Chapter 5: Performance and Optimization of the Everglades Stormwater Treatment Areas

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SUMMARY

As part of Everglades restoration, the construction and operation of six large freshwater treatment wetlands are mandated by the Everglades Forever Act (EFA) (Chapter 373.4592, Florida Statutes). These wetlands, known as the Everglades Stormwater Treatment Areas (STAs), have been constructed as part of the Everglades water quality restoration efforts (www.sfwmd.gov/sta). To date, approximately 45,000 acres of effective treatment area have been created south of Lake Okeechobee to remove excess total phosphorus (TP) from surface waters prior to entering the Everglades Protection Area (EPA) (**Figure 5-1**). The cumulative total area of the STAs, including infrastructure components, is around 65,000 acres. Stormwater Treatment Areas 1 East, 1 West, 2, 3/4, 5, and 6 (STA-1E, STA-1W, STA-2, STA-3/4, STA-5, and STA-6, respectively) operate pursuant to EFA and National Pollutant Discharge Elimination System (NPDES) permits and their associated Administrative Orders (AOs). (AOs are issued with permits and establish schedules for compliance with certain permit criteria.) This chapter and related appendices serve as the reporting mechanism for requirements contained within those permits and AOs related to STA construction, operation, maintenance, performance, and conditions affecting the STAs during Water Year 2010 (WY2010) (May 1, 2009–April 30, 2010). The information presented in this chapter also addresses individual components identified in the Long-Term Plan for Achieving Water Quality Goals in the Everglades Protection Area (Long-Term Plan) (Burns and McDonnell, 2003) (see Chapter 8 of this volume) related to the STAs and summarizes STA research and optimization efforts undertaken during the reporting period.

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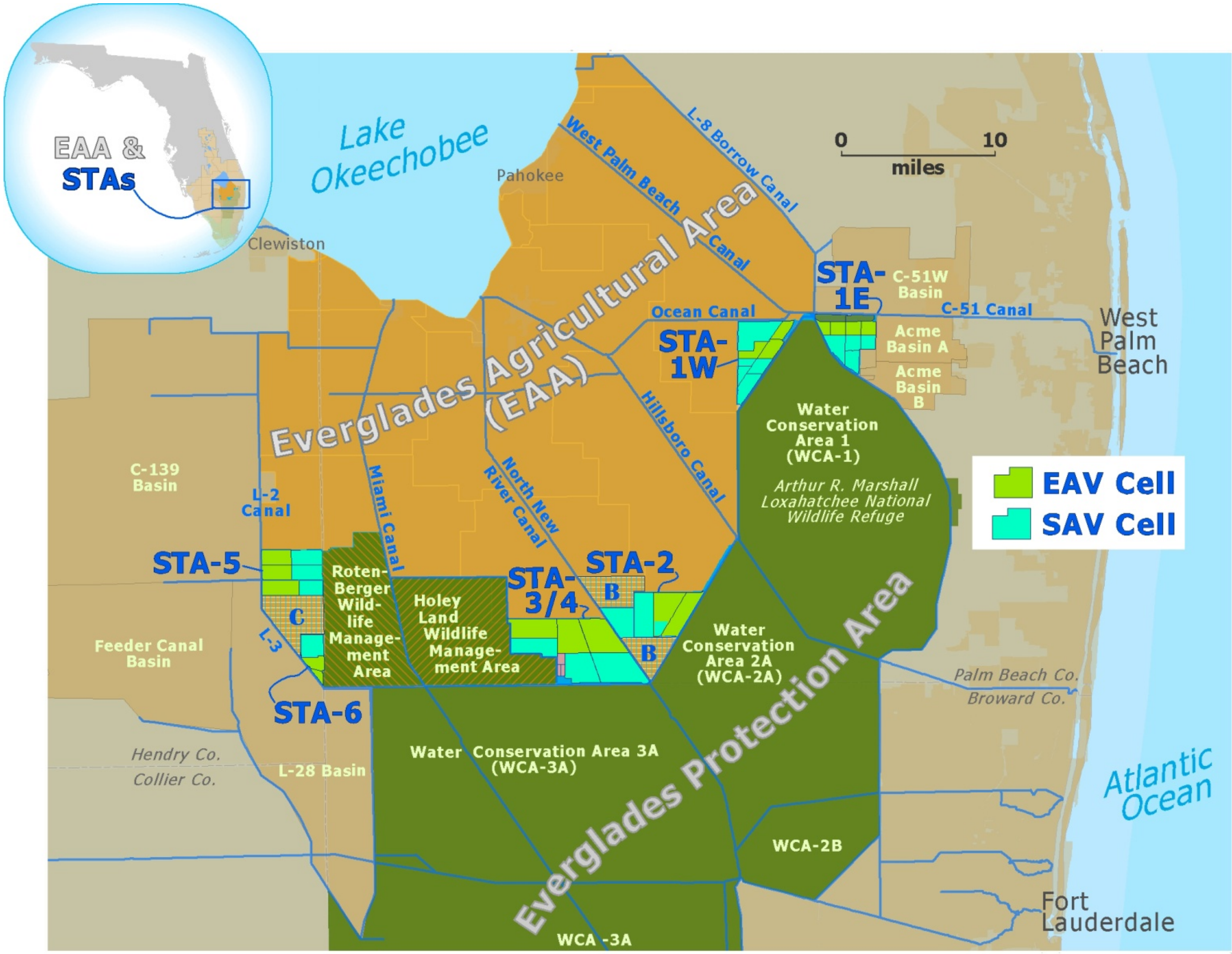


Figure 5-1. Location of the six Everglades Stormwater Treatment Areas (STAs) and the dominant vegetation community for each STA treatment cell [i.e., emergent vegetation (EAV) or submerged aquatic vegetation (SAV)].

WATER YEAR 2010 OVERVIEW

Operational Conditions

Highlights

- Since 1994, the Everglades STAs combined have received over 10 million acre-feet (ac-ft) of inflow and retained 1,403 metric tons (mt) of TP that would have otherwise entered the EPA, reducing TP loads by 73 percent and levels from an overall annual TP flow-weighted mean (FWM) concentration of 145 to 40 parts per billion (ppb) (**Figures 5-2** and **5-3**; **Table 5-1**). The historical performance data were recalculated in WY2010 to account for data corrections and to ensure that a uniform methodology is used when calculating the historical loading estimates (see the *Period of Record Flow and TP Load Estimates* section of this chapter and Appendix 5-2 for details).
- During WY2010, the six STAs received a total of 1.39 million ac-ft of water excluding rainfall, equating to an average hydraulic loading rate of 2.84 centimeters per day (cm/day). The inflow TP load was 253 mt, equating to an average TP loading rate of 1.52 grams per square meter per year ($g/m^2/yr$). An estimated 76 percent load reduction was achieved, with the STAs retaining 192 mt of TP and reducing inflow TP FWM concentrations from 147 to 33 ppb; outflow TP FWM concentrations ranged from 15 to 94 ppb (**Table 5-1** and **Figure 5-4**).

Challenges

- In contrast to the previous three years, WY2010 had above-average rainfall, and the dry season was relatively wet as a result of El Niño weather patterns (see Chapter 2 of this volume). STAs 5 and 6 received rainfall volumes above the range of values that occurred during the period of model simulation used in developing effluent limits. The amount of Lake Okeechobee releases and diversions are listed in **Table 5-2**.
- Permitting issues associated with Compartments B and C Build-outs (**Figure 5-1**) have delayed some of the construction activities and operation of these STA expansion projects (see the *Compartment B Build-out* and *Compartment C Build-out* sections of this chapter for details).

Wildlife Challenges

- Similar to prior years, migratory birds nested within the STA treatment cells during WY2010. Operational decisions were based on protecting migratory birds nesting during the dry season. In accordance with an approved avian protection plan (e.g., Pandion Systems, Inc., 2008), surveys were conducted from April–July 2010 to monitor for the presence of nests and eggs, and related information helped guide STA operations for water quality treatment while minimizing impacts to nests. A total of 227 nests were observed during the 2010 nesting season, with the most black-necked stilt (*Himantopus mexicanus*) nests in STA-1E (see the *Avian Protection* section of this chapter for details).
- Seven Everglade snail kite (*Rostrhamus sociabilis plumbeus*) nests were found in STA-5 in April 2010. The South Florida Water Management District (SFWMD or District) attempted to operate the Northern and Central flow-ways of STA-5 at

water depths specified by the U.S. Fish and Wildlife Service during Endangered Species Act Section 7 consultations about these nests. The envelope of high and low water depths was established during these meetings and followed by the SFWMD to avoid impacts to the snail kite nests in these areas. This was accomplished (in a moderate rainfall year) by re-routing storm water away from STA-5 to STA-6 (see the *Avian Protection* section of this chapter for details).

- In WY2010, the STAs experienced an unusual extended period of cold weather, with minimal temperatures below 13° Celsius experienced sporadically from October 2009−April 2010. The cold extremes during the winter resulted in large-scale die-offs of exotic fish in all the STAs, leaving large amounts of decomposing fish biomass within the treatment cells, collection canals, and structures.

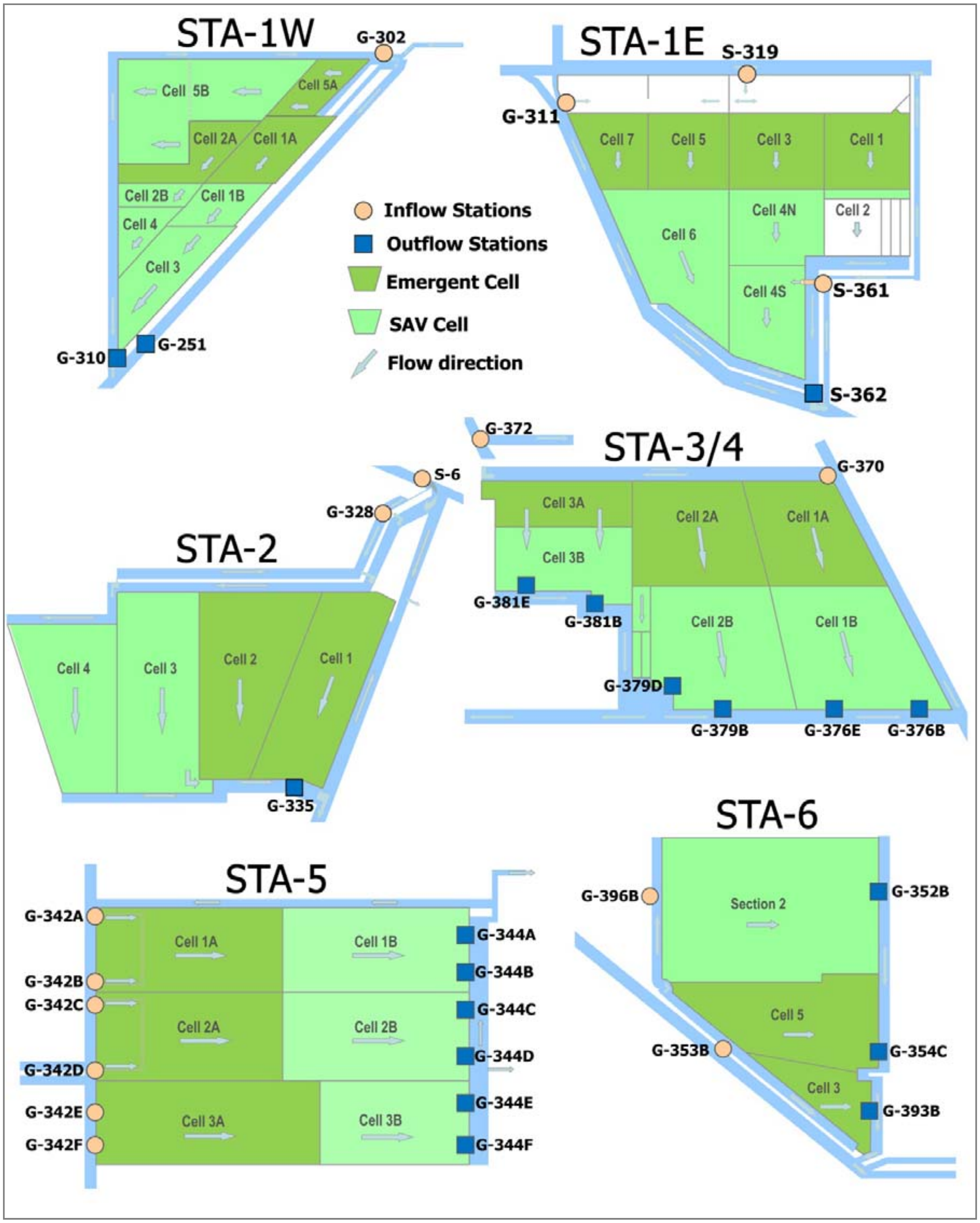
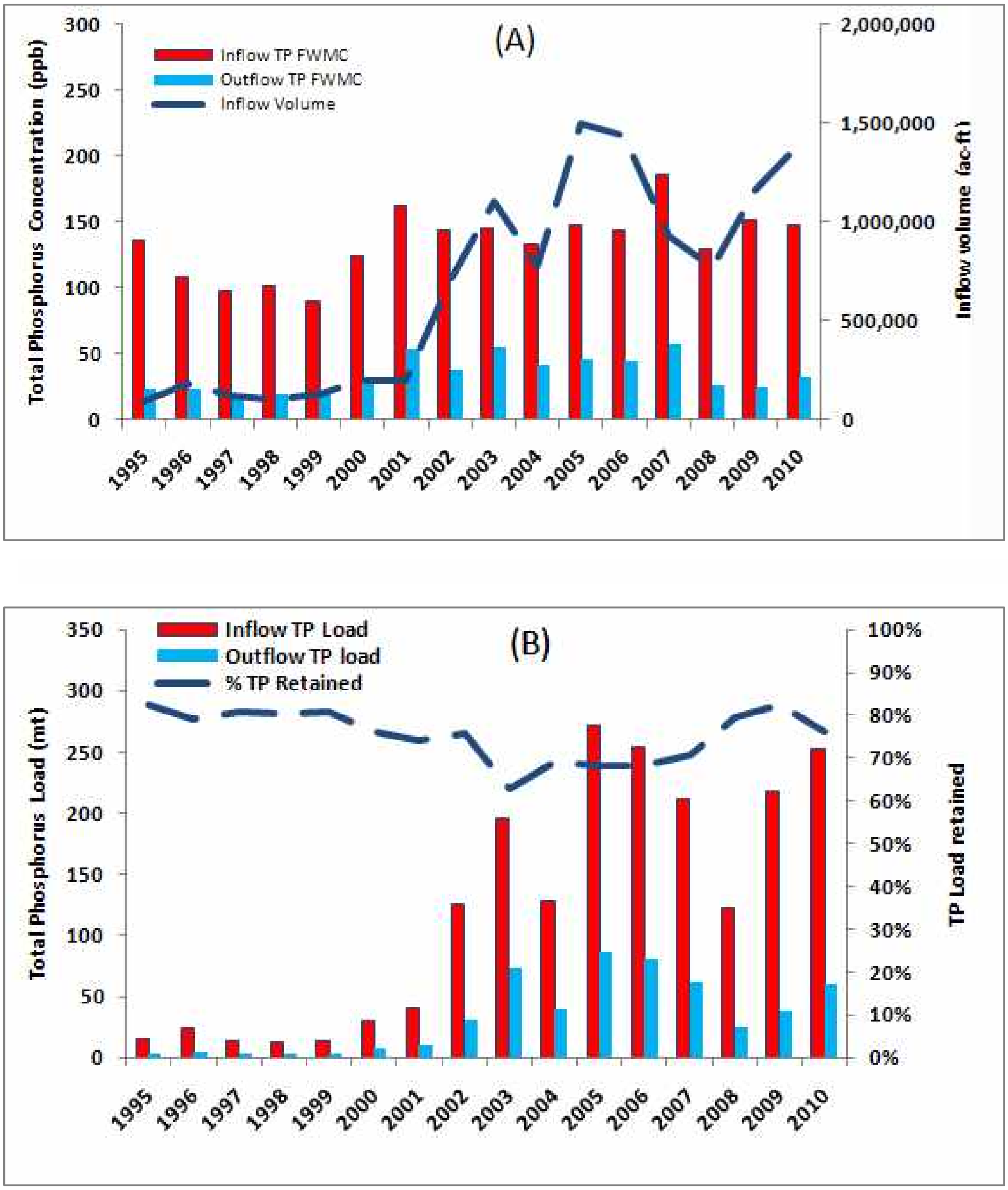


Figure 5-2. STA schematics showing configurations of the treatment cells, flow direction, dominant vegetation type, and locations of permitted inflow and outflow stations. Note that the southern section of STA-2, Cell 2, is currently undergoing a vegetation conversion from emergent to submerged aquatic vegetation (SAV).



[Notes: The effective treatment area in the STAs varies as more treatment cells are built or as existing treatment cells undergo temporary restrictions during maintenance activities. Appendix 5-2 of this volume details flow and load calculations.]

Figure 5-3. (A) Overall annual inflow and outflow total phosphorus (TP) flow-weighted mean (FWM) concentrations and inflow volumes, and (B) overall annual inflow and outflow TP loads and percent TP load retained by all the STAs by water year (May 1–April 30) since 1995.

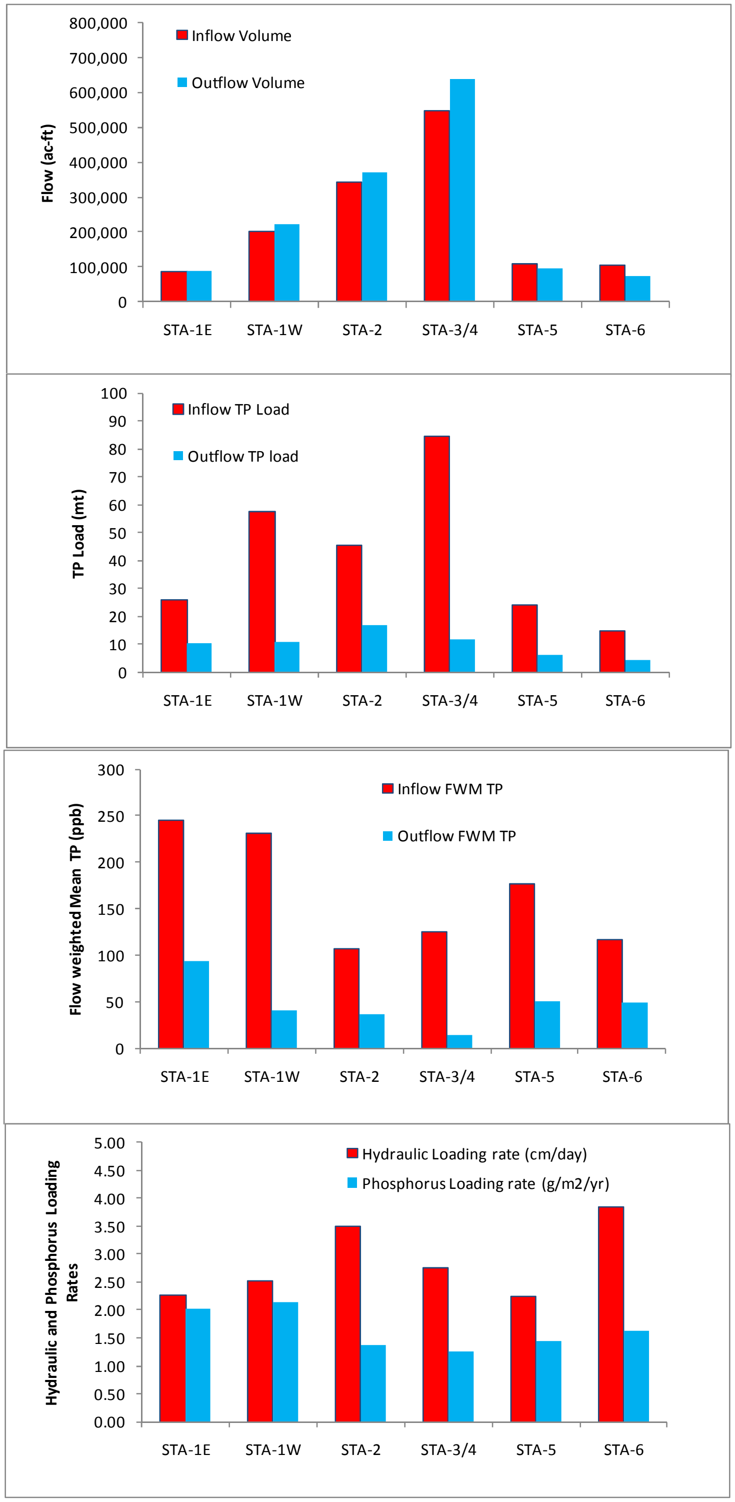


Figure 5-4. Water Year 2010 (WY2010) (May 1, 2009–April 30, 2010) hydraulic and phosphorus loading rates and outflow TP FWM concentrations for the STAs. Hydraulic loading rates (centimeters per day) are calculated by dividing the average daily inflow volume by the effective treatment area. Phosphorus loading rates (grams per square meter) are calculated by dividing the total annual inflow load by the effective treatment area.

Table 5-1. STA performance for Water Year 2010 (WY2010) (May 1, 2009–April 30, 2010) and the period of record (POR) 1994–2010.

	STA-1E	STA-1W	STA-2	STA-3/4	STA-5	STA-6	All STAs
Effective Treatment Area in Permit (acres)	5,132	6,670	8,240	16,543	6,095	2,257	44,937
Adjusted Effective Treatment Area (acres)[b]	3,199	6,670	8,240	16,543	4,082	2,257	40,991
Rainfall							
Total Annual Rainfall (inches)	62.7	58.0	54.6	60.5	62.9[a]	64.7[a]	60.6
SFWMM Simulation Rainfall Range (inches)[c]	39.8–77.5	36.6–77.4	35.4–71.6	32.3–70.7	38.6–61.4	46.8–57.6	---
Inflow							
Total Inflow Volume (ac-ft)	86,582	202,243	344,073	545,471	109,788	103,636	1,391,792
Total Inflow TP Load (mt)	26.099	57.635	45.435	84.466	23.954	14.921	252.511
FWM Concentration Inflow TP (ppb)	244	231	107	126	177	117	147
Hydraulic Loading Rate (HLR) (cm/d)[d]	2.26	2.53	3.49	2.75	2.25	3.83	2.84
TP Loading Rate (PLR) ($g/m^2/yr$)[d]	2.02	2.14	1.36	1.26	1.45	1.63	1.52
Outflow							
Total Outflow Volume (ac-ft)	89,093	221,086	371,342	637,214	96,629	74,825	1,490,190
Total Outflow TP Load (mt)	10.309	10.976	16.804	11.749	6.107	4.554	60.499
FWM Concentration Outflow TP (ppb)	94	40	37	15	51	49	33
FWM Concentration Plus Diversion TP (ppb)	94	40	---	---	---	---	---
Hydraulic Residence Time (d)	13	16	14	20	12	11	---
TP Retained (mt)	15.790	46.659	28.631	72.717	17.848	10.367	192.012
TP Removal Rate ($g/m^2/yr$)	1.22	1.73	0.86	1.09	1.08	1.13	1.16
Load Reduction (%)	60%	81%	63%	86%	75%	69%	76%
Period of Record Performance							
Start date	Sep-04	Oct-93	Jun-99	Oct-03	Oct-99	Oct-97	***1994 - 2010***
Total Inflow Volume (ac-ft)	527,515	3,034,153	2,397,760	3,066,106	1,155,655	598,658	10,779,848
Total TP Load Retained to Date (mt)	80.205	445.963	238.421	380.709	201.190	56.308	1,402.797
FWM Concentration TP Outflow to Date (ppb)	64	53	23	18	96	35	40

[a] The total annual rainfall received by the STA was above the range of values used to develop the IELs.
[b] Adjusted effective treatment areas reflect treatment cells temporarily off-line for plant rehabilitation, infrastructure repairs, or LTP enhancements (see Appendix 5-2 of this volume).
[c] SFWMM – South Florida Water Management Model

Table 5-1. Continued.

Required WY2010 Permit Reporting: Everglades Forever Act (EFA), National Pollutant Discharge Elimination System (NPDES), Administrative Order (AO), Interim Effluent Limit (IEL)							
	STA-1E	**STA-1W**	**STA-2**	**STA-3/4**	**STA-5**	**STA-6**	**All STAs**
Operational Permit Phase[e]	Stabil.	Stabil.	Stabil.	Post-Stabil.[f]	Stabil.	Stabil.	---
In compliance with Permits?	Yes	Yes	Yes	Yes	Yes	Yes	---
Within Operational Envelope?							
Average (Flow/Load)	Yes/No	Yes/No	No/No	NA	No/Yes	No/No	---
Maximum (Flow/Load)	Yes/Yes	Yes/Yes	Yes/Yes	NA	Yes/Yes	No/No	---
Was EFA IEL Achieved?	No[g]	No[g]	No[g]	Yes	No[a,g]	No[a,g]	---
Was NPDES/AO annual IEL Achieved[i]?	No[g]	Yes	No[g]	Yes	No[a,g]	No[a,g]	---
Was NPDES/AO 50 ppb 3-year test Achieved[i]?	Yes	Yes	NA	Yes	NA	NA	---
Were there any Water Quality (other than Phosphorus) excursions?	No	No	No	No	No	No	---
Was Dissolved Oxygen (DO SSAC) achieved?[h]	Yes	Yes	Yes	Yes	No	No	---
Permit Limits							
Operational Envelope[d]:							
Avg. Inflow volume (ac-ft)	130,362	206,987	337,924	NA	104,908	77,677	---
Max. Inflow volume (ac-ft)	191,328	329,169	530,641	NA	140,151	94,234	---
Avg. Inflow TP load (mt)	21.142	44.303	42.619	NA	26.426	8.610	---
Max. Inflow TP load (mt)	31.191	72.273	70.367	NA	42.815	10.714	---
Outflow EFA and NPDES/AO Limits:							
Outflow EFA IEL TP (ppb) Limit	33	34	25	76	50	29	---
Outflow NPDES/AO IEL TP (ppb) Limit	68	76	25	76	50	29	---

[d] Inflow volume or total phosphorus (TP) load/adjusted effective treatment area
[e] See the *Permit Status and Reporting Requirements* section of this chapter. Stabil. = Stabilization, Post-Stabil. = Post Stabilization
[f] STA-3/4 is operated under permits issued in 2004 and is considered to be in the post-stabilization phase and the outflow water quality limit (IEL) is set at 76 ppb as defined in those permits. Operational envelope comparison is not applicable (NA) under present permit.
[g] Excursions to the IEL are detailed further in the *STA Performance* section of this chapter.
[h] See the *Dissolved Oxygen* section of this chapter for details regarding the dissolved oxygen site-specific alternative criteria (DO SSAC).
[i] The NPDES/AO permits for STA-1E, STA-1W, and STA-3/4 require a two-part test for phosphorus compliance. The two-part test states that the annual outflow TP FWM concentration has to be less than the IEL for the reported water year and the TP FWM concentration has to be less than or equal to 50 ppb for three or more consecutive years. For STA-2, STA-5, and STA-6, the NPDES/AO permits require only comparison of the annual outflow TP FWM concentration to the IEL for the reported water year.
Notes: Flow-proportional auto-samplers are used to calculate TP loads and concentrations, if available. Period of record calculations include the amount of inflows and TP loads used to hydrate the STAs during start-up if those data are available. STA-1E flows and TP loads that occurred in WY2004 in response to regional flooding due to Hurricanes Francis and Jeanne are also included. Units: parts per billion (ppb) – micrograms per liter (µg/L); mt – metric tons, ac-ft – acre feet, d – days, $g/m^2/yr$ – grams per square meter per year.

Table 5-2. Information fulfilling the permit-related reporting requirement for the amount of water diverted around the STAs and received by the STAs from Lake Okeechobee as inflows in WY2010[a].

STA	STA Diversion Structure Flow							Inflows from Lake Okeechobee						
	STA Diversion				Water Supply, Gate Maintenance, etc.			Lake Flow-Through[e]				Supplemental Water to Maintain Vegetation		
	Structure	Volume (ac-ft)	TP Load (mt)	FWM TP (ppb)[c]	Volume (ac-ft)	TP Load (mt)	FWM TP (ppb)	Structure	Volume (ac-ft)	TP Load (mt)	FWM TP (ppb)	Volume (ac-ft)	TP Load (mt)	FWM TP (ppb)
STA-1E	G-300	----	----	----	<0.1	<0.001	304	G-311	1,791	0.559	253	----	----	----
								S-319[b]	----	----	----	6,743	1.400	168
	Total	**----**	**----**	**----**	**<0.1**	**<0.001**	**304**	**Total**	**1,791**	**0.559**	**253**	**6,743**	**1.400**	**168**
STA-1W	G-301	----	----	----	0.0	0.000	----	G-302	7,460	2.126	231	----	----	----
	Total	**----**	**----**	**----**	**0.0**	**0.000**	**----**	**Total**	**7,460**	**2.126**	**231**	**----**	**----**	**----**
STA-2	G-338	----	----	----	0.1	<0.001	172	S-6[d]	306	0.036	95	----	----	----
	G-339	----	----	----	23	0.003	94							
	Total	**----**	**----**	**----**	**23.1**	**0.003**	**95**	**Total**	**306**	**0.036**	**95**	**----**	**----**	**----**
STA-3/4	G-371	----	----	----	2,658	0.132	40	G-370	393	0.025	53	----	----	----
	G-373	----	----	----	6,904	0.445	52	G-372	1,031	0.128	101	----	----	----
	Total	**----**	**----**	**----**	**9,562**	**0.577**	**49**	**Total**	**1,424**	**0.153**	**88**	**----**	**----**	**----**
STA-5	N/A	**----**	**----**	**----**	**----**	**----**	**----**	**----**	**----**	**----**	**----**	**----**	**----**	**----**
	Total	----	----	----	----	----	----	**Total**	**----**	**----**	**----**	**----**	**----**	**----**
STA-6	G-407	----	----	----	110	0.013	100	**----**	**----**	**----**	**----**	----	----	----
	Total	**----**	**----**	**----**	**110**	**0.013**	**100**	**Total**	**----**	**----**	**----**	**----**	**----**	**----**

mt – metric tons; ac-ft – acre-feet

[a] Some numbers reported are estimated using Everglades Agricultural Area (EAA) model output; see also Appendix 3A-5 of this volume.

[b] Water was delivered via the S-319 structure for the Periphyton Stormwater Treatment Area (PSTA) Implementation Project as requested by the U.S. Army Corps of Engineers (USACE).

[c] Concentrations expressed as parts per billion (ppb) are equal to micrograms per liter (µg/L).

[d] No water was pumped at S-6 for agricultural irrigation and all water was routed to the STA.

[e] Lake flow-through: A balance of Lake Okeechobee outflow into EAA basins and discharges from EAA basins.

Vegetation Management

Highlights

- During WY2010, vegetation conversion from emergent to submerged aquatic vegetation (EAV to SAV) was initiated in STA-2, Cell 2, and a phased conversion continued in STA-3/4, Cell 1B. Additionally, water stages were lowered in STA-3/4, Cell 1A, to allow for vegetation reestablishment (see the *Vegetation Management* section of this chapter for details).
- Efforts to further improve STA performance continue. Giant bulrush (*Scirpus* spp.) was planted in large open areas and sections with known short-circuiting problems or prevailing deepwater conditions in STA-1W, Cell 5A. Previous plantings of this species in the vegetation strips in STA-1W, Cell 5B, and downstream of the inflow structures at STA-1E, STA-2, and STA-3/4 have been stable and adapting well to fluctuating hydrologic conditions (see the *Vegetation Management* section of this chapter for details).

Challenges

- During 2010, extensive loss in hydrilla (*Hydrilla verticillata*)-dominated communities was observed in STA-1E, STA-1W, STA-2, and STA-5, while declines in musk grass (*Chara* spp.) communities occurred at STA-1W, STA-2, and STA-3/4. Increases in outflow TP concentrations also were observed following SAV loss and decomposition in these areas (see the *Vegetation Management* section of this chapter for details).
- STA-1E, Cells 5 and 7, were not constructed to original design specifications. As a consequence, prevailing deepwater condition in STA-1E, Cells 5 and 7, resulted in unsuccessful vegetation establishment in some areas and gradual decline in vegetation coverage and condition in other areas over the years of operation. As an interim measure, until the topography issues are corrected by the U.S. Army Corps of Engineers (USACE), the District lowered water depths in Cells 5 and 6 to allow for vegetation reestablishment and planted areas of these cells with Giant bulrush in an attempt to increase emergent vegetation cover (see the *Vegetation Management* section of this chapter for details).
- During WY2010, the treatment capacity of STA-1E was reduced by as much as 60 percent due to structural and performance issues in both the Eastern and Western flow-ways. Operations continue to be restricted due to the USACE's PSTA project in the Eastern Flow-way and ongoing performance issues and related interim vegetation rehabilitation activities in the Western Flow-way.

Recreational Highlights

- In WY2010, recreational facilities remained opened for public access to the STAs. Public entry to the STAs is managed in several ways to prevent damaging impacts and ensure that this access does not supplant construction, operations, or other project-related activities.
- The public access sites at the STAs offer substantial bird-watching opportunities. Popular bird-watching tours are conducted by the Hendry-Glades Audubon Society at STA-5, where roughly 1,000 bird enthusiasts participated in birding tours and counts in 2009. Audubon regularly conducts bird counts at STA-5 and STA-1W.

- Alligator (*Alligator mississippiensis*) hunting took place in STA-1W and STA-5 from mid-August through October 2009. During this period, 200 permits were collectively issued and 315 alligators were harvested from the two STAs.
- The STAs contain areas of open water and SAV that provide ideal habitat for waterfowl. STA-1W, STA-3/4, and STA-5 were open for waterfowl hunting in the 2009–2010 season. This program brought 5,582 hunters who bagged 20,743 waterfowl.
- Fishing is allowed in the external canals of the STAs, as are hiking and biking on established trails. STA-3/4 has a boat ramp that leads to 27 miles of canals with trophy-size largemouth bass (*Micropterus salmoides*), and STA-1E allows catch-and-release fishing in the internal cells.

INDIVIDUAL STA OVERVIEW

The District continues to maintain and further optimize STA performance. During WY2010, weekly operational meetings included making recommendations on water deliveries and structure operations in the STAs based on near real-time data. Field assessments continued for monitoring hydrologic conditions, water quality in cell inflows and outflows, soil conditions, and vegetation. Data gathered help in further understanding STA performance and the underlying mechanisms as well as guide management strategies. Research studies aimed at achieving a better understanding of STA performance and finding ways to improve sustainability also continued, including those related to vegetation sustainability and phosphorus treatment patterns within selected treatment cells.

STA-1E

Facility Status

- Due to the assorted design, construction, and performance deficiencies associated with the STA-1E Project, the District has requested formal mediation under its Project Cooperation Agreement with the USACE.
- The Central Flow-way was operational for all of WY2010; the Eastern Flow-way was offline from April 25, 2009–January 24, 2010, for repair of the S-365A and S-365B water control structures, then brought online with restrictions due to operation of the USACE Periphyton-Based Stormwater Treatment Area (PSTA) Demonstration Project in Cell 2 for the rest of the water year; the Western Flow-way was online until October 12, 2009, then offline through June 14, 2010, for rehabilitation activities.
- Repairs of failed structure S-375 continued in WY2010.
- Repairs to the S-365A and S-365B structures were completed in WY2010.

Highlights

- The District balanced inflows to STA-1E and STA-1W and successfully avoided diversions of untreated storm water to the Arthur R. Marshall Loxahatchee National Wildlife Refuge.

Challenges

- STA-1E, Cells 5 and 7, were not constructed to original design specifications. As a consequence, prevailing deepwater conditions in STA-1E, Cells 5 and 7, resulted in unsuccessful vegetation establishment in some areas and gradual decline in vegetation coverage and conditions in other areas over the years of operation. Floating cattail (*Typha* spp.) tussocks were observed in Cells 5 and 7. As an interim measure until the USACE corrects the topographic deficiencies, water levels were drawn down to ground elevation level in Cells 5 and 6 to allow for plant reestablishment. Giant bulrush was transplanted in some of the short-circuited and deep areas in Cell 5 and upstream of the outflow structures in Cell 6. As a pilot strategy, cattail bales, harvested from outside the STAs, were placed across a deep hydraulic short circuit in Cell 5 and additional bulrush plants were planted around the baled area. Portions of a high berm located immediately upstream of the Cell 5 outflow canal was degraded to improve water flow from the cell to the collection canal (see the *Vegetation Management* section of this chapter for details).

- As a result of the vegetation and treatment problems in Cells 5 and 7, high levels of nutrients were delivered to the SAV cells.
- A large-scale hydrilla die-back was observed in Cell 6 shortly after heavy rains in May 2009, and vegetative debris was present in the STA-1E discharge canal from June–August 2009. Mechanical harvesters were used to remove large amounts of hydrilla biomass at the S-362 outflow structure. Additional hydrilla die-off was observed in the Central Flow-way, Cells 4N and 4S, in February–March 2010. Partial plant reestablishment was evident by April 2010 (see the *Vegetation Management* section of this chapter for details).
- Structure S-375 continues to be inoperable and impacts the District's ability to balance inflows among the flow-ways.
- The USACE's PSTA Pilot Project located within Cell 2 continues to limit flows through the Eastern Flow-way and exacerbates an imbalance among flow-ways. The USACE plans to decommission the PSTA Project during 2011.
- While repairs of S-365A and B were completed in January 2010, these repairs restricted the use of the Eastern Flow-way for approximately eight months during WY2010.

STA-1W

Facility Status

- All flow-ways were operational in WY2010.

Challenges

- Decline of the SAV community, primarily hydrilla and musk grass, was observed in Cells 2B, 4, and 5B from September–October 2009; SAV reestablishment occurred at end of the water year (see the *Vegetation Management* section of this chapter).
- This STA received higher inflow and TP loads than the average operational envelope due to basin rainfall runoff and conditions in STA-1E.

STA-2

Facility Status

- All flow-ways were operational in WY2010.

Highlights

- Compartment B, currently under construction, is located west of STA-2 and east of U.S. Highway 27. This build-out is designed to further assist the existing STAs in improving the quality of water entering the EPA and will provide about 6,817 acres of effective treatment area (see the *Compartment B Build-out and Compartment C Build-out* section of this chapter for details).
- Vegetation conversion from EAV to SAV was initiated in April 2009 and continues in the southern section of Cell 2. Approximately 400 acres of existing cattails were sprayed to allow for SAV colonization.

Challenges

- In December 2009, hydrilla die-back was observed on the northern portion of Cell 3, equating to approximately 75 percent of the SAV in the beginning of the cell. A decomposing floating mat remained at the surface for several weeks. A similar decline in SAV coverage occurred near the inflow structures of Cell 4 (see the *Vegetation Management* section of this chapter).
- By the end of the water year, SAV had not established in Cell 2; therefore, SAV inoculation is planned for WY2011.
- Permitting issues associated with the Compartment B Build-out have delayed some of the construction activities and operation of these STA expansion projects (see the *Compartment B Build-out* and *Compartment C Build-out* sections of this chapter for details).

STA-3/4

Facility Status

- All flow-ways were operational in WY2010.

Highlights

- Monitoring of the PSTA Implementation Project (as required by the Long-Term Plan) continued during WY2010.

Challenges

- Cell-wide browning of cattails was observed in Cells 1A, 2A, and 3A in the winter, resulting in a large accumulation of standing dead biomass throughout the cells. Additional field observations in late March 2010 showed gradual signs of cattail recovery for the entire area (see the *Vegetation Management* section of this chapter for details).
- Cell 3A showed a steady reduction of musk grass coverage in early 2010; Cells 1B and 2B did not experience significant SAV changes or community decline.
- Temporary pumps were installed in March 2010 in Cell 1A to lower water levels to allow for cattail reestablishment. The EAV community in this treatment cell has been impacted by extended periods of deep water in previous years.

STA-5

Facility Status

- The Central Flow-way was operational for all of WY2010. The Northern Flow-way was online with restrictions following rehabilitation from June 10, 2009–October 27, 2009, and then taken offline until February 10, 2010, for vegetation establishment; subsequently, it was brought back online for the remainder of the water year. The Southern Flow-way was online from June 12, 2009–November 5, 2009, and then taken offline through the end of the water year due to Compartment C Build-out activities (excavation of the inflow supply canal and construction of G-342G and G-342H).

Highlights

- The Compartment C Build-out Project, located in Hendry County between existing STA-5 and STA-6, is currently under construction and is anticipated to provide about 4,636 additional acres of effective treatment area to the STAs.
- Giant bulrush and other wetland plants were planted in Cell 1A in June 2009 as part of rehabilitation efforts; giant bulrush and cattail were planted in Cells 1B and 2B in an effort to fill gaps in the vegetation strips and reduce hydraulic short circuiting.
- Internal surveys conducted in Cell 1A following the WY2009 rehabilitation showed successful EAV establishment in the former slough area. Water quality measured at the mid-levees showed reduction in TP concentrations compared with inflow concentrations.

Challenges

- Permitting issues associated with the Compartment C Build-out have delayed some of the construction activities and operation of this STA expansion project (see the *Compartment B Build-out* and *Compartment C Build-out* sections of this chapter for details).
- Annual rainfall of 62.5 inches at STA-5 was 1.5 inches above the South Florida Water Management Model (SFWMM) maximum (see **Table 5-1**).
- In November and December 2009, supplemental water was delivered to Cell 1B through the G-507 pump station (3,317 ac-ft; 0.78 mt TP, 19 ppb annual TP FWM concentration), and Cell 2B received water from Cell 1B via the internal G-345 culvert. In general, supplemental water is delivered to SAV treatment cells to maintain water depths for the subsistence of resident plant communities.
- Cell-wide decline in SAV, primarily hydrilla, was observed in Cell 1B in January 2010. Community recovery was minimal through the end of the water year (see the *Vegetation Management* section of this chapter for details).
- Endangered Everglade snail kites were found nesting in Cells 1A and 2A in April 2010, which restricted operations.

STA-6

Facility Status

- All flow-ways were operational in WY2010.

Challenges

- Water stages in all treatment cells were below ground levels in May and part of June 2009.
- Annual rainfall of 64.7 inches at STA-6 was 7.1 inches above the SFWMM maximum (see **Table 5-1**).
- During construction of the Compartment C Build-out, the G-600 pump station was utilized to direct dewatering discharges into the L-3 canal. These discharges produced increased stages in the L-3 canal which, in turn, resulted in inflows into STA-6.

INTRODUCTION

Major problems facing the Everglades are loss of habitat, disruption of hydropatterns and hydroperiod (i.e., duration, timing, volume, and distribution of water), coastal saltwater intrusion, degradation of water quality, and invasion of nonindigenous plants and animals. The 1994 Everglades Forever Act (EFA) addressed some of these issues through the implementation of the Everglades Agricultural Area (EAA) Best Management Practices (BMPs) and the Everglades Stormwater Treatment Areas (STAs). As a major component of Everglades restoration, the STAs are intended to remove excess total phosphorus (TP) from surface waters prior to those waters entering the Everglades Protection Area (EPA). STAs are constructed wetlands that retain nutrients through several mechanisms including plant growth, accumulation of dead plant material in a layer of peat, settling and sorption, precipitation, and microbial activities.

This chapter and related appendices report on the performance and condition of the six Everglades STAs: 1 East, 1 West, 2, 3/4, 5, and 6 (STA-1E, STA-1W, STA-2, STA-3/4, STA-5, and STA-6, respectively) (see **Figure 5-1**). All of the STAs operate under EFA and National Pollutant Discharge Elimination System (NPDES) permits and Administrative Orders (AOs). AOs, issued with each of the STA permits, establish a schedule for achieving compliance with the permit interim effluent limits (IELs). Varying in size, configuration, and period of operation, the STAs are shallow freshwater marshes divided into treatment cells by interior levees. Water flows through these systems via water control structures, such as pump stations, gates, or culverts. The dominant plant communities in the treatment cells are broadly classified into the following general categories: (1) emergent aquatic vegetation (EAV), (2) submerged aquatic vegetation (SAV), and (3) floating aquatic vegetation (FAV). Both native and nonnative vegetation play a role in phosphorus (P) removal in the STAs. Vegetation management activities involve control of undesirable species that impact hydraulics.

Treatment performance, which varies temporally and among STAs, depends on several factors including (1) antecedent land use, (2) nutrient and hydraulic loading, (3) vegetation composition and condition, (4) soil type, (5) cell topography, (6) cell size and shape, (7) extreme weather conditions, (8) construction activities to improve performance (enhancement activities), and (9) regional operations. STA management uses an adaptive approach and near real-time data interpretation tools. These tools apply both stage and water quality information, as well as graphical outputs that compare the actual flow and TP loads to the long-term average annual values anticipated for each STA. General operational principles employed in the STAs help to ensure that inflows (water flows and TP loads) are within design operational envelopes, which are based on 36-year daily simulated flows and TP loads. These principles are intended to (1) prevent dryout and maintain a minimum of 0.5 feet (ft) [or 15 centimeters (cm)] depth of water, (2) avoid keeping the water stage too deep for too long by limiting depth to a maximum of 4.0 ft (122 cm) for three consecutive days, (3) maintain target depths between storm events [e.g., for EAV and SAV: 1.25 ft (38 cm)], and (4) ensure frequent field observations by site managers.

The following sections summarize STA performance, construction, operation and maintenance, research, and optimization efforts during Water Year 2010 (WY2010) (May 1, 2009–April 30, 2010). This section of the chapter fulfills various permit reporting mandates and provides an evaluation of TP compliance with the IEL and other water quality parameters, including dissolved oxygen (DO), mercury (Hg), and other nutrients and major ions. Evaluations of long-term performance for each STA and by individual flow-way are also presented. Summaries of STA research, the status of rehabilitation, optimization activities, vegetation conversions, wildlife issues, recreational opportunities, and the impact of extreme events (storm and drought) on the STAs are also covered. Appendices 5-1 through 5-10 provide supplementary information for this chapter (**Table 5-3**).

Table 5-3. Volume I, Chapter 5 appendices.

Appendix Number	Appendix Title
5-1	Cross-Reference List for Everglades Forever Act Permit Reporting Requirements
5-2	Calculation Methodology for Estimating Flow and Total Phosphorus Loads and for Determining Effective Treatment Areas for the STAs
5-3	Rotenberger Wildlife Management Area Restoration and STA Downstream Transect Monitoring
5-4	Supporting Information on Water Quality Data for the Everglades STAs and Downstream Transects for Water Year 2010
5-5	Annual Permit Compliance Monitoring Report for Mercury in the STAs
5-6	Water Budgets, Total Phosphorus Budgets and Treatment Performance in STA Treatment Cells and Flow-Ways
5-7	Summary Statistics for Water Quality Variables Monitored in the STA-3/4 PSTA Implementation Project
5-8	STA Herbicide Application Summary for Water Year 2010
5-9	STA Black-Necked Stilt Nesting Summary for April–July 2010
5-10	STA Vegetation Survey Results

STA PERFORMANCE

This section presents the annual data required by STA operating permits, AOs, downstream monitoring as part of the Compartments B and C Clean Water Act (Section 404) permits, and reporting on the Avian Protection Plan for Black-necked Stilts and Burrowing Owls Nesting in the Everglades Agricultural Area Stormwater Treatment Areas (Pandion Systems, Inc., 2008). It also includes reporting for hydropattern restoration and STA discharge monitoring in the downstream areas. A cross-reference listing for the permit reporting requirements is presented in Appendix 5-1.

DEFINITIONS OF PHOSPHORUS SPECIES IN THE STAS

- Total phosphorus (TP) = generally includes all forms of phosphorus (soluble, mineral, organic, and particulate-bound)
- Total soluble phosphorus (TSP) refers to total phosphorus in a water sample that has been filtered with a 0.45 micrometer (µm) membrane filter, then analyzed after a sample digestion process; may include soluble reactive P and dissolved organic P (see below).
- Soluble reactive phosphorus (SRP) is the form of phosphorus analyzed in a water sample that has been left undigested, but that has been filtered with 0.45 µm membrane filter; generally represents the most readily available form of P.
- Dissolved organic phosphorus (DOP) is the organic P in a water sample that has gone through a 0.45 µm membrane filter; usually a calculated value: DOP = TSP–SRP.
- Particulate phosphorus (PP) is particulate-bound phosphorus and can include both organic and inorganic forms; usually a calculated value: PP = TP–TSP.

PERIOD OF RECORD FLOW AND TOTAL PHOSPHORUS LOAD ESTIMATES RECALCULATION

The period of record (POR) estimates from the start of operation through WY2009 for STA inflow and outflow flow volumes and TP loadings were recalculated in WY2010. The recalculation of the historical data was done to account for data changes that occur as modifications are made to the flow or water quality estimates and to ensure that a uniform methodology is used when calculating the historical loading estimates. Appendix 5-2, Table 1, lists the flow records and matching water quality data that are used to estimate the STA inflow and outflow loadings. Because the STAs became operational at different times, data periods vary for each STA.

As a result of the recalculations, there were only relatively small changes to the flows and loads for STA-1E, STA-2, STA-5, and STA-6 that were reported in the *2010 South Florida Environmental Report* (SFER) – *Volume I*, *Appendix 5-2*. The POR data compared to those reported in the 2010 SFER changed mainly for STA-1E and STA-2 inflows and STA-6 outflows. The POR changes for STA-1E reflect the modification of G-311 preferred flows by only using water quality from S-319 when S-319 is flowing and when water is leaving STA-1E through G-311 at the same time. STA-1E flow data are expected to change annually with the percent calculation of S-361 inflow volumes using this methodology. For STA-2, inflows were decreased in WY2001 and WY2002 because flows from the S-6 pump station should not have been included prior to June 2001 as S-6 was not an inflow point until after a plug was installed directing flows from pump station to STA-2. The changes that occurred to the STA-5 loads reflect the use of some flagged data in the calculations in the 2010 SFER. At STA-6, the structures were resurveyed, affecting the flow estimates for the STA-6 structures. STA-6 outflow TP flow-weighted mean (FWM) concentrations only changed by 1 part per billion (ppb).

PERMIT STATUS AND REPORTING REQUIREMENTS

Permit Compliance for Phosphorus

The STAs operate under EFA and NPDES permits and AOs issued at various dates due to a phased implementation schedule (**Table 5-4**). As part of the permit compliance for phosphorus, annual STA performance is evaluated in comparison to interim effluent limits (IELs) and operational envelopes. The derivation of the IELs is found in the permit technical support documents, which also identify factors that may impact flows and TP loads associated with the treatment system. IELs are different concentrations for each STA, as defined by their respective operating permits, and are adjusted based on the amount of effective treatment area in operation for each STA (the effective treatment area of an STA may be temporarily reduced due to flow-ways being taken offline for rehabilitation or construction work). Several factors must be taken into account when making a determination on the compliance status of an STA with IELs. These factors include (1) the operational phase of the STA, (2) rainfall conditions, and (3) rehabilitation or major construction activities (see the *Permit Compliance for Phosphorus* section of this chapter). The operating permits also take into consideration that natural systems undergo maturity changes by categorizing STA operations into phases that depend on development and performance (**Table 5-5**).

The permits for STA-1E, STA-1W, STA-2, STA-5, and STA-6 describe three operational phases: Start-up Phase, Stabilization Phase, and Routine Operations Phase (from STA-1E/ STA-1W 2007 EFA permit). During the initial Start-Up Phase of a new treatment cell or new flow-way, phosphorus concentrations within the facility are monitored to demonstrate that the project is achieving a net reduction in phosphorus. Start-Up Phase operation and monitoring within the treatment area consists with the following criteria: (1) manage water depths in the treatment cells to facilitate the recruitment of marsh vegetation in accordance with the Operations Plan, (2) monitor total phosphorus weekly at the upstream side of a flow-ways inflow and outflow structures, (3) demonstrate that an individual flow-way or treatment cell, over a four-week period, is reducing phosphorus [Note: this net reduction is deemed to occur when the four-week geometric mean TP water column concentration from samples collected at the applicable outflow structures is less than the four-week geometric mean TP water column concentration collected at the applicable inflow structure(s)], and (4) discharge operations. Discharge operations, from an individual flow-way or treatment cell that has passed the Phosphorus Start-Up Test described in item No. 3 above, may commence once initial Start-Up Phase documentation and all supporting data and analyses are submitted to the Florida Department of Environmental Protection (FDEP) via regular or electronic mail. For flow-ways or treatment cells that have not met these tests within six months after issuance of the permit, status updates regarding progress toward achieving and identifying strategies and timelines to achieve this test are required. The fifth criteria for Start-Up Phase operations is called Initiation of Individual Flow-way (Stabilization and Routine Operation) Discharges and Monitoring. Once flow-through discharges from a flow-way begin, routine water quality monitoring is initiated for that flow-way consistent with the monitoring program described in the permit.

During the Stabilization Phase (flow-through operations), the treatment vegetation will be maturing and the STA performance will generally be improving toward achieving the IEL. An STA or flow-way may enter the Stabilization Phase after one of four antecedent conditions: (1) once flow-through operations begin following the initial start-up of a new treatment cell, (2) when a treatment cell is taken offline for implementation of Long-Term Plan for Achieving Water Quality Goals in the Everglades Protection Area (Long-Term Plan) (Burns and McDonnell, 2003) enhancements that may have adverse impacts on STA performance, (3) when a treatment cell is taken offline for recovery activities associated with a major event that compromises the structural integrity or performance of the STA, or (4) planned/unplanned maintenance activities which would cause adverse impacts to the STA's treatment capabilities.

Routine Operations Phase. Once the facility achieves the IEL it, enters the Routine Operations Phase. During the Routine Operations Phase, discharges from the STA meets the permit effluent limitations of that phase.

While compliance with the IEL is expected once the facility enters flow-through operations, one or more of the aforementioned conditions may result in an observed excursion from the IEL. Such excursions do not immediately constitute non-compliance with the AO (and hence, the permit) as long as all the activities identified in the compliance schedules are being implemented, the reporting requirements are being met, any necessary recovery measures are being undertaken, and all other relevant conditions are in compliance. STA-1E and STA-1W EFA permits and STA-2, STA-5, and STA-6 EFA and NPDES permits and AOs have an annual maximum IEL for phosphorus, while there is a two-part compliance test for STA-1E and STA-1W NPDES permits/AOs and STA-3/4 EFA and NPDES permits/AOs. The two-part test states that the annual TP FWM concentration has to be less than the IEL for the reported water year or the TP FWM concentration has to be less than or equal to 50 ppb for three or more consecutive years. STAs 1E, 1W, and 3/4 have met this criterion and were in compliance during WY2010. STA discharge concentrations are not compared to the relevant IEL in water years when rainfall in the source basins to the STA exceeds the maximum annual basin rainfall. STAs 5 and 6 had rainfall values above these maximums. For WY2010, the STAs were all in compliance with their AOs and permits. Additional information is provided in **Table 5-1**.

In addition to IELs, operational envelopes (i.e., the assessment of the annual STA inflow volumes and TP loads compared to the 36-year daily simulated flows and TP loads) are additional permit compliance requirements. Operational envelopes are also adjusted based on the amount of effective treatment area in operation for each STA (the effective treatment area of an STA may be temporarily reduced due to flow-ways being taken offline for rehabilitation or construction work). The operational envelope assessment is included in the STA-1E, STA-1W, STA-2, STA-5, and STA-6 permits to account for variable inflows received by the STAs. All STA permits, except for STA-3/4, require annual comparison of the actual volumetric and TP loading to both the average and maximum annual loadings estimated in the operational envelope. STA-3/4 is operated under permits issued in calendar year 2004 prior to the development of operational envelopes. Once new permits for STA-3/4 are issued, it is anticipated that those permits will include operational envelope assessment requirements similar to the other STAs.

Table 5-4. Current permit/AO reporting requirements used during WY2010 to assess Stormwater Treatment Area (STA) phosphorus removal performance for Everglades Forever Act (EFA) and National Pollutant Discharge Elimination System (NPDES) permits, and Administrative Orders (AOs).

STA Permit /AO Reporting Requirements	
Stormwater Treatment Area 1 East (STA-1E) Permit Phase: Eastern Flow-way Restricted Operations; Central and Western flow-ways in Extended Stabilization Phase	
EFA permit 0279499-001-EM (issued 11/16/07) is in effect.	The interim effluent limit (IEL) is applied as the annual phosphorus limitation for discharges under the current permit.
NPDES permit FL0304549 (issued 8/30/05) and AO AO-009-EV (issued 8/30/05) are in effect.	These permits have the annual limit of 68 parts per billion (ppb) for each water year and a not-to-exceed limit of 50 ppb for three or more consecutive water years.
Stormwater Treatment Area 1 West (STA-1W) Permit Phase: All Treatment Cells in Extended Stabilization Phase	
EFA permit 0279499-001-EM (issued 11/16/07) is in effect.	The IEL is applied as the annual phosphorus limitation for discharges under the current permit.
NPDES permit FL0177962-001 (issued 5/11/99) and AO (issued 5/11/99) are in effect.	The NPDES and AO permits have the annual limit of 76 ppb for each water year and a not-to-exceed limit of 50 ppb for three or more consecutive water years.
Stormwater Treatment Area 2 (STA-2) Permit Phase: Cells 1–4 in Stabilization Phase	
EFA permit 0126704-008-EM (issued 3/17/09), NPDES permit FL0177946 (issued 9/4/07), and AO AO-010-EV (issued 3/17/09) are in effect. Note: AO authorizes conditional operations of the existing facility (Cells 1-4) and construction of Compartment B.	The IEL is applied as the annual phosphorus limitation for discharges under the current permit.
Stormwater Treatment Area (STA-3/4) Permit Phase: Post-Stabilization Phase (according to 2004-Issued Permit)	
EFA permit 0192895 (issued 1/9/04). NPDES permit FL0300195 (issued 1/9/04), and AO (issued 1/9/04) are in effect.	These permits have the annual limit of 76 ppb for each water year and a not-to-exceed limit of 50 ppb for three or more consecutive water years.
Stormwater Treatment Area 5 (STA-5) Permit Phase: North and Central flow-ways in Stabilization Phase, Southern Flow-way in Extended Stabilization Phase	
EFA permit 0131842-009-EM (issued 1/29/09), NPDES permit FL0177954 (issued 9/4/07), and AO AO-011-EV (issued 1/29/09) are in effect. Note: AO authorizes continued operation of the existing facility and conditional authorization of the construction of Compartment C.	The IEL is applied as the annual phosphorus limitation for discharges under the current permit.
Stormwater Treatment Area 6 (STA-6) Permit Phase: Section 1 and 2 in Stabilization Phase	
EFA permit 0131842-009-EM (issued 1/29/09), NPDES permit FL0473804-001 (issued 9/4/07), and AO AO-011-EV (issued 1/29/09) are in effect. Note: AO authorizes conditional operations of the existing facility (Sections 1 and 2) and construction of Compartment C.	The IEL is applied as the annual phosphorus limitation for discharges under the current permit.

Note: Refer to **Table 5-1** for the EFA and NPDES/AO outflow limits.

Table 5-5. Phases of each STA based on the conditions outlined in the permits. [Note: Additional details are found in the individual STA permits and supporting documentation.]

STA Permit Phase	Conditions for Permit Phase
STA-1E Stabilization Phase	Eastern Flow-way remains in restricted flow conditions due to the U.S. Army Corps of Engineers' (USACE) Periphyton-Based Stormwater Treatment Area (PSTA) Demonstration Project; dryout experienced in Water Year 2009 (WY2009) (May 1, 2008–April 30, 2009) and May 2010; large-scale vegetation management rehabilitation activities in Western Flow-way (offline October 2009 through end of April 2010); structural failure of S-375; Eastern Flow-way structure repairs for S-365A and S-365B (offline April 25, 2009–January 24, 2010).
STA-1W Stabilization Phase	Reestablishment of Eastern and Western flow-ways following installation of levee and water control structures in WY2008; vegetation conversion in Cells 2B and 3; project at least 24 months reestablishment period; received additional flows and loads redirected from STA-1E.
STA-2 Stabilization Phase	Vegetation conversion initiated WY2010 in Cell 2; dryout occurred in Cell 1 during WY2009 and May 2010.
STA-3/4 Post-Stabilization Phase	As defined in 2004 permit requirements; vegetation conversion under way in Cell 1B.
STA-5 Stabilization Phase	Southern Flow-way taken offline for six months of the water year for construction of Compartment C Build-out; Northern Flow-way offline or under restricted flow due to reestablishment following rehabilitation in WY2009 and operations related to Everglade snail kite (*Rostrhamus sociabilis plumbeus*) nesting; dryout in WY2009 and May 2010 for Cells 2A; 3A and 3B. Anomalous high rainfall received in WY2010.
STA-6 Stabilization Phase	All treatment cells dried out in WY2009. Anomalous low rainfall received in WY2009; anomalous high rainfall received in WY2010.

In WY2010, all the STAs removed a significant amount of the inflow TP loads, ranging from 60 to 86 percent load reduction (see **Table 5-1**); about 192 metric tons (mt) of TP that would have entered the Everglades was instead retained in the STAs. Since 1994, the total amount of TP retained in the STAs is about 1,400 mt.

Comparison of the outflow TP FWM concentration to the IEL shows that STA-3/4 met the EFA and NPDES/AO IELs; STA-1W met the NPDES/AO IEL, but did not meet the EFA permit IEL; and STA-1E, STA-2, STA-5, and STA-6 did not meet their respective EFA or NPDES/AO IELs. Performance for all the STAs was compared to the EFA and NPDES/AO IELs for three water years, WY2008–WY2010, illustrating some increasing and some decreasing trends of the outflow concentrations (**Figure 5-5**).

A comparison of actual inflow volumes to the operational envelope shows that STA-1E and STA-1W inflows were below the average operational envelope value; STA-2 and STA-5 inflows were above the average operational envelope value — but below the maximum operational envelope value; STA-6 inflows were above both the average and the maximum operational envelope values. All the STAs, except for STA-6, received TP loads above the average operational envelope — but below the maximum operational envelope value; STA-6 received TP loads above both the average and the maximum operational envelopes for TP loads.

Current permits also require that when annual flows or TP loads exceed the average operational envelope values or IEL, potential causes are to be reported annually. The operational issues and conditions along with operational actions taken to address the issues are included in this chapter. Because STA-1W, STA-5, and STA-6 did not meet the IEL in WY2009 or WY2010 while in the Stabilization Phase, an assessment of a 12-month rolling outflow TP concentration is required to determine if the affected STA is demonstrating an improvement in performance. For STA-1W, the 12-month rolling outflow TP concentration decreased 33 percent in WY2009 compared to WY2008, but was slightly elevated (13 percent) in WY2010 compared with WY2009 (**Figure 5-6**). For STA-5, the 12-month rolling outflow TP concentrations decreased in WY2008 and WY2009, but were slightly elevated in WY2010. For STA-6, the 12-month rolling outflow TP concentrations decreased substantially (47 percent) in WY2010 compared to WY2009, although WY2010 concentrations were slightly above WY2008 values (**Figure 5-6**). Because STA-6 received TP loads above the maximum operational envelopes, an additional comparison of the relationships between rainfall, runoff, and TP loads was conducted, as required by the permits. In WY2010, the STA-6 inflow TP loads and rainfall volumes were both higher than historical data (**Figure 5-7**).

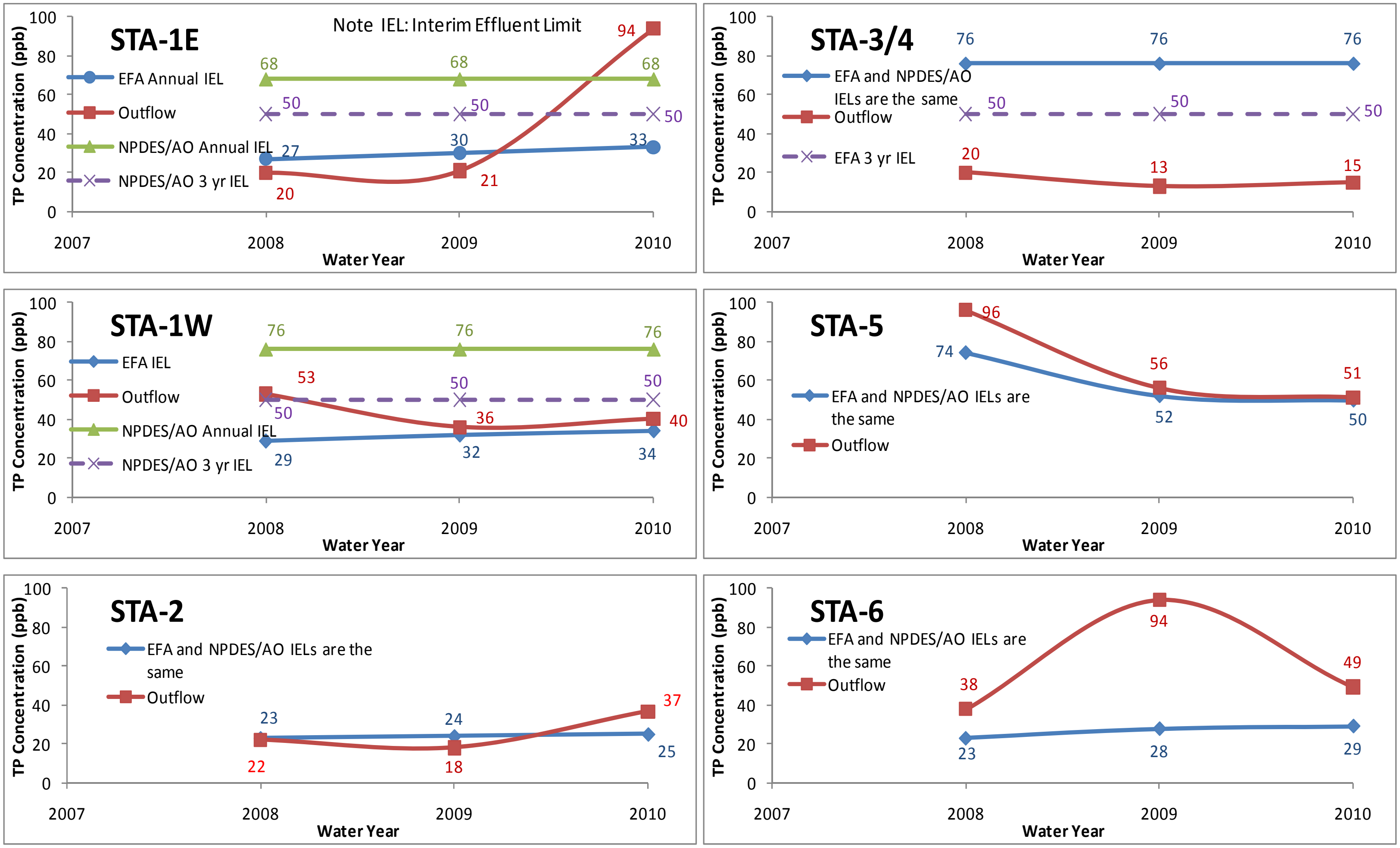


Figure 5-5. STA outflow total phosphorus (TP) concentrations compared to EFA and NPDES/AO IELs.

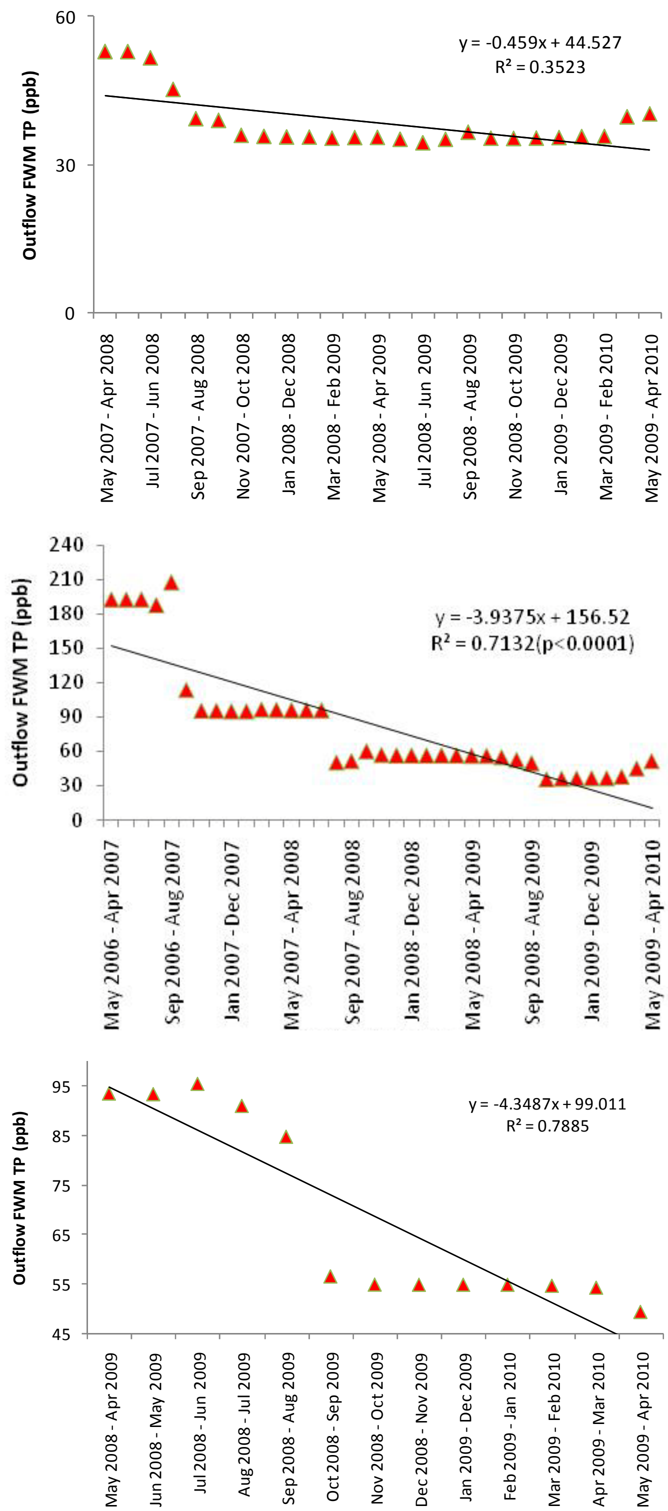


Figure 5-6. Twelve-month moving outflow TP flow-weighted mean (FWM) concentrations for STA-1W (top), STA-5 (center), and STA-6 (bottom). The 12-month moving trend reflects that some of the STAs receive many months of zero inflow and that a majority of the 12-month TP loads are usually from a couple of peak months during each year.

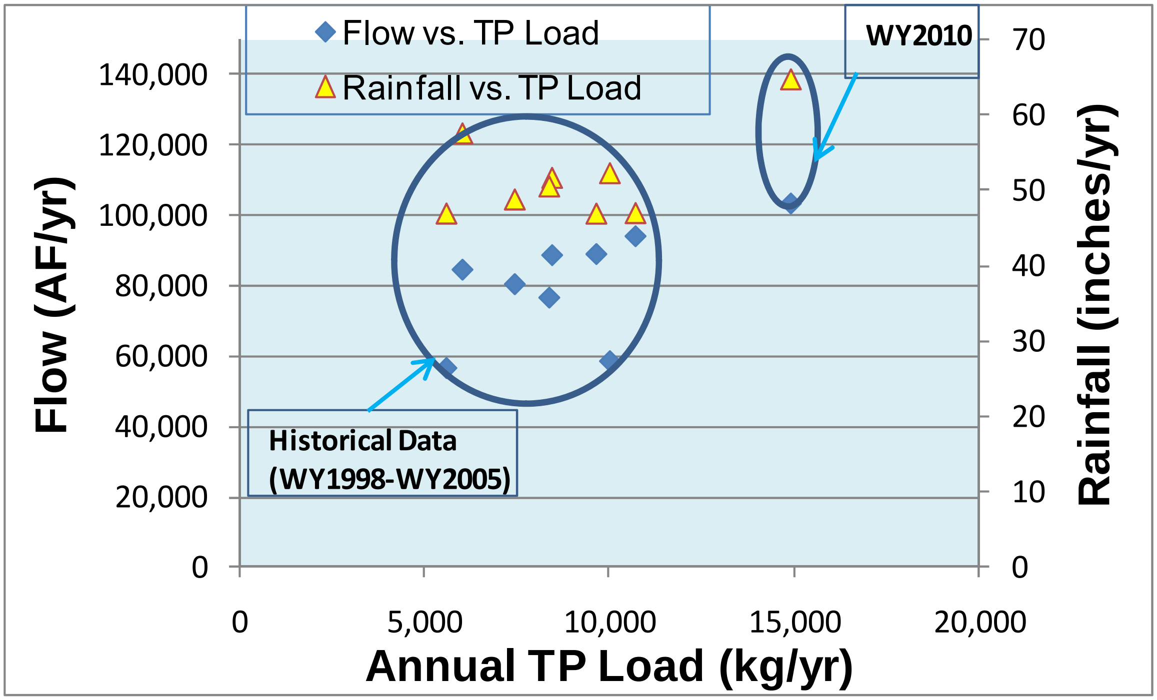


Figure 5-7. STA-6 inflow loads and rainfall for WY2010 compared to basin runoff and rainfall values used in development of the IELs.

STA Operational Issues, Conditions and Response Actions

Presented here is a summary of key conditions within the STAs and management responses geared toward achieving the best performance possible while balancing ecosystem and water supply needs (among others). Other major sections of this chapter, such as *Vegetation Management Activities and Research*, are subdivided by individual STA and include more detail on critical STA components. Current permits require that when annual flows or TP loads exceed the operational envelope values or IEL, a review of potential causes are to be reported annually along with operational actions taken to address the issues. Presented here are the operational issues and conditions and the management responses taken as per the permit reporting requirements for STA-1E, STA-1W, STA-2, STA-5, and STA-6; STA-3/4 is not included because the IEL permit condition was met and comparison to the operational envelopes is not required by the current operating permit for STA-3/4.

Operational Issues and Conditions

The STAs continue to recover from three back-to-back drought years. At the end of WY2009 (a drought year) and the beginning of WY2010, stages in some of the treatment cells in STA-1E, STA-5, and STA-6 were below the average ground elevation, resulting in dryout (see individual STA sections of this chapter for details). Many of the cells that dried out in previous years exhibited a spike in TP levels that lasted for different durations because of other factors such as nutrient and hydraulic loading, vegetation recovery, and soil conditions. All the STAs received large inflow volumes in May and June 2009, following three–five months of little or no flow. These inflows were accompanied by elevated levels of TP. The STAs again received high inflow volumes in March 2010. Two STAs (STA-5 and STA-6) received annual rainfall volumes exceeding the range of SFWMM values (termed “anomalous rainfall” in the EFA permit).

The SFWMM is a regional-scale computer model that simulates the hydrology and the management of the South Florida water resources system. It covers an area of 7,600 square miles and simulates the major components of the hydrologic cycle including rainfall, evapotranspiration, infiltration, overland and groundwater flow, canal flow, canal–groundwater seepage, levee seepage, and groundwater pumping. It incorporates current or proposed water management control structures and current or proposed operational rules. The SFWMM simulates hydrology on a daily basis and has been used and updated through several decades.

During WY2010, large areas of cattail (*Typha* spp.) showed signs of stress (browning) although the extent was different across the STAs. Cattail litter accumulation may have contributed to some TP level increases. There was also an extensive decline in hydrilla (*Hydrilla verticillata*) and musk grass (*Chara* spp.) in all the STAs, resulting in TP concentration spikes as the plant biomass accumulated and decomposed in the marsh areas, canals, and structures. A long period of extremely low temperatures during winter 2010 resulted in widespread fish die-offs in all the STAs. Dead fish accumulated in the marsh areas, outflow canals, and structures, also releasing high levels of nutrients.

Actions

- In WY2010, efforts continued to maintain target stages in all the STAs. As a result of large rain events in mid-May through June 2009, stages in all the treatment cells, including those areas that dried out due to WY2009 drought conditions, were brought to or slightly above target stages for a short duration. All the STAs remained at target stages through the wetter-than-usual dry season (November 2009–May 2010).
- Efforts to improve the performance of the STAs are ongoing. STA-1E, Cells 5 and 7, were not constructed to original design specifications. As a consequence,

prevailing deepwater conditions in STA-1E, Cells 5 and 7, resulted in unsuccessful vegetation establishment in some areas and a gradual decline in vegetation coverage and condition in other areas over the years of operation. As an interim measure until the U.S. Army Corps of Engineers (USACE) corrects the topographic deficiencies, rehabilitation activities were initiated in STA-1E and the Western Flow-way was offline for part of the water year. Inflows were prioritized based on the availability of treatment areas able to provide phosphorus removal.

- Rehabilitation related to cattail reestablishment was initiated in STA-3/4, Cell 1A.
- The Northern Flow-way at STA-5 was offline for part of the water year for rehabilitation purposes. Inflows were prioritized based on the availability of effective treatment areas.
- Operational decisions were based on up-to-date data and operational envelopes. Internal transect sampling was conducted in STA-1E, STA-1W, STA-2, and STA-5 to evaluate the TP removal efficiencies of the treatment flow path and identify problem areas. Vegetation surveys were conducted within the SAV treatment cells at STA-1E, STA-1W, STA-3/4, and STA-5 to evaluate the condition of the communities and to track the reestablishment of vegetation in areas where vegetation decline was observed. Planned areas in STA-1E and STA-2 were identified for inoculation in the early part of WY2011.
- Surveys of cattail vegetation were also conducted in STA-1E, Cell 5, where cattail loss was observed, and STA-3/4, Cells 2A and 3A, where widespread cattail stress was observed. Additionally, in STA-3/4, Cell 3A, a field study was implemented in late WY2010 to examine the impact of the accumulation of cattail litter on cattail growth. To improve conditions for cattail growth, water depths were lowered in STA-3/4, Cell 1A, during the dry season to give the cattail community an opportunity to recover from stress caused by recurring deepwater conditions. Recovery of cattail will be monitored through WY2011.
- Bio-enhancement projects, including the encouragement of multiple vegetation types in treatment cells, were also initiated and results will be evaluated. Giant bulrush (*Scirpus* spp.; *Schoenoplectus californicus*) planting has been escalated, including planting in deepwater areas and vegetation strips in multiple areas within selected cells.
- Studies are planned to better understand hydrilla responses in the STAs and determine ways to have a more sustainable vegetation community. The studies will evaluate the management of hydrilla and identify mechanisms affecting population changes as well as hydrilla eradication methods that may be used to replace hydrilla with more desired SAV species like southern naiad (*Najas guadalupensis*).

STA-1E

Operational Issues and Conditions

The IEL was not met in WY2010 [outflow TP concentration was 61 ppb above the EFA limit (see **Table 5-1**); 26 ppb above the NPDES/AO limit]. This STA has been a focus of discussions among the South Florida Water Management District (SFWMD or District), FDEP, USACE, and other federal agencies for the past several years. Recent performance decline is attributed to various factors including water control structure failures at S-375, S-365A, and S-365B, which limited the District's ability to operate the STA as designed and is, therefore, limiting the use of the entire STA, which has resulted in (1) some of the flow-ways having to treat additional flows and loads, (2) highly uneven topography (as a result of as-built conditions not meeting the design specifications especially in Cells 5 and 7) that created very deep areas in designated EAV cells, and (3) consequential vegetation decline. During WY2009, the between-storm target stages in the SAV cells (Cells 4N, 4S, and 6) were increased by 6 inches in December 2008 to help maintain water levels during the dry months and protect the vegetation from dry-out conditions. Due to the construction of structure G-707, supplemental water was not delivered and, as a result, Cells 1, 2, 3, 4N, and 5 experienced dryout as early as April 2009 (Pietro et al., 2010). Water depths in Cell 3 were below the average ground elevation through June 2009 and in Cell 4N through May 2009 due to regional drought conditions. Daily TP concentrations entering STA-1E during the large rainfall events in May–July 2009 and in March 2010 were relatively high (over 200 ppb in May 2009, spiking up to 592 ppb in June 2009; over 400 ppb in early July 2009; and over 400 ppb in mid-March 2010). Elevated daily outflow concentrations occurred during these high inflow events. TP inflow loads to this STA were 22 percent above the average operational envelope value, but below the maximum level operational envelope value. The operational envelope values were estimated using the adjusted effective treatment area (see Appendix 5-2 for details).

Cattail communities continued to decline in terms of density and condition due to persistent deepwater conditions in Cell 7, resulting in poor performance of this cell and export of TP from decaying biomass. Cattail densities and condition also continued to decline in Cell 5. Floating cattail tussocks were observed in both Cells 5 and 7. As a result, high levels of nutrients were delivered to the SAV cells. In May 2009, there was an extensive decline in SAV (primarily hydrilla) in Cell 6 and the thick biomass accumulated on the water surface, in the outflow canals, and upstream of the outflow structures for about three months, releasing high levels of TP. There was another episode of hydrilla decline in February–March 2010 in Cells 4N and 4S. The Eastern Flow-way remains under restricted operation due to the ongoing USACE Periphyton Stormwater Treatment Area (PSTA) Demonstration Project. As a result of Western Flow-way rehabilitation and Eastern Flow-way activities, only about 62 percent of the effective treatment area for STA-1E was operational in WY2010 (see the *Individual STA Highlights & Challenges* section of this chapter and Appendix 5-2).

Actions

While the USACE has initiated various structural repairs, discussions regarding resolution of the outstanding issues in STA-1E continue. During WY2010, the Eastern Flow-way was taken offline for structure repairs and the Western Flow-way was taken offline for recovery and rehabilitation efforts. The WY2010 recovery and rehabilitation efforts in the Western Flow-way were intended to be an interim measure until the topography issues are corrected by the USACE.

Several field surveys were conducted beginning in July 2009 immediately following the decline in SAV to evaluate the extent of vegetation loss and recovery. Cattail communities were also surveyed in Cells 5 and 7 to assess the condition of the plant communities and determine ways to improve the vegetation in these cells.

Water levels were lowered starting in October 2009 in the Western Flow-way to allow for plant reestablishment in Cells 6 and 7. Giant bulrush was also planted in hydraulic short-circuit areas and deep areas in Cells 5 and 6 that were devoid of vegetation. Portions of high ground areas upstream of the Cell 5 outflow structures were degraded to improve water flow. Weed barrier booms were installed at the outflows of Cells 5 and 7 to impede export of plant material during flow events. A pilot project using cattail bales to address these short-circuited areas was initiated in Cell 6 (see the *STA Vegetation Management Measures* section of this chapter). A large-scale SAV inoculation in Cell 6 is scheduled for WY2011 to aid in the reestablishment of the desired plant communities. The success of these efforts and vegetation reestablishment will continue to be monitored through the next water year.

Internal water quality assessments by transect were also conducted in the Central and Western flow-ways to further describe the treatment pattern within these flow paths (see the *Internal Transect Phosphorus Sampling* section of this chapter for details).

STA-1W

Operational Issues and Conditions

The IEL was not met in WY2010 (outflow TP concentration was 6 ppb above the EFA limit, but below the NPDES/AO limit; see **Table 5-1**). In WY2010, inflow TP loads were 29 percent above the average operational envelope value, but below the maximum operational envelope value; inflow volumes were 98 percent of the average operational envelope value. Large rainfall events and associated basin runoff in May–June 2009 and March 2010 resulted in inflow volumes and TP loads above the average operational envelope value. In addition, structural failures and rehabilitation activities at STA-1E caused STA-1W to receive a portion of the flows and loads that would have otherwise been sent to STA-1E.

Daily TP inflow concentrations in May and June 2009 were above 200 ppb, peaking at 337 ppb. Inflow concentrations continued to range from 131–224 ppb until mid-September 2009 and spiked to 394 ppb in March 2010. During these high inflow periods, the Northern and Western flow-ways received TP loads above the average operational envelope value.

In September–October 2009, an extensive SAV community decline of hydrilla and musk grass was observed in Cells 2B, 4, and 5B. SAV reestablishment was evident in early 2010. Additionally, areas in Cell 5A remained devoid of vegetation, attributed to deepwater conditions in that cell.

Actions

Target stages were achieved in all treatment cells during WY2010. Aerial and ground surveys of the treatment cells were conducted throughout the year to determine cell conditions and identify needs for additional vegetation management actions. SAV cells were closely monitored to evaluate reestablishment of vegetation; the successful reestablishment in WY2010 eliminates the need to inoculate with SAV in WY2011. Giant bulrush planting in the deep zones of Cell 5A occurred in WY2010.

STA-2

Operational Issues and Conditions

The IEL was not met in WY2010 (outflow TP concentration was 12 ppb above the EFA and NPDES/AO limits; see **Table 5-1**). Performance issues in WY2010 are attributed to the flux of TP in Cell 1 upon rehydration after dry conditions during drought months, vegetation conversion in Cell 2 resulting in TP export from litter decomposition, and SAV decline in Cell 3.

For WY2010, TP inflow loads were 6 percent above the average operational envelope value, but below the maximum operational envelope value; and inflow volumes were 1 percent above the average operational envelope value, but below the maximum operational envelope value.

During WY2009, supplemental water was delivered in January 2009 to the SAV cells (Cell 3 and Cell 4), but not the emergent cells (Pietro et al., 2010). Water levels in Cell 1 were below the average ground elevation from February–May 2009, resulting in extended dryout. Upon reflooding in May, TP levels in outflows spiked to 196 ppb. Although the TP FWM concentrations decreased to 26 ppb by July, the levels remained higher than historical outflow concentrations from this cell. Water levels in Cell 2 were below the average ground elevation in April 2009 and the cell dried out; upon rehydration of the cell, outflow TP concentrations were initially as high as 72 ppb. The increase might have been partly attributed to the vegetation conversion (from EAV to SAV) in the southern section Cell 2. About 400 acres of the existing cattail was treated with herbicide in April 2009 to allow for SAV establishment. Outflow TP concentrations from the cell spiked to 249 ppb in August 2009, but were down to 19 ppb by September 2009. As of the end of WY2010, surveys indicated lack of SAV establishment, and the area has been planned for SAV inoculation.

In December 2009, the northern portion of STA-2, Cell 3, also experienced hydrilla decline and hydrilla biomass piled up on the first vegetation strip near the inflow. The uprooted hydrilla created a decomposing floating mat that remained at the surface for several weeks. Cell 4 also experienced a slight decline in SAV near the inflow during this time, but not at the same magnitude as what occurred in Cell 3.

Actions

Following the WY2009 drought conditions, target stages for the treatment cells were achieved in WY2010, except for May 2009.

A large-scale SAV inoculation in the southern portion of Cell 2 was scheduled for WY2011 to aid in vegetation establishment in the conversion area. SAV monitoring in this cell and other SAV cells was conducted throughout WY2010 and will continue in WY2011 to track coverage and condition. The cells will be managed adaptively based on survey findings.

Internal water quality transect sampling was conducted in the SAV cells to evaluate the phosphorus removal efficiencies along the flow path (see the *Internal Transect Phosphorus Sampling* section of this chapter). A study to determine the effects of vegetation resistance in water levels in Cell 2 began in 2008, and related data will be evaluated and findings used to further refine management of this cell.

STA-5

Operational Issues and Conditions

The IEL was not met in WY2010 (outflow TP concentration was 1 ppb above the EFA and NPDES/AO limits; see **Table 5-1**). TP inflow loads were about equal to the average operational envelope value; inflow volumes were less than the average operational envelope value.

During WY2009, in anticipation of drought conditions, the between-storm target stages in the SAV cells were increased by 6 inches in December 2008 to maintain water levels and protect the vegetation from dryout. Water that was pumped out of Cell 1A during rehabilitation construction was redirected into Cells 1B and 2A. However, no other sources of supplemental water were available to be delivered to the Southern Flow-way so it dried out by January 2009. Starting in February 2009, supplemental water was delivered to Cell 1B through the G-507 pump, and Cell 2B received water from Cell 1B via the internal G-345 culvert (Pietro et al., 2010). Water levels in Cells 2A, 3A, and 3B were below the average ground elevation from February 2010 through mid-May 2010 as a result of regional drought conditions. Upon rehydration, the Northern Flow-way was under restricted operation (following WY2009 rehabilitation) to allow for plant reestablishment. The Southern Flow-way was offline half of WY2010 due to Compartment C Build-out construction activities (excavation of the inflow canal and construction of G-342G and G-342H). Because of these conditions, only 67 percent of the effective treatment area was operational in WY2010 (see the *Individual STA Highlights & Challenges* section of this chapter and Appendix 5-2). The operational envelope values were estimated using the adjusted effective treatment area.

In WY2010, STA-5 received anomalous rainfall 1.5 inches above the simulated design range. Operations of the Northern and Central flow-ways were restricted beginning in April 2009 and continued beyond the end of WY2010 due to the presence of Everglade snail kite (*Rostrhamus sociabilis plumbeus*) nests. An extensive SAV community decline occurred in Cells 1B and 2B in January 2010 and persisted through April 2010. SAV biomass decomposition and increased turbidity were observed.

Actions

Following the dry conditions in May 2010, target stages were maintained in the northern and central treatment cells for the remainder of WY2010. Various wetland plants were planted and cattail and sawgrass (*Cladium jamaicense*) seeds were distributed in the areas in Cell 1A affected by rehabilitation earthmoving efforts. Cell operation was restricted to maintain low water levels and allow for plant reestablishment. Interior transect monitoring of this cell was conducted. Giant bulrush was planted in Cells 1B and 2B vegetation strips in April 2010 to reduce hydraulic short circuiting and serve as a wind buffer for the SAV. Vegetation surveys were also conducted in Cell 1B and Cell 2B to determine vegetation reestablishment following the observed decline in SAV.

STA-6

Operational Issues and Conditions

The IEL was not met in WY2010 (outflow TP concentration was 20 ppb above the EFA and NPDES/AO limits; see **Table 5-1**). This STA experienced repeated cycles of dryout and rehydration in Cells 3 and 5 and Section 2 at the beginning of the water year. Elevated outflow TP concentrations resulted upon rehydration. STA-6 also had higher than average inflows throughout the year, partially attributed to nearby Compartment C Build-out construction dewatering activities. Dewatering began on April 21, 2009. During construction of Compartment C, the G-600 pump station was utilized to direct dewatering discharges into the L-3 canal. These discharges produced increased stages in the L-3 canal which, in turn, resulted in inflows into STA-6 (see **Figures 5-1** and **5-2**). Elevated rainfall volumes (7.1 inches above the simulated design range) also added to the increase in flow volumes to STA-6.

In anticipation of drought conditions in WY2009, in December 2008 the between-storm target stage in the SAV cell (Section 2) was increased by 6 inches to maintain water levels and protect the vegetation from dryout;, however, no supplemental water was available to be delivered. As a result, all three flow-ways dried out by January 2009 (Pietro et al., 2010). Prior to the large rain event in mid-May 2009, STA-6 received only minimal inflows from October 2008 through early May 2009 due to drought conditions in the basin. As a result, all three treatment cells dried out with water levels below the average ground elevation for 3–4 months. In June 2009, upon rehydration, TP concentration spiked to 312, 45, and 131 ppb at Cell 3, Cell 5, and Section 2, respectively. Concentrations declined throughout the remainder of WY2010.

WY2010 inflow volume and TP loads that were directed to STA-6 were 1.8 times higher than in WY2009. These volumes resulted in inflow TP loads that were 32 percent above the average operational envelope value, and 10 percent above the maximum operational envelope value; inflow volumes were 80 percent above the average operational envelope value and 10 percent above the maximum operational envelope value.

Actions

Target stages for the treatment cells were achieved in WY2010, except for May 2009. As a result of dry conditions, vegetation communities were stressed and required time to recover. Aerial survey of the treatment cells conducted in mid-March 2010 showed good plant reestablishment. The effect of Compartment C Build-out dewatering is considered to be temporary and is expected to stop once construction in that area is completed. The operations plan may be modified to decrease the gate openings to reduce inflows.

Other Water Quality Permit Requirements

Water quality parameters with Florida Class III standards are identified in **Table 5-6**. Compliance with EFA permits is determined based on the following three-part assessment:

1. If the annual average outflow concentration does not cause or contribute to violations of applicable Class III water quality standards, then the STA shall be deemed in compliance.
2. If the annual average concentration at the outflow causes or contributes to violations of applicable Class III water quality standards, but does not exceed or is equal to the annual average concentration at the inflow stations, then the STA shall be deemed in compliance.
3. If the annual average concentration at the outflow causes or contributes to violations of applicable Class III water quality standards and also exceeds the annual average concentration at the inflow station, then the STA shall be deemed out of compliance.

The determination as to whether or not an STA is contributing to a violation for a specific parameter is a comparison of the average annual inflow concentration to the average annual outflow concentration relative to the three-part assessment. The District has performed all sampling and analysis in compliance with Chapter 62-160, Florida Administrative Code (F.A.C.), and the District's Laboratory Quality Manual (SFWMD, 2009b) and Field Sampling Quality Manual (SFWMD, 2009c). The annual permit compliance monitoring report for mercury in the STAs is presented in Appendix 5-5. Each STA has different permit reporting requirements for annual water quality constituents.

Compliance with the specific conductance (or conductivity) criteria for Class III fresh waters is described in Section 62-302.530, F.A.C., as measured values that are not more than 50 percent above background or do not exceed 1,275 microsiemens per centimeter (µS/cm) (whichever is greater). Because the samples are collected in freshwater systems, conductivities at STA inflows and outflows are typically lower than 1,275 µS/cm.

The Class III criterion for turbidity, as specified under Section 62-302.530, F.A.C., states that measured values shall not be more than "29 NTUs above natural background conditions." Under Chapter 62-303, F.A.C., natural background is defined as:

> "…the condition of waters in the absence of man-induced alterations based on the best scientific information available to the Department. The establishment of natural background for an altered water body may be based upon a similar unaltered water body or on historical pre-alteration data..."

Because the FDEP has not compiled any information on what it considers natural background, the District has determined that any measured value that is greater than 29 nephelometric turbidity units (NTUs) exceeds the turbidity criterion.

Table 5-6. Water quality parameters with Florida Class III criteria specified in Section 62-302.530, Florida Administrative Code.

Parameter	Units	Florida Class III Criteria[1]
Dissolved Oxygen[2]	mg/L	Greater than or equal to (≥) 5.0 mg/L
Specific Conductance	µS/cm	Not >50 percent of background or >1,275 µmhos/cm, whichever is greater
pH	SU	Not less than (<) 6.0 or > 8.5
Turbidity	NTU	≤ 29 NTUs above background conditions
Un-ionized Ammonia	mg/L	≤ 0.02 mg/L
Alkalinity	mg $CaCO_3$/L	Not < 20 mg/L

[1] Because the STAs are freshwater systems, the background concentration for specific conductance is assumed to be less than 1,275 microsiemens per centimeter (µS/cm), and the background concentration for turbidity cannot exceed 29 nephelometric turbidity units (NTUs).
[2] Permits for all STAs, except STA-3/4, require compliance with the site-specific alternative criteria (SSAC) for dissolved oxygen (Weaver, 2004).
$CaCO_3$ – calcium carbonate
mg/L – milligrams per liter
SU – standard units
µmhos/cm – micromhos per centimeter

Water Year 2010 Performance for Other Water Quality Parameters

For water quality parameters that do not have a Florida Class III standard, excursions are noted when the annual outflow FWM concentrations are higher than the annual inflow FWM concentrations. An STA may have individual excursions yet be in overall compliance if it meets the remaining components of the EFA three-part assessment.

WY2010 monitoring data for permitted water quality parameters at the STA inflows and outflows are presented in Appendix 5-4. Annual FWM concentrations at inflows and outflows of the STAs, including excursion analysis, are summarized in **Table 5-7**. In addition, the annual permit compliance monitoring report for mercury in the STAs is included as Appendix 5-5.

Pursuant to EFA permits for each of the STAs (except STA-3/4), dissolved oxygen (DO) compliance is evaluated annually using a statistical analysis to compare DO levels within the STA as set forth in the Everglades marsh DO site-specific alternative criteria (SSAC). Additional details regarding compliance with the DO SSAC are presented in the *Dissolved Oxygen* section of this chapter.

Based on water quality data (excluding TP and DO) collected during WY2010 at inflows and outflows to the STAs, all the annual FWM concentrations measured at the outflows of each STA did not exceed the Class III criteria and were lower than annual FWM concentrations at the inflows to that STA (**Tables 5-6** and **5-7**), except for STA-1E and STA-1W. Annual sulfate FWM concentrations at the outflows from these two STAs were higher by 0.4 milligrams per liter (mg/L) than at the inflows. This difference could be explained by the uncertainty in the analytical method. Total nitrogen concentrations at the outflow of STA-1E were higher than at the inflow during WY2010. Most of the nitrogen present in South Florida surface waters are in the form of dissolved organic nitrogen. This form of nitrogen is not readily bioavailable. Because STAs are biological treatment systems, they are a source of dissolved organic nitrogen. The more labile or biologically available forms of nitrogen (nitrate + nitrite) at STA-1E decreased in concentration by more than twofold from inflow to outflow (**Table 5-7**).

As part of the performance evaluation specified by permit for each STA, a statistical comparison of inflow and outflow FWM concentrations is required to be reported. Statistical significance is determined at a significance level (α) of 0.05. The permits specify that the Student's t-test be used to statistically compare parameter concentrations at inflows and outflows of the STAs. Based on the distributional assumptions of the data, the Student's t-test may not be the most appropriate analysis for assessing these differences. When datasets do not exhibit a statistically significant deviation from a normal distribution, then the Student's t-test can be used to assess differences. However, when datasets deviate significantly from normality, the Student's t-test is not appropriate and can result in incorrect probability determinations. The Shapiro-Wilk test of normality was used to determine if datasets deviated significantly from normality. Those datasets that did not deviate significantly from a normal distribution (i.e., $p > 0.05$) were analyzed using the Student's t-test. However, datasets that deviated significantly from normality ($p < 0.05$), were tested using the Mann-Whitney U test (a non-parametric equivalent of the Student's t-test).

During WY2010, approximately 50 percent of inflow and outflow datasets for the six STAs exhibited deviations from normal distributions. Therefore, both the Mann-Whitney U and Student's t-test were used to statistically compare the inflow and outflow FMW concentrations. These statistical comparisons are summarized in **Table 5-8** by parameter and STA. Of the 33 datasets evaluated, 22 comparisons exhibited statistically significant differences between inflow and outflow FMW concentrations. Inflow FWM concentrations were significantly higher than outflow FWM concentrations for 21 comparisons.

Table 5-7. Summary of annual FWM concentrations of parameters other than TP for inflow and outflow of the STAs during WY2010.

Parameter	Annual Flow-Weighted Means[a] Total Inflow n[b]	Total Inflow Conc.	Total Outflow n[b]	Total Outflow Conc.
STA-1E				
Sulfate (mg/L)[c]	***33 (78)***	***45.9***	***16 (26)***	***46.3***
Alkalinity (mg $CaCO_3$/L)	33 (78)	187	16 (26)	194
Total Nitrogen (mg/L)[c]	***32 (77)***	***2.34***	***15 (25)***	***2.69***
Nitrate + Nitrite as N (mg/L)	32 (77)	0.384	15 (25)	0.171
STA-1W				
Sulfate (mg/L)[c]	***12 (26)***	***66.5***	***22 (52)***	***66.9***
Alkalinity (mg $CaCO_3$/L)	12 (26)	235	22 (52)	204
Total Nitrogen (mg/L)	11 (25)	3.51	22 (50)	2.62
Nitrate + Nitrite as N (mg/L)	11 (25)	0.711	22 (50)	0.332
STA-2				
Sulfate (mg/L)	32 (65)	72.6	18 (26)	61.8
Total Nitrogen (mg/L)	36 (68)	4.09	18 (26)	2.35
Nitrate + Nitrite as N (mg/L)	36 (68)	1.054	18 (26)	0.035
STA-3/4				
Turbidity (NTU)	33 (52)	6.6	113 (156)	0.8
Total Dissolved Solids (mg/L)	33 (52)	681.7	113 (156)	539
Un-ionized Ammonia (mg/L)	30 (43)	0.004	68 (103)	0.006
Soluble Reactive Phosphorus (mg/L)	55 (102)	0.046	211 (302)	0.002
Total Dissolved Phosphorus (mg/L)	55 (104)	0.055	216 (312)	0.007
Sulfate (mg/L)	33 (52)	72.8	113 (156)	56.2
Alkalinity (mg $CaCO_3$/L)	33 (52)	301	113 (156)	222
Dissolved Chloride (mg/L)	33 (52)	119	113 (156)	105
Total Nitrogen (mg/L)	33 (52)	4.2	110 (145)	1.95
Total Dissolved Nitrogen (mg/L)	33 (52)	4	110 (145)	1.87
Nitrate + Nitrite as N (mg/L)	33 (52)	1.753	110 (145)	0.056
STA-5				
Sulfate (mg/L)	61 (115)	7.9	45 (128)	4.7
Total Nitrogen (mg/L)	58 (111)	1.78	44 (126)	1.5
Nitrate + Nitrite as N (mg/L)	58 (111)	0.114	44 (126)	0.011
STA-6				
Sulfate (mg/L)	37 (48)	11.8	43 (72)	9.4
Total Nitrogen (mg/L)	37 (48)	1.7	42 (70)	1.51
Nitrate + Nitrite as N (mg/L)	37 (48)	0.064	43 (71)	0.007

[a] Annual flow-weighted means are computed for inflows and outflows by combining data from individual stations
[b] n = total number of samples collected with flow (total number of samples collected regardless of flow)
[c] Parameters not meeting the three-part assessment for Class III waters

Table 5-8. Statistical comparison of monthly FWM concentrations at inflows and outflows of the STAs for other water quality parameters.

Parameter Name	Variable	Stormwater Treatment Areas					
		STA-1E	STA-1W	STA-2	STA-3/4	STA-5	STA-6
Specific Conductivity	P-Value[a]	0.644	0.082	***0.017***	***<0.001***	0.560	0.111
	Structure[b]	Inflow	Inflow	***Inflow***	***Inflow***	Inflow	Inflow
	Statistical Test[c]	Mann-Whitney	t Test	***t Test***	***t Test***	t Test	t Test
Turbidity	P-Value[a]	NA	NA	NA	***<0.001***	NA	NA
	Structure[b]	NA	NA	NA	***Inflow***	NA	NA
	Statistical Test[c]	NA	NA	NA	***t Test***	NA	NA
Total Dissolved Solids	P-Value[a]	NA	NA	NA	***<0.001***	NA	NA
	Structure[b]	NA	NA	NA	***Inflow***	NA	NA
	Statistical Test[c]	NA	NA	NA	***t Test***	NA	NA
Dissolved Chloride	P-Value[a]	NA	NA	NA	0.362	NA	NA
	Structure[b]	NA	NA	NA	Inflow	NA	NA
	Statistical Test[c]	NA	NA	NA	t Test	NA	NA
Alkalinity	P-Value[a]	0.833	***0.021***	NA	***<0.001***	NA	NA
	Structure[b]	Outflow	***Inflow***	NA	***Inflow***	NA	NA
	Statistical Test[c]	Mann-Whitney	***t Test***	NA	***t Test***	NA	NA
Sulfate	P-Value[a]	0.521	***0.029***	0.364	***0.005***	***0.026***	***0.006***
	Structure[b]	Inflow	***Inflow***	Inflow	***Inflow***	***Inflow***	***Inflow***
	Statistical Test[c]	t Test	***t Test***	t Test	***t Test***	***Mann-Whitney***	***t Test***
Soluble Reactive Phosphorus	P-Value[a]	NA	NA	NA	***<0.001***	NA	NA
	Structure[b]	NA	NA	NA	***Inflow***	NA	NA
	Statistical Test[c]	NA	NA	NA	***Mann-Whitney***	NA	NA
Total Dissolved Phosphorus	P-Value[a]	NA	NA	NA	***<0.001***	NA	NA
	Structure[b]	NA	NA	NA	***Inflow***	NA	NA
	Statistical Test[c]	NA	NA	NA	***Mann-Whitney***	NA	NA
Un-ionized Ammonia	P-Value[a]	NA	NA	NA	0.253	NA	NA
	Structure[b]	NA	NA	NA	Inflow	NA	NA
	Statistical Test[c]	NA	NA	NA	Mann-Whitney	NA	NA
Nitrate + Nitrite	P-Value[a]	***0.029***	***0.003***	***<0.001***	***<0.001***	***0.013***	***<0.001***
	Structure[b]	***Inflow***	***Inflow***	***Inflow***	***Inflow***	***Inflow***	***Inflow***
	Statistical Test[c]	***Mann-Whitney***	***Mann-Whitney***	***Mann-Whitney***	***Mann-Whitney***	***Mann-Whitney***	***Mann-Whitney***
Total Dissolved Nitrogen	P-Value[a]	NA	NA	NA	***<0.001***	NA	NA
	Structure[b]	NA	NA	NA	***Inflow***	NA	NA
	Statistical Test[c]	NA	NA	NA	***Mann-Whitney***	NA	NA
Total Nitrogen	P-Value[a]	***0.041***	0.063	***0.002***	***<0.001***	0.772	***0.043***
	Structure[b]	***Outflow***	Inflow	***Inflow***	***Inflow***	Inflow	***Inflow***
	Statistical Test[c]	***t Test***	Mann-Whitney	***t Test***	***Mann-Whitney***	Mann-Whitney	***t Test***

NA – indicates that data was not collected or there were insufficient data to perform the statistical analyses.

[a] Probability level (p-value) computed using appropriate comparison test. A significance level (α) of 0.05 was used. When $p < 0.05$, the parameter concentrations were significantly different between the inflow and outflow. Significant p-values are presented in the table with an italic, bold-face font.

[b] STA structure(s) exhibiting higher parameter concentrations during the water year.

[c] Statistical test used to compare inflow and outflow water quality data. Choice of test was based on distributional assumptions. If the distribution of the data did not significantly deviate from normality, the Student's t-test (t Test) was used. When the distribution of the data did deviate significantly from normality, the Mann-Whitney U (Mann-Whitney) test (non-parametric equivalent) was used.

Dissolved Oxygen

DO concentrations below 5.0 milligrams per liter (mg/L) occur commonly throughout the Everglades Protection Area (EPA), including interior marsh sites minimally impacted by nutrient enrichment or cattail invasion. Frequent DO levels below 5.0 mg/L are typical in macrophyte-dominated wetlands where marsh processes of photosynthesis and respiration result in wide diel swings in DO levels. Because low DO concentrations often measured in the EPA represent natural variability in this type of ecosystem, the FDEP, pursuant to Chapter 62-302.800(1), F.A.C., has promulgated a SSAC for DO in the Everglades. This SSAC addresses the wide-ranging natural diel fluctuations that influence natural background DO levels. Weaver et al. (2008) explains the SSAC and its development and application in assessing DO excursions. The specific methods for determining compliance are set forth in the DO SSAC (Weaver and Payne, 2004), which was adopted by Secretarial Order on January 26, 2004, and approved by the U.S. Environmental Protection Agency (USEPA) as a revision to the State of Florida's water quality standards on June 16, 2004.

Previous reports (Jorge et al., 2002; Goforth et al., 2003, 2004, and 2005; Pietro et al., 2006 and 2007) provided monitoring results, comparisons, and evaluations for diel DO in the STAs. These reports were used to assess the impact of STA discharges on the downstream Everglades ecological system or downstream water quality with respect to DO and pursuant to five STAs (STA-1E, STA-1W, STA-2, STA-3/4, and STA-5) EFA permits and associated AOs. These reports also provided data to the FDEP for developing the DO SSAC. DO SSAC comparisons have been used to assess the STAs (except STA-6) since WY2007 (Pietro et al., 2008). STA-6 did not have a diel DO permit requirement when the DO SSAC was adopted.

For WY2010, the SSAC is now included in EFA permits and associated AOs of STA-1E, STA-1W, STA-2, STA-5, and STA-6 as a permit compliance criterion. The DO SSAC is also expected to be included in future STA permits for STA-3/4; the NPDES permit issued on January 9, 2004, for this STA stipulates that the permit shall be revised in the event that the State of Florida establishes a DO SSAC in the EPA. (Permitted outflow points for each STA are shown in **Figure 5-2**.)

Permits issued for the six STAs require that the District provide the FDEP with an annual report consisting of an analysis demonstrating that DO levels in STA discharges do not adversely change the downstream Everglades ecology or the downstream water quality. As the DO SSAC has been adopted by the FDEP and formally approved by the USEPA, assessment on possible downstream impacts by the outflows from STAs during WY2010 was performed by applying the DO SSAC at the outflow stations.

Biweekly DO concentrations measured at STA discharge points during WY2010 are provided in Appendix 5-4. A summary of annual DO levels at these permitted outflows and calculated DO SSAC for each STA are provided in **Table 5-9**. A comparison of the measured mean annual DO for an outflow station with the calculated mean annual SSAC determines compliance. When mean annual DO concentrations measured at the outflow stations are greater than the calculated mean annual concentration utilizing the SSAC equation, then the outflow values are in compliance with the permit.

During WY2010, two outflow stations at STA-5 (G-344E and G-344F) and at STA-6 (G-354C and G-393B) had mean annual DO levels that were lower than the SSAC (**Table 5-9**). These deviations from the SSAC probably resulted from low-flow conditions at these discharge locations. For STA-5, more than 96 percent of the total flow was directed through the G-344A-D structures, with less than 4 percent of the total flow released through the G-344E-F structures. Low flow at the G-344E-F structures likely contributed to the mean annual DO levels of 1.4 and 1.8 mg/L (**Table 5-9**), respectively, due to more frequent periods of stagnation (more than 300 days with no flow from these structures). In STA-6, three outflow structures (G-352B, G-354C, and G-393B) were in operation during WY2010. Two of the structures (G-354C and G-393B) accounted for a combined flow of approximately 19 percent of the total flow from the STA. In addition, both outflow stations had mean annual DO levels that were less than 2.0 mg/L and deviated approximately 2.0 mg/L from the SSAC.

Table 5-9. Summary of WY2010 annual dissolved oxygen (DO) levels at outflow stations for each STA compared to site-specific alternative criteria (SSAC).

STA	Outflow Station	No. of Samples	Mean[a]	Standard Deviation	Min.	Max.	Mean Annual SSAC Limit[b]	SSAC Limit Classification[c]
STA-1E	S362	51	5.77	2.16	1.33	12.00	3.14	Above
STA-1W	G251	52	2.51	1.67	0.26	7.19	2.36	Above
	G310	52	4.35	1.90	0.95	8.35	2.23	Above
STA-2	G335	50	4.13	2.28	0.78	8.69	2.44	Above
STA-3/4	G376B	49	4.48	2.36	1.36	11.70	2.31	Above
	G376E	49	4.45	1.78	1.52	9.42	2.44	Above
	G379B	50	4.13	2.12	1.20	10.80	2.61	Above
	G379D	50	4.84	2.28	1.63	11.20	2.76	Above
	G381B	50	5.35	2.33	1.81	11.80	3.27	Above
	G381E	50	6.09	2.42	2.41	11.90	3.42	Above
STA-5	G344A	51	3.11	2.70	0.31	12.60	2.47	Above
	G344B	51	3.55	2.35	0.50	11.70	2.59	Above
	G344C	51	3.53	2.89	0.10	12.60	2.65	Above
	G344D	51	3.78	2.78	0.24	12.10	2.80	Above
	G344E	***22***	***1.45***	***0.84***	***0.47***	***3.51***	***1.84***	***Below***
	G344F	***22***	***1.82***	***1.01***	***0.46***	***3.68***	***1.89***	***Below***
STA-6	G352B	47	3.49	2.82	0.31	10.50	2.72	Above
	G354C	***47***	***0.98***	***1.18***	***0.08***	***7.12***	***3.07***	***Below***
	G393B	***47***	***1.94***	***1.72***	***0.38***	***7.94***	***3.11***	***Below***

[a] Arithmetic mean

[b] Derived using the equation from Weaver (2004) which calculates the limit using water temperature and time of day data recorded at each monitoring location during each monitoring event.

[c] Indicates whether the mean annual DO level measured at an outflow station was above or below the SSAC limit. "Above" indicates that mean annual DO was equal to or greater than the mean annual SSAC limit.

Note: STA-1E and STA-1W, EFA Permit No. 0279499-001-EM
STA-2, EFA Permit No. 0126704-005-EM
STA-3/4, EFA Permit No. 0192895 and NPDES Permit No. FL0300195
STA-5, EFA Permit No. 0131842-006-GL
STA-6, EFA Permit No. 0236905-001 (PATS No. 262918309)

In addition to assessing STA performance in WY2010 relative to the DO SSAC, a comparison of STA performance with the SSAC for the past four water years was also performed. **Figure 5-8** presents the mean annual residual DO levels for STA outflow for WY2007–WY2010. When mean annual DO levels are greater than the SSAC, the mean annual residuals (or difference between mean annual DO levels and SSAC) are positive (or greater than zero). All outflow stations at STA-3/4 had positive residuals and exhibited continued improvement in DO levels. In addition, outflow stations at STA-1E, STA-1W, STA-2, and STA-6 showed improved DO levels compared with WY2009.

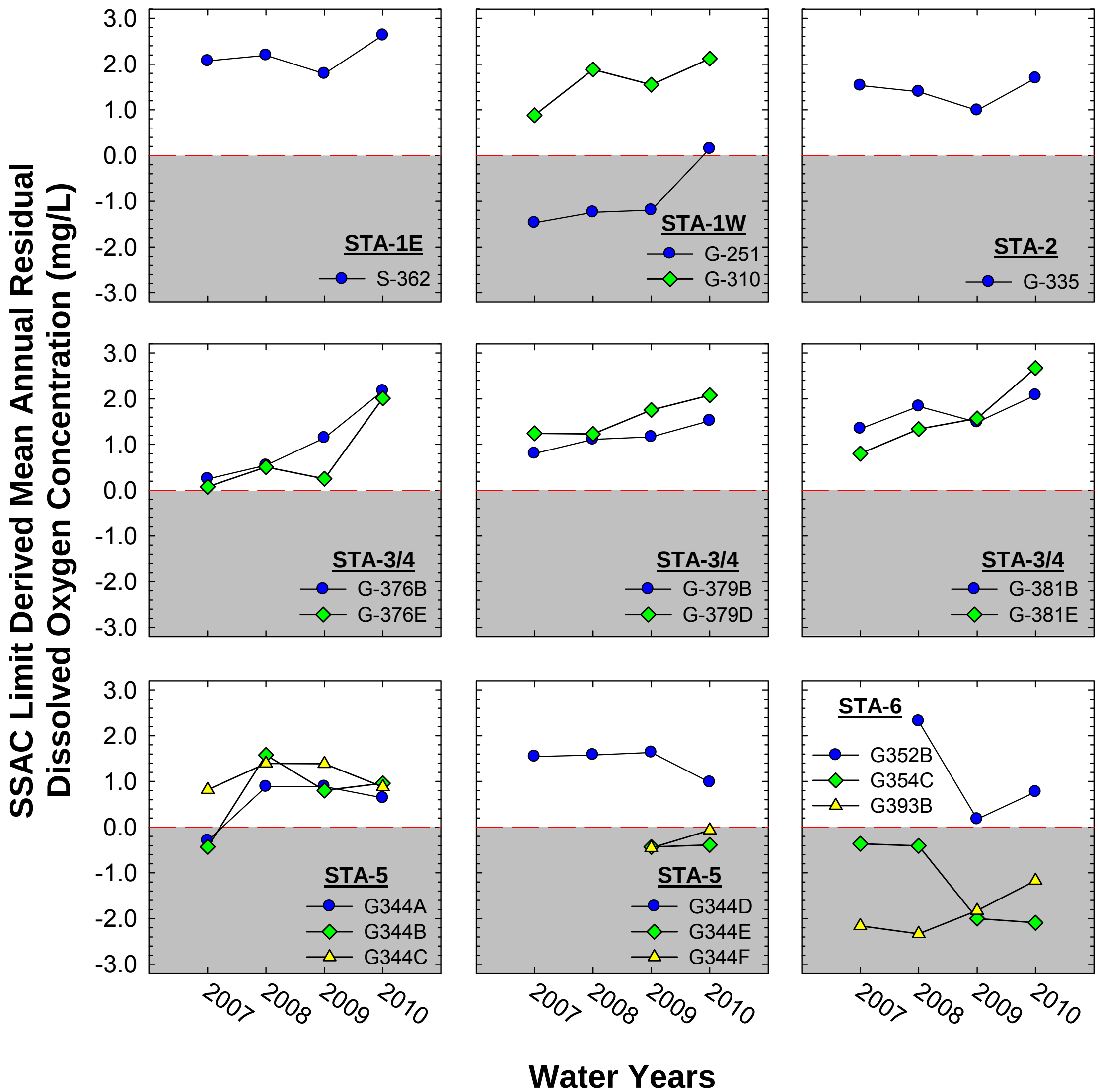


Figure 5-8. The mean annual residual DO plots at STA outflow stations from WY2007–WY2010. Mean annual residuals were computed as the difference between the mean annual DO and mean annual SSAC. Negative residuals indicate that an outflow station was below the SSAC limit, while positive residuals indicate that an outflow station was above the SSAC limit.

Compliance with the DO SSAC at marsh stations is analyzed in Chapter 3A of this volume. A summary table for individual marsh stations in the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge), Water Conservation Areas (WCAs) 2 and 3, and Everglades National Park (ENP or Park) is provided in Appendix 3A-3 of this volume. Based on these results, six marsh stations in the Refuge and nine marsh stations in WCA-2 did not pass the DO SSAC assessment. All marsh stations in WCA-3 and the ENP passed the SSAC assessment.

The six stations in the Refuge (LOXA105, LOXA136, X1, X2, Z1, and Z2) that did not pass the DO SSAC assessment are shown in Chapter 3A, Figure 3A-2. Marsh station LOXA105 is located in the northwestern portion of the Refuge close to the outflows for STA-1W. The annual average DO concentrations for this station (mean = 2.43 mg/L) was lower than the annual SSAC limit by approximately 0.3 mg/L. Based on the DO levels of neighboring stations, it is not believed that the discharge from STA-1W resulted in the depressed DO levels observed for LOXA105. Additionally, station LOXA104, located on the Rim Canal between the outflows from STA-1W and LOXA105, was in compliance with the SSAC (see Appendix 3A-3 of this volume). The mean DO concentration for LOXA104 during WY2010 was 4.65 ± 2.11 mg/L (mean ± standard deviation). In addition, monitoring stations LOXA106 and LOXA107, located around LOXA105, were also in compliance with the DO SSAC.

Annual DO levels from STA-1W discharges during WY2010 averaged 4.35 mg/L and 2.51 mg/L at G-310 and G-251, respectively (**Table 5-9**), with more than 97 percent of the flow being directed through the G-310 structure. Based on DO data for the LOXA104 and G-310 structures, the observed deviations from the DO SSAC for LOXA105 are not likely to have resulted from STA-1W releases as the mean DO levels in the canal and the major discharge structure were approximately twice as high as for the marsh station.

Furthermore, DO levels for marsh stations along the X and Z transects (X1, X2, Z1, and Z2) that did not comply with the DO SSAC do not appear to have been affected by STA-1W releases. Rim Canal stations X0 and Z0 had annual DO levels of 3.62 ± 2.07 mg/L and 3.55 ± 2.09 mg/L (mean ± standard deviation), respectively (see Chapter 3A of this volume), and were in compliance with the DO SSAC. Additionally, X and Z transect data were only available from June–September 2009 and this part of the year does not likely represent DO levels for these transect stations over an entire annual cycle. Therefore, the observed deviations from the DO SSAC at these stations were probably caused by both natural marsh processes as well as insufficient data to properly satisfy the annual SSAC assessment.

Marsh station LOXA136, which also did not pass the DO SSAC assessment, is located in the northeastern portion of the Refuge downstream of the STA-1E discharge structure, S-362. The annual mean DO concentration at this station was 2.54 mg/L, or approximately 0.5 mg/L lower than the SSAC. The deviation from the SSAC at this station is not expected to be attributed to outflows from STA-1E as DO measured at the outflow structure during WY2010 was 5.77 ± 2.16 mg/L. The Rim Canal station (LOXA135) located immediately downstream of S-362 exhibited DO levels averaging 3.78 ± 2.52 mg/L. Both of the Rim Canal stations and the outflow station had higher DO levels LOXA136. In addition, both S-363 and LOXA135 were above the SSAC limit (**Table 5-9**; Appendix 3A-3). Therefore, the lower DO levels observed at LOXA136 are believed to be a result of natural marsh processes. **Figure 5-9** compares annual DO levels for the six marsh stations in the Refuge that deviated from the SSAC limit during WY2010, as well as the DO levels for the stations in the Rim Canal and STA outflow stations.

Marsh stations in WCA-2 that did not meet the annual SSAC limits were E1, E2, E3, E4, F1, F2, F3, F4, and N1 (see Appendix 3A-3, Table 1). Chapter 3A, Figure 3A-3 shows the locations of these marsh stations and their proximity to the STA-2 discharge point (G-335). Based on location, it is evident that only marsh station N1 can be potentially influenced by STA-2 discharge. Due to the distance between the G-335 structure and marsh stations, as well the annual

DO level reported for the structure (4.13 ± 2.28 mg/L) during WY2010, the observed deviation at marsh station N1 from the DO SSAC is not likely to be a result of STA-2 releases.

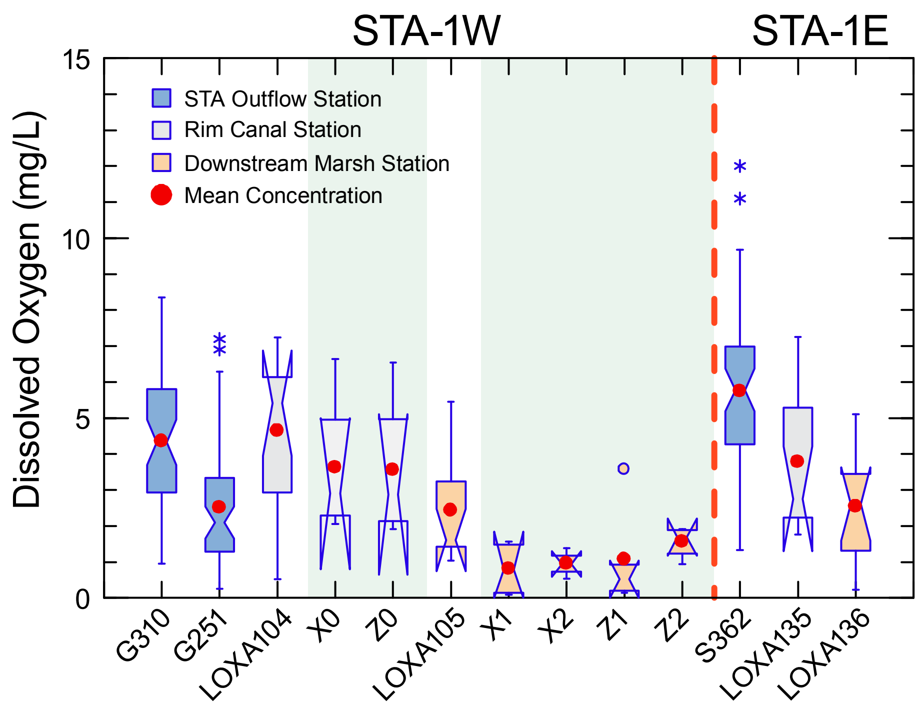


Figure 5-9. Notched-box-and-whisker plots of DO concentrations measured during WY2010 at STA outflow stations (for STA-1W and STA-1E) and downstream marsh stations that did not meet the SSAC in the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge). The notches represent the 95 percent confidence interval around the median value. The shaded region identifies stations sampled from May–September 2009. The dashed line delineates the western (left of dashed line) and eastern (right of dashed line) sections of the Refuge.

Mercury

For WY2010 and calendar year 2009 (CY2009), all STAs met action level requirements listed in the Protocol for Monitoring Mercury and Other Toxicants (Protocol) (SFWMD, 2006). Currently, surface water samples are collected in STA-1E, STA-2, STA-5, and STA-6 for total mercury (THg) and methylmercury (MeHg) analysis. Surface water mercury monitoring within STA-3/4 and STA-1W has been terminated in accordance with the guidelines listed the Protocol (see Appendix 5-5). STA-1E is currently in Phase 2, Tier 1; STA-1W is in Phase 3, Tier 3; STA-2 is in Phase 2, Tier 1; STA-3/4 is in Phase 3, Tier 2; STA-5 Northern and Central flow-ways are in Phase 3, Tier 3, and STA-5 Southern Flow-way is in Phase 2, Tier 1; STA-6, Cell 3 and Cell 5, are in Phase 3, Tier 3, and STA-6 Section 2 is in Phase 2, Tier 1. During WY2010, average annual outflow loading of THg and MeHg for all STAs was lower than inflow.

During CY2009, mercury concentrations in mosquitofish (*Gambusia affinis*) from all interior STA locations showed an average 21 percent decrease since 2008. The largest reduction was observed at STA-6, with a 43 percent decrease. For sunfish (*Lepomis* spp.), half of all sampled STAs demonstrated a reduction in fish collected since 2008. There was an increase for STAs 1E and 2 and a decrease for STAs 5 and 6. The largest increase was seen at STA-2 (23 percent). The largest decrease was observed at STA-5 (40 percent). For largemouth bass (LMB) (*Micropterus salmoides*), all STAs showed a decrease in Hg concentrations for age-standardized 2–3 year old bass [307–385 millimeters (mm) in length] since 2008. The largest decrease in LMB tissue was observed in STA-2, with a 57 percent reduction. Based on U.S. Fish and Wildlife Service (USFWS) and U.S. Environmental Protection Agency (USEPA) predator protection criteria, fish-eating wildlife foraging within all STAs appear to be at an overall moderate risk to mercury exposure. STA mercury performance criteria are evaluated on an annual basis. If respective actions levels are exceeded, then corrective measures are taken in accordance with the FDEP-approved monitoring plans. Additional information on fish mercury concentrations, including spatial and temporal trends within and downstream of each STA, are presented in Appendix 5-5 of this volume.

Rotenberger Wildlife Management Area Restoration and STA Transect Monitoring

The District monitors adjacent wetland areas that receive discharges from the STAs, which include the Refuge (adjacent to STA-1E and STA-1W), WCA-2A (adjacent to STA-2), and the Rotenberger Wildlife Management Area, which is adjacent to STA-5 (**Figure 5-1**). Data are collected at inflow points and along prescribed transects to assess changes in conditions as water moves down-gradient (south). In accordance with the annual reporting requirements of related permits, these WY2010 data are provided in Appendix 5-3.

AVIAN PROTECTION

In accordance with the Avian Protection Plan (APP) for Black-necked Stilts and Burrowing Owls Nesting in the Everglades Agricultural Area Stormwater Treatment Areas (Pandion Systems, Inc., 2008), protective measures were implemented during the 2010 nesting season (March–July 2010). The APP characterizes potential risks to the two avian species — black-necked stilts (*Himantopus mexicanus*) and burrowing owls (*Athene cunicularia*) — from STA construction, operation, start-up, drought conditions, normal operations, routine maintenance, and enhancement activities. The plan also outlines actions to minimize harmful impacts to these migratory birds and nests due to STA operations. For CY2010, survey results on black-necked stilts and related operational efforts are presented in this section. [Note: Similar to last year, no burrowing owl nests were found within the STAs in 2010.] Other avian-related information associated with the STAs during the reporting period is also summarized below.

Black-necked Stilts

Black-necked stilts are the focus of surveys because they are an abundant and a conservative indicator species for ground-nesting birds in the STAs. During CY2010, standardized field surveys were conducted by the District according to the APP, with preliminary surveys conducted from March 17–19, 2010. A few stilts were observed in all the STAs in March, except for STA-6, and the onset of the stilt breeding season was noted in April 2010. Throughout the season, nest surveys of treatment cells were performed from levees to obtain useful operational information for each treatment cell over a relatively large area. Two different types of levee surveys, monthly and spot-check, were executed based on the type of information needed to make operational decisions. Surveys were conducted using binoculars (16 x 50 millimeters) or a spotting scope (20-60 x 80 millimeters). A hand-held Global Positioning System unit provided the latitude and longitude of each observer location on the levee when nests were detected inside a treatment cell, and distance was measured with a rangefinder (6 x 216.0°). Related information including the coordinates, number and distance of nests, observations, and observers' initials was field recorded into a database (see Appendix 5-9, Figure 1, of this volume). Standardized reports were used to pinpoint the location and number of black-necked stilt nests by flow-way and treatment cell. Information regarding stilt nest activities and locations, and the resulting operational restrictions within the STAs, were distributed to District and USFWS staff.

2010 Nesting Season Survey Results

During implementation of the APP guidelines and proactive field operations, dozens of black-necked stilt chicks were observed foraging near adult birds in several STAs from May–July 2010. The 2010 nesting season surveys began in mid-April, with the earliest nests observed on April 19 in STA-1E. Subsequent monthly surveys were conducted from May 18–24 and June 21–30. Most nests were inactive by the June monthly survey, except in STA-1W and STA-2. Four nests were found in each of these STAs during the June survey. The nesting season was finished in early July when spot checks in STA-1W and STA-2 found no nesting stilts. This is consistent with nesting patterns observed in previous years, suggesting that the timing of the stilt nesting season remained relatively constant even though environmental conditions changed.

During the 2010 breeding season, there were 227 black-necked stilt nests observed via the levee surveys, with the highest number found in STA-1E (150 nests), followed by STA-2 (29 nests) (Appendix 5-9, Tables 1 and 2, respectively). Relatively high numbers of nesting stilts were observed in STA-1E, Cell 6, because of the low-water conditions in this cell at the beginning of the nesting season. The cell water level had been lowered to allow for vegetation reestablishment after an extensive hydrilla die-off in prior months. Overall, there were notably fewer stilt nests observed in CY2010 compared to 2009's surveys (with 873 nests observed in

CY2009). The reduction was likely due to extensive amounts of rainfall during the dry season. Higher-than-normal precipitation kept water levels near or at target stages in most STA cells when the nesting season began. Consequentially, there were less exposed bottom sediments within the interior of most STA cells. This decreased the available nesting habitat during the onset of the 2010 nesting season. Regional rainfall was sporadic as the nesting season progressed, and the District was able to manage water levels to minimize flooding in cells where nests were present.

Modified Operational Procedures and Levee and Canal Maintenance

Close coordination among agency scientists, water operators, field stations, and USFWS biologists was maintained throughout the 2010 nesting season. Operational and mechanical procedures related to water flow and levee and canal maintenance were implemented and adjusted accordingly to reduce potential impacts to ground-nesting birds within the STAs. Flow was prioritized in areas that did not have nests. Signs were installed to provide awareness to staff and the public using the STA, and bean-bag markers were used to make nests visible that could potentially be impacted by vehicles. Additionally, mowing and grading schedules at affected areas, as part of levee and canal maintenance, were adjusted to occur outside of the black-necked stilt nesting season. While the schedules were modified based on stilt nesting, the timeframe also accounts for other protected species such as the killdeer (*Charadruis vociferous*), which has similar nesting and gestation periods to those of the stilt. It should also be noted that one common nighthawk (*Chordeiles minor*) was observed nesting on the STA-5 levee in May 2010, which is the month that this species typically begins nesting. An overview of the modifications to operations and maintenance within the STAs is summarized in **Table 5-10**.

Table 5-10. Modified operational and levee and canal maintenance activities implemented during the 2010 black-necked stilt (*Himantopus mexicanus*) breeding season.

STA	Type of Action	Date Implemented	Impact Reduction for Ground Nesters Description of Action
All	Operational	Throughout breeding season	Utilized flow-ways to avoid and/or minimize nest impacts in accordance with the Avian Protection Plan for Black-necked Stilts and Burrowing Owls Nesting in the Everglades Agricultural Area Stormwater Treatment Areas (Pandion Systems, Inc., 2008).
All	Maintenance	Throughout breeding season	Modified mowing and grading schedule to reduce impacts to ground nesters and young on levee roads and embankments.
Operational Changes to Individual STAs			
1W	Operational	May 15, 2010–June 18, 2010	Closed levee roads to vehicular traffic between Cells 2A and 2B and also between Cells 4 and 2A due to a high number of stilt nests.

Everglade Snail Kite

Everglade snail kites were first observed over STAs 5 and STA-3/4 in late March 2010. On April 12, 2010, the District was informed by the USFWS that seven snail kite nests had been discovered at STA-5 by the University of Florida's survey crew, which was contracted by the USACE to perform snail kite nesting surveys throughout Florida. The number of snail kite nests in STA-5 steadily increased from April to July. Notably, this is the first documented nesting by this federally and state-listed endangered avian species in any of the Everglades STAs. While kites were seen in STA-3/4, no nests were observed. Applying guidance given by USFWS biologists, the District adjusted operations of STA-5, Cells 1A and 2A (**Table 5-11**), to minimize potential impacts to the snail kites. During WY2010, snail kites continued to nest undisturbed in STA-5 through summer 2010.

According to unpublished data from Kitchens (personal communication), University of Florida (UF) surveys completed from April 12–July 8 revealed a total of 23 nests in STA-5, Cells 1A and 2A, over the course of the breeding season. As of the July 8 survey, three of the nests had successfully fledged juvenile snail kites (that were banded). Chicks were banded at an additional four nests, but no additional fledglings had been confirmed at the time of this report. Additionally, 11 nests had failed, while six other nests were still being tracked at the time of this report.

Based on UF surveys completed in late June, 50 individual snail kites were spotted in STA-5, including 22 non-breeding snail kites. It is assumed that there is adequate prey, particularly Florida applesnails (*Pomacea paludosa*), for foraging at this location, and therefore, it is expected that nesting may occur again in 2011 in STA-5 and possibly in STA-3/4.

Table 5-11. Modified operational maximum and minimum water stages within STA-5, Cells 1A and 2A, in order minimize impacts to nesting Everglade snail kites (*Rostrhamus sociabilis plumbeus*) during April 12—June 23, 2010.

	April 12, 2010		April 19, 2010		May 10, 2010		June 8, 2010		June 23, 2010	
Cell	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1A	NE	NE	14.0'	13.7*	14.0'	13.7*	15.5'	13.7'*	14.0'	13.7'*
2A	NE	NE	14.0'	13.7*	14.0'	13.7*	15.5'	13.7'*	15.0'	13.7'*

*Efforts were made to maintain minimum stages at 13.7 feet when water was available
NE – Not Established

Environmental Lift of STAs on South Florida Avifauna Study

From February 2008–June 2010, Florida Atlantic University (FAU), in conjunction with UF under contract with the District, conducted a study to determine whether STAs provide a quantifiable environmental lift to South Florida's avian community (Gawlik and Beck, 2010). To evaluate avian use of the STAs, field surveys were conducted each season in 2008 and 2009 at all six STAs, as well as in control areas in a natural marsh (WCA-3A) and the Everglades Agricultural Area (EAA). Survey methods consisted of double observer point counts from levees and airboats, and transects conducted via airboat. STA surveys included open water with SAV and intermittent dense cattail, and open water (MIX) locations.

Study results indicated that there were about four times more total species detected in the STAs than in the natural Everglades marsh and roughly one-fourth more total species in the STAs than in the EAA. A total of 104 avian species were detected in the STAs (**Table 5-12**), 26 in WCA-3A, and 83 in the EAA. Avian densities were similar in the STAs and EAA, but species richness was highest in the STAs during all seasons. There were high proportions of waterfowl, diving fish-eating birds, and secretive marsh birds (e.g., rails and bitterns) in the STAs. In contrast, the EAA had high proportions of perching birds, wading birds, raptors, and shorebirds, while the natural marsh was dominated by perching birds and secretive marsh birds.

The STAs had more than twice the densities observed in the EAA and about 35 times that observed in the natural marsh, as averaged for all seasons. The difference in densities, however, was highly dependent upon season. Bird density in the STAs was significantly higher during fall and winter than in the EAA, but about half that of the EAA in the summer months. Density was higher in the STAs than in WCA-3A all seasons. Seasonal differences reflect that the STAs are numerically dominated by wintering species whereas the EAA is dominated by migrating and resident species. The higher avian density and richness in the STAs compared to the other land types may reflect their combination of high primary production and habitat heterogeneity. The avian community in the STAs is dominated by herbivorous birds, suggesting that the high productivity is increasing food resources at lower trophic levels. Habitat heterogeneity increases the diversity of food resources in an area and provides resources for birds at multiple life stages. The EAA, like the STAs, is highly productive but lacks habitat diversity at the local scale. While WCA-3A is probably more heterogeneous than both the STAs and EAA, its relatively low productivity did not support large populations of birds.

Avian density and richness within the STAs differed little, even though rainfall patterns were very different. This suggests that even over a large range of hydrologic conditions, the STAs still support significantly more species and density of birds than other regional land types. Density was highest in the shallower waters of STA-5 and STA-2, respectively, and species richness was highest in STA-5. These findings are consistent with similar studies sponsored by the USEPA in Florida, Mississippi, and the arid west by McAllister (1992; 1993a; 1993b), which have found high avian densities and richness in constructed wetlands when compared to natural marshes. The high productivity and ecological stability of the STAs seem to attract birds for various purposes including high quality foraging, breeding, migration stopover, and wintering habitat.

Table 5-12. Summary of results from the South Florida avifauna study (from Gawlik and Beck, 2010).

Land Type	Total Species	Overall Density	Most Common Species
STA	104	34.6 birds/hectare	American coot (*Fulica americana*) and common moorhen (*Gallinula chloropus*)
Everglades Agricultural Area	83	13.6 birds/hectare	Red-winged blackbirds (*Agelaius* spp.), tree swallows (*Tachycineta* spp.), and killdeer (*Charadrius vociferous*)
Water Conservation Area 3A	26	0.9 birds/hectare	Red-winged blackbirds, tree swallows, and boat-tailed grackles (*Quiscalus major*)

STA PERFORMANCE AND CONDITION ASSESSMENT

The District continues to maintain and further optimize STA performance. Routine STA operations involve extensive coordinated efforts by multidisciplinary teams and using innovative technologies and integrative diagnostic tools. In weekly operational meetings, recommendations are made on water deliveries and structure operations in the STAs with near real-time data. Field assessments monitor hydrologic conditions, water quality in cell inflows and outflows, soil conditions, and vegetation. Site managers coordinate with various stakeholders to facilitate resolution of day-to-day STA management and operational issues, and maintain an on-site presence to ensure that program objectives are met. Changing environmental and site conditions, maintenance concerns, or infrastructure problems are regularly reported to appropriate staff. Detailed coordination continues during build-out of water quality enhancement components. Monthly data from vegetation management surveys are used to identify priorities and strategies to meet overall programmatic goals. Daily stormwater operations are monitored to ensure that they are consistent with established STA operation plans. Guidance on water deliveries to individual treatment flow-ways is based on collected data (e.g., cumulative average annual inflow volumes and TP loads, treatment cell outflow TP concentrations, or the status of vegetation establishment within the treatment cells). Vegetation management is also organized through multidisciplinary teams, including discussions on operations related to performance and sustainability issues.

This section reports on performance assessment, STA operation and management, STA condition assessment, and applied research studies. Longer-term STA performance is included along with a summary of the impacts of extreme weather conditions (drought/storm) on the STAs. Results of and operating conditions at the STA-3/4 Periphyton-based Stormwater Treatment Area (PSTA) Implementation Project are also included.

INDIVIDUAL TREATMENT CELLS AND FLOW-WAYS PERFORMANCE ANALYSIS

As mandated by the Long-Term Plan, the individual annual (water year) and POR water and TP mass balance budgets (budgets) for individual STA treatment cells and flow-ways are summarized in Appendix 5-6 of this volume. Budgets were developed using available data and may reflect revisions to data reported in previous SFERs. Similar to previous years, water budgets in WY2010 were dominated by surface flow (Appendix 5-6, Tables 1A-F). Groundwater and precipitation in the STAs generally made up less than 15 percent of the total inflow water volume, while surface outflow comprised at least 80 percent of total outflow. Exceptions occurred in some cells of STA-5 and STA-6, where seepage losses and evapotranspiration (ET) made up a larger proportion of total outflow. The head- and tail-water stage recorders at the G-248 levee separating Cells 1A and 1B in STA-1W were recalibrated to a new reference elevation in June 2010 because the previous reference elevation was found to be in error. These changes affect flow computed for this structure and reduce the large water budget errors for these cells. Additional discussion of cell and flow-way water budgets is presented in the 2008 and 2009 SFERs – Volume I, Chapter 5.

As in prior years, TP budgets in WY2010 also were dominated by surface water inflow and outflow TP (Appendix 5-6, Tables 2A-F). Previous SFERs have documented an inverse relationship between cell and flow-way treatment performance and inflow TP measured as FWM concentration, load, or areal loading, i.e., increased inflow TP resulted in higher outflow TP and corresponding reduced treatment (2008 SFER – Volume I, Chapter 5, Figure 5-53; 2009 SFER – Volume I, Chapter 5, Figure 5-11; 2010 SFER – Volume I, Chapter 5, Figure 5-29). In general, STA cell and flow-way treatment performance has been consistent with how other treatment wetlands respond to increasing inflow TP (e.g., Kadlec, 2006; Richardson and Qian, 1999).

Appendix 5-6, Table 3, of this volume presents annual and POR hydraulic loading rates, areal TP loading rates, inflow and outflow TP FWM concentrations and TP removal coefficient (k) values. Previous SFERs provide additional cell and flow-way data analyses. These reports characterize water load/loading relationships (2008 SFER – Volume I, Chapter 5, Figure 5-52) and concentration gradients for other constituents (phosphorus and nitrogen species, chloride, calcium, and alkalinity) (2006 SFER – Volume I, Chapter 4, Figures 4-47 to 4-50), present mass balance budgets for these constituents (see also 2007 SFER – Volume I, Appendix 5-15), and evaluate wetland treatment performance relative to the TP removal coefficient (2009 SFER – Volume I, Chapter 5, Figure 5-11) and different vegetation community types (2010 SFER – Volume I, Chapter 5, Figure 5-29).

INTERNAL PHOSPHORUS SAMPLING in STA-1E AND STA-2

Quantifying phosphorus uptake by the treatment cells helps to better understand large-scale STA performance — knowledge which can then be used to identify areas in need of improved vegetative communities or infrastructure modifications. In WY2010, stations along internal transects in two STAs, STA-1E and STA-2, were sampled and analyzed for phosphorus. Flow data are also presented as the results of internal transect phosphorus composition depends largely on the presence or absence of flow in the cell.

STA-1E

Internal sampling was conducted in July 2009 in the SAV dominated treatment cells (**Figures 5-1** and **5-2**), following the initial decline of hydrilla in June 2009, in order to characterize the spatial pattern of TP concentration along the flow path of each cell. Water samples were collected from the inflow and outflow locations in the upstream EAV cells, then along internal transects established within the SAV dominated treatment cells Cells 4N and 4S, and Cell 6 (**Figure 5-10**). Samples were analyzed for TP, total soluble phosphorus (TSP), and soluble reactive phosphorus (SRP). Dissolved organic phosphorus (DOP) and particulate phosphorus (PP) were calculated using the following equations: PP = TP – TSP; DOP = TSP – SRP.

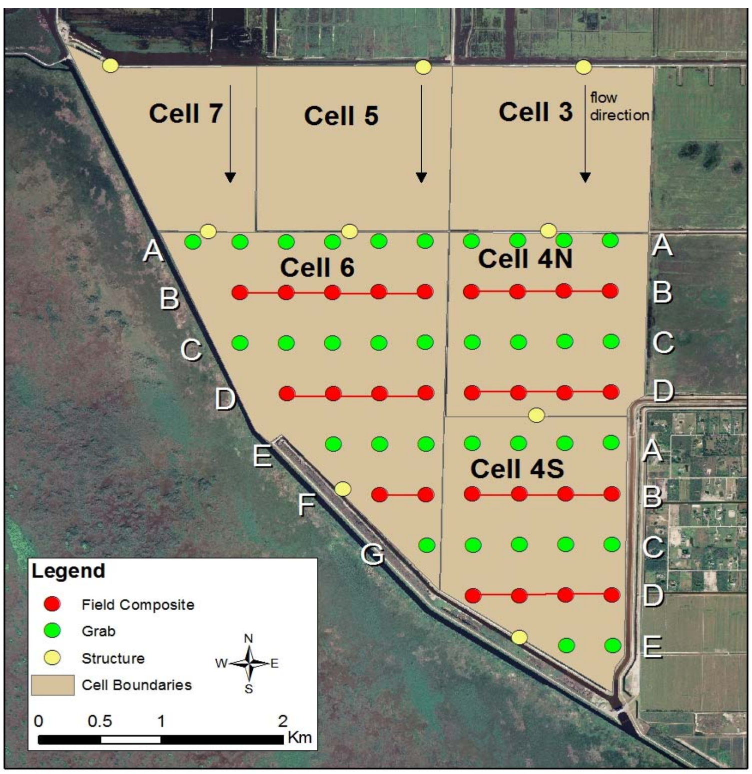


Figure 5-10. Sampling locations for internal water quality transects along the Western and Central flow-ways of STA-1E (July 2009). Transects are identified alphabetically along the north-to-south flow path. Grab samples (green) were analyzed individually, while the individual samples collected along the transects (red) were composited into a single sample for that transect in the field prior to analyses.

Western Flow-way (Cells 5, 6 and 7)

During sample collection, the Western Flow-way of STA-1E was receiving flow at a rate of 735 ac-ft/day, and the average daily inflow to the flow-way (Cells 5 and 7) for the two-week period prior to sample collection was 109 ac-ft/day (**Figure 5-11**). As shown in **Figure 5-12**, although there was no TP removal occurring in Cell 7, there was a change in phosphorus speciation from the inflow to outflow levee, where SRP decreased from 100 to 68 ppb and PP increased from 44 to 76 ppb, respectively. Details regarding the stress response of cattail to deepwater conditions in Cell 7 are presented in the *Impacts of Long-term Deepwater Conditions on Cattail Communities in Cell 7, STA-1E* section of this chapter. In Cell 5, where there was approximately 50 percent treatment, the decrease in TP was primarily due to a reduction of SRP concentrations from 206 (inflow) to 73 ppb (outflow). The mean TP concentration of the initial inflow region transect within Cell 6 increased from 169 and 185 ppb at the outflow of Cells 5 and 7, respectively, to 223 ppb. Along the length of the cell, the TP concentrations fluctuated between 192 and 100 ppb, but the outflow concentration was 227 ppb. While the TP fluctuation within this STA was primarily due to variations in PP concentrations, the increase in TP at the outflow was a result of marked increases in all phosphorus species (162, 80, and 124 percent increases for SRP, DOP, and PP, respectively). This dramatic increase in phosphorus species was clearly a consequence of phosphorus release from decomposing mats of hydrilla biomass that had accumulated at the outflow region of the wetland earlier in the summer.

Central Flow-way (Cells 3, 4N and 4S)

During sample collection, there was very little flow in the Central Flow-way, and the prior two-week daily inflow averaged 108 ac-ft/day (**Figure 5-13**). Monthly outflow flow volumes from May 2009 through April 2010 are shown in **Figure 5-44**. As of early July 2009, the water column TP concentrations at the Cell 3 inflow and outflow were 495 ppb and 1,320 ppb, respectively (**Figure 5-14**). This increase of TP in Cell 3 was primarily due to an increase in SRP concentrations related to the decomposing litter that had accumulated around the outflow structures. TP concentrations gradually declined to 36 ppb at the levee that separates Cells 4N and 4S. Within Cell 4N, SRP concentrations were reduced to 17 ppb, whereas PP concentrations increased from 80 to 129 ppb. Within Cell 4S, TP concentrations fluctuated between 16 and 65 ppb, and exited the cell at 32 ppb. SRP concentrations remained at 3 ppb throughout Cell 4S, while PP concentrations fluctuated between 9 and 21 ppb and exited the cell at 24 ppb. While the decline in Cell 6 vegetation impacted the performance of the Western Flow-way, the standing crop of vegetation in the Central Flow-way has been sufficient to continue to provide effective phosphorus removal. Toward late WY2010, activities were under way to rehabilitate the Western Flow-way through various bio-enhancement efforts, which include allowing EAV to establish in some areas, encouraging SAV reestablishment, and planting bulrush (see the *Vegetation Management Activities* section of this chapter).

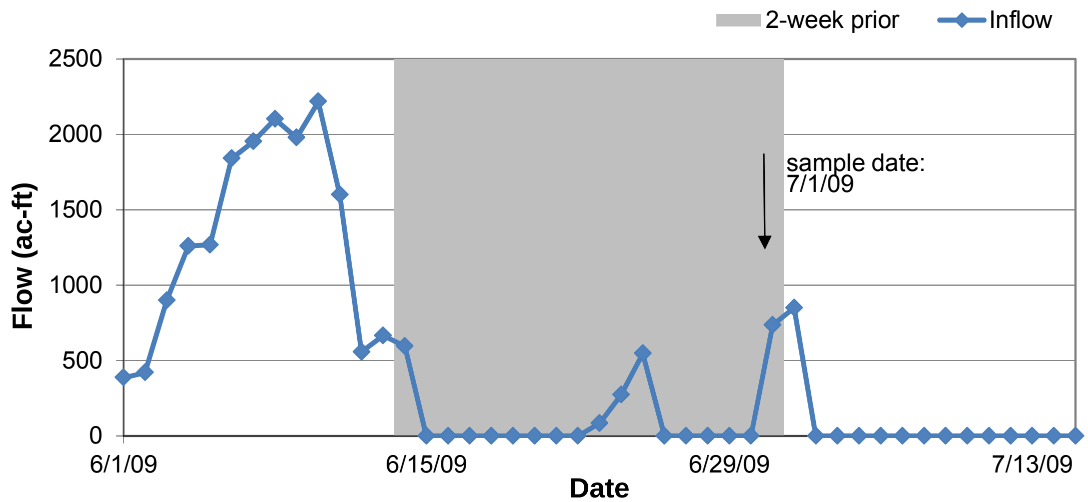


Figure 5-11. Water flow volumes into the Western Flow-way of STA-1E (June 1–July 15, 2009). The internal sampling date within the flow-way is shown with an arrow, and the two-week period prior to the event is highlighted in gray.

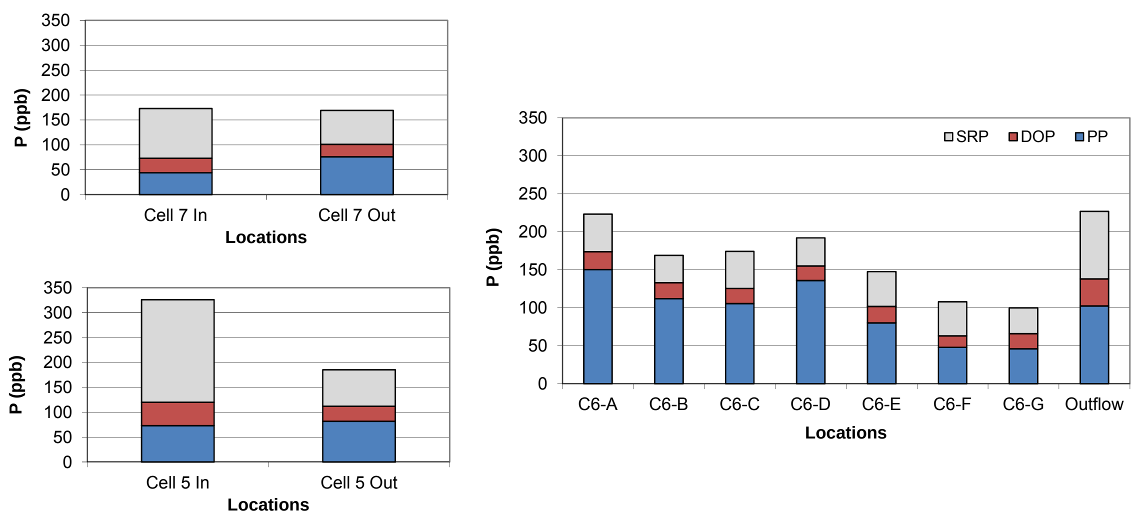


Figure 5-12. Phosphorus concentration profiles along the inflow–outflow gradient for the Western Flow-way of STA-1E on July 1, 2009. The inflow and outflow water quality was sampled from the upstream EAV dominated treatment cells (Cell 5 and Cell 7) and internal transects were sampled from the SAV dominated Cell 6. The water quality survey was conducted one month following a large-scale decline in hydrilla (*Hydrilla verticillata*) communities that was observed in May 2009 shortly after heavy rains. Prior to the May rain event, there were only minimal inflows to the flow-way from October 2008–May 2009.

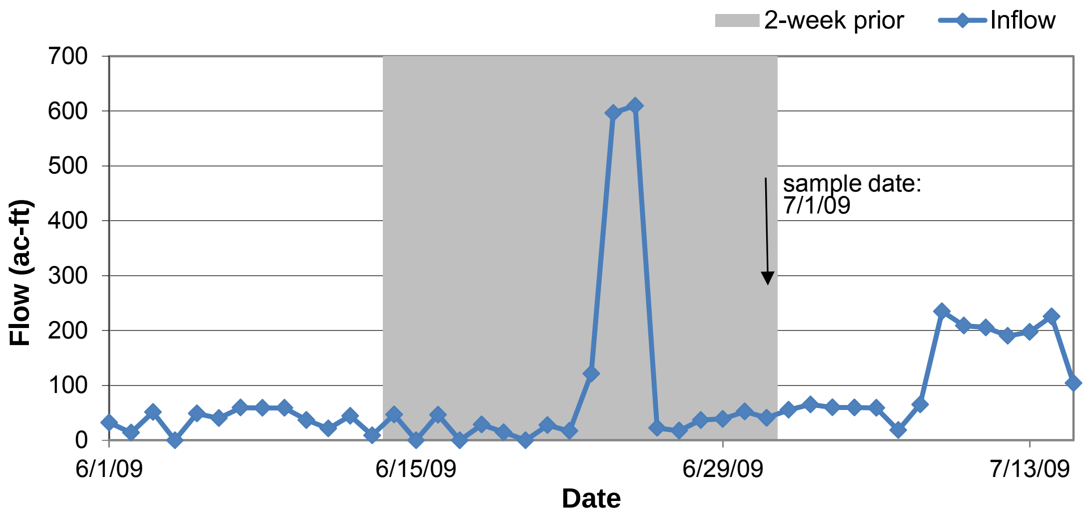


Figure 5-13. Water flow volumes into the Central Flow-way of STA-1E (June 1–July 15, 2009). The internal sampling date within the flow-way is shown with an arrow, and the two-week period prior to the event is highlighted in gray.

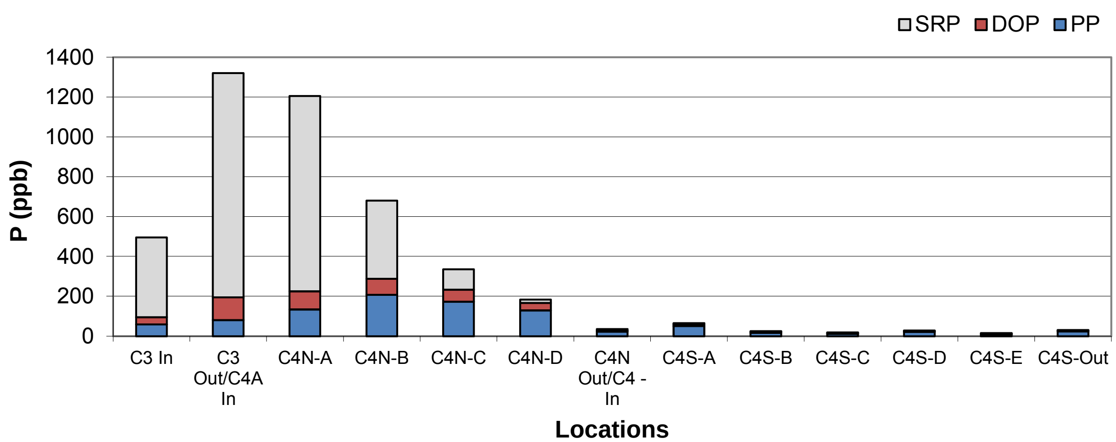


Figure 5-14. Phosphorus concentration profiles along the inflow–outflow gradient for the Central Flow-way of STA-1E (July 1, 2009). The nomenclature for the stations begin with the treatment cell name followed by transect letter (see **Figure 5-10**). There were no inflows to this flow-way for about six months prior to the sampling event. Water levels were below the average ground elevations in Cell 3 from March 2009 to June 2009 and below average ground elevation in Cell 4N in May 2009.

STA-2

Internal water quality measurements within Cell 3 have been performed since 2003, and monitoring in Cells 1 and 2 was initiated in 2007. Internal characterization of Cell 4 water column gradients began in 2008. Findings to date demonstrate that these internal profiles are useful for identifying regions of poor performance, and they also help identify the potential for selected flow-ways to achieve the required low outflow concentrations.

Cell 2

During WY2010, two internal sampling events were performed in STA-2, Cell 2, after a 7.5-month period of no inflows, resulting in dried-out conditions in portions of the cell. The first sampling was performed in May 2009, nine days after rehydration of the cell. The second was performed in August 2009, after a period of flow-through conditions. As shown in **Figure 5-15**, on May 27, 2009, water quality samples were collected along established internal transects in STA-2, Cell 2, using both grab and spatial composite field collection methods. During sampling, the mean daily flow was 1,574 and 1,496 ac-ft/day at the inflow and outflow, respectively (**Figure 5-16**). Respective flows for the prior two weeks averaged 1,098 and 734 ac-ft/day at the inflow and outflow, respectively.

As shown in **Figure 5-17**, data collected along each transect were averaged to produce phosphorus species concentration profiles. The TP concentration at the location adjacent to the inflow culverts was 120 ppb. TP concentrations increased relative to the distance from the inflow at transects A–C, then gradually declined through transect H to 103 ppb. After a sharp concentration decline at transect I (52 ppb), TP concentrations again increased to 86 ppb at the cell outflow. The increase in TP concentrations at transects A–C can primarily be attributed to an increase in SRP from 64 ppb at the inflow to 101 ppb at transect C. This region contains the highest soil elevations in the wetland, and the high water column phosphorus concentrations are likely due to sediment release of phosphorus following dry-down and rehydration (see the *STA Topographic Surveys* section of this chapter for additional details). SRP concentrations sharply declined to 60 ppb at transect D, and then gradually declined further through the remainder of the wetland. Compared to the soluble species, PP concentrations remained relatively low throughout.

On August 20, 2009, water quality samples were collected along the same internal transects (**Figure 5-15**) and analyzed for TP, TSP, and SRP. During sampling, the mean daily flows were 248 and 420 ac-ft/day at the inflow and outflow, respectively. Flows for the two weeks prior averaged 596 and 517 ac-ft/day at the inflow and outflow, respectively (**Figure 5-18**). During this two-week period, the inflow peaked at 2,009 ac-ft/day on August 12, 2009.

Data collected along each transect were averaged to produce phosphorus species concentration gradient profiles for the cell (**Figure 5-19**). The TP concentration adjacent to the inflow culverts was 111 ppb. TP concentrations decreased by 43 percent relative to the inflow at transect A, and continued to gradually decline through transect G to 25 ppb. Through the remaining area, TP concentrations fluctuated between 23 and 25 ppb and exited the cell at 25 ppb (**Figure 5-19**). SRP concentrations entered the cell at 52 ppb and declined along the wetland gradient through transect F, where it reached the laboratory detection limit of 2 ppb. SRP concentrations then remained at that level throughout the wetland. DOP concentrations gradually declined from 89 to 12 ppb at transect D. The concentrations then fluctuated between 11 and 12 ppb through the remainder of the cell and exited at 11 ppb. PP concentrations entered the area at 23 ppb and then ranged from 20 to 25 ppb through transect E, after which the concentrations ranged from 12 to 15 ppb and exited the cell at 12 ppb. This profile is typical of a well-performing STA cell, with a marked reduction in SRP in the first half of the cell, and a more gradual depletion of PP and DOP with distance from the inflow. This profile differs markedly from the one observed during May, soon after cell rehydration (**Figures 5-17** and **5-19**).

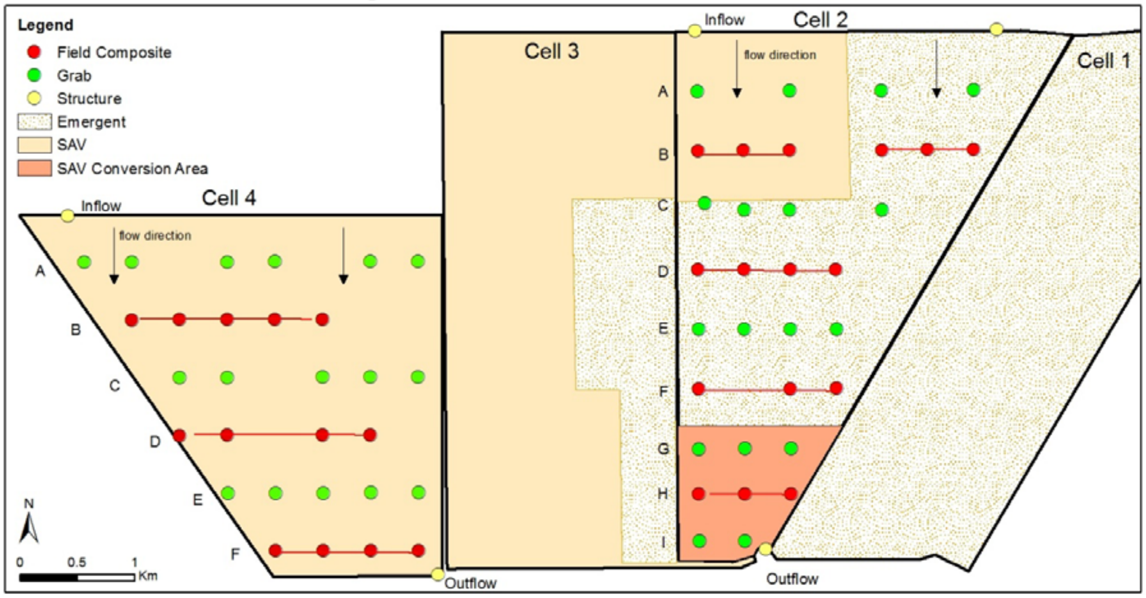


Figure 5-15. Location of internal water quality sampling stations in STA-2, Cell 2 and Cell 4, during 2009. Transects are identified alphabetically along the north-to-south flow path. Grab samples (green) were analyzed individually, while samples collected along the transects (red) were composited in the field prior to analyses.

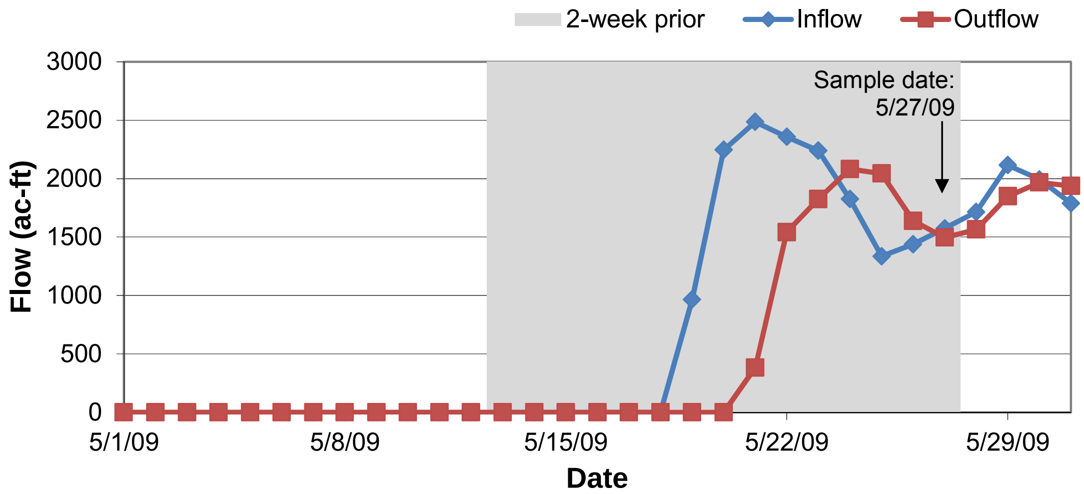


Figure 5-16. Water inflows and outflows of STA-2, Cell 2 (May 2009). The internal sampling date within the flow-way is shown with an arrow and the shaded area represents the two-week period prior to the sampling event. The sampling event occurred nine days after rehydration following a 7.5-month dry period where there were zero inflows to the treatment cell.

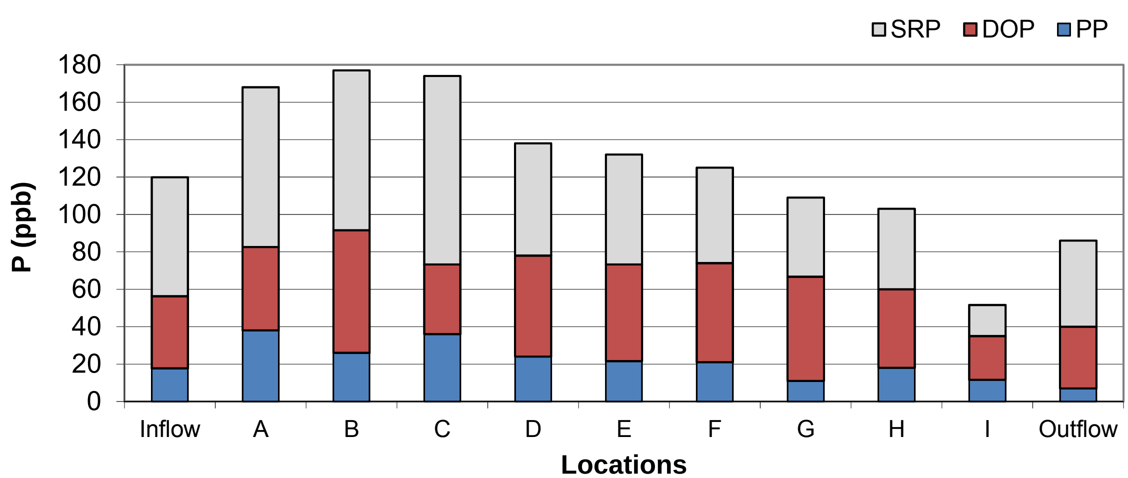


Figure 5-17. Phosphorus concentration profiles along the inflow–outflow gradient for STA-2, Cell 2, on May 27, 2009. See **Figure 5-15** for station locations. This sampling event occurred nine days after rehydration following a 7.5-month dry period where there were zero inflows to the treatment cell.

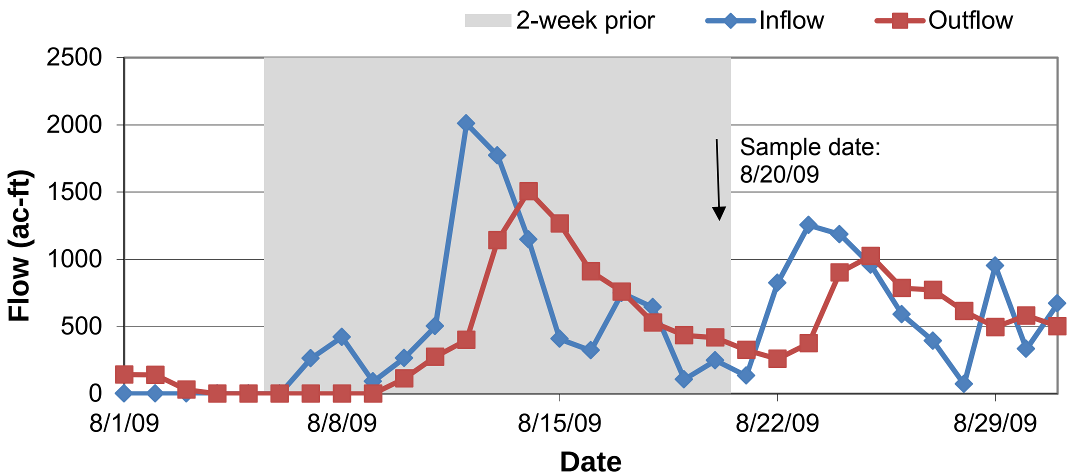


Figure 5-18. Water inflows and outflows of STA-2, Cell 2 (August 20, 2009). The internal sampling date within the flow-way is shown with an arrow and the shaded area represents the two-week period prior to the sampling event.

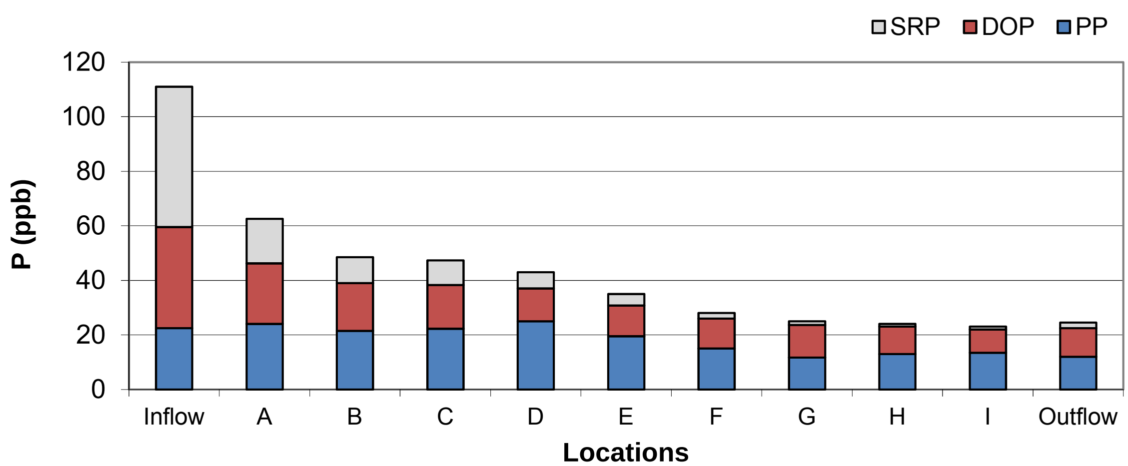


Figure 5-19. Phosphorus concentration profiles along the inflow–outflow gradient for STA-2, Cell 2, on August 20, 2009. **Figure 5-15** shows the transect locations.

Cell 4

Internal sampling was performed in December 2009 at the beginning of a flow event that followed a prolonged period with no discharge (**Figure 5-20**). In the 30 days preceding the water quality sampling event, there were sporadic inflows into Cell 4 and only a small amount of inflow during the internal transect sampling event. There was zero outflow from the treatment cell prior to and during the sampling event. Unlike Cell 2, which is dominated by EAV and therefore has been allowed to periodically dry down, Cell 4 is a SAV-dominated system and is not allowed to dry out. As shown in **Figure 5-21**, inflow water TP concentrations were 76 ppb, and little TP removal was observed in the front end of the cell, with a gradual decline beginning at transect D. PP comprised 82 percent of the inflow TP and was the primary phosphorus species observed along the wetland flow path. DOP concentrations fluctuated between 8 and 17 ppb, and SRP concentrations were at or near the laboratory detection limit. TP concentrations exiting the cell were 36 ppb. PP in the inflow waters and along the flow path is likely due to the presence of phytoplankton, which can proliferate under stagnant and low-flow conditions. The highly variable internal profiles demonstrate the marked influence of vegetation health and antecedent flow (and stage) conditions on phosphorus removal effectiveness of the STAs.

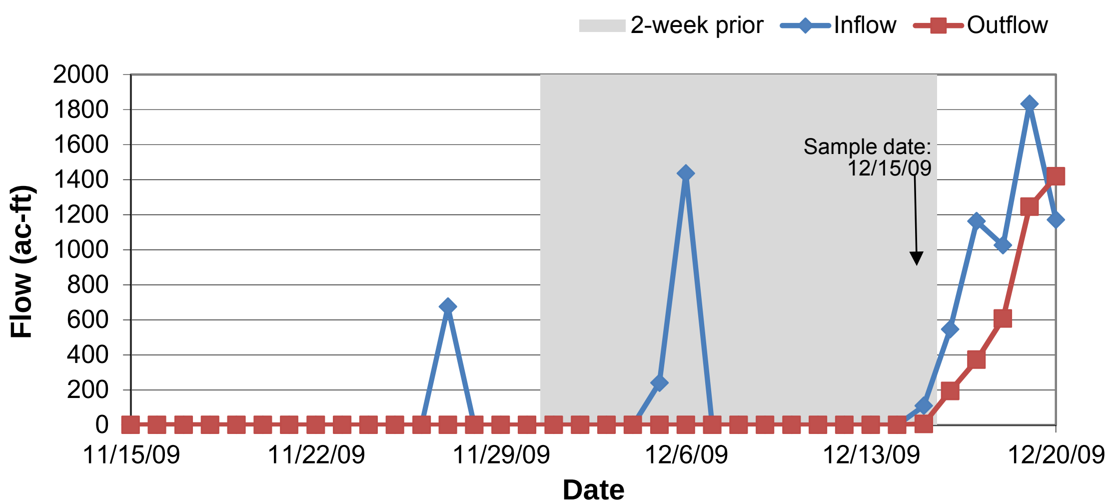


Figure 5-20. Water inflows and outflows of STA-2, Cell 4 (November–December 2009). The shaded area represents the two-week period prior to the sampling event. In the 30 days preceding the water quality sampling event, there were sporadic inflows into Cell 4 and only a small amount of inflow during the internal transect sampling event. There was zero outflow from the treatment cell prior to and during the sampling event.

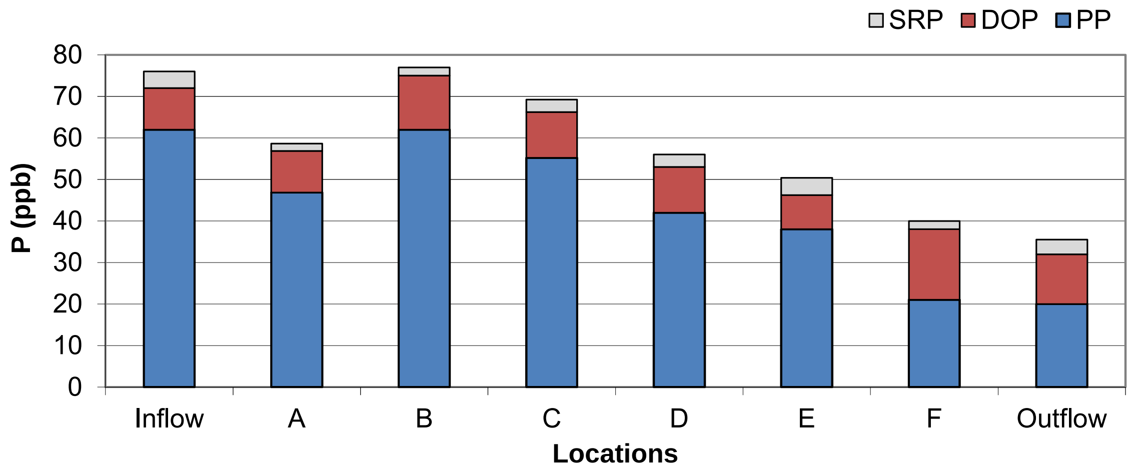


Figure 5-21. Phosphorus concentration profiles along the inflow–outflow gradient for STA-2, Cell 4, on December 15, 2009. **Figure 5-15** shows the transect locations.

STA-5, CELL 1A POST-REHABILITATION ASSESSMENT

To improve the conditions and performance of STA-5, a deep slough area located in the southern section of Cell 1A was filled with soil material from the non-effective treatment areas in Cells 1A and 3A (**Figure 5-22**). The goal of the rehabilitation was to increase TP removal efficiency by creating a more uniform ground elevation to reduce hydraulic short-circuiting and increase sheetflow within Cell 1A. Historically, during normal flow events, water preferentially flowed through the slough area and underutilized the northern portion of the cell. Under low-flow or no-flow events, higher areas in the northern part of the cell tended to dry out and the flux of phosphorus from reflooding these areas was likely contributing to poor cell performance. The rehabilitation activities began in December 2008, and by May 2009, a total of 407,240 cubic yards of material was filled into 80 to 100 acres of the slough area.

In June 2009, Cell 1A was reflooded at incremental depths. To encourage vegetation establishment, the filled slough area and other portions of the cell affected by construction were planted with cattail and sawgrass (*Cladium jamaicense*) seeds and other wetland plants [e.g., giant bulrush, pickerelweed (*Pontederia cordata*), and duck potato (*Sagittaria* spp.)]. The flow-way was under restricted operations where inflow and depth was limited until November 2009 and then completely offline until March 2010 to aid in plant reestablishment. In April 2010, endangered snail kites were found nesting in the Northern and Central flow-ways (see the *Avian Protection* section of this chapter). Since April 2010, these flow-ways have been under restricted operations and maintained at optimal water levels for nest protection. Water depths, vegetation establishment, and water quality were monitored throughout the water year.

Internal transect surveys showed good establishment of the planted and some naturally recruited plants (**Figure 5-23**). Water depths observed were variable, ranging from 0.2 ft (6 cm) to 2.6 ft (80 cm) depending on location, with more shallow depths in the filled slough area and deeper depths in the northwestern section of the cell. After the area was reflooded in June 2009 following rehabilitation construction, TP concentrations at the Cell 1A outflow location spiked to 1,325 ppb (**Figure 5-24**). By August 2009, a notable improvement in TP concentrations was observed and outflow concentrations declined to 60 ppb and were less than 50 ppb by late WY2010. This improvement in water quality may have been attributed to other factors in addition to the rehabilitation efforts. Giant bulrush was also planted in Cell 1B to fill in the gaps in the existing vegetation strips and an additional vegetation strip was created immediately upstream of the outflow structures to alleviate potential pathways for hydraulic short-circuiting and buffer the SAV community from wind and flow. About 500,000 bulrush stems were transplanted from Cell 1A to Cell 1B.

Further monitoring of internal transects along this flow-way will continue in WY2011. A topographic survey of the entire STA is also scheduled for WY2011. Aside from using the elevation data for setting stage targets, elevation data for Cell 1A will be used to evaluate water flow through the flow-way.

Figure 5-22. Top (looking west to east): arrows indicate deeper open-water slough area located in the southern section of STA-5, Cell 1A. Middle (looking east to west): portions of the slough area filled in to meet adjacent cell grade elevations by using material from the western section of the treatment cell. Bottom (looking east to west): 80 to 100 acres of the slough area filled in by completion of the WY2009 rehabilitation (photos by the SFWMD).


Figure 5-23. Rehabilitation construction to fill in a deeper slough area in the southwest section of STA-5, Cell 1A, was conducted in early 2009 (left); after the treatment cell was rehydrated for about six months, relocated wetland plants were healthy and growing (right) (photos by the SFWMD).

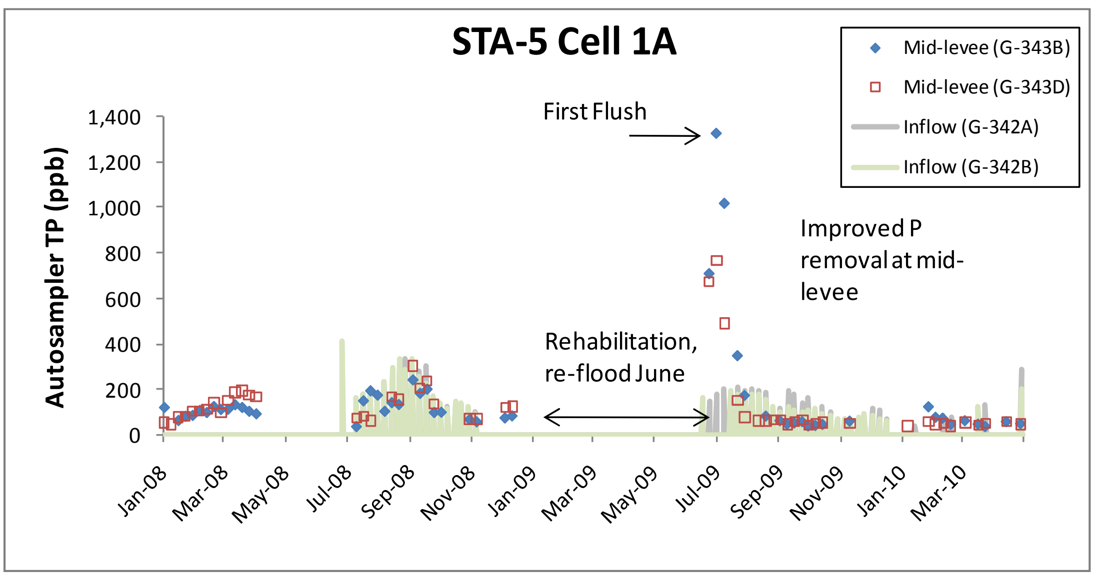


Figure 5-24. TP concentration data collected from auto-samplers in STA-5, Cell 1A, showing a decrease in TP at the mid-levees following rehabilitation activities.

STA-3/4 PERIPHYTON-BASED STA IMPLEMENTATION PROJECT

The Periphyton-Based Stormwater Treatment Area (PSTA) Implementation Project in STA-3/4 is a monitoring project mandated by the Long-Term Plan. The project is being conducted to validate that the basic engineering approach can be used to expand the PSTA technology throughout STA-3/4 and characterize the PSTA Cell relative to the other cells within the project area and relative to the entire STA (e.g., document treatment performance, compare composition of the SAV communities, etc.). Information from this project will be used to design any future build-out of the PSTA in STA-3/4. The PSTA Implementation Project comprises a 400-acre portion of STA-3/4, Cell 2B, that was isolated by the construction of new levees to form an upstream 200-acre cell (Upper SAV Cell) and two adjacent downstream 100-acre (about 40 hectares) cells (Lower SAV and PSTA cells) (**Figure 5-25**). All cells have been managed to promote an SAV community and associated periphyton assemblage through repeated herbicide applications to suppress EAV establishment. The function of the Upper SAV Cell is to provide the SAV component of an EAV–SAV treatment train and deliver water with low TP concentrations to the Lower SAV and PSTA cells. Further information on the history, design considerations, layout, and operating plan of the PSTA Implementation Project is presented in the 2008–2010 SFERs – Volume I, Chapter 5. During WY2010, water quality was monitored at all seven water control structures of the PSTA Implementation Project (**Figure 5-25**). Summary statistics for water quality parameters monitored during WY2010 at all PSTA sampling stations are presented in Appendix 5-7. An overview of the PSTA operations and performance follows.

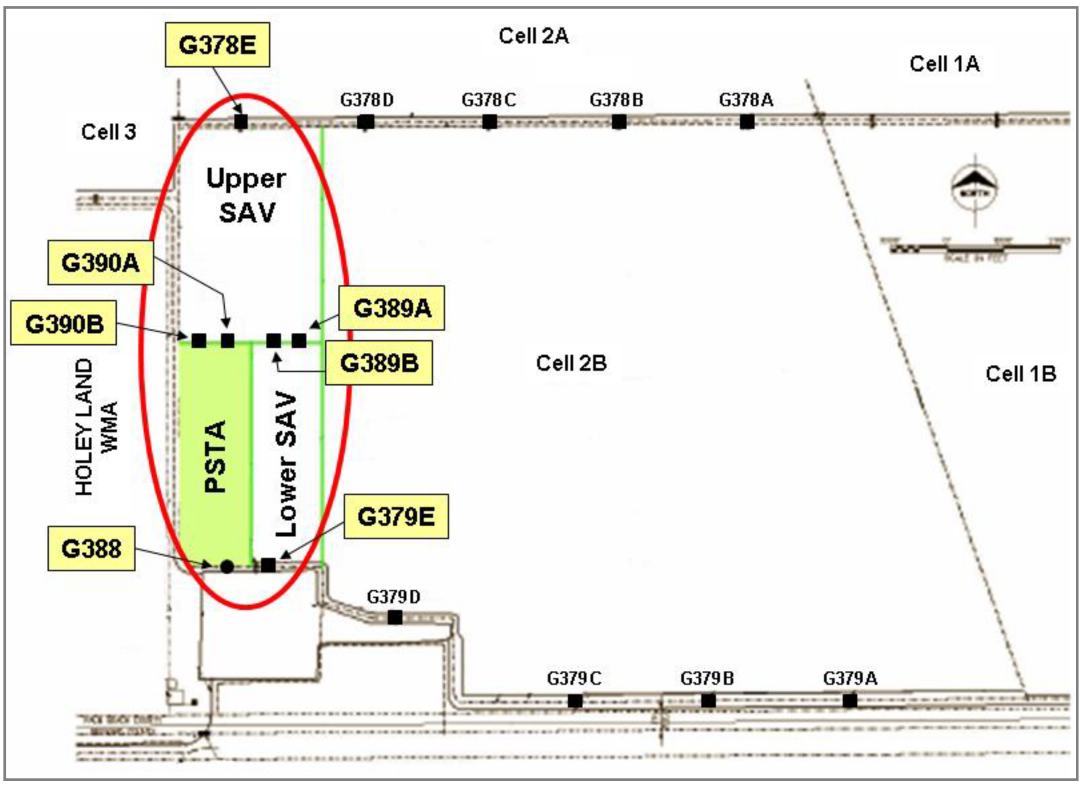


Figure 5-25. Location of Upper and Lower SAV cells, Periphyton-Based Stormwater Treatment Area (PSTA) Cell, and related water control structures. [Note: The adjacent Cell 2B and its water control structures are also shown. Holey Land WMA = Holey Land Wildlife Management Area.]

South Florida experienced drought to varying degrees during the first three water years that the PSTA Implementation Project operated, which reduced stormwater runoff into STA-3/4, especially during the annual dry seasons (winter and spring). The need to maintain minimum water levels in STA-3/4 necessitated that all outflow structures be closed for much of each dry season. These conservation efforts, in turn, curtailed operation of the project; all related culverts were closed and the G-388 pump station was shut down to help conserve water in the STA. Conversely, South Florida had a "wet" dry season in WY2010 (see Chapter 2 of this volume), which enabled the District to operate the PSTA for most of the water year. The presence of sufficient water (i.e., water levels at or above the target elevation that trigger the operation of the flow-ways) in STA-3/4 to operate the PSTA Cell defines the project's operational periods, which were from June–October (115 days) in WY2007, July–December (161 days) in WY2008, July–December (168 days) in WY2009, and May–April (341 days) in WY2010 (**Figure 5-26**).

The PSTA Cell inflow gates (G-390A and B) were not operable during WY2007 and, therefore, no surface water entered the cell. Water discharged from G-388 during that year was primarily groundwater seepage from the adjacent Upper and Lower SAV cells (**Figure 5-26**). The G-390A and B gates were operated in all subsequent years; G-388 discharge in these years included surface water inflow plus seepage. As shown in **Table 5-13**, annual PSTA Cell outflow during WY2008, WY2009, and WY2010 was 57, 54, and 36 percent greater than the corresponding inflow water volumes, respectively.

One of the original objectives of this project was to compare treatment performance; i.e., TP removal of the PSTA Cell versus the Lower SAV Cell. The primary difference in the construction of the PSTA versus the SAV cells is that the peat substrate in the PSTA Cell was removed down to caprock level, while the soil in the Upper and Lower SAV cells was not disturbed. Consequently, the floor elevation of the PSTA Cell is approximately 1.8 ft [55 centimeters (cm)] lower than the adjacent SAV cells. Peat was removed from the PSTA Cell because it provided a rooting medium for emergent plants and was a potential source of phosphorus that would flux back into the water column and reduce treatment efficiency. The two 100 cubic feet per second (cfs) [244,658 cubic meters per day (m^3/d)] pumps in the project's outflow structure (G-388) are activated by a float switch and maintain the PSTA Cell at a nominal average depth of approximately 1.9 ± 0.25 ft (58 ± 8 cm). Surface inflow to the PSTA Cell through its two inflow gates (G-390A and B) is managed to operate this cell at a nominal hydraulic retention time (HRT) of approximately five days. Unfortunately, this plan proved unworkable and the two lower cells have been operated very differently (i.e., comparison between the two lower cells is not technically appropriate). Therefore, the treatment performance of Cell 2B (also an SAV-dominated cell) from WY2008–WY2010 is included to compare with the PSTA Cell. Inflow to the PSTA Cell has been regulated to achieve a target hydraulic retention time (HRT) of about five days, while inflow to the Upper and Lower SAV cells has been dependent upon storm events that delivered water to STA-3/4. Over the past three water years, the PSTA Cell has had surface water hydraulic loading rates (HLRs) (2.5 to 2.8 inches per day or in/d) substantially lower than HLRs in the Lower SAV Cell (4.6 to 15.7 in/d), but higher than those for Cell 2B (0.4 to 1.6 in/d). Nominal HRTs calculated for the PSTA Cell (6.5 to 7.1 d) approximated the target HRT of five days (**Table 5-13**).

Based on the comparison of annual outflow TP FWM concentrations, the PSTA Cell exhibited consistently better treatment performance (8 to 12 ppb) than the Lower SAV Cell (13 to 32 ppb) and Cell 2B (13 to 25 ppb) over the last three water years (**Table 5-13**). It should be noted that the TP surface water areal mass loading to the PSTA Cell was markedly less than 1 gram of phosphorus per square meter per year (g $P/m^2/yr$) in each year (0.369 to 0.629 g $P/m^2/yr$). Monthly outflow TP FWM concentrations and loads were positively correlated with their corresponding inflow concentrations ($r^2 = 0.53$) and loads ($r^2 = 0.28$) (**Figure 5-27**, panels A and B). Annual outflow TP FWM concentrations were highly correlated with annual TP surface-water areal loading (r^2 = 0.95) (**Figure 5-27**, panel C); however, it is important to note that this high correlation coefficient value is based on limited data (i.e., only three data points). Similar relationships between outflow TP concentrations with inflow TP mass and TP areal mass loading have been documented in STA treatment cells (see 2008, 2009, and 2010 SFERs – Volume I, Chapter 5). The PSTA Implementation Project monitoring program is scheduled to continue in Fiscal Year 2011 (FY2011) (October 1, 2010–September 30, 2011).

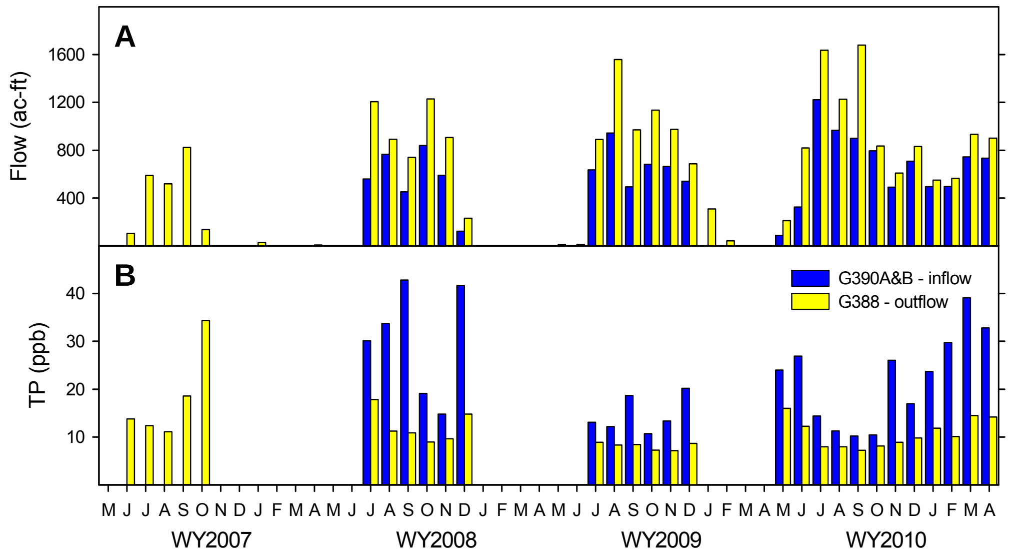


Figure 5-26. Inflow and outflow time-series for (A) monthly flow, and (B) monthly TP FWM concentrations in the STA-3/4 PSTA Cell. [Note: TP concentrations associated with small flows in the intervals between PSTA Cell operational periods are not shown.]

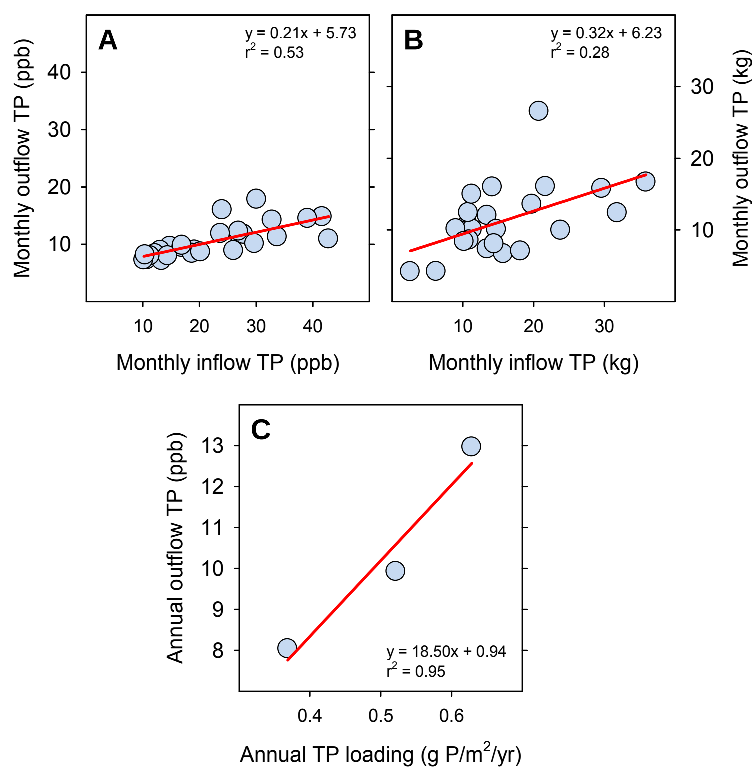


Figure 5-27. Treatment performance relationships in the STA-3/4 PSTA Cell for (A) monthly inflow versus outflow TP FWM concentrations, (B) monthly inflow versus outflow TP loads, and (C) annual TP areal loading from surface water versus annual outflow FWM TP concentration. Data were pooled over all PSTA Cell operational periods.

Table 5-13. Summary of hydraulic characteristics and treatment performance of the PSTA Cell, Lower SAV Cell, and STA-3/4, Cell 2B, during the PSTA Implementation Project operational periods in the past three water years.

	WY2008[1]			WY2009[2]			WY2010[3]		
	PSTA	Lower SAV[4]	Cell 2B[4]	PSTA	Lower SAV[4]	Cell 2B[4]	PSTA	Lower SAV[4]	Cell 2B[4]
Surface-water hydraulic loading (in/d)[5]	2.5	4.6	0.4	2.8	9.9	1.6	2.8	15.7	1.6
Nominal hydraulic retention time (d)	6.8	8.5	33.2	6.5	1.3	11.2	7.1	1.7	8.7
Total surface-water inflow (ac-ft)	3,322	6,691	14,767	3,958	15,002	55,270	7,957	47,986	114,285
Total surface-water outflow (ac-ft)	5,201	2,096	20,238	6,102	18,106	80,850	10,795	20,838	168,599
Surface inflow flow-weighted mean TP (ppb)[6]	28 (4)	26 (2)	27 (4)	14 (1)	32 (9)	15 (1)	20 (3)	22 (3)	24 (1)
Surface outflow flow-weighted mean TP (ppb)[6]	12 (2)	32 (6)	25 (3)	8 (<1)	13 (1)	13 (1)	10 (1)	14 (2)	17 (1)
Surface-water areal TP loading ($g/m^2/yr$)	0.629	1.101	0.112	0.369	2.956	0.221	0.522	3.204	0.357
TP removal coefficient – k (m/yr)[7]	24.2	-6.1	0.5	18.8	95.5	2.7	21.7	45.6	6.5

Notes: 1 inch (in) = 2.54 centimeters (cm); 1 acre-foot (ac-ft) ≈ 1,233 cubic meters (m^3); 1 part per billion (ppb) = 1 (microgram per liter (µg/L)[1] WY2008 operational period ran from July 5–December 12, 2007 = 161 days
[2] WY2009 operational period ran from July 9–December 23, 2008 = 168 days
[3] WY2010 operational period ran from May 25, 2009–April 30, 2010 = 341 days
[4] Calculations based only on positive flow through the water control structures
[5] Calculations based on number of days in operational period for each water year
[6] Values reported as flow-weighted mean (standard error)
[7] $k = \ln(TP_{in}/TP_{out}) \times [((Vol_{in}+Vol_{out})/2)/\text{Wetland Surface Area}] \times (365/d)$; calculation based only on surface flows

STA SOIL CHARACTERIZATION

Soils have a critical role in controlling long-term performance of the STAs. Phosphorus retention in soils occurs through adsorption, precipitation, and deposition of microbial and plant biomass. Characterization of soil conditions and understanding of P storage are important factors in understanding the P retention of each cell. Soil P content can influence a wetland system's ability to be a sink or source of phosphorus, depending on other factors such as pH, redox (oxidation-reduction reaction) potential, and biological activities (Reddy et al., 1999). In the STAs, particularly the ones that have been operational for a number of years, a significant amount of stored phosphorus is in labile pools, which can then determine the direction of phosphorus flux between soils and the overlying water column. Accelerated phosphorus flux into the overlying water column has been observed in STA cells after dryout (Pietro et al., 2008). Soil data for STA-1W and STA-5 were examined in detail recently in an effort to discern some of the various factors controlling the STAs' performance. In STA-1W, this investigation resulted in soil removal at two of the cells (Cell 4 and Cell 1B), and soil disking in another cell (Cell 2B) (Pietro et al., 2008). These management actions were necessary, not just to reduce phosphorus flux to the water column, but in the case of the SAV cells, the amount of unsettleable floc also became problematic for SAV establishment. Soil data are also examined in other areas when performance of an STA is declining.

An effort to comprehensively analyze historical soil and other data was initiated in 2008–2009 (Reddy et al., 2009), and highlights of findings related to soil P storage is included in this section. Further analysis of these data at smaller spatial scale, e.g., cell phosphorus storage pattern versus phosphorus uptake performance, is under way. In cases when P storage becomes a concern, options will be evaluated and adaptive management operations conducted, such as what was done in STA-1W.

The Long-Term Plan requires sampling of floc and a 0–10-cm layer of soil in each cell at 1,333' x 1,333' grids for each STA every three years. Samples are analyzed for bulk density (BD), organic matter content (estimated using ash-free dry weight, AFDW), total carbon (TC), total nitrogen (TN), and TP. Soil basic chemistry data from past years' sampling events have been reported in previous SFERs.

Historical Soil Data Analysis

A summary of estimated P storage in floc (flocculent, newly accreted material) and soil (consolidated substrate) in the different STAs is presented in **Tables 5-14** and **5-15**. Soil P storage (SPS) and floc phosphorus storage (FPS) were calculated using the following equation :

$$Phosphorus\ Storage\ (PS), \frac{g}{m^2} = \frac{TP\ \left(\frac{mg}{Kg}\right) x\ BD\ \left(\frac{g}{cc}\right) x\ depth\ (cm)}{100}$$

where PS is storage in floc or soil layer, TP is the concentration of total phosphorus in the substrate, BD is the bulk density, and depth is the depth of sampling for either the floc or soil layer.

An analysis of historical soil data indicates that although floc material contains generally higher concentrations of TP than the underlying consolidated material, P storage per unit area is generally higher in the underlying soil (**Figure 5-28**). Based on 2007 results, FPS was higher in STA-2 and STA-3/4 than either STA-1W or STA-5. It should be noted that the 2007 data for STA-1W reflects the post-rehabilitation soil condition. During rehabilitation, the Western and Eastern flow-ways in STA-1W underwent some earthwork (dewatering, removal of tussocks, removal of floc in Cell 4, disking of soil in Cell 2B, and leveling in some of the cells). Phosphorus storage in the upper 10-cm soil layer was generally higher in STA-5 than in other STAs, except STA-6, and lower in STAs 1E and 1W than in the other STAs. A more detailed discussion on P storage in STA-2, based on data collected up to 2009, is discussed later under the *Water Year 2010 Soil Monitoring* section of this chapter.

Table 5-14. Mass of total phosphorus (TP) storage in the floc layer* as grams per phosphorus per square meter (g P/m^2; mean ± standard deviation (SD) (Reddy et al., 2009).

Sampling Year	Phosphorus storage in the floc layer, g P/m^2					
	STA-1E	STA-1W	STA-2	STA-3/4	STA-5	STA-6
2003	NA	NA	NA	NA	3.3 ± 1.7	NA
2004	NA	9.6 ± 4.8	2.8 ± 2.1	NA	4.4 ± 2.3	3.2 ± 2.6
2007	NA	4.4 ± 1.6**	8.7 ± 4.9	8.5 ± 4.6	6.7 ± 3.1	NA

* NA means no data due to one or more of the following conditions:
–no sampling conducted that year for that STA
–little to no floc in new cells and cells that periodically dry-out; floc is either not present or insignificant
–the number of floc samples collected is too small to be included in the analysis
** Some of the cells in STA-1W were disturbed as soil material was removed or disked-in and areas were leveled during the 2006–2007 rehabilitation project

Table 5-15. Mass of total phosphorus (TP) storage in the upper 10-centimeter (cm) soil layer (g P/m^2; mean ± SD) (Reddy et al., 2009).

Sampling Year	Phosphorus storage in the soil layer, g P/m^2					
	STA-1E	STA-1W	STA-2	STA-3/4	STA-5	STA-6
1995	NA	7.7 ± 1.5	NA	NA	NA	NA
1996	NA	3.5 ± 1.1	NA	NA	NA	NA
2000	NA	6.9 ± 3.0	NA	NA	NA	NA
2001	NA	NA	12.7 ± 5.6	NA	15.2 ± 2.9	10.8 ± 2.4
2003	NA	NA	NA	NA	19.1 ± 9.6	--
2004	NA	5.8 ± 2.6	12.2 ± 8.2	NA	18.9 ± 8.0	23.3 ± 11.8
2005	13.2 ± 7.8	NA	NA	23.3 ± 8.5	NA	NA
2006	NA	11.3 ± 6.1	NA	NA	NA	NA
2007	10.1 ± 6.2	14.6 ± 5.9*	12.5 ± 6	16.13 ± 6.7	20.7 ± 13.7	NA
2008	NA	10.7 ± 4.7*	NA	NA	NA	NA

* NA means no data due to one or more of the following conditions:
–no sampling conducted that year for that STA
–little to no floc in new cells and cells that periodically dry-out; floc is either not present or insignificant
–the number of floc samples collected is too small to be included in the analysis

** Some of the cells in STA-1W were disturbed as soil material was removed or disked-in and areas were leveled during the 2006–2007 rehabilitation project

Table 5-16. Comparison of phosphorus removed from the water column and the mass of TP stored in the floc and top 10-cm soil layer, based on 2007 soil data for STAs 1E, 1W, 2, 3/4, and 5, and 2004 soil data for STA-6 (Reddy et al., 2009).

STA	Area (hectares)	Total P mass in floc and soil (mt)	TP removed from surface water* (mt)
STA-1E	1,629	165	24
STA-1W	2,700	527	339
STA-2	3,336	704	181
STA-3/4	6,698	1,603	222
STA-5	1,664	455	158
STA-6	352	93	25

* Period of record data for P removed from surface water was from WY2007 (Pietro et al., 2008).

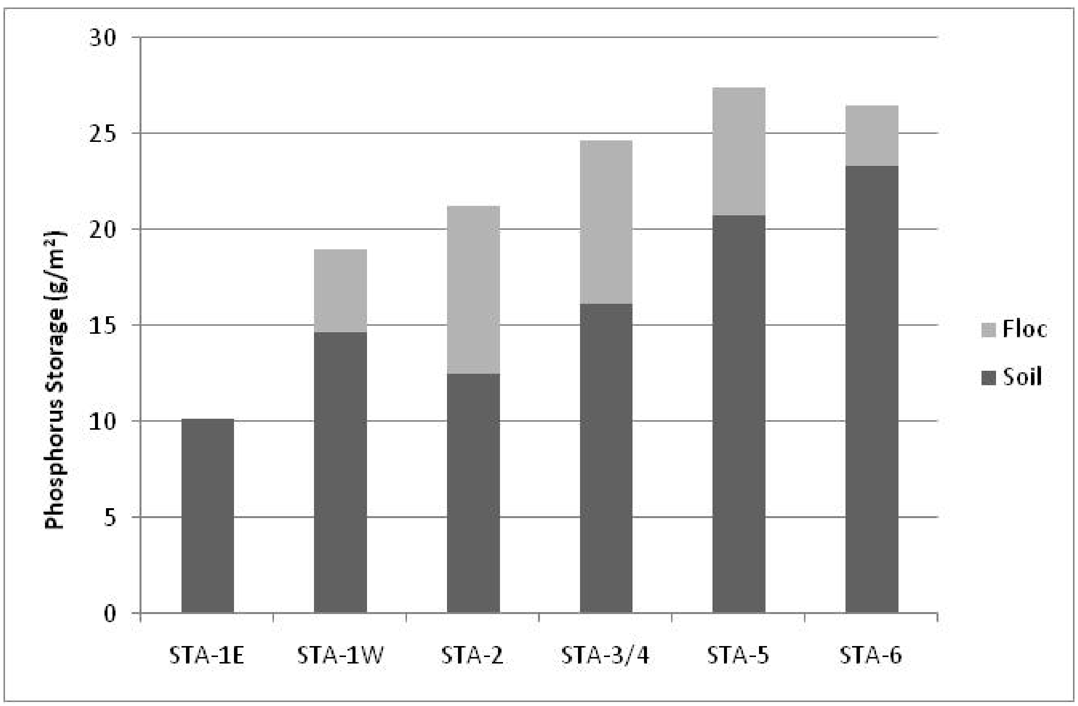


Figure 5-28. Phosphorus storage in the floc and upper 10-cm soil layer based on 2007 soil data (STA-1E, STA-1W, STA-2, STA-3/4, and STA-5) and 2004 (STA-6) data.

A comparison of the calculated SPS+FPS values with retained TP values based on inflow–outflow water TP loading results show a big discrepancy between the two values; with four-to-10 times greater values were estimated from calculated SPS+FPS than from retained TP results calculated from the difference between inflow and outflow water P loads (**Table 5-16**). Aside from inherent errors associated with sampling, measuring, and load calculations, a likely cause of this discrepancy could be due to P deposition from biomass on the floc and soil surfaces, as plants uptake phosphorus from subsurface soil layers (root zone) and go through a natural or accelerated mortality and decomposition process. Further studies and evaluation are needed to validate and quantify the contribution of "P mining" from the subsurface soil layers. **Figure 5-29** displays a very strong relationship ($r^2 = 0.96$) between STA size and TP storage in the floc and upper 10-cm layer based on soil chemistry data. This relationship is not demonstrated when simply comparing P mass data from inflows and outflows.

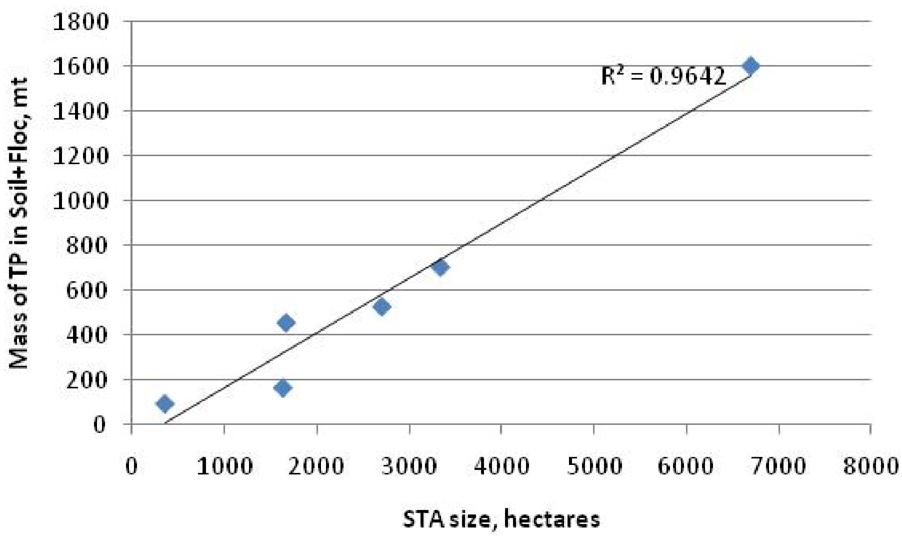


Figure 5-29. Relationship between STA size and the mass of TP stored in the floc and upper 10-cm soil layer. Each data point represents mean of all data from each STA based on 2007 (STA-1E, STA-1W, STA-2, STA-3/4, and STA-5) and 2004 (STA-6). [Note: 1 hectare = 2.4710 acres.]

Water Year 2010 Soil Monitoring

Soil cores were collected from STA-2 and STA-3/4 in August–November 2009 and February–May 2010, respectively, for routine chemistry analysis, i.e., floc depth, bulk density (BD), ash-free dry weight (AFDW), total phosphorus (TP), total carbon (TC), and total nitrogen (TN). Current sampling requirements in the Long-Term Plan specify collection of floc and 0-10 centimeter (cm) soil layer at 1,333' x 1,333' grid locations within each STA cell. Samples were sent to DB Environmental Laboratory (Rockledge, FL) and Florida International University Southeast Environmental Research Center's Freshwater Biogeochemistry Laboratory (Miami, Florida) for routine laboratory analysis. In addition to the routine chemical analysis of the required cores, additional cores were taken to evaluate actual temporal sediment and nutrient accretion at a finer scale and up to 30-cm soil depth. This additional collection was necessary because the current methodology of sectioning at 0–10 cm does not give an accurate representation of sediment and nutrient accretion since the start of STA operation. For these additional cores, sectioning was done at 2-cm intervals and in addition to routine chemistry, samples were analyzed for stable isotopes to determine the age and general source of nitrogen, carbon, and P. Based on the results obtained, the sampling methodology for any future soil sampling may be modified. Details on this set of analyses are planned to be reported in the 2012 SFER, along with soil results for STA-3/4. Results for STA-2 routine chemistry follow.

STA-2 Floc and Surface Soil Total Phosphorus

TP in floc was 1,172 ± 428, 1,436 ± 423, 827 ± 298, and 932 ± 285 milligrams per kilogram (mg/kg) in Cells 1 (EAV), 2 (EAV), 3 (SAV), and 4 (SAV), respectively (**Figures 5-30** and **5-31**). Cell 1 and Cell 2 floc TP concentrations were approximately 1.5 times higher than concentrations found in the 2007 sampling event. Cell 3 floc TP concentrations also increased, though at a much lower rate, for an approximate increase of less than 50 mg/kg compared to 2007. The average floc TP concentrations were approximately 1.5 times higher in EAV cells compared with the two SAV cells. The role of cattail vegetation in internal phosphorus cycling within the soil column (e.g., P mining from the root zone) needs to be investigated. The floc TP distribution within each cell was also very different between the EAV cells (floc TP about 1,500 mg/kg in the first half of the cell down to about 1,000 mg/kg closer to the outflow location) and SAV cells (floc TP about 1,000 mg/kg to about 700 mg/kg). The floc TP concentrations tended to decrease soon after the beginning of the flow path (transect A), concentrations remained within a narrow range of fluctuation towards the middle transects, and then declined again closer to the outflow locations (**Figure 5-31**). The underlying surface soil layer (0–10 cm) generally had lower TP values than floc material, with 450 ± 209 mg/kg in the EAV cells compared with 531 ± 313 mg/kg in the SAV cells. There was little to no change in TP concentration in the 0–10 cm soil layer between 2007 and 2009 sampling events.

STA-2 Floc and Soil Phosphorus Storage

There was a notable increase in floc phosphorus storage in EAV cells between 2003 and 2007, while the trend between 2007 and 2009 was reversed (**Figure 5-32**). The EAV cells in this STA experienced dryout during the recent drought periods, including WY2010. Dryout–rewet cycles of wetland soils have been shown to accelerate decomposition and flux of P into the water column (Reddy, 1983; Reddy and Rao, 1983; Pietro et al., 2008). Phosphorus storage in floc is consistently higher in Cell 2 [mean = 3.4–11.1 grams per square meter (g/m^2)] than Cell 1 (mean = 1.0–6.2 g/m^2) in 2003, 2007, and 2009. In Cell 3 (SAV cell), there was a gradual increase from 3.8 to 9.0 g/m^2 from 2003 to 2009. In 2009, FPS in Cell 3 (SAV cell) was approximately 2.5 times greater than either Cell 2 (EAV cell) or Cell 4 (newer SAV cell).

Based on 2003–2009 soil analyses, storage of P in the upper 10-cm soil layer is generally higher than in the floc layer. The upper 10-cm soil layer has approximately three and two times as much phosphorus storage than in floc in Cells 2 and 3, respectively. Soil P storage in SAV cells is also generally much higher than in EAV cells; Cell 3 SPS was 17.2 ± 18.4 g/m^2 compared to 7.4 ± 3.6 g/m^2 and 10.3 ± 4.1 g/m^2 in Cell 1 and Cell 2, respectively. This trend, which was not observed in other STAs in previous sampling events, may be because the EAV cells in STA-2 repeatedly dried out during the dry season, particularly during the drought period in the past three water years. Mineralization and flux of phosphorus, as well as increased P in cattails likely resulted in reduced P storage in the EAV cells. Further analysis of historical data is continuing to better understand the TP removal mechanism and differences in mechanism and response among STAs and between EAV and SAV cells.

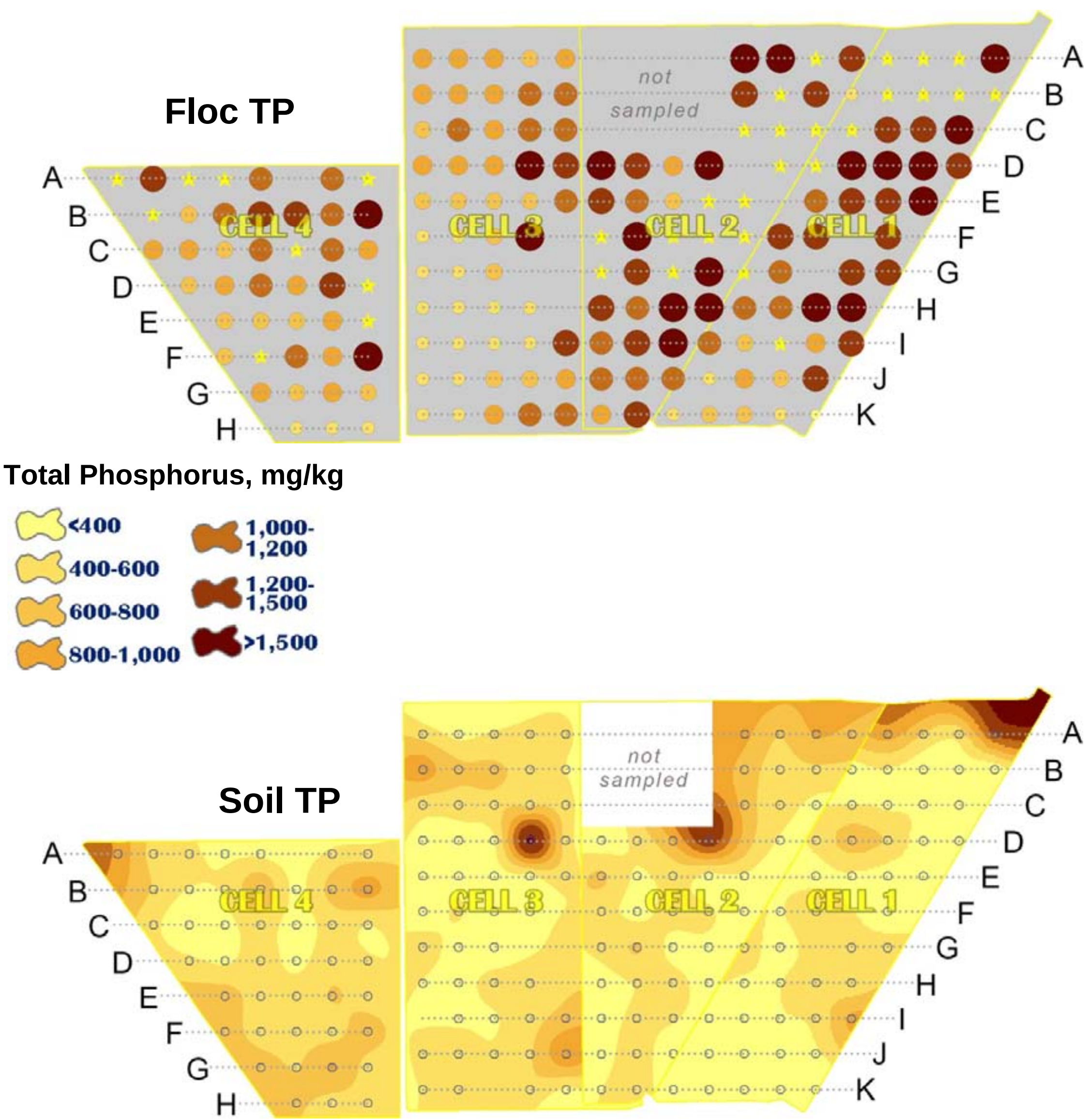


Figure 5-30. STA-2 TP in the floc and upper 10-cm soil layer based on results from the 2009 sampling event. Sampling locations are designated with dots along the transects.

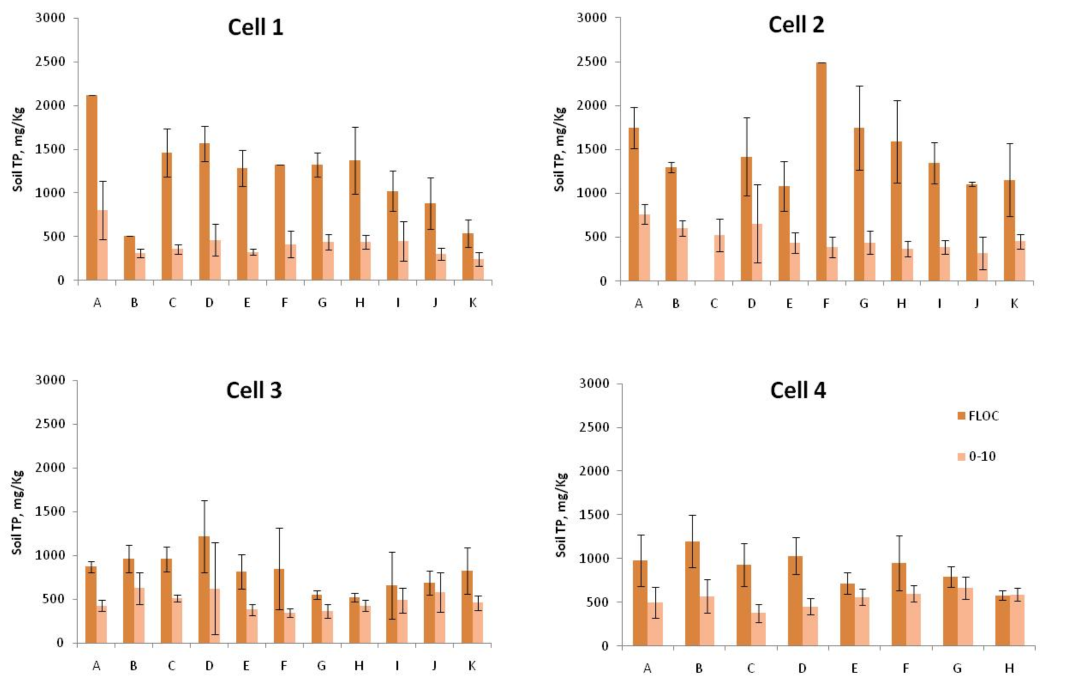


Figure 5-31. Total phosphorus concentration in STA-2, Cells 1-4, floc and upper 10-cm soil layer along the flow path in each cell in 2009. The letters on the x-axis designate the transects; the A transect is the closest to the inflow structure and the K transect is closest to the outflow structure. Each bar represents mean concentration ± SD from all stations along that transect.

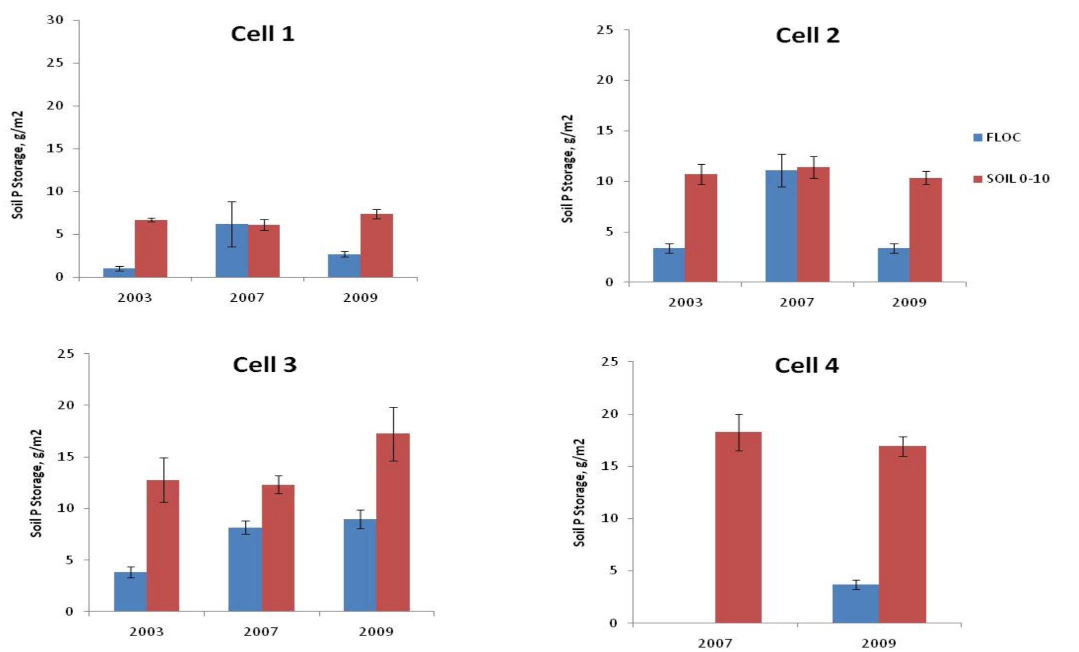


Figure 5-32. Mean temporal phosphorus storage in floc and upper 10-cm soil layer in STA-2 cells from 2003–2009. Error bars represent standard deviation (SD). For Cell 4, floc samples were not collected in 2007 because that was the baseline characterization sampling for this cell and the floc layer did not yet exist.

STA-2 Floc Depth

Mean floc depth in the EAV cells in 2009 (Cells 1 and 2) was 5.1 ± 2.6 cm, approximately 2 cm lower than what was found in 2003 (7.1 ± 3.6 cm) (**Figure 5-33**). This decrease was likely a result of soil consolidation and accelerated oxidation due to the dry condition in these cells that occurred during drought periods in 2007–2009. **Figure 5-34** shows a comparison of temporal changes in floc depth between Cells 1 and 3, which have two different types of vegetation communities and hydrologic regimes. Cell 1, which is an EAV (cattail) cell and has experienced repeated cycles of dryout and reflooding, showed a decline in floc depth, but Cell 3, which is continually wet and has SAV, showed a gradual increase in floc depth from 2003 to 2009. Mean floc depth in Cell 3, which had been in operation for about 10 years in 2009 was 9.0 ± 4.5 cm; in Cell 4, a relatively new cell (operational for less than two years), floc depth was 5.8 ± 3.9 cm. No clear gradient on floc depth was observed from inflow to outflow locations in any of the cells. The difficulty and subjectivity in delineating the floc boundary in the STA soil profile, particularly in EAV cells, likely influenced these and other findings related to floc material.

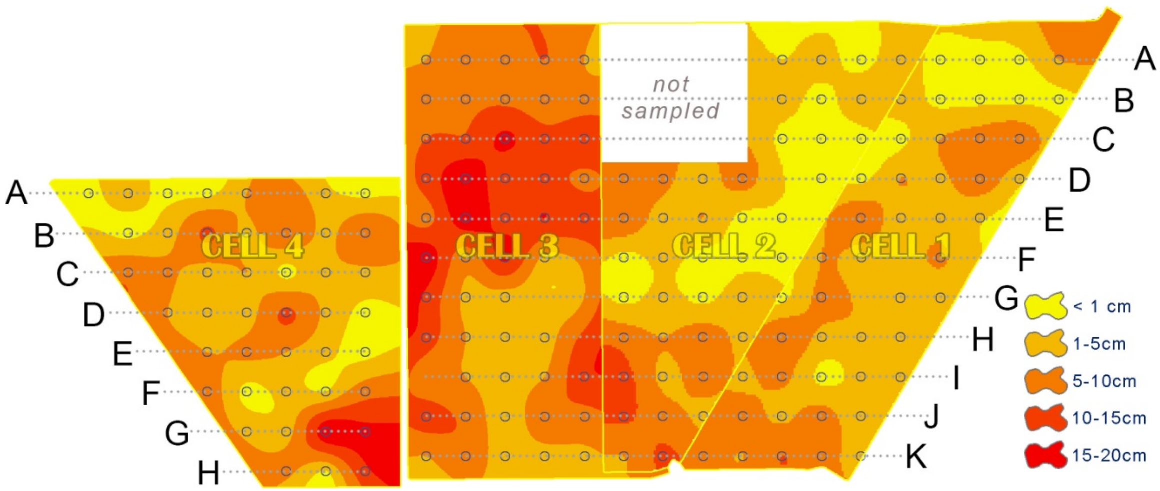
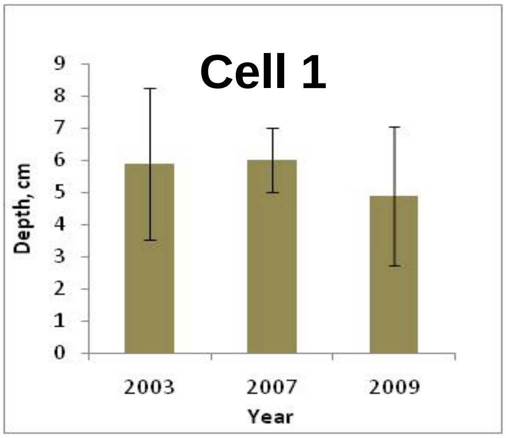


Figure 5-33. Floc depth distribution in STA-2, Cells 1, 2, 3, and 4, based on 2009 sampling. Sampling locations are designated with dots on the map. Letters A-K represent transect designation; transect A is closest to the inflow and transects H/K are closest to the cell outflow.



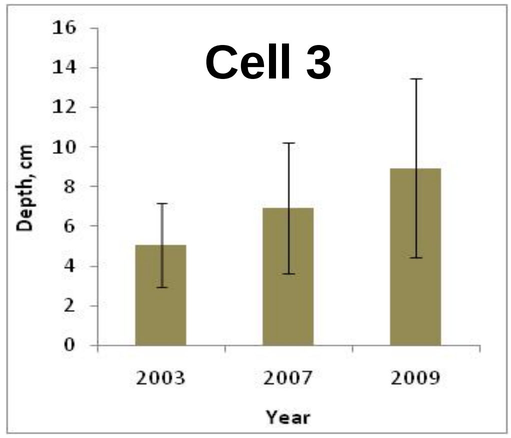


Figure 5-34. Floc depths in STA-2, Cell 1 (EAV cell) and Cell 3 (SAV cell), in 2003, 2007, and 2009. Cell 1 has experienced repeated cycles of dry and reflooded conditions due to drought conditions while Cell 3 has remained continually wet. [Note: Due to the inaccessibility of many sites as a result of drought conditions, there were very limited data available in 2007.]

STA-2 Bulk Density and Ash-Free Dry Weight

Mean floc BD decreased from 0.14 ± 0.05 in 2007 to about 0.05 grams per cubic centimeter (g/cc) in 2009 in both Cells 1 and 2. The decrease in floc depth and increase in bulk density could be an indication that the previously accumulated floc has consolidated or oxidized as a result of dryout, and that what was observed in the 2009 sampling was freshly formed floc with lower bulk density (**Figure 5-35**). Separate studies were under way at the time this report was written to further understand the behavior and pattern of soil accretion, including floc changes in some of the STA cells in STA-1W, STA-2, and STA-3/4. Floc bulk density in Cells 3 and 4 are higher than in the EAV cells (consistent with the other STAs) due to a higher mineral content in SAV cells. At the upper 10-cm soil layer, bulk density remained in the same range as in 2007 for Cells 1, 2, and 4, while a slight increase was observed in Cell 3.

In 2009, the percent AFDW for floc in EAV and SAV cells were 69.7 ± 12.1 and 38.9 ± 16.6, respectively, and in underlying soil (all cells) was 78.4 ± 11.2 (**Figure 5-36**). Higher AFDW in EAV cells than SAV cells is due to accumulation of organic material from decomposing litter in the EAV cells, while SAV cells accumulate floc of higher mineral content. Also, based on AFDW, Cell 2 contains approximately 20 percent less organic matter than the newer SAV cell, (Cell 4); AFDW in Cell 2 was 30.7 ± 14.2 percent compared to 50.4 ± 12.6 percent in Cell 4. Highly mineral floc builds up in SAV cells during years of operation. Cell 4, which is relatively newer than the other cells, was undergoing vegetation-type transition in the years prior to the 2009 sampling. AFDW content of the underlying soil layer is generally higher than the floc layer. Percent AFDW in EAV cells increased by approximately 20 percent between 2007 and 2009, probably due to vegetation litter accumulation in these cells. In Cell 3 (SAV cell), there was a much smaller increase (5 percent) in AFDW from 2007 to 2009.

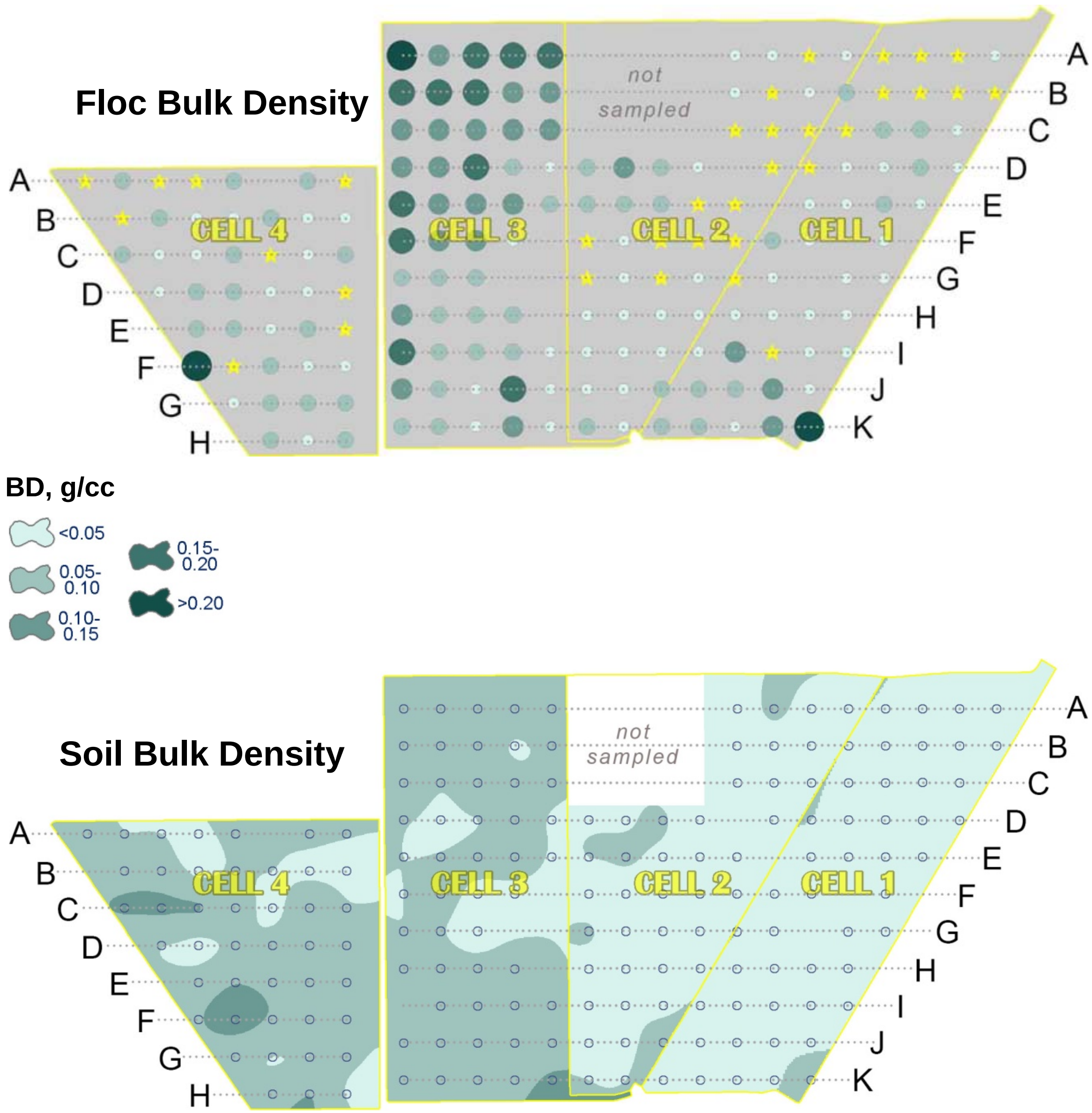


Figure 5-35. STA-2 bulk density (BD) of floc and the upper 10-cm soil layer based on 2009 soil analysis in grams per cubic centimeter (g/cc). Sampling locations are designated with dots on the map. Letters A-K represent transect designation; the A transect is closest to the inflow and H/K transects are closest to the cell outflow.

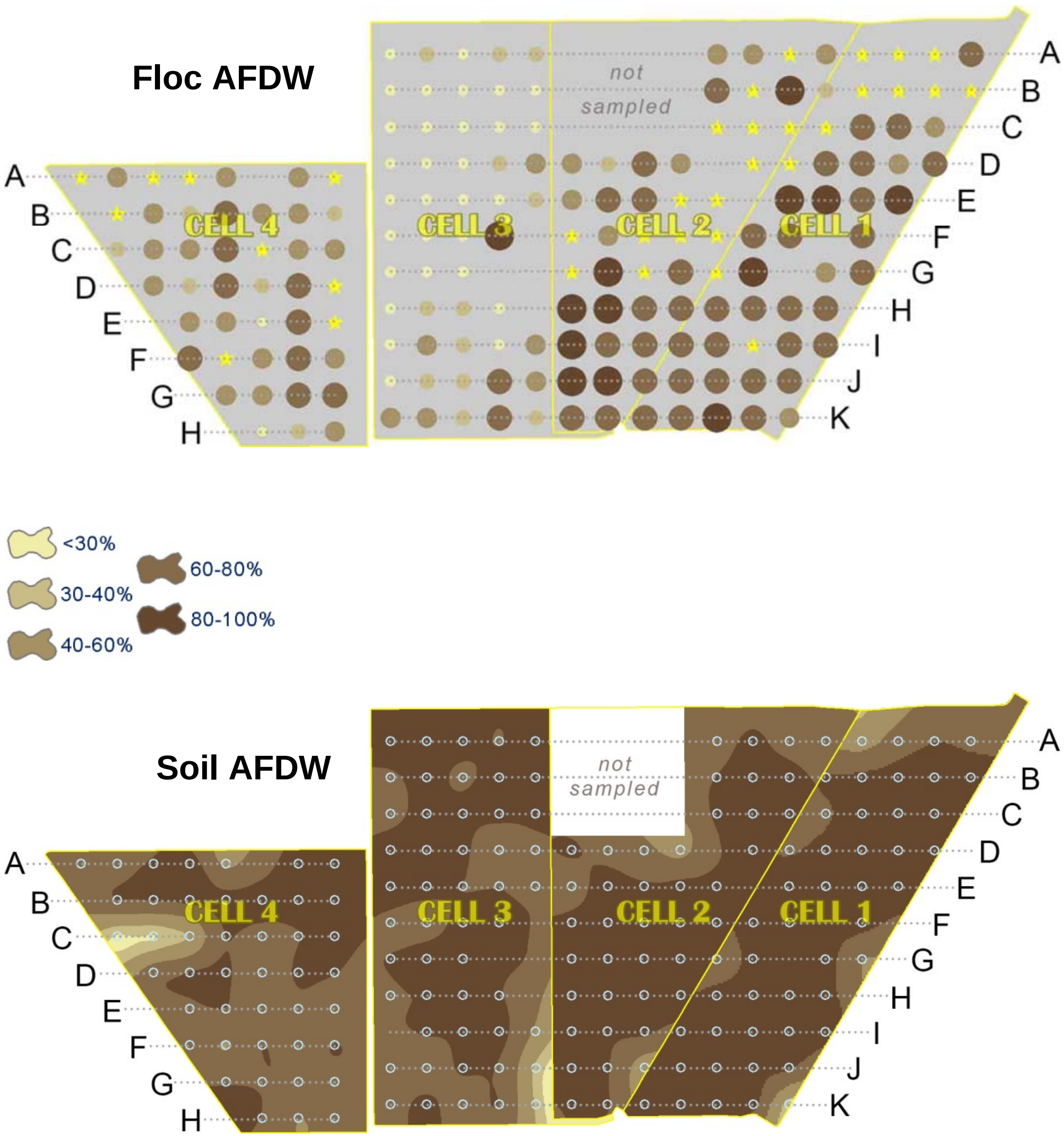


Figure 5-36. Percent ash-free dry weight (AFDW) in floc and the upper 10-cm soil layer based on 2009 soil analysis. Sampling locations are designated with dots along the transects. Letters A-K represent transect designation; the A transect is closest to the inflow and H/K transects are closest to the cell outflow.

STA-2 Soil Total Nitrogen and Total Carbon

Total nitrogen (TN) in STA-2 floc averaged 19.6 ± 6.8 g/kg. In underlying soils, the mean concentration was 27.0 ± 3.8 g/kg for the entire STA (**Figure 5-37**). TN concentrations (24.6 ± 3.9 g/kg) in EAV cells' floc were approximately twice the concentrations found in SAV cells, particularly in Cell 3 where TN averaged 12.6 ± 5.0 g/kg. In the upper 10-cm soil layer, TN concentrations were similar between EAV and SAV cells. In Cell 4 (a relatively new SAV cell), TN was slightly higher in the upper 10-cm soil layer than in the floc layer. TN in floc was generally lower in the front end of the EAV cells, and a more defined gradient was observed in Cell 3 where concentrations gradually increased from the inflow to the outflow locations. Total carbon (TC) for the entire STA was 313 ± 85.6 g/kg and 433 ± 58.8 g/kg in floc and in the upper 10-cm soil layer, respectively (**Figure 5-38**). The temporal and spatial patterns observed in TC concentrations were very similar to the TN results. These findings indicate that as the EAV cells accumulate a higher proportion of organic material from macrophyte litter decomposition, the TN and TC concentrations in the floc layer in these cells correspondingly increase. On the contrary, floc TN and TC concentrations in SAV cells decrease as more mineral matter is deposited from decomposing SAV biomass.

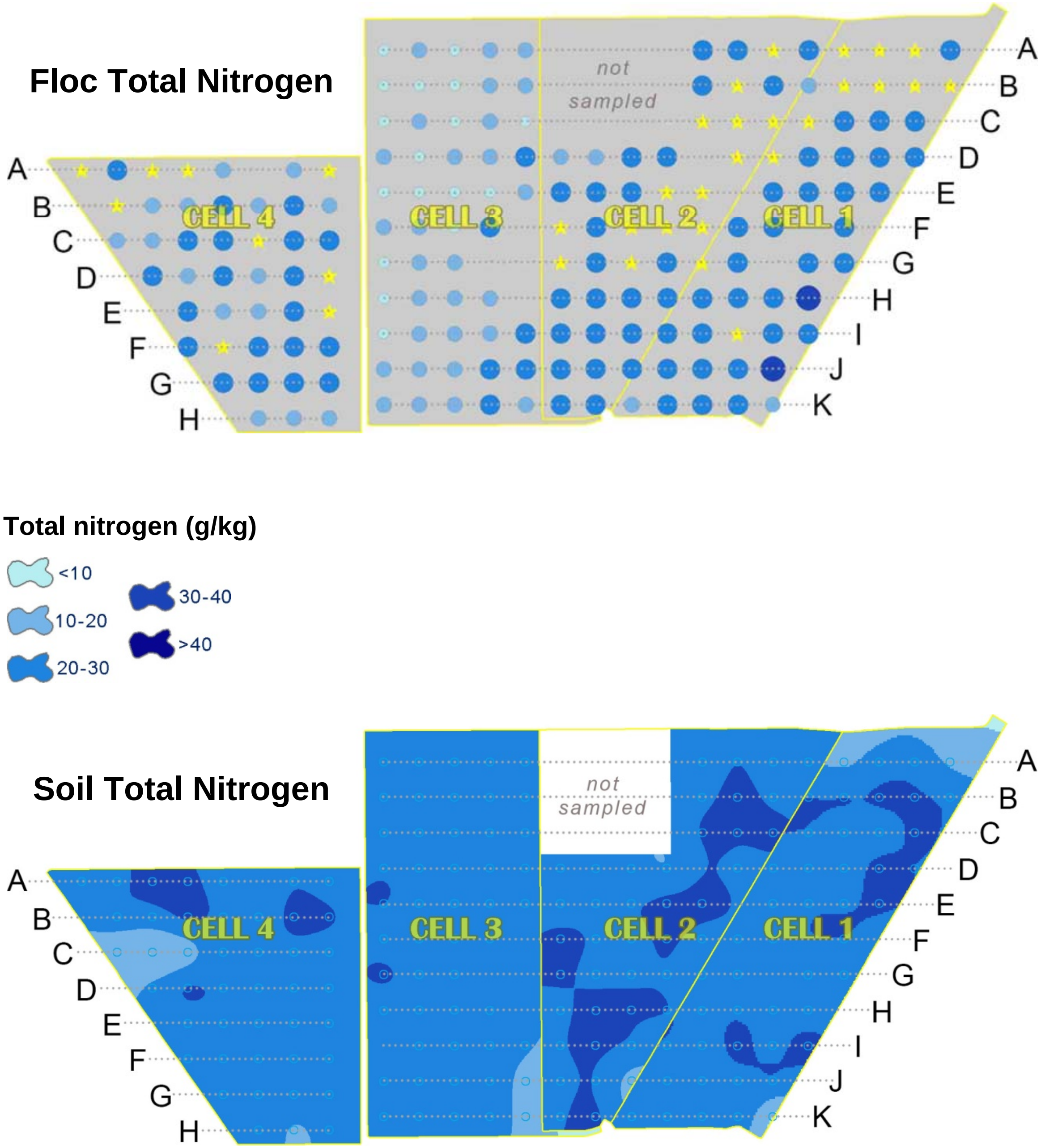


Figure 5-37. STA-2 total nitrogen in floc and upper 10 cm soil layer, in grams per kilogram (g/kg), based on 2009 soil analysis. Sampling locations are designated with dots along the transects. Letters A-K represent transect designation; the A transect is closest to the inflow and H/K transects are closest to the cell outflow.

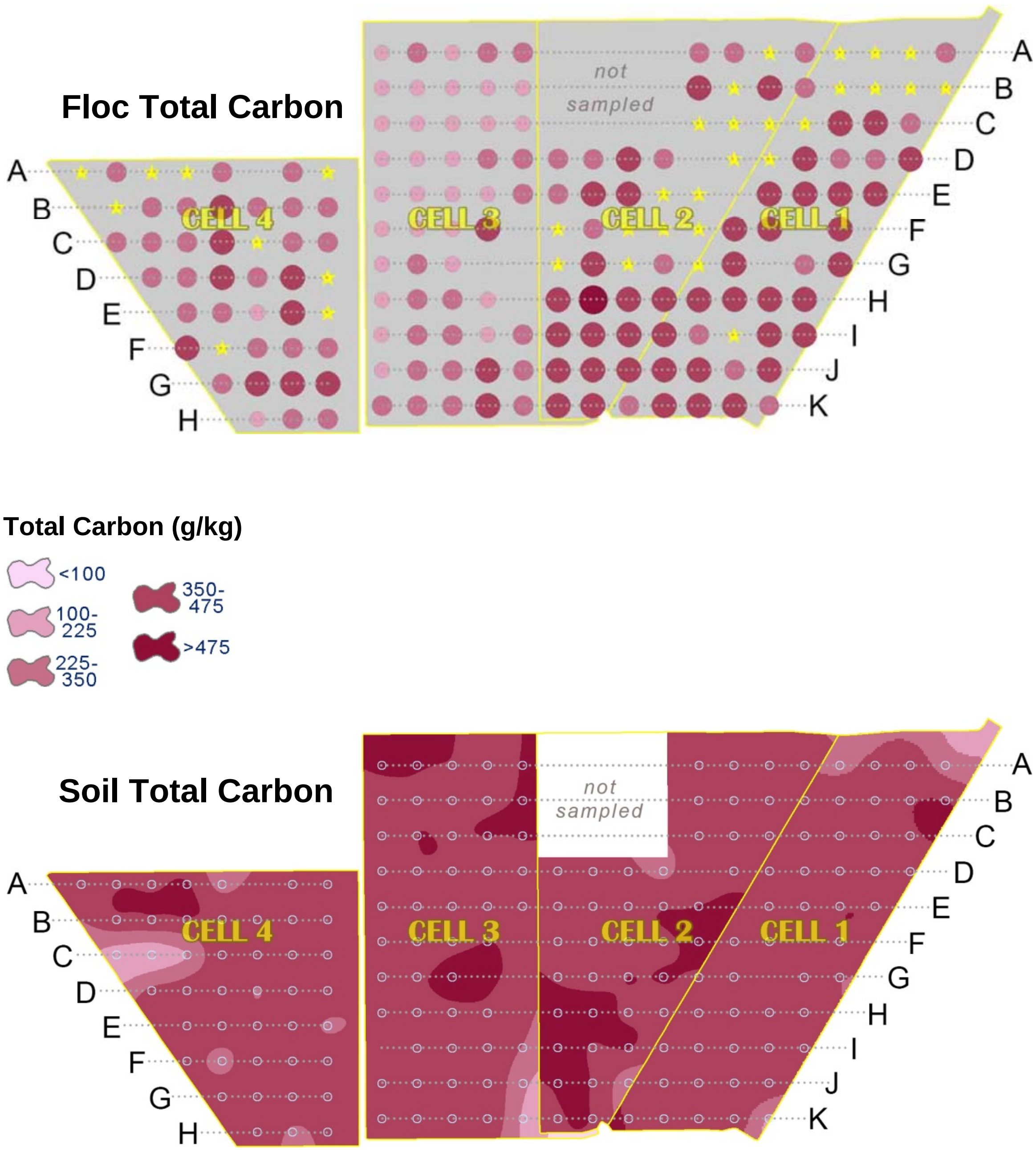


Figure 5-38. STA-2 total carbon concentrations in floc and the upper 10-cm soil layer in grams per kilogram (g/kg) as determined by a 2009 soil analysis. Sampling locations are designated with dots along the transects. Sampling locations are designated with dots on the map. Letters A-K represent transect designation; the A transect is closest to the inflow and H/K transects are closest to the cell outflow.

STA TOPOGRAPHIC SURVEYS

The Process Development and Engineering component of the Long-Term Plan requires continued engineering evaluations to increase the certainty in overall operations and performance of integrated water quality improvement strategies. Part of this effort is the acquisition of topographic survey data. Results are used in setting the target stage levels for each cell, in determining any areas with short-circuiting issues, and in other hydraulic analysis. Surveys are conducted under the direct supervision of a professional surveyor and mapper, in accordance with the Minimum Technical Standards for Surveying in Florida.

In WY2010, professional surveying began to obtain updated topographic data for STA-1W, STA-2, STA-5, and STA-6. STA-1E, STA-1W, STA-2, STA-5, and STA-6 were previously surveyed from 2003 through 2005, while STA-3/4 was last surveyed in 2008. Topographic points in the STA were certified previous to this survey. Spot surveys were also done in STA-1W in 2006 and 2007 as part of rehabilitation activities. STA-2 survey results are presented in this report (**Table 5-17** and **Figure 5-39**); surveys for STA-1W will be completed in WY2011 and are expected to be presented in the 2012 SFER; STA-5 and STA-6 surveys also continue. For comparison purposes, all 2010 survey points were collected at the same general locations where previous topographic surveys were conducted. Efforts were made to ensure that each data point was representative of the surrounding marsh. No survey points were taken on levees, remnant farm roads, in remnant farm ditches, or canals.

Results from STA-2 indicate that there are some differences between the 2003 and 2010 surveys. Mean elevation estimates have changed by +0.66 ft in Cell 1, -0.24 ft in Cell 2, and +0.16 ft in Cell 3. Based on the mode, ground elevation estimates have increased by 0.60 ft in Cell 1 and 0.20 ft in Cell 2, while Cell 3 has remained the same (**Table 5-17**). The WY2010 topographic data for Cell 4 is the initial topographic dataset as it was a fallow, agricultural field in 2003. Field verifications will be made prior to making any adjustments to current stage targets.

Table 5-17. Summary of STA-2 topographic surveys.

Cell Type	Cell	Year	STA-2 Elevation Survey Points (feet National Geodetic Vertical Datum 1929)					Operations Estimated Ground Elevations
			Average	Mode	Median	Min.	Max.	
EAV	1	2003	11.29	11.70	11.56	8.77	14.16	11.80
		2010	11.95	12.30	12.00	9.80	13.20	
	2	2003	10.70	10.80	10.70	8.44	14.28	10.30
		2010	10.46	11.00	10.70	8.90	12.00	
SAV	3	2003	9.35	9.00	9.19	7.26	13.03	9.60
		2010	9.51	9.00	9.30	7.72	11.40	
	4	2005	8.90	8.80	8.84	8.29	10.29	8.70
		2010	9.19	8.90	9.12	7.13	11.16	

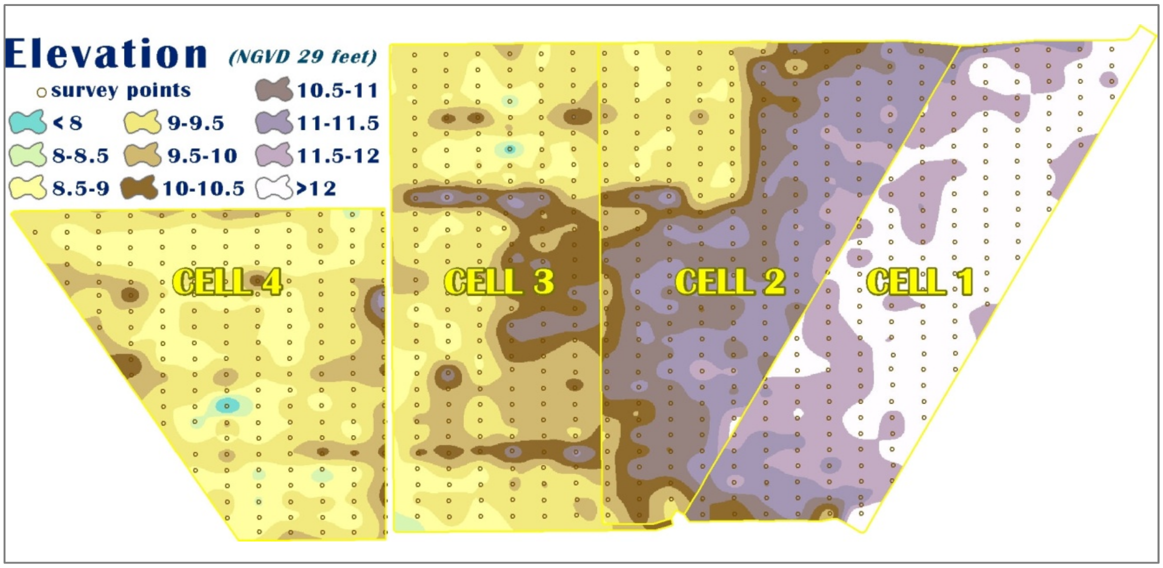


Figure 5-39. STA-2 ground elevation data from the 2010 topographic survey.

STA-1W PHOSPHORUS MESOCOSM STUDY

Although the STAs have substantially reduced TP loading to the Everglades over the past decade, investigations continue to identify management strategies to enhance their treatment performance. For instance, a three-year, proof-of-concept study at the mesocosm scale began in 2010. The study examines various native aquatic macrophytes to further improve STA treatment performance. It is hypothesized that fragrant water lily (*Nymphaea odorata*)-dominated slough type of vegetation or sawgrass-dominated emergent vegetation will be able to reduce water-column phosphorus concentrations to levels below that of the cattail–SAV treatment trains that are established in these wetlands. This belief is based on the ecology of the unimpacted areas of the Water Conservation Areas (WCAs) where such species dominate the plant community, and results from previous District research on the ecophysiology of these species.

The study objectives are to (1) quantify phosphorus removal of water lily and sawgrass species and compare those results with other common vegetation in the STAs, (2) identify the major pathways of nutrient storage in each species, and (3) determine the optimum water depth at which water lily and sawgrass achieve maximum phosphorus removal. If this research rejects the null hypothesis, phosphorus removal could be increased by planting water lily or sawgrass at the backend portion of SAV cells. The study, which is located at the South Research Site in STA-1W, uses a randomized block design with one factor (vegetation type) at six levels: (1) water lily monoculture, (2) water lily/spike rush (*Eleocharis* spp.)/periphyton mixture, (3) sawgrass, (4) cattail, (5) SAV, and (6) a control with no vegetation (**Figure 5-40**). Each level is replicated three times, resulting in 18 mesocosms. The experiment is at acclimation stage and planned for completion in December 2012.

Figure 5-40. Vegetation types of the STA-1W Phosphorus Mesocosm Study (photos by the SFWMD).

VEGETATION MANAGEMENT ACTIVITIES AND RESEARCH STUDIES

This section also reports on the work being completed pursuant to the Long-Term Plan. The following summarizes the research projects initiated or ongoing in WY2010 that have been designed to strengthen understanding about the mechanisms that control STA performance. These include water quality surveys, soil sampling, monitoring of newly rehabilitated STA cells, assessment of floc soil biogeochemistry, and several large-scale experiments that examined biomass effects on SAV establishment and the influences of hydrologic extremes on cattail growth and survival to help identify stress indicators.

SUBMERGED AQUATIC VEGETATION CONDITIONS AND THE EFFECTS OF HYDRILLA AND MUSK GRASS DECLINE

Submerged aquatic vegetation, the dominant community in "back-end" STA treatment cells, can be subject to various disturbances, including herbivory, hurricane winds, and excessive loadings of nutrient or particle-laden waters. Reductions in SAV cover, in turn, can lead to impaired STA performance. Because the cover and species composition of SAV communities can be detected only sporadically with aerial or satellite images (i.e., when plants top out in the water column), efficient ground-level survey methods must be implemented to assess temporal changes in distribution of SAV coverage. For this effort, the District is performing at least one airboat survey in each of the 13 existing SAV-dominated STA cells annually (**Figures 5-1** and **5-2**). Additional surveys are conducted as needed (e.g., to evaluate decline in performance, following unusual events, or after rehabilitation or enhancement activities). SAV survey results, including those from previous years, are presented in Appendix 5-10, Figures 9–16.

During WY2010, dramatic changes were observed for SAV communities in several STA cells. Hydrilla, which often occurs as a dominant SAV species, exhibited a decline in most STAs. Factors that influence the density and distribution of SAV species in the STAs remain largely unknown and remain an important topic of investigation. There was extensive decline in hydrilla populations throughout most of the STAs, and the greatest impacts were observed in STA-1E, STA-1W, and STA-5 in areas where hydrilla was the dominant SAV species. Field surveys were conducted to evaluate the extent of the SAV decline and changes in water quality were evaluated. SAV dominated communities exist in many of the treatment cells and a decline of the communities can be detrimental to the performance of treatment cells.

STA-1E Submerged Aquatic Vegetation Survey

Typically, hydrilla has been the dominant SAV species in STA-1E (Cells 4N, 4S, and 6). Hydrilla coverage in these cells has been very stable with occasional die-off events occurring as a result of storms or dryout. Beginning in May 2009, a cell-wide hydrilla decline was observed in Cell 6, soon after this STA received a large amount of rainfall. Shortly thereafter, a mass of floating hydrilla mats migrated to the outflow canals and began reaching the outflow structures during high flow events in early July 2009 (**Figure 5-41**). Along with the biomass movement, there was a spike in water turbidity and nutrient concentrations that lasted several months after the event was first observed. Much of the SAV that remained in Cell 6, after the export event, was no longer anchored to the sediment and was decomposing in the water column. Several truckloads of hydrilla biomass were harvested from the outflow canals from July–August 2009 (**Figure 5-42**). Field visits in October 2009 showed that only a portion of the hydrilla community remained in the cell, with a majority of plants floating unanchored and beginning to decompose in the water column. Cell 6 continued to be devoid of SAV throughout the remaining portion of

WY2010, and rehabilitation planning was initiated to improve the conditions and performance in this cell. Screened booms were also installed in major structures, including the outflow structure S-362.

Additional losses of hydrilla also occurred in Cells 4N and 4S in February–March 2010, when most of the hydrilla communities in both cells declined in overall coverage. However, portions of the hydrilla community remained viable. Appendix 5-10, Figure 7, depicts the change in hydrilla density and cover for STA-1E, Cells 4S, 4N, and 6 from February 2009–February 2010. Additional vegetation surveys in May 2010 revealed that both Cells 4N and 4S regained extensive SAV coverage, with Cell 4N dominated by hydrilla and Cell 4S populated by southern naiad and hydrilla (see Appendix 5-10, Figure 8).

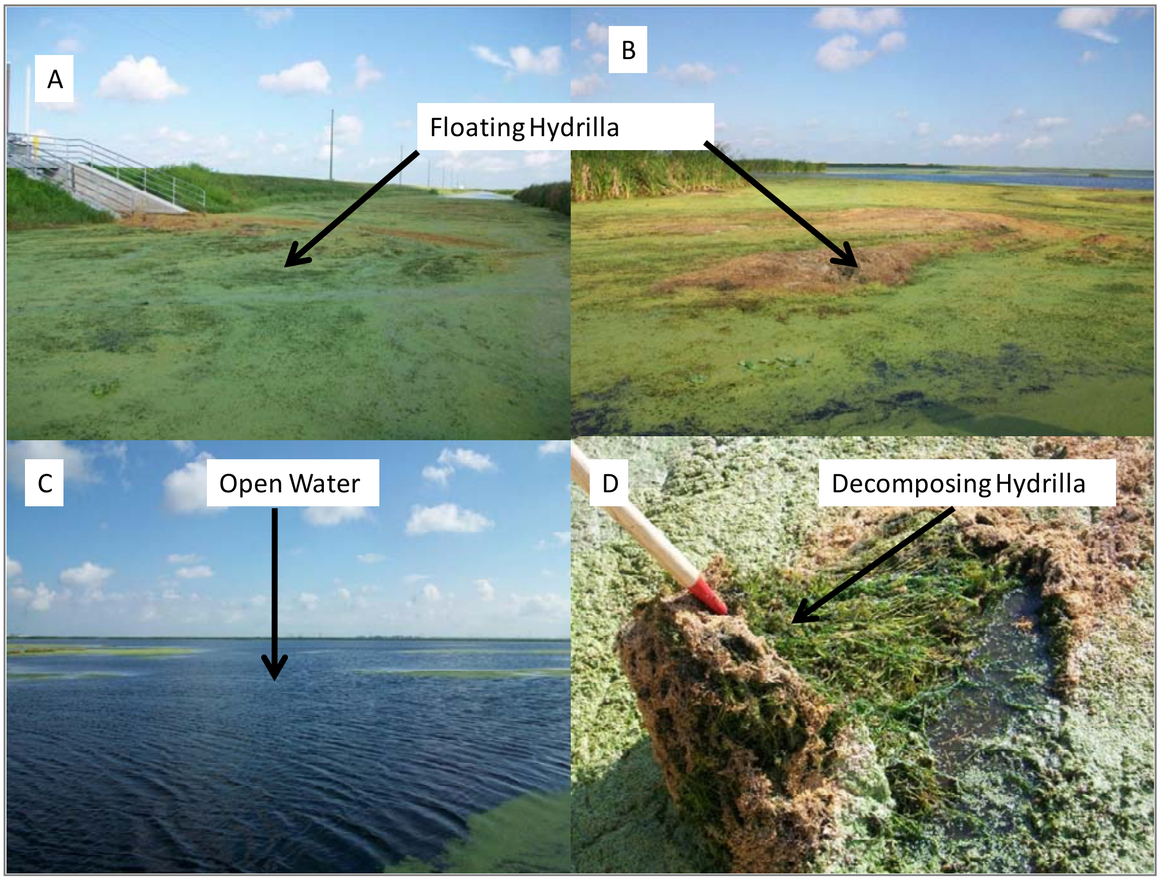


Figure 5-41. Vegetation in STA-1E, Cell 6: (A) accumulated biomass at the G-372B outflow structure, (B) floating hydrilla mat in the central portion of Cell 6, (C) open water in the northern portion of Cell 6 as a result of the hydrilla die-off, and (D) decomposing hydrilla mat (photos by the SFWMD).

Figure 5-42. Harvesting and trucking of hydrilla biomass from the STA-1E outflow canal as a result of a hydrilla decline that occurred in Cell 6 beginning in May 2009 and migrated to the outflow canal beginning in July 2009. The unexpected decline in SAV prompted field surveys to be conducted to evaluate the extent of plant loss. The effects on water quality were also monitored (photos by the SFWMD).

Impacts to Water Quality in STA-1E

Target stages in the treatment cells of STA-1E are set at 1.25 ft above average ground elevation for EAV and SAV cells. Stages in all of the STA-1E flow-ways remained around target stage throughout the entire water year (**Figure 5-43**). Efforts to enhance the vegetative community in Cell 6 of STA-1E began in April 2010 and required stage-lowering activities.

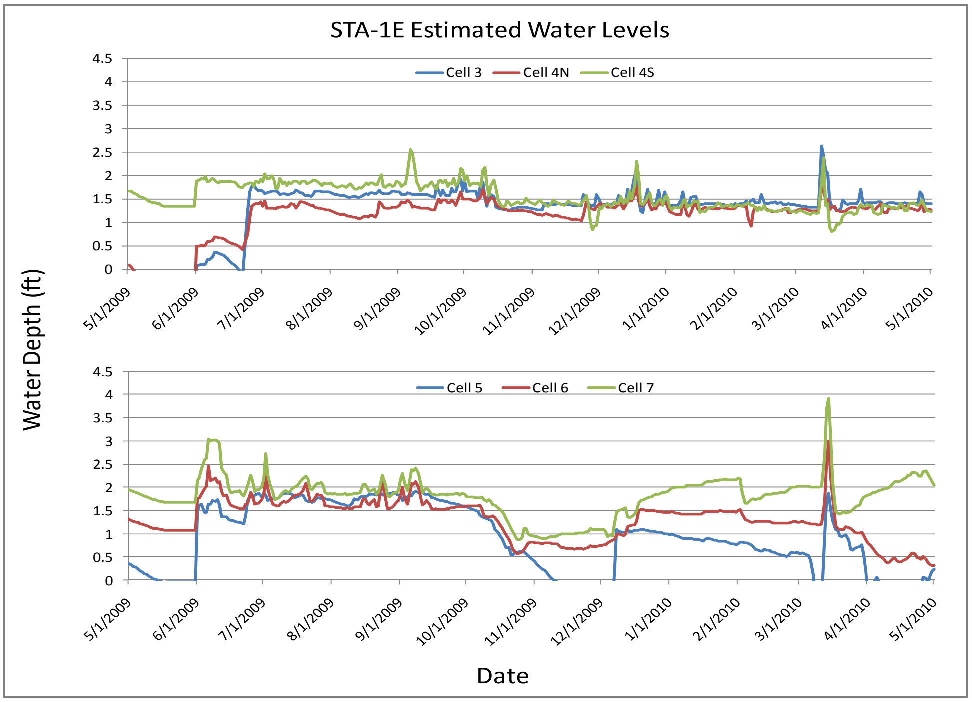
High levels of TP were observed in the Western Flow-way outflow following hydrilla decline, reaching up to 234 ppb in June 2009. Internal transect sampling in that flow-way conducted June–July 2009 showed a reduction in phosphorus concentrations along the gradient, although overall concentrations remained elevated (see the *Internal Transect Phosphorus Sampling, STA-1E and STA-2* section of this chapter). Monthly outflow TP values at the STA-1E outflow structure (S-362), which were below 20 ppb prior to this incident, spiked to 123 ppb and continued to be at levels greater than 50 ppb until September 2009, despite very little to no flows from the Western Flow-way (**Figure 5-44**). Outflow concentrations increased to 105 ppb in February 2010 when the Western Flow-way was used for a short time, and additional hydrilla decline was observed in the Central Flow-way. The Central Flow-way also had increased outflow TP FWM concentrations in March–April 2010 due to decreased SAV (hydrilla) coverage and water being pumped into Cell 4N from Cell 6 while stage reduction efforts were under way in the Western Flow-way to aid in vegetation enhancement. Internal transect sampling in the Central Flow-way conducted June–July 2009 showed that TP concentrations were elevated in Cells 3 and 4N, with much of the TP consisting of SRP. TP concentrations were much lower going into Cell 4S and remained low throughout the treatment area (see the *Internal Transect Phosphorus Sampling, STA-1E and STA-2* section of this chapter).

STA-1W Submerged Aquatic Vegetation Survey

Observations during the early part of 2009 suggested that hydrilla had been expanding in portions of Cells 2B and 4. In July 2009, SAV communities in Cells 2B, 4, and 5 also declined but with less extensive hydrilla loss than that observed in STA-1E. Musk grass is also widely established in SAV cells in this STA and also exhibited a decline, particularly in Cells 1B, 2B, and 4. An April 2010 survey indicated that southern naiad had taken over most open areas where hydrilla once dominated in Cells 2B, 4, and 5B.

Impacts to Water Quality in STA-1W

Target stages in the STA-1W treatment cells are set at 1.25 ft above average ground elevation for EAV and SAV cells. Stages in all of the flow-ways remained around target stage throughout the entire water year (**Figure 5-43**). The impacts of the hydrilla decline in STA-1W were not as extensive as that in STA-1E. Average monthly outflow TP FWM (G-310 auto-sampler) concentrations were 32 ppb during May–July 2009. Average monthly TP FWM concentrations increased slightly from 40 to 49 ppb during August–October 2009. The Western Flow-way outflow TP FWM concentration averaged around 35 ppb in June 2009, and gradually increased to a peak of 132 ppb in October 2009, when the hydrilla community had declined and was in the process of decomposing. There were similar observations in the Northern Flow-way, where TP FWM concentrations increased from 23 ppb (May 2009) to about 90 ppb (September–October 2009). The system showed some signs of recovery during periods of low to no flow, but levels spiked again during March and April 2010 when STA-1W received high flows and nutrient loading as a result of heavy rainfall events (**Figure 5-45**). Extensive musk grass loss was also observed in Cells 2B and 4 in June 2009 (**Figure 5-46**), and this likely contributed to the TP spikes observed in spring (**Figure 5-45**).



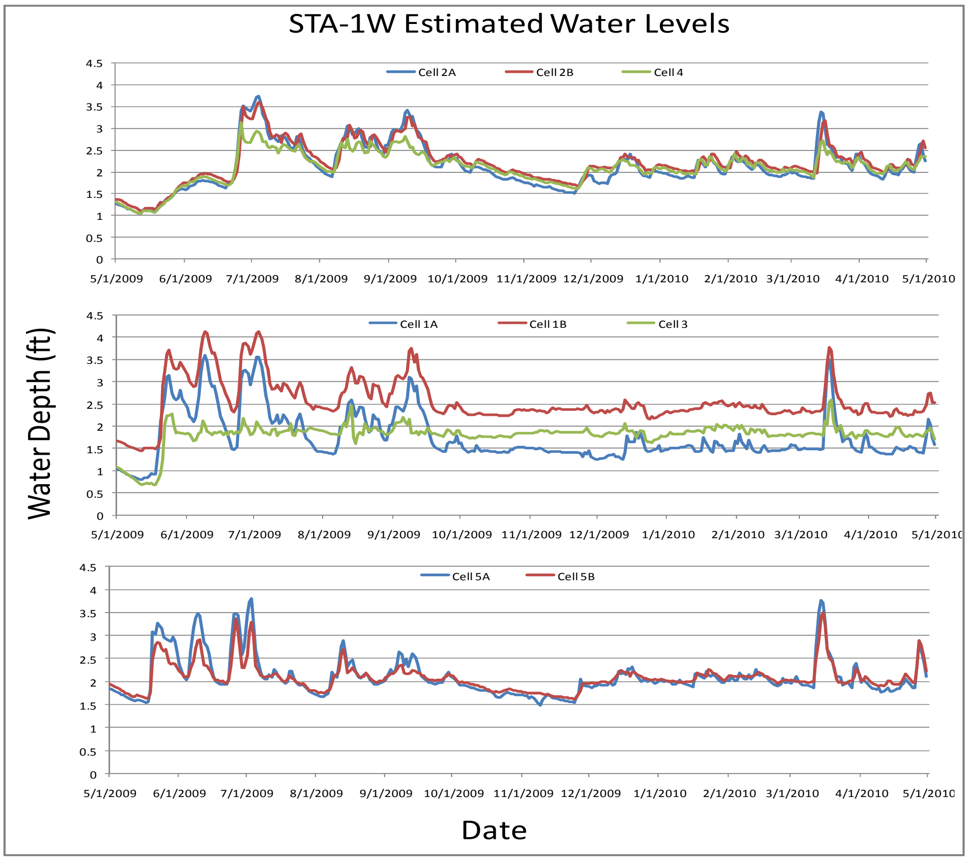


Figure 5-43. Estimated water levels for STA-1E (top) (excluding the Eastern Flow-way) and STA-1W (bottom) during WY2010.

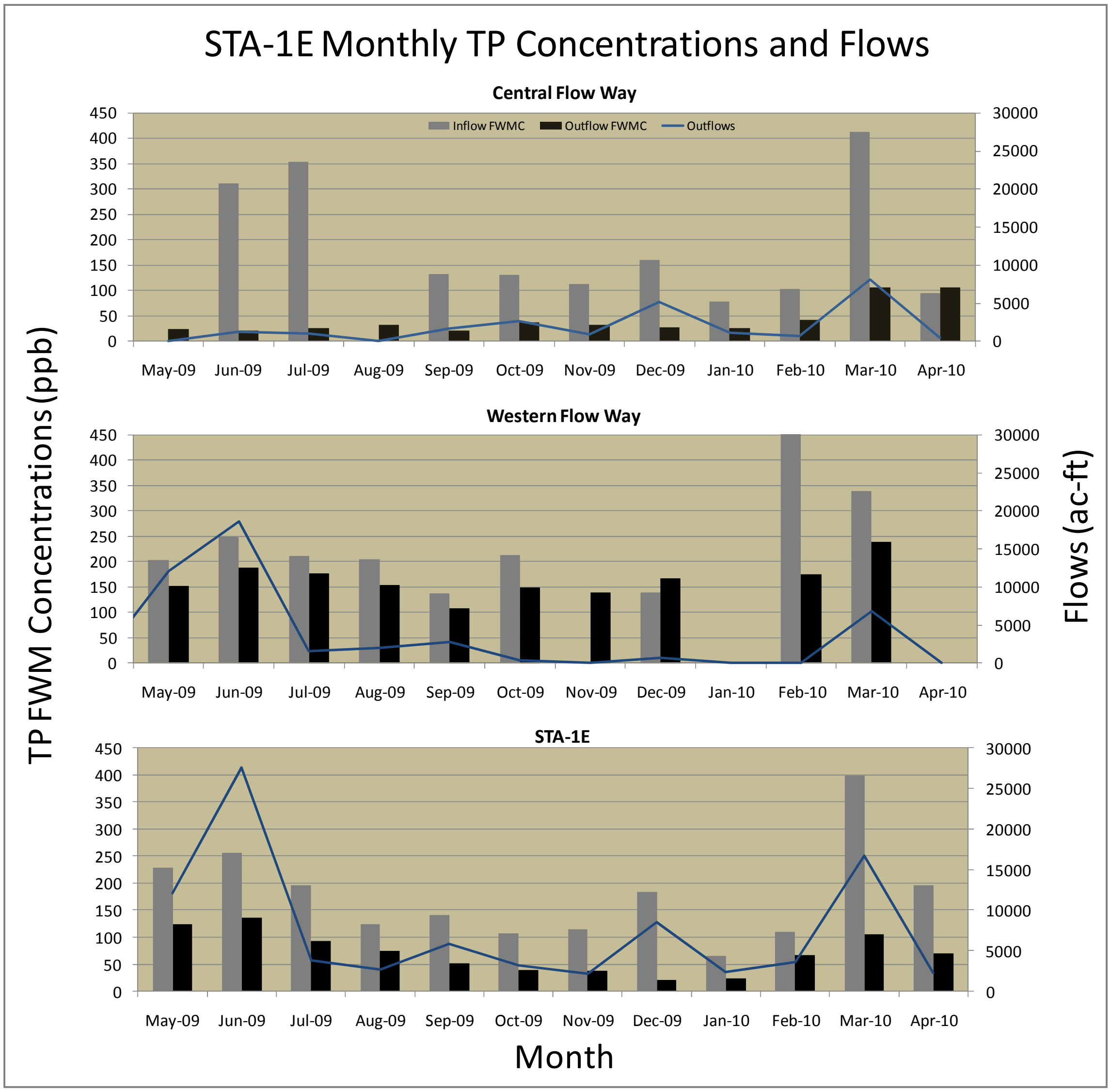


Figure 5-44. STA-1E monthly outflows (ac-ft) and monthly TP FWM concentrations (ppb) during WY2010.

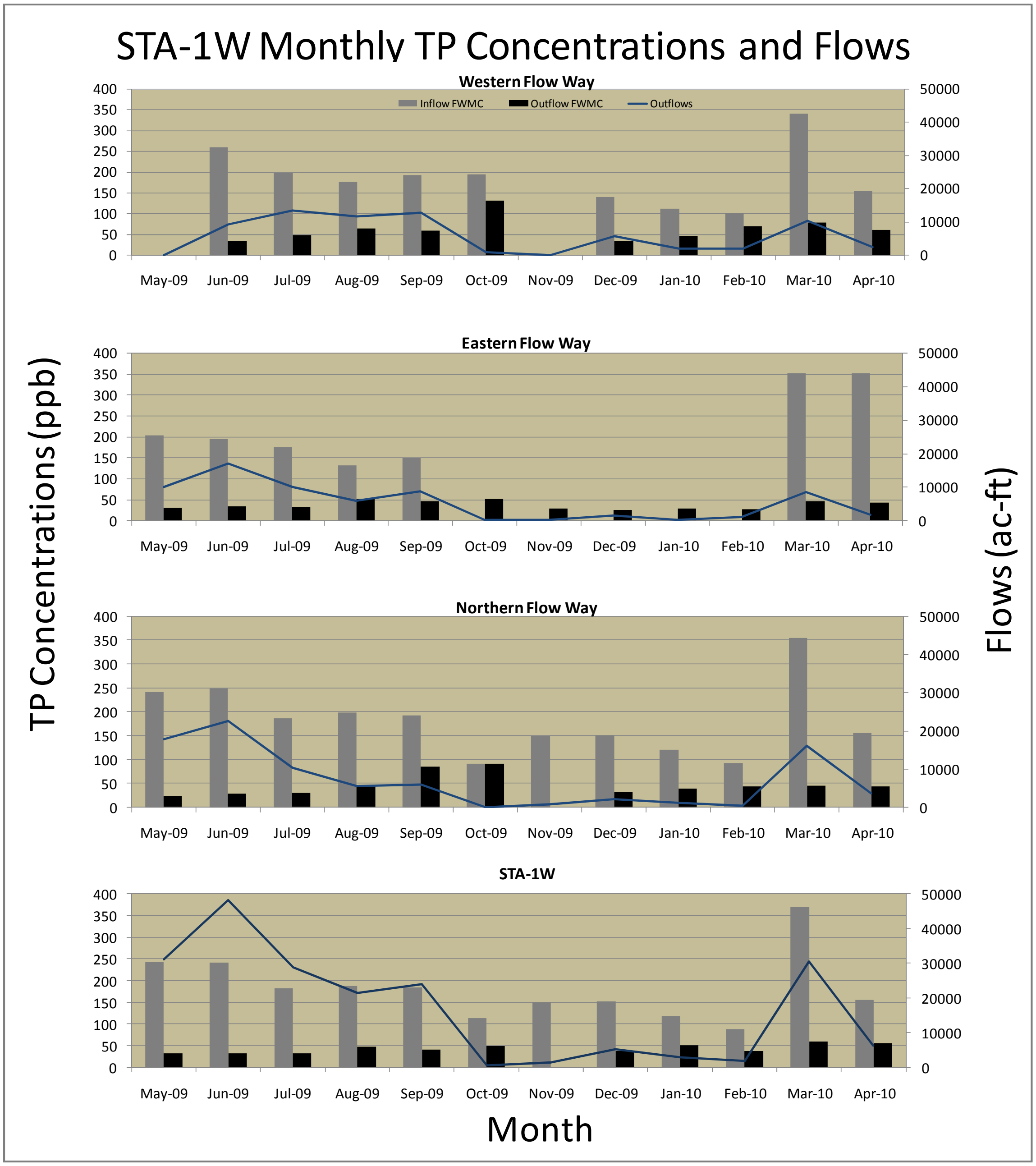


Figure 5-45. STA-1W monthly outflows (ac-ft) and monthly TP FWM concentrations (ppb) during WY2010.

Figure 5-46. Extensive beds of musk grass (*Chara* sp.) forming a white surface crust in STA-1W, Cells 2B and 4, according to field observations in June 2009 (top); low water level conditions in the preceding months are likely the cause of musk grass loss; the area was void of live vegetation underneath the decomposing mats (bottom) (photos by the SFWMD).

STA-2 Submerged Aquatic Vegetation Survey

In the winter months of 2009, a hydrilla die-off was observed in STA-2 and a large amount of biomass piled on the first vegetation strip on the northern portion of Cell 3. The extent of biomass was estimated to be approximately 75 percent of the entire SAV located in this portion of the cell. The decomposing, floating mats of hydrilla remained on the surface water for several weeks. Cell 4 also experienced a decline in SAV near the inflow during this time, but that loss was not as significant as observed in Cell 3. The affected area in Cell 3 had a minimal impact in outflow TP concentration during the first two weeks of December 2009 in which slightly higher TP concentrations were observed. No other TP concentrations increases were observed in Cell 3 during the subsequent weeks. In Cell 4, the minimal decline of SAV did not noticeably affect the outflow TP concentrations. Overall, STA-2 did not suffer an impact to water quality due to SAV changes in WY2010.

STA-3/4 Submerged Aquatic Vegetation Survey

STA-3/4 did not experience any significant SAV decline during WY2010.

STA-5 Submerged Aquatic Vegetation Survey

The SAV-dominated treatment cells (Cells 1B and 2B) at STA-5 experienced extensive SAV decline in WY2010. Cell-wide SAV decline was noted at STA-5 in early 2010 in the Northern and Central SAV treatment cells (Cells 1B and 2B). During this period, the Southern Flow-way was offline due to construction activities associated with the Compartment C Build-out construction. These treatment cells had been dominated by hydrilla. Surveying conducted in March 2010 showed little to no SAV present in Cell 1B (Appendix 5-10, Figures 15 and 16). The sparse SAV that was found consisted of small sprigs of hydrilla and coontail (*Ceratophyllum demersum*). Turbidity was also elevated, attributed to the decay of the SAV biomass (**Figure 5-47**). Cell 2B also had a similar sparse presence of SAV, but turbidity conditions were not as severe as those found in Cell 1B. The SAV in these cells was only moderately reestablished by the end of WY2010.

Impacts to Water Quality in STA-5

For the entire Northern Flow-way (Cells 1A and 1B), outflow TP concentrations from March 2009–February 2010 were below 50 ppb, with some values below 20 ppb. By the end of the water year, outflow TP concentrations went up slightly, attributed to the decline of SAV communities creating open-water conditions in early 2010 and subsequent planting activities in April 2010 (**Figure 5-48**). When the Northern Flow-way was taken offline, Cells 1A and 1B received no inflows for about four months from November 2009–January 2010. Elevated outflow TP concentrations were also observed in the Central Flow-way during this time, although FWM TP concentrations were not as high as those from the Northern Flow-way.

STA-6 Submerged Aquatic Vegetation Survey

STA-6 did not experience any significant SAV decline during WY2010.

Figure 5-47. Increased turbidity and sparse SAV growth observed in STA-5, Cell 1B, in March 2010; plant species present consisted of coontail (*Ceratophyllum demersum*) and hydrilla sprigs (photo by the SFWMD).

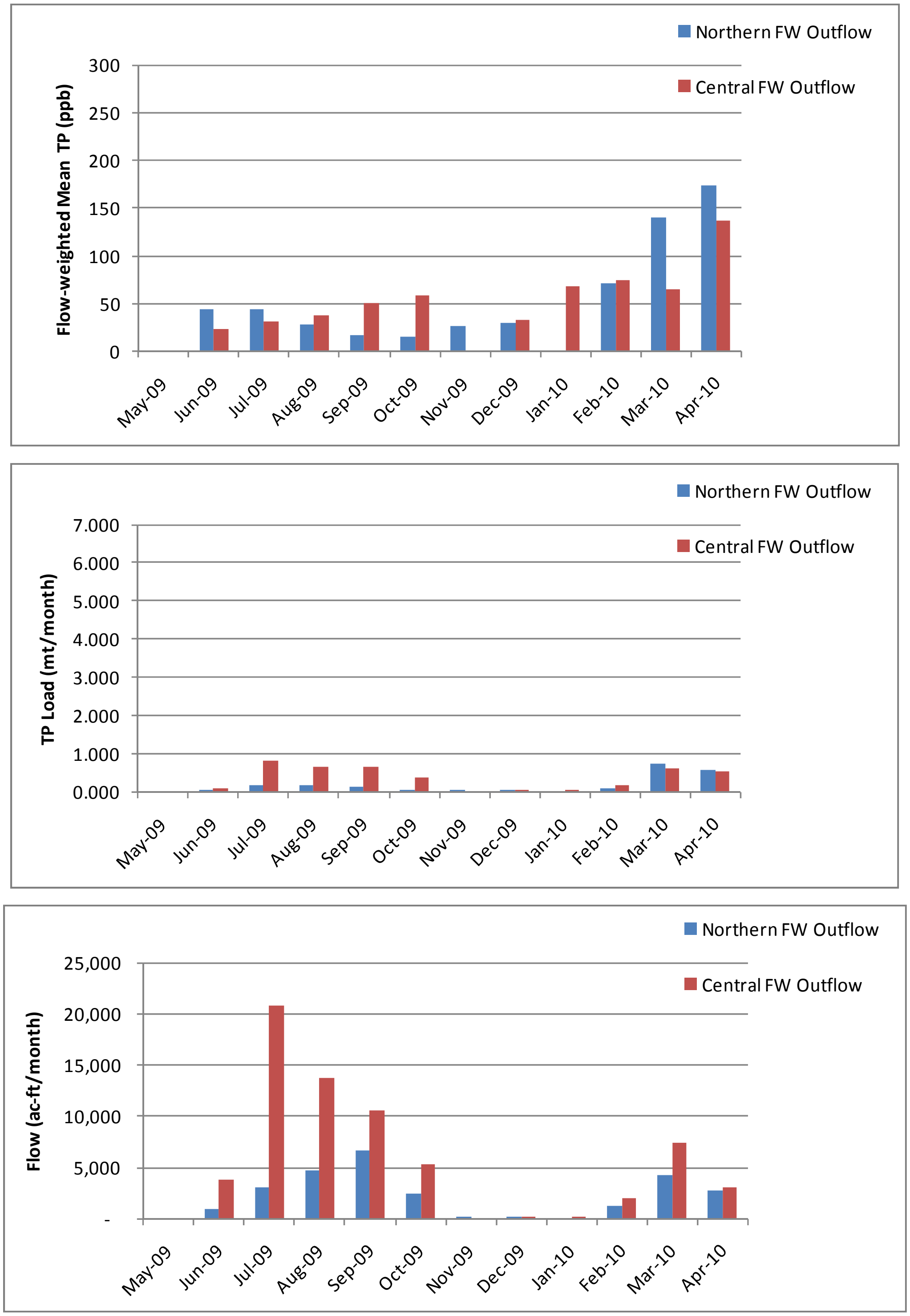


Figure 5-48. Flows (top), TP loads (middle), and TP FWM concentration (bottom) data collected in STA-5 during WY2010. Starting in January 2010, increased outflow TP concentrations were observed, peaking up to over 130 ppb in April 2010. Increased TP outflow concentrations were attributed to dying SAV biomass and April 2010 vegetation planting activities.

VEGETATION COVERAGE AND CONDITION ASSESSMENT BASED ON 2007–2009 AERIAL IMAGES

Vegetation has a major role in water quality improvement in the STAs through reduction in water velocity, thereby allowing suspended particles to settle (Brueske and Barrett, 1994), and through nutrient uptake and burial (Reddy and DeBusk, 1985). Vegetation in treatment wetlands also influences microbial processes by increasing oxygen availability in the rhizosphere (Allen et al., 2002) and providing additional surfaces for growth and proliferation of microbial populations (Wetzel, 1990).

The Process Development and Engineering component of the Long-Term Plan and the EFA STA permits require assessing vegetation extent and condition through annual aerial imagery and through short-term vegetation monitoring in individual cells as needed. A detailed vegetation class map was presented in previous SFERs. A comparison EAV versus SAV+open water coverage (SAV-OW) based on aerial images from the most recent three–year period (2007–2009) (see Appendix 5-10, Figures 1–6) is summarized in this section. During the POR, the STAs experienced extreme weather conditions, including a three-year drought followed by heavy, out-of-season rainfall events in 2009 (see Chapter 2 of this volume). It should be noted that aerial imagery flights occur in the middle of the dry season, which could potentially bias analyses. Also, aerial imagery does not allow for distinction of areas colonized with SAV versus open water areas with no SAV, so the coverage analysis is limited to either EAV or SAV-OW.

STA-1E

Vegetation coverage in STA-1E remained relatively constant from 2007–2009 except in Cell 5 (Appendix 5-10, Figure 1). In this cell, the EAV coverage increased by 15 percent and the SAV-OW coverage decreased by 15 percent between the 2007 and 2008 surveys. The EAV coverage was also 20 percent lower in Cell 5 than in other EAV cells. During 2007–2009, the three SAV cells (Cells 4N, 4S, and 6) had 92 to 95 percent of SAV-OW coverage which had historically been dominated by mostly hydrilla. In Cell 7, EAV coverage from 2007–2009 remained around 60 percent of the treatment area. There was also observed decline in plant density as reported in the 2010 SFER. Field observations showed impacts of prolonged deepwater condition on cattails in Cell 7, which caused not only lack of P uptake from this cell, but P export due to flux from decomposing litter. Further details on cattail stress in this cell are presented in the *Impacts of Long-term Deepwater Conditions on Cattail Communities* section in this chapter.

STA-1W

From 2007–2009, there was little to no change in vegetation coverage in STA-1W, Cells 2A, 5A, and 5B (Appendix 5-10, Figure 2). However, drought caused portions of Cells 1A, 1B, 2B, 3, and 4 to dry out in 2007, which led to EAV expansion in some areas. Overall, the EAV coverage in Cell 1A decreased to 59 percent from 2007–2008 and remained at the same extent in 2009. Following the 2007 drought, Cells 1B, 2B, and 4 were reflooded and SAV reestablished in the areas that dried out; since that time, SAV-OW coverage has ranged from 77 to 94 percent of the total cell areas. Cell 3, which was still undergoing conversion from EAV to SAV in 2007 and 2008, had 60 percent SAV-OW coverage at the 2008 and 2009 surveys.

STA-2

Cells 1 (EAV cell), 2 (EAV cell), and 3 (SAV cell), had consistent EAV and SAV-OW area coverage that remained constant from 2007–2009 (Appendix 5-10, Figure 3). The coverage of the EAV was 95 to 99 percent, 74 to 76 percent, and 24 to 28 percent of the treatment areas in Cells 1, 2, and 3, respectively. Dryout or low-water conditions due to drought did not appear to influence the EAV:SAV-OW coverage in Cells 1 and 2. Cell 4, which began operations in 2007, exhibited an increase in SAV-OW coverage from 28 percent to 95 percent within the first year under flooded conditions. Rapid SAV establishment in Cell 4 was due to both SAV inoculation and the use of herbicide to control EAV and FAV.

The proportion of areal coverage for EAV and SAV-OW in Cell 2 remained relatively the same during 2007–2009. However, since the date of aerial imagery in 2009, approximately 400 acres of cattails (17 percent of the total area) in this cell have been sprayed to initiate partial conversion of the southern portion into an SAV community (in accordance with a 2009 revision to the Long-term Plan). The initial plan was to spray about 300 acres of cattails, but the actual area sprayed was increased to avoid over spraying into existing sawgrass. Conducted in April 2009, spraying effectively killed the cattail, but dead litter remained standing for months. Visual inspection one year after spraying indicated little to no SAV establishment in the sprayed area, except in the northwest corner where high densities of musk grass and southern naiad were observed. Some of the sprayed cattail had also reestablished, and inoculation of SAV was planned for early WY2011.

STA-3/4

During 2007–2009, vegetation coverage in STA-3/4 remained relatively constant (Appendix 5-10, Figure 4). Cell 1B, which has been undergoing a phased conversion to SAV, had 59 to 73 percent of EAV cover during the three-year period. From December 2009–February 2010, cell-wide browning of cattails was observed in Cells 1A, 2A, and 3A, resulting in an accumulation of a large amount of standing dead biomass and litter throughout the cells (**Figure 5-49**).

Figure 5-49. Large-scale browning of cattail and accumulation of standing and dead litter observed in STA-3/4, Cell 3A, in January 2010 (photo by the SFWMD).

STA-5

Vegetation coverage in Cells 1B, 2A, and 2B remained relatively constant from 2007–2009 (Appendix 5-10, Figure 5). The EAV coverage increased from 73 to 100 percent in Cell 1A from 2008 to 2009. Cells 3A and 3B began operation in 2008. It should be noted that Cell 3B, as an SAV cell, had a relatively high coverage of EAV ranging from 80 to 93 percent in 2008–2009.

STA-6

In STA-6, Cells 3 and 5, vegetation coverage remained relatively constant from 2007–2009 (Appendix 5-10, Figure 6). In contrast, vegetation in Section 2 was dynamic, primarily due to highly uneven topography and variable hydrologic conditions. In 2007 and 2009, Section 2 was dominated by EAV with 79 to 90 percent coverage but by 2008, this cell had 40 percent EAV areal coverage and 60 percent SAV-OW.

EMERGENT AQUATIC VEGETATION MANAGEMENT MEASURES

In addition to routine vegetation management efforts (e.g., herbicide treatments of nuisance and undesirable plant species), specific measures were implemented in several cells and flow-ways to improve conditions (e.g., vegetation health and cover) for maximizing and sustaining phosphorus uptake. In this section, measures taken to actively manage the composition and spatial distribution of plant species within STA treatment cells are discussed in terms of EAV management.

STA-3/4, Cell 1B Vegetation Conversion

Conversion of STA-3/4, Cell 1B, from an EAV to SAV marsh has been implemented in incremental phases since 2005. The ongoing conversion required eliminating cattail (primarily *Typha domingensis*) and willow (*Salix caroliniana*) that covered most of the cell, and establishing one or more of the desirable SAV species [southern naiad, musk grass or pondweed (*Potamogeton illinoensis*)] for STAs. Initial conversion measures were taken in November 2005, when an herbicide was applied aerially to 650 acres of cattail and willow in the southernmost portion of the cell. The second phase of the incremental conversion was initiated in December 2007, when an aerial herbicide treatment was applied to an additional 800 acres of cattail immediately north of the first treatment area. In October–November 2008, another 400 acres of cattail were treated. The final aerial herbicide application occurred in September 2009, when 345 acres of cattail were treated in the northern end of the cell. Although emergent vegetation has been eliminated over most of the cell, linear strips of cattail have been retained to compartmentalize SAV cover. Compartmentalization with EAV provides greater resilience to SAV cells by dissipating wind and wave energy during storms and by providing an additional phosphorus uptake mechanism (functional redundancy) to complement phosphorus removal by the SAV community.

In July 2007, SAV (southern naiad and musk grass) were inoculated via helicopter at 11 sites in the southernmost section of the cell. As a result of these founder-site inoculations and subsequent natural colonization, SAV has been established and covered approximately 50 percent of Cell 1B, based on a qualitative survey in June 2010.

Emergent Aquatic Vegetation Planting and Monitoring

Even distribution of flow (i.e., sheetflow) through vegetation across and along cells is a basic assumption and requirement for phosphorus uptake performance in STAs. However, channels of variable dimensions (width, length, and depth) have developed in many cells and represent hydraulic short circuits for flow and associated phosphorus loads. These short circuits can compromise performance because they reduce contact between inflows and the phosphorus-uptake mechanisms associated with vegetated portions of the cell.

STA-1E, STA-1W and STA-5

During the 2010 dry season, efforts were undertaken to eliminate hydraulic short circuits in STA-5, Cell 1B, and STA-1E, Cell 5. The short circuit in STA-5, Cell 1B, extends through beds of hydrilla, the dominant cover in this SAV cell, and is exacerbated by gaps in existing EAV strips that extend perpendicular to flow through the cell. Plantings of giant bulrush (*Schoenoplectus californicus*), harvested from established beds in the adjacent upstream cell (Cell 1A), were done to close these gaps. This closure is expected to block the short circuit and encourage more desirable distribution of flow for water quality treatment (**Figure 5-50**).


Figure 5-50. Large-scale planting of bulrush, collected from STA-5, Cell 1A, (left) and transplanted to Cell 1B (right) to fill in the gaps in the vegetation strips, which compartmentalize the treatment cell and aid in protecting SAV from wind and wave damage.

Plantings of giant bulrush also were employed to establish treatment capabilities in large unvegetated areas in the northeastern section of STA-1W, Cell 5A, the southeastern portion of STA-1E, Cell 7, and in STA-1E, Cell 6. Widespread uprooting of hydrilla in spring 2009 severely impacted the treatment capability of Cell 6 and thereby constrained use of the Western Flow-way of this STA. Hydrilla is expected to reestablish (e.g., from buried tubers) during WY2011, but the plant has been shown to be prone to extreme temporal oscillations in density and cover. Management measures need to be implemented to alleviate the detrimental impacts of hydrilla growth cycles and susceptibility to uprooting so that more consistent water quality treatment capabilities and use of flow-ways in which it is the dominant SAV species. Compartmentalization with EAV (e.g., cattail and bulrush) is expected to buffer hydrilla beds from wind and discharge-related disturbances that can cause uprooting and will provide an additional phosphorus removal pathway. This increased compartmentalization will also facilitate management options for replacing hydrilla with more desirable and persistent SAV species.

Initial steps for more effective containment of hydrilla beds were taken in December 2009, when cattail and bulrush were planted in gaps in existing EAV strips. Further compartmentalization of STA-1E, Cell 6, was accomplished during March–May 2010 by lowering stages to facilitate additional planting and to allow for colonization of cattail seedlings. Stages were lowered to ground levels in Cell 6 by the installation of two (30 and 50 cfs) temporary pumps along the east-central perimeter of the cell, which redirected required discharge from this cell to the southwestern end of Cell 4N. These outflows from Cell 6 to Cell 4N received treatment in the Central Flow-way and mixed with other treated inflows prior to discharge (through Cell 4S) out of the STA (through S-362). Extensive plantings of bulrush were used to create new EAV strips. The slow return of water levels to target stages during the following wet season was used to provide optimal conditions for the plantings, cattail seedlings that emerged during the drawdown period, and hydrilla regrowth. There will also be attempted efforts to replace hydrilla with more desirable SAV by large-scale aerial inoculations of southern naiad in select portions of the cell.

STA-3/4, Cell 1A Cattail Rehabilitation

Frequent deepwater events in STA-3/4, Cell 1A, over the past several years have impacted the condition and associated density of the emergent cattail stand and threaten the sustainability of associated phosphorus uptake and performance pathways. A dry-season drawdown of water levels was attempted to revitalize the cattail stand by providing for seed germination and subsequent colonization of seedlings, clonal expansion, and elimination of floating tussocks.

To facilitate the drawdown, two temporary pumps were installed along the levee between Cells 1A and 1B so that Cell 1B, which is undergoing conversion from EAV to SAV, could be kept hydrated with the discharged water from Cell 1A. Pumping was initiated in late March 2010, but because of unseasonably high rainfall, stages in Cell 1A did not decline until late April. Low water levels were maintained in the southern portion of the cell through most of May but remained high in the northern end until one of the pumps was moved to the northwestern levee (i.e., to discharge from the northern end of the cell into Cell 2A) in mid-May. Relocation of the pump successfully lowered stages in the northern portion of the cell to average ground elevations (i.e., 9.2 ft) for approximately 10 days, but early wet season rainfall in June 2010 reestablished high stages throughout the cell. The effect of this brief drawdown on cattail densities will be evaluated in WY2011 utilizing randomly selected permanent plots that were initially sampled in February 2010.

STA-1E, Cell 5 Cattail Bales

STA 1E, Cell 5, is an emergent cell with a short-circuit channel along its western side, which is due to uneven cell topography; this cell was not constructed to the original design specifications. Several management measures were employed to address this short circuit. A 30 cfs pump was installed along the northwest corner of Cell 5 to lower water depths to approximately 6 inches and facilitate planting of giant bulrush throughout the short-circuit areas (approximately 60 acres were planted). The pump discharged from Cell 5 into the western distribution cell of the STA. The plantings were complemented by a pilot bio-enhancement project where bales of cattail (created from a mowed and harvested stand in the southern portion of the Compartment B Build-out) were placed at three locations across the short circuit to divert flow from the channel and newly planted bulrush (**Figure 5-51**). To further alleviate the effects of this short circuit and the topographic conditions in the cell, a berm upstream of the outflow canal at the southern end of the cell was degraded to marsh elevations at five locations (a total of approximately 600 feet of degraded berm). All of these measures are expected to provide for more even and effective sheetflow across the cell. The utility of the cattail bales in redistributing flow and blocking the short circuit will be evaluated by measurements of bulrush survival and expansion downstream of the bales.

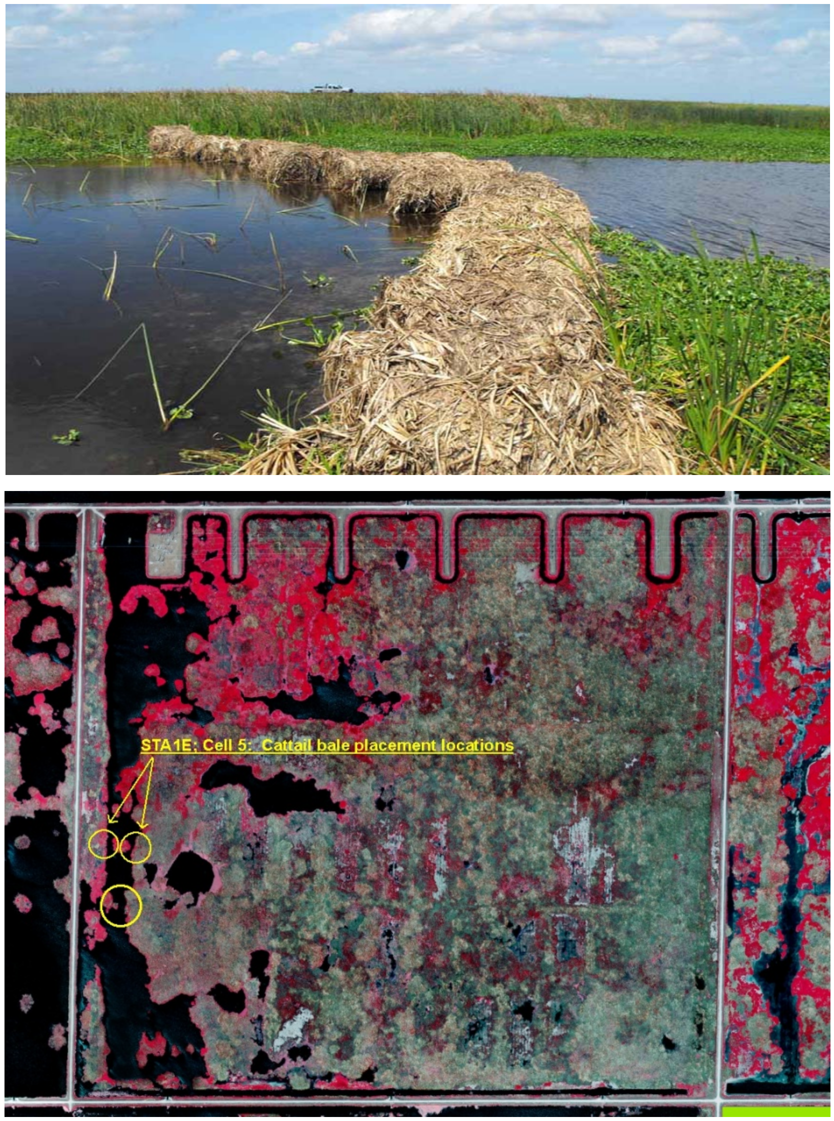


Figure 5-51. Areas in STA-1E, Cell 5, where cattail bales were placed in open water areas of the treatment cell (top) to reduce hydraulic short-circuiting and protect newly planted bulrush (bottom) (photos by the SFWMD).

STA-1E, Cell 7 Long-Term Deepwater Conditions and Cattail Communities

Long-term deepwater flooding adversely affects cattail community health and TP removal performance in the STAs. This field study is a follow-up to a previous mesocosm study (see 2010 SFER – Volume I, Chapter 5). The objective was to assess the growth and photosynthesis responses of cattail to deepwater conditions in the field to provide scientific evidence for STA vegetation management during and after storm events. Cattail communities have continuously experienced repeated and extended periods of high water depths in STA-1E, Cell 7 (**Figure 5-52**), primarily due to the fact that this cell and Cell 5 were not constructed to original design specifications and their cell elevations were uneven. Under prolonged deepwater conditions, cattail tends to separate from the base substrate and form floating mats (Chimney et al., 2000; Pietro et al., 2010). These mats can be undesirable in the STAs because of their negative impact on multiple water quality parameters.

In May 2009, 16 plots [2 meter x 4 meter (m)] were established in cattail communities within STA-1E, Cells 6 and 7, providing a wide range of hydrological conditions (water depths) for this study. Cell 6, which is predominately an SAV cell, had plots created in the northwestern corner, near a levee, and cattails there generally experienced only shallow-water condition. Cell 7, a deepwater marsh populated mostly by cattail, had high water conditions during the study. These cells together represent some of the varied conditions present throughout the STAs, making them ideal for examining the relationship between water depth and the condition of local vegetation.

Unlike the persistent deepwater condition in Cell 7, Cell 6 maintained lower water depths, particularly in three established plots. Plant density, shoot elongation, and photosynthesis were examined in each of the plots in June, August, and October 2009. Water depth data from February 1, 2005–May 25, 2010, indicated that Cell 7 experienced 837 days of water depths exceeding 2 ft and 96 days exceeding 3 ft above the average ground elevation. The Pearson Correlation test indicated that both total and adult cattail shoot densities were significantly negatively impacted by the water depth in all three survey months at a significance level of $p < 0.05$. The relationship between juvenile shoot density and water depth was not significant (**Figures 5-53** through **5-56**). Shoot elongation was significantly impacted by water depth in all three months. However, the relationship between photosynthesis and water depth was weak. These results indicate that long-term deepwater conditions of above-target-stage-depth (see the *Introduction* of this chapter for target depths) adversely affected growth and clonal reproduction of cattail in terms of shoot elongation and plant density, which is consistent with results of a previous mesocosm study (Chen et al., 2010; Pietro et al., 2010). In Cell 7, deepwater conditions created two types of cattail communities: floating cattail mats and stressed, but rooted, cattail stands (**Figure 5-57**). Floating cattail mats move with winds, scrape the base substrate below, and cause suspension of sediments and turbid waters (Chimney et al., 2000).

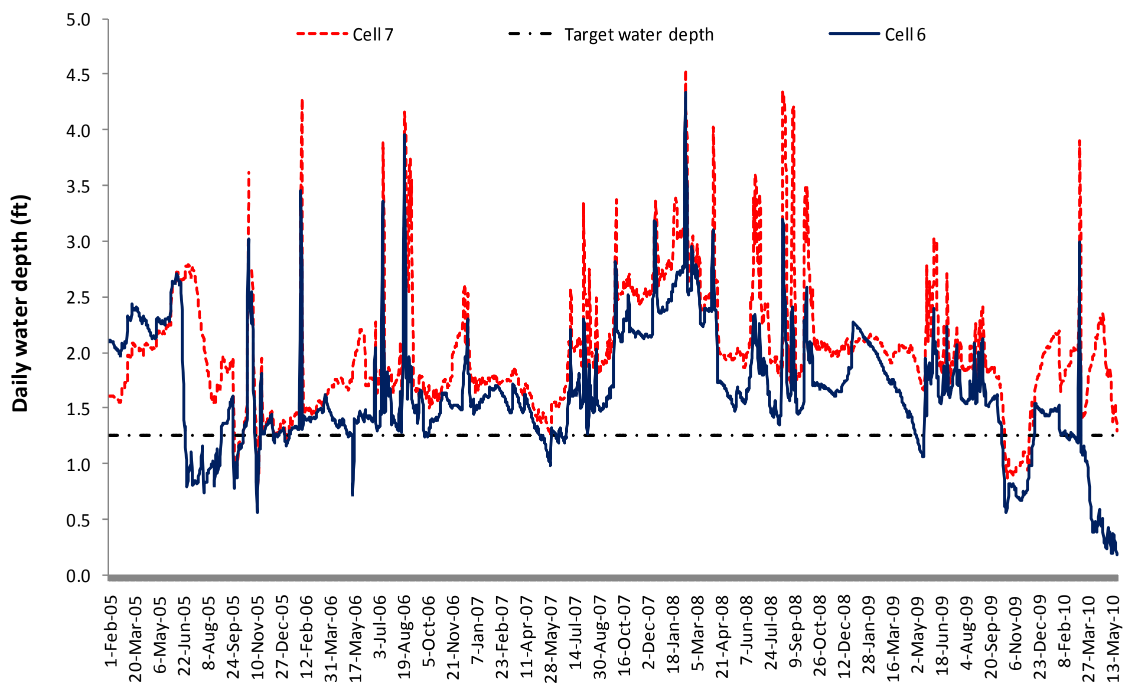


Figure 5-52. Daily water depths in STA-1E, Cells 6 and 7, (February 1, 2005–May 25, 2010).

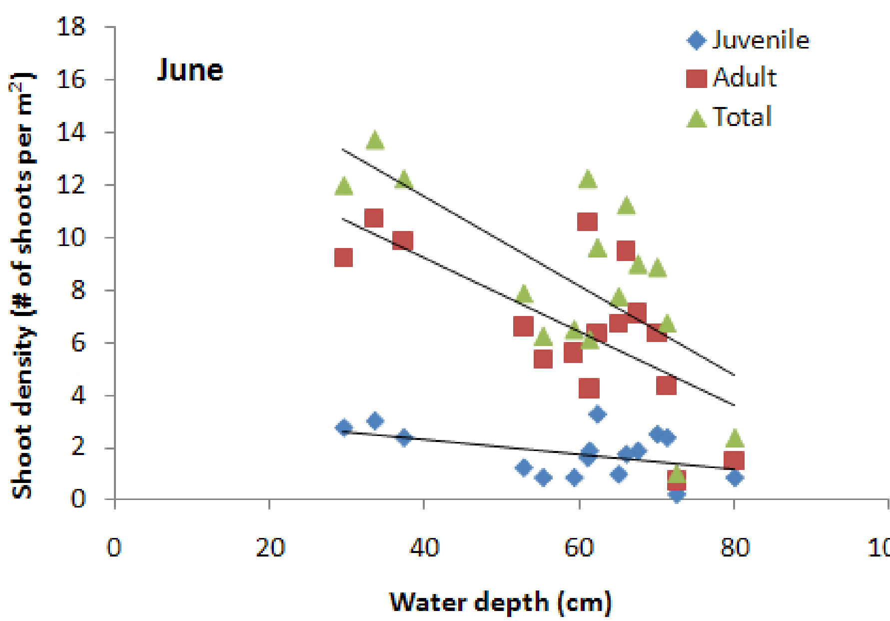


Figure 5-53. Relationship between cattail shoot density and water depth in STA-1E (June 2009). Data from both cells were lumped together to explore the relationship between varied water depths and local plant conditions.

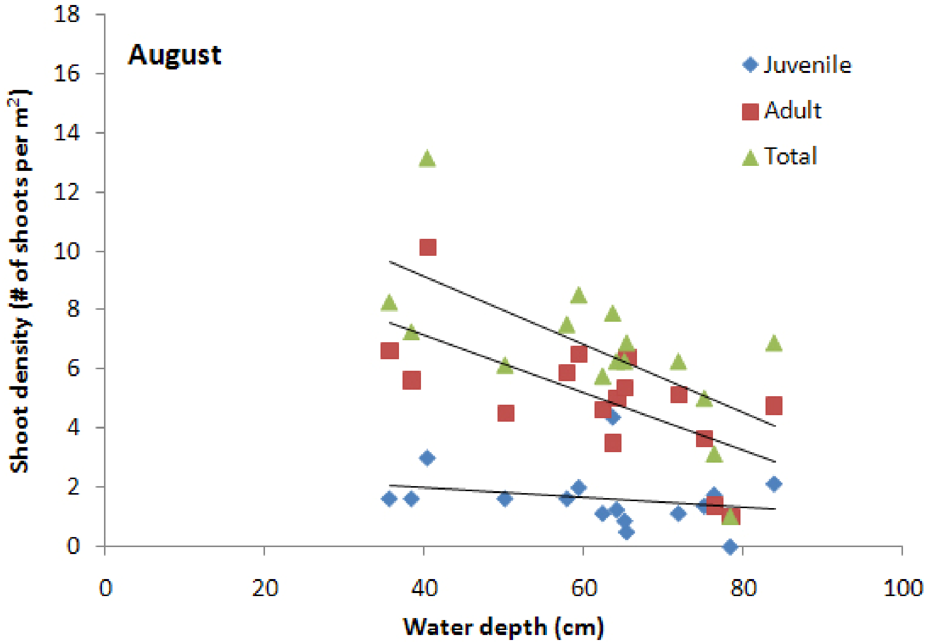


Figure 5-54. Relationship between cattail shoot density and water depth in STA-1E (August 2009).

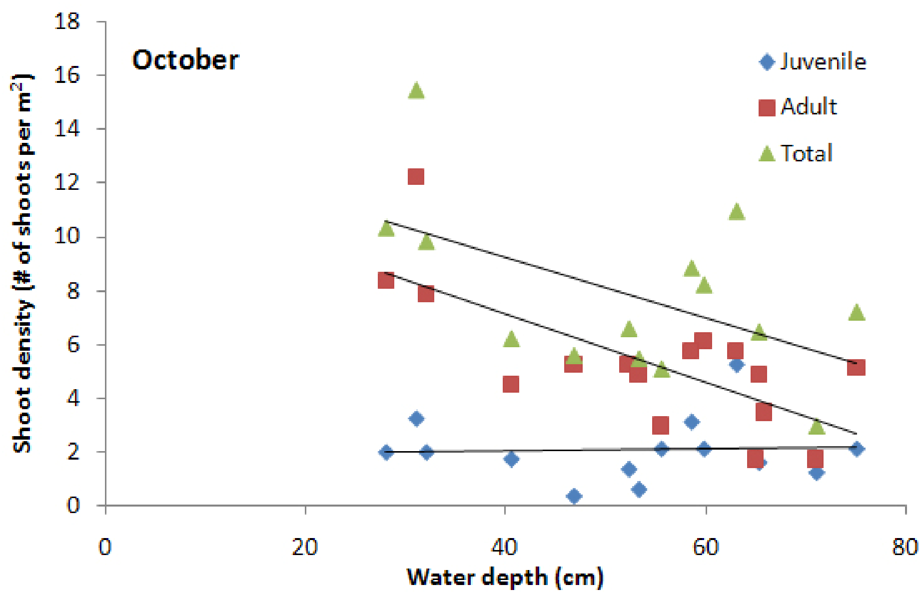


Figure 5-55. Relationship between cattail shoot density and water depth in STA-1E (October 2009).

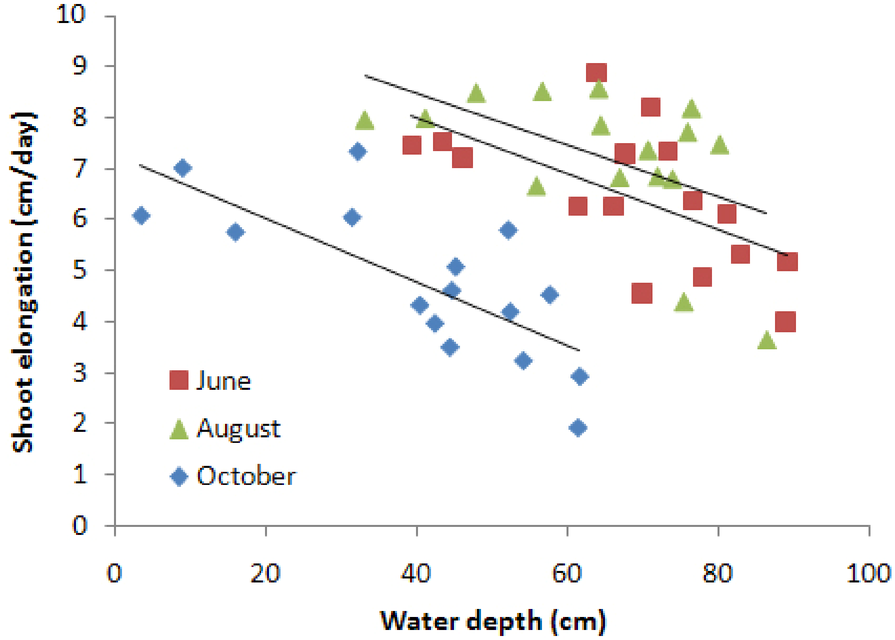


Figure 5-56. Relationship between cattail shoot elongation and water depth in STA-1E (June, August, and October 2009).

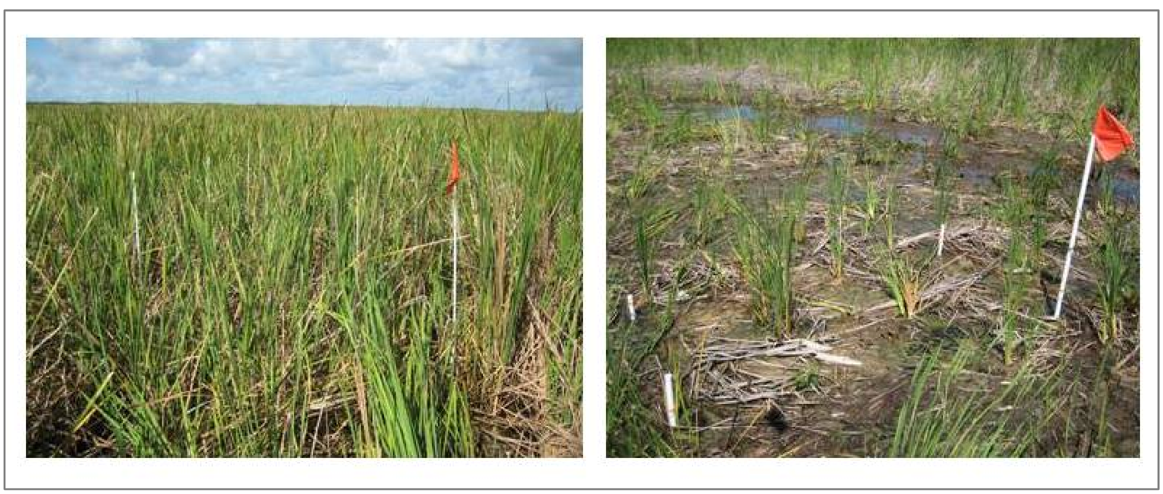


Figure 5-57. Prolonged deepwater conditions created two types of cattail communities: stressed, but rooted, cattail stands (left) and floating cattail mats (right) in STA-1E, Cell 7 (photos by the SFWMD).

STATUS OF OTHER LONG-TERM PLAN PROJECTS

UPDATE AND MAINTENANCE OF HYDRAULIC MODELS

A major effort that was completed in previous reporting periods was the development of nearly 100 new preferred datasets for flow monitoring stations located at interior STA structure monitoring sites. A preferred dataset is defined as the best available data and consists of data that have undergone post-processing quality assurance. In FY2010, there was continued use of the Weekly STA Performance Summaries (including the operational envelope values) for operational decision making in lieu of the use of two-dimensional hydraulic models. As improvements to the preferred datasets continue, data used to create the Weekly STA Performance Summaries will also improve, thereby resulting in better-informed operational decision making.

REVIEW AND CORRECTION OF FLOW MEASUREMENT ANOMALIES

The goal of this project is to address flow estimate uncertainties and to provide high quality flow data at all major flow stations in the STAs. Stream-gauging data are collected in the field for use in calibrating flow equations, and flow-rating analysis is conducted to improve computed flows, detect and correct anomalies in flow data, and estimate missing data. AutoCAD® three-dimensional configurations are prepared for the computational fluid dynamic model, which is then able to generate synthetic flow data for flow rating.

Improved flow equations have been completed and implemented in all six STAs. Theoretical flow equations for flow computation have been implemented for structures in the STAs expansion project.

Quality analysis was performed for the following stations in the STAs: G-251, G-255, G-259, G-302, G-303, G-304A-J, G-306A-J, G-308, G-309, G-310, G-311, G-328, G-329A-D, G-330A-E, G-331A-G, G-332, G-333A-E, G-334, G-335, G-337, G-342A-D, G-343, G-344A-D, G-349A&B, G-350A &B, G-352, G-354, G-357, G-370, G-371, G-372, G-373, G-374A-F, G-375A-E, G-376B, G-377A-E, G-379A-D, G-380A-F, G-381A-C & E, G-388, G-393, S-319_P, S-361_P, S-362_P, S-363A-C, S-365 A&B, S-365B_C, S-366A-E, S-369A-D, S-370A-C, S-372A-E, S-373A-B, S-375_C, and S-5A_P.

Water balance analysis was also conducted for STA-1E, STA-2, STA-3/4, STA-5, and STA-6 as needed. The flow rating improvement has been conducted for spillways and culverts, including the following STA structures: STA-1E: G-311_S; STA-1W: G-301_S, G-302_S, G-308_S, G-309_S, G-303_S, G-300_S, and S-155A_S; STA-2: G-334_S, G-332_S, and G-368; STA-3/4: G-371_S, G-373_S; G-374B-E, G-377A-E, G-381A-F, G-384, and G-375; STA-5: G-342A-F, G-344A-F, G-343I-J, and G-342A-D; and STA-6: G-396A-C and G-396A-C.

In order to minimize uncertainties in the flow data at major water control structures in the STAs, calibration of the flow-rating equations at these structures is done using stream-gauging data. However, because the opportunities to stream gauge at some of these water control structures are very limited for a variety of reasons (e.g., flow conditions, site accessibility), there may be none or few field flow measurements for certain structures. To supplement field flow measurements, Computational Fluid Dynamic (CFD) modeling is used to generate synthetic flow data for rating calibration. CFD is a high-tech fluid-flow simulation tool that can be used to generate flow data at water control structures under various operational settings. Use of hybrid datasets (i.e., field measurements and synthetic data that cover the expected range of operations for a site) leads to more accurate ratings than those that would be obtained with limited stream-gauging data. A total of 52 CFD synthetic discharge data points have been simulated for STA structures: S-364_C: 10 datasets; S-365_C: 10 datasets; G-337A: eight datasets; G-338C: eight datasets; G-333A: eight datasets; and G-259: eight datasets. In WY2010, 124 field-measured datasets underwent the quality assurance process. This effort included the following structures: G-248B_C, G-259_C, G-304I_C, G-333D_C, G-342A_C, G-342B_C, G-342C_C, G-342D_C, G-353A_C, G-375D_C, G-376B_C, G-376E_C, G-378C_C, G-379D_C, G-380B_C, G-380E_C, G-381B_C, G-381E_C, G-384C_C, G-406_C, S-367C_C, S-370A_C, S-371B_C, S-373B_C, S-374B_C, G-368_C, G-92_C, S-382_P, S-6_P, and S7_P. About 54 additional streamflow measurements were completed in early WY2011.

In total, 45 structures have been digitized and have three-dimensional configuration drawings developed. Structure configurations and photos are an important part of quality assurance post-processing, as these visual aids can help calibrating engineers determine whether a flow rating equation truly characterizes the flow through an area. The 45 structures include: G-342A, G-300, G-301, G-302, G-304A, G-305, G-308, G-309, G-343A, G-344A, S-343A, S-344, S-37B, G-119, G-327A, G-338, G-371, G-382A, S-165, S-166, S-167, S-195, S-196, S-235, S-351, S-155, S-364, S-365, S-369, S-339, S-340, S-143, S-124, and S-151.

The survey data for a total of 37 structures have undergone quality assurance performance evaluation. These structures include the following: S-366E, S-367B-E, S-368B-E, S-369B-D, S-370C, S-372A-B, G-389A, G-390A, G-382B, G-384A, S-363A, S-364A, S-365A, S-366A, S-367A, S-368A, S-369, S-370B, G-384B-F, G-389B, G-390B, S-363B-C, S-364B-C, S-365B, and S366B-C.

COMPARTMENTS B AND C BUILD-OUT STATUS

Compartment B Build-out

The Compartment B Build-out Project is located in Palm Beach County, east of U.S. Highway 27 and STA-3/4 and north and south of STA-2. The project's goal is to expand the size and enhance the performance of the existing STA-2 created as part of the Everglades Construction Project (ECP) and the Long-Term Plan.

The Compartment B Build-out Project consists of two general areas known as North Build-out (Cells 4, 5, and 6) and South Build-out (Cells 7 and 8) which includes internal treatment works, pump stations, and bridge construction. Compartment B is expected to provide approximately 6,817 acres of additional effective treatment area to STA-2. Final design of the three project pump stations (G-434, G-435, and G-436), and two project bridges were completed in the District's Fiscal Year 2009 (FY2009) (October 1, 2008–September 30, 2009). Construction of Compartment B started on June 1, 2009; construction of the three pump stations began on September 14, 2009 (G-434 & G-436), and September 17, 2009 (G-435); and construction of the two bridges started on August 16, 2010.

Construction of the North and South build-out areas is scheduled to be completed by June 2011, and construction of the pump stations is scheduled to be completed by February 2012. The District met the mandated flow-capable date of December 31, 2010. Initial operations may begin when the FDEP and USACE agency permit authorizations are completed.

On March 10, 2010, the FDEP issued a modification to the EFA permit (0126704-013) for L-6 canal modifications to convey a larger quantity of treated water from STA-2 and Compartment B to the northern portion of Water Conservation Area 2A. Subsequent permitting issues caused the District to place construction of the L-6 modifications on hold.

Compartment C Build-out

The Compartment C Build-out Project is located in Hendry County between existing STA-5 and STA-6, west of the Rotenberger Wildlife Management Area (Rotenberger WMA) and east of the L-3 canal. The Compartment C Build-out consists of construction of internal treatment works and an inflow pump station (G-508) and is expected to provide approximately 4,636 acres of additional effective treatment area.

The EFA permit for construction of Compartment C Build-out was issued on January 12, 2009. Construction of the internal treatment works is scheduled to be completed by August 2011, and construction of the G-508 inflow pump station is scheduled to be completed by March 2012. The District met the mandated flow-capable date of December 31, 2010.

Final design of a second inflow pump station (G-708) into the Rotenberger WMA has been completed. This pump station will deliver treated STA water into the Rotenberger WMA to augment the current inflow capacity provided by the existing G-410 inflow pump station. Assuming that appropriate environmental permit authorizations are issued in a timely manner, the District plans to initiate construction of G-708 in May 2011.

Looking ahead, cultural resource coordination with the Miccosukee and Seminole Tribes may cause portions of Compartment C to remain off-line. Additionally, initial operations of Compartments B and C may not be authorized due to the FDEP's legal constraint on taking agency action on the EFA and NPDES operational permits.

LITERATURE CITED

Allen, W.C., P.B. Hook, J.A. Biederman and O.R. Stein. 2002. Temperature and Wetland Plant Species Effects on Wastewater Treatment and Root Zone Oxidation. *J. Environ. Qual*., (31): 1010-1016.

Brueske, C.C. and G.W. Barrett. 1994. Effects of Vegetation and Hydrologic Load on Sedimentation Patterns in Experimental Wetland Ecosystems. *Ecol. Eng.,* (3): 429-447.

Burns and McDonnell. 2003. Long-Term Plan for Achieving Water Quality Goals in the Everglades Protection Area. Prepared for the South Florida Water Management District, West Palm Beach, FL.

Chen, H., F. Zamorano and D. Ivanoff. 2010. Effect of Flooding Depth on Growth, Biomass, Photosynthesis, and Chlorophyll Fluorescence of *Typha domingensis*. *Wetlands* (30): 957-965.

Chimney, M.J., M. Nungesser, J. Newman, K. Pietro, G. Germain, T. Lynch, G. Goforth and M.Z. Moustafa. 2000. Chapter 6: Stormwater Treatment Areas – Status of Research and Monitoring to Optimize Effectiveness of Nutrient Removal and Annual Report on Operational Compliance. In: *2000 Everglades Consolidation Report*, South Florida Water Management District, West Palm Beach, FL.

Gawlik, D.E. and T. Beck. 2010. Assessment of the Environmental Lift of Stormwater Treatment Areas on South Florida Avifauna: Phase II Long-Term Study, Deliverable 4. Submitted to the South Florida Water Management District, West Palm Beach, FL.

McAllister, L.S. 1992. Habitat Quality Assessment of Two Wetland Treatment Systems in Mississippi: A Pilot Study. PB-93-135614/XAB, ManTech Environmental Technology, Inc., Corvallis, OR.

McAllister, L.S. 1993a. Habitat Quality Assessment of Two Wetland Treatment Systems in Florida: A Pilot Study. Environmental Research Laboratory, U.S. Environmental Protection Agency, Corvallis, OR.

McAllister, L.S. 1993b. Habitat Quality Assessment of Two Wetland Treatment Systems in the Arid West: A Pilot Study. PB-93-222305/XAB, ManTech Environmental Technology, Inc., Corvallis, OR.

Pandion Systems, Inc. 2008. Avian Protection Plan for Black-necked Stilts and Burrowing Owls Nesting in the Everglades Agricultural Area Stormwater Treatment Areas. Prepared by Pandion, Gainesville, FL, for the South Florida Water Management District, West Palm Beach, FL.

Pietro, K., G. Germain, R. Bearzotti and N. Iricanin. 2010. Chapter 5: Performance and Optimization of the Everglades Stormwater Treatment Areas. In: *2010 South Florida Environmental Report – Volume I*, South Florida Water Management District, West Palm Beach, FL.

Pietro, K., G. Germain, R. Bearzotti and N. Iricanin. 2009. Chapter 5: STA Performance, Compliance and Optimization. In: *2009 South Florida Environmental Report – Volume I*, South Florida Water Management District, West Palm Beach, FL.

Pietro, K., G. Germain, R. Bearzotti and N. Iricanin. 2008. Chapter 5: STA Performance, Compliance and Optimization. In: *2008 South Florida Environmental Report – Volume I*, South Florida Water Management District, West Palm Beach, FL.

Reddy, K.R. 1983. Soluble Phosphorus Release from Organic Soils. *Agriculture, Ecosystems, and Environment*, 9:373-382.

Reddy, K.R. and W.F. DeBusk. 1985. Nutrient Removal Potential of Selected Aquatic Macrophytes. *J. Environ. Qual.,* (14): 459-462.

Reddy, K.R., M. Jerauld, R. Paudel and J. Jawitz. 2009. Comprehensive Analysis and Evaluation of Historical Data and Information for the Stormwater Treatment Areas. Report prepared by University of Florida, Wetland Biogeochemistry Laboratory, under Contract No. 4500023251 to the South Florida Water Management District, West Palm Beach, FL.

Reddy, K.R., E. Lowe, and T. Fontaine. Phosphorus in Florida's Ecosystems: Analysis of Current Issues. Reddy, K.R., G.A. O-Connor, and C.L. Schelske, eds.. 1999. In: *Phosphorus Biogeochemistry in Subtropical Ecosystems*. Lewis Publishers, Boca Raton, FL.

Reddy, K.R., and P.S.C. Rao. 1983. Nitrogen and Phosphorus Fluxes from a Flooded Organic *Soil. Soil Sci*., 136:300-307.

Weaver, K. and G. Payne. 2004. Chapter 2A: Status of Water Quality in the Everglades Protection Area. In: *2004 Everglades Consolidated Report*, South Florida Water Management District, West Palm Beach, FL.

Weaver, K., G. Payne and S.K. Xue. 2008. Chapter 3A: Status of Water Quality in the Everglades Protection Area. In: *2008 South Florida Environmental Report – Volume I*, South Florida Water Management District, West Palm Beach, FL.

Wetzel, R.G., 1990. Land-Water Interfaces: Metabolic and Limnological Regulators (Edgardo Baldi Memorial Lecture). *Ver. Int. Ver. Limnol.,* (24): 6-24.