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

Delia Ivanoff, Kathleen Pietro,
Hongjun Chen and Lawrence Gerry

Contributors: Rupesh Bhomia, Tom DeBusk[1], Michael Chimney,
Stacey Galloway[1], Brian Garrett, Gary Goforth[2], Kevin Grace[1], James Jawitz[3],
Bijaya Kattel, Michelle Kharbanda[1], Neil Larson, ShiLi Miao, William Mitsch[4],
Chung Nguyen[4], Rajendra Paudel[3], Tracey Piccone, Lou Toth, Yao Yan,
Manuel Zamorano, Li Zhang[5] and Hongying Zhao

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 total area of the STAs including infrastructure components is around 65,000 acres, with approximately 45,000 acres of effective treatment area currently operational. An additional 12,000 acres of treatment area have been completed in Compartments B and C. These areas have been created south of Lake Okeechobee to remove excess total phosphorus (TP) from surface waters prior to entering the Everglades Protection Area (EPA) (**Figure 5-1**). Stormwater Treatment Areas 1 East, 1 West, 2, 3/4, 5, and 6 (STA-1E, STA-1W, STA-2, STA-3/4, STA-5*, and STA-6*, respectively) are managed by the South Florida Water Management District (District or SFWMD). This chapter and related appendices (Appendices 5-1 through 5-7 of this volume) summarize the short and long term STA performance analyses, evaluation of conditions relevant to STA performance, facility status, operational challenges, and enhancements during Water Year 2012 (WY2012) (May 1, 2011–April 30, 2012). A detailed analysis of the annual STA performance in terms of permit compliance is reported in Volume III, Appendix 3-1. A summary

---

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

[2] Gary Goforth, Inc., Stuart, FL

[3] University of Florida, Gainesville, FL

[4] Ohio State University, Columbus, OH

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

* Note: In this report, STA-5 and STA-6 are also referred to as STA-5/6, with the completion of construction of Compartment C in mid-2012. The Compartment C build-out will not be operational until permits for this expanded area are issued by the Florida Department of Environmental Protection.]

of individual components identified in the Long-Term Plan for Achieving Water Quality Goals in the Everglades Protection Area (Long-Term Plan) (Burns and McDonnell, 2003) is also covered in this chapter. More information on the STAs is also available at www.sfwmd.gov/sta. Highlights of WY2012 STA performance and optimization are presented below.

- WY2012 outflow concentrations in STA-1W, STA-2, and STA-5 improved compared to values observed in WY2011. In WY2012, the STAs received 712,483 acre-feet (ac-ft) of water and retained 80.7 metric tons of TP. This equates to an 83 percent TP load reduction and a decrease in flow-weighted mean (FWM) TP concentration from 111 to 19 parts per billion [ppb]. STA-1E, STA-1W, STA-2, and STA-3/4 achieved outflow concentrations below 25 ppb; the lowest outflow concentration of 12 ppb was in STA-2. As a result of the dryout and consequent loss in SAV, STA-3/4 outflow TP concentration in WY2012 increased to 19 ppb FWM, slightly higher than the previous year's outflow FWM concentration of 17 ppb. Partial diversion of water from STA-3/4 in July 2011 and restricted operation of the flow-ways between July and August 2011 were necessary to allow for STA-3/4 vegetation to reestablish. STA-5 achieved its lowest concentration over its period of operation of 32 ppb FWM outflow TP. STA-6 was the only STA that did not meet its interim effluent limit; the annual outflow concentration was influenced by an extreme TP spike that occurred once flow resumed in July and August 2011 after approximately eight months of dry conditions.

- The outstanding performance can be attributed to the lower hydraulic and TP loading during WY2011 and WY2012 compared to previous water years, effective operational management, and continued enhancements in various areas of the STAs. Further details on STA conditions, operational status, management activities, and enhancements are discussed within this chapter.

- STA-1E operation continued to be impacted by structural and elevation issues, vegetation impacts, and Eastern Flow-way (former Periphyton Stormwater Treatment Area) restriction. Repairs of major structures, led by the U.S. Army Corps of Engineers (USACE), also continued in STA-1E, including S-367B, S-375, S-370C, S-373B, and S-374A. Flow to the Western Flow-way has also been restricted. The District implemented multiple vegetation enhancements and trials to maintain treatment until long-term repairs are completed by the USACE. These enhancements and trials are discussed in the *STA-1E* section of this chapter.

- Vegetation enhancements continued in other STAs, including vegetation conversion in STA-3/4 and STA-2, extensive bulrush (*Scirpus acutus*) planting in areas that are too deep for cattail (*Typha* spp.) to thrive and in areas where short-circuiting is visible. In STA-3/4, Cell 1A water level was drawn down to encourage cattail reestablishment; vegetation in this area has been impacted by chronic deep water conditions. Details of the evaluation of the drawdown are included in the *Applied Science* section of this chapter.

- Many of the STA cells were adversely affected by the regional drought in WY2012. Approximately 33,000 ac-ft of water from Lake Okeechobee was delivered during the water year to hydrate priority cells in the STAs. However, due to high evapotranspiration rates, seepage loss, and delayed start of the wet season, some of the cells dried out in the early and later part of the water year. The worst impacts were observed in STA-3/4 and STA-6, where the entire STA dried out and consequently resulted in short-term TP spikes at the outflow. The SAV in STA-3/4 continues to recover and vegetation monitoring is planned to continue in WY2013. The dry condition resulted in new cattail recruitment and expansion, particularly in the open areas of Cell 1A and 2A. Further information on the drought-related impacts is included in individual STA sections of this chapter.

- Construction of STA Compartments B and C continued in WY2012 and is scheduled to be complete in August 2012. Vegetation start-up for these areas, which were flow-capable in December 2010, continued in WY2012. While the District has not been issued permits to operate Compartments B and C, assessment of environmental conditions (soil, vegetation, and water quality) have been initiated.
- Avian protection surveys, specifically for black-necked stilt (*Himantopus mexicanus*) nesting, were conducted during the calendar year 2011 and 2012 (CY2011 and CY2012) nesting seasons, as required under the Avian Protection Plan. Utilizing the survey results, operational priorities were adjusted, specifically affecting STA-1E, in early WY2012. CY2011 and CY2012 surveys are summarized in Appendix 5-4; impacts to STA operations are included under each STA section in this chapter.

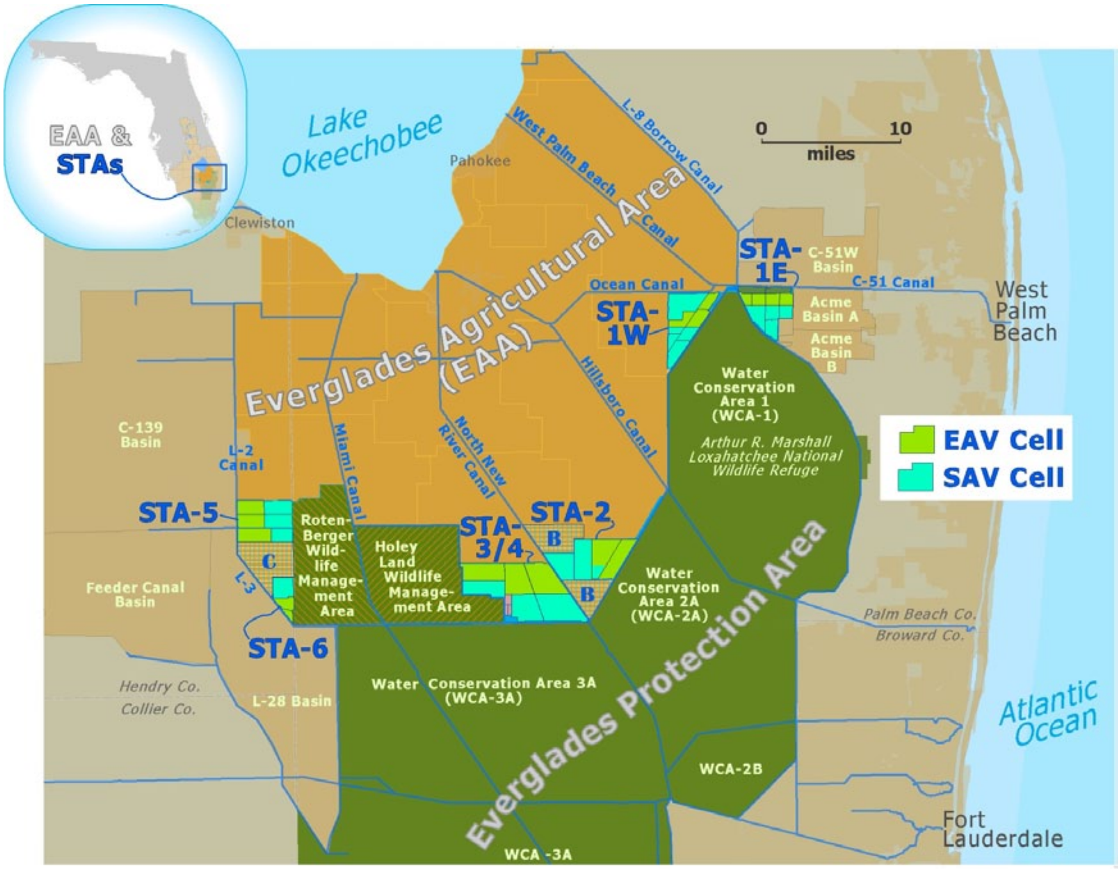


Figure 5-1. Location of the Everglades Stormwater Treatment Areas (STAs) 1 East (1E), 1 West (1W), 2, 3/4, 5, and 6 in relation to the Everglades Protection Area (EPA), their dominant vegetation community [emergent vegetation (EAV) or submerged aquatic vegetation (SAV)], and major basins south of Lake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

INTRODUCTION

As a major component of Everglades restoration, the Everglades Construction Project Stormwater Treatment Areas (STAs) were built and operated to remove excess total phosphorus (TP) from surface waters prior to those waters entering the Everglades Protection Area (EPA). STAs are constructed wetlands that retain nutrients through several mechanisms including plant nutrient uptake and litter decay, settling and sorption, sedimentation, and microbial activities. This chapter describes the performance and condition of the Everglades STAs (STA-1E, STA-1W, STA-2, STA-3/4, STA-5, and STA-6, respectively), the highlights, and operational challenges as they relate to the treatment performance and capabilities of the STAs and individual flow-ways (**Figure 5-1**). The South Florida Water Management District (District or SFWMD) manages these 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 period of operation, the STAs are shallow freshwater marshes divided into treatment cells by interior levees (**Figure 5-2**). Water flows through these systems via water control structures, such as pump stations, gates, or culverts. The dominant plant communities in the treatment cells are broadly classified as (1) emergent aquatic vegetation (EAV), (2) submerged aquatic vegetation (SAV), and (3) floating aquatic vegetation (FAV). Some cells have a mixture of these vegetation types, particularly cells that are presently undergoing vegetation conversion from emergent to SAV. Periphyton communities are interspersed among this vegetation, where conditions are favorable.

Treatment performance, which varies temporally and among STAs, depends on several factors including (1) antecedent land use, (2) nutrient and hydraulic loading, (3) vegetation condition, (4) soil type, (5) cell topography, (6) cell size and shape, (7) hydrologic pattern (continuously flooded versus periodic dryout), (8) maintenance and enhancement activities, and (9) regional operations. District staff uses an adaptive approach in managing the STAs using weekly data and information, including examination of stage levels, outflow TP concentrations, hydraulic and TP loading, vegetation condition, and any wildlife restriction issues.

This chapter includes an assessment of each STA and individual flow-way performance, information on STA operational status and conditions information on maintenance activities and enhancements, applied scientific studies relevant to the STAs, recreational facilities and activities, and implementation of the Long-Term Plan for Achieving Water Quality Goals in the Everglades Protection Area (Long-Term Plan).

OVERVIEW OF WATER YEAR 2012 STA PERFORMANCE

Overall, the STAs performed well in WY2012 in terms of outflow concentrations and TP load removal (**Table 5-1**). During the water year, the STAs received a total of 712,483 acre-feet (ac-ft) of inflow and retained 80.7 metric tons (mt) of TP. This equates to an average of 83 percent TP load reduction and a decrease in flow-weighted mean (FWM) TP concentration from 111 to 19 parts per billion (ppb). STA-1E, STA-1W, STA-2, and STA-3/4 achieved outflow concentrations below 25 ppb, with the lowest outflow concentration in STA-2 (12 ppb). Despite almost a month-long dryout of all cells which resulted in vegetation loss, STA-3/4 maintained good long-term performance with an outflow TP FWM concentration of19 ppb. The performance of STA-5 continued to improve, achieving the lowest concentration for its period of record (32 ppb). Due to an extended period of dryout and resulting TP spike after resumption of flow, STA-6 outflow concentrations were the highest in its operational history (75 ppb). Details about the condition and operational issues related to observed performance are included under each individual STA section in this chapter.

While the WY2012 annual inflow TP concentration remained comparable to average levels observed over the period of record (POR) for each STA, the mean outflow concentration for all STAs was among the lowest since 1995 (**Figure 5-3**). This can be attributed to factors such as a reduction in inflow TP load compared to WY2002–WY2010 time period, improved STA management, including strategic flow distribution and supplemental water deliveries to keep priority cells hydrated even during drought periods, and various vegetation and physical enhancements over the years. The performance summarized above was achieved despite the fact that several of the flow-ways were off-line or under restricted operation during the water year (**Figure 5-4**). Details about the off-line status or restricted operation are included under the individual STA sections within this chapter.

An analysis of the POR data indicates that at very low outflow concentrations (≤20 ppb), there is no definitive relationship between outflow TP concentration and key operational factors, i.e., inflow concentration, phosphorus loading rate (PLR), or hydraulic residence time (HRT) (**Figure 5-5**). Data shows that there were cells that received inflow concentrations of 50-150 ppb that still produced outflow TP concentrations of ≤20 ppb or less. Correspondingly, there were cells that received loading rates higher than 1 g/m^2/yr that resulted in outflow concentrations of ≤20 ppb or less. This is consistent with previous findings reported in the 2012 SFER – Volume I, Chapter 5, and suggests that other factors may influence an individual treatment cell's ability to produce low outflow TP concentrations (Ivanoff et. al., 2012). Additional data analysis and research studies (e.g., the STA-3/4 Periphyton STA Project) will provide a better understanding of these factors and processes.

Table 5-1. STA performance for Water Year 2012 (WY2012) (May 1, 2011–April 30, 2012) and the period of record (POR) 1994–2012[a].

	STA-1E	**STA-1W**	**STA-2**	**STA-3/4[b]**	**STA-5**	**STA-6**	**All STAs**
Effective Treatment Area (acres)	5,132	6,670	8,240	16,543	6,095	2,257	44,937
Adjusted Effective Treatment Area (acres)[c]	5,099	6,670	6,338	16,543	6,095	836	41,581
Inflow							
Total Inflow Volume (ac-ft)	85,692	96,847	195,651	269,737	47,500	17,055	712,483
Total Inflow TP Load (mt)	11.533	17.121	20.984	36.327	9.159	2.585	97.709
Inflow TP FWMC (ppb)	109	143	87	109	156	123	111
Hydraulic Loading Rate (HLR) (cm/d)	1.40	1.21	2.58	1.36	0.65	1.70	1.43
TP Loading Rate (PLR) ($g/m^2/yr$)	0.56	0.63	0.82	0.54	0.37	0.76	0.58
Outflow							
Total Outflow Volume (ac-ft)	76,208	94,011	217,570	291,838	41,779	9,061	730,468
Total Outflow TP Load (mt)	2.010	2.598	3.278	6.668	1.659	0.833	17.047
Outflow TP FWMC (ppb)	21	22	12	19	32	75	19
Hydraulic Residence Time (d)	15	41	19	31	46	3	
TP Retained (mt)	9.523	14.523	17.706	29.658	7.500	1.753	80.662
TP Removal Rate ($g/m^2/yr$)	0.46	0.54	0.69	0.44	0.30	0.52	0.48
Load Reduction (%)	83%	85%	84%	82%	82%	68%	83%
Period of Record Performance							
Start date	Sep-04	Oct-93	Jun-99	Oct-03	Oct-99	Oct-97	***1994 - 2012***
Inflow Volume (ac-ft)	636,213	3,256,934	2,764,199	3,719,561	1,226,472	687,759	12,291,137
Inflow TP FWMC to Date (ppb)	176	171	102	114	225	100	140
TP Retained to Date (mt)	93.891	479.820	268.581	441.474	211.892	65.317	1,561
Outflow TP FWMC to Date (ppb)	57	51	22	18	93	34	37

[a] Data presented reflects changes in flow and TP data in DBHYDRO during WY2012; values maybe different from what were reported in prior SFERs.

[b] Excludes G-388 outflow data.

[c] Adjusted effective treatment areas excludes specific area where and time period when cells are temporarily off-line for plant rehabilitation, infrastructure repairs, or Long-Term Plan enhancements.

FWMC=flow-weighted mean concentration

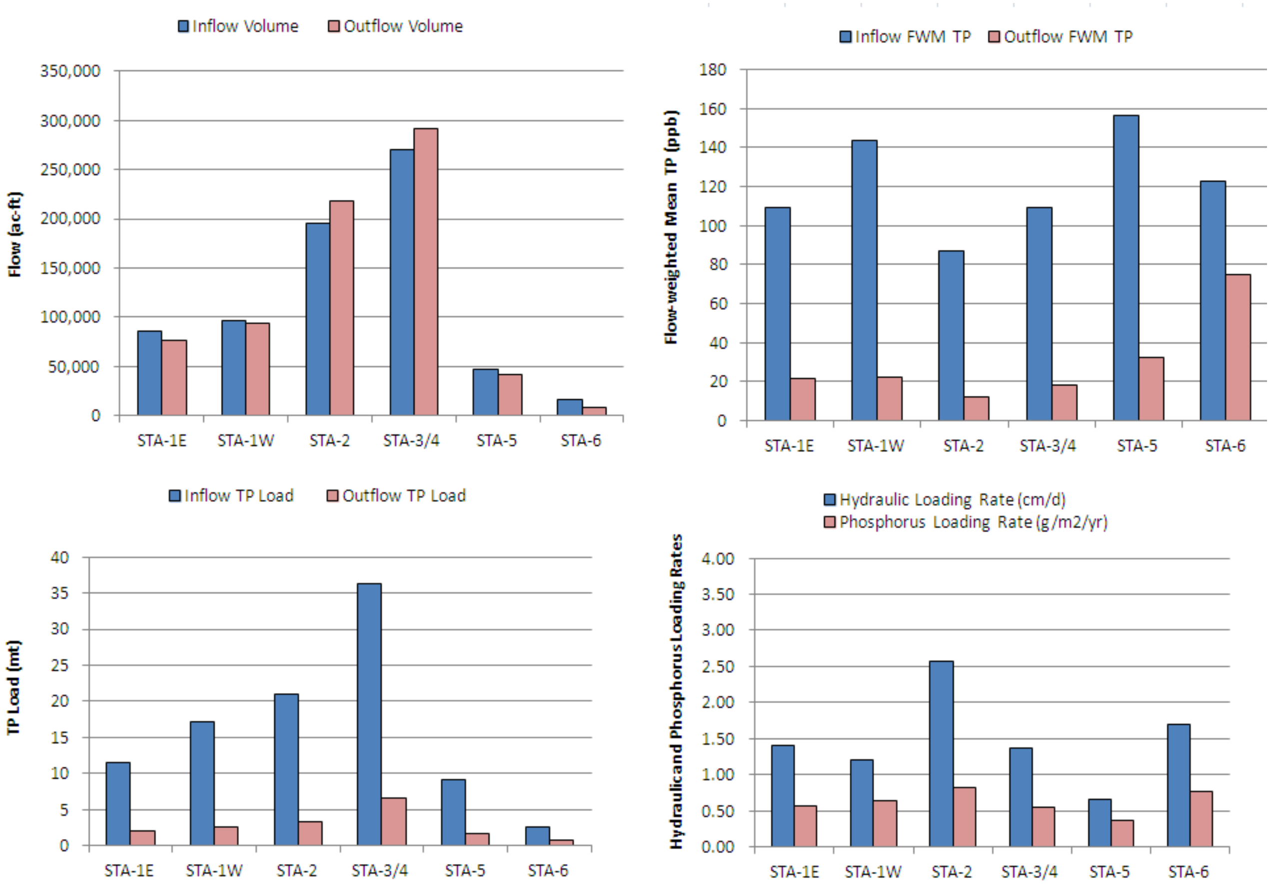
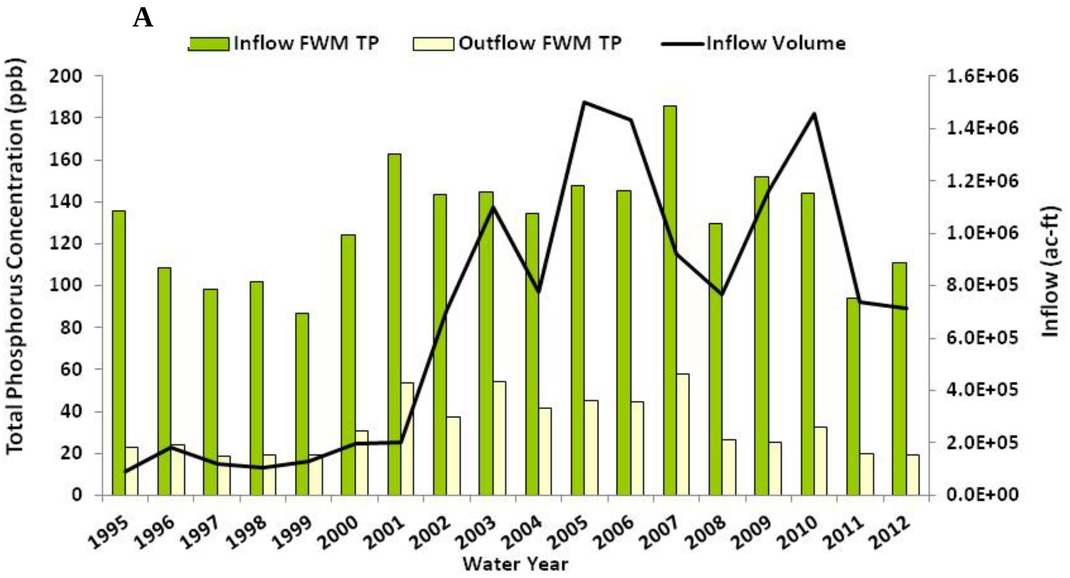


Figure 5-2. WY2012 hydraulic and phosphorus loading rates and total phosphorus (TP) concentrations in the STAs.



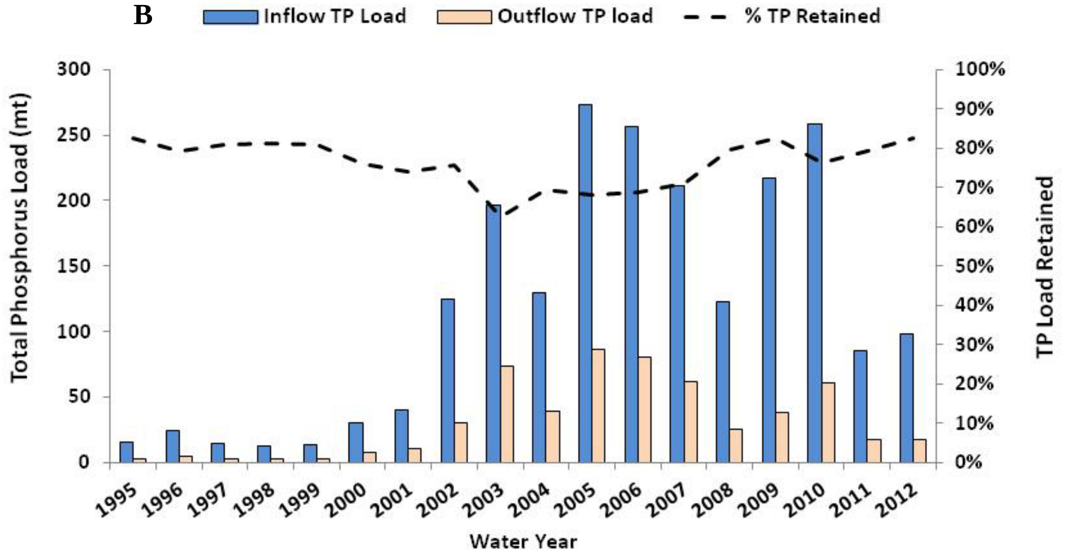
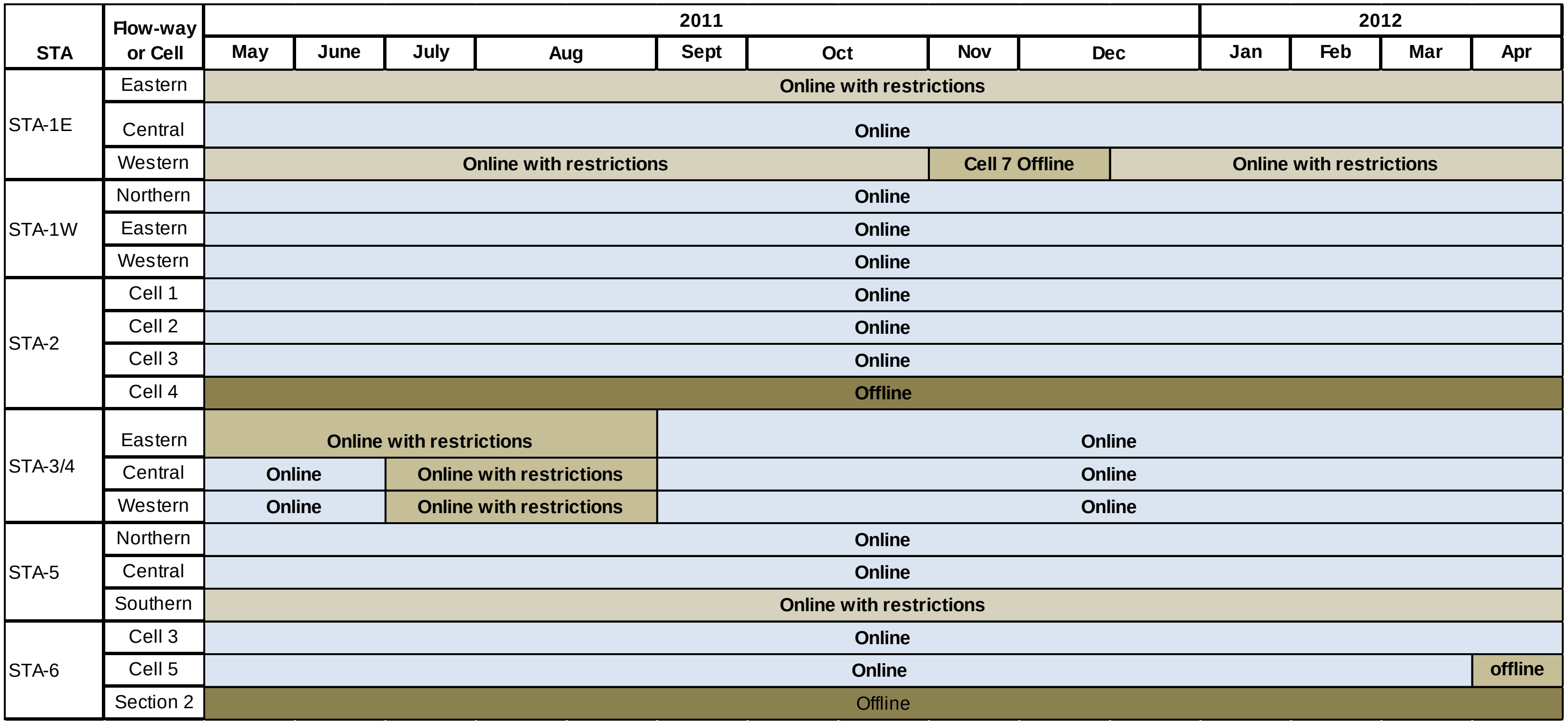


Figure 5-3. Annual inflow and outflow TP flow-weighted mean (FWM) concentrations and inflow volumes (A), and overall annual inflow and outflow TP loads and percent TP load retained by all the STAs (B) by water year (May 1–April 30) since 1995.



<table>
<tr><th rowspan="2">STA</th><th rowspan="2">Flow-way or Cell</th><th colspan="10">2011</th><th colspan="4">2012</th></tr>
<tr><th>May</th><th>June</th><th>July</th><th colspan="2">Aug</th><th>Sept</th><th>Oct</th><th>Nov</th><th colspan="2">Dec</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th></tr>
<tr><td rowspan="3">STA-1E</td><td>Eastern</td><td colspan="14">Online with restrictions</td></tr>
<tr><td>Central</td><td colspan="14">Online</td></tr>
<tr><td>Western</td><td colspan="7">Online with restrictions</td><td colspan="2">Cell 7 Offline</td><td colspan="5">Online with restrictions</td></tr>
<tr><td rowspan="3">STA-1W</td><td>Northern</td><td colspan="14">Online</td></tr>
<tr><td>Eastern</td><td colspan="14">Online</td></tr>
<tr><td>Western</td><td colspan="14">Online</td></tr>
<tr><td rowspan="4">STA-2</td><td>Cell 1</td><td colspan="14">Online</td></tr>
<tr><td>Cell 2</td><td colspan="14">Online</td></tr>
<tr><td>Cell 3</td><td colspan="14">Online</td></tr>
<tr><td>Cell 4</td><td colspan="14">Offline</td></tr>
<tr><td rowspan="3">STA-3/4</td><td>Eastern</td><td colspan="5">Online with restrictions</td><td colspan="9">Online</td></tr>
<tr><td>Central</td><td colspan="2">Online</td><td colspan="3">Online with restrictions</td><td colspan="9">Online</td></tr>
<tr><td>Western</td><td colspan="2">Online</td><td colspan="3">Online with restrictions</td><td colspan="9">Online</td></tr>
<tr><td rowspan="3">STA-5</td><td>Northern</td><td colspan="14">Online</td></tr>
<tr><td>Central</td><td colspan="14">Online</td></tr>
<tr><td>Southern</td><td colspan="14">Online with restrictions</td></tr>
<tr><td rowspan="3">STA-6</td><td>Cell 3</td><td colspan="14">Online</td></tr>
<tr><td>Cell 5</td><td colspan="13">Online</td><td>offline</td></tr>
<tr><td>Section 2</td><td colspan="14">Offline</td></tr>
</table>

Figure 5-4. STA operational status during WY2012. [Note: STA-1E Cell 7 was off-line from November 29–December 19, 2011, for vegetation enhancement. STA-3/4 Eastern Flow-way was online with restrictions from May 1–August 23, 2011, for vegetation rehabilitation in Cell 1A; STA-3-4 Western and Central flow-ways were also online with restrictions from July 5–August 23, 2011 for vegetation reestablishment after an extended dryout period. STA-6 was off-line from April 1, 2012 to August 2012 for redundant levee removal.

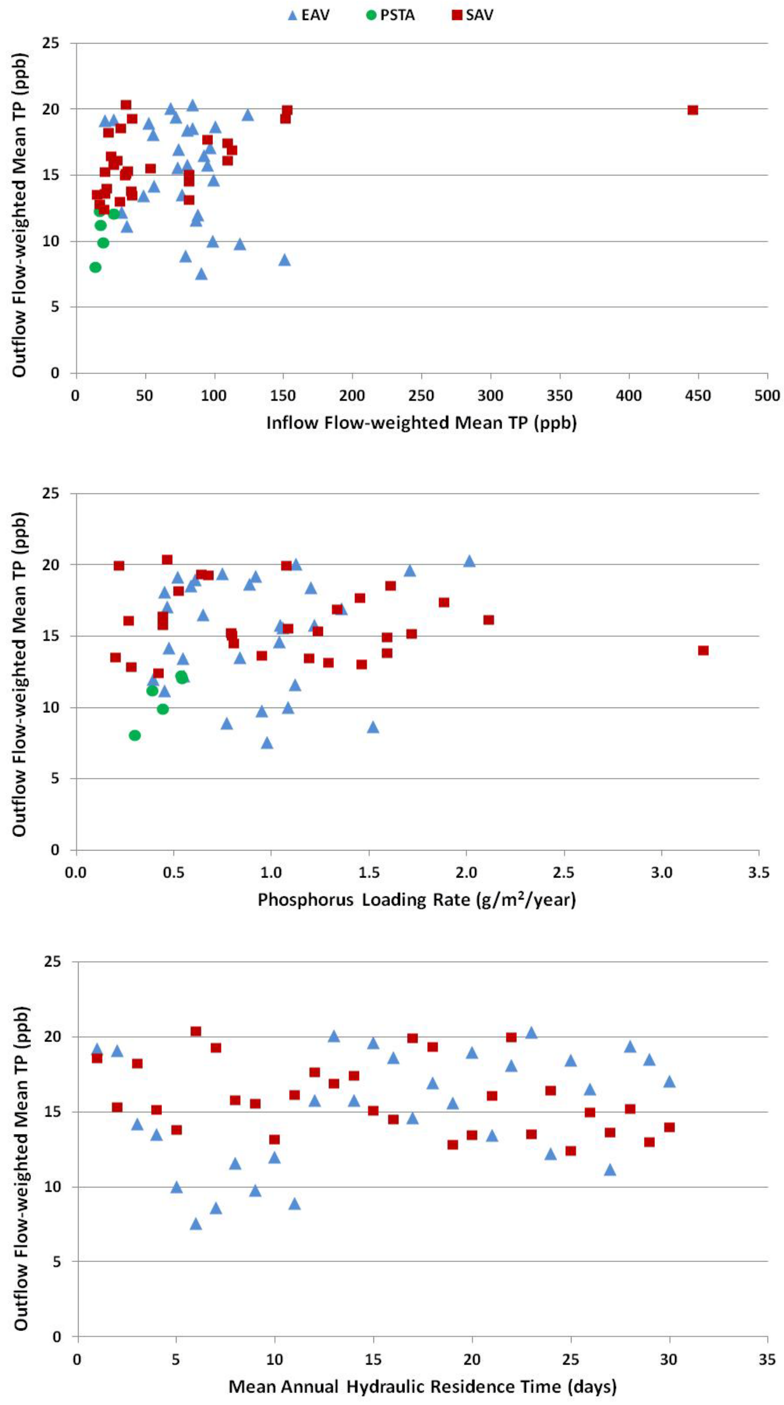
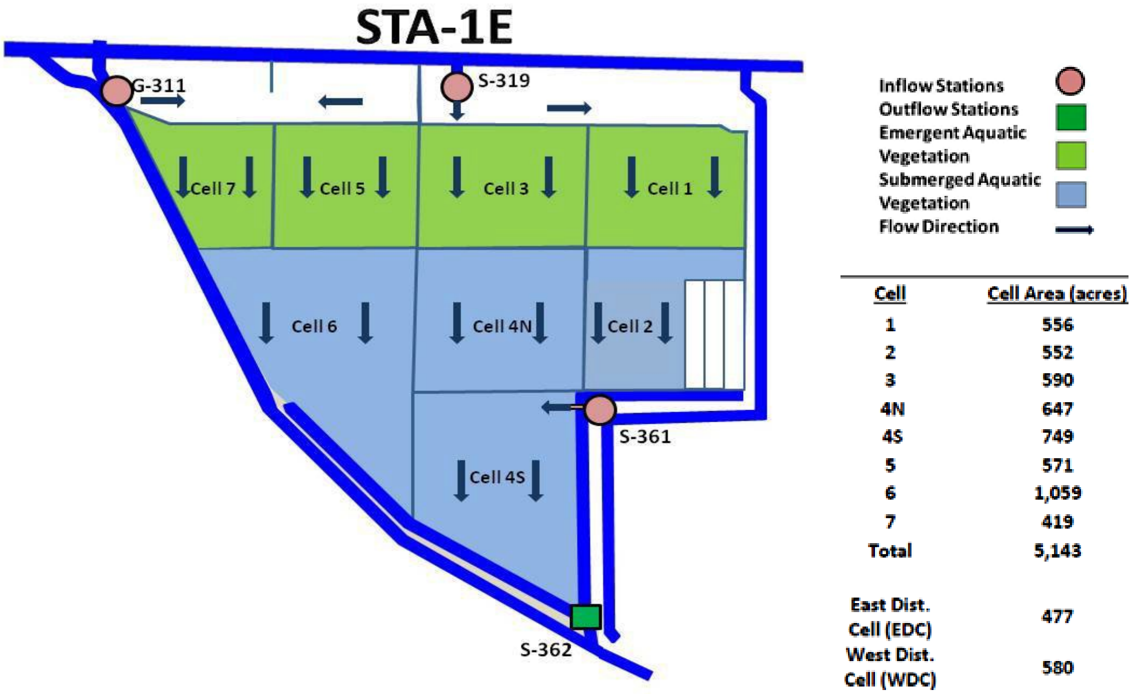


Figure 5-5. Relationship between inflow and outflow TP concentrations versus inflow TP concentrations, TP loading rate, and hydraulic residence time in cells that achieved 20 parts per billion (ppb) or less for all STAs since 1995.

STA-1E

Stormwater Treatment Area 1 East (STA-1E) is located northeast of the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge) and was first operated in WY2005 (**Figure 5-1**). The STA, which is comprised of the Eastern, Central, and Western Flow-ways, consists of approximately 5,200 acres (**Figure 5-5**). The Eastern Flow-way was off-line until WY2008, then was online with restrictions through WY2012 due to limitation of the Periphyton Stormwater Treatment (PSTA) Demonstration Project. This STA receives inflow primarily from the C-51 West basin through the S-319 pump station and from the S-5A basin through the G-311 structure. In WY2008, STA-1E started receiving inflows from a new source (runoff from Wellington Acme Basin B). During dry months, supplemental water is delivered from Lake Okeechobee to maintain hydration of priority cells.

Several issues have adversely affected STA-1E condition, operation, and performance, including high hydraulic loading during storm events (particularly in 2006), structural failures, topographic issues (particularly in Cells 5 and 7), dryout of some cells during drought periods and vegetation die off (e.g., Cell 7 cattail vegetation decline over time, and Cell 6 hydrilla die off in WY2010). Through WY2012, STA-1E treated over 600,000 ac-ft of water and retained approximately 94 metric tons of TP. The POR inflow FWM TP concentration is 176 ppb, while the POR outflow concentration is 57 ppb (**Table 5-1**).



Cell	Cell Area (acres)
1	556
2	552
3	590
4N	647
4S	749
5	571
6	1,059
7	419
Total	5,143
East Dist. Cell (EDC)	477
West Dist. Cell (WDC)	580

Figure 5-5. Simplified schematic of STA-1E showing major inflow and outflow structures, flow directions, and dominant/target vegetation types. [Note: A more detailed schematic is included in Appendix 5-1.]

STA PERFORMANCE

Despite some structural and vegetation issues, STA-1E performance was strong during WY2012, with a FWM TP outflow concentration of 21 ppb and TP load retention of 83 percent of inflow load. It is important to note that operational adjustments were necessary (see the *Facility Status and Operational Condition* section of this chapter), and that the outflow concentration was also influenced by seepage coming from the Refuge. The 12-month moving average plot for STA-1E shows a dramatic improvement since WY2011, as this STA recovered from the strong influence of TP spikes that occurred between May–June 2009 (hydrilla die off) and toward the end of WY2010 (**Figure 5-6**). The outflow FWM TP concentration continued to improve as vegetation in Cell 6 began to recover and while flow through the Western Flow-way was restricted toward the end of WY2011 and early WY2012.

Dramatic improvements in the outflow concentrations of the Central and Western flow-ways occurred between WY2011 and WY2012 (**Table 5-2**). The most notable improvement was in the Western Flow-way, where outflow concentrations dropped from 165 to 36.4 ppb. Operation of this flow-way was restricted part of the year, and the hydraulic loading rate (HLR) was limited to 0.8 cm/day; total inflow volume was 19,433 ac-ft. The Central Flow-way outflow concentration also decreased from 44.7 ppb in WY2011 to 18.2 ppb in WY2012 despite the fact that the HLR for the Central Flow-way (2.3 cm/day) was about eight times greater than for the Western Flow-way (0.8 cm/day).

Table 5-2. Comparison of flow-way performance in STA-1E between WY2011 and WY2012.

Flow-way/WY	Area (acres)	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	1,986							
WY2011		0.1	0.3	6,857	120	44.7	0.4	42
WY2012		0.9	2.3	54,384	112	18.2	6.3	84
Western Flow-way	2,038							
WY2011		0.0	0.1	1,389	77	165	0.0	25
WY2012		0.4	0.8	19,422	125	36.4	2.1	70

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

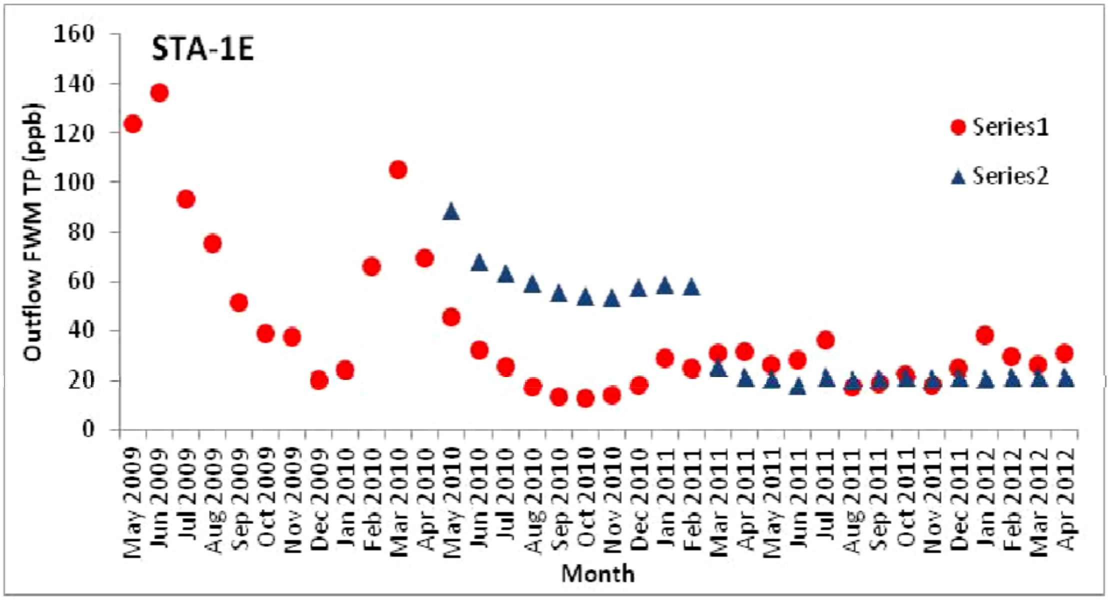


Figure 5-6. Monthly FWM TP phosphorus concentration and 12-month moving average TP concentration in STA-1E.

FACILITY STATUS AND OPERATIONAL ISSUES

The Eastern Flow-way of STA-1E remained online with restrictions in WY2012 due to structural constraints caused by USACE PSTA Demonstration Project in Cell 2 (**Figure 5-7**). As a result, Cells 1 and 2 were dry for the most part of the water year. The USACE PSTA Demonstration Project is scheduled to be deconstructed in November 2012, which will require that Cell 2 be completely dry no later than September 2012. In the interim, approximately 500 linear feet of an earthen berm separating the upper SAV and the PSTA cell, was degraded to allow for more flow through the flow-way (**Figure 5-8**).

The Central Flow-way remained fully operational during the water year. Target stages at this flow-way were raised by six inches above the normal target stage of 1.25 feet during the WY2012 dry season as a drought contingency measure. The Western Flow-way, which had been off-line due to structural failures, vegetation decline, and TP uptake performance issues, was online with restrictions for several months during the water year. It was off-line briefly from November 29–December 19, 2011, for vegetation enhancements in Cell 7. Because the Western Flow-way was off-line, the adjusted effective treatment area acreage was reduced to reflect the acreage that was operational (**Table 5-1**). Due to concerns about the condition and performance of Cells 6 and 7 in early WY2012 wet season, temporary pumps were installed to route water from Cell 6 to Cell 4N and 4S. The USACE continued to perform repairs of the Western and Central flow-ways structures. The repairs required taking one structure in each cell off line for construction which resulted in limiting flow to each cell and flow-way.

As previously noted, structural repairs in STA-1E are under way, including S-367B, S-375, S-370C, S-373B and S-374A. In March 2012, downstream coffer dams were constructed at S-370C, S-373B, and S-374A at the inflows of Cells 5, 6, and 7, respectively, for necessary repairs to these structures. Consequently, these structures have been taken off-line until construction is completed.

Drought Impacts

Despite delivery of supplemental water (approximately 4,111 ac-ft from Lake Okeechobee), drought and the delayed onset of the WY2012 wet season resulted in dryout in Cells 3 and 5; Cells 1 and 2 were already dry from the lack of flow during most of the water year **Figure 5-9**. Dry and low water condition in some areas, particularly Cell 5, resulted in expansion of *Ludwigia* in approximately 60 percent of the cell. This species is not desired in the STAs due to its less efficient role in phosphorus uptake. Upon resumption of flow and with a systematic water management, such as the use of a temporary pump to deliver water from Cell 6 into Cell 4N and restricting flows through the Western flow-way, the outflow concentration began to stabilize in both the Central and Western flow-ways. Due to various issues, such as uneven flow distribution, declining vegetation, and ongoing construction activities, assessment of the effects of WY2012 drought in STA-1E is challenging.

Impacts of Migratory Bird Nesting

Two nesting survey periods occurred during the WY2012 reporting period for all STAs: May–July 2011 and April 1–30, 2012 (Appendix 5-4). Nesting information for the remainder of 2012 (May–July 2012) is also included in Appendix 5-4. A total of 42 black-necked stilt nests were counted from STA-1E levee surveys between April and July 2011, the majority of which were observed in the Eastern Distribution Cell, and up to 9 nests in Cell 4S (May 2011). Necessary adjustments to flow-way prioritization were made weekly during this period, avoiding operation of the Eastern distribution cell and the Central Flow-way during the nesting period, in order to minimize impacts to nests. Toward the end of WY2012, nesting activities were limited, with a total of five nests observed only at Cell 5 (April 2012). There were no noted impacts to operations in April 2012, primarily due to low inflows to the STA.

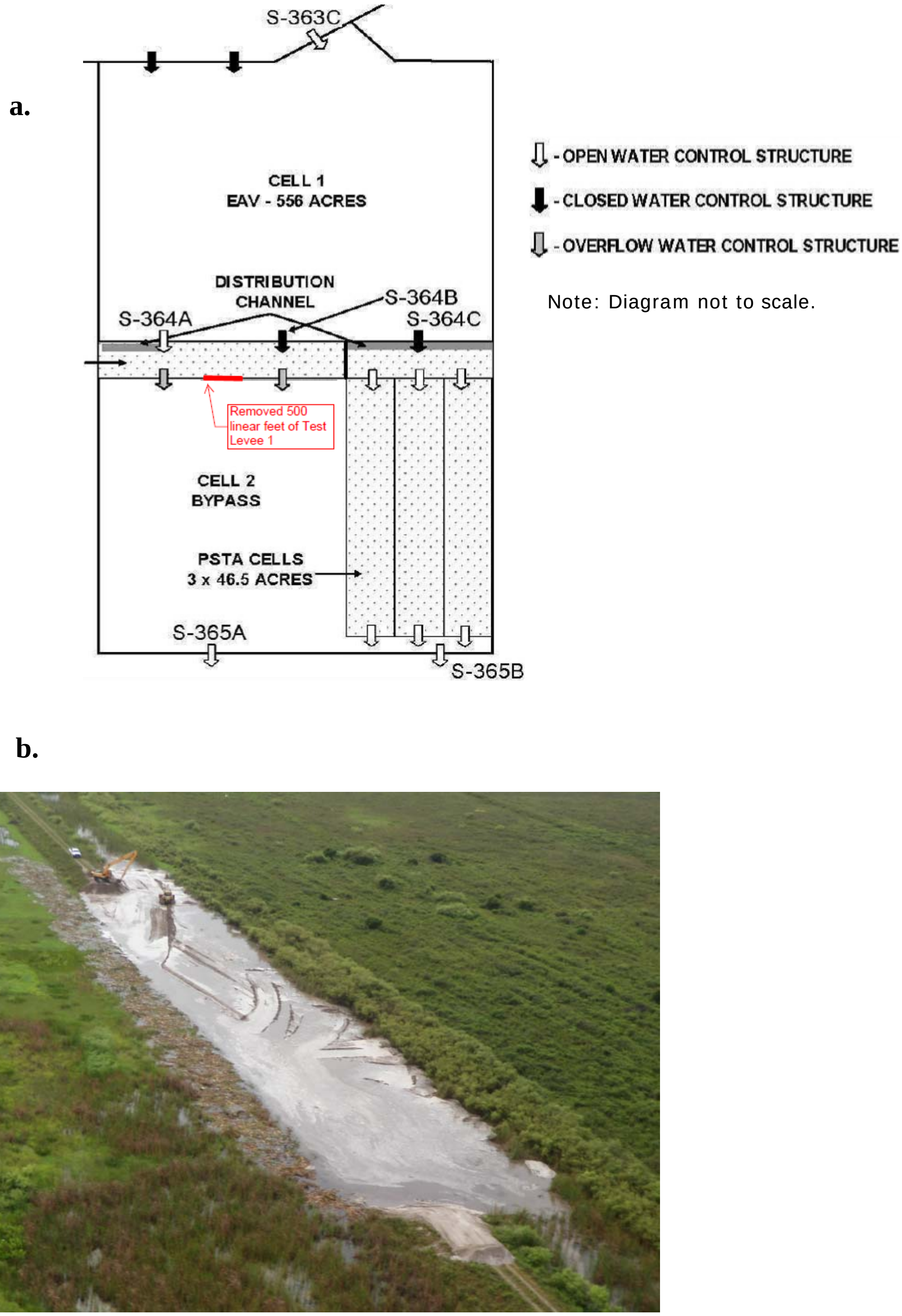


Figure 5-8. Location of degraded berm in STA-1E Cell 2 at the former Periphyton STA Demonstration Project site (a), and photo of the degraded berm (b) (photo by the SFWMD). Approximately 500 linear feet of the berm was degraded as an interim measure to allow for more flow through the Eastern Flow-way of STA-1E.

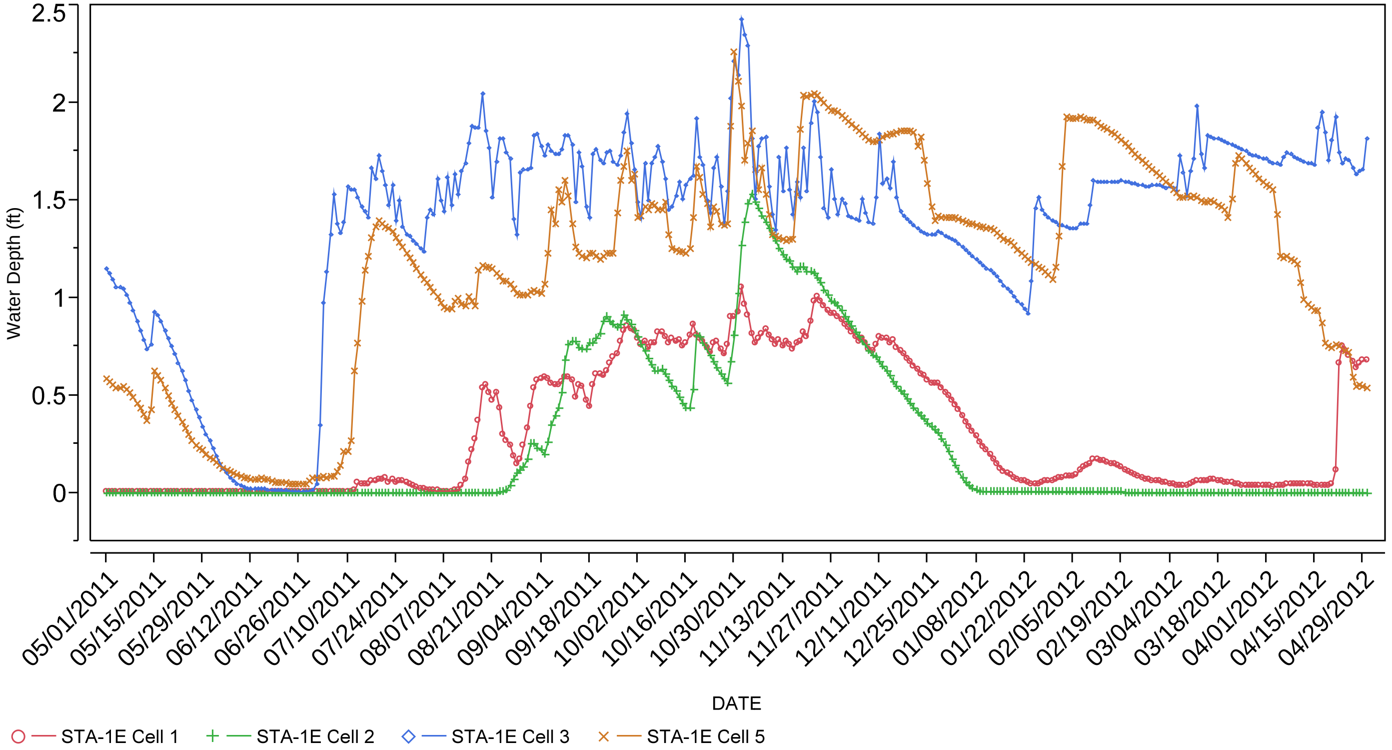


Figure 5-9. Daily average water depths in STA-1E Cells 1, 2, 3, and 5 in WY2012.

MAINTENANCE AND ENHANCEMENTS

Routine vegetation management in STA-1E included control of FAV in inflow distribution canals and in outflow collection canals to provide an even distribution of flow across each cell, and to ensure the efficiency of discharge structures. Within the cells, water lettuce and other floating plants such as water hyacinth and frog's bit were routinely treated to promote growth of submerged beds of aquatic vegetation in SAV cells. Routine maintenance and optimization of emergent cells primarily involved herbicide treatments of willow and primrose willow. A summary of herbicide use in the STAs is included in Volume III, Appendix 3-1, Attachment E.

Due to topographic deficiencies and soil characteristics, cattail cover in Cell 7 of STA 1E has been in steady decline and now exists primarily as floating tussocks. Parallel projects to replace the floating tussocks with more effective water quality treatment processes were initiated in November–December 2011. A mechanical harvester was used to remove 15 acres of floating tussocks in the northwest corner of the cell while another 15 acres of floating tussocks in the south end of the cell were treated with herbicides. In April 2012, giant bulrush was planted throughout the harvested area and the treated area will be similarly planted in May-June 2012. These two projects will allow for comparative analyses of the effectiveness and costs of these measures and their potential utility for implementation in a larger scale.

In Cell 5, shallower water depths, caused by topographic issues and extended dry season, resulted in colonization and spread of primrose willow (*Ludwigia peruviana*), which covers over 60 percent of the cell. Primrose willow is an invasive exotic shrub that forms dense thickets with little or no understory cover and is not a desired species for effective water quality treatment in emergent cells. In November 2012, a pilot project to establish more effective vegetation was implemented in a 60-acre area in the east central portion of the cell. Herbicide treatments were applied to kill the primrose willow, followed by manual cutting in February 2012. While field observations indicate extensive cattail colonization, and recruitment has occurred within the treated area, there are also indications of new primrose willow growth in the pilot area. Unvegetated areas will be planted with giant bulrush in June-July 2012 and additional selective primrose willow treatments will be undertaken in WY2013 when target water stages are achieved. Additional bulrush planting was also done on new emergent vegetation strips in Cells 4S and 6, to further protect SAV from wind action or high flow events.

VEGETATION SURVEYS

Vegetation Coverage Estimates Based on Aerial Imagery

Based on an annual imagery flight, area coverage of EAV and SAV+open area is estimated for each STA (**Table 5-3**; Appendix 5-5). Imagery for CY2011 (conducted in May 2011) is presented in this chapter; a comparison with the previous year (conducted in April 2010) is also included. For STA-1E, data shows that there is little change in terms of vegetation coverage; the biggest changes were observed in Cell 1 and Cell 7, with a 7 percent decrease and a 10 percent increase, respectively. It is important to note that area coverage estimates does not consider vegetation density. In Cell 7, for example, while coverage data indicates a 10 percent increase, visual observations indicate a drastic decline of cattail vegetation density in the past three years. Chronic deep water condition in this cell, due to very low ground elevation compared to surrounding areas, has impacted the cattail community in terms of mortality and formation of floating tussocks (**Figure 5-10**).

Table 5-3. Summary of vegetation coverage in STA-1E.
[Note: Numbers shown are expressed as percentage of total cell area.]

Cover Category	Cell 1	Cell 2	Cell 3	Cell 4N	Cell 4S	Cell 5	Cell 6	Cell 7
% EAV	86	68	79	41	11	89	14	65
% SAV+open area	14	32	21	59	89	11	86	35
% change in EAV cover from 2010 to 2011	-7	N/A	-6	1	0	4	-2	10

N/A=not available; negative numbers indicate a decrease in EAV coverage in 2011.

Figure 5-10. A portion of STA-1E Cell 7 showing vegetation mortality and sparse live cattail density, typical for the entire cell, as a result of chronic deepwater condition in the cell (photo by the SFWMD).

Ground Survey for Submerged Aquatic Vegetation

An SAV ground survey, performed in Cells 4N, 4S, and 6 of STA-1E on May 5, 2011, indicates that *Hydrilla* remains the dominant submerged vegetation in this STA, followed by *Ceratophyllum* (**Figure 5-11**). Although the data indicates improvement in Cell 6 from the previous water year, most of the SAV was observed in the inflow region of the cell, with sparse vegetation in the outflow region. Within both cells of the central flow path (Cells 4N and 4S), *Hydrilla* is also the dominant SAV observed. Some *Najas*, *Chara*, and *Ceratophyllum* were also observed within Cell 4N. Similar to Cell 6, there are areas in both Cells 4N and 4S that are devoid of SAV.

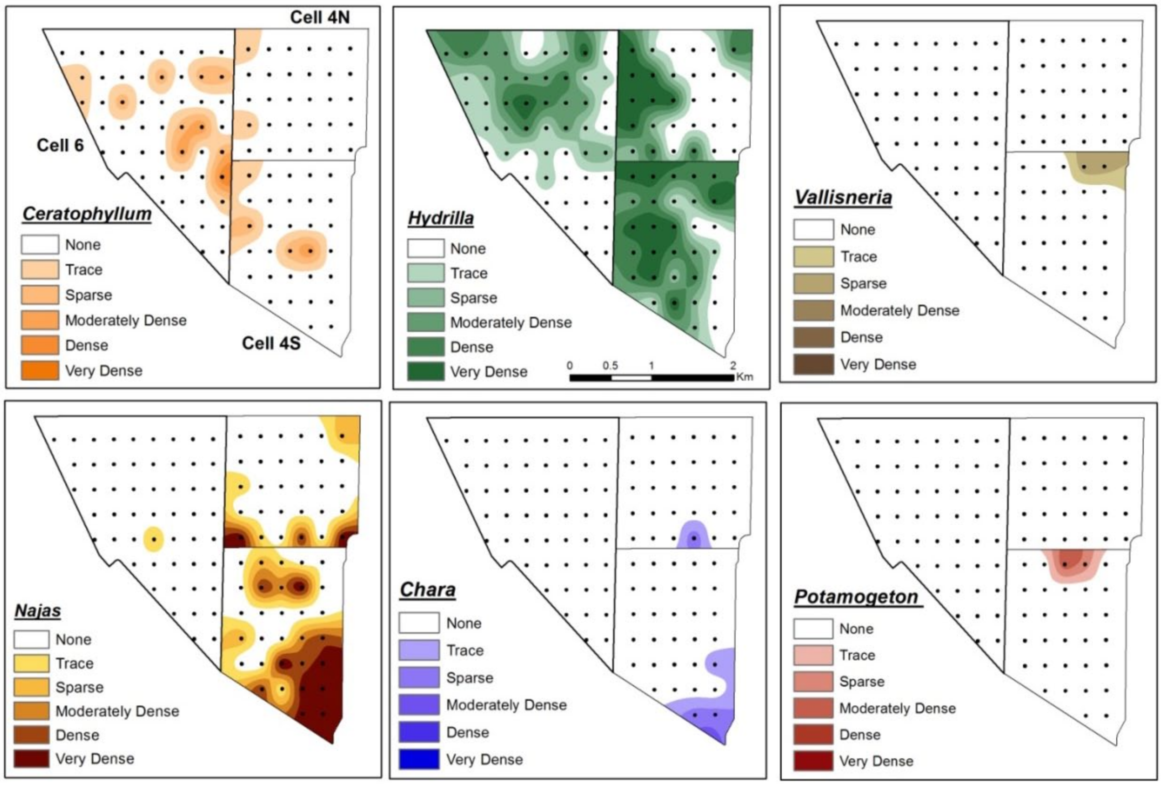


Figure 5-11. Vegetation survey results depicting the spatial coverage of *Chara, Najas, Hydrilla, Ceratophyllum*, *Vallisneria,* and *Potamogeton* in STA-1E Cells 4N, 4S, and 6 on May 5, 2011.

STA-1W

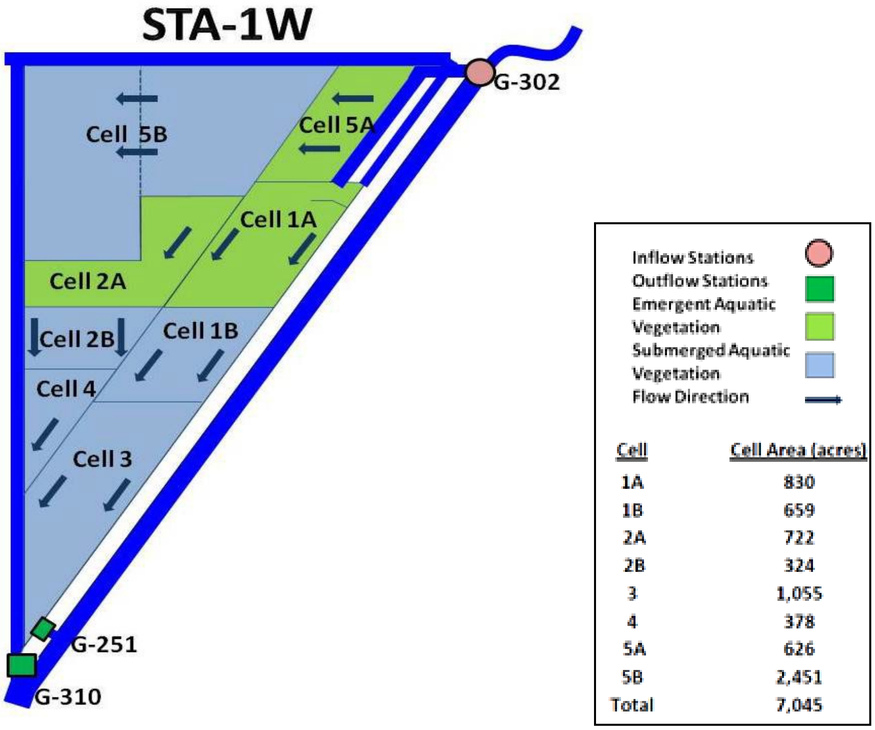
Stormwater Treatment Area 1West, which began operation in 1994 (WY1995), is located northwest of the Arthur R. Marshall Loxahatchee National Wildlife Refuge (**Figure 5-1**). It is comprised of three flow-ways totaling 6,670 acres of effective treatment area: Eastern Flow-way (Cell 1A, Cell 1B, and Cell 3), Western Flow-way (Cell 2A, Cell 2B, and Cell 4), and Northern Flow-way (Cell 5A and Cell 5B) (**Figure 5-12**; Appendix 5-1). The Eastern and Western Flow-ways were formerly known as the Everglades Nutrient Removal Project; the Northern Flow-way was added in 1999 (WY2000). Compartmentalization of the former Cell 1 and former Cell 2 were completed in 2007, creating Cell 1A, Cell 1B, Cell 2A, and Cell 2B. This STA receives its inflow primarily from S-5A drainage basins. During dry months, supplemental water is also delivered from Lake Okeechobee to maintain hydration on priority cells.

Since becoming operational in WY1995 until WY2012, STA-1W has treated over 3.3 million ac-ft of water and retained approximately 480 mt of TP. The POR mean inflow FWM TP concentration is 171 ppb while the POR mean outflow concentration in this STA is 51 ppb (**Table 5-1**). Over its period of operation, STA-1W has been impacted by extreme weather events (regional drought and storm events), construction enhancement activities which included water level drawdown and earthwork, and high hydraulic and nutrient loadings. The condition in STA-1E which resulted in flow-ways being off-line or under restricted operation, as discussed previously, has also impacted the hydraulic and nutrient loadings in STA-1E. A series of major rehabilitation activities were implemented between 2005 and 2007 to improve cell condition and restore the treatment capability of the cells.

STA PERFORMANCE

The performance of STA-1W continues to improve; the STA achieved FWM TP outflow concentration of 22 ppb, which was slightly lower than that in WY2011 (25 ppb), and retained 83 percent of the inflow TP load (**Table 5-1**; **Figure 5-2**). A total of 96,847 ac-ft of inflow was treated, with an annual average inflow FWM TP concentration of 143 ppb. The 12-month moving average plot for STA-1W shows a significantly decreasing trend between since WY2011 and the end of WY2012 (**Figure 5-13**).

At the flow-way level, WY2012 TP outflow concentrations (20, 23, and 19 ppb for the Eastern, Western, and Central flow-ways, respectively) are slightly but consistently lower than WY2011 outflow concentrations (23.6, 25.4, and 20.5, respectively) (**Table 5-4**). The most change in TP load retention was in the Eastern Flow-way, with 79 percent in WY2011 and 85 percent in WY2012; percent TP retention for the Western and Northern flow-ways were 84 percent, which were at similar levels as WY2011. The moderate hydraulic and TP loading, absence of any major activities or weather disturbance to impact STA-1W performance, improved strategies in water management (e.g., better distribution of flows among flow-ways, increasing stages during the dry season, and delivering supplemental water when necessary), and continuing vegetation improvements all contributed to the good performance observed in these flow-ways.



Cell	Cell Area (acres)
1A	830
1B	659
2A	722
2B	324
3	1,055
4	378
5A	626
5B	2,451
Total	7,045

Figure 5-12. Simplified schematic of STA-1W showing major inflow and outflow structures, flow directions, and dominant/target vegetation types. [Note: A more detailed schematic is included in Appendix 5-1.]

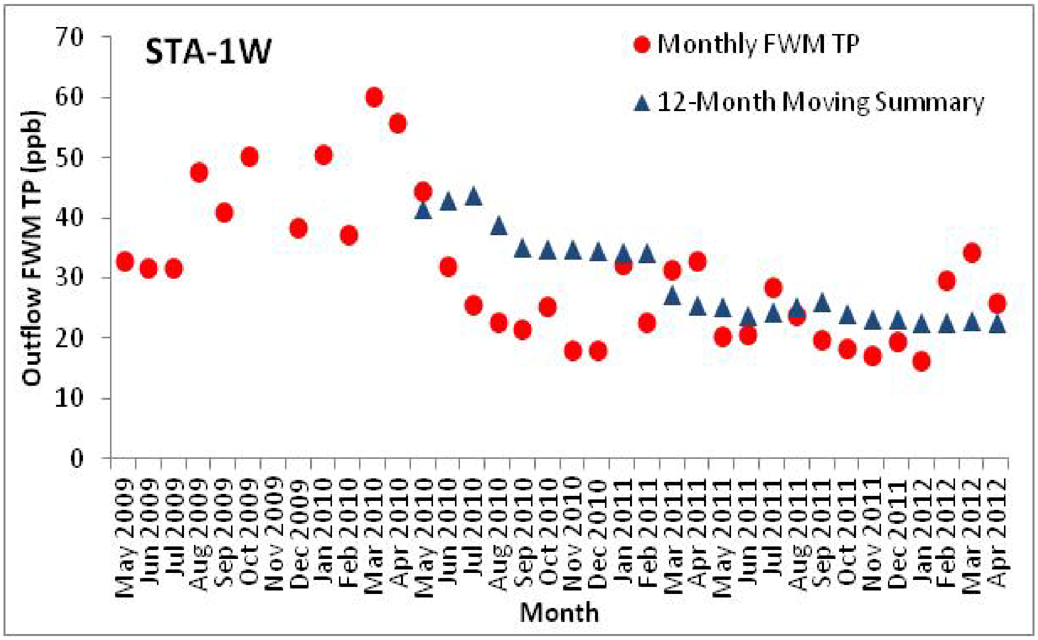


Figure 5-13. Monthly flow-weighted mean TP concentration and 12-month (WY2012) moving average TP concentration in STA-1W.

Table 5-4. Comparison of flow-way performance in STA-1W between WY2011 and WY2012.

Flow-way/WY	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	2516							
WY2011		0.5	1.0	30,896	125	23.6	3.8	79%
WY2012		0.4	0.9	27,485	131	20.3	3.8	85%
Western Flow-way	1299							
WY2011		1.1	2.1	32,590	148	25.4	5.2	87%
WY2012		0.9	2.1	31,964	116	22.6	3.9	84%
Northern Flow-way	2855							
WY2011		1.1	2.0	69,759	148	20.5	10.8	85%
WY2012		0.7	1.2	42,017	152	19.3	6.7	84%

FACILITY STATUS AND OPERATIONAL ISSUES

In WY2012, all flow-ways in STA-1W were operational (**Figure 5-7**).

Drought Impacts

By implementing drought contingency strategies, the WY2012 drought had no observable impact on STA-1W performance or condition. To prepare for the anticipated drought season, water levels were held at the drought contingency stages (6 inches above the normal target stages) during the WY2012 dry season. Also, approximately 3,368 ac-ft of supplemental water from Lake Okeechobee was delivered to STA-1W in WY2012. These combined measures enabled STA-1W to stay hydrated through the drought periods of the water year.

Impacts of Migratory Bird Nesting

Between May–July 2011, there were a total of 105 nests observed from levee surveys in STA-1W, all of which were located in the Western flow-way (Appendix 5-4). Due to a regional drought and lack of flows to the STA, the impact to STA-1W operation was minimal. By the beginning of the wet season in early July 2011, there were no observed active nests. There were also no nests observed in April 2012. Nesting information on the remainder of CY2012 is also included in Appendix 5-4.

MAINTENANCE AND ENHANCEMENTS

In May 2011, additional bulrush planting was conducted in Cell 5A. Some regions of Cell 5A have remained devoid of cattails, likely a result of the chronic deep water condition; however, previously planted bulrush (WY2010) has shown good establishment and continues to expand. Additional bulrush vegetation strips were also created in Cell 5B during October–November 2011 and in March–April 2012, Additional strips are anticipated to provide more protection against strong winds and flows to maintain good SAV establishment. Looking ahead, construction is planned to begin in June 2012 on a new trash rake at G-251. This structure will be off-line while construction is ongoing.

Figure 5-14. New vegetation strip in STA-1W Cell 5B (April 2012). Additional strips are anticipated to provide additional protection to the existing SAV community against strong winds and flows (photo by the SFWMD).

VEGETATION SURVEYS

Vegetation Coverage Estimates Based on Aerial Imagery

Due to the fact that the stages have been maintained at target levels which are optimal to the desired vegetation, EAV coverage has been stable in STA-1W. For most cells, EAV coverage was similar to what was observed in CY2010 (**Table 5-5** and **Appendix 5-5**). The biggest change was in Cell 2A, where EAV coverage declined by approximately 9 percent. This analysis does not take into account vegetation density, which is an equally important parameter to consider when assessing cell condition relevant to nutrient uptake.

Ground Survey for Submerged Aquatic Vegetation

Based on a survey conducted on July 29, 2011, *Chara* was the dominant SAV in Cells 2B and 4 (**Figure 5-15**). Both *Ceratophyllum* and *Najas* were also present along the northern and eastern levees, in regions where *Chara* was less dense. *Chara* was also the dominant SAV present in Cells 1B and 3 based on February 24, 2012 survey (**Figure 5-16**). *Najas* was present in a few areas of Cell 3 and trace amounts of *Ceratophyllum* were observed in the inflow and eastern regions of Cell 1B. Except for the inflow region, *Najas* was the dominant SAV within Cell 5B on April 4, 2012 (**Figure 5-17**). Within the inflow region, some areas were devoid of vegetation and *Ceratophyllum* was observed in others. *Chara* was also observed in the mid-to-outflow region of the cell.

Table 5-5. Summary of vegetation coverage in STA-1W based on May 2011 aerial imagery. Numbers shown are expressed as percentage of total cell area.

Cover Category	Cell 1A	Cell 1B	Cell 2A	Cell 2B	Cell 3	Cell 4	Cell 5A	Cell 5B
% EAV	82	27	86	8	44	16	50	11
% SAV+open area	18	73	14	92	56	84	50	89
% change in EAV cover from 2010 to 2011	2	6	-9	4	-2	-3	-4	0

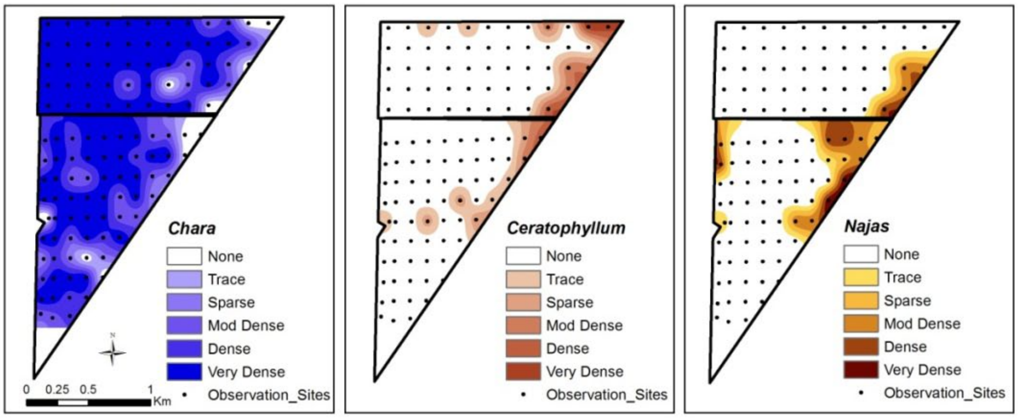


Figure 5-15. Vegetation survey results depicting the spatial coverage of *Chara*, *Najas*, and *Ceratophyllum* in STA-1W Cells 2B and 4 on July 29, 2011.

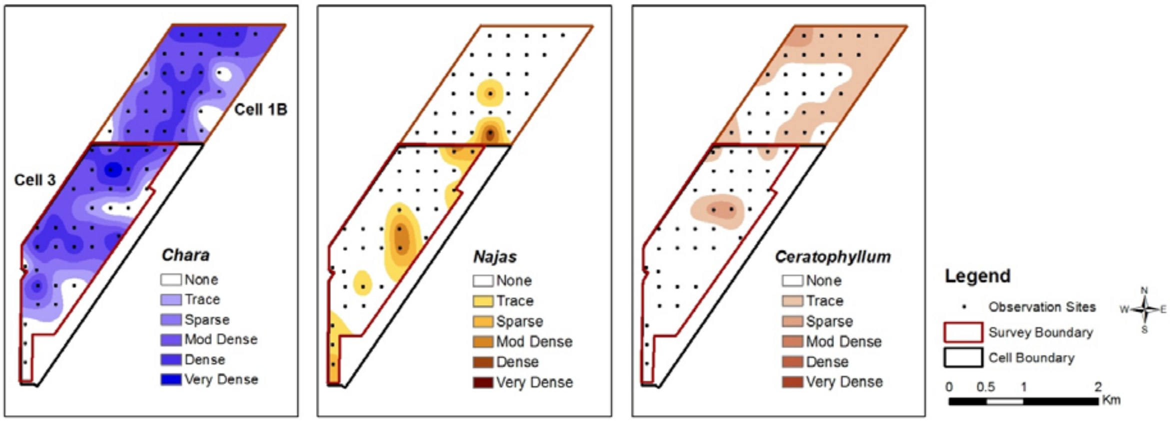


Figure 5-16. Vegetation survey results depicting the spatial coverage of *Chara*, *Najas*, and *Ceratophyllum* in STA-1W Cells 1B and 3 on February 24, 2012.

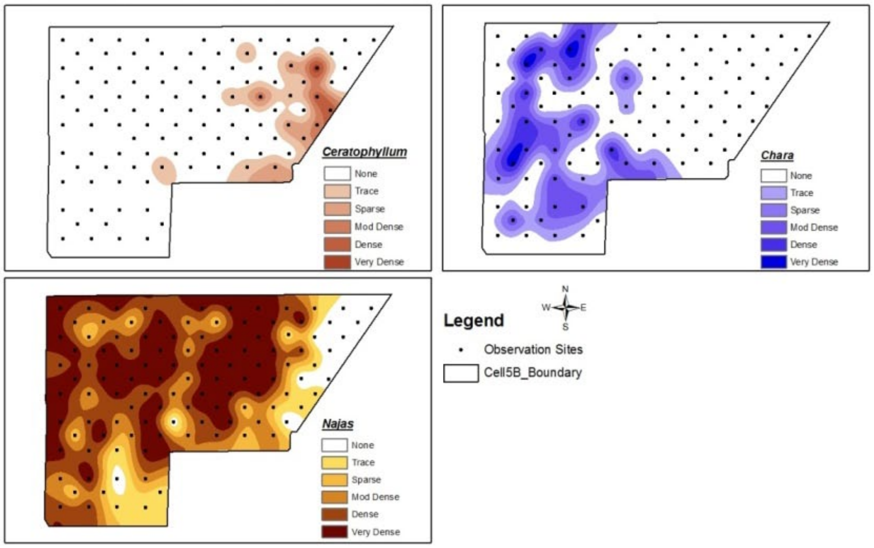


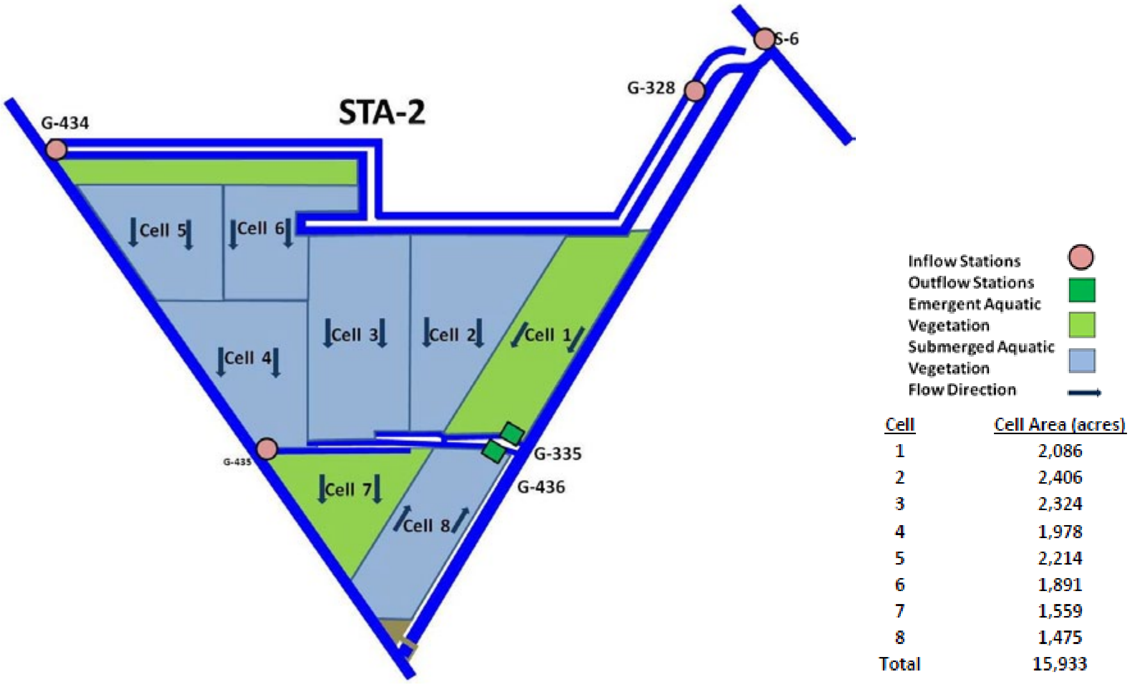
Figure 5-17. Vegetation survey results depicting the spatial coverage of *Chara, Najas,* and *Ceratophyllum* in STA-1W Cell 5B on April 4, 2012.

STA-2

Stormwater Treatment Area 2 (STA-2) is located in western Palm Beach County immediately west of Water Conservation Area 2A (WCA-2A) (**Figure 5-1**). The original STA-2 consisted of three treatment cells (1, 2, & 3) with 6,338 acres of effective treatment area and began operation in 2000. The treatment area was expanded by 1,902 acres with the construction of Cell 4, which was flow capable by December 2006, but this cell went off-line in WY2010 for Compartment B construction. Upon completion of Compartment B construction, adding approximately 6,817 acres of treatment area, STA-2 will have a total of eight treatment cells and five flow-ways, and the total area will be approximately 15,933 acres (**Figure 5-18**).

The primary source of STA-2 inflow water is the Hillsboro canal, which collect flows from a variety of sources, including agricultural runoff and discharges from the S-6/S-2 Basin, a portion of runoff from the S-5A Basin, and runoff from Chapter 298 Drainage Districts (Brown and Caldwell, 2011). During dry months, supplemental water is also delivered from Lake Okeechobee and other sources to maintain hydration on priority cells.

Since WY2000–WY2012, STA-2 has treated over 2.8 million ac-ft of water and retained approximately 269 mt of TP. The POR inflow FWM TP concentration is 102 ppb while the POR outflow concentration in this STA is 22 ppb, which is the second lowest average POR value achieved in the STAs (**Table 5-1**). One attribute of STA-2 that leads to consistently good performance of this STA is that over half of its current operational areas were never farmed prior to becoming a treatment area. Like the other STAs, STA-2 has also been impacted by extreme weather events (regional drought and storm events) over its period of operation. Parts of or the entire area of Cells 1 and 2 have dried out previously during drought periods or extended dry season when supplemental water was limited. The District continuously improves its operational management strategies to minimize impacts of extreme weather events. During both WY2011 and WY2012, methodical water management, including an increase in dry season target stages and delivery of supplemental water from Lake Okeechobee, prevented or minimized the impacts of drought in STA-2. In WY2009, conversion of approximately 300 acres at the southern portion of Cell 2 was initiated in an effort to further improve the performance of this cell.



Cell	Cell Area (acres)
1	2,086
2	2,406
3	2,324
4	1,978
5	2,214
6	1,891
7	1,559
8	1,475
Total	15,933

Figure 5-18. Simplified schematic of STA-2 showing major inflow and outflow structures, flow directions, and dominant/target vegetation types. [Note: A more detailed schematic is included in Appendix 5-1.]

STA PERFORMANCE

In WY2012, STA-2 treated 195,651 ac-ft of inflow and retained approximately 18 mt of TP. STA-2 had the lowest outflow TP concentration (12 ppb FWM) than any of the other STAs while its HLR and PLR were highest among all the STAs, at 2.58 cm/d and 0.82 g/m^2/yr, respectively (**Table 5-1**). The 12-month moving average plot shows a very slight decreasing trend in outflow TP concentration through the end of WY2012 (**Figure 5-19**). As previously noted, this strong performance is largely because a large portion of this STA was never farmed and as a result of the successful operational management strategies in this area.

At the flow-way level, Cell 1 produced the lowest outflow TP concentration (9 ppb FWM), compared to Cells 2 and 3 (15 and 14 ppb FWM, respectively) (**Table 5-6**). All flow-ways showed lower outflow concentrations compared to WY2011, where Cells 1, 2, and 3 achieved 12, 19, and 15 ppb FWM TP concentration, respectively. Although Cell 1 received less volume of inflow (57,632 ac-ft) than Cells 2 and 3 (78,193 and 73,549 ac-ft, respectively) in WY2012, the HLR for the three cells was comparable (2.7-2.9 cm/day). Cells 1 and 3 also have the same PLR (0.8 g/m^2/yr), while Cell 3 had slightly higher PLR (1 g/m^2/yr).

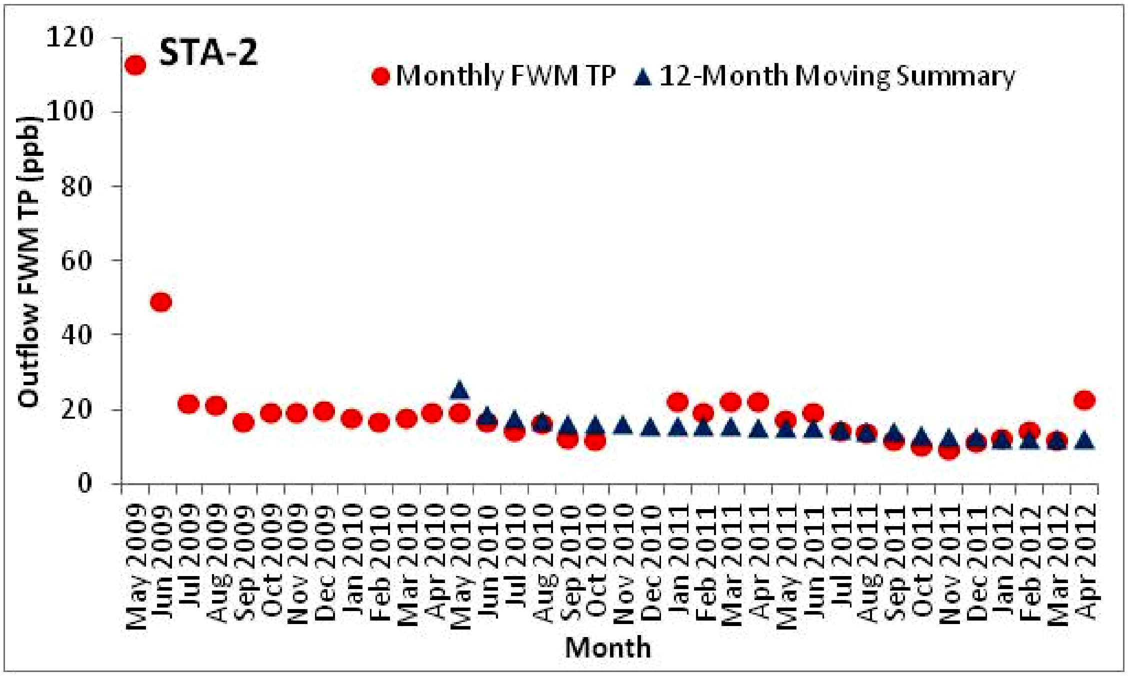


Figure 5-19. Monthly flow-weighted mean TP concentration and 12-month (WY2012) moving average TP concentration in STA-2.

Table 5-6. Comparison of flow-way performance in STA-2 between WY2011 and WY2012.

Flow-way/WY	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 (%)
STA-2, Cell 1	1798							
WY2011		0.4	1.2	26590	88	12.0	2.5	86%
WY2012		0.8	2.7	57632	79	8.9	5.1	91%
STA-2, Cell 2	2270							
WY2011		0.9	2.4	65696	101	18.7	6.6	80%
WY2012		1.0	2.9	78193	99	14.6	8.0	83%
STA-2, Cell 3	2270							
WY2011		0.8	2.7	72493	82	15.1	6.0	81%
WY2012		0.8	2.7	73549	82	14.5	5.8	77%

FACILITY STATUS AND OPERATIONAL ISSUES

Cells 1, 2, and 3 were fully operational, while Cell 4 remained off-line due to construction activities in Compartment B (**Figure 5-7**). Because Cell 4 was off-line, the adjusted effective treatment area acreage was reduced to reflect the acreage that was operational (**Table 5-1**). In March 2011, one of the three pumps in S-6 failed, limiting the structure's pumping capacity. Subsequently, temporary pumps were put in place to deliver water to STA-2 during pump repairs, which were completed and allowed S-6 to be fully operational on September 27, 2011.

Compartment B Build-out

The Compartment B Build-out Project is located in Palm Beach County, west and south of the existing STA-2 (**Figure 5-1**). Construction of this STA and its three pump stations began in WY2010 and the system was flow-capable by December 2010. Construction of two inflow canal bridges was completed in May 2011, while construction of the G-435 pump station was completed on January 24, 2012. Compartment B North and South build-outs were completed on October 22 and November 8, 2011, respectively. Construction of the G-434 and G-436 pump stations is scheduled to be completed by the end of August 2012. Operation of the Compartment B Build-out Project is dependent on the acquisition of state and federal discharge permits.

Vegetation start-up measures were initiated in Compartment B, In Cell 4, the SAV cover that was previously present died back as a result of draining this cell for Compartment B construction. The low water condition also led to extensive colonization of cattail. Efforts to reverse this cattail encroachment and reestablish SAV were initiated in January 2012 when 700 acres of cattail were treated with an aerial herbicide application. Within the new cells, extensive coverage of willow and primrose willow present a similar impediment for establishment of desired wetland species. In November 2011, ground crews treated, cut, and piled some of the smaller patches of willow and primrose willow in Cell 6. Aerial herbicide treatment of the remaining tree and shrub cover is scheduled for the beginning of WY 2013. Additional startup measures to be completed in WY 2013 include conversions of Cell 8 and downstream portions of Cells 5 and 6 to SAV, including aerial inoculations to establish founder beds of SAV in these cells.

Backflow from G-368 into Cell 4 occurred, as needed, during March and April 2012 in order to stimulate SAV growth through increased hydration. Water was added to Cells 5 and 6 via S-6 and G-337A beginning on April 23, 2012 to facilitate vegetative growth.

Drought Impacts

During the early part of WY2012, water level of the EAV cells (Cells 1 and 2) receded quickly; Cell 1 eventually dried out by the last week of June 2011 (**Figure 5-20**). However, with the onset of the 2011 wet season, the cells were rehydrated quickly and remained wet for the rest of the water year. By implementing drought contingency strategies, the WY2012 drought had no significant impact on STA-2 condition or performance, aside from visible browning of cattail leaves in Cells 1 and 2 (**Figure 5- 21**). To prepare for the anticipated drought season, water levels were held at the drought contingency stages (additional 6 inches) during the WY2012 dry season. Also, 10,992 ac-ft of supplemental water from Lake Okeechobee was delivered to STA-2 in WY2012. These combined measures enabled the cells the cells in this STA to stay hydrated through the dry months during the water year. In June 2011, Cell 1 water level receded to below minimum target, but quickly resumed to target levels at the onset of the 2011 wet season. Cell 3 remained hydrated through the dry season.

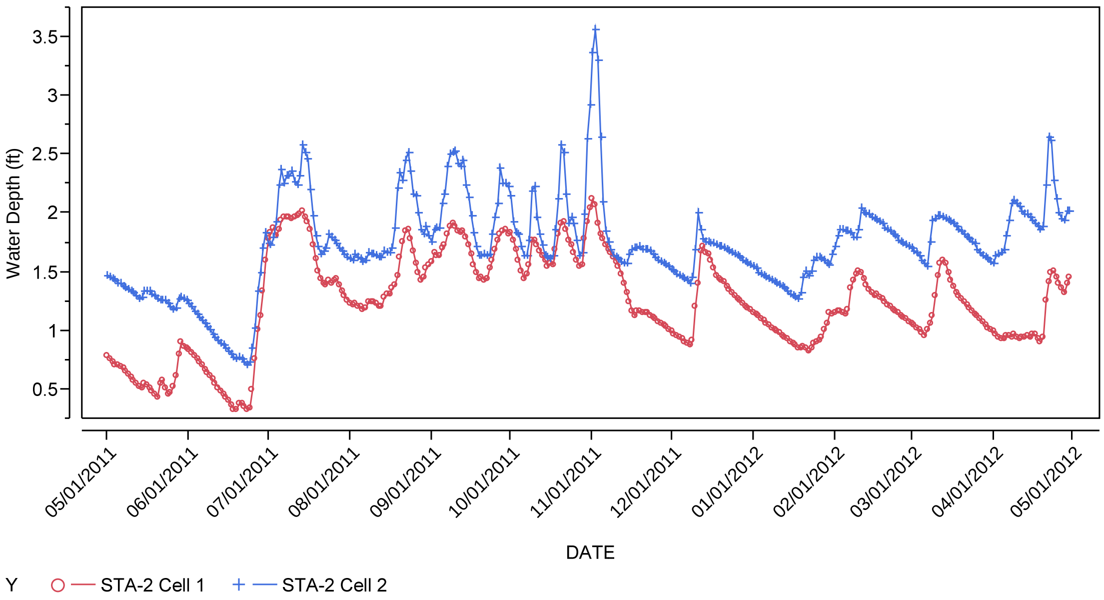


Figure 5-20. Daily average water depths in STA-2 Cells 1 and 2 during WY2012. Cell 3 water depths were not included; this cell remained hydrated through the water year.

Figure 5-21. Dry condition in STA-2 Cell 1 as a result of low water conditions and brief dryout period in June 2011 (photo by the SFWMD).

Impacts of Migratory Bird Nesting

STA-2 operation was not impacted by migratory bird nesting in WY2012. Between May–July 2011, there were a total of 39 black-necked stilt nests observed via levee surveys in STA-2, all of which were in non-operational cells (Cells 4 and 6) (Appendix 5-4). No nests were found in STA-2 in April 2012.

MAINTENANCE AND ENHANCEMENTS

Routine vegetation management included control of FAV in inflow distribution canals and in outflow collection canals to provide an even distribution of flow across each cell, and to ensure the efficiency of discharge structures. Within the cells, water lettuce and other floating plants such as water hyacinth and frog's bit were routinely treated to promote growth of submerged beds of aquatic vegetation in SAV cells. A summary of herbicide use in the STAs is included in Volume III, Appendix 3-1, Attachment E.

The partial conversion of the southern portion (approximately 300 acres) of Cell 2 is considered complete, based on good establishment of *Chara* throughout the cell. In July, 2011, the southern portion of Cell 2 was also inoculated with *Najas* in an effort to obtain a more diverse SAV population in this area. The most recent survey, as mentioned earlier, shows an indication of *Najas* establishment along with a widespread cover of *Chara*. Cattail expansion in the conversion area was controlled as part of routine vegetation management in STA-2.

During the water year, one of the pumps at the S-6 pump station underwent emergency repairs on November 21, 2011, limiting the structure's pumping capacity. Gate 2 of G-339 was removed for overhaul repairs and stop gates were installed, halting flow through this structure from February 21–March 29, 2012, when the gate was successfully replaced.

VEGETATION SURVEYS

Vegetation Coverage Estimates Based on Aerial Imagery

Based on an annual imagery flight, area coverage of EAV and SAV+open area is estimated for each STA. Imagery for CY2011 (conducted in May 2011) and comparison with the previous year (conducted in April 2010) is included in this report (**Table 5-7**; Appendix 5-5). For STA-2, data shows that there is little change in terms of vegetation coverage in Cells 1-3, while Cell 4 had 36 percent increase in EAV coverage as a consequence of the dry condition in the cell due to Compartment B construction (**Table 5-7**). Field observations in Cells 1 and 2 indicate healthy, dense cattail stands and sparse areas of sawgrass.

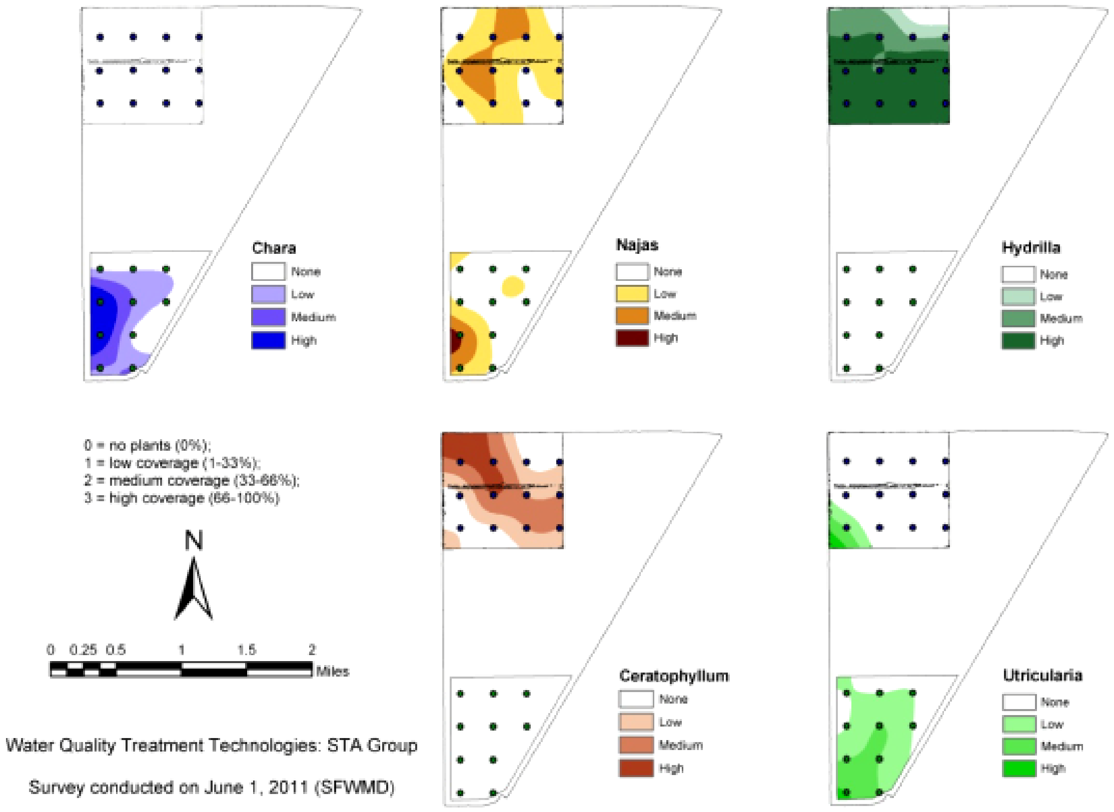
Table 5-7. Summary of vegetation coverage in STA-2 based on May 2011 aerial imagery. Numbers shown are expressed as percentage of total cell area.

Cover Category	Cell 1	Cell 2	Cell 3	Cell 4
% EAV	97	65	31	48
% SAV+open area	3	35	69	52
% change in EAV cover from 2010 to 2011	0	3	3	36

Ground Survey for Submerged Aquatic Vegetation

At the conversion area in the southern portion of Cell 2, survey data shows a good coverage of Chara. On June 1, 2011 (post-drought assessment) and July 8 and 12, 2011, SAV surveys were performed in the southern and northern SAV regions of this cell, respectively. Within the northern region, a mixture of *Hydrilla* and *Ceratophyllum* was the dominant SAV (**Figures 5-22** and **5-23**). *Potamogeton* and *Najas* were also present at much less density within this region. The conversion area in the southern region of the cell was dominated by *Chara* with some *Najas* present. Medium density and good coverage of *Utricularia* was also observed in the June 2011 survey.

SAV surveys performed in Cell 3 on August 5, 2011 and February 29, 2012, indicate stable vegetation coverage during the water year (**Figure 5-24**). A mixture of *Najas*, *Ceratophyllum*, and *Hydrilla* was observed in the inflow region of the cell, while the middle to outflow region was dominated by *Chara*, with some *Potamogeton* and *Najas*.



Water Quality Treatment Technologies: STA Group

Survey conducted on June 1, 2011 (SFWMD)

Figure 5-22. Post-drought submerged aquatic vegetation survey in STA-2 Cell 2; plots depict the spatial distribution and relative density of *Hydrilla*, *Chara, Najas, Potamogeton,* and *Ceratophyllum* species in STA-2 Cell 2 on June 1, 2011.

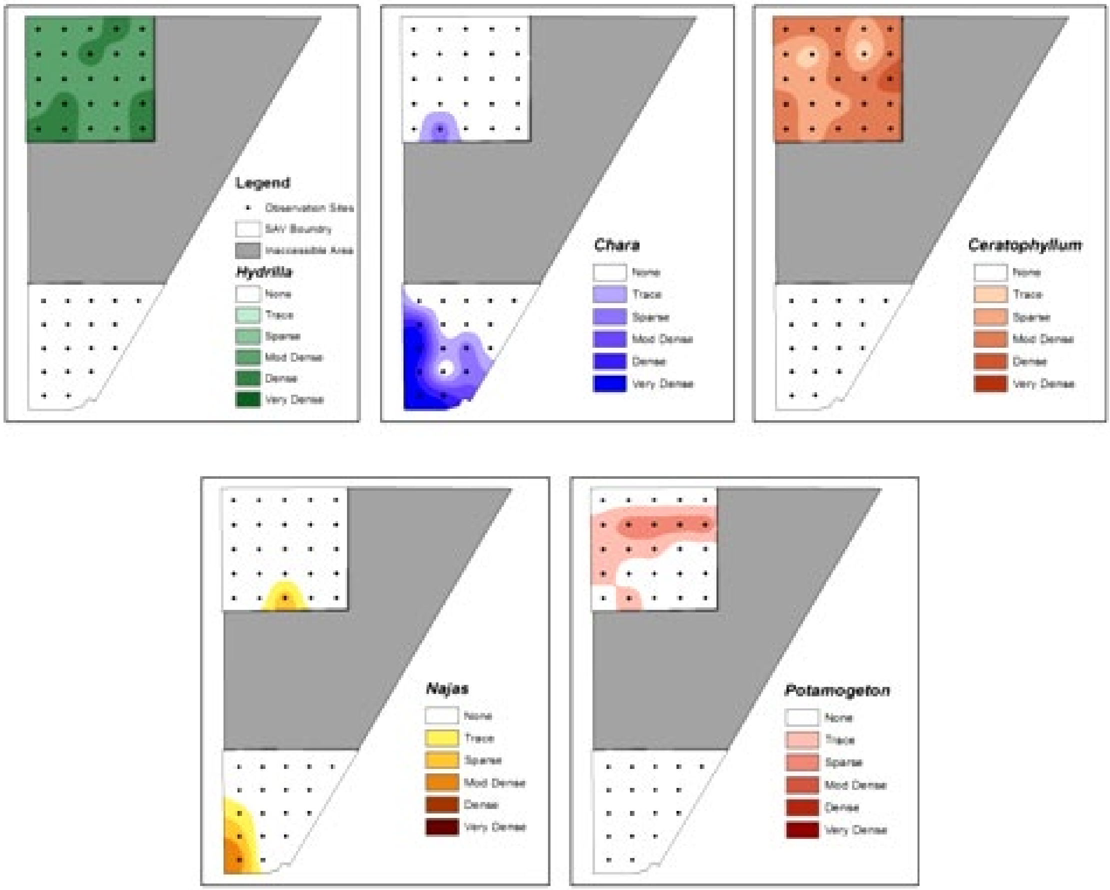


Figure 5-23. Vegetation survey results depicting the spatial distribution and relative density of *Hydrilla*, *Chara, Najas, Potamogeton,* and *Ceratophyllum* in STA-2 Cell 2 on July 8 and 12, 2011.

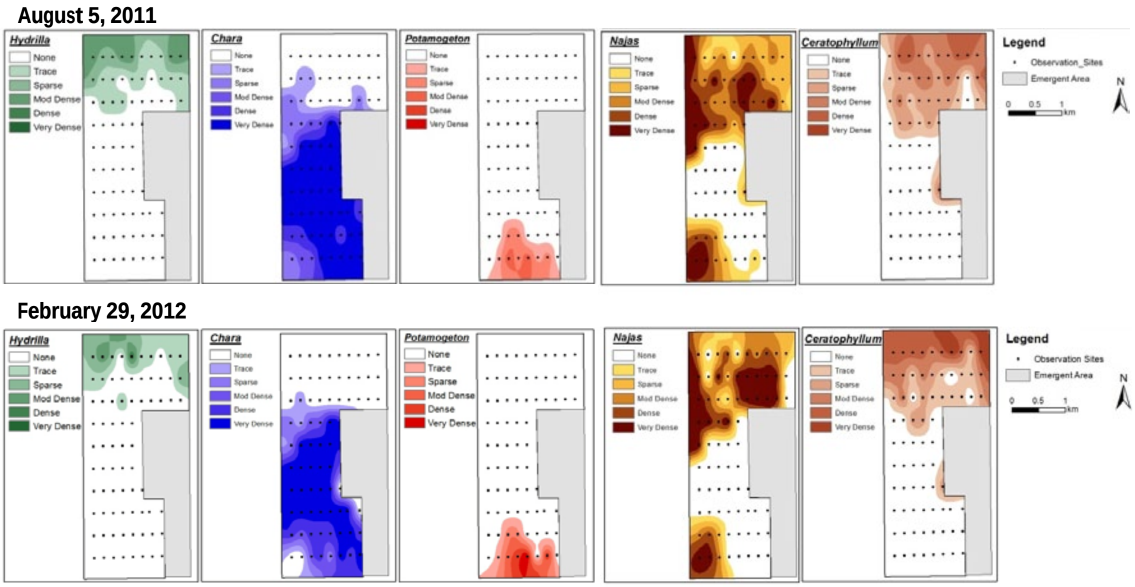


Figure 5-24. Vegetation survey results depicting the spatial coverage of Hydrilla, *Chara, Najas, Potamogeton,* and *Ceratophyllum* in STA-2 Cell 3 on August 5, 2011 and February 29, 2012.

STA-3/4

Stormwater Treatment Area 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 5-1**). It provides a total treatment area of 16,535 acres to treat stormwater runoff originating within the S-2/7, S-3/8, S-236, and C-139 basins and Lake Okeechobee (SFWMD, 2007). During dry months, supplemental water is also delivered from Lake Okeechobee to maintain hydration on priority cells. STA-3/4 is comprised of three flow-ways, i.e. Eastern Flow-way (Cells 1A and 1B), Central Flow-way (Cells 2A and 2B), and Western Flow-way (Cells 3A and 3B) (**Figure 5-25**). A 445-acre (162-ha) section of Cell 2B is the site of the STA-3/4 PSTA Project, aimed at testing and evaluating PSTA treatment technology.

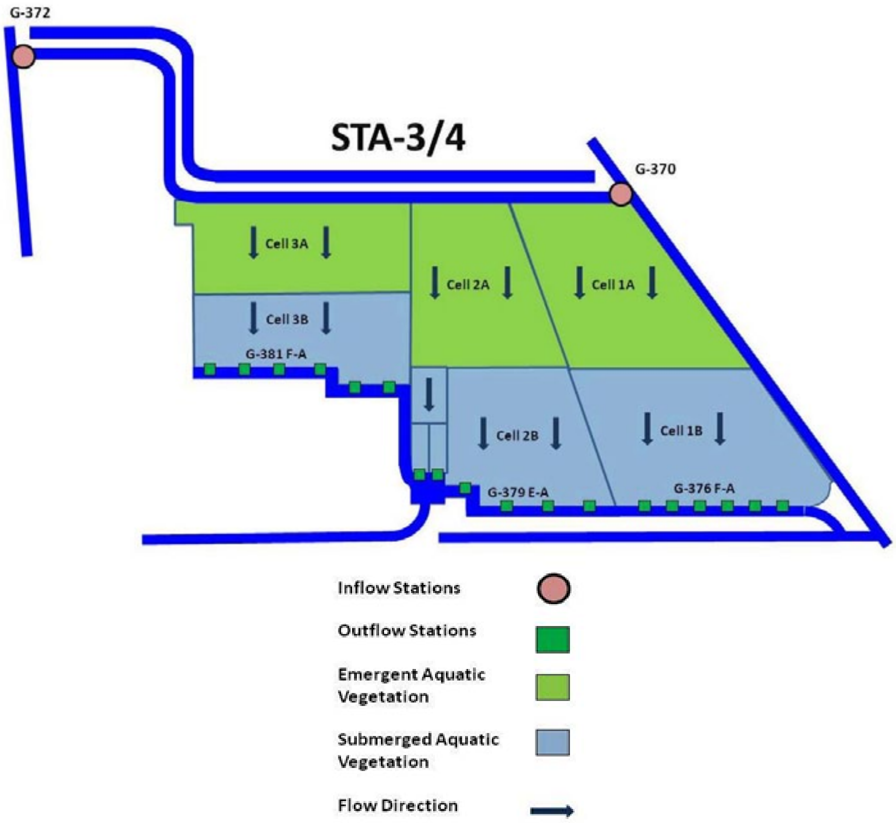
Since it began operation in October 2003, STA-3/4 has treated approximately 3.7 million ac-ft of runoff water, retaining over 440 metric tons of TP, and reducing TP concentration from 114 ppb to 18 ppb (**Table 5-1**; **Figure 5-3**). Similar to the other STAs, STA-3/4 has been impacted by extreme weather events (regional drought and storm events) and high hydraulic loadings during the wet season. The WY2011 drought season resulted in dryout in all cells in STA-3/4 in June 2011. Details of the impacts and other effects of dry condition is discussed in the Drought Impacts subsection.

Another issue for this STA is relatively high water depths for extended periods in the EAV cells during and following storm events. As a consequence of the persistent deep water conditions in Cells 1A and 2A, cattail communities have been negatively impacted, particularly in the northern portion of the cells. A detailed discussion of operational adjustments made in this STA in July–August 2011 is included under the STA-3/4 Facility Status and Operational Issues subsection within this chapter. Also, a report on preliminary evaluation of the effects of Cell 1A drawdown in WY2011 and 2012 is included in the *Applied Scientific Studies* section of this chapter.

STA PERFORMANCE

Considering the dryout that occurred in the entire STA in the early part of the water year and the subsequent high flows in the later part of June through early July 2011, STA-3/4 had considerably excellent performance in WY2012. This STA treated almost 270 thousand ac-ft of runoff water, retained 29.7 mt of P, and reduced TP concentration from 109 ppb (inflow FWM) to 19 ppb (outflow FWM) (**Table 5-1**; **Figure 5-2**). This outflow concentration is two ppb higher than what was reported in WY2011 and is likely a result of the P spike after dryout period and subsequent rehydration, the disturbance in the soil substrate resulting from high flows following the dryout period, and the loss of vegetation. The calculated HLR and PLR are 1.36 cm/d and 0.54 g/m^2/yr, respectively. The impacts of dryout and subsequent rehydration, which involved high hydraulic loading and disruption in underlying peat substrate, resulted in TP spikes during the period from late June to July 2011. Consequently, the 12-month moving summary increased significantly between WY2011 and through the end of WY2012 (**Figure 5-26**).

At the flow-way level, the Western flow-way treated the highest volume of inflow (123,600 ac-ft) among the three flow-ways (**Table 5-8**). The HLR and PLR observed in WY2012 for each of the three flow-ways were comparable to the values in WY2011. While the Western flow-way had the highest HLR of the three flow-ways, the resulting outflow TP concentration (15 ppb FWM) is much lower than outflow TP concentrations in either the Eastern or the Central flow-ways (20 and 21 ppb FWM, respectively). This trend is consistent to the values observed in WY2011. In terms of TP load reduction, the flow-ways had consistently less reduction in WY2012 than in WY2011, primarily due to the impacts of SAV loss during dryout period and also from internal loading upon rehydration.



Cell	Cell Area (acres)
1A	3,052
1B	3,504
2A	2,533
2B	2,888 (includes PSTA Project cells)
3A	2,444
3B	2,114
Total	16,535

Figure 5-25. Simplified schematic of STA-3/4 showing major inflow and outflow structures, flow directions, and dominant/target vegetation types. [Note: A more detailed schematic is included in Appendix 5-1.]

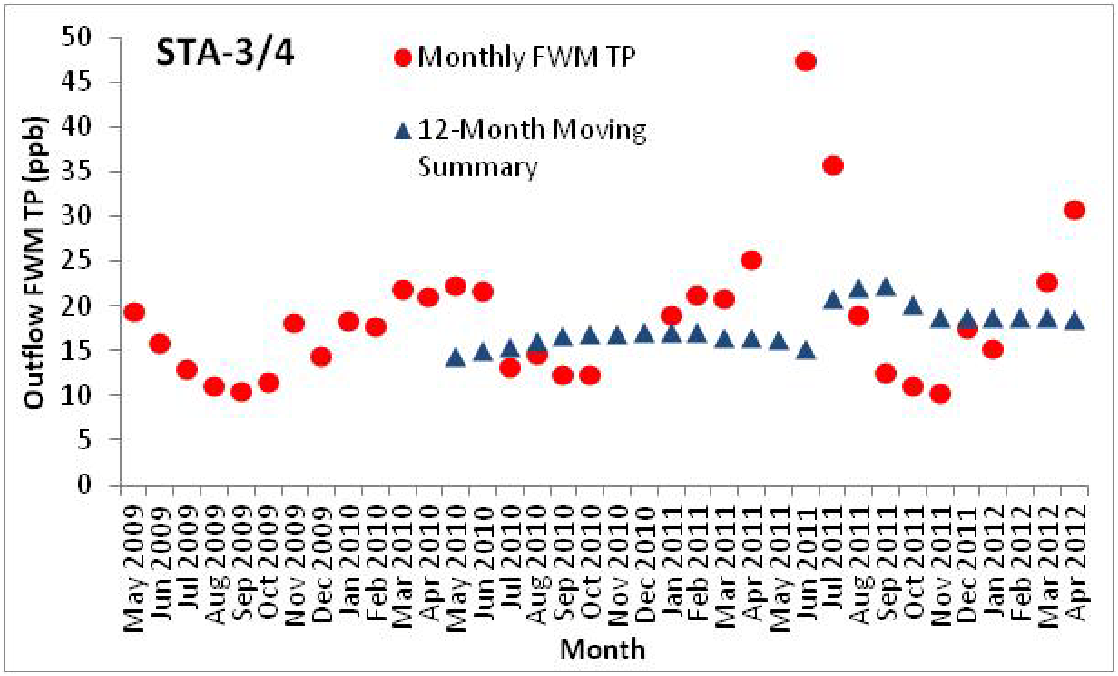


Figure 5-26. Monthly flow-weighted mean TP concentration and 12-month (WY2012) moving average TP concentration in STA-3/4.

Table 5-8. Comparison of flow-way performance in STA-3/4 between WY2011 and WY2012.

Flow-way & WY	Area (acres	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	6527							
WY2011		0.4	1.2	93,579	84	16.1	7.7	79%
WY2012		0.2	1.0	80,369	60	20.0	3.8	62%
Central Flow-way	5436							
WY2011		0.3	1.5	97,230	52	20.5	3.9	61%
WY2012		0.3	1.4	93,373	49	21.1	3.2	55%
Western Flow-way	4580							
WY2011		0.4	2.1	112,832	51	13.6	5.2	72%
WY2012		0.3	2.3	123,600	35	15.2	3.1	57%

FACILITY STATUS AND OPERATIONAL ISSUES

Water level drawdown in Cell 1A, which was initiated in the later part of WY2011 to encourage cattail reestablishment, continued in WY2012. The Eastern Flow-way was online with restrictions due to vegetation enhancement activities in Cell 1A during the period from May 1–August 23, 2011. The Western and Central flow-ways were fully operational during most of the water year; however flow and stage restrictions were implemented from July 5 and August 23, 2011, to allow for vegetation reestablishment following an extended dryout period where much of the SAV was lost in all the SAV cells.

Drought Impacts

Following the driest period of record for South Florida during the period from October 2010–to June 2011 and late start of the wet season, water levels in STA-3/4 cells receded gradually and by June 2011, all cells dried out despite providing supplemental water from Lake Okeechobee (**Figures 5-27** and **5-28**). Consequently, SAV was lost in all cells. At the onset of the wet season in late June, water stages rose rapidly in STA-3/4, causing previously desiccated soil layer to rise to the top of the water column, an increase in turbidity, and spikes in outflow P concentration (78 ppb during the first week after rehydration). Deep water conditions threatened the recovery of cattail, particularly the new growth in the EAV cells, and inhibited the recovery of SAV. In order to minimize impacts to vegetation and applying the provisions under the Everglades Forever Act Specific Condition 23, a 28-day partial diversion of runoff through G-371 and G-373 occurred from July 2 through July 29, 2011. Approximately 55,000 ac-ft was diverted, equating to approximately 5.9 metric tons of TP. During the diversion period, EAV and SAV was allowed to acclimate to increasing depths and by August 30, when field observations indicate that vegetation has began to recover, STA operations were returned to normal.

While complete dryout is not desired for the STAs, primarily due to negative impacts on SAV vegetation and the resulting TP spike upon rehydration, field surveys indicate positive benefits in terms of cattail regrowth. Thick establishment of cattail seedlings were observed throughout Cells 1A and 2A upon cell rehydration. A more detailed discussion on the benefits of dry condition on cattail re-establishment is included in the Applied Scientific Studies of this chapter. Contingency drought strategies and weekly monitoring of water stages were implemented to avoid recurrence of dryout that was experienced in the beginning of WY2012. Target stages were raised by six inches and approximately 17,860 ac-ft of supplemental water was delivered from Lake Okeechobee during WY2012.

Impacts of Migratory Bird Nesting

Due to the receding water level in STA-3/4 during the early part of WY2012, a large number of black-necked stilt nests (142 nests) was observed via a levee survey from May to June 16, 2011 (Appendix 5-4). A majority of these nests (95 nests) were found in the PSTA project area, specifically at the upper and lower SAV cells. There were also nests found in the Eastern Flow-way, Cell 2B, and Cell 3B during this time period. Due to lack of flows to the STA during this survey period, there was little to no impact to STA operation. By the start of the wet season in early July, nesting season was over. No nests observed in April 2012 in STA-3/4.

STA-3/4 Periphyton Stormwater Treatment Area

The PSTA project in STA-3/4 was constructed to investigate the performance of a periphyton-dominated treatment system. The project comprises 400 acres of STA-3/4 within Cell 2B that is divided into one 200-acre Upper SAV cell and two adjacent parallel downstream 100-acre cells (lower SAV and PSTA cells). All cells have been managed to promote an SAV community and associated periphyton assemblage. In WY2012, the PSTA cell annual inflow

FWM TP concentration was 17 ppb while the annual outflow FWM TP concentration was 12 ppb, which was within the 8-12 ppb range achieved over its period of operation. Further details concerning the STA-3/4 PSTA project is included in the Applied Scientific Studies section of this chapter.

MAINTENANCE AND ENHANCEMENTS

As mentioned previously, water level in Cell 1A was drawn down in an effort to revitalize the cattail stand by providing conditions conducive for vegetative expansion, enable planting of bulrush, and for colonization of new seedlings. The drawdown occurred between March 1 and June 1, 2011, using two temporary pumps. Due to a regional drought, the water level in this cell and the rest of STA-3/4 receded naturally, and the temporary pumps were removed by May 2011. During the drawdown and in April 2012, bulrush was also planted in some of the open areas. A more detailed evaluation of the success of drawdown on cattail reestablishment is included in the *Applied Scientific Studies* section of this chapter.

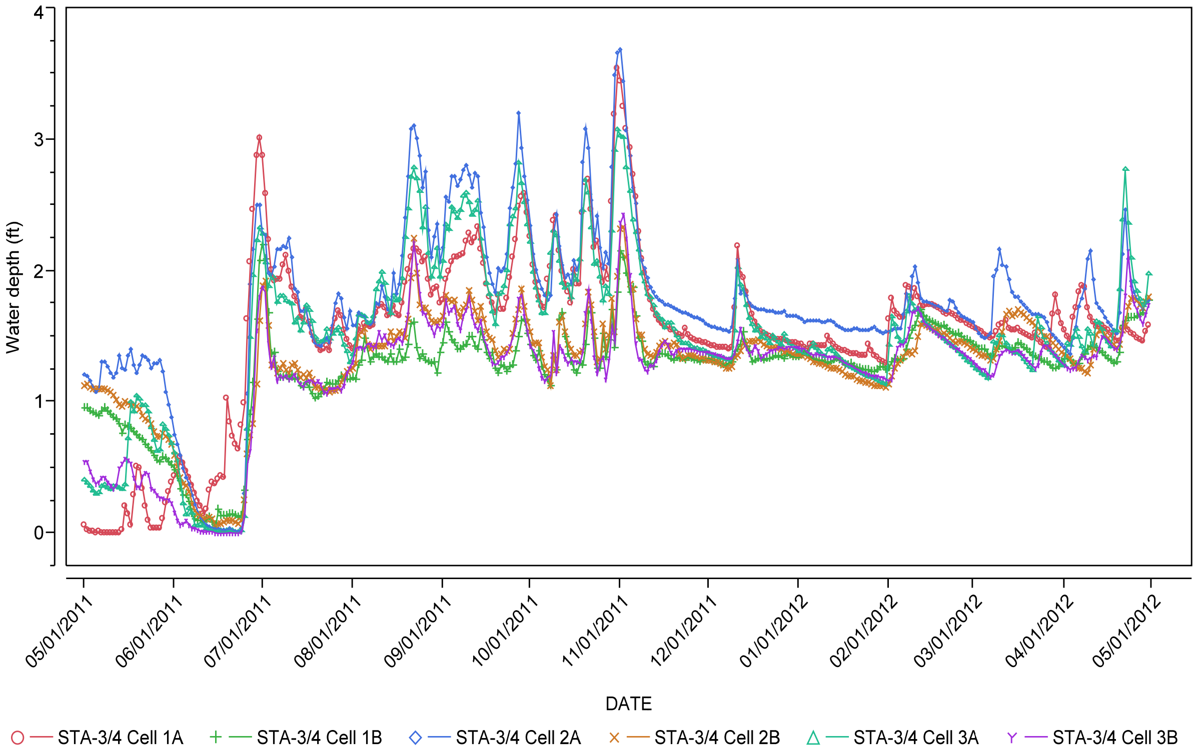


Figure 5-27. Daily average water depths in Cells 1A, 1B, 2A, 2B, 3A, and 3B of STA-3/4 during WY2012.

Figure 5-28. Dried out cells in STA-3/4 as a result of a regional drought, high evapotranspiration rates, seepage losses, and delayed wet season; aerial photos taken by SFWMD on June 16, 2012.

VEGETATION SURVEYS

Vegetation Coverage Estimates Based on Aerial Imagery

Based on an annual imagery flight, area coverage of EAV and SAV+open area is estimated for each STA. Imagery for CY2011 (conducted in May 2011) is presented in this chapter; a comparison with the previous year (conducted in April 2010) is also included (**Table 5-9**; Appendix 5-5). For STA-3/4, data shows that the biggest changes in terms of vegetation coverage were in Cells 1A and 1B. Cell 1A, which was intentionally drawn down for vegetation rehabilitation purposes, had 13 percent increase in EAV coverage at the time of 2011 aerial imagery (May 2011). Field observations during this time period and six months later confirm large areas with new cattail growth and a successful germination of cattail seeds particularly in areas that were previously devoid of vegetation (**Figure 5-29**).

Table 5-9. Summary of vegetation coverage in STA-3/4, based on May 2011 aerial imagery. Numbers shown are expressed as percentage of total cell area.

Cover Category	Cell 1A	Cell 1B	Cell 2A	Cell 2B	Cell 3A	Cell 3B
% EAV	79	48	80	25	95	32
% SAV+open area	21	52	20	75	5	68
% change in EAV cover from 2010 to 2011	13	-11	3	-1	0	-2

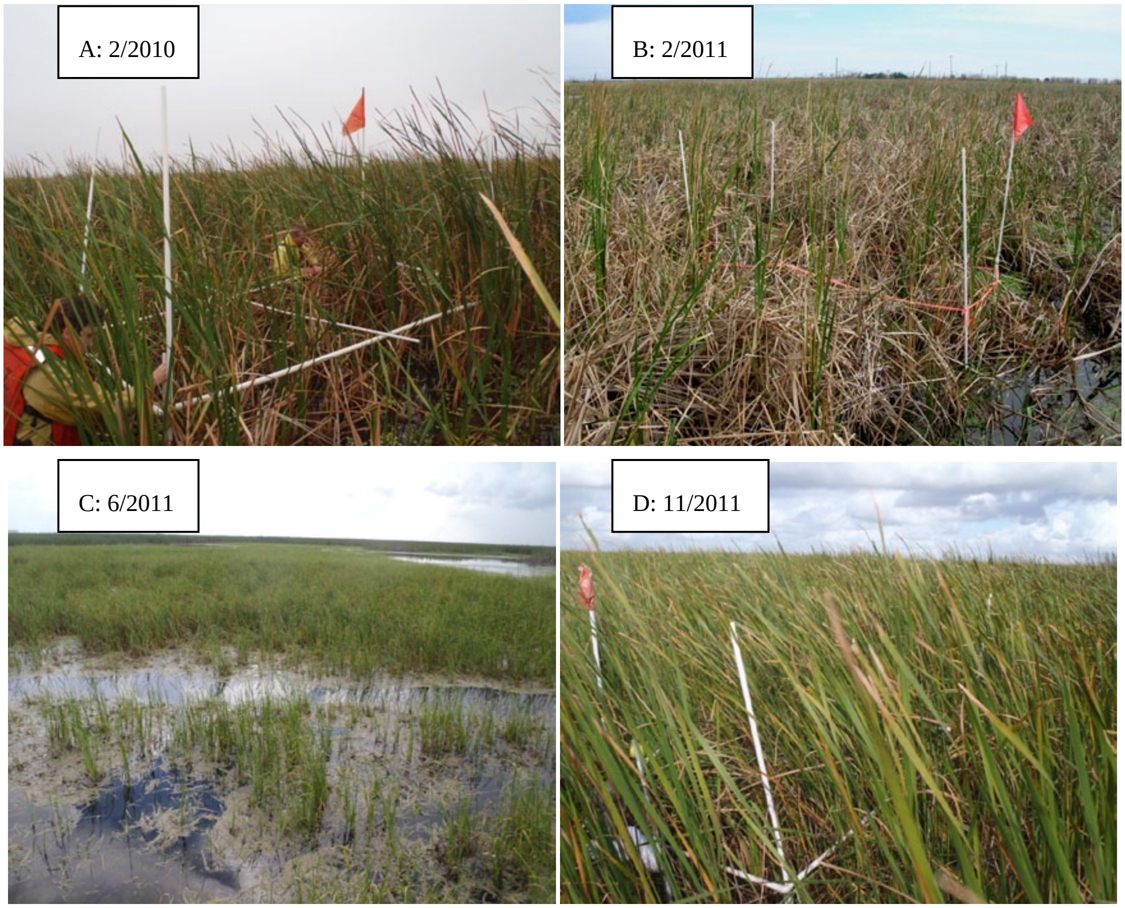


Figure 5-29. Cattail vegetation in STA-3/4 Cell 1A in February 2010 (A), February 2011 (B, pre-2011 drawdown), June 2011 (C, post-drawdown), and November 2011 (D, six months after rehydration) (photos by the SFWMD).

Ground Survey for Submerged Aquatic Vegetation

SAV surveys in Cells 1B, 2B, and 3B were performed immediately following the reflooding of the cell to assess the impacts of dryout and begin monitoring SAV reestablishment. Results were compared with pre-dryout information. As a large portion of Cell 1B is inaccessible by airboat, the surveys could not be performed in those areas (**Figure 5-30**). In September 2010, the dominant SAV species in this cell were primarily *Chara* and *Najas*. Following the drydown (July 7, 2011), these SAV species were still present but at much lower densities. During the two subsequent surveys, an increase in both *Chara* and *Najas* were observed.

In August 2010, *Chara* dominated Cell 3B with just a small amount of *Najas* observed (**Figure 5-31**). Upon rehydration, following the dryout period (7/7/11), a reduction in the density of *Chara* was observed; however, during the two subsequent surveys, *Chara* appeared to be quickly reestablishing to pre-drydown densities within this cell.

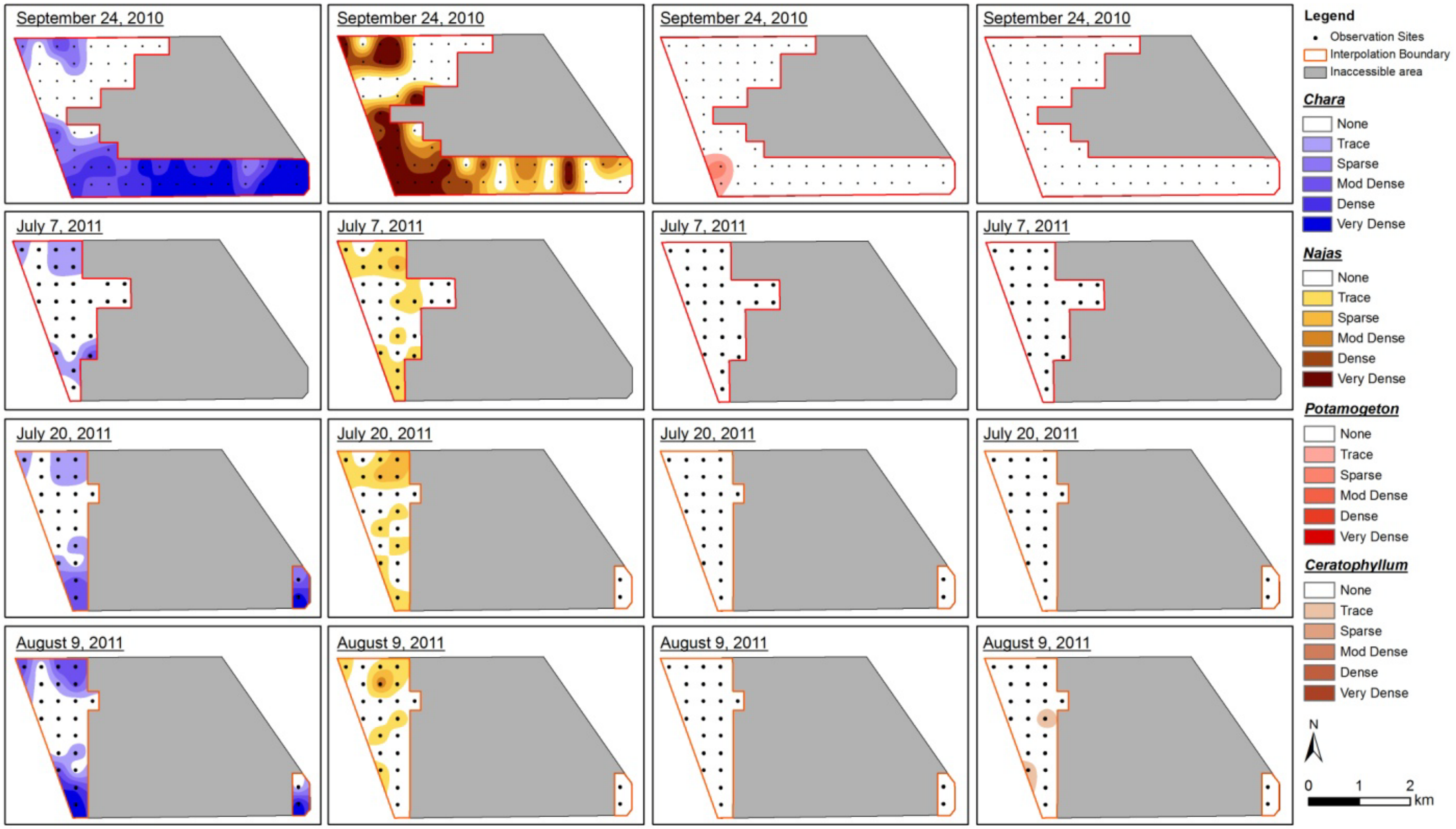


Figure 5-30. Vegetation survey results depicting the spatial distribution and relative density of *Chara*, *Najas*, *Potamogeton*, and *Ceratophyllum* in STA-3/4 Cell 1B on September 24, 2010, and July 7, July 20, and August 9, 2011.

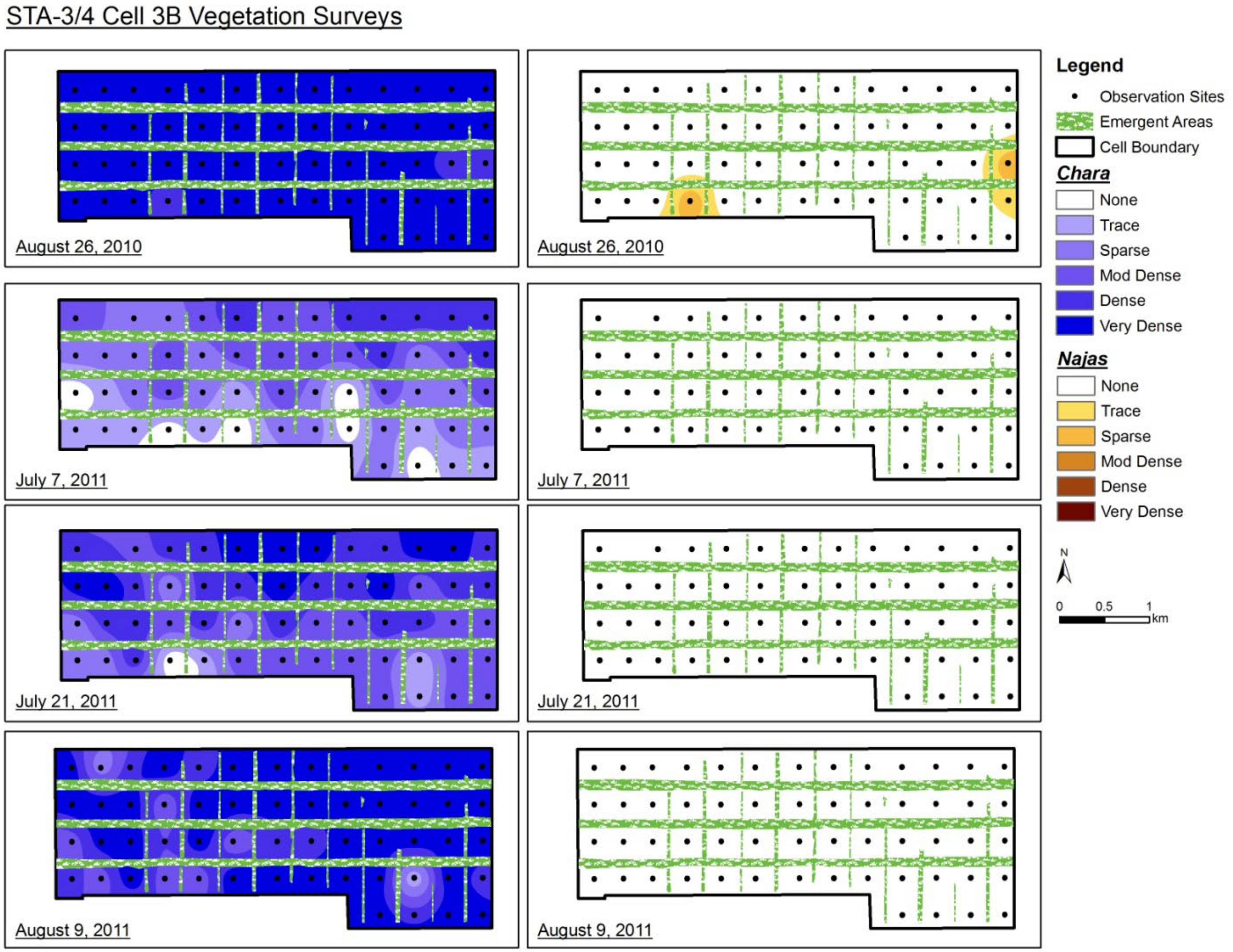


Figure 5-31. Vegetation survey results depicting the spatial coverage and relative density of *Chara* and *Najas* in STA-3/4 Cell 3B on August 26, 2010, and July 7, July 21, and August 9, 2011.

STA-5/6

The original STA-5, which began operation in WY2000, consisted of Cells 3 and 5, totaling 4,110 acres of effective treatment area. In 2006, a third flow-way (Flow-way 3) was added, with approximately 6,095 acres of treatment area (Goforth, 2008). The lack of sufficient inflows due to the regional drought has delayed vegetation grow-in and flow-through in Flow-way 3. The original STA-6 consisted of 870 acres of effective treatment area and began operation in 1997. STA-6 was initially expanded by 1,387 acres area in 2006 with the addition of Section 2, yielding a total of approximately 2,257 acres of effective treatment area for STA-6. In this section, STA-5 and STA-6 are also referred to as STA-5/6 (**Figure 5-33**), following the completion of Compartment C construction in mid-2012. However, it should be noted that the Compartment C build-out will not be operational until permits for this expanded area are issued by the FDEP.

Since October 1999 (WY2000), STA-5 has treated over 1.2 million ac-ft of runoff water and retained approximately 212 mt of TP. STA-6 has treated 687,759 ac-ft of runoff water and retained approximately 65 mt of P. The POR inflow FWM TP for STA-5 (225 ppb) is the highest among all STAs and more than twice as much as the POR inflow TP FWM concentration in STA-6 (100 ppb). The POR outflow concentration in STA-5 is 93 ppb, also the highest among all STAs, while STA-6 has produced a POR outflow FWM TP concentration of 34 ppb (**Table 5-1**).

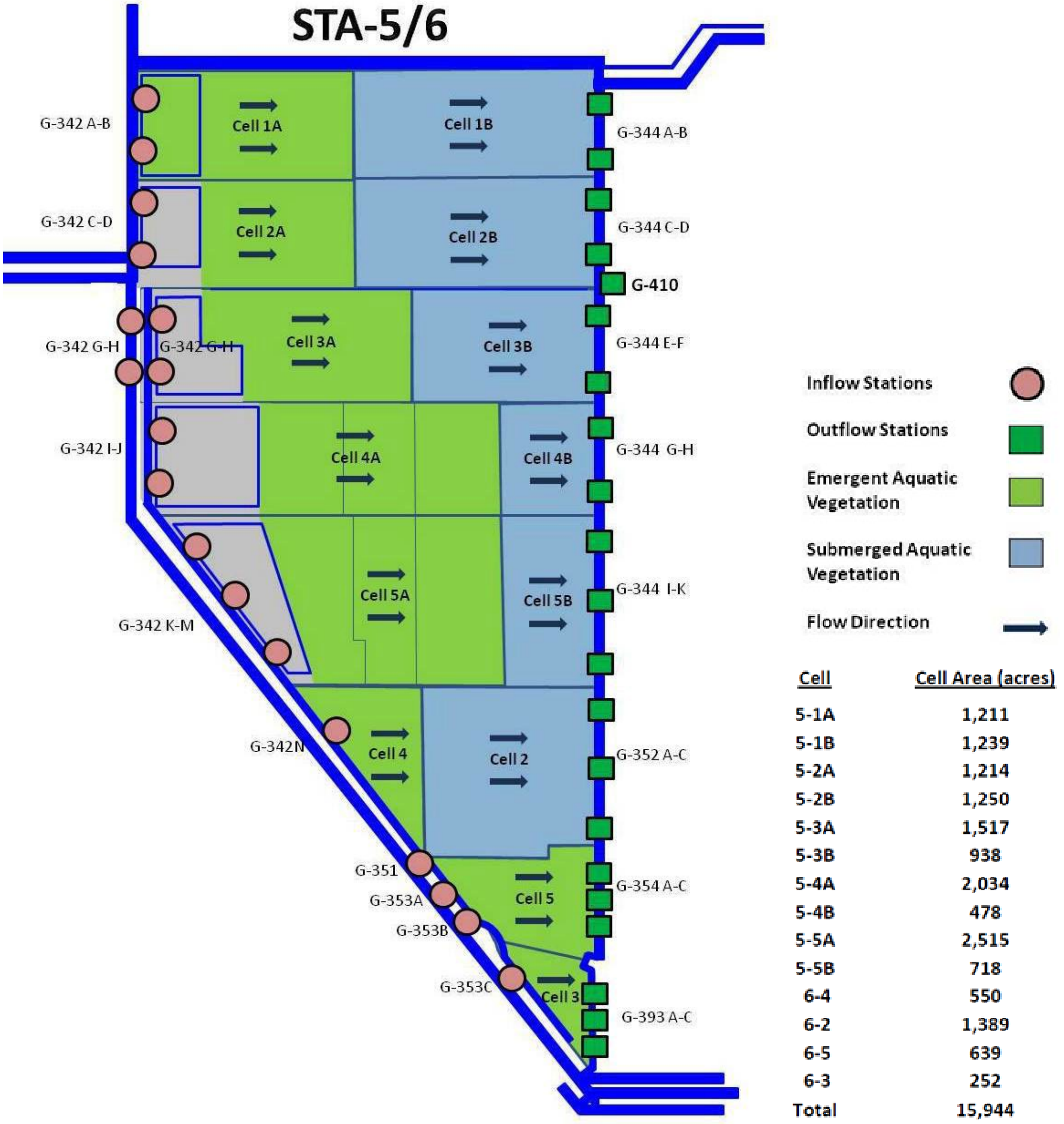
Over its period of operation, STA-5/6 has been impacted by high inflow concentrations and extreme weather events (regional drought and storm events). Almost every year during the dry season, dryout occurs in STA-5 Cells 1A and 2A and STA-6 Cells 3 and 5. High TP flux follows rehydration of these cells, usually resulting in temporary spikes in outflow TP concentration . In WY2012, methodical water management, including delivery of supplemental water from Lake Okeechobee, prevented or minimized the impacts of drought in STA-5 Cells 1B and 2B. A discussion on recent enhancements in STA-5 is in the *Maintenance and Enhancement* subsection of this section.

STA PERFORMANCE

In WY2012, STA-5 and STA-6 treated 47,508 and 17,055 ac-ft and retained 7.5 (82 percent of inflow load) and 1.8 mt (68 percent of inflow load) P, respectively. (**Table 5-1**) These STAs, particularly STA-5, continue to receive higher inflow concentrations than the other STAs; inflow TP annual FWM concentration was 156 ppb and 125 for STA-5 and STA-6, respectively. The 12-month moving average for STA-5 shows a significantly improving trend in outflow TP concentration (**Figure 5-34**); outflow concentration in WY2012 was 32 ppb, which has been the lowest achieved over its period of operation. This can be attributed to the combined effects of effective operation, recent enhancements (including Cell 1A rehabilitation, enhancement of vegetation strips in the SAV cells, and improved vegetation establishment), and reduced HLR and PLR. As mentioned earlier, the ability to maintain hydration of the SAV cells (Cells 1B and 2B) during dry months and delaying discharge upon rehydration help control outflow TP levels. The modification of the former non-effective treatment area in Flow-way 1 is also likely contributing to the performance observed in that flow-way.

In STA-6, the 12-month moving average plot shows an increase in WY2012, primarily due to TP spikes (>300 ppb FWM) that occurred upon resumption of flow in this STA in July 2011 (**Figure 5-34**). Due to the high amount of P flux upon resumption of flow, the resulting outflow concentration from STA-6 in WY2012 was 75 ppb. The STA has received little to no flow from October 2011 through the end of WY2012. Consequently, the 12-month moving average slowly decreased toward the end of the water year.

At the flow-way level, both STA-5 Flow-ways 1 and 2 yielded lower outflow TP concentration in WY2012 than in WY2011, and these values are also much lower than WY2012 outflow concentrations in STA-6 Cells 3 and 5 (**Table 5-10**). The PLR for STA-5 Flow-ways 1 and 2 and STA-6 Cells 3 and 5 were comparable (0.6-0.7 g/m^2/yr), and the HLR were comparable among STA-5 Flow-way 1 and STA-6 Cells 3 and 5 (1.5-1.8 cm/d), while STA-5 Flow-way 2 had a lower HRL (1.0 cm/d).



Cell	Cell Area (acres)
5-1A	1,211
5-1B	1,239
5-2A	1,214
5-2B	1,250
5-3A	1,517
5-3B	938
5-4A	2,034
5-4B	478
5-5A	2,515
5-5B	718
6-4	550
6-2	1,389
6-5	639
6-3	252
Total	15,944

Figure 5-33. Simplified schematic of STA-5/6 showing major inflow and outflow structures, flow directions, and dominant/target vegetation types. [Note: A more detailed schematic is included in Appendix 5-1.]

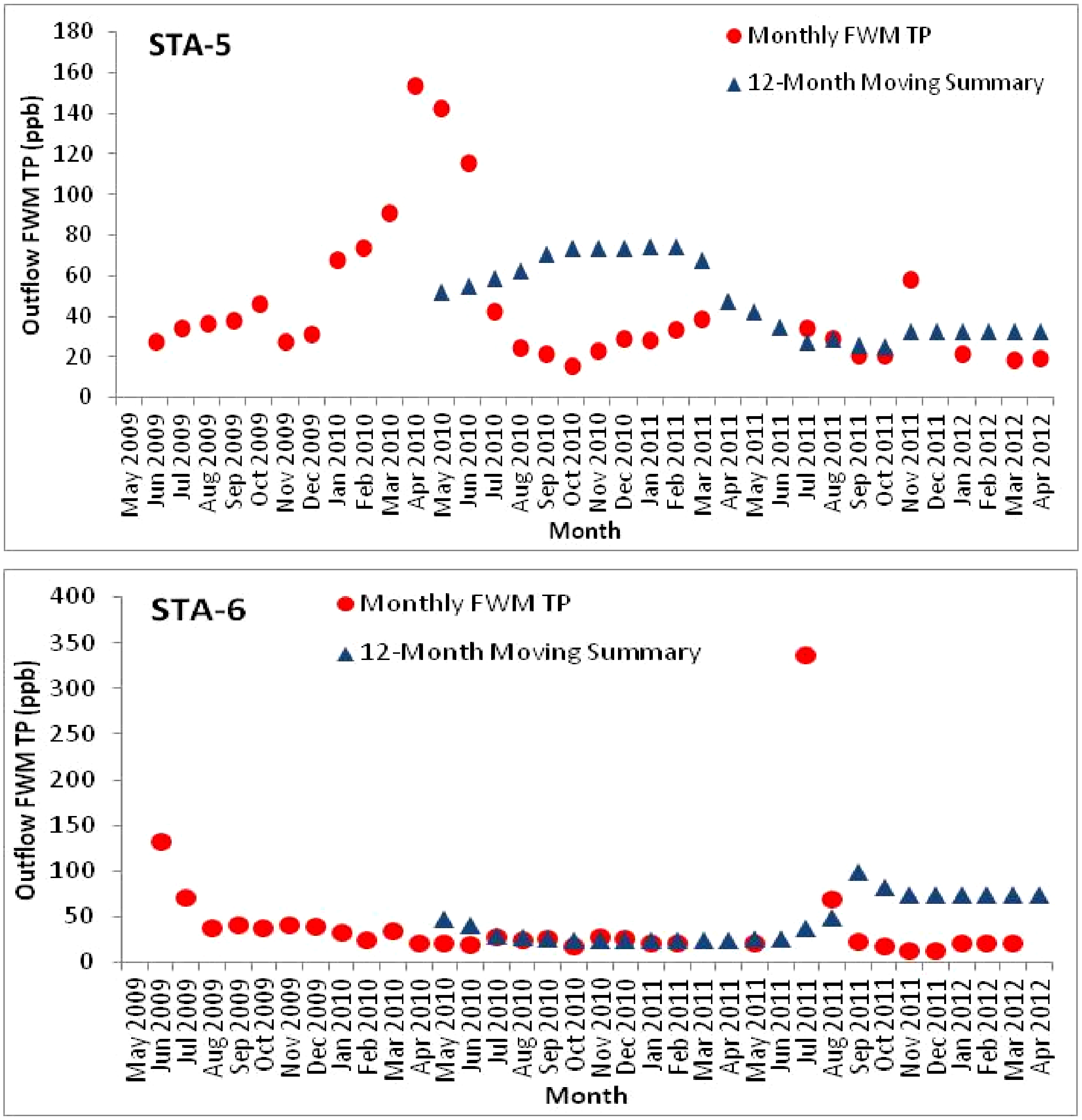


Figure 5-34. Monthly flow-weighted mean TP concentrations and 12-month (WY2010-WY2012) moving average TP concentrations in STA-5 (top) and STA-6 (bottom).

Table 5-10. Comparison of flow-way performance in STA-5/6 between WY2011 and WY2012.

Flow-way/WY	Area (acres)	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 (%)
STA-5 Flow-way 1	2055							
WY2011		0.4	1.4	33,423	84	40.8	2.6	75
WY2012		0.6	1.5	36,393	106	35.7	3.8	79
STA-5 Flow-way 2	2055							
WY2011		0.2	0.4	9,379	149	53.8	1.4	81
WY2012		0.6	1.0	24,515	165	28.1	4.3	86
STA-6 Cell 3	245							
WY2011		0.6	1.9	5,629	93	16.5	0.5	82
WY2012		0.7	1.8	5,251	112	53.1	0.6	80
STA-6 Cell 5	625							
WY2011		0.5	1.3	9,941	97	17.1	1.0	81
WY2012		0.7	1.6	11,650	129	84.8	1.2	63

PERMIT-RELATED PERFORMANCE ISSUES AND ACTION PLANS

In WY2012, STA-6 is the only STA that did not meet the interim effluent limit specified in the EFA permit. Due to the regional drought and lack of an efficient way to bring supplemental water to STA-6, the operational cells in this STA, i.e., Cells 3 and 5, dried out during the drought period beginning in October 2010 to July 2011, and again from December 2011 to the end of WY2012. Consequently, extremely high TP values (greater than 300 ppb at initiation of flow) were observed upon resumption of flow in July 2012, as a result of P flux from the oxidized soil. The twelve-month moving average TP concentration shows that the trend was slowly decreasing toward the end of the water year; however, TP spikes are anticipated again upon rehydration. Interim measures includes a gradual hydration of the cell, with no flow-through (no discharge), until there are indications of stabilization of TP levels within the cell. Once Compartment C is operational, it is anticipated that flow can be distributed more evenly among the eight flow-ways that now comprise the STA-5/6 flow path. The added capacity may help prevent discharging from a flow-way immediately after rehydration.

FACILITY STATUS AND OPERATIONAL ISSUES

All flow-ways in STA-5 were operational in WY2012 (**Figure 5-7**). Cells 1A, 2A, 3A, and 3B dried out beginning in April, 2012 and remained dry for the remainder of the water year as a result of drought (**Figure 5-36**). The North and Central flow-ways were fully operational during WY2012, despite the fact that some of the cells dried out during the dry season. Beginning on May 18, 2010, the south flow-way was off-line because flow into the G-342E and G-342F structures stopped due to Compartment C construction. Cells 1A, 2A, and 3B dried out beginning in December 2011 and remained dry for the remainder of the water year as a result of dry conditions in the basin. Restricted flow through the new G-520 and G-521 has allowed some flow into Cell 3A in October 2011. Water was added to Cell 2B in June 2011 for SAV hydration**.** This hydration was facilitated using the existing G-350B structure and the newly constructed culvert, G-510, located at the Southeast corner of Cell 2B.

In STA-6, Cells 3 and 5 were operational in WY2012 (**Figure 5-7**); however both cells dried out during the dry season as a result of basin conditions (**Figure 5-35**). Section 2 has been off-line since WY2010 for Compartment C construction. Construction began on April 11, 2012, to remove the redundant levee upstream of STA-6 Cell 5 (**Figure 5-36**). The fill from this removal will be used in Cell 5B of STA 5 for the environmentally sensitive area and for a new boat ramp on the L-3 canal. Because Section 2 was off-line the entire water year and STA-6 Cell 5 was off-line for redundant levee removal, the adjusted effective treatment area acreage was reduced to reflect the acreage that was operational (**Table 5-1**).

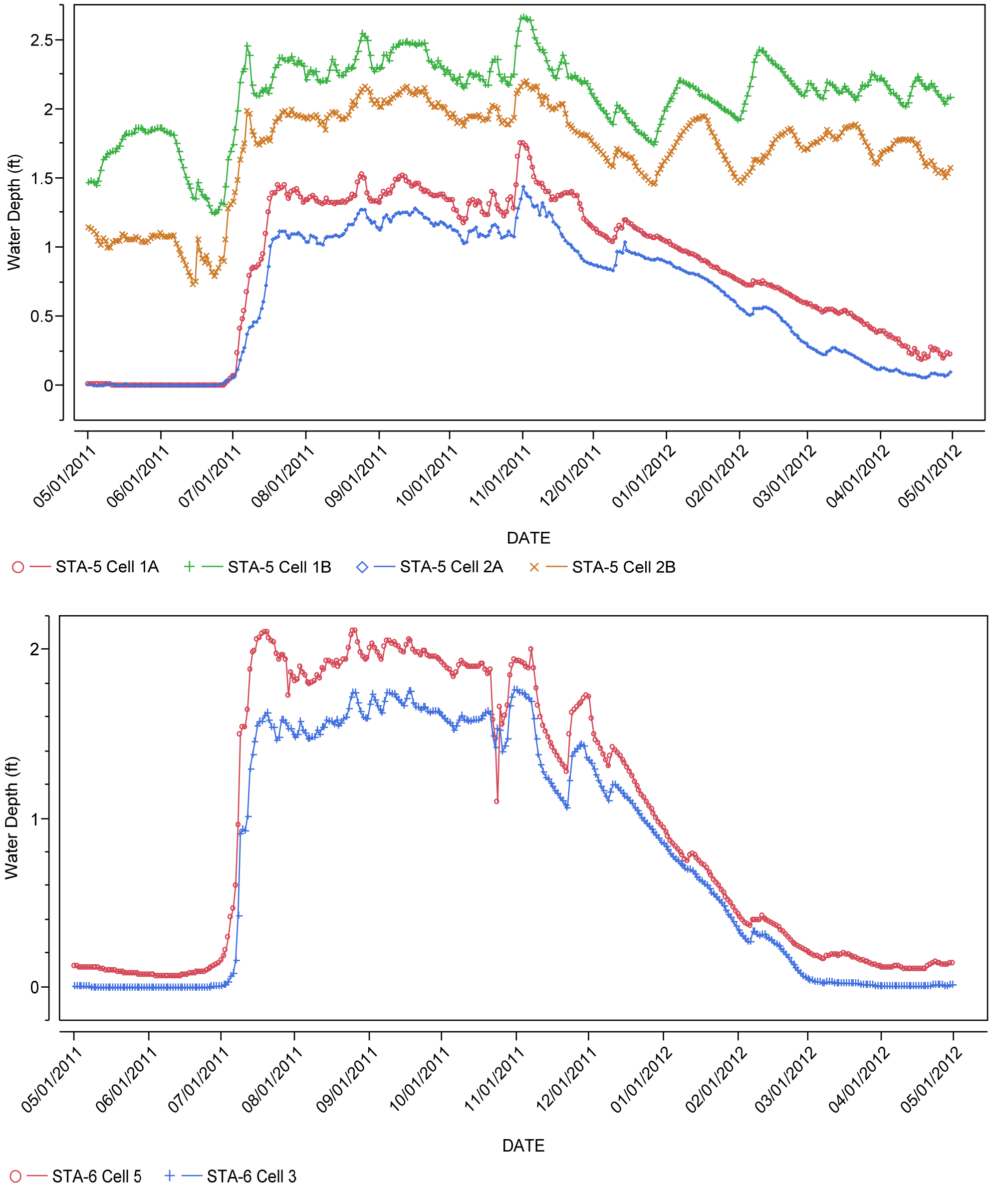


Figure 5-35. Daily average water depths in Cells 1A, 1B, 2A, and 2B of STA-5, and Cells 3 and 5 of STA-6 during WY2012.

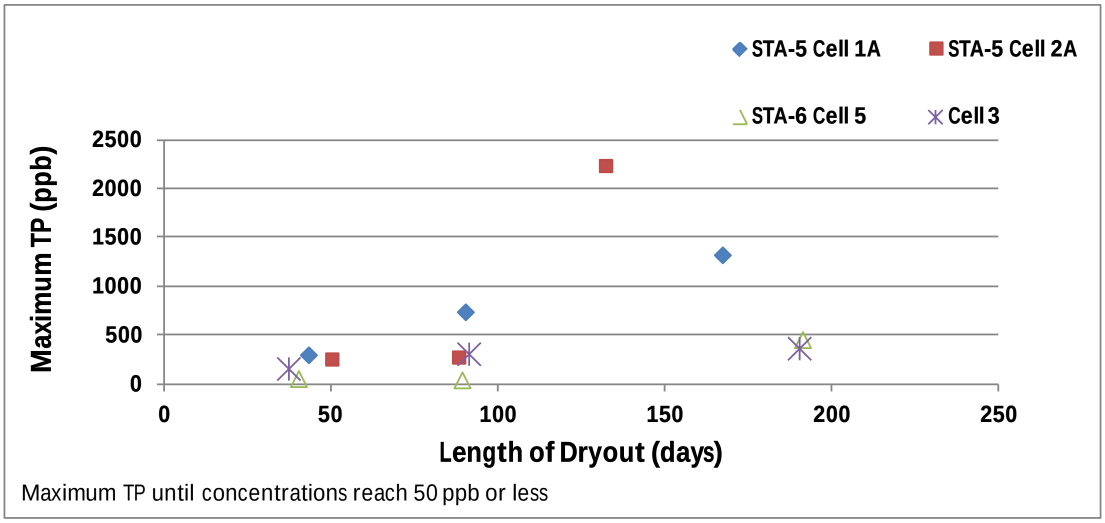


Figure 5-36. Relationship between the length of dryout (water level below ground elevation) and total phosphorus spikes after resumption of flow in STA-5 and STA-6 (period of record).

Drought Impacts

The EAV cells (Cells 1A, 2A, and 3A) as well as Cell 3B dried out during WY2012 drought period (**Figure 5-35**). Approximately 9,827 ac-ft of supplemental water was delivered to STA-5 SAV cells during the drought period was delivered through G-507, G-350B, and G-349B . These two cells were held at the drought contingency stages (6 inches above the normal target stage) during the 2012 dry season. As a result of this combined efforts Cells 1B and 2B remained hydrated during WY2012 drought season. Cells 3A and 3B have been dry for majority of the time since it became operational in 2008; as a result, SAV establishment in Cell 3B has not been successful.

STA-6 was dry from the beginning of May 2011–July 5, 2011, and went online during the week of July 11, 2011 (**Figure 5-35**). The STA began drying out again during the week of January 23, 2012, and Cells 3 and 5 and Section 2 reached dryout conditions of March 26, 2012. The effects of dryout-rehydration cycles in STA-6 have been presented in the 2010 SFER – Volume I, Chapter 5 (Pietro et. al., 2010). An initial evaluation of the dryout period effects on the STAs show that the highest TP concentration spikes (values greater than 50 ppb (POR) in STA-5 and STA-6 were positively correlated with the duration of dryout (**Figure 5-36**). Further analysis is under way to quantify the effects of water depth, hydropattern, and lag time between rehydration and discharge.

Impacts of Migratory Bird and Snail Kite Nesting

Migratory bird nesting did not affect either STA-5 or STA-6 in WY2012. In May 2011, there were a small number of nests in Cells 1A, 2B, and 3A (Appendix 5-4), but STA-5 and STA-6 operations were not impacted due to a lack of flows during the nesting season. Ground nesting was also observed in the Compartment C construction area in May and July 2011 surveys; nests were marked accordingly and construction personnel avoided the nest area until the eggs were hatched. Nests observed in April 2012 were located in non-operational cells (Cells 5A and 5B, and Section 2), so there was no impact to STA operations.

There was one unconfirmed snail kite nest in STA-5 Cell 2B, based on a report from the Hendry County Audubon Society (Appendix 5-4). As a precaution, target stage for this cell was maintained at 13.0 feet, and activities were withheld within a 500 m distance from the potential nest site until May 10, 2012. Fledglings were observed within the area on April 17, 2012.

Compartment C Build-out

The Compartment C Build-out Project is located in Hendry County between existing STA-5 and STA-6 (**Figure 5-1**). The Everglades Forever Act (EFA) permit for construction of the Compartment C Build-out was issued on January 12, 2009; construction activities started in April 2009, and pump station construction began in September 2009. The project was flow-capable as of December 2010 and achieved final completion on September 18, 2011. Construction of the G-508 inflow pump station is scheduled to be complete by September 2012 (**Figure 5-37**). Operation of the Compartment C Build-out Project is dependent on the acquisition of state and federal discharge permits.

Startup activities in Compartment C began in August 2011 when approximately 1,100 acres of primarily Brazilian pepper (*Schinus terebinthifolius*) in the non-effective treatment areas along the western side of the new cells were aerially treated with herbicide. Subsequently, extensive measures were undertaken to prepare the new cells in Compartments C to support the desired wetland vegetation cover to establish the mechanisms for water quality treatment. In October 2011, an aerial herbicide application was used to treat extant trees and shrubs, which covered approximately 1,700 acres of STA-5 Cells 4A and 4B and STA-6 Cell 4. This included primrose willow, which is an invasive exotic shrub that forms dense thickets that can rapidly spread and outcompete herbaceous wetland vegetation, and stands of the native Carolina willow, which appear to have established in depressions in the former agricultural fields and have expanded since these lands have been laid fallow and not subjected to previous levels of active drainage activity. Both the willow and primrose willow have little or no understory cover, and as result do not have the litter- based filtration and phosphorus uptake mechanisms that provide water quality treatment in emergent cells, and similarly preclude growth of the submerged aquatic vegetation and associated periphyton. In addition to the herbicide treatments, ground crews cut the larger shrubs and trees. In STA-5 Cells 4B and 5B, vegetation control was done through airboat-based herbicide treatments of approximately 500 acres of paragrass (*Urochloa mutica*), West Indian marsh grass (*Hymenachne amplexicaulis*), and wild taro (*Colocasia esculenta*) between December 2011 and April 2012. Additional vegetation startup measures are planned for WY2013, including herbicide treatments of tree and shrub cover in Cells 5A and 5B of STA-5, and SAV inoculation in the new SAV-designated treatment cells.

Environmentally Sensitive Areas in Compartment C

The District continues to work with the Seminole Tribe of Florida, the Miccosukee Tribe of Indians of Florida, USACE, and Florida's State Historic Preservation Office toward completion of the permanent protective measures on the environmentally sensitive cultural resource areas in Flow-way 5. The permanent protective measures under construction will ensure that the areas within Compartment C boundaries will be preserved and protected from permanent inundation. Soil material from degradation of a redundant levee in STA-6 (**Figure 5-38**) was brought to the area for berm construction. This construction effort is planned to be completed by October 2012. It is anticipated that rainfall and limited stormwater inflows (depending on water availability) will begin to establish wetland vegetation within Flow-way 5 during the latter part of the 2012 wet season. Flow-way 5 will not be placed into normal operation until the permanent protective measures have been implemented. Once in place, the District will monitor and evaluate operations in a concerted effort to maintain preservation and protection of these areas.

Figure 5-37. Construction of the G-508 pump station in Compartment C, December 2011 (photo by the SFWMD).

Figure 5-38. A portion of a redundant levee in STA-6 between the G-601 and G-602 structures (top photo); approximately 2,800 linear feet of levee was removed (bottom photo) and the spoil material was used in Cell 5A for the environmentally sensitive area protection (photos by the SFWMD).

MAINTENANCE AND ENHANCEMENTS

Routine vegetation management included control of FAV in inflow distribution canals and in outflow collection canals to provide an even distribution of flow across each cell, and to ensure the efficiency of discharge structures. Within the cells, water lettuce and other floating plants such as water hyacinth and frog's bit were routinely treated to promote growth of submerged beds of aquatic vegetation in SAV cells. A summary of herbicide use in the STAs is included in Volume III, Appendix 3-1, Attachment E. Vegetation control activities related to Compartment C cells are discussed under the *Compartment C Build-out* section of this chapter.

In STA-5 Cell 1B, deep gaps in existing vegetation strips along the southernmost region of the cell were plugged with earthen material in June 2011, and giant bulrush was planted over the newly filled gaps in July 2011 (**Figure 5-39**). This is anticipated to remedy observed short-circuiting and help in improving treatment performance in this region of the cell.

In October 2011, approximately 400 acres of cattail in the eastern half of STA-5 Cell 3B were aerially treated with herbicide in an effort to begin an incremental conversion of this area to SAV. Cell 3B is intended to function with dominant cover of submerged aquatic vegetation, but due to hydrologic and hydraulic limitations, this cell has not received the consistent inundation needed to establish and sustain SAV species, and is presently covered with an emergent cattail marsh. The installation of the new G508 pump station is expected to alleviate this hydrologic constraint. Incremental conversion has proven successful in other areas, e.g. STA-3/4 Cell 1B and STA-2 Cell 2, since treatment capability of the cell is retained within the EAV region while the converted area is stabilizing.

Another significant enhancement in STA-5 was the improvement in elevation of the former high pad area just west of Cell 1A, formerly referred to as a non-effective treatment area due to its high elevation. This area was degraded in WY2010 to obtain fill material for a slough area in Cell 1A. As a result, the ground elevation of the high pad area was lowered by approximately one foot and consequently has allowed more flow and more desired wetland vegetation establishment since the modification. Field observations on September 7, 2011, also indicate water levels ranging from 7.4 to 39 inches and good coverage of mixed wetland species, including EAV (e.g. *Sagittaria*, *Pontederia*, *Typha*), SAV, and periphyton. If this area can stay hydrated, along with the remainder of the flow-way, then coverage of desired wetland vegetation species is likely to improve and expand.

Figure 5-39. To alleviate hydraulic short circuiting in the southern region of Cell 1B in STA-5, deep gaps in existing vegetation strips (left photo) were plugged with earthen fill and planted with giant bulrush (right photo) during June-July 2011 (photos by the SFWMD).

VEGETATION SURVEYS

Based on an annual imagery flight, areal vegetative coverage of EAV and SAV+open area is estimated for each STA. Imagery for CY2011 (conducted in May 2011) is presented in this chapter; a comparison with the previous year (conducted in April 2010) is also included (**Table 5-11**; Appendix 5-5). For STA-5, the most significant gains in EAV coverage were observed in Cell 1A and 2B, with 24 and 11 percent gain between CY2011 and CY2012, likely as a result of dry condition. The highest decrease in EAV coverage was in Cell 3A (-11 percent between CY2010 and CY2011). In STA-6, both Cells 3 and 5 gained in EAV coverage, also due to dry conditions. Section 2 (Cell 6-2) of STA-6, which was formerly an SAV cell, had a 20 percent gain in EAV coverage as the cell was dry for Compartment C construction.

Also, based on ground surveys of SAV in STA-5 Cells 1B and 2B on November 2, 2011, *Hydrilla* remains as the dominant SAV within both cells. *Ceratophyllum* was also present in patchy beds throughout the cells, while *Najas* was observed primarily in the northeastern region of Cell 1B (**Figure 5-40)**.

Table 5-11. Summary of vegetation coverage in STA-5/6 based on May 2011 aerial imagery. Numbers shown are expressed as percentage of total cell area.

Cover Category	**STA-5**						**STA-6**		
	Cell 1A	**Cell 1B**	**Cell 2A**	**Cell 2B**	**Cell 3A**	**Cell 3B**	**Section 2**	**Cell 3**	**Cell 5**
% EAV	88	21	91	30	72	91	80	86	97
% SAV+open area	12	79	9	70	28	9	20	14	3
% change in EAV cover (2010–2011)	24	8	5	11	-11	-3	20	3	4

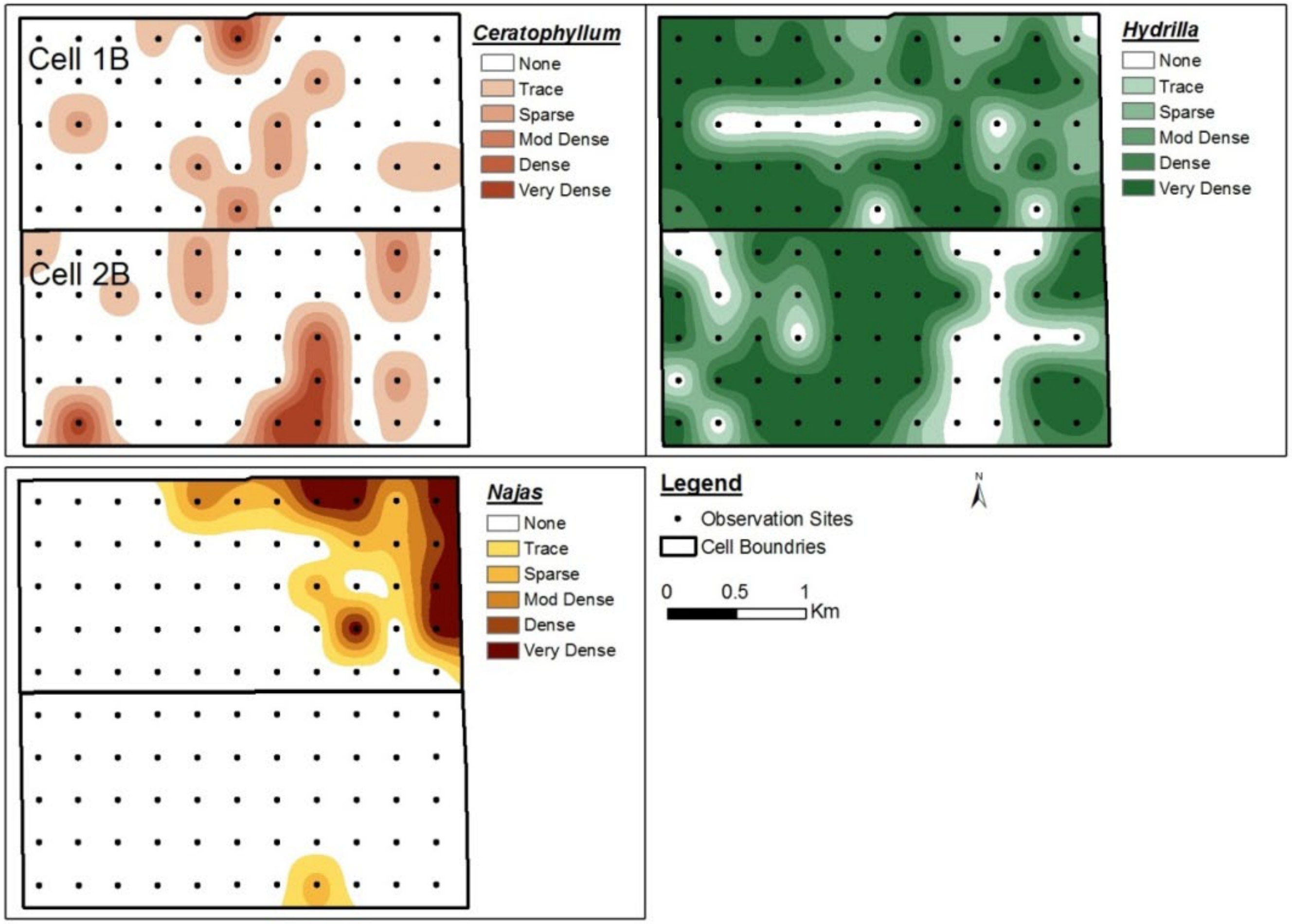


Figure 5-40. Vegetation survey results depicting the spatial coverage of *Najas, Hydrilla,* and *Ceratophyllum* in STA-5 Cells 1B and 2B on November 2, 2011.

APPLIED SCIENTIFIC STUDIES

Due to the complexity of the STAs, the many operational challenges, and the demand to achieve and sustain low TP outflow concentrations, scientific investigations and research are continuing in the STAs. These activities include short-term and long-term studies, mesocosm scale and field-scale studies, as well as analysis of existing data with goals of enhancing our knowledge of the complex treatment systems, the factors affecting performance, and the various TP removal mechanisms. The mesocosm and field-scale studies are conducted to address key issues including (1) understanding and documenting the condition of the STA during the water year reporting period, (2) evaluating proposed and completed enhancements, (3) evaluating impacts of extreme weather condition, (4) investigating failing or poor performance, and (5) finding ways to further improve performance. **Table 5-12** summarizes these studies grouped into two categories according to their primary purpose: monitoring and documenting STA condition, and evaluating ongoing or potential management strategies or technologies. The objectives of some of these studies are discussed earlier in this chapter. Some studies are directly linked to ongoing field implementation of management strategies (e.g., STA-3/4 Cell 1A drawdown evaluation), and some are directly linked to permit requirements such as the research and STA optimization activities described in the Long-Term Plan (e.g., vegetation surveys).

In WY2012, no new research projects were started due to funding limitations, although studies initiated in previous years continued. An extensive multivariate analysis of historical data is also under way, with the primary goal of understanding the factors that control TP removal in the STAs. Preliminary data screening and verification of assumptions for various statistical options have been conducted, including principal component analysis and multi-regression. This effort is continuing and results are expected to be reported in 2014 SFER as the analyses are completed. As indicated in **Table 5-12**, the discussion of findings for many studies are included in this section, while some STA-specific findings are incorporated in the *Vegetation Surveys* or *Maintenance and Enhancements* sections under the individual STA sections of this chapter.

Table 5-12. Summary of applied scientific studies in the STAs during WY2012.

Study	Description and Objective	Finding and Status (as of April 30, 2012)
Purpose: *Evaluate different management strategies to improve treatment performance of the STAs*		
STA-3/4 PSTA Project	This project, which began in WY2007, is a field implementation of PSTA technology aimed at further lowering outflow TP concentrations in STA discharges. The outflow concentrations to date have been promising, but further evaluation of the data will aid in a better understanding of the P removal mechanisms of PSTA technology and allow a more accurate assessment of its performance.	The STA-3/4 PSTA project structures and operations were modified in WY2012 to improve flow data accuracy. A more in-depth scientific evaluation also began in WY2012. Further information on the ongoing scientific investigation is included in this section.
STA-1W Phosphorus Mesocosm	This is a three-year 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 second year for the mesocosm study, the first year being a grow-in period, and a period of adjustment of controls and instrumentations. Initial findings are presented in this section. Data collection is continuing in WY2013.
Potential Water Quality Benefits and Constraints of "Front-end" FAV communities in the STAs	This test cell-scale study, initiated in 2008, and mesocosm-scale study, initiated in 2010, are being performed to document the TP removal effectiveness of floating aquatic vegetation (FAV) as a front-end vegetation for the STAs, as well as to evaluate the influence of herbicide applications to FAV on water quality. Duplicate test cells were maintained with the following vegetation: cattail, cattail + FAV mix, and FAV.	Biweekly water quality sampling for SRP, TP, total soluble P, and pH was conducted at the test cell inflow and outflow until April 2011. Sampling for pH and TP at S-5A facility mesocosms was initiated in February 2011. Data collection continues and findings are planned to be reported in future SFERs.
Purpose: *Document STA condition, success of STA enhancements, impact of extreme events, and trends in treatment performance and other issues of critical importance to the STAs*		
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 in the STAs are 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, and findings are reported annually in the SFER.	Results of the 2011imagery are presented in this chapter (STA Conditions, under each STA subheading). The 2012 imagery is being processed and will be presented in the future. Further analysis of vegetation density index for selected areas in the STA is under way and results will be presented in a future SFER.

Study	Description and Objective	Finding and Status (as of April 30, 2012)
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 in the SFER and as needed for performance-related evaluations.	Results for STA-1E are presented in the chapter. Additional SAV maps are expected to be presented in future SFERs.
STA-3/4 Cell 1A Drawdown Evaluation	Evaluate baseline and post-drawdown condition of vegetation in STA-3/4 Cell 1A, which has been negatively impacted by extended periods of deep water (e.g., greater than 2ft). Results were compared with data from the adjacent cell (Cell 2A), which was not drawn down. Monitoring includes site surveys and vegetation analysis. Results from this study will help in determining if water-level drawdown can be incorporated as a routine management strategy to maintain healthy emergent vegetation in the STAs.	Results to date are discussed in this section. Additional measurements and surveys, including evaluation of biomass and tissue nutrient concentrations, is planned to be done in WY2013.
STA Water Quality Internal Transects Evaluation	Evaluate phosphorus 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.	Data from STA-5 transects are presented in this section. Previous results have also been utilized to help characterize particulate P (PP) transformations in STA-2 Cell 3 (Dierberg and DeBusk, 2008) and as evidence of background P concentrations in SAV-dominated wetlands constructed on previously farmed muck soils (Juston and DeBusk, 2011).
STA-2 Cell 2 Partial SAV Conversion Evaluation	Emergent vegetation in the southern portion of STA-2 Cell 2 was treated with herbicide in April 2009 to allow for conversion of this area to SAV. Several different efforts are linked to this project, including SAV surveys, sampling along water quality transects and water level monitoring.	An update on the SAV establishment in the initial vegetation conversion area is presented in this chapter under individual STA heading, *Maintenance and Enhancements*.
Impacts and Benefits of Dryout on Cattail Communities	This mesocosm-scale study, which was concluded in WY2009, was originally aimed at determining early signs of cattail stress due to dryout conditions because during periods of low rainfall, there are many emergent vegetation cells in the STAs that are prone to dryout. During the course of the study, it appeared that short periods of dryout may be beneficial to cattail health by allowing new growth to occur. Final evaluation of the study includes determining both the impacts and benefits of dryout conditions on cattail growth and survival.	An initial discussion of study results is included in this section.

Study	Description and Objective	Finding and Status (as of April 30, 2012)
Investigation of Factors Influencing SAV Performance and Sustainability in STAs	A better understanding is needed of the individual factors (e.g., water chemistry, soil chemistry, soil physical characteristics, herbivory), and interactions, 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) an investigation on the potential impacts of bird herbivory on SAV communities; (3) a mesocosm study to determine the effects of mixed EAV and SAV communities on water quality and stability of sediment P; and, (4) a large sediment core evaluation study to assess impacts of sediment treatments (dry down, floc removal, etc.) on SAV recruitment and water column turbidity.	SAV surveys were conducted on potential bird herbivory study sites. Exclosures were installed at STA-1E Cell 4S and STA-1W Cell 5B in January 2011. Initial findings indicate that birds were actively feeding in and around the plot areas and that SAV beds exhibited damage caused by grazing. The density of hydrilla and naiad in the exclosures increased relative to the biomass density in the open plots whereas *Chara* exhibited a decline in density in the enclosed plots. Data analysis for this effort continued in WY2012; results are expected to be presented in future SFERs.
Characterization of Hydraulic Resistance of Emergent Macrophytes in STA-2 Cell 2	Many of the emergent macrophyte-dominated STA cells now contain dense vegetation stands, consisting of both living and dead plant material. Under high flow events, hydraulic resistance by the dense vegetation could be contributing to the high water depths in the front-end of many of the STA flow-ways. For this effort, water stage monitoring devices were deployed throughout an EAV cell in 2008 to help characterize internal stage changes as a function of flow rate as well as vegetation community type and condition.	A synopsis of the results from this study is presented in this section. Journal publication on this topic is also in review process.

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

Tracey Piccone, Hongying Zhao, ShiLi Miao, Kevin Grace[1],
Tom DeBusk[1] and Delia Ivanoff

The STA-3/4 Periphyton-based Stormwater Treatment Area (PSTA) Project is a 400-acre project built in 2005 to study and implement field-scale PSTA treatment (**Figure 5-40**). Peat was scraped from the 100-acre PSTA cell to the caprock removing a potential source of TP. Emergent vegetation strips were planted perpendicular to flow to improve the PSTA cell's hydraulic efficiency. The STA-3/4 PSTA Project has been in operation since WY2008 and its performance and operational parameters have been reported in previous annual SFERs.

Over the first four water years (WY2008–WY2011) of operation, the PSTA cell achieved an average annual FWM TP concentration of about 10 ppb. However, over this period, there were various issues with the hydraulic data associated with the PSTA Project. First, there were significant issues with the accuracy of the flow data at all the project's water control structures. Second, the amount of seepage entering the PSTA cell from the surrounding water bodies (i.e., the surrounding PSTA Project cells, STA-3/4 treatment cell, and discharge canal) was not known but was assumed to be quite large as evidenced by higher outflow than inflow volumes. Third, the quality of the seepage water was not known, making it difficult to calculate the TP budget for the PSTA cell. Finally, of the four water years of operation, there was only one year (WY2010) that the PSTA cell was operated year-round, whereas the PSTA cell was operated less than half a year for the other three years. As a result of these various hydrologic and hydraulic issues, interpreting the PSTA cell's strong performance over the first four water years is problematic.

Therefore, in WY2012, various efforts were initiated to improve understanding of the PSTA cell's performance, including structural, monitoring, and operational changes, as well as improvements to data evaluation and research efforts. These efforts will be implemented over the next three water years (WY2013–WY2015) and are planned to be reported in this and future SFERs as information and results become available.

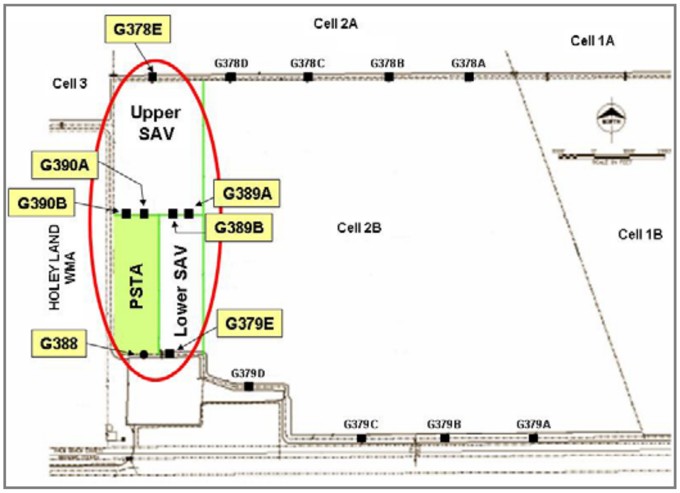


Figure 5-41. Location of Upper and Lower SAV cells, PSTA cell, and related water control structures.

Structural, Monitoring and Operational Improvements

To improve the hydraulic data associated with the PSTA Project and thereby improve understanding of the PSTA cell's performance, various structural, monitoring and operational improvements were initiated in WY2012. In August 2011, the pump speed of Pump #2 in the G-388 PSTA cell outflow pump station was changed from 350 rpm to 224 rpm to reduce the pump on/off frequency. The flow rating equation for Pump #2 was subsequently updated to reflect the decrease in speed and capacity. In October 2011, the PSTA cell inflow culvert G-390B was modified to improve flow measurements (**Figure 5-42**). The inflow cross-sectional area was reduced by inserting a 36" diameter aluminum pipe inside the existing 6-foot by 6-foot concrete box culvert thereby allowing for a higher flow velocity that can be measured with better accuracy. A new rating was developed for G-390B after the structure modification was completed.

Vegetation strip modifications in the PSTA cell were also implemented in late WY2012 through early WY2013 to improve the cell's conveyance capacity; herbicide was applied to six of the twelve vegetation strips and degradation of the treated vegetation was implemented. Efforts are planned to install a headwater sensor at the G-378E culvert to improve inflow estimates for the upper SAV cell and a tail water sensor at the G-379E culvert to improve outflow estimates for the lower SAV cell and thereby improve the water and TP budgets associated with the PSTA Project components. Groundwater levels and water quality data are being collected at the existing monitoring wells located in the PSTA cell levees. The well monitoring information will be used to improve seepage estimates and thereby improve water budget and TP removal performance evaluations for the PSTA cell.

Figure 5-42. Modifications at G-390B (left photo) to improve flow data collection. A 36" diameter aluminum pipe was inserted inside the existing 6-foot by 6-foot concrete box culvert (right photo) (photos by the SFWMD).

Performance Results

As part of ongoing efforts to better understand the PSTA cell's performance, five-year POR (WY2008–WY2012) results are summarized in **Table 5-13**. These data reflect some revisions compared to previous years' SFER reporting of the PSTA cell's performance. Similar to previous reporting, the performance calculations shown in this table take into account the operational period for the PSTA cell, which is defined as the days that one or both of the PSTA cell inflow structures (G-390A and G-390B) were open. Days with no inflow to the PSTA cell as a result of bird nesting, structure maintenance, or to preserve water during drought conditions are excluded from the operational period, and days with no inflow due to normal hydrological conditions are included. From WY2008–WY2012, the operational periods are defined as follows:

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

Compared to previous SFERs, this year's summary includes improved flow data for structures G-390A and G-390B for the period from May 1, 2007–December 31, 2010 based on the water balance analysis conducted by District staff. The summary also utilizes different approaches to calculating the surface water hydraulic loading rate (HLR), the phosphorus loading rate (PLR), the nominal hydraulic residence time (HRT), and the TP settling rate (k). Literature terminology in wetland hydrology is somewhat ambiguous concerning hydrologic variables (Kadlec and Wallace, 2009). The definitions used in this report are specified below.

$$\mathrm{HLR} = \frac{\mathrm{Q_d}}{A} \times 30.48 \qquad (1)$$

$$\mathrm{HRT} = \frac{\mathrm{V}}{\mathrm{Q}} \qquad (2)$$

$$\mathrm{k} = \frac{\frac{(\mathrm{V_{in}}+\mathrm{V_{out}})\times \mathrm{N}}{2}}{\mathrm{A}} \times \left(\left(\frac{\mathrm{C_{in}}-\mathrm{C}^*}{\mathrm{C_{out}}-\mathrm{C}^*}\right)^{\frac{1}{\mathrm{N}}} - 1\right)/3.28 \qquad (3)$$

where:

HLR is the hydraulic loading rate in cm/day;
HRT is the nominal hydraulic residence time in days;
k is the TP settling rate in m/yr;
$Q_d = V/n$, Q_d is the daily flow rate in ac-ft/day during the operational period, n;
V is the average daily volume (ac-ft) in the PSTA cell during the operational period;
Q is the average of the inflow and outflow rates in ac-ft/day during the operational period;
V_{in} is the total inflow volume (ac-ft/yr) to the PSTA cell during the operational period;
V_{out} is the total outflow volume (ac-ft/yr) from the PSTA cell during the operational period, n;
A is the PSTA cell effective treatment area in acres;
N is the number of continuously stirred tanks in series, N = 6 (DB Environmental, Inc., 2009);
C* is the background TP concentration, C* = 4 ppb; 4 ppb of C* was a typical value applied in normal STA design;
C_{in} is the inflow flow weighted mean concentration in ppb;
C_{out} is the outflow flow weighted mean concentration in ppb.

Overall, changes to the PSTA cell's inflow data did not have a major impact on the annual inflow FWM TP concentrations which ranged from 14 to 27 ppb. No major changes were made to the PSTA cell's outflow data, and results continue to show that the PSTA cell consistently yielded annual outflow FWM TP concentrations of 12 ppb or less. In WY2012, the HLR and PLR of 14 cm/day and 0.39 g/m^2/yr, respectively, are almost twice as much as WY2011. Note that in contrast to previous reporting, the surface-water aerial phosphorus loading rates for the PSTA cell's POR data are not presented as a predicted annual loading rate. Utilizing this year's changes to the POR data, the PSTA cell's phosphorus settling rate for WY2012 is 12.5 m/yr and is within the same range as that observed in previous water years.

Table 5-13. Summary of annual operational and performance parameters in the STA-3/4 P STA cell from WY2008–WY2012.

Water Year	Surface-water hydraulic loading rate (cm/d)	Nominal hydraulic residence time HRT (d)	Total surface-water inflow (ac-ft)	Total surface-water outflow (ac-ft)	Surface inflow flow-weighted mean TP (ppb)	Surface outflow flow-weighted mean TP (ppb)	Surface-water areal TP loading ($g/m^2/yr$)	Operation Period (days)	TP settling rate k (m/yr)
WY2008	5.5	4.3	2,919	5,201	27	12	0.24	161	14.2
WY2009	6.2	4.2	3,309	6,105	14	8	0.14	168	13.8
WY2010	13.2	4.5	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

PSTA Project Research Plan

A PSTA Project Research Plan is being implemented to provide more accurate assessment of the PSTA technology performance, to determine design and operational factors that contribute to that performance, and to develop replication options. Specifically, the PSTA Project Research Plan will focus on the following questions:

1. What are the important design elements and biogeochemical characteristics that enable the PSTA cell to achieve ultra-low outflow TP levels?
2. What are the key operational ranges that enable the PSTA cell to achieve ultra-low outflow TP levels?
3. What management practices are required to sustain the PSTA cell's good performance?

The current strategy is to implement the PSTA Research Plan over the next three water years (WY2013–WY2015) and to produce a document summarizing the results of the Research Plan that can be used to design future PSTA cells with the lowest construction and operational costs.

Sub-study: Influence of Soil and Enzyme Activities on Outflow Phosphorus Concentration

Examination of outflow phosphorus speciation in the PSTA cell suggests that ultra-low outflow TP levels are achieved through slight reductions in both particulate phosphorus (PP) and dissolved organic phosphorus (DOP), beyond what appears achievable in SAV communities on previously farmed lands. Reductions in these constituents may be due to activity of phosphatase enzymes produced by microbial communities, and/or due to the presence of a relatively inert (with respect to P release) underlying substrate, such as provided by the limerock base.

Methods

During late 2011 and early 2012, detailed characterizations of water quality and soils in the STA-3/4 PSTA cell were initiated. Sampling was also performed in the outflow region of adjacent cells (2B and 3B) in STA-3/4 that support healthy SAV communities and yield 14-16 ppb outflow TP levels. Water samples were collected along transects within the PSTA cell, at varying distances from the inflow levee, under different flow regimes. Samples from the water column, floating periphyton, and the benthic floc layer were assayed to determine the activity of phosphatase enzymes, which may be important to the breakdown of DOP molecules. Sediment accretion depth was measured spatially within the cell, and sediments will be analyzed for TP, TN, TC, TOC, and Ca contents at a subset of those stations.

A series of soil core studies also were conducted to examine differences in sediment P flux and enzyme activity between the PSTA cell and muck-based treatment cells in STA-3/4. Intact 15 cm diameter cores were retrieved from the PSTA cell, Cell 2B, and Cell 3B. The core sediment depth was approximately 10 cm, with a water column depth of 30 cm. Cores were incubated outdoors, under a shade structure, with water exchanges performed biweekly. Water column TP removal and phosphatase enzyme activity was characterized routinely during the incubations.

Results and Discussion

On December 8, 2011, surface water in the PSTA cell was sampled along internal transects to evaluate the spatial variability of P species and other important constituents. The average inflow rate on the day of sampling was 6 cfs and the mean outflow was 15 cfs, suggesting a range in hydraulic residence times (HRT) of 11 to 4 days. The results of the internal survey indicated highest TP concentrations along the A transect (in the first compartment, between the inflow and the first vegetation strip), and decreasing TP concentrations with distance through the cell

(**Figure 5-43**). Mean surface water TP concentrations were below 10 ppb along the E, G, I, K. and M transects, and at the outflow structure G-388. A reduction of PP between inflow and the mid-point of the cell (G-transect) was apparently responsible for the decrease in TP levels. DOP was the dominant P species exported from the cell.

During mid-January, a sediment depth survey revealed a mean floc (entire accrued layer above either bedrock or remnant peat layer) depth of 9.2 cm, with a range of 3.5–19 cm (**Figure 5-44**). We observed no clear inflow-to-outflow gradient in floc depths: the greatest depth of accrued material was observed adjacent to the cell inflow levee, and also along the western levee.

Sediment core incubations (**Figure 5-45**) demonstrated that outflow region sediments from STA-3-4 Cell 2B exhibited a higher release of TP and DOP as compared to the PSTA cell or Cell 3B outflow region sediments (**Figure 5-46**). Water column phosphatase enzyme activity was highest in the PSTA-sediment treatments (**Figure 5-46**). Additional studies are under way to clarify the relative stability of P forms in the muck and accrued sediments of the PSTA and SAV cells, and to better define the substrates (surficial soils, periphyton, etc) responsible for greatest levels of phosphatase enzyme activity in the PSTA cell. Future efforts also will include algal growth studies to examine periphytic biofilm development in the PSTA and adjacent muck-based SAV treatment cells. The standing crop, nutrient content, growth rates and taxonomic composition of the periphytic biofilms on artificial substrates (glass slides) will be used to examine whether the taxonomy and chemistry of PSTA periphyton differs from that in muck-based cells.

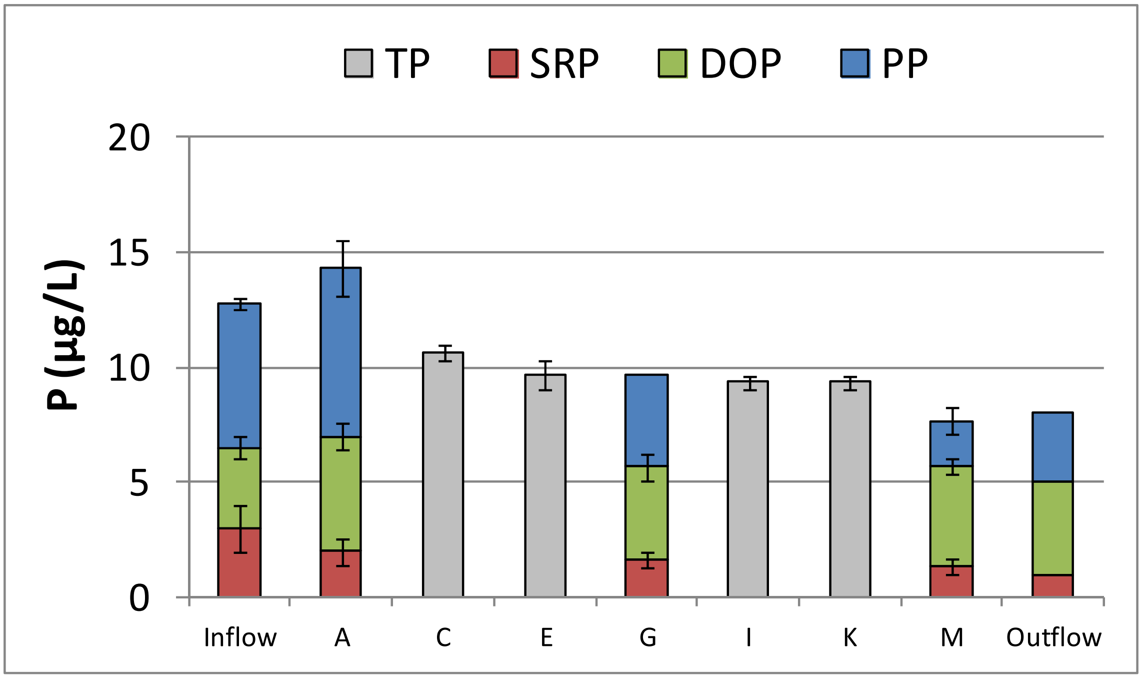


Figure 5-43. PSTA cell water column TP and phosphorus species concentrations during December 2011. Data is depicted for the inflow, outflow and three internal transects. Error bars denote ± SE around the mean of three stations along each internal transect, or two stations at the inflow levee. Outflow values were derived from a single grab sample at the G-388 outflow structure.

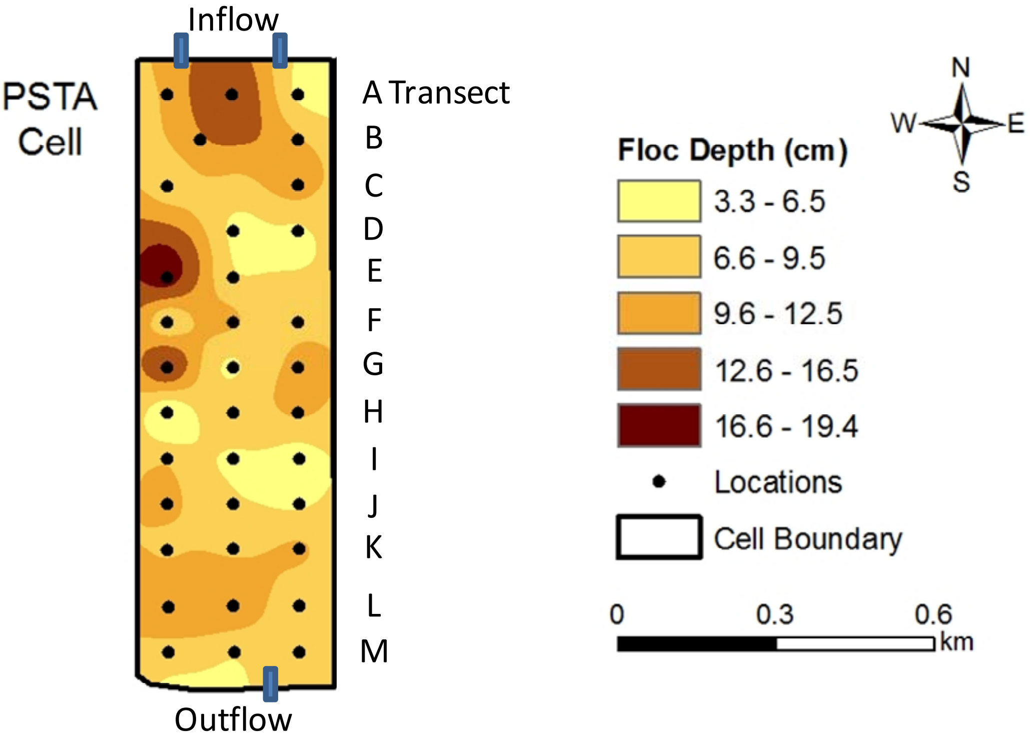


Figure 5-44. Spatial interpolation of floc depth measured at 39 locations within the PSTA cell in STA-3/4 in January 2012.

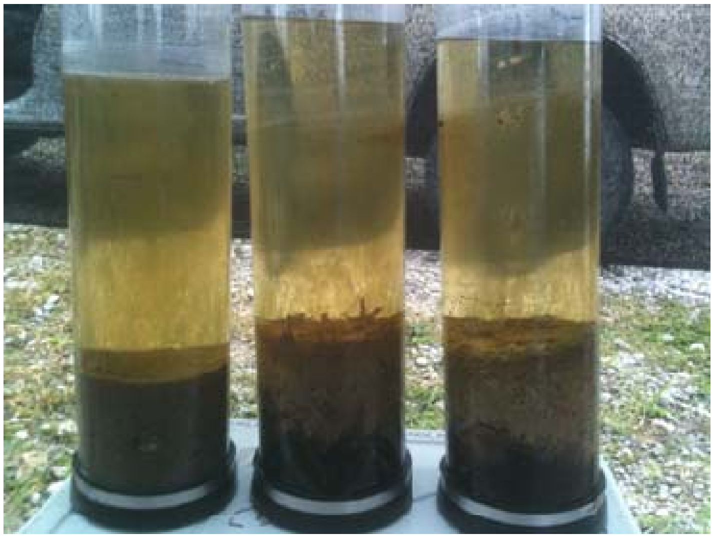


Figure 5-45. Intact sediment cores were used to examine differences in sediment P flux and enzyme activity between the PSTA cell and muck-based treatment cells in STA-3/4. Depicted are cores from the PSTA cell (left), and the adjacent SAV-dominated Cells 2B (middle) and 3B (right) (photo by the SFWMD).

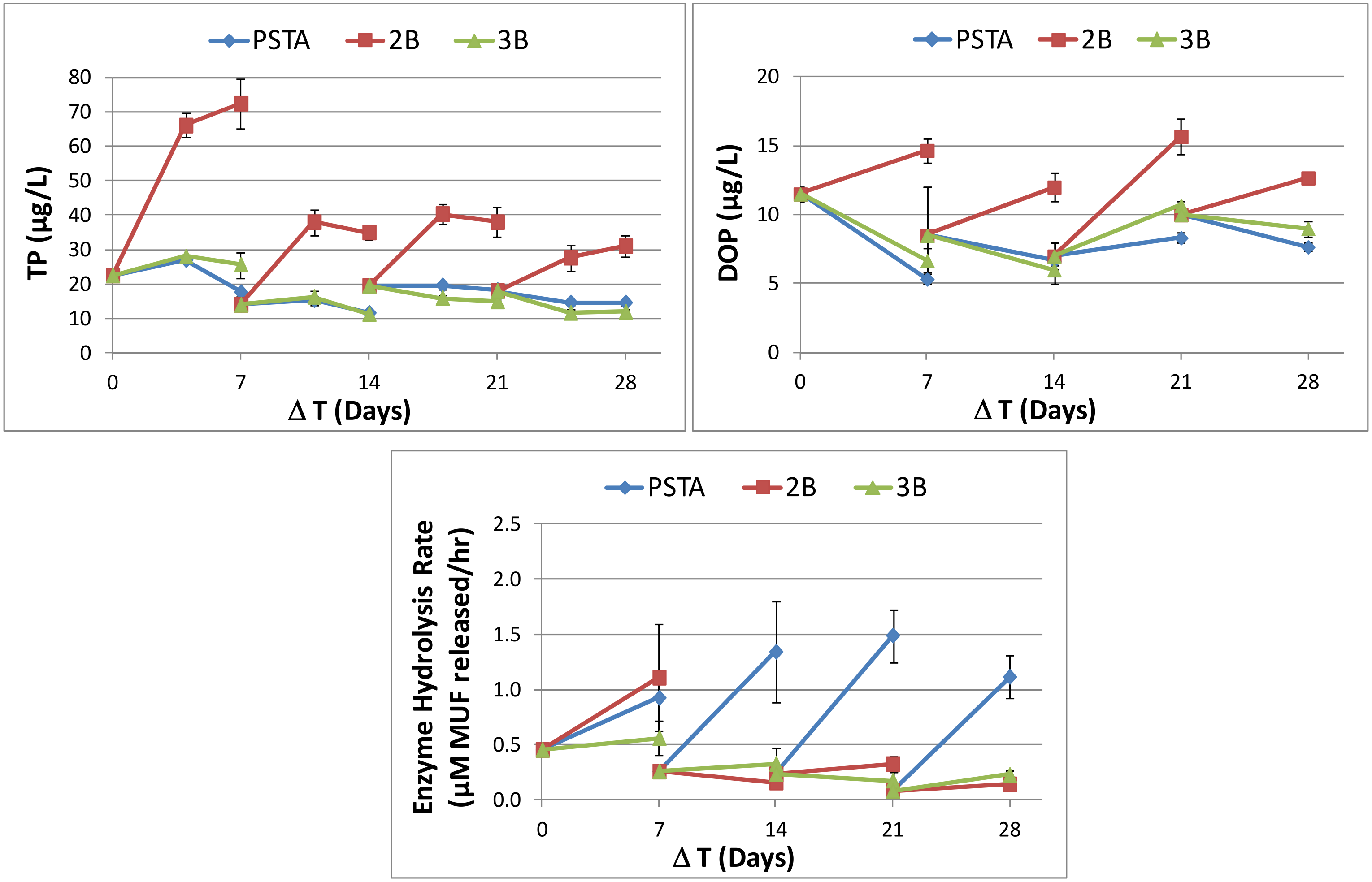


Figure 5-46. TP concentration (top left), dissolved organic phosphorus (DOP) concentration (top right), and alkaline phosphatase (monoesterase) (bottom) activity in the overlying water column from the outflow region of the PSTA cell and STA-3/4 Cells 2B and 3B during outdoor core incubation with no vegetation present. The water column was refreshed with PSTA cell inflow water every 7 days.

STA-1W PHOSPHORUS MESOCOSM STUDY

ShiLi Miao, Chung Nguyen[4],
William Mitsch[4] and Li Zhang[5]

Although the STAs have substantially reduced TP loading to the Everglades over the past decade, the District has a pressing need to find additional technologies to further lower the outflow TP concentration of the STAs. The historical Everglades as well as the current reference areas of the WCAs is oligtrophic and dominated by sawgrass (*Cladium jamaicense*) ridge and water lily (*Nymphaea odorata*) sloughs. The survival mechanisms of these native vegetation types, particularly for P uptake, utilizing, storage, and retention may provide vital information for further P removal and new management strategies to enhance the treatment performance of the STAs. The District initiated a three-year (2010–2013) proof-of-concept mesocosm study in collaboration with the Ohio State University.

Objectives

The key objectives of the study are to assess nutrient removal efficacy of six vegetation types under a very low TP concentration and examine major mechanisms in water, soil and plants underlying TP removal function. It is hypothesized that historical native vegetation treatments, including sawgrass and water lily, may be able to reduce water-column TP concentrations to levels below that of the cattail and SAV treatments.

Methods

The study was established at STA-1W Research Site in late April 2010 using a randomized block design with six vegetation types: (1) sawgrass (*C. jamaicense*), (2) water lily (*N. odorata*) monoculture, (3) water lily and spikerush (*Eleocharis* sp.) mixture, (4) cattail (*Typha domingensis*), (5) SAV (*Najas guadalupensis* and *Chara* sp.), and (6) a control with no vegetation (soil only, but changed to control-SAV treatment about three months later) (**Figure 5-47**). Each vegetation type is replicated three times, resulting in 18 mesocosms. Each mesocosm is a 6 m × 1 m × 1 m fiberglass tank filled with 40 cm of soil previously obtained from STA-1W. All plant materials were obtained from STA-1W. The plants were transplanted in the mesocosms with different densities based on the vegetation treatment. After transplanting, the water depth in each mesocosm was gradually raised to 40 cm. The inflow water to the mesocosms is pumped from a nearby STA-1W outflow canal. About four months after transplanting (by late August 2010), when vegetation in the mesocosms became established, the hydrological loading rate (HLR) in all mesocosms has been maintained at approximately 2.6 cm/d and retention time at about 13-15 days. Briefly, each of the mesocosms received inflow pulse twice (3 am and 3 pm) a day with about 20 gallons each time. Baseline soil and nutrient content were determined at the time of planting. Measurements for water, soil, and plants were started in late August 2010. Water quality has been monitored bi-weekly at the main inflow and at the outflow chamber located at the end of each mesocosm. Water quality parameters measured include TP, DOC, total dissolved Kjeldahl nitrogen (TDKN), and dissolved calcium (Ca^{2+}). All measurements will be completed by December 2012.

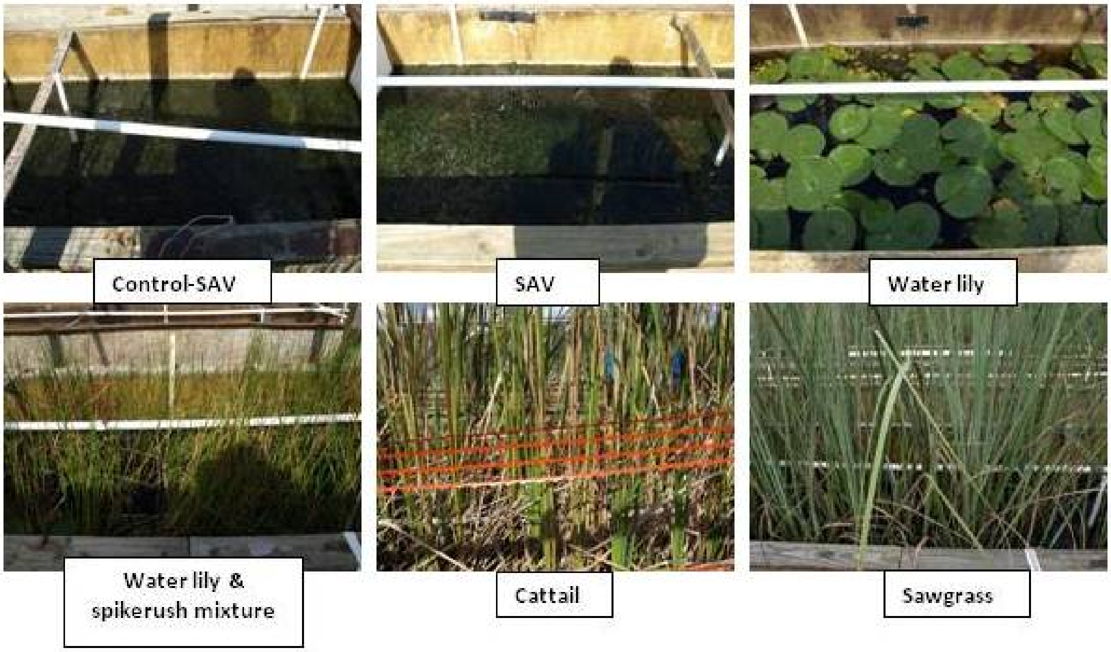


Figure 5-47. Six vegetation types being tested for the STA-1W phosphorus mesocosm study to determine the efficacy of the different species in removing low level P (photos by the SFWMD).

Results and Discussion

Surface water TP (both inflow and outflow) is the primary parameter measured to assess P removal efficacy among the six vegetation treatments. Average inflow TP concentrations were 24.1±6.1 ppb ranging from 13 to 37 ppb during late August 2010 and May 2012 (a period of 20 months). The outflow TP concentrations can be divided into two major different periods, although they varied with the vegetation treatments (**Figure 5-48**). About four months after the initiation of the study, all treatments exhibited markedly higher outflow TP relevant to the inflow, up to three to four times as high. This suggested that soil flux might be affecting the outflow TP concentration during that period regardless of vegetation treatment. Afterwards, the outflow TP concentrations of all the vegetation treatment mesocosms (except for the water lily and spikerush mixture) showed a gradual decrease, but remained higher than the inflow TP. By February 2012, approximately 19 months from start-up, the outflow TP concentrations were similar to the inflow for five of the six treatments. This trend lasted until May 2012. However, the outflow TP concentrations of the water lily and spikerush mixture were exceptional in terms of magnitude and duration of P spike. Starting around December 2010, the outflow TP concentration of this treatment increased to approximately 300 ppb in March 2011, then gradually decreased, but remains higher than inflow almost two years after the study. The extremely high outflow TP concentration and an extended period of such high outflow TP is likely associated with the quick growth and decomposition rates of spikerush.

Results indicate that the seasonal variation in inflow concentration DOC, TDKN, and Ca is not comparable with the observed variation in inflow TP (**Figure 5-49**). The seasonal patterns of inflow DOC and TDKN concentrations were similar with an apparent decrease between March and June 2011 regardless of the vegetation treatments. However, the differences between the inflow and outflow for the two parameters differed. For DOC the outflow concentrations were, in general, greater than the inflow concentrations during the first 14 months after start-up; then they approached the inflow concentration levels. In contrast, for TDKN the outflow concentrations regardless of the vegetation treatments were, in general, lower than the inflow concentrations, except for the three months between March and June 2011. For Ca, differences between the inflow and outflow concentrations varied greatly with the vegetation treatments (**Figure 5-49**). For the two treatments with SAVs (SAV and control-SAV treatments); the outflow Ca concentrations were consistently lower than the inflow concentration. The sawgrass treatment showed an opposite trend; the outflow Ca concentrations were consistently higher at the outflow than at the inflow up to April 2012. Yet, for the other three treatments (water lily, water lily and spikerush mixture, and cattail) the outflow Ca concentrations were similar to the inflow concentrations. Further data collection and analyses are in progress and is planned to continue until WY2013. Results will be presented and discussed as they become available.

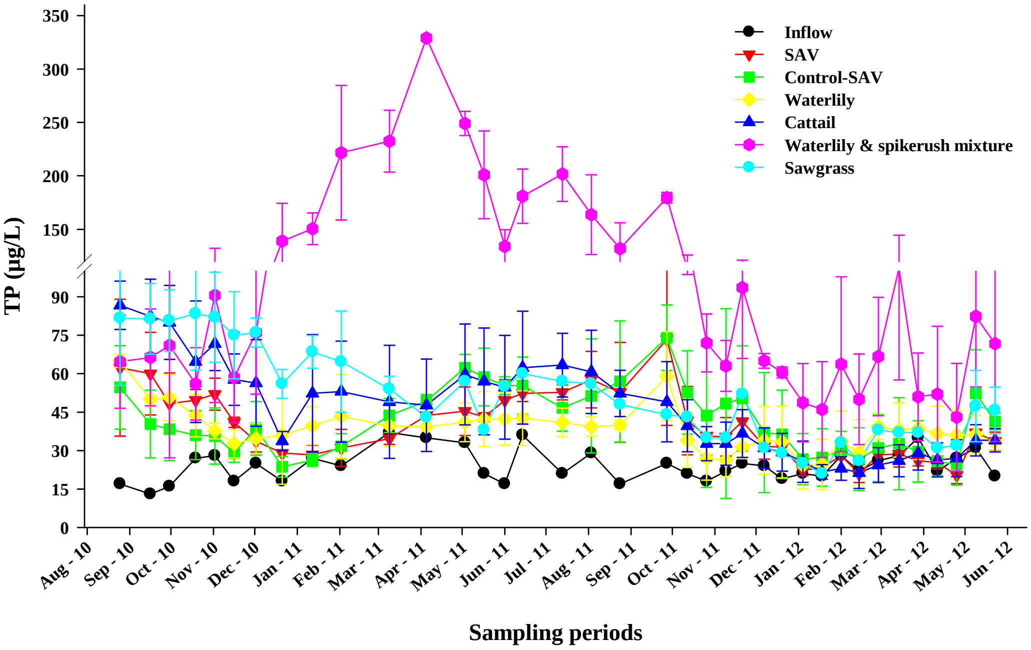


Figure 5-48. Temporal dynamics of surface water TP of inflow and outflow for six vegetation treatments between August 2010 and May 2012.

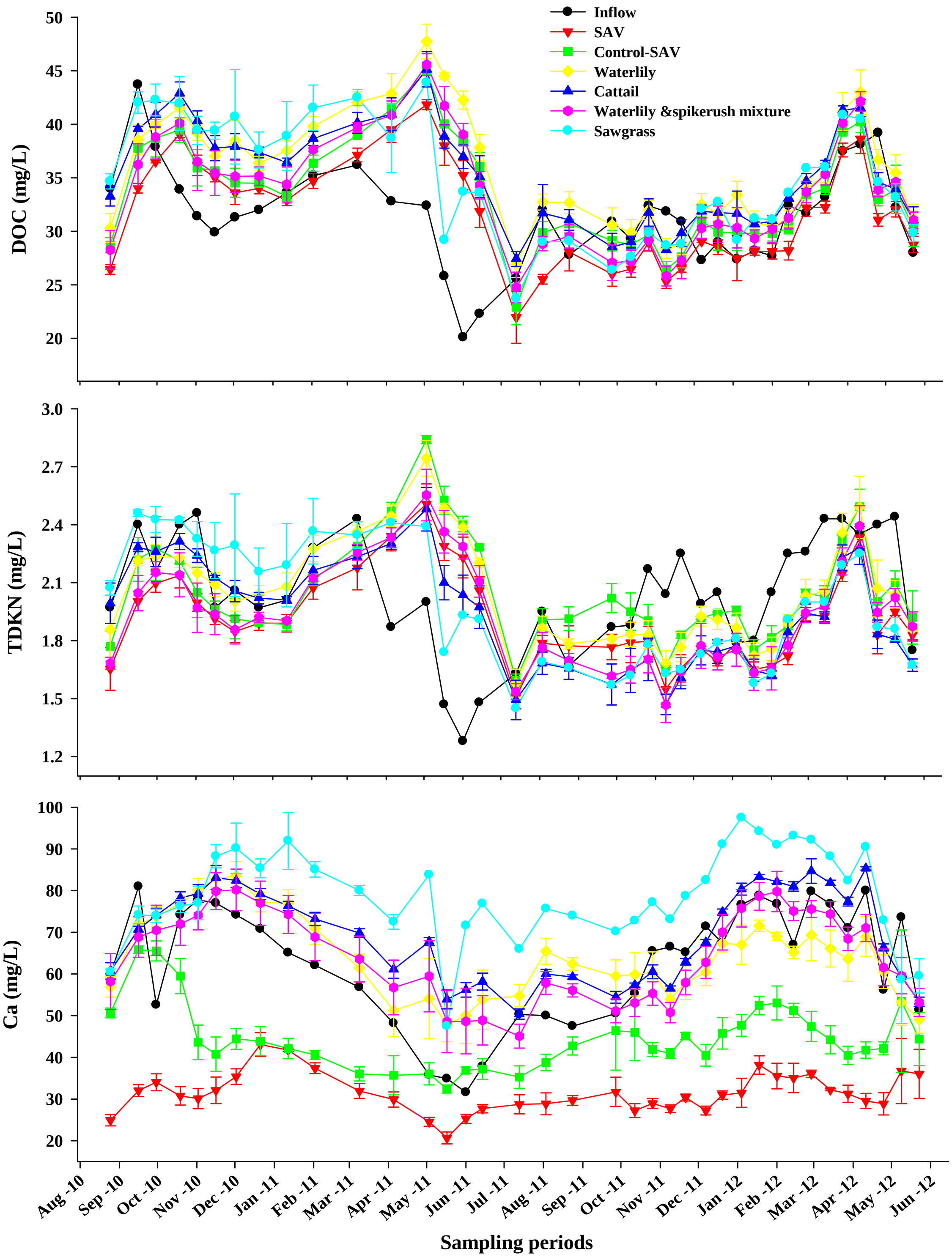


Figure 5-49. Temporal dynamics of TDKN, DOC, and Ca of surface water inflow and outflow for six vegetation treatments between August 2010 and May 2012.

EFFECT OF WATER-LEVEL DRAWDOWN ON CATTAIL COMMUNITIES IN STA-3/4 CELL 1A

Hongjun Chen

Changes in hydrologic regimes in a marsh can have subtle to drastic effects on *T. domingensis* (Grace, 1989; Chen et al., 2010). Cattail species can be eliminated under extended periods of deeper water level conditions (Apfelbaum, 1985; Sojda and Solberg, 1993). Shallow water is an ideal condition for *T. latifolia* germination (Sojda and Solberg, 1993). After *T. latifolia* is established, this species withstands water level fluctuation between 55 and 120 cm for a two-year period, but following 2 years of deepwater condition, about half of the species cannot produce living sprouts and stem densities are 50 percent lower than the previous year (Beule, 1979). Also, extended deepwater conditions can cause the formation of *T. domingensis* floating mats in the STAs (Chen et al., 2010). Apfelbaum (1985) has reported mature *T. latifolia* mortality at water depths of 64 cm. Therefore, maintaining water depths at levels optimal to cattail growth and survival is an important management strategy in the STAs.

Cell 1A of STA-3/4 has been experiencing prolonged periods of deep water conditions since it began operation in 2003 (Pietro et al. 2010). A target water depth has been set at 1.25 feet (38 cm) for EAV treatment cells in the STAs. However, heavy hydraulic loading, particularly during storm events has impacted cattail coverage and density in the northern portion of this cell and the adjoining Cell 2A (Pietro et al. 2010). Water level in this cell was drawn down during the dry season of 2010 and 2011 to encourage new cattail growth and improve overall vegetation condition. The objective of this study was to evaluate if water level drawdown provides significant benefits to cattail communities and make recommendations on whether this practice can be used as a periodic management strategy in the STAs.

Methods

Water-level drawdown events were carried out through the use of temporary pumps in Cell 1A in March 2010 and March 2011, respectively. During the dry season of 2010 and 2011 water levels in this cell were lowered to near ground elevation in an effort to encourage vegetation to re-grow. In 2010, early rainfall occurrence in the last week of May resulted in a short drawdown period with water depths of less than six inches for 17 days. In 2011, the water-level drawdown lasted approximately 110 days (from March 1 to June 23) with water depths of less than six inches for >100 days. As a result of a regional drought and lack of supplemental water, the cell dried out completely (water level below the ground surface) for 63 days in 2011.

Twenty-four plots were established for vegetation-related monitoring in Cell 1A. For comparison purposes, ten plots were randomly selected and established in Cell 2A of STA-3/4 to serve as a reference site because of the similarity in vegetation and hydrology between the two treatment cells. Each plot was 2m×4m and marked with PVC pipes. All plants in each plot were counted according to two categories, juvenile (<1.5 m tall) and adult (>1.5 m tall) in February and July 2010, and February, July, and November 2011. Water depth was measured at the four corners of the plots during the vegetation survey.

Results and Discussion

During the 2010 dry season, there was little change in hydrologic conditions caused by the brief drawdown period in Cell 1A (**Figure 5-50**). The water level was lowered to six inches for about 17 days (from May 12 to May 28). In 2011, the drawdown started on March 1and ended on June 23. During the drawdown period, the cell had a 63-day dry-out (water level below the ground surface). Heavy rainfall events in the basin followed the drawdown period, necessitating the delivery of water into the STA treatment cells and resulting in water depths of 2.4 ft in Cell 1A in a week (June 26 to July 2).

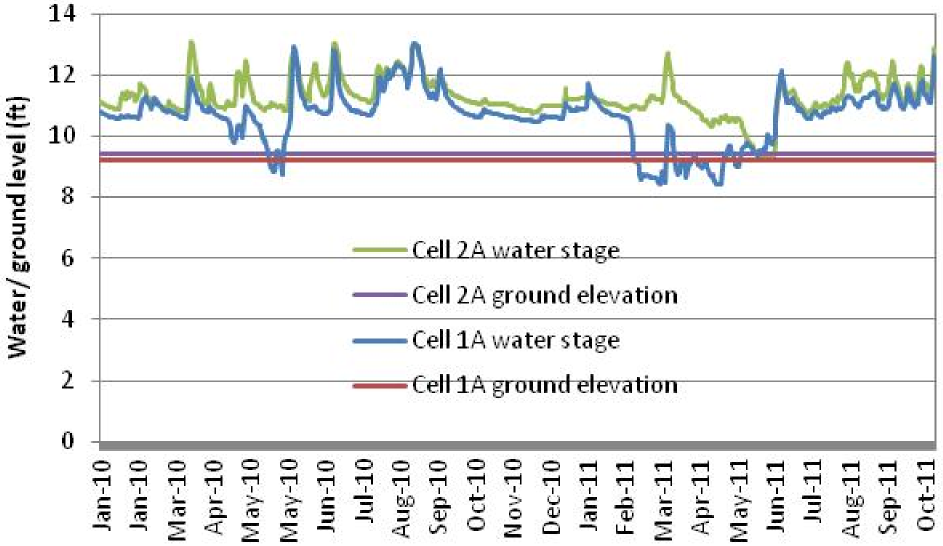


Figure 5-50. Average water stages and ground elevations in STA-3/4 Cells 1A and 2A from January 2010–October 2011.

Due to the short-period drawdown in 2010, the difference in total, adult, and juvenile cattail density between the two treatment cells was not substantial in July 2010 (**Figure 5-51**). In contrast, the difference in total and adult cattail density between the two cells was obvious in July and November 2011, following the second drawdown. However, juvenile cattail density did not reflect changes in hydrologic conditions and was likely not affected by the water-level drawdown but by the season. Also, total cattail density increased in Cell 1A in July and November 2011 compared to the pre-drawdown in February 2010.

Both the field observation (**Figure 5-52**) and quantitative vegetation survey indicated successful recruitment and establishment of cattail seedlings in southern end of Cell 1A following the 2011 drawdown. A short drawdown period such as the 2010 drawdown event did not result in significant improvement in cattail establishment.

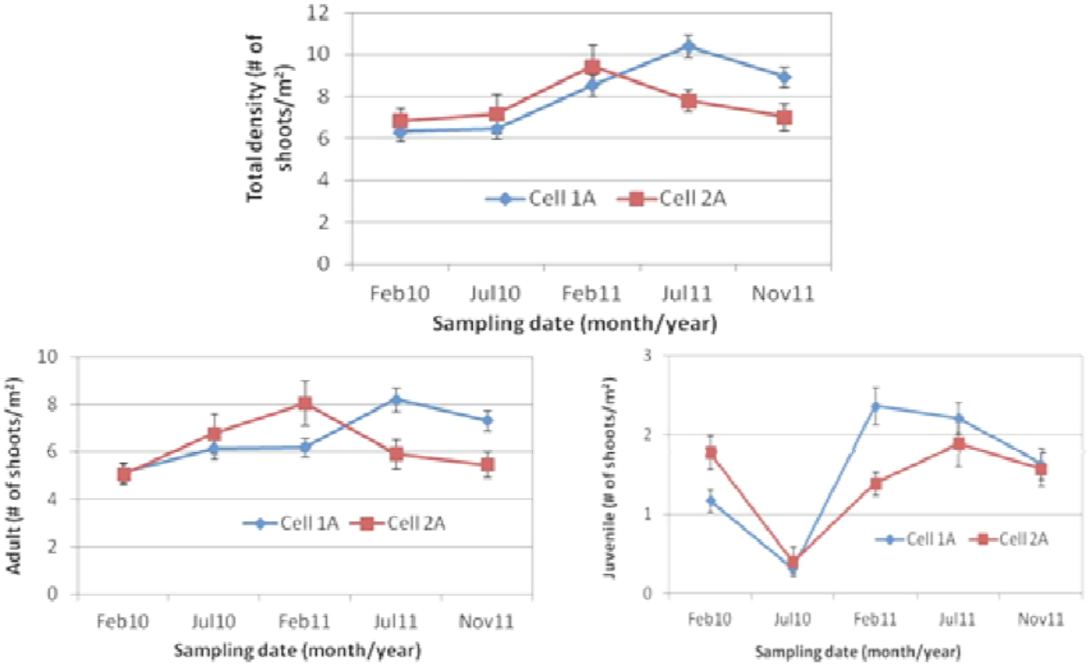


Figure 5-51. Changes in total cattail shoot density, adult cattail density, and juvenile cattail density (mean ± SE) in STA-3/4 Cells 1A and 2A from February 2010–November 2011.

Figure 5-52. Recruitment and establishment of seedlings following water level drawdown in southern Cell 1A of STA-3/4 (upper; July 25, 2011). Pre-drawdown (lower left, February 16, 2010) and post-drawdown (lower right, November 21, 2011) cattail communities in plots of Cell 1A.

COMPARISON OF SOIL CHARACTERISTICS AND PHOSPHORUS STABILITY BETWEEN EMERGENT AND SUBMERGENT AQUATIC VEGETATION CELLS OF STA-2

Delia Ivanoff, Manuel Zamorano and Rupesh Bhomia

Phosphorus reduction in the STAs is carried out by the various physical, chemical, and biological processes such as settling, filtration, oxidation-reduction, adsorption, co-precipitation, and plant uptake. These processes primarily take place at the soil-water-plant roots interface, assisted by microbes in the water column and within the soil layer. STAs exhibit variable treatment performance over time and space, as influenced by factors such as antecedent land use, nutrient and hydraulic loading, vegetation composition and condition, soil type, cell topography, cell size and shape, extreme weather conditions, construction activities and regional operations (Germain and Pietro, 2011). Detailed knowledge of these inter-related factors and linked process could play a key role in finding ways to optimize and sustain STA performance.

STA-2 Cell 1 became operational in WY2002, Cells 2 and 3 in WY2003, and Cell 4 from WY2009 to WY2010. Three of these cells contain areas that were previously not farmed (Cell 1, most of Cell 2, and a small portion of Cell 3) while the remainder of these three cells and Cell 4 were previously under agricultural production. The antecedent soil in this STA is primarily muck. The dominant plant communities in Cells 1 and 2 are cattail with sparse sawgrass. The northwestern portion of Cell 2 is SAV/open water and in 2009, the southernmost portion of Cell 2 was sprayed to allow for establishment of SAV communities. For the purpose of this study, Cells 1 and 2 are designated as EAV cells and Cells 3 and 4 are SAV cells.

The pattern of P accretion and the nature of P forms found in STA soils have a direct implication on the short-term bioavailability and long-term sequestration of P. Improved understanding of the quality and quantity of P pools in accreted soil layer of STAs could help in developing management strategies for optimizing P removal performance. As discussed earlier, there are three primary differences between STA-2 cells, i.e. antecedent land use, dominant vegetation types, and hydrologic pattern. These are hypothesized to influence the characteristics of the soil that affects P accretion and stability in these cells. The objective of this study was to i) compare key soil characteristics and spatial patterns in P distribution between EAV and SAV cells, and ii) determine relative proportion of reactive and stable P pools in floc, recently accreted soil (RAS), and pre-STA soils, as indication of soil P stability.

Methods

Soil Characteristics

Data analysis and evaluation were performed on floc and soil samples from Cells 2 and 3 that were collected in 2009 (**Figure 5-52).** Sampling locations followed a systematic grid design at 1,333' x 1,333'. Intact cores were obtained using a 9.6 cm internal-diameter stainless steel corer, then extruded and sectioned into floc and upper 10 cm soil layers. Floc and soil samples were analyzed for bulk density (BD), ash-free dry weight (AFDW), TP, total nitrogen (TN), total carbon (TC), and total calcium (TCa). Summary statistics were performed for each chemical parameter; values were plotted with means, medians, interquartile ranges, and the 10th and 90th percentiles.

Spatial analysis for TP concentration was also performed on the floc and soil layers using a spline tension interpolation method (Arc GISv9 Spatial Analyst, Environmental Systems Research Institute, Redlands, CA), to include as many observations in the calculation process as possible. Interpolated maps were created to depict any spatial variability in soil characteristics within each cell.

Soil Phosphorus Stability

A total of 27 intact soil cores were collected from May to June 2011 from STA-2 Cells 1, 2, 3, and 4 along transects parallel to water flow direction (**Figure 5-53**). Soil P pools, i.e., inorganic P (Pi), organic P (Po), and residual P, were measured using a sequential chemical fractionation based on the method used by Ivanoff et al. (1998). The procedure involved extraction (1:50 dry sediment-to-solution ratio) with 1 M HCl followed by 0.5M `NaOH. The fraction extracted by HCl is comprised of labile inorganic P and also P that is bound to Ca, Mg, Fe, and Al, while the fraction that was extracted by NaOH represents organic P associated with fulvic and humic fractions. Phosphorus remaining in the sediment after sequential extraction, which is considered non-reactive or stable, was measured by ignition method (Andersen, 1976). Extracts from each of these fractions were analyzed for SRP and TP. Results were compared using Student's t test, assuming equal variances.

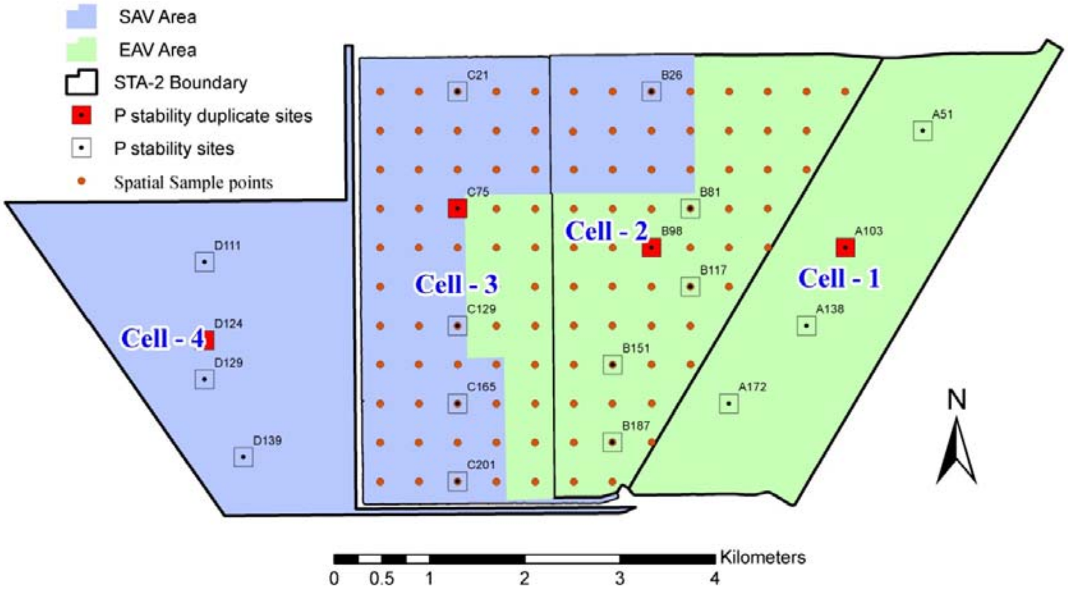


Figure 5-53. Locations of spatial soil sampling in Cells 2 and 3 (top), and for the P stability study in Cells 1-4 of STA-2 (bottom).

Results and Discussion

Bulk Density, Ash-Free Dry Weight, Total Nitrogen, Total Carbon and Total Calcium

Floc and upper soil layer BD in Cell 3 were significantly higher than in Cell 2, primarily as a result of the type of residue that has accreted in these two cells (**Figure 5-54**). Based on the BD, AFDW, and TCa results, Cell 3 has been accreting more mineral matter in the floc layer from SAV decomposition while Cell 2 has been accreting more organic matter in the floc layer from EAV decomposition. There were no differences in AFDW in the soil layer. As an indicator of organic matter (OM) content, AFDW values reflect the properties of the primary source of soil accretion, e.g., areas with larger macrophytes are expected to accrue materials with higher AFDW. In Cell 2, floc AFDW was significantly higher than in Cell 3, while the soil layer showed comparable AFDW results for both cells.

Total carbon and TN were significantly higher in Cell 2 floc than in Cell 3 floc, likely a result of high productivity of the emergent vegetation in Cell 2 compared to SAV in Cell 3. At the soil layer, there was no significant difference in TC concentration while TN was significantly higher in Cell 2 than in Cell 3 soil. Total Ca accrued in the STAs as a result of precipitation, particle settling, and through biomass turnover. Results show a significantly higher floc TCa concentration in Cell 3 than in Cell 2 (**Figure 5-54**). There was no significant difference on soil layer TCa between the two cells.

Total Phosphorus

In both cells, floc TP concentration was significantly higher than soil TP concentration (**Figure 5-55**). Cell 2 floc TP concentration was also much higher than in Cell 3, at 1436±423 and 827±298 mg/kg, respectively. There was no significant difference in TP concentration in the underlying soil layer (490 ± 219 and 484 ± 208 mg/kg in Cells 2 and 3, respectively). Results did not indicate a definitive downstream (inflow to outflow) gradient in floc TP concentration in either of the two cells (**Figure 5-56**). Based on this observation, and the floc depth distribution within these two cells, it is likely that there is some movement of floc material within the cells. Within the upper 10 cm soil layer, results show generally higher concentrations of TP in the upper than the lower region of Cell 2 (**Figure 5-57**). This pattern was not observed in Cell 3, where there was no distinct downstream gradient on soil TP concentration.

Cell 3 floc and soil P storage (3.39± 2.51 and 10.35 ± 4.1 g/m^2, respectively) were higher than those found in Cell 2 floc and soil (8.97 ± 6.49 and 14.84 ± 7.01 g/m^2, respectively) (**Figure 5-55**). Generally, P storage is higher in the soil layer than in the floc layer. These values are calculated based on bulk density, hence, the higher values P storage was found in Cell 3 (with predominantly mineral soil) than in Cell 2. Also higher P storage was found in the consolidated soil than in the floc layers of both cells.

Reactive and Stable Phosphorus Pools

Within the floc layer, Po concentration was significantly higher in EAV than in SAV cell ($p<0.001$); corespondingly, Pi was higher in the SAV cell floc than in the EAV cell floc layer (**Table 5-14**). Within the RAS layer, Pi was also significantly higher in SAV cells, while in pre-STA soil layer, Pi, Po and residual P concentrations were significantly higher in SAV than in EAV cells (**Table 5-14**).

The relative size of Pi and Po pools (percentage of soil TP) differs between the EAV (Cells 1 and 2) and the SAV cells (Cells 3 and 4) at the floc, RAS, and pre-STA soil layers (**Figure 5-58**). In all cases, reactive P pool is much larger than the stable P pool. Within the floc layer, 71 percent of the EAV cell (Cells 1 and 2) soil TP was in reactive form, which was slightly greater than the reactive P pool found in the SAV cells (Cells 3 and 4) with 66 percent reactive P. At the RAS layer, the proportions of reactive and labile fractions are comparable between the EAV and SAV cells, with 64 and 67 percent of TP, respectively, as reactive and the remaining fraction as stable P. In the EAV cells, the higher percentage of residual (stable) P in the RAS (29 percent of soil TP) than in the floc layer (36 percent of soil TP) indicates potential stabilization of the reactive Po fraction into residual P forms, likely accelerated as a result of periodic dryout of these cells. This trend was not observed in SAV cells, which have not experienced dryout prior to this study. Within the pre-STA soil layer, the stable P fraction is much higher in the EAV cells (32 percent of soil TP) than in SAV cells (17 percent of soil TP).

Table 5-14. Phosphorus fractions (Pi, Po, and residual P) in floc, RAS and pre-STA soil for EAV and SAV cells of STA-2. Concentration values are means ±SD in mg/kg; values in parenthesis represent the number of samples.

P Fraction	Floc			RAS			Pre-STA		
	EAV	SAV	P-value	EAV	SAV	P-value	EAV	SAV	P-value
Pi	258±115 (14)	359±198 (7)	0.178	65±54 (14)	200±109 (13)	0.001	30±28 (14)	102±72 (13)	0.002
Po	521±189 (14)	145±47 (7)	<0.001	182±53 (14)	209±124 (13)	0.470	104±35 (14)	162±51 (13)	0.002
Residual P	241±70 (14)	220±37 (7)	0.481	147±47 (14)	193±100 (13)	0.141	71±32 (14)	110±39 (13)	0.012

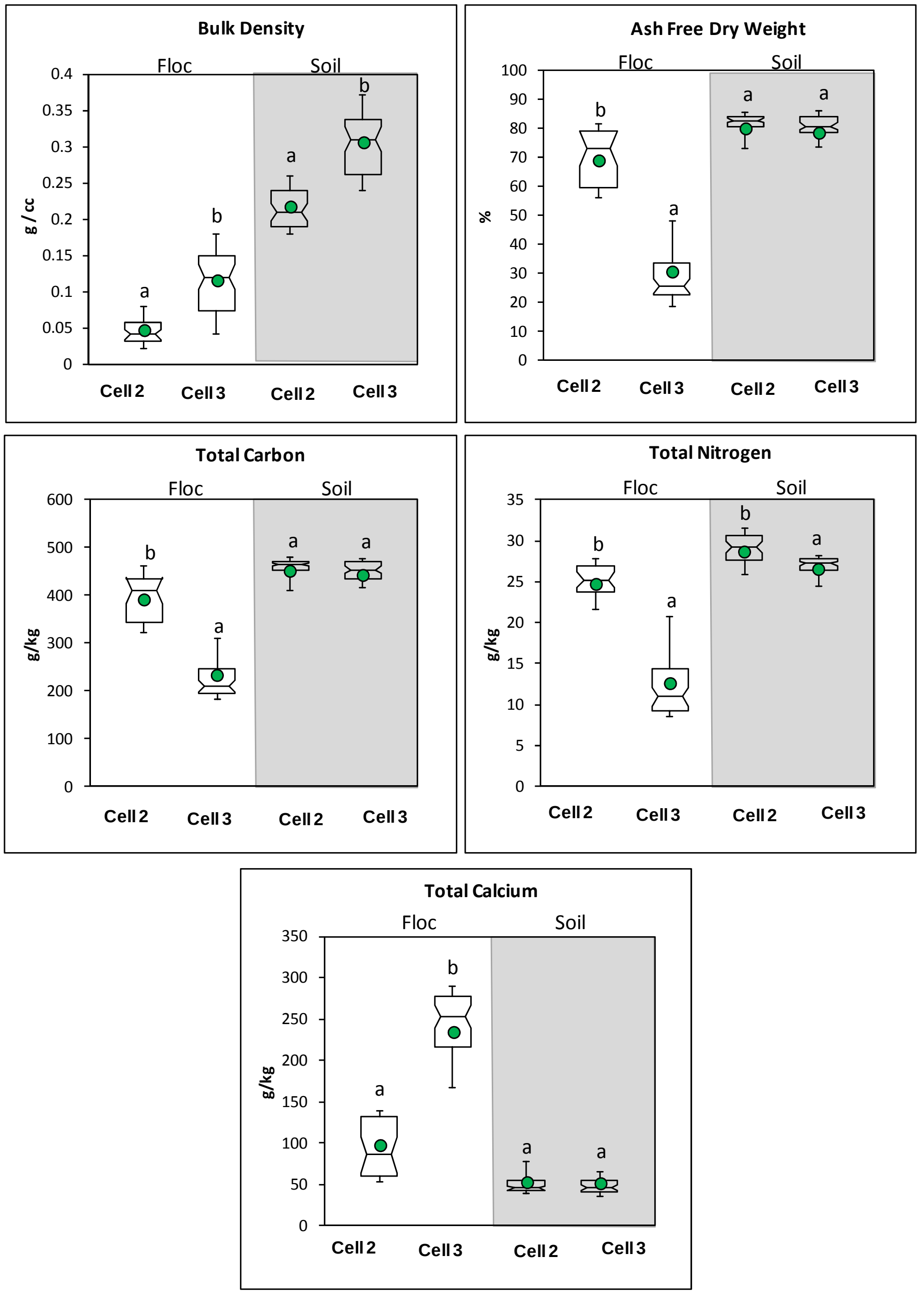


Figure 5-54. Comparison of bulk density, ash-free dry weight, total carbon, total nitrogen, and total calcium between Cell 2 and Cell 3 floc and upper 10 cm soil layers. The letters (a, b) represent significance of difference in results between Cell 2 and Cell 3 for each of the layers; difference in letters denotes significant difference.

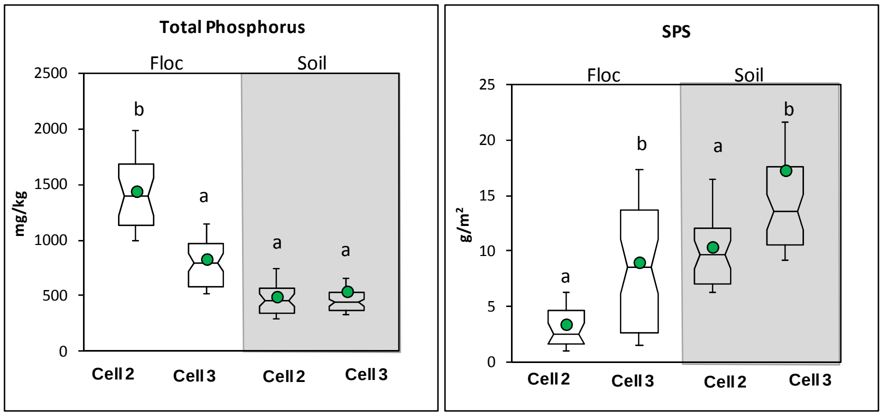


Figure 5-55. Comparison of total phosphorus concentration and soil P storage between Cell 2 and Cell 3 floc and upper 10 cm soil layers. The letters (a, b) represent significance of difference in results between Cell 2 and Cell 3 for each of the layers; difference in letters denotes significant difference.

The SAV and EAV cells of STA-2 did not differ significantly in relative proportion of reactive and stable P pools (**Figure 5-58**). Reactive P constituted a major pool of TP in floc and RAS sections of EAV cells and SAV cells, respectively. Floc and RAS sections of EAV cells showed higher organic P fractions (48 and 47 percent of TP, respectively) compared to SAV (19 and 34 percent of TP, respectively). Data suggests that approximately 35 percent of soil TP is in stable form, whereas 65 percent is potentially available over a range of soil accretion time scales. Floc, RAS, and pre-STA soil showed some difference in P pools, but no significant difference were observed between reactive and non-reactive pools. Accretion of Ca-rich marl layer in SAV cells suggest Ca-P co-precipitation as a major P removal mechanism. Organic P pool is subject to mineralization in EAV cells particularly during periods of dry out, and therefore could potentially contribute to internal P loading in the STAs.

Conclusions and Recommendations

There are differences in the basic characteristics of floc and accrued soil layer between STA-2 Cell 2 and Cell 3. Data confirms that emergent vegetation accrues soils that have higher organic matter content, while SAV results in accrual of mineral soil with high Ca content. Floc, which is the most recently deposited material, has lower BD than consolidated soil layer. A downstream gradient was evident in the upper 10 cm soil layer in Cell 2, indicating higher P retention in the upper region of the cell. Floc layer TP concentration was significantly higher in Cell 2 than in Cell 3, while there were no significant differences in TP concentration in the underlying soil layers between the two cells. Soil P storage shows the opposite trend, i.e., Cell 3 floc and soil had significantly higher TP storage than Cell 2 floc and soil layers.

Reactive P pools comprise more than 60 percent of soil TP in STA-2, with significantly higher fraction in the floc layer, indicating a large pool of P that could be potentially released into the overlying water column. The biogeochemical turnover of P is dependent upon various environmental conditions and processes. For example, highly organic sediment accreted in EAV cells, containing a higher proportion of Po, is subject to oxidation during dryout. When re-flooded, mineralized P is released back into the water column, resulting in P spikes. These cells should be managed in such a way that they can stay hydrated when possible, or if extended dryout occurs, discharge from the affected cells should be delayed until fluxed P can be re-absorbed by the system. Mining of P through plant root uptake from the soil porewater may also be a concern, as vegetation turnover could expedite transport and release of P from the underlying soil column into the overlying water column. Further research is needed to identify means to promote retention of more stable pools of P, and to determine the differences in the form of P (SRP, PP, or organic P) fluxed into the water column between the two cell types.

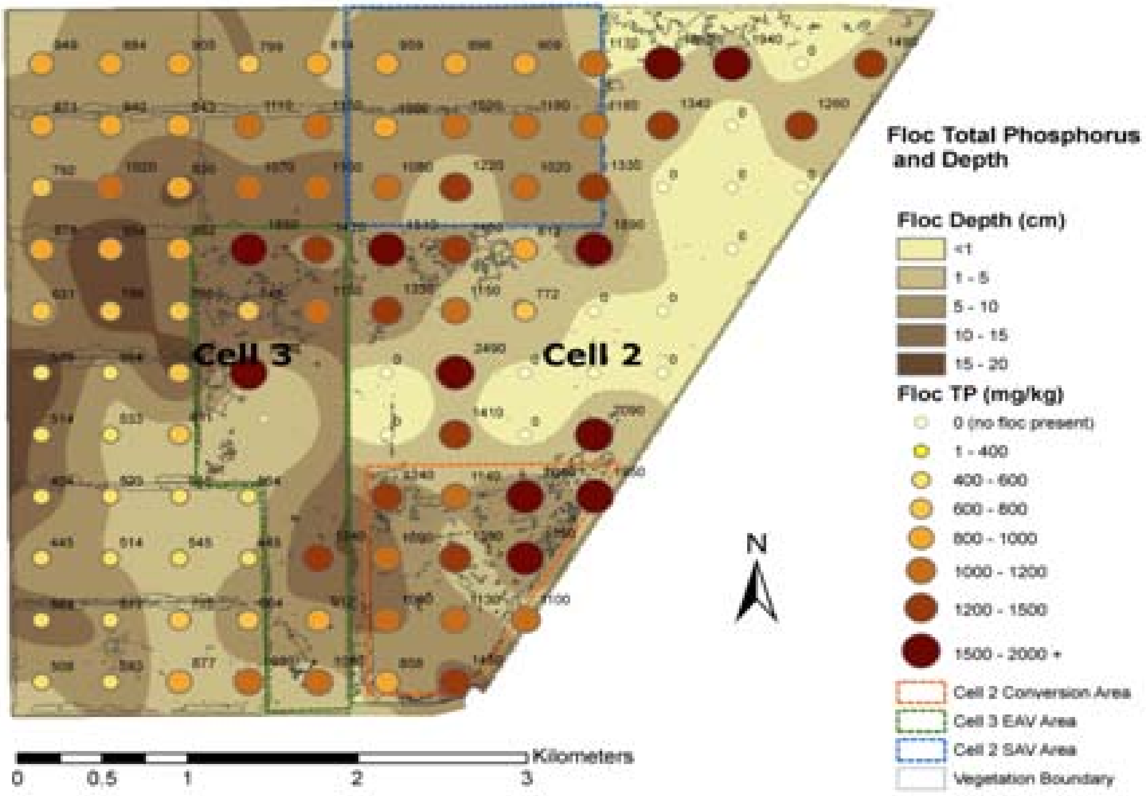


Figure 5-56. Spatial distribution of total phosphorus in the floc layer in STA-2 Cells 2 and 3 based on 2009 soil sampling event.

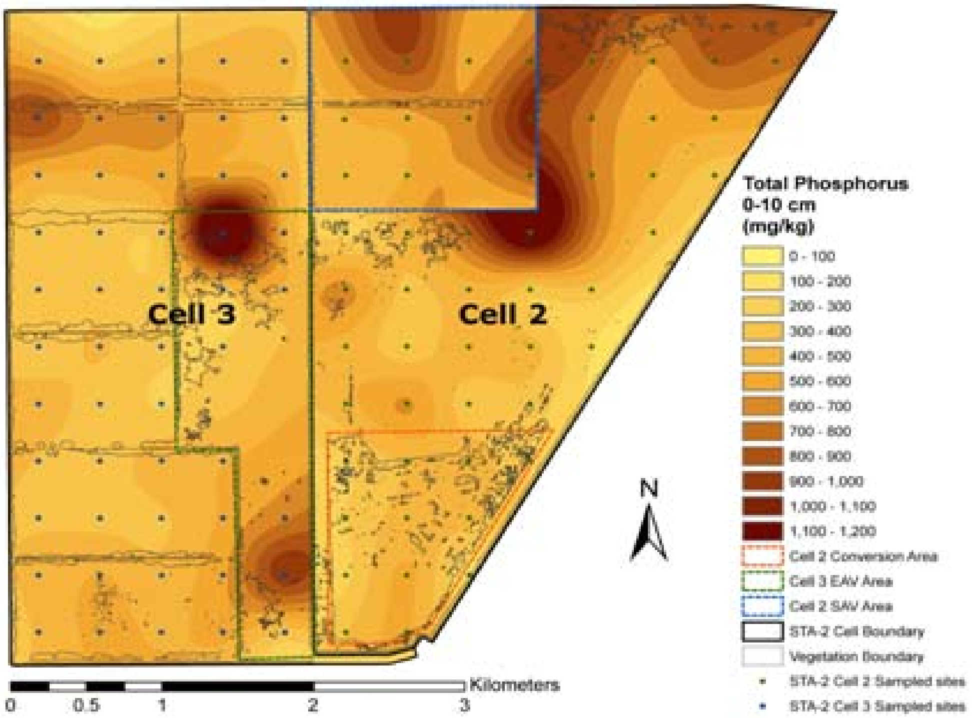


Figure 5-57. Spatial distribution of total phosphorus in the upper 10 cm soil layer in STA-2 Cells 2 and 3 based on 2009 soil sampling event.

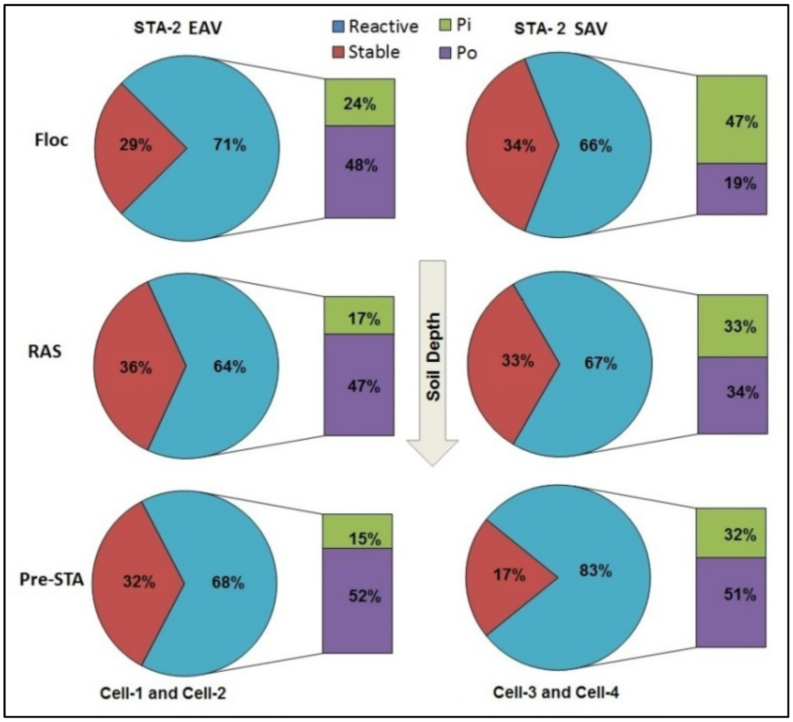


Figure 5-58. Non-reactive and reactive phosphorus pools (percent) in EAV and SAV cells in floc, recently accreted soil (RAS), and pre-STA soils of STA-2. Reactive fraction is the sum of extractable inorganic P (Pi) and organic P (Po).

SPATIAL PATTERNS IN SOIL NUTRIENT RELEASE AND VEGETATION COVER CHANGES IN RESPONSE TO STA DRYOUT

Tom DeBusk[1] and Michelle Kharbanda[1]

STAs periodically experience dryout events as a result of drought conditions or management related activities. Upon re-flooding, P stored in the soils can be re-mobilized into the water column and released into downstream canals and/or wetlands. Several factors can potentially affect P release from STA soils. These include, but are not limited to, the degree of prior sediment enrichment, hydrologic pattern (i.e. continuously flooded versus periodic dryout), forms and concentrations of P in soil, minerals, inflow water chemistry, oxidation-reduction potential (Eh), vegetation conditions, and management activities. In SAV cells, dryout events can also have adverse effects on the vegetation and may further exacerbate nutrient release, and potentially alter the community characteristics following rehydration.

The central flow-way of STA-3/4 experienced a dryout during the 2011 drought. Stage levels were below the mean ground elevation for 23 days (6/3–6/25/11). Upon re-flooding, elevated outflow TP concentrations were observed for over one month. We compared constituent concentrations in surface waters and porewaters collected within the wetland before and after the dryout event. In addition, SAV cover in the back-end cell of the flow-way was monitored to record the impacts of dryout, as well as the temporal and spatial patterns in SAV reestablishment. These data can provide insight into the impacts of dryout on STA performance (magnitude and duration of P export) and sustainability (recovery and long-term impacts).

Methods

The STA-3/4 central flow-way is comprised of two cells in-series: Cell 2A (EAV) and Cell 2B (SAV) (**Figure 5-59**). SAV cover in Cell 2B was monitored using a semi-qualitative technique in which vegetation species and relative density were visually surveyed. Vegetation monitoring was conducted at 123 stations before (8/12/10) and after (7/6, 7/20, and 8/9/11) the dryout-reflood event. Data were analyzed with ESRI's ArcView Spatial Analyst using the spline/tension method.

In December 2009, four monitoring transects, one in the inflow and outflow regions of Cells 2A and 2B, were established (**Figure 5-59**). Porewater and surface water samples were collected at three stations along each transect. Surface water was also collected at one of the five culverts at each of the three levees. Surface waters were analyzed for TP, SRP, ammonia-N, and other constituents. Soil porewaters were collected using a 'sipper' at a depth of 6–10 cm below the surface water/soil interface, and were analyzed for a similar suite of parameters, along with redox potential (Eh). Porewater and surface water sampling was performed on 12/3/09 under low flow conditions, and again under similar flow conditions following the dryout subsequent rehydration event, on 6/30/11.

Results and Discussion

Vegetation Effects

The SAV community in Cell 2B was markedly affected by the dryout. During the preceding year, the wetland was dominated by *Najas* and secondarily by *Chara* (**Figure 5-60**). Upon re-flooding, a sharp decline in cover and density of both species was observed. A rapid expansion of SAV was observed in subsequent surveys during the weeks following re-flooding. By 8/9/11, *Najas* populations remained relatively sparse, whereas *Chara* was observed in moderate densities throughout the cell (**Figure 5-60**). Visual assessments of the SAV in early 2012 confirmed that *Chara* has remained the dominant SAV species since the dryout event.

Water Quality Effects

Following the 23-day dryout period, re-flooding of the STA-3/4 central flow-way began on 6/26/11 and wetland discharges began four days later, on 6/30/11. Surface water TP concentrations on 6/30/11 were extremely high in the outflow region (transect E) of Cell 2B, suggesting TP export (**Figure 5-61**). A broader spatial distribution of high concentrations was observed for ammonia-N, which exhibited elevated levels from Cell 2A, through the entire length of Cell 2B. A prior water quality sampling effort performed on 12/3/09 under low flow conditions depicted little internal loading of either TP or ammonia-N (**Figure 5-61**). Outflow TP concentrations from Cell 2B declined to below 20 ppb (pre-dryout levels) by 8/29/11, which appeared to coincide with the successful regeneration of SAV within the wetland (**Figure 5-61**).

Porewater data collected on 6/30/11 were averaged along each transect to examine SRP, ammonia-N, and Eh gradient profiles. Porewater SRP concentrations varied temporally in a manner similar to ammonia-N, with Cell 2A transect E and Cell 2B transect B exhibiting substantial concentration increases immediately following rehydration (**Figure 5-62**). The similarity in pattern of porewater ammonia-N and SRP, along with the increased Eh at three of the four transects following re-flooding (**Figure 5-62**), suggests that organic matter decomposition and oxidation during the dryout may have contributed to the observed nutrient load to the water column.

In conclusion, the STA-3/4 dryout/re-flood event resulted in a dramatic change in the SAV community from a *Najas* and *Chara* co-dominated to a *Chara* dominated system. Continued monitoring in WY 2013 will be performed. Surface water and porewater sampling suggests a broad spatial internal loading of ammonia-N but a more localized internal loading of SRP (primarily at the outflow region of 2B) as a result of dryout-re-flooding. Data and observations show that both the massive loss of SAV and soil organic matter decomposition contributed to a spike in internal loading in Cell 2B following a 23-day dryout period.

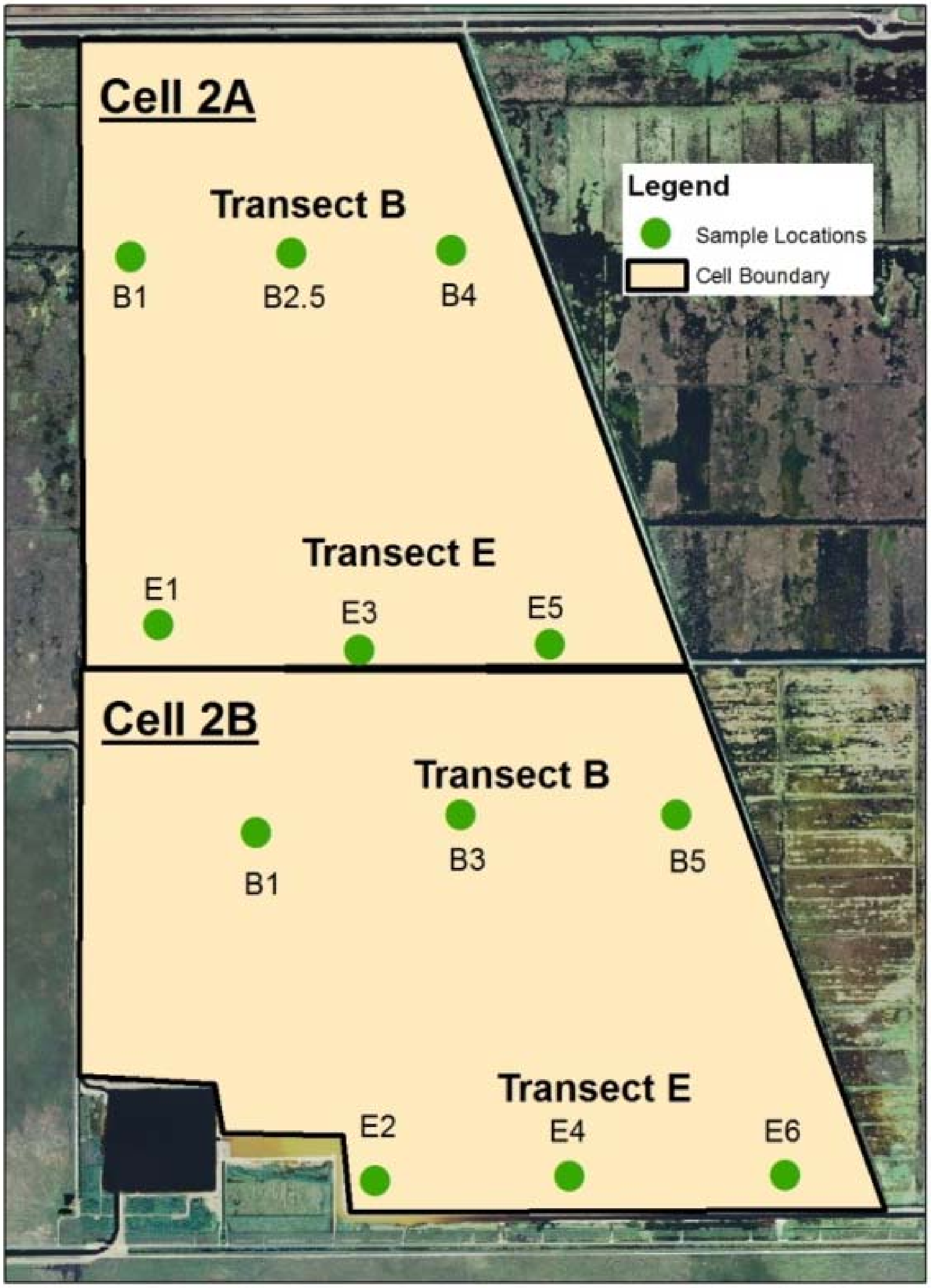


Figure 5-59. Location of internal water quality sampling stations within STA-3/4 Cells 2A and 2B. Transects are identified alphabetically along the north-to-south flow-way. Surface water samples were also collected at one of the five culverts at each levee.

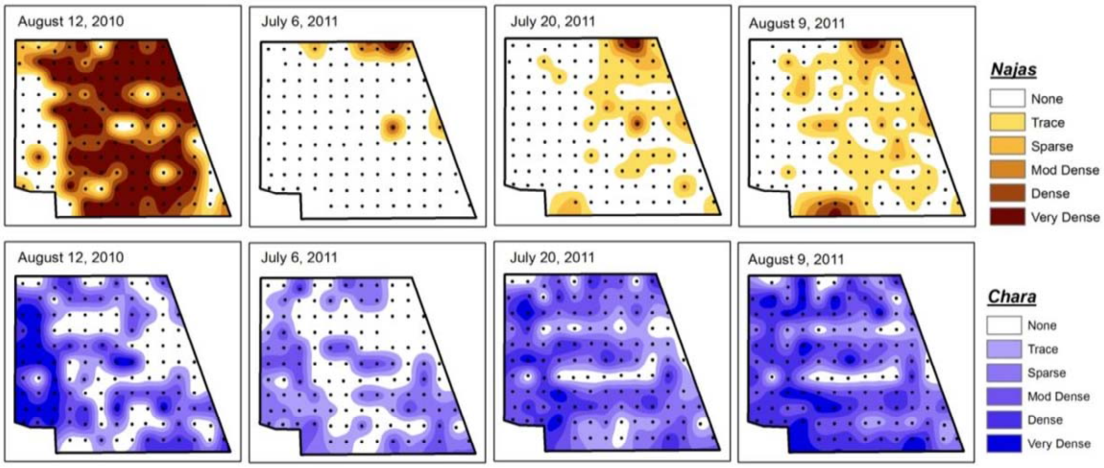


Figure 5-60. Spatial coverage and density of the two dominant SAV species (*Najas* and *Chara*) in late summer 2010 prior to the June 2011 dry down (left panels), and during the two months following wetland rehydration.

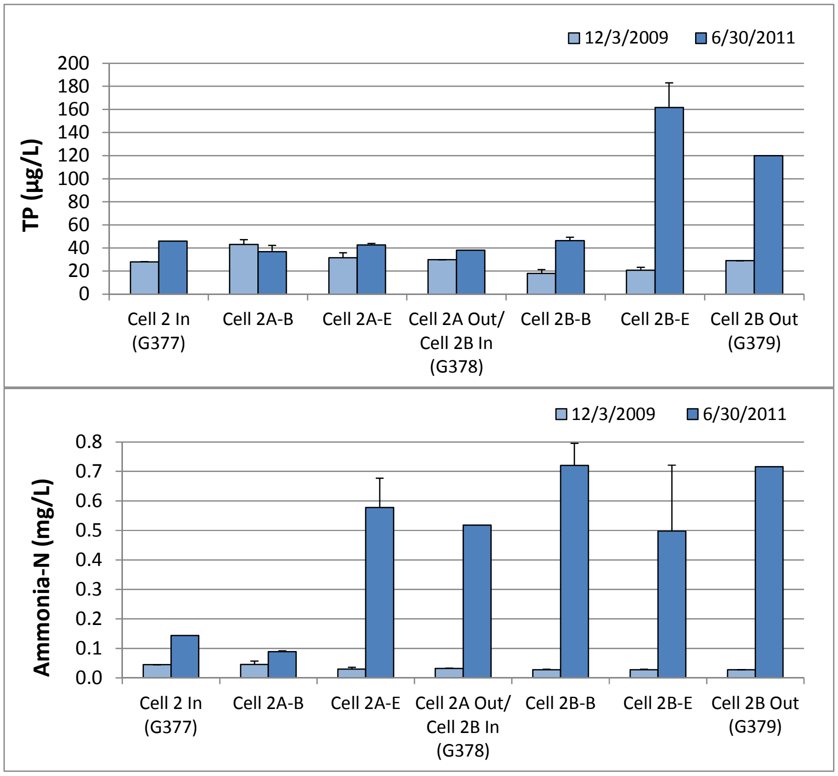


Figure 5-61. Surface water TP (top) and ammonia-N (bottom) concentrations on two sampling dates at the inflow and outflow levees of Cells 2A and 2B, as well as along internal sampling transects.

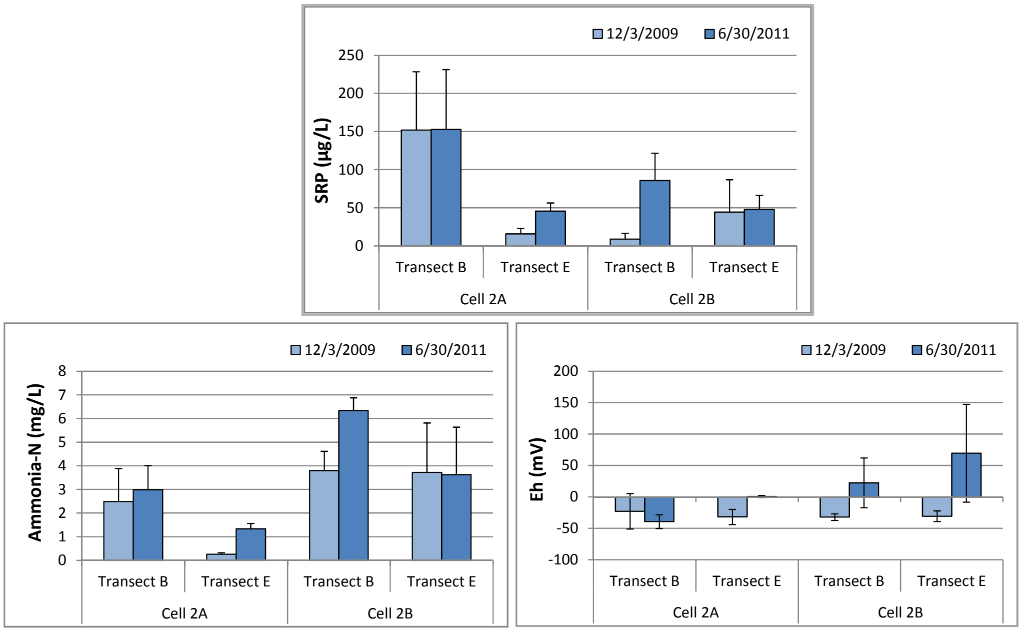


Figure 5-62. Soil porewater SRP (top) and ammonia-N (bottom-left) concentrations, and oxidation-reduction potential (Eh) (bottom-right) on two sampling dates along two internal sampling transects in Cells 2A and 2B.

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

Tom DeBusk[1] and Michelle Kharbanda[1]

Internal water quality monitoring of P species along STA flow-ways has proven useful for identifying regions of particularly effective (or ineffective) treatment performance along the inflow-to-outflow gradient. Additionally, when being coupled with vegetation surveys, internal transect water quality monitoring enables comparisons of vegetation cover and health with treatment performance. Internal monitoring may also assist with the interpretation of various management activities (e.g., TP loading rate, vegetation management) on STA flow-way TP removal performance and sustainability.

During WY2012, one monitoring event was performed in STA-5 Northern and Central flow-ways (Flow-ways 1 and 2 from the new STA-5/6 scheme). Internal monitoring events also were scheduled to coincide with key operational events (e.g., startup after period of stagnation or dry-down). Collectively, data from numerous internal monitoring events over time for a flow-way and/or cell facilitate the assessment of key performance factors, such as minimum attainable outflow TP concentration (Juston and DeBusk 2011).

Methods

For SAV cells, monitoring was performed on multiple internal transects, while for EAV cells, water samples were collected along inflow, mid-region and outflow transects (**Figure 5-63**). Samples are analyzed for TP, total soluble P (TSP), SRP, and selected field parameters (e.g., temperature, pH). Other key constituents (e.g. calcium, DOC) that may influence STA P cycling were analyzed, as deemed appropriate. Data collected along each transect were averaged to produce TP, P species (DOP, SRP, and PP) concentrations profiles.

Results and Discussion

During summer 2011, flows to the EAV cells of the northern and central flow-ways began in the first week of July, whereas flow to the SAV cells began on July 17. Due to regional drought conditions, these flow-ways did not receive any water for approximately nine months prior to this time. During the period of no flows, mean stages in Cells 1A and 2A were below mean ground elevation for approximately 200 and 130 days, respectively. SAV Cells 1B and 2B generally remained flooded during this period as a result of delivery of supplemental water directly to these cells from the STA-5 discharge canal. On the day of the internal sampling event (August 3, 2011) and the preceding 2-week period, both flow-ways were receiving low to moderate inflows (**Figure 5-64**).

Surface water TP concentrations within Cell 1A fluctuated between 136 and 252 ppb, indicating minimal P removal (inflow and outflow TP was 252 and 240 ppb, respectively) (**Figure 5-65**). These fluctuations were primarily driven by the PP fraction, whereas, SRP concentrations declined from 146 to 60 ppb. Although little P removal occurred within Cell 1A, TP concentrations within the Cell 2A steadily declined from 240 to 17 ppb (**Figure 5-65**).

Surface water P removal exhibited a dramatically different trend along the central flow-way. TP concentrations within Cell 2A steadily increased from 147 ppb at the inflow transect to 355 ppb at the outflow transect, indicating substantial internal P loading. The majority of the increase can be attributed to SRP (**Figure 5-65**). Field observations indicate cattail mortality throughout transects A-D, which is a likely source of the internal P loading. Although inflow TP concentrations to Cell 2A were higher than concentrations found at transect A (271 ppb), the inflow sample was collected at G-342C, the culvert that had not received flow since the previous wet season. Surface water TP concentrations within Cell 2B remained high along transects A through F, ranging from 274 to 413 ppb, then declined to 120 ppb at transect G before exiting the flow-way at 206 ppb (**Figure 5-65**). Similar to the observations in the EAV cell, these high concentrations can be attributed to SRP and DOP.

The data depicts a uniform reduction in TP with distance from the inflow for Cell 1B (**Figure 5-66**). These data also show that the higher surface water TP concentrations within the central flow-way were located in the mid to southern region of Cell 2A and the mid to northern regions of Cell 2B (**Figure 5-66**). Within these same regions of the central flow-way, high SRP concentrations were also observed (data not shown).

Dissolved Ca concentrations in Cells 1A and 2A were similar, ranging from 53−58 ppm and 55−65 ppm, respectively (**Figure 5-67**). However, dissolved Ca concentrations in Cell 1B was dramatically lower than in Cell 1A, ranging from 25-41 ppm, whereas concentrations in Cell 2B remained similar to those found in Cell 2A, ranging from 48-61 ppm (**Figure 5-67**).

Collectively, the data demonstrates different rehydration responses for the two flow-ways. While both EAV cells provided little initial P removal, which would be expected due to the drought-related dry down, the two SAV cells differed markedly in initial performance, with only Cell 1B exhibiting a pronounced inflow-to-outflow P removal gradient. SAV cover in the two cells was comparable (based on recent surveys), and the high TP concentration zones depicted in **Figure 5-66** do not represent higher elevation regions that might have been subjected to a more prolonged dry down. The lack of Ca removal in Cell 2B suggests minimal photosynthetic activity by the SAV (effective SAV P removal often occurs in concert with Ca removal), so turbid water conditions may have been responsible for the reduced P removal observed upon post dryout rehydration. Other potential reasons for these short-term flow-way performance differences are still under investigation.

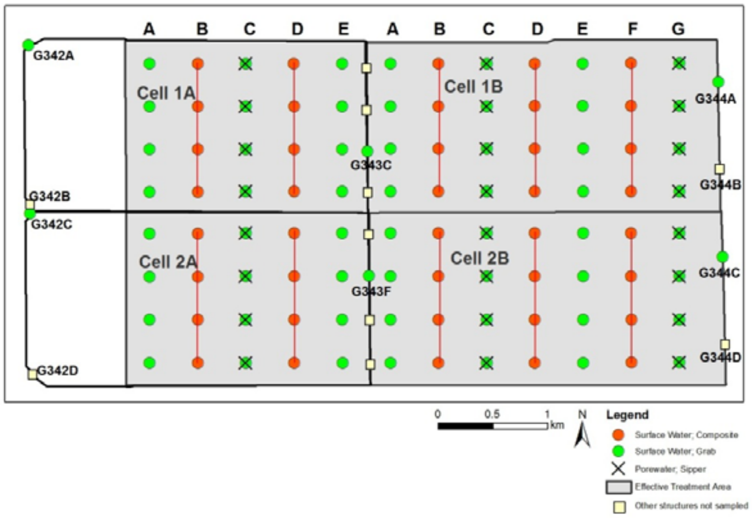


Figure 5-63. Location of internal water quality sampling stations within STA-5 Cells 1A, 1B, 2A, and 2B on August 3, 2011. Transects are identified alphabetically within each cell along the west-to-east flow-way. Grab samples (in green) were analyzed individually, while the samples collected along the red transects were composited in the field prior to analyses.

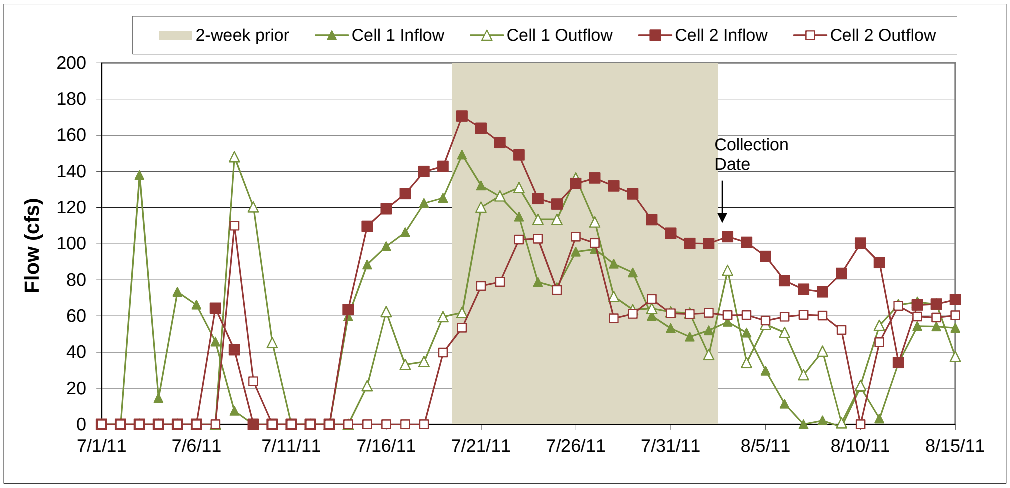


Figure 5-64. Time series of flow into and out of STA-5 northern (Cell 1) and central (Cell 2) flow-ways from July 1–August 15, 2011.

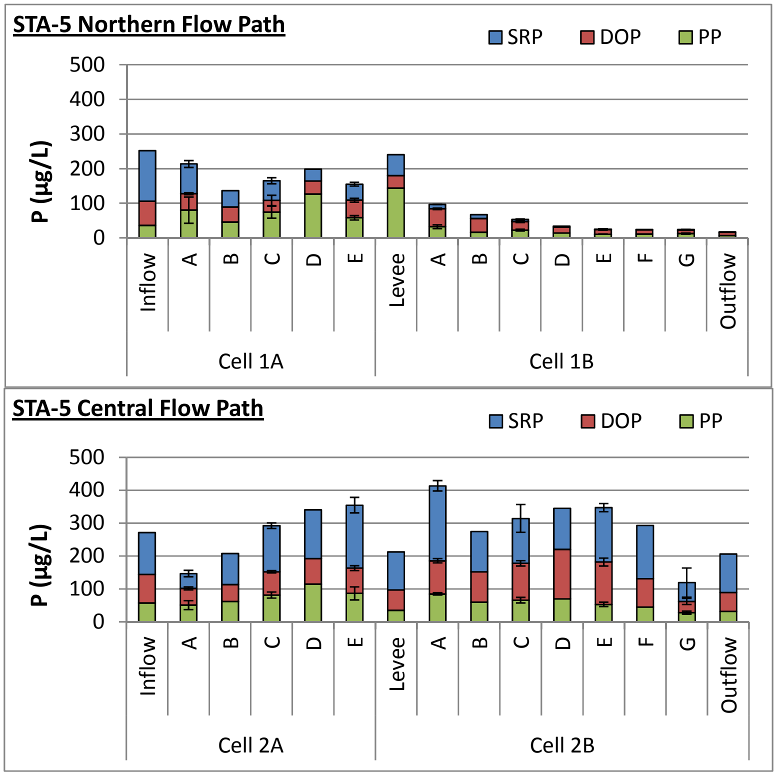


Figure 5-65. Mean surface water phosphorus concentration profiles along the inflow-outflow transects for the northern and central flow-ways in STA-5 on August 3, 2011. Error bars represent the ±1 standard error of grab stations collected along each transect (n=4). Cell 2A inflow sample was collected at culvert G-342C that had not received flow nine months prior to this sampling event.

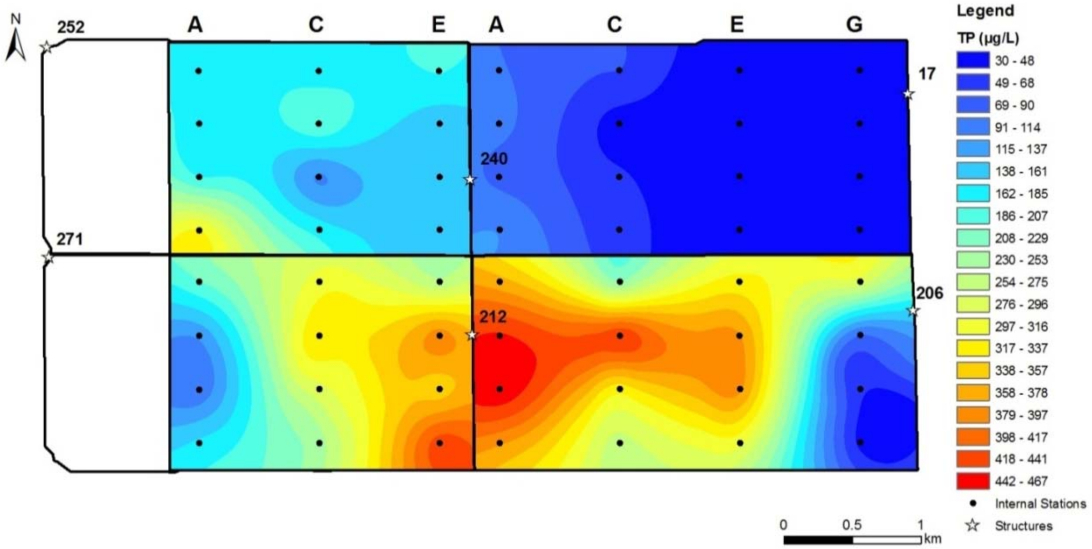


Figure 5-66. Spatial interpolations of surface water TP concentration data collected along the inflow/outflow transects in the northern and central flow-ways of STA-5 on August 3, 2011. Note that the TP concentrations from the inflow, mid and outflow structures were not included in the spatial interpolations.

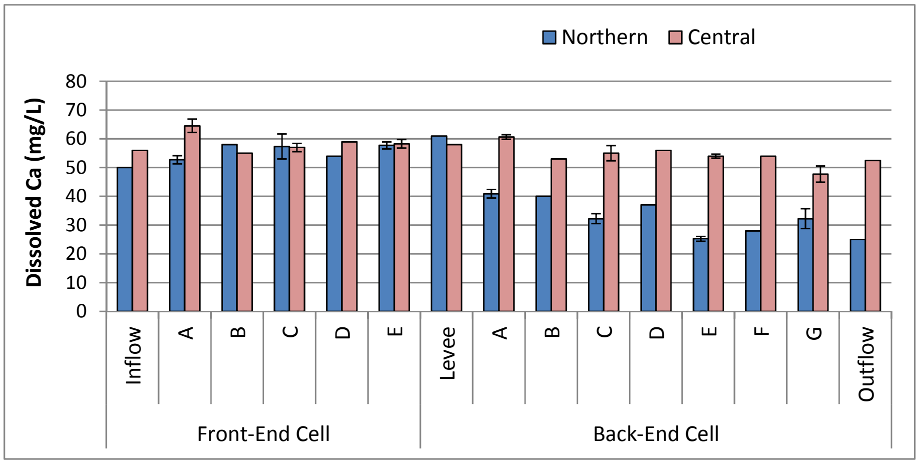


Figure 5-67. Mean surface water dissolved calcium concentration along inflow-outflow gradient for northern and central flow-ways in STA-5 on August 3, 2011. Error bars represent ±1 standard error of grab stations collected along each transect (n=4).

EFFECTS OF EMERGENT VEGETATION ON FLOW DYNAMICS IN STA-2 CELL 2

Rajendra Paudel[3], James W. Jawitz[3],
Kevin A. Grace[1] and Stacey Galloway[1]

After years of operation, many of the STA cells now contain dense vegetation stands, consisting of both living and dead plant material. Under high flow events, it is hypothesized that the hydraulic resistance created by the dense vegetation contributes to the high water depths observed in the front end of the STA flow-ways. For this effort, water stage monitoring devices were deployed throughout STA-2 Cell 2, which provided data to develop a physically based, spatially distributed dynamic flow model for this wetland. Several model scenarios addressed the following management questions:

1. How does stage vary internally within Cell 2, especially under peak inflows?
2. What is the spatial extent and duration of water depths greater than 4 ft (1.22 m) for designated peak-inflows? Do these trends change in relation to burning/herbicide scenarios (reduced hydraulic resistance by vegetation)?
3. Can we use these estimates to evaluate the benefits of vegetation management approaches to minimize hydraulic resistance, such as burning/herbicide?

A synopsis of findings is provided below: more details can be found in Paudel et al., 2012.

Methods

A physically-based, spatially distributed hydrodynamic model of STA-2 Cell 2 was developed based on the framework of the Hydrologic Simulation Engine (HSE) of the Regional Simulation Model (Lal et al., 2005; SFWMD, 2005b), which simulates the coupled movement and distribution of overland and groundwater flow. In addition, HSE also simulates hydraulic structures, canal networks, well pumping, levee seepage, and other operational rules and conditions that are common features in the STAs.

The cell was represented by a two-dimensional, variable size finite-element mesh of 1135 unstructured triangular elements and 632 nodes, generated in Groundwater Modeling System v5.1 (Brigham Young University, 2004) (**Figure 5-68**). The triangular mesh elements were approximately 150 m on a side, or about 1 hectare in area, with smaller elements used to define inflow and outflow structures and perimeter canal features. The mesh density was refined along the eastern levee and narrow ditches/channels to better capture local hydrologic effects, and at the inflow/outflow zones to better represent the locations of flow control structures. This mesh resolution was selected to trade-off computation time of each simulation with a reasonable representation of spatial data inputs (topography and vegetation) and outputs (water levels).

Daily average inflow rates and stages at inflow and outflow structures along with daily cumulative rainfall and evapotranspiration (ET) depths were additional inputs to the model. Cell 2 receives inflows through seven gated culverts (G-331A-G, **Figure 5-68**). Water flows southward through the treatment cell into the discharge canal and through a gated outflow spillway (G-332). Topographic data was available from 2010 (**Figure 5-69**, panel a). The model was calibrated to internal stage data recorded at 15-minute intervals for the period 9/23/2008 to 7/31/2011, by pressure transducers at eight monitoring locations within the cell (**Figure 5-68**, panel a).

Vegetation maps were developed from aerial photographs collected on February 11, 2005. Three major vegetation types cover 89 percent of the Cell 2 treatment area (**Figure 5-68**, panel b). These include 53 percent cattail, 19 percent open water with or without submerged aquatic vegetation (SAV), and 17percent sawgrass. The ET depths were based on lysimeters installed in cattail, open water/algae system, and mixed marsh and/or predicted from meteorological conditions (Abtew and Obeysekera, 1995; Abtew, 1996).

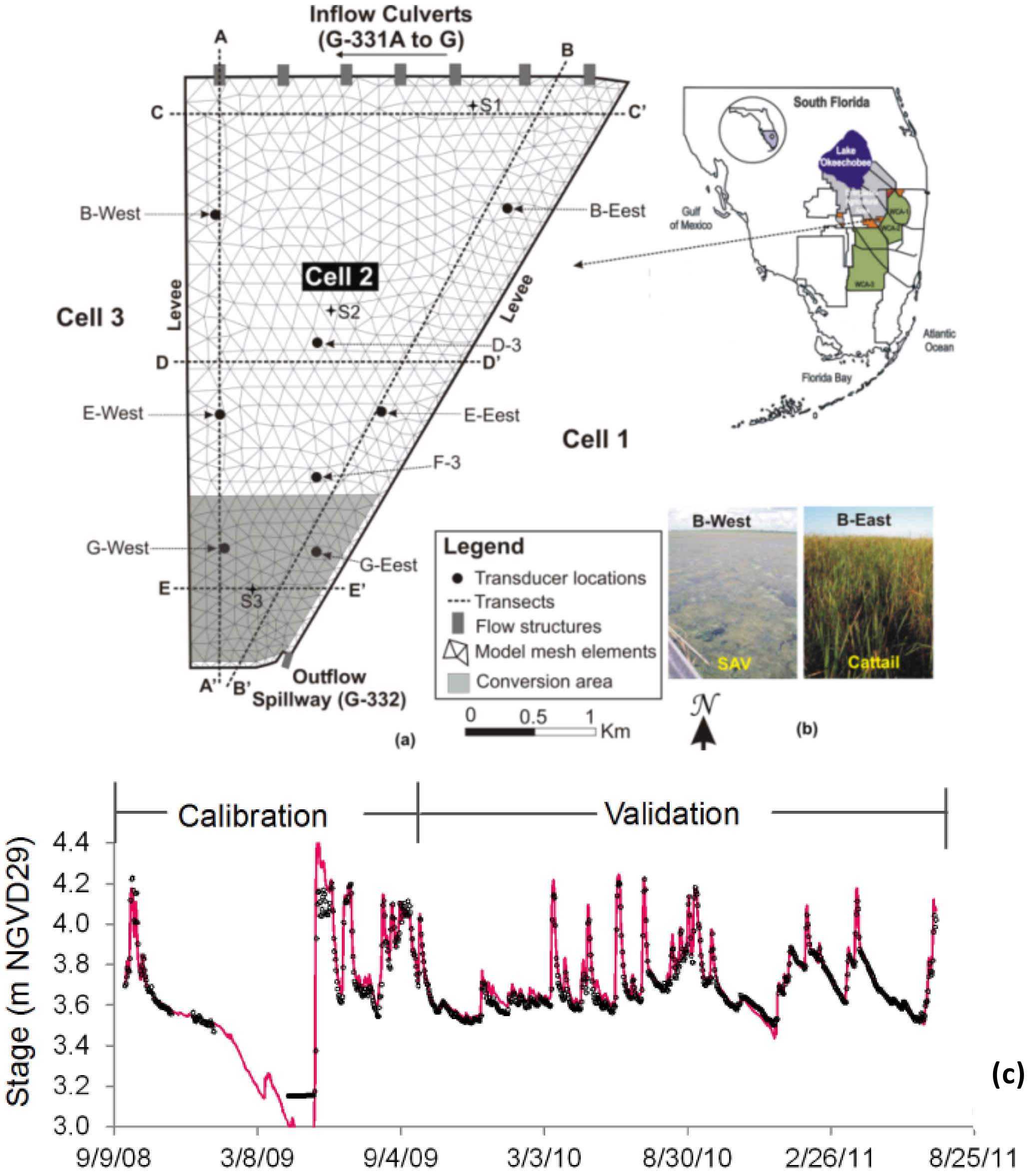


Figure 5-68. Study area in STA-2 Cell 2 location and plan with inflow and outflow hydraulic structures, sampling locations, transects, and computational model mesh (a); photos of vegetation at two sites (b); and daily observed (circles) and simulated (red lines) stage at an internal location (B-East) during the model calibration and validation periods (c).

In April 2009, vegetation in the southern 400 acres of Cell 2 (Conversion Area) was treated with herbicide to convert from EAV to SAV (**Figure 5-68**, panel a). In addition to potential TP removal benefits, conversion of outflow region vegetation to SAV may relieve enough hydraulic resistance to decrease the extent and duration of deep water levels within the cell. To examine the question mentioned above in concurrence with the vegetation conversion, the model was used to compare the outcome of this management action with management alternatives. The primary factor which varied across model scenarios was the spatial extent of the vegetation conversion.

The emergent macrophyte-dominated areas were divided into three "zones": Z1, Z2, and Z3 (**Figure 5-69**, panel c). Changes in hydrodynamic variables (i.e., water depth and water level) were evaluated along both longitudinal (AA', and BB') and transverse (CC', DD', and EE') transects (**Figure 5-68**, panel a). The UNB scenario ("unburned") simulated the existing or pre-burn condition. Scenarios BZ1, BZ1-2, and BZ1-3 simulated the effects of "burning" vegetation in zones 1 only, zones 1 and 2, or zones 1 through 3, respectively. Thus, the scenarios ranged from the existing conditions to complete thinning of all areas supporting emergent vegetation. These scenarios were expected to demonstrate the potential benefits to reducing the flow resistance within the STA-2 Cell 2 as a result of thinning emergent macrophytes via burning or herbicide application. Sixteen peak flow events identified from the time-series inflow data were evaluated because these pulse inflows are generally responsible for deep water conditions in the treatment cell. The wetland area and duration of water depths greater 4 ft immediately after each peak were determined.

Results and Discussion

The sixteen peak flow rates ranged from 11.2 to 37.9 cubic meters per second with a median of 28.9 cubic meters per second. A gradual stage gradient was observed from north to south (inflow-inflow to outflow-outflow structures) along the flow direction (**Figure 5-70**, panels a and b). However, a sharp change in stage gradient was observed approximately 1.8 and 3.5 km from the inflow-inflow culverts along transect AA' and BB', respectively. After these distances, stage gradients were consistently sharp and stabilized at the bottom end of the cell.

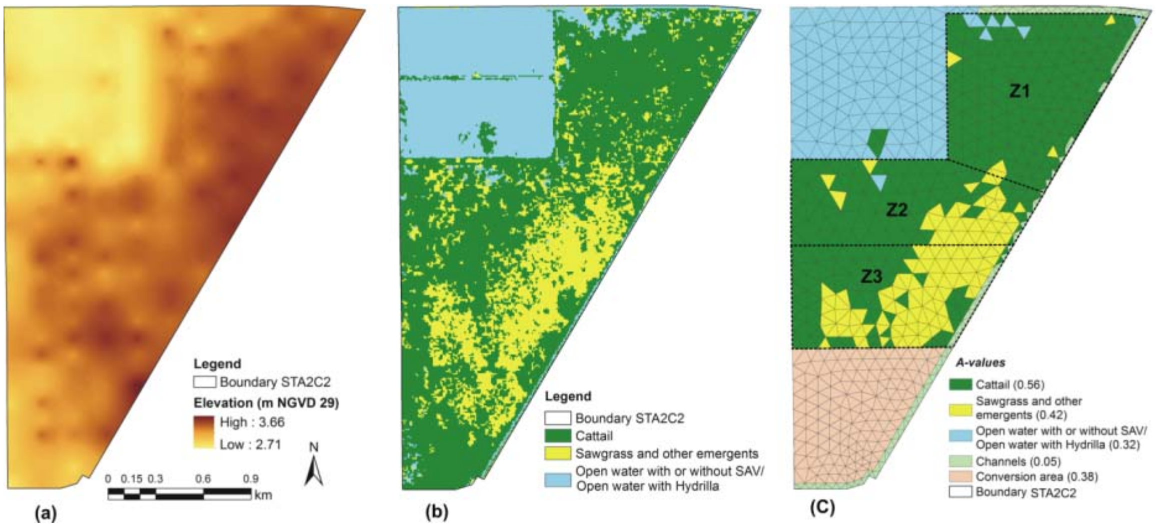


Figure 5-69. Spatial maps of STA-2 Cell 2 (a) bathymetry, (b) major vegetation classes, and (c) flow resistance coefficients used in the model, and model scenario zones.

The relationships between daily inflow rates and stage showed a strong regression ($r^2 = 0.70$) between changes in daily inflow rate and stages near the inflow structures; however, the relationship at the outflow region was relatively weak ($r^2 = 0.06$; outflow site). In contrast, changes in daily outflow discharges were not correlated to changes in stages at the outflow region ($r^2 = 0.06$; outflow site), suggesting that outflow operations have less control over the changes in stages. The range of calibrated hydraulic resistance factors (0.56 for cattail and- 0.05 for open water/channel) were consistent with the range of Manning's 'n' reported for corresponding mean water depths and similar vegetation class by previous investigators in the STAs (Sutron Corporation, 2007; Min and Wise, 2010).

Most areas within the EAV region remained below the 4 ft water depth even after a large flow pulse (**Figure 5-71**). A maximum 2-percent of the total Cell 2 area was reduced below the 4 ft level by BZ1-3, while above that threshold under existing conditions. Deep water conditions were sustained for long periods when a peak inflow was followed by consecutive flow pulses. For example, depths > 4 ft were sustained for 24 days after a peak inflow in May 2009, even in scenario BZ1-3 where all emergent vegetation was thinned, because the peak flow was followed by additional inflow pulses. Therefore, managing both magnitude and timing of peak inflows if possible might be necessary to achieve the desired water depths.

Vegetation thinning operations simulated in this study produced limited reduction in water depths that are probably of little ecological significance. All cattail burning scenarios reduced stages by increasing the discharge capacity of the treatment cell; however, the amount of reduction was much less than expected. Even the scenario with the largest burning area (BZ1-3) resulted in a maximum reduction in stage of about 12 cm at the inflow region and less than 1 cm at the outflow region (**Figure 5-70,** panels c, d, and e). It should be noted that the 22-percent increase in mean velocity after cattail burning may have been too small a change to translate into large stage differences between burned and unburned scenarios.

Collectively, findings suggest that vegetation thinning (i.e., reduced hydraulic resistance from vegetation) may not be effective in minimizing deep water conditions in Cell 2. Potentially damaging periods of sustained high depths were controlled more by reducing inflows to Cell 2 than by vegetative hydraulic resistance. The model presented is flexible and provides a powerful tool to predict spatially and temporally variable responses to structural and operational modifications. With the growing interest in managing emergent macrophytes in the STAs, these results have important implications for developing and testing new strategies to maintain desired water depths and avoid negative ecological consequences or loss of treatment efficacy. However, the generality of these conclusions to other STAs and treatment cells should be investigated.

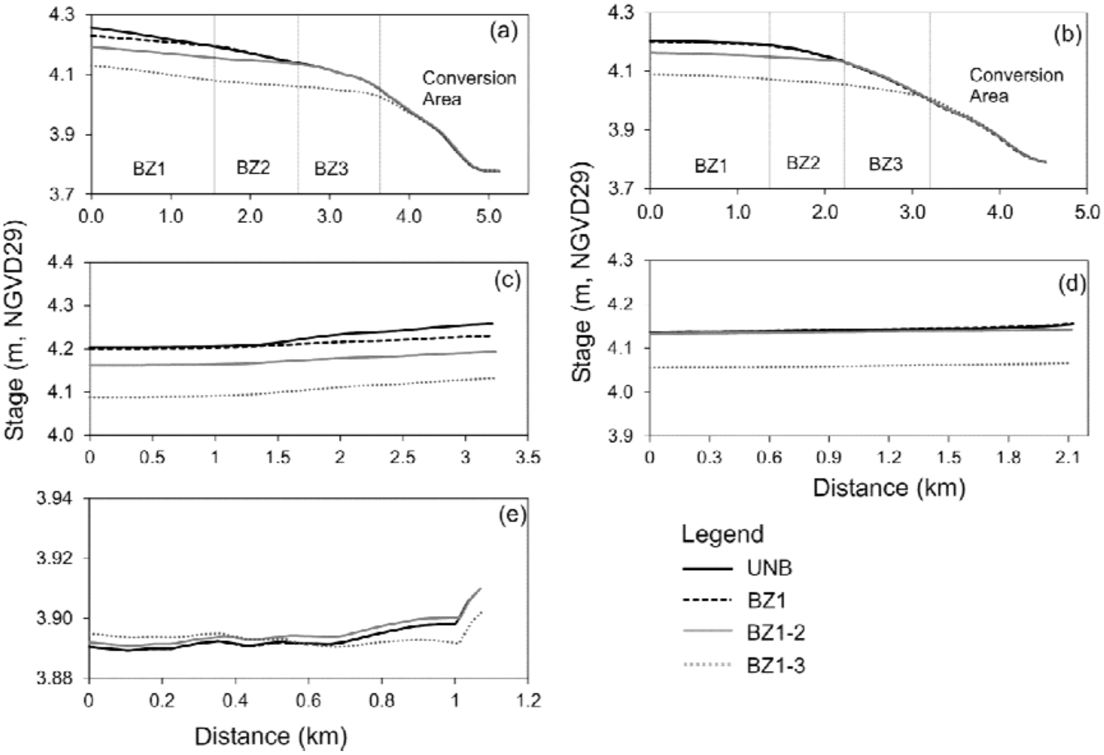


Figure 5-70. Simulated stage profile after a flow pulse in July 2010, along transects: (a) BB', (b) AA', (c) CC', (d) DD', and (e) EE'.

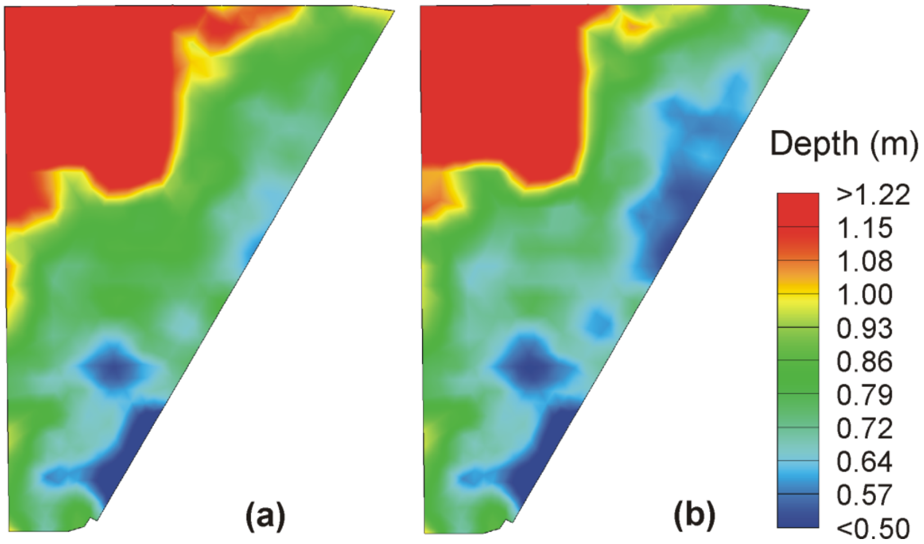


Figure 5-71. Model output of simulated water depths in the emergent vegetation zone after the cell's largest inflow pulse (July 2010), under existing conditions or after vegetation thinning (reduced hydraulic resistance to increase overland flow velocities by 22 percent). Water depths in the white region in the northwest corner were >1.15 m under both scenarios, a result of previous agricultural production; vegetation in that area is typically SAV-dominated.

RECREATIONAL OPPORTUNITIES AND ACTIVITIES

RECREATIONAL FACILITIES

Various public access and recreational opportunities are available in STA-1E, STA-1W, and STA-3/4, including trailheads, boardwalks, and viewing platforms to provide opportunities for scenic and wildlife viewing. Catch and release fishing is allowed from the banks inside the levees at STA 1E. Fishing is allowed by boat or from the bank in the perimeter canals of STA-1W and STA-3/4. A public dual-lane boat ramp offers access to 27 miles of perimeter canals in STA-3/4. STA-1E, STA-1W, and STA-3/4 public facilities are open to the public Fridays, Saturdays, Sundays, and Mondays. In STA-5, a 100-yard wheelchair-accessible boardwalk/bird blind allows disabled visitors to bird watch and hunt. A trailhead will also be established in this area for foot access to public in WY2013.

BIRD WATCHING PROGRAM

The public access sites in the STAs offer substantial bird watching opportunities. Organized bird watching tours are led by Hendry-Glades Audubon Society on STA-5. The diversity and abundance of birds has made STA-5 and other STA areas favorite bird watching destinations (**Figure 5-72**). In WY2012, approximately 900 bird enthusiasts participated in STA-5 birding tours and bird counts, including the annual North American, Christmas, and backyard bird counts in STA-5 and STA-1W. A similar organized bird watching tours have been initiated on STA1E in cooperation with the Audubon Society of the Everglades starting January 2012.

Figure 5-72. Visitors at an STA-1E bird watching event coordinated by the Audubon Society of the Everglades, January 2012 (photo by the SFWMD).

HUNTING

The STA hunting program (which includes alligator and waterfowl hunts) is managed by the Florida Fish and Wildlife Conservation Commission (FWC) in close coordination with the District. Hunting is limited to weekend days to prevent interference with the ongoing STA management or monitoring activities. The effective oversight, high quality of hunts, and the limited opportunity results in strict compliance with the set hunting and facility use rules. One of these rules forbids the use of motorized boats during hunting in the STAs; only non-motorized vessels (kayaks or canoes) are permitted.

From mid-August to November 1, 2011, alligator hunting took place in STA-1W, STA-2, STA-3/4, and STA-5. A total of 550 permits were issued and 427 alligators were harvested. A Youth Hunting event, a new program intended to educate conservation among future hunters, was also conducted in STA2 in August 2011. Waterfowl hunting occurred in STA-1W, STA2, STA-3/4, and STA-5 from mid-November 2011 to February 2012. The waterfowl hunting season includes migratory birds and the bag limits are determined by the FWC. In WY2012, hunting permits were granted to 10,761 hunters and the total bagged count was 40,659 birds.

IMPLEMENTATION OF THE LONG-TERM PLAN FOR ACHIEVING WATER QUALITY GOALS IN THE EVERGLADES PROTECTION AREA

Pursuant to the Everglades Forever Act [EFA; Section 373.4592(13), Florida Statutes],this section presents an update on implementation of the Long-Term Plan for Achieving Water Quality Goals in the Everglades Protection Area (Long-Term Plan) and subsequent amendments. Achieving Everglades water quality standards by implementing the Long-Term Plan is one of the strategic priorities of the District and is required by state and federal law. For this period, a cross-walk of Long-Term Plan-related reporting is presented in Appendix 5-7 of this volume. A schematic of the Everglades Protection Area and Tributary basin is presented in **Figure 5-73**. Additional supporting information on Long-Term Plan reporting is available in the 2005-2012 SFERs – Volume I, Chapter 8.

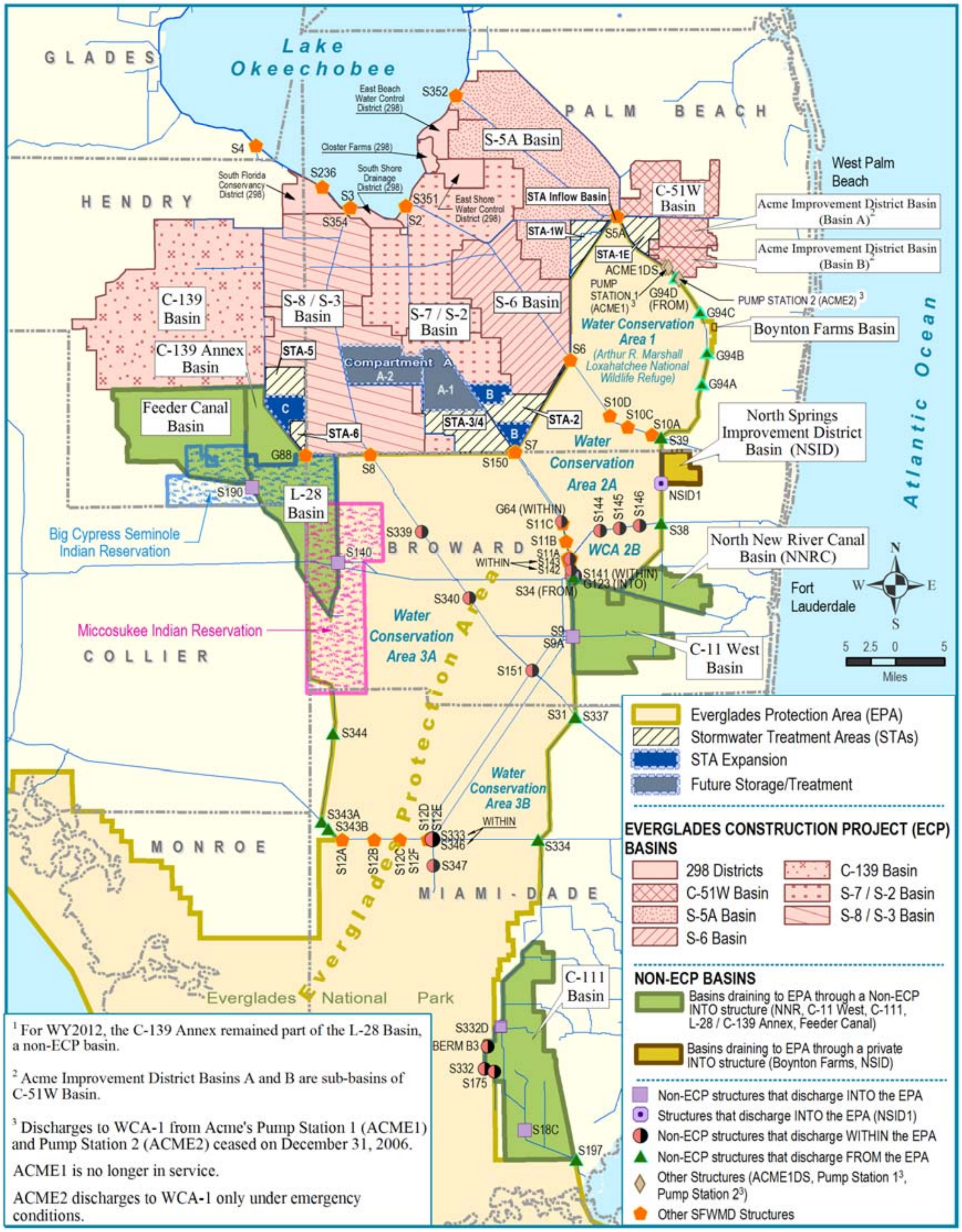
BACKGROUND

In 1994, the Florida legislature enacted the EFA which required the District to submit to the FDEP a plan by December 31, 2003, for achieving compliance with the total phosphorus (TP) criterion and other state water quality standards in the Everglades Protection Area (EPA), and to include the estimated costs, funding mechanisms and implementation schedules associated with the plan. A plan was developed and in the EFA amendments of 2003, the Florida legislature incorporated the plan by reference into the EFA. The legislature also amended the EFA to include two phases for the Long-Term Plan; the initial phase which was developed in October 2003 (Burns and McDonnell, 2003), and a second phase, which was to be developed if the elements of the initial phase were unsuccessful in achieving water quality standards in the EPA. The initial phase included STA expansions, enhancements to existing STAs, expanded best management practices (BMPs), and integration with the Comprehensive Everglades Restoration Plan (CERP) projects. The key STA expansions and enhancements described in the initial phase of the Long-Term Plan have been completed and significant stormwater quality improvements have been realized.

As of April 30, 2012, the Everglades Agricultural Area's BMPs and the ECP STAs have collectively removed more than 4,060 metric tons[3] of TP that otherwise would have entered the Everglades. The STAs accounted for approximately 1,560 metric tons of TP since 2004 and BMPs were responsible for removing approximately 2,503 metric tons. As described in Chapter 3A of this volume, the effectiveness of the BMP and STA TP removal efforts is demonstrated by

---

[3] The inception-to-date numbers for the STAs include start-up flows and loads.



▭ Everglades Protection Area (EPA)
▨ Stormwater Treatment Areas (STAs)
▩ STA Expansion
▩ Future Storage/Treatment

EVERGLADES CONSTRUCTION PROJECT (ECP) BASINS

▭	298 Districts	▨	C-139 Basin
▩	C-51W Basin	▨	S-7 / S-2 Basin
▨	S-5A Basin	▨	S-8 / S-3 Basin
▨	S-6 Basin		

NON-ECP BASINS

🟩 Basins draining to EPA through a Non-ECP INTO structure (NNR, C-11 West, C-111, L-28 / C-139 Annex, Feeder Canal)

🟨 Basins draining to EPA through a private INTO structure (Boynton Farms, NSID)

■ Non-ECP structures that discharge INTO the EPA
● Structures that discharge INTO the EPA (NSID1)
● Non-ECP structures that discharge WITHIN the EPA
▲ Non-ECP structures that discharge FROM the EPA
◆ Other Structures (ACME1DS, Pump Station 1³, Pump Station 2³)
⬟ Other SFWMD Structures

[1] For WY2012, the C-139 Annex remained part of the L-28 Basin, a non-ECP basin.

[2] Acme Improvement District Basins A and B are sub-basins of C-51W Basin.

[3] Discharges to WCA-1 from Acme's Pump Station 1 (ACME1) and Pump Station 2 (ACME2) ceased on December 31, 2006.

ACME1 is no longer in service.

ACME2 discharges to WCA-1 only under emergency conditions.

Figure 5-73. Overview of the Everglades Protection Area and tributary basins.

the decreased TP loading to the Water Conservation Areas (WCAs) in recent periods compared to the baseline period, despite increased flows to the EPA. Yet despite STA enhancements and continued decreases in discharge TP concentrations, the existing STAs in combination with BMPs did not achieve compliance with the Everglades numeric criterion during WY2012.

To improve the performance of the initial phase of the Long-Term Plan STAs, a science-based and adaptive implementation approach was used to develop nine revisions to the initial Long-Term Plan between 2004 and 2007. These revisions were vetted with stakeholders and approved by the FDEP (see 2005–2009 SFERs – Volume I, Chapter 8).

In 2008, in Miccosukee Tribe v. USEPA, the court determined that portions of the 2003 amendments to the EFA and Florida's Everglades TP rule constituted improper changes in water quality standards and were invalid under the Clean Water Act. In general, the court invalidated provisions allowing the discharge of TP concentrations above the phosphorus criterion even if the District was implementing the requirements of the Long-Term Plan. [Note: The District was not a party to that case.] Although the Long-Term Plan may no longer be used as a moderating provision, it was a District planning document for WY2012 and its implementation continues to be mandated under state law until the EFA is amended directing otherwise. The court further determined that a two-part Water Quality Based Effluent Limit (WQBEL) for each STA is a critical component of a framework to ensure compliance with the numeric criterion in the EPA.

STATUS OF THE WATER QUALITY BASED EFFLUENT LIMIT IMPLEMENTATION

During this reporting period, the District, FDEP and U.S. Environmental Protection Agency jointly develop a consensus WQBEL for the STAs and a new suite of projects that, based on the best available science and experience derived through operation of the existing STAs, is intended to achieve the WQBEL. These projects comprise the second phase of the Long-Term Plan, which must be approved by the Florida legislature and codified in the EFA prior to implementation.

STATUS OF INITIAL PHASE LONG-TERM PLAN PROJECTS AND ACTIVITIES

The initial phase of the Long-Term Plan included 48 individual projects and processes, each having a schedule, scope, and cost estimate. As the Long-Term Plan overlaps with other agency Everglades restoration efforts, updates for Long-Term Plan projects and processes appear in other chapters of this volume, (see Appendix 5-5 of this volume).. The Long-Term Plan projects that address the non-Everglades Construction Project (non-ECP) basins and source controls are discussed in Chapter 4 of this volume; the Long-Term Plan projects relating to the ECP STAs and Compartments B and C STA expansion projects are discussed in this chapter. **Figure 5-73** identifies the locations of the ECP and non-ECP basins addressed in the Long-Term Plan. Financial reporting related to the implementation of the Long-Term Plan is summarized in Appendix 1-5 of this volume. Detailed data summaries and findings related to the individual performance of the BMPs and STAs can be found in Chapter 4 and earlier sections of this chapter. A list of the basins addressed in the Long-Term Plan is presented in Appendix 5-7.

LITERATURE CITED

Abtew W. 1996. Evapotranspiration measurements and modeling for three wetland systems in south Florida. *Water Resources Bulletin*, 32(3):465-73.

Abtew W., J. Obeysekera and G. Shih. 1995. Spatial variation of daily rainfall and network design. *Transactions of the ASAE*, 38(3):843-5.

Andersen, J.M. 1976. An ignition method for determination of total phosphorus in lake sediments. *Water Research*, 10:329-331.

Apfelbaum, S.I. 1985. Cattail (Typha spp.) management. *Natural Areas Journal*, 5(3): 9-17.

Beule, J.D. 1979. Control and management of cattails in southeastern Wisconsin wetlands. *Wisconsin Department Natural Resources Tech. Bulletin*, 112, Madison. 41p.

Brigham Young University. 2004. The Department of Defense Groundwater Modeling System, GMS v5.1, Environmental Modeling Laboratory.

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

Chen, H., M. Zamorano and D. Ivanoff. 2010. Effect of Flooding Depth on the Growth, Biomass, Photosynthesis, and Chlorophyll Fluorescence of Typha Domingensis. *Wetlands*, 30: 957-965.

Dierberg, F.E. and T.A. DeBusk. 2008. Particulate Phosphorus Transformations in South Florida Stormwater Treatment Areas Used for Everglades Protection. *Journal of Ecological Engineering*, 34(2):100-115.

Germain, G. and K. Pietro. 2011. Chapter 5: Performance and Optimization of the Everglades Stormwater Treatment Areas. In: *2011 South Florida Environmental Report – Volume I*, South Florida Water Management District, West Palm Beach, FL

Ivanoff, D.B., K.R. Reddy, and S. Robinson. 1998. Chemical fractionation of organic phosphorus in selected histosols. Soil Science 163:36-45.

Ivanoff, D.B., H. Chen and L. Gerry. 2012. Chapter 5: Performance and Optimization of the Everglades Stormwater Treatment Areas. In: *2012 South Florida Environmental Report – Volume I*, South Florida Water Management District, West Palm Beach, FL

Juston, J.M. and T.A. DeBusk. 2011. Evidence and Implications of the Background Phosphorus Concentration in Submerged Aquatic Vegetation Wetlands in Stormwater Treatment Areas Used for Everglades Restoration. Water Resources Research, 47, W01500, doi:10.1029/2010WR009294.

Kadlec, R.H. and S.D. Wallace. 2009. *Treatment Wetlands*. Second Edition. Taylor and Francis Group, Boca Raton, FL.

Lal A.M.W., R. Van Zee and M. Belnap. 2005. Case study: Model to simulate regional flow in South Florida. *Journal of Hydraulic Engineering-ASCE*, 131(4):247-58.

Min J. and W.R. Wise. 2010. Depth-averaged, spatially distributed flow dynamic and solute transport modelling of a large-scaled, subtropical constructed wetland. *Hydrological Processes*, 24(19):2724-37.

Paudel, R., K.A. Grace, S. Galloway, M. Zamorano, and J.W. Jawitz. Effects of hydraulic resistance by vegetation on stage dynamics of a stormwater treatment wetland. *Manuscript in review process.*

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. 2005b. RSM Theory Manual – HSE v1.0. South Florida Water Management District, West Palm Beach, FL, pp. 308.

SFWMD. 2007. Operation Plan Stormwater Treatment Area-3/4. South Florida Water Management District, West Palm Beach, FL.

Sojda, R. S., Solberg, K. L. 1993. Management and Control of Cattails. U.S. Fish and Wildlife Service Fish and Wildlife Leaf. 13.4.13, Washington, D.C.

Sutron Corporation. 2007. Updated STA-2 Hydraulic Analyses. Final Report submitted to the South Florida Water Management District, West Palm Beach, FL, pp. 68.