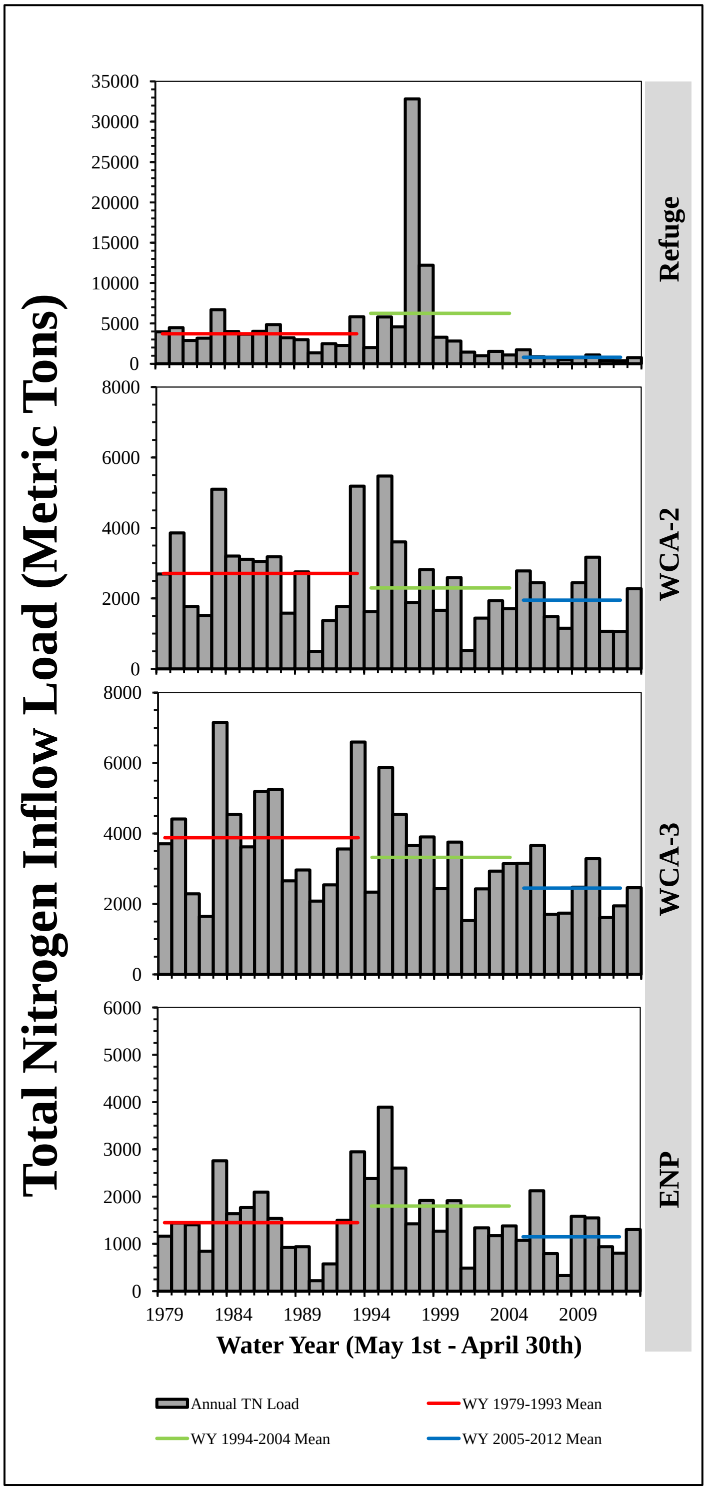

Figure 3A-17. Annual inflow TN loads for the Refuge, WCA-2, WCA-3 and ENP from WY1979–WY2013. The horizontal lines indicate the mean annual loads and flows for the Baseline (WY1979–WY1993), Phase I (WY1994–WY2004), and Phase II (WY2005–WY2012) periods.

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