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

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## SUMMARY

As part of the ongoing efforts to restore the Everglades, the construction and operation of six large freshwater treatment wetlands was mandated by the Everglades Forever Act (Chapter 373.4592, Florida Statutes) and the Everglades Settlement Agreement. The overall efforts to improve water quality in the Everglades watershed and throughout the South Florida ecosystem involve the cooperation of the South Florida Water Management District (District or SFWMD), the U.S. Army Corps of Engineers, the Florida Department of Environmental Protection, and other agencies and private landowners. The mandates specifically required the construction of treatment wetlands, referred to as the Everglades Stormwater Treatment Areas (STAs). Over 65,000 acres of STAs (approximately 45,000 acres of effective treatment area) have been constructed south of Lake Okeechobee to remove excess phosphorus from surface waters prior to entering the Everglades Protection Area. 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 operated under the Everglades Forever Act and National Pollutant Discharge Elimination System permits. This chapter serves as the reporting mechanism for STA performance, status, and condition during Water Year 2009 (WY2009) (May 1, 2008–April 30, 2009).

Since 1994, the STAs combined have retained more than 1,200 metric tons of total phosphorus that would have otherwise entered the Everglades. Despite the challenges of operating under regional drought conditions for the third consecutive water year, the six STAs together removed about 82 percent of the inflow total phosphorus load. During the dry season, the District implemented proactive operational strategies to protect the STAs, in accordance with the

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STA Drought Contingency Strategy Document (SFWMD, 2007). During the WY2009 drought period, the water levels in most of the interior cells dominated by submerged aquatic vegetation (SAV) were maintained at about six inches above minimum target stage levels. During the WY2009 drought period, the water levels in many of the interior cells dominated by SAV were maintained at about six inches above minimum target stage levels. In some STAs, alternative means of water delivery were utilized to hydrate cells. For example, water was pumped from cells vegetated with emergent plants into SAV cells; construction dewatering water during the rehabilitation activities at STA-5, Cell 1A, was pumped into Cell 1B; construction and related dewatering activities at STA-1E provided supplemental water to STA-1W; and STA-1W, STA-2, STA-3/4, and STA-5 received about 20,676 acre-feet of supplemental water from Lake Okeechobee. Despite these efforts, parts of or entire SAV cells experienced dryouts and consequently SAV loss.

Agency staff and consultants continue to work together to maintain and further optimize STA performance. During WY2009, weekly operational meetings included making decisions on water flows and structure operation in the STAs based on near real-time data. Field assessments to monitor hydrologic conditions, water quality in cell inflows and outflows, soil condition, and vegetation continued. Rehabilitation efforts conducted in STA-1W in 2006–2007 continue to yield positive results in establishing desired plant communities and improving phosphorus removal performance. Research studies aimed at achieving better understanding STA performance and finding ways to improve sustainability also continued. Among these studies is mesocosm-scale research to determine cattail (*Typha* spp.) tolerance and stress patterns as affected by extreme water conditions, vegetation management studies, and internal water quality and soil transect studies to determine treatment gradient.

Detailed analysis of STA data also continued in WY2009. Notably, in STA-5, Cell 1A, results showed short-circuiting, resulting from a preexisting deep slough area, as one of the potential causes of this STA's poor performance. In response, the District completed earthwork to fill a large portion of this slough as part of the overall larger effort to rehabilitate this STA. For STA-6, analysis of historical data indicated that its declining performance was likely due to frequent cycles and extended periods of dryout.

SAV conversion of STA-3/4, Cell 1B, continued while SAV conversion in STA-1W, Cell 3, has been completed. Also, a partial conversion of STA-2, Cell 2, from emergent to submerged aquatic vegetation also began in this year.

In WY2009, there were large numbers of migratory birds that nested within the treatment cells. The presence of migratory bird nests within treatment cells restricts the ability to operate those cells due to protections set forth in the Migratory Bird Treaty Act. In accordance with the Avian Protection Plan for black-necked stilts (*Himantopus mexicanus*) and burrowing owls (*Athene cunicularia*) nesting in the STAs (Pandion Systems, Inc., 2008), nesting surveys were conducted through the nesting season, starting in mid-April 2009. Survey results were used in operational meetings during which water flow into the STAs was prioritized based on nest locations. A total of 873 nests were observed during levee surveys through July 2009.

Over the past year, several STAs had recreational facilities open for public access. These facilities include boardwalks, informational kiosks, and designated areas for bird watching and alligator and duck hunting. In late 2008, a customized boardwalk with a duck blind was constructed at STA-5 to provide hunting opportunities for the public, including access for disabled residents.

# INTRODUCTION

Major problems facing the Everglades are loss of habitat, disruption of hydropatterns and hydroperiod (i.e., duration, timing, volume, and distribution of water), coastal saltwater intrusion, degradation of water quality, and invasion of exotic plants. The 1994 Everglades Forever Act (EFA) addressed some of these issues through the implementation of the Everglades Agricultural Area (EAA) Best Management Practices (BMPs) and the Everglades Stormwater Treatment Areas (STAs). The STAs are a major component of the South Florida Water Management District's (District) Everglades restoration efforts. These are constructed wetlands that remove and store nutrients through several mechanisms including plant growth, accumulation of dead plant material in a layer of peat, settling and sorption, and microbial activities.

This chapter reports on the performance and condition of the six STAs (STA-1E, STA-1W, STA-2, STA-3/4, STA-5, and STA-6) (**Figure 5-1** and Appendix 5-2). The STAs operate under the Everglades Forever Act and National Pollutant Discharge Elimination System (NPDES) permits and Administrative Orders (AOs). Varying in size, configuration, and period of operation, the STAs are shallow freshwater marshes divided into treatment cells by interior levees. Water flows through these systems via water control structures, such as pump stations, gates, or culverts. The dominant plant communities in the treatment cells are broadly classified into the following general categories: (1) emergent aquatic vegetation (EAV), (2) submerged aquatic vegetation (SAV), and (3) floating aquatic vegetation (FAV). This chapter includes permit-mandated reporting requirements, analysis of STA conditions and performance, highlights of key research and optimization activities, highlights of STA operation and maintenance activities, and a report on recreational and wildlife-related activities. *[**Note:** The STA-6 flow data is currently under review. The final chapter will be revised to include the updated flow data for all inflow and outflow structures, as well as the load estimates. The revisions will affect both WY2008 and WY2009 performance estimates for STA-6 and the overall POR estimates for all the STAs.]*

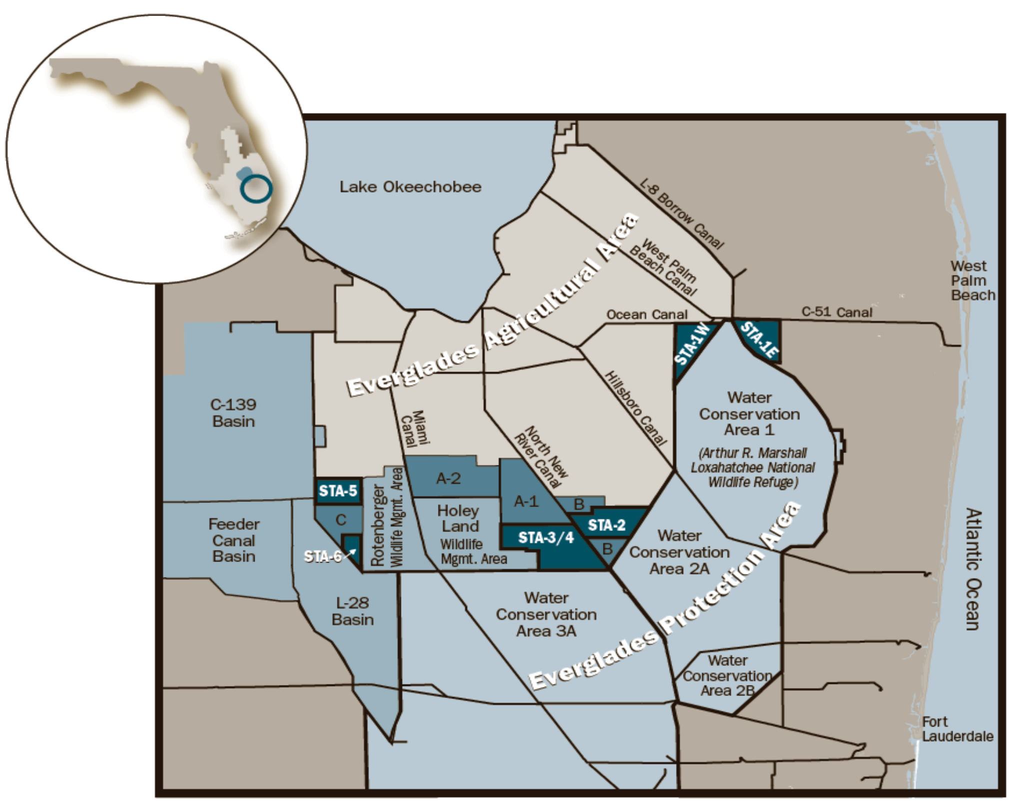


**Figure 5-1.** Location of the six Everglades Stormwater Treatment Areas (STAs) – STA–1E, STA–1W, STA–2, STA–3/4, STA–5, and STA–6).

STA treatment performance, which varies temporally and among STAs, depends on several 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 to improve performance (enhancement activities), and regional operations. This chapter summarizes STA performance, construction, operation and maintenance, research, and optimization efforts during Water Year 2009 (WY2009) (May 1, 2008– April 30, 2009). The chapter serves to fulfill various permit reporting mandates (see the *Permit Status and Reporting Mandates* section of this chapter and Appendix 5-1) and provides an evaluation of phosphorus (P) target compliance and other water quality parameters, including dissolved oxygen (DO), mercury (Hg), and other nutrients and major ions. An evaluation of long-term performance for each STA and by individual flow-ways is also presented.

Additionally, WY2009 results from the research and monitoring conducted in areas receiving STA discharges, i.e., Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge), Water Conservation Area 2A (WCA-2A), and the Rotenberger Wildlife Management Area (RWMA), are summarized in this chapter. Summaries of STA research, the status of rehabilitation, optimization activities, vegetation conversions, wildlife issues, recreational opportunities, and the impact of the extreme events (storm and drought) on the STAs are also covered.

Appendices 5-1 through 5-14 provide supplementation information for the chapter (see **Table 5-1**). Further details about individual STA performance are provided in Appendix 5-2, which contains period of record (POR) time series graphs for inflow and outflow volume, total phosphorus (TP) load, TP flow-weighted mean concentration (FWMC), and hydraulic and TP loading rates. Other appendices contain a timeline of major operational activities in the STAs from 2004 to present (Appendix 5-3), black-necked stilt nest survey results (Appendix 5-14), compliance monitoring for mercury in the STAs (Appendix 5-6), information about herbicide application in the STAs (Appendix 5-13), and raw data for other water quality parameters (Appendices 5-4 and 5-5).

**Table 5-1.** Volume I, Chapter 5, appendix list.

| Appendix Number | Appendix Title |
|---|---|
| 5-1 | Cross-Reference List for Everglades Forever Act Permit Reporting Requirements |
| 5-2 | Calculation Methodology for Estimating Flow and Total Phosphorus Loads and for Determining Effective Treatment Areas for the STAs |
| 5-3 | Individual Performance Time Series Plots and Period of Record Flow and Total Phosphorus Load Estimates for the STAs |
| 5-4 | Water Year 2009 Water Quality Data for STA-1E, STA-1W, STA-2, STA-3/4, STA-5 and STA-6 |
| 5-5 | Water Year 2009 Dissolved Oxygen Data for STA-1E, STA-1W, STA-2, STA-3/4 and STA-5 and Site-Specific Alternative Criteria Estimates |
| 5-6 | Annual Permit Compliance Monitoring Report for Mercury in the STAs |
| 5-7 | Monthly Water Quality Data for Marsh Transect Stations at STA-1W, STA-1E, STA-2 and STA-5 |
| 5-8 | Dow nstream Monitoring Station Database Codes |
| 5-9 | 2008 Rotenberger Wildlife Management Area Topographic Map |
| 5-10 | Water Budgets, Total Phosphorus Budgets and Treatment Performance in STA Treatment Cells and Flow -w ays |
| 5-11 | Summary Statistics for Water Quality Variables Monitored in the STA-3/4 PSTA Implementation Project |
| 5-12 | STA-3/4 PSTA Implementation Project Submerged Aquatic Vegetation Coverage Maps |
| 5-13 | STA Herbicide Application Summary for Water Year 2009 |
| 5-14 | STA Black-Necked Stilt Nesting Summary for Water Year 2009 |
| 5-15 | Supporting Information on Water Quality Data for the Everglades Stormw ater Treatment Areas for Water Year 2009 |

## WATER YEAR 2009 HIGHLIGHTS

- STA-1E, STA-1W, STA-2, STA-3/4, STA-5, and STA-6 are in compliance with the EFA and NPDES operating permits and AOs for WY2009 (**Figures 5-1** and **5-2**). New operating permits were issued in 2009 for STA-2, STA-5, and STA-6.
- Since 1994, the ECP STAs have retained 1,209 metric tons (mt) of TP that would have otherwise entered the EPA, reducing TP loads by 72 percent and concentrations from an overall annual TP FWMC of 144 to 40 parts per billion (ppb) (**Figure 5-3**, **Table 5-2**[3], and Appendix 5-3).
- During WY2009, the six STAs received a total of 1,135,554 acre-feet (ac-ft) of water, equating to an average hydraulic loading rate of 2.24 centimeters per day (cm/day). The TP load received was 214.308 mt, equating to an average TP loading rate of 1.37 grams per square meter per year ($g/m^2/yr$). An estimated 82 percent load reduction was achieved, with the STAs retaining 176 mt of TP and reducing inflow TP FWMC from 153 ppb to 25 ppb (**Table 5-2** and **Figure 5-4**). Lake Okeechobee releases and diversions are listed in **Table 5-4**.
- For the third consecutive year, drought conditions impacted the region. The STA Drought Contingency Strategy Document (SFWMD, 2007) was again implemented in an attempt to maintain minimum water levels in many STA cells. STA-1W, STA-2, STA-3/4, and STA-5 received about 20,676 ac-ft of supplemental water from Lake Okeechobee. While supplemental water was delivered to some STA cells during WY2009, there were still several cells that experienced dry-out conditions.
- Further refinements were made in the STA performance tool that is used to generate weekly reports. The tool was enhanced to include additional information to evaluate STA performance as it relates to the permit compliance limits. It utilizes near real-time data in comparing long-term performance estimates for operational decision making.
- The Avian Protection Plan for black-necked stilts (*Himantopus mexicanus*) and burrowing owls (*Athene cunicularia*) nesting in the STAs (APP) (Pandion Systems, Inc., 2008) was accepted by the U.S. Fish and Wildlife Service (USFWS) in September 2008. The APP is intended to minimize impacts to migratory birds nesting in the STAs while acknowledging that the STAs are operated for water quality treatment and flood control purposes. The plan provides an avian risk assessment methodology, mortality reduction measures, and reporting protocols.
- STA operations were affected with migratory birds nesting during the dry period. In accordance with the APP, surveys were conducted during the nesting season (April to June) to monitor for the presence of nests and eggs; information collected helped guide STA operations for water quality treatment while minimizing impacts to nests (see the *Wildlife and Avian Protection* section of this chapter).

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[3] ***Note:*** *The STA-6 flow data is currently under review. The final chapter will be revised to include the updated flow data for all inflow and outflow structures, as well as the load estimates. The revisions will affect both WY2008 and WY2009 performance estimates for STA-6 and the overall POR estimates for all the STAs.*

- The phased vegetation conversion from EAV to SAV in STA-3/4, Cell 1B, continued with positive results while the STA-1W, Cell 3, conversion was considered complete (see the *Vegetation Conversion Status Updates* section of this chapter).
- STA-5 Southern Flow-way (Cells 3A and 3B) passed start-up criteria for TP and Hg and began flow-through operations in August 2008. However, by January 2009, the Southern Flow-way was dried out and supplemental water was not available to keep the cells hydrated.
- While the STA-5 Southern Flow-way and STA-6 Section 2 became flow-capable in December 2006, flow-through conditions did not occur until WY2009.
- Rehabilitation construction occurred in STA-5, Cell 1A, to help improve water flow and treatment (see the *STA-5 Performance Analysis and Rehabilitation* section of this chapter).
- Many of the STA recreational areas remained open for public access. In response to a public request, a customized boardwalk with a duck blind was constructed in STA-5 to provide hunting opportunities for the public, including access for the disabled (see the *Recreational Facilities and Activities* section of this chapter).

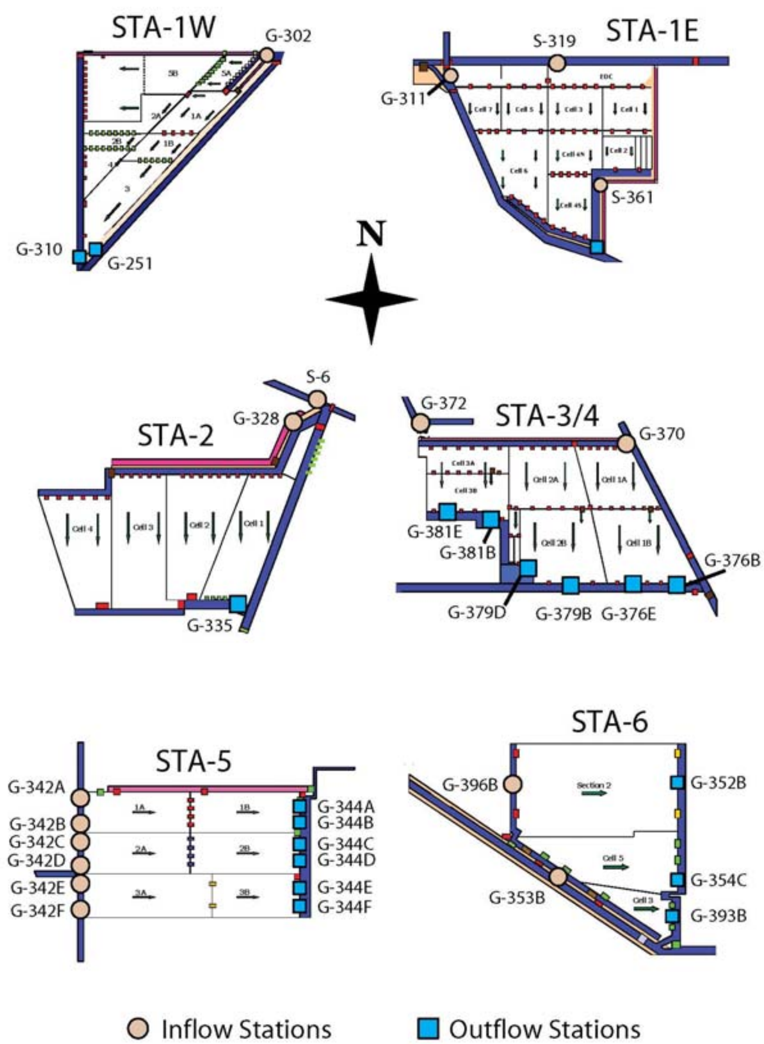


**Figure 5-2.** Schematics of the STAs showing orientation of the treatment cells and locations of the permitted inflow and outflow stations.

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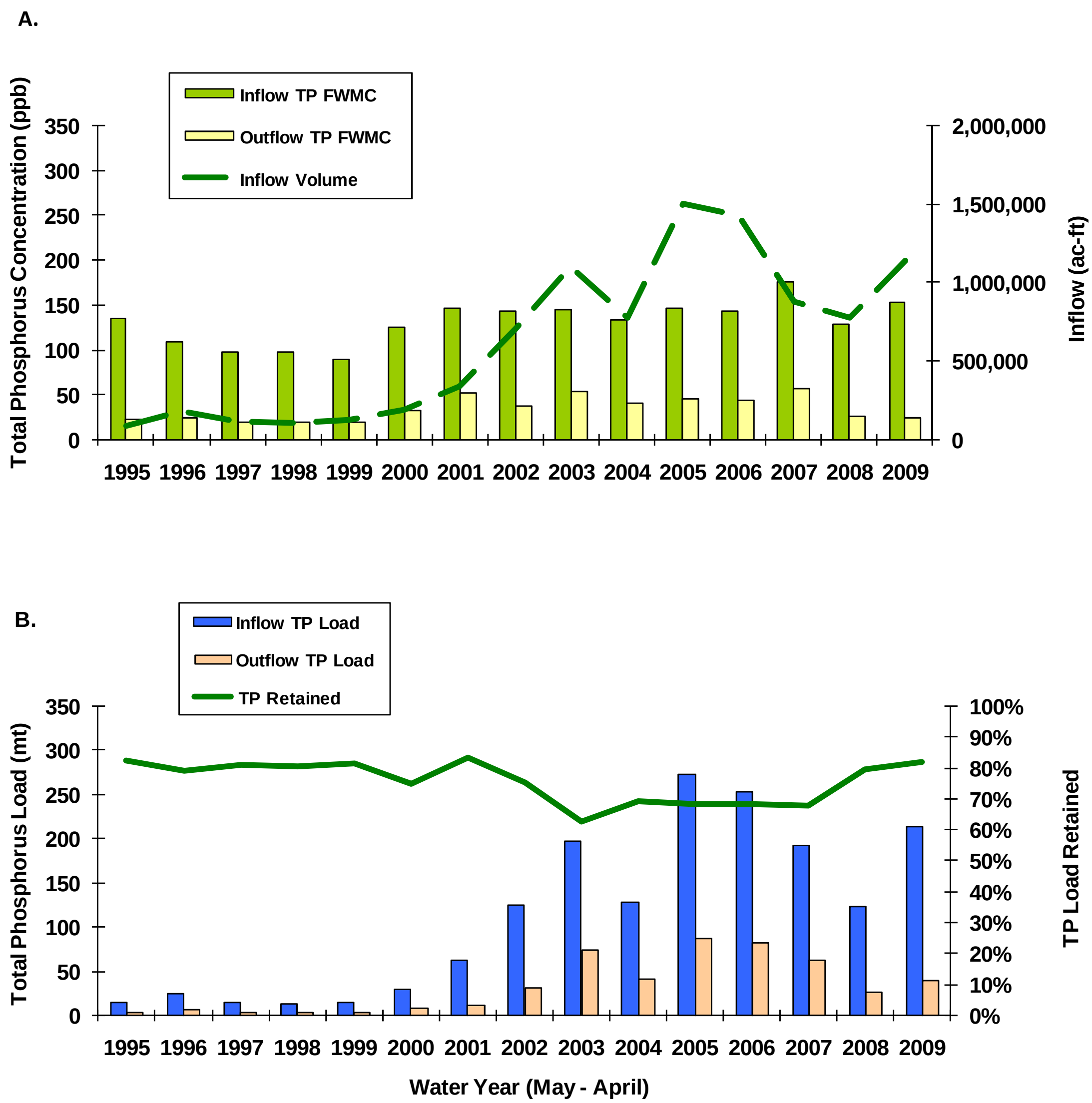


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**Figure 5-3.** (A) Overall annual inflow and outflow total phosphorus (TP) flow-weighted mean concentration (FWMC) and inflow volume, and (B) overall annual inflow and outflow TP loads and percent TP load retained by all the STAs. The amount of effective treatment area in the STAs varies as more treatment cells are built or as existing treatment cells undergo temporary restrictions during maintenance activities.

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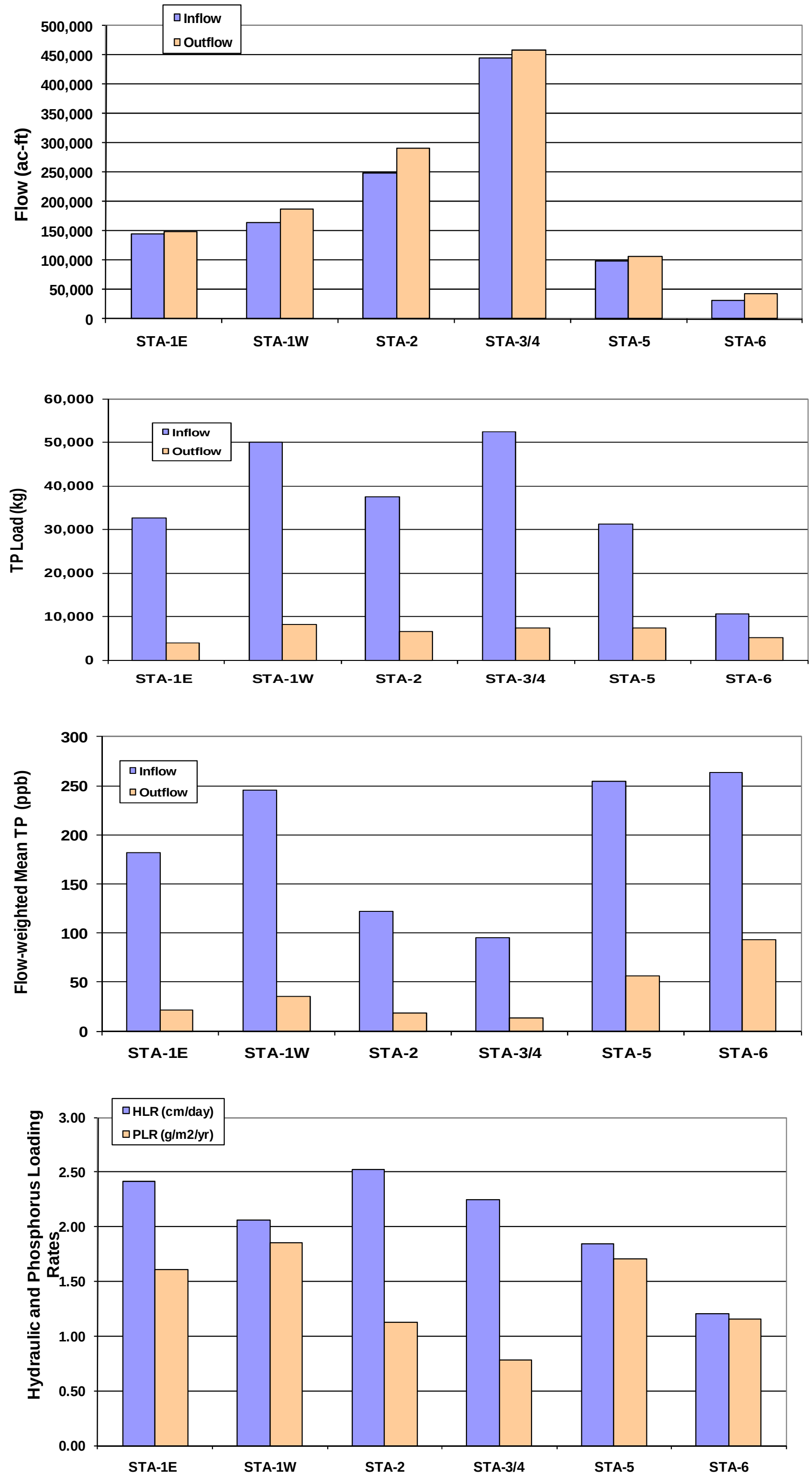


**Figure 5-4.** Water Year WY2009 (WY2009) (May 1, 2008–April 30, 2009) hydraulic and phosphorus loading rates and outflow TP FWMC for the STAs.

**Table 5-2.** STA Performance for Water Year 2009 (WY2009)
(May 1, 2008–April 30, 2009) and period of record (POR) 1994–2009.

| | STA-1E | STA-1W | STA-2 | STA-3/4 | STA-5 | STA-6[f] | All STAs |
|---|---|---|---|---|---|---|---|
| Average Effective Treatment Area (acres)[a] | 5,011 | 6,670 | 8,240 | 16,543 | 4,505 | 2,257 | 43,226 |
| **Rainfall** | | | | | | | |
| Total Annual Rainfall (inches) | 51.3 | 51.3 | 49.1 | 48.0 | 42.8 | 44.4 | 47.8[g] |
| SFWMM Simulation Rainfall Range | 39.8 - 77.5 | 36.6 - 77.4 | 35.4 - 71.6 | 32.3 - 70.7 | 38.6 - 61.4 | 46.8 - 57.6 | --- |
| **Inflow** | | | | | | | |
| Total Inflow Volume (ac-ft) | 145,192 | 164,425 | 250,382 | 445,610 | 99,285 | 32,552 | 1,137,446 |
| Total Inflow TP Load (mt) | 32.612 | 49.917 | 37.604 | 52.515 | 31.155 | 10.595 | 214.398 |
| Flow-weighted Mean Inflow TP (µg/L) | 182 | 246 | 122 | 96 | 254 | 264 | 153 |
| Hydraulic Loading Rate (HLR) (cm/d) | 2.42 | 2.06 | 2.54 | 2.25 | 1.84 | 1.20 | 2.24 |
| TP Loading Rate (PLR) ($g/m^2/yr$) | 1.61 | 1.85 | 1.13 | 0.78 | 1.71 | 1.16 | 1.37 |
| **Outflow** | | | | | | | |
| Total Outflow Volume (ac-ft) | 148,532 | 187,208 | 291,408 | 459,427 | 106,217 | 44,169 | 1,236,961 |
| Total Outflow TP Load (mt) | 3.874 | 8.208 | 6.503 | 7.357 | 7.315 | 5.068 | 38.325 |
| Flow-weighted Mean Outflow TP (µg/L) | 21 | 36 | 18 | 13 | 56 | 93 | 25 |
| Hydraulic Residence Time (d) | 23 | 14 | 19 | 21 | 12 | 5 | --- |
| TP Retained (mt) | 28.738 | 41.709 | 31.101 | 45.158 | 23.840 | 5.527 | 176.073 |
| TP Removal Rate ($g/m^2/yr$) | 1.42 | 1.55 | 0.93 | 0.67 | 1.31 | 0.61 | 1.01 |
| Load Reduction (%) | 88% | 84% | 83% | 86% | 77% | 52% | 82% |
| **Period of Record Performance** | | | | | | | |
| Start date | Sep-04 | Oct-93 | Jun-99 | Oct-03 | Oct-99 | Oct-97 | ***1994 - 2008*** |
| Inflow Volume (ac-ft) | 407,026 | 2,832,614 | 2,197,055 | 2,520,635 | 1,049,406 | 478,121 | 9,484,857 |
| TP Retained to Date (mt) | 44.475 | 399.189 | 231.952 | 307.991 | 184.039 | 41.821 | 1,209.467 |
| TP Outflow to Date (µg/L) | 58 | 54 | 21 | 18 | 101 | 30 | 40 |

**Permit Mandated Reporting for WY2009 for the permits:**
**Everglades Forever Act (EFA), National Pollutant Discharge Elimination System (NPDES), Administrative Order (AO)**

| | STA-1E | STA-1W | STA-2 | STA-3/4 | STA-5 | STA-6 |
|---|---|---|---|---|---|---|
| Operational Permit Phase[h] | Stabilization | Stabilization | Stabilization | Post | Stabilization | Stabilization |
| In compliance with Permits? | Yes | Yes | Yes | Yes | Yes | Yes |
| Within Operational Envelope (Flow/Load)? | Yes/Yes | Yes/No | Yes/Yes | Yes/Yes | Yes/No | Yes/No |
| Was EFA TBEL Achieved? | Yes | No[b] | Yes | Yes[c] | No[b] | No[b] |
| Was NPDES/AO TBEL Achieved? | Yes | Yes | Yes | Yes | Yes | No[b,d] |
| Was Dissolved Oxygen (DO SSAC) achieved?[e] | Yes | No | Yes | Yes | No | No |
| Were there any Water Quality (other than phosphorus) excursions?[e] | No | No | No | No | No | No |
| **Permit Limits** | | | | | | |
| **Operational Envelope:** | | | | | | |
| *Avg. Inflow volume (ac-ft)* | 199,395 | 207,014 | 339,630 | 576,021 | 117,557 | 78,572 |
| *Max. Inflow volume (ac-ft)* | 290,661 | 329,169 | 530,641 | 977,270 | 154,674 | 94,234 |
| *Avg. Inflow TP load (mt)* | 33.441 | 44.510 | 42.823 | 64.821 | 28.912 | 8.290 |
| *Max. Inflow TP load (mt)* | 48.870 | 72.273 | 70.367 | 117.668 | 47.252 | 10.714 |
| **Outflow EFA and NPDES/AO Limits:** | | | | | | |
| *Outflow EFA TBEL TP (ppb) Limit* | 30 | 32 | 24 | 76 | 52 | 22 |
| *Outflow NPDES/AO TBEL TP (ppb) Limit* | 68 | 76 | 24 | 76 | 52 | 22 |

***Comments:***

[a] *Average effective treatment areas reflect treatment cells temporarily off-line for plant rehabilitation or LTP enhancements. Refer to Appendix 5-7 for details on how the effective treatment areas were estimated.*

[b] *Because the STA is in the stabilization phase of the permit, excursions to the TBEL limit are allowed. Details found in "ECP STA Performance" section of this chapter.*

[c] *STA-3/4 is operated under permits issued in 2004 and is considered to be in the post-stabilization phase and the TBEL limit is set at 76 ppb as defined in those permits.*

[d] *The total annual rainfall received by the STA was below the range of values used to develop the TBELs.*

[e] *See "Dissolved Oxygen", "STA Performance Water Year Synopsis" and "Water Quality" sections of this chapter for details.*

[f] *Flows recorded at STA-6 structures are questionable; surveying of structures being performed to correct flow data. Values associated with this STA will be revised.*

[g] *Average Annual Rainfall*

[h] *See "Permit Status and Reporting Mandates" section of this chapter for details.*

***Notes:***

*Flow-proportional autosamplers samples are used to calculate TP loads and concentrations, if available.*

*Period of record calculations Include start-up data.*

*Concentrations expressed as parts per billion (ppb) are equal to µg/L.*

*The STA-6 flow data is currently under review. The final chapter will be revised to include the updated flow data for all inflow and outflow structures, as well as the load estimates. The revisions will affect both WY2008 and WY2009 performance estimates for STA-6 and the overall POR estimates for all of the STAs*

**Table 5-3.** Current permit status and reporting criteria used during WY2009 to assess the STA phosphorus removal performance for the Everglades Forever Act (EFA) and National Pollutant Discharge Elimination System (NPDES) permits, and Administrative Orders (AOs). The AO, issued in conjunction with each of the STA permits, establishes a schedule for achieving compliance with the permit effluent limit.

| | |
|---|---|
| **STA-1E Permit Phase: Eastern Flow-way Restricted Operations; Central and Western flow-ways in Extended Stabilization Phase** | |
| EFA permit 0279499-001-EM (issued 11/16/07) is in effect. | The TBEL criterion is applied to assess the phosphorus removal and for the reporting requirements. |
| NPDES permit FL0304549 (issued 8/30/05) and AO AO-009-EV (issued 8/30/08) are in effect. | These permits have the annual limit of 68 ppb and three-year target of 50 ppb, in lieu of the newer TBEL. |
| **STA-1W Permit Phase: All Treatment Cells in Extended Stabilization Phase** | |
| EFA permit 0279499-001-EM (issued 11/16/07) is in effect. | The TBEL criterion is applied to assess the phosphorus removal and for the reporting requirements. |
| NPDES permit FL0177962-001 (issued 5/11/99) and AO (issued 5/11/99) are in effect. | The NPDES and AO permits have the annual limit of 76 ppb and three-year target of 50 ppb, in lieu of the newer TBEL, for the STA when it is in the Post-stabilization Phase. |
| **STA-2 Permit Phase: Cells 1–4 in Stabilization Phase** | |
| EFA permit 0126704-008-EM (issued 3/17/09), NPDES permit FL0177946 (issued 9/4/07), and AO AO-010-EV (issued 3/17/09) are in effect.<br><br>Note: AO authorizes continued operation of STA-2 and conditional authorization of the construction of Compartment B. | The TBEL criterion is applied to assess the phosphorus removal and for the reporting requirements. |
| **STA-3/4 Permit Phase: Post-Stabilization Phase (according to 2004 Issued Permit)** | |
| EFA permit 0192895 (issued 1/9/04). NPDES permit FL0300195 (issued 1/9/04), and AO (issued 1/9/04) are in effect. | These permits have the annual limit of 76 ppb and three-year target of 50 ppb, in lieu of the newer TBEL, for the STA when it is in the Post-stabilization Phase. |
| **STA-5 Permit Phase: North and Central Flow-way in Stabilization Phase, Southern Flow-way in Start-up Phase** | |
| EFA permit 0131842-009-EM (issued 1/29/09), NPDES permit FL0177954 (issued 9/4/07), and AO AO-011-EV (issued 1/29/09) are in effect.<br><br>Note: AO authorizes continued operation of STA-5 and STA-6 and conditional authorization of the construction of Compartment C. | The TBEL criterion is applied to assess the phosphorus removal and for the reporting requirements. |
| **STA-6 Permit Phase: Section 1 and 2 in Stabilization Phase** | |
| EFA permit 0131842-009-EM (issued 1/29/09), NPDES permit FL0473804-001 (issued 9/4/07), and AO AO-011-EV (issued 1/29/09) are in effect. | The TBEL criterion is applied to assess the phosphorus removal and for the reporting requirements. |

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**Table 5-4.** Information fulfilling the permit-related reporting requirement for the amount of water diverted around the STAs and received by the STAs from Lake Okeechobee as regulatory inflows in WY2009.

| STA | STA Diversion Structure Flow | | | | | | | Inflows from Lake Okeechobee[c] | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | STA Diversion[a] | | | | Water Supply, Gate Maintenance, etc.[b] | | | Regulatory Release | | | | Water Supply Release | | |
| | Structure | Volume (ac-ft) | TP Load (mt) | FWM TP (ppb)[d] | Volume (ac-ft) | TP Load (mt) | FWM TP (ppb) | Structure | Volume (ac-ft) | TP Load (mt) | FWM TP (ppb) | Volume (ac-ft) | TP Load (mt) | FWM TP (ppb) |
| **STA-1E** | G300 | ---- | ---- | ---- | 12.4 | 0.005 | 304 | G311 | 988 | 0.124 | 102 | 5,243 | 0.455 | 70 |
| | | | | | | | | S319 | 26,418 | 5.151 | 158 | ---- | ---- | ---- |
| | **Total** | **----** | **----** | **----** | **12.4** | **0.005** | **304** | **Total** | **27,406** | **5.275** | **156** | **5,243** | **0.455** | **70** |
| **STA-1W** | G301 | ---- | ---- | ---- | 1.5 | 0.001 | 326 | G302 | 2,556 | 0.326 | 103 | 13,568 | 1.793 | 107 |
| | **Total** | **----** | **----** | **----** | **1.5** | **0.001** | **326** | **Total** | **2,556** | **0.326** | **103** | **13,568** | **1.793** | **107** |
| **STA-2** | G338 | ---- | ---- | ---- | 0 | 0 | ---- | S6 | 501 | 0.012 | 19 | 5,587 | 0.286 | 42 |
| | G339 | ---- | ---- | ---- | 4.5 | 0.0002 | 40 | | | | | | | |
| | **Total** | | | | **4.5** | **0.0002** | **40** | **Total** | **501** | **0.012** | **19** | **5,587** | **0.286** | **42** |
| **STA-3/4** | G371 | 3,963 | 0.660 | 135 | 20,124 | 1.512 | 61 | G370 | ---- | ---- | ---- | 3,248 | 0.338 | 84 |
| | G373 | ---- | ---- | ---- | 24,219 | 2.085 | 70 | G372 | ---- | ---- | ---- | 5,250 | 0.455 | 70 |
| | **Total** | **3,963** | **0.660** | **135** | **44,343** | **3.597** | **66** | **Total** | **----** | **----** | **----** | **8,498** | **0.793** | **76** |
| **STA-5** | | ---- | ---- | ---- | ---- | ---- | ---- | | ---- | ---- | ---- | ---- | ---- | ---- |
| | **Total** | **----** | **----** | **----** | **----** | **----** | **----** | **Total** | ---- | ---- | ---- | ---- | ---- | ---- |
| **STA-6** | G407 | ---- | ---- | ---- | 28.8 | 0.007 | 192 | | ---- | ---- | ---- | ---- | ---- | ---- |
| | **Total** | **----** | **----** | **----** | **28.8** | **0.007** | **192** | **Total** | **----** | **----** | **----** | **----** | **----** | **----** |

**Operational Notes:**

[a] *The G-371 structure discharged approximately 650 ac-ft on September 5, 2008, approximately 2,600 ac-ft on September 6, 2008, and approximately 707 ac-ft on September 7, 2008. As a result of these actions, inflows to STA-3/4 were reduced, but the ability to divert stormwater through G-371 was limited due to the need to keep water levels in the North New River Canal lower in order to accommodate high EAA basin runoff.*

[b] *Water was delivered via the G-373 structure to WCA-3A from January 15 to April 30 2009 and via G-371 to WCA-2A from February 5 to March 18th, 2009 for water supply deliveries during dry times. Some water delivered via G373 was delivered to Big Cypress Seminole Indian Reservation.*

[c] *Water was delivered via the G-311, G-302, S-6, G-370 and G-372 structures from January 15 to April 30 2009 for water supply deliveries during dry times.*

[d] *Concentrations expressed as parts per billion (ppb) are equal to µg/L.*

# INDIVIDUAL STA HIGHLIGHTS

## STA-1E

- In WY2009, the Central and Western Flow-ways were operational. Discharges began in the Eastern Flow-way on June 10, 2008, but flow restrictions remained due to the U.S. Army Corps of Engineers (USACE) Periphyton-based Stormwater Treatment Area (PSTA) Demonstration Project in Cell 2.
- Structure S-375 was taken offline in March 2008 due to structural failure of the culverts. It is expected that the structure will remain offline for repairs during WY2010 and be operational by June 2010.
- Installation of a temporary structure (G-707) was completed in March 2009 to partially replace part of the conveyance through the failed S-375 structure. In addition, four 100 cubic feet per second (cfs) temporary pumps, installed in May 2008, are also available to move water from the East Distribution Cell to the West Distribution Cell until S-375 is repaired.
- As part of damage assessment activities after Tropical Storm Fay in August 2008, some settlement and joint separation was identified at S-365A and S-365B. In April 2009, S-365A was taken offline for inspection and repair activities, which are anticipated to be complete by August 2009. An assessment of S-365B is planned to occur after S-365A repairs are complete.
- Improved rating equations, based on revised flow ratings were developed for G-311, S-319, S-361, and S-362 flow data. The current ratings at these stations are effective since November 17, 2008, for S-319; August 25, 2008, for S-316; August 26, 2008, for S-362; and October 5–7, 2008, for G-311.
- In December 2008, the target stages in the SAV cells (Cells 4N, 4S and 6) were increased by six inches to help maintain water levels during the dry months and protect the vegetation from dry-out conditions. Due to the construction of structure G-707, supplemental water was not delivered, and as a result, Cells 1, 2, 3, 4N, and 5 reached dry-out conditions as early as April 2009.

## STA-1W

- In WY2009, all three flow-ways (Eastern, Western, and Northern) were operational.
- In December 2008, in accordance with the Drought Contingency Plan, target stages in the SAV cells (Cells 1B, 2B, 3, 4, and 5B) were increased by six inches to help maintain water levels during the dry months and protect the vegetation from dry-out conditions. Starting in January 2009, supplemental water was delivered, including water that was redirected from STA-1E as a result of dewatering activities related to installation of G-707. This action allowed the SAV cells in this STA stayed hydrated through the dry season.

## STA-2

- In WY2009, all four flow-ways (Cells 1–4) were operational.
- Improved rating equations were developed for G-328I and G-337A, resulting in changes to the preferred flow record for G-328I from April 28, 2005 to August 10, 2009 and for G-337A from July 18, 2008 to August 10, 2009.
- In anticipation of drought conditions, in December 2008 the between-storm target stages in the SAV cells were increased by six inches to maintain water levels and

protect the vegetation from dry-out conditions. Starting in January 2009, supplemental water was delivered to the SAV cells.

- The vegetation conversion from EAV to SAV in Cell 2 was initiated.

## STA-3/4

- In WY2009, all three flow-ways (Eastern, Central, and Western) were operational.
- The vegetation conversion from EAV to SAV in STA-3/4, Cell 1B, continued with positive results (see the *Vegetation Conversion Status Updates* section of this chapter).
- In anticipation of drought conditions, in December 2008 the between-storm target stages in the SAV cells (Cells 1B, 2B, and 3B) were increased by six inches to maintain water levels and protect the vegetation from dry-out conditions. Starting in January 2009, supplemental water was delivered and pumping from the EAV cells to the SAV cells was also initiated.

## STA-5

- In WY2009, the Central Flow-way (Cells 2A and 2B) was operational. The Northern Flow-way (Cells 1A and 1B) was offline starting in December 2008 for the Cell 1A Rehabilitation Project. The Southern Flow-way (Cells 3A and 3B) passed start-up criteria for TP and Hg and discharge operations in August 2008; however, it was offline again starting in April 2009 for activities related to the Cell 1A Rehabilitation Project.
- Rehabilitation construction for Cell 1A started in December 2009 (see the *STA-5 Data Analysis and Rehabilitation* section of this chapter).
- In anticipation of drought conditions, in December 2008 the between-storm target stages in the SAV cells were increased by six in. to maintain water levels and protect the vegetation from dry-out conditions. Water that was pumped out of Cell 1A during construction was redirected into Cells 1B and 2A. However, no other sources of supplemental water was available to be delivered to the Southern Flow-way and, as a result, it dried out by January 2009. Starting in February 2009, supplemental water was delivered to Cell 1B through the G-507 pump (1.28 mt of TP; 10,643 ac-ft; annual TP FWMC 98 ppb), and Cell 2B received water from Cell 1B via the internal G-345 culvert.
- A new survey was conducted during WY2009 at the Cell 3A and Cell 3B structures to improve stage measurements and flow estimates.

## STA-6

- IN WY2009, all three flow-ways (Cell 3, Cell 5, and Section 2) were operational.
- In anticipation of drought conditions, in December 2008 the between-storm target stage in the SAV cell (Section 2) was increased by six inches to maintain water levels and protect the vegetation from dry-out conditions, however, no supplemental water was available to be delivered. As a result, all three flow-ways dried out by January 2009.
- A new elevation survey was conducted during WY2009 at all inflow and outflow structures and is intended to improve stage measurements and flow estimates.

# STA PERFORMANCE

## PERMIT STATUS AND REPORTING MANDATES

### Permit Phases and Phosphorus Loading Requirements

In calendar year 2007 (CY2007), new operating permits (EFA, NPDES, and AOs) were issued for all STAs, except for STA-3/4, requiring Technology Based Effluent Limits (TBELs) for total phosphorus (TP) as well as comparisons of actual TP loads to the operational envelopes (**Table 5-3**). STA-3/4 is still operating under permits issued in CY2004. The new STA-3/4 permit is currently being developed and, in the interim, the existing permit has been extended to allow time to complete processing of the new permit. The Technical Support Documents for the TBELs explain the derivation of the TBEL limits and identify factors that may impact flows and loads associated with the treatment system. The Operational Envelope criterion was added to account for the variable inflows the STAs receive. The original conceptual design of the STAs was based on a first-order phosphorus removal model and annual-average data. Because this design approach did not consider the temporal/seasonal characteristics of the inflows, there was little reference against which actual inflows and resulting STA performance could be assessed. By contrast, the design of the STA enhancements and projections of performance were based on a dynamic model utilizing a 31-year set of simulated daily flows and TP loads, also referred to as the Operational Envelope. This design approach captures the variability of inflows and provides a reference against which actual inflows can be compared to the predicted inflows. Weekly summaries comparing the actual inflows to the Operational Envelopes are used to assist in operational decision making to try to ensure that the STAs are not subject to overload of either flow or nutrients.

The operating permits recognize that the natural systems undergo maturity changes and the STAs are categorized into phases, depending on the developmental and performance phase of the system. The permits describe three phases with regard to application of the TBEL: Start-up Phase, Stabilization Phase, and Routine Operations Phase. The TBEL does not apply until the STA is in the Routine Operations Phase. STA-1E, STA-1W, STA-2, STA-5, and STA-6 operations are in the Stabilization Phase, which ends when the STA achieves the annual TP limits as defined in the TBEL. Because STA-3/4 is operating under permits issued in CY2004, it is considered to be in the Post-stabilization Phase and the TBEL identified in that permit applies. As defined in the EFA permit issued in CY2007, during the Stabilization Phase, the vegetation will be maturing and the STA performance will generally be improving toward achieving the TBEL. It is anticipated that the vegetation may require one to three years after flow-through operations begin for the treatment cells to achieve optimal treatment performance. During the stabilization phase, the TBEL applies, and it is also acknowledged that exceedances of the TBEL may occur. An STA or flow-way may enter the Stabilization Phase after one of four antecedent conditions occurs (1) once flow-through operations begin following the initial start-up of a new treatment cell, (2) when a treatment cell is taken offline for implementation of Long-Term Plan enhancements that may have adverse impacts on STA performance, (3) when a treatment cell is taken offline for recovery activities associated with a major event that compromises the structural integrity or performance of the STA, or (4) when planned or unplanned maintenance activities would cause adverse impacts to the STA treatment capabilities.

The STA flow volumes are based on daily average surface water flow, and the TP loads are calculated using weekly flow or time-proportional auto-sampler data. If auto-sampler data are not available, then TP data from grab samples collected during flow events are used instead. The TP loads in surface water inflow and outflow were calculated using a Microsoft Excel VBA application that accessed the District's hydrometeorologic database DBHYDRO (Reardon and

Germain, 2005). Both positive and negative (i.e., reverse) flows at water control structures were used in these calculations.

# WATER YEAR 2009 PERFORMANCE

## STA Hydraulic and Phosphorus Loading

In WY2009, about 176 metric tons (mt) of TP that would have entered the Everglades was instead retained in the STAs. The percent of TP retained (i.e., a comparison of outflow to inflow) for the year ranged from 52 percent for STA-6 to 88 percent for STA-1E. The STAs reduced the inflow TP load by 82 percent, decreasing total inflow TP flow-weighted mean concentration (FWMC) from 153 to 25 parts per billion (ppb). Since 1994, the total amount of TP retained in the STAs is about 1,200 mt (**Table 5-2**, **Figure 5-3**, and Appendix 5-2 of this volume). The annual STA TP mass removal rates (also referred to as the effective settling rate) for WY2009 increased for all the STAs compared to WY2008, and ranged from 5 to 19 meters per year (STA-6 and STA-1E, respectively) (Appendix 5-2 of this volume).

During WY2009, the flows and TP loads into the STAs were not constant, which is consistent with the seasonality effects of weather anticipated in the design of the STAs. Inflows occurred from June through October 2008, and were small to non-existent during the remaining months of the water year. Peak inflows occurred in all the STAs in August 2008 due to Tropical Storm Fay (details about the storm are presented in Chapter 2 of this volume and impacts on the STAs are presented in the *Tropical Storm Fay Impacts on the STAs* section of this chapter). Ironically, Tropical Storm Fay arrived in the midst of the third consecutive year of the regional drought conditions. The 2006 –2009 drought in South Florida is considered to be one of the most severe droughts in the region. For WY2009, the STAs received about 20 to 30 percent less inflow volume compared to the Operational Envelope long-term average annual volumes (**Table 5-2**). For TP loads, STA-1E, STA-2, and STA-3/4 received less than the long-term average annual Operational Envelope TP loads, while STA-1W, STA-5, and STA-6 received more than the long-term average annual Operational Envelope TP loads. All six of the STAs loadings were below the maximum Operational Envelope TP loads. *[**Note:** The STA-6 flow data is currently under review. The final chapter will be revised to include the updated flow data for all inflow and outflow structures, as well as the load estimates. The revisions will affect both WY2008 and WY2009 performance estimates for STA-6 and the overall POR estimates for all the STAs.]*

All the STAs demonstrated a reduction in outflow TP concentrations as compared to inflows. Inflow TP FWMC ranged from 96 ppb for STA-3/4 up to 264 ppb for STA-6. Outflow TP FWMC were below 25 ppb for STA-1E, STA-2, and STA-3/4 (21 ppb, 18 ppb, and 13 ppb respectively); slightly higher for STA-1W and STA-6 (26 ppb and 56 ppb, respectively); and highest for STA-6 (93 ppb).

STA-3/4 and STA-6 had some apparent negative flow events. The negative flows at STA-3/4 occurred at the outflow structures, indicating reverse flow from the discharge canal into the treatment cell. Because the flows went into the STA, these negative flows are not a permit-related issue. The apparent negative flows at the STA-6 inflow structures are currently under investigation and the Florida Department of Environmental Protection (FDEP) has been notified via the monthly Discharge Monitoring Reports.

## Permit Compliance for Phosphorus

In WY2009, STA-1E, STA-2, and STA-3/4 outflows met the permit TBEL limits, while STA-1W, STA-5, and STA-6 did not meet their limits (**Table 5-2**). For STA-1W and STA-5, outflow TP FWMC was 4 ppb above the TBEL limit and, for STA-6, the outflow was about 71 ppb above the TBEL limit. Although the STA-6 flow data is still under review, it appears that this STA received inflow loads nearly at the annual maximum Operational Envelope TP load. All the STAs received large TP loads in August 2008 due to Tropical Storm Fay (see the *Tropical Storm Fay Impacts on the STAs* section of this chapter for additional details). In August 2008, STA-1W received 29 mt of TP, which is over half of the anticipated average annual TP load. Under the permit, it is recognized that STA-1W may receive flows and TP loads higher than anticipated until regional improvements are completed. At STA-5, Cell 1A was taken off-line in December 2008 for rehabilitation activities which temporarily decreased the amount of effective treatment area in the STA (see the *STA-5 Performance Analysis and Rehabilitation* section of this chapter).

With the completion of STA-6 Section 2 and the modifications to the STA-6 Section 1 inflow structures, STA-6 began accepting runoff from the C-139 basin, a new inflow source for this STA. C-139 basin runoff has had higher TP concentrations compared to the runoff that previously was treated by STA-6; therefore, this appears to be a reason for the increase in TP loading. Both STA-5 and STA-6 had treatment cells that were dry in WY2009 because of the drought conditions (see the *Drought Impacts on the STAs* section of this chapter for more details). According to the STA permits issued in 2007 and 2009 for all the STAs (except for STA-3/4, which is still operating under the 2004 permit), the STAs are considered to be in the Stabilization Phase (**Table 5-3**) and the permits recognize that the TBEL may not be met during this phase.

## Other Water Quality Parameters

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

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

The determination as to whether or not an STA is contributing to a violation for a specific parameter is a comparison of the average annual inflow concentration to the average annual outflow concentration relative to the three-part assessment. The District has performed all sampling and analysis in compliance with Chapter 62-160, Florida Administrative Code (F.A.C.), and the District's Laboratory Quality Manual (SFWMD, 2009b) and Field Sampling Quality Manual (SFWMD, 2009c). The Annual Permit Compliance Monitoring Report for Mercury in the STAs is located in Appendix 5-6. Each STA has different permit reporting requirements for annual water quality constituents. The required parameters are shown in **Table 5-6**. For WY2009, the ECP STAs are in compliance with all requirements of the EFA and NPDES operating permits.

**Table 5-5.** Water quality parameters with Florida Class III criteria specified in Section 62-302.530, Florida Administrative Code. Because the STAs are freshwater systems, background concentration for specific conductivity is assumed to be less than 1,275 micromhos per centimeter (µmhos/cm), and background concentration for turbidity cannot exceed 29 nephelometric turbidity units (NTUs).

| Parameter | Units | Class III Criteria |
|---|---|---|
| Dissolved Oxygen[a] | mg/L | Greater than (>) or equal to (=) 5.0 mg/L |
| Conductivity | µmhos/cm | Not > 50 percent of background or > 1,275 µmhos/cm, whichever is greater |
| pH | SU | Not less than (<) 6.0 or > 8.5 |
| Turbidity | NTU | < or = 29 NTU above background conditions |
| Unionized Ammonia | mg/L | < or = 0.02 mg/L |
| Alkalinity | mg $CaCO_3$/L | Not < 20 mg/L |

[a] Permits for all STAs, except STA-3/4, require compliance with the Site-Specific Alternative Criteria (SSAC) for dissolved oxygen (Weaver, 2004).

mg/L – milligrams per liter

µmhos/cm – micromhos per centimeter

SU – standard units

NTU – nephelometric turbidity unit

$CaCO_3$ – calcium carbonate

420

**Table 5-6**. Summary of annual flow-weighted mean concentrations (FWMC) for parameters other than total phosphorus (TP) at inflow and outflow of STAs to the Everglades Protection Area (EPA) during WY2009. Excursions occurred when FWMC at outflows are greater than those at inflows. There were no excursions in WY2009.

| Stormwater Treatment Area | Data Classification | Flow-Weighted Mean Concentrations | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Alkalinity (mg $CaCO_3$/L) | Chloride (mg/L) | Sulfate (mg/L) | Un-ionzied Ammonia (mg $NH_3$/L) | Nitrate+Nitrite (mg N/L) | Total Dissolved Nitrogen (mg/L) | Total Nitrogen (mg/L) | Total Dissolved Phosphorus (mg/L) |
| STA-1E | Inflow | 174 | ---- | 42.5 | ---- | 1.296 | ---- | 3.26 | ---- |
| | Outflow | 139 | ---- | 29.4 | ---- | 0.068 | ---- | 1.25 | ---- |
| | Excursions | No | ---- | No | ---- | No | ---- | No | ---- |
| STA-1W | Inflow | 275 | ---- | 81.0 | ---- | 0.596 | ---- | 3.67 | ---- |
| | Outflow | 201 | ---- | 61.6 | ---- | 0.044 | ---- | 2.19 | ---- |
| | Excursions | No | ---- | No | ---- | No | ---- | No | ---- |
| STA-2 | Inflow | 333 | ---- | 77.5 | ---- | 0.605 | ---- | 3.40 | ---- |
| | Outflow | 265 | ---- | 58.3 | ---- | 0.137 | ---- | 2.32 | ---- |
| | Excursions | No | ---- | No | ---- | No | ---- | No | ---- |
| STA-3/4 | Inflow | 263 | 88 | 61.5 | 0.004 | 1.931 | 4.22 | 4.41 | 0.069 |
| | Outflow | 207 | 87 | 49.3 | 0.001 | 0.009 | 1.78 | 1.81 | 0.007 |
| | Excursions | No | No | No | No | No | No | No | No |
| STA-5 | Inflow | ---- | ---- | 6.1 | ---- | 0.037 | ---- | 1.74 | ---- |
| | Outflow | ---- | ---- | 4.7 | ---- | 0.009 | ---- | 1.36 | ---- |
| | Excursions | ---- | ---- | No | ---- | No | ---- | No | ---- |
| STA-6 | Inflow | 143 | ---- | 8.6 | ---- | 0.096 | ---- | 1.67 | ---- |
| | Outflow | 140 | ---- | 3.7 | ---- | 0.011 | ---- | 1.31 | ---- |
| | Excursions | No | ---- | No | ---- | No | ---- | No | ---- |

## Water Year 2009 Performance for Water Quality Parameters Other Than Phosphorus

Water quality parameters with Florida Class III standards applicable to the STAs are provided in **Table 5-5**. Compliance with EFA permits is determined based on the three-part assessment presented in the *Water Quality Permit Requirements* section of this chapter. The description of background for specific conductance criteria is described as follows: For conductivity, the value "shall not be increased more than 50 percent above background or to 1,275, whichever is greater". Because the standards are for fresh water, background conductivities are typically lower than 1,275 microsiemens per centimeter (µS/cm). The description of background for turbidity is described as follows: "For turbidity, the measured value shall be "< 29 above natural background conditions." Under Chapter 62-303, F.A.C., natural background is defined as "…the condition of waters in the absence of man-induced alterations based on the best scientific information available to the Department. The establishment of natural background for an altered water body may be based upon a similar unaltered water body or on historical pre-alteration data." Since the Florida Department of Environmental Protection (FDEP) has not compiled any information on what it considers natural background, the District determines that any measured value that is greater than 29 nephelometric turbidity units (NTUs) is considered to exceed the turbidity criterion. For the other water quality parameters that do not have Class III standard, excursions are noted when the outflow FWMCs are higher than the inflow. An STA may have excursions and still be considered to be in compliance with the permit.

WY2009 monitoring data for permitted water quality parameters at the STA inflows and outflows are presented in Appendix 5-5. Annual FWMC at inflows and outflows of the STAs, including excursion analysis, is summarized in **Table 5-6**. In addition, the annual permit compliance monitoring report for mercury in the STAs is included as Appendix 5-4.

Pursuant to EFA permits for each of the STAs (except STA-3/4), dissolved oxygen compliance shall be evaluated annually using a statistical analysis to compare DO levels within facility as set forth in the Everglades Marsh Dissolved Oxygen Site-Specific Alternative Criteria (DO SSAC). Additional details regarding compliance with the DO SSAC is presented in the *Dissolved Oxygen* section.

Based on water quality data (excluding TP and DO) collected during WY2009 at inflows and outflow to the STAs, all of the annual mean FWMCs measured at outflows of a specific STA did not exceed the Class III criteria and were lower than annual mean FWMC at the inflows to that STA (**Tables 5-5** and **5-6**). Therefore, all STAs were within permit compliance requirements for parameters other than phosphorus.

As part of the performance evaluation specified by permit for each STA, a statistical comparison of inflow and outflow FWMC is required to be reported at a significance level ($\alpha$) of 0.05. The test (i.e., Student's t-test) specified in the permits to statistically compare the parameter concentrations may not be the most appropriate based on distributional assumptions of the data. When datasets to be compared are not significantly different from a normal distribution, then the Student's t-test can be applied. However, when data are significantly different from normality, the Student's t-test is not appropriate and can result in incorrect significance. For the purpose of this report, distribution of the datasets was determined using the Shapiro-Wilks test of normality at $\alpha = 0.05$. Those datasets exhibiting probability values (p-values) greater than 0.05 do not deviate significantly from a normal distribution and could be tested using the Student's t-test. However, datasets with distributions deviating significantly from normality (p-value < 0.05), will be tested using the Mann-Whitney U test (a non-parametric equivalent of the Student's t-test).

During WY2009, inflow and outflow datasets for the six STAs exhibited deviations from normal distributions. **Table 5-7** summarizes these statistical comparisons for parameter FWMC at

STA inflows and outflow. Of the 33 datasets evaluated, nine comparisons exhibited statistically higher concentrations at the inflows than outflows.

**Table 5-7.** Statistical comparison flow-weighted mean concentrations at inflows and outflows of STAs that discharge to the EPA during WY2009. Highlighted probability values (p-values) indicate a statistically significant difference between inflows and outflows for a parameter.

| Parameter Name | Variable | Storm Water Treatment Areas | | | | | |
|---|---|---|---|---|---|---|---|
| | | STA-1E | STA-1W | STA-2 | STA-3/4 | STA-5 | STA-6 |
| Specific Conductivity | P-Value[a] | 0.750 | 0.440 | 0.460 | 0.720 | 0.850 | 0.160 |
| | Structure[b] | Inflow | Inflow | Inflow | Inflow | Inflow | Inflow |
| | Statistical Test[c] | Mann-Whitney | Mann-Whitney | Mann-Whitney | Mann-Whitney | Mann-Whitney | Mann-Whitney |
| Turbidity | P-Value[a] | NA | NA | NA | ***<0.01*** | NA | NA |
| | Structure[b] | NA | NA | NA | ***Inflow*** | NA | NA |
| | Statistical Test[c] | NA | NA | NA | ***Mann-Whitney*** | NA | NA |
| Dissolved Chloride | P-Value[a] | NA | NA | NA | 0.890 | NA | NA |
| | Structure[b] | NA | NA | NA | Inflow | NA | NA |
| | Statistical Test[c] | NA | NA | NA | Mann-Whitney | NA | NA |
| Alkalinity | P-Value[a] | 0.310 | 0.710 | 0.240 | 0.060 | 0.600 | ***0.030*** |
| | Structure[b] | Inflow | Outflow | Inflow | Inflow | Inflow | ***Inflow*** |
| | Statistical Test[c] | Mann-Whitney | Mann-Whitney | Mann-Whitney | Mann-Whitney | Mann-Whitney | ***Mann-Whitney*** |
| Sulfate | P-Value[a] | 0.430 | 0.100 | 0.600 | 0.150 | 0.070 | ***0.020*** |
| | Structure[b] | Outflow | Inflow | Outflow | Inflow | Inflow | ***Inflow*** |
| | Statistical Test[c] | Mann-Whitney | Mann-Whitney | Mann-Whitney | Mann-Whitney | Mann-Whitney | ***Mann-Whitney*** |
| Total Dissolved Phosphorus | P-Value[a] | NA | NA | NA | ***<0.01*** | NA | NA |
| | Structure[b] | NA | NA | NA | ***Inflow*** | NA | NA |
| | Statistical Test[c] | NA | NA | NA | ***Mann-Whitney*** | NA | NA |
| Unionized Ammonia | P-Value[a] | NA | NA | NA | 0.200 | NA | NA |
| | Structure[b] | NA | NA | NA | Inflow | NA | NA |
| | Statistical Test[c] | NA | NA | NA | Mann-Whitney | NA | NA |
| Nitrate + Nitrite | P-Value[a] | 0.270 | ***<0.01*** | ***<0.01*** | ***<0.01*** | ***<0.01*** | 0.060 |
| | Structure[b] | Inflow | ***Inflow*** | ***Inflow*** | ***Inflow*** | ***Inflow*** | Inflow |
| | Statistical Test[c] | Mann-Whitney | ***Mann-Whitney*** | ***Mann-Whitney*** | ***Mann-Whitney*** | ***Mann-Whitney*** | Mann-Whitney |
| Total Dissolved Nitrogen | P-Value[a] | NA | NA | NA | 0.090 | NA | NA |
| | Structure[b] | NA | NA | NA | Inflow | NA | NA |
| | Statistical Test[c] | NA | NA | NA | Mann-Whitney | NA | NA |
| Total Nitrogen | P-Value[a] | 0.220 | 0.430 | 0.190 | 0.090 | ***<0.01*** | 0.170 |
| | Structure[b] | Inflow | Inflow | Inflow | Inflow | ***Inflow*** | Inflow |
| | Statistical Test[c] | Mann-Whitney | Mann-Whitney | Mann-Whitney | Mann-Whitney | ***Mann-Whitney*** | Mann-Whitney |

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

[a] Probability level (p-value) computed using appropriate comparison test. A significance level (α) of 0.05 was used. When p-value was less than 0.05, the parameter concentrations were significantly different between the inflow and outflow. Significant p-values are identified by shading and are presented in the table as italicized and bolded values.

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

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

## Dissolved Oxygen

Dissolved oxygen (DO) concentrations below 5.0 milligrams per liter (mg/L) occur commonly throughout the EPA, including interior marsh sites minimally impacted by nutrient enrichment or cattail invasion. Frequent DO levels below 5.0 mg/L are typical in macrophytic dominated wetlands where marsh processes of photosynthesis and respiration result in wide diel cycle swings in DO levels. Since low DO concentrations often measured in the EPA represent natural variability in this type of ecosystem, the FDEP, pursuant to Chapter 62-302.800(1), F.A.C., has promulgated a Site-Specific Alternative Criterion (SSAC) for DO in the Everglades. This SSAC addresses the wide-ranging natural daily (diel) fluctuations that influence natural background DO levels. In the *2008 South Florida Environmental Report* (SFER) – *Volume I*, Chapter 3A explains the SSAC and its development and application in assessing DO excursions (Weaver, 2008). The specific methods for determining compliance are set forth in the DO SSAC (Weaver, 2004), which was adopted by Secretarial Order on January 26, 2004, and approved by the U.S. Environmental Protection Agency (USEPA) as a revision to the state of Florida's water quality standards on June 16, 2004.

Previous reports (Jorge et al, 2002; Goforth et al., 2003; Goforth et al., 2004; Goforth et al., 2005; Pietro et al., 2006; Pietro et al., 2007) provide monitoring results, comparisons and evaluations with regard to diel DO for the STAs. These reports were used to assess the impact of STA discharges on the downstream Everglades ecological system or downstream water quality with respect to DO and pursuant to the STA-1E, STA-1W, STA-2, STA-3/4, and STA-5 EFA permits and associated AOs. This also provided data to the FDEP for developing the DO SSAC.

In the 2008 SFER – Volume I, Chapter 5, DO levels measured at outflow stations from the five STAs (STA-1E, STA-1W, STA-2, STA-3/4, and STA-5) were assessed using the developed SSAC rather than diel DO evaluation as performed in previous reports. This change was agreed to by the FDEP and the District. Since the STA-6 permit did not have diel requirements, no SSAC comparison was performed for this STA for WY2007.

The SSAC is presently included in EFA permits and associated AOs of five STAs (STA-1E, STA-1W, STA-2, STA-5, and STA-6) as permit compliance criterion. The SSAC is also expected to be included in future STA permits for STA-3/4. The NPDES permit issued on January 9, 2004, for this STA stipulates that it shall be revised in the event the state of Florida establishes a DO SSAC in the EPA. A map showing the permitted outflow points for each STA is provided in Figure 5-2.

Permits issued for the six STAs require that the District provides the FDEP with an annual report consisting of an analysis demonstrating that DO levels in STA discharges do not adversely change the downstream Everglades ecology or the downstream water quality. Since the SSAC has been adopted by the FDEP and formally approved by the USEPA, assessment on possible downstream impacts by the outflows from STAs during WY2009 were performed by applying the SSAC limit with respect to DO at the outflow stations.

Biweekly DO concentrations measured at STA discharge stations during WY2009 were used to summarize annual DO levels (Appendix 5-5). A summary of these annual DO levels for permitted outflows at each STA and calculated SSAC DO limits are provided in **Table 5-8**. By comparing the measured mean annual DO for an outflow station with the calculated mean annual SSAC limit, a determination can be made if the station complies with the permitted limit. When mean annual DO concentrations measured at the effluent compliance points (outflow stations) are greater than the calculated mean annual lower limit utilizing the SSAC equation, then the outflow values are above the SSAC limit or comply with the permitted limit. During WY2009, one outflow station at STA-1W (G-251), two new outflow stations at STA-5 (G-344E and G-344F), and two outflow stations at STA-6 (G-354C and G-393B) had mean annual DO levels that were lower than the SSAC limit (**Table 5-8**). These deviations from the SSAC limit probably resulted from a combination of low-flow conditions at these discharge locations and drought conditions during part of WY2009.

More than 96 percent of the total flow from STA-1W was directed through G-310 during WY2009 with less than four percent of the total flow being released at G-251. The low flow at G-251 contributed to the mean annual DO level being 1.2 mg/L due to more frequent periods of stagnation. The combined flow at the two new outflow structures from STA-5 (G-344E and G-344F) accounted for less than three percent of the total outflow from this STA. Mean annual DO levels at both structures were less than 0.5 mg/L below the SSAC limit (**Table 5-8**). During WY2009, STA-6 had three outflow structures in operation. Two of the structures (G-354C and G-393B) had a combined flow that was less 17 percent of the total flow from the STA. In addition, both outflow stations had mean annual DO levels that deviated approximately 2.0 mg/L from the SSAC limit. In all cases, outflow structures that had limited flow during WY2009 did not meet the SSAC limit for DO.

In addition to determining STA performance to the SSAC for WY2009, a comparison of STA performance with the SSAC for the past three years was performed. **Figure 5-5** presents the mean annual residual DO levels for STA outflow for WY2007–WY2009. When mean annual DO levels are greater than the SSAC, the mean annual residuals (difference between mean annual DO levels and SSAC limit) are positive (or greater than zero). All outflow stations at STA-3/4 had positive residuals with four structures (G-376B, G-379B, G-379C, and G-381E) exhibiting continued improvement in DO (**Figure 5-5**). Only G-344C in STA-5 exhibited a three-year improvement in DO levels.

**Table 5-8.** Summary of annual dissolved oxygen (DO) levels at outflow stations for each STA and their comparison with Site-Specific Alternative Criteria (SSAC) in WY2009.

| STA | Outlfow Station | No. of Samples | Mean[a] | Standard Deviation | Minimum | Maximum | Mean Annual SSAC Limit[b] | SSAC Limit Classification[c] |
|---|---|---|---|---|---|---|---|---|
| STA-1E | S362 | 53 | 5.93 | 1.82 | 2.47 | 8.81 | 4.14 | Above |
| STA-1W | ***G251*** | ***53*** | ***1.99*** | ***1.31*** | ***0.16*** | ***6.97*** | ***3.19*** | ***Below*** |
| | G310 | 53 | 4.51 | 1.58 | 1.07 | 7.76 | 2.96 | Above |
| STA-2 | G335 | 52 | 5.70 | 1.42 | 2.55 | 9.18 | 4.21 | Above |
| STA-3/4 | G376B | 52 | 4.64 | 1.67 | 1.46 | 7.78 | 3.07 | Above |
| | G376E | 52 | 4.14 | 2.09 | 0.88 | 9.60 | 3.14 | Above |
| | G379B | 52 | 4.49 | 2.19 | 1.81 | 10.10 | 3.35 | Above |
| | G379D | 52 | 3.87 | 1.85 | 0.57 | 8.76 | 3.62 | Above |
| | G381B | 52 | 4.90 | 1.88 | 1.21 | 10.40 | 3.73 | Above |
| | G381E | 52 | 5.81 | 2.14 | 0.37 | 10.60 | 4.05 | Above |
| STA-5 | G344A | 53 | 4.26 | 2.32 | 0.31 | 9.69 | 3.37 | Above |
| | G344B | 53 | 4.39 | 2.10 | 0.95 | 8.71 | 3.59 | Above |
| | G344C | 53 | 5.02 | 2.05 | 1.48 | 9.78 | 3.63 | Above |
| | G344D | 53 | 5.44 | 2.33 | 1.48 | 10.20 | 3.80 | Above |
| | ***G344E*** | ***25*** | ***3.26*** | ***1.30*** | ***1.25*** | ***5.11*** | ***3.69*** | ***Below*** |
| | ***G344F*** | ***25*** | ***3.40*** | ***1.45*** | ***0.85*** | ***5.89*** | ***3.86*** | ***Below*** |
| STA-6 | G352B | 37 | 3.93 | 2.02 | 0.25 | 7.27 | 3.76 | Above |
| | ***G354C*** | ***32*** | ***1.71*** | ***1.20*** | ***0.18*** | ***5.19*** | ***3.71*** | ***Below*** |
| | ***G393B*** | ***32*** | ***1.72*** | ***1.23*** | ***0.29*** | ***5.44*** | ***3.55*** | ***Below*** |

Note: [a] Arithmetic mean

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

[c] SSAC limit indicates whether the mean annual DO level measured at an outflow station was above or below the SSAC limit. To be above the SSAC limit, mean annual DO must be equal to or greater than the mean annual SSAC limit.

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

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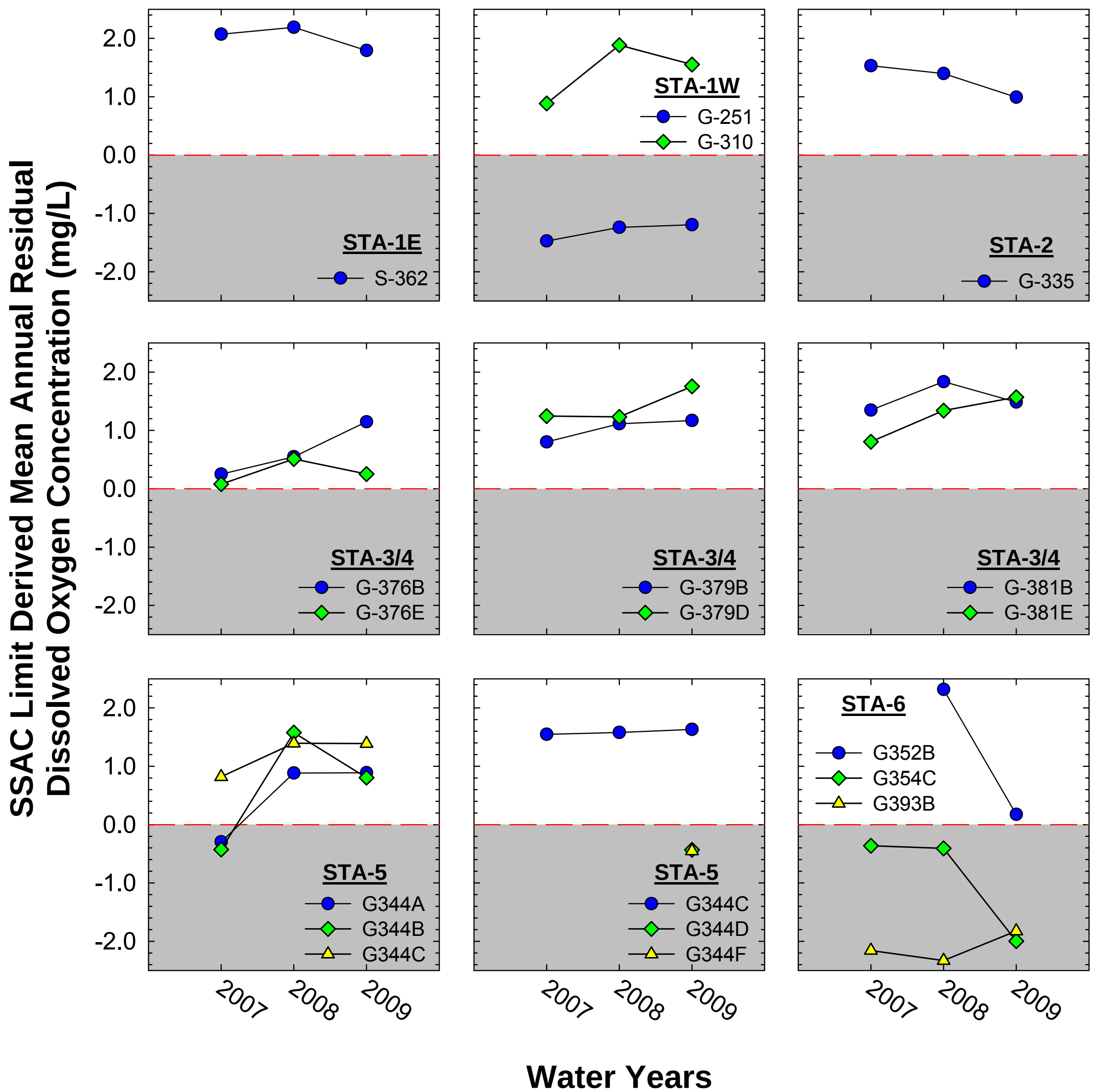


**Figure 5-5.** The mean annual residual DO plots at STA outflow stations for WY2007, WY2008, and WY2009. Mean annual residuals were computed as the difference between the mean annual DO and mean annual SSAC. Negative residuals indicate that an outflow station was below the SSAC limit, while positive residuals indicate that an outflow station was above the SSAC limit.

### Mercury

In WY2009, there were no violations of the Florida Class III numerical water quality standard of 12 nanograms of total mercury per liter (THg/L) during the reporting year at any STAs. Currently, surface water samples are collected in STA-1E, STA-2, STA-5, and STA-6 for THg and methylmercury (MeHg) analysis. Surface water mercury monitoring within STA-3/4 and STA-1W has been terminated in accordance with guidelines listed the mercury monitoring protocol. During WY2009, average annual outflow loading of THg and MeHg from STA-1E were lower than inflow. For STA-2, outflow loading of MeHg was lower than inflow; however, outflow loading of THg was greater than inflow. Higher outflow loading for THg in STA-2 is likely related to the start-up of Cell 4 in 2008. Due to a large number of surface water THg and MeHg quality assurance/quality control failures during WY2009, loadings estimates could not be calculated for STA-5 and STA-6.

For calendar year 2008, mercury concentrations in mosquitofish (*Gambusia holbrooki*) from all interior STA locations showed an average 48 percent increase since 2007. The only STA that showed a decrease was STA-1E. Sunfish (*Lepomis* spp.) showed an average 10 percent reduction across all STAs and largemouth bass (*Micropterus salmoides*) (age and length-standardized) showed a 63 percent reduction. [Note that the reduction in largemouth bass only relies on data from two STAs due to age standardization restrictions.] The large increase in mosquitofish mercury concentrations for 2008 was highly influenced by increases within STA-5, STA-6, and STA-2 from the start-up of Flow-way 3, Section 2 and Cell 4. A common occurrence during and after cell/operating unit start-up is a temporary increase in fish-related mercury concentrations particularly for low trophic levels fish species, in this case, mosquitofish. However, even with these increases, there was no exceedance of any action criterion listed in the mercury monitoring protocol  related to fish mercury monitoring.

Based on the U.S. Fish and Wildlife Service (USFWS) and U.S. Environmental Protection Agency (USEPA) predator protection criteria, fish-eating wildlife foraging within all STAs appear to be at an overall moderate risk to mercury exposure. STA mercury performance criteria are evaluated on an annual basis. If respective actions levels are exceeded, then corrective measures are taken in accordance with the FDEP-approved monitoring plans. Additional information on fish mercury concentrations, including spatial and temporal trends within and downstream of each STA, is presented in Appendix 5-6.

## HYDROPATTERN RESTORATION AND STA DISCHARGE MONITORING ON THE DOWNSTREAM AREAS

This section presents results from the research and monitoring conducted in the areas downstream of the STAs including the Arthur R. Marshall Loxahatchee National Wildlife Refuge (WCA-1), Water Conservation Area 2 (WCA-2A), and the Rotenberger Wildlife Management Area (RWMA). Part of the EFA permit requirements for STA-1W, STA-1E, STA-2, and STA-5 is characterizing the effects of STA discharges on adjacent marsh areas. This characterization is based on monthly samples collected for specific conductance (conductivity) and TP. Water quality monitoring stations in the marsh areas have been chosen along a transect from the discharge points and are categorized as “impacted” or “unimpacted” based on sediment TP levels. Those transect stations in areas where sediment TP levels are greater than 500 milligrams per kilogram (mg/kg) are identified as impacted. Monitoring data for each transect are provided in Appendix 5-9. A summary of conductivity and TP collected for these transects is provided in **Tables 5-9** and **5-10**, respectively. These water quality data are also graphically presented as notched box-and-whisker plots along with the results of the monitoring conducted as part of the hydropattern restoration monitoring, which includes vegetation, water level, and soil monitoring.

## Arthur R. Marshall Loxahatchee National Wildlife Refuge

Discharges from STA-1W and STA-1E are released into the rim canal surrounding the Arthur R. Marshall Loxahatchee National Wildlife Refuge. These discharges enter the rim canal from the northwestern (STA-1W) and northeastern (STA-1E) quadrats of the Refuge. Marsh transects downstream from both discharges extend approximately 4 kilometers (km) into the Refuge (**Figure 5-6**). Impacted stations extend approximately 2 km (downstream of STA-1W) and 1 km (downstream of STA-1E) into the marsh (**Tables 5-9** and **5-10**). A total of 12 stations are monitored in the Refuge, with seven stations along the western transect and five stations along the eastern transect. One station from each transect is monitored in the rim canal.

Transects in the Refuge exhibited a substantial decrease in both conductivity and TP concentrations within 1 km from the rim canal (**Figure 5-7**). TP concentrations measured in the western transect (downstream of STA-1W outflows) decreased by approximately 19 micrograms per liter [(µg/L), or parts per billion (ppb)], and conductivity decreased by approximately 370 µS/cm within 1 km from the rim canal station. The eastern transect (downstream of the STA-1E outflow) exhibited a decrease of approximately 280 µS/cm in conductivity and 20 ppb in TP within the first kilometer from the rim canal. Stations on both transects located at a distance greater than 1 km from the rim canal had median TP concentrations ranging from 6 to 8 ppb. Median conductivity values for these stations ranged from 99 to 274 µS/cm. All conductivity levels measured at Refuge transect stations were below the Class III criterion of 1,275 µS/cm. A Kruskal-Wallis test was used to determine if TP and conductivity levels between stations along both transects were statistically different. Both parameters exhibited a statistically significant ($p < 0.01$) decrease in both TP concentrations and conductivity levels across each transect.

**Table 5-9.** Summary statistics for conductivity (in microsiemens per centimeter, or µS/cm) measurements collected during WY2009 at transect stations from STA outflows.

| STA Transects | Station Information | | Distance from Canal (km) | Number of Samples | Mean | Standard Deviation | Minimum | Percentiles | | | Maximum |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Name | Category[1] | | | | | | 25th | 50th (Median) | 75th | |
| STA-1W | LOXA135 | Rim Canal | 0.0 | 12 | 710.2 | 126.4 | 512 | 625 | 680 | 810 | 908 |
| | LOXA136 | Impacted | 0.6 | 9 | 547.8 | 163.0 | 206 | 480 | 562 | 679 | 735 |
| | LOXA137 | Impacted | 1.1 | 9 | 367.0 | 202.9 | 104 | 173 | 402 | 492 | 743 |
| | LOXA138 | Impacted | 2.1 | 9 | 279.0 | 119.2 | 114 | 194 | 274 | 375 | 460 |
| | LOXA139 | Impacted | 4.0 | 8 | 97.7 | 31.5 | 43 | 79 | 99 | 127 | 130 |
| | LOXA104 | Unimpacted | 0.0 | 12 | 652.0 | 167.5 | 303 | 521 | 716 | 748 | 900 |
| | LOXA104.5 | Unimpacted | 0.4 | 9 | 607.7 | 197.5 | 306 | 427 | 639 | 783 | 804 |
| STA-1E | LOXA105 | Rim Canal | 0.8 | 9 | 510.3 | 229.0 | 220 | 332 | 484 | 693 | 866 |
| | LOXA106 | Impacted | 1.1 | 9 | 378.2 | 189.8 | 180 | 239 | 347 | 463 | 792 |
| | LOXA107 | Impacted | 2.2 | 8 | 203.2 | 134.4 | 111 | 126 | 172 | 198 | 524 |
| | LOXA107U | Unimpacted | 3.4 | 8 | 119.0 | 25.4 | 80 | 98 | 126 | 137 | 152 |
| | LOXA108 | Unimpacted | 4.1 | 8 | 111.0 | 21.2 | 75 | 96 | 117 | 126 | 138 |
| STA-2 Transect 1 | $N_{0.25}$ | Impacted | 0.2 | 6 | 1,122.5 | 75.6 | 1,018 | 1,042 | 1,150 | 1,170 | 1,206 |
| | $N_{1.0}$ | Impacted | 0.9 | 6 | 1,081.0 | 91.2 | 914 | 1,054 | 1,105 | 1,131 | 1,177 |
| | $N_{2.0}$ | Impacted | 1.9 | 4 | 1,053.9 | 88.8 | 960 | 979 | 1,054 | 1,129 | 1,147 |
| | $N_{4.0}$ | Impacted | 3.7 | 4 | 1,053.7 | 105.9 | 940 | 967 | 1,050 | 1,140 | 1,174 |
| | $C_{4.0}$ | Unimpacted | 6.8 | 4 | 1,013.8 | 107.5 | 869 | 932 | 1,044 | 1,096 | 1,099 |
| STA-2 Transect 2 | $FS_{0.25}$ | Impacted | 0.4 | 6 | 1,111.5 | 70.0 | 1,040 | 1,059 | 1,091 | 1,186 | 1,203 |
| | $FS_{1.0}$ | Impacted | 1.0 | 5 | 1,063.6 | 56.6 | 1,023 | 1,025 | 1,053 | 1,082 | 1,161 |
| | $FS_{3.0}$ | Impacted | 3.1 | 6 | 1,037.2 | 139.2 | 817 | 960 | 1,065 | 1,143 | 1,173 |
| | CA29 | Unimpacted | 5.6 | 15 | 898.7 | 153.3 | 621 | 768 | 890 | 1,009 | 1,181 |
| STA-5 | RC1 | Impacted | 0.2 | 11 | 606.8 | 198.6 | 290 | 503 | 583 | 715 | 1,009 |
| | RC2 | Impacted | 2.3 | 9 | 500.3 | 179.9 | 186 | 396 | 527 | 660 | 724 |
| | RC3 | Impacted | 4.2 | 8 | 467.0 | 206.4 | 142 | 315 | 473 | 655 | 709 |

**Table 5-10.** Summary statistics for TP (in micrograms per liter, or µg/L) measurements collected during WY2009 at transect stations from STA outflows.

| STA Transects | Station Information | | Distance from Canal (km) | Number of Samples | Mean | Standard Deviation | Minimum | Percentiles | | | Maximum |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Name | Category[1] | | | | | | 25th | 50th (Median) | 75th | |
| STA-1W | LOXA104 | Rim Canal | 0.0 | 12 | 32.2 | 12.7 | 20 | 24 | 27 | 40 | 55 |
| | LOXA104.5 | Impacted | 0.4 | 9 | 39.0 | 54.0 | 15 | 17 | 22 | 26 | 182 |
| | LOXA105 | Impacted | 0.8 | 9 | 12.4 | 5.7 | 6 | 9 | 12 | 15 | 25 |
| | LOXA106 | Impacted | 1.1 | 9 | 9.9 | 5.5 | 6 | 7 | 8 | 10 | 24 |
| | LOXA107 | Impacted | 2.2 | 8 | 7.1 | 1.7 | 5 | 6 | 8 | 8 | 10 |
| | LOXA107U | Unimpacted | 3.4 | 8 | 6.3 | 1.4 | 4 | 6 | 6 | 8 | 8 |
| | LOXA108 | Unimpacted | 4.1 | 8 | 9.6 | 2.8 | 6 | 8 | 9 | 12 | 14 |
| STA-1E | LOXA135 | Rim Canal | 0.0 | 12 | 35.5 | 19.3 | 13 | 21 | 29 | 48 | 77 |
| | LOXA136 | Impacted | 0.6 | 9 | 21.1 | 21.5 | 9 | 10 | 14 | 20 | 77 |
| | LOXA137 | Impacted | 1.1 | 9 | 12.0 | 10.8 | 5 | 7 | 9 | 11 | 40 |
| | LOXA138 | Unimpacted | 2.1 | 9 | 7.0 | 2.4 | 5 | 6 | 6 | 7 | 13 |
| | LOXA139 | Unimpacted | 4.0 | 8 | 7.0 | 1.9 | 5 | 6 | 6 | 8 | 11 |
| STA-2 (Transect 1) | $N_{0.25}$ | Impacted | 0.2 | 7 | 23.6 | 12.0 | 7 | 17 | 17 | 35 | 39 |
| | $N_{1.0}$ | Impacted | 0.9 | 7 | 15.4 | 7.5 | 6 | 11 | 15 | 18 | 30 |
| | $N_{2.0}$ | Impacted | 1.9 | 5 | 10.2 | 3.3 | 6 | 8 | 10 | 12 | 15 |
| | $N_{4.0}$ | Impacted | 3.7 | 5 | 6.8 | 1.5 | 5 | 6 | 7 | 8 | 9 |
| | $C_{4.0}$ | Unimpacted | 6.8 | 5 | 4.8 | 1.3 | 3 | 4 | 5 | 6 | 6 |
| STA-2 (Transect 2) | $FS_{0.25}$ | Impacted | 0.4 | 7 | 17.6 | 5.0 | 7 | 17 | 20 | 21 | 21 |
| | $FS_{1.0}$ | Impacted | 1.0 | 6 | 13.8 | 2.6 | 10 | 13 | 14 | 15 | 18 |
| | $FS_{3.0}$ | Impacted | 3.1 | 7 | 7.4 | 2.6 | 4 | 5 | 8 | 10 | 11 |
| | CA29 | Unimpacted | 5.6 | 16 | 4.9 | 1.1 | 3 | 4 | 5 | 6 | 7 |
| STA-5 | RC1 | Impacted | 0.2 | 11 | 26.0 | 9.0 | 13 | 18 | 28 | 30 | 44 |
| | RC2 | Impacted | 2.3 | 9 | 11.9 | 3.1 | 7 | 10 | 12 | 14 | 17 |
| | RC3 | Impacted | 4.2 | 8 | 14.3 | 6.7 | 8 | 9 | 13 | 19 | 26 |

[1] Categories of "impacted" and "unimpacted" refer to station identification based on sediment phosphorus concentrations. Impacted stations have sediment phosphorus levels greater than 500 mg/kg.

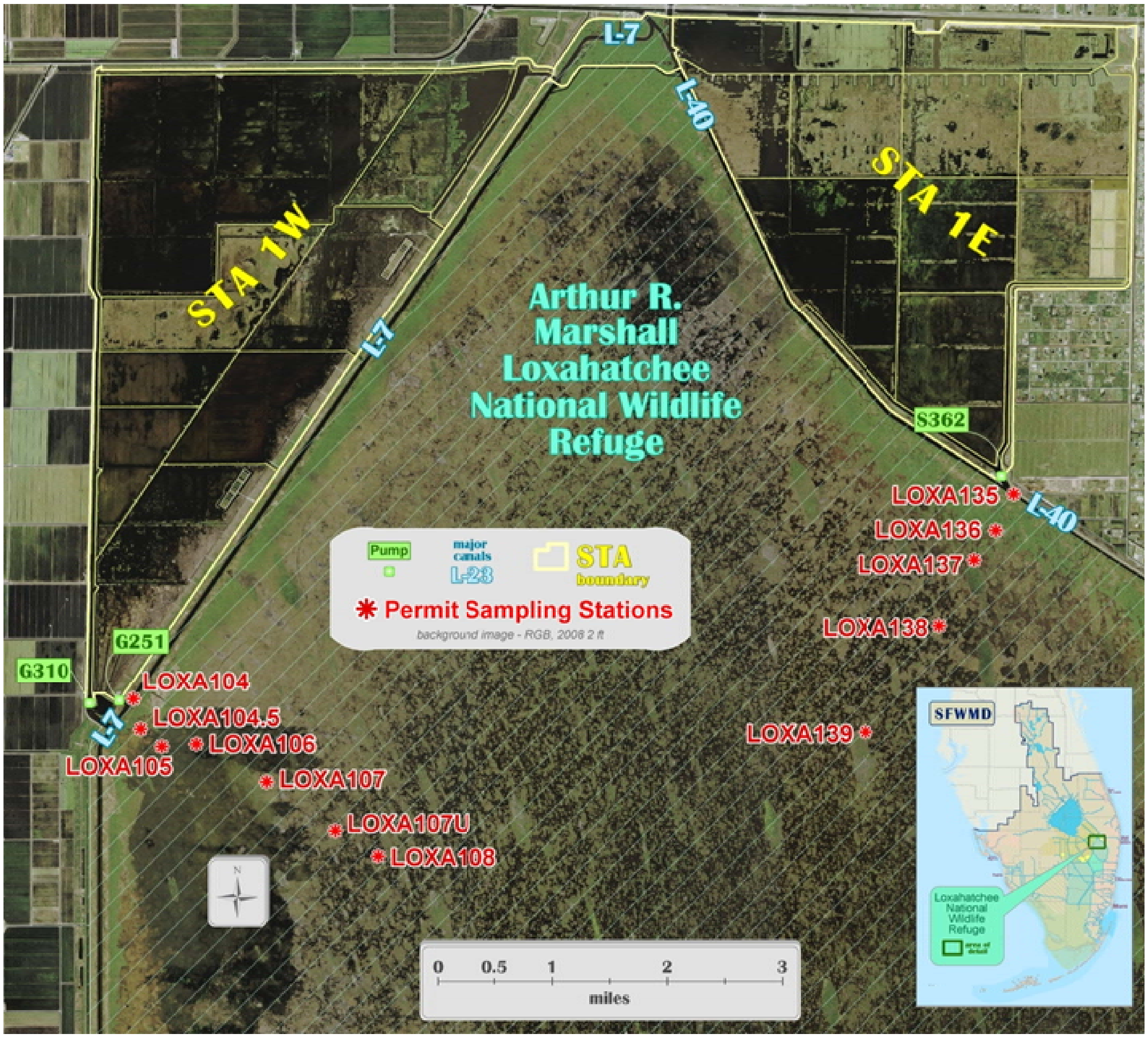


**Figure 5-6.** Locations of marsh transect stations in the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge) and outflow structures from STA-1W and STA-1E.

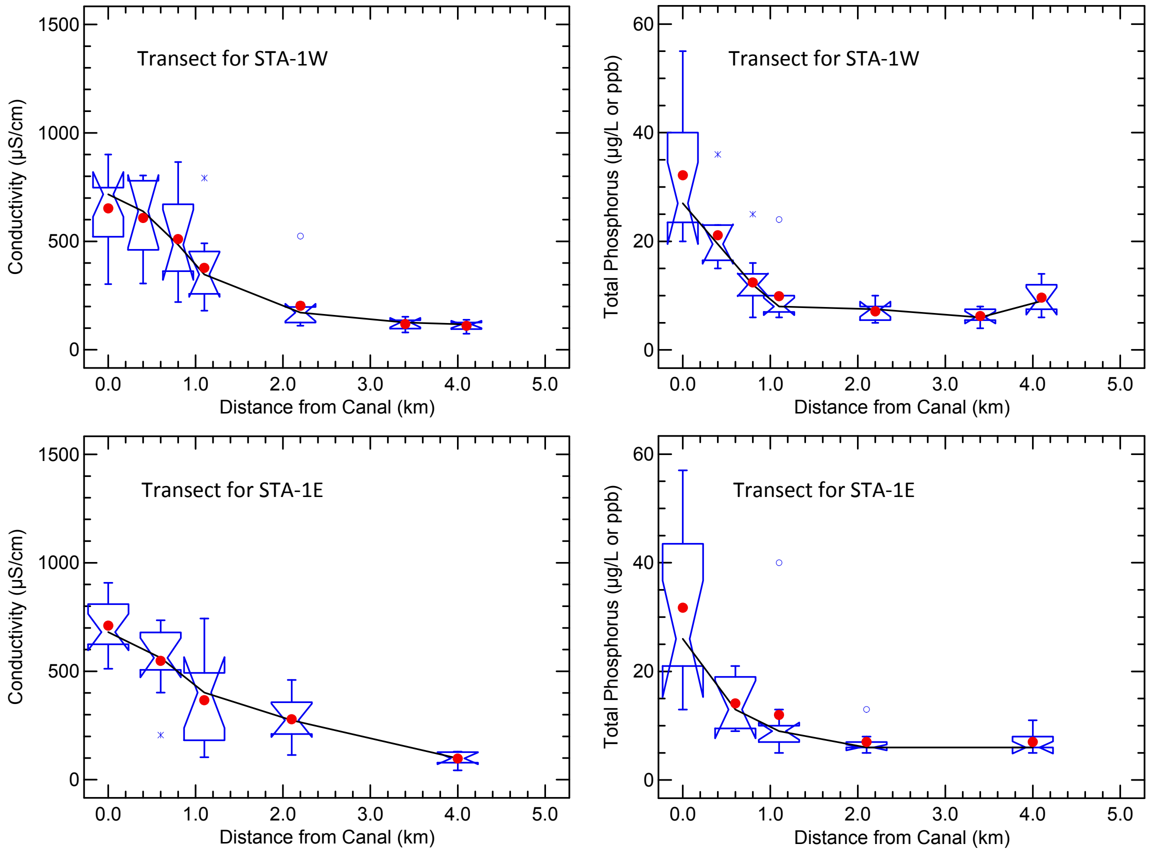


**Figure 5-7.** Notched box and whisker plots of conductivity and total phosphorus levels measured at transect stations during WY2009 for STA-1W and STA-1E. The notch on a box represents the 95% C.I. about the median, which is represented by the narrowest part of the notch. The top and bottom of the box represent the 75$^{th}$ and 25$^{th}$ percentiles, respectively. The whiskers represent the highest and lowest data values that are within two standard deviations of the median. Values above and below the whiskers are greater than two standard deviations from the median. Notches that do not overlap indicate that the data represented by the boxes being compared are significantly different at the 95% C.I.

## Northwestern Water Conservation Area 2A

### WCA-2A Monitoring Objectives

In accordance with the EFA, the District has been monitoring the effect of water discharged from STA-2 into the northwestern region of Water Conservation Area 2A (WCA-2A). These releases are intended to restore the hydropattern and ecological functionality of the marshes downstream of STA-2. The STA-2 EFA permit requires that the District implement a monitoring and assessment program to monitor and evaluate ecological changes associated with STA-2 discharges into the area. The annual report addresses the following issues: (1) what are the beneficial environmental effects, including changes in water quality, soil, vegetative conditions, inundation and timing of discharges; and (2) are there any adverse environmental effects, including imbalances in natural populations of flora or fauna, changes in periphyton communities, increased P accumulation rates in soil, expansion of cattail (*Typha* spp.) or other undesirable or exotic vegetation, or other undesirable consequences of the hydropattern restoration.

### WCA-2A Configuration

STA-2 primarily discharges into WCA-2A through six culverts (G-336A–F structures) (**Figure 5-8**). Additional STA-2 effluent is released through G-336G into the discharge canal south of STA-2. Approximately 1 km northeast of the S-7 pump station, the levee separating this discharge canal from WCA-2A is degraded, allowing discharge passing through G-336G to passively enter WCA-2A. Monitoring transects (N-, C-, and S-transects) were established in 1998 to monitor environmental and ecological changes in the area. In 2005, a new transect (FS-transect) was established to monitor the additional STA-2 discharge. Monitoring data for the stations downstream of STA-2 can be located within two District databases, ERDP and DBHYDRO (Appendix 5-8).

### WCA-2A Hydropattern Restoration

Hydropattern improvements resulting from STA-2 discharges are presented in the 2009 SFER – Volume I, Chapter 5 (Pietro et al., 2009) and Hydropattern Restoration in Water Conservation Area 2A Report (Garrett and Ivanoff, 2008). To monitor water levels, water depth recorders were set up at eight stations between 2004 and 2006. The accuracy of these depth recorder measurements was assessed during 2006 and 2007 by comparing them with periodic water depth measurements collected manually in the field. These accuracy measurements were reported in the 2009 SFER – Volume I, Chapter 5. Water depths at these stations during WY2009 are presented in **Figure 5-9**. Unfortunately, the data record for only four of the eight depth recorders ($N_{0.25}$, $N_{4.0}$, $C_{0.25}$, and $C_{1.0}$) was uninterrupted due to equipment malfunctions in WY2009. The mean inundation periods at these four stations ranged from 245 days at $N_{0.25}$ to 251 days at $N_{4.0}$. Mean water depth ranged from 42 cm at $N_{0.25}$ to 26 cm at $N_{4.0}$. Due to repairs, the $S_{1.0}$ depth recorder was only active for only 64 days during WY2009. The recorder at the $C_{4.0}$ station began to fail during the last month of WY2009. The $FS_{0.25}$ and $FS_{3.0}$ depth recorders were also non-operational, so the inundation period could not be estimated for the southern portion of the monitoring area. Water depths increased throughout in the entire area during August and early September due to Tropical Storm Fay.

Permanent stage recorders were installed at the $N_{1.0}$ (WC2AN1) and $S_{1.0}$ (WC2AS1) stations in WY2009 and both gauges began to record data in June 2009. Future hydropattern restoration reports in relation to this portion of WCA-2A will be based on measurements from these two instruments.

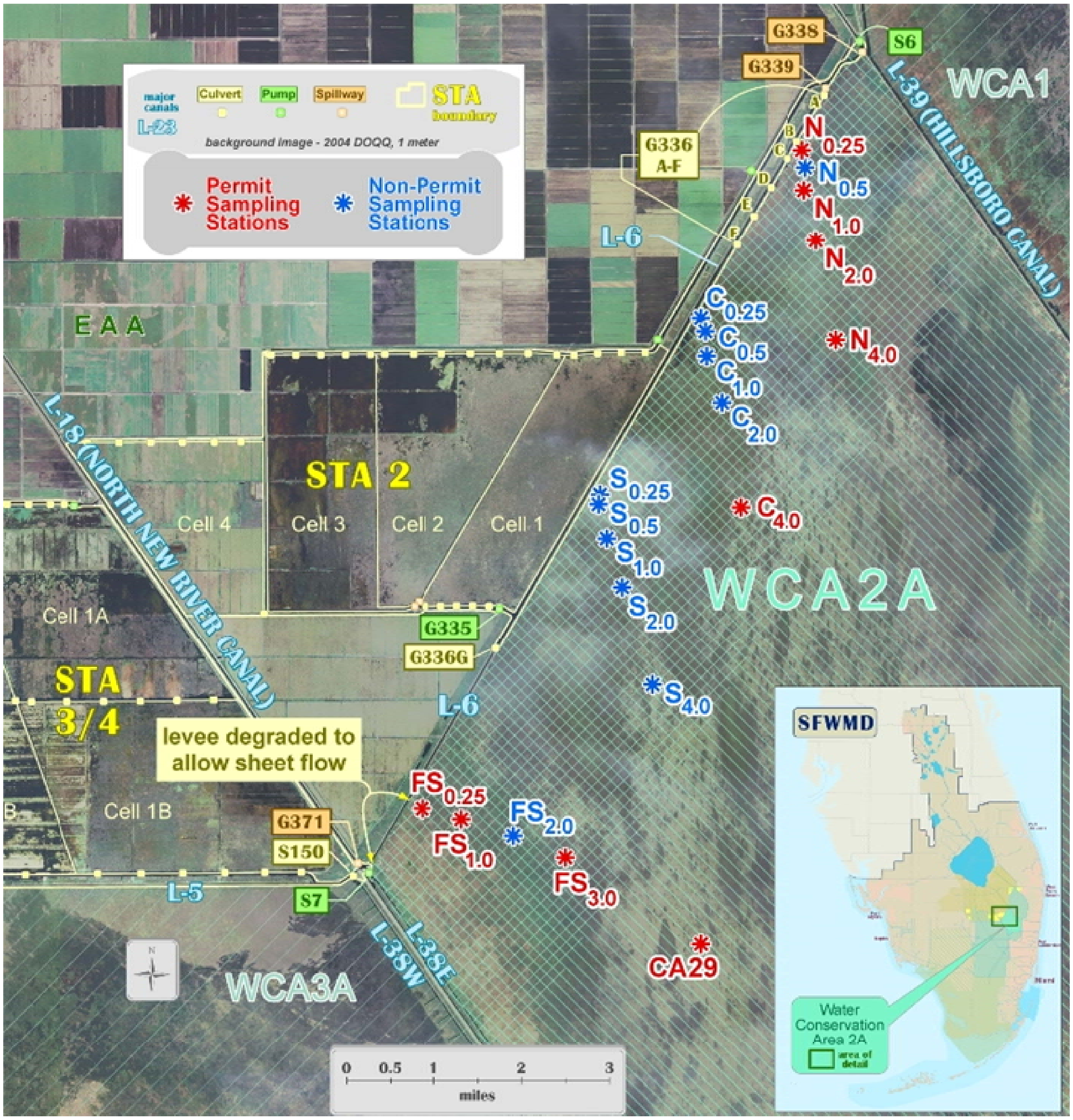


**Figure 5-8.** Location of STA-2 discharge structures, including the G-336A–G discharge culverts in relation to sampling stations along transects in the northwestern section of Water Conservation Area 2A (WCA-2A).

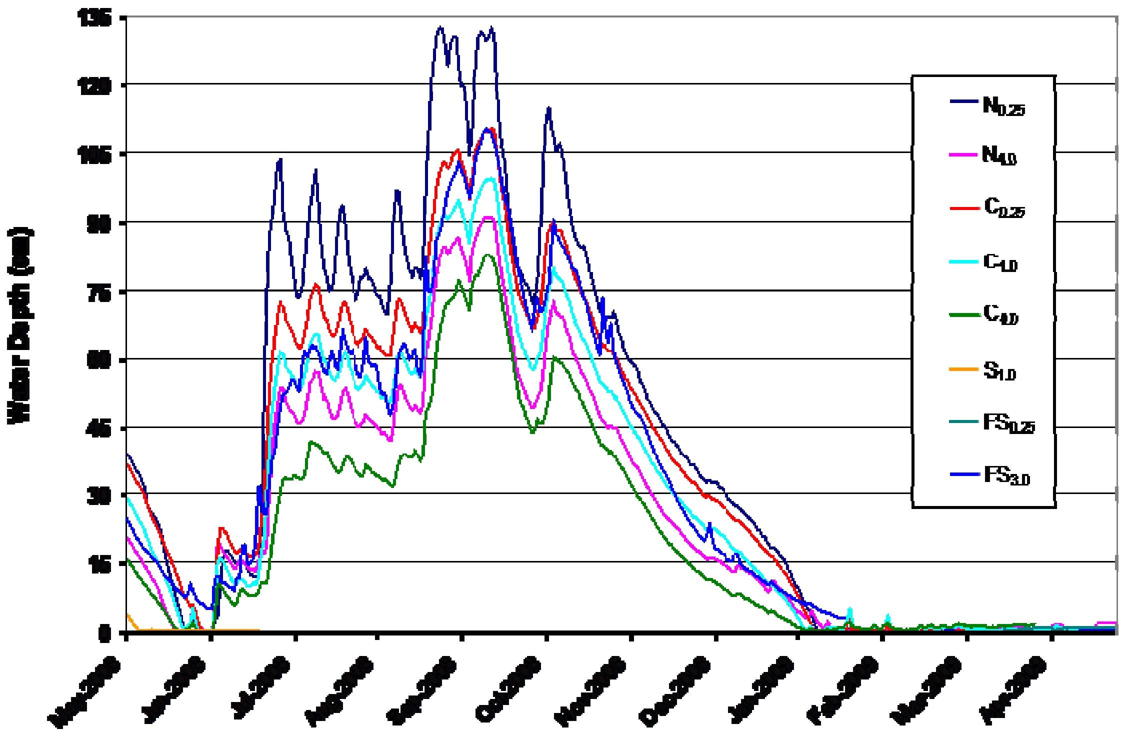


**Figure 5-9.** Daily mean water depths (cm) obtained from depth recorders deployed at eight stations in the northwestern region of WCA-2A during WY2009. See **Figure 5-8** for location of these stations.

### *WCA-2A Surface Water Quality*

Surface water samples were collected monthly at 17 sites when sufficient water (depth ≥10 cm) was available for representative sampling. During WY2009, surface water TP gradients existed along the N-, C-, and FS-transects with stations nearest to the L-6 levee demonstrating higher P concentrations and those locations downstream demonstrating lower concentrations (**Table 5-11**). The S-transect displayed near background level concentrations along the entire transect. Mean TP concentrations were highest at $N_{0.25}$ and $FS_{0.25}$, at 24 ppb and 18 ppb, respectively. The $C_{4.0}$, $S_{4.0}$, and CA29 stations had the lowest mean TP concentration, all at 5 ppb. Annual mean surface water TP concentrations decreased at 14 stations compared to WY2008 levels. Mean TP concentrations at $N_{0.25}$, $C_{2.0}$, and $S_{1.0}$ remained at similar levels as in WY2008.

Mean specific conductivity ranged from 899 µS/cm (CA29) to 1140 µS/cm ($C_{0.25}$) in WY2009 (**Table 5-12**). These ranges are comparable to WY2008 values. In general, stations along the L-6 levee had greater annual mean specific conductivity than those located farther into the marsh.

Mean WY2009 total Kjeldahl nitrogen (TKN) concentrations ranged from 1.88 mg/L ($S_{4.0}$) to 2.19 mg/L ($N_{0.25}$) (**Table 5-13**). Annual mean TKN concentrations were comparable among all stations, and were similar to mean concentrations observed in WY2008.

WY2009 mean sulfate ($SO_{4)}$ concentrations were highest at $FS_{1.0}$ (62 mg/L), and lowest at CA29 (39 mg/L) (**Table 5-14**). $SO_4$ concentrations at all stations except for $FS_{3.0}$ increased from WY2008 to WY2009. However, these concentrations were generally lower than the mean concentrations observed from 2001 to 2006 (Garrett and Ivanoff, 2008). The exception was at $FS_{2.0}$, with similar mean $SO_4$ concentrations during both periods.

### *EFA Permit Compliance Transect Total Phosphorus and Conductivity at STA-2 Downstream Area (WCA-2A)*

The EFA permit compliance transects to characterize the effects of STA-2 discharges on the marsh are located in the western portion of the WCA, with one transect located in the northern portion and the other in the southern portion of WCA-2A (**Figure 5-8**). The northern transect comprises five monitoring stations extending approximately 7 km. The southern transect extends approximately 6 km into WCA-2A and contains four monitoring stations.

Conductivity and TP levels changed more gradually at the two transects located in WCA-2A with median conductivity ranging from 890 to 1150 µS/cm (**Table 5-9**). Conductivity levels along the northern transect were not statistically different (p-value ~ 0.35 based on the Kruskal-Wallis test). However, a statistically significant ($p = 0.01$) decrease in conductivity levels was observed for the southern transect. A decrease in median conductivity levels of approximately 175 µS/cm occurred between 3 and 6 km from the canal along this transect (**Figure 5-10**). No conductivity measured along the northern or southern transect exceeded the Class III criterion of 1,275 µS/cm. Median TP concentrations were ≤ 10 ppb at a distance of more than 3 km from the canal (**Figure 5-10**; **Table 5-10**). Both transects exhibited a statistically significant ($p < 0.001$) decrease in median TP concentrations.

**Table 5-11.** Summary statistics for surface water TP concentrations (± standard deviations) measured at WCA-2A transect locations during WY2009. Asterisk (*) indicates permit compliance location.

| Station | Mean TP (ppb) | N | Min | Median | Max |
|---|---|---|---|---|---|
| $N_{0.25}$* | 24 ± 12 | 7 | 7 | 17 | 39 |
| $N_{1.0}$* | 15 ± 8 | 7 | 6 | 15 | 30 |
| $N_{2.0}$* | 10 ± 3 | 5 | 6 | 10 | 15 |
| $N_{4.0}$* | 7 ± 2 | 7 | 5 | 7 | 10 |
| $C_{0.25}$ | 16 ± 4 | 7 | 11 | 15 | 22 |
| $C_{1.0}$ | 9 ± 3 | 6 | 6 | 10 | 14 |
| $C_{2.0}$ | 9 ± 3 | 7 | 5 | 8 | 15 |
| $C_{4.0}$* | 5 ± 1 | 5 | 3 | 5 | 6 |
| $S_{0.25}$ | 7 ± 2 | 5 | 4 | 8 | 9 |
| $S_{1.0}$ | 6 ± 2 | 5 | 4 | 6 | 8 |
| $S_{2.0}$ | 6 ± 1 | 5 | 5 | 6 | 7 |
| $S_{4.0}$ | 5 ± 1 | 6 | 3 | 5 | 6 |
| $FS_{0.25}$* | 18 ± 5 | 7 | 7 | 20 | 21 |
| $FS_{1.0}$* | 14 ± 3 | 6 | 10 | 14 | 18 |
| $FS_{2.0}$ | 9 ± 2 | 7 | 6 | 9 | 13 |
| $FS_{3.0}$* | 7 ± 3 | 7 | 4 | 8 | 11 |
| CA29* | 5 ± 1 | 17 | 3 | 5 | 7 |

**Table 5-12.** Summary statistics for surface water specific conductivity (± standard deviations) measured at WCA-2A transect locations during WY2009. Asterisk (*) indicates permit compliance location.

| Station | Mean Sp Cond (μS/cm) | N | Min | Median | Max |
|---|---|---|---|---|---|
| $N_{0.25}$* | 1123 ± 76 | 6 | 1018 | 1150 | 1206 |
| $N_{1.0}$* | 1081 ± 91 | 6 | 914 | 1105 | 1177 |
| $N_{2.0}$* | 1054 ± 89 | 4 | 960 | 1054 | 1147 |
| $N_{4.0}$* | 1054 ± 106 | 4 | 940 | 1051 | 1174 |
| $C_{0.25}$ | 1140 ± 64 | 6 | 1063 | 1132 | 1245 |
| $C_{1.0}$ | 1093 ± 78 | 5 | 1013 | 1093 | 1194 |
| $C_{2.0}$ | 1122 ± 147 | 6 | 958 | 1145 | 1345 |
| $C_{4.0}$* | 1014 ± 108 | 4 | 869 | 1044 | 1099 |
| $S_{0.25}$ | 1037 ± 128 | 4 | 845 | 1094 | 1114 |
| $S_{1.0}$ | 1019 ± 144 | 4 | 810 | 1070 | 1126 |
| $S_{2.0}$ | 958 ± 125 | 4 | 798 | 986 | 1063 |
| $S_{4.0}$ | 926 ± 138 | 5 | 747 | 966 | 1105 |
| $FS_{0.25}$* | 1112 ± 70 | 6 | 1040 | 1091 | 1203 |
| $FS_{1.0}$* | 1064 ± 57 | 5 | 1023 | 1053 | 1161 |
| $FS_{2.0}$ | 1044 ± 114 | 6 | 858 | 1038 | 1181 |
| $FS_{3.0}$* | 1037 ± 139 | 6 | 817 | 1065 | 1173 |
| CA29* | 899 ± 150 | 16 | 621 | 853 | 1181 |

**Table 5-13.** Summary statistics for surface water total Kjeldahl nitrogen (TKN) concentrations (± standard deviations) measured at WCA-2A transect locations during WY2009. Asterisk (*) indicates permit compliance location.

| Station | Mean TKN (mg/L) | N | Min | Median | Max |
|---|---|---|---|---|---|
| $N_{0.25}$* | 2.19 ± 0.13 | 6 | 2.04 | 2.15 | 2.39 |
| $N_{1.0}$* | 2.10 ± 0.30 | 6 | 1.61 | 2.11 | 2.55 |
| $N_{2.0}$* | 2.10 ± 0.12 | 5 | 2.00 | 2.08 | 2.30 |
| $N_{4.0}$* | 2.09 ± 0.16 | 5 | 1.85 | 2.08 | 2.28 |
| $C_{0.25}$ | 2.14 ± 0.12 | 6 | 1.96 | 2.11 | 2.29 |
| $C_{1.0}$ | 2.13 ± 0.13 | 5 | 2.01 | 2.10 | 2.35 |
| $C_{2.0}$ | 2.11 ± 0.17 | 6 | 1.95 | 2.05 | 2.40 |
| $C_{4.0}$* | 2.05 ± 0.19 | 5 | 1.82 | 2.01 | 2.33 |
| $S_{0.25}$ | 2.09 ± 0.12 | 5 | 1.94 | 2.06 | 2.25 |
| $S_{1.0}$ | 2.02 ± 0.16 | 5 | 1.86 | 1.94 | 2.27 |
| $S_{2.0}$ | 1.93 ± 0.19 | 5 | 1.73 | 1.86 | 2.20 |
| $S_{4.0}$ | 1.88 ± 0.23 | 5 | 1.50 | 1.95 | 2.12 |
| $FS_{0.25}$* | 2.13 ± 0.09 | 6 | 2.03 | 2.12 | 2.25 |
| $FS_{1.0}$* | 2.11 ± 0.17 | 5 | 1.90 | 2.08 | 2.37 |
| $FS_{2.0}$ | 2.05 ± 0.11 | 5 | 1.88 | 2.08 | 2.17 |
| $FS_{3.0}$* | 1.99 ± 0.16 | 6 | 1.76 | 2.04 | 2.16 |
| CA29* | 1.91 ± 0.26 | 12 | 1.56 | 1.99 | 2.23 |

**Table 5-14.** Summary statistics for surface water sulfate ($SO_4$) concentrations (± standard deviations) measured at WCA-2A transect locations during WY2009. Asterisk (*) indicates permit compliance location.

| Station | Mean $SO_4$ (mg/L) | N | Min | Median | Max |
|---|---|---|---|---|---|
| $N_{0.25}$* | 58 ± 17 | 6 | 29 | 59 | 82 |
| $N_{1.0}$* | 55 ± 16 | 6 | 28 | 57 | 73 |
| $N_{2.0}$* | 56 ± 10 | 5 | 47 | 53 | 72 |
| $N_{4.0}$* | 55 ± 8 | 5 | 46 | 52 | 65 |
| $C_{0.25}$ | 60 ± 11 | 6 | 49 | 58 | 79 |
| $C_{1.0}$ | 57 ± 9 | 5 | 52 | 53 | 72 |
| $C_{2.0}$ | 50 ± 11 | 6 | 33 | 49 | 66 |
| $C_{4.0}$* | 53 ± 8 | 5 | 43 | 55 | 62 |
| $S_{0.25}$ | 54 ± 9 | 5 | 43 | 56 | 65 |
| $S_{1.0}$ | 52 ± 9 | 5 | 41 | 54 | 62 |
| $S_{2.0}$ | 50 ± 9 | 5 | 42 | 44 | 60 |
| $S_{4.0}$ | 45 ± 10 | 5 | 28 | 46 | 53 |
| $FS_{0.25}$* | 58 ± 18 | 6 | 30 | 57 | 85 |
| $FS_{1.0}$* | 62 ± 10 | 5 | 52 | 60 | 79 |
| $FS_{2.0}$ | 56 ± 11 | 5 | 44 | 54 | 72 |
| $FS_{3.0}$* | 51 ± 15 | 6 | 28 | 51 | 67 |
| CA29* | 39 ± 14 | 12 | 7 | 40 | 63 |

**Table 5-15.** Summary statistics for surface water TP, specific conductivity, TKN, and $SO_4$ concentrations (± standard deviations) measured at WCA-2A transect locations during WY2008. WY2009 data for these parameters is shown in **Tables 5-11** through **5-14**. Asterisk (*) indicates permit compliance location.

| Station | WY 2008 Mean TP (ppb) | WY 2008 Mean Sp Cond (µS/cm) | WY 2008 Mean TKN (mg/L) | WY 2008 Mean $SO_4$ (mg/L) |
|---|---|---|---|---|
| $N_{0.25}$* | 23 ± 6 | 1131 ± 126 | 2.17 ± 0.26 | 52 ± 8 |
| $N_{1.0}$* | 19 ± 5 | 1098 ± 146 | 2.03 ± 0.31 | 50 ± 9 |
| $N_{2.0}$* | 15 ± 5 | 1004 ± 247 | 1.80 ± 0.37 | 44 ±15 |
| $N_{4.0}$* | 8 ± 3 | 966 ± 244 | 1.75 ± 0.45 | 41 ± 16 |
| $C_{0.25}$ | 25 ± 15 | 1113 ± 135 | 2.15 ± 0.31 | 51 ± 9 |
| $C_{1.0}$ | 11 ± 2 | 1024 ± 189 | 1.92 ± 0.35 | 45 ± 13 |
| $C_{2.0}$ | 9 ± 2 | 991 ± 237 | 1.85 ± 0.45 | 42 ± 15 |
| $C_{4.0}$* | 7 ± 2 | 917 ± 262 | 1.72 ± 0.48 | 42 ± 17 |
| $S_{0.25}$ | 9 ± 2 | 997 ± 208 | 1.85 ± 0.41 | 45 ± 12 |
| $S_{1.0}$ | 6 ± 1 | 960 ± 253 | 1.73 ± 0.47 | 44 ± 15 |
| $S_{2.0}$ | 7 ± 2 | 837 ± 264 | 1.92 ± 0.55 | 37 ± 15 |
| $S_{4.0}$ | 6 ± 1 | 945 ± 242 | 1.97 ± 0.56 | 37 ± 23 |
| $FS_{0.25}$* | 20 ± 6 | 1088 ± 266 | 2.05 ± 0.52 | 44 ± 17 |
| $FS_{1.0}$* | 19 ± 9 | 1066 ± 272 | 2.01 ± 0.52 | 45 ± 17 |
| $FS_{2.0}$ | 12 ± 4 | 1114 ± 254 | 2.21 ± 0.64 | 53 ± 32 |
| $FS_{3.0}$* | 9 ± 2 | 1094 ± 271 | 2.19 ± 0.63 | 57 ± 56 |
| CA29* | 7 ± 2 | 1009 ± 220 | 2.11 ± 0.43 | 29 ± 11 |

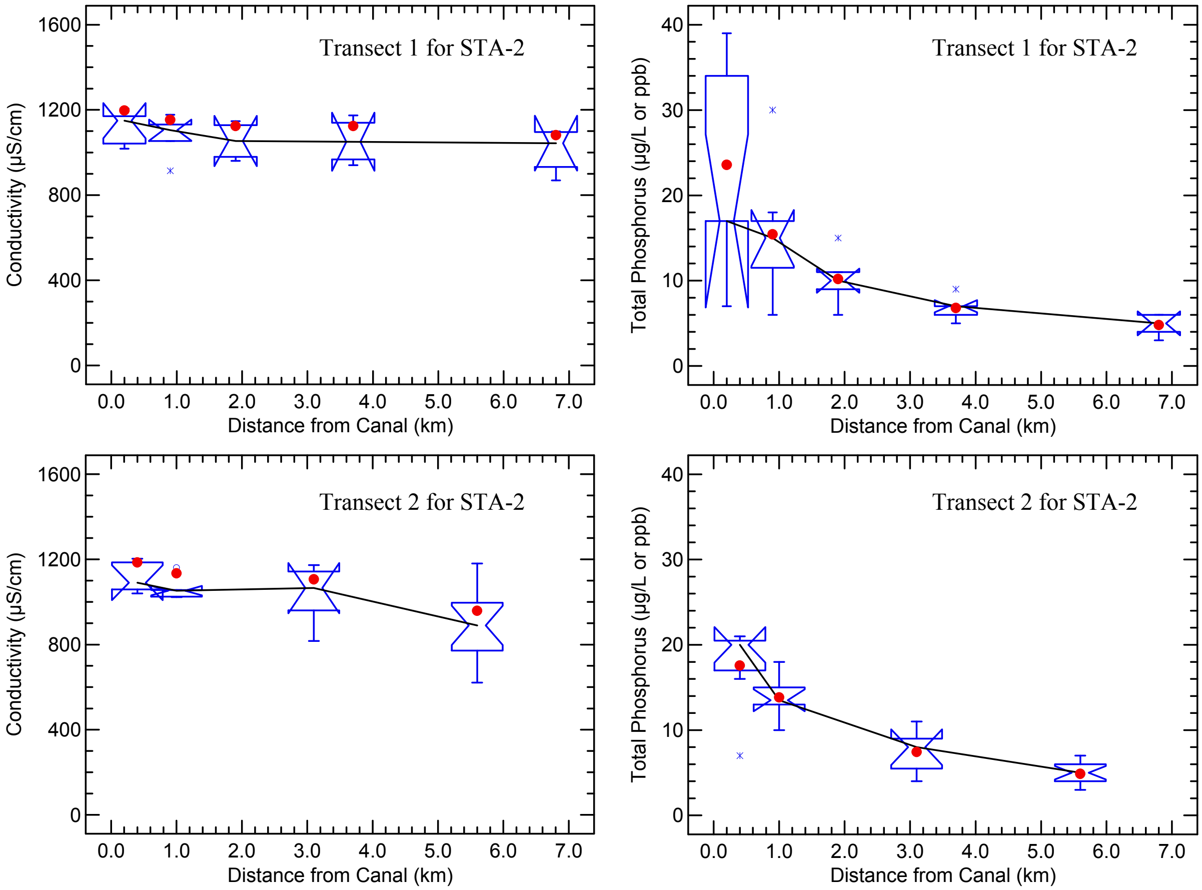


**Figure 5-10.** Notched box and whisker plots of conductivity and total phosphorus levels measured at transect stations during WY2009 for STA-2. The notch on a box plot represents the 95% C.I. about the median, which is represented by the narrowest part of the notch. The top and bottom of the box represent the 75th and 25th percentiles, respectively. The whiskers represent the highest and lowest data values that are within two standard deviations of the median. Values above and below the whiskers are greater than two standard deviations from the median. Notches that do not overlap indicate that the data represented by the boxes being compared are significantly different at the 95% C.I.

### WCA-2A Soil Chemistry

Soil samples are collected every other year at 19 monitoring sites in northwestern WCA-2A. Samples were last collected in March 2008; these data were included in the 2009 SFER – Volume I, Chapter 5. The 2008 data showed no notable changes from prior soil phosphorus concentrations reported (Garrett and Ivanoff, 2008). Soils will be collected again at the same stations in WY2010.

### WCA-2A Periphyton Nutrient Data

Periphyton samples have been collected annually at permit compliance stations since 1998. The relative abundance of algal species indicative of higher TP surface water concentrations (> 16 ppb) decreased from 1998 to 2004, while the relative abundance of species indicative of lower TP surface water concentrations (< 16 ppb) generally increased (**Figure 5-11**). Similar trends were observed at other monitoring stations throughout the Everglades system during the same time period (Garrett and Ivanoff, 2008). Therefore, this positive change in terms of periphyton community indicators cannot be attributed solely to the STA-2 discharge. In WY2009, periphyton collections were attempted at all permit-compliance stations in October 2008; however, not every site had sufficient amounts of periphyton for processing and analysis. From 2005 to 2008, the relative abundance of both high and low TP indicator species remained fairly constant. Water quality concentrations at these locations have changed little during this period.

Periphyton tissue TP concentrations are reported for the six permit compliance stations that had sufficient amounts of periphyton at the time of collection (**Table 5-16**). Metaphyton (floating periphyton) and epiphyton (periphyton attached to standing macrophytes) were collected separately. Mean periphyton tissue TP concentrations at the $N_{0.25}$ and $FS_{0.25}$ stations were approximately twice that found in periphyton tissues collected farther downstream of each respective transect.

### WCA-2A Macrophyte Nutrient Data and Composition

Where present, cattail and sawgrass (*Cladium jamaicense*) live leaves were sampled at permit compliance stations semiannually and analyzed for total nitrogen (TN) and TP. In WY2009, this sampling occurred in October 2008 and April 2009; however, data from the April 2009 collection were not available in time to include in this report. Using the TP and TN data, mean N:P ratios were calculated for each station.

Koch and Reddy (1992) found nitrogen: phosphorus (N:P) ratios between 3:1 and 20:1 within sawgrass tissues from eutrophic regions of WCA-2A and between 37:1 and 132:1 in less impacted regions of WCA-2A. Between 2006 and 2008, sawgrass leaf tissue N:P ratios from the $N_{0.25}$, $N_{1.0}$, $FS_{0.25}$, and $FS_{1.0}$ stations ranged from 15:1 to 27:1 (**Table 5-17**), which indicates that these areas fall between highly impacted and intermediately impacted zones. Other permit compliance stations had sawgrass N:P ratios that were representative of less-impacted conditions.

Koch and Reddy (1992) reported that N:P ratios in cattail tissues ranged between 12:1 and 1:1 from a eutrophic region of WCA-2A and between 18:1 and 6:1 from a less impacted region of WCA-2A. Cattail leaf tissue N:P ratios measured at the permit-compliance sites between 2006 and 2008 ranged from 8:1 to 21:1(**Table 5-18**). These values are indicative of intermediately impacted conditions.

The areal coverage of several dominant macrophyte species has been measured along fixed transects twice a year (dry season and wet season) since 2005. Using point-intercept survey methodology, the presence of sawgrass and/or cattail at meter intervals along 10 m transects was recorded. These surveys were performed at 19 locations; only data from the permit compliance sites are presented in this report. **Tables 5-19** and **5-20** show the frequency of occurrence of cattail and sawgrass along each transect. There were no observed changes in sawgrass and cattail coverage at stations $N_{0.25}$, $N_{2.0}$, $C_{4.0}$, and $FS_{3.0}$ over the survey period. These stations were predominantly sawgrass, except for $N_{0.25}$. The $N_{4.0}$ station experienced a fire in 2006. Although the sawgrass coverage at this station decreased for several years thereafter, it nearly returned to pre-fire conditions after three years by 2009. The $N_{1.0}$ and $FS_{1.0}$ stations showed increases in cattail coverage, but no overall change in sawgrass coverage over the four-year survey period. The $FS_{0.25}$ station had the reverse trend, with cattail coverage decreasing and sawgrass coverage remaining constant over the survey period. It is important to note that transect poles had to be moved in November 2008 at several sites ($N_{1.0}$, $N_{2.0}$, $N_{4.0}$, $FS_{0.25}$, and $FS_{1.0}$). This was due to the impact of drift from an herbicide application to clear helicopter landing areas for safe access to sites. In addition, one transect ($N_{2.0}$) was relocated in April 2006 due to trails worn next to the transect that affected the vegetation along the transect. In each of these cases, transect poles were moved to the closest possible location away from the disturbance that had the same vegetation communities.

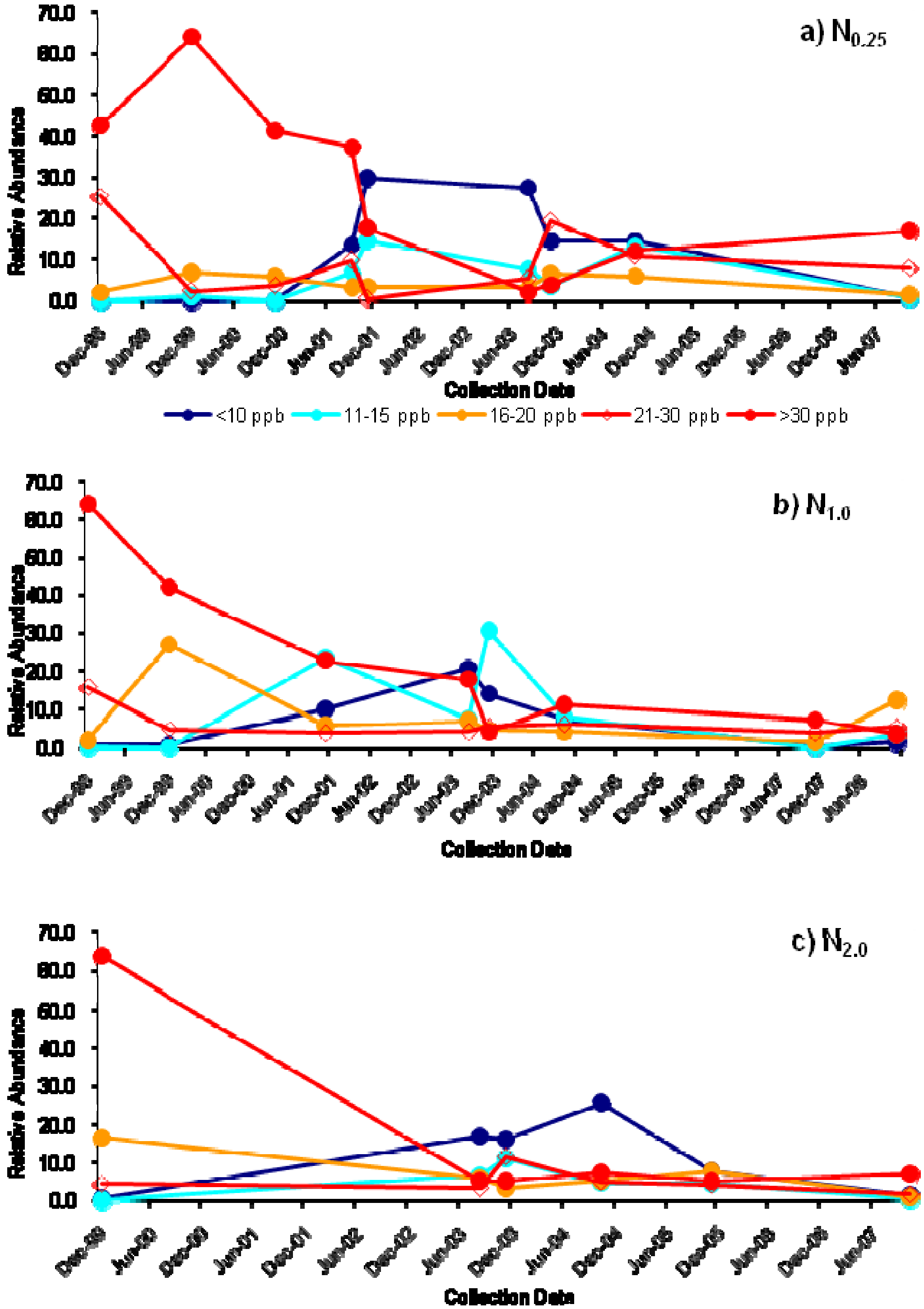


**Figure 5-11.** Relative abundances (%) of periphyton type for six of the permit compliance stations, $N_{0.25}$ (a), $N_{1.0}$ (b), $N_{2.0}$ (c), $N_{4.0}$ (d), $C_{4.0}$ (e), and $FS_{3.0}$ (f), from 1998 to 2008, based on five indicator classes:(1) TP < 10 ppb, (2) TP = 11-15 ppb, (3) TP = 16-20 ppb, (4) TP = 21-30 ppb, and(5) TP > 30 ppb.

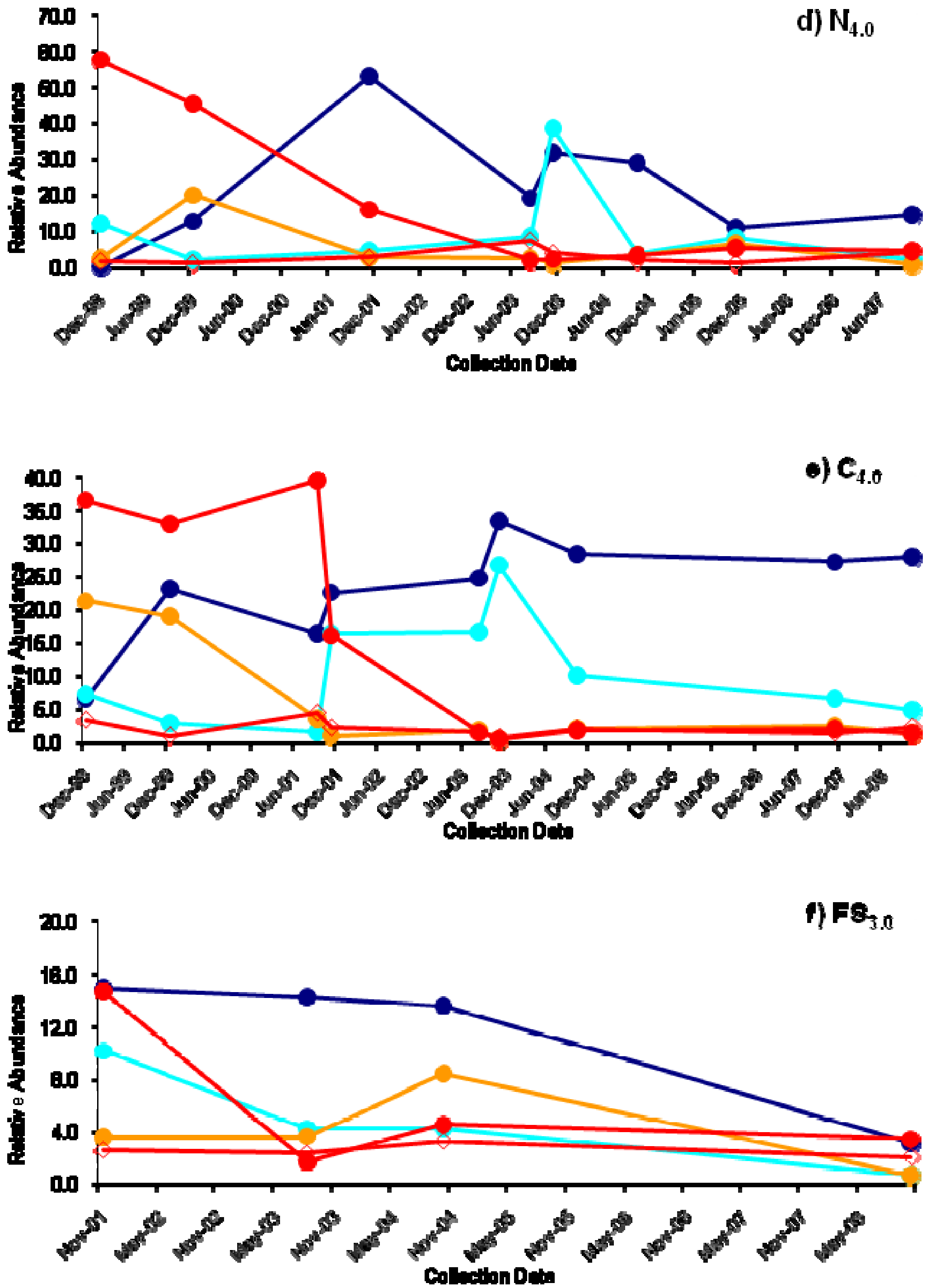


**Figure 5-11.** Continued.

**Table 5-16.** Summary statistics for WY2009 periphyton tissue TP concentrations (mg/kg) measured at the permit compliance sampling locations at WCA-2A.

| Station | Epiphyton TP Concentration (mg/kg) | N | Metaphyton TP Concentration (mg/kg) | N |
|---|---|---|---|---|
| $N_{0.25}$ | 1120 | 1 | - | 0 |
| $N_{1.0}$ | - | 0 | - | 0 |
| $N_{2.0}$ | 460 ± 16 | 3 | - | 0 |
| $N_{4.0}$ | 345 ± 6 | 3 | 237 ± 19 | 3 |
| $C_{4.0}$ | - | 0 | - | 0 |
| $FS_{0.25}$ | - | 0 | 1620 ± 44 | 3 |
| $FS_{1.0}$ | 888 ± 94 | 3 | - | 0 |
| $FS_{3.0}$ | 425 ± 5 | 2 | 246 ± 19 | 3 |

**Table 5-17.** Nitrogen:Phosphorus ratios in live sawgrass *(Cladium jamaicense)* leaf tissues at the permit compliance sampling locations in WCA-2A from 2006 to 2008.

| | 2006 | | 2007 | | 2008 | |
|---|---|---|---|---|---|---|
| Station | Spring | Fall | Spring | Fall | Spring | Fall |
| $N_{0.25}$ | 21 ± 6 | - | - | - | - | - |
| $N_{1.0}$ | 17 ± 3 | 15 ± 6 | 22 ± 5 | 21 ± 5 | 26 ± 1 | 20 ± 2 |
| $N_{2.0}$ | 24 ± 4 | 28 ± 1 | 21 ± 4 | 26 ± 1 | 34 ± 2 | 20 ± 3 |
| $N_{4.0}$ | 35 ± 5 | 22 ± 2 | 36 ± 5 | 39 ± 5 | 41 ± 0.4 | 35 ± 4 |
| $C_{4.0}$ | 37 ± 7 | 28 ± 1 | 42 ± 3 | 37 ± 2 | 33 ± 1 | 34 ± 5 |
| $FS_{0.25}$ | 19 ± 7 | 20 ± 3 | 24 ± 2 | 27 ± 1 | 23 ± 2 | 18 ± 1 |
| $FS_{1.0}$ | 20 ± 6 | 19 ± 3 | 22 ± 2 | 24 ± 3 | 23 ± 1 | 20 ± 1 |
| $FS_{3.0}$ | 37 ± 2 | 31 ± 8 | 45 ± 4 | 38 ± 3 | 34 ± 1 | 30 ± 1 |

**Table 5-18.** Nitrogen:Phosphorus ratios in live cattail *(Typha domingensis)* leaf tissues at the permit compliance sampling locations in WCA-2A from 2006 to 2008.

| | 2006 | | 2007 | | 2008 | |
|---|---|---|---|---|---|---|
| Station | Spring | Fall | Spring | Fall | Spring | Fall |
| $N_{0.25}$ | 15 ± 3 | 8 ± 4 | 15 ± 1 | 18 ± 5 | 14 ± 0.4 | 13 ± 2 |
| $N_{1.0}$ | 19 ± 0.4 | 14 ± 1 | 17 ± 3 | 15 ± 1 | 17 ± 0.4 | 12 ± 3 |
| $N_{2.0}$ | - | 14 ± 3 | 20 ± 1 | 21 ± 3 | 19 ± 2 | 13 ± 2 |
| $N_{4.0}$ | - | - | - | - | - | - |
| $C_{4.0}$ | - | - | - | - | - | - |
| $FS_{0.25}$ | 9 ± 4 | 13 ± 1 | 16 ± 1 | 14 ± 1 | 20 ± 13 | 11 ± 1 |
| $FS_{1.0}$ | 13 ± 6 | 14 ± 1 | 17 ± 1 | 14 ± 1 | 15 ± 0.4 | 11 ± 1 |
| $FS_{3.0}$ | - | - | - | - | - | - |

**Table 5-19.** Number of points (out of 10 possible points at 1 m intervals along each line transect) at the northern transect locations where sawgrass or cattail was present. Surveys were completed during the dry and wet seasons each year.

| | $N_{0.25}$ | | $N_{1.0}$ | | $N_{2.0}$ | | $N_{4.0}$ | | $C_{4.0}$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Saw | Cat | Saw | Cat | Saw | Cat | Saw | Cat | Saw | Cat |
| Apr 05 | 1 | 10 | 10 | 0 | 10 | 0 | 10 | 0 | 10 | 0 |
| Oct 05 | 1 | 10 | 9 | 0 | 10 | 0 | 10 | 0 | 10 | 0 |
| Apr 06 | 1 | 10 | 9 | 0 | 10[W] | 0[W] | 10 | 0 | 10 | 0 |
| Nov 06 | 1 | 10 | 10 | 5 | 9 | 0 | 1[F] | 0[F] | 10 | 0 |
| Apr 07 | 1 | 10 | 10 | 9 | 10 | 0 | 6 | 0 | 10 | 0 |
| Oct 07 | 0 | 9 | 10 | 2 | 10 | 0 | 2 | 0 | 10 | 0 |
| Mar 08 | 0 | 10 | 10 | 0 | 10 | 0 | 4 | 0 | 10 | 0 |
| Oct 08 | 1 | 10 | 5 | 2 | 10 | 0 | 8 | 0 | 10 | 0 |
| Apr 09 | 1 | 10 | 10[S] | 4[S] | 10[S] | 0[S] | 9[S] | 0[S] | 10 | 0 |

[S] indicates that transect areas moved due to herbicide overspray.
[W] indicates that transect was moved due to worn trails next to transect.
[F] indicates the site experienced a fire prior to that survey period.

**Table 5-20.** Number of points (out of 10 possible points at 1 m intervals along each line transect) at the southern transect locations where sawgrass or cattail was present. Surveys were completed during the dry and wet seasons each year.

| | $FS_{0.25}$ | | $FS_{1.0}$ | | $FS_{3.0}$ | |
|---|---|---|---|---|---|---|
| Date | Saw | Cat | Saw | Cat | Saw | Cat |
| Apr 05 | 7 | 8 | 7 | 0 | 10 | 0 |
| Oct 05 | 3 | 9 | 3 | 3 | 10 | 0 |
| Apr 06 | 7 | 4 | 7 | 6 | 10 | 0 |
| Nov 06 | 8 | 5 | 8 | 7 | 10 | 0 |
| Apr 07 | 8 | 5 | 8 | 8 | 9 | 0 |
| Oct 07 | 8 | 2 | 8 | 5 | 10 | 0 |
| Mar 08 | 8 | 4 | 8 | 8 | 10 | 0 |
| Oct 08 | 6 | 6 | 6 | 5 | 10 | 0 |
| Apr 09 | 8[S] | 4[S] | 8[S] | 2[S] | 10 | 0 |

[S] indicates that transect poles were moved due to herbicide overspray.

## Rotenberger Wildlife Management Area

### Rotenberger Configuration

The Rotenberger Hydropattern Restoration Project is a component of the District's Everglades restoration efforts. The project goal is to slow, alter, and eventually reverse the ecosystem degradation within the Rotenberger Wildlife Management Area (RWMA) (**Figure 5-12**), primarily by restoring a more natural hydropattern. This degradation is predominantly caused by overly dry conditions that have resulted in repeated peat fires, soil oxidation and compaction, nutrient release from surface soils, and conversion of obligate wetland vegetative communities to upland-type communities. Anticipated benefits include the preservation and encouragement of additional desirable wetland vegetation species and the initiation of peat formation. Project features include a 240 cfs electric pump station (G-410) to withdraw treated water from the STA-5 discharge canal for release into the RWMA. This pump station distributes water through a 3.5-mile spreader canal located parallel to the west perimeter levee of the RWMA. Surface water that is released out of the RWMA goes into the Miami Canal (L-28 Canal) through four gated culverts (G-402A through G-402D) along the eastern boundary of the RWMA. There is a quarter-mile-long collection canal upstream of each outlet structure.

There are 20 monitoring stations within the area distributed across five transects that span out across the entire area from the G-410 inflow point. Eight of these stations (the entire RA- and RC-transects) are monitored for various water quality parameters. These stations are also sampled for periphyton tissue nutrients and taxonomic species composition. In addition, soil sampling and vegetation composition monitoring occurs at these sites as well as the remaining 12 stations. The RC1, RC2, and RC3 stations are EFA permit compliance locations within the RWMA. Monitoring data for the stations downstream of STA-5 can be located within two District databases, ERDP and DBHYDRO (Appendix 5-8).

Water levels have historically been monitored at the Rott.N and Rott.S stage gauges. New groundwater wells were installed next to each of the older stage gauges in late 2008. These new wells have the ability to detect lower groundwater levels than the older stage gauges. Beginning January 1, 2009, the hydrologic stages reported were obtained from the new groundwater wells instead of the older stage gauges; however, all gauges will remain in service.

### Rotenberger Water Budget

Annual water budgets from 2003–2008 are presented in **Table 5-21**. Approximately 80 to 90 percent of the inflows and outflows in each water budget were attributed to rainfall and evapotranspiration (ET). Seepage values were not accounted for in these calculations. Errors noted on WY2006 and WY2007 budgets could have been due to the large-scale fire that occurred in 2006, which resulted in loss of surface vegetation in sizable portions of the area.

### Rotenberger Hydrologic and Total Phosphorus Loads

In WY2009, approximately 32,297 acre-feet (ac-ft) of STA-5 water was discharged into the RWMA through G-410 (**Figure 5-13**). The inflow TP FWMC was 47 ppb, yielding an inflow TP load of about 1.88 mt. Approximately 25,125 ac-ft of water was released through G-402A–C. The outflow TP FWMC concentration was 69 ppb and outflow TP load was about 2.15 mt (**Figure 5-14**). A limited amount of water was released via G-402D from August 26 to September 14, 2008, after heavy rainfall from Tropical Storm Fay. While flow through G-402D is not currently measured, the District estimated that 2,344 ac-ft passed through this structure during the 19.7 days that its gate was fully open.

**Table 5-21.** Water budgets calculated for WY2003 through WY2008. Inflows (ac-ft) represent discharges into the RWMA from the G-410 and outflows (ac-ft) represent water releases from the G-402A–D structures.

| WY | Inflow | Rainfall/ Seepage In | Total Inflow | Outflow | ET/ Seepage Out | Total Outflow | ERROR % |
|---|---|---|---|---|---|---|---|
| 2003 | 54306 | 111179 | 165485 | 25312 | 125410 | 150722 | -9.3 |
| 2004 | 16849 | 114620 | 131469 | 352 | 123546 | 123897 | -5.9 |
| 2005 | 44414 | 113868 | 158281 | 33788 | 123847 | 157634 | -0.4 |
| 2006 | 29886 | 114605 | 144491 | 54648 | 124451 | 179100 | 21.0 |
| 2007 | 16195 | 85538 | 101733 | 4630 | 123403 | 128033 | 22.3 |
| 2008 | 11646 | 108725 | 120371 | 0 | 124900 | 124900 | 13.8 |
| TOTAL | 173296 | 648535 | 821831 | 118730 | 745557 | 864287 | 6.4 |

| | G-410 Inflow | Rainfall/ Seepage |
|---|---|---|
| % Inflow | 21.1 % | 79 % |

| | G-402 Outflow | ET/ Seepage |
|---|---|---|
| % Outflow | 13.8 % | 86.3 % |

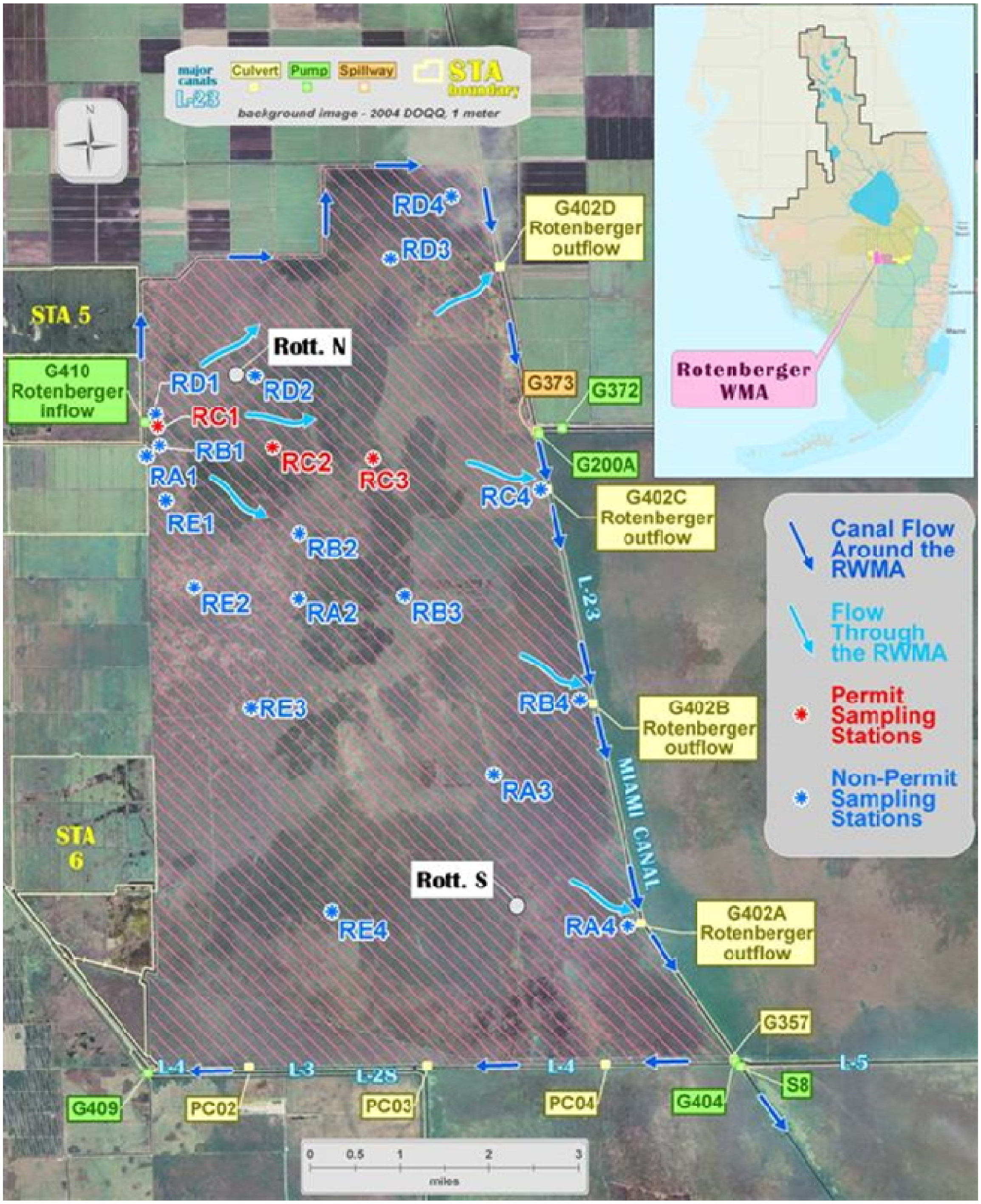


**Figure 5-12.** Map of Rotenberger Wildlife Management Area (RWMA) showing major structures and monitoring transects RA, RB, RC (permit compliance monitoring transect), RD, and RE.

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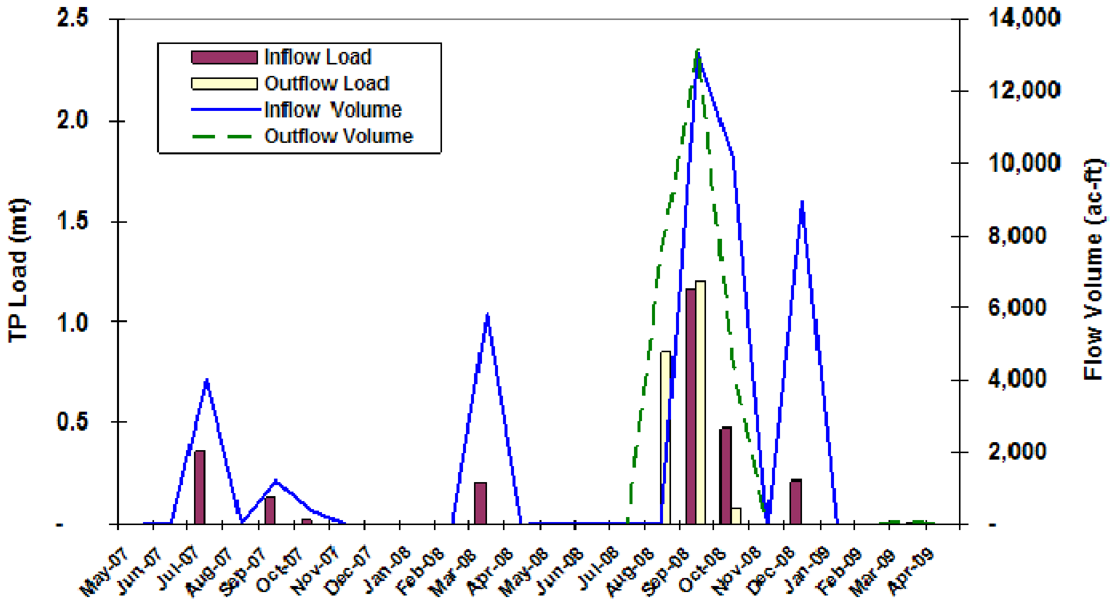


968 **Figure 5-13.** Monthly flow and TP loads for the RWMA for WY2008 and WY2009.

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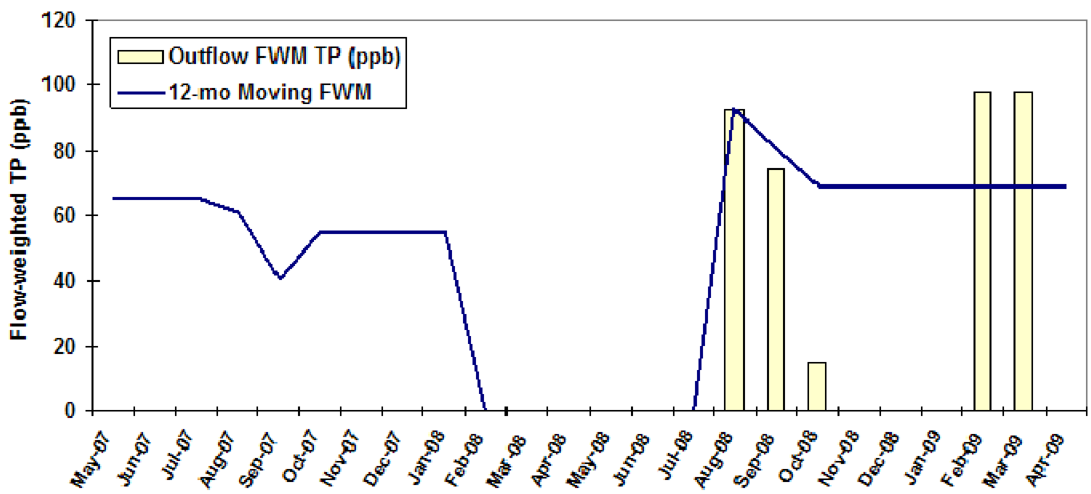


971 **Figure 5-14.** Comparison of monthly to 12-month moving average TP
972 concentrations for the RWMA outflow during WY2008.

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### *Rotenberger Hydropattern Restoration*

Daily target stages for the RWMA are set based on the District's Natural System Model (NSM) values plus 0.25 ft. Rainfall during the beginning of WY2008 was well below average, and as a result, the stage dropped over 1 foot below NSM targets for most of this water year (**Figure 5-15**). During May 2007 and a portion of June 2007, the water level receded below the bottom of the stage recorder's stilling wells. Therefore, the mean stage appeared to hold steady at approximately 10.90 feet, but most certainly was lower. The stage gauges malfunctioned in mid-October 2007 and data were unavailable until repairs were completed in March 2008. Treated water from STA-3/4 was delivered into the area in March 2008.

Average stages were typically within five or six inches of the target stage from May 2008 to March 2009. Tropical Storm Fay delivered approximately seven inches of rain to the RWMA in August 2008. Stages rose to 13.67 feet National Geodetic Vertical Datum of 1929 (ft NGVD), but the water level was quickly lowered by opening the G-402 structures. The stages dropped rapidly in March and April 2009 due to lack of rainfall. Stages measured with the new groundwater wells were below 10 ft NGVD at the end of April 2009.

In June 2008, the District met with representatives from the Florida Fish and Wildlife Conservation Commission and the FDEP to review and update the RWMA Operation Plan (SFWMD, 2004) in order to improve the operational water delivery strategy for the area. It was determined that an updated topographic survey was needed to develop the Operation Plan. The RWMC was last surveyed in 2004; this survey utilized 31 points, and the average elevation was 12.12 ft NGVD 29. In November 2008, 70 points were surveyed. This survey included the same 31 points from 2004, plus an additional 39 points. The average marsh elevation using the 70-point grid was 12.07 ft NGVD 29. However, when comparing the same 31 points that were surveyed in both 2004 and 2008, the calculated ground elevation from the new survey was 12.14 ft NGVD 29. Appendix 5-9 shows topographic maps derived from the 2004 and 2008 surveys.

The revised RWMA Operation Plan will give the District the ability to hold another quarter foot of water in the marsh at the onset of the dry season to help minimize the impacts of future drought conditions. It is recognized that during severe droughts, due to the lack of outside supplemental water, the RWMA will inevitably dry out. The revised Operation Plan has not yet been finalized.

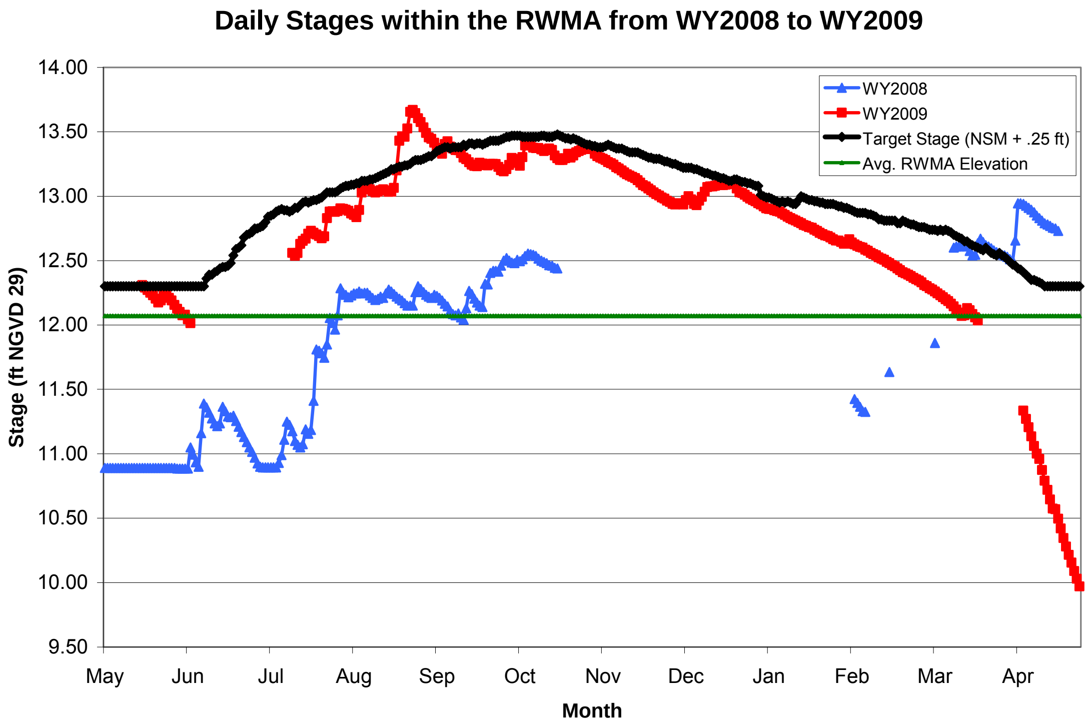



**Figure 5-15.** Daily target stage levels and mean daily stage readings (average of Rott.N and Rott.S stages) for WY2008 and WY2009. The average ground elevation is also displayed. Erroneous readings due to gauge failure were excluded. Target stages were based on Natural System Model for the RWMA plus 0.25 ft.

### Rotenberger Surface Water Quality

Surface water quality samples were collected at eight stations within the RWMA on a monthly basis when sufficient water (depth ≥ 10 cm) was available for retrieving representative samples. Mean surface water TP concentrations (**Table 5-22)** and specific conductivity measurements (**Table 5-23**) were calculated for each station. There were notable decreases in TP and specific conductivity in WY2009 compared to WY2008 (**Table 5-24**). This could be attributed to various factors, including increased rainfall, a longer hydroperiod, and reduced TP loads and specific conductivity concentrations from STA-5. It should be noted that WY2008 data is presented in this report because calendar year data was presented in the previous SFER.

### EFA Permit Compliance Transect Total Phosphorus and Conductivity at STA-5 Downstream Area (Rotenberger Wildlife Management Area)

As previously mentioned, the RWMA EFA permit compliance transect comprises three monitoring stations (RC-1, RC-2, and RC-3) that extend approximately 4 km downstream of pump station G-410 (**Figure 5-12**). All stations along this transect are identified as impacted.

All specific conductivity levels along the RWMA transect were well below the 1,275 μS/cm for Class III waters (**Table 5-9**). While conductivity levels did not change substantially along the RWMA transect, median TP concentrations decreased by at least 15 ppb over a distance of 4 km from the canal (**Figure 5-16**). The overall change in TP concentrations along the RWMA transect was statistically significant ($p < 0.001$) **(Table 5-10).**

### Rotenberger Soil Chemistry

Soil samples are collected every other year at 20 monitoring stations in the RWMA. Samples were collected in March 2005, 2007, and 2009. Triplicate cores were collected from each station. Cores were originally split into 0-2 and 2-10 cm sections for analysis, but results are presented for the entire 0-10 cm soil core in this report. Samples were corrected for bulk density when combining the results of both soil layers. Mean values were then calculated for each station from the triplicate cores. No samples were collected along the RE-transect in 2005.

The average soil TP concentrations varied among sites and between years (**Table 5-25**). An overall decrease in mean soil TP concentrations (± standard deviation) was observed between 2007 and 2009 cores. Mean soil TP concentration in 2007 was 994 ± 80 milligrams per kilogram (mg/kg). In 2009, mean soil TP concentration was 736 ± 59 mg/kg. The 2007 results were influenced by the large-scale fire that occurred in May 2006, which included several peat fires in northern sections of the RWMA (Pietro et al., 2008). The reduction in the mean TP concentration from 2007 to 2009 may represent post-fire soil recovery.

Among the 60 soil cores collected in 2009, five contained a floc layer above the consolidated soil, indicating recent soil accretion. The depth of this floc layer and its TP concentration are displayed in **Table 5-26**.

### Rotenberger Periphyton and Macrophytes

Periphyton collections were attempted at eight stations in October 2008; however, only five stations had sufficient biomass for collection. This sampling will continue annually during the late wet season in 2009 (WY2010). Periphyton taxonomic data from this single collection is insufficient to make determinations using species composition as an indicator of changing water quality status. Additional data is expected to be reported in future SFERs.

Periphyton tissue TP concentrations are listed in **Table 5-27**. Using an ANOVA combined with a post-hoc test, it was determined that the RA1 and RC1 stations had significantly ($p < 0.0001$) higher periphyton tissue TP concentrations than samples collected farther downstream of the G-410 pump station. This could be due to the fact that these two locations are within an area that experienced peat fires in 2006 and because they are closest to the G-410 pump station, both factors that could result in increased surface water TP and therefore increased periphyton tissue nutrients.

Cattail and sawgrass live leaf and root tissues were sampled in April 2009 at the RC1, RC2, and RC3 stations. These collections are planned to occur semiannually. It is anticipated that data from these analyses will be included in future SFERs.

Using point intercept survey methodology, the areal coverage of dominant macrophyte species has been surveyed along fixed 10 m long transects twice a year (dry and wet seasons) since 2005. These surveys were performed at 20 locations across the RWMA; only the RC1, RC2, and RC3 data are presented in this report because the remaining sites are in review. The presence of sawgrass and/or cattail 1 m intervals along each transect was recorded (**Table 5-28)**. Sawgrass coverage decreased and cattail coverage increased at the RC1 station over the four-year survey period, while the reverse trend was observed at RC2. The 2006 fire likely had a strong effect on the vegetative change at the RC1. This site was located in area that experienced peat fires, and nearly all the vegetation along the transect was removed in the fire. In addition, this site was flooded in order to suppress the peat fires, while the other two sites remained dry one month post-fire. Sawgrass and cattail coverage at the RC3 site remained fairly constant over the survey period.

### *Rotenberger Restoration Activities*

The District is currently developing plans to construct a supplemental inflow pump station (approximately 100 cfs capacity) on the western side of the RWMA to allow discharge of treated water from STA-5 and future Compartment C STAs into the RWMA. This supplemental pump station is intended to provide water managers more flexibility in achieving the desired water depths and hydroperiods within the RWMA.

The District, in cooperation with the Florida Game and Fish Conservation Commission, is in the process of restoring approximately 19 acres of tree islands in the southwestern corner of the RWMA. These islands were overgrown with exotics, primarily Brazilian pepper (*Schinus terebinthifolius;* **Figure 5-17***)* and Peruvian primrose-willow *(Ludwigia peruviana).* Both species have been classified as Category I invasive species in Florida (FLEPPC, 2007). The pepper and primrose-willow were cut and sprayed with herbicide to prevent regrowth (**Figure 5-18**). In July 2009, an assortment of 3,000 native trees and shrubs will be planted on the islands. It is expected that this native vegetation will be beneficial to wildlife within the RWMA. The newly planted trees and shrubs will be monitored to determine the planting success. Additional monitoring will include measurement of soil accretion/subsidence, stress levels of the newly planted trees and shrubs, canopy development, and wildlife usage.

Several large areas (some greater than 2,000 acres in size) within the northern section of the RWMA have become dominated by Carolina willow (*Salix caroliniana*) and Peruvian primrose-willow. In June 2009, the District aerially applied herbicide to a 100-acre area of the RWMA to test effectiveness of spraying to eliminate these large stands found in the P-enriched soils. The District will replant these areas with sawgrass following the 2010 dry season. If planting proves successful, then the method will be used to return thousands of acres of the RWMA now dominated by willow and primrose-willow back to sawgrass habitat.

A vegetation mapping effort is under way for the RWMA based on 2008 overflight imagery. The vegetation in the RWMA was last mapped in 2004. Maps and an analysis of changes in the vegetation community between 2004 and 2008 are expected to be presented in future SFERs.

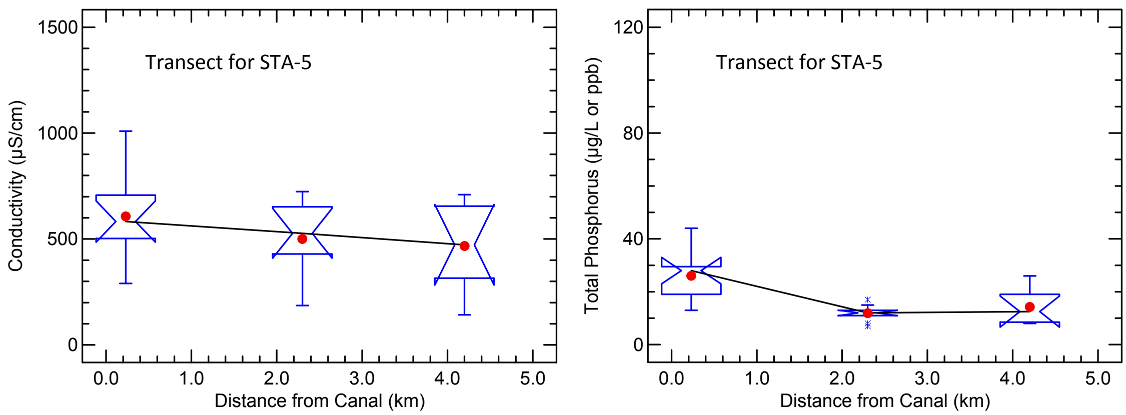



**Figure 5-16.** Notched box and whisker plots of conductivity and total phosphorus levels measured at permit compliance transect stations (RC1, RC2, and RC3) during WY2009 for STA-5. The notch on a box plot represents the 95% C.I. about the median, which is represented by the narrowest part of the notch. The top and bottom of the box represent the $75^{th}$ and $25^{th}$ percentiles, respectively. The whiskers represent the highest and lowest data values that are within two standard deviations of the median. Values above and below the whiskers are greater than two standard deviations from the median. Notches that do not overlap indicate that the data represented by the boxes being compared are significantly different at the 95% C.I.

**Figure 5-17.** Dense standing Brazilian pepper (*Schinus terebinthifolius)* in the RWMA (photo by the SFWMD).

**Figure 5-18.** Brazilian pepper removal in the RWMA. Very little vegetation was left after the pepper was removed (photo by the SFWMD).

**Table 5-22.** Mean surface water TP concentrations ± standard deviations measured during WY2009 in the RWMA. Asterisk (*) indicates permit compliance location.

| Station | WY2009 TP (ppb) | N | Min | Median | Max |
|---|---|---|---|---|---|
| RA1 | 23 ± 17 | 11 | 11 | 18 | 72 |
| RA2 | 11 ± 3 | 8 | 7 | 11 | 15 |
| RA3 | 12 ± 3 | 7 | 8 | 11 | 17 |
| RA4 | 13 ± 5 | 9 | 8 | 10 | 22 |
| RC1* | 26 ± 9 | 11 | 13 | 28 | 44 |
| RC2* | 12 ± 3 | 9 | 7 | 12 | 17 |
| RC3* | 14 ± 7 | 8 | 8 | 13 | 26 |
| RC4 | 17 ± 6 | 8 | 10 | 16 | 28 |

**Table 5-23.** Mean surface water specific conductivity ± standard deviations measured during WY2009 in the RWMA. Asterisk (*) indicates permit compliance location.

| Station | WY2009 Sp Cond (µS/cm) | N | Min | Median | Max |
|---|---|---|---|---|---|
| RA1 | 599 ± 152 | 11 | 358 | 588 | 822 |
| RA2 | 415 ± 192 | 8 | 108 | 444 | 669 |
| RA3 | 163 ± 53 | 7 | 96 | 143 | 248 |
| RA4 | 218 ± 57 | 9 | 142 | 202 | 321 |
| RC1* | 607 ± 199 | 11 | 290 | 583 | 1009 |
| RC2* | 500 ± 180 | 9 | 186 | 527 | 724 |
| RC3* | 467 ± 206 | 8 | 142 | 473 | 709 |
| RC4 | 248 ± 78 | 8 | 148 | 254 | 359 |

**Table 5-24.** Mean surface water TP and specific conductivity ± standard deviations measured during WY2008 in the RWMA. Asterisk (*) indicates permit compliance location.

| Station | WY2008 TP (ppb) | Samples collected WY2008 | WY2008 Sp Cond (µS/cm) | Samples collected WY2008 |
|---|---|---|---|---|
| RA1 | 47 ± 36 | 4 | 713 ± 123 | 3 |
| RA2 | 16 | 1 | 419 | 1 |
| RA3 | 13 | 1 | 239 | 1 |
| RA4 | 24 ± 10 | 3 | 385 ± 96 | 3 |
| RC1* | 56 ± 28 | 5 | 734 ± 94 | 4 |
| RC2* | 30 ± 23 | 3 | 766 ± 182 | 2 |
| RC3* | 32 | 1 | 547 | 1 |
| RC4 | 32 | 1 | 312 | 1 |

**Table 5-25.** Mean soil TP concentrations (milligrams per kilogram, or mg/kg) ± standard errors from 2005, 2007, and 2009 collections in the RWMA. Each value is the mean of results from three soil cores collected to a depth of 10 cm. The RE-transect was not sampled in 2005. Asterisk (*) indicates permit compliance location.

| Station | 2005 Mean $TP_{0-10}$ (mg/kg) | 2007 Mean $TP_{0-10}$ (mg/kg) | 2009 Mean $TP_{0-10}$ (mg/kg) |
|---|---|---|---|
| RA1 | 375 ± 22 | 483 ± 76 | 377 ± 141 |
| RA2 | 378 ± 80 | 372 ± 106 | 606 ± 40 |
| RA3 | 452 ± 44 | 605 ± 114 | 678 ± 4 |
| RA4 | 735 ± 115 | 664 ± 102 | 799 ± 20 |
| RB1 | 495 ± 55 | 633 ± 142 | 1699 ± 954 |
| RB2 | 468 ± 122 | 818 ± 72 | 675 ± 19 |
| RB3 | 372 ± 23 | 534 ± 65 | 493 ± 61 |
| RB4 | 563 ± 33 | 816 ± 29 | 683 ± 41 |
| RC1* | 467 ± 25 | 2847 ± 388 | 1521 ± 33 |
| RC2* | 510 ± 37 | 669 ± 77 | 534 ± 109 |
| RC3* | 334 ± 13 | 634 ± 98 | 614 ± 46 |
| RC4 | 639 ± 16 | 712 ± 76 | 711 ± 42 |
| RD1 | 447 ± 28 | 1858 ± 475 | 808 ± 154 |
| RD2 | 500 ± 85 | 792 ± 50 | 647 ± 40 |
| RD3 | 561 ± 65 | 889 ± 80 | 875 ± 29 |
| RD4 | 802 ± 257 | 1573 ± 209 | 851 ± 180 |
| RE1 | - | 666 ± 75 | 537 ± 57 |
| RE2 | - | 687 ± 120 | 512 ± 43 |
| RE3 | - | 1671 ± 451 | 692 ± 77 |
| RE4 | - | 447 ± 82 | 405 ± 44 |

**Table 5-26.** Flocculent soil TP concentrations (mg/kg) of the five cores that contained flocculent soil development during the 2009 collections in the RWMA. Each flocculent soil sample represents a single sample. Asterisk (*) indicates permit compliance location.

| Station | Flocculent Soil Depth (cm) | Floc TP Concentration (mg/kg) |
|---|---|---|
| RB2 | 0 – 0.5 | 719 |
| RC1* | 0 – 0.5 | 3090 |
| RE2 | 0 – 2.0 | 1010 |
| RE2 | 0 – 2.0 | 752 |
| RE3 | 0 – 2.0 | 559 |

**Table 5-27.** Mean periphyton tissue TP concentrations (mg/kg) ± standard errors from 2008 collections in the RWMA. RA3, RC2, and RC4 did not have sufficient amounts of periphyton for collection. Asterisk (*) indicates permit compliance location.

| Station | Periphyton TP Concentrations (mg/kg) |
|---|---|
| RA1 | 3253 ± 74 |
| RA2 | 814 ± 34 |
| RA3 | - |
| RA4 | 798 ± 8 |
| RC1* | 2910 ± 174 |
| RC2* | - |
| RC3* | 889 ± 13 |
| RC4 | - |

**Table 5-28.** Number of points along fixed transects where sawgrass or cattail was present, out of 10 possible points. Each point represents a distance of 1 m. Surveys were completed during the dry (April) and wet (October or November) seasons each year. Surveys were not completed at RC3 in October 2007 due to site inaccessibility. Asterisk (*) indicates permit compliance location.

| | RC1* | | RC2* | | RC3* | |
|---|---|---|---|---|---|---|
| **Date** | **Saw** | **Cat** | **Saw** | **Cat** | **Saw** | **Cat** |
| Apr 05 | 9 | 4 | 7 | 6 | 10 | 0 |
| Nov 05 | 9 | 0 | 10 | 6 | 10 | 0 |
| Apr 06 | 9 | 0 | 10 | 6 | 10 | 0 |
| Oct 06 | 3 | 4 | 5 | 2 | 10 | 1 |
| Apr 07 | 3 | 3 | 7 | 4 | 10 | 4 |
| Oct 07 | 2 | 1 | 9 | 3 | - | - |
| Apr 08 | 4 | 1 | 9 | 1 | 10 | 0 |
| Oct 08 | 5 | 5 | 9 | 0 | 10 | 1 |
| Apr 09 | 3 | 7 | 10 | 0 | 10 | 1 |

# ANALYSIS AND INTERPRETATION

This section reports on the Process Development and Engineering (PDE) component of the Long-Term Plan for Achieving Water Quality Goals in the Everglades Protection Area (Long-Term Plan). The longer-term STA performance is included along with a summary of the impact of extreme weather conditions (drought/storm) on the STAs. The performance of the individual treatment cells in each STA as well as updates on various rehabilitation activities that have occurred in the STAs are presented.

## DROUGHT IMPACTS ON THE STAS

Operating plans have been established for each the six STAs which specify the stages in which cells are to be maintained throughout the year during routine operation (SFWMD, 2007a-d; 2009a). The STA Drought Contingency Strategy Document (SFWMD, 2007e) has also been established in an effort to prepare the STAs when a drought period is forecasted at which time target water stages are adjusted slightly higher in attempt to keep each cell hydrated throughout the drought period. The drought contingency approach prioritizes SAV cells to maintain a minimum of six inches water depth to minimize impacts to the SAV. When supplemental water is not available to maintain the drought target stages, some cells dry out (**Figures 5-19** and **5-20**). Dry-out conditions in SAV cells can be detrimental to the plant community. Field observations in the past indicates that dry-out conditions in the emergent community for shorter periods do not seem to significantly impact the emergent plant communities and, in fact, they can be beneficial in encouraging new growth. However, extended periods of dryout condition have visibly impacted the emergent plant communities in terms of die-off of standing vegetation. When cells are rewetted, the vegetation tends to recuperate. In the STA Operation Plans, the minimum target for emergent cells is 6 inches below the average ground elevation. A study on evaluating the effects of duration and extent of dry outs on cattails in the STAs is under way.

**Table 5-29** shows a list of STA cells that dried out by the end of WY2009. In general, except for a couple of cells, the SAV cells remained hydrated throughout the entire dry season. The emergent cells in STA-2, STA-3/4, STA-5, and STA-6 experienced periods in which the cells dried out. Water levels remained above ground level in STA-1W and STA-3/4 throughout the entire dry season. Aerial flights and field visits throughout the dry season showed that there was very little impact to the vegetation in any of the cells as a direct result of the drought conditions. Evaluation of impacts of dry out to phosphorus flux and the effects of subsequent flows following a dryout period on vegetation is expected to be reported in future SFERs.

**Table 5-29.** Drought conditions resulted in low water levels and some of the water quality monitoring stations within the STAs were suspended during the dry conditions and resumed after rehydration.

| STA | Location | Inflow | | | | | Outflow | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Structure | Grabs Suspended | A/S Suspended | Date Suspended | Date Resumed | Structure | Grabs Suspended | A/S Suspended | Date Suspended | Date Resumed |
| STA-1E | Cell 1 | S-363 C | Yes | No | 04/16/09 | 05/27/09 | S-364 A | Yes | No | 04/16/09 | 06/29/09 |
| | Cell 2 | Cell 2 inflow is the Cell 1 outflow | | | | | S-365 A&B | Yes | Yes | 04/16/09 G<br>05/21/09 A/S | Not until USACE S-365 repairs are complete |
| | Cell 3 | S-366 B&D | Yes | No | 04/16/09 | 06/30/09 | S-367 B | Yes | No | 04/16/09 | 06/22/09 |
| | | | | | | | S-376 D | Yes | No | 04/16/09 | 06/29/09 |
| | Cell 4N | Cell 4N inflow is the Cell 3 outflow | | | | | S-368 B&D | Yes | No | 04/16/09 | 06/29/09 |
| | Cell 5 | S-370 A&C | Yes | No | 05/15/09 | 05/19/09 | S-371 A&C | Yes | No | 05/15/09 | 05/26/09 |
| STA-2 | Cell 1 | G-329B | Yes | No | 05/06/09 | 05/20/09 | G-330D | Yes | No | 04/15/09 | 05/27/09 |
| | Cell 2 | G-331D | Yes | No | 05/13/09 | 05/20/09 | G-332 | Yes | No | 05/13/09 | 05/20/09 |
| STA-5 | Cell 1A | G-342A & B | Yes | Yes | 12/10/08 | Offline | G-343B & C | Yes | Yes | 12/18/08 | Offline |
| | Cell 1A | G-349A (PS) | Yes | Yes | 02/04/09 | Offline | G-343B & C | Yes | Yes | 12/18/08 | Offline |
| | Cell 2A | G-342C & D | Yes | Yes | 04/15/09 | 06/03/09 | G-343F & G | Yes | Yes | 04/15/09 | 06/17/09 |
| | Cell 3A | G-342 E & F | Yes | Yes | 01/14/09 | 06/25/09 | G-343I & J | Yes | Yes | 01/14/09 | 06/25/09 |
| | Cell 3B | Cell 3B inflow is the Cell 3A outflow | | | | | G-344E & F | Yes | Yes | 01/14/09 | 06/25/09 |
| STA-6 | Sec 2 | G-396B | Yes | Yes | 01/13/09 | 06/02/09 | G-352B | Yes | Yes | 01/13/09 | 06/02/09 |
| | | G-396A&C | Yes | N/A | 01/13/09 | 06/16/09 | G-352A&C | Yes | N/A | 01/13/09 | 06/16/09 |
| | Cell 5 | G-353A & B | Yes | Yes | 01/13/09 | 06/02/09 | G-354C | Yes | Yes | 01/13/09 | 06/02/09 |
| | Cell 3 | G-353C | Yes | Yes | 01/13/09 | 06/02/09 | G-393B | Yes | Yes | 01/13/09 | 06/02/09 |
| | End of L3 Supply Canal | G-407 Div. Structure | Yes | Yes | 01/13/09 | 06/02/09 | N/A | | | | |

*Notified FDEP on 06/03/09 of resumption of sampling.* (yellow)

*Notified FDEP on 06/04/09 of resumption of sampling.* (green)

*Notified FDEP on 07/01/09 of resumption of sampling.* (purple)
*STA-5, Cell1A and 1B, Flow-way 1, have been offline due to maintenance activities; they were not suspended as part of dryout.*
*STA-6, G-396A and C and G-352A and C do not have autosamplers; they are grab-only sites.*

A/S *= Autosampler*
G *= Grab sampling*
PS *= Pump Station*

**Figure 5-19.** An aerial photo of STA-1E, Cell 4, in May 2009, showing cell dryout, resulting in loss of SAV (photo by the SFWMD).

**Figure 5-20.** An aerial photo of STA-2, Cell 2, in May 2009, showing emergent vegetation communities during dryout periods as a result of low water conditions (photo by the SFWMD).

# TROPICAL STORM FAY IMPACTS ON THE STAS

In August 2008, Tropical Storm Fay dumped five to six inches of rain over a two-week period across large parts of South Florida causing severe flooding. Immediately after the storm passed, the District conducted a post-storm assessment in all STAs to document any damage to the vegetation caused by winds or high water conditions (**Figure 5-21**). The STAs were resurveyed by the District in February 2009 to evaluate recovery of the affected areas. The assessments were conducted by driving along the levees and, in some cases, inspection of the cell interiors via airboat, and included photographic documentation, water depth measurements, and qualitative assessment of vegetation conditions.

## Initial Vegetation Assessment

To minimize damage resulting from deepwater conditions, STA Operation Plans specify that water depth and duration in emergent aquatic vegetation (EAV) cells should not exceed more than 4 ft for three consecutive days, 3.5 ft for seven consecutive days, and 3 ft for 10 consecutive days. The District monitors water depths closely during peak periods.

The initial post-storm vegetation assessment focused on EAV cells where the water depth and duration threshold had been exceeded specifically, the survey involved visual inspection of the vegetation in the interior of STA-1E, Cell 7; STA-1W, Cell 1A; and STA-3/4, Cells 1A and 2A (**Table 5-30**). Although STA-3/4, Cell 3A, exceeded the 3 ft depth for 19 days, no internal site visit was performed. In general, minimal impacts to SAV communities in these cells were observed, involving only a small amount of plant material washed out and deposited along the levees.

**Table 5-30.** STA cells that exceeded Operating Plan water depth/duration thresholds following Tropical Storm Fay, September 11, 2008.

| Water Depths | Number of days of inundation | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | STA-1W | | | STA-1E | | | | STA-2 | |
| | Cell 1A | Cell 2A | Cell 5A | Cell 1 | Cell 3 | Cell 5 | Cell 7 | Cell 1 | Cell 2 |
| 3 ft | 19 | 15 | 10 | 0 | 4 | 2 | 16 | 0 | 9 |
| 4 ft | 9 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 0 |

| Water Depths | Number of Days of inundation | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | STA-3/4 | | | STA-5 | | | STA-6 | | |
| | Cell 1A | Cell 2A | Cell 3A | Cell 1A | Cell 2A | Cell 3A | Cell 3 | Cell 5 | Section 2 |
| 3 ft | 25 | 24 | 19 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 ft | 13 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

### STA-1E

Water depths in the Eastern Flow-way remained well below two feet. Water depth in both Cells 3 and 4N exceeded 3 ft for approximately four days. The Western flow-way experienced the greatest increase in water depth, with Cell 7 experiencing seven days with water depths above 4 ft and 16 days with depths greater than 3 ft.

Majority of cattail establishment in Cell 7 has been poor, primarily due to repeated and persistent high water conditions. Over 40 percent of the cell lack vegetation. Post-storm assessment indicate a large portion of the standing cattails were stressed, e.g., sparse density and loosely anchored cattail roots that are easily dislodged (**Figure 5-22**), while some remained intact with standing plants throughout the cell. There are many individual floating plants throughout portions of the cell, and these plants were found to have poor below ground structure (**Figure 5-23**). There were no floating tussocks observed during this survey.

### STA-1W

All the EAV cells in STA-1W exceeded the depth and duration threshold guidelines with the exception of Cell 5A, which was at the limit of the 3 ft threshold at the time of survey. Cell 1A had depths greater than 4 ft for nine days and 3 ft for 19 days, Cell 2A had depths greater than 3 ft for 15 days, and Cell 5A depths went above 3 ft for 10 days.

Overall, the cattail community appeared to be expanding slowly throughout Cell 1A from the 2007 rehabilitation efforts and the storm seemed to have had little effect on the vegetation, except in a few cases where the cattail had uprooted (**Figure 5-24**). Floating tussocks formation has historically been a concern in this cell. Tussock islands observed along the western edge of Cell 1A could have been reformed from old tussocks. There were also a few small areas where new floating peat mats were observed (**Figure 5-25**). All floating tussocks or floating peat mats appear to be isolated to a small area; however, this could become more problematic as this material begins to migrate throughout the cell.

### STA-2

Based on stage data, the EAV cells in STA-2 did not exceed the depth/duration threshold guidelines; therefore, no internal evaluation was necessary. A levee survey of STA-2 conducted in August 2008 found no visible damage to the cattail community.

### STA-3/4

Water depths in all the EAV cells of STA-3/4 had been higher than 3 ft for more than 15 consecutive days. Cell 1A experienced water depths greater than 4 ft for 13 days. Cell 2A surpassed the 4 ft threshold only for one day, but field observations showed areas in which depths reached as high as 4.5 ft for a longer period of time.

There were large areas in Cells 1A and 2A with floating cattail. In areas where cattails were still standing, the plants were only loosely anchored and were easily uprooted from the ground, indicating poor root structure. Visible weakness in the roots and rhizomes and evidence of etiolation in the shoots were evident.

### STA-5

Water levels in STA-5 remained at or below 2.75 ft throughout the duration of the high flow event. There were no visible signs of stress on the EAV or the SAV. There was a significant reduced cattail stands throughout all three EAV cells due to low water conditions during the previous two year drought period.

#### *STA-6*

There were no visible signs of stress on the EAV or the SAV in STA-6. There was a lack of cattail stands in this STA due to impacts of the prior two-year drought period.

### Aerial Vegetation Assessment

An aerial survey of the STAs conducted on September 30, 2008, also confirmed the findings of the levee and interior surveys. In STA-1E, Cell 7, while significant amounts of cattail remained standing, there was a large portion of the cell where the cattail was either floating or had fallen over. Similarly, in STA-1W, Cell 5A, there was a large portion of the cattail community that was either floating or had fallen over. In STA-3/4, the northern quarter portion of all three EAV cells had large areas where the cattail coverage had been substantially reduced.

### Post-Storm Recovery Assessment

#### *STA-1E, Cell 7*

The cattail community in STA-1E, Cell 7, struggled due to persistent high water conditions resulting from its lower ground elevation (approximately one foot lower than adjacent cells). Water depth up to 3.5 ft was still observed in this cell in the months after Tropical Storm Fay. The observed conditions pose a concern that massive mortality of existing cattail stands will occur and will result in difficulty of reestablishing emergent vegetation in this area. A field study to evaluate the effects of the hydraulic conditions on cattail growth was started in June 2009.

#### *STA-1W, Cell 1A*

The EAV in STA-1W, Cell 1A, was expanding and appeared to be healthy at the time of the survey. The floating tussock problems still existed; however, the low-water levels seemed to have allowed the tussocks to settle to the bottom at least on an interim basis.

#### *STA-3/4, Cell 1A*

At the time of survey, STA-3/4, Cell 1A, showed visible signs of recovery. Large numbers of dead cattail plants remained floating in previously impacted areas. Water depths averaged slightly over 2 ft in impacted areas allowing some new sprouting of cattails. Although water depths in STA-3/4 had returned to the target levels, Cell 1A continued to exhibit higher water depths than the other cells. After a reviewing of the 2008 topographic surveys, it was concluded that the differences in water depths among cells in STA-3/4 and internal locations in Cell 1A could be attributed to variations in micro-topography.

**Figure 5-21.** SAV wash-up in STA-1W, Cell 5B, following Tropical Storm Fay, August 2008 (photo by the SFWMD).


**Figure 5-22.** Evidence of uprooted or floating cattail in STA-1E, Cell 7, September 2008 (photo by the SFWMD).

**Figure 5-23.** Comparison of cattail root system from shallow and deep areas in STA-1E, September 11, 2008. Left panel: healthy rhizome formation; right panel: poor root system from deep areas in Cell 7 (photo by the SFWMD).

**Figure 5-24.** Uprooted cattail in STA-1W, Cell 1A (photo by the SFWMD).

**Figure 5-25.** Floating tussocks in STA-1W, September 2008 (photos by the SFWMD).

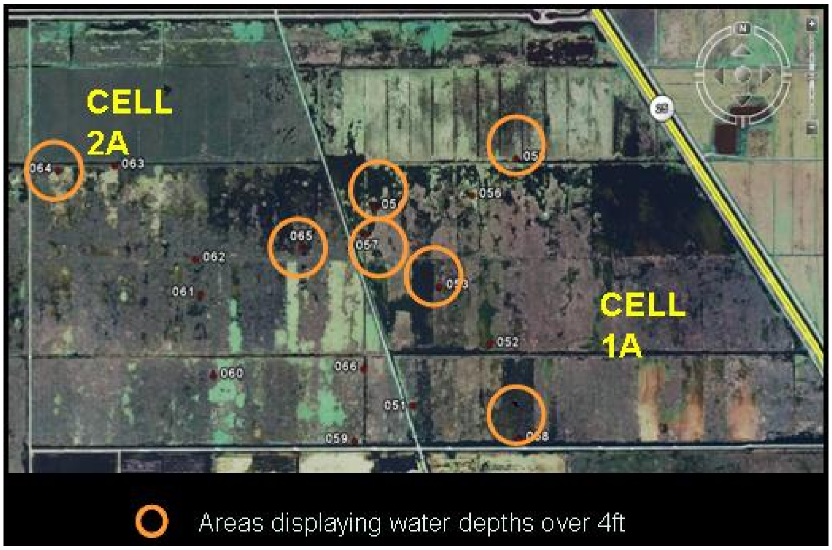



**Figure 5-26.** Areas in STA-3/4 with water depth greater than 4 feet.

**Figure 5-27.** New cattail sprouting in STA-3/4, Cell 1A,
six months after Tropical Storm Fay (photo by the SFWMD).

## CELL AND FLOW-WAY ANALYSIS AND INTERPRETATION

This section includes the individual annual (water year) water and TP mass balance budgets (hereafter "budgets") for individual STA treatment cells or flow-ways (hereafter "cells"). The District conducts the field sampling and laboratory analyses associated with this effort under the Everglades Construction Project (ECP) Operations Monitoring Project. The assumptions and methods used in the computation of cell budgets (Appendix 5-10, Tables 1 and 2) are provided in the 2008 and 2009 SFERs – Volume I, Chapter 5. Budgets were prepared for each of the cells listed below; changes or additions to the WY2009 budgets from budgets in previous SFERs are noted:

- **STA-1E.** Cells 3, 4N, 4S, 5, 6, and 7.
- **STA-1W.** Cells 1A, 2, 1B and 3, 4, and the North Flow-way (Cells 5A and 5B): flow monitoring has been discontinued at the G-253 levee separating Cells 1 and 3 and initiated at the G-248 levee separating Cells 1A and 1B, which necessitated that WY2009 budgets be computed for Cell 1A and a combination of Cell 1B and 3 rather than for Cells 1 and 3 as has been done in previous years.
- **STA-2.** Cells 1, 2, 3, and 4: Cell 4 flow and TP data became available in WY2009 and budgets are included in this year's report.
- **STA-3/4.** Cells 1A, 1B, 2A, 2B, 3A, and 3B: flow monitoring was initiated at the G-384 levee that divides Cell 3, which enabled the calculation of separate budgets for Cells 3A and 3B this year rather than combined Cell 3 budgets as has been done in previous years.
- **STA-5.** Cells 1A, 1B, 2A, 2B, 3A, and 3B: flow monitoring was initiated at the G-343 levee, which enabled the calculation of separate budgets for Cells 1A, 1B, 2A, and 2B this year rather than combined budgets for the North and Center Flow-way as has been done in previous years (Note that the cells which now comprise the Center Flow-way [Cells 2A and 2B] were referred to as the South Flow-way in previous SFERs); Cell 3A and 3B flow and TP data became available in WY2009 and budgets are included in this year's report.
- **STA-6.** Cells 3 and 5 and Section 2: Section 2 flow and TP data became available in WY2009 and budgets are included to this year's report.

Budgets were developed using available data at the time of this report, which may reflect revisions to data reported in previous SFERs. Water budgets in WY2009 were dominated by surface flow as in previous years (Appendix 5-10, Table 1). Groundwater and precipitation in the STAs generally made up less than 15 percent of the total inflow water volume, while surface outflow comprised at least 80 percent of total outflow. Exceptions occurred in some cells of STA-5 and STA-6, where seepage losses and ET made up a larger proportion of total outflow. More detailed discussions of water budgets are presented in the 2008 and 2009 SFERs – Volume I, Chapter 5.

TP budgets in WY2009 were again dominated by surface water inflow and outflow TP as in previous years (Appendix 5-10, Table 2). Previous SFERs have documented an inverse relationship between cell treatment performance and inflow TP (measured as flow-weighted mean concentration, load, or areal loading); increasing inflow TP resulted in higher outflow TP and correspondingly reduced treatment. In general, cell treatment performance has been consistent with how other treatment wetlands respond to increasing inflow TP (e.g., Kadlec, 2006; Richardson and Qian, 1999). In this report, the cell treatment performance is examined from the perspective of vegetation community type (Appendix 5-10, Tables 2 and 3). Cells were classified as being EAV, SAV, or both in cases such as the North flow-way of STA-1W that has EAV and SAV cells. The annual outflow TP load and FWMC were plotted against the corresponding annual TP inflow load and FWMC, respectively; both TP outflow load and FWMC also were both plotted against the corresponding annual TP areal loading (**Figure 5-28**). There were weak regression relationships ($r^2$ values ranged from 0.23 to 0.37) for data pooled over all vegetation community types, indicating that annual inflow TP generally accounted for only a small amount of the variation in treatment performance. Much of the unexplained variance in outflow TP is attributed to other factors such as soil characteristics, the occurrence and duration of dryout, or changes in plant community species composition. **Figure 5-28** reveals that the individual data points for the different vegetation community types were not segregated from each other; rather, there was considerable overlap among data points over almost the entire range in inflow TP levels. The EAV and SAV designations used to classify cells clearly do not correspond with distinct differences in annualized treatment performance.

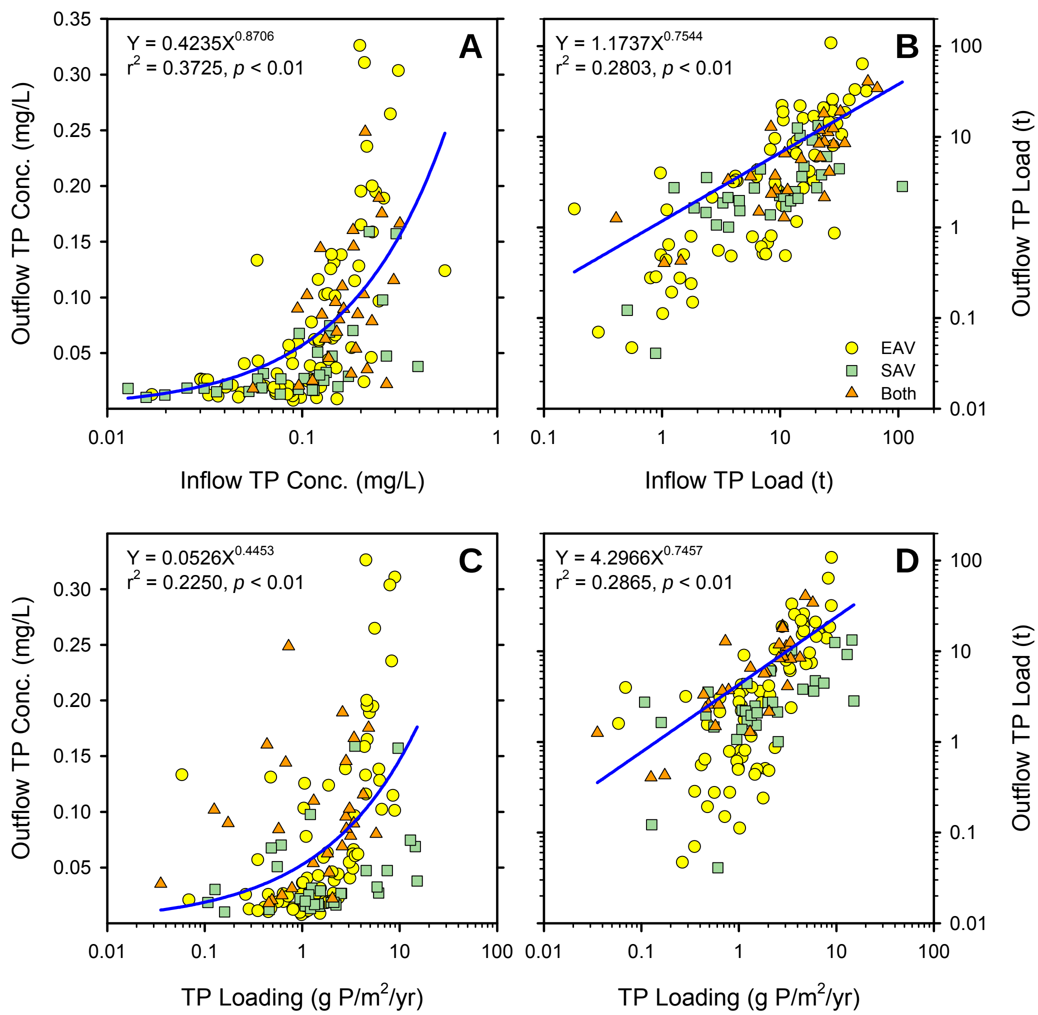



**Figure 5-28.** Comparison of annual treatment performance in STA treatment cells and flow-ways with variation in annual inflow TP levels. Insets show inflow versus outflow TP flow-weighted mean concentration (FWMC) (A), inflow versus outflow TP load (B), inflow TP areal loading versus outflow TP FMWC (C), and inflow TP areal loading versus outflow TP load (D). Treatment cells were classified as either EAV or SAV based on their description in **Table 5-1**; flow-ways with both EAV and SAV treatment cells are designated as "both".

## STA-1W POST-REHABILITATION UPDATE

Details of the 2006 and 2007 rehabilitation efforts in STA-1W were reported in the 2008 and 2009 SFERs – Volume I, Chapter 5. Rehabilitation was done to make environmental conditions more favorable for SAV recruitment and establishment in Cells 1B, 2B, 4, and 5B (**Figure 5-29**). In 2007, an effort to convert from EAV to SAV was also implemented in Cell 3, in accordance with the Long-Term Plan requirements. An updated evaluation of these cells is provided below.

Since May 2003, STA-1W has been impacted by major storm or construction events and has received variable inflow TP concentrations (**Figure 5-30**). Inflow and outflow hydraulic and TP loads have been variable (**Figure 5-31**). TP loads into STA-1W were reduced in WY2007–WY2009 (26 to 50 mt annually) compared to WY2003–WY2005 (51 to 112 mt annually). Changes in overall water quality and vegetation indicate that STA-1W continued to improve since the rehabilitation completion. Outflow TP and total suspended solids (TSS) concentrations continued to decrease in WY2009 (**Figure 5-32**). Individual flow-way outflow data also indicated improved treatment performance. It should also be noted that reduced hydraulic and TP loads into the STA during the two-year period could have also contributed to this trend (**Figure 5-31**).

**Northern Flow-way:** Effluent water quality from the Northern Flow-way has improved in terms of TP and TSS concentrations compared to pre- rehabilitation years. Average annual arithmetic mean outflow TP concentrations decreased dramatically from about 240 ppb (WY2006 prior to rehabilitation) to less than 45 ppb (WY2007–WY2009) (**Figure 5-31**). Examination of the individual cell outflow water quality indicated that Cell 5B is providing most of the treatment for this flow way. Cell 5B continued to have very high SAV coverage throughout the cell, which is credited to the 2006 rehabilitation efforts, with Southern naiad (*Naiad quadalupensis*) and *Hydrilla sp*. as the most dominant species. In Cell 5A, cattail continued to be restricted to shallow areas, while deeper areas continued to have poor or lack of vegetation. Efforts to plant bulrush are planned for early WY2010, with results anticipated to be included in future SFERs.

**Eastern Flow-way:** TP and TSS concentrations continued to improve in the Eastern Flow-way (**Figures 5-32** and **5-33**). Initial annual average TP concentrations in WY2008 were high (105 ppb) and may be attributed to (1) the “first flush” associated with restarting the flow-way after rehabilitation, (2) decomposing biomass associated with vegetation conversion efforts in Cell 3, and (3) minimal SAV coverage in Cell 3. Since that time, average annual outflow TP concentrations have decreased to 33 ppb. Data indicate that all three cells in this flow-way continue to have improved treatment performance (**Figure 5-32** and **5-33**).

Field observations indicate that cattail coverage continues to increase throughout Cell 1A, while *Chara* sp. continues to dominate in Cell 1B. A vegetation survey conducted in Cell 3 in September 2008 found that *N. quadalupensis* was the dominant SAV species although *Chara* and *Hydrilla* were abundant in some portions of the cell. Based on the extent of the SAV coverage in Cell 3, the vegetation conversion effort initiated in this cell in 2007 is considered to be complete (**Figure 5-34**).

**Western Flow-way:** As reported in the 2008 and 2009 SFERs – Volume I, Chapter 5, the 2007 rehabilitation has resulted in dramatic increase in SAV coverage throughout Cells 2B and 4. Water quality has also improved. Outflow TP concentrations in Cell 2 for WY2003–WY2005 and Cell 2B in WY2007 exceeded 100 ppb, while outflow from Cell 4 approached 100 ppb prior to rehabilitation. Outflow TP concentrations in both cells declined substantially in WY2008 and WY2009 with average annual arithmetic mean of less than 70 ppb (Cell 2B) and 32 ppb (Cell 4) (**Figure 5-32**).

*Chara* continued to dominate the vegetation community in Cell 2B, however pockets of *Hydrilla* and *N. quadalupensis* appear to be expanding in coverage. In Cell 4, both *Chara* and *N. quadalupensis* were found in dense beds throughout the cell.

**Summary:** SAV coverage increased significantly throughout Cells 1B, 2B, 3, 4, and 5B. Current data and field investigations indicate that the SAV communities successfully established and continued to persist in these cells since completion of rehabilitation. TP and TSS outflow concentrations have improved dramatically in all three flow-ways since rehabilitation. In summary, (1) the rehabilitation efforts of 2006 and 2007 have been successful, and (2) STA-1W is on the path to providing optimal treatment performance. Efforts to further examine conditions and implement more optimization strategies will continue to further improve performance of this STA.

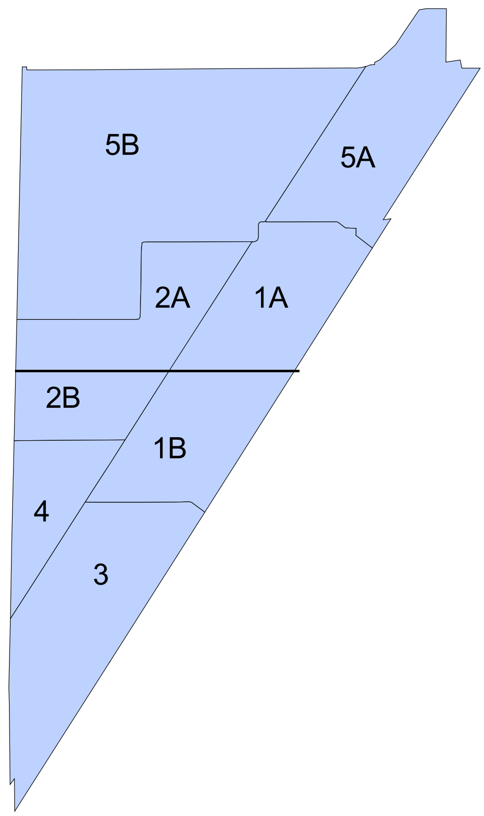



**Figure 5-29.** Schematic of STA-1W showing the layout of treatment cells.

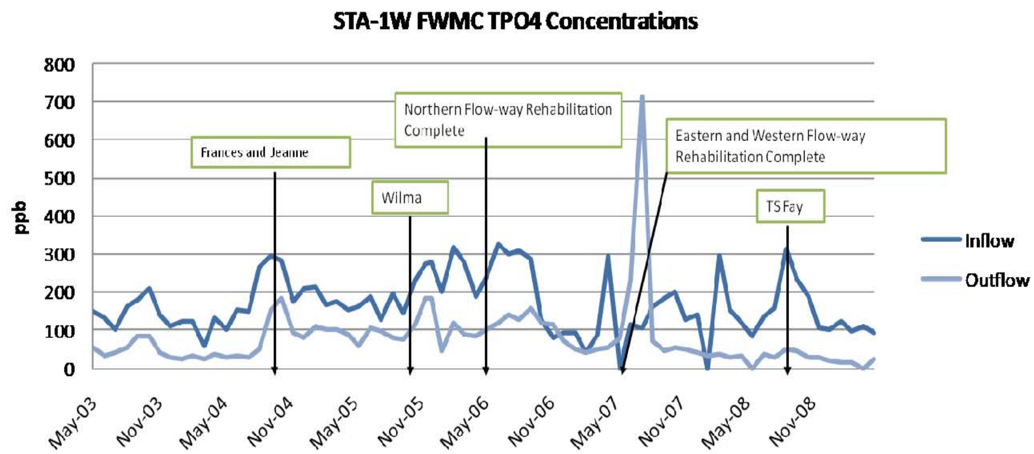



**Figure 5-30**. Monthly inflow and outflow TP flow-weighted mean concentrations in STA-1W.

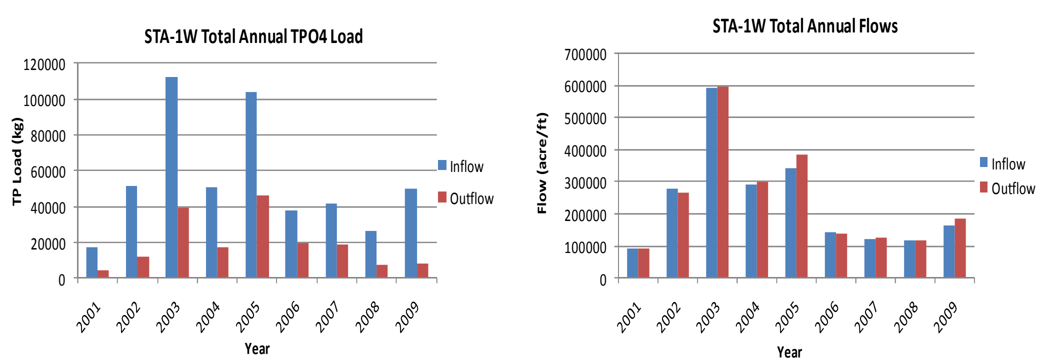



**Figure 5-31**: Annual average inflow and outflow TP loads and flows in STA-1W.

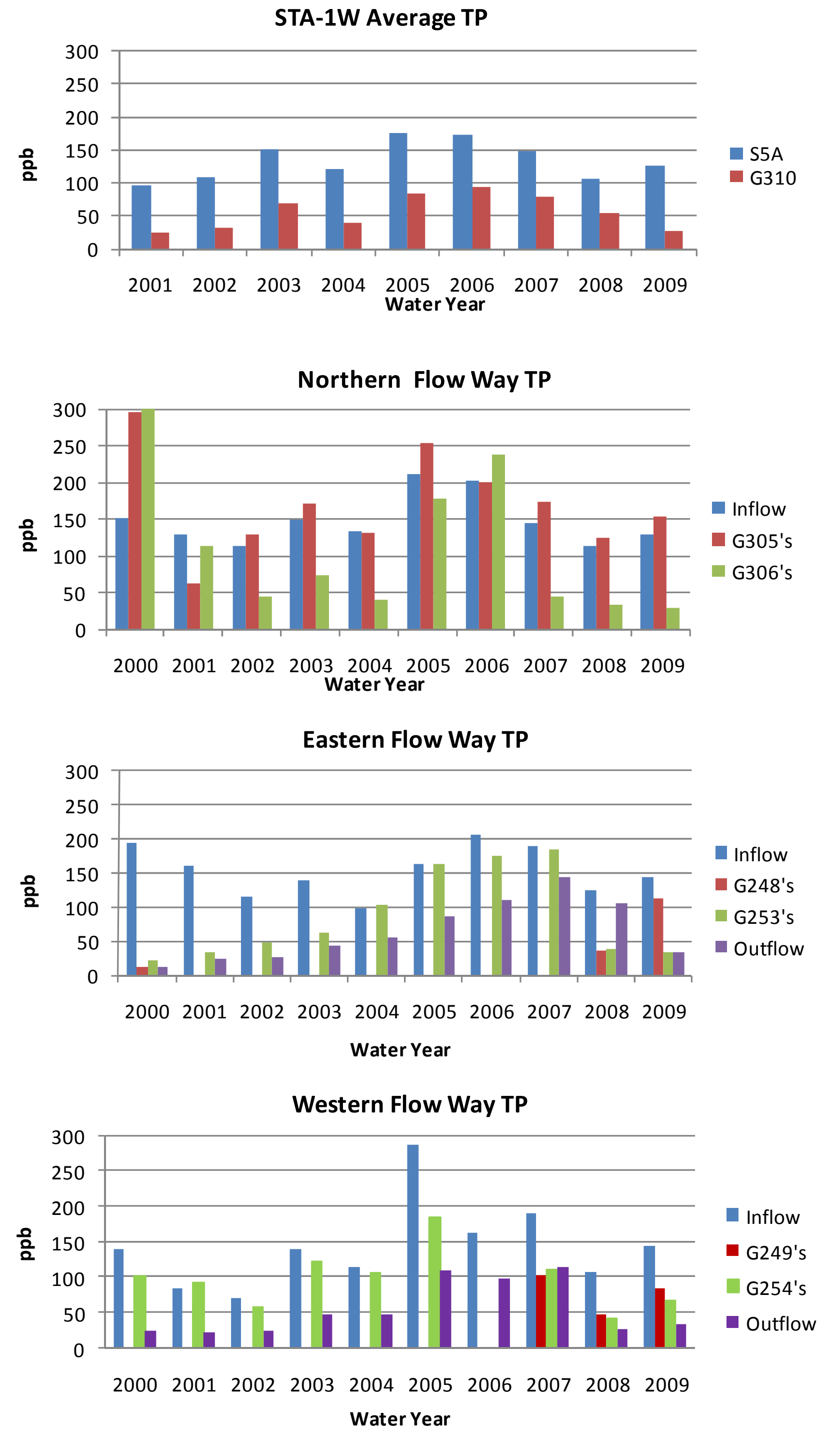



**Figure 5-32:** Average annual arithmetic mean TP concentrations in STA-1W.

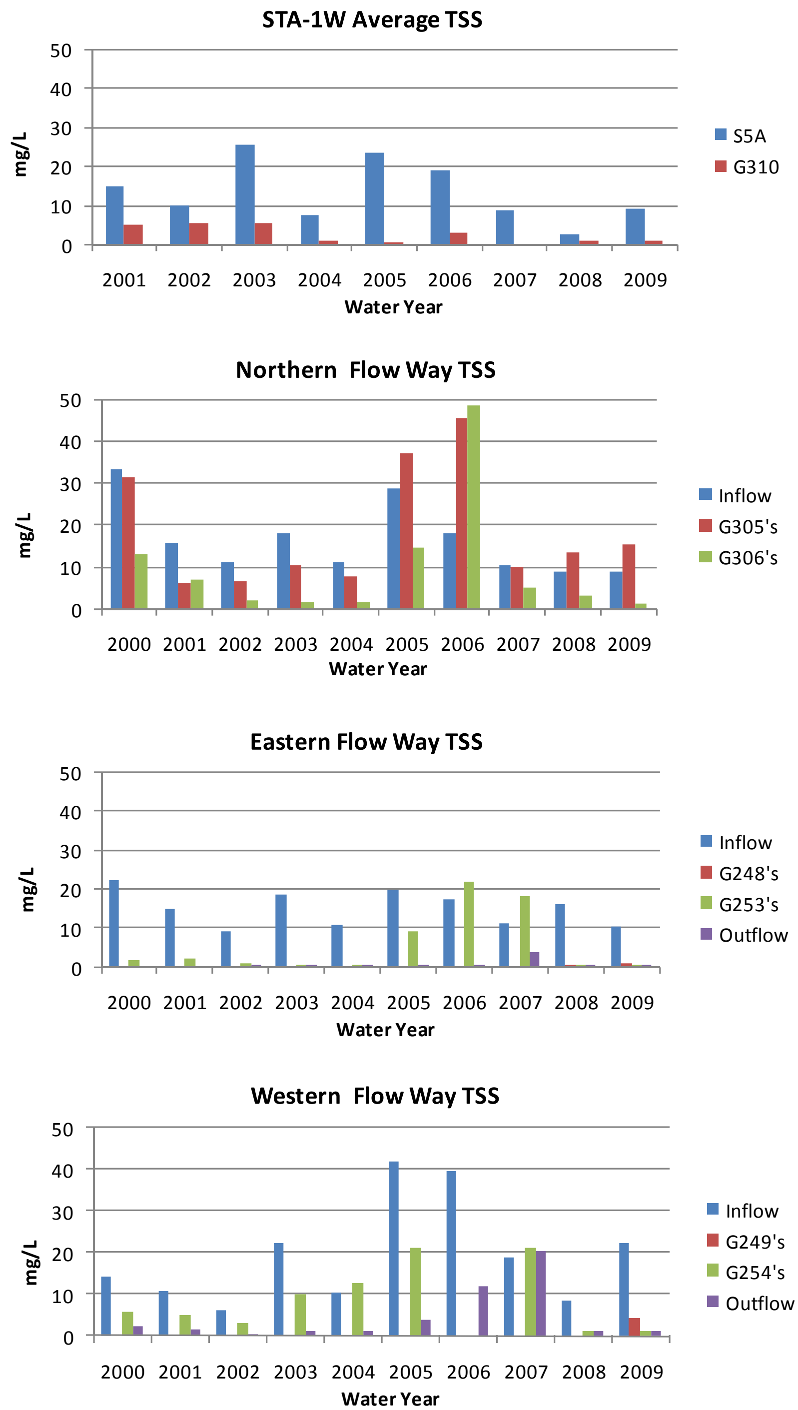



**Figure 5-33:** Average annual arithmetic mean total suspended solids (TSS) concentrations in STA-1W.

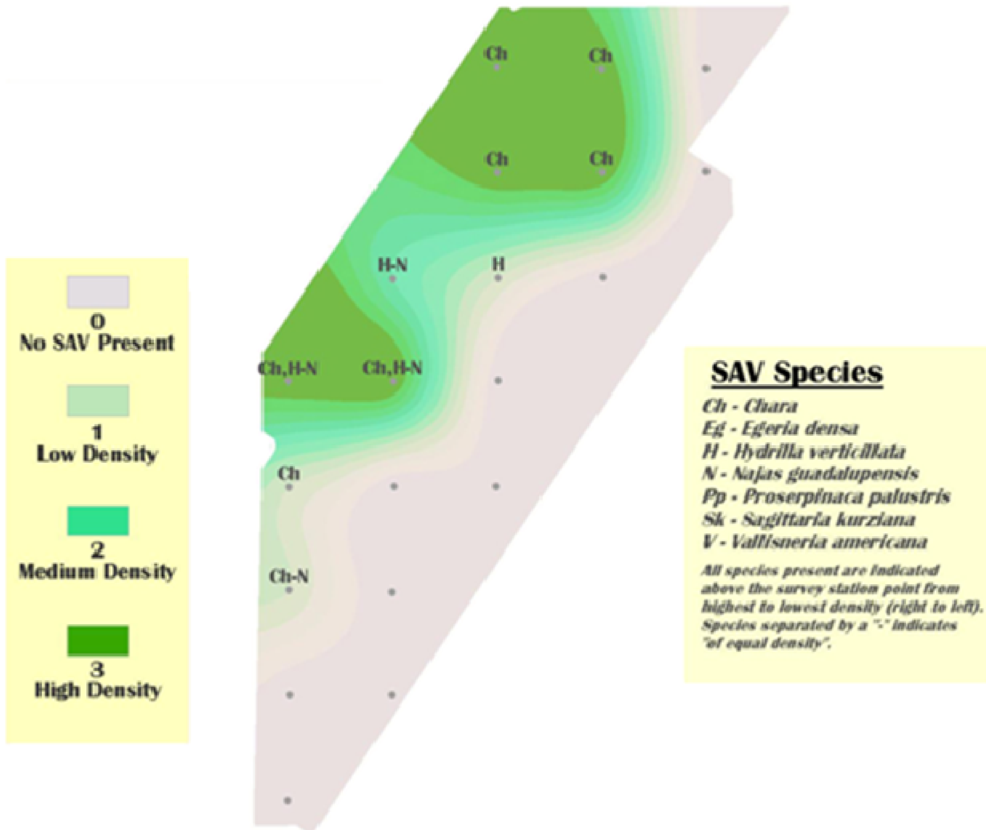



**Figure 5-34:** Vegetation map of STA-1W, Cell 3, illustrating the extent of SAV coverage.

## STA-5 PERFORMANCE ANALYSIS AND REHABILITATION

Stormwater Treatment Area 5 (STA-5) is one of six treatment wetlands constructed to reduce phosphorus levels in runoff from agricultural and urban areas prior to being discharged into the Everglades Protection Area. Since becoming operational in 1999, TP mass removal by STA-5 has ranged from 41 to 74 percent; the average removal rate for all Everglades STAs is about 85 percent. Outflow FWMC TP from STA-5 has also been higher than any of the other STAs (**Figure 5-35**). To understand the reasons for the relatively poor performance and implement remedial strategies, the District evaluated performance data and causal variables, including hydraulic and TP loading, soil chemical and physical properties, vegetation characteristics, and topography. Using the information gleaned from the research and monitoring, a series of rehabilitation options were evaluated (see **Table 5-31**).

Over the STA operational period, the hydraulic and phosphorus loading rates (HLR and PLR, respectively) to each STA treatment cell (or flow-way as in the case of STA-5) was compared (see 2009 SFER – Volume I, Appendix 5-8). The Northern and Southern flow-ways have similar HLRs as the other STAs; the HLRs at STA-5 were slightly lower than STA-1W, STA-3/4, and STA-6 and about equal to STA-2. The PLR for STA-5 was greater than the PLR in STA-2, STA-3/4, and STA-6 but less than in STA-1W (Pietro, et al., 2008).

Focusing on the Northern Flow-way (Cells 1A and 1B), TP concentrations at the mid-levee structures (G-343A-D) showed little phosphorus reduction, indicating that there was limited treatment occurring in the upstream areas of the cell (**Figure 5-36**). This was also confirmed through an internal transect water quality sampling conducted by DB Environmental Laboratories, Inc. The internal transects showed very little TP removal in Cell 1A and that treatment in the Northern Flow-way occurs primarily in the SAV cell (Cell 1B) (**Figure 5-37**).

Soil TP levels in STA-5 surface soil layer (0-10 cm) were similar during the first three years of operation (2000, 2002, and 2003) (**Figure 5-38**). Soil TP levels in 2007 were notably higher, which could be due to the accumulation of detrital matter that became part of the 0-10 cm layer in time over cycles of drying and re-wetting in these areas. Soil floc TP was also measured (when present) and concentrations ranged from 1,000 to 1,500 mg/kg.

Hydraulic efficiency, hydrologic patterns, and vegetation coverage are critical in effective wetland phosphorus removal. The movement of water throughout the treatment cell is influenced by the topographic profile in the area. In 2008, the topographic survey conducted in Cell 1A showed that the treatment cell had highly variable topography (**Figure 5-39**). A lower slough area located in the southern section of the treatment cell was found to be about 1.5 to 3 feet lower in elevation on average as compared to the northern part of the cell. The lower slough area was virtually devoid of vegetation based on 2005 aerial imagery (**Figure 5-40**) and the same was observed in the field in subsequent years. These findings indicated that a deeper water slough was creating a hydrologic "short circuit," therefore underutilizing the rest of the cell and not providing sufficient time for treatment, thus contributing to poor phosphorus treatment performance. This cell's emergent vegetation was impacted by regional drought conditions and uneven water distribution throughout the cell, resulting in vegetation communities with dominance of mixed grasses with little cattail coverage.

Based on these analyses, the poor performance at STA-5 might be due to several factors (**Table 5-31**). The data analysis indicated that the key potential causes of the poor performance in this STA were (1) high inflow load since it began operation in 1999 (Appendix 5-2); (2) highly variable topography, resulting in frequent cycles of alternating wet-dry periods in some areas; (3) short-circuiting, including the presence of a slough in Cell 1A; (4) poor vegetation establishment in both the EAV (Cell 1A) and SAV (Cell 1B) cells; and (5) presence of high levels of easily hydrolyzable phosphorus in the floc and the surface soil layer (0-10 cm).

Several remedial strategies and improvement options were evaluated to improve the performance of STA-5. The suggested options included vegetation management components, operational changes, and construction activities. It was determined that the hydrology of the cell was the primary reason for poor performance in Cell 1A, and the option chosen for implementation focused on improvements in the northern inflow treatment cell, Cell 1A, specifically in filling the slough area.

## Cell 1A Rehabilitation

On January 29, 2009, construction work began in Cell 1A to fill the deeper slough area using material from the westernmost sections of the treatment cell (previously referred to as the non-effective treatment area) to remedy the short-circuiting in this area and distribute the water to the rest of the cell for improved treatment.

To evaluate sediment phosphorus release as a function of location within the STA-5 footprint, laboratory incubations were performed to characterize the impacts of internal loading on performance for the soil used for fill material. Following completion of this construction effort, soil cores were collected from the filled-in slough as well as from an adjacent wetland area that was not impacted by construction activity (**Figure 5-41**). The cores were transported to the laboratory, reflooded with waters containing low levels of soluble reactive phosphorus (SRP) and incubated under anoxic conditions.

During two, 14-day incubations, the slough site exported little SRP to the water column, whereas the waters overlying the wetland site soils exhibited an increase in P concentrations to as high as approximately 1,600 ppb (**Figure 5-42**). This could be attributed to the fact that the average soil TP in the 0-10 cm layer in the wetland area is 694 mg/kg, while the fill material has a soil TP concentration of 71 mg/kg. These data suggest that in addition to providing hydraulic benefits (elimination of a short circuit), the recently completed construction effort will help reduce internal sediment P loading within the wetland.

Prior to any fill moving activities, the plants in the non-effective treatment area of the cell were burned to reduce the amount of vegetation biomass and to aid in soil scraping. The non-effective treatment area is located within the STA-5, Cell 1A, levee boundaries and is considered to be non-effective because the ground elevations were high in this area. By the end of May 2009, using fifteen 30-ton dump trucks, three bulldozers, and three excavators, approximately 80 to 100 acres of the slough area were filled, totaling 407,240 cubic yards of material moved. The slough filling portion of the rehabilitation project was successful and the field team far exceeded the original expectations for the effort, almost tripling the amount of fill to the slough than was originally anticipated. In June 2009, the filled areas were planted with cattail and sawgrass seeds. Various wetland plants were also planted to encourage vegetation establishment. A post-rehabilitation monitoring plan has been initiated to assess the success of the rehabilitation effort using interior sampling sites monitored for water quality, stage, and hydraulics along with an evaluation of the vegetation establishment. The results of the interior monitoring evaluation are expected to be presented in future SFER reports.

**Table 5-31.** Summary of performance issues contributing to the poor phosphorus removal at STA-5 and the goals of the rehabilitation efforts to provide optimized and sustainable performance.

| STA-5 Performance issues |
|---|
| High historic phosphorus loading rates and inflow concentrations |
| Experiences periods of high flows/loads followed by periods of low to no inflow |
| Historically, has lowest TP removal efficiency (58%) as compared to other STAs (80%) |
| Experiences regular dry-out conditions in parts of or entire cells, particularly the EAV cells |
| Poor vegetation establishment and sustainability |
| Increasing TP levels in floc and surface soil layers |
| **Rehabilitation goals:** |
| Optimize TP removal efficiency |
| Reduce hydraulic short-circuiting |
| Increase effective treatment area |
| Provide long-term fix (sustainability of performance) |
| |
| Cost-Savings Approach: |
| Take advantage of low water conditions (opportunistic scheduling) |
| Use fill from high elevation areas within the STA |
| Fully utilize Field Station personnel |
| Encourage growth of more efficient and sustainable plant communities |

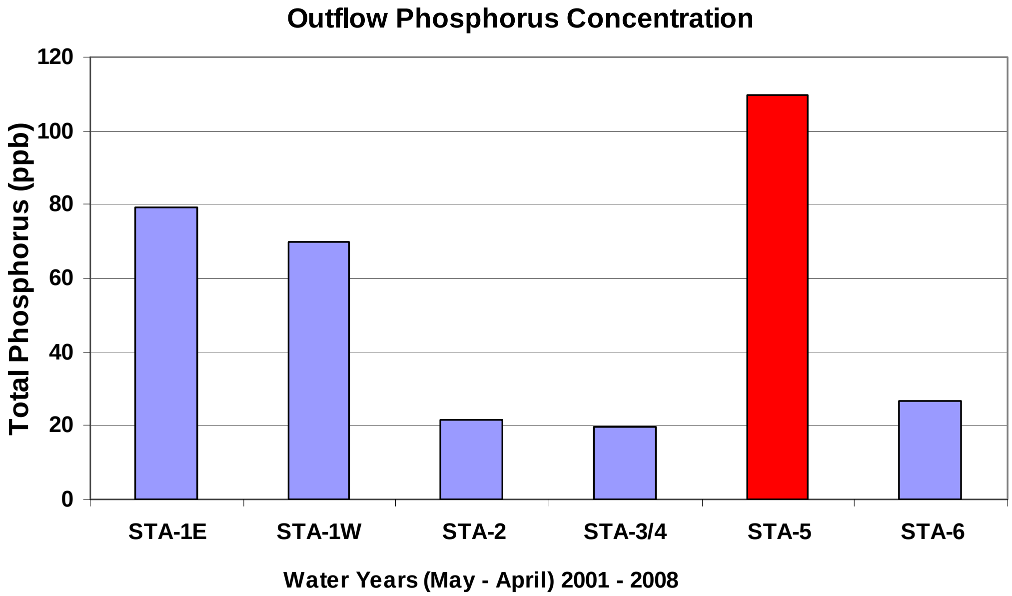



**Figure 5-35.** Comparison of STA outflow TP FWMC from WY2001–WY2008. [Note that the TP FWMC from STA-5 is the highest of all the STAs].

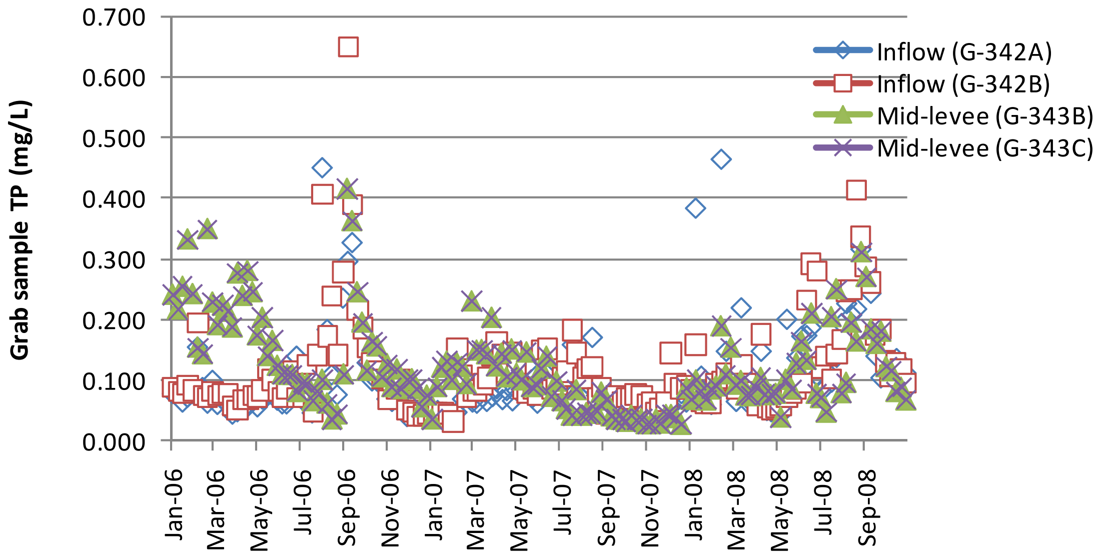



**Figure 5-36.** Grab samples collected at the inflows and mid-levee structures of STA-5, Cell 1A, showing that there is very little reduction in TP concentrations.

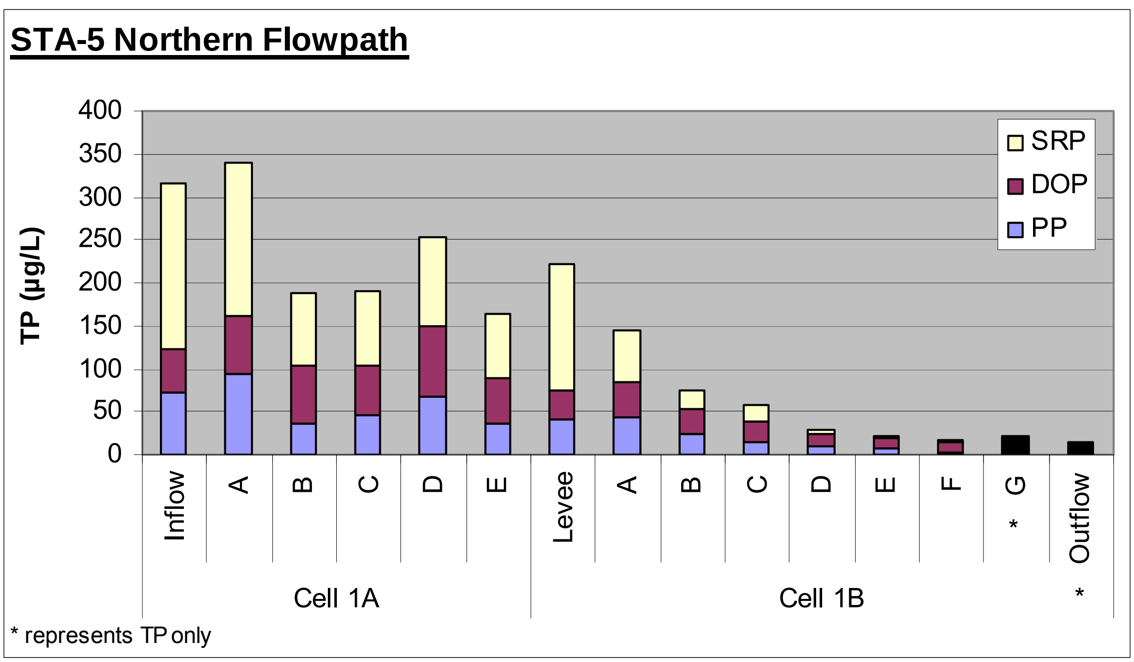



**Figure 5-37.** Surface water TP along internal transects in the Northern Flow-way of STA-5, sampled in August 2008 by DB Environmental Laboratories, Inc. Mean inflow for two weeks prior to sampling was 244 cubic feet per second (cfs). SRP = soluble reactive phosphorus, DOP = dissolved organic phosphorus, PP = particulate phosphorus.

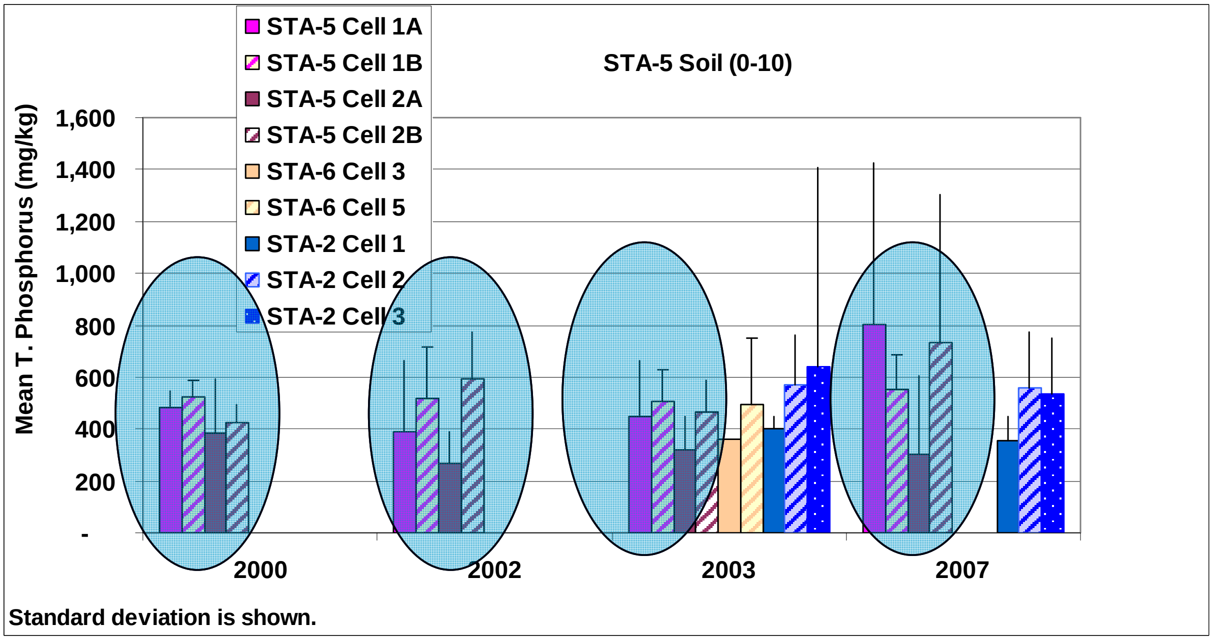



**Figure 5-38.** TP concentration in the surface soil layer (0-10 cm) of STA-5 from 2000 to 2007, compared with values from in well-performing STAs (STA-2 and STA-6). STA-5 data are circled.

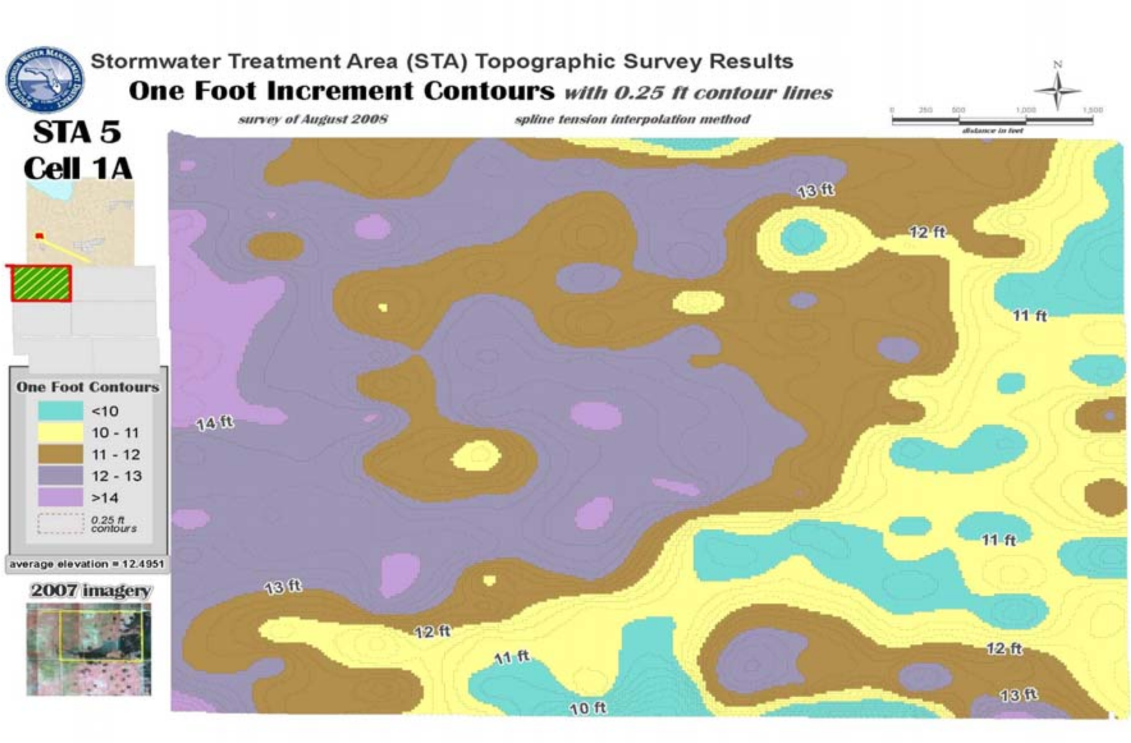
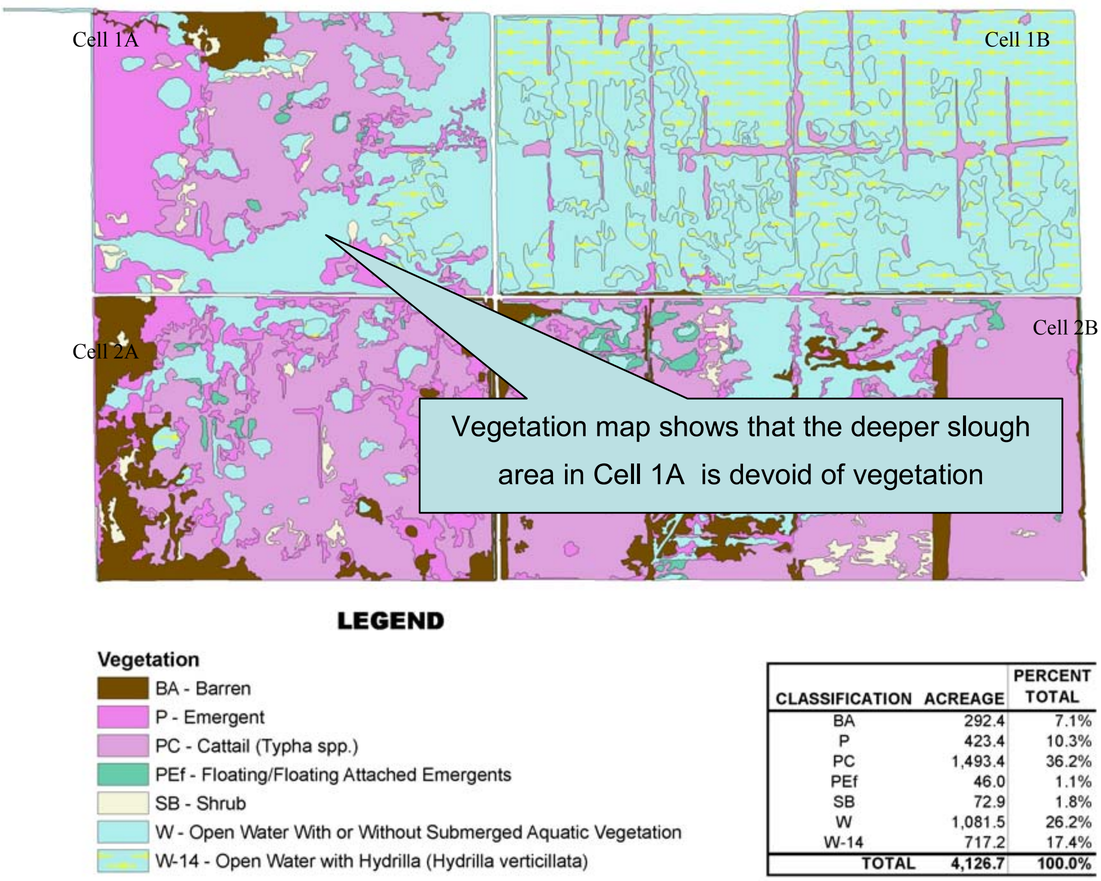



**Figure 5-39.** 2008 topographic map of STA-5, Cell 1A, showing that the ground elevation in the slough in the southern portion of the cell was about 1.5 to 3 feet lower than the rest of Cell 1A.




| CLASSIFICATION | ACREAGE | PERCENT TOTAL |
|---|---|---|
| BA | 292.4 | 7.1% |
| P | 423.4 | 10.3% |
| PC | 1,493.4 | 36.2% |
| PEf | 46.0 | 1.1% |
| SB | 72.9 | 1.8% |
| W | 1,081.5 | 26.2% |
| W-14 | 717.2 | 17.4% |
| TOTAL | 4,126.7 | 100.0% |

**Figure 5-40.** Vegetation map of STA-5 derived from aerial photographs taken in 2005.

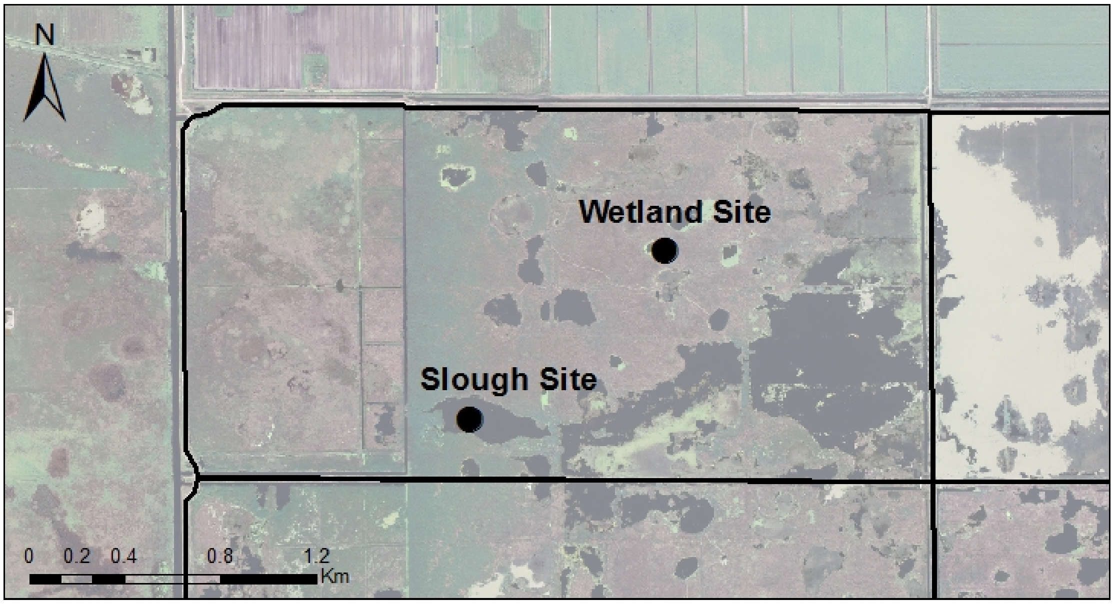



**Figure 5-41.** Soil sampling locations in STA-5, Cell 1A, for the laboratory core incubations. At the time of sampling, the slough station had been filled in with mineral soils borrowed from a higher elevation region to the west.

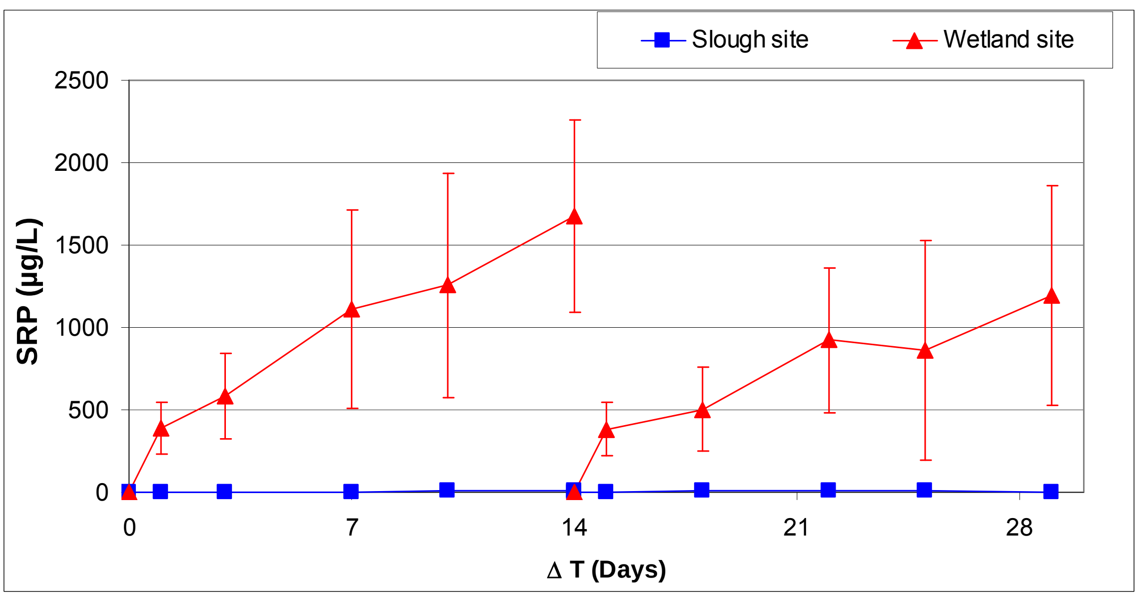



**Figure 5-42.** Soluble reactive phosphorus (SRP) release into the water column from STA-5, Cell 1A, soil cores incubated in the laboratory under anoxic conditions. Two, 14-day batch incubations were performed. Soil cores were obtained from the slough site recently filled in with mineral soils, and from a wetland site, unimpacted by construction activities (see **Figure 5-41**).

## STA-6 PERFORMANCE EVALUATION

Until WY2007–WY2008, annual outflow TP concentrations at STA-6 were some of the lowest compared to the other Everglades STAs. Since 1999, average annual outflow TP FWMC from Cells 3 and 5 combined was between 20 and 30 ppb for all years except for WY2007 and WY2008, where outflows rose to 45 ppb and 38 ppb, respectively[4]. In WY2009, outflow concentrations were lower (28 ppb). Because operations at STA-6 changed due to the use of the new expansion cell (Section 2), the inflow also changed so that comparisons of inflow to outflow in this analysis do not include the current water year. The following discussion summarizes an investigation that was conducted in spring 2009 into the possible reasons for the increase in outflow TP concentration in WY2007 and WY2008 in order to identify the major drivers leading to the decline in performance.

The performance data were examined to determine if the increases in outflow TP concentrations could be attributed to higher loadings or other operating conditions, such as sporadic inflows, prolonged dry-out conditions in the soil, loss of wetland vegetation, or fluctuating water depths in the marsh. The trends in inflow water load, TP load and TP FWMC were considered along with the water depths in the marsh and soil nutrient data. For most of the period of record (POR), STA-6 was operational except for February and March 2007 when inflows to the STA were stopped for Long-Term Plan Enhancements construction. Other times of no inflow are reflective of the variable rainfall in the contributing basin. From October 1999 until April 2005, STA-6 received runoff from sugarcane farms. After that, the fields were fallow and inflows were limited to what was needed for flood control within the basin.

An analysis of POR data showed that the outflow TP FWMC was higher in WY2007–WY2008 than WY1999–WY2006 (**Figure 5-43**). Inflow hydraulic and TP loads appear to be unlikely causes for the recent increase in outflow TP because they were substantially reduced in WY2007–WY2008 compared to previous years. Although the mean inflow TP concentration was about 25 ppb higher in WY2007–WY2008, there were also comparable annual values during the WY1999–WY2006 period, which did not elicit high outflow values; therefore, higher inflow TP concentration does not appear to explain the change in performance (**Figure 5-44)**. The annual data show that the inflow loads, TP FWMC, and the hydraulic and TP loads were about the same over the years, except for WY2008 that had much reduced inflow and outflow loads and volumes. During drought years (WY2001, WY2006, WY2007, and WY2008), annual outflow concentrations have been higher.

Monthly data show that there were substantially higher outflow concentrations following flow events that were preceded by periods of little to no inflow. Following periods of no inflows or outflows, the outflow concentrations have been magnitudes higher than the average concentrations that range from 25 to 40 ppb (**Figure 5-45)**. High outflow concentrations persisted for about one to two months after rehydration. High concentrations observed in June 2005 and August 2007 had very low associated monthly flows (5 and 139 ac-ft, respectively) and, although the concentrations were high, the resulting loads were low (**Table 5-32**). The duration of lack of inflow has also increased in the later water years. In WY2007 and WY2008, there were four and seven months of no inflow, respectively, as compared to previous years where lack of inflow only lasted for one to two months. The sporadic flows and resulting decreases in water depths and resulted in dry-out conditions in parts of or the entire cells which notably affected the outflow concentrations (**Figure 5-46**).

[4] Only Cells 3 and were evaluated because STA-6 Section 2 was not operational until WY2008.

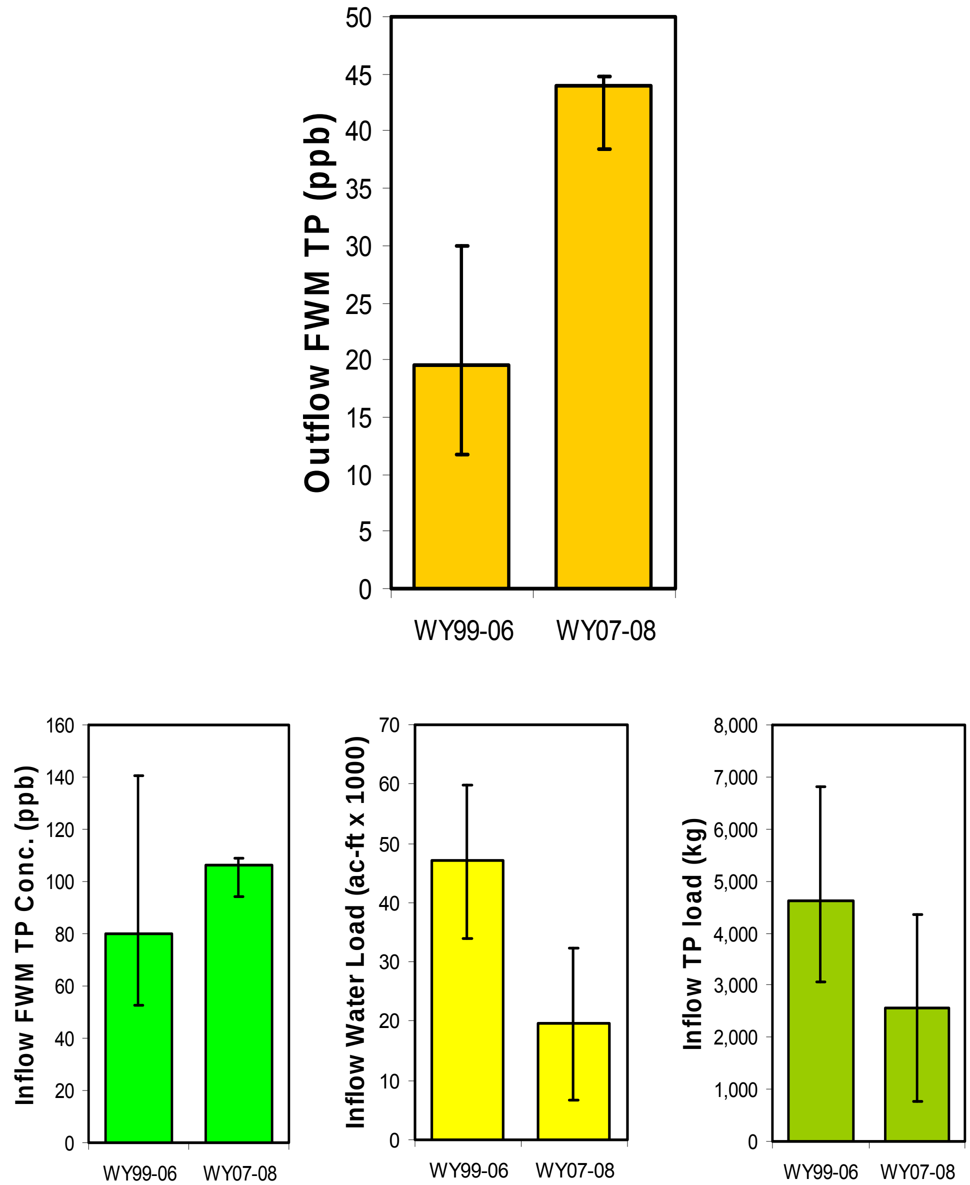



**Figure 5-43.** Comparison of STA-6 inflow FWMC TP, water load, and inflow TP load between WY1999–WY2006 and WY2007–WY2008. The bars represent mean values for each period while the spreader lines represent the range of annual values. The inflow FWMC TP was higher in WY2007–WY2008, but the inflow volume and inflow TP load were about half that of previous years.

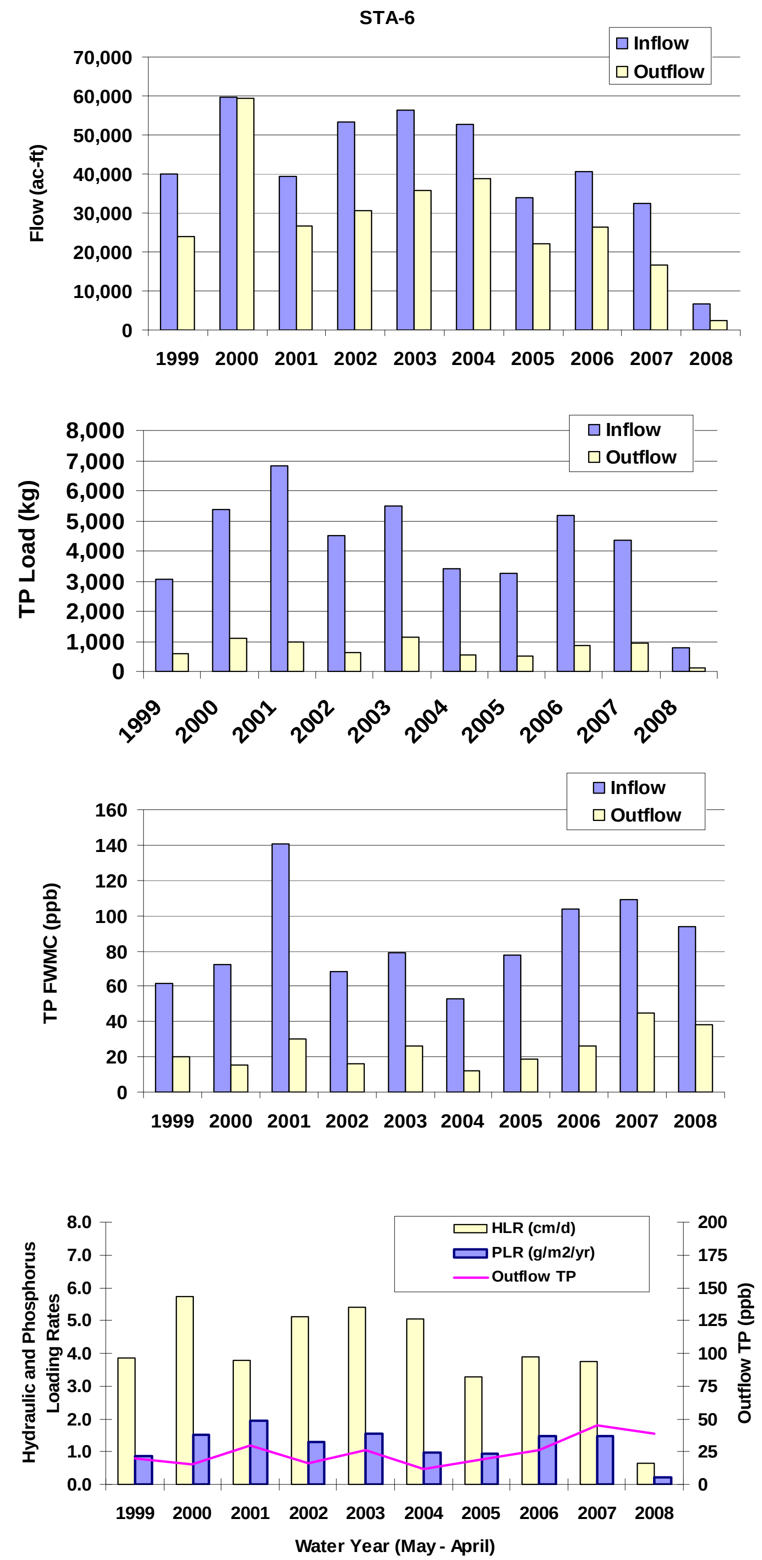



**Figure 5-44.** Annual flow, TP load, and FWMC TP, hydraulic and phosphorus loading rates, and outflow flow-weighted mean TP for STA-6 over the period of operation (WY1999–WY2008).

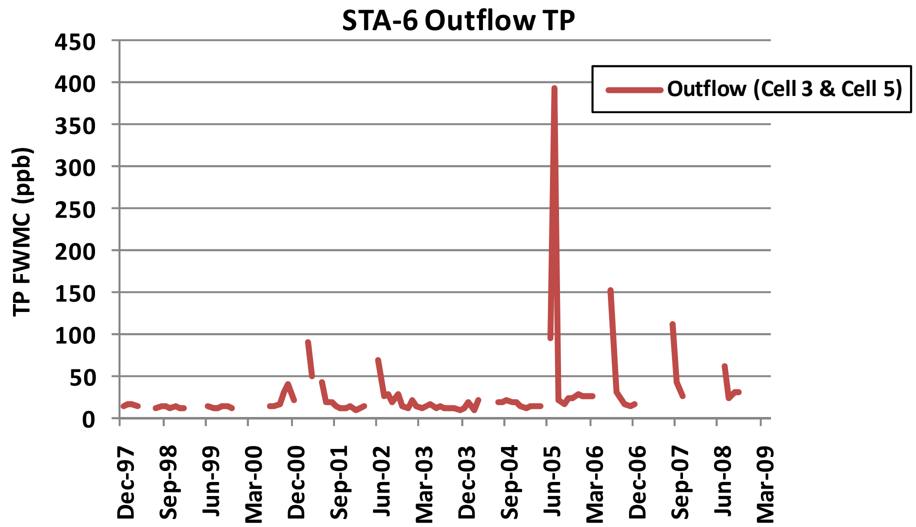



**Figure 5-45.** Monthly TP FWMC from STA-6, Cells 3 and 5 outflow. Spikes in outflow concentrations have been observed following periods of no inflow and dry-out conditions.

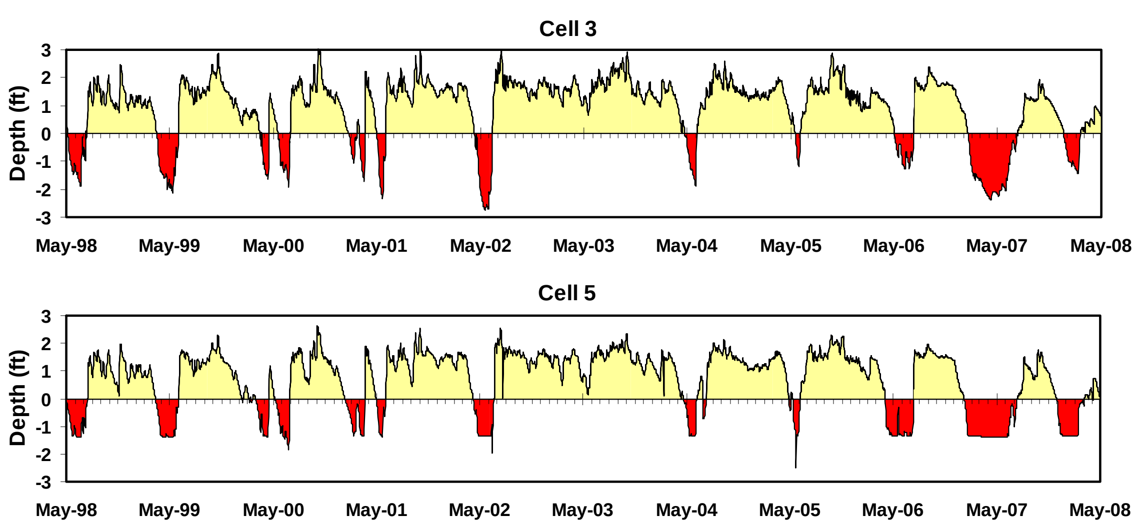



**Figure 5-46.** Daily mean water depth in STA-6, Cells 3 and 5. Red areas indicate depths that were below mean ground elevation.

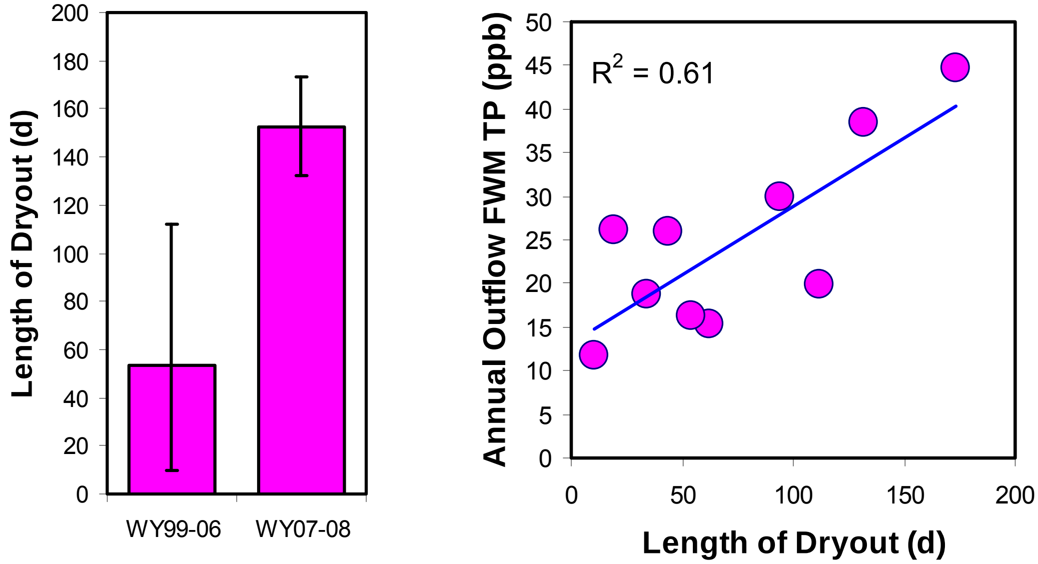



**Figure 5-47.** Effects of dry-out conditions in STA-6 performance: (A) duration of dry-out period in WY2007–WY2008 compared to WY1999–WY2006; and (B) annual outflow FWMC TP as affected by the duration of dry-out conditions.

**Table 5-33.** Peak outflow load and concentrations observed after periods of no inflow and low stage conditions.

| Date | Outflow Flow (ac-ft) | Outflow TP Load (mt) | Outflow FWMC TP (ppb/month) |
|---|---|---|---|
| Jun-05 | 5 | 0.002 | 248 |
| Jul-05 | 1007 | 0.191 | 153 |
| Jul-06 | 2708 | 0.513 | 154 |
| Aug-07 | 139 | 0.019 | 112 |

Stage data indicate that the water levels within the treatment cells fluctuated widely within and among years. During the dry season in almost every year, water levels fell below the ground level in both cells (**Figure 5-46**). The marsh water depth was estimated by averaging the stage data measured at the inflow and outflow structures, then subtracting the average ground elevation. A scatter plot of dry out duration and outflow TP concentrations shows a moderate correlation (r= 0.61) between these two variables (**Figure 5-47**).

Nutrient analysis of the soil collected in November 2008 from 0-10 cm cores from Cells 3 and 5 shows that the soil TP ranged from 98–1,880 mg/kg (**Figure 5-48)**. These concentrations are considered to be moderately high and P flux from the sediment into the water column may have contributed to the increases in surface water concentrations. During dry-out conditions, the rate of soil mineralization greatly increases and consequently results in spikes in TP concentration upon rehydration.

The analysis of the performance data indicates that the decreased performance over the last two years was probably related to the duration of dryout. In addition, severe dry-out conditions influenced vegetation condition and coverage. The vegetation in Cell 5 is a mixture of cattail and grasses at inflow locations and SAV at outflow regions while Cell 3 is mostly a mixture of sawgrass and willow. During the extended drought periods, there was visible browning throughout Cells 3 and 5, indicating plant stress in some areas. Decomposing biomass from severely affected vegetation is suspected to have contributed to the spike in TP concentrations upon rehydration. Also, aerial inspection during dry conditions revealed a shift of vegetation from wetland to mainly terrestrial plant species, especially in Cell 5. When the treatment cells were reflooded, these terrestrial plants died and decomposed upon rehydration contributing phosphorus to the surface water. In STA-6, the first flush following dry-out conditions shows the relatively large outflow TP concentrations peak for one to two months after rehydration. The duration of dry-out conditions has increased in WY2007, WY2008, and WY2009. The lack of sufficient inflows to maintain hydrated conditions for viable wetland (treatment) vegetation was found to have negative impacts on performance, particularly in this STA.

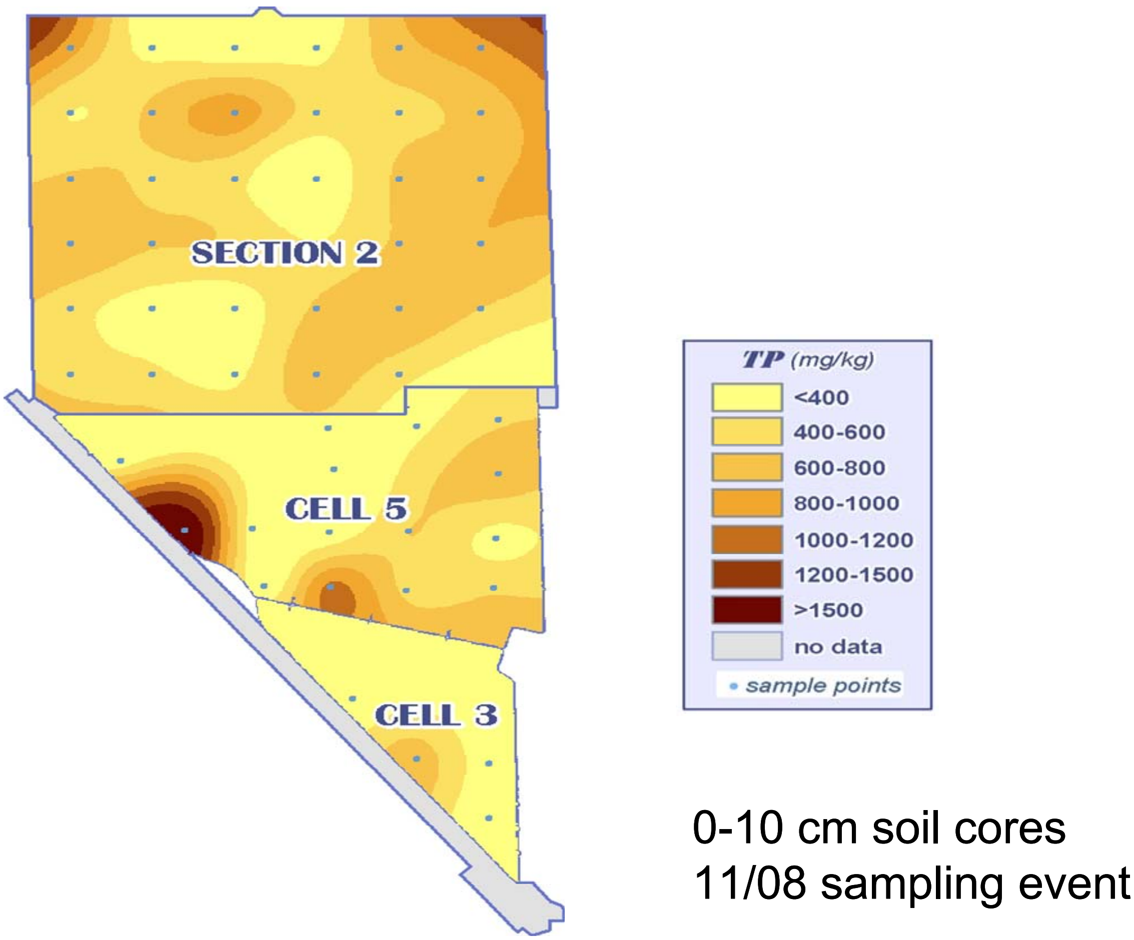



**Figure 5-48.** Soil TP concentrations at 0-10 cm layer collected in STA-6 on November 2008. The average soil TP concentration ranged from 98–1,880 mg/kg in Cells 3 and 5.

## TEMPORAL CHANGES IN COVERAGE AND DENSITY OF CATTAIL IN SELECTED EMERGENT AQUATIC VEGETATION CELLS BASED ON AERIAL IMAGERY

Vegetation is known to have a major role in water quality improvement in constructed treatment wetlands through reduction in water velocity, thereby allowing suspended particles to settle (Brueske and Barrett, 1994), and through nutrient uptake (Reddy and DeBusk, 1985). Vegetation in treatment wetlands also influences microbial processes by increasing oxygen availability in the rhizosphere (Allen et al., 2002), releasing exudates like carbohydrates and amino acids (Brix, 1997; Coleman et al., 2001), and providing additional surfaces for growth and proliferation of microbial populations (Wetzel, 1990).

However, there have been relatively limited studies on long-term vegetation dynamics in treatment wetlands (Chimney et al. 2000; Luckeydoo et al., 2002, Ray and Inouye 2007). Changes in vegetation in the STAs have been documented in vegetation maps derived from aerial photographs and (Nick Miller, Inc., 2003 and 2005; Pickett Surveying & Photogrammetry, 2006), but these maps have not been quantitatively analyzed. Chimney et al. (2000) reported changes in vegetation coverage in the Everglades Nutrient Removal Project from 1993 to 1998 and observed loss in cattail coverage in portions of some treatment cells. Those changes in vegetation coverage did not have an observable impact on P removal efficiency of the treatment wetland.

The objective of this study was to quantify changes in vegetation aerial coverage and density in terms of normalized difference vegetation index (NDVI) as a surrogate for density of cattail communities in three EAV treatment cells in the STAs during a multiyear POR. This analysis will provide insight for future vegetation management strategies in the STAs.

The study sites used in this analysis, STA-1E, Cells 5 and 7, and STA-3/4, Cell 1A, have been managed as an EAV system and were dominated by cattail. STA-1E was initially flooded in summer 2004 and it began start-up in September 2004. STA-3/4 began start-up in October 2003 and achieved full flow-through operation in September 2004. The study sites were selected due to the fact that these cells have experienced numerous extended periods of deepwater conditions (i.e., greater than 3 feet) during calendar years 2004–2009.

Twelve 1/16 acre quadrats in both Cells 5 and 7 of STA-1E and eight 1/16 acre quadrats in the northern one-third of Cell 1A of STA-3/4 (**Figure 5-49**) were selected for analysis from aerial photographs taken on February 2005, March 2006, April 2007, and April 2008.

The NDVI value of cattail (dimensionless) in each quadrate was calculated based on the intensity of aerial imagery bands with the following equation:

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

where, NIR= intensity of near infrared band and Red = intensity of red band in the subject imagery (Jensen, 2004). The NDVI values output by the above equation and analyzed in this study were averaged within the selected 1/16 acre quadrats.

The Raster Calculator in ESRI's ArcGIS Spatial Analyst Extension was employed to calculate the NDVI based on the four consecutive years of high resolution (< 2 ft ground resolution) aerial imagery. The NDVI ranges from -1.0 to +1.0, with negative values indicative of clouds and water, positive values near zero suggestive of bare soil, and higher positive values indicative of sparse (0.1 to 0.5) to dense (0.6 and above) green vegetation.

The area of cattail in each cell dominance was defined by examining existing vegetation maps and/or digitizing the annual aerial images from 2005 to 2008. Acreages corresponding to each year's cattail dominance extent were obtained from the resultant vector files. The vector files of each year's cattail dominance area were then geometrically intersected using the "Intersect" tool in ArcToolbox to establish the area of dominance common to all four years – the area of cattail persistence. Quadrats for NDVI calculation were sited within the area of cattail persistence in the three study areas cells.

Cattail coverage was calculated as a percentage of cell area as well as a percentage of total emergent vegetated area. Emergent vegetation extent was obtained by unsupervised classification utilizing ERDAS Imagine, a remote sensing software application. An initial 40-class classification scheme was re-classed to two groups (open water and emergent vegetation) and further processed using other ERDAS tools. The classified raster image was converted to a vector file for analysis, display, and acreage calculation.

Differences in the NDVI value among years in each cell were analyzed with one-way analysis of variance (ANOVA) at $\alpha < 0.05$. Differences among years were tested using a post hoc Tukey's HSD (Honestly Significant Difference) test.

Cattail coverage as a percent of Cell 5 surface area greatly increased from calendar years 2005 to 2008, reaching 67 percent in 2008 (**Figure 5-50**). Annual mean NDVI values differed significantly (**Table 5-33**). Average NDVI value in the 12 quadrats decreased from 0.37 in 2006 to 0.13 in 2008 (**Figure 5-51**).


**Figure 5-49.** Locations of selected quadrats in STA-1E, Cells 5 and 7, and STA-3/4, Cell 1A. Labeled points such as P1 and P3 indicate selected quadrats.

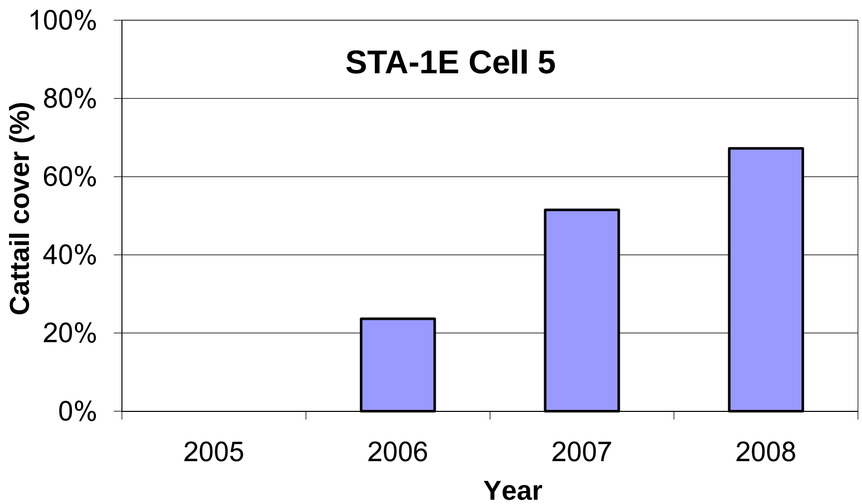



**Figure 5-50.** Changes in cattail aerial coverage in STA-1E, Cell 5, from 2005–2008. Note that cattail community was not present in Cell 5 in 2005 when the aerial photograph was taken.

**Table 5-33.** Results of one-way analysis of variance (ANOVA) comparing yearly normalized difference vegetation index (NDVI) values of cattail communities in STA-1E, Cells 5 and 7, and STA-3/4, Cell 1A, from 2005–2008.

| STA Cells | Source | DF | SS | Mean square | F values | Pr>F |
|---|---|---|---|---|---|---|
| STA-1E Cell 5 | Year | 2 | 0.3495 | 0.1747 | 57.91 | <0.0001 |
| STA-1E Cell 7 | Year | 3 | 0.2526 | 0.0843 | 24.80 | <0.0001 |
| STA-3/4 Cell 1A | Year | 3 | 0.0941 | 0.0314 | 10.12 | <0.0001 |

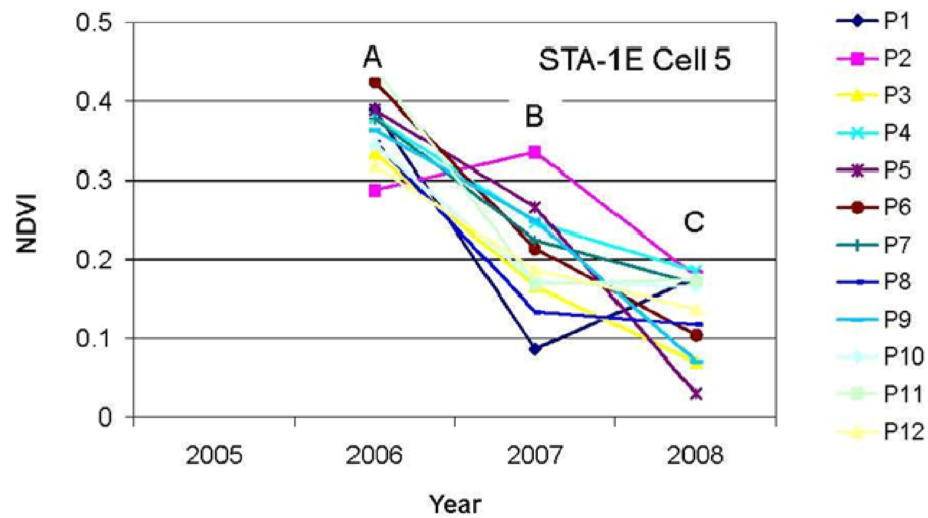



**Figure 5-51.** Individual NDVI values for cattail as a function of year in STA-1E, Cell 5, during 2005–2008. Each line represents a 1/16 acre quadrat, labeled P1 to P12. Years with different letters were significantly different from each other. Note that cattail was observed in Cell 5 in 2005.

## Cattail Coverage and Normalized Difference Vegetation Index Values in STA-1E, Cell 7

Cattail coverage in STA-1E, Cell 7, increased over the four years following the startup of this STA in 2004. The cattail cover changed only slightly from 2005 to 2006 but subsequently increased to approximately 55 percent in 2007–2008 (**Figure 5-52**).

The NDVI value of cattail among the four years significantly differed in Cell 7 (**Table 5-33**). The average of the NDVI values in the 12 quadrats significantly increased from 0.12 in 2005 to 0.31 in 2006 and subsequently decreased to 0.22 in 2007 and to 0.16 in 2008. There was no significant difference in the NDVI value between 2005 and 2008 (**Figure 5-53**).

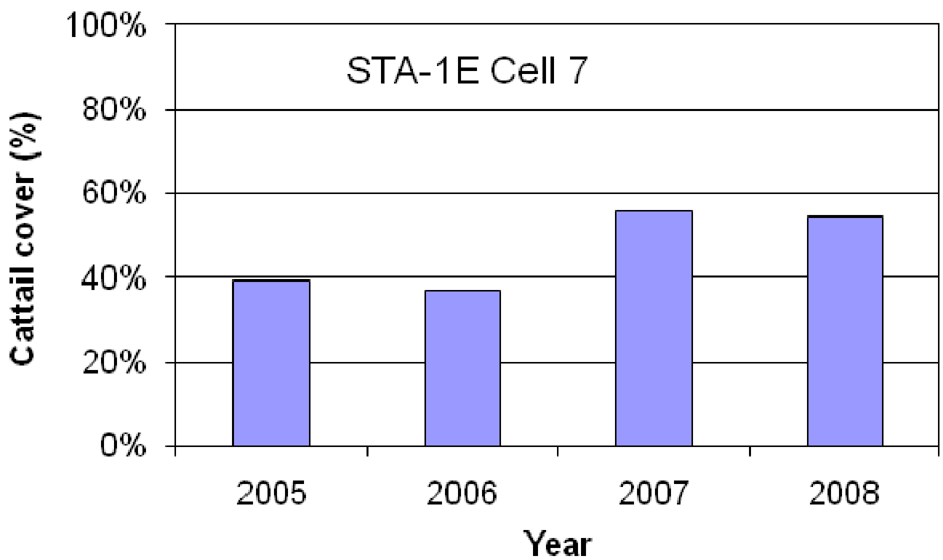



**Figure 5-52.** Changes in cattail coverage in STA-1E, Cell 7, from 2005–2008.

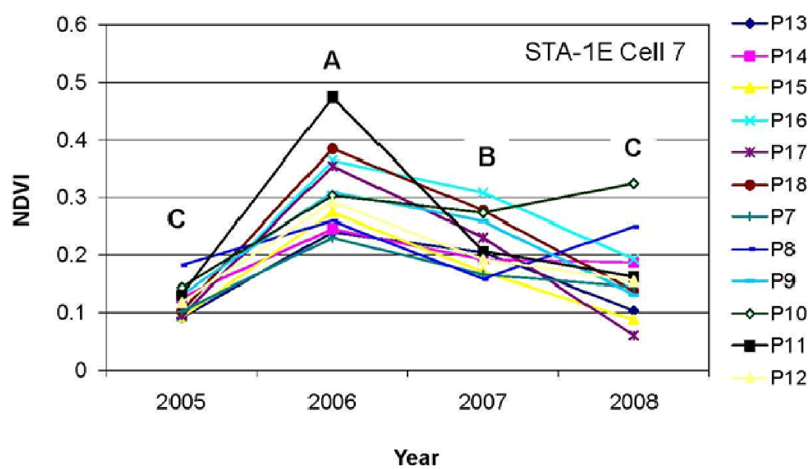



**Figure 5-53.** Individual NDVI values for cattail as a function of year in STA-1E, Cell 7, from 2005–2008. Years with different letters were significantly different each other.

### Cattail Coverage and Normalized Difference Vegetation Index Values in STA-3/4 Cell 1A

Cattail coverage in Cell 1A changed slightly in the first two years from 2005 to 2006 but subsequently decreased to approximately 41 percent in 2007 and increased to the previous level in 2008 (**Figure 5-54**).

The NDVI value significantly differed in Cell 1A over the four years (**Table 5-33**). The average NDVI value for eight quadrats significantly increased from 0.20 in 2005 to 0.27 in 2006 and subsequently decreased from 0.13 in 2007 to 0.11 in 2008. There was no significant difference in the NDVI value between 2007 and 2008 (**Figure 5-55**).

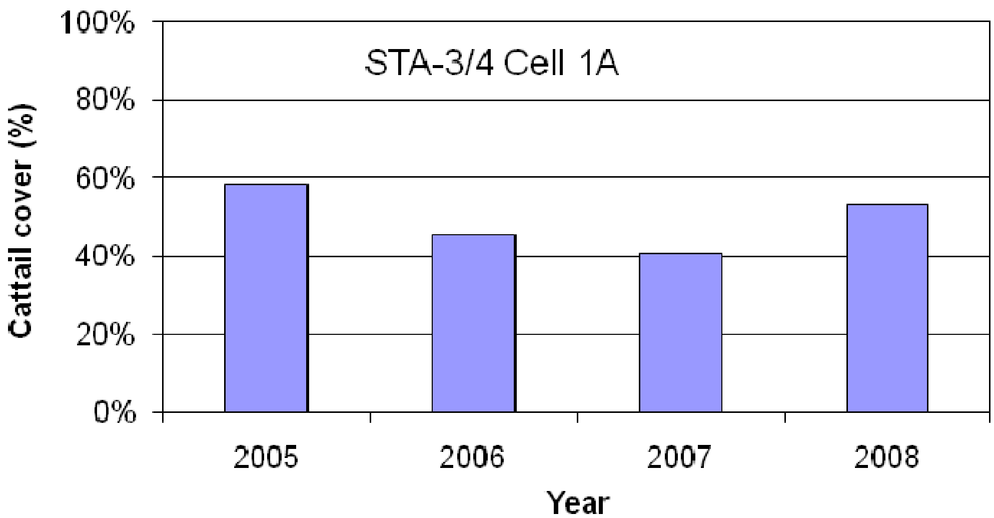



**Figure 5-54.** Changes in cattail coverage in selected northern one-third area of STA-3/4, Cell 1A, from 2005 to 2008.

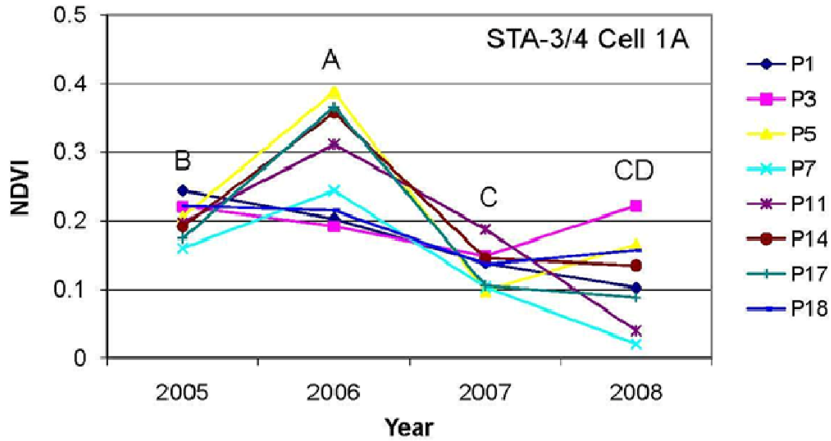



**Figure 5-55.** NDVI values of cattail communities in the northern one-third of STA-3/4, Cell 1A, during 2005–2008. Each line in the graph designates a 1/16 acre quadrat, labeled P1, P3, P5, P7, P11, P14, P17, and P18. The letters above the data points indicate significant difference among the years; data points with the same letter are not significantly different.

Results indicate that interpretation of the emergent vegetation condition in a cell should not only take into account the amount of area covered, but also the density, i.e., NDVI values. The coverage assessment includes the aerial extent of vegetation in a cell regardless of vegetation conditions while the NDVI value is indicative of live green vegetation. While cattail coverage generally shows an overall increase or even a minimal decrease over the past four years in STA-1E, Cells 5 and 7, and STA-3/4, Cell 1A, the NDVI value varied.

The pattern of the NDVI values calculated is consistent with field observations in these cells during the study period. The significant decrease in NDVI values from 2006 to 2007 and 2008 may reflect the impacts on emergent communities of the severe two-year drought followed by long periods of high water conditions. In general, the results of this study suggest that the NDVI is a promising surrogate for monitoring the dynamics of cattail communities and as a measure of extreme weather events impacts on vegetation.

This study is an initial attempt to apply the NDVI as an indicator of vegetation density in the STAs. Further investigation will attempt to correlate vegetation index values with actual ground-based vegetation density measurements. Ground measurements taken contemporaneously with remotely-sensed imagery can cross-validate each density detection method. Once validated and established, this methodology may be used in future monitoring of vegetation dynamics in the STAs.

# STA RESEARCH AND OPTIMIZATION STUDIES

This section also reports on the work being completed pursuant to PDE component of the Long-Term Plan. The following summarizes the research projects initiated or ongoing in WY2009 that have been designed to strengthen understanding about the mechanisms that control STA performance. These include vegetation surveys, soil sampling, monitoring of newly rehabilitated STA cells, assessment of floc soil biogeochemistry, and several large-scale experiments that examined biomass effects on SAV establishment and the influences of hydrologic extremes on cattail growth and survival to help identify stress indicators.

## PHYSIOLOGICAL RESPONSE OF CATTAIL TO DROUGHT CONDITIONS

Wetlands may experience periods of dry conditions when the vegetation within the wetland will experience stress. The objective of this experiment was to examine the response of cattails to varying water deficient conditions. Cattails are a dominant emergent plant species in the STAs. This field study was conducted in outdoor greenhouse enclosures located at the south research site at STA-1W. Cattail harvested from the adjacent treatment cell (Cell 1B) was planted in large pots constructed from 30-gallon, heavy-duty trash cans (22.5 x 22.75 in.). The experiment had three soil moisture treatments (100 percent soil moisture [control], 70 to 85 percent soil moisture, and < 70 percent moisture). The plants were subjected to water deficient conditions for three months where each pot received only periodical water inflows from rain events because of structural problems with the greenhouse enclosures. The greenhouse enclosures were fortified to prevent rainfall from getting into the cattail pots and the pots were then subjected to a more intense drought condition for four month. After, all pots were rehydrated to saturated water conditions (100 percent soil moisture). At each water regime change, some pots were destructively harvested and metabolic indicators of plant stress were measured.

The study was completed in April 2009; related data are currently being processed and are expected to be presented in future SFERs. Plant stress will be assessed based on plant survival, plant biomass by tissue type (leaves, roots, and rhizomes), length of tallest live leaf, shoot-base culm width, and rate of plant growth. The following physiological and biochemical parameters – soil percent moisture; photosynthesis rate, transpiration rate, and leaf fluorescence – will also be evaluated. Preliminary evaluation of these data have shown the following:

- Soil moisture of 70 to 100 percent provides optimum conditions for cattail growth.
- Rhizomes and roots extend to a depth of at least 25 in.
- Soil moisture below 70 percent causes most of the above ground biomass to die back (**Figure 5-56**). These plants did not flower. Pots maintained at 70 to 85 percent soil moisture flowered earlier than the controls.
- Below-ground tissue morphology was different among the treatments, with roots and rhizomes growing at the top of the pot for the controls and 70 to 85 percent treatments while pots under the most extreme drought conditions had the roots and rhizomes extending to the bottom of the pot.
- Physiological measurements showed little difference between control and all treatment pots when subjected to periodic watering; changes between the treatments were found when subjected to four-month, water-deficient conditions.
- All plants exhibited regrowth when rehydrated. When rehydrated after four months of dry conditions, those plants below 70 percent moisture had the highest amount of new shoots (**Figure 5-56**).


**Figure 5-56.** Subjected to low water conditions, much of the above-ground biomass started to die (photo by the SFWMD). Upon rehydration, many new shoots came up after two months of saturated conditions.

### Effects of Deepwater Condition on Growth, Chlorophyll Fluorescence and Nutrient Composition of Cattail

Cattail is one of most dominant aquatic plant in the STAs. During the wet season, many cattail-dominated cells in the STAs experience extended periods of deepwater conditions. The objectives of the study were to examine the response of cattail (specifically *T. domingensis*) to deepwater conditions, and investigate the potential of this species to recovery after experiencing deepwater stress.

The study consisted of two experimental phases: a six-week period of different flooding depth treatments followed by a four-week recovery period. The flooding treatments included three water depths: 1.3 ft (control water depth), 3.0 ft (moderate water depth), and 4.5 ft (extreme water depth) above the soil surface. Following the flooding depth treatments, half of the plants from each treatment were randomly harvested for growth and biomass measurement. The remaining plants were used for the four-week recovery study, during which the plants were maintained at a water depth of 1.3 ft. Photosynthesis and chlorophyll fluorescence were measured weekly throughout the flooding depth treatment and recovery portions of the study.

Moderate and extreme flooding depths significantly reduced the number of new shoots ($P$ value $< 0.001$) and total biomass ($P$ value $< 0.001$) per plant (**Figures 5-57** and **5-58**). Flooding impact in terms of new shoot growth and biomass was 4.5 ft > 3.0 ft > 1.3 ft.

At the end of the four-week recovery period, cattails previously exposed to the different flooding depth treatments showed remarkable signs of recovery in terms of the number of new shoots and the number of live leaves per plant. However, total biomass was significantly lower for plants from at the 4.5 ft depth treatment than for at the 3 ft depth treatment and the control plants. There was no significant difference in total biomass between the 3 ft depth and the control (**Figure 5-61**).

During the four-week recovery, cattail plants that were stressed by extended flooding at 3.0 ft and 4.5 ft water depths showed improved photosynthesis (**Figure 5-62**), but continued to have lower chlorophyll fluorescence (**Figure 5-63**). Chlorophyll fluorescence was significantly lower at the 4.5 ft depth than in the control. However, there was no difference between moderate flooding and the control.

In summary, moderate and extreme flooding depths significantly reduced the number of new shoots that emerged from parent plants, total biomass, photosynthesis, and chlorophyll fluorescence. When the water level was reduced to 1.3 ft for four weeks (recovery phase), cattail that was exposed to moderate flooding depth showed signs of recovery in total biomass, photosynthesis, and chlorophyll fluorescence, while plants subjected to extreme flooding depths did not recover their total biomass or chlorophyll fluorescence. This study indicates that impacts to cattails from extended periods of extreme water depths could be irreversible, while those exposed to moderate flooding depths can recover if water depth reduced to a level where sprouting of new shoots and regrowth are encouraged. Further studies, including validation of these findings by field observation and inclusion of more depth measurements, are needed to determine narrower depth-duration thresholds for STA cattail vegetation.

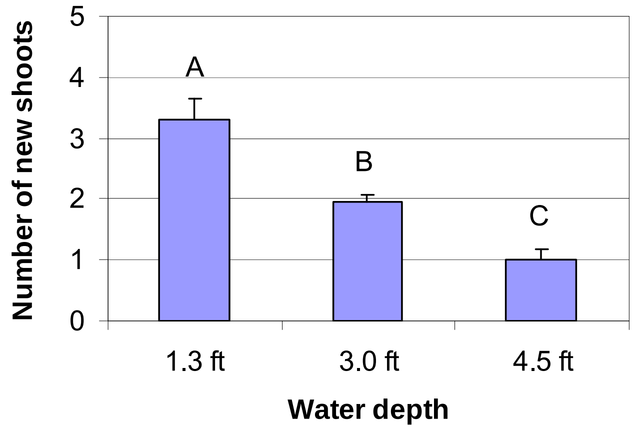



**Figure 5-57.** Number of new shoots per cattail plant (*T. domingensis*) (mean ± SE) as a function of water depth following six-week duration of flooding. Bars with different letters are significantly different.

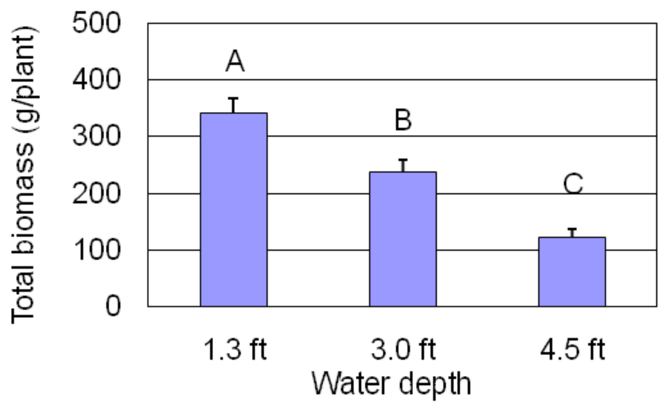



**Figure 5-58.** Total biomass (mean ± SE) per cattail plant (*T. domingensis*) as a function of water depth following six-week duration of flooding. Bars with different letters are significantly different.

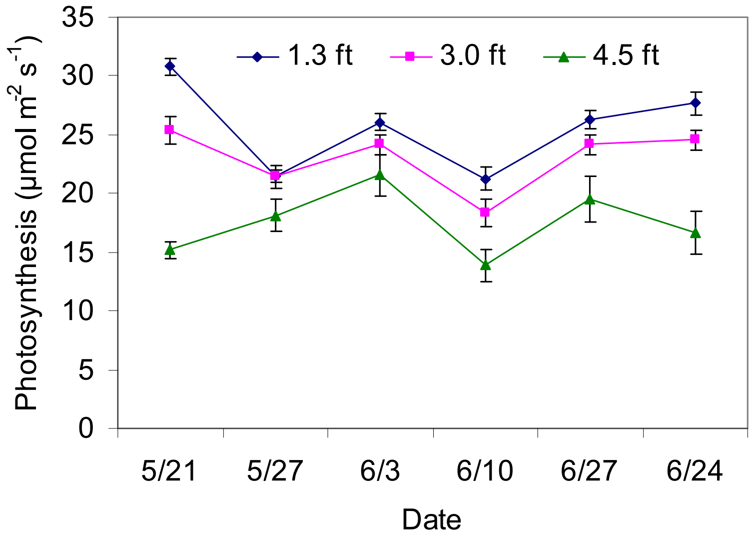



**Figure 5-59.** Photosynthesis (mean ± SE) of cattail (*T. domingensis*) during a six-week duration of flooding. Measurements were made in May and June 2008.

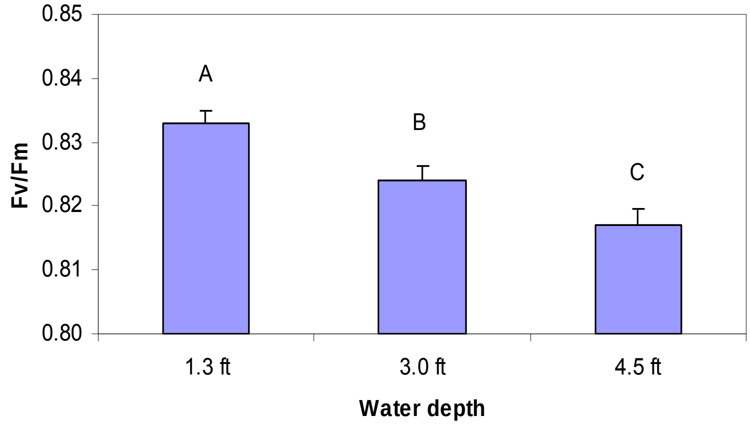



**Figure 5-60.** Chlorophyll fluorescence Fv/Fm (mean ± SE) of cattail (*T. domingensis*) as a function of water depth during six-week duration of flooding. Bars with different letters are significantly different.

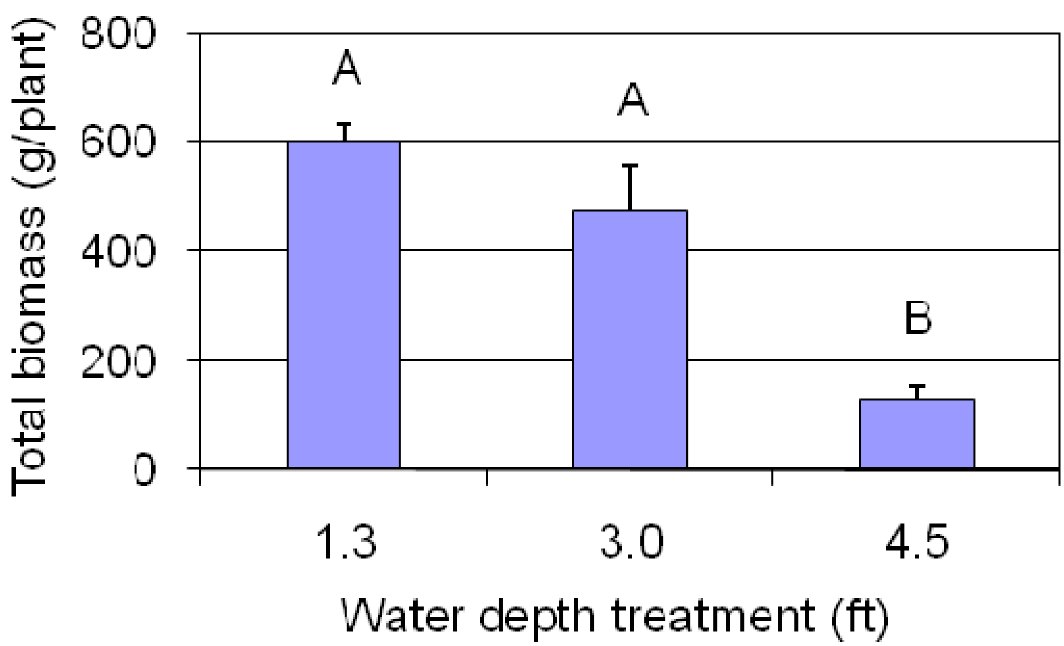



**Figure 5-61.** Total biomass of cattail (*T. domingensis*) following four week recovery. Bars with different letters are significantly different.

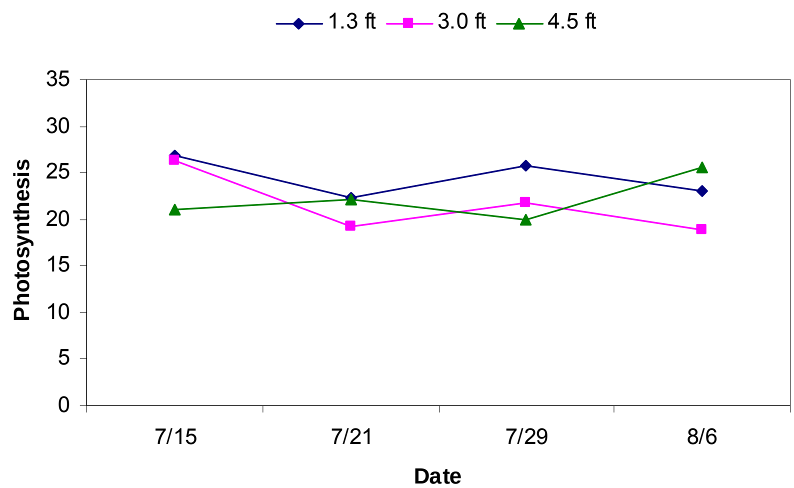



**Figure 5-62.** Effects of previous flooding depths and recovery duration on photosynthesis of cattail (*T. domingensis*) during the four-week period of recovery from July to August 2008.

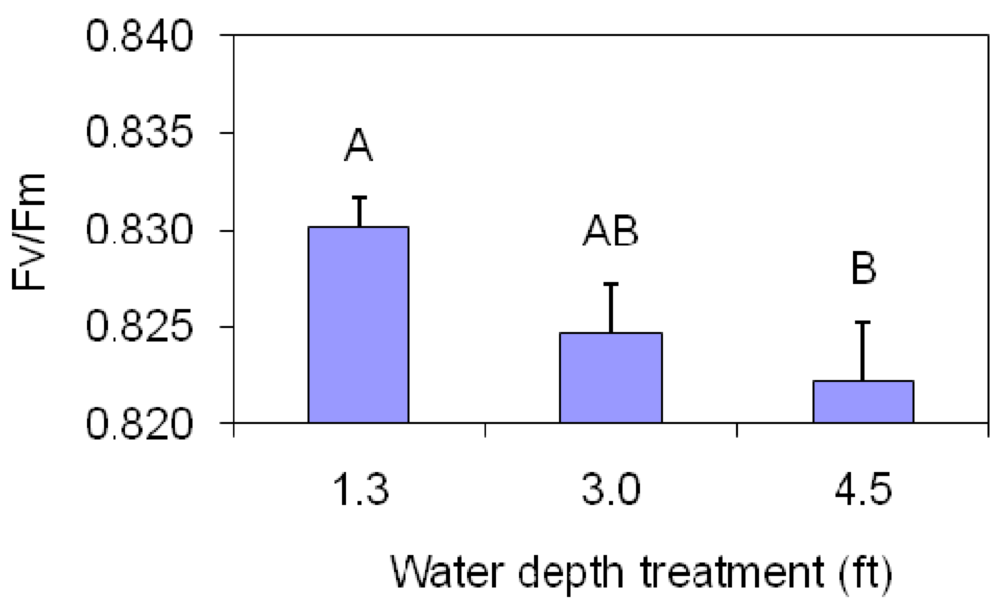



**Figure 5-63.** Effects of previous flooding depth on chlorophyll fluorescence (Fv/Fm) of cattail (*T. domingensis*) during the four-week period of recovery. Bars with different letters are significantly different.

### Internal Water Quality Transects in STA-1E and STA-1W

Careful monitoring of both STA-1W and STA-1E is critical, since these wetlands discharge to sensitive receiving waters (WCA-1 and WCA-2A), and because both treatment wetlands contain flow-ways that historically have exhibited markedly different treatment performance. Internal water quality sampling is useful for pinpointing problem areas with respect to excessive external TP loadings, soil phosphorus release, or vegetation community constraints. Internal monitoring also is useful for assessing regions of the cell that are providing exceptional treatment, for example to characterize the most effective vegetation community types responsible for phosphorus removal. For this effort, an internal water quality survey will be conducted in each of the STA-1E and STA-1W flow-ways during the rainy season in 2009 (WY2010).

During a large flow pulse in August 2008, the District performed an internal sampling event to characterize the internal water column TP gradient under short hydraulic retention time conditions. On the day of sample collection (August 21, 2008), average daily flow into the Central Flow-way of STA-1E was 1,137 cfs, and the prior two-week daily inflow averaged 405 cfs (**Figure 5-64**). Internal sampling locations are depicted in **Figure 5-65**.

On this sampling date, water column TP concentrations entered STA-1E Cell 3 at 143 ppb and exited at 135 ppb (**Figure 5-66**). The minimal TP reduction in the cell, coupled with the high concentration of readily bioavailable SRP in the cell outflow indicates poor phosphorus removal performance in this “front-end” cattail-dominated wetland. By contrast, along the sampling transects within the downstream Cell 4N, which is dominated by the SAV species hydrilla and Southern naiad, TP concentrations declined from 115 to 29 ppb (**Figure 5-66**). Essentially, all the readily available SRP was removed within Cell 4N. Within the final cell in the flow-way (Cell 4S), TP concentrations declined further, exiting the cell at 9 ppb. As noted in previous SFERs, the outflow TP was comprised principally of particulate P and dissolved organic P (**Figure 5-66**).

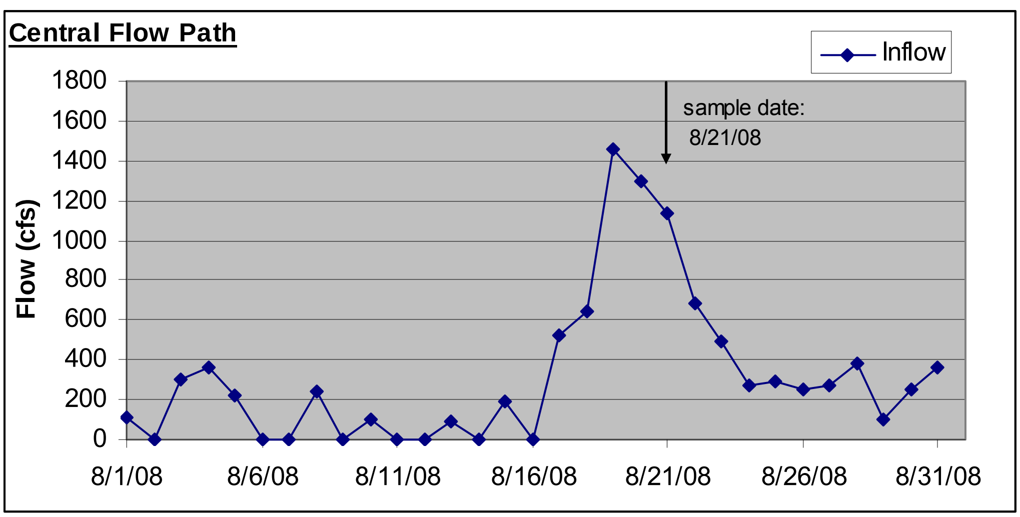



**Figure 5-64.** Water loading into the Central Flow-way of STA-1E during August 2008. Internal samples were collected on 8/21/08.

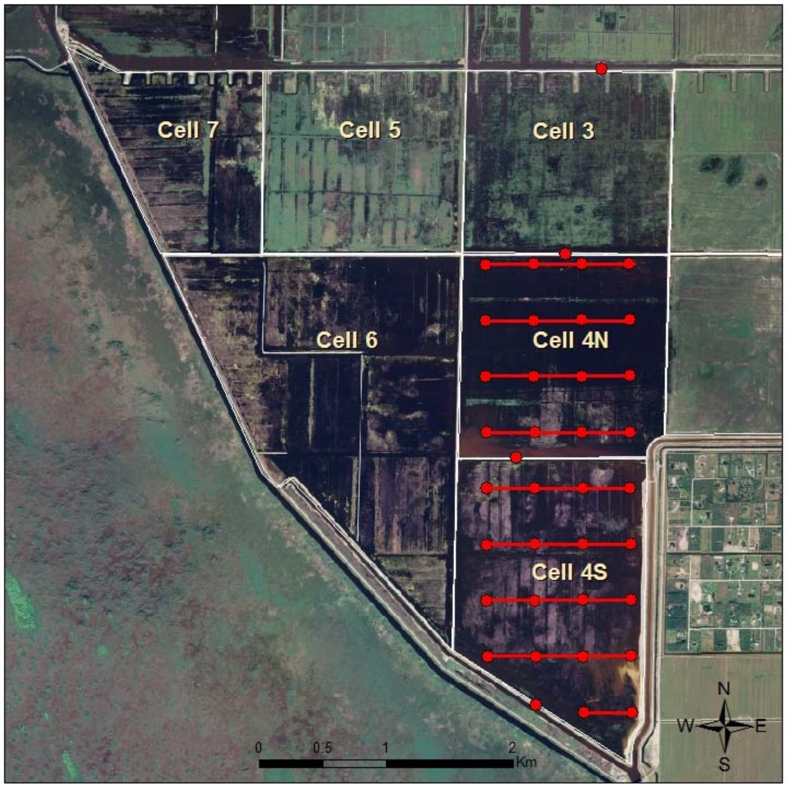



**Figure 5-65.** Internal sampling locations in the Central Flow-way of STA-1E. Cell 3 is an EAV dominated wetland, and Cells 4N and 4S are dominated by SAV.

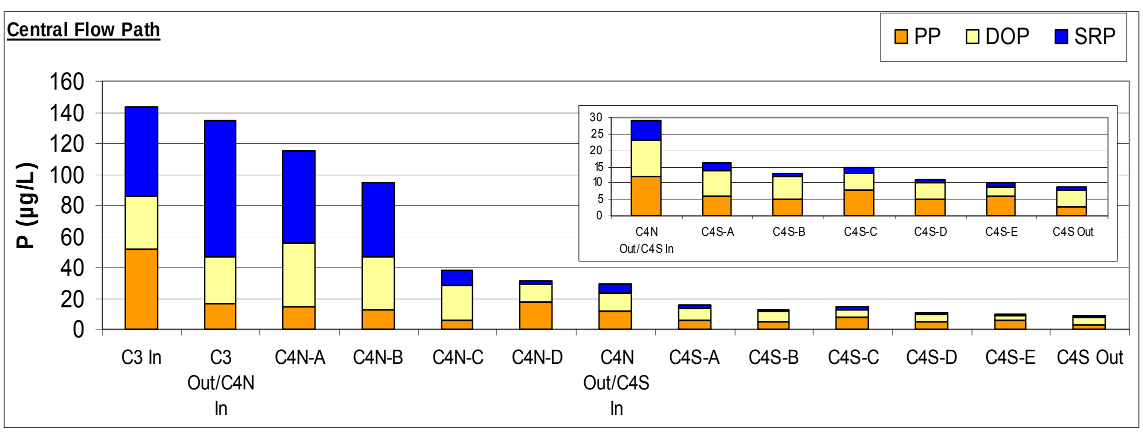



**Figure 5-66.** Internal water column phosphorus species concentrations within the Central Flow-way of STA-1E (Cells 3, 4N, and 4S) on August 21, 2008. The inset depicts concentrations in Cell 4S, with a reduced Y-axis scale.

### STA-2 Internal Phosphorus Storage and Stability Gradients

Sediments represent the ultimate storage reservoir for P removed from the water column within the STAs. Because internal P loading from the underlying sediment can influence wetland treatment efficiency, it is important to quantify the stability of P that accrues in STA sediments. Assessments of sediment P stability along the length of the flow path will provide a better understanding of factors that influence wetland treatment longevity, and the minimum achievable outflow TP concentrations. The three cells of STA-2 are excellent candidates for sediment stability characterization: the cells have been subjected to widely different P loadings, and are exhibiting markedly different levels of P removal performance. Additionally, STA-2 is one of the two best-performing STAs. During past years, the District has performed internal characterization of sediments in STA-2, Cells 2 and 3 (**Figure 5-67**). Some comparisons in the chemical characteristics of these sediments are provided below.

Cell 3 is dominated by SAV, with a small region of EAV, whereas Cell 2 is dominated by EAV (primarily cattail, with some sawgrass), with a small region of SAV. The data presented herein address trends in surficial soils (0 to 4 cm), with Cell 3 soils sampled in 2005 and Cell 2 soils characterized in 2008. Differences noted in sediment characteristics, therefore, may be related to differences in vegetation, and/or differences in operations since both cells were subjected to initial flow-through conditions in 2001.

Surficial soil (0 to 4 cm) TP concentrations were higher in Cell 2 than in Cell 3, potentially due to the longer operational period of the former (seven years for Cell 2 versus four years for Cell 3), but also possibly due to differences in plant community type. Maximum soil TP levels for Cell 2 were found in the mid-region of the wetland, whereas a gradual decline in soil TP with distance from the inflow was noted in Cell 3 (**Figure 5-68**). Outflow region soil TP in Cell 2 averaged 980 mg/kg, while outflow region soil TP in Cell 3, sampled three years earlier, was approximately 580 mg/kg.

Several other soil constituents exhibited little inflow to outflow gradient within the wetlands, but differed markedly between cells (**Figure 5-69**). Average nitrogen (N) and total organic carbon (TOC) contents were markedly higher in the emergent macrophyte–dominated wetland (Cell 2), while bulk density and calcium contents were much higher in the SAV-dominated system (Cell 3).

By contrast, surficial soil porewater soluble reactive (SRP) concentrations exhibited a marked spatial gradient in both wetlands, declining from 306 to 19 ppb in Cell 2 and 150 to 7 ppb in Cell 3 (**Figure 5-70**). Porewater SRP has been used previously as an indicator of internal loading in STA wetlands, and the observed low concentrations in outflow region soils suggests that the soil in these zones probably are not contributing a substantial phosphorus load to the water column. A repeat sampling effort is planned for Cell 3 in late summer 2009, which will provide invaluable information on temporal changes in sediment chemistry in STA flow paths.

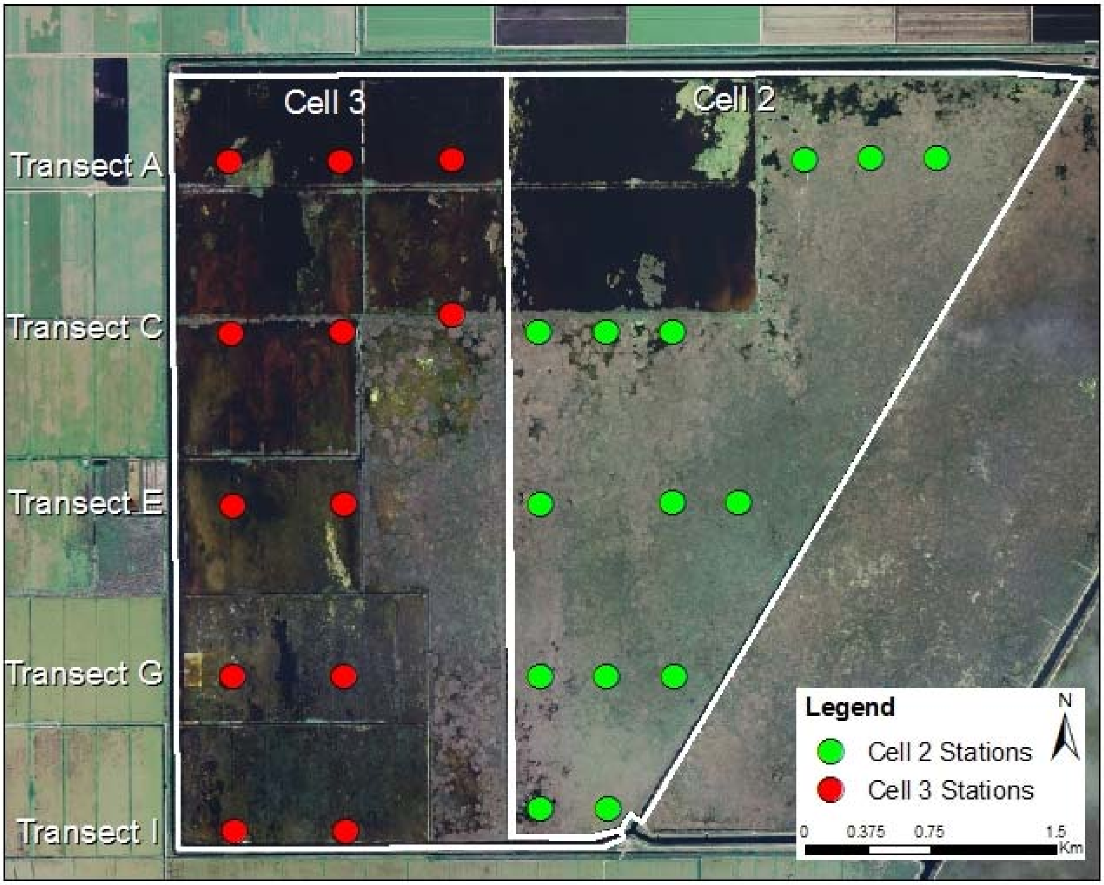



**Figure 5-67.** Surficial soils were collected along transects oriented perpendicular to flow in Cells 2 and 3 of STA 2. Zones not sampled along each transect represent regions containing sub-dominant vegetation (i.e., SAV in Cell 2; emergent vegetation in Cell 3).

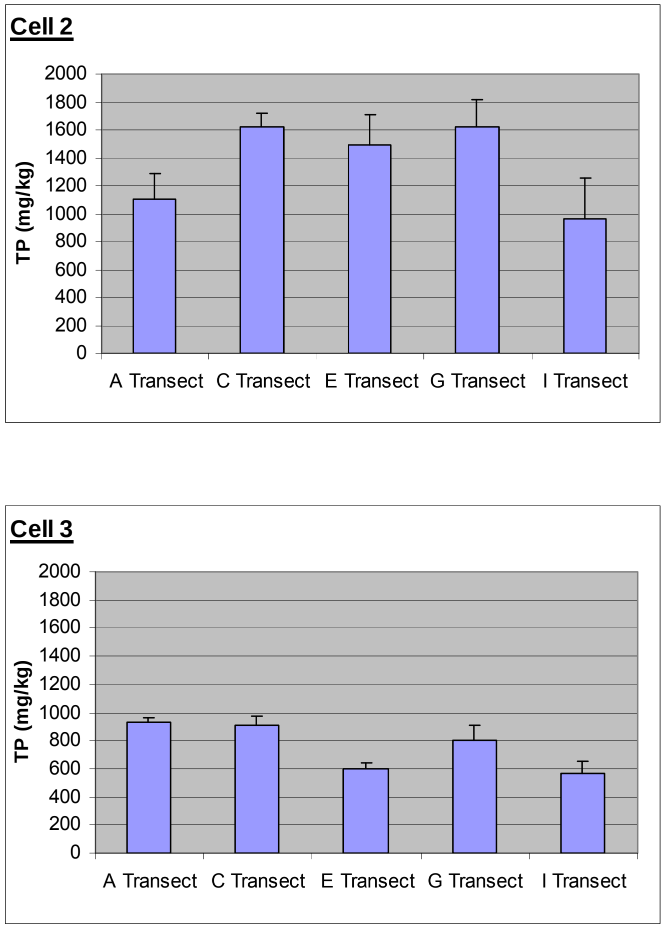



**Figure 5-68.** Surficial (0 to 4 cm depth) soil TP contents for STA-2, Cell 2 (emergent macrophyte-dominated, sampled in 2008) and Cell 3 (SAV dominated, sampled in 2005). Units are in milligrams per kilogram (mg/kg).

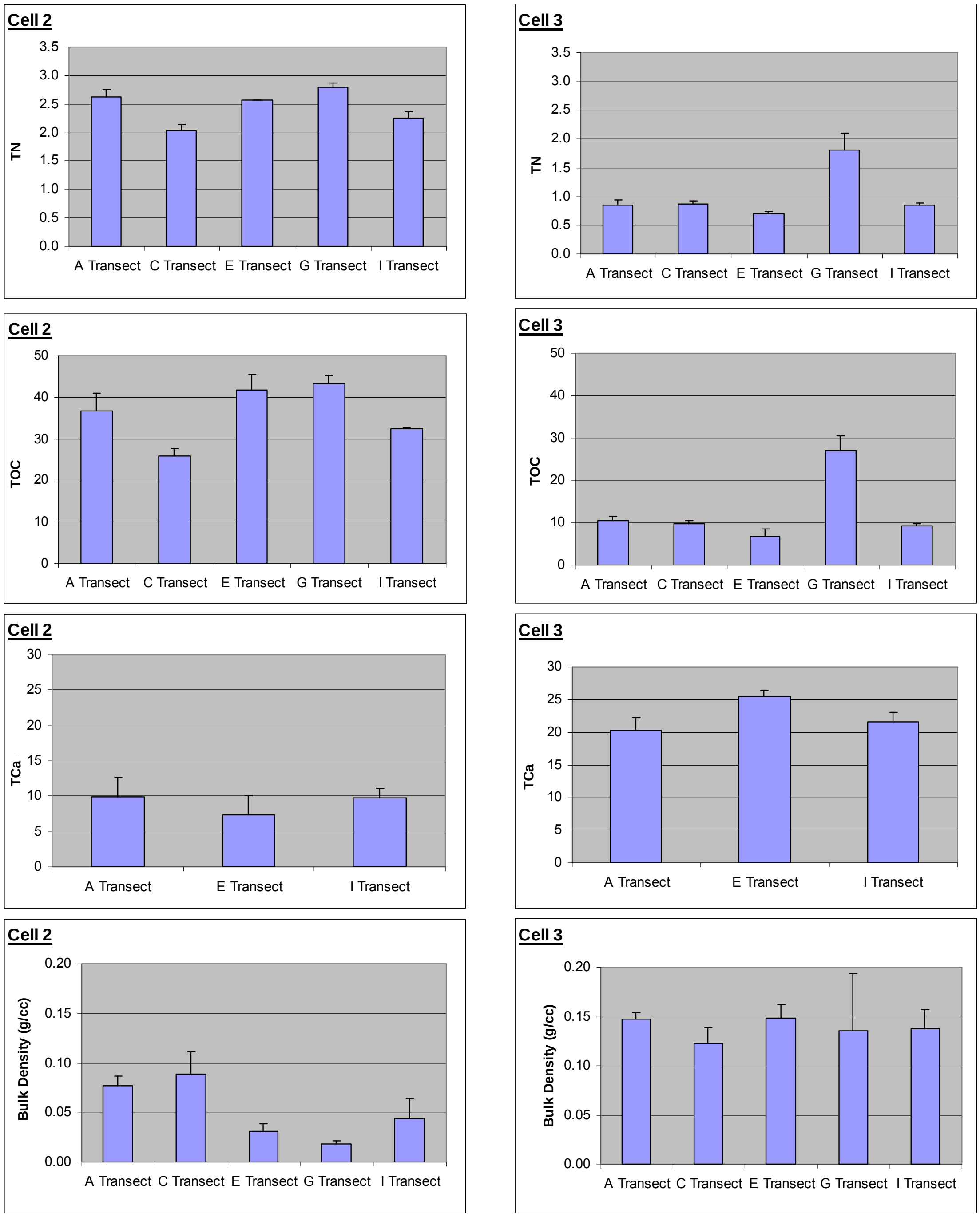



**Figure 5-69.** Surficial soil TN, TOC, total Ca, and bulk density for STA-2, Cells 2 (emergent macrophyte-dominated, sampled in 2008) and 3 (SAV dominated, sampled in 2005). Units for TN, TOC, and total Ca are in milligrams per kilogram (mg/kg); units for bulk density are in grams per cubic centimeter (g/cc).

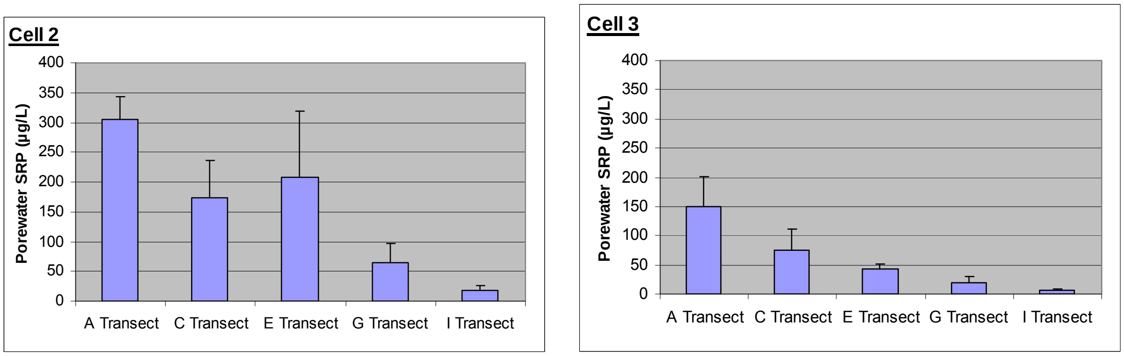



**Figure 5-70.** Surficial soil porewater soluble reactive P contents for STA-2, Cell 2 (emergent macrophyte-dominated, sampled in 2008) and Cell 3 (SAV dominated, sampled in 2005). Units are in parts per billion (ppb), or micrograms per liter (µg/L).

## Phosphorus Fractions in Floc and Surface Soil Layers in STA-2, Cell 4

One critical aspect in managing the STAs is maximizing the capacity to store phosphorus. A large portion of the runoff P treated by the STAs is stored in the soils via physical, chemical, and biological processes. The characterization of the different P pools stored in the soils is an important step to establish baseline conditions in order to track changes in P storage over time. This soil characterization was conducted to determine the current labile and non-labile pools of P in soils from STA-2, Cell 4. STA-2, Cell 4 (1,902 acres), is the newest of the four cells in this STA and became operational in 2008.

In March 2009, 10 stations were sample in STA-2, Cell 4, for baseline phosphorus-fractionation (**Figure 5-71**). All samples sites were selected from the District's routine soil sampling grid to include locations in a spatial distribution manner from the inflow to the outflow of the cell. Samples were collected by driving a 10 cm diameter, stainless steel corer into the soil profile. Each core was sectioned into the floc layer (when present) and 0-10 cm of the consolidated soil layer. Samples were cleared of vegetation roots, placed in water-proof plastic bags, and placed in an ice cooler for transport to the laboratory. Sediment samples were collected at all ten sites, while floc was present and collected at only eight sites. Samples were processed and analyzed by DB Environmental Laboratories, Inc.

### *Results and Discussion*

Soil analysis results generally indicated higher concentrations of TP (736 ± 195 mg kg-1) in the floc layer than in the underlying 0-10 cm soil layer (514 ± 129 mg kg-1) (**Table 5-71**). Bulk density of the floc material is nearly half of the consolidated soil's bulk density. Results from the P fractionation analysis indicate that even after only one year of operation, the floc layer shows higher levels of inorganic P than the 0-10 cm soil layer. The largest fraction (approximately 54 percent of TP) in the 0-10 cm soil layer was in the form of residual P, a form that is not readily released into the water column or readily available for rooted plant uptake (**Figure 5-72**). The organic P fraction comprised 28 and 23 percent of soil TP in the floc and 0-10 cm layers, respectively.

**Table 5-34.** Soil properties and concentration of the different inorganic (Pi) and organic (Po) phosphorus fractions from floc and 0-10 cm soil layer in STA-2, Cell 4. Values represent mean ± one standard deviation. Floc depth sites n=8 samples, sediment 0-10 cm layer n=10 samples.

| | n | Depth | BD | Labile-Pi | FeAl-Pi | CaMg-Pi | Po | Residue TP | Soil TP |
|---|---|---|---|---|---|---|---|---|---|
| | | cm | g/cc | $mg\ kg^{-1}$ | $mg\ kg^{-1}$ | $mg\ kg^{-1}$ | $mg\ kg^{-1}$ | $mg\ kg^{-1}$ | $mg\ kg^{-1}$ |
| Floc | 8 | 5.7 ± 3.1 | 0.1 ± 0.04 | 3.7 ± 3.8 | 49 ± 27 | 212 ± 38 | 205 ± 72 | 267 ± 86 | 736 ± 195 |
| Soil | 10 | 0-10 | 0.26 ± 0.07 | 1.2 ± 1.0 | 26 ± 9 | 89 ± 40 | 118 ± 50 | 269 ± 77 | 514 ± 129 |

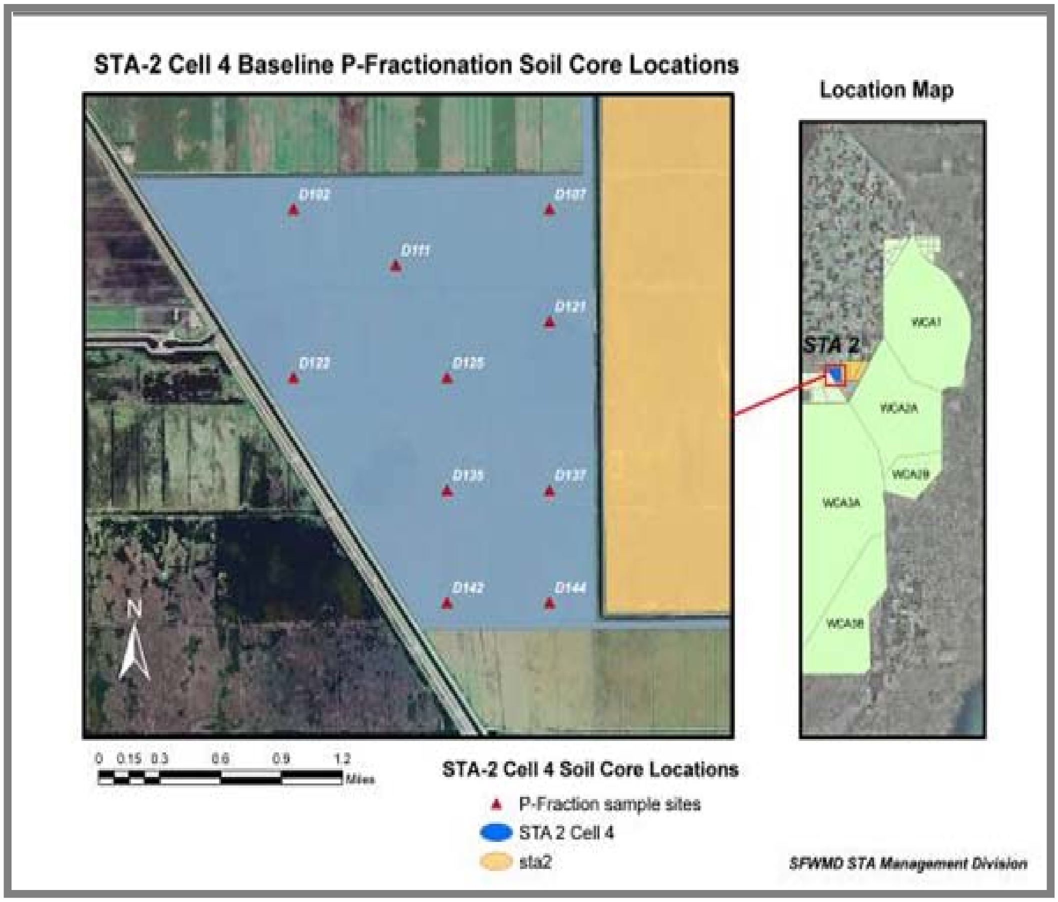



**Figure 5-71.** Soil sampling locations in STA-2, Cell 4.

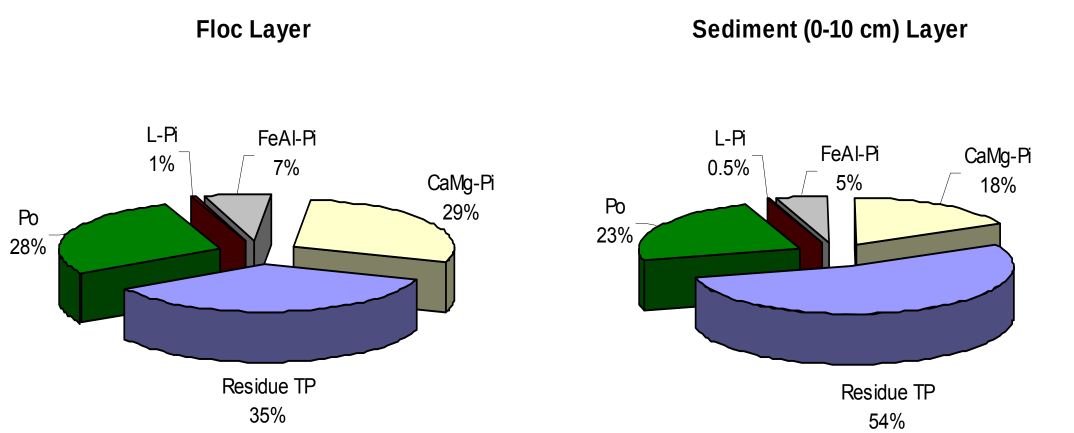



**Figure 5-72.** Relative distribution of inorganic (Pi) and organic (Po) phosphorus fractions in soils from STA-2 Cell 4 in the floc layer and the 0-10 cm soil layer. CaMg-Pi = calcium- and magnesium-bound phosphorus; FeAl-Pi = iron and aluminum-bound phosphorus; L-Pi = labile inorganic phosphorus; Po = organic phosphorus.

### STA-2 Internal Water Quality

Internal water quality measurements are being performed in the four flow-ways of STA-2 to characterize water column P removal profiles as a function of vegetation type, flow, P loading, and season. Monitoring within Cell 3 has been performed since 2003, and monitoring in Cells 1 and 2 was initiated in 2007. Internal characterization of Cell 4 water column gradients began in 2008. The data have demonstrated that these internal profiles are useful for identifying regions of poor performance, and that they also help define the potential for selected flow-ways to achieve target outflow concentrations.

### Characterize Hydraulic Resistance of Emergent Macrophytes in STA-2, Cell 2

Many of the EAV-dominated STA cells contain dense stands of vegetation, consisting of both living and dead plant material. Under high flow events, it is thought that the hydraulic resistance created by the dense vegetation contributes to the high water depths observed in the front-end of many of the STA flow-ways. For this project, the District has deployed pressure transducers at various locations along the wetland flow path in STA-2, Cell 2. These instruments are being used to characterize water stage changes within the wetland as a function of flow regime. These data will help clarify hydraulic resistance for STA emergent communities, and also provide background information that may facilitate selected vegetation management practices (i.e., burning to thin dead cattail biomass; conversion of cattail to SAV) in STAs. This project started in 2008; the end date has yet to be determined and will depend on the utility of findings.

### STA-1W Biomass and Decomposition Study

In 2006 and 2007, major efforts were conducted to rehabilitate multiple cells in STA-1W in order to make the environmental conditions more favorable for vegetation establishment and improved P removal performance. SAV serves as the "polishing" or downstream cells in the flow-way of the STAs. As part the rehabilitation efforts, agricultural rice (*Oryza sativa*) was planted in Cells 1B, 2B, 4, and 5B. Rice was planted as an interim vegetation to help reduce the resuspension of sediments into the water column, thereby encouraging SAV establishment. Rice was selected because it was readily available, inexpensive, and easily planted using standard farming practices. Details of rice planting were provided in the 2008 and 2009 SFERs – Volume I, Chapter 5.

With a focus on rice, cattail, barnyard grass *(Enchinocloa walteri*), and common grass *(Paspalum distichum*), this study was conducted to (1) evaluate and compare the amount of biomass from rice versus other common emergent aquatic vegetation species, and (2) to quantify the decomposition rates for each species.

#### *Biomass Estimation*

Biomass was harvested for each species, excluding cattail, using 0.25 $m^2$ quadrats to evaluate the amount of biomass per species present at each sampling point. Key elements are as follows:

1. Three 0.25 $m^2$ plots were randomly selected in STA-1W for each species.
2. All materials contained within each plot were harvested, including above-ground (leaves and stems) and below-ground (roots and rhizomes) components.
3. Above-ground and below-ground were separated, washed, and dried at 60 $^{\circ}$C.
4. Dry weights were recorded for each plot collected and recorded accordingly.
5. Biomass was calculated, where: Biomass/$M^2$= Weight of plant material/0.25
6. Tukey's HSD test was used to verify that significant differences in biomass estimations between species existed when ANOVAs were significant.

### *Decomposition*

Plant material obtained through the biomass estimation section of the study was used to conduct the decomposition portion of the study. Three separate locations within STA-1W were selected for field incubation, i.e., Cells 2B, 4, and 1B. It should be noted that ideally this incubation should have been done using air-dried or fresh biomass. Key elements are as follows:

1. A total of 10 to 20 grams of dried material from each species was placed into 45 individually numbered mesh bags for deployment.
2. All samples were weighed to obtain a baseline weight prior to deployment.
3. Three plots were used as replicate experimental units.
4. Within each experimental unit, a total of 15 bags for each species were submerged to mimic natural conditions.
5. Three bags of each species were collected from each experimental unit (one from each plot) at days 31, 61, 186, 295, and 389 after the start of incubation.
6. After each sampling event all materials were washed and dried at $60^0$C for a period of two weeks. Each bag of dried material was then weighed.
7. Decomposition rates were calculated as percent biomass remaining for each sampling event and was calculated, where:

   Percent Remaining = ((100-(Initial Weight-Final Weight))/Initial Weight)*100
8. Tukey's HSD test was used to verify that significant differences in biomass estimations between species existed when ANOVAs were significant.

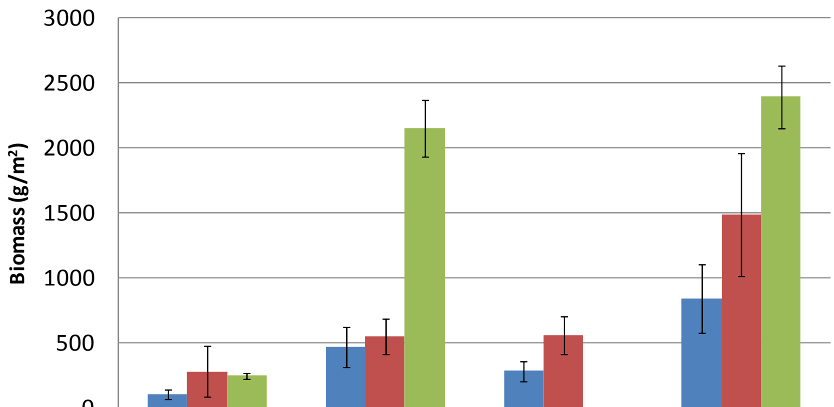
### *Results*

Results show that rice produced the least amount of total plant biomass when compared to both barnyard grass and common grass (**Figure 5-73**). No significant differences were observed between the three species in terms of below ground biomass. Biomass in leaf material was significantly higher in the *Paspalum* species compared to both rice and *Echinochloa*. A significant portion of the rice and the *Echinochloa* plants are made up of stem material, while the *Paspalum* was completely made up of leafy material. Overall biomass per square meter was significant different amongst all three species with *Paspalum* having the highest total biomass followed by the *Echinochloa* species. Rice contained the least amount of biomass in this study.

The results from decomposition study indicated that rice decomposes in a much shorter timeframe than *Echinochloa*, *Paspalum*, and *Typha*. Approximately 70 percent of the rice biomass decomposed in 30 days, 95 percent by six months, and fully decomposed by 210 days (**Figure 5-73**). Barnyard grass and common grass biomass decomposed at virtually the same rate with approximately 50 percent of the biomass remaining after 30 days and less than 20 percent remaining after 295 days. Cattail decomposition rates were significantly lower ($P$ value $\leq 0.0001$) than the other species; this finding is in line with other decomposition studies conducted on this species (Pietro and Chimney, 2006). Approximately 70 percent of cattail biomass remained after 30 days and about 30 percent remained after 289 days. After 186 days, the decomposition rates for cattail and the two grass species are not significantly different.

### *Discussion*

In this study it was found that (1) rice contained less biomass in a per unit area than the other two grass species tested in this study, and (2) the decomposition rate of the rice plant is significantly faster than that of *E. walteri*, *P. distichum*, and *T. domingensis*. These findings are expected to be useful when planning future rehabilitation efforts in the STAs where the SAV community may be struggling to survive due to sediment resuspension into the water column. Previous studies, as described in 2008 and 2009 SFERs – Volume I, Chapter 5, have proven that *O. saptiva* is an optimal tool used to reduce problems with the resuspension of sediments into the water column in SAV cells. Other common emergent species may provide a similar function as rice; however, it is not desired for such species to persist for long periods of time throughout the SAV cells. Therefore, the fact that rice is an annual plant, has a relatively low amount of biomass, and decomposes in a relatively short period of time, makes this species optimal for use in future rehabilitation efforts in SAV cells within the STAs.




| | Roots | Leaves | Stem | Total Biomass |
|---|---|---|---|---|
| Rice | 98 | 464 | 280 | 842 |
| Echinocloa | 279 | 546 | 558 | 1482 |
| Paspalum | 243 | 2151 | 0 | 2394 |

**Figure 5-73.** Above-ground and below-ground biomass estimations per square meter of area planted with rice.

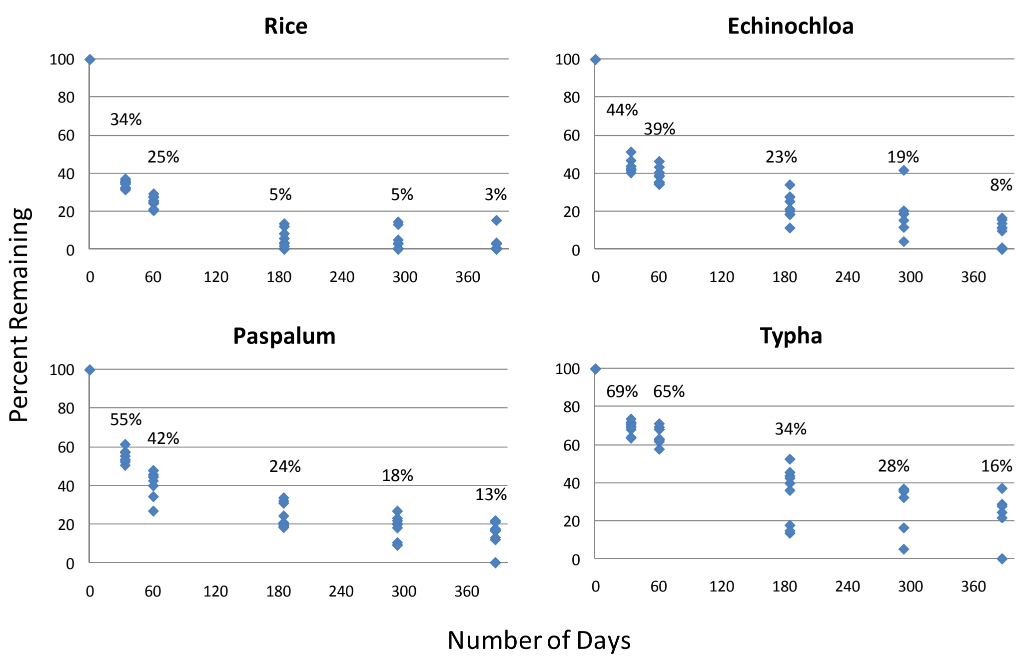



**Figure 5-74.** Percent of biomass remaining for each species for rice, barnyard grass and common grass, and cattail over time under submerged conditions.

### Effects of Water Column Calcium Concentrations on Phosphorus Removal by a Mesocosm-Scale STA Flow-way

In this study, the District is evaluating whether the approximately twofold higher calcium (Ca) levels found in Everglades Agricultural Area (EAA) farm runoff, in comparison to Lake Okeechobee waters, can lead to lower outflow TP concentrations from a sequence of cattail, SAV, and calcareous periphyton mesocosms operated at a low P loading rate. To date, Ca levels appear to exert a slight influence on the minimum attainable outflow TP levels in the system, with low [about 35 milligrams per liter (mg/L)] and high (70 mg/L) Ca systems achieving outflow TP concentrations of 20 and 16 ppb, respectively. As part of this effort, internal profiles in water column Ca concentrations are being measured in several full-scale STA flow-ways, as a function of vegetation community type and hydraulic loading rate.

### Vegetation Conversion Status Updates

#### *STA-3/4, Cell 1B, Conversion*

Per revision to the Long-Term Plan, conversion of STA-3/4, Cell 1B, from an emergent to an SAV marsh is intended to occur incrementally while keeping the cell online. The ongoing conversion requires elimination of the cattail and willow (*Salix caroliniana*) that cover most of the cell, and subsequent establishment of one or more of the desirable SAV species (i.e., southern naiad, muskgrass, or pondweed) for the STAs. Initial conversion measures were taken in November 2005 when an herbicide was applied aerially to 650 acres of cattail and willow in the southernmost portion of the cell. The second phase of the incremental conversion was initiated on December 6, 2007, when an aerial herbicide treatment was applied to an additional 800 acres of cattail immediately north of the first treatment area. In October and November 2008, another 400 acres of cattail were treated. These three increments have cumulatively treated EAV cover on 53 percent of the effective treatment area of Cell 1B.

Due to limited natural colonization of SAV following the initial herbicide treatment, in July 2007 SAV was inoculated (via helicopter) at 11 sites in the southernmost section of the cell. As a result of these founder site inoculations and subsequent natural colonization, SAV has been established and presently covers approximately 35 percent of Cell 1B based on a qualitative survey in July 2009. This increase from the previous year (i.e., based on the 2008 survey, SAV was covering an estimated 15 percent of the cell) indicates that the incremental conversion strategy has been successful and will continue to proceed with an iterative adaptive implementation process.

## VEGETATION MANAGEMENT RESEARCH

### Submerged Aquatic Vegetation Establishment Research

Several studies have been initiated to facilitate SAV establishment and conversion efforts and to investigate alternative vegetation management strategies for sustaining STA performance. Effects of dead and decomposing cattail litter on rates of “natural” (i.e., unassisted) colonization of SAV and periphyton are being evaluated in experimental 480 $m^2$ (12 m x 20 m) plots that were established in a dense cattail stand within two of the emergent vegetation strips in STA-3/4, Cell 2B, in spring 2007. Bimonthly random standing-crop biomass sampling has indicated no natural colonization of SAV has occurred in the two-year period following the herbicide treatments. These results suggest that the dense untreated cattail above the treated plots (i.e., the emergent vegetation strip) may be impeding influx of SAV propagules from established beds upstream and thereby precluding establishment of SAV. Although periphyton colonization of dead (treated) cattail during the summer of 2007 likely provided an interim P uptake pathway following the treatments, very little periphyton was found in treated plots after the decomposing cattail litter sank in the water column (i.e., during sampling periods after February 2008).

Preliminary conclusions from the vegetation strip study in Cell 2B appear to be supported by a complementary study in the southern section of STA-3/4, Cell 1B, where the incremental conversion of emergent vegetation to SAV has been ongoing since November 2007. Sample data from study plots (36 $m^2$ ) in Cell 1B indicates that SAV propagules from established beds upstream of the 1,850 acres of treated cattail has led to comparable average (± standard error) SAV cover in uninoculated study plots (46 ± 9 percent) and in plots that had been inoculated with muskgrass and Southern naiad (49 ± 5 percent).

Results of these two studies are expected to clarify the time frame required for SAV conversions and associated need for SAV inoculations and/or measures to remove dead emergent plant biomass (through harvesting, tilling, fire etc.). These and other associated planned studies may have implications for alternative vegetation management strategies such as the potential value of rotation of emergent and SAV cover to maintain sustainability of STA cells.

### Bulrush Planting

An investigation was undertaken to evaluate the potential for establishing giant bulrush (*Schoenoplectus californicus*) in the front ends of STAs where water depths during high inflow periods have resulted in conditions that have not been conducive to sustained vegetative growth. To evaluate this potential vegetation management option for the STAs, giant bulrush was planted in unvegetated areas immediately downstream of inflow structures in STA-1E, Cell 7; STA-2, Cell 3; and STA-3/4, Cell 1A.

In May 2007, approximately 1,100 giant bulrush culms were planted in 20 x 20 m plots at each of these three locations, which provided an initial density of 2.8 bulrush culms $m^2$. Water depths on planting dates were 11-12 cm in the plot in STA-3/4, Cell 1A; 30-31 cm in STA-1E, Cell 7; and 37-38 cm in STA-2, Cell 3. Post planting monitoring was conducted in July, September, October, and November 2007, and in January, March, May and July 2008 (**Figure 5-75**). During each of these sampling dates, the number of bulrush culms was counted in 10 randomly selected 1 $m^2$ quadrats in each plot. July 2007 sampling indicates initial post-planting mortality was 29 percent in STA-1E, Cell 7, 57 percent in STA-2, Cell 3, and 64 percent in STA-3/4, Cell 1A. Culm densities remained constant during August and September; by January 2008, vegetative reproduction by surviving plants increased mean (± standard error) densities to 5.7 ± 2.8 culms in STA-3/4, Cell 1A, and 13.9 ± 4.5 culms in STA-1E, Cell 7. Rates of bulrush expansion in these cells increased through subsequent sampling dates and mean densities reached 28.5 ± 9.7 culms $m^2$ in STA-3/4, Cell 1A, and 117.7 ± 14.8 culms $m^2$ in STA-1E, Cell 7, in July 2008. Establishment of bulrush was least successful in STA-2, Cell 3, where survival from initial planting provided patchily distributed culms that attained a mean density of 11.6 ± 8.4 culms $m^2$ during the last sampling date in 2008.

Water depth regimes at these locations were determined by mean plot elevations and daily tailwater stage data at the nearest gauging station (i.e., S-373B for STA-1E, Cell 7; G-333C for STA-2, Cell 3; and G-374E for STA-3/4, Cell 1A). Mean plot elevations were derived by subtracting the mean of 20 random depth measurements, which were taken from each plot on June 8 and 17, 2007, from the tailwater stage at the reference gauge on these dates. Based on these plot elevations and stage hydrographs from these gauging stations, four flow events during the period from the date of planting through the last sampling date in July 2008 resulted in depths at planted bulrush plots (**Figure 5-76**) that were substantially higher than target depths for these STAs. These events resulted in depths > 90 cm for 54 days in the bulrush plot in STA-2, Cell 3, 37 days in the plot in STA-3/4, Cell 1A, and 20 days in the plot in STA-1E, Cell 7 (**Figure 5-77**).

The relative success of bulrush plantings at these sites, as indicated by relative culm densities one year after planting, appeared to be correlated with differences in depth regimes at the three plot locations. Highest culm densities, for example, were attained in STA-1E, Cell 7, where high water depths occurred for only a brief time period, while STA-2, Cell 3, had deep water for the longest period of time and the lowest densities of bulrush culms during the last sampling date. However, there were differences in soil characteristics at the three plot locations that also could have led to the differences in the rate in which planted bulrush established and spread. Soils at the bulrush planting site in STA-2, Cell 3, where bulrush plantings were least successful, were very dense and compact (almost peat-like), and were unlike soils in the bulrush plot in STA-3/4, Cell 1A, which consisted of soft muck. The most successful planting site, STA-1E, Cell 7, had a sandy muck soil, which visibly had a higher mineral content than soils at the other two sites.

While it could not be determined if differences in depth regimes and/or soil characteristics (or neither of these conditions) led to the differences in establishment success and subsequent expansion rates of planted bulrush, bulrush did become established at all three sites and thereafter showed a capability of withstanding high depth periods. These preliminary results provide support for continued evaluation of more extensive plantings of bulrush in portions of STA cells where periodic deep water regimes inhibit establishment and/or sustained growth of other EAV species (e.g., cattail). Any future planting efforts should account for the likelihood of high initial (planting) mortality, as indicated by results of this study, but should exploit the potential for high rates of vegetative expansion by established culms. Plantings consisting of numerous, small dispersed clumps with about 50 bulrush culms/150 $m^2$, for example, could be used to potentially establish bulrush over large areas of open water, which could include sufficient topographic variability to simultaneously provide for a more rigorous evaluation of the influence of water depth regimes on the establishment, expansion, and persistence of this species in the STAs.

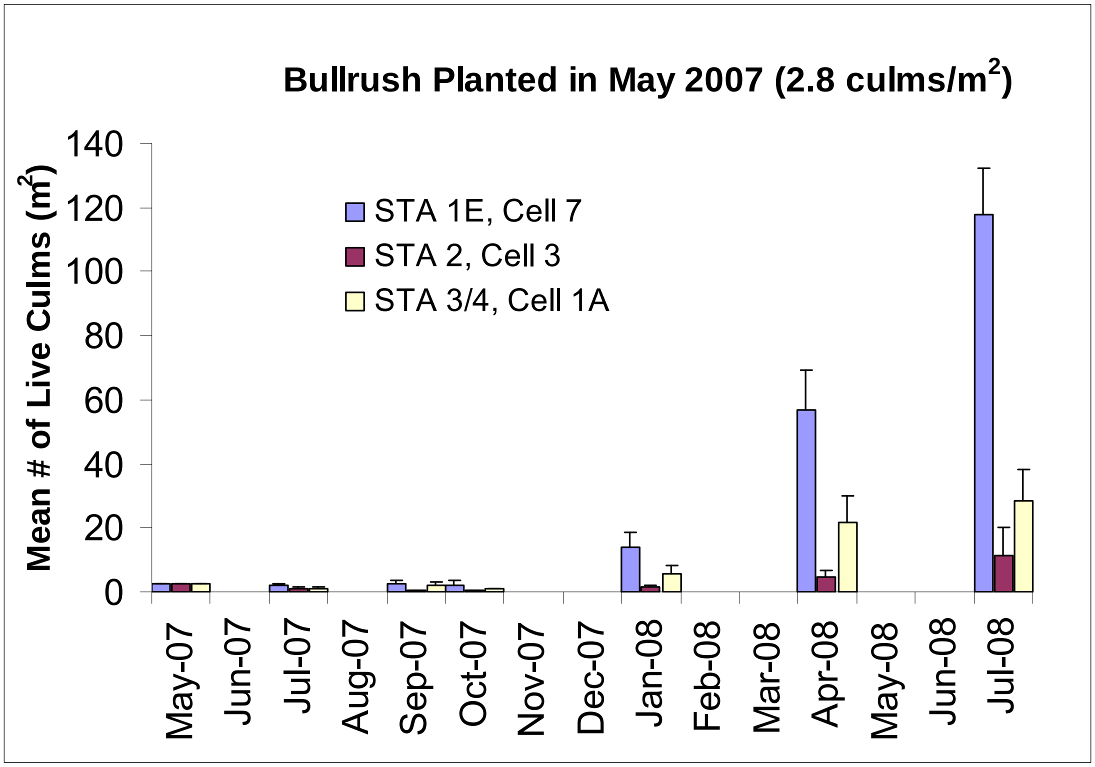



**Figure 5-75.** Post-planting monitoring measurements used to determine the success of the establishing giant bulrush (*Schoenoplectus californicus*) planting effort.

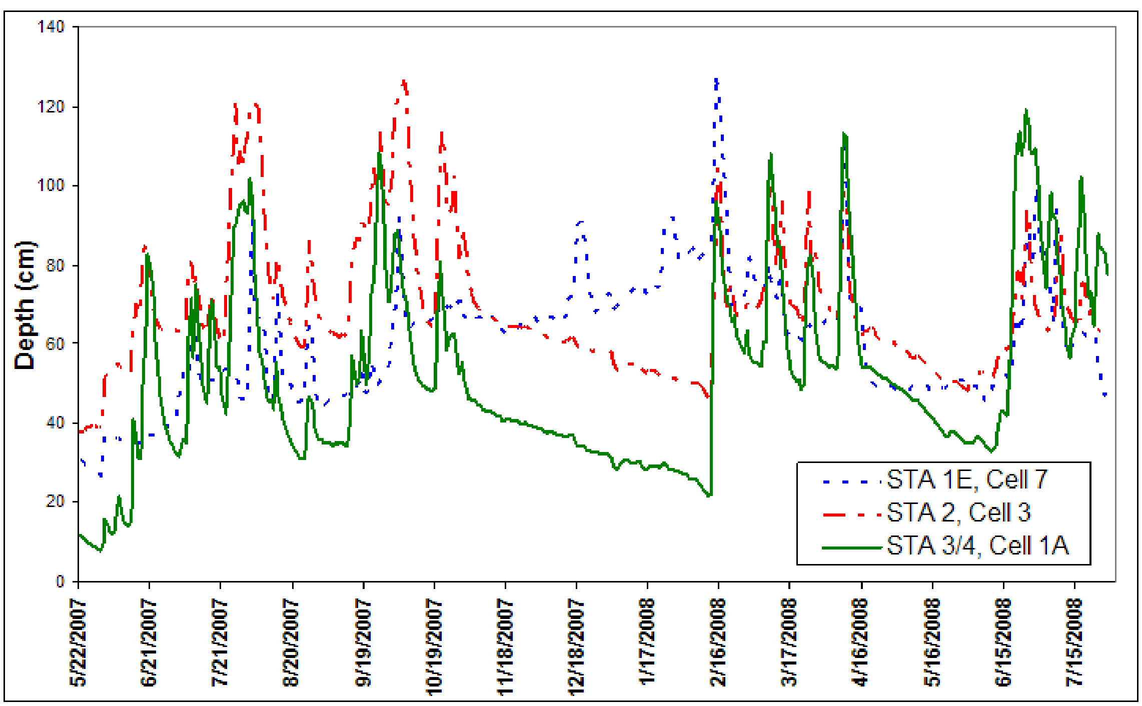



**Figure 5-76.** Water depth regimes measured as part of the bulrush planting study.

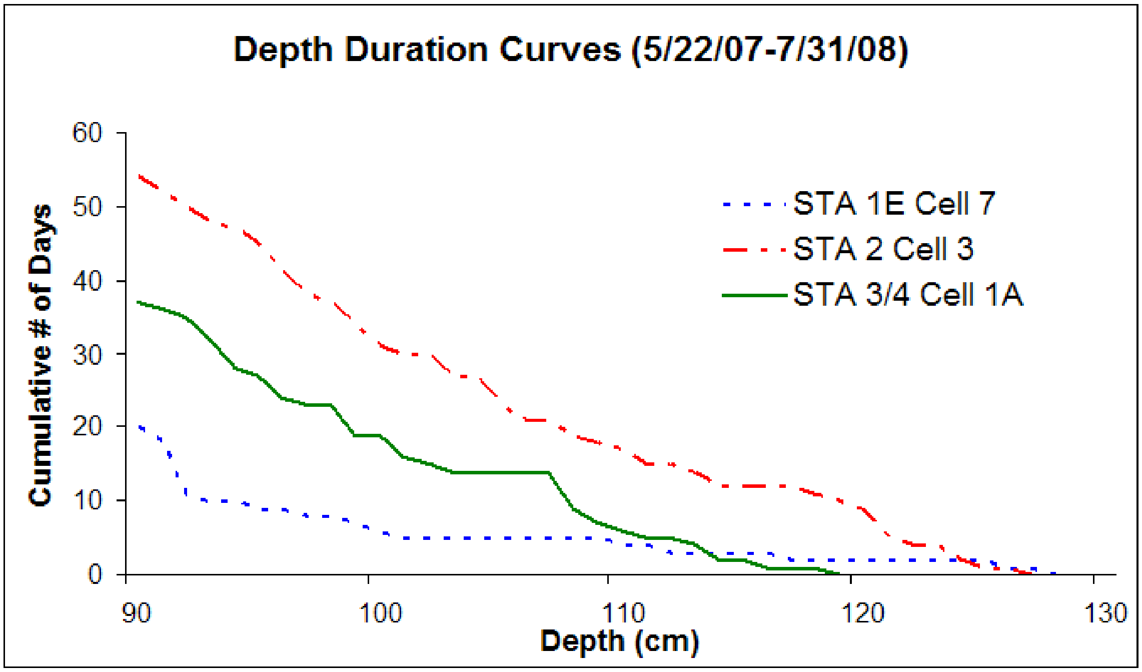



**Figure 5-77.** Water depth duration curves measured to evaluate the success of the bulrush planting study.

## Submerged Aquatic Vegetation Surveys

Submerged aquatic vegetation (SAV), the dominant community in downstream STA cells, are subject to various disturbances, including herbivory, tropical cyclone winds, and excessive loadings of nutrient or particle-laden waters. Reductions in SAV areal coverage can lead to impaired STA performance. Because the coverage and species composition of SAV communities can be detected only sporadically with aerial or satellite images (i.e., when the plants "top out" in the water column), efficient ground-level survey methods must be implemented to assess temporal changes in the spatial distribution of SAV coverage. For this effort, the District annually performs at least one airboat survey in each of the 13 SAV-dominated STA cells. This information will be used to develop relationships between SAV coverage, species type, and cell treatment performance. Additionally, it will help define potential impacts of external perturbations on SAV community health.

As an example, **Figure 5-78** depicts changes in SAV coverage and speciation from 2003–2008 in STA-2, Cell 3, a well-performing STA cell. In 2003, pondweed and Southern naiad were the dominant SAV species, with beds of hydrilla and coontail (*Ceratophyllum demersum)* occurring in the inflow region coverage. Muskgrass was not present in the wetland at this time. Hydrilla began to increase in spatial distribution over time, but the inflow region cover of this plant, along with that of other SAV species, was sharply reduced by Hurricane Wilma in late 2005 (see the May 2006 survey, **Figure 5-78**). With respect to long-term fluctuations in SAV coverage, the dominant changes that have occurred are the gradual decline in pondweed in the cell, and increase in coverage by the non-vascular species, muskgrass. The decline in pondweed is probably related to the gradual soil enrichment of the inflow and mid- regions of the cell, since this species appears to prefer low water column nutrient conditions. Reasons for the gradual expansion of muskgrass are unknown; however, in many South Florida ecosystems, *Chara* acts as a colonizing species, rather than a component of mature SAV stands.

This same monitoring approach has been utilized to characterize temporal changes in SAV coverage in the downstream end SAV cells of STA-1E, one of the newer STAs. A total of 30, 31, and 53 observation sites have been established within Cells 4N, 4S, and 6, respectively (**Figure 5-79**). In March 2006, Southern naiad was the dominant SAV species in Cells 6 and 4N, while hydrilla dominated Cell 4S. Maximum density and coverage for Southern naiad in these cells occurred in August 2006, after which time this species exhibited a gradual decline. By contrast, hydrilla has become the dominant SAV species in all three downstream cells. Coontail is now the second most prominent SAV species in STA-1E, exhibiting fairly widespread coverage in Cell 6.

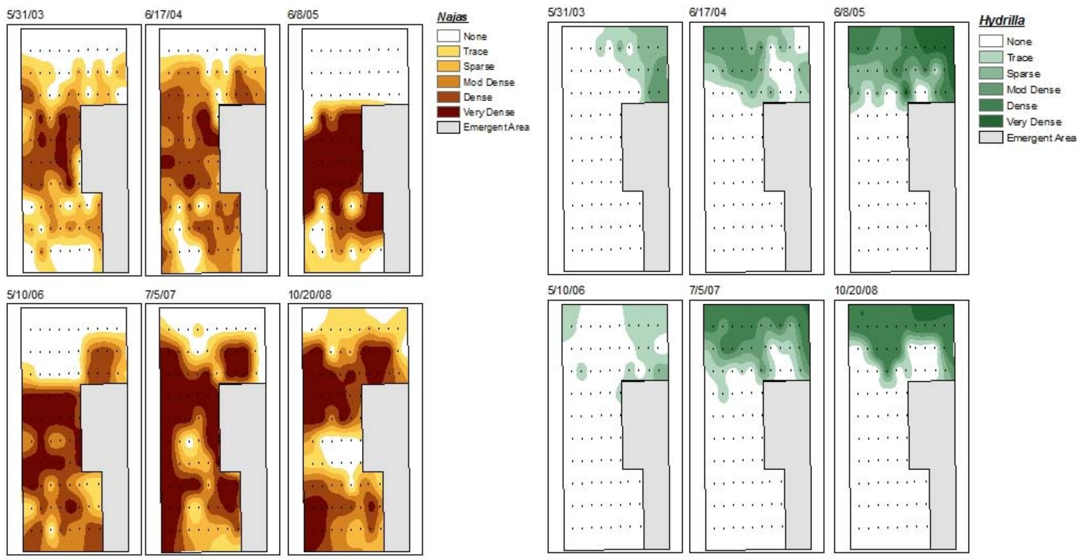



**Figure 5-78.** Changes in STA-2, Cell 3, areal SAV coverage from May 2003 to October 2008. Darker colors represent higher vegetation densities. SAV measurement locations are depicted by the black dots.

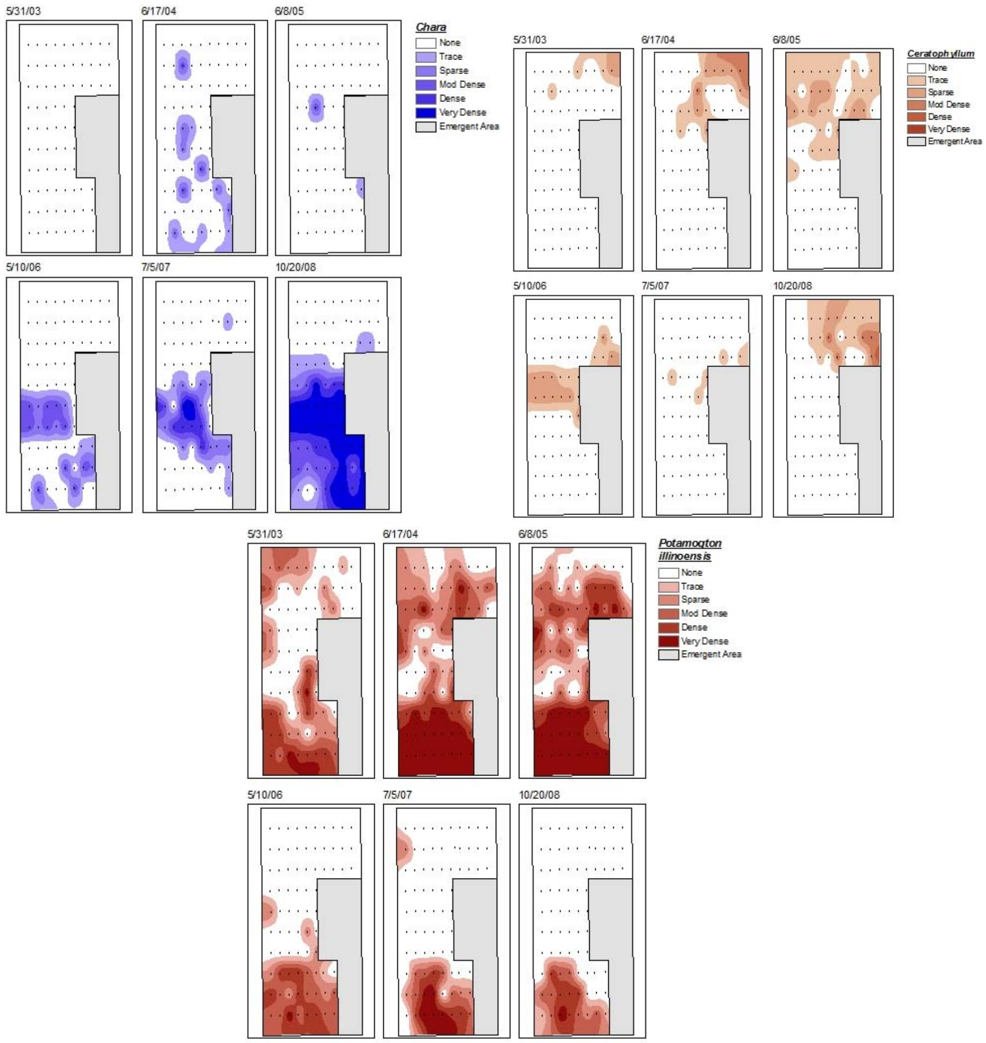



**Figure 5-78.** Continued.

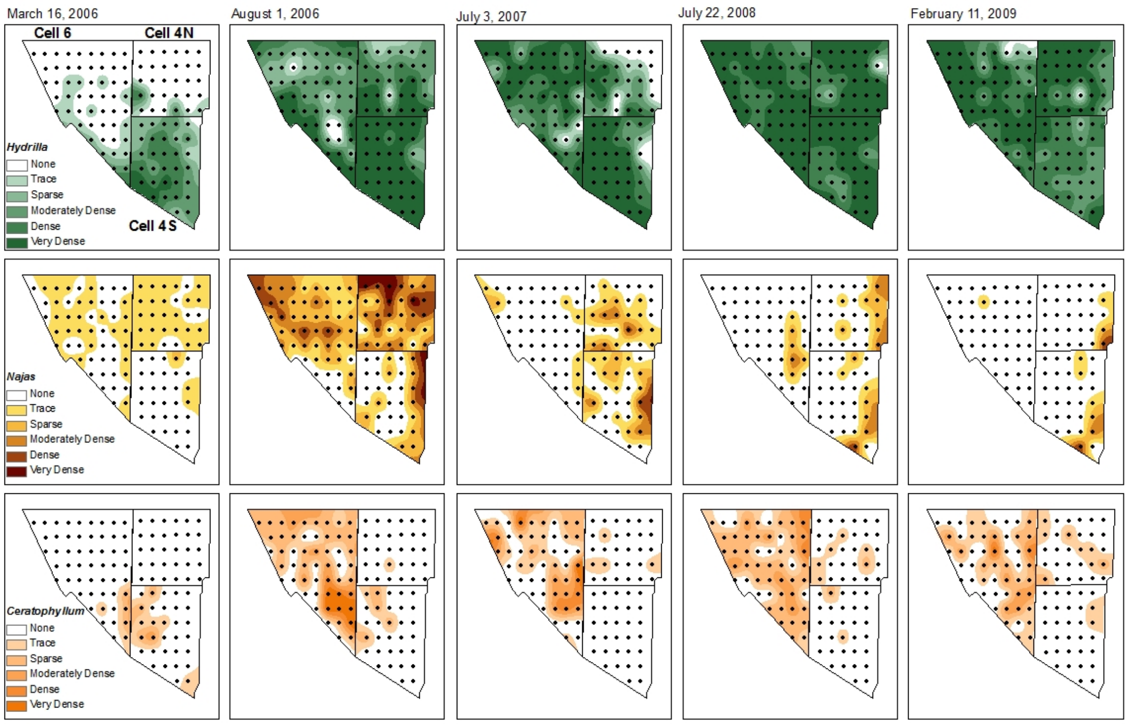



**Figure 5-79.** Changes in SAV cover in STA-1E from March 2006 through February 2009. These schematics depict the downstream cells of the Western (Cell 6) and Central (Cells 4N and 4S) Flow-ways.

## Vegetation Management Strategies

The vegetation management activities in the STAs during WY2009 focused on treating cattails and willow in STA-3/4, Cell 1B (700 acres); grasses and willow in STA-5, Cell 1A; cattails in STA-1W, Cell 1B (100 acres) and Cell 3 (300 acres) and STA-3/4, Cell 2B (200 acres); and willow in STA-5 Cell 1A (343 acres) and STA-6 Cell 3 (74 acres). As part of the vegetation conversion from EAV to SAV, 300 acres of cattails were treated in STA-2, Cell 2. Appendix 5-13 presents the type and amount of herbicide used in WY2009.

## Effects of Vegetation Management Strategies on the Establishment of SAV in STA-1W

A monitoring study was conducted in STA-1W Cell 5B to evaluate efficacy of four vegetation management strategies on the reestablishment of SAV at different sites with rice, sprangletop grass (*Leptochloa fascicularis*), barnyard grass, or miscellaneous dominant plant species (Chen et al., 2009). This treatment cell underwent rehabilitation to mitigate damage done to the vegetation communities after Hurricane Wilma in 2005. As part of the vegetation reestablishment efforts, rice was planted to aid in SAV growth. The vegetation management strategies evaluated in this study include (1) grass detritus left undisturbed, (2) grass detritus removed to allow reestablishment of SAV from the sediment seed bank, (3) grass detritus left undisturbed and healthy SAV transplanted directly on top of the detritus, and (4) grass detritus removed and healthy SAV transplanted directly into the empty water column. The study was conducted from November 2006 to December 2007. It should be noted that during this time period the STAs, including this cell, experienced a two-year drought period which may have affected the outcome of this experiment.

Primary findings from this study are:

- Hydrilla and coontail showed increased coverage from April to December in 2007. In contrast, *Chara* coverage did not significantly change.
- Vegetation management strategies significantly affected coontail areal coverage in stations with different vegetation types. Coontail coverage in harvested stations was higher than in stations with transplanting SAV alone. In sites with miscellaneous dominant plant species, coontail coverage was higher in stations with grass detritus removed and healthy SAV transplanted than in stations with other three types of vegetation.
- Vegetation management strategies did not influence Southern naiad or hydrilla coverage but significantly affected *Chara* coverage. The combination of harvesting and transplanting SAV improved *Chara* establishment.
- Rice-dominated stations generally had higher coontail coverage than sprangletop and barnyard grass-dominated stations.

## Sawgrass Mesocosm Assessment

During 2006–2007, the District continued monitoring two mesocosm experiments related to the sustainability of STA communities. The purpose of this study is to evaluate the P removal performance of sawgrass cultured in mesocosms. In natural stands, sawgrass has been able to achieve outflow concentrations of 10 ppb and has proven resistant to hurricane winds. To date, the mean outflow TP concentrations from sawgrass experiment systems have averaged 23 ppb. When the experiment is terminated, accrued soils in the sawgrass and PSTA mesocosms will be characterized with respect to P content, and stability of the associated P. This project started in

2006 and is expected to end in 2010. Further studies may be needed to validate the results of the mesocosm study at a field-scale.

### Effects of SAV Species on Soil Accrual Rate and Soil Phosphorus Stability

In a mesocosm experiment, the soil accrual rate and soil P stability of *Chara*, pondweed, and Southern naiad (three common SAV species) are being characterized. The mesocosms have been in operation since July 2006, and have received waters with an average inflow TP concentration of 36 ppb, at a mean P loading rate of 0.6 g P/m$^2$/yr. Through May 2009, average outflow TP levels for the *Chara*, Southern naiad, and pondweed mesocosms has been 13, 15 and 18 ppb, respectively. Later in 2009, the accrued soils within the three vegetated systems will be collected and compared with respect to stability of their associated P content. The project started in 2006 and is anticipated to end in late 2009.

### Impacts of Previously Enriched Soils on Outflow Phosphorus Concentrations in a Submerged Aquatic Vegetation Wetland

This mesocosm assessment, which began in 2005, was conducted to determine the effects of previously enriched soils on outflow P quality within SAV-dominated STA flow-ways. The term "previously enriched" refers to soil that was farmed prior to the land being converted to an STA. To date, the SAV communities cultured on native muck and Cell 4 outflow soils have provided the lowest outflow TP concentrations, whereas SAV on previously-enriched Cell 4 inflow soils have provided only a slight reduction from inflow TP levels. At the beginning of the study, porewater SRP levels in Cell 4 inflow sediments were high, but have gradually declined, presumably due to the gradual flux of SRP from the sediments into the water column. This project started in 2005 and is scheduled for completion in late 2009.

### Low-Level Phosphorus Loading Rate Mesocosm Assessment

Several mesocosm assessments are being conducted to characterize and optimize STA phosphorus removal performance. The Low-Level Phosphorus Loading Rate Mesocosm Assessment has been in operation since spring 2004, with the objective of determining if substantial improvements in outflow quality can be achieved by operating STAs at extremely low loading rates. Each treatment consists of a treatment train of two SAV tanks in series, followed by a calcareous periphyton system cultured on limerock. To date, only marginal improvements in outflow TP concentrations (13 versus 12 ppb) have been achieved by providing a 50 percent reduction in loading rates (from 0.51 to 0.25 g P/m$^2$/yr).

### Assessing the Ability of STA Outflows to Support Pristine Everglades Flora

The goal of this study is to determine whether pristine species (e.g., calcareous periphyton and *Utricularia* spp.) can thrive downstream of the STAs at water column phosphorus concentrations in excess of 10 ppb (the TP criterion value for the EPA). Much of the TP in waters discharged from well performing STAs consists of particulate P and dissolved organic P (some of which is not readily bioavailable), and this appears to facilitate growth of the pristine species in STA outflows that do not achieve TP levels as low as 10 ppb. While the best performing STA, STA-3/4, has produced annual outflow TP concentrations ranging from 13 ppb to 23 ppb, some flow paths have achieved short term outflow TP concentrations of 10-12 ppb. This project started in 2004; the end data has yet to be determined and will depend on the utility of findings.

### Potential Water Quality Benefits of a Floating Aquatic Vegetation Inflow Region

FAV commonly occurs in the inflow regions of STA flow-ways and is typically controlled by the District with herbicides. However, because many FAV species exhibit explosive growth as well as rapid assimilation of nutrients, it is hypothesized that FAV communities may actually enhance STA inflow region P removal effectiveness. FAV species are unaffected by the deepwater conditions that can occur in the inflow regions of STA cells during high-flow events. For this project, which started in 2007, test cells at STA-1W are being used to document the P removal effectiveness of FAV versus cattail, and sequential combinations of FAV-cattail, as inflow region communities for STAs. The project started in 2007; the end date has yet to be determined and depends on the utility of findings.

### Optimization of Submerged Aquatic Vegetation Communities

Sequenced communities of EAV followed by SAV, as specified in the Long-Term Plan, have provided effective P removal in many of the STAs. However, SAV communities are susceptible to damage from hurricane winds. The superior P removal performance of SAV communities, however, provides a compelling reason to encourage and maintain SAV beds in the outflow regions of STA flow-ways.

Steps that have been taken in the past three years to increase SAV sustainability include the incorporation of EAV strips perpendicular to flow, and the encouragement of discrete EAV stands within large SAV beds. The District and DB Environmental Laboratories, Inc. are performing a series of investigations to characterize the impacts of EAV presence, and EAV management techniques on water quality and sustainability of SAV beds.

### STA-1W, Cell 5B, Vegetation Strip Status Update

After a series of hurricanes and storms in 2004 and 2005, visual observations showed physical impacts to the SAV communities in most of the STA cells. Hurricane Wilma caused extensive damage to the SAV communities causing them to be uprooted and pushed or “rolled” up onto the surrounding levees (**Figure 5-80**). Damage was typically excessive in the larger cells where wide-open areas exist. Since that time, emergent vegetation strips were planted or allowed to establish in higher grounds, e.g., old farm roads, to serve as buffer against wind effects during storms. This report is an assessment of the condition and performance of these vegetation strips in STA-1W, Cell 5B. Actual performance, as far as wind protection, is difficult to quantify in the field and is beyond the scope of this evaluation. In Cell 5B, four north-south vegetation strips were planted utilizing five common plant species. In STA-1W, SAV cells are dominated by Southern naiad and pondweed, and hydrilla. These species are either non-rooted or weakly rooted, leaving them susceptible to high wind events.

Visual observations in the initial two years from time of planting indicate that all species successfully established and withstood the variable water depths in the cell. After three years, it is evident that fire flag (*Thalia geniculata)* and bulrush appear to be the most successfully established, based on density of establishment and plant condition in the dry and wet seasons. Both species formed very thick vegetation strips ranging from 10 to 50 feet in width and up to 10 feet in height. These two species seem to be the best suited for the creation of vegetation strips.

The three remaining species established only in areas where water depths did not exceed water depths of two feet or more (**Figure 5-83**). Pickerelweed (*Pontederia cordata)* and spikerush (*Eleocharis interstincta)* formed thick vegetation strips in some of the areas but they were limited in stature and therefore probably would not provide the desired performance during high wind events. Duck potato (*Sagittaria lancifolia)* appeared to be in very poor condition and sparse coverage and is therefore considered unsuitable for future vegetation strip creation.

**Figure 5-80:** Photographs of SAV "roll-up" in (A) STA-2, Cell 3, and (B) STA-1W, Cell 5B, following Hurricane Wilma in 2005 (photos by the SFWMD).

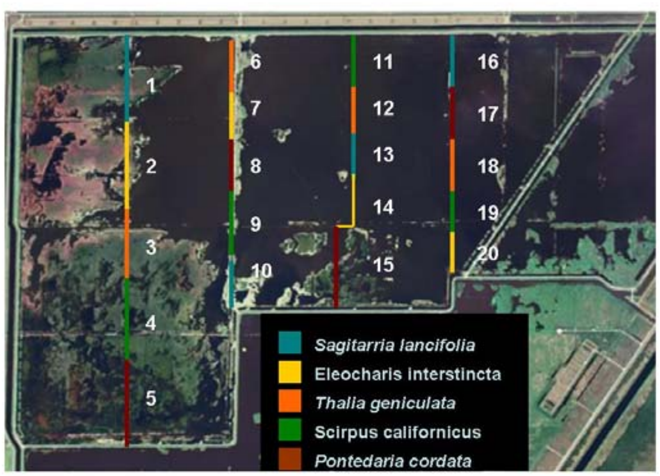



**Figure 5-81:** STA-1W, Cell 5B, 2006 vegetation strip planting map illustrating planting locations for each of the five species used in the creation of the vegetation strips.

In summary, establishment of vegetation strips in STA-1W Cell 5B along the old farm roads was generally successful. Utilizing higher ground, such as old farm roads in establishment of vegetation strips is recommended, especially for duck potato. The species that thrive best in variable water depths were pickerelweed, bulrush, and fire flag form continuous strips through the planted areas. Fire flag and bulrush were able to tolerate variable water depths and persisted even in areas where water depth exceeded two feet for extended periods. Planting of spikerush in areas with variable water depths is not recommended. Due to their limited stature or plant height and therefore less performance during high wind events, planting of duck potato and pickerelweed is also less desirable.

**Figure 5-82:** Photographs of established vegetation strips containing (A) bulrush (*Scirpus californicus*) and (B) fire flag (*Thalia geniculata*) (photos by the SFWMD).

**Figure 5-83:** Photographs of (A) pickerelweed (*Pontederia cordata*), (B) spikerush (*Eleocharis lancifolia*), and (C) duck potato (*Sagittaria lancifolia*) three years after planting (photos by the SFWMD).

## PERIPHYTON-BASED STORMWATER TREATMENT AREA IMPLEMENTATION PROJECT

The Periphyton-dominated Stormwater Treatment Area (PSTA) Implementation Project comprises a 400-acre portion of STA-3/4, Cell 2B, that was isolated by the construction of levees to form an upstream 200-acre cell (Upper SAV Cell) and two adjacent downstream 100 acre cells (Lower SAV and PSTA cells) (**Figure 5-84**). All cells have been managed to promote an SAV community and its associated periphyton through repeated herbicide applications to suppress emergent aquatic plants. The primary difference in the construction of the PSTA versus the SAV cells is that the peat substrate in the PSTA Cell was removed down to caprock level, while the soil in the Upper and Lower SAV cells was not disturbed. Consequently, the floor elevation of the PSTA Cell is approximately 1.8 feet (54 cm) lower than the adjacent SAV cells. Peat was removed from the PSTA Cell because it provided a rooting medium for emergent plants and was a potential source of phosphorus that would flux back into the water column and reduce treatment efficiency. The two 100 cfs (244,658 $m^3$/d) pumps in the project's outflow pump station (G-388) are activated by a float switch and maintain the PSTA Cell at a depth of approximately 1.9 ± 0.25 foot (58 ± 8 cm). Surface inflow to the PSTA Cell through its two inflow gates (G-390A and B) was adjusted to operate this cell at a nominal hydraulic retention time (HRT) of approximately 5 days. The function of the Upper SAV Cell was to provide the SAV component of an emergent aquatic vegetation (Cell 2A) SAV treatment train and deliver low TP concentration water to the Lower SAV and PSTA cells. The original objective of this project was to compare treatment performance, i.e., TP removal, of the PSTA Cell versus the Lower SAV Cell; however, comparison between the two cells is not technically appropriate, as described below. Therefore, the treatment performance of Cell 2B was added to this year's report to provide another point of reference to compare against the PSTA Cell. The history of the PSTA Project, design considerations, project layout, and the project's Operating Plan are discussed in previous SFERs.

Water quality was monitored at all seven water control structures in the PSTA Project during WY2009 (**Figure 5-84**). Water temperature, dissolved oxygen, conductivity, and pH were measured in situ in conjunction with the collection of water samples. SRP, TP, and total dissolved phosphorus (TDP) were monitored weekly; nitrite + nitrate-nitrogen, ammonium-nitrogen, TKN, calcium, chloride, and TSS were monitored monthly; and sodium, potassium, magnesium, sulfate, hardness, and alkalinity were monitored quarterly. Samples were collected at the upstream side of each structure. TP was collected with both grab and auto-sampler samples; all other parameters were collected only with grab samples. A quarterly sampling program was initiated in October 2008 to document the pattern of downstream changes in TP, TDP, and SRP concentrations within the PSTA Cell; grab samples were collected at paired locations along two longitudinal transects in the cell.

The SAV community in the PSTA Project was surveyed on two dates during WY2009 (August 2008 and February 2009) using a geo-referenced grid of regularly spaced sampling stations in each cell: 104 sites in the Upper SAV Cell and 48 sites in both the Lower SAV and PSTA cells. The areal coverage of all SAV taxa combined and each SAV taxon individually at all sites was categorized as low (up to one-third coverage), medium (one-third to two-thirds coverage), or high (> two-thirds coverage).

### Operations and Performance

South Florida experienced drought conditions during the last three water years, which reduced stormwater runoff into STA-3/4, especially during each year's dry season (winter and spring). The need to maintain minimum water levels in the STA necessitated that all outflow structures be closed for much of each dry season. These conservation efforts, in turn, curtailed operation of the PSTA Project. The dates when there was sufficient water in the STA to operate the PSTA Cell define the PSTA Project's "operational period" for that water year. The operational period was from June–October (115 d) in WY2007, July–December (161 d) in WY2008, and July–December (168 d) in WY2009 (see **Figure 5-85A**). G-388 was shut down at the end of each operational period to help conserve water in the STA. The discussion of PSTA Project operation and data analyses presented below are limited to the operational period in each water year unless noted otherwise.

The PSTA Cell inflow gates (G-390A and B; **Figure 5-84**) were not operable during WY2007, therefore no surface water entered the cell. Water discharged from G-388 during this year was primarily groundwater seepage from the adjacent Upper and Lower SAV cells (**Figure 5-85**, Panel A). The G-390A and B gates were operated in WY2008 and WY2009; G-388 discharge in these years included surface water inflow plus seepage. Monthly PSTA Cell outflow during WY2008 and WY2009 was 17 to 115 percent greater than the corresponding inflow. This relationship (outflow > inflow) is reflected in the monthly inflow-outflow regression line, which had a slope greater than one (slope = 1.48) (**Figure 5-85**, Panel B). Mean monthly outflow exceeded inflow during WY2008 and WY2009 by 56 percent and 57 percent, respectively.

The original intent of this study was to operate the PSTA and Lower SAV cells such that each cell received half of the inflow to the Upper SAV Cell (i.e., equal hydraulic loading to each cell) to facilitate a comparison of the treatment efficiency of the PSTA versus SAV technologies. Unfortunately, this plan proved unworkable and the two cells have been operated very differently. Inflow to the PSTA Cell was regulated to achieve a target HRT, while inflow to the Upper and Lower SAV cells was dependent upon storm events that delivered water to STA-3/4. The PSTA Cell had surface-water hydraulic loading rates (HLRs) during the last two years (2.5 and 2.8 in/d) substantially lower than HLRs in the Lower SAV Cell (5.1 and 8.5 in/d) but higher than those for the Cell 2B (0.4 and 1.6 in/d). Nominal HRTs calculated for the PSTA Cell in WY2008 and WY2009 (5.9 and 5.2 d, respectively) were very close to the target of 5 d (**Table 5-35**).

Transect sampling has revealed the existence of well-defined downstream P gradients in the STA treatment cells (e.g., see Figure 5-27 in the 2009 SFER). However, similar gradients were not evident in the PSTA Cell for TP or SRP (**Figure 5-86**). A small gradient was observed for TDP. Note that most of the SRP samples were at the method detection limit of 2 ppb.

Summary statistics for water quality parameters monitored at all PSTA Project sampling stations throughout WY2009 and during the WY2009 operational period are presented in Appendix 5-11. Based on comparison of flow-weighted mean (FWM) outflow TP concentrations, the PSTA Cell exhibited better treatment performance than either the Lower SAV Cell or Cell 2B in each water year (**Table 5-35**). The PSTA Cell had a FMW outflow TP concentration of 8 ppb in WY2009; all monthly outflow FWM TP concentrations during the year were less than 10 ppb (**Figure 5-85**, Panel C). This performance was achieved at a surface-water TP loading rate of 0.368 g/m$^2$/yr. In contrast, the PSTA Cell outflow FWM TP concentration and surface-water TP loading rate in WY2008 were 12 ppb and 0.630 g/m$^2$/yr, respectively. Monthly outflow FMW TP concentrations exhibited a moderate linear relationship ($r^2$ = 0.50) with monthly inflow concentrations (**Figure 5-85**, Panel D).

SAV was widespread throughout the PSTA Project in WY2009 (**Figure 5-87**). Six SAV taxa were observed over the two sampling dates: hydrilla, muskgrass, pondweed, red ludwigia (*Ludwigia repens*), Southern naiad, and spiny naiad (*Najas marinas*) (Appendix 5-12) compared to 11 taxa found in WY2007 and 10 taxa in WY20008. The most frequently encountered taxa in WY2009 were muskgrass and southern naiad as in previous years. It is thought to be of no particular importance that fewer uncommon taxa were recorded in WY2009 compared to previous years. The distribution of hydrilla continued to be restricted primarily to the Upper SAV Cell.

The PSTA Project monitoring program will continue for the remainder of FY2009, and a report summarizing operations and performance since inception is planned to be prepared in FY2010. This report will include a summary of any findings of the tracer project conducted in the PSTA Cell in FY2009 as well as updated costs and design considerations associated with the construction and operation of PSTA treatment cells. It is anticipated that the information in the report will assist in decision-making about further implementation of PSTA treatment technology features.

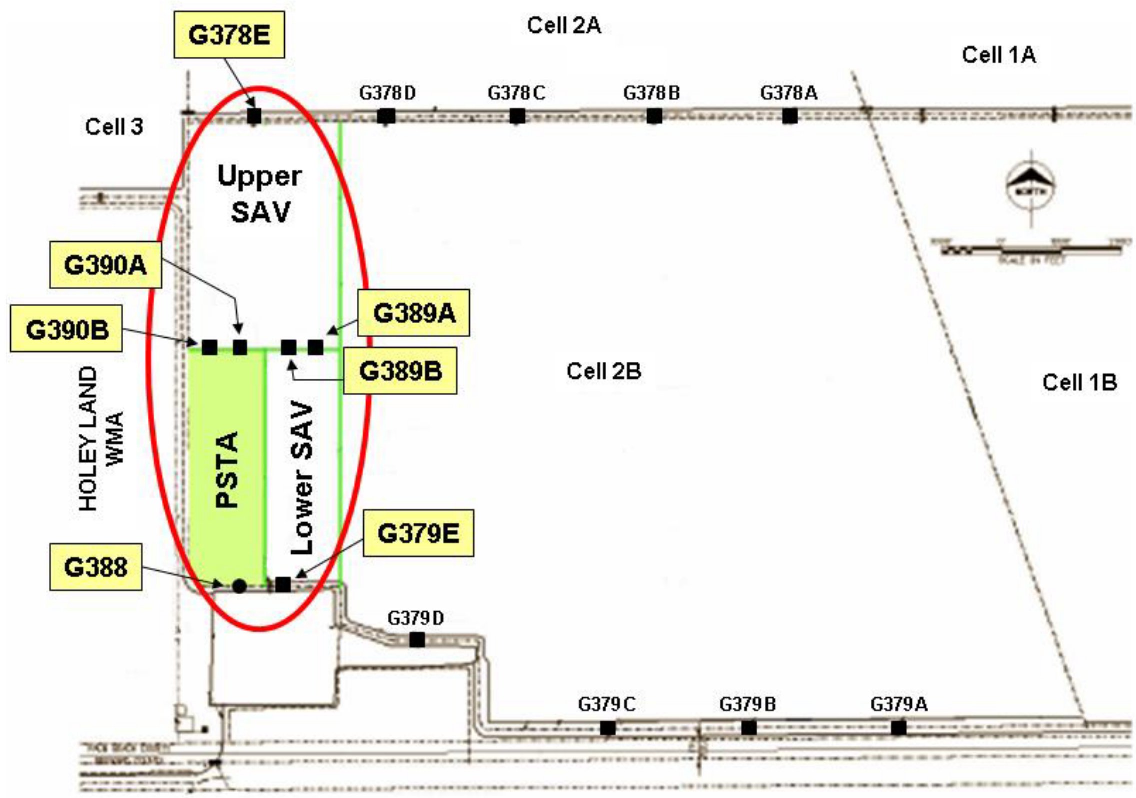



**Figure 5-84.** Map of the Periphyton-based Stormwater Treatment Area (PSTA) Implementation Project showing the location of water control structures, the Upper SAV Cell, the Lower SAV Cell, and the PSTA Cell. The adjacent Cell 2B and its water control structures are also shown.

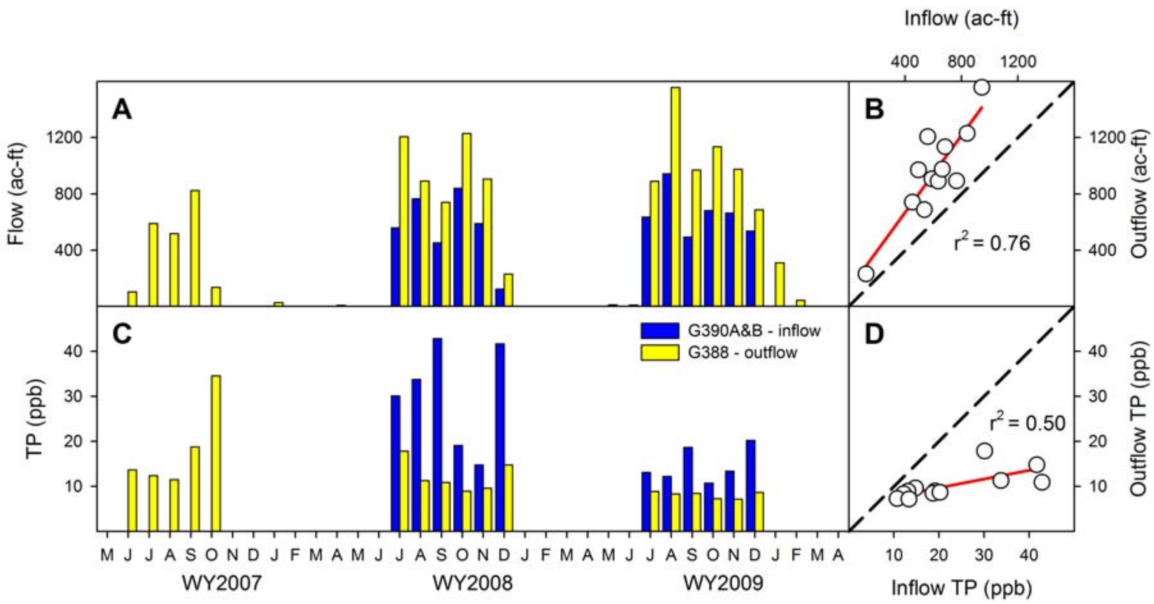



**Figure 5-85.** Monthly surface flows and flow-weighted mean TP concentrations in the PSTA Cell for WY2007 to WY2009. Panels A and C: inflow and outflow time-series showing operational periods. Panels B and D: bi-plots of inflow versus outflow; dashed lines represent 1:1 relationships. The inflow water control structures (G-390A and B) were not operational in WY2007. [Note: TP concentrations associated with small flows recorded between operational periods are not shown in Panels C and D.]

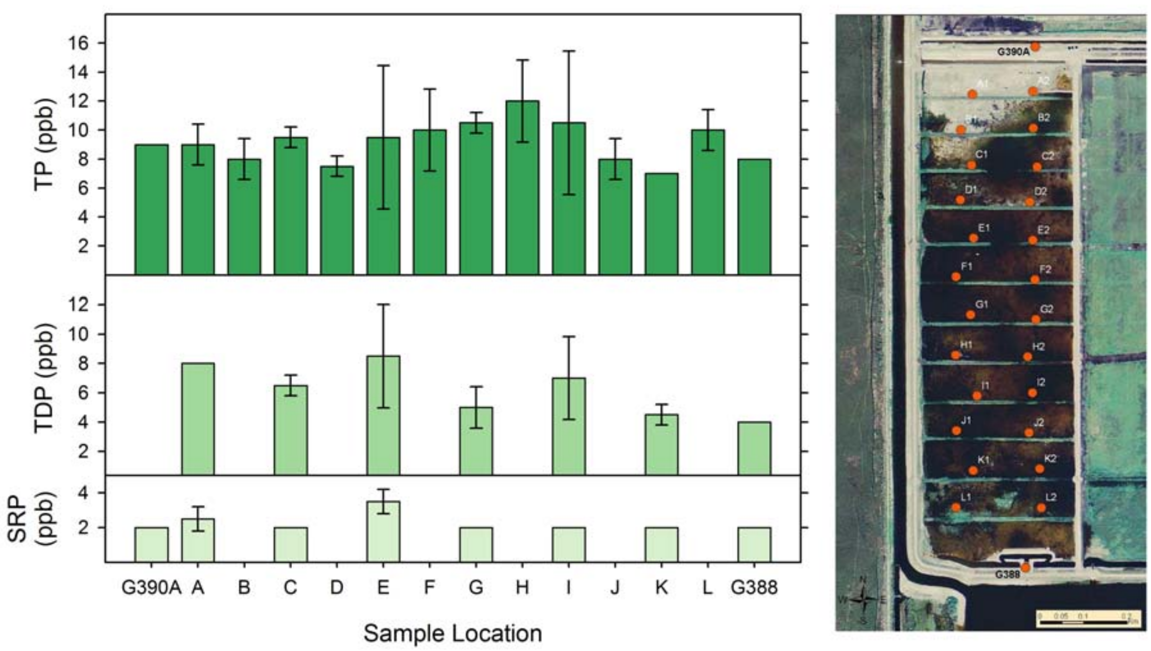



**Figure 5-86.** Concentration of TP, TDP, and SRP in grab samples collected along two longitudinal transects in the PSTA Cell, October 2008. Bars = mean values; error bars = ± 1 standard deviation. Map shows sampling locations in the PSTA Cell.

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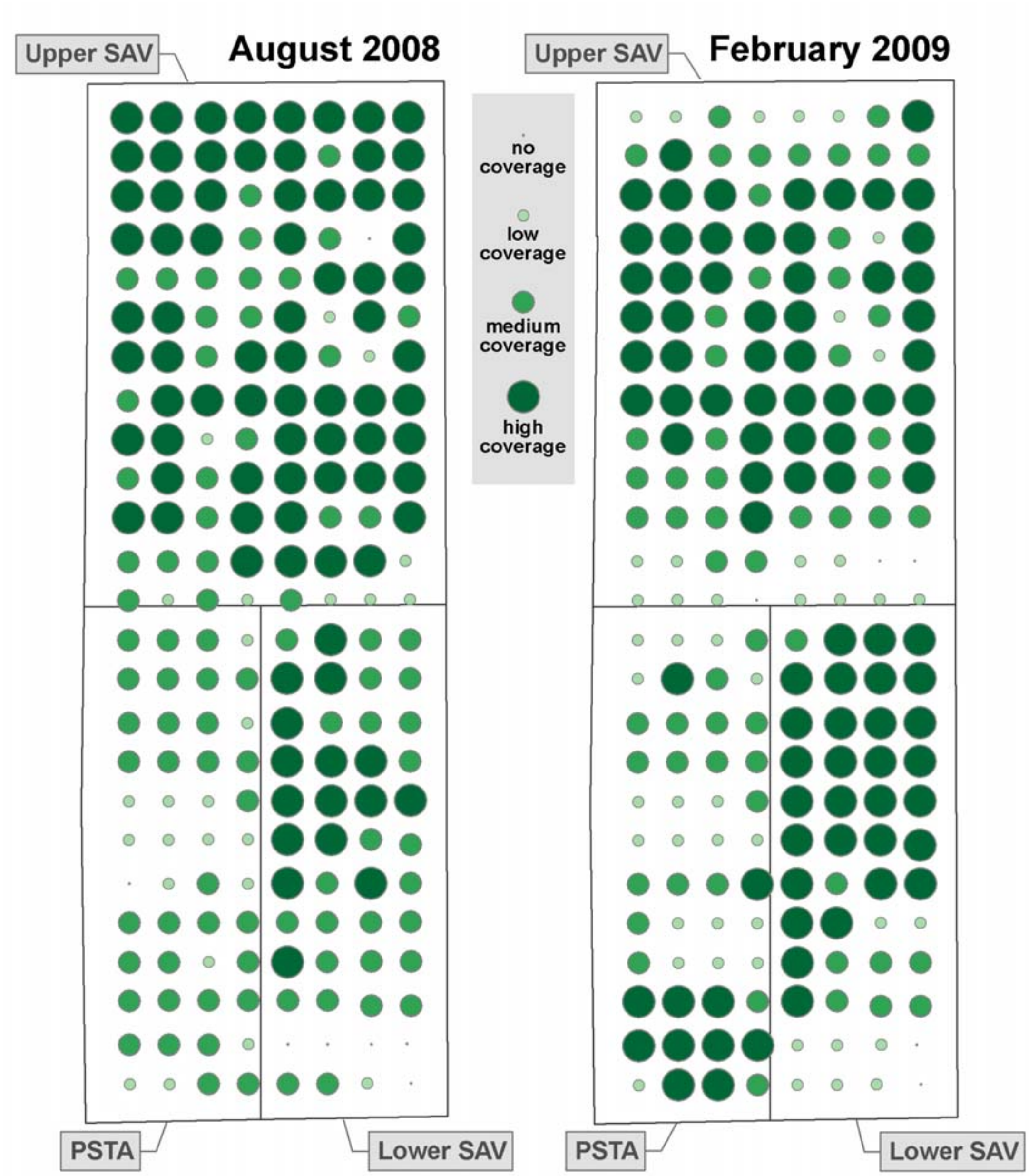


**Figure 5-87.** Distribution of SAV in the Upper SAV, Lower SAV, and PSTA cells during August 2008 and February 2009. [Note: each closed circle represents the total areal coverage level of all SAV taxa at that site. Dots indicate sites without SAV. The depiction of cell boundaries is based on the PSTA Project's Geographic Information Systems shapefile.]

**Table 5-35.** Hydraulic characteristics and treatment performance of the PSTA Cell, the Lower SAV Cell, and STA-3/4, Cell 2B, during the WY2007, WY2008, and WY2009 PSTA Project operational periods.

| | WY2007[1] | | | WY2008[2] | | | WY2009[3] | | |
|---|---|---|---|---|---|---|---|---|---|
| | PSTA | Lower SAV4 | Cell 2B | PSTA | Lower SAV5 | Cell 2B5 | PSTA | Lower SAV5 | Cell 2B5 |
| Surface-water hydraulic loading (in/d) | 0 | -- | 4.1 | 2.5 | 5.1 | 0.4 | 2.8 | 8.5 | 1.6 |
| Nominal hydraulic retention time (d) | 10.1 | -- | 4.7 | 5.9 | 8.7 | 33.8 | 5.2 | 1.3 | 10.3 |
| Mean surface-water inflow (cfs) | 0 | -- | 431 | 10 | 23 | 46 | 12 | 38 | 166 |
| Mean surface-water outflow (cfs) | 9 | -- | 530 | 16 | 7 | 63 | 18 | 54 | 243 |
| Total surface-water inflow (ac-ft) | 0 | -- | 90714 | 3326 | 7388 | 14767 | 3953 | 12828 | 55245 |
| Total surface-water outflow (ac-ft) | 2162 | -- | 111365 | 5201 | 2096 | 20103 | 6102 | 18106 | 80871 |
| Surface inflow flow-weighted mean TP (ppb)[6] | -- | -- | 33 (8) | 28 (4) | 22 (1) | 26 (5) | 14 (1) | 21 (9) | 15 (1) |
| Surface outflow flow-weighted mean TP (ppb)[6] | 16 (3) | -- | 20 (1) | 12 (2) | 32 (6) | 20 (3) | 8 (<1) | 13 (1) | 12 (1) |
| Surface-water areal TP loading ($g/m^2/yr$) | 0 | -- | 1.270 | 0.630 | 1.030 | 0.109 | 0.368 | 1.674 | 0.219 |
| TP removal coefficient - k (m/yr)[7] | -- | -- | 22.0 | 24.2 | -11.5 | 0.9 | 18.8 | 50.1 | 4.7 |

Notes: 1 cm ≈ 0.39 in; 1 cfs ≈ 2,447 $m^3$/d or 1.98 ac-ft/d; 1 ac-ft ≈ 1,233.5 $m^3$; 1 ppb = 1 mg/L

[1] WY2007 operational period from June 17 to October 9, 2006 = 115 days
[2] WY2008 operational period from July 5 to December 12, 2007 = 161 days
[3] WY2009 operational period from July 9 to December 23, 2008 = 168 days
[4] The Lower SAV Cell was not operated in WY2007
[5] Calculations based only positive flow through the water control structures
[6] Values reported as mean (standard error)
[7] $k = \ln(TP_{in}/TP_{out}) \times [((Vol_{in}+Vol_{out})/2)/\text{Wetland Surface Area}] \times (365.25/d)$; calculation based only on surface flows

# WILDLIFE AND AVIAN PROTECTION

The Avian Protection Plan (APP) for Black-necked Stilts and Burrowing Owls nesting in the Everglades Agricultural Area Stormwater Treatment Areas discussed in the 2008 SFER – Volume I, Chapter 5, has been finalized and accepted by the U.S. Fish and Wildlife Service (USFWS). This plan was implemented during WY2009, and protective measures underlined in the plan were taken during this season.

This APP is unconventional in that it has been developed to help manage the operation of constructed treatment wetlands, i.e., the STAs that already provide important benefits to migratory birds compared to the previous land use (agriculture). This plan outlines actions intended to minimize harmful impacts to migratory birds and nests due to operation of the STAs. Results of this year's STAs bird surveys are presented in this section.

During WY2009, the District also continued a study to evaluate and quantify the environmental lift of the STAs on avifauna community. This study, which is being conducted jointly by Florida Atlantic University and the University of Florida, Institute of Food and Agricultural Services (UF-IFAS) under contract to the District and Everglades Agricultural Area Environmental Protection District (EAA EPD), involves scientific evaluation of the bird population, their prey, and habitat among three different habitat categories: agricultural, cropland, natural marsh, and the STAs. Initial results indicate that the STAs create significant environmental lift.

The District in cooperation with the USFWS developed the APP for the existing STAs and their expansions focusing on black-necked stilts (*Himantopus mexicanus*) and burrowing owls (*Athene cunicularia floridana*). The APP characterizes the risk to these species from STA construction, operation start-up, drought conditions operations, routine maintenance, and enhancement activities.

## Burrowing Owls

No burrowing owl nests were found in the STAs during this survey season.

## Black-necked Stilts

Through implementation of the APP guidelines and proactive field operations, a majority of observable nesting birds exhibited a successful breeding season. Standardized survey and information-sharing methods were utilized, and operational procedures related to levee and canal maintenance were implemented to reduce impacts to ground-nesting birds within the STAs.

Increased nesting of black-necked stilts in WY2009 occurred due to an extended drought that resulted in low water levels and exposed bottom sediments in the STAs, which increased available nesting habitat. During WY2008, a total of 191 nests were observed compared to a total of 873 during WY2009 (Appendix 5-14, Table 1). During the heavy rains beginning mid-May, the District was able to manage water levels and minimize flooding of locations where the greatest numbers of nests were present. It is assumed that some nests were flooded as a result of the rain events and the need to provide upstream flood protection based on the lower number of nests recorded during the spot check surveys after the storms.

On March 24 and 25, 2009, preliminary levee surveys were conducted to record the status of nesting of black-necked stilts in the STAs. At this time, field staff noted increased activity of the birds flying and foraging in STA-1E cells 4N, 4S; a few birds were spotted in STA-2, while the remaining STAs did not have any black-necked stilts that were visible from the levees.

In mid-April, surveys determined the onset of the black-necked stilt breeding season. Per the APP, black-necked stilts were the focus of the surveys as they are an abundant and conservative indicator species for ground-nesting birds in the STAs. Additionally, black-necked stilts nest directly on the ground, often close to the water's edge. Nest sites are vulnerable to any increase in water level, more so than other ground-nesting species that select sites farther upslope or in standing vegetation, and STA operating strategies are designed to minimize impacts to the sites.

Internal black-necked stilt nest surveys of treatment cells were performed from the levee (levee surveys) by field personnel from BEM Systems, Inc. Levee surveys represent a resourceful way to observe a large area to obtain useful information regarding the potential number of nests within a treatment cell. Two different types of levee surveys were executed based on the type of information needed to make operational decisions:

- ***Monthly.*** This survey was performed every 30 days from the start of the breeding season; all treatment cells were surveyed to provide baseline nesting information and the basis for operational decisions throughout the season.
- ***Spot-check.*** This survey was performed on an as-needed basis depending on water conditions. Inspections were done on specific nest locations previously recorded, and/or treatment cells of operational interest; nest numbers in cells not surveyed are assumed to remain as previously observed.

Black-necked stilt survey information was obtained using binoculars [10 x 50 millimeter (mm)] or a spotting scope (20-60 x 80 mm). A hand-held Global Positioning System unit provided latitude and longitude of observer location on the levee where nests were detected inside of a treatment cell. Distance was measured with a rangefinder (6 x 216.0°). Information including coordinates of observer, number and distance of nests, observations, and observer initials were recorded in the field using an Access database (Appendix 5-14, Figure 1). Once the survey was completed, data were sent to the District via electronic mail for analysis and report generation. Standardized reports were used to inform District staff of the location of black-necked stilt nests and the number of nests by flow-way and treatment cell (Appendix 5-14, Figure 2). Reports regarding black-necked stilt nest activity and the resulting activity restrictions within the STAs were distributed by email internally and to the USFWS, and by installing signage in the field at nesting areas.

### *Modification of Operational Procedures and Levee and Canal Maintenance*

Adjustments to operational and mechanical procedures were developed in accordance with the APP to reduce impacts to ground-nesting birds within the STAs. Operational adjustments were typically implemented on a case-by-case basis and were based on stilt nesting activity and available flow alternatives. Mowing and grading schedules, as part of levee and canal maintenance, were adapted to occur annually before April or after July, which is outside of the black-necked stilt breeding season. The mowing schedule is based on the species observed nesting in the STAs.

WY2009 surveys indicated that there were only two identified species of ground nesters, i.e. the black-necked stilt and the killdeer (*Charadruis vociferous*), that nest on the levee roads and slopes in the STAs. While the mowing schedule within the STAs is modified based on the black-necked stilt's breeding season, it also includes the killdeer's breeding season. Both species start nesting on levee roads between the months of April and May and have a similar gestation period of 20 to 30 days. Modifications to operations and maintenance within the STAs are presented in **Table 5-36**.

**Table 5-36.** Modified operational and levee and canal maintenance activities implemented during the 2008 black-necked stilt breeding season.

| STA | Type of Action | Date Implemented | Impact Reduction of Ground Nesters Description of Action |
|---|---|---|---|
| All | Operational | 12/9/08 – held throughout the season when possible | Increased the water depth in SAV cells by 0.5 ft from the normal target stage (typically 1.25 ft) in response to predicted drought impacts. |
| All | Operational | Throughout breeding season | Utilized flow-ways to avoid and/or minimize nest impacts in accordance with the Avian Protection Plan. |
| All | Maintenance | Throughout breeding season | Modified mowing and grading schedule to reduce impacts to ground nesters and young on levee roads and embankments. |
| **Operation Changes to Individual STAs** | | | |
| 1W | Operational | Throughout breeding season | Closed levee road to vehicular traffic between Cells 2A and 2B due to high number of stilt nests. |

### *Status of the 2009 Black-Necked Stilt Breeding Season*

The 2009 breeding season surveys began in mid-April, with the earliest nests observed on April 15-17, 2009, in STA-1E, Cells 3, 4N, and 4S; STA-1W, Cell 2B; and STA-3/4, Cell 1B. Monthly surveys were implemented from May 11-15, 2009, and were again performed from June 15-19, 2009. Spot check surveys were performed when needed depending on the water conditions. Most nests were inactive by the June monthly survey, with the exception of STA-5 Cell 1A, where 7 nests were found during the June survey. The nesting season was finished in July 9, 2009. Previous nesting surveys done in 2006–2008 also indicated that peak-breeding season began in early May and extended into late June or early July. This suggests that the black-necked stilt-nesting season remained relatively consistent despite changes in environmental conditions.

There were 873 black-necked stilt nests observed via levee surveys during the 2009 breeding season, compared to 191 during the 2008 season (Appendix 5-14, Table 1), with the highest number found in STA-1W (360 nests), followed by STA-2 (237 nests) (Appendix 5-14, Table 2). The District was able to manage water levels and prevent flooding of next locations in the flow-ways with the most nests, however, it is assumed that some nests were flooded in STA-2, Cell 4, and STA-1W, Cell 2B, due to heavy rains in mid-May, which was evident in the lower count of nests recorded during the spot check surveys in these areas after the rain events (Appendix 5-14, Table 2).

## RECREATIONAL FACILITIES AND ACTIVITIES

Over this past year, one additional public access site was opened in the STAs, and one boardwalk designed specifically to enhance recreation opportunities for disabled people was constructed. The public access site has several "green" elements and is located at the southeast corner of STA-3/4. The boardwalk is located in STA-5 and is accessible to hunters and participants of bird-watching tours.

The STA-3/4 southeast recreational facility opened in February 2009. This facility includes a four-mile trail provided for hiking, biking, and enjoying wildlife. The trail goes past the different types of vegetation cells in the STA. Fishing from the bank is allowed in the waters outside the treatment footprint of the STA. The recreational site incorporates "green technology" because it includes the use of a dry vault composting toilet instead of a septic field that has the potential to seep nutrients into the marsh. In addition, a solar-powered fan is used in the bathroom to circulate air, and the automated gates at the front entrances are solar-powered. The parking area has a shade shelter with interpretive signs explaining the functions of the STA and animals that can be seen in the area.

In STA-5, a customized boardwalk was constructed to enhance recreation opportunities for the public including the disabled (see **Figure 5-88**). The boardwalk which was built 100 yards into the STA has cutouts in the railing that allow people in wheelchairs to see the marsh in a less obstructed manner. The end of the boardwalk is closer to the water and has a 10 foot by 10 foot platform with lowered railings to accommodate a person in a wheelchair or in a seated position while shooting a firearm during waterfowl hunting. The boardwalk is accessible to participants in the bird-watching tours conducted by the Hendry-Glades Audubon Society and the duck hunting conducted by the Florida Fish and Game Conservation Commission (FWC).


**Figure 5-88.** Bird watching on the STA-5 boardwalk (photo by the SFWMD).

### Hunting

The STA hunting program is coordinated through the FWC, and hunts are closely coordinated with STA staff. The STAs host alligator and waterfowl hunting quota hunts. Many precautions have been put in place for the STA hunting program and these have become part of the FWC rules as the program has evolved. Hunting is limited to weekend days to coordinate with the ongoing management of the STAs. The high quality of the hunts and the limited opportunities through the permit process encourage high compliance with the additional rules. Unlike traditional alligator (*Alligator mississippiensis*) hunting, motorized boats are not allowed in the STAs however canoes are allowed to be used by the hunters.

Alligator hunting took place in STA-1W and STA-5 in 2008. Alligator hunts in the STAs are managed by the FWC, and the season traditionally runs from mid-August to November 1$^{st}$. The alligator hunt permit numbers are determined by FWC to be sustainable harvest quantities. There were 100 and 50 permits issued for STA-1W and STA-5, respectively, and each permit allowed two alligators to be harvested. There were 133 alligators harvested from STA-1W and 61 from STA-5.

The STAs contain areas of open water and SAV, which provide ideal habitat for waterfowl. The FWC also coordinates the waterfowl hunting program. STA-5 opened for duck hunting as an experiment in 2002, with 25 permits issued per hunt day. Because of its popularity and no apparent impact to the functioning of the treatment areas, the hunting program was expanded to include the other STAs. STA-1W, STA-2, STA-3/4, and STA-5 were open for hunting in the 2008–2009 season. The waterfowl season involves migratory birds, and the bag limits are determined by the FWC with the federal government. Hunting was permitted on one weekend day per STA during the 2008–2009 waterfowl hunting season, for a total of 11 hunt days (including one hunt for youths) from mid-November to the first week of February. The hunting program brought 5,712 hunters who bagged 22,714 waterfowl.

### Bird-watching Program

The public access sites at the STAs offer substantial bird-watching opportunities. Organized bird-watching tours are conducted by Hendry-Glades Audubon Society at STA-5. Birding tours have been extremely popular in the birding community with participants commonly spending the night at local hotels to facilitate the tour. The diversity of birds has made STA-5 a destination for Lifetime sightings. In addition to the diversity, birders are drawn to abundance of a number of species. The Audubon Society conducts regularly scheduled bird counts at STA-5 and also STA-1W.

### Other Activities

STA-1E, STA-1W, and STA-3/4 are open to the public Friday through Monday. These sites are open daylight hours and the areas open to the public start at the public access site. Each site has a dry vault toilet and a shade shelter with information about the wildlife and the project. The STAs provide excellent opportunities for wildlife viewing, whether hiking, or biking. Fishing is allowed in the external canals of the STAs. STA-3/4 has a motor boat ramp that leads to 27 miles of canals with trophy-size bass. STA-1E allows catch and release fishing in the internal cells of the STA. The guided bird-watching tour at STA-1E has been discontinued as birding enthusiasts can now access the area on their own. However, the guided bird-watching tour at STA-5 will continue to be conducted by volunteer members of Hendry-Glades Audubon Society.

# STATUS OF OTHER LONG-TERM PLAN PROJECTS

## COMPARTMENT B AND COMPARTMENT C BUILD-OUT STATUS

The Compartment B Build-out Project is located in Palm Beach County, west and south of the existing boundaries of STA-2 (**Figure 5-1**). This project will enhance the performance of STA-2 by creating additional wetland treatment area. Construction of Compartment B Build-out started in FY2009. The project is expected to be flow-capable by the end of 2010 and all construction will be completed by the end of 2011. The EFA permit for the project requires modifying the existing STA-2 discharge locations. These modifications are currently in design.

The Compartment C Build-out Project, located in Hendry County between the existing boundaries of STA-5 and STA-6, will expand the size and enhance the performance of these STAs by creating additional wetland treatment area. Construction of Compartment C Build-out, started in FY2009 (**Figure 5-1**). The project is expected to be flow-capable by the end of 2010 and all construction will be completed by end of 2011.

## HYDROLOGIC AND HYDRAULIC ASSESSMENT AND INTERNAL MEASUREMENTS

No activities were completed for this project in FY2009.

## ECP OPERATIONS MONITORING PROJECT

The objective of the ECP Operations Monitoring Project is to collect water quality samples and monitor flow at inflow and outflow locations of all treatment cells within the STAs that are not specified as compliance sampling locations by the STA operating permits. Flow is monitored on a continuous basis. Water quality samples analyzed for flow-proportional TP concentrations are collected weekly; all other water quality parameters are monitored biweekly. The TP data are routinely used to assess the performance of each treatment cell and contribute to the development of strategies for improving the efficiency of the TP load retained in the STAs as a whole.

## STA SITE MANAGEMENT

The operation of the STAs involves extensive coordinated efforts by multidisciplinary teams and the use of innovative technologies and integrative diagnostic tools. The primary function of STA site management is to coordinate among various departments, divisions, and external stakeholders to facilitate resolution of day-to-day STA management and operational issues. Site managers maintain an on-site presence at STAs to ensure the program's objectives are met.

Site managers routinely report observations of changing environmental and site conditions, maintenance concerns, or infrastructure problems to appropriate SFWMD staff. Significant additional coordination by the site managers has been and will continue to be required during the build-out of the Long-Term Plan components. Additionally, site managers coordinate monthly vegetation management surveys to identify priorities and strategies to meet the overall vegetation goals of the STA program. Site managers also monitor daily stormwater operations and confirm that these operations are consistent with the established STA Operation Plans.

Research and optimization studies provide data used to guide operations. For example, guidance regarding water deliveries to the individual treatment flow-ways is based on information such as cumulative average annual inflow volumes and TP loads, treatment cell outflow TP concentrations, or the status of vegetation establishment within the treatment cells. Vegetation management activities are coordinated with multidisciplinary teams, and staff meets weekly to discuss operations related to performance and sustainability issues.

## ACQUISITION OF SURVEY DATA

The Acquisition of Survey Data Project as described in the October 27, 2003, the Long-Term Plan was completed in FY2005. As new STA facilities and structures are completed, or as new survey information is needed in support of optimization or rehabilitation efforts, acquisition of the survey data is collected at that time.

## ADDITIONAL FLOW AND WATER QUALITY MONITORING STATIONS

The Additional Flow and Water Quality Monitoring Project as described in the October 27, 2003, Long-Term Plan is complete. As new flow and water quality monitoring stations are needed, for example, for facilities associated with the Compartment B and C STA Build-out projects, they are included in the design and construction contracts for the overall STA facilities.

## REVIEW AND CORRECTION OF FLOW MEASUREMENT ANOMALIES

The goal of this project is to address flow estimate uncertainties and to provide good quality flow data at all major flow stations in the STAs. Stream-gauging data are collected in the field for use in calibrating flow equations, and flow rating analysis is conducted to improve computed flows, detect and correct anomalous data, and estimate missing data.

Improved flow equations have been completed and implemented at 100 percent in STA-1E, STA-1W, STA-2, STA-3/4, STA-5, and STA-6. Theoretical flow equations for flow computation have been implemented at 100 percent for structures in the STAs expansion project.

Quality analysis was performed for following stations in STAs: G-251, G-255, G-259, G-302, G-303, G-304A–J, G-306A–J, G-308, G-309, G-310, G-311, G-328, G-329A–D, G-330A–E, G-331A–G, G-332, G-333A–E, G-334, G-335, G-337, G-342A–D, G-343, G-344A–D, G-349A and B, G-350A and B, G-354, G-357, G-370, G-371, G-372, G-373, G-374A–F, G-375A–E, G-376B, G-377A–E, G-379A–D, G-380A–F, G-381A–C and E, G-388, and G-393.

Water balance analysis was conducted for STA-1E, STA-1W, STA-2, STA-3/4, STA-5, and STA-6 on as-needed basis, e.g., STA-2 inflow/outflow canal water budget analysis.

The dimensional analysis rating approach has been used to perform culvert ratings and stream-gauging planning, the case studies including STA-3/4: G-374B, G-374E, G-375D, G-376B, G-376E, G-377B, G-377D, G-378C, G-379B, G-379D, G-380B, G-380E, G-381B, G-381E; STA-1E: S-370A, S-366D, S-369C, S-368C; STA-5: G-342, G-344, G-406; STA-2: G-368C, G-333A–E, G-331A–F, G-329A–C, and G-328I.

Improved flow rating equations have been developed for: G-368A–E, S-5AE, S-5AW, G-344C–D, G-330A–E, G-393A–E, S-392, G-328I, G-337A, G-354A–C, S-371A–C, S-374A–C, G-378A–E, G-328I, G-200B, G-250G, G-349B, G-350B, G-349A, G-388, and G-50.

A total of 368 field measured datasets have undergone the quality assurance process. They include: S-370A, S-367C, S-371B, S-374B, S-368C, G-378C, G-337A, G-378C, G-384C, G-381B, G-381E, G-379D, G-380B, G-328I, G-377D, G-304I, G-375D, G-376B, G-376E, G-379B, G-331A–F, G-379B, G-379D, G-329A–C, G-333B–E, G-354C, G-344A, G-344D, G-378C, G-393B, G-380B, and G-380E.

About 139 additional stream-flow measurements in the same were completed until July. The stream-gauging plan was completed for STA-1E.

## UPDATE AND MAINTENANCE OF HYDRAULIC MODELS

A major effort that was completed in FY2008 and early FY2009 in support of the STA hydraulic models was the development of nearly one hundred new “preferred” datasets for flow monitoring stations located at interior STA sites. A “preferred” dataset is defined as the "best available data," and consists of data that has undergone post-processing quality assurance. In FY2009, the focus was on the use of the STA Operational Envelopes for operational decision-making in lieu of the use of the hydraulic models, therefore the new “preferred” data were used to improve the information contained in the Operational Envelope weekly summary sheets. Future improvements to the STA hydraulic models will be performed using the improved flow data.

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