Appendix 4-2: Supplemental Information for the C-139 Basin in the Southern Everglades

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INTRODUCTION

The 1994 Everglades Forever Act (EFA), Section 373.4592, Florida Statutes (F.S.), set into motion an aggressive and comprehensive restoration program of construction, research, and regulation projects designed to ensure that all waters discharging into the Everglades Protection Area achieve and maintain compliance with phosphorus and other water quality standards (SFWMD 2002). One of the goals of the EFA was to ensure that the historical average annual phosphorus load from the C-139 Basin not be exceeded. In Water Year 2000 (WY2000) (May 1, 1999–April 30, 2000), however, the C-139 Basin exceeded this goal triggering additional actions. At the time, the EFA directed the South Florida Water Management District (SFWMD or District) to require landowners within the C-139 Basin to implement best management practices (BMPs) if SFWMD determines that the basin is collectively exceeding the average loading of total phosphorus (TP) based proportionately on historic rainfall during the period of October 1978 to September 30, 1988. The EFA also required the SFWMD to develop and implement a water quality monitoring program to evaluate the quality of the discharge from the C-139 Basin. The EFA stated that new surface water inflows shall not increase the annual average loading referenced by the EFA, and SFWMD was mandated to establish a compliance determination method under Chapter 40E-63, Florida Administrative Code (F.A.C.), to implement this statutory loading requirement. The EFA also establishes that if the C-139 Basin would be determined to exceed the collective TP loading requirements, compliance determinations for individual landowners for remedial action shall be based on the landowners' proportional share of the TP load. Finally, the EFA also establishes that the provisions in Section 373.4592(4)(f)2 to 4, F.S., which encompass permitting, BMP research, and water quality improvement measures, also apply to the C-139 Basin.

Chapter 4 provides an overview of the regulatory source control program established by SFWMD to address EFA mandates including the WY2016 compliance determination and source control strategy. This appendix provides detailed information on the procedures SFWMD followed to determine whether the C-139 Basin maintained historic TP loads in runoff. This includes the water quality and quantity collection sources and methods currently applied. A water quality monitoring network is maintained by SFWMD at the C-139 Basin-level and at hydrologic subbasins to assess program performance, determine compliance, and make adjustments when necessary to assure compliance. Basin-level data are used for the C-139 Basin collective compliance determination, while subbasin data can be used to represent individual landowner proportional share of the C-139 Basin TP load for remedial action under a noncompliance scenario.

Individual landowners can also voluntarily implement a permit-level discharge monitoring plan to be used in-lieu of the SFWMD subbasin data associated with their property. On a case-by-case basis, synoptic upstream-level monitoring is conducted for priority areas (e.g., stations that can serve as indicator locations in the long-term, or stations associated with specific projects or activities). This appendix provides a summary of the upstream level monitoring currently conducted. Supplemental evaluations of the rainfall, flow, and TP load distribution among the C-139 subbasins are also included.

This appendix also expands on the background for the development of the C-139 Basin regulatory program, as it explains the basis for the source control strategies and the magnitude of the efforts and investigations associated with the program.

C-139 BASIN REGULATORY PROGRAM BACKGROUND

Since water quality monitoring data from the C-139 Basin demonstrated that the landowners within the basin collectively exceeded historical annual phosphorus loading levels, Chapter 40E-63, F.A.C., was amended in 2002 to include Part IV. Part IV describes BMP Regulatory Program requirements for the C-139 Basin. A historical timeline of the C-139 Basin activities leading up to the current source control program in the basin is in **Table 1**.

Table 1. Historical timeline of the C-139 Basin. Years under timeframe are calendar years.

Timeframe	Event
1999	As of Calendar Year 1999 (CY1999), the reported land uses in the C-139 Basin were agriculture (126,061 acres or ac), natural areas (41,098 ac), urban (808 ac), barren land (698 ac), water (519 ac), and transportation (30 ac) for a total of 169,214 ac (685 square kilometers or km^2) (ADA Engineering, Inc. 2006).
2002	SFWMD amended Chapter 40E-63, F.A.C., in January 2002, requiring implementation of a BMP regulatory program in the C-139 Basin in accordance with the EFA. The goal of the program is to maintain TP loads at or below levels observed during WY1980–WY1988. The BMP regulatory program requires landowners within the C-139 Basin to implement a BMP plan that includes a multi-level approach to implementation and operation via Works of the District (WOD) permits. All permits are renewed on the same five-year cycle.
2002	SFWMD launched the C-139 Basin and Western Basins (Feeder Canal and L-28 basins) Grant Program in partnership with the Natural Resources Conservation Service through a contract with Hendry Soil and Water Conservation District (HSWCD) to administer the program. The grant program provided funding to landowners for implementation of BMPs to reduce phosphorus in discharges. The BMP projects ranged from canal cleaning operations and installation of water control structures to construction of surface water reservoirs. The initial grant cycle started in CY2002 with $91,400 awarded to one project.
2003	The initial compliance determination period for the C-139 Basin was completed (WY2003). The basin was determined to be out of compliance. The compliance determination represented a basic level of 15 BMP equivalent points with no verification by SFWMD.
2004	The Florida Department of Agriculture and Consumer Services (FDACS) joined the C-139 Basin and Western Basins Grant Program by contributing funds to the program. The second grant cycle started in CY2005 with $202,000 awarded to four projects

Table 1. Continued.

Timeframe	Event
2004	SFWMD commissioned Community Watershed Fund (CWF) and DB Environmental, Inc. (DBE) to review phosphorus water quality data collected for the C-139 Basin from all prior monitoring initiatives. Historic data for the period of May 10, 1999, through May 10, 2004, were reviewed. The data suggested that much of the TP exported from the C-139 Basin came from relatively few sites in the central and southern basin (CWF and DBE 2004). The Deerfence and S&M canals serve the southern area of the basin. The data showed that phosphorus was exported as primarily total dissolved phosphorus with some evidence of particulate phosphorus in the S&M Canal.
2005	SFMWD commissioned CWF and DBE to conduct an exploratory investigation of phosphorus cycling and transport in the Deerfence and S&M canals (CWF and DBE 2005). The consultants evaluated the water quality effects of one storm event and found the S&M Canal to be the largest source of TP. Phosphorus transported down the Deerfence and S&M canals was primarily dissolved phosphorus. Canal sediments were not found to be a significant source (via reflux) or sink of phosphorus. They recommended that an upstream water quality monitoring program (supplementary to the compliance monitoring) be initiated to obtain a better understanding of TP sources, cycling, and transport mechanisms in order to improve the effectiveness of the BMP program.
2005	Following the recommendations made by CFW and DBE in CY2004 and CY2005, SFWMD initiated supplemental monitoring at 18 sites that represent locations upstream of basin regulatory compliance points that were previously monitored. These sampling locations gave "snapshots" of phosphorus concentrations throughout the basin during the wet season (April 1–October 30) and did not necessarily represent hydrologic subbasins. The samples were collected weekly when flowing. Parameters tested include TP, total dissolved phosphorus, and ortho-phosphorus.
2005	The C-139 Basin Vegetable Production Demonstration project was initiated. This six-year project (CY2005–CY2011) was conducted through a cooperative agreement between SFWMD and FDACS. FDACS oversaw development of the project by the University of Florida Institute of Food and Agricultural Sciences (IFAS) Southwest Florida Research and Education Center (SWFREC) in Immokalee in cooperation with C-139 Basin vegetable growers. The goal of the project was to develop technical information to optimize nutrient management BMPs to prevent unnecessary application and phosphorus losses in runoff, and effectively disseminating this information (Morgan and McAvoy 2012)
2006	The third grant cycle of the C-139 Basin and Western Basins Grant Program was started with $535,600 awarded to six projects. The Grant Program ends in CY2007 with a total of $829,000 spent to cost-share six projects between CY2002 and CY2007.
2006	Phase I of the C-139 Basin Phosphorus Water Quality and Hydrology Analysis (A.D.A. Engineering, Inc. 2006) was completed. The analysis defined 8 hydrologic subbasins and identified 4 monitoring locations where flow and TP concentration could be measured to supplement the existing basin-level monitoring network.
2006	SFWMD initiated the C-139 Basin Monitoring Network Optimization in accordance with the findings from the hydrologic study conducted by A.D.A. Engineering, Inc. The objective of this effort was to facilitate measurement of water quality and quantity of the subbasins identified in the hydrologic study. The data collected is used for BMP optimization and to prioritize water quality improvement activities.

Table 1. Continued.

Timeframe	Event
2007	SFWMD commissioned CWF to evaluate the data collected during WY2006 and a report entitled *WY06 Analysis of C-139 Basin Phosphorus Sources, Transport, Cycling, and Export* was produced (CFW 2007). Major findings were (1) fifty percent of the C-139 Basin annual load was exported to Stormwater Treatment Area (STA) 5, and 41 percent to the L-3 Canal via the G-406 structure; (2) there are significant differences in TP concentration levels among subbasins and locations; (3) there is TP attenuation along segments of canal in the S&M Canal and southern L-2 Canal subbasin; (4) soluble reactive phosphorus (SRP) was the predominant species in the S&M Canal and Deerfence Canal subbasins; and (5) particulate phosphorus was more prominent in the L-2 subbasin.
2007	An integrated regulatory initiative was initiated together with consumptive water use and stormwater management system permitting groups within SFWMD to ensure comprehensive solutions and a streamlined approached with permittees.
2007	The fourth compliance determination period for the C-139 Basin was completed (WY2007). The compliance determination represented a level of 35 BMP equivalent points with verification by SFWMD. The C-139 Basin was out of compliance for four consecutive water years (WY2003–2006). Pursuant to paragraph 40E-63.460(3)(d), F.A.C., SFWMD was required to revise Part IV of Chapter 40E-63, F.A.C., to ensure the objectives of the EFA are met. To allow time for SFWMD to revise Part IV, the duration of the existing permits was extended until the new rules and criteria were adopted and effective. The proposed rule amendments extended the C-139 Basin WOD permits for an initial one-year term followed by six-month administrative extensions until the amended rules became effective in November 2010. All permits were set to expire 90 days from the rule effective date.
2008	A partnership between SFWMD and HSWCD was initiated to fund demonstration of innovative and/or optimized BMPs. Two projects were selected: (1) Evaluation of the Effectiveness of Structural Modifications (i.e., discharge structure relocation and creation of internal cells) made to a surface water reservoir; and (2) Evaluation of the Effectiveness of Chemical Precipitation in Removing Phosphorus in Agricultural Discharges. Results from the first project indicated that farm phosphorus loads could be further reduced, in comparison to typical reservoirs, by constructing internals berms within an existing reservoir and flowing water through these constructed cells (Obern 2011b). Data collection under the second project was limited by the dry conditions observed during the project term. It was recommended to extend the water quality monitoring period for one more year to determine BMP effectiveness, its feasibility, and any factors potentially affecting BMP performance (Obern 2011a).
2008	A regional feasibility study, encompassing the C-139 Basin, the Feeder Canal Basin, and the L-28 Basin began in September 2008. This study intended to address two significant water resources issues in this region: (1) water quality of discharges to downstream water and (2) balancing annual climate patterns with flood, natural resources (wetlands) protection, and water availability. The project was completed in CY2012.
2009	The C-139 Basin land uses were reviewed and updated as follows: pasture and natural areas (127,575 ac), agriculture (38,269 ac), institutional, urban, and industrial (1,748 ac), and water (669 ac). A map is presented in **Figure 1**. A SFWMD land use data set update based on 2014–2015 aerial photography will be made available by May 2017.
2009	SFWMD entered into a two-year contract with University of Florida IFAS SWFREC to quantify the phosphorus nutrient treatment efficiency of an impoundment located in a vegetable farm and to identify design modifications (e.g., increasing residence times by changing inflow locations, dividing the impoundment into multiple treatment cells, etc.) to increase its treatment efficiency. Results from this study (Shukla et. al. 2011) indicated that the treatment efficiency for the impoundment was 20 percent or 14 kilograms per hectare. The lower-than-expected treatment efficiency was likely due to dead zones, long-term phosphorus loading that has used most of the soil phosphorus retention capacity, lower residence time, and short-circuiting. Modifications (structural and managerial) to improve this efficiency were identified. However, they need to be field tested to evaluate their feasibility and associated costs.

Table 1. Continued.

Timeframe	Event
2010	Amendments to Part IV of Chapter 40E-63, F.A.C., (C-139 Basin Rule) became effective in November 2010, requiring the implementation of comprehensive BMP plans to reduce phosphorus in runoff within 90 days after the rule effective date (February 2011).
2010	SFWMD commissioned Soil and Water Engineering Technology, Inc. to (1) evaluate phosphorus sources, transport, and cycling throughout the C-139 Basin through analysis of water quality data collected from May 1, 2005, to April 30, 2009; (2) recommend optimization of upstream monitoring efforts; and (3) provide ideas to support adaptive management for implementation of the regulatory source control program, supplementary activities, or regional projects. The final report was submitted in November 2010 (SWET 2010).
2011	C-139 Basin Phosphorus Source Control permits were renewed in accordance with the amended rule. The permittees were required to implement comprehensive BMP plans as of February 2011.
2012	SFWMD commissioned DBE to (1) conduct a tracer test to evaluate how features (soil, topography, configuration, etc.) affect transport and removal in a typical impoundment, thus justifying modification to improve its performance, and (2) assess the hydrologic characteristics of a modified impoundment that better uses existing storage to ensure sufficient detention time. The final reports (DBE 2013a, b) were submitted in January 2013 with the following findings and recommendations: (1) the tracer test results revealed poor hydraulic conditions of the impoundment, but by increasing the retention time and minimizing the dispersion within the impoundment, phosphorus removal performance could be improved, and (2) historic and recent survey data collected in the modified impoundment indicated that short circuits exist in areas that do not receive flow. However, due to project cost and effort, the consultant recommended that any future tracer study focus on a subset of the internal cells.
2013	The first water year of compliance determination under the amended rule was completed. The C-139 Basin was found to be in compliance.
2014–2015	Approximately 26,000 ac (105 km^2) within the C-139 Basin enrolled in the Natural Resources Conservation Service Wetland Reserve Program. The goal is to restore the hydrology and habitat function of previously impacted wetlands. However, lands may continue to be used for cow-calf operations. The projects are expected to be completed in CY2016.

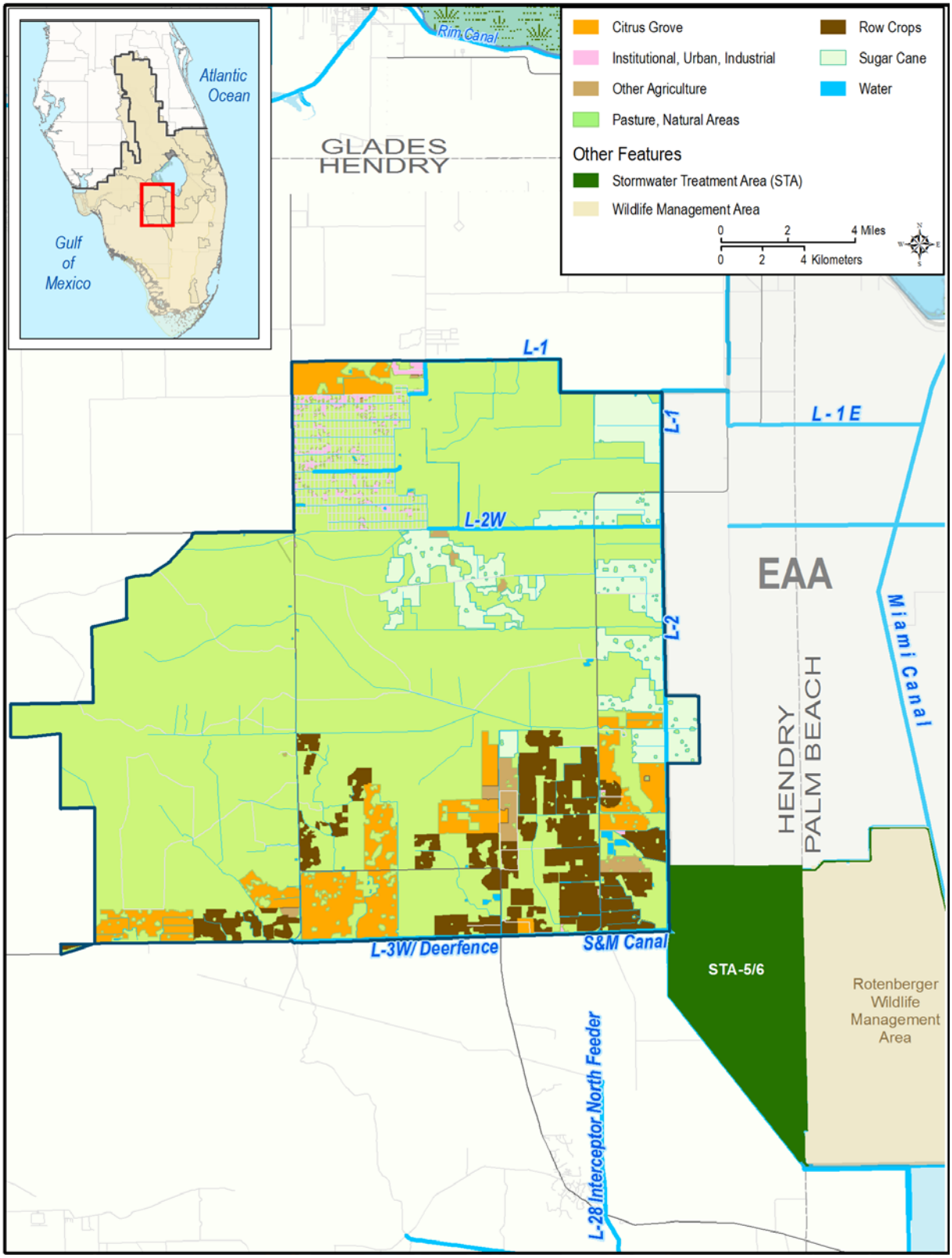

Figure 1. Land use data for the C-139 Basin (Calendar Year 2009).

Similar to the EAA Basin, Chapter 40E-63, Part IV, F.A.C., established a compliance methodology for comparing current annual phosphorus loading levels, measured during implementation of the BMP program, with historic phosphorus levels measured during a period when the program did not exist. The program relies on a permit that describes the approved BMP plan, including implementation, documentation, and reporting requirements. However, the BMP program in the C-139 Basin included four levels of BMP implementation designated as Levels I, II, III, and IV. Incremental increases in levels of BMP implementation occurred because of noncompliance with the basin-level performance measure.

After finding the C-139 Basin to be out of compliance for the fourth consecutive year in WY2006, with Level IV BMP implementation, SFWMD initiated rule development to improve the program and bring the basin into compliance. Through the initial program implementation, basin-specific constraints were identified and considered for improving future program effectiveness. SFWMD conducted technical investigations including water quality analyses, hydrology evaluations, and BMP demonstration projects, to improve BMP effectiveness and water quality. Also, SFWMD cost-shared implementation of infrastructure projects, conducted integrated regulatory approaches with consumptive water use and stormwater management system permitting groups within SFWMD, enhanced stakeholder interaction and outreach, and contracted modeling to evaluate the feasibility of potential subregional projects. It was determined that ensuring onsite water management in concert with optimized nutrient management was essential.

Since permittees in the C-139 Basin were not required to collect water quality and quantity data to characterize farm-level discharges, SFWMD initiated a phased installation of water quality and quantity monitoring instrumentation to collect data for upstream areas throughout the basin in WY2006. The monitoring network provides data to evaluate the relative contribution of the hydrologic subbasins within the C-139 Basin, the timing of releases, and the different phosphorus species.

As a result of these activities and lessons learned from implementation of the program, Chapter 40E-63, F.A.C., Part IV, was amended in 2010 to require implementation of a comprehensive BMP plan, which includes all defined categories of BMPs (nutrient management, water management, and sediment controls) in order to control the different phosphorus species. The water quality monitoring network representing hydrologic subbasins was incorporated in the rule, and refinements to the compliance methodology were made to account for regional system changes and assumptions that were not considered when the methodology was originally developed.

C-139 BASIN SUPPLEMENTAL EVALUATION

C-139 BASIN PERFORMANCE MEASURE METHODOLOGY

Chapter 40E-63, F.A.C., Part IV, outlines the performance measure and compliance methodology for determining whether the C-139 Basin is meeting the annual phosphorus load requirements described in the EFA. The EFA requires that TP loads discharged from the C-139 Basin be maintained at or below historic levels. Historic levels are as represented by TP loads measured during the baseline period of WY1980–WY1988 before the BMP program was implemented and the hydrologic conditions that occurred during a calibration period (WY2000–WY2009), as described in the model incorporated in Chapter 40E-63, F.A.C. The measured TP runoff load is determined each water year, with the BMP program implemented, based on flow and water quality data measured by SFWMD at each C-139 Basin outfall structure.

The list of outfall structures used in the annual compliance assessment may be adjusted by SFWMD to account for changes in C-139 Basin boundary structures. SFWMD may also make adjustments to reduce basin boundary flows that are not representative of historic conditions. Examples include discharges related to SFWMD's operation of the regional water management system for purposes other than flood control and inflows to the historic hydrologic boundary. No adjustments have been made to date, including WY2016.

If any such adjustments are made in the future, the associated reductions and their technical basis will be documented in the *South Florida Environmental Report* (SFER). As established in Chapter 40E-63, F.A.C., also, new inflows to the C-139 Basin are subject to the requirements of the source control program.

The compliance methodology incorporates a two-prong test using a target load and a limit load to account for the possibility of statistical error. The target load is the baseline period load estimated considering the current water year rainfall characteristics. The target load is estimated by applying the current water year rainfall characteristics to a baseline period model to account for the hydrologic variability between WY2016 and the baseline period. The target load, with a 90 percent confidence interval applied based on the regression statistics, provides a base period limit load. The target and limit loads are used to determine annual compliance with the EFA requirement of maintaining baseline period loading rates. The C-139 Basin is out of compliance when the measured runoff TP load is above the target load for three successive years or above the limit load in any one year, within the rule-designated rainfall range. The regression model equations and coefficients are presented in **Figure 2**. **Figure 3** presents the regression model equation with the WY2016 coefficients and the monthly rainfall levels.

The measured runoff TP load for WY2016 is above the estimated target load for the baseline period adjusted for rainfall. WY2016 is year one of the three-year target test because the basin TP runoff load for WY2015 was below the target load for the baseline period. Therefore, the basin was determined to be in compliance with the performance measure because the TP load did not exceed the one-year limit or three-year target test for WY2016.

RULE 40E-63 C-139 BASIN COMPLIANCE MODEL (from Chapter 40E-63, F.A.C.)

The target, limit and adjusted rainfall will be calculated according to the following equations and explanation:

Target = exp (-17.0124 + 4.5995 X + 3.9111 C – 1.0055 S)

Explained Variance = 74.2%, Standard Error of Estimate = 0.5440

Predictors (X, C, S) are calculated from the first three moments (m_1,m_2,m_3) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the current year:

$m_1 = \text{Sum}[\, r_i \,] / 12$

$m_2 = \text{Sum}[\, r_i - m_1 \,]^2 / 12$

$m_3 = \text{Sum}[\, r_i - m_1 \,]^3 / 12$

$X = \ln(12\, m_1)$

$C = [\, (12/11)\, m_2]^{0.5} / m_1$

$S = (12/11)\, m_3 / m_2^{\,1.5}$

Limit = Target exp (1.440 SE)

SE = standard error of predicted ln(L) for May-April interval

$$SE = 0.5440\, [\, 1 + 1/10 + 4.8500\,(X-X_m)^2 + 8.1932\,(C-C_m)^2 + 0.9247\,(S-S_m)^2 + 4.5950\,(X-X_m)(C-C_m) - 0.3624\,(X-X_m)(S-S_m) - 4.0048\,(C-C_m)(S-S_m)\,]^{0.5}$$

Adjusted Rainfall = $\exp[X + 0.8503\,(C - C_m) - 0.2186\,(S - S_m)]$

Where:

Target = predicted load for future rainfall conditions (metric tons/year)

Limit = upper 90% confidence limit for Target (metric tons/year)

Adjusted Rainfall = equivalent rainfall for mean C and S variables (inches)

X = the natural logarithm of the 12-month total rainfall (inches)

C = coefficient of variation calculated from 12 monthly rainfall totals

S = skewness coefficient calculated from 12 monthly rainfall totals

X_m = average value of the predictor in calibration period = 3.8434

C_m = average value of the predictor in calibration period = 0.9087

S_m = average value of the predictor in calibration period = 0.8200

Figure 2. Chapter 40E-63, F.A.C. (referred to as Rule 40E-63 in the figure), Appendix B2 excerpts of hydrologic adjustment and basin compliance mathematical equations to calculate annual TP load reductions.

WY2016 C-139 Basin estimated TP load calculation

See 40E-63 Appendix B2 for "Target" equation

Month	Rainfall	(in)			
May	2.5	in	m_1 =	4.39	
Jun	6.2	in	m_2 =	12.30	
Jul	3.8	in	m_3 =	37.97	
Aug	10.7	in	X =	3.964	
Sep	7.9	in	C =	0.835	
Oct	1.2	in	S =	0.961	
Nov	2.3	in	SE =	0.603	
Dec	2.8	in			
Jan	11.1	in	Target[1] TP Load =	33	t
Feb	2.1	in	Limit[2] TP Load =	80	t
Mar	1.4	in	Runoff TP Load =	43	t
Apr	0.8	in	Estimated[3]=	33	t
Total Rainfall	52.6	in	% Reduction =	-30%	

Notes:

[1] Target load is adjusted for reduction in C139 land area (168450 ac./ 169700 ac.)

[2] Limit load in upper 90% confidence limit for Target

[3] Estimated (Predicted) load = Target load

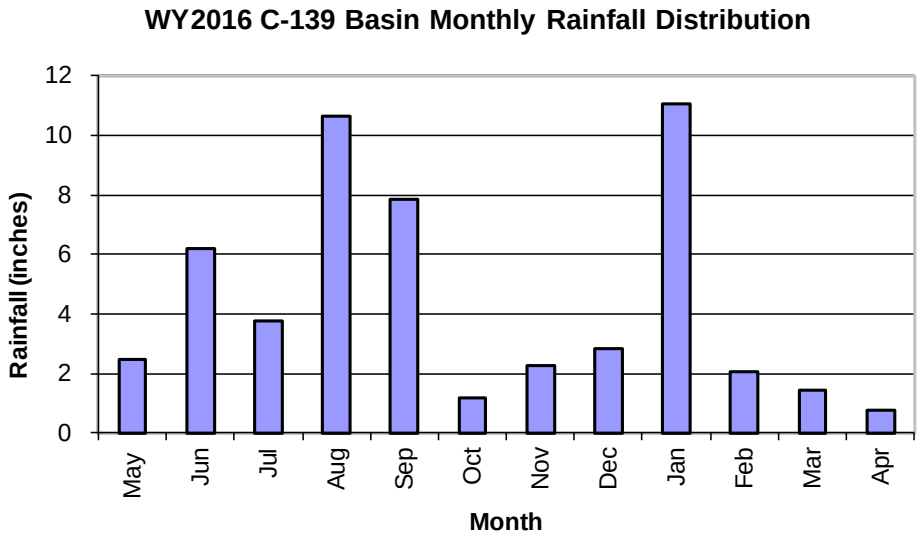

Figure 3. WY2016 C-139 Basin monthly rainfall, total rainfall, calculated target, limit, and runoff TP loads, based upon Chapter 40E-63, F.A.C., Appendix B2. [Notes: ac. = acres; in = inches; and t = metric tons.]

C-139 BASIN-LEVEL DATA COLLECTION SOURCES AND METHODS

Chapter 40E-63, F.A.C., requires SFWMD to report on the C-139 Basin TP load reductions and their technical basis. Appendix B2 of Chapter 40E-63, F.A.C., outlines data collection requirements. Data collection efforts for WY2016 were consistent with Chapter 40E-63, F.A.C., and supporting appendices.

During WY2016, eight structures comprised the modeling boundary of the C-139 Basin and seven water quality monitoring sampling points represented the water quality of flow through those structures. The water quality monitoring at structure G-508 represents both G-508 and G-342O. The G-136 structure serves as an outflow boundary point of the C-139 Basin into the Everglades Agricultural Area (EAA) Basin. **Table 2** provides WY2016 TP sampling statistics for all SFWMD-monitored stations in the C-139 Basin. The locations of the monitoring stations in **Table 2** are provided in **Figure 7** later in this chapter.

Table 2. Summary statistics for WY2016 TP monitoring data for the C-139 Basin.

Structure	Sampling Site Name	Sample Type	Number of Samples	Number Used in Load Calculation	Minimum (µg/L) [a]	Maximum (µg/L) [a]	Number Flagged	Flow [b] Curve Rating
G-342A	G342A	Grab	52	0	40	237	0	Good
		Composite [c]	25	25	51	373	0	
G-342B	G342B	Grab	52	1	52	236	0	Good
		Composite [c]	24	24	54	236	0	
G-342C	G342C	Grab	52	2	53	287	0	Good
		Composite [c]	27	27	68	259	0	
G-342D	G342D	Grab	51	1	66	254	0	Good
		Composite [c]	24	24	52	525	0	
G-406	G406	Grab	52	3	44	433	0	Good
		Composite [c]	3	3	154	162	0	
G-136	G136	Grab	26	9	17	204	0	Poor
		Composite [c]	21	21	31	145	0	
G-508	G508	Grab	52	6	51	306	0	Excellent
		Composite [c]	35	35	50	518	0	

a. µg/L = microgram per liter; 1 µg/L ≈ 1 part per billion.

b. Flow curve rating – discharge estimates derived from theoretical equations are within a range of expected values based on streamflow measurements used to calibrate the theoretical equations and are classified as excellent (< 5%), good (< 10%), fair (< 15%), or poor (> 15%).

c. Composite samples could be time-proportional, flow-proportional, or a combination of the two.

C-139 BASIN-LEVEL WATER QUALITY SUMMARY

As in the EAA Basin, the SFWMD is required to collect monitoring data from the C-139 Basin to determine collective compliance with TP load limitations. The TP load ultimately discharging to the Everglades is not the same as the TP loads leaving C-139 Basin outflow structures because discharges are directed into other water bodies. The outfall structures accounting for the loads in the C-139 Basin compliance determination include G-136 discharging to the L-1 canal; G-342A, G-342B, G-342C, and G-342D discharging into Stormwater Treatment Area (STA) 5 Flow-ways 1 and 2; and G-406, G-508, and G-342O discharging into the L-3 canal leading to STA-5 Flow-ways 3, 4, and 5, and STA-6. **Table 3** summarizes the overall WY2016 flow, TP load, and TP flow-weighted mean concentration (FWMC) at these eight primary basin outflow structures. TP is made up of total dissolved phosphorus (TDP) and total particulate phosphorus (TPP), and the proportion of each species is also presented for each structure in **Table 3**. The speciation per structure indicates lower TPP at structures G136, G342D, G342O, and G508,

compared to G342A, G342B, G342C, and G406. In WY2016, the majority of the TP load measured in runoff for the C-139 Basin as a whole was of the TDP species. The locations of the C-139 primary outfall structures in **Table 3** are depicted in **Figure 7** later in this chapter. During WY2016, 41.1 metric tons (t) of TP (94.6 percent) was exported to STA-5 and STA-6 via the G-342A through G-342D structures, G-406, G-342O, and G-508, and 2.4 t (5.4 percent) was exported to the L-1 canal via G-136.

Table 3. C-139 Basin loads, flows, and TP FWMC by source for WY2016.

Structure	TP Load (t) [a]	TDP percentage of TP load [b]	TPP percentage of TP load [b]	Flow (10^3 ac-ft) [a]	TP FWMC (µg/L)[a]	Percent of C-139 Basin TP Load	Percent of Total Flow
C-139 Basin to EAA Basin							
G-136 Total [c]	2.4 [d]	82%	18%	18.2 [d]	105 [d]	5.4%	11.1%
C-139 Basin to STA-5/6							
G-342A	4.3	75%	25%	16.7	210	10.0%	10.2%
G-342B	3.9	75%	25%	19.5	162	9.0%	11.9%
G-342C	2.3	75%	25%	12.8	147	5.3%	7.8%
G-342D	2.4	83%	17%	9.8	202	5.6%	6.0%
G-406 [e]	0.2	75%	25%	1.2	160	0.6%	0.8%
G-508	27.8	80%	20%	84.7	266	63.9%	51.8%
G-342O	0.1	81%	19%	0.5	143	0.2%	0.3%
STA-5/6 Total	41.1	78.6%	21.4%	145.3	229	94.6%	88.9%
C-139 Basin							
Basin Total	43	79%	21%	164	216	100%	100%

a. t = metric tons, 1 t = 10^3 kg; 10^3 ac-ft = thousands of acre-feet, 1 ac-ft = 1,233 cubic meters (m^3); µg/L = micrograms per liter, 1 µg/L ≈ 1 part per billion.

b. The TP species data are collected via weekly grab samples. Therefore, the TP load represented by the TP species data may differ from the TP load measured via autosampler representing the TP Load, flow, and TP FWMC.

c. G-136 discharges runoff from C-139 Basin lands that are tributary to the L-1 canal. Conveyance of runoff through the G-136 structure into the Miami Canal for eventual treatment in STA-3/4 is for flood control in the L-1 canal and to address capacity limitations in sending the runoff to the south through the L-2 and L-3 canals for treatment in STA-5/6.

d. These values differ from the ones reported in Tables 6, 7, and 8 of Appendix 3A-5 of this volume based on the receiving body. This table represents TP load, flow, and FWMC in C-139 Basin landowner runoff discharged to the east through structure G-136. Discharges from G-136 can flow either to the north (Lake Okeechobee) or to the south (e.g. STAs). Appendix 3A-5 represents the TP load, flow, and FWMC in C-139 Basin discharges only to the south, which is 2.0 t for WY2016.

e. G-406 is no longer a STA-5 diversion structure. Discharge through G-406 flows south typically to STA-5/6, unless diversion is necessary through G-407 to Water Conservation Area 3.

C-139 Basin Short-Term and Long-Term Variations

The 2008 SFER – Volume I, Chapter 4 (Van Horn et al. 2008), presents a preliminary review of rainfall, runoff volumes, and water quality data conducted to identify causes of the recurring out of compliance results for the C-139 Basin, specifically focusing on WY2007. Further analysis including WY2008 and WY2009 data supports the conclusion that the temporal distribution of rainfall substantially affects the ability of the basin to retain runoff. Detailed discussions of potential factors that contribute to the variation of the basin runoff and loads are presented in the 2009 and 2010 SFER – Volume I, Chapter 4 (Van Horn et al. 2009, Van Horn and Wade 2010), under the *C-139 Basin Short-Term and Long-Term Variations*

section. In part, the results of these analyses were incorporated in the amendment to Chapter 40E-63, F.A.C., refining the load performance methodology for the basin to incorporate monthly rainfall statistics to the regression for determining performance relative to baseline period conditions. The following discussion focuses on the derivation of relationships from monthly rainfall, flow, and TP load data over the period of record. These efforts are intended to provide a more accurate representation of the effects of BMPs on C-139 Basin TP discharges compared to the baseline period.

WY2016 rainfall in the C-139 Basin was approximately 3.1 inches above the average rainfall, relative to the WY1980–WY2016 period, as shown in **Figure 4**. This was the first water year since WY2011 for which rainfall was above the historic average. **Figure 5** depicts how the amount of annual rainfall in the C-139 Basin compares with the amount of rainfall translated into excess runoff. In general, a higher annual rainfall corresponds with a higher fraction of rainfall that results in runoff (runoff coefficient). However, monthly rainfall distribution also affects the runoff coefficient. Evaluation of the intra-annual data has contributed to better understanding, future prediction, and control of TP discharges. WY2016 had the highest runoff coefficient since WY2011.

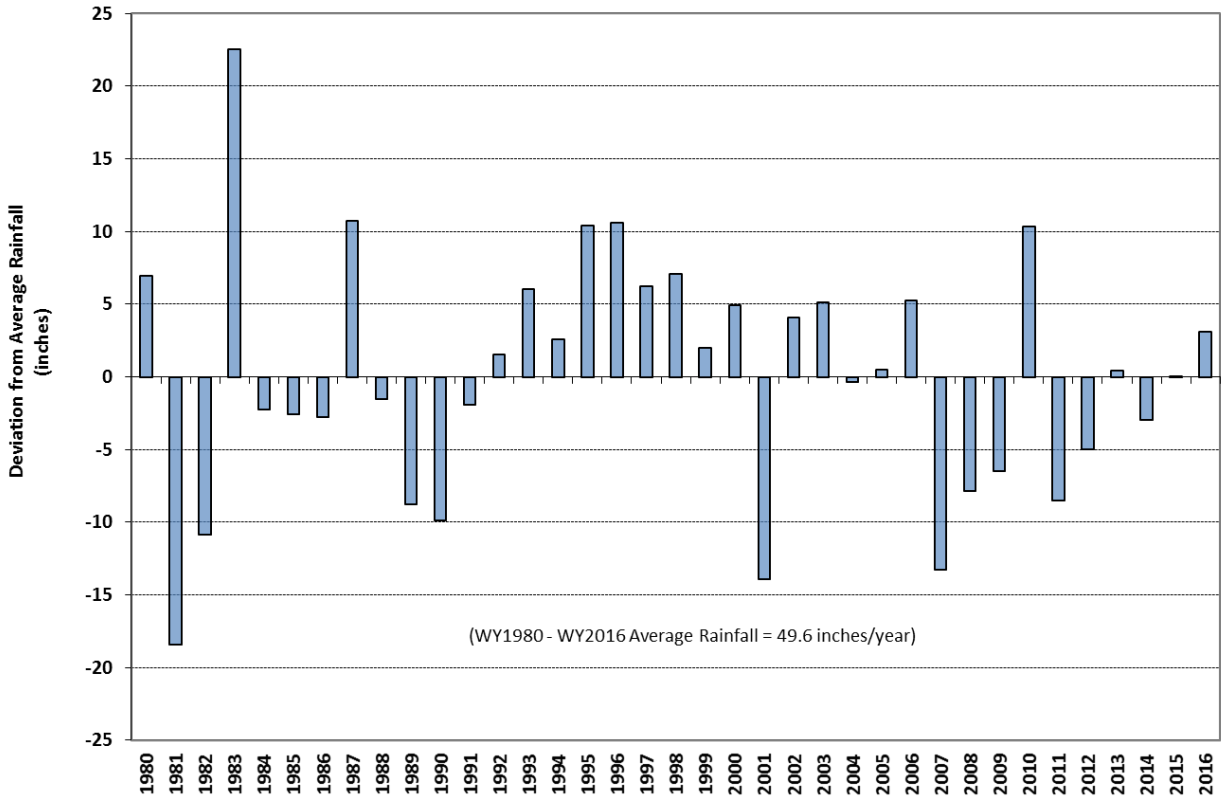

Figure 4. WY1980–WY2016 C-139 Basin annual rainfall deviation from the long-term average.

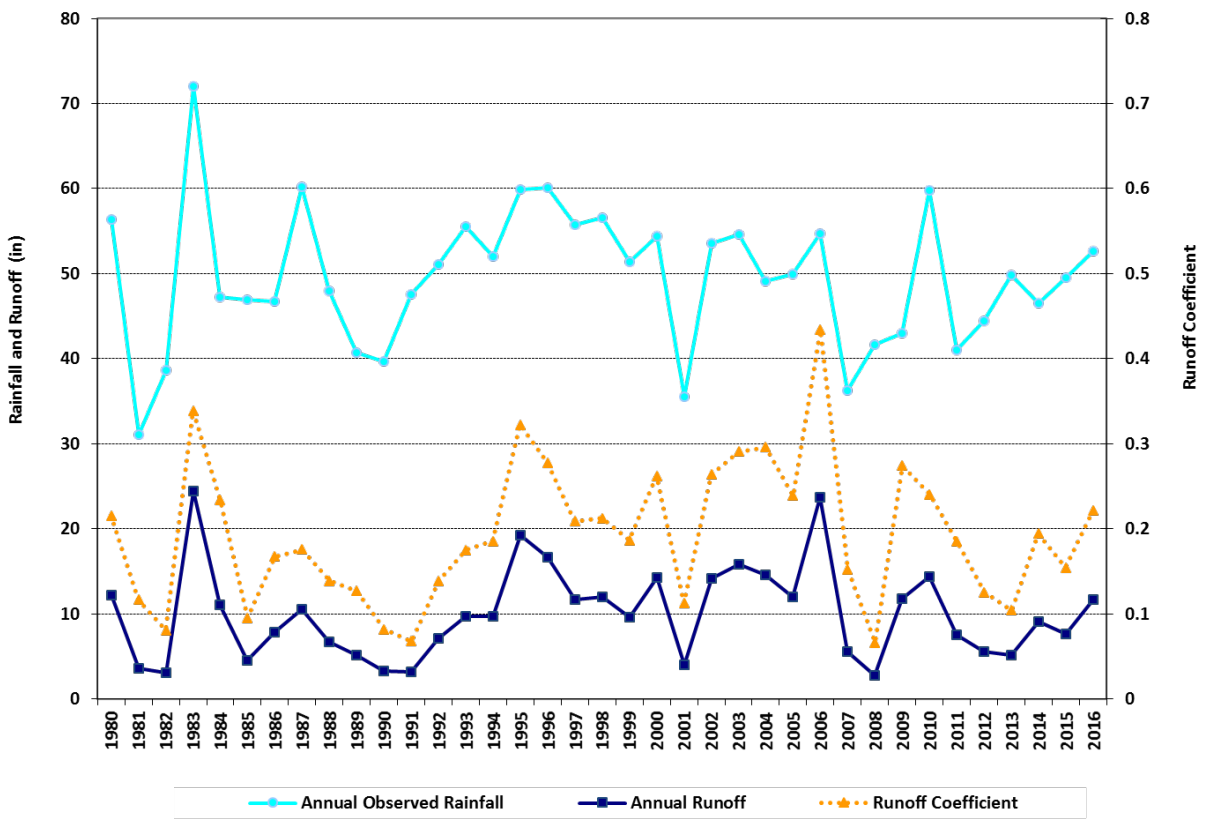

Figure 5. WY1980–WY2016 C-139 Basin annual rainfall in inches (in) and runoff relationship.

The scatter plot of monthly flow versus monthly TP FWMC in **Figure 6** suggests that, above monthly discharges of 2 thousand acre-feet (10^3 ac-ft), TP concentrations from the C-139 Basin increase with flow. Within the same levels of monthly flow, TP concentrations may vary depending on the specific activities occurring during the month. In general, the WY2016 monthly flow and TP FWMC follow the trend stated above.

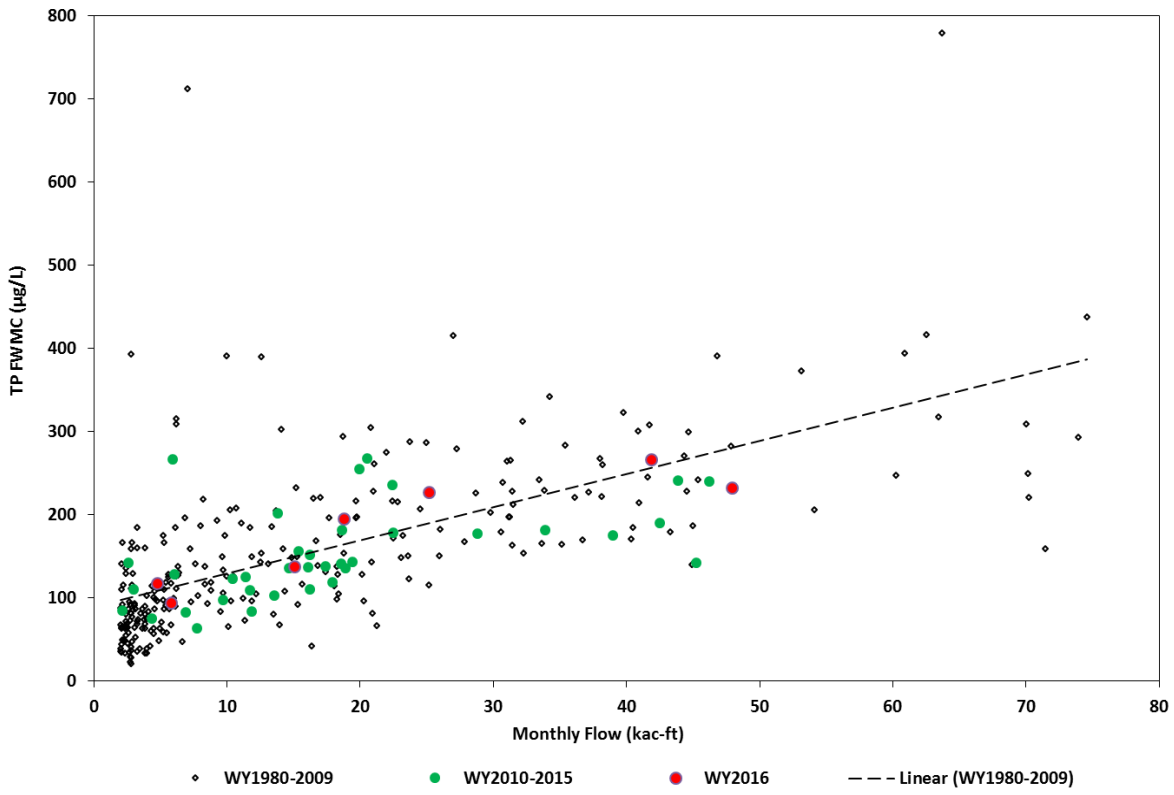

Figure 6. C-139 Basin monthly flow volume versus monthly TP FWMC in micrograms per liter (µg/L) for selected water years.

C-139 Subbasin Level Monitoring

The EFA mandates that if the C-139 Basin compliance determination is not met for the basin as a whole, remedial action by individual permittees shall be based on the permittee's proportional share of the TP loading. Permittees have the option to implement an individual monitoring plan to measure their proportional share or to rely on SFWMD monitoring considered to be representative of their runoff. For this purpose, SFWMD maintains an upstream subbasin monitoring network for flow and phosphorus concentration.

Appendix B3.1 of Chapter 40E-63, F.A.C., defines a process to verify whether monitoring at each subbasin site was adequate for the data to be representative of subbasin discharges. It also contains adjustments to ensure comparability with C-139 Basin unit area load (UAL) target results. This network currently has eight monitoring stations for collecting water quality and flow data from C-139 subbasins (**Figure 7**). Autosamplers are used to collect TP samples for the purpose of subbasin performance calculations. Additionally, grab samples are collected weekly at the same sites for TP, TDP, and soluble reactive phosphorus (SRP). **Table 4** summarizes station names, sampling start date, and number of samples for each collection type during WY2016. The water quality data from these sites are stored in SFWMD's corporate environmental database DBHYDRO under project name C139D.

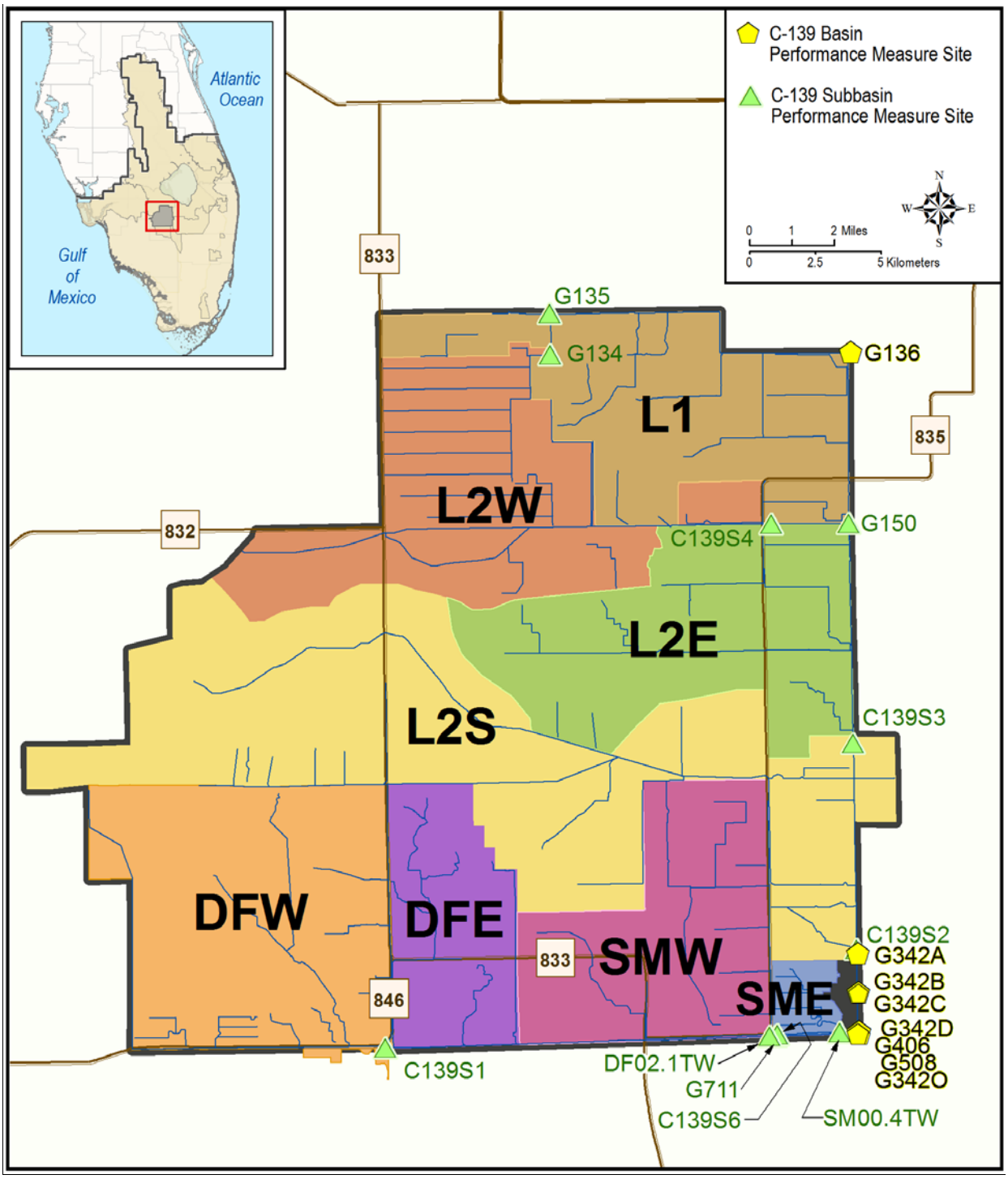

Figure 7. WY2016 C-139 Basin discharge (performance), subbasin, and upstream synoptic monitoring sites and subbasins location map.

Table 4. C-139 Basin upstream automatic sampling stations under the C139D Monitoring Project for WY2016.

Flow Station Name	Sampling Site Name	Type of Flow Calculation	First Flow or Velocity Record	First Auto Collection	Number of WY2016 Samples Grab/Auto
G150	G150	Culvert	5/3/1989	10/25/2006	11/19
C139S1	C139S1	index velocity	2/28/2007	12/20/2006	52/43
C139S2	C139S2	index velocity	8/30/2006	10/25/2006	52/51
C139S3	C139S3	index velocity	10/20/2006	10/25/2006	52/51
C139S4 [a]	C139S4	index velocity	9/27/2007	1/2/2008	40/49
C139S6	C139S6	index velocity	3/6/2008	6/11/2008	45/32
SM00.4TW [b]	SM00.4TW [c]	Weir	11/3/2014 [b]	6/18/2014 [c,d]	19/21
G711	DF02.1TW	Culvert	4/18/2011	4/25/2006	31/48

a. Prior to WY2015, flow station G151, located approximately 1,000 upstream of flow station C139S4, was used.

b. Prior to WY2015, flow station SMSBV, located approximately 1,200 feet downstream of flow station SM00.4TW, was used. Flow for period May 1, 2014, through November 2, 2014, was calculated based on a manual daily log record at flow station SM00.4TW, which is not archived in SFWMD's DBHYDRO database.

c. Prior to WY2015, water quality station SM00.2TW, located approximately 1,200 downstream of flow station SM00.4TW, was used.

d. No flow occurred at flow station SM00.4TW from May 1, 2014, through June 17, 2014.

SFWMD continuously works to improve data collection processes and equipment to ensure accurate and representative data are collected. For WY2015, such improvements included SM00.4TW, a new weir structure station located approximately 1,200 feet upstream of the previously used SMSBV site. Due to issues such as low flows, presence of vegetation, and missing flow data, the SMSBV index velocity meter was no longer considered appropriate for flow monitoring at this location. SM00.4TW represents WY2016 flow and load from the SM subbasin. During WY2016, the new G-151W structure on the L-2W canal was completed. Water quality station C139S4, representing the L2W subbasin, was relocated to the upstream side of the structure G-151W from its previous location. However, flow continues to be monitored at the original C139S4 location, as the flow monitoring installation at G-151W is not yet complete.

Appendix B3.1 of Chapter 40E-63, F.A.C., defines use of the data to compute loads and UALs at the subbasin level to quantify a proportional share performance measure. **Table 5** provides a summary of WY2016 runoff flow, TP FWMC, and observed UAL for the monitoring sites. The table also identifies the C-139 subbasins represented by each monitoring site. The summary is for informational purposes only because the C-139 Basin as a whole has met its WY2016 performance measure. However, if the C-139 Basin were to exceed the target for three consecutive water years including WY2016, the subbasin data shown by **Table 5** would be used to calculate the assigned phosphorus UAL, and for calculating their corresponding proportional share based on performance measures established in Appendix B3. Individual landowners can voluntarily implement a permit-level discharge monitoring plan to be used in-lieu of the SFWMD subbasin data associated with their property, however no landowner has elected this alternative to date.

Table 5. C-139 TP load monitoring site, subbasins, contributing area, runoff flow volume, TP FWMC in micrograms per liter (µg/L), and observed UAL in pounds per acre (lbs/ac) for WY2016.

Sampling Site Name	Subbasins [a]	Contributing Area (acres) [b]	Runoff Flow (inches) [b]	Observed TP FWMC (µg/L) [b]	Observed UAL (lbs/ac) [b]
G136	L1	20,742	10.5	105	0.25
G342A-D, G342O, G406, G508	L3 [c]	147,709	11.8	229	0.61
C139S2	L2E + L2W + L2S	91,097	13.3	167	0.50
G711	DFE + DFW	36,764	11.2	205	0.52
SM00.4TW	SME + SMW	19,288	3.2	678	0.49
C139S4	L2W	23,278	17.2	123	0.48
C139S1	DFW	25,945	Unable to Calculate [d]	Unable to Calculate [d]	Unable to Calculate [d]
C139S6	SMW	17,525	3.5	810	0.64

a. Subbasins L2E, L2S, DFE, and SME runoff values are not directly measured and therefore not included.
b. 1 acre = 0.004 square kilometers (km^2); 1 inch = 2.54 centimeters; 1 µg/L ≈ 1 part per billion; 1 lb/ac = 112.1 kilogram per km^2.
c. Subbasin L3 includes subbasins L2E, L2W, L2S, DFE, DFW, SME, and SMW, and the area adjacent to STA-5.
d. Unable to calculate indicates the data quality requirement of greater than 75 percent sampled load was not achieved.

The C-139 subbasin data plots are also used to analyze trends, changes, significance to specific events, and to identify future opportunities to improve water quality. Comprehensive BMP plans serve to control the different types of phosphorus species (particulate or dissolved). By analyzing the phosphorus speciation data, one can glean the potential effects on water quality of subbasin-specific characteristics, on-farm activities, BMP implementation, and other factors. For example, if high dissolved phosphorus is observed, the nutrient management BMPs may need attention, and in cases where high particulate phosphorus is observed, the particulate matter and sediment control BMPs may need attention. **Figures 8** through **11** depict the daily phosphorus speciation data for WY2016 for the four major subbasins. Presenting the data in a daily format allows one to relate the water quality data to typical activities that may occur within each subbasin.

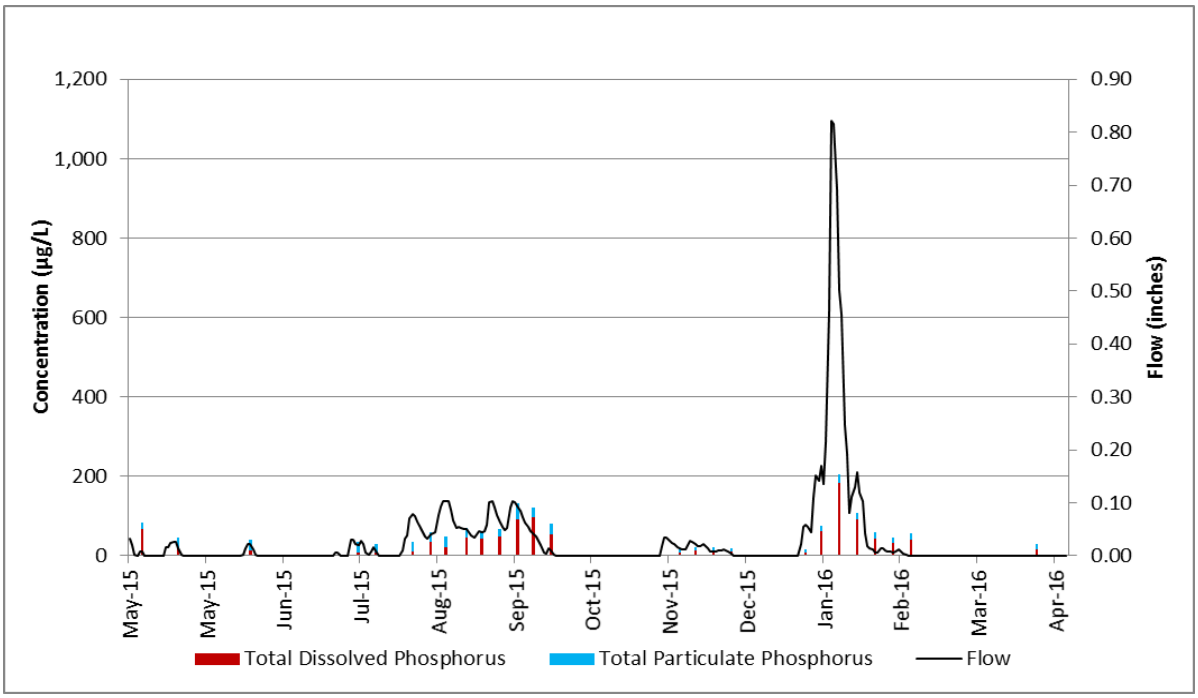

Figure 8. WY2016 daily phosphorus concentrations for the L1 subbasin.

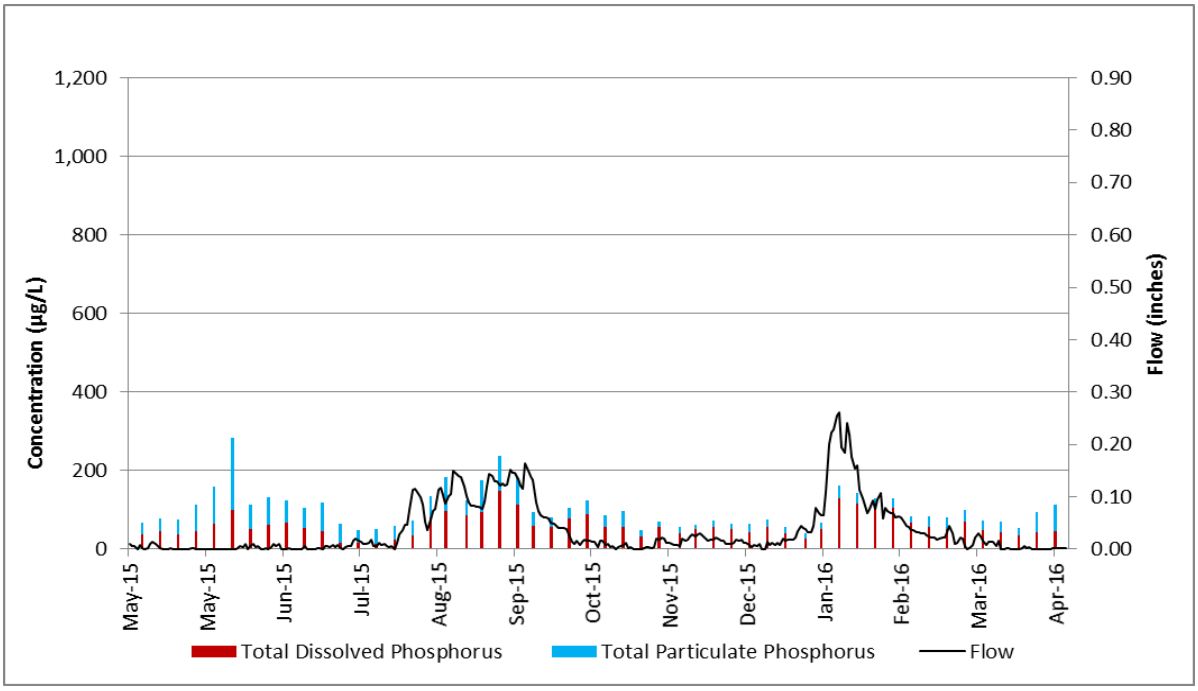

Figure 9. WY2016 daily phosphorus concentrations for the L2E, L2W, and L2S subbasins.

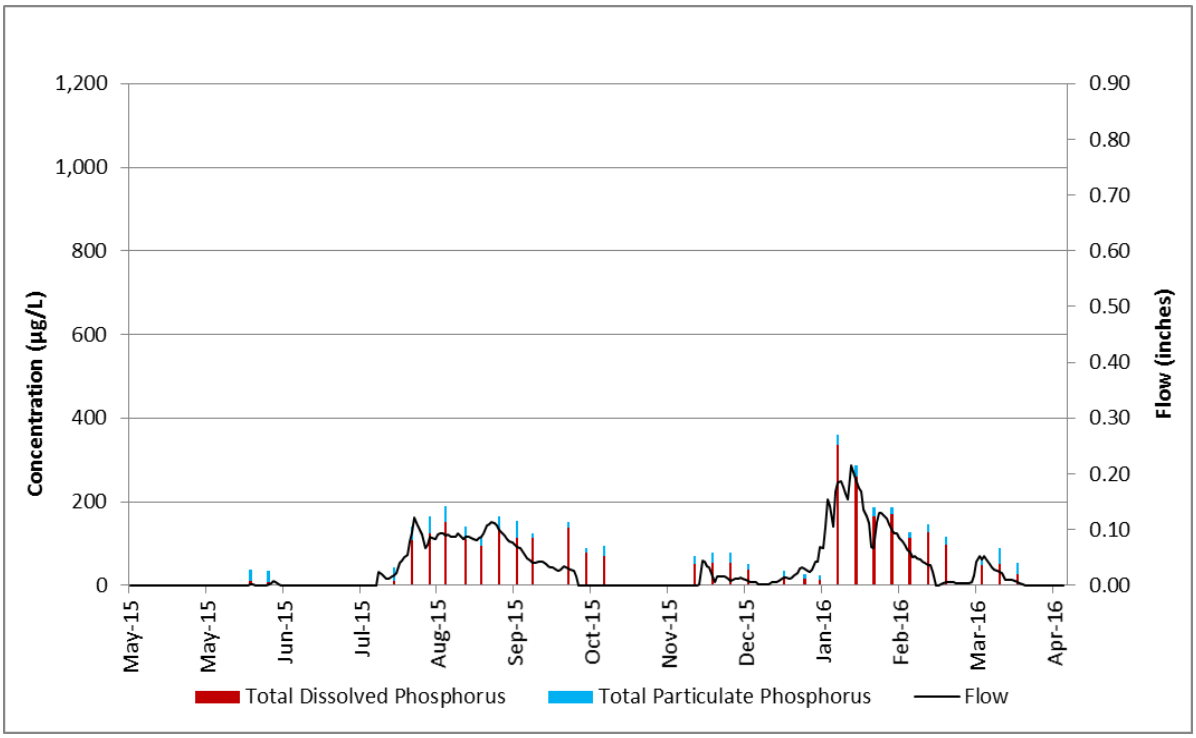

Figure 10. WY2016 daily phosphorus concentrations for the DFE and DFW subbasins.

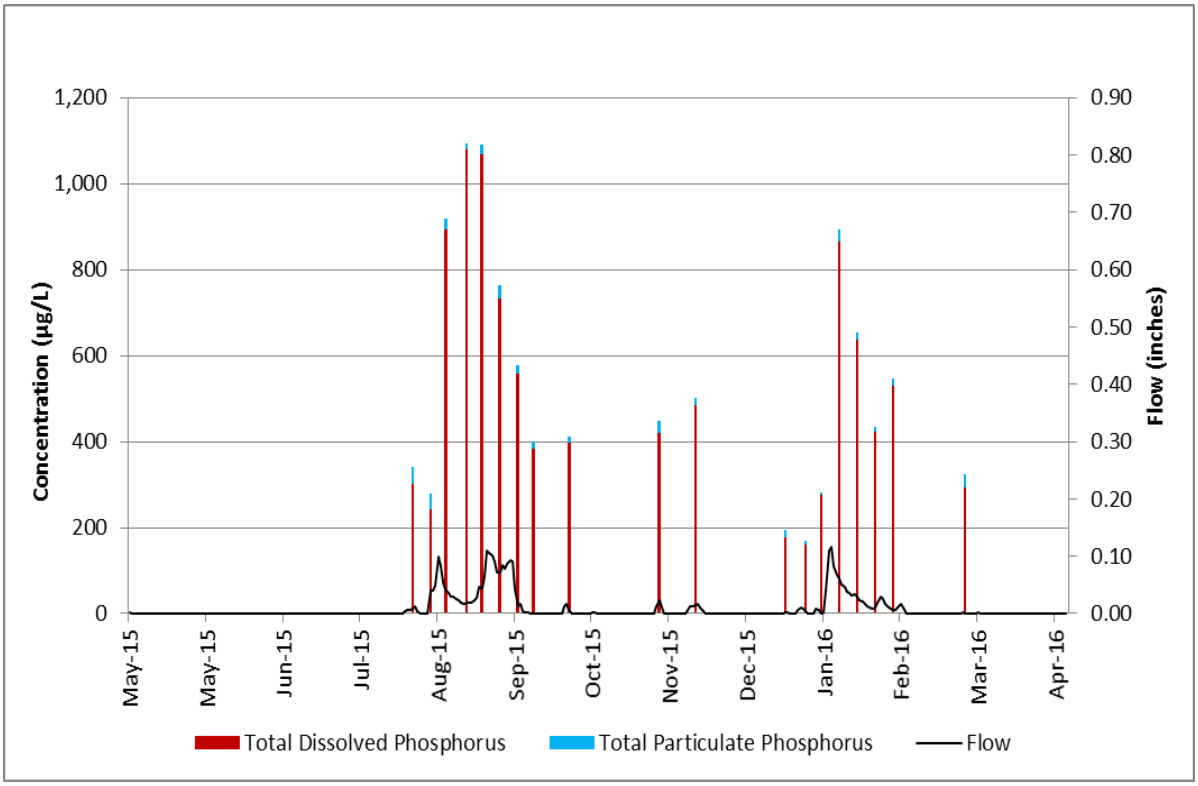

Figure 11. WY2016 daily phosphorus concentrations for the SME and SMW subbasins.

C-139 Basin Upstream Level Monitoring

As part of monitoring initiatives, SFWMD also collected water samples at 12 sites that represent locations upstream of regulatory basin and subbasin level compliance points. This monitoring project was initiated in WY2006 to identify potential phosphorus sources within subbasins. The project was suspended after the WY2009 wet season based on improved C-139 Basin performance. In WY2016, this project was reinstated to evaluate potential impacts to the C-139 Basin load as increasing concentrations are observed in recent years. These sampling locations give snapshots of TP concentrations throughout the watershed during the wet season (April through October) and their locations are presented in **Figure 7**. **Figures 12** through **14** present the average TP concentrations since the project started in WY2006. The water quality data from these sites are stored in SFWMD's DBHYDRO database under project name C139B.

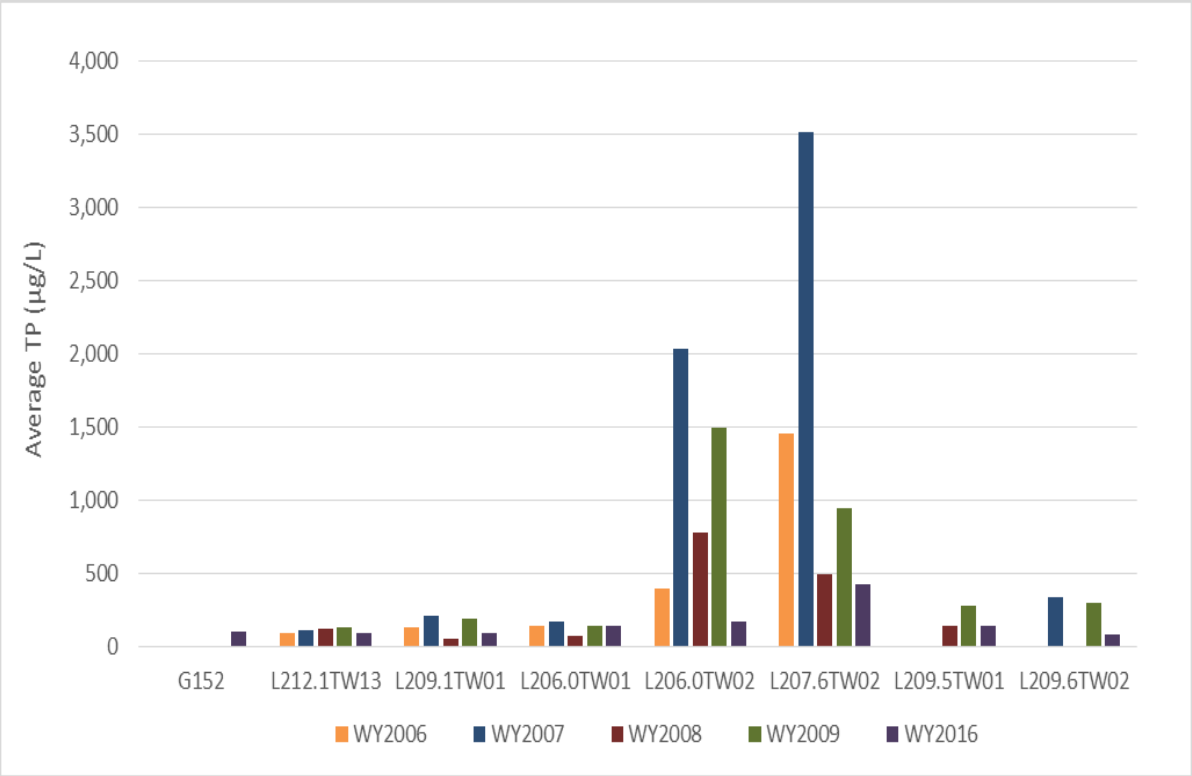

Figure 12. Average TP concentration for the L2E, L2W, and L2S subbasins.

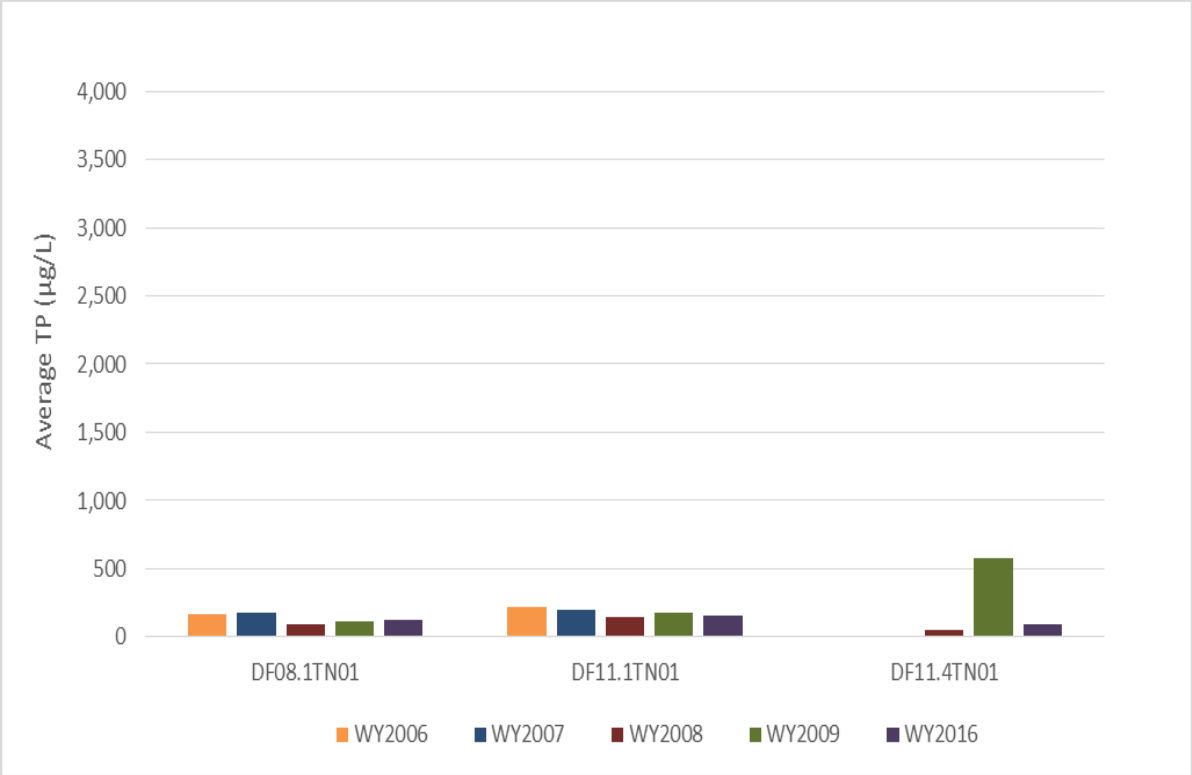

Figure 13. Average TP concentrations for the DFE and DFW subbasins.

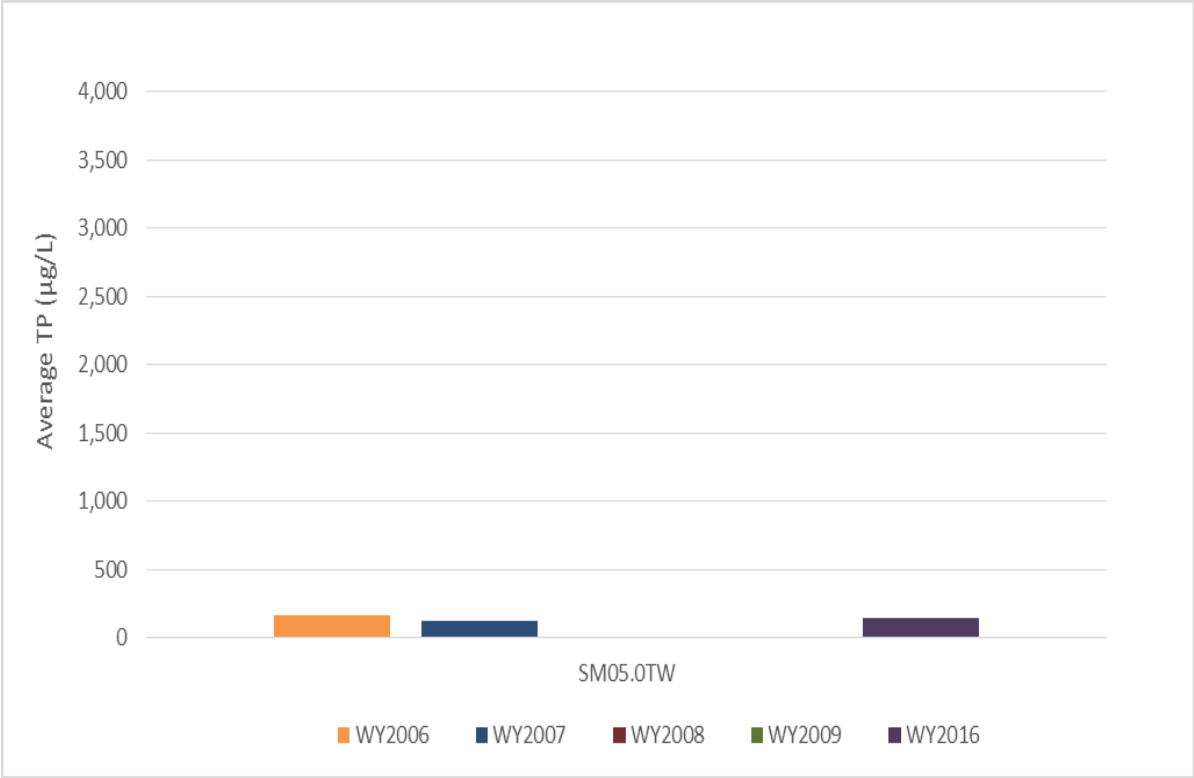

Figure 14. Average TP concentrations for the SME and SMW subbasins.

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