Chapter 5B: Performance of the Everglades Stormwater Treatment Areas

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SUMMARY

As part of Everglades restoration, the construction and operation of large freshwater treatment wetlands, known as the Everglades Stormwater Treatment Areas (STAs), are mandated by the Everglades Forever Act (EFA) (Section 373.4592, Florida Statutes). The Everglades STAs [STA-1 East (STA-1E), STA-1 West (STA-1W), STA-2, STA-3/4 and STA-5/6] were built south of Lake Okeechobee to reduce total phosphorus (TP) concentration in surface water runoff prior to discharging this water into the Everglades Protection Area (EPA) (**Figure 5B-1**). The STAs are managed by the South Florida Water Management District (District or SFWMD). The total area of the STAs, including infrastructure components, is roughly 68,000 acres, with approximately 57,000 acres of effective treatment area currently permitted to operate including recently completed treatment cells in Compartments B and C. This chapter and related appendices (Appendices 5B-1 through 5B-3 of this volume) summarize short- and long-term STA treatment performance, conditions relevant to STA treatment performance, facility status, operational challenges, and enhancements made during Water Year 2013 (WY2013) (May 1, 2012–April 30, 2013). A detailed analysis of annual STA treatment performance in terms of permit compliance is reported in Volume III, Appendix 3-1. A status update on implementing the Long-Term Plan for Achieving Water Quality Goals in the Everglades Protection Area (Long-Term Plan) (Burns and McDonnell, 2003) is covered in Appendix 5B-4 of this volume. More information about the STAs is available at www.sfwmd.gov/sta. Highlights from this chapter are presented below.

- Over their combined operational histories, the STAs have treated approximately 13,400,000 ac-ft of water (~ 4 cubic miles) and retained 1,727 metric tons (mt) of total phosphorus (TP) with a 74 percent TP load reduction. The overall outflow flow-weighted mean (FWM) TP concentration from these treatment wetlands has been 37 micrograms per liter (µg/L) [or parts per billion (ppb)].

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- The STAs during WY2013 treated a combined 1,160,000 ac-ft of water and retained 166 mt of TP, which equated to an 84 percent TP load reduction and produced an outflow FWM TP concentration of 21 ppb. This was the highest combined annual TP load reduction achieved to date and one of the lowest combined annual outflow FWM TP concentrations.
- STA-3/4 over its 10-year operational history has treated the most runoff (~4,200,000 ac-ft), retained the most TP load (493 mt), achieved the highest % TP load retained (84 percent), and discharged water at the lowest outflow FWM TP concentration (17 ppb) of all the STAs.
- The outflow FWM TP concentrations for individual STAs in WY2013 ranged from 14 (STA-3/4) to 36 ppb (STA-1W), while the percent TP load retained ranged from 78 (STA-2) to 90 percent (STA-5/6).
- The Eastern Flow-way in STA-1E, Flow-ways 4 and 5 in STA-2, and Flow-ways 4, 5, 6, and 7 in STA-5/6 were offline for at least part of WY2013. In addition, all the flow-ways in STA-1E, the Eastern Flow-way in STA-1W, and the Central Flow-way in STA-3/4 were online with restrictions for at least part of the year.
- With the completion of construction of Compartment C in mid-2012, the original footprints of STA-5 and STA-6 have been combined with Compartment C into an integrated facility, currently known as STA-5/6. Construction of Compartment B also was completed in WY2013, which has substantially increased the effective treatment area of STA-2.
- Bird surveys were conducted in all the STAs during the 2012 and 2013 nesting seasons to document the presence of nesting black-necked stilts (*Himantopus mexicanus*) as required under the District's Avian Protection Plan. Utilizing the survey results, operational priorities were adjusted in STA-1E, STA-1W, the PSTA Cell in STA-3/4, and STA-5/6 to avoid flooding active nests. Bird survey results are summarized in Appendix 5B-2.
- Everglade snail kites (*Rostrhamus sociabilis*), an endangered species, were found nesting in STA-1E Cells 2 and 4N this year. Operation of STA-1E and STA-1W was adjusted to avoid disturbing the nests.
- High hydraulic and TP loads associated with runoff from Tropical Storm Isaac in August 2012 affected all STAs, except STA-5/6, to some degree; STA-1E was the most impacted facility. The record volume of runoff exceeded the treatment capacity of STA-1E and STA-1W, forcing the District to divert some water directly into Water Conservation Area 1A.
- With the exception of cells in STA-5/6 and the Eastern Flow-way of STA-1E, all the other STAs were kept fully hydrated this year and did not dry out. STA-5/6 Cells 5-1A, 5-2A, 5-3A, 5-3B, 6-3, and 6-5 went dry for some period at the start of WY2013. The spike in weekly outflow TP concentrations after these cells were reflooded ranged from 43 ppb in Cell 5-3A to 423 ppb in Cell 5-2A.

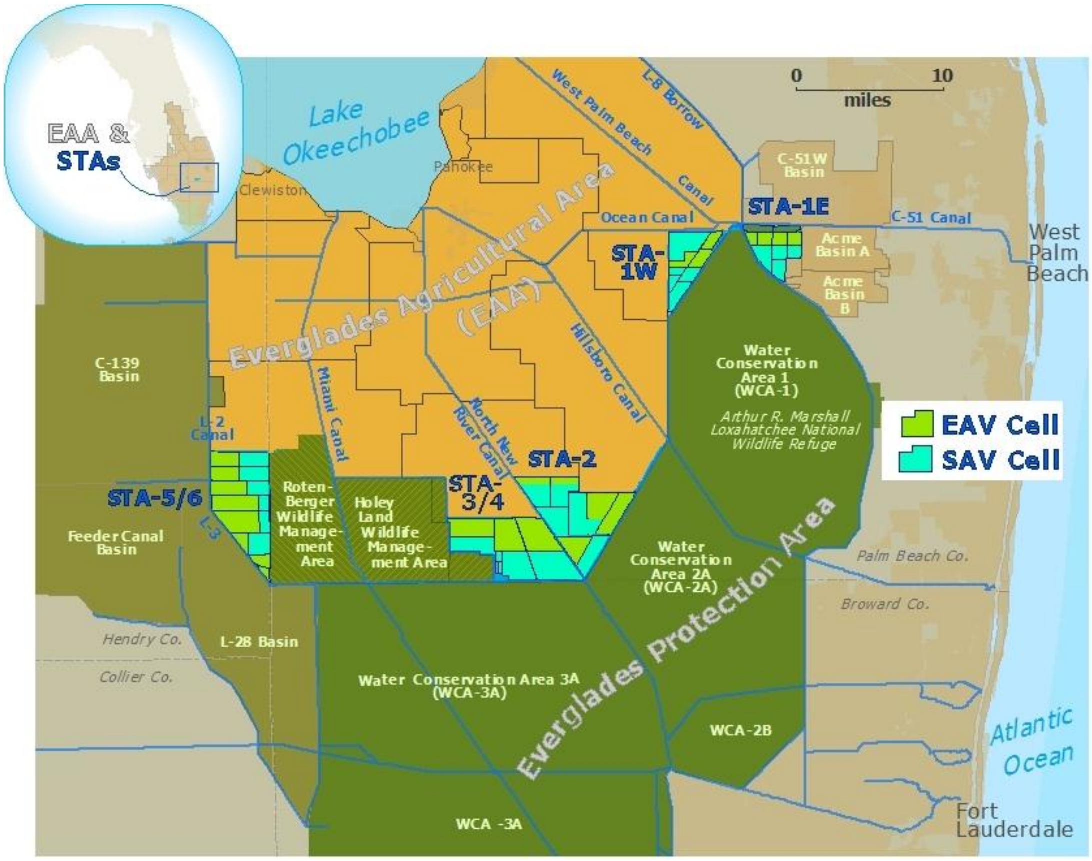


Figure 5B-1. Location of the Everglades Stormwater Treatment Areas (STAs) 1 East (1E), 1 West (1W), 2, 3/4, and 5/6 in relation to the Everglades Protection Area, the dominant STA vegetation communities [emergent vegetation (EAV) or submerged aquatic vegetation (SAV)] in the STAs, and major drainage basins south of Lake Okeechobee.

INTRODUCTION

As a major component of Everglades restoration, the Everglades Stormwater Treatment Areas (STAs) were built and operated to reduce total phosphorus (TP) concentration in surface water runoff prior to these waters entering the Everglades Protection Area (EPA). STAs are constructed wetlands that retain nutrients through plant and microbial nutrient uptake, particulate settling, chemical sorption, and ultimately accretion of plant and microbial biomass to the sediments. This chapter describes the treatment performance and condition of the Everglades STAs (STA-1E, STA-1W, STA-2, STA-3/4, and STA-5/6, respectively; **Figure 5B-1** and Appendix 5B-1 of this volume) and the operational challenges related to treatment performance of entire STAs and individual flow-ways within each STA. The South Florida Water Management District (District or SFWMD) operates all the STAs, while the United States Army Corps of Engineers (USACE) continues to be responsible for structural maintenance and repairs in STA-1E.

Varying in size, configuration, and length of operation, the STAs are shallow freshwater marshes divided into cells by interior levees (Appendix 5B-1). Water flows through these systems via water control structures, such as pump stations, gates, and culverts. The plant communities in the STA cells have three categories of plants based on their growth habit: emergent aquatic vegetation (EAV), submerged aquatic vegetation (SAV), and floating aquatic vegetation (FAV). While all cells contain a mixture of these vegetation types, cells differ as to their dominant community, i.e., cells are classified as either SAV or EAV-dominated. Periphyton (i.e., communities of attached algae and other microbes growing on substrates in aquatic systems) is ubiquitous throughout the STAs.

STA treatment performance, which has varied temporally in each STA and spatially among STAs, is influenced by factors such as weather conditions, antecedent land use, nutrient and hydraulic loading, vegetation condition, soil type, cell topography, hydropattern (continuously flooded versus periodic dryout), maintenance and enhancement activities, and regional flood-control operations. The District uses an adaptive approach to manage the STAs based on weekly evaluation of interior stage (i.e., water levels), outflow TP concentrations, hydraulic and TP loading, vegetation condition, and any operation restrictions related to wildlife.

This chapter includes assessments of each STA and individual flow-way treatment performance, information on STA operational status, maintenance activities and enhancements, and updates on applied scientific studies relevant to the STAs. Supporting information on protected birds in the STAs during the 2012 and 2013 nesting seasons and on EAV and SAV coverage in the STAs is presented in Appendices 5B-2 and 5B-3 of this volume, respectively. Discussion of recreational facilities and activities and implementation of the Long-Term Plan for Achieving Water Quality Goals in the Everglades Protection Area, which was included in this chapter in previous *South Florida Environmental Reports* (SFER) is now available in Volume II, Chapter 6B, and Appendix 5B-4 of this volume, respectively. Details on the District's Restoration Strategies Program and Science Plan for the Everglades STAs are provided in Chapters 5A and 5C, respectively, of this volume.

OVERVIEW OF WATER YEAR 2013 STA TREATMENT PERFORMANCE

The STAs over their combined operational history have treated approximately 13,500,000 acre-feet (ac-ft) of water (~ 4 cubic miles) and retained 1,727 metric tons (mt) of TP or 74 percent of the TP load that entered these facilities. The period of record (POR) inflow flow-weighted mean (FWM) TP concentration for all the STAs was 140 micrograms per liter (µg/L) [or parts per billion (ppb)], while the POR outflow FWM TP concentration was 37 ppb (**Table 5B-1**).

All the STAs received a combined 1,160,000 ac-ft of inflow and retained 166 mt of TP (**Table 5B-1**) during the past water year. There was a decrease from inflow to outflow in FWM TP concentration (138 to 21 ppb, respectively), which represented an 84 percent reduction in the total TP load that entered the STAs. This was the highest annual TP load reduction recorded in the STAs to date and one of the lowest annual outflow FWM TP concentrations (**Figure 5B-2**, panel C). The combined water and TP loads received by the STAs this year were comparable in magnitude to inflow loads in past water years (**Figure 5B-2**, panels A and C). Significant linear relationships were detected between annual inflow and outflow FWM TP concentrations and annual inflow and outflow TP loads (coefficients of determination, R^2 = 0.63 and 0.87, respectively; see regression lines in **Figure 5B-2**, panels B and D).

STA-2, STA-3/4, and STA-5/6 all had annual outflow FWM TP concentrations less than 23 ppb in WY2013, while annual outflow FWM TP concentrations in STA-1E and STA-1W were 26 and 36 ppb, respectively (**Figure 5B-3**, panel B). STA-3/4 received the largest water and TP loads this year and STA-5/6 received the lowest (**Figure 5B-3**, panels A and C). The hydraulic loading rates (HLR) in all the STAs during WY2013 were greater than 2 cm/day except for STA-5/6, which had a HLR of only 0.6 cm/day (**Figure 5B-3**, panel E). The corresponding P loading rates (PLR) were ~ 2 $g/m^2/yr$ in STA-1E and STA-1W, ~ 1 $g/m^2/yr$ in STA-2 and STA-3/4, and only 0.3 $g/m^2/yr$ in STA-5/6. The TP removal coefficient, the k value, was greater than 15 m/yr in all STAs except for STA-5/6, which had a k value of only 3.8 m/yr (**Figure 5B-3**, panel D). It should be noted that STA-5/6 was the only STA in which cells dried out during WY2013. The treatment performance in the STAs described above was achieved despite the fact that several flow-ways were offline or under restricted operation during the water year (**Table 5-2**).

Table 5B-1. Summary of treatment performance of each STA and all STAs combined for Water Year 2013 (WY2013) (May 1, 2012–April 30, 2013) and the period of record (WY1994–WY2013) for each STA and all STAs combined.

Parameter	STA-1E	STA-1W	STA-2	STA-3/4[a]	STA-5/6	All STAs
Effective Treatment Area (acres)	4,994	6,544	15,495	16,327	13,685	57,045
Adjusted Effective Treatment Area (acres)[b]	4,265	6,544	10,152	16,327	8,383	45,671
WY2013 Inflow						
Inflow Water Volume (ac-ft)	134,822	166,113	321,477	479,761	58,773	1,160,945
Inflow TP Load (mt)	34.4	50.1	42.1	62.1	9.5	198.3
Flow-weighted Mean Inflow TP (ppb)	207	245	106	105	131	138
Hydraulic Loading Rate (HLR) (cm/d)	2.6	2.1	2.6	2.5	0.6	2.1
TP Loading Rate (PLR) ($g/m^2/yr$)	2.0	1.9	1.0	0.9	0.3	1.1
WY2013 Outflow						
Outflow Water Volume (ac-ft)	141,185	194,829	327,430	500,655	42,711	1,206,810
Outflow TP Load (mt)	4.5	8.5	9.1	8.9	0.9	31.9
Flow-weighted Mean Outflow TP (ppb)	26	36	22	14	17	21
Hydraulic Residence Time (d)	5.7	24.1	16.4	21.2	47.8	--
TP Retained (mt)	29.8	41.6	33.0	53.3	8.6	166.2
TP Removal Rate ($g/m^2/yr$)	1.7	1.6	0.8	0.8	0.3	0.9
TP Load Retained (%)	87%	83%	78%	86%	90%	84%
Period of Record						
Start Date	Sep 2004	Oct 1993	Jun 1999	Oct 2003	Dec 1997	WY1994-WY2013
Inflow Water Volume (ac-ft)	782,893	3,423,046	3,085,727	4,199,322	1,972,996	13,463,984
Flow-weighted Mean Inflow TP [1 SD][c] (ppb)	179 [54]	175 [56]	103 [38]	113 [29]	179 [59]	140[25]
TP Inflow Load (mt)	173.0	739.0	391.8	583.7	435.6	2323.2
TP Retained (mt)	124.5	521.5	301.9	493.1	286.0	1727.1
TP Load Retained (%)	72%	71%	77%	84%	66%	74%
Flow-weighted Mean Outflow TP [1 SD] (ppb)	52 [115]	50 [31]	22 [9]	17 [4]	74 [40]	37 [13]

[a] Excludes outflow from G-388.
[b] Adjusted effective treatment area is time and area-weighted to exclude cells that were are temporarily off-line for plant rehabilitation, infrastructure repairs, or Long-Term Plan enhancements (refer to **Table 5B-2**).
[c] SD =standard deviation

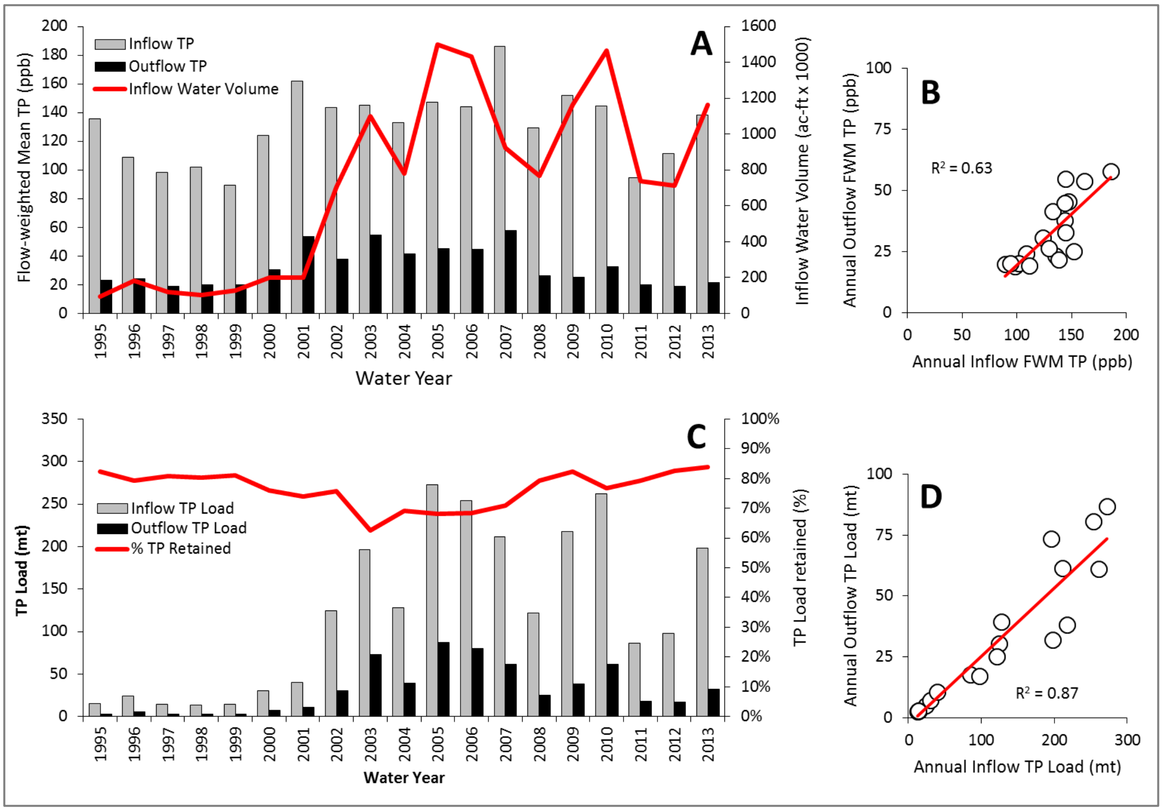


Figure 5B-2. Comparison over the period of record in all the STAs combined of (A) time-series of annual inflow and outflow flow-weighted mean (FWM) total phosphorus (TP) concentrations with corresponding inflow water volumes, (B) scatterplot of annual inflow versus outflow FWM TP concentrations, (C) time-series of annual inflow and outflow TP loads with percent TP load retained, and (D) scatterplot of annual inflow versus outflow TP loads.

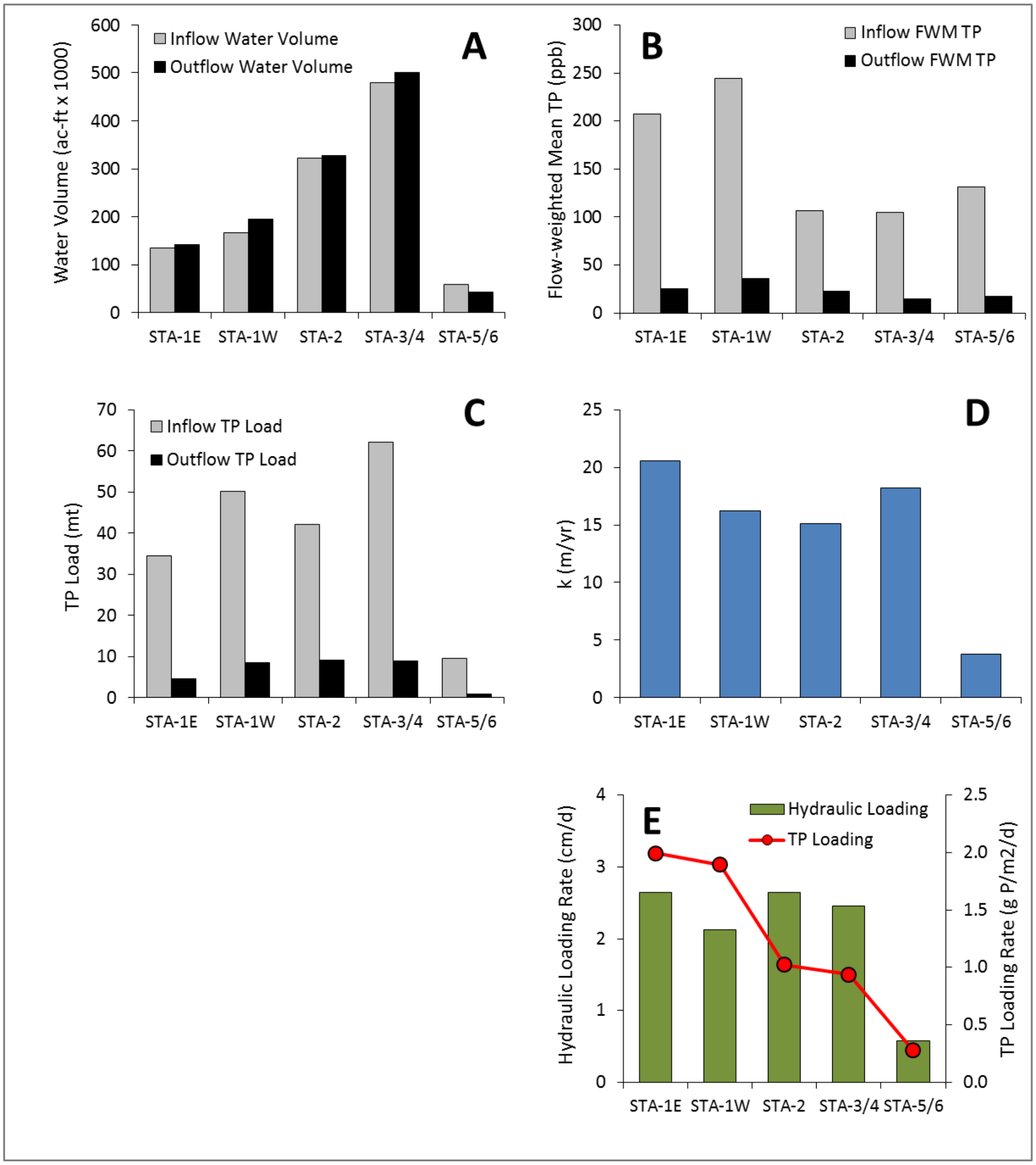


Figure 5B-3. Comparison of (A) inflow and outflow water volumes, (B) inflow and outflow FMM TP concentrations, (C) inflow and outflow TP loads, (D) TP removal coefficients (k values), and (E) hydraulic and TP loading rates during WY2013 in the STAs.

FLOW-WAY OPERATIONAL STATUS

Operation of a flow-way may be suspended entirely in response to environmental conditions that may adversely affect P uptake, allow for construction, or rehabilitation activities (operational status: offline) or be restricted to use only during emergencies, e.g., large storm events, (operational status: online with restrictions) based on environmental or vegetation conditions that may adversely affect P uptake or to allow for construction or rehabilitation activities. The treatment performance summarized in this chapter was achieved despite the fact that a least one flow-way in each STA was offline or under restricted operation during WY2013. The Eastern Flow-way in STA-1E, Flow-ways 4 and 5 in STA-2, and Flow-ways 4, 5, 6, and 7 in STA-5/6 were offline for at least part of the year (**Table 5B-2**). In addition, all the flow-ways in STA-1E, the Eastern Flow-way in STA-1W, and the Central Flow-way in STA-3/4 were online with restrictions for at least part of the year. Details of operational status of each flow-way are included under the individual STA sections within this chapter.

ADJUSTMENT OF THE EFFECTIVE TREATMENT AREA VALUES

Effective treatment area values were used to calculate the treatment performance data shown in **Table 5B-1**, specifically for the following parameters that are reported in this chapter:

- Hydraulic loading late (HLR)
- Phosphorus loading rate (PLR)
- TP removal rate

Effective treatment areas in WY2013 were adjusted using to the following equation based on the operational period of each flow-way (**Table 5B-2**):

$$Adjusted\ Effective\ Treatment\ Area = Total\ Area \times \frac{\sum_{1}^{365} Daily\ Online\ Percentage}{365} \tag{1}$$

Effective treatment areas were adjusted for STA-1E (the Eastern Flow-way was offline from October 2, 2012 to April 30, 2013), STA-2 (Flow-way 4 was offline from May 1, 2012 to September 20, 2012; Flow-way 5 was offline the entire water year), and STA-5/6 (Flow-way 4 was offline from May 1, 2012 to December 18, 2012; Flow-way 5 was offline the entire water year; Flow-way 6 was offline from May 1, 2012 to December 18, 2012; Flow-way 7 was offline from April 11, 2012 to October 1, 2012).

CALCULATION OF ANNUAL LOADS AND FLOW-WEIGHTED MEAN CONCENTRATIONS

TP loads and FWM TP concentrations were calculated based on surface water inflow to and outflow from the STAs and STA flow-ways over the entire water year as follows:

$$Load = \sum_{1}^{n}(C_i V_i + C_{i+1} V_{i+1} + \dots\ C_{i+n} V_{i+n}) \tag{2}$$

$$FWM\ Conc. = Load / \sum_{1}^{n}(V_i + V_{i+1} + \dots\ V_{i+n}) \tag{3}$$

where:

C_i = TP concentration for the i^{th} sampling interval during the water year (g/m^3);
V_i = Water volume for the i^{th} sampling interval during the water year (m^3).

VEGETATION MANAGEMENT

Vegetation management in the STAs includes herbicide applications to control undesired FAV, SAV, and emergent herbaceous and woody species. Controlling FAV, such as water lettuce

(*Pistia stratiotes*) and water hyacinth (*Eichhornia crassipes*), is necessary, particularly in SAV cells, where FAV can form dense beds that shade out the SAV species underneath. Dense FAV also can impede flow through cells. Woody species, such as primrose willow (*Ludwigia* spp.), are controlled because they tend to displace cattail (*Typha* spp.) and do not provide the same level of P removal as cattail or sawgrass (*Cladium jamaicense*). The District uses U.S. Environmental Protection Agency-registered herbicides applied by licensed applicators at the dosages recommended by the manufactures. None of these products bioaccumulates and none are restricted category herbicides. While these products are certainly toxic to plants, toxicity is negligible to non-plant organisms at the application rates used in the STAs and elsewhere throughout the District. The District's vegetation management program is regulated by the Florida Department of Protection and fully complies with our NPDES operating permit regulations. An accounting of herbicide application rates and quantities used, the acreage treated in each STA, and the species targeted during WY2013 are provided in Volume III, Appendix 3-1, Attachment E.

Vegetation management also includes planting EAV, primarily giant bulrush (*Schoenoplectus californicus*), and inoculations of SAV, such as southern naiad (*Najas quadalupensis*) and muskgrass (*Chara* sp.). Giant bulrush was planted to eliminate hydraulic short-circuits, buffer other plants from uprooting caused by high wind and discharge events, or provide plant cover at locations where the water is too deep for sustained growth of cattail. In EAV cells, the most desired species are cattail (*T. latifolia* and *T. domingensis*), giant bulrush, and sawgrass. Other desirable native species that thrive in certain areas of the STAs are arrowhead (*Sagittaria latifolia*), duck potato (*S. lancifolia*), and spikerush (*Eleocharis* sp.). In SAV cells, the most desired species are coontail (*Ceratophyllum demersum*), muskgrass, pondweed (*Potamogeton illinoensis*), and southern naiad. Another species commonly found in the STAs is hydrilla (*Hydrilla verticillata*); however, despite this species' ability to remove P, it is not a desired species due to its tendency for sudden population crashes. Hydrilla, which thrives in areas of high water column TP concentrations, was the dominant SAV species in STA-1E and STA-5/6 during WY2013.

VEGETATION SURVEYS

The areal coverage of EAV and SAV + open-water was estimated based on analysis of digital imagery captured for each STA (see method description in Appendix 5B-3 of this volume). Vegetation coverage from imagery taken in April 2012 is presented in this chapter and compared with areal coverage in April 2011. Changes in areal coverage are presented as the gain or loss of EAV coverage between years. Because there were only two vegetation classes in these analyses, the percent positive or negative change in EAV coverage would be balanced by the opposite percent change in SAV coverage. Vegetation coverage maps for each STA are provided in Appendix 5B-3 of this volume. The image resolution and mapping units used for vegetation mapping were 1 ft. Note that the areal coverage values derived in these analyses are not estimates of relative abundance. Change in the vegetation community is described relative to the gain or loss of EAV and the desired vegetation type (EAV or SAV). An increase in EAV (i.e., a + percent change in EAV coverage) is regarded as a positive change in an EAV cell and a negative change in an SAV cell, whereas a decrease in EAV (i.e., a - percent change in EAV coverage) is regarded as a negative change in an EAV cell and a positive change in an SAV cell.

Ground surveys were conducted by airboat within SAV cells on a periodic basis to map the distribution of SAV species. Assessments were made at a network of fixed geo-referenced sites established within each cell where the relative abundance of each SAV species was assessed by visual inspection using a 4 or 6-point ordinal scale.

Table 5B-2. Operational status of STA flow-ways and effective treatment area adjustments for WY2013.

STA	Flow-way	Effective Treatment Area (acres)	Offline (OFF) or Online with Restriction (ONR) Schedule	Comments	% Time Online	Adjusted Effective Treatment Area (acres)
STA-1E	Entire STA	4,994			85.4	4,265
	Eastern FW	1,082	ONR: 05/29/2012 to 08/06/202: OFF: 10/02/2012 to 04/30/2013	Berm removed PSTA Demonstration Project removal	32.6	
	Central FW	1,939	ONR: WY2013	Structural repairs (USACE)	100	
	Western FW	1,973	ONR: WY2013	Structural repairs (USACE)	100	
STA-1W	Entire STA	6,544			100	6,544
	Eastern FW	2,171	ONR: 04/15/2012 to 05/10/2012	Bulrush planting in Cell 1A	100	
	Western FW	1,369			100	
	Northern FW	3,004			100	
STA-2	Entire STA	15,494			65.4	10,152
	Flow-way 1	1,840			100	
	Flow-way 2	2,373			100	
	Flow-way 3	2,296			100	
	Flow-way 4	5,990	OFF: 05/01/2012 to 09/20/2012	Passed start-up criteria on 09/21/2012	60.8	
	Flow-way 5	2,995	OFF: all WY2013		0	
STA-3/4	Entire STA	16,324			100	16,327
	Eastern FW	6,476			100	
	Central FW	5,349	ONR: 01/29/2013 to 07/08/2013	Cattail planting	100	
	Western FW	4,502			100	
STA-5/6	Entire STA	13,685			61.3	8,383
	Flow-way 1	2,418			100	
	Flow-way 2	2,068			100	
	Flow-way 3	1,922			100	
	Flow-way 4	1,871	OFF: 05/01/2012 to 12/18/2012	Passed start-up criteria on 12/19/2012	36.4	
	Flow-way 5	2,642	OFF: all WY2013		0	
	Flow-way 6	1,900	OFF: 05/01/2012 to 12/18/2012	Passed start-up criteria on 12/19/2012	36.4	
	Flow-way 7	621	OFF: 04/11/2012 to 10/01/2012	Redundant levee removed	57.8	
	Flow-way 8	242			100	

DRYOUT IMPACTS

One of the challenges in managing the STAs is dealing with periodic dryout. During the region's dry season, particularly during prolonged droughts, portions of or entire STA cells can dry out. This is especially problematic for cells that have a higher ground elevation than surrounding areas (seepage loss issues) and cells that are not capable of receiving supplemental water to keep them hydrated. Dryout is known to affect STA treatment performance and the health of their vegetation communities, as well as encourage bird nesting that can result in conflicts with the operation of flow-ways. Dry conditions promote the rapid oxidation of soil organic matter and subsequent reflooding results in outflow P spikes due to the flux of mineralized soil P to the water column (Bostic and White, 2007; DeBusk and Reddy, 2003; Martin et al., 1996). The impact of dryout on outflow TP concentrations from the STAs is influenced by factors such as the extent and duration of dry conditions, soil characteristics, type of vegetation, and the lag time between reflooding and cell discharge following the dryout. Operational experience indicates that brief dryout periods in peat-based STA cells usually do not result in large outflow TP spikes, likely due to the ability of the peat material to retain water within the soil matrix. However, in areas where the substrate has a higher mineral content, such as the soil found in STA-5/6, the upper soil column dries out much more quickly upon loss of surface water and is prone to fluxing soil P upon rewetting. The impact of annual cycles of dryout and reflooding in Cells 6-3 and 6-5 of STA-5/6 has been discussed in detail in the 2010 SFER – Volume I, Chapter 5 (Pietro et al., 2010).

While prolonged dryout conditions in SAV cells can be detrimental to the plant community, dryout in EAV cells for short periods does not appear to have negative impacts and actually may benefit the plant community. For example, managed water-level drawdowns have been effective in encouraging recruitment of new of cattail in STA-3/4. Extended periods of dryout, however, have visibly affected EAV communities causing die-off of wetland vegetation and invasion of terrestrial plants. When dried cells are rehydrated, EAV generally recovers more quickly than SAV. Operation plans for the STAs set the minimum target stages in EAV and SAV cells during drought conditions at 6 inches below and 6 inches above the average ground elevation, respectively.

The District has implemented a Drought Contingency Plan (DCP) since 2008 to minimize dryout during periods of drought (SFWMD, 2008). When dry conditions are anticipated, the DCP provides guidance regarding raising cell target stages before the end of the wet season to increase storage volume in SAV cells, the use of temporary pumps to deliver water to the STAs from nearby sources when available, and the delivery of supplemental water when available from Lake Okeechobee to the STAs. The DCP prioritizes hydration of SAV cells over EAV cells to minimize impact to the SAV community. The DCP is reviewed annually and lessons learned from previous years are incorporated into the plan for use during future droughts. Flow Equalization Basins (FEBs), scheduled to be constructed as part of the Restoration Strategies Program, are anticipated to increase the supply of water for the STAs during the dry season. The FEBs also may allow the District to hold water longer in the STAs at the onset of the wet season without discharging from flow-ways that have dried out and therefore allow more of the flux of soil P to be reassimilated before water is released.

South Florida received a normal amount of rainfall for the region in WY2013. Supplemental water was provided to SAV cells in STA-1E, STA-1W, STA-2, and STA-5/6 during the dry season. These water deliveries and timely dry-season rainfall events were sufficient to keep all the STAs, with the exception of STA-5/6, hydrated throughout the year. Some cells in STA-5/6 did dry out this year; additional details are provided in the *STA-5/6* section of the chapter.

IMPACTS OF MIGRATORY BIRD AND SNAIL KITE NESTING

The District, in cooperation with the U.S. Fish and Wildlife Service (USFWS), finalized an Avian Protection Plan (APP) in 2008 for the Everglades STAs focusing on black-necked stilts (*Himantopus mexicanus*) and Florida burrowing owls (*Athene cunicularia floridana*) (Pandion Systems, 2008). These two species are afforded protected status under the Migratory Bird Treaty Act (MBTA) of 1918. Additional protected status has been given to the burrowing owl since it is also listed as a species of special concern in the state of Florida. The APP provides the District with a framework to modify STA operations to minimize impacts to active nests of either species. This is accomplished by diverting water around cells with nests or regulating inflow to these cells to avoid raising water levels and flooding nests[4]. Although the District is committed to mortality reduction measures, there may be situations where bird mortality is unavoidable as the District fulfills its flood control and water quality responsibilities. Specifically, during storm events, the District seeks to minimize sending untreated water directly to the Water Conservation Areas (WCAs). Operation of the STAs at these times may result in the inadvertent taking of migratory birds or nests. Standardized black-necked stilt nesting surveys were conducted in all the STAs from May–June 2012 and April–July 2013[5] following protocols outlined in the APP. Survey results are summarized in each STA section of this chapter and reported in more detail in Appendix 5B-2 of this volume. No active burrowing owl nests were observed within any of the STAs in WY2013.

The University of Florida conducts Everglade snail kite (*Rostrhamus sociabilis*) nest surveys annually in the STAs. The USFWS is consulted on modifying construction, maintenance, and STA operations to avoid disturbing any active nests. Survey results are summarized in each STA section of this chapter and reported in more detail in Appendix 5B-2.

EFFECTS OF TROPICAL STORM ISAAC

Tropical Storm Isaac (hereafter Isaac) affected South Florida on August 24-28, 2012. Hydrologic impacts from the storm were severe (see Appendix 2-2 of this volume). Although the center of the storm passed far to the west of the District, rainfall in outer feeder-bands was concentrated on the east coast resulting in record rainfall totals, especially in the C-51 and L-8 basins. The extreme rainfall from the storm resulted in wide-scale flooding which caused erosion and structure damage in District waterways. The record volume of runoff exceeded the treatment capacity of STA-1E and STA-1W, forcing the District to divert some water directly into WCA-1A.

The full impact of Isaac on the STAs due to increased inflow volumes, TP loads, TP concentrations and water depths, may not be fully manifested for another year or two (Goforth, 2013a). Storm impacts to the STAs were generally greatest from east to west: STA-1E was most impacted, followed by STA-1W, STA-2, and STA-3/4; STA-5/6 received minimal impacts. The volume of inflow to the STAs remained elevated through September 2012, long after Isaac had passed. The 365-day moving-average outflow TP concentration in all the STAs was declining or stable prior to Isaac but as of April 30, 2013, these outflow concentrations had not returned to pre-storm levels in STA-1E, STA-1W, and STA-2[6]. In general, the increased hydraulic and TP loading due to Isaac also resulted in a short-term spike in 28-day moving-average outflow TP concentrations followed by a return to pre-event levels. However, this short-term increase in

[4] The District is not obligated to alleviate flooding in cells with nests that is caused by direct rainfall.
[5] These periods constituted the 2012 and 2013 nesting seasons for black-necked stilts in South Florida. Survey results for both seasons are reported in this chapter even though May and June 2013 are in WY2014.
[6] TP concentrations in STA-3/4 and STA-5/6 had returned to pre-storm levels by this date.

outflow TP concentration may likely result in a longer-term decrease in STA TP removal performance, as observed in the 365-day outflow concentrations, due to the high volume of discharge during the period of elevated outflow TP concentrations. During the 30-day period from August 24 to September 22, 2012, STA-1E, STA-1W, STA-2, and STA-3/4 received inflow TP loads and concentrations that would be ranked among the top ten monthly values recorded over each STA's period of record (POR), respectively.

There were marked increases in water depth in the STAs in response to Isaac. Daily average water depths exceeded 4 ft in at least one of the EAV cells in STA-1E, STA-1W, STA-2, and STA-3/4. The highest estimated depth was 5.0 ft in Cell 7 of STA-1E. The daily average water depth in STA-1W was elevated for the longest duration, with depths greater than 4 ft for over a week, and above 3.5 ft for almost two weeks.

STA-1E

STA-1E, which began operation in WY2005, is located approximately 20 miles west of West Palm Beach, just south of State Road 80 and Canal C-51, adjacent to the northeast boundary of the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge), and directly east of the STA-1 Inflow and Distribution Works (referred to as the STA-1 Inflow Basin) (**Figure 5B-1**). STA-1E provides a total effective treatment area of 4,994 acres arranged into three parallel treatment paths, or flow-ways, with eight cells flowing from north to south (Piccone et al., 2013; **Figure 5B-4**). Note that the East and West Distribution Cells are not considered part of STA-1E effective treatment area. STA-1E receives inflow primarily from the C-51 West basin and smaller volumes from the L-8 and S-5A basins, Lake Okeechobee regulatory releases, and the Rustic Ranches subdivision. In WY2007, STA-1E started receiving inflows from a new source: runoff from Wellington Acme Basin B. During the dry season, supplemental water is delivered from Lake Okeechobee, when available, to maintain hydration of priority cells, i.e., cells dominated by SAV. The flow-way nomenclature for STA-1E is as follows:

- Eastern Flow-way = Cells 1 and 2,
- Central Flow-way = Cell 3, 4N, and 4S, and
- Western Flow-way = Cell 5, 6, and 7.

Several issues have affected STA-1E operations over its POR, including high hydraulic loadings during large storm events (particularly Hurricane Wilma in 2005, an unnamed storm in February 2006, and Tropical Storm Isaac in 2012), the repair of internal water control structures by the USACE, uneven topography causing excessively deep water and hydraulic short-circuiting (particularly in Cells 5 and 7), dryout of cells during dry periods, and vegetation die-off (i.e., the gradual decline of cattail in Cell 7 over time and the sudden hydrilla die-off in Cell 6 during WY2010).

STA TREATMENT PERFORMANCE

Over its POR, STA-1E treated approximately 783,000 ac-ft of water and retained 125 mt of TP or 72 percent of the inflow TP load (**Table 5B-1**). The POR inflow flow-weighted mean (FWM) TP concentration to this facility was 179 ppb, while the POR outflow FWM TP concentration was 52 ppb.

STA-1E received its highest inflow TP load and second highest inflow water load during WY2013 (34 mt and ~135,000 ac-ft, respectively) compared to all other annual inflow TP and water loads (**Figure 5B-5**, panels A and C). Inflow and outflow FWM TP concentrations this water year were 207 and 26 ppb, respectively, while the HLR and PLR were 2.6 cm/day and 2.0 g/m^2/yr, respectively (**Table 5B-1**). There were no significant relationships detected between annual inflow and outflow FWM TP concentrations or annual inflow and outflow TP loads (**Figure 5B-5**, panels B and D).

Despite high water and TP loads this water year and the issues noted in the *Facility Status and Operational Issues* section below, the outflow FWM TP concentration and % TP load retained in STA-1E (26 ppb and 87 percent, respectively) were comparable to the best annual treatment performance observed in this STA to date (20 ppb and 88 percent, respectively; **Figure 5B-5**, panels A and C). It is important to note that the STA-1E outflow TP concentrations may be influenced to some degree by groundwater seepage from the Refuge that enters the STA-1E discharge canal; at times, seepage from the Refuge may dilute the TP concentration in effluent from the flow-ways.

The annual HLR and PLR in the Central and Western Flow-ways of STA-1E both increased substantially from WY2011 to WY2013 (**Table 5B-3**). The high water and TP loadings in WY2013 can be attributed, in part, to runoff from Tropical Storm Isaac. Based on a comparison of annual outflow FWM TP concentration and % TP load retained, the Central Flow-way had better treatment performance than the Western Flow-way. Using these metrics as measures of treatment efficiency, the efficiency of each flow-way declined in WY2013 compared to WY2012, which was attributed, in part, to the increased TP and water loads received by each flow-way in WY2013.

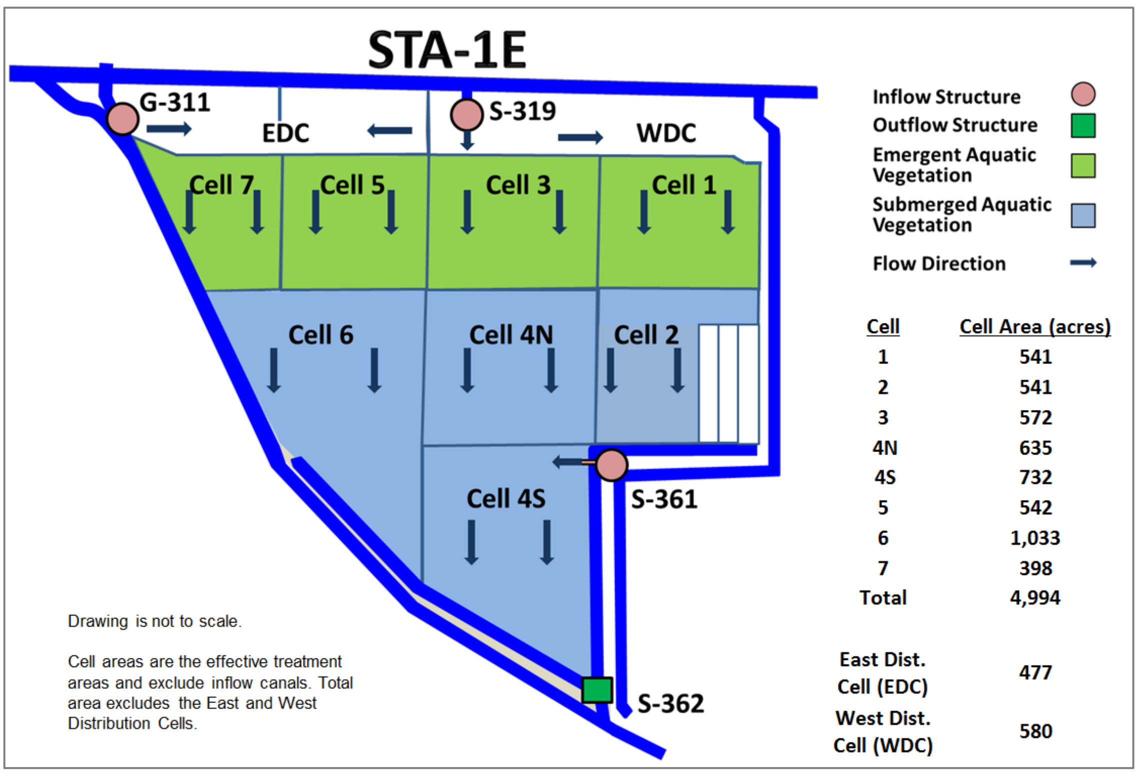


Figure 5B-4. Simplified schematic of STA-1E showing major inflow and outflow water-control structures, effective treatment area of each cell, flow direction, and dominant/target vegetation types. [Note: A detailed structure map of STA-1E is provided in Appendix 5B-1 of this volume; effective treatment areas do not include pump stations, levees, roads, or other upland areas.]

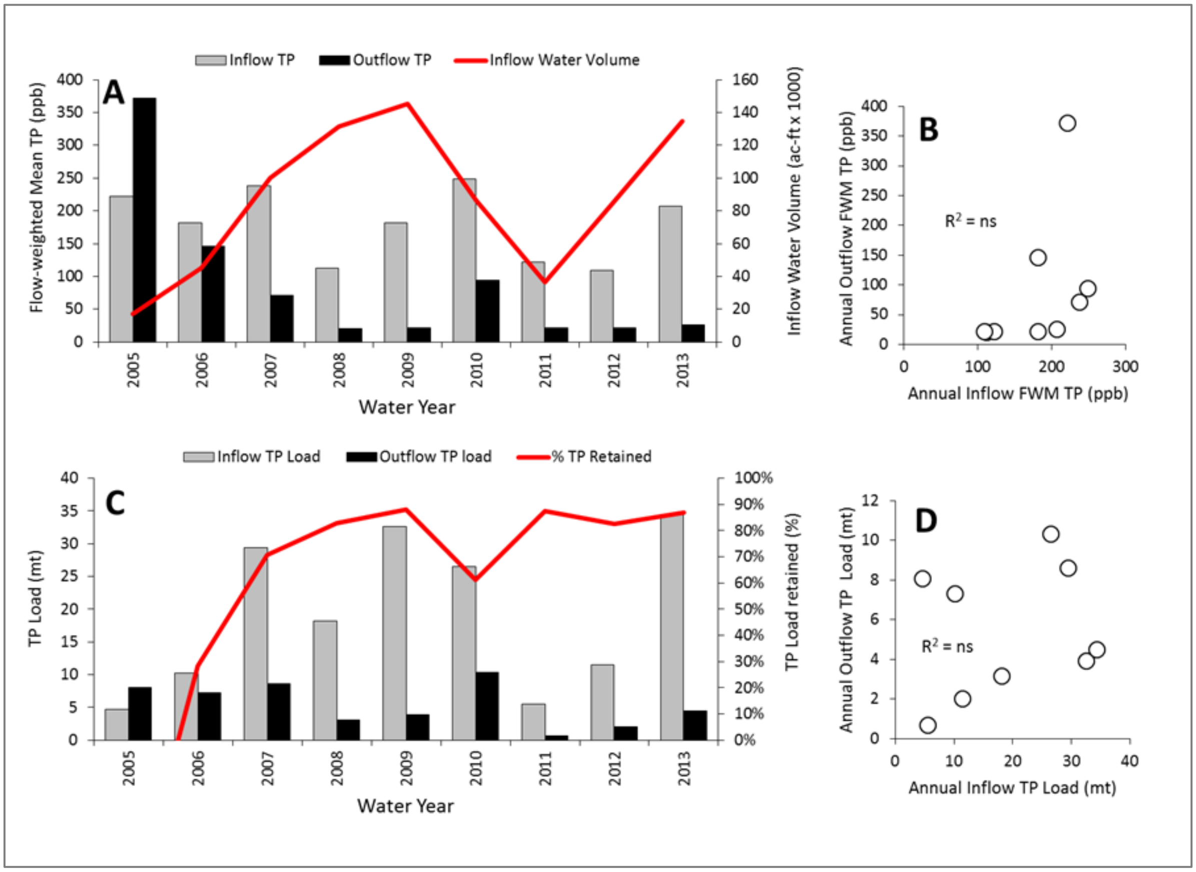


Figure 5B-5. Comparison over the period of record in STA-1E of (A) time-series of annual inflow and outflow flow-weighted mean (FWM) TP concentrations with corresponding inflow water volumes, (B) scatterplot of annual inflow versus outflow FWM TP concentrations, (C) time-series of annual inflow and outflow TP loads with percent TP load retained, and (D) scatterplot of annual inflow versus outflow TP loads.

Table 5B-3. Comparison of flow-way treatment performance in the Central and Western Flow-ways of STA-1E from WY2011 to WY2013.

Flow-way/ Water Year	Effective Treatment Area (acre)	PLR ($g/m^2/yr$)	HLR (cm/day)	Inflow Volume (ac-ft)	Inflow FWM TP (ppb)	Outflow FWM TP (ppb)	TP Retained (mt)	TP Retained (%)
Central Flow-way	1,939							
WY2011		0.2	0.6	13,177	75	45	0.6	52%
WY2012		1.0	2.6	60,472	104	18	6.6	85%
WY2013		1.8	3.5	82,016	136	27	10.9	79%
Western Flow-way	1,973							
WY2011		0.02	0.1	1,389	77	190	0.1	95%
WY2012		0.4	0.8	19,422	127	38	2.1	69%
WY2013		1.0	1.5	34,584	191	90	3.8	47%

Note: PLR = phosphorus loading rate; HLR = hydraulic loading rate

FACILITY STATUS AND OPERATIONAL ISSUES

The Eastern Flow-way of STA-1E was offline most of WY2013 due to activities associated with removing the U.S. Army Corps of Engineers (USACE) PSTA Demonstration Project in Cell 2 (see Appendix 5B-1, Figure 1) and re-grading the cell to a uniform ground elevation (**Table 5B-2**). From May to August 2012, approximately 500 linear feet of an earthen berm separating the PSTA Project from the rest of Cell 2 was degraded to allow for increased water delivery to the flow-way. Once decommissioning is complete, the District will be able to operate the Eastern Flow-way fully.

The Central and Western Flow-ways remained online but under operational restrictions throughout WY2013 due to structural repairs and vegetation enhancement activities (**Table 5B-2**). For a brief period, the water level in Cell 7 was lowered 0.2 ft below target stage for bulrush planting. From May 1 to June 5, 2012, the water level in Cell 5 was lowered 2 ft below the target stage to encourage cattail recruitment; bulrush was planted in open areas of this cell in June and July 2012. Recovery of SAV in Cell 6 continued this year following a cell-wide hydrilla die-off in the early part of WY2010. Throughout WY2013, target stage in Cell 6 was maintained between 12.7 and 13.0 ft to promote hydrilla establishment and improve the treatment performance of existing SAV (primarily hydrilla). Stage in Cell 4N was restricted for much of the water year due the presence of nesting snail kites, a species protected under the Endangered Species Act (see below and Appendix 5B-2 of this volume). A total of 4,428 ac-ft of supplemental water from Lake Okeechobee was delivered to STA-1E this year (1,325 and 3,103 ac-ft through the G-311 and S-319 structures, respectively) to maintain water levels in SAV cells.

During Tropical Storm Isaac in August 2012, substantial flow (~ 21,000 ac-ft) and TP mass (10 mt) (Volume III, Appendix 3-1, Table 6) were diverted through structure G-300 (see Appendix 5B-1, Figure 1) directly into WCA-1A and not treated by STA-1E. This diversion was equivalent to 16 and 29 percent of the total WY2013 inflow water and TP loads, respectively, to this STA. Diversion of water into WCA-1A began on August 27, 2012, and stopped on September 3, 2012.

The USACE continued with repairs to several water control structures in the Western and Central Flow-ways during WY2013. At the District's request, one structure in each cell was taken off line at a time, which allowed for partial operation of these two flow-ways. As of June 25, 2013, repairs to structures S-370A, S-370C, S-373A, S-373B, S-366A, S-367B, S-368A, S-371B, S371C, S-374A were complete; S-370B, S-366B, S-367A, S-368B, S-371A, S-374B, S-374C, S-363A, and S-363B were still undergoing repair; and repair of S-369A-D, S-366C-D, S-367C-D, S-368C-D, and S-372A-D is scheduled to begin in WY2014. The reconstruction of S-375, the conveyance structure between East and West Distribution Cells, was completed and as-built drawings were submitted to the Florida Department of Environmental Protection (FDEP) on February 27, 2013. The reconfiguration of the S-362 trash rake was completed by a USACE contractor in April 2013.

Dryout Impacts

All cells in the Western and Central Flow-ways of STA-1E were fully hydrated during WY2013. The Eastern Flow-way was dry due to removing the USACE's PSTA Demonstration Project in Cell 2.

Impacts of Migratory Bird and Snail Kite Nesting

Nine black-necked stilts nests were observed in STA-1E between April and July 2012 (the 2012 nesting season); all nests were located in Cell 5 (**Figure 5B-4**). No other nesting activity occurred during WY2013, although a single nest was observed in Cell 5 in May 2013 and 21 additional nests were found in Cell 2 in July 2013[7]. While nests were being incubated, the stage in Cell 5 was held at or below 15.20 ft NGVD to avoid flooding the nests. Cell 2 was not in operation while black-necked stilts were nesting, so no adjustments to cell stage were required.

Everglade snail kites were confirmed nesting in STA-1E Cell 4N (**Figure 5B-4**) on January 22, 2013, the first time nesting by this species had been observed in STA-1E. From January 22 to June 30, seven nests in Cell 4N were monitored by the University of Florida Snail Kite Lab; five of these nests successfully fledged juvenile snail kites. A range of water stages that would protect snail kite nests was established for Cell 4N in consultation with USFWS (Appendix 5B-2 of this volume). Snail kite nesting continued beyond the end of WY2013; between January 22 and August 1, 2013, 20 active snail kite nests were found in STA-1E Cell 4N.

There were no documented impacts to STA-1E treatment performance due to nesting black-necked stilts or Everglade snail kites in WY2013 and the magnitude of stage restrictions imposed this year likely will not affect future operations. However, constraints imposed on STA-1E in response to nesting birds, i.e., the inability to control the spread of FAV and maintain vegetation strips near active nests or the disproportionate redistribution of flow among flow-ways may reduce the ability of this STA to achieve optimum treatment performance in the future. Any long-term impacts to the functioning of STA-1E related to the presence of nesting birds cannot be assessed at this time.

MAINTENANCE AND ENHANCEMENTS

Due to construction associated with removing the USACE's PSTA Demonstration Project in Cell 2 (see Appendix 5B-1, Figure 1) and re-grading the cell to a more uniform ground elevation, vegetation management in the Eastern Flow-way during WY2013 was restricted to control of FAV near the inflow and outflow structures. In the Central Flow-way, over 300 acres of water lettuce were treated in Cell 4N to maintain conditions conducive for sustained growth of SAV, although control of FAV was restricted due to the presence of nesting Everglade snail kites. New strips of giant bulrush were planted in Cell 4S.

Efforts to improve the impaired EAV community in the Western Flow-way continued with herbicide treatment of undesired species and plantings of giant bulrush in all three cells. In Cell 5, pennywort (*Hydrocotyle* spp.) and water hyacinth were treated in the northwest portion of the cell to facilitate vegetative expansion of giant bulrush, which had been planted to eliminate a hydraulic short circuit. One hundred thirty acres of pennywort and of primrose willow were treated, and giant bulrush was planted in the eastern side of Cell 5 where vegetation enhancement measures have been ongoing since December 2011. Similar vegetation maintenance efforts occurred in Cell 7 where 230 acres of pennywort, primrose willow, water hyacinth, and water lettuce were treated and additional plantings of giant bulrush were made in the northeast, north-central, and southwest portions of the cell. In Cell 6, a 46-acre unvegetated area in the southeast portion of this cell was planted with giant bulrush and alligator flag (*Thalia geniculata*), and 165 acres of water lettuce were treated to sustain the growth of SAV beds.

VEGETATION SURVEYS

Vegetation Coverage Estimates Based on Aerial Imagery

Fluctuation in vegetation coverage from April 2011 to April 2012 in STA-1E ranged from almost no change in Cell 7 (< 1 percent) to a 10 percent decrease and a 16.5 percent increase in

[7] Surveys conducted in May–July of the 2013 nesting season occurred in WY2014 but are reported for completeness.

EAV in Cells 5 and 6, respectively (**Table 5B-4**). Comparatively small changes in EAV were observed in Cells 2 and 4N (~3-5 percent) and moderate increases in EAV occurred in Cells 4S and 3 (~7-9 percent). The composition of the vegetation community exhibited a positive change in Cells 1 (EAV), 2 (SAV), 3 (EAV), and 7 (EAV), whereas there were negative changes in Cells 4N (SAV), 4S (SAV), 5 (EAV), and 6 (SAV). At this time, it cannot be determined whether the negative changes in the vegetation community adversely affected treatment performance in STA-1E.

Table 5B-4. Summary of vegetation coverage in cells of STA-1E based on analysis of aerial imagery. Percent coverage calculated relative to total surface area of each cell.

Cell	Coverage Type	% Coverage 2011	% Coverage 2012	% Change in EAV Coverage from 2011–2012
Cell 1	Water/SAV	13.46	5.59	
	EAV	86.54	94.41	7.87
Cell 2	Water/SAV	11.68	16.35	
	EAV	88.32	83.65	-4.67
Cell 3	Water/SAV	21.36	12.04	
	EAV	78.64	87.96	9.32
Cell 4N	Water/SAV	59.40	56.07	
	EAV	40.60	43.93	3.32
Cell 4S	Water/SAV	89.26	81.77	
	EAV	10.74	18.23	7.48
Cell 5	Water/SAV	11.17	21.22	
	EAV	88.83	78.78	-10.05
Cell 6	Water/SAV	85.54	69.02	
	EAV	14.46	30.98	16.52
Cell 7	Water/SAV	34.75	34.23	
	EAV	65.25	65.77	0.52

Ground Surveys for Submerged Aquatic Vegetation

SAV was widespread in STA-1E Cells 4N, 4S, and 6 during ground surveys conducted in WY2013 where the community comprised four species: coontail, southern naiad, hydrilla, and muskgrass (**Figure 5B-6**). Hydrilla was the dominate species with respect to both spatial coverage and relative abundance in all cells. This species was followed in importance by southern naiad and coontail. Conversely, muskgrass was found at only a few sites in Cells 4N and 4S. Some areas in all three cells remained devoid of SAV as observed in previous SAV ground surveys.

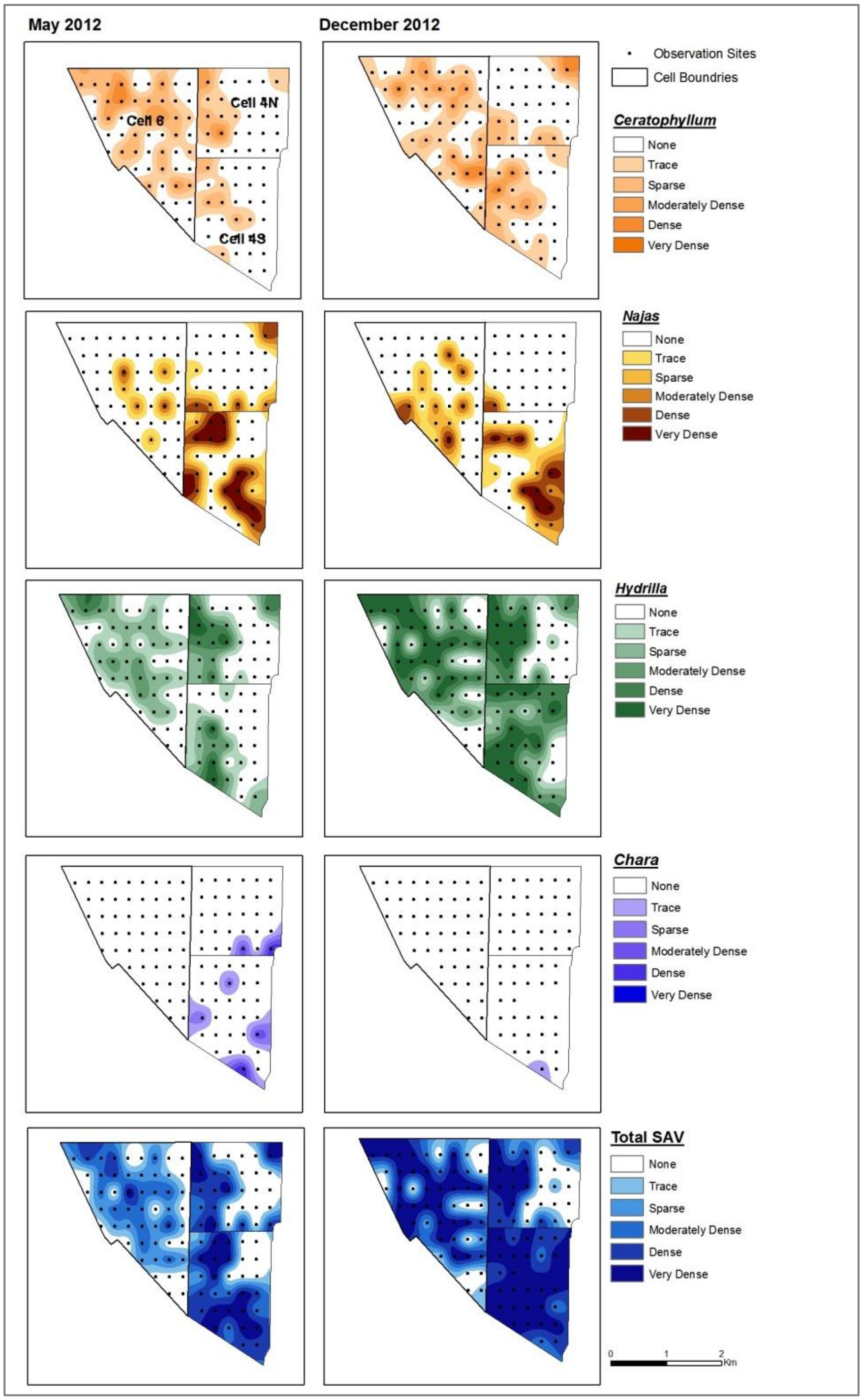


Figure 5B-6. Ground survey results depicting the spatial coverage and relative abundance of coontail (*C. demersum*), southern naiad (*N. guadalupensis*), hydrilla (*H. verticillata*), muskgrass (*Chara* sp.), and all SAV species grouped together in STA-1E Cells 4N, 4S, and 6 on May 23 and December 4, 2012. Dots indicate location of SAV ground survey sites.

STA-1W

STA-1W, which began operation in 1994 as the Everglades Nutrient Removal (ENR) Project, is located northwest of the Arthur R. Marshall National Wildlife Refuge (**Figure 5B-1**). This STA presently encompasses 6,544 acres of effective treatment area arranged into three flow-ways with eight treatment cells (Piccone et al., 2013; **Figure 5B-7**). The Eastern and Western Flow-ways comprised the ENR Project and the Northern Flow-way was added in 1999. Compartmentalization of former Cells 1 and Cell 2 was completed in 2007, creating Cells 1A, 1B, 2A, and 2B. This STA receives inflow primarily from the S-5A drainage basin. During dry months, supplemental water is delivered from Lake Okeechobee, when available, to maintain hydration of priority cells, i.e., cells dominated by SAV. The flow-way nomenclature for STA-1W is as follows:

- Eastern Flow-way = Cells 1A, 1B and 3,
- Western Flow-way = Cell 2A, 2B, and 4, and
- Northern Flow-way = Cells 5A and 5B.

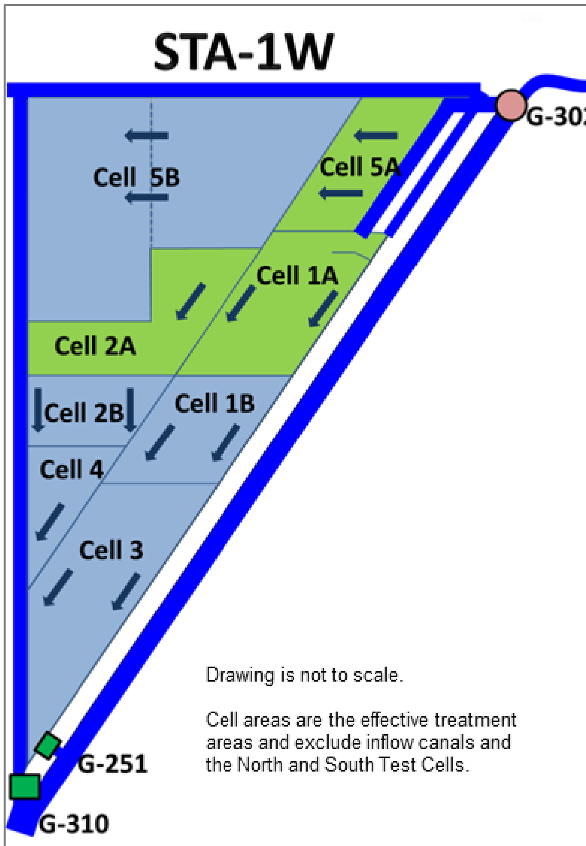
Over its operational history, STA-1W has been affected by extreme weather events (regional droughts and large storms), enhancement activities that included water level drawdowns and construction, and high hydraulic and nutrient loadings. The restrictions on operation of STA-1E discussed above also impacted STA-1W in that the District treated some of the runoff that ordinarily would have been processed in STA-1E in STA-1W and thereby increased the water and nutrient loading in STA-1W. A series of major rehabilitation activities were implemented in STA-1W between 2005 and 2007 to reestablish the vegetation communities that were damaged by hydraulic overloading in previous years and restore the treatment performance of all cells.

STA TREATMENT PERFORMANCE

Over its POR, STA-1W has treated approximately 3,420,000 ac-ft of water and retained 522 mt of TP or 71 percent of the total inflow TP load (**Table 5B-1**). The POR inflow FWM TP concentration was 175 ppb, while the POR outflow FWM TP concentration was 50 ppb.

In WY2013, STA-1W treated approximately 166,000 ac-ft of runoff with an inflow FWM TP concentration of 245 ppb and an outflow FWM TP concentration of 36 ppb (**Table 5B-1**). STA-1W retained 42 mt of TP or 83 percent of the inflow TP load this year and had a HLR and a PLR of 2.1 cm/day and 1.9 g/m^2/day, respectively. Treatment performance in STA-1W has fully recovered from the dramatic decline that occurred from WY2001 to WY2006 as demonstrated by the increase in % TP load retained since WY2006, (**Figure 5B-8**, panels A and C). The % TP load retained in STA-1W has been 80 percent or greater since WY2009, which is comparable to the treatment performance in the period preceding WY2001. Significant linear relationships were detected between annual inflow and outflow FWM TP concentrations and annual inflow and outflow TP loads (coefficients of determination, R^2 = 0.49 and 0.86, respectively; see regression lines in **Figure 5B-8**, panels B and D.

The HLRs and PLRs in the Eastern, Central and Western Flow-ways of STA-1W in WY2013 (1.6 to 3.3 cm/day and 1.4 to 2.4 g/m^2/yr, respectively) all increased compared to rates in WY2012 and WY2011; the inflow water load to the flow-ways in WY2013 was 12 to 42 percent higher relative to the previous two years (**Table 5B-5)**. This was attributed, in part, to heavy runoff from Tropical Storm Isaac in August 2012. The Western and Northern flow-ways have been loaded more heavily than the Eastern Flow-way on a consistent basis over the past three water years. However, all three flow-ways have had similar treatment performance.



Cell	Cell Area (acres)
1A	713
1B	577
2A	701
2B	309
3	881
4	359
5A	602
5B	2,402
Total	6,544

Figure 5B-7. Simplified schematic of STA-1W showing major inflow and outflow water-control structures, effective treatment area of each cell, flow direction, and dominant/target vegetation types. [Note: A detailed structure map of STA-1W is provided in Appendix 5B-1 of this volume; effective treatment areas do not include pump stations, levees, roads, or other upland areas.]

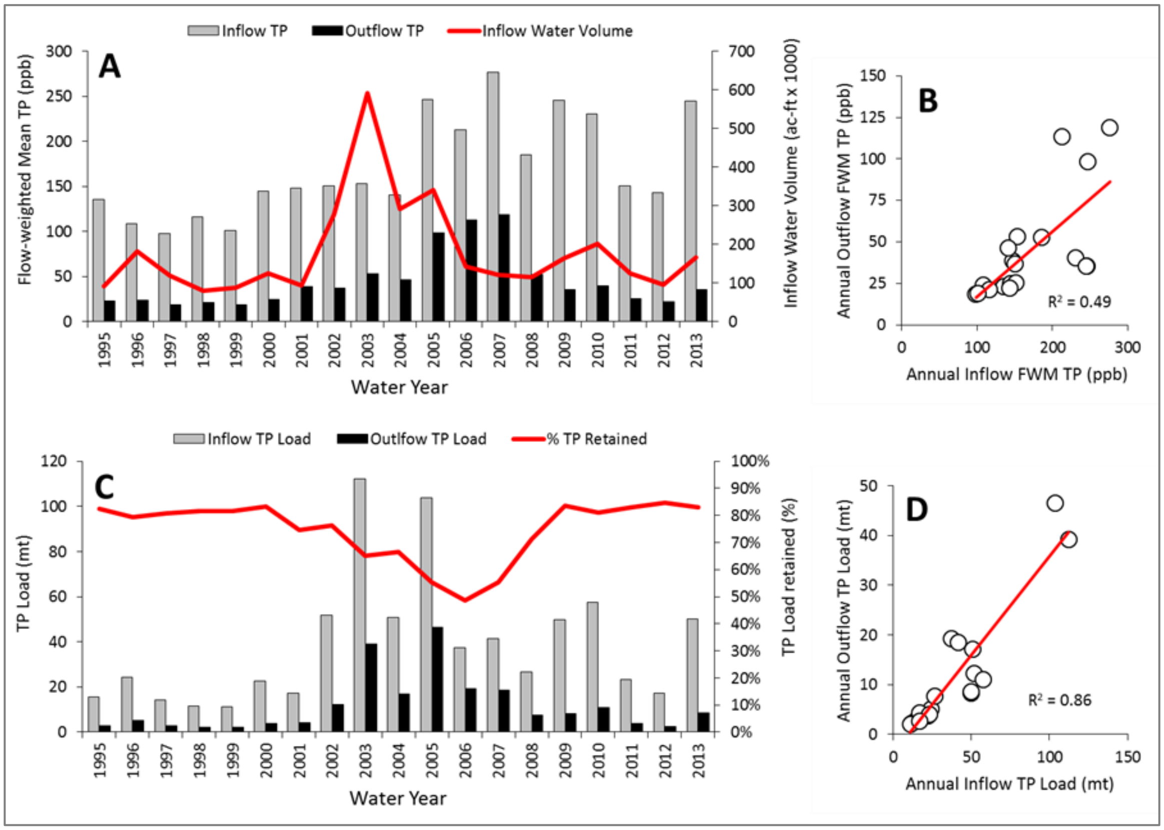


Figure 5B-8. Comparison over the period of record in STA-1W of (A) time-series of annual inflow and outflow flow-weighted mean (FWM) TP concentrations with corresponding inflow water volumes, (B) scatterplot of annual inflow versus outflow FWM TP concentrations, (C) time-series of annual inflow and outflow TP loads with percent TP load retained, and (D) scatterplot of annual inflow versus outflow TP loads.

Table 5B-5. Comparison of flow-way treatment performance in STA-1W from WY2011 to WY2013.

Flow-way/ Water Year	Effective Treatment Area (acres)	PLR (g/m2/yr)	HLR (cm/day)	Inflow Volume (ac-ft)	Inflow FWM TP (ppb)	Outflow FWM TP (ppb)	TP Retained (mt)	TP Retained (%)
Eastern Flow-way	2,171							
WY2011		0.5	1.2	30,896	125	24	3.8	79%
WY2012		0.5	1.1	27,485	131	18	3.9	87%
WY2013		1.4	1.6	41,256	246	19	11.3	90%
Western Flow-way	1,369							
WY2011		1.1	2.0	32,590	148	25	5.2	87%
WY2012		0.8	1.9	31,964	116	23	3.9	84%
WY2013		2.4	3.3	54,850	197	43	10.7	80%
Northern Flow-way	3,004							
WY2011		1.1	2.1	74,536	140	21	10.9	85%
WY2012		0.7	1.4	48,992	133	19	6.8	85%
WY2013		2.2	2.3	84,223	260	30	23.1	86%

FACILITY STATUS AND OPERATIONAL ISSUES

All flow-ways in STA-1W were operational during WY2013 (**Table 5B-2**). Due to structural, hydrological, and vegetation issues in STA-1E, STA-1W treated most of the runoff from the S-5A drainage basin this year. During Tropical Storm Isaac in August 2012, flow (~ 6,000 ac-ft) and TP mass (3 mt) (Volume III, Appendix 3-1, Table 6) were diverted through structure G-301 (see Appendix 5B-1, Figure 2) directly into Water Conservation Area 1A (WCA-1A) and not treated by STA-1W. This diversion was equivalent to 4 and 6 percent of the total WY2013 inflow water and TP loads, respectively, to this STA. Diversion of water into WCA-1A began on August 27, 2012, and stopped on September 2, 2012. Unusual high outflow TP concentrations from the Western Flow-way occurred from October 2012 through February 2013. G-307 was used as the preferred Cell 4 discharge structure, while G-309 was kept closed whenever possible. A total of 3,433 ac-ft of supplemental water from Lake Okeechobee was delivered to STA-1W this year through the G-302 structure to maintain water levels in SAV cells.

Various vegetation enhancements were performed this year in STA-1W including bulrush collection and planting and southern naiad collection and inoculation in Cells 1A, 1B, 2B, 4, 5A, and 5B. Overgrowth of SAV and other debris were removed from the canal immediately upstream of G-309 to maintain conveyance to this structure. A Tuff-Boom weed barrier was installed upstream of G-309 by District staff. Retrofitting the G-251 trash rake began in May 2012 and the pump station was operational by March 2013. Work on hardening the S-5A Pump Station was initiated in November 2012 and is currently ongoing.

Dryout Impacts

All the cells in STA-1W were fully hydrated in WY2013. There were no negative impacts due to dryout this year.

Impacts of Migratory Bird and Snail Kite Nesting

Five black-necked stilt nests were observed in STA-1W between April and July 2012 (the 2012 nesting season); all nests were located in Cell 2B (**Figure 5B-7**). The District attempted to maintain stage in Cell 2B at or below 11.35 ft NGVD during this period to minimize impacts to nests. However, heavy rainfall in May 2012 resulted in water levels quickly rising above the elevation of the nests, which likely caused them to fail. No other black-necked stilt nesting activity in STA-1W occurred during WY2013. Thirteen stilt nests were observed in Cells 2B and 4 during May 2013 (surveys conducted in WY2014). The District attempted to maintain stage in Cells 2B and 4 at or below 11.00 ft to NGVD to minimize impacts to nests. However, heavy rainfall in early June associated with a tropical weather system inundated any nests there were still active. Based on the date when the nests were first observed and the date of the storm event, it is believed that at least four nests successfully hatched and fledged young black-necked stilts, while the other nests likely failed due to flooding.

There were no documented impacts to STA-1W treatment performance due to nesting black-necked stilts in WY2013, and the magnitude of stage restrictions imposed this year likely will not affect future operations. However, the redirection of flow from the Western to Eastern Flow-way resulted in the loss of giant bulrush plantings that were intended to revitalize a large portion of Cell 1A that had reduced EAV density and may reduce the ability of STA-1W to achieve optimum treatment performance in the future. Any long-term impacts to the functioning of STA-1W related to the presence of nesting birds cannot be assessed at this time. No active Everglade snail kite nests were observed in STA-1W during WY2013.

MAINTENANCE AND ENHANCEMENTS

Giant bulrush plantings continued in the Northern Flow-way during WY2013 to enhance water quality treatment in the unvegetated northeast portion of Cell 5A and increase compartmentalization of Cell 5B. Approximately 720 acres of FAV were treated in these two cells. A vegetation revitalization effort was initiated in Cell 1A of the Eastern Flow-way where dense cattail cover was limited and the EAV community was dominated by floating mats/clumps of leather fern (*Acrostichum daneifolium*); 230 acres of FAV were treated in the southeast portion of Cell 1A, and giant bulrush was planted in this area and in the cell's unvegetated northwest corner. Limited FAV treatments were needed in Cell 1B, while 162 acres of cattail were treated in Cell 3 to allow for expansion of extant beds of SAV. Similar treatments of cattail (91 acres) were done in Cell 4 of the Western Flow-way and new strips of giant bulrush were planted in this cell and Cell 2B after the widespread loss of muskgrass in August 2012 led to reduced TP uptake. To increase species diversity of SAV cover, southern naiad was transplanted to the inflow region of Cell 2B and the central portion of Cell 4.

VEGETATION SURVEYS

Vegetation Coverage Estimates Based on Aerial Imagery

Because water depth had been maintained at levels optimal for maintaining desired vegetation, EAV coverage was stable in STA-1W from April 2011 to April 2012. For most cells (Cells 1A, 1B and 2B), EAV coverage in 2012 was similar to coverage in 2011 (**Table 5B-6**). There were moderate changes in Cells 3 and 4, both with ~7 percent decreases in EAV coverage. The biggest changes occurred in Cells 2A, 5A, and 5B, where EAV coverage declined approximately 13 percent in Cell 2A and increased more than 14 percent in Cells 5A and 5B. The composition of the vegetation community exhibited a positive change in Cells 1B (SAV), 2B (SAV), 3 (SAV), 4 (SAV), and 5A (EAV), whereas there were negative changes in Cells 1A (EAV), 2A (EAV), and 5B (SAV). At this time, it cannot be determined whether the negative changes in the vegetation community adversely affected treatment performance in STA-1W.

Table 5B-6. Vegetation coverage in cells of STA-1W based on analysis of aerial imagery. Percent coverage calculated relative to total surface area of each cell.

Cell	Coverage Type	% Coverage 2011	% Coverage 2012	% Change in EAV Cover from 2011–2012
Cell 1A	Water/SAV	17.65	21.05	
	EAV	82.35	78.95	-3.40
Cell 1B	Water/SAV	73.25	76.26	
	EAV	26.75	23.73	-3.01
Cell 2A	Water/SAV	13.27	26.50	
	EAV	86.73	73.50	-13.23
Cell 2B	Water/SAV	91.26	92.26	
	EAV	8.74	7.74	-1.00
Cell 3	Water/SAV	56.07	63.44	
	EAV	43.93	36.56	-7.37
Cell 4	Water/SAV	83.37	90.71	
	EAV	16.62	9.29	-7.33
Cell 5A	Water/SAV	49.26	34.82	
	EAV	50.74	65.18	14.44
Cell 5B	Water/SAV	88.61	73.79	
	EAV	11.39	26.21	14.82

Ground Surveys for Submerged Aquatic Vegetation

SAV was widespread in STA-1W Cells 1B, 2B, 3, 4, 5A, and 5B during ground surveys conducted in WY2013 where the community comprised three species: muskgrass, southern naiad, and coontail. Muskgrass was the dominate species with respect to both spatial coverage and relative abundance in Cells 1B, 3, 2B and 4 as noted in previous SAV ground surveys (**Figures 5B-9** and **5B-10**). Southern naiad and coontail were much less abundant in these four cells. In contrast, southern naiad was the dominant species found in Cell 5B with smaller amounts of coontail and muskgrass (**Figure 5B-11**).

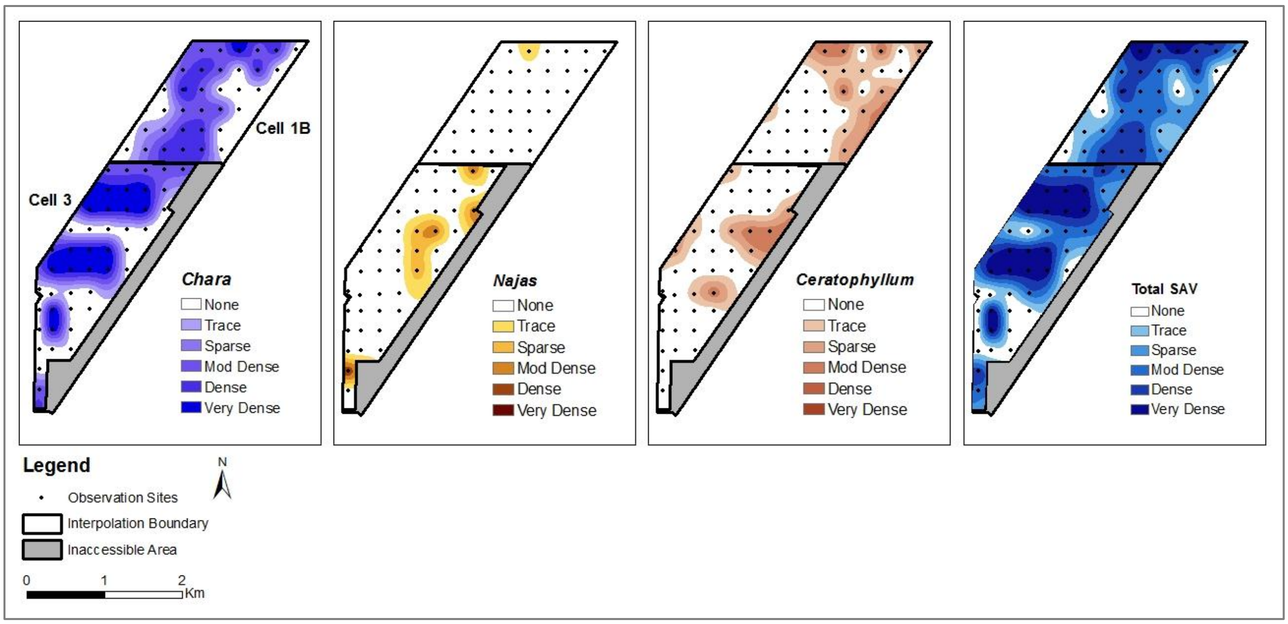


Figure 5B-9. Ground survey results depicting the spatial coverage and relative abundance of muskgrass (*Chara* sp.), southern naiad (*N. guadalupensis*), coontail (*C. demersum*), and all SAV species grouped together in STA-1W Cells 1B and 3 on December 12, 2012. Dots indicate location of SAV ground survey sites.

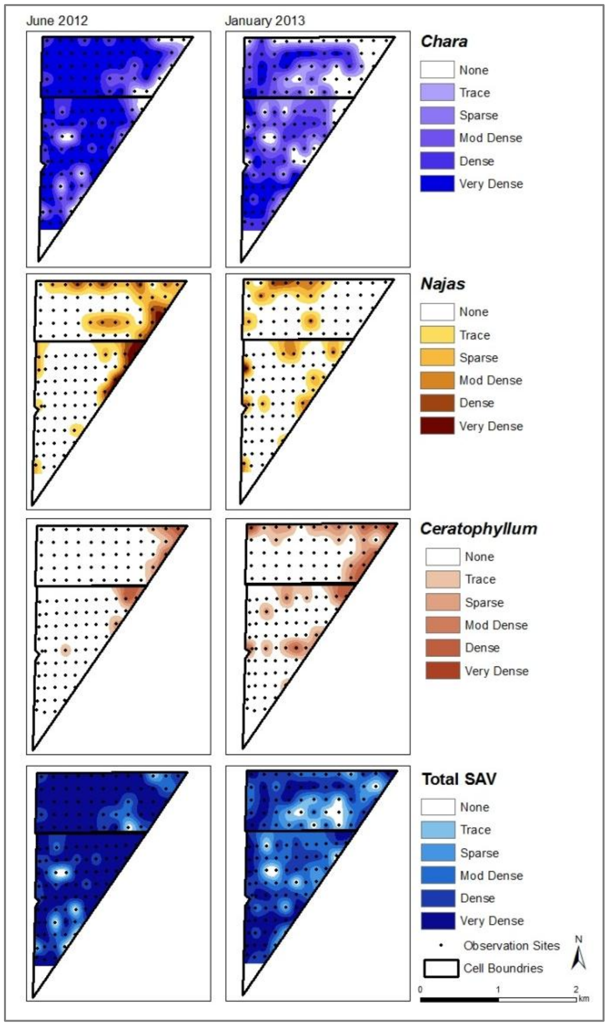


Figure 5B-10. Ground survey results depicting the spatial coverage and relative abundance of muskgrass (*Chara* sp.), southern naiad (*N. guadalupensis*), coontail (*C. demersum*), and all SAV species grouped together in STA-1W Cells 2B and 4 on June 12, 2012 and January 9, 2013. Dots indicate location of SAV ground survey sites.

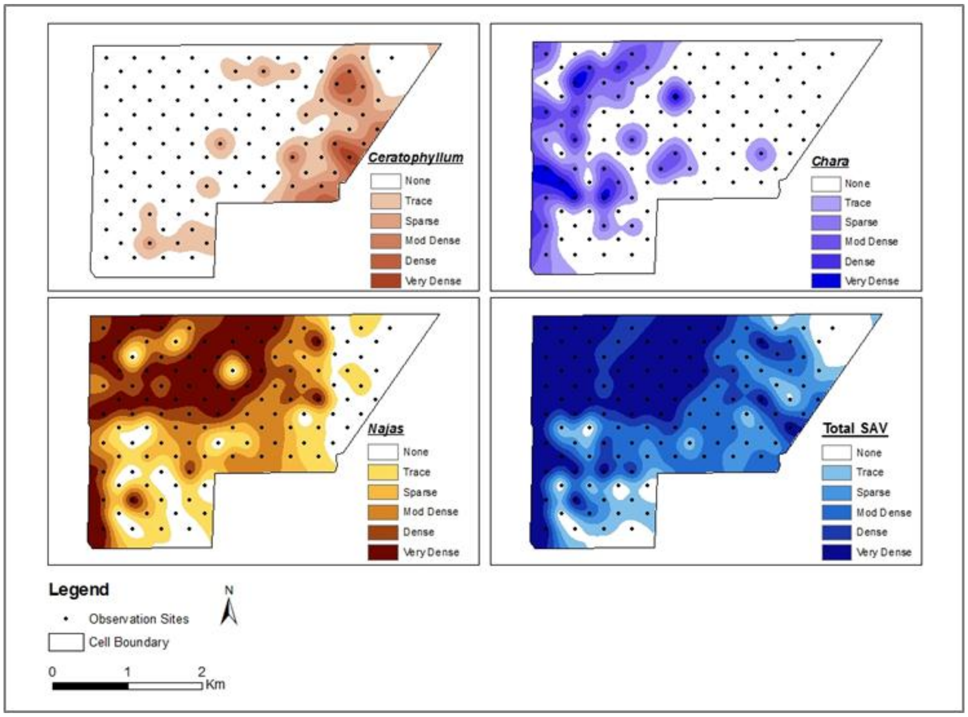


Figure 5B-11. Ground survey results depicting the spatial coverage and relative abundance of coontail (*C. demersum*), muskgrass (*Chara* sp.), southern naiad (*N. guadalupensis*), and all SAV species grouped together in STA-1W Cell 5B on December 15, 2012. Dots indicate location of SAV ground survey sites.

STA-2

STA-2 is located in western Palm Beach County immediately west of Water Conservation Area 2A (WCA-2A; **Figure 5B-1**). STA-2 originally consisted of three treatment cells (Cells 1, 2, and 3) and began operation in 2000. This facility was expanded with the construction of Cell 4, which was flow capable by December 2006; however, Cell 4 went off-line in WY2010 during the construction of Compartment B. With the recent completion of Compartment B, STA-2 now has eight treatment cells arranged into five flow-ways with a total effective treatment area of 15,495 acres (Piccone et al., 2013; **Figure 5B-12**). STA-2 receives agricultural runoff from three basins: runoff primarily comes from the S-6 and (a portion of the) S-2 basins but also can come from the S-7 and (the remaining portion of the) S-2 basins. During dry months, supplemental water is delivered from Lake Okeechobee, when available, to maintain hydration of priority cells, i.e., cells dominated by SAV. The flow-way nomenclature for STA-2 is as follows:

- Flow-way 1 = Cell 1,
- Flow-way 2 = Cell 2,
- Flow-way 3 = Cell 3,
- Flow-way 4 = Cell 4 and new Cells 5 and 6 in Compartment B, and
- Flow-way 5 = new Cells 7 and 8 in Compartment B.

Like the other STAs, STA-2 has been affected by regional droughts and storm events over its POR. The District seeks to improve operation of the STAs to minimize impacts from such events.

For example, Cells 1 and 2 have dried out, either partially or entirely, during past droughts when the supply of supplemental water was limited. As a proactive measure, stages throughout STA-2 were increased to hold more water in the system in advance of the WY2011 and WY2012 dry seasons, which helped minimize dryout. One feature of STA-2 thought partly responsible for its good treatment performance is that all of Cell 1 and part of Cell 2 were never farmed prior to these areas becoming part of the STA. The hypothesis is that there is reduced P flux from the unfarmed soils back to the water column, which leads to lower outflow TP concentrations from these cells. Starting in WY2009, the vegetation community in approximately 300 acres at the southern end of Cell 2 was converted from cattail to SAV to improve treatment performance.

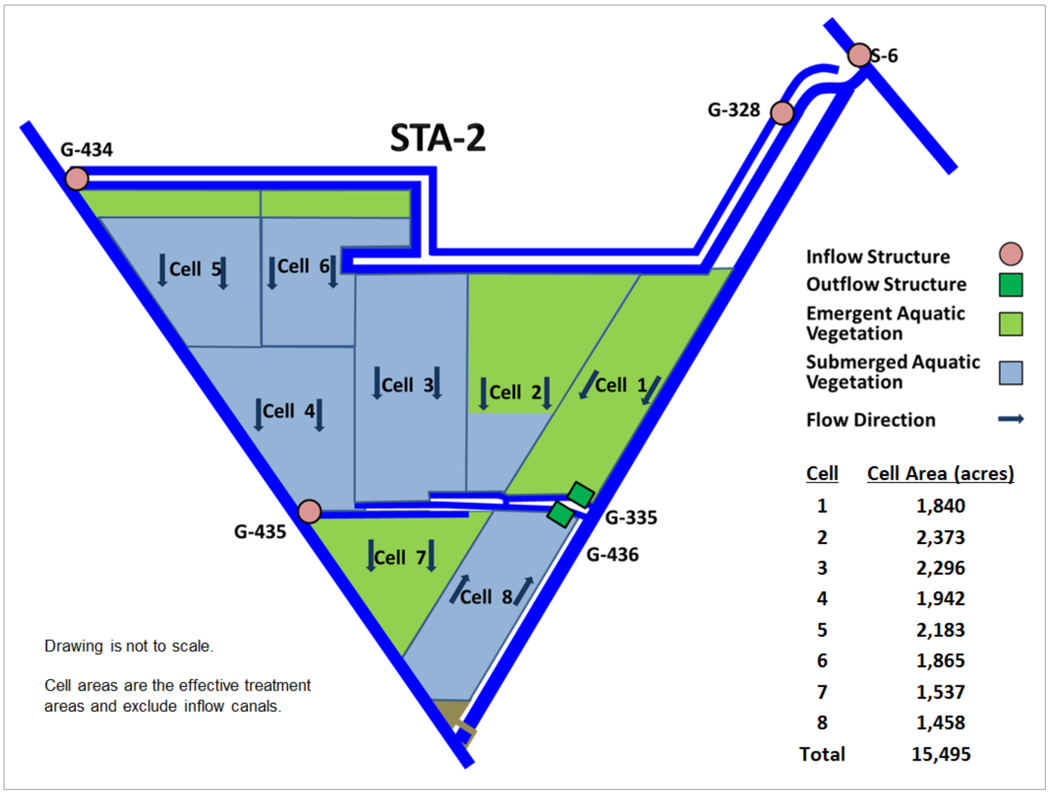


Figure 5B-12. Simplified schematic of STA-2 showing major inflow and outflow water-control structures, effective treatment area of each cell, flow direction, and dominant/target vegetation types. [Note: A detailed structure map of STA-2 is provided in Appendix 5B-1 of this volume; effective treatment areas do not include pump stations, levees, roads, or other upland areas.]

STA TREATMENT PERFORMANCE

STA-2, over its operational history, has treated approximately 3,089,000 ac-ft of water and retained 302 mt of TP or 77 percent of the TP load that entered this facility (**Table 5B-1**). The POR inflow FWM TP concentration to this facility was 103 ppb, while the POR outflow FWM TP concentration was 22 ppb.

STA-2 treated approximately 321,000 ac-ft of runoff in WY2013 that had an inflow FWM TP concentration of 106 ppb and produced an outflow FWM TP concentration of 22 ppb (**Table 5B-1**). This facility retained 33 mt of TP, or 78 percent of the inflow TP load received this year and had a HLR and PLR of 2.6 cm/day and 1.0 $g/m^2/yr$, respectively. The treatment performance of STA-2 in WY2013, as measured by its outflow FWM TP concentration and % TP load retained, was within the range of values observed in this STA over its POR (**Figure 5B-13**, panels A and C). Significant linear relationships were detected between annual inflow and outflow FWM TP concentrations and annual inflow and outflow TP loads (coefficients of determination, R^2 = 0.49 and 0.63, respectively; see regression lines in **Figure 5B-13**, panels B and D).

The HLRs and PLRs in Flow-ways 1, 2, and 3 of STA-2 in WY2013 (3.1 to 5.2 cm/day and 1.2 to 2.3 $g/m^2/yr$, respectively) all increased compared to rates in WY2012 and WY2011 (**Table 5B-7**); inflow water loads to Flow-ways 2 and 3 in WY2013 were 31 to 56 percent higher than in the previous two years. This was attributed, in part, to heavy runoff from Tropical Storm Isaac in August 2012. One conspicuous difference in treatment performance among the flow-ways was the consistently lower outflow FWM TP concentrations from Flow-way 1 (8 to 12 ppb) than from Flow-ways 2 and 3 (14 to 26 ppb). As noted above, the soils in Cell 1 had never been cultivated.. However, there is some question as to whether the unfarmed soil in Cell 1 after 12 years of operation and nutrient loading still has different physico-chemical characteristics from the previously farmed soils in STA-2. An alternative hypothesis to account for the superior treatment performance in Cell 1 has recently been proposed. Cell 1 has a higher average ground elevation than the other flow-ways in STA-2 and therefore may have a higher outflow seepage rate. Increased downwelling of seepage in Cell 1 may partially counteract the upward P flux from the soil leading to greater net P removal. Further investigation of the factors responsible for the consistently low outflow TP concentrations from Cell 1 will be conducted as part of the District's Restoration Strategies Science Plan (see Chapter 5C of this volume).

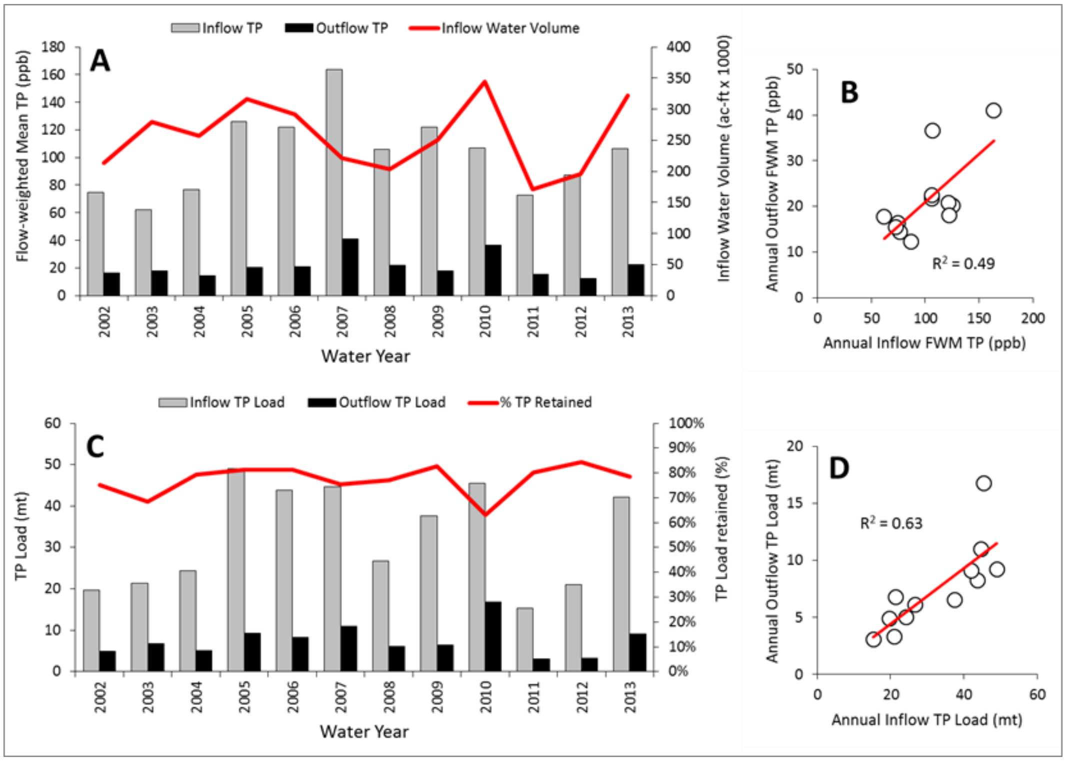


Figure 5B-13. Comparison over the period of record in STA-2 of (A) time-series of annual inflow and outflow flow-weighted mean (FWM) TP concentrations with corresponding inflow water volumes, (B) scatterplot of annual inflow versus outflow FWM TP concentrations, (C) time-series of annual inflow and outflow TP loads with percent TP load retained, and (D) scatterplot of annual inflow versus outflow TP loads.

Table 5B-7. Comparison of flow-way treatment performance in STA-2 from WY2011 to WY2013.

Flow-way/ Water Year	Effective Treatment Area (acre)	PLR (g/m2/yr)	HLR (cm/day)	Inflow Volume (ac-ft)	Inflow FWM TP (ppb)	Outflow FWM TP (ppb)	TP Retained (mt)	TP Retained (%)
Flow-way 1	1,840							
WY2011		0.4	1.2	26,590	88	12	2.5	87%
WY2012		0.8	2.6	57,632	79	9	5.1	91%
WY2013		1.2	3.1	69,490	103	8	8.3	94%
Flow-way 2	2,373							
WY2011		0.9	2.3	65,696	101	19	6.6	81%
WY2012		1.0	2.7	78,193	99	15	8.0	83%
WY2013		2.3	5.2	147,786	123	23	17.4	78%
Flow-way 3	2,296							
WY2011		0.8	2.6	72,493	82	15	6.0	82%
WY2012		0.8	2.7	73,549	82	14	5.8	78%
WY2013		1.6	3.9	106,266	111	26	10.5	72%
Flow-way 4	1,942							
WY2013		0.6	1.3	29,748	132	23	4.1	84%

FACILITY STATUS AND OPERATIONAL ISSUES

Cells 1, 2, and 3 in STA-2 were operational throughout WY2013, while Cell 4 was off-line from May to September 2012 during the start-up of Cells 5 and 6 (**Table 5B-2**). Flow-way 4 (Cells 4, 5 and 6) passed its start-up criteria on September 21, 2012 and went online. Flow-way 5 (Cells 7 and 8) passed its start-up criteria on May 17, 2013. Starting in January 2013, Lake Okeechobee water was delivered to Flow-ways 1 and 2 to maintain water levels at target stages. Additional lake water was also added to Cell 4. Per guidance from the 2008 Lake Okeechobee Regulatory Schedule, Lake Okeechobee water was sent through Flow-way 4 and continued south into WCA-2. This water delivery was initiated on April 10, 2013 and lasted about two weeks. A total of 6,437 ac-ft of supplemental water from Lake Okeechobee was delivered to STA-2 this year (3,882 and 2,555 ac-ft through S-6 pump station and the G-434/G-435 structures, respectively) to maintain water levels in SAV cells.

Vegetation start-up activities in Cells 5, 6, 7 and 8 that had been initiated in WY2012 continued this year. Approximately 1,100 to 1,600 acres in Cells 5 and 6 containing willow (*Salix caroliniana*) and primrose willow were aerially treated with herbicide (500-1000 acres in May 2012 and 500 acres in August 2012). Another 800 acres of cattail, willow, paragrass, and Bermuda grass in these two cells were treated in February and March 2013. Three hundred sixty acres of cattail in Cell 4 were treated in June 2012. Other management activities in STA-2 this year included bulrush collection and planting in Cell 3 and aerial herbicide treatment in Cell 2.

Structure maintenance activities in STA-2 during WY2013 included replacing stilling wells, repairing the RPM sensor for the S-6 Pump Station pump #2, repairing the G-441 gate, repairing structures G-331C (Cell 2) and G-333D (Cell 3) using divers, and other routine maintenance.

Compartment B Build-out

The Compartment B Build-out Project is located in Palm Beach County, west and south of the original boundaries of STA-2 (Cells 1, 2, 3, and 4; **Figures 5B-1** and **5B-12**) and greatly expands the treatment area of this facility. As-built Certification Forms were submitted to the FDEP for (a) the G-434, G-434, and G-436 Pump Stations, (b) the North Build-out Components of Compartment B, and (c) the South Build-out Components of Compartment B on September 26, February 7, and May 8, 2013, respectively.

The new Everglades Forever Act (EFA) operating permit for STA-2 was received by the District on September 10, 2012, accompanied by, and issued in reliance upon, Consent Order OGC# 12-1149. On September 21, 2012, the FDEP acknowledged that a net reduction in TP concentration had occurred from inflow to outflow in Flow-way 4 and, therefore, discharge could commence from the G-368 structure. On May 17, 2013, the FDEP acknowledged that a net reduction in TP concentration had occurred from inflow to outflow in Flow-way 5 and therefore, discharge activities could commence from the G-441 structure. The FDEP also approved the District's consolidated Mercury and Other Toxicants Monitoring Plan for Compartment B on February 21, 2013.

Established aquatic vegetation provided for the successful start-up of the new cells in Compartment B. Cattail cover exceeded 80 percent in Cells 5 and 6 and herbicide applications were used to promote desired plant species and enhance vegetation-mediated P uptake. Incremental conversion of the southern (downstream) portions of these cells from EAV to SAV was initiated at the end of WY2013 with the treatment of 535 acres of cattail. In Cell 4, 686 acres of cattail that had established when this cell dried out during construction of Compartment B were treated to reestablish SAV cover. Cells 7 and 8 had more than 95 percent cattail cover and also achieved successful start-up. Plans to convert Cell 8 to SAV will be initiated in early WY2014.

Dryout Impacts

All the cells in STA-2 were fully hydrated in WY2013. There were no negative impacts due to dryout this year.

Impacts of Migratory Bird and Snail Kite Nesting

STA-2 operations were not impacted by migratory bird nesting in WY2013 as no black-necked stilt nests were observed during the 2012 nesting season (April to July 2012) nor in April 2013. However, 12 stilt nests were detected in STA-2 Cells 3, 5, and 6 (**Figure 5B-12**) in May 2013 (surveys conducted in WY2014). The District attempted to maintain stage in STA-2 Cells 3, 5, and 6 during this period at or below 10.90, 10.70, and 10.70 ft NGVD, respectively, to minimize potential impacts to nests. However, heavy rainfall in early-June from a tropical weather system inundated many nests that were still active. Based on the time between the date when nests were first observed and the date of the storm event, as well as the presence of several black-necked stilt chicks in June, it is believed that several nests successfully hatched and fledged young black-necked stilts, while all other nests were flooded and failed.

There were no documented impacts to STA-2 treatment performance due to nesting black-necked stilts in WY2013, and the magnitude of stage restrictions imposed this year likely will not affect future operations. However, constraints imposed on STA-2 in response to nesting birds, i.e., the disproportionate redistribution of flow among flow-ways, may reduce the ability of this STA to achieve optimum treatment performance in the future. Any long-term impacts to the functioning of STA-2 related to the presence of nesting birds cannot be assessed at this time. No active Everglade snail kite nests were observed in STA-2 during WY2013.

MAINTENANCE AND ENHANCEMENTS

No significant vegetation maintenance or enhancement work was required in Cell 1 during WY2013. Incremental conversion of EAV to SAV in the southern (downstream) half of Cell 2 continued with herbicide treatment of 440 acres of cattail. Gaps in the southernmost vegetation strip in Cell 3 were closed with plantings of giant bulrush. In Cell 4, 686 acres of cattail that had established when this cell partially dried out during construction of Compartment B were treated to reestablish SAV. There was intensive management of Cells 5 and 6 where 2,780 acres of willow were treated, and conversion of EAV to SAV in the southern (downstream) portions of these cells was initiated with the treatment of 535 acres of cattail.

VEGETATION SURVEYS

Vegetation Coverage Estimates Based on Aerial Imagery

Changes in vegetation coverage in STA-2 from April 2011 to April 2012 ranged from very little change in Cell 3 (< 1 percent), small decreases in EAV coverage in Cells 1 and 2 (~2-5 percent), and a 10 percent decrease in Cell 4 (**Table 5B-8**). Field observations noted healthy, dense cattail stands and sparse areas of sawgrass in Cells 1 and 2. The composition of the vegetation community exhibited a positive change in Cells 3 (SAV) and 4 (SAV), whereas there was a negative change in Cell 1 (EAV). Cell 2 had both EAV and SAV so it was not possible to evaluate the coverage change in this cell. At this time, it cannot be determined whether the negative changes in the vegetation community adversely affected treatment performance in STA-2.

Table 5B-8. Summary of vegetation coverage in cells of STA-2 based on analysis of aerial imagery. Percent coverage calculated relative to total surface area of each cell.

Cell	Coverage Type	% Coverage 2011	% Coverage 2012	% Change in EAV Cover from 2011–2012
Cell 1	Water/SAV	3.07	8.1	
	EAV	96.93	91.9	-5.07
Cell 2	Water/SAV	35.05	37.1	
	EAV	64.95	62.9	-2.09
Cell 3	Water/SAV	68.53	69.3	
	EAV	31.47	30.7	-0.78
Cell 4	Water/SAV	44.20	54.4	
	EAV	55.80	45.6	-10.22

Ground Surveys for Submerged Aquatic Vegetation

An SAV survey conducted in October 2012 at the outflow region of Cell 2 (i.e., the area where the aquatic plant community had been converted from cattail to SAV) found widespread SAV coverage with muskgrass the dominant species and southern naiad expanding its coverage (**Figure 5B-14**) from that observed in June 2011 (see Figure 5-21 in Ivanoff et al., 2013). A second survey conducted in April 2013 noted a decline in the coverage and relative abundance of both species.

Surveys conducted in Cell 3 on March 2012 and April 2013 found abundant SAV coverage throughout the cell (**Figure 5B-15**). A mixture of southern naiad, muskgrass, coontail, and hydrilla dominated the cell's inflow region, while the middle and outflow regions were dominated by muskgrass, with small areas of dense pondweed and southern naiad at the outflow. Spiny naiad (*Najas marina*) was present in low abundance near the cell outflow.

A survey of Cell 4 on April 2013 found that muskgrass, spiny naiad, and pondweed were becoming reestablished at the inflow and outflow regions of the cell, areas previously treated with herbicide to reduce cattail encroachment and encourage SAV growth (**Figure 5B-16**).

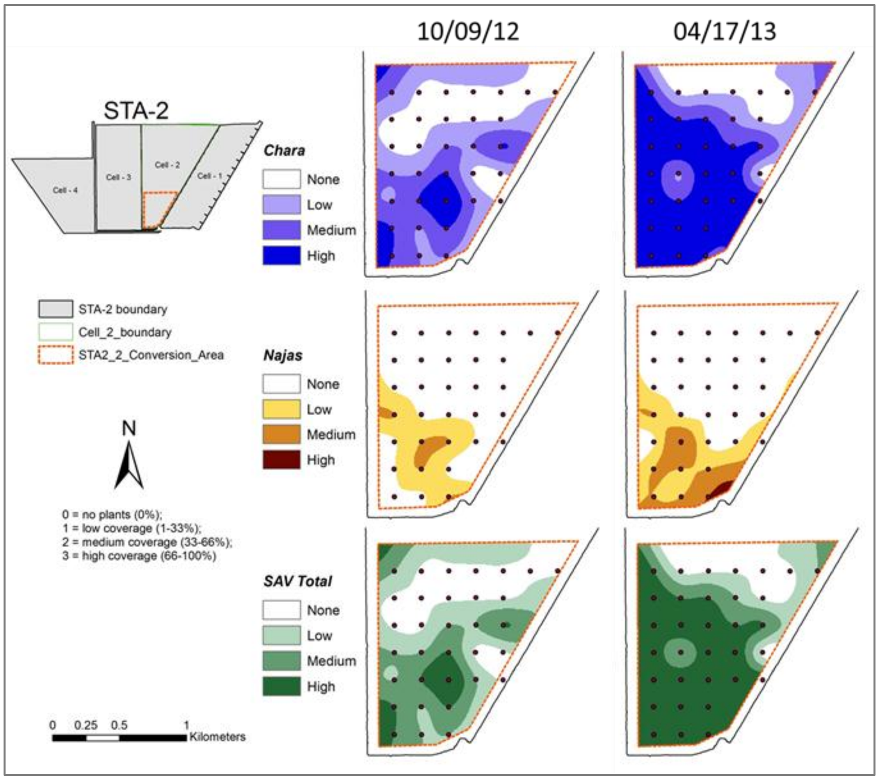


Figure 5B-14. Ground survey results depicting the spatial coverage and relative abundance of muskgrass (*Chara* sp.), southern naiad (*N. guadalupensis*), and all SAV species combined in the STA-2 Cell 2 Conversion Area on October 9, 2012 and April 17, 2013. Dots indicate location of SAV ground survey sites and location of the Conversion Area is noted on the STA-2 map insert.

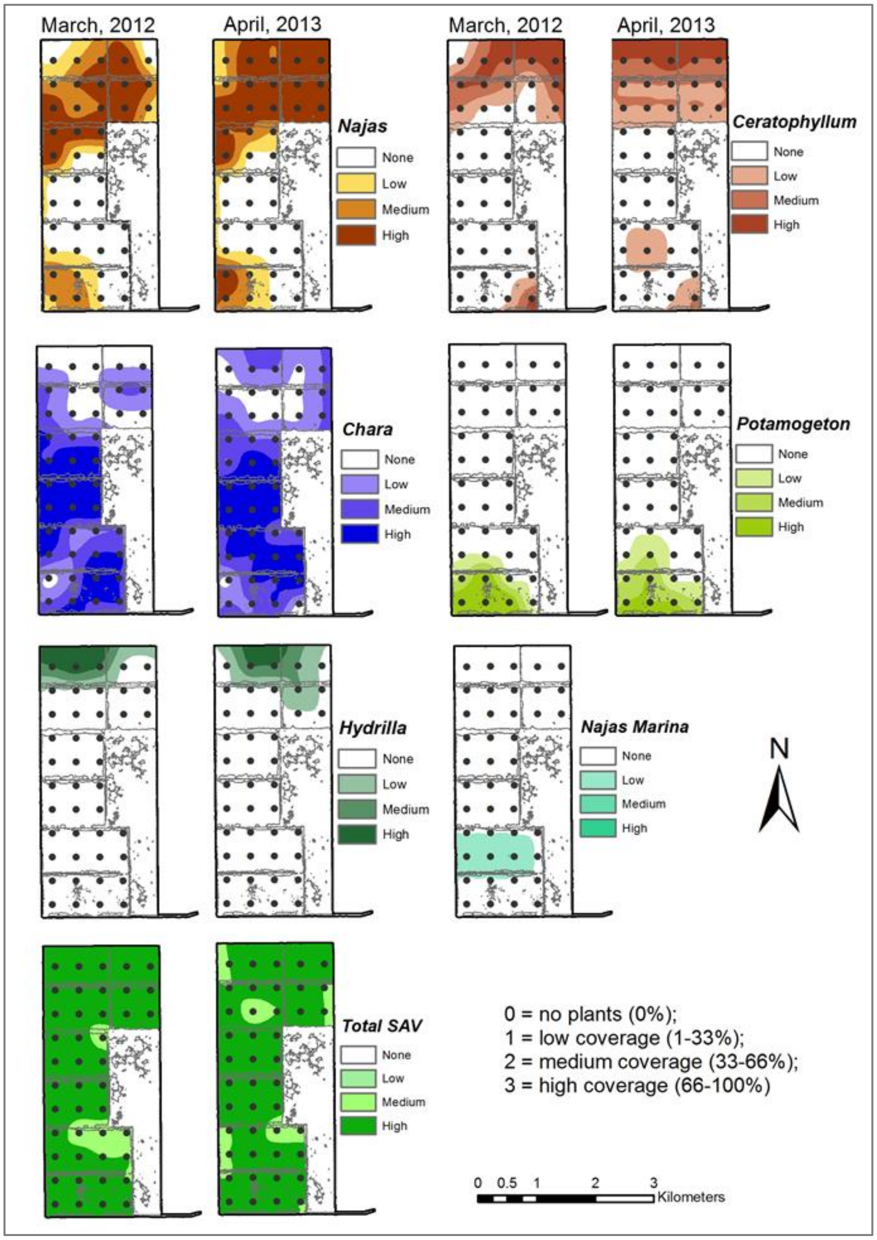


Figure 5B-15. Ground survey results depicting the spatial coverage and relative coverage of southern naiad (*N. guadalupensis*), coontail (*C. demersum*), muskgrass (*Chara* sp.), pondweed (*P. illinoensis*), hydrilla (*H. verticillata*), spiny naiad (*N. marina*), and all SAV species grouped together in STA-2 Cell 3 on March 15, 2012 and April 11, 2013. Dots indicate location of SAV ground survey sites.

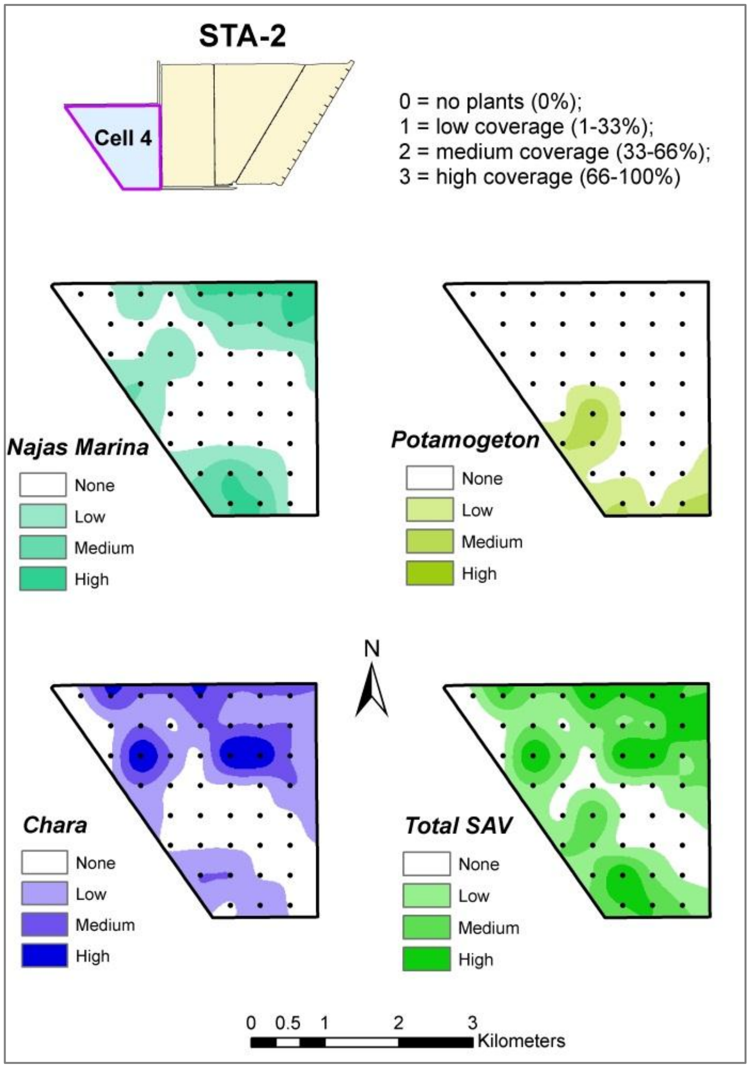


Figure 5B-16. Ground survey results depicting the spatial coverage and relative abundance of spiny naiad (*Najas marina*), pondweed (*P. illinoensis*), muskgrass (*Chara* sp.), and all SAV species grouped together in STA-2 Cell 4 on April 9, 2013. Dots indicate location of SAV ground survey sites.

STA-3/4

STA-3/4 is located northeast of the Holey Land Wildlife Management Area and north of Water Conservation Area 3A (WCA-3A) (**Figure 5B-1**). This STA is comprised of six treatment cells arranged into three flow-ways with a total effective treatment area of 16,327 acres (Piccone et al., 2013; **Figure 5B-17**). A 445-acre section of Cell 2B is the site of the District's STA-3/4 PSTA Project, constructed as the first phase of implementing the PSTA treatment technology in this STA. STA-3/4 treats stormwater runoff from the S-2/S-7, S-3/S-8, S-236, and C-139 basins, and releases from Lake Okeechobee. During dry months, supplemental water is delivered from Lake Okeechobee, when available, to maintain hydration of priority cells, i.e., cells dominated by SAV. The flow-way nomenclature for STA-3/4 is as follows:

- Eastern Flow-way = Cells 1A and 1B,
- Central Flow-way = Cell 2A and 2B, and
- Western Flow-way = Cell 3A and 3B.

Similar to the other STAs, STA-3/4 has been affected by extreme weather events (regional droughts and large storms). This STA has received high hydraulic loads during and following large storms, which resulted to excessively deep water for extended periods in cells at the top of the flow-ways. Persistent deep-water conditions stressed the cattail populations in Cells 1A and 2A causing widespread mortality, especially at the inflow regions of these cells.

STA TREATMENT PERFORMANCE

STA-3/4 over its operational history has treated the largest volume of water (~4,200,000 ac-ft) and retained the most TP (493 mt) with the greatest treatment efficiency, based on its % TP load retained (84 percent) of all the STAs (**Table 5B-1**). The POR inflow FWM TP concentration STA-3/4 was 113 ppb, while the POR outflow FWM TP concentration was 17 ppb, which is the lowest POR outflow TP concentration among the STAs. Based on the rank order of these metrics, STA-3/4 has been the best performing STA over its POR.

STA-3/4 treated approximately 480,000 ac-ft of runoff in WY2013 that had a FWM TP concentration of 105 ppb and produced an outflow FWM TP concentration of 14 ppb (**Table 5B-1**). This facility retained 53 mt of TP, or 86 percent of the inflow TP load received this year and had a HLR and PLR of 2.5 cm/day and 0.9 $g/m^2/yr$, respectively. The treatment performance of STA-3/4 in WY2013, as measured by its outflow FWM TP concentration and % TP load retained, was within the range of values observed in this STA over its POR (**Figure 5B-18**, panels A and C) and ranked STA-3/4 first in treatment performance among all STAs this year (**Table 5B-1**). A significant linear relationship was detected between annual inflow and outflow TP loads (coefficient of determination, $R^2 = 0.81$) but not for annual inflow and outflow FWM TP concentrations (see regression line in **Figure 5B-18**, panel D).

The HLRs and PLRs in the Eastern, Central and Western Flow-ways of STA-3/4 in WY2013 (2.2 to 3.6 cm/day and 0.5 to 0.7 $g/m^2/yr$, respectively) all increased compared to rates in WY2012 and WY2011 (**Table 5B-9**); inflow water loads to the three flow-ways were 30 to 53 percent higher in WY2013 than in the previous two years. Treatment performance based on outflow FWM TP concentration has been slightly better in the Western Flow-way over the past three years (13 to 15 ppb) compared to the other two flow-ways (15 to 21 ppb). However, there was relatively little difference among flow-ways with respect to the annual % TP load retained in these years.

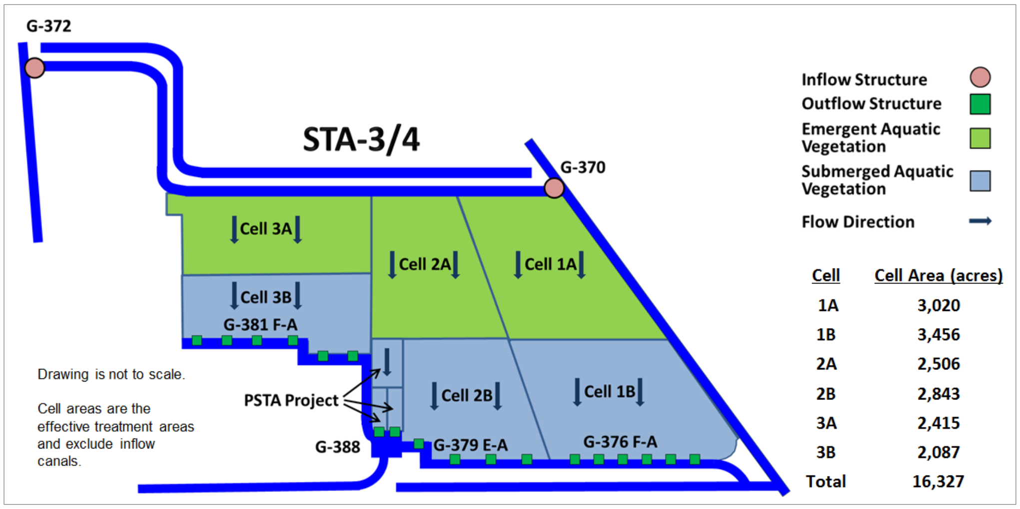


Figure 5B-17. Simplified schematic of STA-3/4 showing major inflow and outflow water-control structures, effective treatment area of each cell, flow direction, and dominant/target vegetation types. [Note: A detailed structure map of STA-3/4 is provided in Appendix 5B-1 of this volume; effective treatment areas do not include pump stations, levees, roads, or other upland areas. Cell 2B area includes the area of the PSTA Project.]

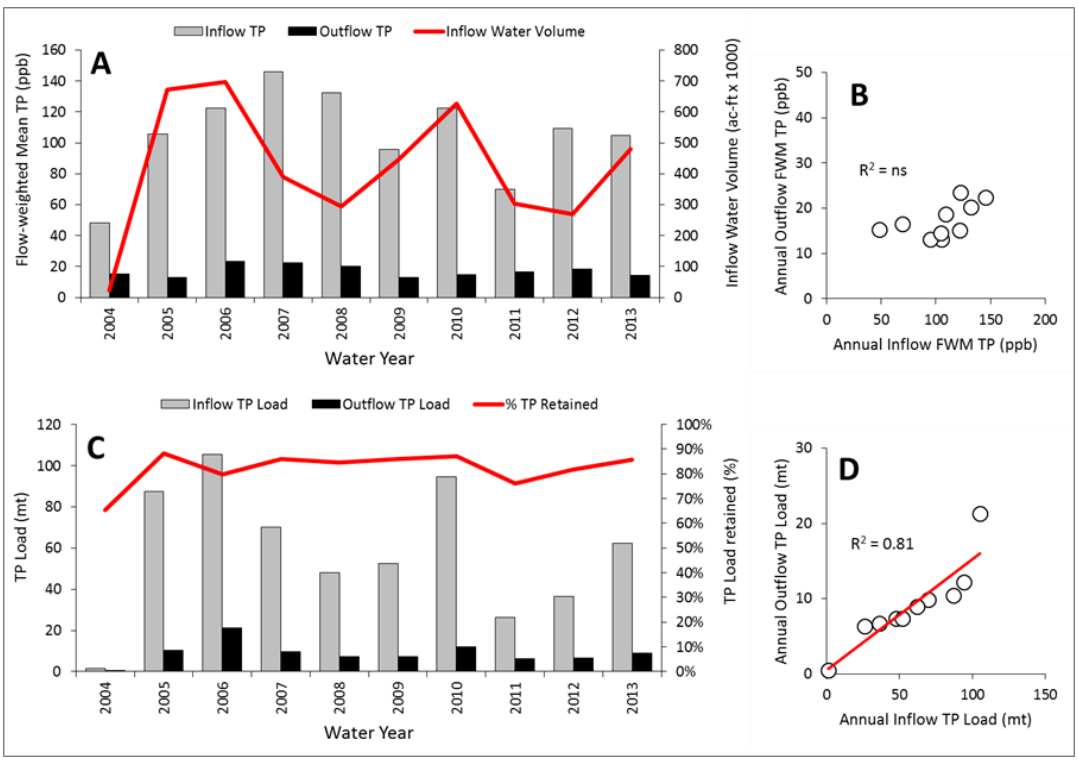


Figure 5B-18. Comparison over the period of record in STA-3/4 of (A) time-series of annual inflow and outflow FWM TP concentrations with corresponding inflow water volumes, (B) scatterplot of annual inflow versus outflow FWM TP concentrations, (C) time-series of annual inflow and outflow TP loads with percent TP load retained, and (D) scatterplot of annual inflow versus outflow TP loads.

Table 5B-9. Comparison of flow-way treatment performance in STA-3/4 from WY2011 to WY2013.

Flow-way/ Water Year	Effective Treatment Area (acre)	PLR ($g/m^2/yr$)	HLR (cm/day)	Inflow Volume (ac-ft)	Inflow FWM TP (ppb)	Outflow FWM TP (ppb)	TP Retained (mt)	TP Retained (%)
Eastern Flow-way	6,476							
WY2011		0.4	1.2	93,579	84	16	7.7	80%
WY2012		0.2	1.0	80,369	60	20	3.8	64%
WY2013		0.6	2.2	172,401	79	15	13.2	79%
Central Flow-way	5,349							
WY2011		0.3	1.5	97,230	52	21	3.9	62%
WY2012		0.3	1.5	93,373	49	21	3.2	57%
WY2013		0.5	2.2	139,650	59	17	7.8	76%
Western Flow-way	4,502							
WY2011		0.4	2.1	112,832	51	14	5.2	72%
WY2012		0.3	2.3	123,600	35	15	3.1	57%
WY2013		0.7	3.6	196,412	51	13	9.5	77%

FACILITY STATUS AND OPERATIONAL ISSUES

All flow-ways in STA-3/4 were operational in WY2013 (**Table 5B-2**). In January 2013, a regulatory release from Lake Okeechobee was moved through STA-3/4 into WCA-3. To help quantify the role that vegetation resistance plays in STA flow dynamics, a flow-resistance study was conducted in Cell 3A from November 2012 to January 2013. Flow rates ranging from 200 to 900 cfs were tested. This study was part of the District's Restoration Strategies Science Plan (see Chapter 5C of this volume).

Starting in January 2013, Cell 2A was placed on restricted operation in preparation for a drawdown to lower water level in this cell and recruit new cattail. The small G-386 Pump Station located at the south end of the cell was operated continuously to remove water. Two temporary pumps were deployed in March 2013 to assist with the drawdown. The drawdown operation was interrupted for a short period in March 2013 by heavy rainfall. Other vegetation management activities in STA-3/4 during WY2013 included bulrush collection and planting in Cell 1A and aerial herbicide treatments of undesired macrophytes in Cells 1A, 2A, 1B, 2B, and 3B. No supplemental water from Lake Okeechobee was delivered to STA-3/4 this year.

Structure maintenance activities in STA-3/4 this year included repairing a gearbox at the G-385 Pump Station, replacing the G-378 tailwater stage sensor, and other routine maintenance.

Dryout Impacts

All the cells in STA-3/4 were fully hydrated in WY2013. There were no negative impacts due to dryout this year.

STA-3/4 PSTA Project

The STA-3/4 PSTA Project was constructed as the first phase of implementing this treatment technology in STA-3/4. The project comprises 400 acres in the far western side of Cell 2B (**Figure 5B-17**) that is divided into a single 200-acre upper SAV Cell and two side-by-side downstream 100-acre cells (the lower SAV and PSTA Cells). All cells have been managed to promote a SAV community and associated periphyton assemblage. All the sediment in the PSTA Cell was removed exposing the underlying caprock (i.e., limestone bedrock). In WY2013, the PSTA Cell's annual inflow FWM TP concentration was 16 ppb while the corresponding outflow TP concentration was 11 ppb, which was within the 8–12 ppb range achieved in this cell over its six-year POR. Further details concerning the STA-3/4 PSTA project are included in the *Applied Scientific Studies* section of this chapter.

Impacts of Migratory Bird and Snail Kite Nesting

The STA-3/4 PSTA Cell had five black-necked stilt nests during WY2013. Four of these nests occurred during the 2012 nesting season (April to July 2012). Stage in the PSTA Cell during this period was held at or below 10.67 ft NGVD to minimize impacts to nests. One nest was observed in the PSTA Cell in April 2013 and stage was held at or below 10.50 ft NVGD to minimize impact to this nest. Three stilt nests were observed in STA-3/4 Cells 2A and 3B during May 2013 (WY2014). Stage in these cells during the nesting period was held at or below 9.50 and 11.10 ft NGVD, respectively, to minimize impacts to these nests.

There were no documented impacts to STA-3/4 treatment performance due to nesting black-necked stilts in WY2013 and the stage restrictions imposed this year likely will not affect future operations. However, constraints imposed on STA-3/4 in response to nesting birds, i.e., the disproportionate redirection of flow among flow-ways, may reduce the ability of this STA to achieve optimum treatment performance in the future. Any long-term impacts to the functioning of STA-3/4 related to the presence of nesting birds cannot be assessed at this time. No active Everglade snail kite nests were observed in STA-3/4 during WY2013.

MAINTENANCE AND ENHANCEMENTS

Vegetation enhancement measures in the Eastern Flow-way during WY2013 followed up on the 2011 water drawdown in Cell 1A with herbicide treatments of 276 acres of FAV (particularly water hyacinth) and plantings of giant bulrush in the northern half of this cell. The management focus in Cell 1B was to reduce the coverage of cattail (790 acres treated) that had recolonized the southern portion of this SAV cell. A drawdown of water levels in the northern third of Cell 2A in the Central Flow-way was conducted during spring 2013 to enhance the density and health of the existing cattail population. During the drawdown, 180 acres of water hyacinth were treated to provide areas for colonization of cattail seedlings and, if needed, plantings of giant bulrush. Herbicide treatments of cattail expansion in Cell 2B (50 acres) and Cell 3B (430 acres) were conducted to promote the expansion of SAV beds in these cells.

VEGETATION SURVEYS

Vegetation Coverage Estimates Based on Aerial Imagery

Changes in vegetation coverage in STA-3/4 from April 2011 to April 2012 ranged from almost no change in EAV coverage in Cell 3A (< 1 percent), small increases in Cells 1A, 2A, and 2B (~3 percent), a moderate increase in Cell 3B (~6 percent), and a 16.7 percent decrease in Cell 1B (**Table 5B-10**). The composition of the vegetation community exhibited a positive change in Cells 1A (EAV), 1B (SAV), and 2A (EAV), whereas there were negative changes in Cells 2B (SAV), 3A (EAV), and 3B (SAV). At this time, it cannot be determined whether the negative changes in the vegetation community adversely affected treatment performance in STA-3/4.

Table 5B-10. Summary of vegetation coverage in cells of STA-3/4 based on analysis of aerial imagery. Percent coverage calculated relative to total surface area of each cell.

Cell	Coverage Type	% Coverage 2011	%Coverage 2012	% Change in EAV Cover from 2011-2012
Cell 1A	Water/SAV	21.19	18.23	
	EAV	78.81	81.77	2.96
Cell 1B	Water/SAV	52.28	68.93	
	EAV	47.72	31.07	-16.65
Cell 2A	Water/SAV	19.64	16.85	
	EAV	80.36	83.15	2.79
Cell 2B	Water/SAV	75.31	72.09	
	EAV	24.69	27.91	3.22
Cell 3A	Water/SAV	5.24	5.75	
	EAV	94.76	94.25	-0.51
Cell 3B	Water/SAV	68.43	62.00	
	EAV	31.57	38.00	6.43

Ground Surveys for Submerged Aquatic Vegetation

SAV was widespread in STA-3/4 Cells 1B and 2B during ground surveys conducted in WY2013 where the community comprised six species: muskgrass, bladderwort, southern naiad, spiny naiad, coontail, and pondweed (**Figures 5B-19** and **5B-20**). Muskgrass and southern naiad were the dominate species with respect to both spatial coverage and relative abundance in both cells, while the other species were sparsely distributed.

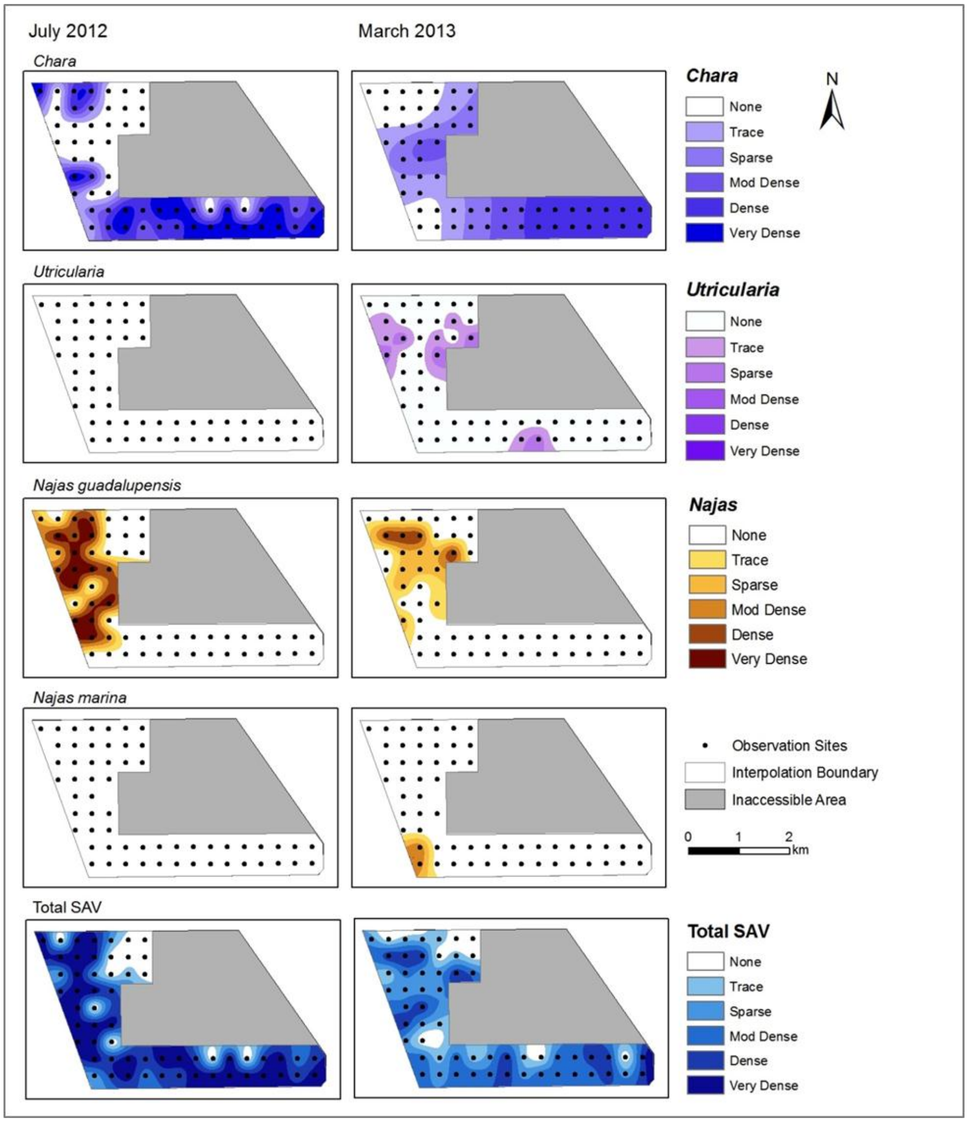


Figure 5B-19. Ground survey results depicting the spatial coverage and relative abundance of muskgrass (*Chara* sp.),bladderwort (*Utricularia* spp.), southern naiad (*N. guadalupensis*), spiny naiad (*N. marina*), and all SAV species grouped together in STA-3/4 Cell 1B on July 18, 2012, and March 20, 2013. Dots indicate location of SAV ground survey sites.

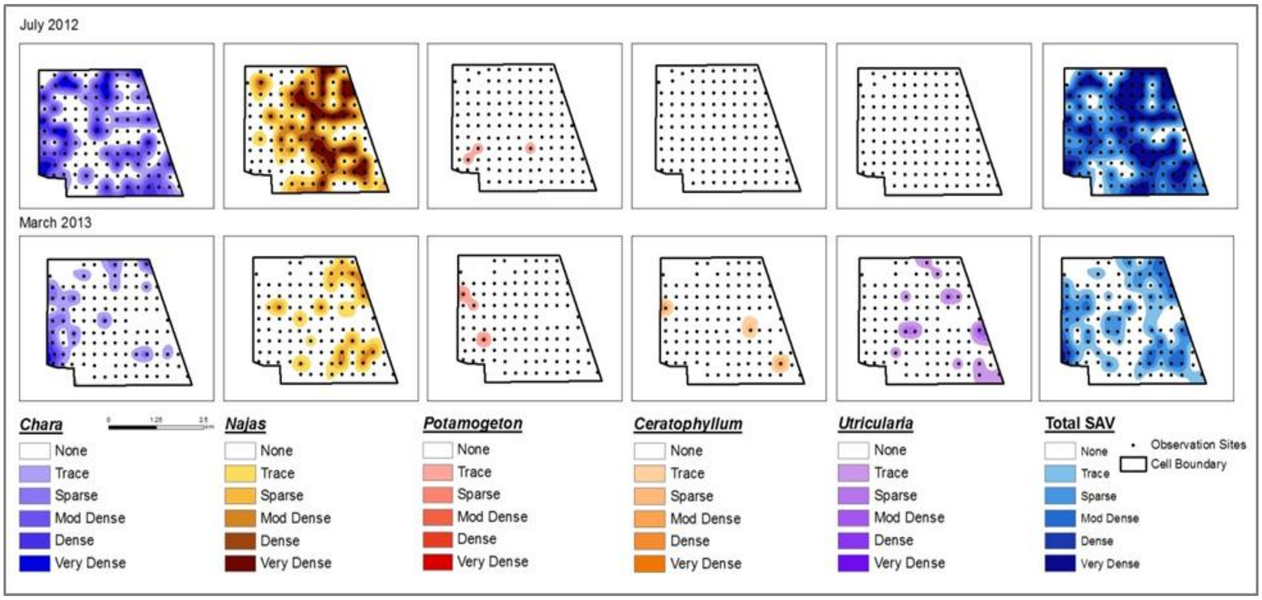


Figure 5B-20. Ground survey results depicting the spatial coverage and relative abundance of coontail (*C. demersum*), southern naiad (*N. guadalupensis*), pondweed *(P. illinoensis*), muskgrass (*Chara* sp.), bladderwort (*Utricularia* spp.), and all SAV species grouped together in STA-3/4 Cell 2B on July 17, 2012, and March 19–20, 2013. Dots indicate location of SAV ground survey sites.

STA-5/6

STA-5, which receives inflows primarily from the C-139 Basin, is located in Hendry County and bordered by the C-139 and C-139 Annex Basins on the west and the Rotenberger Wildlife Management Area on the east (**Figure 5B-1**). The original STA-5 (Flow-ways 1 and 2) began operating in 2000. STA-6, also located in Hendry County, is south of STA-5, east of the L-3 borrow canal, and west of the Rotenberger Wildlife Management Area (**Figure 5B-1**). The original STA-6, which consisted of Cells 6-3 and 6-5, began operation in 1997 and treated agricultural runoff from the United States Sugar Corporation's Southern Division Ranch, Unit 2. After Unit 2 was purchased for restoration purposes and farming operations ended, this area became known as Compartment C. In 2006, Section 2 (now Cell 6-2) was added to STA-6, and a third flow-way (Flow-way 3) was added to STA-5 on a portion of what was to become Compartment C. In 2012, construction of treatment facilities was completed on the remaining portion of Compartment C. The STA-5/6 complex, consisting of the former STA-5, Compartment C, and the former STA-6, has 14 treatment cells arranged into eight flow-ways with a total effective treatment area of 13,685 acres (Piccone et al., 2013; **Figure 5B-21**) and is operated as an integrated facility to treat runoff from the C-139 Basin. The analysis of treatment performance in this section is based on past and present operation of the integrated facility. Performance measures for STA-5 and STA-6 that were reported individually in past annual reports have been recalculated as STA-5/6 for this year's analysis.

The flow-way nomenclature for STA-5/6 is as follows:

- Flow-way 1 = Cells 5-1A and 5-1B (former STA-5 Northern Flow-way),
- Flow-way 2 = Cells 5-2A and 5-2B (former STA-5 Central Flow-way),
- Flow-way 3 = Cells 5-3A and 5-3B (former STA-5 Southern Flow-way),
- Flow-way 4 = Cells 5-4A and 5-4B (new cells in Compartment C),
- Flow-way 5 = Cells 5-5A and 5-5B (new cells in Compartment C),
- Flow-way 6 = Cells 6-4 and 6-2 (new cell in Compartment C and former STA-6 Section 2)
- Flow-way 7 = Cell 6-5, and
- Flow-way 8 = Cell 6-3.

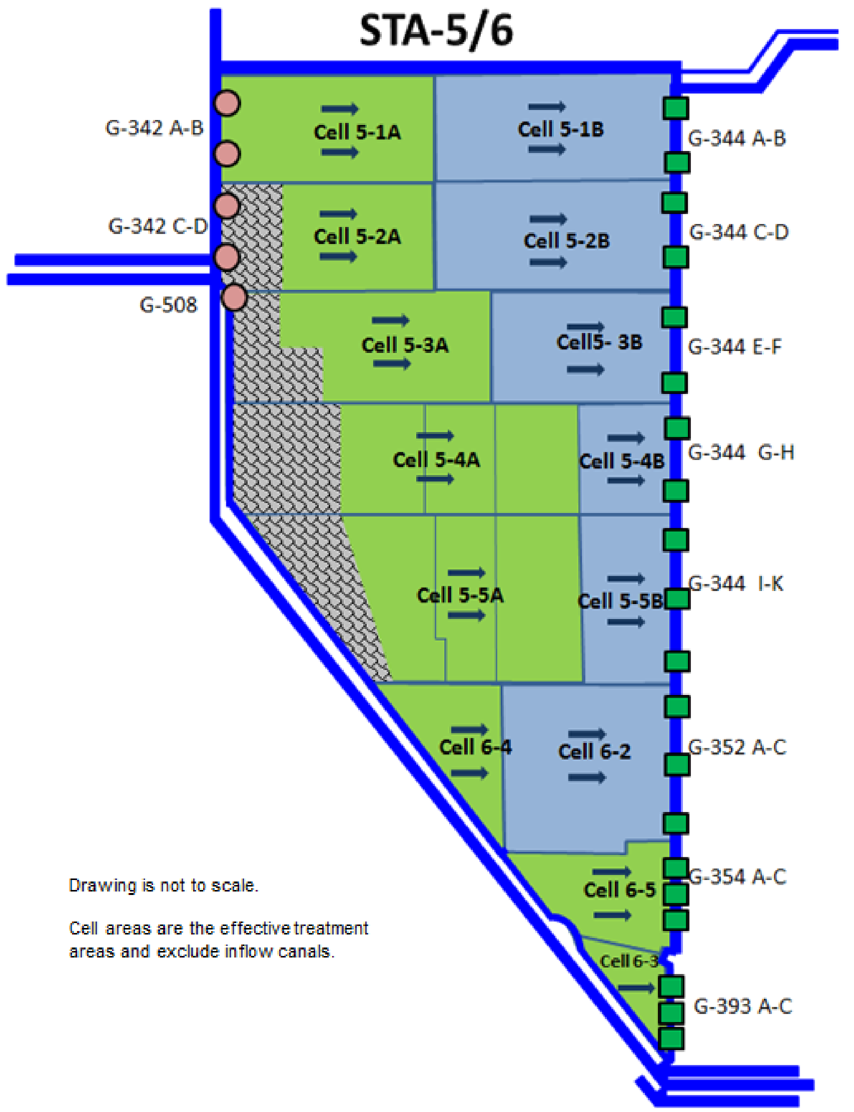
Over its period of operation, STA-5/6 has been affected by high inflow TP concentrations and extreme weather events (regional droughts and large storms). The EAV cells in this STA have dried out almost every dry season, and WY2013 was no exception. High soil P flux has followed rehydration of these cells, usually resulting in temporary spikes in outflow TP concentration. The District implemented drought contingency strategies, including delivery of supplemental water from Lake Okeechobee, which reduced dryout impacts in STA-5/6 this year and is discussed in the *Facility Status and Operational Issues* section of this chapter.

STA TREATMENT PERFORMANCE

STA-5/6 over its operational history has treated approximately 1,970,000 ac-ft of water and retained 286 mt of TP or 66 percent of the POR inflow TP load (**Table 5B-1**). The POR inflow flow-weighted mean (FWM) TP concentration was 179 ppb, while the POR outflow FWM TP concentration was 74 ppb. Based on the rank order of its overall outflow FWM TP concentration and % TP load retained, STA-5/6 has been the poorest performing STA over its operational history.

STA-5/6 treated approximately 58,800 ac-ft in WY2013 and retained 9 mt of TP with 90 percent of the inflow TP load retained (**Table 5B-1**). The inflow FWM TP concentration this year was 131 ppb while the outflow FWM TP concentration was just 17 ppb. This was one of the lowest outflow TP concentrations and the highest annual treatment efficiency ever recorded in STA-5/6 (and the highest annual treatment efficiency for any STA) (**Figure 5B-22**, panels A and C). This good performance can be attributed to the combined effects of effective operation, recent enhancements (including the Cell 5-1A rehabilitation, improvements made to vegetation strips in the SAV cells, and improved vegetation establishment), and reduced HLR and PLR. The HLR and PLR in STA-5/6 were quite low this year with rates (0.6 cm/day and 0.3 $g/m^2/yr$, respectively) that were one-third or less the rates observed in other STAs (**Table 5B-1**). Furthermore, the inflow TP loads to STA-5/6 over the last three water years were much lower than most of the inflow TP loads from WY2002 to WY2010 (**Figure 5B-22**, panel C). Significant linear relationships were detected between annual inflow and outflow FWM TP concentrations and annual inflow and outflow TP loads (coefficients of determination, R^2 = 0.55 and 0.87, respectively; see regression lines in **Figure 5B-22**, panels B and D).

There was no consistent pattern in treatment performance among STA-5/6 flow-ways; outflow FWM TP concentrations decreased in Flow-ways 1 and 2 from WY2011 to WY2013 while outflow TP concentrations increased markedly in Flow-ways 7 and 8 (**Table 5B-11**). The poor treatment performance in the latter two flow-ways was attributed to the prolonged periods of dryout in WY2012 and WY2013 (see the *Dryout Impacts* section below) and the subsequent spikes in outflow TP that occurred when the cells were rehydrated. The effects of dryout in Flow-ways 1 and 2 were lessened because the SAV cell in each flow-way was kept hydrated in both water years.



Cell	Cell Area (acres)
5-1A	1,195
5-1B	1,223
5-2A	835
5-2B	1,233
5-3A	1,002
5-3B	920
5-4A	1,403
5-4B	468
5-5A	1,938
5-5B	704
6-4	539
6-2	1,361
6-5	621
6-3	242
Total	13,685

Figure 5B-21. Simplified schematic of STA-5/6 showing major inflow and outflow water-control structures, effective treatment area of each cell, flow direction, and dominant/target vegetation types. [Note: A detailed structure map of STA-5/6 is provided in Appendix 5B-1 of this volume; effective treatment areas do not include pump stations, levees, roads, or other upland areas.]

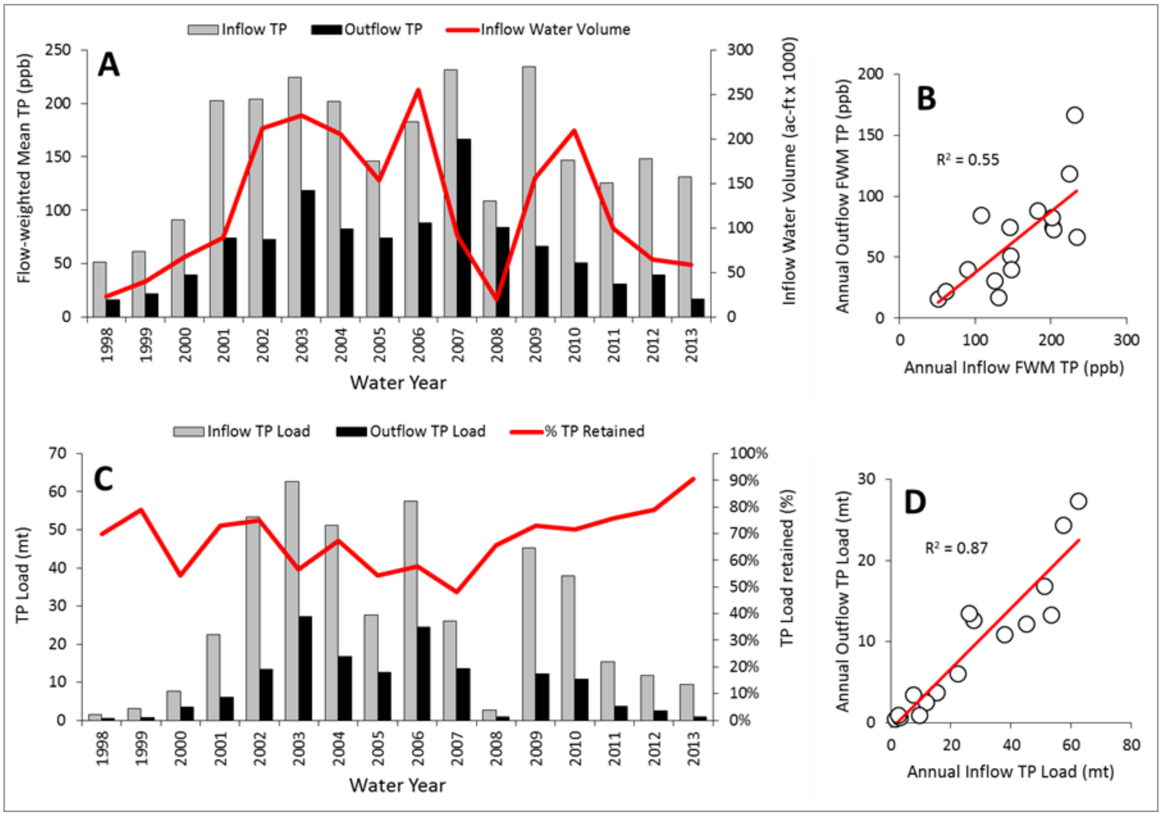


Figure 5B-22. Comparison over the period of record in STA-5/6 of (A) time-series of annual inflow and outflow flow-weighted mean (FWM) TP concentrations with corresponding inflow water volumes, (B) scatterplot of annual inflow versus outflow FWM TP concentrations, (C) time-series of annual inflow and outflow TP loads with percent TP load retained, and (D) scatterplot of annual inflow versus outflow TP loads.

Table 5B-11. Comparison of flow-way treatment performance in STA-5/6 from WY2011 to WY2013.

Flow-way/ Water Year	Effective Treatment Area (acre)	PLR ($g/m^2/yr$)	HLR (cm/day)	Inflow Volume (ac-ft)	Inflow FWM TP (ppb)	Outflow FWM TP (ppb)	TP Mass Retained (mt)	TP Mass Retained (%)
Flow-way 1	2,418							
WY2011		0.4	1.2	33,423	84	41	2.6	75%
WY2012		0.5	1.3	36,393	106	36	3.8	79%
WY2013		0.4	0.9	26,343	111	15	3.2	89%
Flow-way 2	2,068							
WY2011		0.2	0.4	9,379	149	54	1.4	82%
WY2012		0.6	1.0	24,515	165	28	4.3	87%
WY2013		0.6	1.1	27,710	151	16	4.8	92%
Flow-way 3	1,942							
WY2013		0.1	0.1	1,290	81	14	0.4	<99%
Flow-way 7	621							
WY2011		0.5	1.3	9,941	97	17	1.0	82%
WY2012		0.7	1.6	11,650	129	85	1.2	63%
WY2013		0.02	0.1	538	73	100	0.03	53%
Flow-way 8	242							
WY2011		0.7	1.9	5,629	93	17	0.5	83%
WY2012		0.7	1.8	5,251	112	53	0.6	80%
WY2013		0.2	0.5	1,444	105	60	0.1	55%

FACILITY STATUS AND OPERATIONAL ISSUES

Flow-ways 1, 2, 3, and 8 of STA-5/6 were operational throughout WY2013 (**Table 5B-2**). Flow-way 7 was offline from April to October 2012 for removal of a redundant interior levee, which also assisted the construction of the protective measures for Environmentally Sensitive Areas (ESAs) in Flow-way 5, but was operational thereafter. Flow-ways 4 and 6 passed their start-up criteria and became available for use in December 2012. Start-up operations were not initiated in Flow-way 5 during WY2013 due to the construction of protective measures for ESAs. Supplemental water was delivered through structures G-507 and G-509 (see Appendix 5B-1, Figure 5) to Cells 5-1B, 5-2B, and 5-4B to keep SAV beds in these cells hydrated during the dry season. However, Cells 5-1A, 5-2A, 5-3A, 5-3B, and Flow-ways 7 and 8 did dry out during this period due to lack of rainfall in the drainage basin or the inability to deliver supplemental water to these cells. Accordingly, water quality sampling was suspended in these cells until they reflooded at start of the rainy season.

Vegetation start-up activities in newly constructed Cells 5-4A, 5-4B, 5-5A, 5-5B, and Cell 6-4 continued in WY2013. Approximately 900 acres of non-effective treatment area in Flow-ways 4 and 5 received aerial herbicide treatments. Cells 5-3B and 5-4B were inoculated with SAV collected from STA-2 Cell 2 and STA-3/4 Cell 2B. Other vegetation management activities in STA-5/6 during WY2013 included briefly lowering the stage in Cells 5-1B and 5-2B to improve hydrilla establishment and enable herbicide treatments of 1,000 acres of primrose willow in Cells 5-1A, 5-2A, 5-3A, and 5-4A and 300 acres of cattail in Cell 5-3B. The stage in several cells in STA-5/6 was restricted in April 2013 due to the presence of nesting black-necked stilts, a species protected under the MBTA (see the *Impacts of Migratory Bird and Snail Kite Nesting* section below and Appendix 5B-2 of this volume).

A new culvert, G-715, was constructed in the northeast corner of Cell 5-3B and is intended to assist in maintaining minimum water levels and vegetation health in the cell. Other structure maintenance activities during WY2013 include repairing structures G-352B and G-353C, and other routine maintenance.

Dryout Impacts

Dryout in the STAs, by definition, occurs when the daily average water stage in a cell is equal to the cell's average ground elevation, i.e., the cell's daily average water depth is zero[8]. Cells in STA-5/6 started to reach dryout conditions in February or March 2012 (**Figure 5B-23**). Cells 5-1A, 5-2A, 5-3A, 5-3B, 6-3, and 6-5 were dry for some period at the start of WY2013. The duration of dryout ranged from 85 days in Cell 5-3A to 208 days in Cell 5-1A (**Table 5B-12**). Supplemental water could not be delivered to these cells to keep them hydrated. Outflow TP concentrations from these cells spiked immediately after reflooding and resumption of STA operations. The maximum weekly outflow TP concentrations ranged from 43 ppb in Cell 5-3A to 423 ppb in Cell 5-2A. The EAV communities in STA-5/6 tolerated the dryout well. The only negative impact was an increase in the areal coverage of willow in Cells 6-3 and 6-5 (L. Toth, SFWMD, personal communication).

Table 5B-12. The period and duration of dryout and the maximum FWM TP outflow concentrations upon rehydration in STA-5/6 cells that dried out during WY2013.

	Cell 5-1A	Cell 5-2A	Cell 5-3A	Cell 5-3B	Cell 6-3	Cell 6-5
Period of dryout	02/01/12 - 08/26/12	02/23/12 - 06/09/12	03/18/12 - 06/22/12	03/28/12 - 08/13/12	03/20/12 - 08/26/12	02/24/12 - 08/25/12
Duration of dryout (day)*	208	108	85	118	160	184
Max. outflow TP upon rehydration (ppb)	85	423	43	108	83	71

*The duration of dryout represents the number of days that the average water depth was ≤ 0 ft during the period of dryout and may be less than the total number of days between the period's start and end dates.

[8] Daily average water stage across a STA cell is calculated as the average of the tailwater stage at the inflow structures and the headwater stage at the outflow structures on a given day. Daily average water depth is then calculated as the difference between the daily average stage and the average ground elevation.

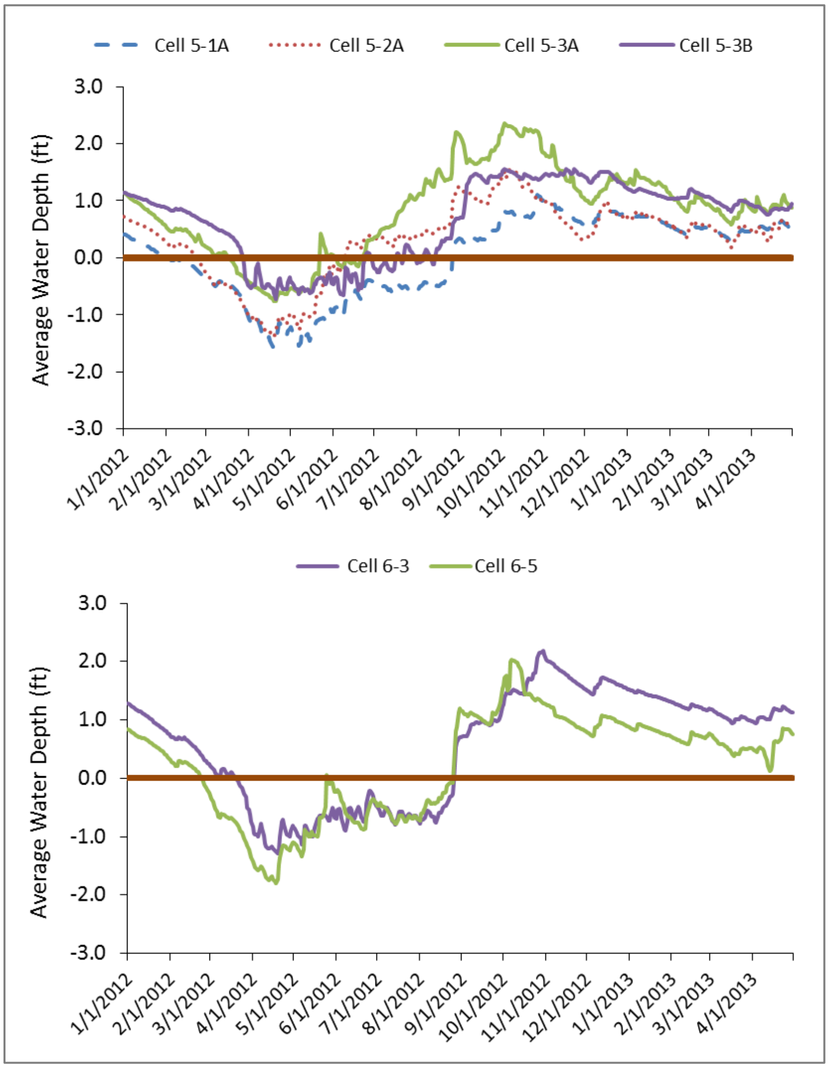


Figure 5B-23. Daily average water depths in STA-5/6 cells that dried out in WY2013: Cells 5-1A, 5-2A, 5-3A, and 5-3B (top panel) and Cells 6-2 and 6-5 (bottom panel). Dryout conditions started in February 2012 and persisted until June to August 2012, depending on the cell. Daily Average water depth was computed as the average stage of the inflow structure's tailwater and the outflow structure's headwater minus the average ground elevation.

Impacts of Migratory Bird and Snail Kite Nesting

Eleven black-necked stilt nests were observed during May and June 2012 in STA-5/6. All nests were located in cells that were under construction as part of the Compartment C build-out and therefore were not in operation; these nests did not affect construction activities. Ten nests were observed in Cells 5-1B, 5-2B, 5-3B, and 5-5B (**Figure 5B-21**) during April 2013. Stage in these cells during the nesting period was held at or below 12.50, 12.50, 13.30, and 13.60 ft NGVD, respectively, to minimize impacts to these nests. No other stilt nests were found in STA-5/6 during WY2013. Thirty-five stilt nests were found in STA-5/6 Cells 5-1B, 5-2B, 5-3B, 5-4A, and 5-4B in May and June 2013 (surveys conducted in WY2014). Stage in these cells during the nesting period were held at or below 12.50, 12.30, 13.60, 13.30, and 13.20 ft NGVD respectively to minimize impacts to these nests. There appeared to be a high level of nesting success by black-necked stilts in STA-5/6 based on the large number of chicks observed in June and July 2013.

An Everglade snail kite was reported nesting within 500 ft of STA-5/6 in March 2013. The presence of this nest did not require a change in STA operations, but District maintenance staff operating near the nest was mindful of its presence. The nest was considered to have been successful. No other snail kite nests were discovered in STA-5/6 during WY2013. Twenty-two snail kite nests were observed and monitored in STA-5/6 Cell 5-3B from May to August 2013 (WY2014). The District, in consultation with USFWS, maintained stage in this cell at levels to protect the nests (Appendix 5B-2 of this volume).

There were no documented impacts to STA-5/6 treatment performance due to nesting black-necked stilts or Everglade snail kites in WY2013, and the magnitude of stage restrictions imposed this year likely will not affect future operations. However, constraints imposed on STA-5/6 in response to nesting birds, i.e., the inability to control the spread of FAV and maintain vegetation strips near active nests or the disproportionate redistribution of flow among flow-ways, may reduce the ability of this STA to achieve optimum treatment performance in the future. Any long-term impacts to the functioning of STA-5/6 related to the presence of nesting birds cannot be assessed at this time.

Compartment C Build-out

The Compartment C Build-out Project is located in Hendry County between the original footprints of STA-5 and STA-6 (**Figure 5B-1**). As-built construction drawings and FEDP As-built Certification Forms were submitted to the FDEP for the Compartment C Build-out and the G-508 Pump Station on January 24, 2012 and January 11, 2013, respectively.

The new EFA operating permit for STA-5/6 was received by the District on September 10, 2012 accompanied by, and issued in reliance upon, Consent Order OGC# 12-1149. On December 19, 2012, the FDEP acknowledged that a net reduction in TP concentration had occurred from inflow to outflow in Flow-ways 4 and 6 and therefore, discharge from Flow-way 4 (via the G-344 G & H structures) and Flow-way 6 (via the G-352 A-C structures) could commence. The FDEP also approved of the consolidated Mercury and Other Toxicants Monitoring Plan for Compartment C on February 21, 2013.

Inoculations of muskgrass and southern naiad in Cell 5-4B resulted in the establishment of widespread SAV cover (75 percent), which promoted the successful start-up of this new flow-way. Approximately 364 acres willow, primrose willow and Brazilian pepper (*Schinus terebinthifolius*) were treated in Cell 5-4A, which had approximately 30 percent cattail cover. Vegetation startup activities in Flow-way 5 were delayed by the completion of ESA protective measures; startup activities are scheduled for completion in WY2014. Approximately 1,040 acres of mostly paragrass (*Urochloa mutica*) and torpedograss (*Panicum repens*) were treated in the non-effective treatment areas of Cells 5-4A and 5-5A to comply with Compartment C permit mitigation requirements for elimination of Category 1 and Category 2 exotic plants from these areas. Establishment of a desired EAV community in Cell 6-4 was hindered by lack of water needed to flood this cell throughout most of WY2013.

Environmentally Sensitive Areas in Compartment C Build-out

The District in cooperation with the Seminole Tribe of Florida, the Miccosukee Tribe of Indians of Florida, USACE, and Florida's State Historic Preservation Office completed construction of permanent protective measures for ESAs found in Flow-way 5. In addition, Flow-way 5 was placed on limited operations to reduce inflow into these cells, dependent upon the District's flood-control obligations. The District will continue to evaluate STA-5/6 operations in a concerted effort to preserve the ESAs in their current state and protect them from inundation in the future.

MAINTENANCE AND ENHANCEMENTS

Intensive vegetation management activities were initiated in WY2013 to establish desired EAV and SAV communities in the new cells of Compartment C, reduce cover of willow and primrose willow throughout STA-5/6, convert Cell 5-3B to SAV, and eliminate exotic plant species from the non-effective treatment areas (a permit requirement for Compartment C). Over 1,000 acres of primrose willow and willow were treated in EAV cells of Flow-way 1 (Cell 5-1A), Flow-way 2 (Cell 5-2A), and Flow-way 4 (Cell 5-4A). Giant bulrush was planted in unvegetated areas of the eastern (downstream) portion of Cell 5-1A and added to existing vegetation strips in Cells 5-1B and 5-2B. Expansive growth of FAV (1,128 acres), particularly water lettuce, was treated to sustain SAV in Cells 5-1B and 5-2B. Efforts to convert Cell 5-3B to SAV included herbicide treatments of 294 acres of cattail, 111 acres of willow, and 103 acres of primrose willow along with inoculations of southern naiad. Cell 5-4B was inoculated with muskgrass and southern naiad to achieve start-up conditions in Flow-way 4. Approximately 1,040 acres of mostly paragrass and torpedograss were treated in the non-effective treatment areas of Cells 5-4A and 5-5A.

VEGETATION SURVEYS

Vegetation Coverage Estimates Based on Aerial Imagery

Changes in vegetation coverage in STA-5/6 from April 2011 to April 2012 ranged from almost no change in EAV coverage in Cell 5-1A (< 1 percent), small increases in EAV in Cells 5-1B, 5-2A, 5-2B, and 6-5 and a small decease in Cell 5-3B (~2-5 percent), moderate EAV gains in Cells 6-2, 6-4 and 6-3 (~5-9 percent), and an 11 percent gain in coverage in Cell 5-3A. The increases in EAV coverage in Cells 5-3A, 6-2, 6-3, and 6-4 were attributed to dry conditions during the year. The composition of the vegetation community exhibited a positive change in Cells 5-1A (EAV), 5-2A (EAV), 5-3A (EAV), 5-3B (SAV), 6-3 (EAV), and 6-5 (EAV), whereas there was negative changes in Cells 5-1 (SAV) and 5-2B (SAV). At this time, it cannot be determined whether the negative changes in the vegetation community adversely affected treatment performance in STA-5/6.

Table 5B-13. Summary of vegetation coverage in cells of STA-5/6 based on analysis of aerial imagery. Percent coverage calculated relative to total surface area of each cell.

Cell	Coverage Type	% Coverage 2011	% Coverage 2012	% Change in EAV Cover from 2011–2012
Cell 5-1A	Water/SAV	11.72	11.09	
	EAV	88.28	88.91	0.64
Cell 5-1B	Water/SAV	79.43	74.71	
	EAV	20.57	25.29	4.71
Cell 5-2A	Water/SAV	9.25	5.93	
	EAV	90.75	94.07	3.32
Cell 5-2B	Water/SAV	69.93	66.77	
	EAV	30.07	33.23	3.15
Cell 5-3A	Water/SAV	28.15	16.44	
	EAV	71.85	83.56	11.71
Cell 5-3B	Water/SAV	9.40	11.95	
	EAV	90.60	88.05	-2.55
Cells 6-2 & 6-4	Water/SAV	19.61	14.10	
	EAV	80.39	85.90	5.51
Cell 6-3	Water/SAV	14.01	4.51	
	EAV	85.99	95.49	9.50
Cell 6-5	Water/SAV	3.02	1.27	
	EAV	96.99	98.73	1.74

Ground Surveys for Submerged Aquatic Vegetation

The SAV community in STA-5/6 during WY2013 comprised four species: coontail, hydrilla, southern naiad, and bladderwort. Ground surveys conducted in February 2013 in Cells 5-1B, and 5-2B found widespread SAV coverage with hydrilla, coontail, and southern naiad the dominant species in Cell 5-1B and coontail and hydrilla dominant in Cell 5-2B (**Figure 5B-24**). A survey of Cell 5-3B in March 2013 noted an absence of SAV throughout much of the cell with only a few beds of hydrilla observed near the inflow. A survey conducted in Cell 5-4B in January 2013 found dense areas of southern naiad at the inflow and outflow regions and a few beds of bladderwort near the middle of the cell (**Figure 5B-25**).

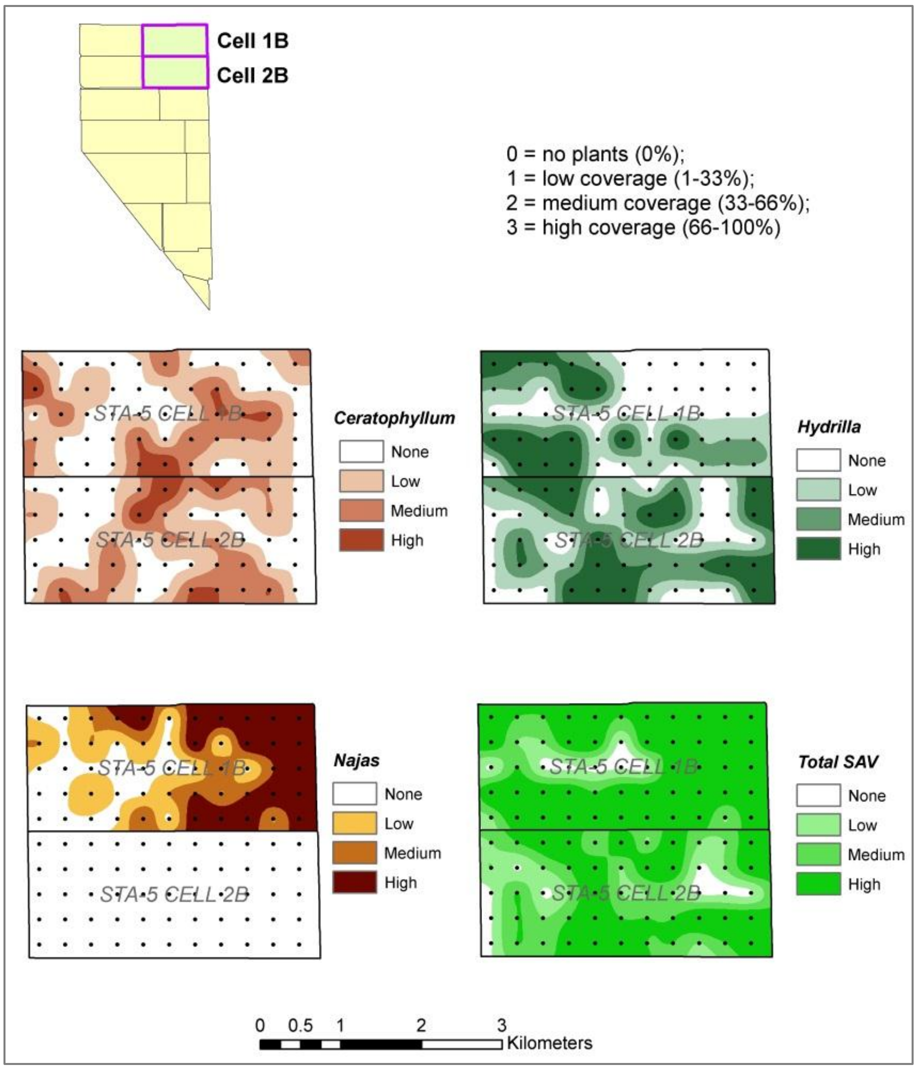


Figure 5B-24. Ground survey results depicting the spatial coverage and relative abundance of coontail (*C. demersum*), hydrilla (*H. verticillata*), southern naiad (*N. guadalupensis*), and all SAV species grouped together in STA-5/6 Cells 5-1B and 5-2B on February 7 and 21, 2013. Dots indicate location of SAV ground survey sites.

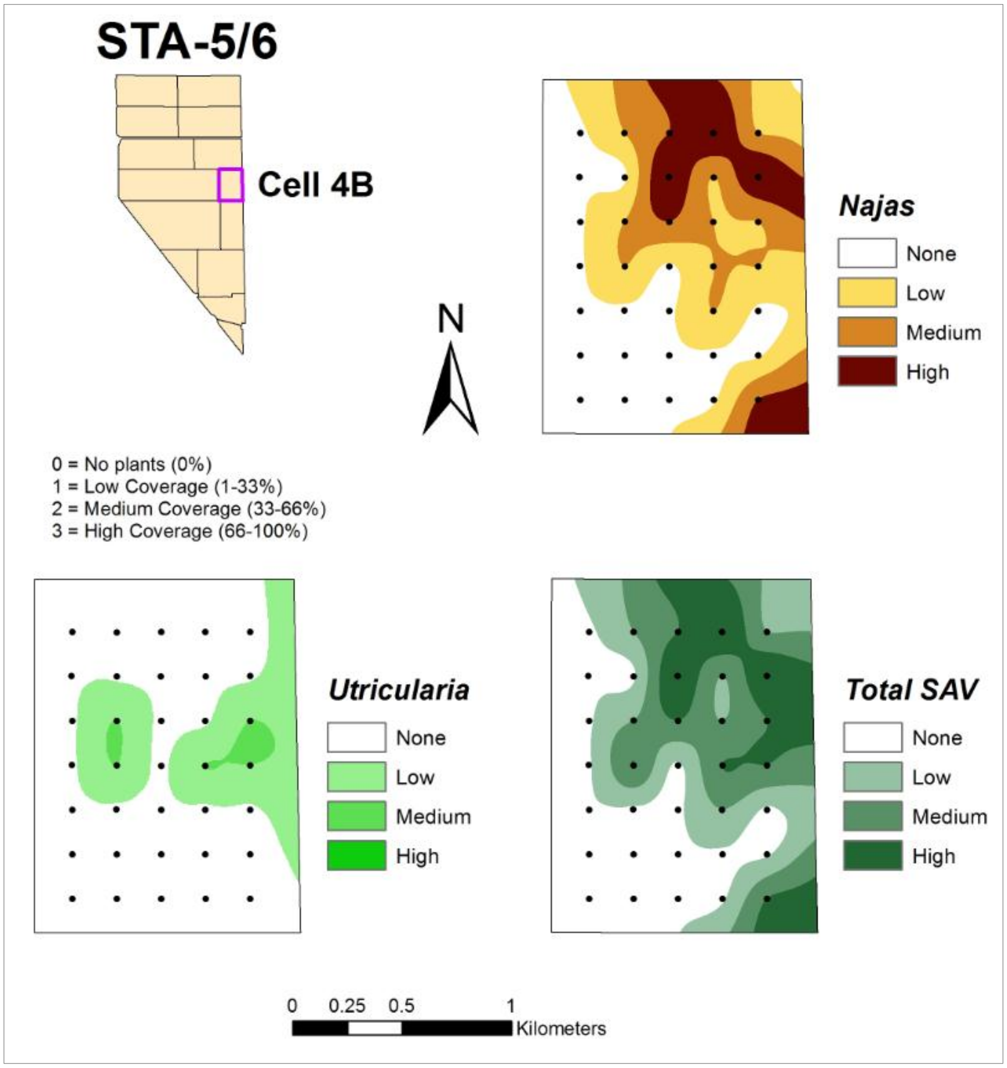


Figure 5B-25. Ground survey results depicting the spatial coverage and relative abundance of southern naiad (*N. guadalupensis*), bladderwort (*Utricularia* sp.), and all SAV species grouped together in STA-5/6 Cell 5-4B on January 29, 2013. Dots indicate location of SAV ground survey sites.

APPLIED SCIENTIFIC STUDIES

Research and monitoring associated with the Everglades STAs are conducted to help document their complexity, better understand the many challenges related to their operation, and help achieve mandated treatment performance. These activities include short- to long-term studies that range in size from mesocosm to field-scale, as well as analysis of existing data. Projects are conducted to address key issues including (1) documenting the condition of the STAs during the water year, (2) evaluating proposed and completed STA enhancements, (3) evaluating impacts of extreme weather events, (4) investigating failing or poor treatment performance, and (5) devising strategies to improve nutrient removal as summarized in **Table 5B-14**). The objectives of some of these studies are discussed in this chapter. Some studies are linked to ongoing implementation of management strategies (e.g., STA-3/4 Cell 1A drawdown evaluation), while other studies are linked to operating permit requirements such as STA optimization activities described in the Long-Term Plan (e.g., vegetation surveys).

No new research projects were started in WY2013, although studies initiated in previous water years continued. Research in the STAs will be conducted as part of the District's Restoration Strategies Science Plan (see Chapter 5C of this volume). District staff spent much of WY2013 developing study plans for a number of new STA-related initiatives that will start in WY2014. Preliminary findings for several studies listed in **Table 5B-14** are presented in this section, while some STA-specific findings are incorporated in the individual STA sections of this chapter (e.g., vegetation surveys or maintenance and STA enhancements).

Table 5B-14. Description, objectives, and WY2013 status of current applied scientific studies conducted in the Everglades STAs.

Study	Description and Objectives	WY2013 Status
STA-3/4 PSTA Project	This project began in WY2007and is a field implementation of periphyton-based STA (PSTA) technology aimed at further lowering outflow TP concentrations in STA discharges. The primary objective is to have a more accurate assessment of the PSTA treatment performance and the design, operational factors, and biogeochemical mechanisms that help achieve the observed treatment performance. Study includes field sampling/testing, core studies, and microcosm studies.	The STA-3/4 PSTA project structures and operation were modified in WY2012 to improve flow data accuracy. A more in-depth scientific evaluation also began in WY2012. Monitoring for water quality, soil, vegetation, and microbial activities were conducted at different flow scenarios. Water and TP budgets have been updated based on these additional data. Cell target stage was raised by 6 inches and outflow pump operation setting was adjusted in April 2013 to test for effects on the water budget and determine effects on treatment performance. ***Status**: ongoing.*
STA-1W Phosphorus Mesocosm	This is a three-year proof-of-concept study to investigate whether several species of native aquatic macrophytes (sawgrass, water lily, spikerush, and water lily + spikerush) can be used to enhance the treatment performance (TP removal) of the STAs. The TP removal capability of these species is being compared to that of cattail and SAV, plant communities that currently dominate the STAs. The study is being conducted at the STA-1W South Research Site.	This is the third year for the mesocosm study. ***Status**: ongoing; expected completion: November 2013.*
STA Vegetation Monitoring: Aerial Imagery	Aerial photographs (using high-contrast infrared film) of the STAs are taken annually during the summer to document vegetation coverage (emergent vegetation versus SAV+open water areas) in accordance with the STA operating permits. Specific areas of interest are also mapped in more detail on an as-needed basis. Aerial photographs, together with ground-truthing data, have been used to evaluate vegetation density on a relative basis in selected areas. Vegetation maps and GIS interpretation efforts are associated with this project.	The 2012 imagery is in process; the 2013 imagery was taken in March 2013 and will be processed for future analysis and reporting. Further calibration to enable the use of imagery for normalized vegetation density index estimation in the STAs is under way. ***Status**: recurring, annual.*
STA Vegetation Monitoring: Ground Surveys	Ground surveys are conducted to assess SAV species coverage and relative abundance. Surveys are also conducted as part of extreme event assessments. Spatial species distributions are mapped and reported annually and as needed for STA treatment performance-related evaluations.	***Status**: recurring, ongoing.*
Spatial Soil Sampling	Spatial soil sampling and testing to estimate P storage in floc and accrued layer, soil accretion, and determine potential effects on treatment performance.	***Status**: There was no sampling performed in WY2013. Sampling program is being reviewed to develop a cost-effective and meaningful soil data acquisition plan.*

Table 5B-14. Continued.

Study	Description and Objectives	WY2013 Status
STA Water Quality Internal Transects Evaluation	Evaluate P removal from the water column along transects of selected flow-ways in STA-1E, STA-1W, STA-2, and STA-5. Data are being used to monitor P cycling within STA flow-ways under various operational and environmental conditions. Over time, these data may provide insight about key processes such as internal P transformations and spatial relationships between vegetation type/health and P retention or sediment P release.	***Status****: recurring, ongoing.*
Investigation of Factors Influencing SAV Treatment performance and Sustainability in STAs	There is a need to understand better the factors that influence SAV species distribution, persistence, and colonization/recovery in STAs. This investigation includes (1) SAV distribution and speciation as a function of water depth; (2) investigation on the potential impacts of bird herbivory on SAV communities; (3) mesocosm study to determine effects of mixed EAV and SAV communities on water quality and stability of sediment P; and (4) large sediment core evaluation study to assess impacts of sediment treatments (dry down, floc removal, etc.) on SAV recruitment and water column turbidity.	***Status****: ongoing; herbivory study was discontinued due to difficulty in field assessment.*
STA-2 Supply/Inflow Canal Analyses	In recognition of the potential need to perform canal maintenance in STA canals after a period of operation, studies have been under way to determine the potential contribution of sediment in the STA-2 Supply/Inflow Canal to the surface water quality in the inflows to the treatment flow-ways	***Status****: ongoing; an updated analysis was conducted this reporting period, however results were inconclusive, and further analysis and field studies are recommended.*

STA-3/4 PERIPHYTON-BASED STORMWATER TREATMENT AREA PROJECT

Manuel Zamorano, Hongying Zhao, Kevin Grace[9], Michael Jerauld[9], Thomas A. DeBusk[9], Tracey Piccone and Delia Ivanoff

The STA-3/4 Periphyton-based Stormwater Treatment Area (PSTA) Project is a 400-acre facility built in 2005 as part of the District's implementation of this treatment technology in STA-3/4 (**Figure 5B-26**). Most of the peat soil within the 100-acre PSTA Cell was excavated down to the caprock (i.e., limestone bedrock) to (1) remove a potential source of P that could flux back to the water column and (2) inhibit the establishment of EAV that would shade out SAV and periphyton[10]. Twelve emergent vegetation strips were planted perpendicular to flow to improve the PSTA Cell's hydraulic characteristics. Prior to April 2012, the spread of vegetation out from the strips into the PSTA Cell was suppressed with periodic herbicide applications. In April 2012, every other strip (six strips in total) was removed with a combination of herbicide and mechanical compaction to allow for greater conveyance of water through the cell. The STA-3/4 PSTA Project has been in operation since WY2008 and its treatment performance and operational parameters have been reported in previous SFERs.

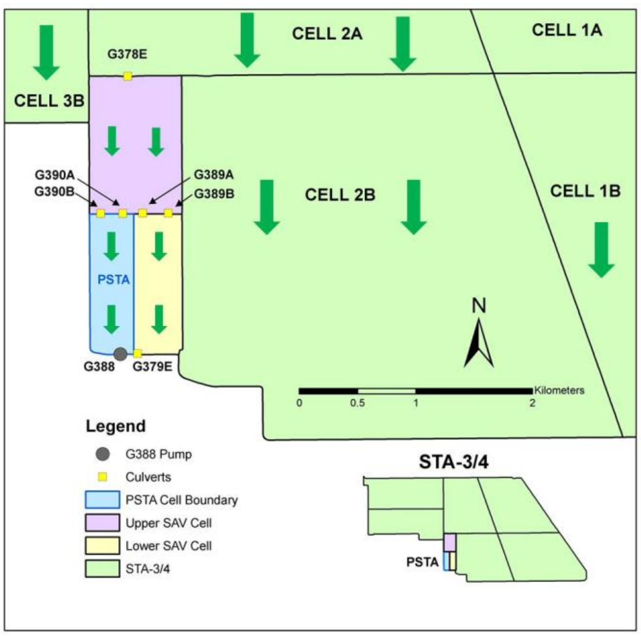


Figure 5B-26. Schematic of the STA-3/4 PSTA Project within Cell 2B showing the arrangement of the Upper and Lower SAV cells, the PSTA Cell, and associated water control structures. Arrows indicate direction of flow.

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[9] DB Environmental, Inc., Rockledge, FL

[10] The primary difference in the construction of the PSTA Cell versus SAV cells in all other STAs is that the peat substrate in the PSTA Cell was scraped down to caprock level and removed for the reasons noted, while the soil in SAV cells was not removed. The operating depth in the PSTA Cell was sufficient to allow the establishment of dense beds of SAV, which have been colonized by periphyton.

Over the first five years of operation (WY2008–WY2012), the PSTA Cell achieved an average annual outflow FWM TP concentration of 11 ppb. However, there were issues with the PSTA Project's hydraulic and water quality data that added uncertainty to the cell's TP budget. First, there was a question regarding the accuracy of the flow data at all the water-control structures. Second, the volume of groundwater seepage entering the PSTA Cell appeared large based on higher outflow compared to surface inflow but was not measured directly. Third, the P load associated with seepage was not known.

Investigations are continuing to improve our understanding of the PSTA Cell's treatment performance; this study is planned to continue through WY2017 as part of the Restoration Strategies Science Plan (see Chapter 5C of this volume).

Treatment Performance Results (WY2008–WY2013)

To assess the PSTA Cell's treatment performance, data from WY2008 to WY2013 were used to calculate the cell's annual hydraulic loading rate (HLR), phosphorus loading rate (PLR), hydraulic retention time (HRT), and TP settling rate (k) (**Table 5B-15)**. As in previous annual reports, these calculations accounted for the duration of the PSTA Cell's operational period each year. The operational period was defined as the span of time over which one or both of the PSTA Cell's inflow structures (G-390A and G-390B) were open. Days when both gates were closed due to protective measures for nesting birds, structure maintenance, or to preserve water during droughts were excluded from the operational period.

For WY2008 through WY2013, the operational periods were defined as follows:

- WY2008: July 5 to December 12, 2007 (161 days)
- WY2009: July 9 to December 23, 2008 (168 days)
- WY2010: May 25, 2009 to April 30, 2010 (341 days)
- WY2011: May 1 to June 1, 2010; August 3 to December 7, 2010 (159 days)
- WY2012: July 19, 2011 to April 5, 2012 (262 days)
- WY2013: May 1, 2012 to April 30, 2013 (365 days)

This year's PSTA Project summary accounted for differences in the operational period when calculating HLR, PLR, HRT, and k for the PSTA Cell. The equations used for these calculations are as follows:

$$\text{HLR} = \frac{Q_{in}}{A} \times 30.48 \tag{4}$$

$$\text{PLR} = \frac{\left[(C_{in}/10^3)\times(V_{load}\times 1233.5)\right]}{A\times 4046.8} \tag{5}$$

$$\text{HRT} = \frac{V}{(Q_{in} + Q_{out})/2} \tag{6}$$

$$k = \frac{\frac{(V_{in}+V_{out})\times N}{2}}{A} \times \left(\left(\frac{C_{in}-C^*}{C_{out}-C^*}\right)^{\frac{1}{N}} - 1\right)/3.28 \tag{7}$$

where:

HLR = the surface water hydraulic loading rate (cm/day);
PLR = the TP loading rate (g/m^2/yr);
HRT = the nominal hydraulic residence time (day);
k = the TP settling rate (i.e., removal coefficient) (m/yr);

V = the PSTA Cell's average storage volume during the operational period (ac-ft);
V_{in} = the total surface water inflow volume (ac-ft/yr);
V_{out} = the total surface water outflow volume (ac-ft/yr);
V_{load} = the total surface water inflow water volume during the operational period (ac-ft);
Q_{in} = the average daily surface water inflow rate during the operational period (ac-ft/day);
Q_{out} = the average daily surface water outflow rate during the operational period (ac-ft/day);
A = the PSTA Cell effective treatment area (ac);
N = the number of continuously stirred tanks-in-series (= 6)[11];
C^* = the background TP concentration (= 4 ppb)[12];
C_{in} = the surface water inflow FWM TP concentration during the operational period (ppb); and
C_{out} = the surface water outflow FWM TP concentration during the operational period (ppb).

As shown on **Table 5B-15**, the PSTA Cell has consistently achieved annual outflow FWM TP concentrations of 12 ppb or less throughout its operational history. In WY2013, the HLR and PLR of 17.5 cm/day and 0.45 g/m^2/yr, respectively, were the highest rates observed to date and the TP settling rate (17.8 m/yr) was within the range of k values calculated for previous water years. Based on the PSTA Cell's treatment performance, the PSTA technology implemented in this project appears capable of reducing outflow TP concentrations to the relatively low levels required by the FDEP operating permit for the Everglades STAs. Therefore, the PSTA design is under consideration as a final polishing step in both existing and future STAs. However, the specific mechanisms contributing to the superior treatment performance of the PSTA Cell are not well understood. The objectives of this project include, but are not limited to, the following questions:

- What are the important design elements, biogeochemical factors, and range of operating conditions that enable the PSTA Cell to achieve low outflow TP levels?
- What management practices are required to sustain the PSTA Cell's good treatment performance?

Table 5B-15. Summary of annual hydraulic and treatment performance parameters in the STA-3/4 PSTA Cell during each operational period from WY2008 to WY2013.

Water Year	HLR (cm/d)	HRT (d)	Q_{in} (ac-ft)	Q_{out} (ac-ft)	FWM TP_{in} (ppb)	FWM TP_{out} (ppb)	PLR (g/m^2/yr)	Operational Period (day)	k (m/yr)
WY2008	5.5	4.3	2,919	5,201	27	12	0.24	161	14.2
WY2009	6.2	4.1	3,309	6,105	14	8	0.14	168	13.8
WY2010	13.2	4.4	7,022	10,078	20	10	0.42	341	27.4
WY2011	6.0	4.9	3,198	3,933	18	11	0.17	159	7.3
WY2012	14.0	3.3	7,463	9,610	17	12	0.39	262	12.5
WY2013	17.5	2.7	9,326	11,166	16	11	0.45	365	17.8

[11] A tanks-in-series value of 6 was based on the findings of DB Environmental, Inc. (2009).
[12] A concentration of 4 ppb was typically used for the background TP concentration in STA design.

Spatial Characterization of Surface Water Quality

Examination of the P species at the PSTA Cell outflow suggests that its low TP levels result primarily through slight reductions in both PP and DOP, beyond what is achievable in SAV cells that still have their original soil. Reductions in these constituents were attributed to the activity of alkaline phosphatase (APA) produced by the microbial community to degrade DOP, the reduction of P flux from the soil, sorption of P to the caprock, or some combination of these factors.

In addition to routine sampling at the PSTA Cell's inflow and outflow structures, surface water was sampled at several internal locations within the cell (**Figure 5B-27**) on 11 occasions during WY2013 to document the spatial variability of P species and other important constituents. Two flow-pulse experiments were carried out in July–August 2012 and October 2012 to evaluate the effect that hydraulic pulses similar in magnitude to those experienced in the STA cells had on PSTA Cell outflow TP concentration and key biogeochemical factors such as microbial activity. Samples were collected immediately before the flow pulses, on the second or third day during the pulse events, and approximately one week after flow returned to pre-pulse levels (**Figure 5B-28**).

Beginning in December 2012, water quality monitoring associated with the project was expanded to include upstream and neighboring muck-based SAV cells (Cells 2B and 3B) in STA-3/4 (**Figure 5B-17**) in order to better characterize the quality of inflow to the PSTA Cell and provide a basis of comparison with PSTA Cell treatment performance. Water quality at the inflow and outflow structures of Cell 2A and the Upper SAV Cell (both upstream of the PSTA Cell) was also characterized through routine sampling of relevant parameters. During the period of flow in WY2013 (see **Figure 5B-28**), there was a reduction in TP concentration in the upper end of the PSTA Cell, followed by a plateau slightly below 10 ppb throughout the remainder of the cell (**Figure 5B-29**).

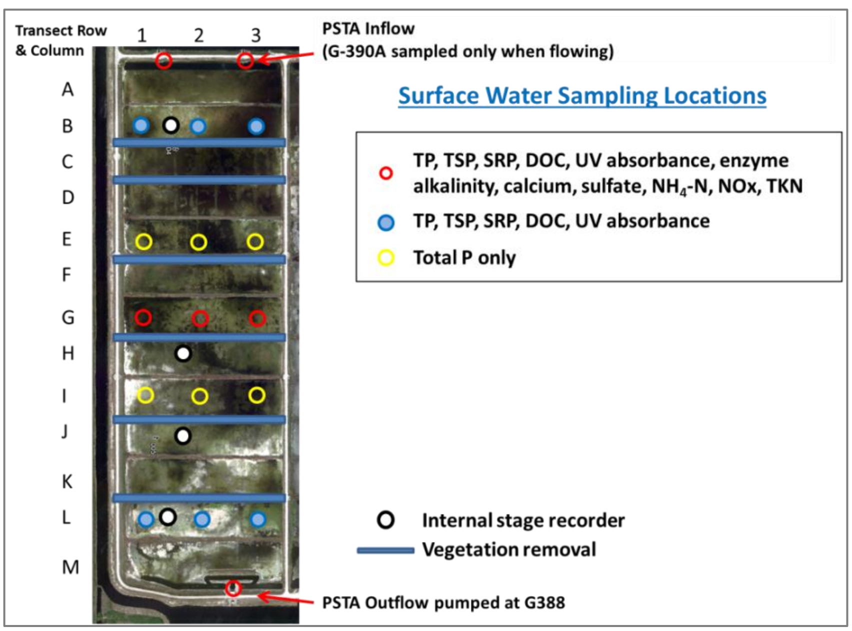


Figure 5B-27. STA-3/4 PSTA Cell showing locations of inflow, outflow, and interior water quality sampling sites and the suite of constituents analyzed in collected samples. "Vegetation removal" refers to locations where emergent vegetation was removed from transverse earthen berms to accommodate higher flow rates.

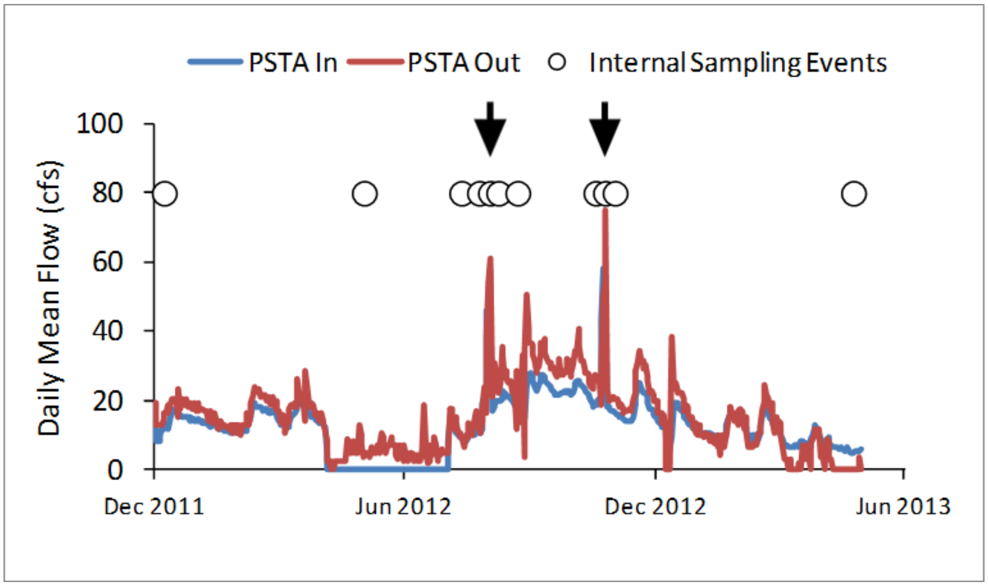


Figure 5B-28. Daily flow rates at the STA-3/4 PSTA Cell inflow and outflow locations during WY2012 and WY2013. Dates of internal water quality sampling events are also shown, with most events occurring immediately before, during, and after the flow-pulse experiments (indicated by arrows) in WY2013.

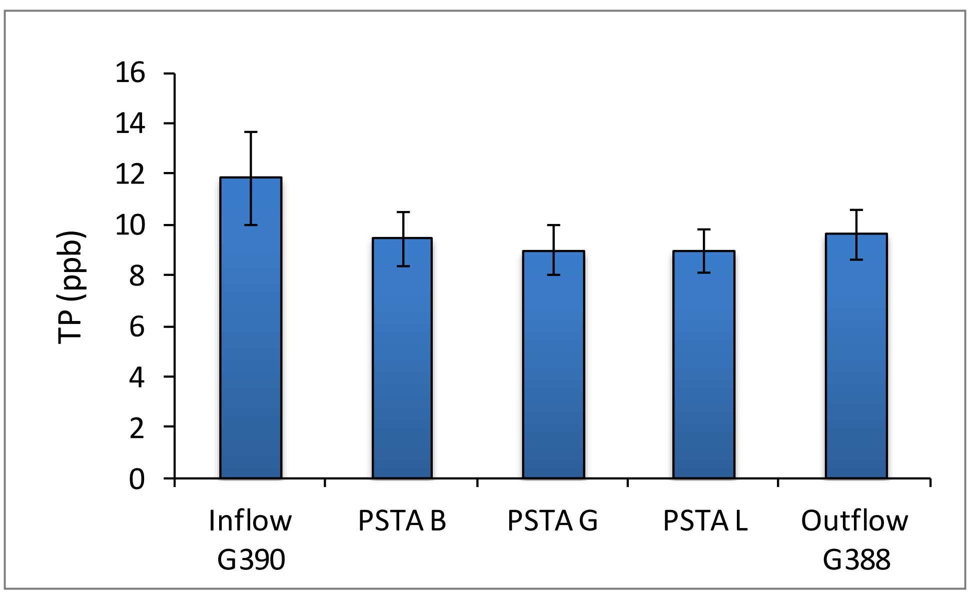


Figure 5B-29. Mean ± SE water column TP concentrations within the STA-3/4 PSTA Cell during the nine sampling events that occurred under flowing conditions in WY2013 (see **Figure 5B-27** for station locations).

Macrophyte and Algae Characterization

The spatial coverage and relative abundance of dominant SAV species in the PSTA Cell were characterized on two dates in WY2013 (**Figure 5B-30**). Pondweed and muskgrass dominated the community at the inflow region. The remainder of the cell was dominated by muskgrass. Little change in SAV distribution was observed between the two sampling dates.

Periphyton associated with sparse macrophyte vegetation is a key feature of the PSTA technology and thought to play a critical role in reducing water column P concentrations to low levels. However, few data are available to support this hypothesis. Therefore, the role of periphyton in P removal is being addressed using several complementary techniques in this study.

First, the relative abundance and enzymatic activity of SAV epiphytes were characterized. Tissues samples from the host SAV species were collected in August 2012 and December 2012 and analyzed for P content. Efforts are under way to correlate the tissue P content with periphyton characteristics. The biomass of epiphytes easily dislodged from SAV thalli, as a percentage of host plant biomass, decreased down the length of the PSTA Cell (**Figure 5B-31**). Taxonomic analysis found a greater proportion of blue-green algae at the PSTA Cell outflow region, whereas diatoms and filamentous green chlorophytes dominated the PSTA Cell inflow region and neighboring muck-based SAV cells, respectively.

Second, artificial substrates (periphytometers) were used to monitor periphyton growth rates and nutrient content. Periphyton was scraped from the slides and assayed for dry weight biomass, nutrient content, chlorophyll, enzyme activity, and community species composition. The N and P content of periphyton in the PSTA Cell were consistently highest at the outflow region, while levels of these constituents were lower at the inflow and mid-regions (**Figure 5B-32**). The P content of periphyton in the PSTA Cell was comparable to the lower end of the range of literature values for the nutrient-limited interior of WCA-2A and considerably lower than values observed in STA-3/4 Cell 2B after six weeks of growth (**Table 5B-16** and **Figure 5B-32**). Total N content for periphyton in the PSTA Cell and the Cell 2B outflow was considerably lower than literature values for interior sites in WCA-2A. It should be noted that the literature values for WCA-2A periphyton are for samples collected from floating mats or vegetation rather than from artificial substrates, which may account for the difference in P and N values between this study and the WCA-2A data.

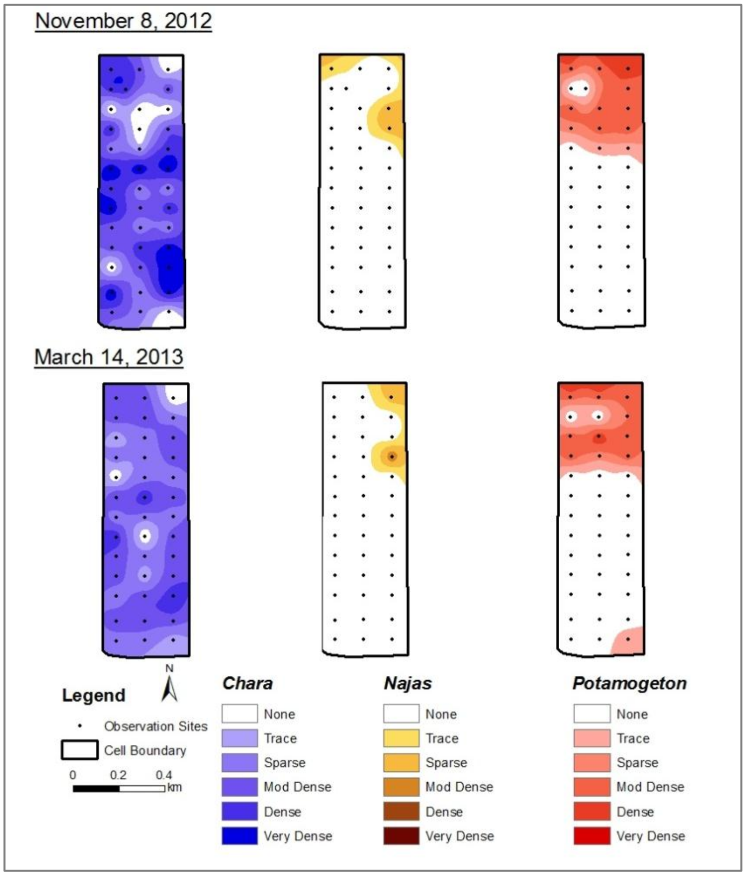


Figure 5B-30. Spatial coverage and relative abundance of muskgrass (*Chara* sp.), southern naiad (*N. guadalupensis*) and pondweed (*P. illinoensis*) in the STA-3/4 PSTA Cell on two sampling dates in WY2013.

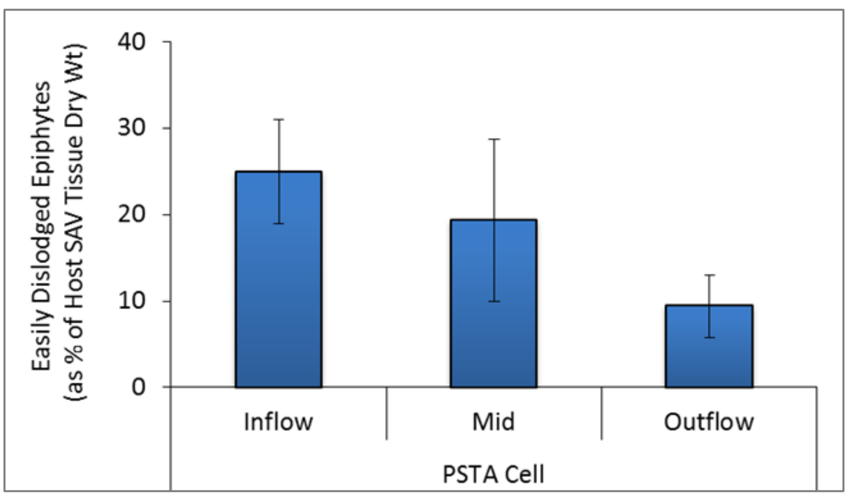


Figure 5B-31. Epiphytic periphyton biomass as a percentage of host SAV biomass collected from inflow, mid-, and outflow regions of the STA-3/4 PSTA Cell.

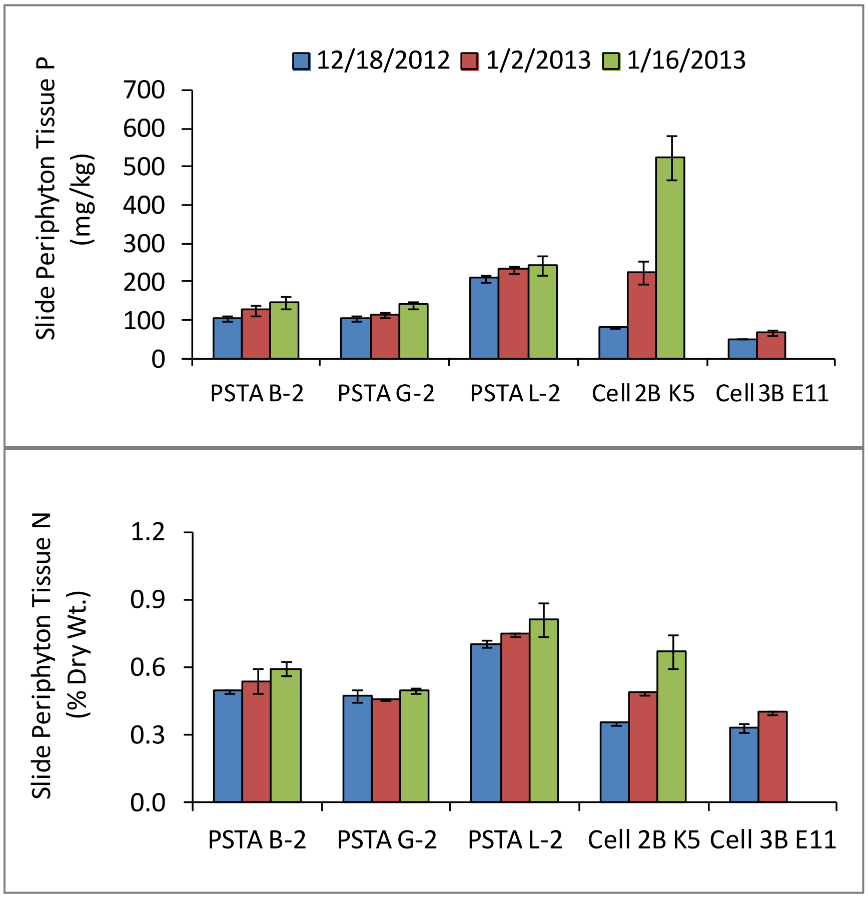


Figure 5B-32. Tissue N and P content of periphyton collected from periphytometers incubated at the STA-3/4 PSTA Cell inflow (B-2), middle (G-2), and ouflow (L-2) regions and at the outflow regions in adjacent muck-based Cells 2B and 3B in STA-3/4. The periphyton at each site was characterized at 2, 4, and 6 weeks following initial deployment. Note: The 6-week data from Cell 3B are missing due to loss of the periphytometer.

Table 5B-16. Periphyton tissue N and P content collected from periphytometers incubated 6 weeks in STA-3/4 during the current study and values from the nutrient-limited interior of WCA-2A.

Site	Study	N (%wt)	P (mg/kg)
Interior WCA-2A	Vymazal and Richardson (1995)	1.23 – 2.72	117 – 454
Interior WCA-2A	Swift (1981)	1.12 – 3.01	60 – 490
PSTA Cell Inflow	This study	0.55 – 0.66	120 – 170
PSTA Cell Mid	This study	0.47 – 0.52	130 – 160
PSTA Cell Outflow	This study	0.67 – 0.90	190 – 272
STA 3/4 Cell 2B Outflow	This study	0.56 – 0.82	427 – 629

PSTA Cell Sediment Surveys

Most of the pre-STA peat soil was removed during construction of the PSTA Cell, exposing the underlying caprock layer. Nevertheless, small pockets of residual organic soil remained, and this material, along with the newly accrued sediment, contributed to the distinct character of the PSTA Cell sediments. Sampling has demonstrated that, with a few exceptions, the sediment chemical composition was spatially uniform (**Figure 5B-33**). Accrued sediment TP ranged from 150-371 mg/kg at individual sites within the cell (N=9) with an overall average of 272 ± 24 mg/kg. The N content of accrued sediment ranged from 0.41 to 1.32 %N with a mean value (± SE) of 0.96 ± 0.09 %N. The residual peat soil had a lower mean P content than the accrued sediment but a comparable mean N content: 188 ± 19 mg/kg TP and 0.96 ± 0.14 %N, respectively. Accrued sediments were Ca-rich (16-28 %wt) compared to the residual soil (9-15 %wt). Both the accrued sediment and residual soil had total organic carbon (TOC) content less than 20 percent by weight.

Accrued sediment in the PSTA Cell generally had lower TP, TN, and TOC content than in the muck-based Lower SAV Cell, (**Figure 5B-34**). Soil TP at individual sites in the Lower SAV cell (N=6) ranged from 527–773 mg/kg TP, with a mean of 618 ± 40 mg/kg. Calcium content in the Lower SAV cell was 17–23 %wt, similar to the accrued sediment in the PSTA Cell. Efforts are under way to determine whether the differences in chemical composition of the accrued sediment between the PSTA Cell and the Lower SAV Cell were correlated with different P loading histories to the two cells, or with the presence of the underlying muck in the Lower SAV Cell.

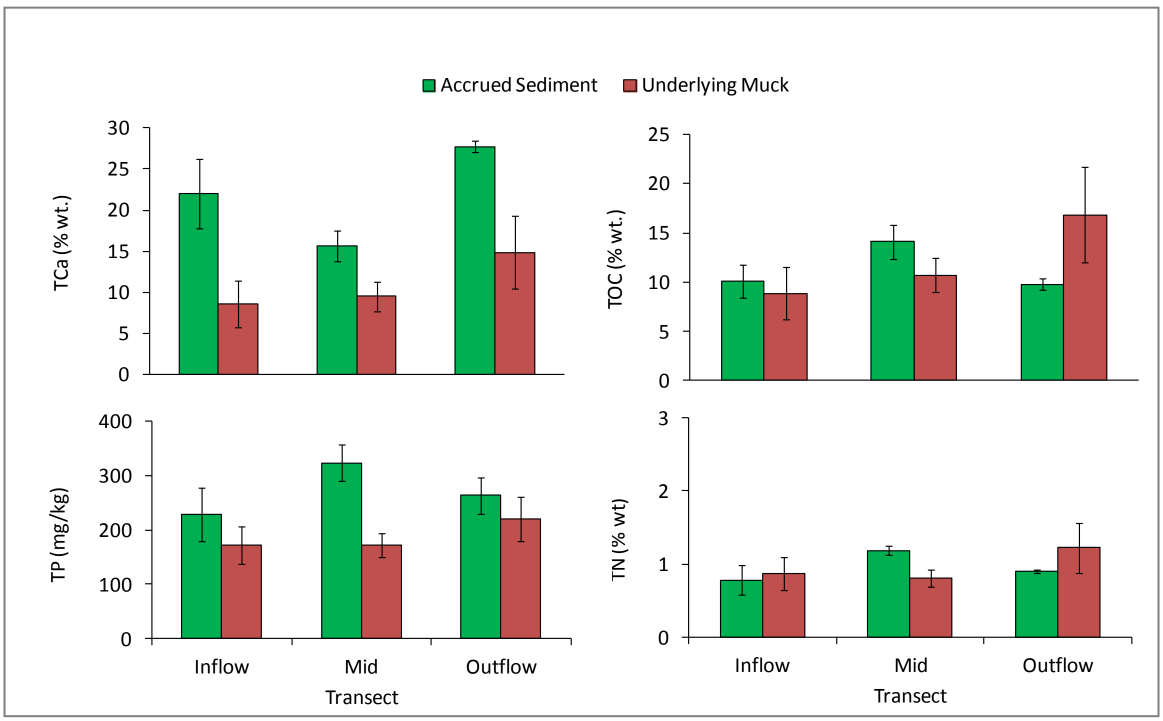


Figure 5B-33. Total calcium (TCa), total organic carbon (TOC), total phosphorus (TP), and total nitrogen (TN) content of the accrued sediment and residual muck soil in the STA-3/4 PSTA Cell. Values represent the mean ± SE of three stations sampled along each transect.

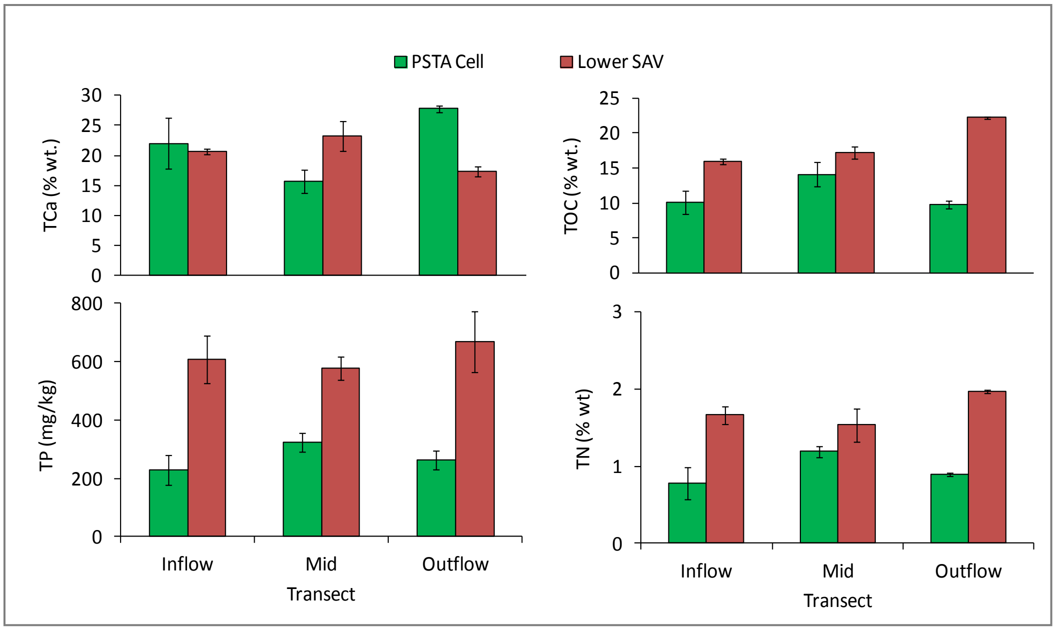


Figure 5B-34. TCa, TOC, TP, and TN content of accrued sediments collected May 2012 from three transects in the STA-3/4 PSTA Cell and transects in the adjacent muck-based Lower SAV Cell in STA-3/4. Values represent the mean ± SE of three stations sampled along each transect.

Characterization of Enzyme Activity

Sampling in WY2013 demonstrated that APA levels increased with passage through the PSTA Cell (**Figure 5B-35**). Surface water that enters the PSTA Cell first passes through Cell 2A (EAV-dominated) and then the Upper SAV Cell. Enzyme activity was comparatively low in these upstream cells, but increased markedly at the inflow region of the PSTA Cell and continued to increase along a gradient through the cell. Under high flow conditions, e.g., October 25, 2012, APA levels decreased in response to the higher nutrient P loading associated with increased flow. Such flow-induced reductions in enzyme activity could diminish the PSTA Cell's capacity to break down DOP, and limit its treatment performance.

Alkaline phosphatase activity in PSTA Cell sediments decreased from inflow to outflow (**Figure 5B-36**). This trend was opposite the trend in water column APA levels, which increased downstream. Sediment APA activity in the Lower SAV Cell was relatively constant along the flow-path, and markedly lower compared to the inflow and mid-regions of the PSTA Cell. High APA in the PSTA Cell sediments, especially at the cell's inflow region, suggests a high potential for DOP hydrolysis.

Within the PSTA Cell, enzyme activity associated with epiphytes collected from the dominant macrophyte species was lowest at station G2 (**Figure 5B-37**), the only station at which periphyton was collected from spikerush rather than SAV. Epiphytes showed the same spatial trend as sediments, i.e., the highest epiphyte enzyme activity was in the PSTA Cell inflow region (**Figure 5B-37**). Enzyme activity of periphyton collected from periphytometers was also higher at the PSTA Cell inflow than at the mid- and outflow regions (**Figure 5B-38**). These findings differ from the trend in water column enzyme activity, which repeatedly showed a steady increase in activity with distance through the cell. Efforts are under way to understand better the different spatial patterns in extracellular phosphatase enzyme activity among PSTA Cell ecosystem compartments.

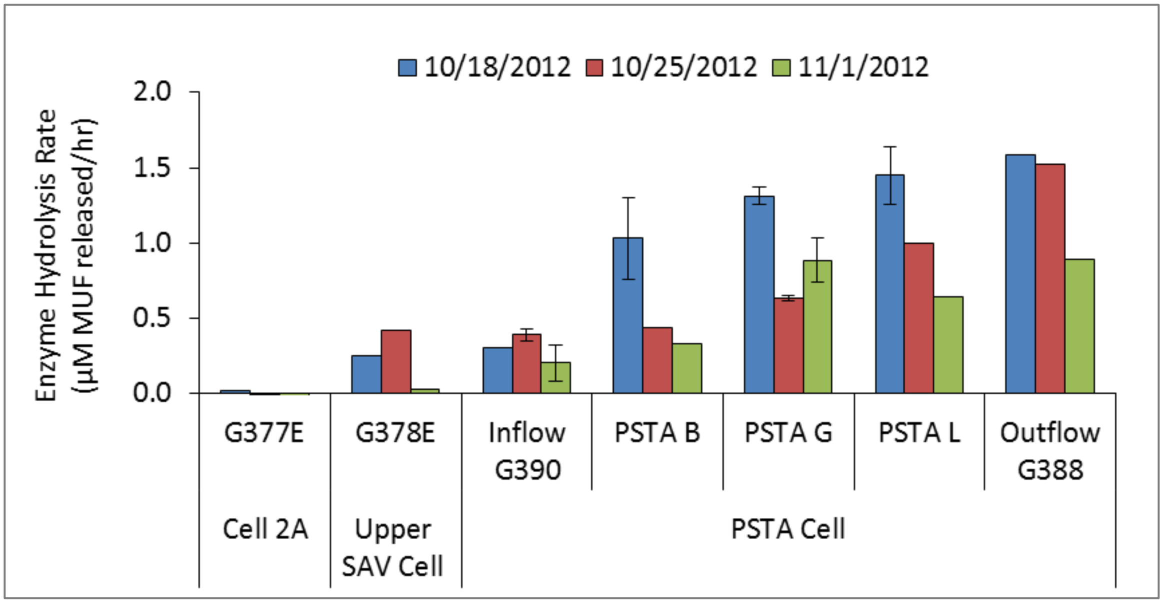


Figure 5B-35. Mean (± SE) alkaline phosphatase activity in unfiltered surface water collected during three sampling events before (10/18/12), during (10/25/12), and after (11/1/12) a pulsed-flow event in the STA-3/4 PSTA Cell. G-377E is inflow to upstream EAV cell (Cell 2A); G-378E is inflow to 2nd cell in the series (the Upper SAV Cell); and G-390 is the inflow to STA-3/4 PSTA Cell. Typical daily flow rates in the PSTA Cell were 10-20 cfs, while the pulsed-flow event from October 23–25, 2012 achieved a three-day mean flow rate of ~60 cfs.

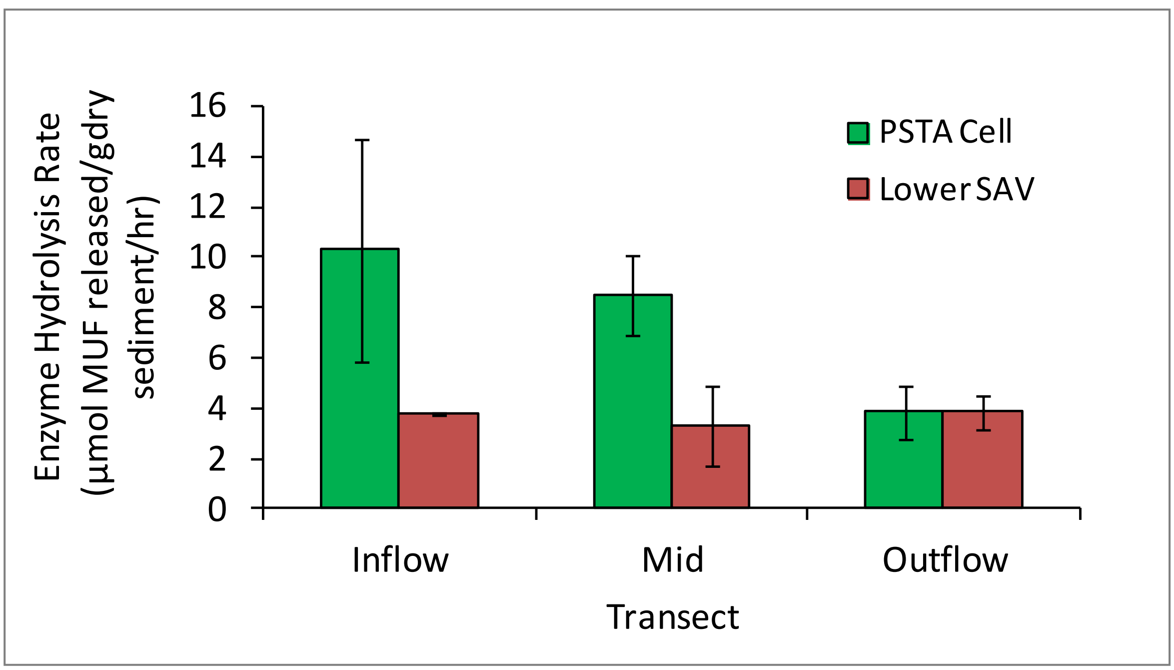


Figure 5B-36. Mean (± SE) alkaline phosphatase activity of surficial sediments collected in May 2012 from three stations along each transect in the STA-3/4 PSTA Cell and two stations along each transect in adjacent muck-based Lower SAV Cell.

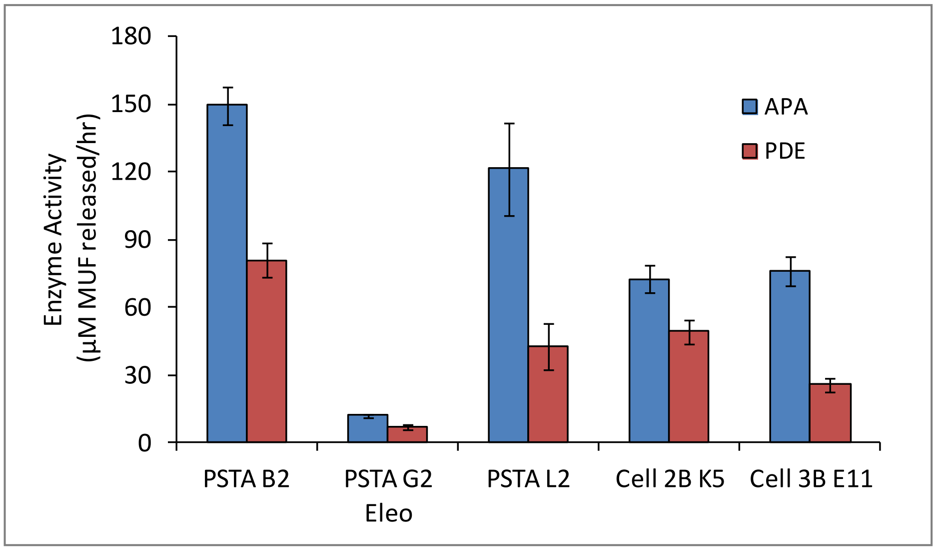


Figure 5B-37. December 2012 bioassay of mean (±SE) alkaline phosphatase activity (APA) and phosphodiesterase (PDE) activity by epiphytes on the dominant macrophyte vegetation (largely muskgrass, except in the middle of the STA-3/4 PSTA Cell where spikerush dominated the plant community).

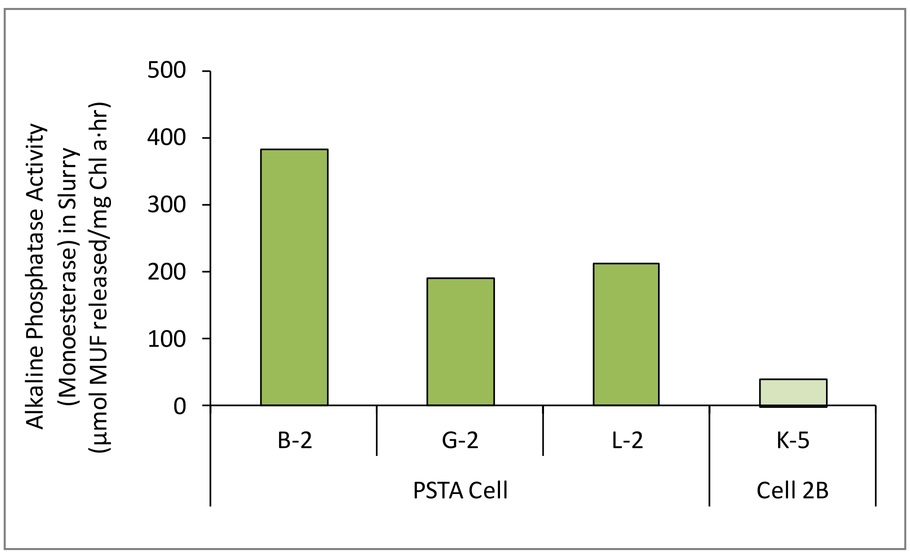


Figure 5B-38. APA of periphyton collected from periphytometers incubated in the STA-3/4 PSTA Cell and Cell 2B normalized to units of pheophytin-corrected chlorophyll *a*.

Seepage Analysis Using Well Data

The amount of seepage entering the PSTA Cell from adjacent water bodies (primarily the Lower SAV Cell and the STA-3/4 Discharge Canal) was assumed to be large as evidenced by higher outflow at G-388 compared to surface water inflow through the G-390 structures. An important difference between the PSTA Cell and adjacent cells is that most of the soil from the PSTA Cell was removed down to the caprock to reduce potential source of P flux back to the water column. As a result, the floor of the PSTA Cell is about 2 ft lower than the surrounding ground elevations. To maintain water depths optimal for periphyton growth, the PSTA Cell has been operated at a lower stage than the adjacent water bodies, which creates a head difference between the PSTA Cell and surrounding waters. Consequently, the PSTA Cell receives inflow from horizontal (and possibly vertical) groundwater seepage. In order to document the sources and quantity of seepage coming into and leaving the PSTA Cell, a seepage study was initiated in early 2012.

Methods

Static groundwater levels in the perimeter levee surrounding the PSTA Cell were monitored at 20 shallow (8 ft) and deep (36 ft) wells located within the levee (**Figure 5B-39**) for one year (February 2012–February 2013). Groundwater and surface water samples were collected quarterly and analyzed for major ions, TP, and SRP. The source of seepage water entering the PSTA Cell was inferred based on comparing the composition of major ions in the well samples and surface water from adjacent water bodies.

Results and Discussion

During WY2013, stage in the PSTA Cell was very often lower than water levels in the adjacent water bodies. From May 1 to July 3, 2012, the inflow structures to the PSTA Cell were closed while the outflow structure operated continuously with a mean flow of 5.6 cfs (**Figure 5B-40**). Operation of the outflow pump in the absence of surface water inflow indicated constant groundwater movement into the PSTA Cell. Groundwater levels in wells located next to the Lower SAV Cell were often higher than the wells next to the STA-3/4 Discharge Canal, suggesting a greater contribution of seepage from the Lower SAV Cell (due to greater head differences with the PSTA Cell) than from the STA-3/4 Discharge Canal.

Total P and SRP concentrations in the 8-ft wells were generally higher than in the 36-ft wells. The predominant cation in groundwater samples was Ca, which is typical for groundwater in this region. Chloride concentrations within the wells were also influenced by surface water primarily from the Lower SAV Cell (**Figure 5B-41**). While these results suggest a greater contribution from surface water seepage, possible contributions from groundwater underflow may have played a greater role during the wet season because of groundwater recharge. Further analysis of the different water types using a Piper diagram for major ions (**Figure 5B-42**) indicated two possible water sources: freshwater recharge (FW-I) from rainfall or surface runoff, and transitional water (TW-I) from mixed water recharge (Frazee, 1982). The transitional water could have resulted from vertical mixing of groundwater with surface water from the PSTA Cell, Lower SAV Cell, and the STA-3/4 discharge canal waters**.** Additional sampling and analysis is planned to continue through WY2014 to investigate further the sources and quantity of seepage into the PSTA Cell.

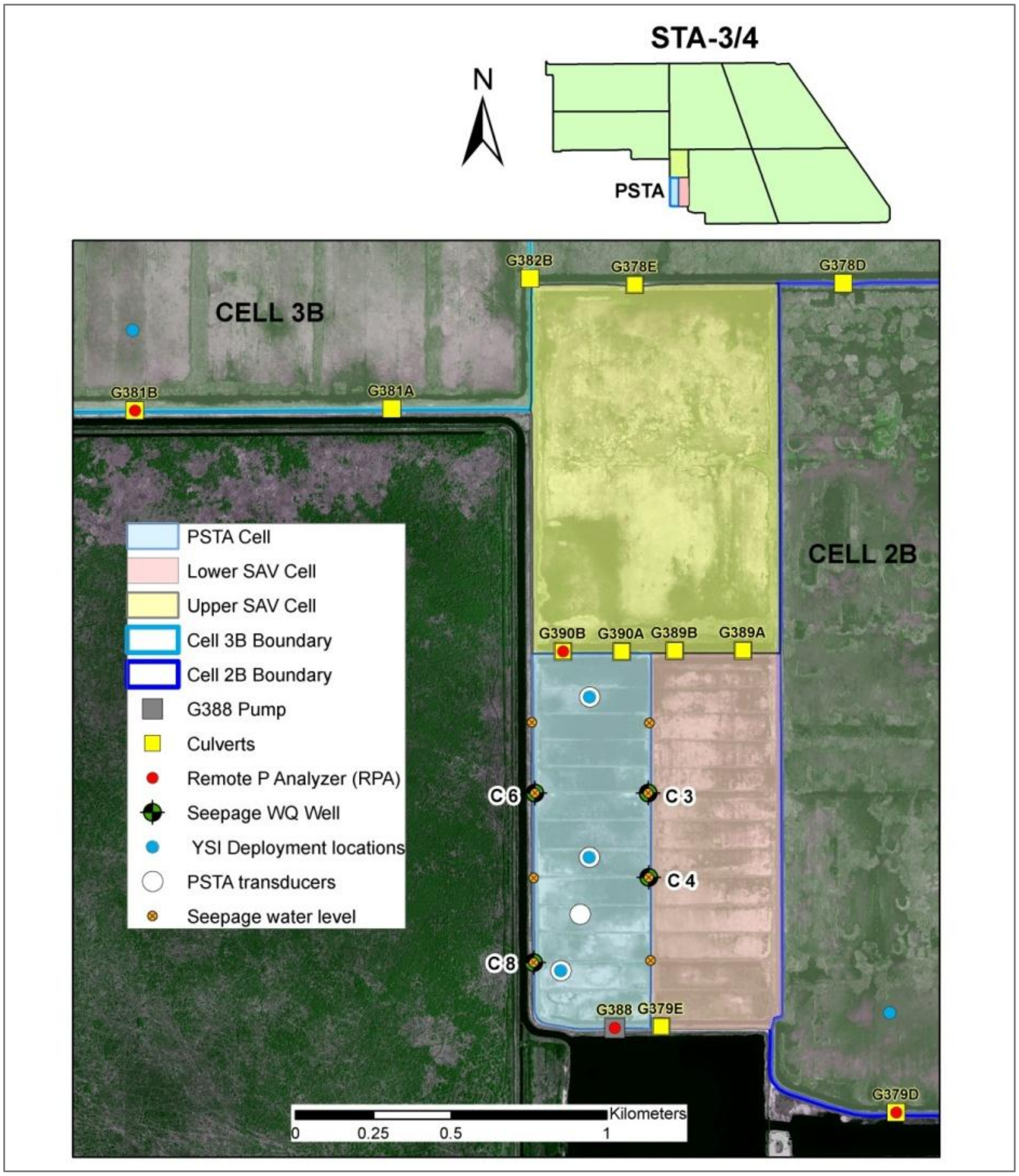


Figure 5B-39. Location of surface water monitoring stations, groundwater wells, multi-parameter probes (YSI), remote phosphorus analyzers (RPAs), and pressure transducers within the STA-3/4 PSTA Cell. Additional RPAs were deployed at one outflow structure from Cells 2B (G-379D) and 3B (G-381B).

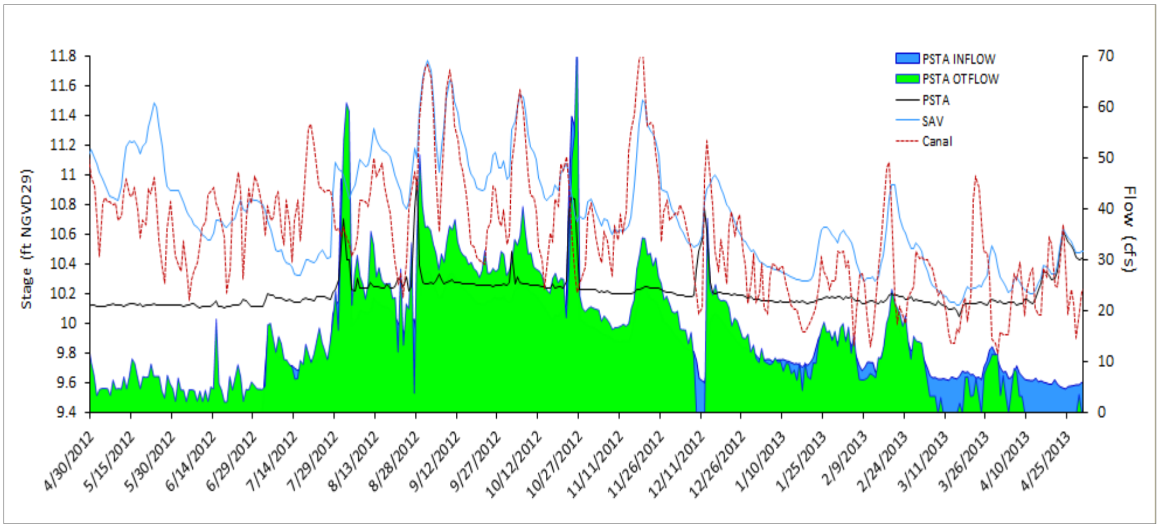
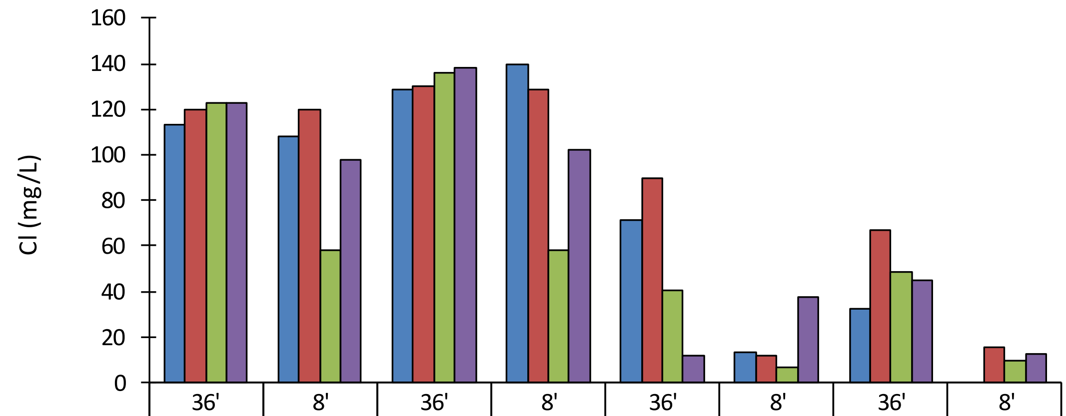


Figure 5B-40. Temporal dynamics of stage in the STA-3/4 PSTA Cell, Lower SAV Cell, and STA-3/4 Discharge Canal and the PSTA Cell surface water inflow and outflow. Note that outflow from the PSTA Cell exceeded inflow on most dates.



	Cluster 2 36'	Cluster 2 8'	Cluster 3 36'	Cluster 3 8'	Cluster 6 36'	Cluster 6 8'	Cluster 8 36'	Cluster 8 8'
2/15/2012	113	108	129	140	72	13	32	
6/13/2012	120	120	130	129	89	12	67	15
9/26/2012	123	58	136	58	40	7	49	10
2/5/2013	123	98	138	102	12	37	45	13

Figure 5B-41. Chloride concentration in the STA-3/4 PSTA Cell 8-ft and 36-ft deep perimeter wells. Well clusters 2 and 3 are in the levee between the Lower SAV Cell and the PSTA Cell; well clusters 6 and 8 are in the levee between the PSTA Cell and the STA-3/4 Discharge Canal.

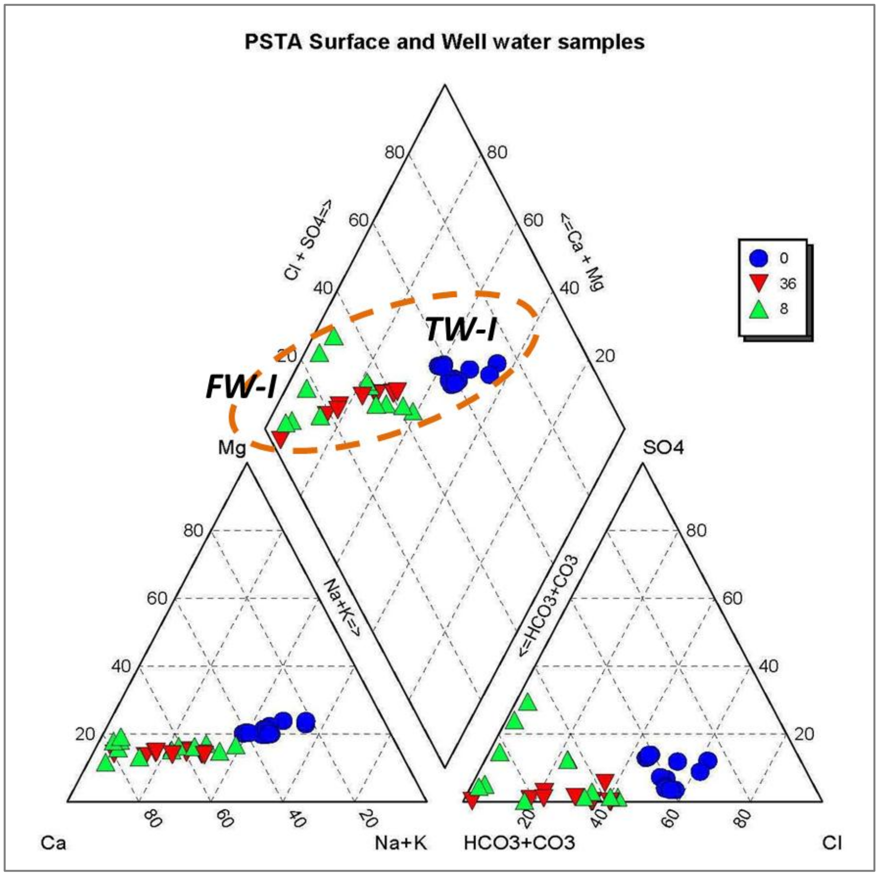


Figure 5B-42. Piper diagram showing the chemical composition of surface water (0) and groundwater collected from shallow (8-ft) and deep (36-ft) wells along the STA-3/4 PSTA Cell perimeter levee indicating the areas of freshwater recharge (FW-I) and transition (TW-I) recharge.

Diel Patterns within the PSTA Cell and at Inflow and Outflow Structures

Phosphorus removal in the STAs results from a combination of abiotic and biotic processes. Important abiotic factors in the PSTA Cell could include the reduction of soil P flux to the water column, presence of calcitic surfaces with affinity for P sorption, and calcium-P co-precipitation from the water column. The primary biotic factors in the PSTA Cell are SAV and periphyton nutrient uptake. Knowing the diel pattern of fluctuation in P and field parameters, i.e., pH, temperature, specific conductivity (SpC), and dissolved oxygen (DO) concentration, could provide an understanding on the dominance of biotic versus abiotic influences. The specific objectives of this study are to: 1) document water quality and P diel trends within the PSTA Cell, and 2) examine temporal and spatial diel differences in water quality and P in the cell in response to high- and low-flow conditions.

Methods

Beginning on April 5, 2012, two remote phosphorus analyzers (RPA) were deployed at the inflow and outflow structures of the PSTA Cell. The RPAs collected water samples every three hours to document diel patterns in TP and total reactive P (TRP) concentrations in waters entering and leaving the cell. Additionally, automated YSI multi-parameter probes were deployed throughout the year at the inflow, outflow, and interior cell locations to monitor pH, temperature, SpC, and DO throughout the day. Additional RPAs and YSI probes were deployed in adjacent SAV-dominated Cells 2B and 3B (**Figure 5B-39**) to compare diel trends in these cells with the PSTA Cell.

Results and Discussion

This study is still in the early stages of implementation, however preliminary results of RPA data (April to October 2012) suggest higher TP values occurred during the day at the inflow structure (G-390B) under no-flow conditions (**Figure 5B-43**, panel A). Under flow conditions, day-night differences at both stations were less pronounced (**Figure 5B-43**, panel B). Total reactive P values were consistently at or near the method detection level (2 ppb) and did not display diel or flow patterns.

Dissolved oxygen and pH values were consistently higher during the day and lower at the night due to photosynthetic activity during the day (**Figure 5B-44**). The diel pattern observed in water temperature was in response to solar heating of the water column during the day. Water temperature peaked at 35 °C during the day and decreased to 25 °C during the night. Dissolve oxygen concentrations peaked near dusk with maximum values ranging from 14.5 to 25.8 mg/L and gradually declined through the night to approximately 1 mg/L just before dawn. The mean pH in the PSTA Cell was 8.23 ± 0.6, with higher pH values observed in Cell 3B. Specific conductance exhibiteda small diel pattern and was higher in Cell 3B than the PSTA Cell, a possible effect of dilution from seepage entering the PSTA Cell. Field parameter data collected at the inflow and outflow of the PSTA Cell did not differ from interior sites. Efforts to evaluate diel patterns inside the PSTA Cell are continuing.

Auto-samplers were deployed within the PSTA Cell between the inflow and the outflow structures to complement the TP data collected by the RPAs. As the auto-samplers were closer to vegetated areas, data obtained are expected to show a more pronounced diel pattern. Auto-samplers will be deployed several times during the year to obtain representative data during flow and no-flow regimes.

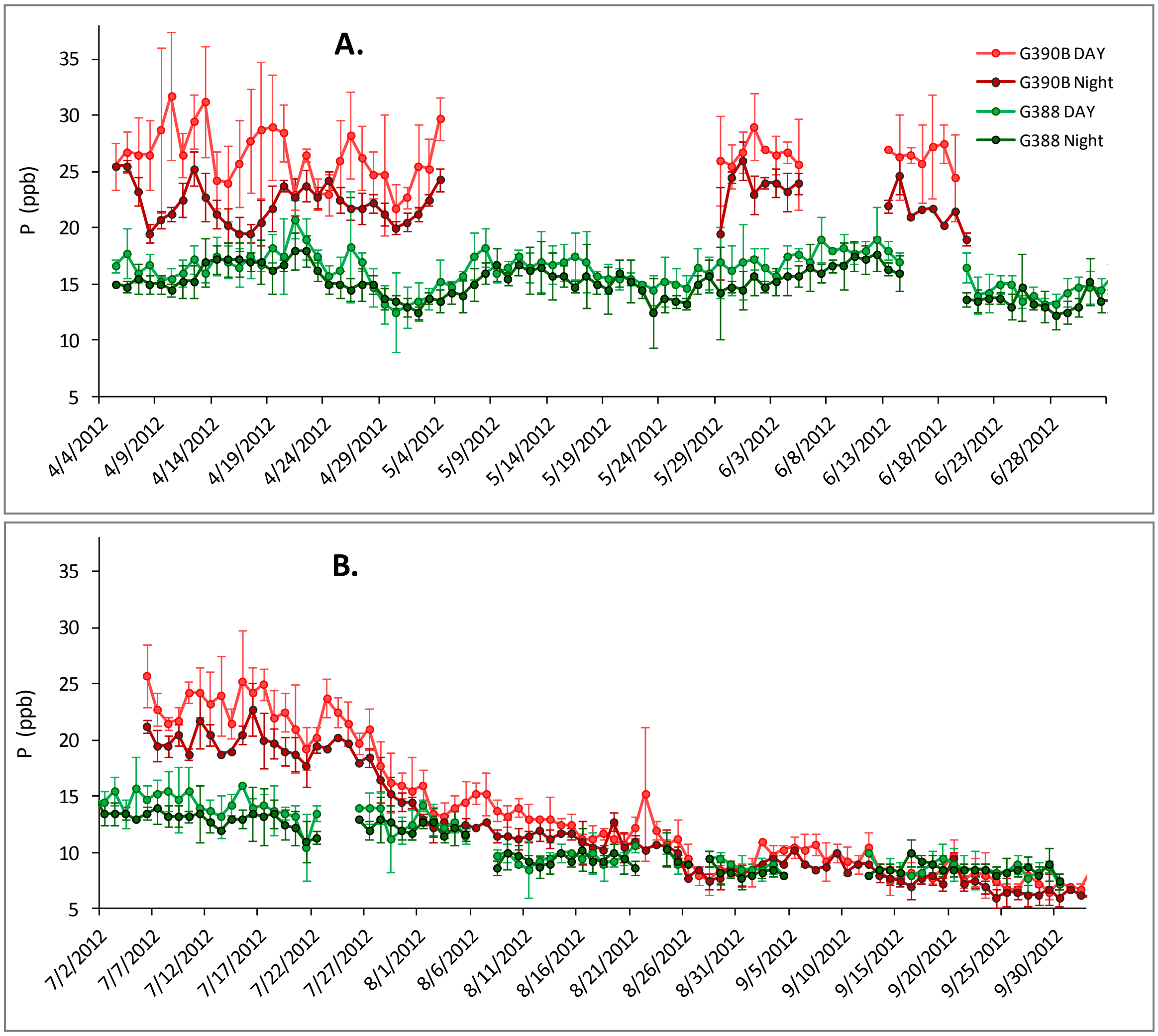


Figure 5B-43. Temporal patterns of TP concentrations at STA-3/4 PSTA Cell inflow (G-390B) and outflow (G-388) structures under (A) no-flow and (B) flow conditions. Values represent daily means ± SD separated for daytime and nighttime samples.

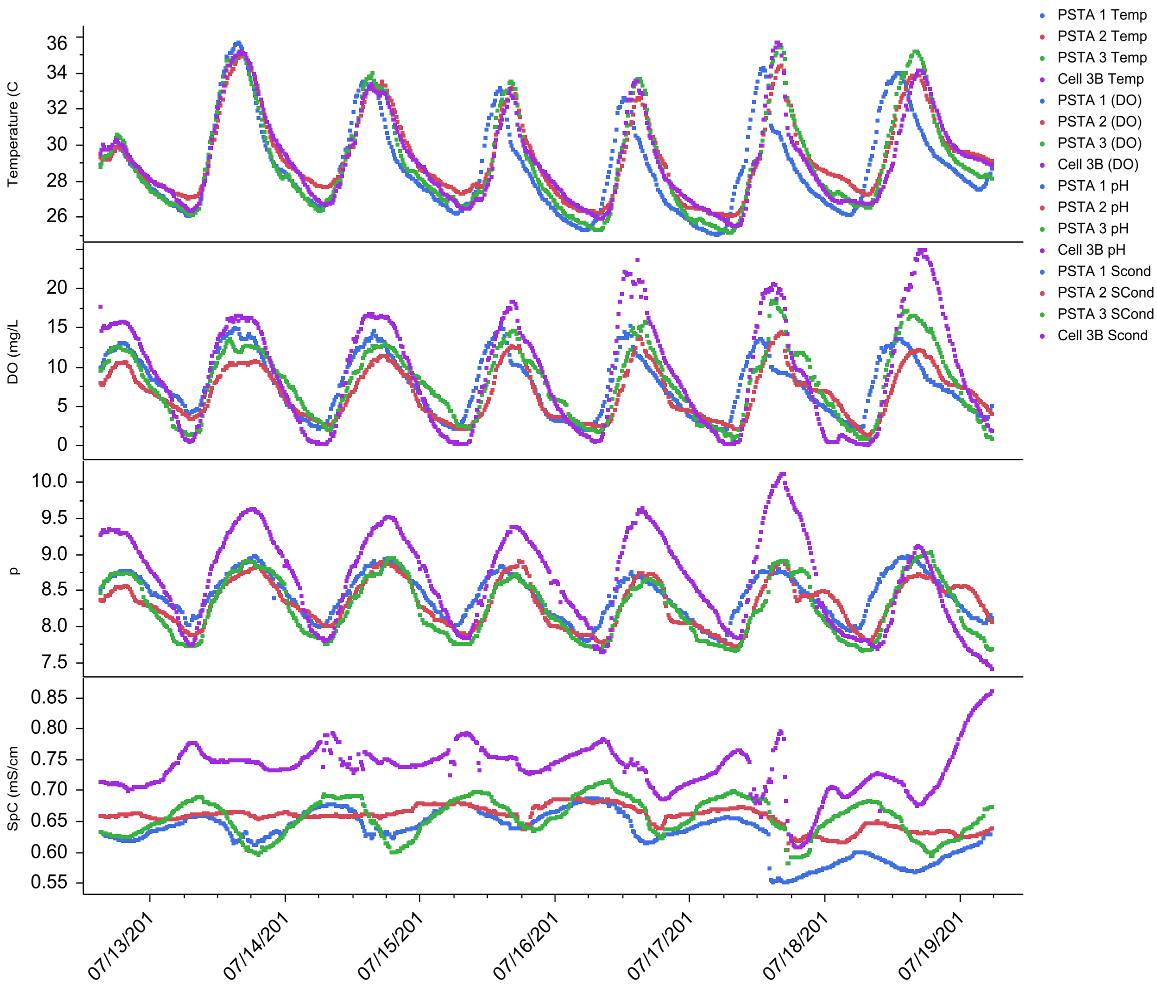


Figure 5B-44. Diel patterns in specific conductance, temperature, pH, and dissolved oxygen at multiple sites within the interior of the STA-3/4 PSTA Cell during a one-week period in July 2012 under flowing conditions.

Water and Total Phosphorus Budgets for the PSTA Cell

Water and TP budgets for the PSTA Cell were developed to better characterize the cell's P removal performance. During the five-year period from WY2008 –WY2012, this analysis utilized surface water and groundwater monitoring data presented above and improved flow estimates for the inflow and outflow structures described in Piccone et al. (2012). In addition, seepage coefficients for the levees surrounding the PSTA Cell were developed as part of this effort.

Methods

The District's Water Budget Program was used for this analysis, which was based on the following water balance equation:

$$I_{G390A+G390B} + R - O_{G388} + I_s - ET - \Delta S = r \quad (8)$$

where:

$I_{G390A+G390B}$ = surface water inflow to the PSTA Cell (ac-ft);
R = rainfall (ac-ft);
O_{G388} = surface water outflow from the PSTA Cell (ac-ft);
I_s = net seepage into the PSTA Cell (ac-ft)
ET = evapotranspiration (ac-ft);
ΔS = change in storage in the PSTA Cell (ac-ft); and
r = remainder in the water budget (ac-ft).

Daily rainfall over the PSTA Cell area was obtained from the District's Nexrad-based rainfall database and daily ET was obtained from weather station ROTNWX (Dbkey RW486). No direct measurements of seepage into the PSTA Cell were available, therefore, seepage was estimated as follows:

$$G = 1.983 \times K_{sp} \times L \times \Delta H \tag{9}$$

where:

G = estimated seepage (ac-ft/day);
K_{sp} = coefficient of seepage for the PSTA Cell levees (cfs/mi/ft);
L = length along a seepage boundary (mi);
ΔH = hydraulic head difference across a seepage boundary (ft); and
1.983 = constant to convert flow in cfs to ac-ft/day.

Seepage coefficients were developed for the levees surrounding the PSTA Cell. From April 6 to July 3, 2012, the PSTA Cell inflow structures (G-390A and G-390B) were closed for vegetation maintenance activities and the presence of nesting black-necked stilts in the cell. The outflow pump station (G-388) was operated during this period to maintain the cell at target stage. This period was selected for seepage coefficient calibration because inflows to the PSTA Cell were limited to seepage and rainfall, and any uncertainty associated with surface inflow was eliminated from the analysis. Seepage coefficients were calibrated to minimize the mean daily water balance remainder. The resulting seepage coefficients (2.4 and 5.8 cfs/mi/ft for the west&south and the north&east levees, respectively) were used to compute the water and TP budgets.

Monitoring well data (see the *Seepage Analysis* section above) were used to develop estimated ranges of the TP load contributed by seepage to the PSTA Cell. Seepage TP concentrations of 5, 10, and 17 ppb were used for comparative purposes in the PSTA Cell TP budgets. Median values for estimates of rainfall TP concentrations in south Florida range between 5 and 8 ppb (Brezonik et al., 1983; Ahn and James, 2001). A rainfall TP concentration of 6 ppb was used in this analysis. Two terms, the TP load reduction rate and TP flow-weighted mean concentration (FWMC) reduction rate, were calculated to evaluate the PSTA Cell TP removal performance:

$$\Delta TP_{load} = (TP_{in} - TP_{out}) / TP_{in} \times 100; \tag{10}$$

$$\Delta TP_{FWMC} = (FWMC_{in} - FWMC_{out}) / FWMC_{in} \times 100 \tag{11}$$

where:

ΔTP_{load} = TP load reduction rate (%);
ΔTP_{FWMC} = TP flow-weighted mean concentration reduction rate (%);
TP_{in} = inflow TP load (kg);
TP_{out} = outflow TP load (kg);
$FWMC_{in}$ = inflow flow-weighted mean concentration (ppb); and
$FWMC_{out}$ = outflow flow-weighted mean concentration (ppb).

Water Budget Summary

Annual water budgets were compiled from daily water balances computed using Equation 8 and summarized by water year (**Table 5B-17**). The water budget residual error ranged from -0.1 to 15.9 percent. Annual net seepage as a percentage of the total PSTA inflow volume ranged from 18 to 37 percent.

Table 5B-17. Annual water budgets for the STA-3/4 PSTA Cell from WY2008–WY2012.

Water Year	G-390A and G-390B Inflow (ac-ft)	Net Seepage (ac-ft)	Rain (ac-ft)	Total Inflow (ac-ft)	G-388 Outflow (ac-ft)	ET (ac-ft)	Total Outflow (ac-ft)	Change in Storage (ac-ft)	Water Budget Remainder (ac-ft)	Water Budget Residual Error* (%)
WY2008	2,922	1,840	562	5,324	5,200	491	5,691	131	498	9.0
WY2009	3,298	2,229	452	5,979	6,587	504	7,091	-73	1,038	15.9
WY2010	7,020	2,395	627	10,042	10,076	494	10,570	-8	521	5.1
WY2011	3,289	785	409	4,483	3,973	511	4,484	-9	-8	-0.1
WY2012	7,462	2,181	536	10,179	9,826	500	10,326	-8	139	1.4
TOTAL	23,991	9,430	2,586	36,007	35,662	2,500	38,162	33	2,188	5.9

* % water budget residual error = {water budget remainder ÷ [(surface inflow + surface outflow)/2]} × 100

Total Phosphorus Budget Summary

Annual TP budgets, TP load reduction rates and TP flow-weighted mean concentration reduction rates for the PSTA Cell are summarized in **Table 5B-18**. Over the period of five water years, the annual inflow TP FWMC through G-390A and G-390B ranged from 14 to 27 ppb with an overall average of 19 ppb, while the annual outflow TP FWM concentration discharged through G-388 ranged from 8 to 12 ppb with an overall average of 11 ppb.

Summary

These water and TP budgets are first steps in developing a better understanding of the TP removal performance of the PSTA Cell. These analyses are products of the enhanced PSTA Cell monitoring and research studies initiated in WY2012. The PSTA Project is planned to continue through WY2017. Therefore, these preliminary water and TP budgets will be updated accordingly, as additional flow and water quality data as well as updated topographic and seepage data become available.

Table 5B-18. Annual STA-3/4 PSTA Cell TP budgets from WY2008–WY2012 calculated with a range of estimated net seepage TP concentrations.

					Net Seepage TP = 5 ppb			Net Seepage TP = 10 ppb			Net Seepage TP = 17 ppb		
Water Year	Total Inflow [G-390A+ G-390B + rainfall + seepage] (ac-ft)	Surface Inflow TP FWMC [G-390A + G-390B] (ppb)	Surface Outflow [G-388] (ac-ft)	Surface Outflow FWMC [G-388] (ppb)	Total Inflow FWMC (ppb)	TP load Reduction rate (%)	TP conc. Reduction rate (%)	Total Inflow FWMC (ppb)	TP load Reduction rate (%)	TP conc. Reduction rate (%)	Total Inflow FWMC (ppb)	TP load Reduction rate (%)	TP conc. Reduction rate (%)
WY2008	5,324	27	5,200	12	17	32%	31%	19	42%	37%	22	56%	44%
WY2009	5,979	14	6,587	8	10	12%	20%	12	30%	32%	15	57%	45%
WY2010	10,042	20	10,076	10	15	34%	35%	17	42%	39%	18	53%	45%
WY2011	4,483	18	3,973	11	14	32%	23%	15	38%	28%	17	47%	33%
WY2012	10,179	17	9,826	12	14	17%	14%	15	25%	20%	17	35%	27%
TOTAL	36,007	19	35,662	11	14	26%	26%	16	32%	32%	17	40%	39%

STA-1W PHOSPHORUS MESOCOSM STUDY

ShiLi Miao, William Mitsch[13],
Darryl Marois[13], and Li Zhang[13]

Introduction

Although the STAs have substantially reduced total TP loading to the Everglades over the past decade, the District needs to lower TP concentrations in STA outflow even further to reach mandated TP levels (13 to 19 ppb). However, achieving additional P removal in these treatment wetlands has proven to be difficult. One research topic of interest to the District is whether there are alternative vegetation other than existing SAV species that can grow in a low-P environment and remove additional water column P. Pristine areas of the remaining Everglades are oligotrophic and dominated by sawgrass ridges and water lily (*Nymphaea odorata*) sloughs. The survival mechanisms of these native species, particularly their P uptake and storage, may provide information vital for developing new management strategies to enhance STA treatment performance. Thus, the District initiated a proof-of-concept mesocosm study in FY2010 using native plants to evaluate the potential role of alternative vegetation to remove water column P.

Objectives

The key objectives of the Phosphorus Mesocosm Study are to (1) determine P removal rates for different native plant communities receiving water with low P concentration; (2) compare the P removal capabilities of vegetation found in the Everglades (sawgrass and water lily communities) to that of existing plant communities in the STAs (cattail and SAV); and (3) identify and compare the major nutrient pathways and storage compartments in these plant communities.

Methods

This study was initiated at the STA-1W South Research Site in April 2010. Experimental treatments were assigned to mesocosms (fiberglass tanks that are 6 m L × 1 m W × 1 m D in size) with one factor (vegetation type) representing five native plant communities including (1) sawgrass monoculture, (2) water lily monoculture, (3) mixed spikerush and water lily, (4) cattail (*T. domengensis*) monoculture, (5) SAV (southern naiad and muskgrass), and (6) soil (non-vegetated as a control). (**Figure 5B-45**). The first three treatments represent communities native in pristine areas of the Everglades, and the next two treatments represent plant communities found in the STAs. Each of the six treatments was run in triplicate (= 18 mesocosms in total).

Each mesocosm was filled with 30 cm of soil and stocked with plants in late April 2010 at densities that varied according to the vegetation treatment. Soil and plants were obtained from STA-1W. The baseline nutrient content of soil and plants was measured at planting time. After setup, the water depth in each mesocosm was gradually raised to 40 cm. Inflow to the mesocosms is pumped from the outflow region of STA-1W, which typically has low P concentrations. By late August 2010, after vegetation in the mesocosms had become established, the HLR to all mesocosms was adjusted to approximately 2.6 cm/d resulting in a nominal HRT of 13-15 days. Each mesocosm received an inflow water pulse of 20 gallons twice a day (3 AM and 3 PM).

[13] Florida Gulf Coast University, Fort Myers, FL

Sampling water quality, soil, and plant parameters related to P removal processes began in August 2010. Water quality was monitored bi-weekly at the common inflow to all the mesocosms and at the outflow from each mesocosm. Water quality parameters include TP, SRP, total dissolved P (TDP), dissolved organic carbon (DOC), total dissolved Kjeldahl nitrogen (TDKN), dissolved calcium (Ca^{2+}), dissolved oxygen (DO), pH, temperature, and conductivity. Particulate P (PP) was calculated as TP – TDP. Dissolved organic P was calculated as TDP – SRP. Soil samples were collected from each mesocosm every six months and analyzed for total P, N, and C and a P fractionation series. The amount of TP, PP, DOP, and SRP expressed as a percent removed by each vegetation treatment was calculated using mean inflow and outflow concentrations: [(inflow -outflow)/inflow] x 100. Diel DO cycling in the water column in each mesocosm was measured several times in 2011 and 2012. Other important ecological processes including water column productivity, plant biomass accumulation, and phosphatase enzyme activity, were measured to understand P removal mechanisms. Additional study results will be presented in the future. This study was originally scheduled to end in January 2013. However, sampling was extended to August 2013 to obtain additional data. Results of some water quality parameters monitored during the study through May 2013 are presented below.

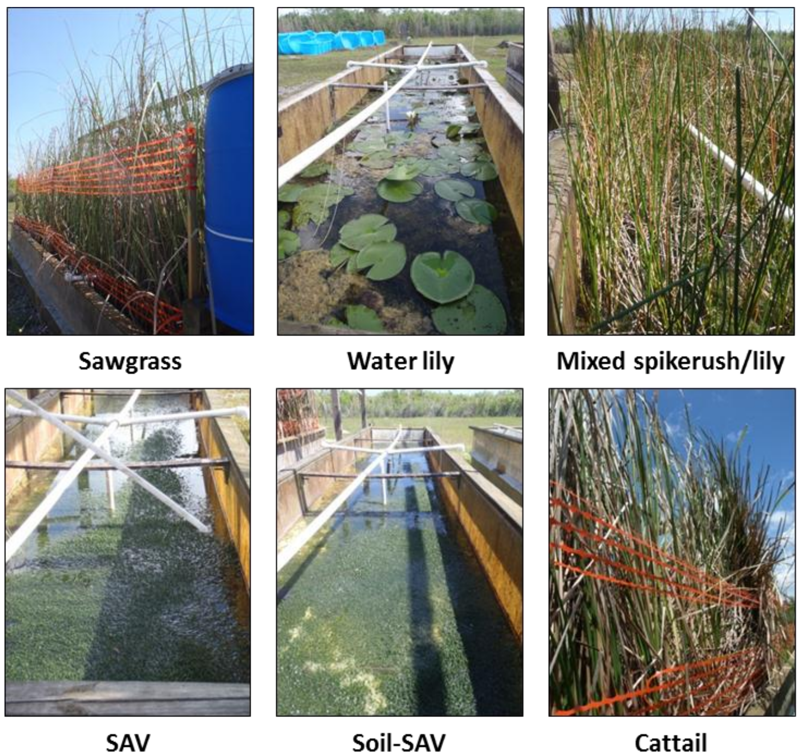


Figure 5B-45. The six vegetation treatments employed in the STA-1W Phosphorus Mesocosm Study as they appeared three years after initiation of the study (photos by the SFWMD).

Results and Discussion

It is important to note that the non-vegetation control treatment was colonized by SAV species after the experiment began, and is referred to as soil-SAV. In addition, two of the monoculture treatments, the sawgrass treatment and the water lily treatment, were also colonized with SAV species.

Inflow Phosphorus (August 2010–May 2013)

The average inflow TP concentration to the mesocosms over the 34-month POR (August 2010 to May 2013) was 24.7 ± 8.9 ppb. Average inflow PP concentration accounted for approximately 70 percent of TP and both TP and PP had a similar range of temporal variation (**Figure 5B-46**) although their concentrations were only weakly correlated (r = 0.28). Average inflow DOP concentration was approximately 23 percent of TP and fluctuated little over the POR compared to the variation in TP and PP. Average inflow SRP concentration, on the other hand, comprised only 9 percent of TP, and averaged 2.1 ± 0.5 ppb. Most SRP measurements were at the method detection limit of 2 ppb.

Phosphorus Removal (November 2012–May 2013)

Outflow TP concentrations were used to evaluate P removal efficacy in the six vegetation treatments, whereas the concentration of P species (TP, SRP, PP and DOP), particularly the concentration differences between the inflow and outflow, can provide insights into P removal mechanisms. The outflow P speciation data reported here are for the period November 2012 through May 2013 when net P removal occurred in some of the mesocosm vegetation treatments.

Three trends in TP removal were noted among the six treatments during this period. First, the water lily, soil-SAV, and cattail treatments had lower mean outflow TP concentrations (14.4, 17.8, and 19.7 ppb, respectively) compared to the mean inflow TP (22.6 ppb) (**Table 5B-19**) and generally had lower concentrations on most sampling dates (**Figure 5B-47**). Second, the sawgrass and SAV treatments showed the opposite trend; their mean outflow TP concentrations (30.4 and 27.0 ppb, respectively) were approximately 35 and 19 percent higher, respectively, than the mean inflow TP concentration (**Table 5B-19**) and generally had higher concentrations on most sampling dates (**Figure 5B-47**). Third, the mixed spikerush + water lily treatment had a mean TP outflow concentration (22.7 ppb) that was virtually identical to the mean inflow TP concentration (**Table 5B-19).**

Outflow PP concentrations from all treatments decreased relative to inflow PP concentrations, although the size of the decreases varied among treatments (**Figure 5B-47** and **Table 5B-19**). The opposite relationship was true for DOP, where mean outflow concentrations for all treatments increased compared to the inflow mean by 21 percent (water lily) to 220 percent (sawgrass). There were minimal differences between inflow and outflow SRP concentrations in the water lily, cattail, soil-SAV, and mixed spikerush + water lily treatments. However, outflow SRP concentrations in the sawgrass and SAV treatments, for both mean values and values on numerous individual sampling dates were substantially higher than corresponding inflow values.

The highest percent TP removal for the period November 2012 to May 2013 was in the water lily treatment (36.5 percent) followed by soil-SAV (21.4 percent) and cattail (12.7 percent) (**Table 5B-20)**. The sawgrass and SAV treatments, on the other hand, exhibited negative TP removal (i.e., net export) of -34.6 and -19.6 percent, respectively. TP removal in the mixed spikerush + water lily treatment was close to zero (-0.3 percent). All treatments exhibited positive PP removal (range from 26.9 to 59.2 percent), whereas all treatments exported DOP (range from -20.8 to -220.3 percent).

Summary

The inflow water delivered to the STA-1W mesocosms had TP concentrations ≤ 34 ppb. PP comprised the largest fraction of TP and SRP the smallest fraction. From November 2012 to May 2013, the water lily, soil-SAV, and cattail treatments exhibited net TP removal with the water lily treatment being the most efficient, whereas the sawgrass and SAV treatments exported TP, i.e., no treatment was provided In addition, mean outflow PP concentrations from all treatments decreased relative to mean inflow PP concentrations and the mean DOP outflow concentrations for all treatments increased as compared to the mean inflow DOP concentrations. Although all treatments removed PP, their outflow TP concentrations were different. This suggests that under the low P conditions (1) DOP and SRP might play important roles in determining surface water TP concentrations, and (2) different P removal mechanisms might be involved among the vegetation. For the water lily treatment, TP removal largely resulted from PP and SRP removal. In contrast, sawgrass exported P as DOP and SRP.

Although the experiment had the potential to shed light on the difference of plant type on performance, the change that occurred in the one factor evaluated (vegetation type) has limited the ability to evaluate the difference of plant type on performance due to the loss in treatment fidelity. Even with P speciation data, the loss in treatment fidelity also makes it difficult to evaluate the possible removal mechanisms at play. Therefore, the study was discontinued in August 2013. Additional study results will be presented in the future. These results suggest that additional research be performed on the ability of alternate vegetation, particularly water lily, to remove additional water column P to very low levels, and that P speciation be evaluated in these experiments to better evaluate possible P removal mechanisms at play.

Table 5B-19 Mean concentrations of total P (TP), particulate P (PP), dissolved organic P (DOP), and soluble reactive P (SRP) at the common inflow to the STA-1W mesocosms and outflows from the six vegetation treatments, November 2012 to May 2013. Sample size was 61 in all cases.

		Outflow					
P Species	**Inflow**	**Water lily**	**Soil-SAV**	**Cattail**	**Mixed**	**SAV**	**Sawgrass**
TP (ppb)	22.6	14.4	17.8	19.7	22.7	27.0	30.4
PP (ppb)	15.9	6.8	9.0	6.6	11.5	11.6	6.5
DOP (ppb)	4.6	5.6	6.8	10.6	9.1	11.6	14.7
SRP (ppb)	2.1	2.0	2.0	2.5	2.1	3.4	9.2

Table 5B-20. Percent of TP, PP, DOP, and SRP concentration removed by the six vegetation treatments, November 2012 to May 2013. Sample size was 14 in all cases. Negative values indicated an increase in outflow mean concentration relative to the inflow mean, i.e., a net export of material.

	Outflow					
P Species	**Water lily**	**Soil-SAV**	**Cattail**	**Mixed**	**SAV**	**Sawgrass**
TP (%)	36.5	21.4	12.7	-0.3	-19.6	-34.6
PP (%)	57.1	43.1	58.4	27.6	26.9	59.2
DOP (%)	-20.8	-47.3	-130.9	-98.1	-153.1	-220.3
SRP (%)	6.3	8.3	-17.7	3.1	-60.4	-332.3

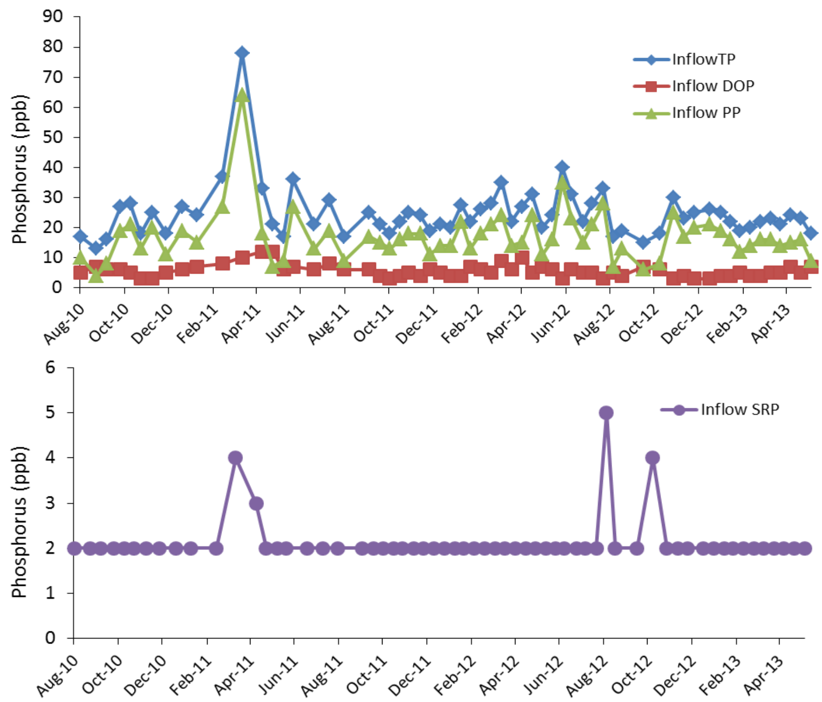


Figure 5B-46. Temporal dynamics of total P (TP), particulate P (PP), dissolved organic P (DOP), and soluble reactive P (SRP) concentrations at the common inflow to the STA-1W mesocosms, August 2010 to May 2013.

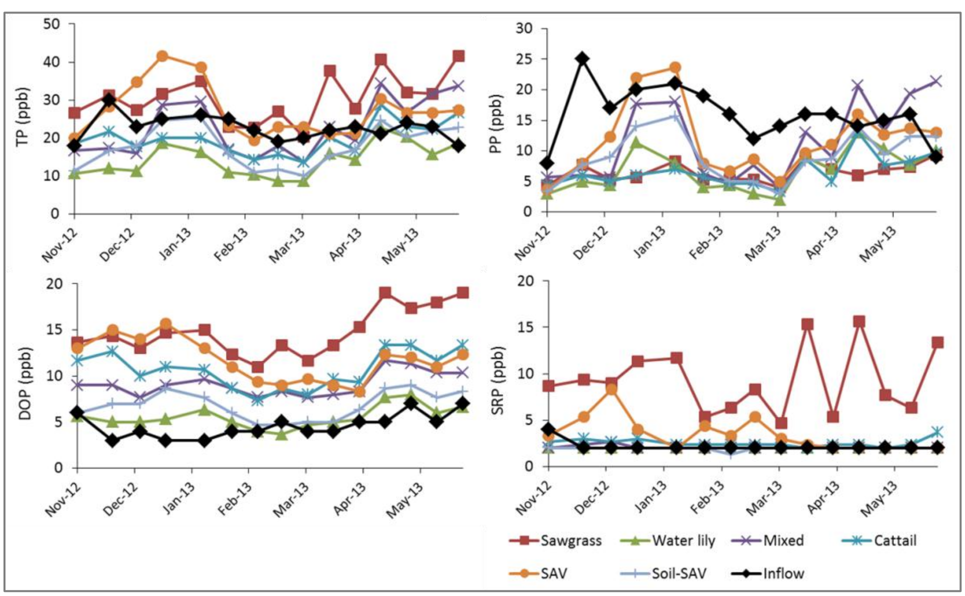


Figure 5B-47. Temporal dynamics of TP, PP, DOP, and SRP concentrations at the common inflow to the STA-1W mesocosms and outflows from the six vegetation treatments, November 2012 to May 2013.

TEMPORAL DYNAMICS OF SUBMERGED AQUATIC VEGETATION COVERAGE IN STA-3/4

Thomas A. DeBusk[14], Mike Jerauld[14]
and Michelle Kharbanda[14]

Introduction

STA flow-ways that have upstream EAV-dominated communities followed by downstream SAV-dominated communities, as specified in the District's Long Term Plan, have provided effective P removal. However, SAV communities have not proven entirely sustainable, due in part to wind damage from hurricanes, as well as to unexplained declines in stands of some species (primarily hydrilla, and to a lesser extent, muskgrass). Additionally, there is concern that the fine marl sediments deposited in SAV cells can adversely affect vegetation health after years of STA operation. The superior P removal performance of SAV communities, however, provides a compelling reason to encourage and maintain SAV beds in the outflow regions of STA flow-ways.

A better understanding is needed of the individual factors (e.g., water chemistry, soil chemistry, soil physical characteristics, herbivory), and interactions among factors, that influence SAV species distribution, persistence and colonization/recovery in STAs. Observations of recent marked fluctuations in SAV communities in STA-3-4 Cell 3B are described below.

Objectives

The objective of this monitoring effort was to utilize routine field assessments of SAV communities to facilitate our understanding of factors that influence cover and speciation of submerged plants in the "polishing" cells located at the bottom of STA flow-ways.

Methodology

The STA-3/4 Western Flow-way is comprised of two cells arranged in series: Cell 3A (EAV dominated) and Cell 3B (SAV dominated) (**Figures 5B-17** and **5B-48**). SAV cover in Cells 2B and 3B was assessed using a semi-qualitative technique in which each species present at a site was assigned a relative abundance score from 0 to 5, with 0 being no plants observed and 5 being 80 to 100 percent cover based on visual inspection. Vegetation monitoring was conducted at 56 stations on August 26, 2010 before, and on July 7 and August 9, 2011, July 12, 2012, and March 19, 2013 after a dryout-reflood event that occurred in early summer of 2011. Species coverage data were analyzed with ArcView Spatial Analyst (ESRI, Redlands, CA) using the spline/tension method.

Surface water grab samples were collected within the Western Flow-way on September 26, 2012 and April 18, 2013 (**Figure 5B-48**). Surface water also was collected at four of the six culverts at the inflow, mid flow-way and outflow levees. All samples were analyzed for TP, TDP, and SRP. Hydraulic inputs to the flow-way during the September 2012 and April 2013 sampling events were 484 and 253 cfs, respectively. Mean inflows for the 2 weeks prior to each sampling were 529 and 121 cfs, respectively.

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[14] DB Environmental, Inc., Rockledge, FL

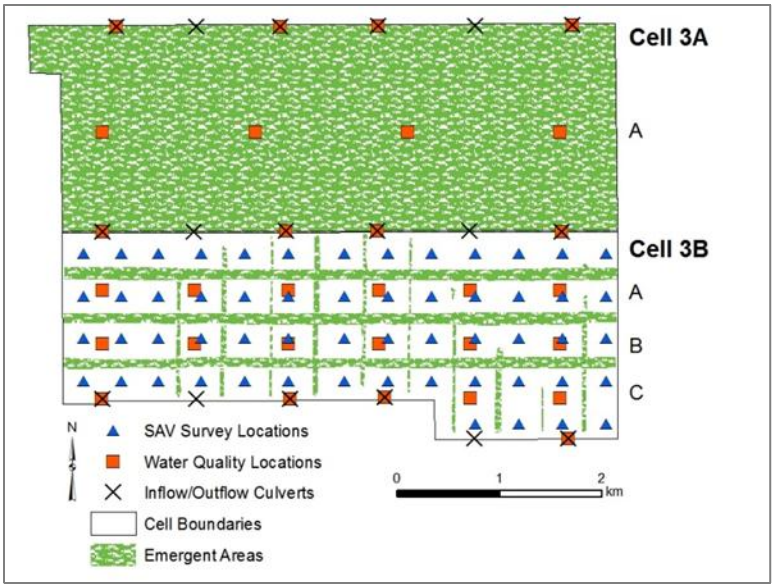

Figure 5B-48. Location of water quality sampling and SAV ground survey sites along transects within the Western Flow-way of STA-3/4. Water samples also were collected at four of the six culverts along the inflow, mid flow-way and outflow levees. Letters identify east-west oriented sampling transects within each cell.

Results and Discussion

Water depths in Cells 3B and the adjacent Cell 2B of STA-3/4 fell to record low levels in June 2011 during a drought and large portions of these cells dried out. In response to the dryout, the coverage of dense SAV within these two cells declined markedly (**Figures 5B-49** and **50**). While the SAV community recovered quickly after the cells reflooded, SAV coverage again declined dramatically between the July 2012 and March 2013 surveys (**Figures 5B-49** and **50**) for unknown reasons. Anecdotal evidence indicated that the SAV community began to recover by the end of WY2013 (data not shown).

Internal water quality monitoring in Cell 3B found much lower internal and outflow TP concentrations in September 2012 than in April 2013 (**Figure 5B-51**), two dates with comparable HLRs. Field observations indicated a relatively healthy SAV community on the first sampling event, and a markedly unhealthy community on the latter event. Concentrations of both PP and DOP remained elevated throughout Cell 3B in April, whereas levels of these constituents were dramatically reduced during the September sampling event. Comparable internal monitoring was not performed in Cell 2B, since a controlled drawdown in the upstream cell, Cell 2A[15] precluded operating the downstream Cell 2B during spring 2013.

One potential explanation for the recent decline of SAV in Cell 3B (**Figure 5B-50**) was increased herbivory from crayfish. Two species of crayfish, the Everglades crayfish (*Procambarus alleni*) and the deceitful (a.k.a. marbled or slough) crayfish (*P. fallax*) are native to the Everglades and other south Florida waters (Hendrix and Loftus, 2000). Studies of Everglades'

[15]Water levels in Cell 2A were purposely lowered during spring 2013 as a management strategy to rejuvenate the cattail population in this cell.

wetlands have demonstrated that when crayfish populations are uncontrolled, they can reduce or eliminate standing stocks of submerged plants. Largemouth bass (*Micropterus salmoides*), yellow bullhead (*Ameiurus natalis*) and some sunfish species, in particular warmouth (*Lepomis gulosus*), are major predators of crayfish in south Florida marshes. These fish populations can be sharply reduced by a drawdown, such as the one that occurred in STA-3/4 in June 2011. Therefore, the crayfish population in Cell 3B may have increased dramatically in response to reduced predation pressure from fish. Field monitoring and mesocosm (e.g., crayfish and fish exclosure studies) investigations will be conducted during WY2014 to evaluate this hypothesis further.

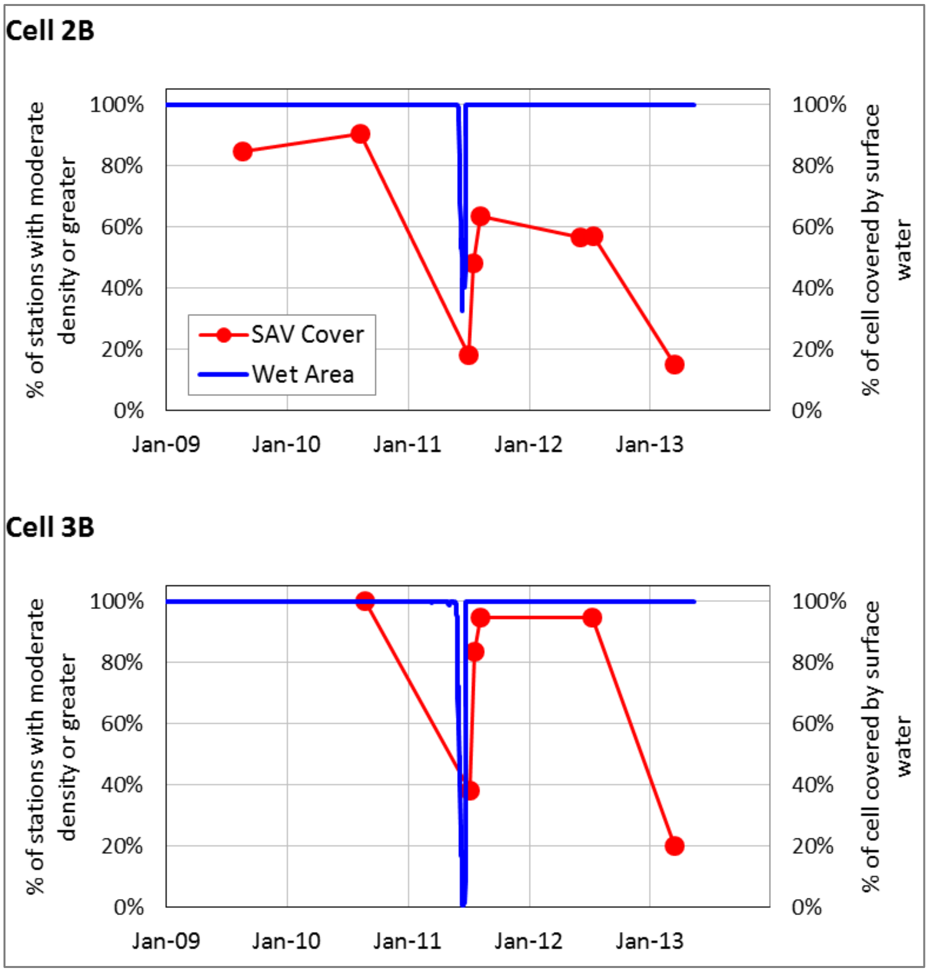

Figure 5B-49. SAV cover as the percentage of survey points with moderate or greater relative abundance (scores ≥ 3) and relative wetted surface area in Cells 2B and 3B of STA-3/4 from August 2010 to March 2013.

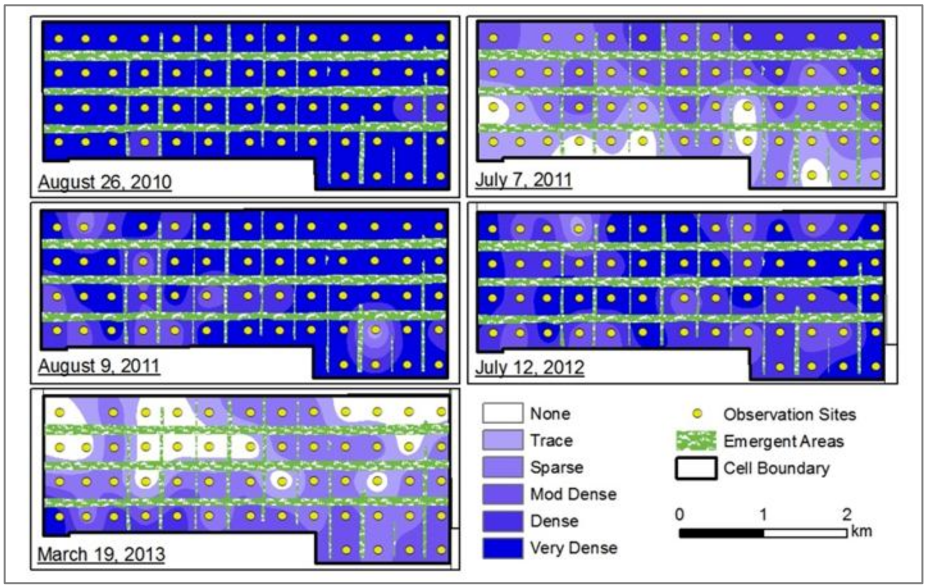

Figure 5B-50. The spatial coverage and relative abundance of muskgrass in STA-3/4 Cell 3B from August 2010 through March 2013 based on SAV ground surveys. Cell 3B dried out in early summer 2011, resulting in a decline of muskgrass in July 2011 (top right map). Note the decline in muskgrass between July 2012 and March 2013. Dots identify SAV ground survey locations.

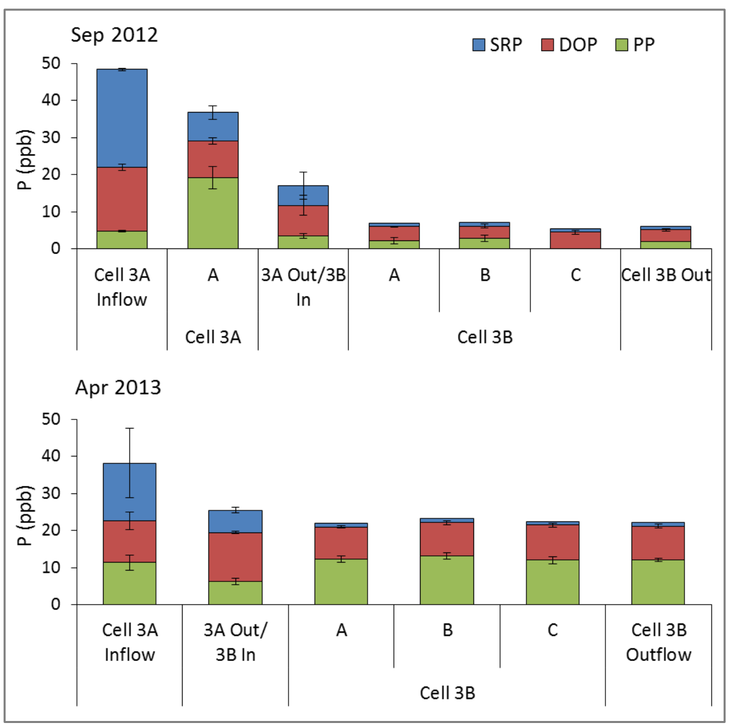

Figure 5B-51. Mean concentration profiles for SRP, DOP, and PP from inflow-to-outflow in the Western Flow-way of STA-3/4 on September 26, 2012, and April 18, 2013. Error bars represent ± 1 SE of the mean for grab samples collected along each transect (n = 2–4).

EVALUATION OF PHOSPHORUS REMOVAL CHARACTERISTICS USING INTERNAL WATER QUALITY TRANSECTS IN STA-5/6

Thomas A. DeBusk[16] and Michelle Kharbanda[16]

Introduction

Internal water quality monitoring of P fractions in the STA flow-ways has proven useful for identifying regions of effective (or ineffective) treatment performance along the inflow-to-outflow flow-path. Additionally, when coupled with vegetation surveys, internal water quality monitoring enables comparisons of vegetation cover and health with treatment performance. Internal monitoring also can assist with the evaluation of various management activities (e.g., adjustments to flow-way P loading, vegetation management, etc.) on STA treatment performance and sustainability.

Over 55 internal water quality monitoring events have been conducted in the STAs since WY2003 under a range of hydraulic and P loading conditions. Different flow-ways typically are monitored on a rotating basis, so that internal treatment performance of all the STAs ultimately can be characterized under a range of operating conditions. When possible, internal monitoring events were scheduled to coincide with key operational events (e.g., startup after a period of no flow or dryout). Collectively, data from numerous internal monitoring events over time for a flow-way or cell facilitates the assessment of key treatment performance factors, such as minimum attainable outflow TP concentrations and P removal characteristics along the inflow-to-outflow flow-path. Recent efforts have focused on sampling in STA-1W, STA-3/4, and STA-5/6, along with the new flow-ways in STA-2 (Compartment B). Findings of internal monitoring efforts in STA-5/6 Flow-ways 1 and 2 (**Figure 5B-52**; Appendix 5B-1, Figure 5) during WY2013 are described below.

Objectives

The objective of this monitoring effort was to characterize the temporal and spatial variability of water column P fractions within "polishing" cells located at the bottom of flow-ways in STA-5/6, a facility with a long operational history.

Methodology

Surface water grab samples were collected in STA-5/6 Flow-ways 1 and 2 on September 11 and 12, 2012 (during the wet season) and April 9, 2013 (during the dry season). Airboat access to the inflow cells of these flow-ways can be constrained during the dry season when water levels are low. Therefore, the SAV cell in each flow-way (Cells 5-1B and 5-2B) was monitored at multiple internal transects, while samples in the EAV cells (Cells 5-1A and 5-2A) were collected only along inflow, mid-cell and outflow transects (**Figure 5B-52**). Samples were unable to be collected from Cells 5-1A and 5-2A in April 2013 due to low water. All samples were analyzed for TP, TDP, and SRP. Data collected along each transect were averaged to produce inflow to

[16] DB Environmental, Inc., Rockledge, FL

outflow TP and P fraction[17] concentration profiles. Spatial analyses of the data were performed with ArcView Spatial Analyst (ESRI, Redlands, CA) using the spline/tension method.

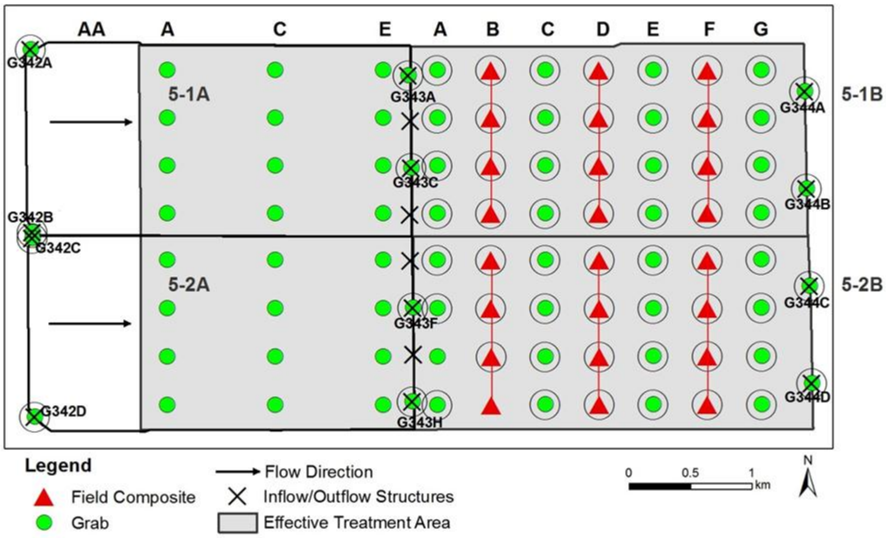

Figure 5B-52. Location of water quality sampling stations along transects in STA-5/6 Flow-way 1 (Cells 5-1A and 5-1B) and Flow-way 2 (Cells 5-2A and 5-2B) in September 2012 (at all stations) and April 2013 (only at stations enclosed within black circles). Letters identify north-to-south oriented sampling transects within each cell. Grab samples (green circles) were analyzed individually, while the samples collected along the red transects B, D, and F were composited in the field prior to analysis.

Results and Discussion

Flow-ways 1 and 2 exhibited exceptional treatment performance in September 2012, with consistent downstream reduction in TP throughout the wetland (**Figure 5B-53**) under flowing conditions (mean inflow = 91 cfs). Two conveyance canals converge near the inflow region of Cells 5-1A and 5-2A, and District scientists have previously noted that TP concentrations can vary widely among these inflow culverts. At the time of our spatial assessment, the influence of high P inflow concentrations at the southernmost inflow culvert, presumably influenced by discharge from the upstream drainage basin, can be seen in anomalously high TP, DOP and SRP spatial profiles in the southwest corner of Cell 5-2A (**Figures 5B-53** and **5B-54)**. However, these high P values were reduced a short distance down the flow-path.

TP concentrations in the SAV cells of Flow-ways 1 and 2 demonstrated markedly different inflow-to-outflow P concentration profiles during the two sampling events (**Figure 5B-55**). In September 2012, inflow to each flow-way averaged more than 100 cfs for the two-week period prior to sampling (**Figure 5B-56**). In comparison, there was virtually no surface water input to Flow-way 2 during the two weeks prior to sampling in April 2013 and much reduced inflow to Flow-way 1 (mean = 13.5 cfs). Internal TP concentrations were much higher in both cells in April

[17] Phosphorus fractions included TDP, SRP, dissolved organic P [DOP = TDP – SRP], and particulate P [PP = TP - TDP].

2013 **(Figure 5B-55)**, suggesting that sediment-to-water column P loading occurred under conditions of little or no flow. This internal P loading may be attributed to the presence of P-enriched sediments, which undoubtedly resulted from excessively high P loadings to the flow-ways during the early years of STA operation (**Figure 5B-22**). High internal P loading may compromise the ability of this STA to achieve low outflow P levels during low-flow conditions for years to come.

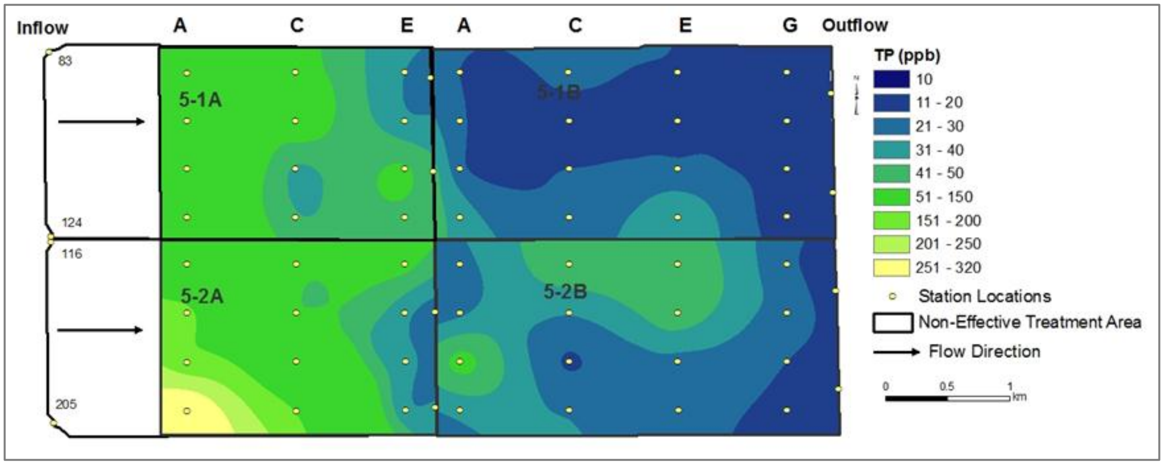

Figure 5B-53. Spatial interpolation of TP concentrations along transects in STA-5/6 Flow-ways 1 and 2 in September 2012. TP concentrations from the inflow structures to Cells 5-1A and 5-2A were not included in the analysis. Note the anomalously high TP value near the southernmost inflow culvert to Cell 5-2A. Letters identify north-to-south oriented sampling transects within each cell. Dots indicate location of sample sites.

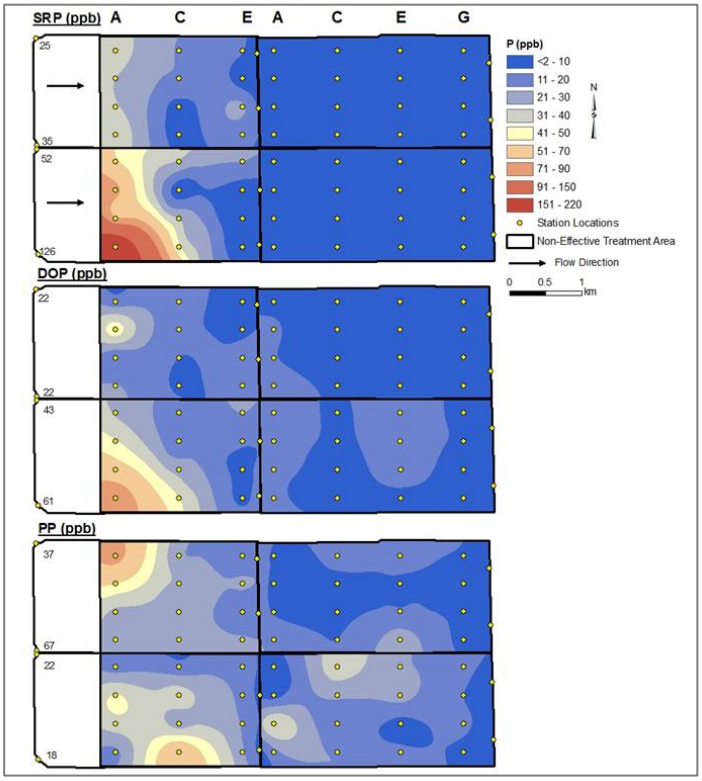

Figure 5B-54. Spatial interpolations of SRP, DOP, and PP concentrations along transects in STA-5/6 Flow-ways 1 and 2 in September 2012. Phosphorus concentrations from the inflow structures to Cells 5-1A and 5-2A were not included in the analyses. Letters identify north-to-south oriented sampling transects within each cell. Dots indicate location of sample sites.

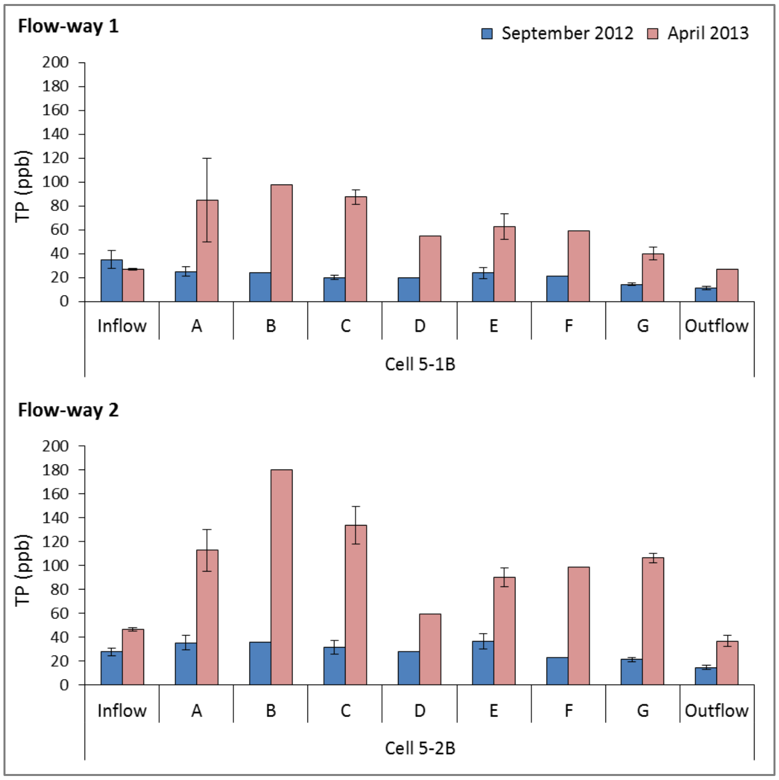

Figure 5B-55. Mean TP concentration profiles from inflow to outflow in the SAV cells of STA 5/6 Flow-ways 1 and 2 (Cells 5-1B and 5-2B) in September 2012 and April 2013. Error bars represent ±1 SE of the mean for grab samples collected along each transect (n=4).

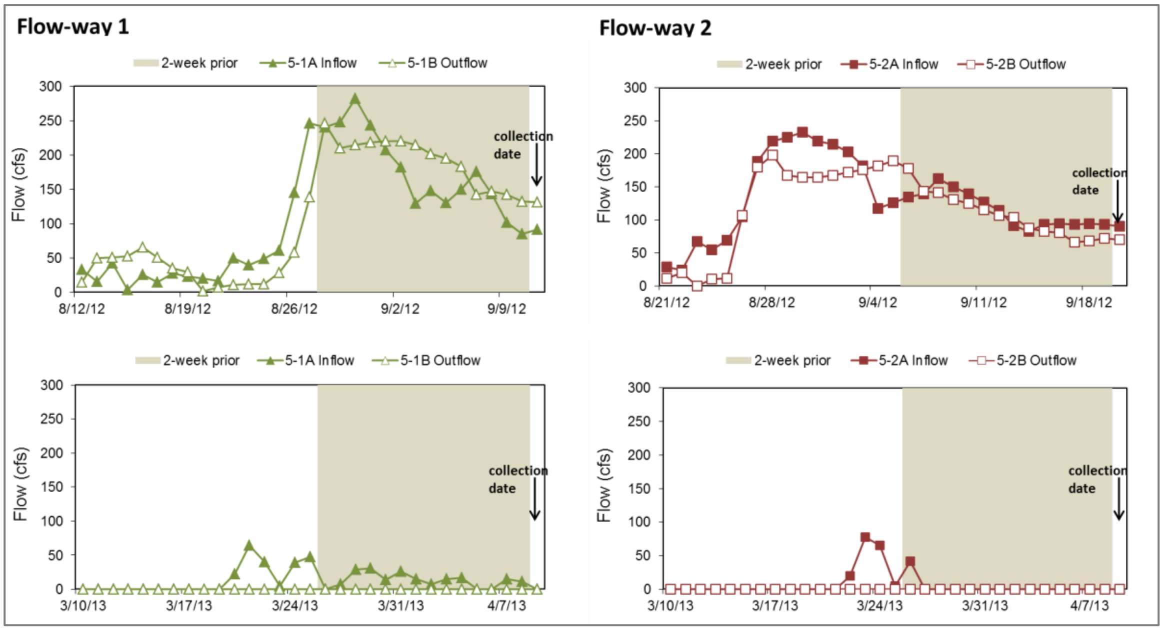

Figure 5B-56. Rate of inflow and outflow to Flow-ways 1 and 2 of STA-5/6 on the day of, and 30 days prior to sample collection in September 2012 (wet season; top panels) and April 2013 (dry season; bottom panels).

STA-2 SUPPLY/INFLOW CANAL ANALYSES – PAST, PRESENT AND FUTURE EFFORTS

Tracey Piccone

In recognition of the potential need to perform canal maintenance in STA canals after a period of operation, the District initiated a STA canal sediment sampling effort in 2006 (CSI, 2007). The objective of this study was to identify candidate locations for accrued sediment removal upstream of STA inflow structures where there might be sediment resuspension to the water column. The 2006 canal sampling effort included the STA-2 Inflow Canal reach between the G-331G and G-333E structures (see Appendix 5B-1, Figure 3). Within this reach, three locations were sampled: one sample was taken from near the downstream side of both G-331G and G-333E, with a third sample taken approximately equidistant to these two structures. The depth of the surficial sediments (peat and silts) ranged from approximately 21 to 61 cm, in thickness. These results were used to develop estimated dredging volumes for this canal reach (Taylor Engineering, 2007). However, because of the limited number of samples collected, and because a surveyor subsequently "determined there to be no substantial muck sediment present," the results of this study were deemed inconclusive and no dredging activities were conducted in the STA-2 Inflow Canal. Instead, subsequent dredging efforts were focused on the STA-5 Inflow Canal where the results of the study were more conclusive.

Additional data analyses were conducted in 2009 and 2010, the objective of which was to assess the influence of sediment in the STA-2 Supply/Inflow Canal on water quality at the inflows to the treatment flow-ways (Gary Goforth, Inc., 2009 and 2010). These efforts used flow and water quality data collected from WY2003 through WY2010 to develop a TP budget for the STA-2 Inflow Canal. Results suggested that the canal sediments were a potential source of TP to the water column, however in recognition of uncertainties with flow estimates and sediment TP concentrations from the 2006 field sampling effort, further evaluation and field sampling was recommended.

A canal sediment chemistry and water quality study was conducted in 2011 to evaluate the potential contribution of sediment P to the water column within selected STA canals (DB Environmental, Inc., 2011). Sediment cores were collected from the inflow and outflow canals of STA-2, as well as from the outflow canals of STA-1W, STA-5, and STA-6. Phosphorus release rates measured in the laboratory for the STA-2 inflow canal sediments were substantially higher than P flux from any of the outflow canal sediments. This study cautioned against extrapolating findings from a limited set of samples to the entire canal bottom, and included recommendations for further field sampling.

Goforth (2013b) updated previous data analyses to estimate the potential TP load contribution from sediment to the water column in the STA-2 Supply/Inflow Canal, the canal that supplies water to STA-2[18]. This effort utilized flow and water quality data collected from WY2003 through WY2012 as well as the results from the 2011 canal sediment sampling study (DB

[18] STA-2 Supply Canal extends from the S-6 pump station to the Cell 1-3 Inflow Canal at the northeast corner of STA-2, a distance of appropriately 23,950 ft. The Supply Canal has a bottom width of 57.0 ft at elevation -4.0 ft NGVD 29 and minimum side slope of 2.5:1 (H:V). The Inflow Canal extends westward from the Supply Canal along the northern boundary of Cells 1-3 to Structure G-337A. The total length of the Inflow Canal is approximately 41,000 ft. The Inflow Canal in the reach along the top of Cell 1 has a bottom width of 20.0 ft at elevation -4.0 ft NGVD 29 and side slope of 3:1 (H:V). The Inflow Canal in the reach along the top of Cells 2 and 3 has a bottom width of 20.0 ft at elevation -2.0 ft NGVD. The mean depth in this canal over its POR has been approximately 17.4 ft

Environmental, Inc., 2011), and a 2012 canal sediment sampling effort conducted by District staff. While this new analysis documented an increase in TP load that occurred within the STA-2 Supply/Inflow Canal, the source(s) of this "new" TP were unknown, and additional field investigations were recommended. It was not known if the new TP was derived from the canal sediments, groundwater entering the canal, or a computation artifact caused by errors in flow measurement along the canal reach. This updated analysis was done with the recognition that when structure flow measurements are improved for the STA-2 Supply/Flow Canal in the near future, the TP load calculations can be updated accordingly and can be used to help define further analyses, data collection, and field investigations. This updated analysis also serves as an example of the type of preliminary analysis that can be conducted for other STA inflow and outflow canals as part of Phase I of the Restoration Strategies Science Plan study, Evaluation of the Influence of Canal Conveyance Features on STA and FEB Inflow and Outflow TP Concentrations (see Chapter 5C of this volume).

LITERATURE CITED

Ahn H. and R.T. James. 2001. Variability, uncertainty, and sensitivity of phosphorus deposition load estimates in south Florida. *Water, Air, and Soil Pollution*. 126: 37-51.

Bostic, E.M. and J.R. White. 2007. Soil Phosphorus and Vegetation Influence on Wetland Phosphorus Release after Simulated Drought. *Soil Science Society of America Journal*, 71(1): 238-244.

Brezonik, P.L., C.D. Hendry, Jr., E.S. Edgerton, R.L. Schulze and T.L. Crisman. 1983. Acidity, nutrients, and minerals in atmospheric precipitation over Florida: deposition patterns, mechanisms, and ecological effects. EPA/600/3-84/004, U.S. Environmental Protection Agency, Corvallis, OR.

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.

Cepero, C. and B. Khosrozadeh [CSI]. 2007. Updated Report of Physical and Chemical Characterization of Sediments, Everglades Agricultural Area (EAA) Stormwater Treatment Areas (STA) 1, 2 and 5 Inflow Canals, Palm Beach and Hendry Counties, Florida, Contract No. CN040896-W0#04 Civil Services, Inc., Jacksonville, FL. April 10, 2007.

DB Environmental. 2009. Tracer Study: PSTA Cell, STA-3/4. A Technical Memorandum. Submitted to the South Florida Water Management District, West Palm Beach, FL.

DB Environmental, Inc. 2011. Final Report: Stormwater Treatment Area Outflow and Inflow Canal Sediment Characterization, August 2011. Submitted to the South Florida Water Management District, West Palm Beach, FL.

DeBusk, W.F. and K.R. Reddy. 2003. Nutrient and Hydrology Effects on Soil Respiration in a Northern Everglades Marsh. *Journal or Environmental Quality*, 32:702-710.

Frazee, Jr., J.M. 1982. Geochemical Pattern Analysis: Method of Describing the Southeastern Limestone Regional Aquifer System. Studies of Hydrogeology of the Southeastern United States, Special Publications: Number 1, Georgia Southwestern College, Americus, GA, 46-58.

Gary Goforth, Inc. 2009. Technical Memorandum, Analysis of STA-2 Supply and Inflow Canals, to Tracey Piccone, South Florida Water Management District West Palm Beach, FL. April 27, 2009.

Gary Goforth, Inc. 2010. Technical Memorandum, Draft STA-2 Total Phosphorus Analysis, to Tracey Piccone, South Florida Water Management District West Palm Beach, FL. February 6, 2010.

Gary Goforth, Inc. 2013a. Technical Memorandum, Preliminary Impacts of Tropical Storm Isaac on the STAs, South Florida Water Management District West Palm Beach, FL. August 21, 2013.

Gary Goforth, Inc. 2013b. Final Technical Memorandum, STA-2 Supply/ Inflow Canal Analysis, to Hongying Zhao, South Florida Water Management District. June 7, 2013.

Ivanoff, D., K. Pietro, H. Chen and L. Gerry. 2013. Chapter 5: Performance and Optimization of the Everglades Stormwater Areas. In: *2013 South Florida Environmental Report – Volume I*, South Florida Water Management District, West Palm Beach, FL. 102 pp.

Hendrix, A.N. and W.F. Loftus. 2000. Distribution and relative abundance of the crayfishes *Procambarus alleni* (Faxon) and *P. fallax* (Hagen) in southern Florida. *Wetlands*, 20:194-199.

Martin, H.W., D.B. Ivanoff, D.A. Graetz and K.R. Reddy. 1996. Water Table Effects on Histosol Drainage Water Carbon, Nitrogen, and Phosphorus. *Journal of Environmental Quality*, 6:1062-1071.

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 Systems, Inc., Gainesville, FL for the South Florida Water Management District, West Palm Beach, FL.

Piccone, T., H. Zhao, D. Ivanoff, S. Miao, K. Grace and T. DeBusk. 2012. Chapter 5: Performance and Optimization of the Everglades Stormwater Treatment Areas. STA-3/4 Periphyton-Based Stormwater Treatment Area Project section. In: *2013 South Florida Environmental Report – Volume I*, South Florida Water Management District, West Palm Beach, FL.

Piccone, T., J. McBryan, H. Zhao and Y. Yan. 2013. 2012 Updated Everglades Stormwater Treatment Area Ground Elevations, Stage-Area/Stage-Volume Relationships and Effective Treatment Areas, May 2013 Revision. Technical Publication ASB-WQTT-12-02. South Florida Water Management District, West Palm Beach, FL. 50 pp.

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.

SFWMD. 2008. South Florida Water Management District Everglades Construction Project (ECP) Stormwater Treatment Areas (STAs) Drought Contingency Recommendations and Considerations. South Florida Water Management District, West Palm Beach, FL.

Swift, D.R.1981. Preliminary Investigations of Periphyton and Water Quality Relationships in the Everglades Water Conservation Areas. Tech. Publication 81-5, South Florida Water Management District, West Palm Beach, 83 pp.

Taylor Engineering. 2007. Dredging Feasibility Evaluation of Everglades Agricultural Areas Stormwater Treatment Areas 1, 2, & 5 and Inflow Canals Palm Beach and Hendry Counties, Florida. Prepared for the South Florida Water Management District, SFWMD Contract No. CN040896-W0#04, as sub-consultant to Civil Services, Inc. April 2007.

Vymazal, J. and C.J. Richardson. 1995. Species composition, biomass, and nutrient content of periphyton in the Florida Everglades. *Journal of Phycology*, 31:343-354.