Chapter 5B: Performance and Operation of the Everglades Stormwater Treatment Areas

Edited by Kathleen Pietro

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SUMMARY

The Everglades Stormwater Treatment Areas (STAs) are freshwater wetlands located south of Lake Okeechobee and north of the Everglades Protection Area (**Figure 5B-1**). These large wetlands were constructed to reduce total phosphorus (TP) from surface water runoff, thus serving as a critical component in the restoration of the Everglades. The STAs retain nutrients through physical, chemical, and biological action. The construction and operation of the STAs is mandated by the Everglades Forever Act (EFA), Section 373.4592, Florida Statutes and the STAs are operated under EFA and National Pollutant Discharge Elimination System (NPDES) permits.

The short-term and long-term trends in TP removal performance of the five STAs [STA-1 East (STA-1E), STA-1 West (STA-1W), STA-2, STA-3/4[2], and STA-5/6[2]] are presented in this chapter along with discussion pertaining to the factors that affected the performance. The factors described here include the status of the facility, coverage and general condition of the vegetation in the STA treatment cells, management activities, and operational challenges during Water Year 2015 (WY2015) (May 1, 2014–April 30, 2015). In WY2015, several STA flow-ways were under restricted operation to protect endangered bird nests, or due to construction, repair, or vegetation management activities. All of the STAs except for STA-5/6 received unprecedented volumes of Lake Okeechobee regulatory releases, necessary for regional water management purposes, i.e. above normal rainfall north of Lake Okeechobee and below normal rainfall south of Lake Okeechobee. The releases helped in managing lake stages and reducing the lake discharges to the St. Lucie and Caloosahatchee estuaries.

Additional details on wildlife surveys, submerged aquatic vegetation (SAV) surveys, and a status update on implementing the Long-Term Plan for Achieving Water Quality Goals in the Everglades Protection Area (Long-Term Plan; Burns and McDonnell 2003) are included in Appendices 5B-1 through 5B-7 of this volume. STA performance data are also presented in Volume III, Appendix 3-1, as part of permit compliance reporting. Research activities conducted as part of the Restoration Strategies Science Plan for the Everglades Stormwater Treatment Areas (SFWMD

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[2] STA-3/4 and STA-5/6 are reported as combined STAs, respectively.

2013) to further understand and improve STA performance to meet the water quality based effluent limit are presented in Chapter 5C of this volume.

The STAs are an integral part of the regional restoration efforts and have many stakeholders and varied types of audience including scientists, engineers, policy makers, regulators, and legislators. The Everglades restoration program has spanned over decades and the permitting, legal, design and operation documents associated with the STAs use non-standard reporting units. To preserve the continuity of understanding with the stakeholders, the STA performance data is reported using a mixture of standard and non-standard units. Phosphorus (P) and hydraulic loading rates (HLR) are in grams per square meter per year ($g/m^2/yr$) and centimeters per day (cm/d), respectively, TP loads are in metric tons (mt), concentrations are in parts per billion (ppb) or parts per million (ppm), surface area in acres (ac), flow in cubic feet per second (cfs), water volume in acre feet (ac-ft), and water depth in feet (ft). The conversion factors to express these values in standard units are included in the footnotes of the tables and figures and can also be found in the Units of Measurement table in the front matter of the final *2016 South Florida Environmental Report* (www.sfwmd.gov/sfer).

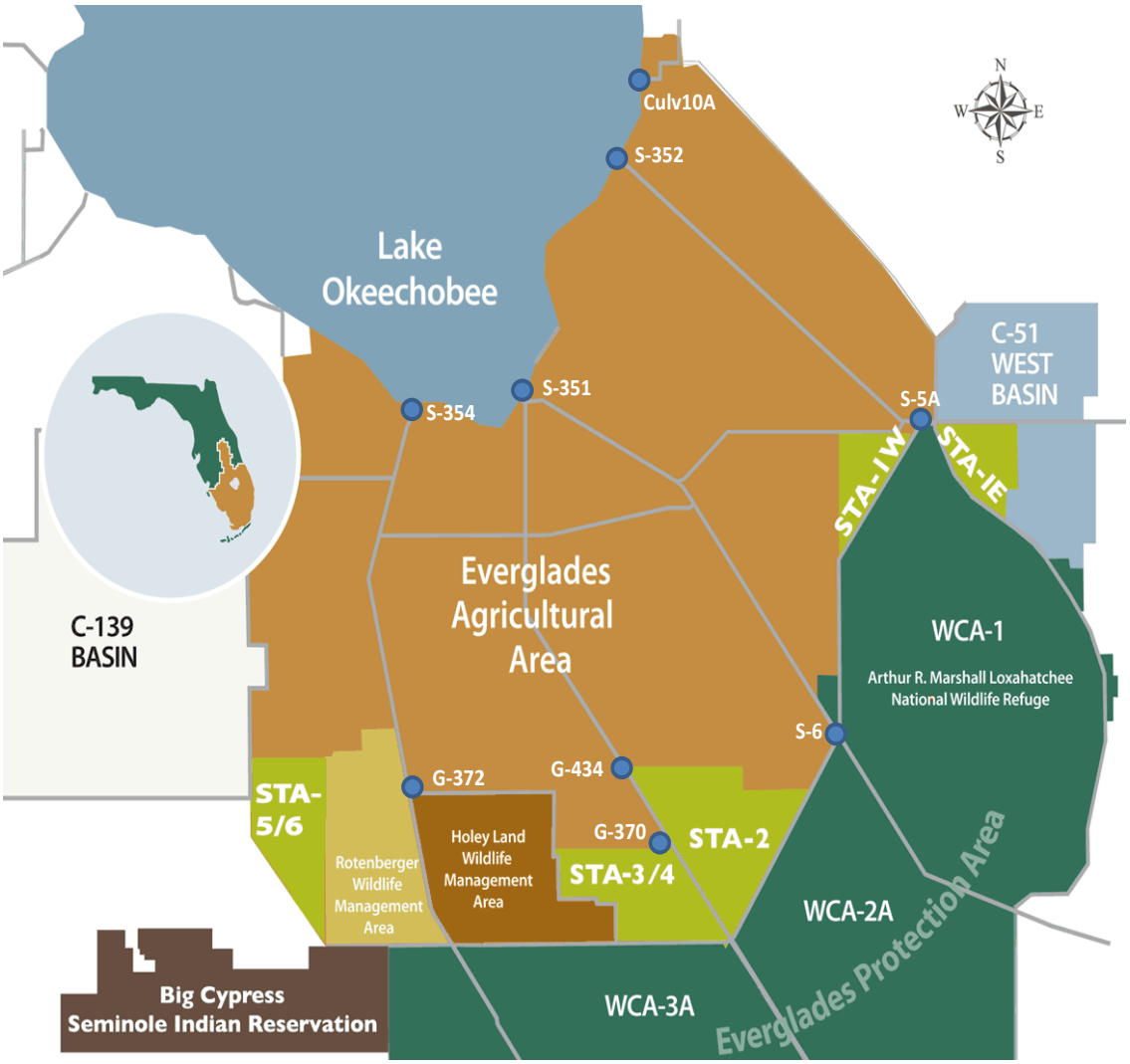


Figure 5B-1. Location of the STAs—STA-1E, STA-1W, STA-2, STA-3/4, and STA-5/6—and select major water control structures in relation to Lake Okeechobee and the Everglades Protection Area.

STA PERFORMANCE

- In WY2015, the STAs combined achieved the lowest outflow flow-weighted mean (FWM) TP concentration over the period of record, reducing inflow FWM TP concentration from 99 to 17 ppb at the outflow. The STAs treated approximately 1.4 million ac-ft of inflow water, retaining 83 percent of the inflow TP load (138 mt).
- Over the period of record (POR) since 1994, the STAs received over 16 million ac-ft of flows and 2,600 mt of TP. Inflow FWM TP concentration has been reduced from 134 ppb at the inflow to 33 ppb at the outflow and 75 percent of the inflow TP load has been retained (approximately 2,000 mt).
- The individual STA outflow FWM TP concentrations for WY2015 were 21, 19, 16, 15, and 32 ppb for STA-1E, STA-1W, STA-2, STA-3/4, and STA-5/6 respectively.

WY2015 STA OPERATION AND MANAGEMENT

- In addition to treating stormwater runoff, approximately 578,713 ac-ft Lake Okeechobee regulatory releases were directed to the STAs, with a majority of the flows directed to STA-2 and STA-3/4 and lesser volumes delivered to STA-1E and STA-1W. This amount does not include the volume of water delivered from the lake to the STAs to hydrate the SAV cells. An evaluation of the effects of the lake regulatory releases to the STAs is included in the chapter.
- Water depths were maintained at or above target depths in the STA treatment cells, with the exception of STA-5/6 Flow-ways 6, 7, and 8 that dried out early in the water year, from April 10 to June 24, 2014. In WY2015, only STA-5/6 received Lake Okeechobee supplemental water deliveries to keep the SAV hydrated. A small volume was also delivered from the Arthur R. Marshall Loxahatchee National Wildlife Refuge (LNWR) into STA-1W to keep the SAV cells hydrated. There were no named storm events or regional drought conditions in WY2015.
- Construction activities to grade the topography in STA-1E Cell 2 following the removal of the United States Army Corps of Engineers (USACE) PSTA demonstration project and near the discharge structure of STA-2 Cell 8 were completed in WY2015. Construction of an independent inflow canal to the STA-1W Western Flow-way began in April 2015 and was completed in July 2015. Repairs were done to selected water control structures in STA-1E and STA-2.
- The vegetation management and enhancement activities in the STAs included post-construction vegetation establishment efforts in STA-1E Eastern Flow-way and STA-2 Flow-way 5; large-scale vegetation rehabilitation in STA-1W; planting to ameliorate hydraulic short-circuiting areas in STA-1E, STA-1W, STA-2, and STA-3/4; creation of emergent vegetation strips in some of the cells; and herbicide treatment of floating aquatic vegetation, willow (*Salix caroliniana*), primrose willow (*Ludwigia* spp.), and cattail (*Typha* spp.) encroachment.
- Bird surveys to document presence of Florida burrowing owls (*Athene cunicularia floridana*) and nesting black-necked stilts (*Himantopus mexicanus*) were conducted in the STAs as per the Avian Protection Plan for Black-necked Stilts and Burrowing Owls in the Everglades Agricultural Area Stormwater Treatment Areas (Pandion Systems, Inc. 2008). There were no burrowing owls found in WY2015, but there were a total of 170 black-necked stilt nests observed in the STAs. Operational stages and inflow priorities were adjusted to avoid flooding active nests.

A total of 152 endangered Everglade snail kite (*Rostrhamus sociabilis*) nests were observed in STA-1E and STA-5/6. STA operations, such as stage maintenance and levee/treatment cell access, were adjusted to protect the nests.

INTRODUCTION

The Everglades STAs are a critical component of Everglades restoration that were built and are operated to reduce TP in surface water runoff before it is discharged into the Everglades Protection Area. The STAs are large freshwater wetlands dominated by a mixture of emergent aquatic vegetation [EAV; cattail (*Typha latifolia* and *T. domingensis*)] and SAV [southern naiad (*Najas* q*uadalupensis*), hydrilla (*Hydrilla verticillata*), and muskgrass (C*hara* spp.)]. These wetlands are operated as part of a regional flood control system and inflows are primarily from basin runoff. The STAs were constructed in a phased approach starting in early 1990 so not all of the STAs have been operational for the same period and the effective treatment area for a particular STA increases when additional flow-ways or treatment cells are added. Currently, the STAs combined have an effective treatment area of over 57,000 acres and a total area including infrastructure of about 68,000 acres. The STAs are divided into cells and flow-ways by internal levees and water flows through the STAs via water control structures, such as pump stations, gated spillways, and culverts.

The performance of the five STAs (STA-1E, STA-1W, STA-2, STA-3/4[3], and STA-5/6[3]) is closely monitored and outflow TP concentrations are a primary metric used to evaluate performance (**Figure 5B-1**). The operation of an STA depends upon the hydrologic conditions in the basins as well as STA restrictions due to construction or vegetation management activities and nesting activities of protected bird species within the cells. Hydraulic loading varies seasonally and annually. Over the POR, the STAs have been subjected to high hydraulic loading events associated with large storm events (e.g., Hurricanes Francis and Jeanne in 2004, Hurricane Wilma in 2005, an unnamed storm in February 2006, Tropical Storm Isaac in 2012, and Tropical Storm Andrea in 2013). The STAs have also been subjected to regional drought periods (e.g., WY2001–WY2002, WY2007–WY2009, and WY2011–WY2012), where inflows were reduced and dryout conditions occurred.

It is a goal of the South Florida Water Management District (District or SFWMD) to improve and enhance the TP removal efficiency of the STAs. To achieve this goal, the STAs are operated in an adaptive management approach where TP inflow concentrations, TP loading rates, vegetation conditions, water depths, and restrictions are taken into account to prioritize water deliveries and set target water stages. There are times when an STA cell or flow-way is taken offline or when flow is restricted to allow for construction or critical rehabilitation activities that may adversely affect P uptake, or nesting of protected birds.

The purpose of this chapter is to document the performance of the Everglades STAs for WY2015, analyze short-term and long-term trends in STA performance, describe the status of the STAs, and summarize the operational challenges, repairs, and management activities. The chapter also presents information on the effects of Lake Okeechobee regulatory releases on STA condition and performance. Since the performance of the STAs is of interest to a broad group of stakeholders and the permitting, legal, design, and operation documents associated with the STAs present area, flow volume, and water depths in non-standard international units (SI), the same units are used in this chapter. The chapter format includes an assessment of the overall STA performance followed by assessments of each individual STA, including facility status, performance, operation, bird nesting impacts, and management activities. Appendices 5B-1 through 5B-7 provide additional supporting information for this chapter. Details about the District's Restoration Strategies Program

[3] WY2015 performance for STA-3/4 and STA-5/6 are reported as combined STAs, respectively.

and Science Plan for the Everglades STAs are provided in Chapters 5A and 5C, respectively. STA performance is also presented in Volume III, Appendix 3-1, for permit compliance reporting purposes.

STA OVERVIEW

WATER YEAR 2015 TREATMENT PERFORMANCE AND PERIOD OF RECORD

In WY2015, the STAs combined received over 1.4 million ac-ft of inflow water volume with a TP load of approximately 166 mt (**Table 5B-1**).[4] HLRs were influenced in part by the Lake Okeechobee regulatory releases that were directed to STA-1E, STA-1W, STA-2, and STA-3/4. The highest HLRs were at STA-2 and STA-3/4 (3.0 and 2.6 cm/d) and these STAs had the highest flow volumes, approximately four times higher than the other STAs (**Table 5B-1** and **Figure 5B-2**). The lowest HLR was at STA-5/6 (0.5 cm/d). Phosphorus loading rate (PLR) was also lowest for STA-5/6 (0.4 $g/m^2/yr$) but comparable among the other STAs (0.7–1.1 $g/m^2/yr$).

Despite the fact that some flow-ways were either offline or operated under restricted stage or flow conditions (see individual STA Performance and Activities sections in this chapter) and treating large volume of Lake Okeechobee regulatory releases in WY2015, the combined FWM outflow TP concentration was the lowest achieved over 21 years of operation (**Figure 5B-3)**. Inflow FWM TP concentration was reduced from 99 to 17 ppb [or micrograms per liter (µg/L)] at the outflow and 83 percent of the inflow TP load (138 mt) was retained. Among the STAs, outflow FWM TP concentration ranged from 15 ppb (STA-3/4) to 32 ppb (STA-5/6), with three of the STAs achieving outflow FMW TP concentration ≤ 19 ppb (**Table 5B-1** and **Figure 5B-2**). The good performance of the Everglades STAs in WY2015, except for STA-5/6, can be attributed to a moderate rainfall in the water year, with no significant storm events or dry-outs (except for STA-5/6 EAV-dominated cells), consistent moderate P loading rates for all the STAs. The increased treatment area in STA-2 (Compartment B, North and South buildouts) allowed for distribution of STA-2 flows among five flow-ways in this STA.

Comparing the WY2015 performance data to the POR of WY1995–WY2014 for all STAs, the inflow FWM TP concentration was lower by 38 ppb and the outflow FWM TP concentration was approximately half the POR value (17 versus 34 ppb) (**Figure 5B-3**). The HLR for all STAs in WY2015 was comparable to the POR (2.1 and 2.4 cm/d, respectively) and the PLR for all STAs was lower in WY2015 compared to the POR (0.7 versus 1.2 $g/m^2/yr$, respectively).

[4]Details pertaining to the Everglades STA performance calculation methodology are found in Appendix 5B-2 of this volume.

Table 5B-1. Summary of treatment performance in each of the Everglades STAs and all STAs combined for WY2015) and the POR.

Water Year 2015						
	STA-1E	**STA-1W**	**STA-2**	**STA-3/4**	**STA-5/6**	**All STAs**
Effective Treatment Area in Permit (acres)	4,994	6,544	15,495	16,327	13,685	57,045
Adjusted Effective Treatment Area (acres)[a]	4,502	5,972	14,697	16,327	13,685	55,183
Inflow Volume (ac-ft)	111,287	140,087	528,675	501,653	83,064	1,364,765
Inflow TP Load (mt)	19.5	27.1	47.2	48.9	23.6	166.3
Inflow TP Concentration (ppb)	142	157	72	79	230	99
Hydraulic Loading Rate (HLR) (cm/d)	2.1	2.0	3.0	2.6	0.5	2.1
TP Loading Rate (PLR) ($g/m^2/yr$)	1.1	1.1	0.8	0.7	0.4	0.7
Outflow Volume (ac-ft)	97,818	146,753	532,471	453,009	85,877	1,315,928
Outflow TP Load (mt)	2.6	3.4	10.2	8.4	3.4	28.0
Outflow TP Concentration (ppb)	21	19	16	15	32	17
TP Retained (mt)	16.9	23.7	37.0	40.6	20.2	138.4
TP Removal Rate ($g/m^2/yr$)	0.9	1.0	0.6	0.6	0.4	0.6
TP load Retained (%)	87%	87%	78%	83%	86%	83%
Period of Record Performance (Water Years 1994 - 2015)						
Start date	Sep 2004	Oct 1993	Jun 1999	Oct 2003	Dec 1997	
Inflow Volume (ac-ft)	1,021,648	3,790,766	3,990,524	5,168,435	2,159,173	16,130,546
Inflow TP Load (mt)	218.5	814.9	478.9	673.9	484.3	2,670.6
Inflow TP Concentration (ppb)	173	174	97	106	182	134
Outflow Water Volume (ac-ft)	984,991	3,903,653	4,274,071	5,202,386	1,825,272	16,190,373
Outflow TP Load (mt)	57.4	227.9	109.8	107.3	155.9	658.3
Outflow TP Concentration (ppb)	47	47	21	17	69	33
TP Load Retained (mt)	161.1	587.0	369.2	566.5	328.4	2,012.2
% TP Retained	74%	72%	77%	84%	68%	75%

[a] Adjusted effective treatment area is time and area weighted to exclude cells that were temporarily off-line for plant rehabilitation, infrastructure repairs, or Long-Term Plan enhancements (refer to the individual STA sections in this chapter).

Conversions: 1 acre = 0.405 hectares = 4,050 m^2; 1 ac-ft = 1,233 m^3= 0.123 ha-m; 1 ppb = 1 µg/L; 1 metric ton (mt) = 1,000 kg

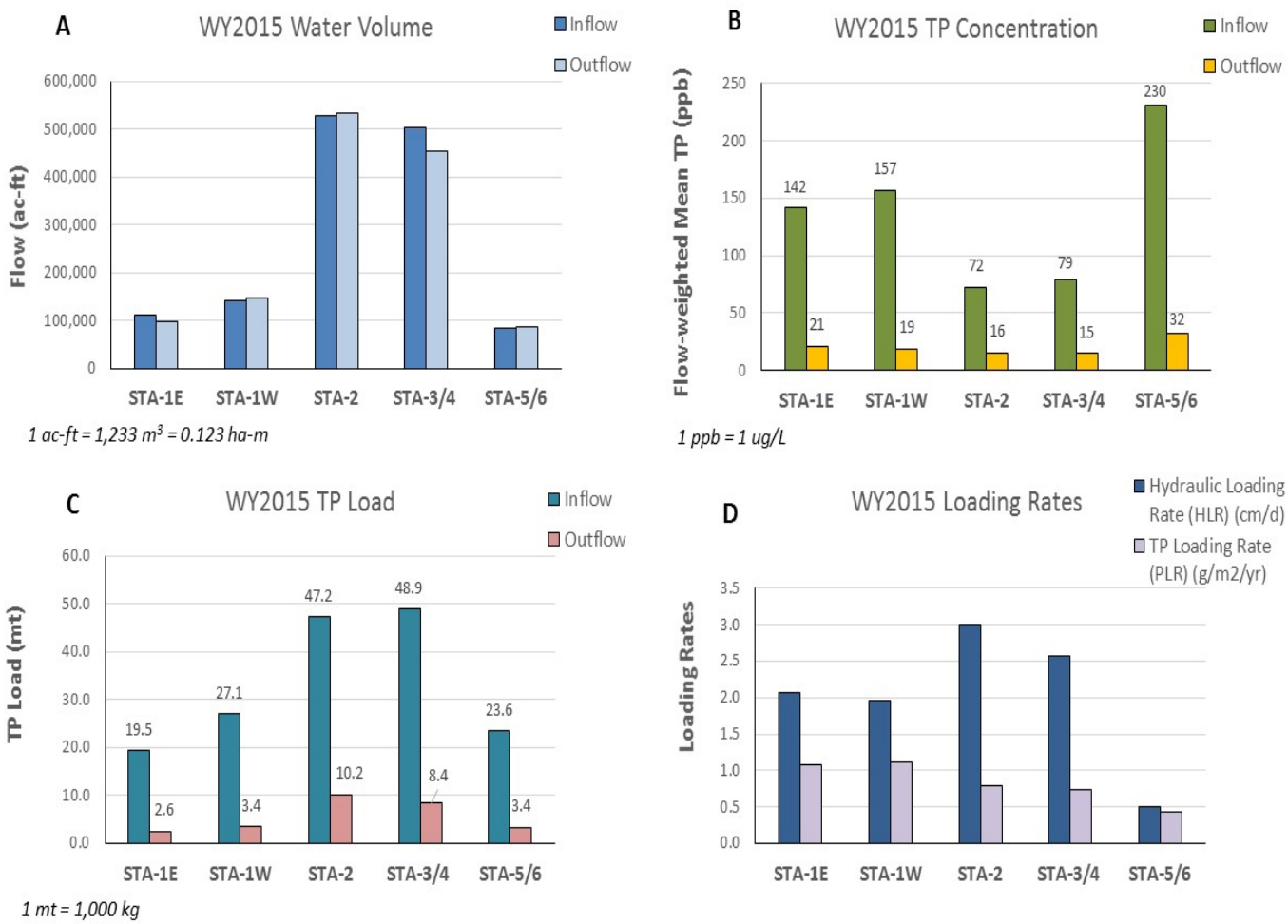


Figure 5B-2. Comparison of (A) inflow and outflow water volumes, (B) inflow and outflow flow-weighted mean TP concentrations, (C) inflow and outflow TP loads, and (D) HLR and PLR during WY2015 in the STAs. [Note: ha-m – hectare meter, kg – kilograms, and m3 – cubic meter.]

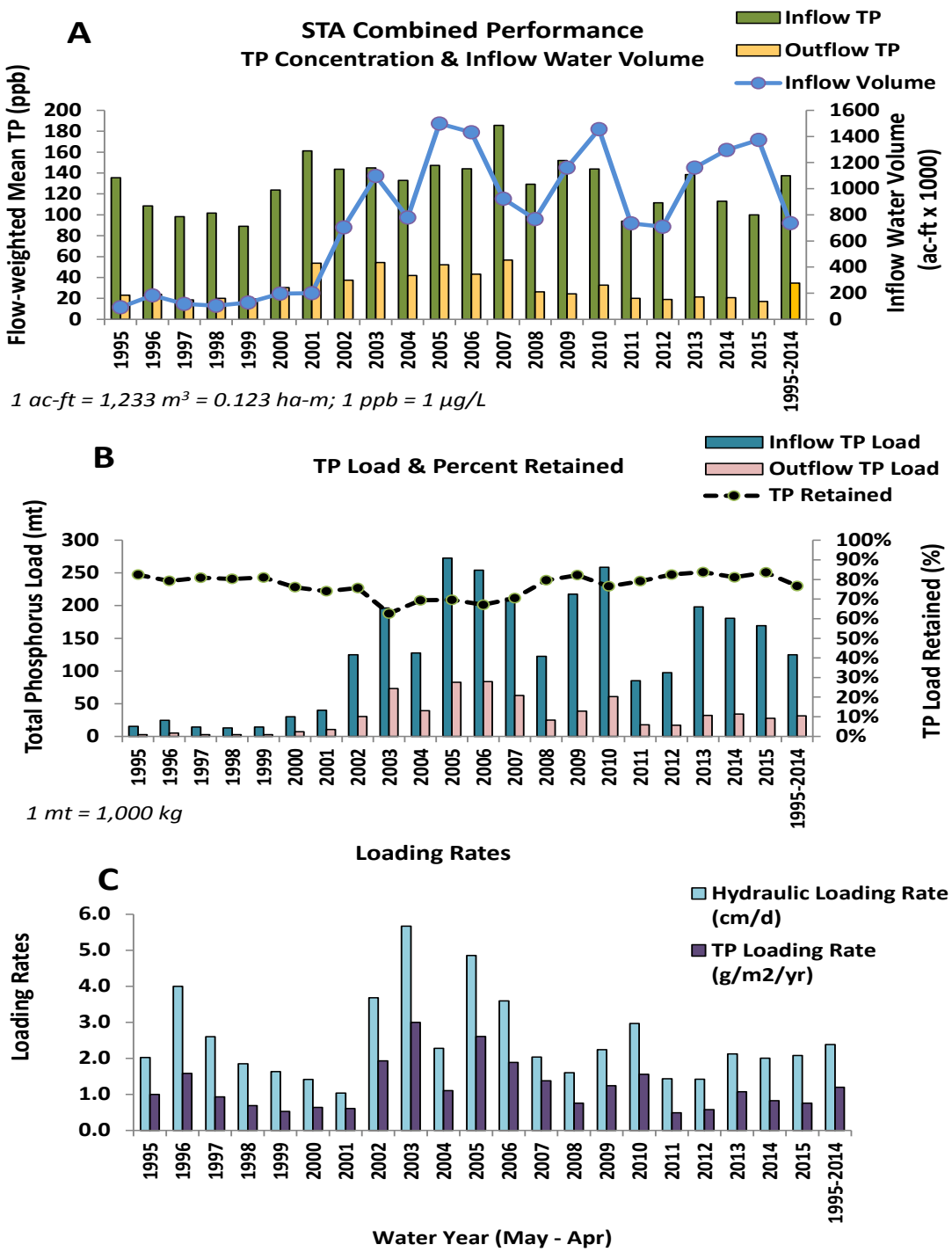


Figure 5B-3. POR time series for all the STAs combined showing (A) annual and POR average inflow and outflow FWM TP concentration and inflow water volume, (B) inflow and outflow TP load and percent TP load retained, and (C) annual inflow HLR and PLR. The STAs were constructed in a phased approach.

FLOWS FROM LAKE OKEECHOBEE REGULATORY RELEASES

In WY2015, the District conveyed a total of approximately 586,098 ac-ft of water to the STAs, of which 7,385 ac-ft was delivered to hydrate the SAV cells[5] and the remainder (578,713 ac-ft) was a result of Lake Okeechobee regulatory releases. (**Table 5B-2**). The volume of Lake Okeechobee regulatory releases delivered to the STAs in WY2015 is more than three times the volume of lake releases sent to the STAs in WY2014. Approximately 82 percent of these flows were delivered to STA-2 and STA-3/4, with the remainder delivered to STA-1E and STA-1W. STA-2 and STA-3/4 received a majority of the lake regulatory releases primarily due to the better water quality of flows from the S-354 and S-351 lake discharge structures (**Figure 5B-1**), particularly during winter months. Deliveries to STA-1E and STA-1W were also reduced because of structure repairs and vegetation management activities. STA-5/6 did not receive any lake regulatory releases because it does not have the infrastructure necessary to receive the lake releases. The unprecedented volume of lake flows delivered to the STAs was necessary for regional water management purposes, largely because of atypical rainfall patterns, i.e. above average rainfall north of Lake Okeechobee and below average rainfall in the WCAs and Everglades. The 2008 Lake Okeechobee Regulation Schedule (LORS2008) called for maximum discharges to the WCAs for all but a few weeks in late May and early June 2014. Runoff from the agricultural basins was moderately low, so the STAs were able to receive larger volumes of lake water. These conditions created an opportunity for the District to assess the effects of sustained, moderate, flows of Everglades Agricultural Area runoff and Lake Okeechobee water on STA vegetation and treatment performance. Similar sustained flows to the STAs are not anticipated under more normal rainfall patterns. Additional lake flows were delivered to the STAs for maintaining target stages for vegetation growth and for water supply to downstream areas. Further details of the lake flows and the associated enhanced monitoring of STA condition and performance are included in the individual STA sections. A more detailed analysis of Lake Okeechobee regulatory releases water quality that may have implications on the STAs is included in Appendix 5B-4 of this volume.

[5] The volume of Lake Okeechobee water delivered to the STAs to hydrate the SAV was determined from the period of Low Lake Water Supply Operation when structure G-373 diversion occurred from May 28, 2014, through June 9, 2014.

Table 5B-2. Monthly volume of Lake Okeechobee water delivered to the STAs, including water sent for regulatory releases, water supply, and STA cell hydration during dry months of WY2015.

Month/ Year	Volume of Lake Okeechobee Releases (ac-ft)								
	STA-1E		STA-1W	STA-2			STA-3/4		STA-5/6
	S319	G311	G302	S6	G434	G435	G370	G372	G507/G349B/ G350B
5/2014	2,878	3,906	1,942	541	9,006	30	313	6,862	189
6/2014	1,364	1,409	6,242	354	1,324	0	207	1,434	618
7/2014	666	445	737	89	1,873	4	8	4,100	-
8/2014	989	7,907	26,092	21,831	5,765	1,199	5,693	33,363	-
9/2014	27	3,668	1,873	9,924	3,239	590	451	14,813	-
10/2014	20	1,511	3,073	7,833	25	246	2,875	7,114	-
11/2014	712	0	108	5,566	35	29	3,336	14,251	-
12/2014	16,644	2,070	7,971	32,566	11,110	4,929	357	28,689	-
1/2015	2,009	0	1	39,519	12,665	2,298	165	30,331	-
2/2015	1,612	1,351	958	30,621	9,259	0	175	26,294	-
3/2015	696	1,550	1,352	14,636	10,015	4,710	455	31,252	-
4/2015	864	2,424	438	4,987	4,372	1,466	71	14,520	0
TOTAL	**28,481**	**26,240**	**50,786**	**168,467**	**68,687**	**15,501**	**14,106**	**213,023**	**808**

1 ac-ft = 1,233 m^3 = 0.123 ha-m

VEGETATION MANAGEMENT ACTIVITIES

Vegetation management plays a critical role in maintaining and optimizing treatment within the STAs. The coverage and general condition of the vegetation were evaluated in a variety of ways: digital aerial imagery taken in May 2014 at an altitude of 15,650 feet above ground level, ground SAV monitoring, and qualitative aerial assessments conducted monthly by helicopter. Vegetation coverage estimates from the 2007–2014 aerial imageries are shown in Appendix 5B-7 of this volume. The observations from the assessments were used to schedule vegetation maintenance activities and to develop strategies to enhance the vegetation communities.

There were a variety of vegetation maintenance and enhancement activities conducted this water year. Herbicides were applied to control nuisance vegetation, particularly floating plants, which can impede water flow and also interfere with SAV growth through shading.[6] Herbicide treatments were also used to reduce or eliminate cover of species such as willow (*Salix caroliniana*) and primrose willow (*Ludwigia* spp.) in emergent cells, and to control cattail (*Typha* spp.) encroachment in SAV cells. The total acres of vegetation treated with herbicides in each cell is shown in Volume III, Appendix 3-1, Attachment E. Enhancement measures included plantings of emergent species, giant bulrush (*Schoenoplectus californicus*) and alligator flag (*Thalia geniculata*), and inoculations of SAV such as southern naiad and the macrophytic algae muskgrass. Giant bulrush and alligator flag are planted in emergent cells to alleviate hydraulic short-circuits and at other locations where conditions, particularly water depths, are not conducive for sustained growth of cattail. Linear strips of giant bulrush and alligator flag are planted in SAV cells to buffer beds of SAV from uprooting by wind and high flow events. This compartmentalization of SAV cells with EAV also provides functional redundancy (i.e., complementary phosphorus uptake pathways) for sustaining optimal treatment performance. Summaries of major maintenance and enhancement measures for each STA are included in the individual STA Performance and Activities sections found in this chapter. A summary of the findings from a mesocosms study comparing the TP removal performance of cattail and giant bulrush is presented in Appendix 5B-6 of this volume.

MIGRATORY BIRD AND SNAIL KITE NESTING IN THE STAS

In accordance with the 2008 Avian Protection Plan for the Everglades STAs (Pandion Systems, Inc. 2008), the District conducted a series of surveys for the presence of nests within the STA cells, focusing on black-necked stilts and Florida burrowing owls. The plan provides the District with a framework to modify STA operations to minimize impacts to active nests of either species by restricting flows and water levels to avoid raising water levels and flooding nests.

Standardized black-necked stilt nesting surveys were conducted in all the STAs from May through July 2014 and April 2015 following protocols outlined in the plan. During this period, 170 black-necked stilt nests were observed in the Everglades STAs. During the time when the nests were active, the STAs were operated under restricted flow conditions to protect the nests. Survey results by STA are summarized and reported in more detail in Appendix 5B-5 of this volume. No active burrowing owl nests were observed within any of the STAs in WY2015.

[6] Widespread harvesting has been suggested as a way to manage vegetation in the STAs. However, harvesting is not under consideration for several reasons, including (1) mechanical removal is very expensive and would be disruptive to the STA ecosystem if done on a large scale, (2) the lack of biomass disposal locations and high associated costs, (3) a viable market for plant byproducts, such as conversion to biofuel, has not materialized in South Florida.

In addition, 152 Everglade snail kite nests were observed by the University of Florida (Appendix 5B-5). To protect the nests, target water levels were established in the cells where the nests were found and some of the levees were closed or access was restricted.

CONCLUSIONS

In WY2015, the STAs combined treated about 1.3 million ac-ft of water, retained 83 percent of the inflow TP load, and achieved the lowest outflow FWM TP concentration over the period of record (17 ppb), despite the fact that some STA flow-ways were either offline or operated under restricted stage or flow conditions, and the STAs received unprecedented volumes of Lake Okeechobee regulatory releases. Individually, the annual outflow FWM TP concentration was lower in WY2015 compared to WY2014 for STA-1E, STA-1W, and STA-2, about the same for STA-3/4, and slightly higher for STA-5/6. Although the outflow FWM TP concentrations continue to improve for the individual STAs, further enhancement of treatment capabilities is needed to consistently meet the water quality based effluent limit established to achieve compliance with the State of Florida's numeric TP criterion in the Everglades Protection Area. As such, the District is constructing additional water quality improvement projects that will work in conjunction with the existing STAs. These projects include the L-8 Flow-Equalization Basin (FEB), the STA-1W Expansion, the A-1 FEB, STA-5/6 Earthwork, and the C-139 FEB (details in Chapter 5A of this volume). Applied research efforts are currently underway in the STAs as part of the Restoration Strategies Science Plan for the Everglades Stormwater Treatment Areas to further understand the impact of inundation depth and duration for cattail sustainability; the P sources; forms, flux and transformation processes in the STAs; the performance, design, and operational factors associated with periphyton-based stormwater treatment systems (PSTA); and the influence of the canal conveyance features on STA and FEB inflow and outflow TP concentrations (SFWMD 2013) (details in Chapter 5C of this volume).

OVERVIEW OF INDIVIDUAL STA PERFORMANCE AND ACTIVITIES

STA-1E OVERVIEW OF PERFORMANCE AND ACTIVITIES

STA-1E is located adjacent to the northeast boundary of the LNWR (or WCA-1) and east of STA-1W (**Figure 5B-1**). STA-1E consists of East and West distribution cells and eight treatment cells arranged in three flow-ways (**Figure 5B-4**; Appendix 5B-1, Figure 1). The treatment cells, not including the distribution cells, provide a total effective treatment area of 4,994 acres (Piccone et al. 2014). STA-1E was flooded in WY2005 to establish wetland vegetation and began treating water in WY2006.

The flow-way nomenclature for STA-1E is as follows:

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

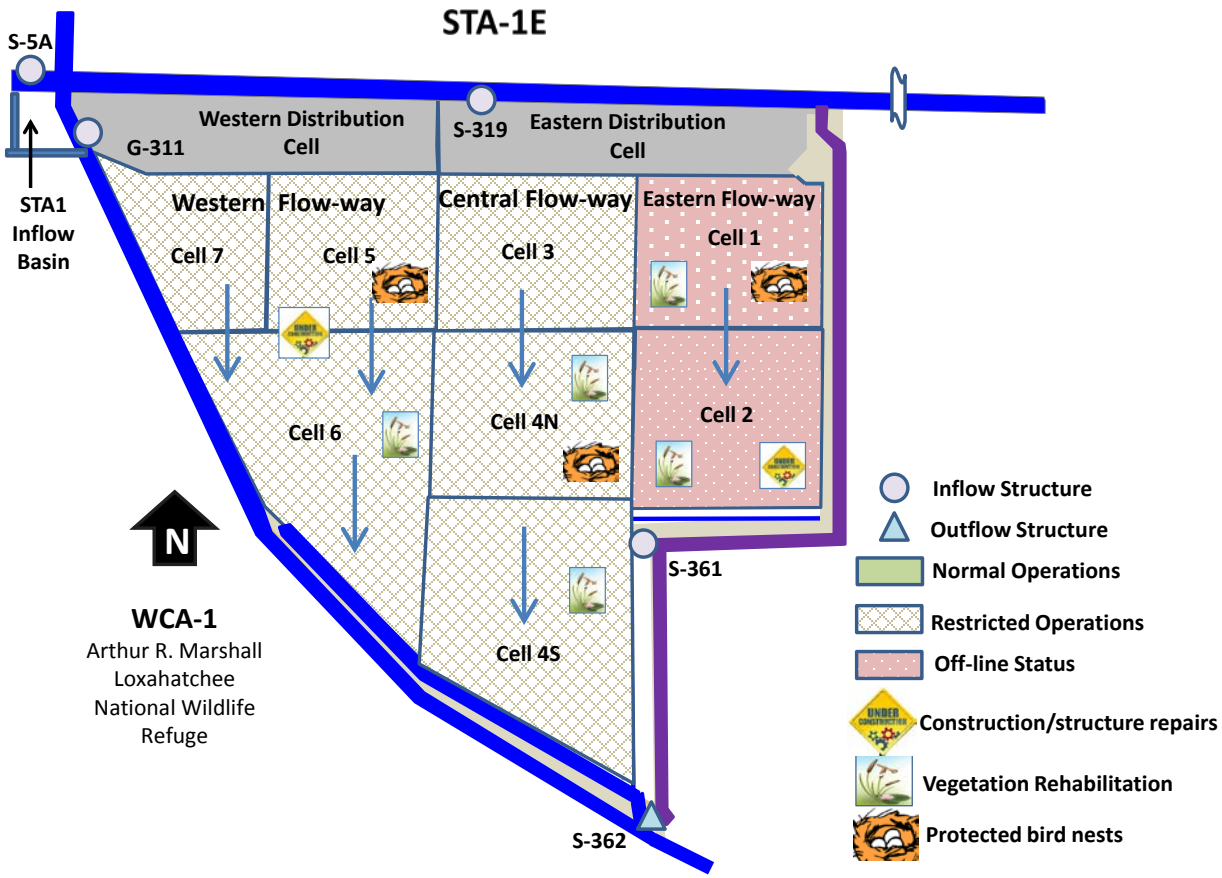


Figure 5B-4. Simplified schematic of STA-1E showing the different factors that affected the operations of the STA, which include construction or structure repairs, vegetation management activities, or the presence of protected bird nests. See **Figure 5B-5** for specific dates. A detailed structure map is provided in Appendix 5B-1, Figure 1, of this volume.

Over the POR, several issues affected STA-1E operations. In addition to the challenges related to large storm events, regional drought conditions, and the presence of black-necked stilt and Everglade snail kite nests, STA-1E continues to be impacted by structural and topographic issues. Such issues include repairs to various water control structures that have been on-going since 2008 and deficient topography in Cells 5 and 7 that results in deep water conditions and hydraulic short-circuiting. Despite the District's implementation of substantial vegetation management, and enhancements and activities, there have also been issues related to health and persistence of the vegetation communities, such as the gradual decline in cattail cover in Cell 7, increased coverage of primrose willow, willow, and pennywort (*Hydrocotyle* spp.), and devastating loss of SAV communities. Declines in SAV cover have been observed in many of the STAs, particularly in the dry season but in STA-1E, hydrilla underwent a catastrophic die-off in Cell 6 in WY2010 and SAV in Cell 4S was completely eliminated by herbivory by the exotic island apple snail (*Pomacea maculata*) in July 2013. Additionally, the USACE's PSTA project was located in the Eastern Flow-way and until October 2010 when the project ended, the flow-way was operated under restricted flow conditions. Between late 2010 and the middle of WY2015, the flow-way was offline for PSTA decommissioning activities including grading the cell and vegetation establishment.

Since WY2005, STA-1E has received over 1.0 million ac-ft of inflow water with an average FWM TP concentration of 173 ppb (**Table 5B-1**). STA-1E has retained 74 percent of the inflow load with an average outflow FWM TP concentration of 47 ppb. In WY2015, all of the flow-ways in STA-1E were operated either under restricted flow conditions (Central and Western flow-ways for the entire year) or offline for part of the year (Eastern Flow-way off-line until October 2014) (**Figures 5B-4** and **5B-5**). Operational challenges include start-up conditions in the Eastern Flow-way, continued repairs to the water control structures, vegetation enhancement activities, and presence of snail kite nests.

Online, Restricted, or Offline Operations Timeframes for the STA-1E Flow-ways

Calendar Year	2014									2015				
Water Year	WY2014	WY2015												WY2016
Flow-way (% time online)	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
STA-1E														
Distribution Cells														
Eastern (54.5%)	PSTA decommissioning & vegetation establishment (online starting 10/14/14)											SK nests		
Central (100%)	Structure repairs, vegetation enhancements, SK nests													
Western (100%)	Structure repairs, vegetation enhancements, BNS nests													

= Online; = Online with restrictions; = Offline

BNS: black-necked stilt; SK: Everglades snail kite, PSTA: Periphyton-based Stormwater Treatment Area

Figure 5B-5. Timeline showing the STA-1E flow-ways that were online, offline, or operated online with restrictions due to the presence of protected bird nests, vegetation management activities, construction or infrastructure repairs.

STA-1E Facility Status and Operations

The Eastern Flow-way was offline for part of WY2015 to allow for vegetation establishment in Cell 2 following grading activities associated with the removal of the PSTA project (**Figure 5B-4**). The Eastern Flow-way was returned to online status on October 14, 2014. Due to the presence of nesting Everglade snail kites, a species protected under the Endangered Species Act, stages in Cell 1 were restricted starting on March 30, 2015, through the end of the water year. The Central Flow-way remained online but under operational restrictions throughout WY2015 due to structure repairs, presence of snail kite nests, and vegetation establishment and enhancement activities. Stages and levee access in Cell 4N were restricted during April and May 2014 and again starting on March 6, 2015, through the end of the water year due to the presence of Everglade snail kite nests. In Cell 4S, the vegetation was severely damaged in July 2013 due to exotic apple snail herbivory. Starting in fall 2013, stages in Cell 4S were managed between 13.7 and 15.0 ft National Geodetic Vertical Datum of 1929 (NGVD29) to provide conditions that might ameliorate the exotic apple snail population infestation. This effort ended on May 24, 2014. As of July 1, 2015, apple snail populations are not impacting any of the cells in STA-1E. The Western Flow-way remained online but under operational restrictions throughout WY2015 due to structure repairs, presence of nests, vegetation enhancement activities, and topographic deficiencies. Stages in Cell 5 were restricted starting in April 2015 due to the nesting of black-necked stilts, a species protected under the Migratory Bird Treaty Act.

During WY2015, Lake Okeechobee regulatory releases were sent south through STA-1E for treatment prior to delivery to WCA-1. The regulatory releases to the STA-1E were suspended during the period of December 2014 to January 2015 due to high turbidity levels in the releases.

The USACE continued with repairs to several water control structures in the Central and Western flow-ways during WY2015. At the District's request, no more than one structure in each cell was taken offline, which allowed for partial operation of these two flow-ways. As of June 15, 2015, repairs to structures S-369B, S-369C, S-369D, S-366C, S-366D, S-367C, S-367D, S-368C, S-368D, S-372D, and S-372E were completed. Structures S-366E, S-367E, S-368E, S-369A, and S-372C remained offline for repairs (Appendix 5B-1, Figure 1). S-319 trash rack replacement construction commenced on December 2014 and was 99 percent complete as of June 1, 2015.

STA-1E Performance

In WY2015, STA-1E received inflow volume and TP load slightly lower than WY2014 and comparable to the POR (Figure 5B-6). Despite having flow-ways operated under restricted flow or offline, the FWM TP outflow concentration in WY2015 was 21 ppb. This was 51 percent lower than in WY2014 (41 ppb). In WY2015, STA-1E reduced inflow FWM TP concentrations from 142 ppb to 21 ppb at the outflow, retaining 87 percent of the inflow TP load. The loading rates in WY2015 were slightly lower compared to WY2014 and comparable to the average POR rates. The HLR in WY2015 (2.1 cm/d) was slightly higher than the average HLR for the POR (1.9 cm/d) and the PLR in WY2015 was approximately equal to the average PLR for the POR (1.1and 1.2 $g/m^2/yr$, respectively). Over the POR including WY2015, STA-1E received more than 1 million ac-ft inflow and approximately 218 mt TP load, retaining approximately 73 percent of the inflow TP load.

In WY2015, the HLR and PLR for the Western Flow-way was approximately twice as high as those for the Eastern and Central Flow-ways. This is mainly due to the Eastern Flow-way being off-line for part of the water year for start-up activities following the PSTA project decommissioning and the Central Flow-way being operated under strict stage ranges due to the snail kite nests. Inflow TP concentration was also highest for the Western Flow-way (111 ppb) and lowest for the Central Flow-way (79 ppb). The Eastern Flow-way achieved the lowest outflow FWM TP (12 ppb) and had the highest percentage of TP load retained (93 percent). The FWM outflow TP concentration from the Central and Western Flow-ways were almost twice as high (22 and 25 ppb, respectively) and TP retained was 71 and 75 percent, respectively.

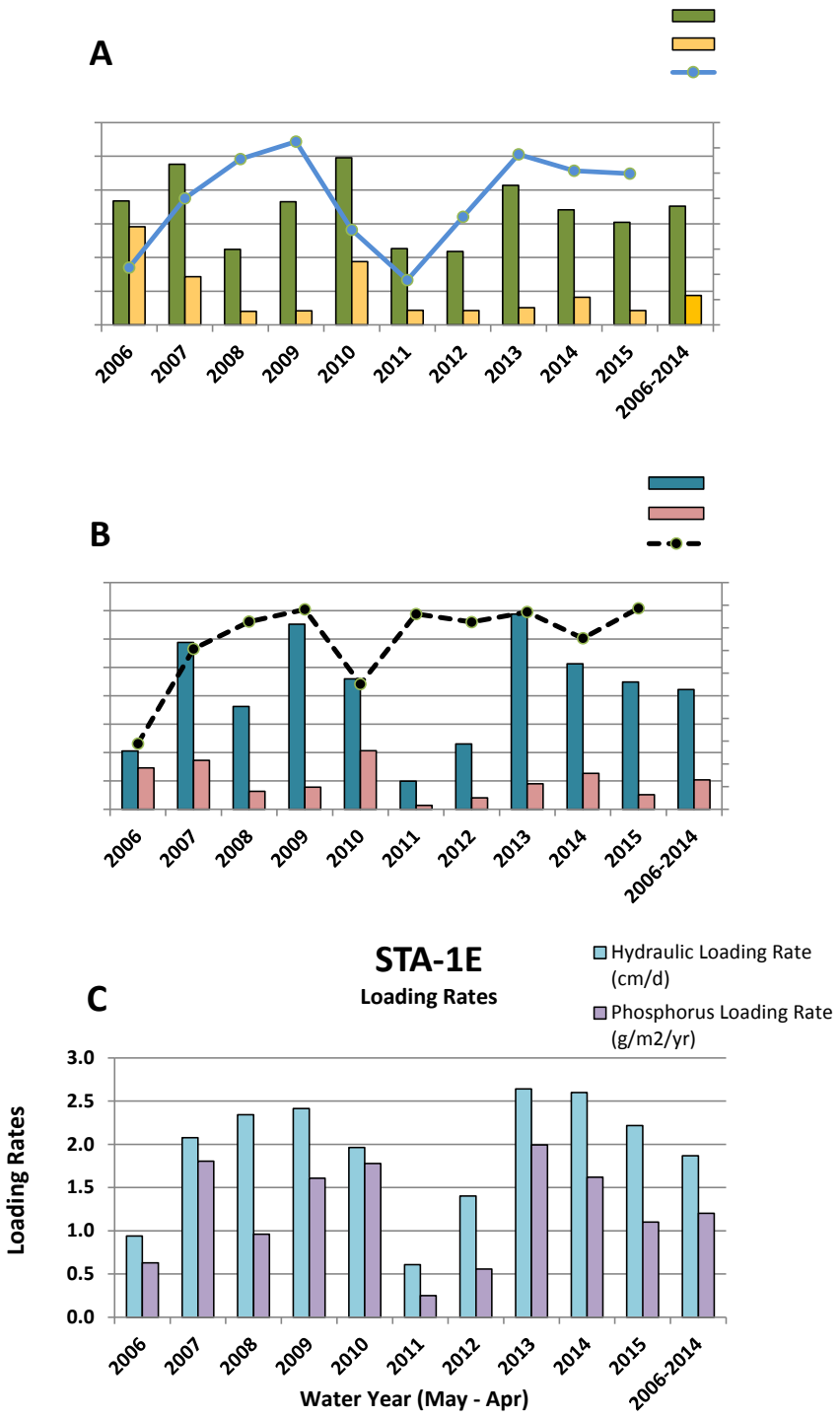


Figure 5B-6. Annual time series in STA-1E over POR of (A) inflow and outflow FWM TP concentrations and inflow water volume, (B) annual inflow and outflow TP loads and percent TP load retained, and (C) annual inflow HLR and PLR.

Lake Okeechobee Regulatory Releases to STA-1E

Approximately 54,721 ac-ft of lake regulatory releases were treated in STA-1E in WY2015 (**Table 5B-2**). Regulatory releases into STA-1E were suspended from December 19, 2014, through the end of WY2015 due to high turbidity levels from S-352 and CULV-10A lake discharge structures (**Figure 5B-1**). Median turbidity was 45 nephelometric turbidity units (NTUs) at these structures, with highest turbidity values (96–297 NTUs) measured in late January to early February, 2015 (Appendix 5B-4). Turbidity measured during this period at the primary inflow structure for the overall STA-1 inflow basin that conveys water to STA-1W and STA-1E (S-5A Pump Station) (**Figure 5B-1**) was lower (median value of 20 NTUs), but was much higher than the values measured at the S-5A structure in the preceding five water years (median of 5 NTUs) (**Figure 5B-7**). There were no turbidity measurements at either G-311 or S-319 (STA inflow structures) in WY2015, however, total suspended solids (TSS) during August, September, and December 2014, when most of the lake flows were delivered to STA-1E, were 11 ppm and generally higher than the preceding five water years. For WY2015, G-311 TSS had a median of 10 ppm compared to the preceding five years (WY2010–WY2014) with a median of 6 ppm (**Figure 5B-8**). Values for TSS measured at the STA outflow structure S-362 were generally less than the method detection limit (MDL) of 3 ppm, indicating effective removal of particulates in the water column and reduction in turbidity within the STA.

Although lake regulatory releases to STA-1E were suspended in December 2014, small amounts of lake water continued to be delivered to this STA, on an as-needed basis, until the end of WY2015 for cell hydration, i.e. for maintaining vegetation health. For this purpose, lake water was delivered to the western distribution cell, then moved through EAV (cattail) cells to allow the particulates to settle and thereby protecting the SAV cells from high turbidity levels.

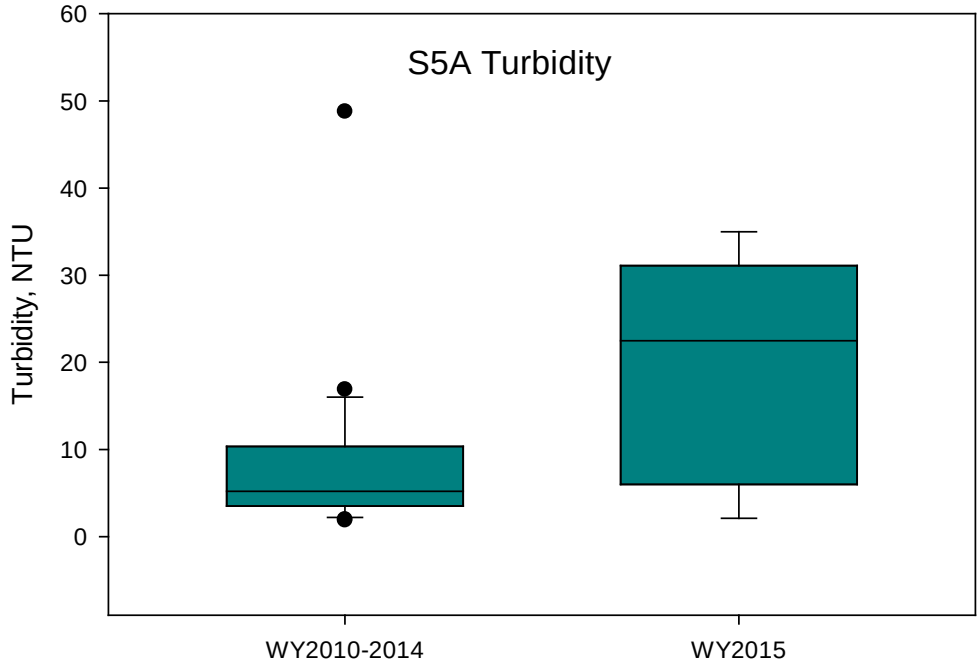


Figure 5B-7. Comparison of turbidity values measured at the STA inflow basin inflow structure S-5A in WY2015 and the preceding five water years (WY2010–WY2014).

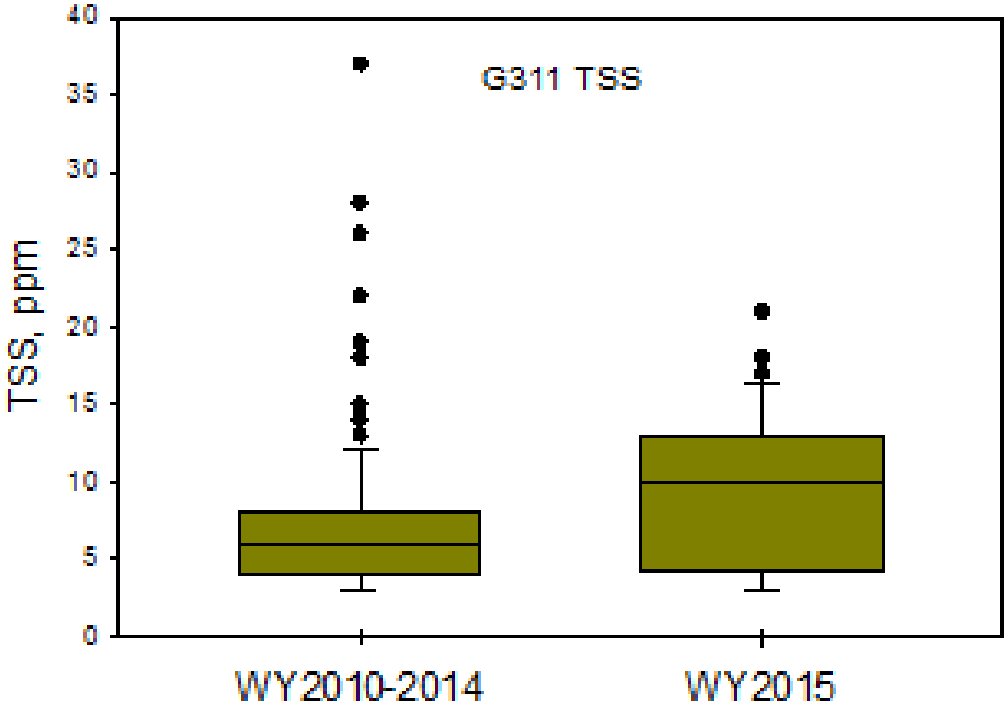


Figure 5B-8. Comparison of TSS values measured at outflow structure G-311 in WY2015 and the preceding five water years (WY2010–WY2014).

The spikes in TP concentrations observed at the Eastern Flow-way outflow structure in January and February 2015 (94 and 158 ppb, respectively; **Figure 5B-9**), were likely due to the dryout and rehydration of this flow-way preceding these months, and not due to the lake regulatory releases. This was based on the lack of corresponding spikes in TP in the adjoining two flow-ways (STA-1E Central and Western flow-ways) that also received lake regulatory releases during the same time period.

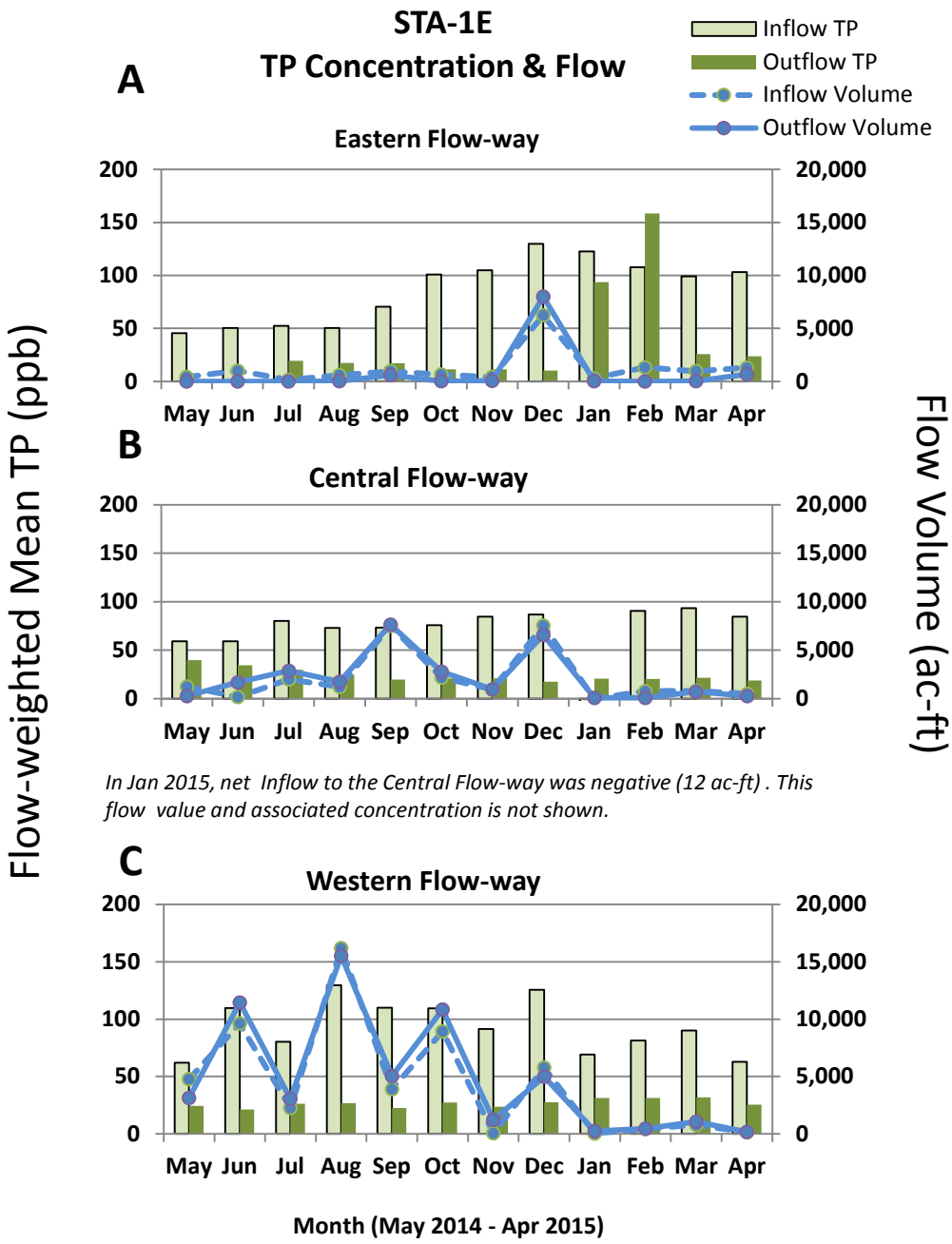


Figure 5B-9. Monthly time series for the STA-1E flow-ways inflow and outflow FWM TP concentrations and water volume for the (A) Eastern Flow-way, (B) Central Flow-way, and (C) Western Flow-way in WY2015. Although it is unintentional and infrequent, negative (reverse) flows can occur at gated culverts, as observed in the Central Flow-way for January 2015.

STA-1E Vegetation

Enhancements and Maintenance

Vegetation management and enhancement in STA-1E focused on startup of the Eastern Flow-way and compartmentalization of the SAV cells (Cells 2, 4N, 6; **Table 5B-3**).

Table 5B-3. Vegetation management and enhancement activities conducted in STA-1E in WY2015.

Flow-way/Cell	Activities
Eastern Flow-way/Cell 1	Aerial herbicide application in Cell 1 (250 ac).
Eastern Flow-way/Cell 2	Inoculated with southern naiad (July 2014). Planted alligator flag and giant bulrush to create vegetation strips.
Central Flow-way/Cell 4N	Planted alligator flag and giant bulrush to create vegetation strips at the cell inflow. Inoculated with southern naiad (May 2014). Repeated herbicide treatments to prevent floating aquatic vegetation (FAV) from impacting SAV growth (200 ac).
Central Flow-way/Cell 4S	Inoculated with southern naiad (May 2014).
Western Flow-way/Cell 5	Planted EAV in the deep short-circuit along the western side of the cell.
Western Flow-way/Cell 6	Planted alligator flag and giant bulrush in the gaps in the vegetation strips and short-circuit channels in the downstream end of the cell. Repeated herbicide treatments to prevent FAV from impacting SAV growth (620 ac).

Qualitative Assessment of STA-1E Vegetation Coverage (Helicopter Surveys)

The Eastern Flow-way, which recently began normal operation (following the PSTA project decommissioning), experienced a grow-in period in WY2015. Cell 1 had approximately 30 percent EAV coverage by the end of the water year. In Cell 2, muskgrass started to colonize the cell by the middle of the water year, but coverage declined in February 2015 due to low water stages. Upon rehydration, SAV began to reestablish in approximately 40 percent of the cell

In the Central Flow-way, expansion of willow, primrose willow, and floating aquatic vegetation (FAV) cover was noted in Cell 3. At the beginning of WY2015, SAV coverage in Cells 4N and 4S was poor with (20 and 10 percent of the area, respectively)[7]. Vegetation management activities focused on establishing and compartmentalizing these cells. By the end of WY2015, SAV coverage increased to approximately 70–75 percent in both Cell 4N and Cell 4S.

In the Western Flow-way, there was good cattail recruitment along the eastern portion of Cell 5 and willow, primrose willow, and pennywort were observed throughout the remainder of the cell. In Cell 7, thinning of cattail areas was observed and although the giant bulrush that was planted the previous water year was well established, by the end of WY2015 there was approximately 30 percent EAV coverage in the cell. In Cell 6, there were some areas in the northeast central

[7] Following the apple snail herbivory during summer 2013.

portion of the cell that lacked SAV cover but overall vegetation coverage throughout the water year in Cell 6 was considered to be good (estimated 90 percent of the cell).

Vegetation Coverage Estimates in STA-1E Based on Aerial Imagery

Estimated coverage of EAV and SAV in the treatment cells from the aerial photographs taken in 2014 shows that there was relatively little net change in EAV coverage in Cells 1, 3, and 5 relative to the last eight years (2007–2014), but an increase in EAV coverage in Cell 7 (81 percent coverage in 2014 compared to 63 percent coverage in 2013) (Appendix 5B-7). Despite the increased coverage, the health and density of cattails in this cell remains a concern, due to persistent deep water condition. Floating cattail communities have been noted in the past. SAV coverage in Cells 4N, 4S, and 6 increased over this period, from approximately 4–6 percent coverage in 2007, to 40–56 percent coverage in 2014, with the greatest percentage of cover observed in 2014 compared to the POR.

Qualitative Ground Surveys for SAV Coverage in STA-1E

An internal survey of STA-1E Cell 2 was conducted on February 24, 2015. The average daily water depth in Cell 2 on the day of the survey was slightly over one foot. Daily average water depths observed in the previous month indicated that Cell 2 experienced a gradual decline in water depths in the month of January resulting in a brief period of 7 days from January 30 to February 5 in which the cell appeared dry. After the dry period, internal water levels in the cell rapidly increased to approximately 1.2 feet. Internal water depths obtained during the survey indicated similar water levels throughout the cell with a slightly deeper area near the southwestern portion of the cell (**Figure 5B-10**). Turbidity readings obtained internally in different areas of the cell showed values below 1.8 NTU, with a higher value of 7.1 NTU observed near the boat ramp.

Results from the SAV survey showed muskgrass as the only species present at that time. This species was observed in low coverages (1–2 percent) and was primarily found in the eastern and western regions of the cell with small traces found throughout the cell (**Figure 5B-10**). Overall, Cell 2 was largely covered by what appeared to be dense maidencane (*Panicum hemitomon*), with open areas observed in the eastern portions of the cell. Recently planted bulrush strips were observed at the inflow, middle, and outflow regions of the cell. There were also several interspersed areas planted with alligator flag. Other observations included a few dense periphyton mats located in the eastern open areas.

Internal surveys were also conducted in the SAV cells in the Central and Western flow-ways (Cells 4N, 4S, and 6). The spatial coverage and relative abundance of SAV were documented in the Western and Central flow-ways on July 17, 2014 (**Figure 5B-11**). During this survey, moderately dense to very dense SAV beds were observed throughout Cells 6 and 4S, whereas in Cell 4N, SAV beds generally occurred in the western region of the wetland. Southern naiad and coontail (*Ceratophyllum demersum*) were the dominant SAV species observed in Cell 6. By contrast, hydrilla was dominant in Cell 4S, followed by muskgrass, which was found primarily in the eastern region of the cell.

The survey in Cell 4S documents the recovery of the SAV community from a dramatic loss due to herbivory by the exotic apple snail during summer 2013 (Chimney 2015). The percentage of moderately dense to very dense SAV beds observed in July 2014 was similar to that found in May 2012, prior to the snail infestation (**Figure 5B-12**). SAV cover prior to and following the 2013 herbivory event indicated an increase in muskgrass and decrease in southern naiad (**Figure 5B-12**).

A second survey was performed in STA-1E Cell 6 on December 22, 2014. During this survey, spatial SAV coverage was similar to that observed during July 2014, although overall vegetation densities were lower (**Figures 5B-11** and **5B-13**).

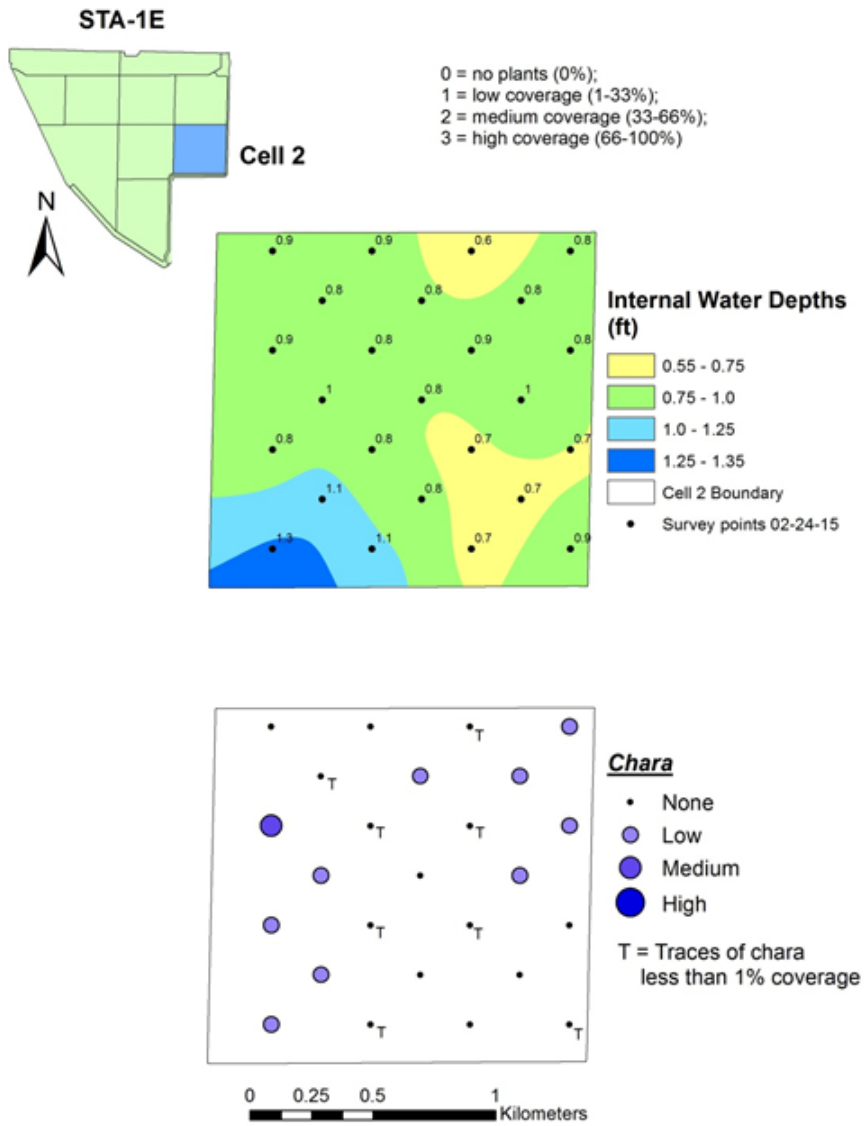


Figure 5B-10. Ground survey results depicting internal water depth measurements in STA-1E Cell 2, and the relative coverage of muskgrass (*Chara,* spp.) recorded on February 24, 2015. Dots indicate the location of SAV ground survey sites.

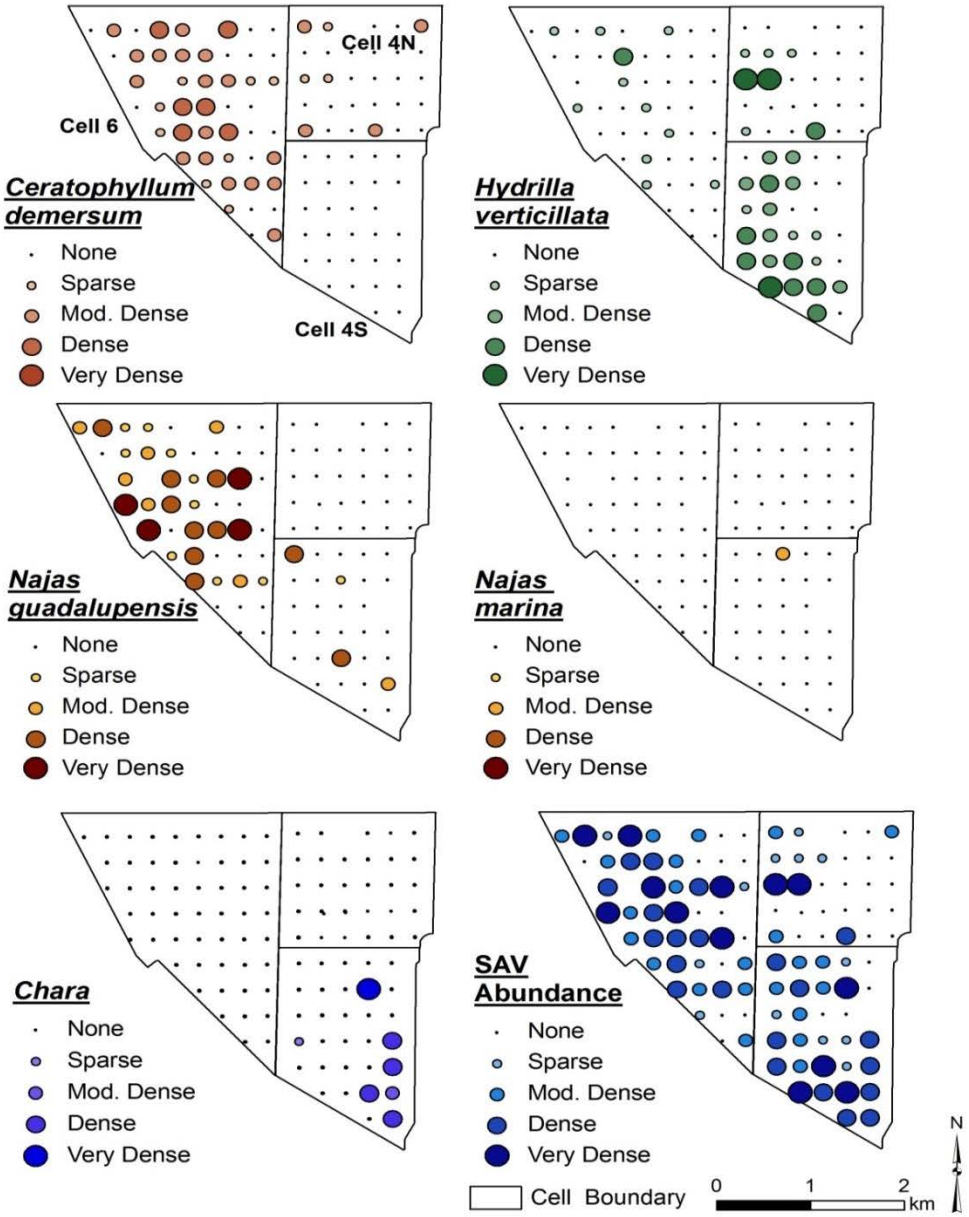


Figure 5B-11. Spatial coverage and relative abundance of coontail (*Ceratophyllum demersum*), hydrilla (*Hydrilla verticillata*), southern naiad (*Najas guadalupensis*), spiny naiad (*Najas marina*), muskgrass (*Chara*, spp.), and all SAV species grouped together in STA-1E Cells 4N, 4S, and 6. Cells 4N and 4S were surveyed on July 31, 2014, and Cell 6 on July 17, 2014. Dots indicate locations of SAV ground survey sites.

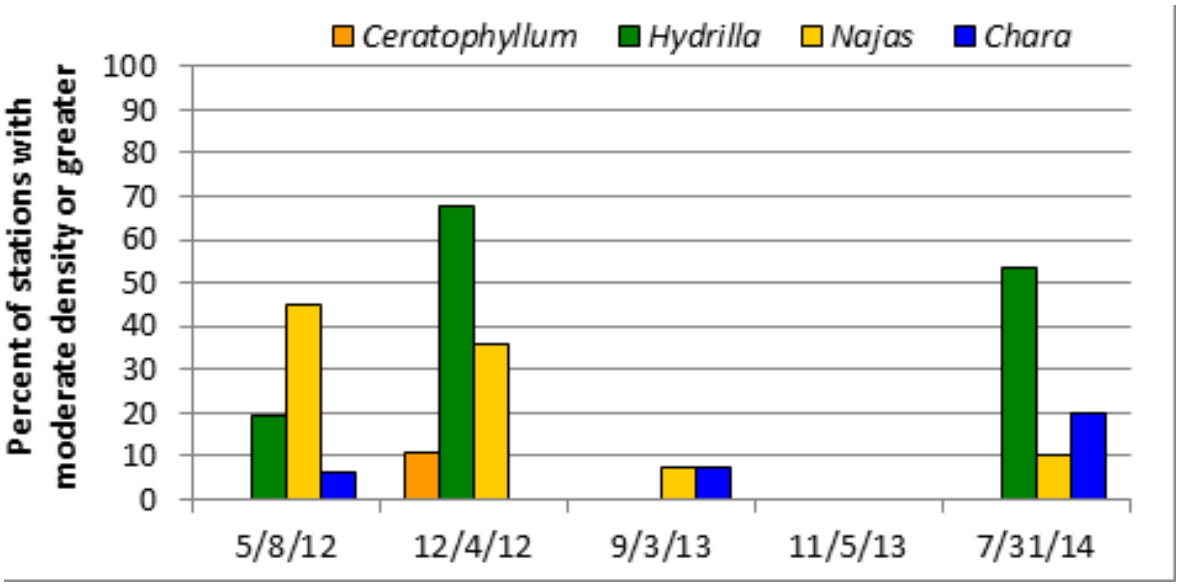


Figure 5B-12. SAV cover (as percentage of survey points with moderate density or greater) of coontail (*Ceratophyllum demersum*), hydrilla (*Hydrilla verticillata*), southern naiad (*Najas guadalupensis*), and muskgrass (*Chara,* spp.) within STA-1E Cell 4S from May 2012 through July 2014.

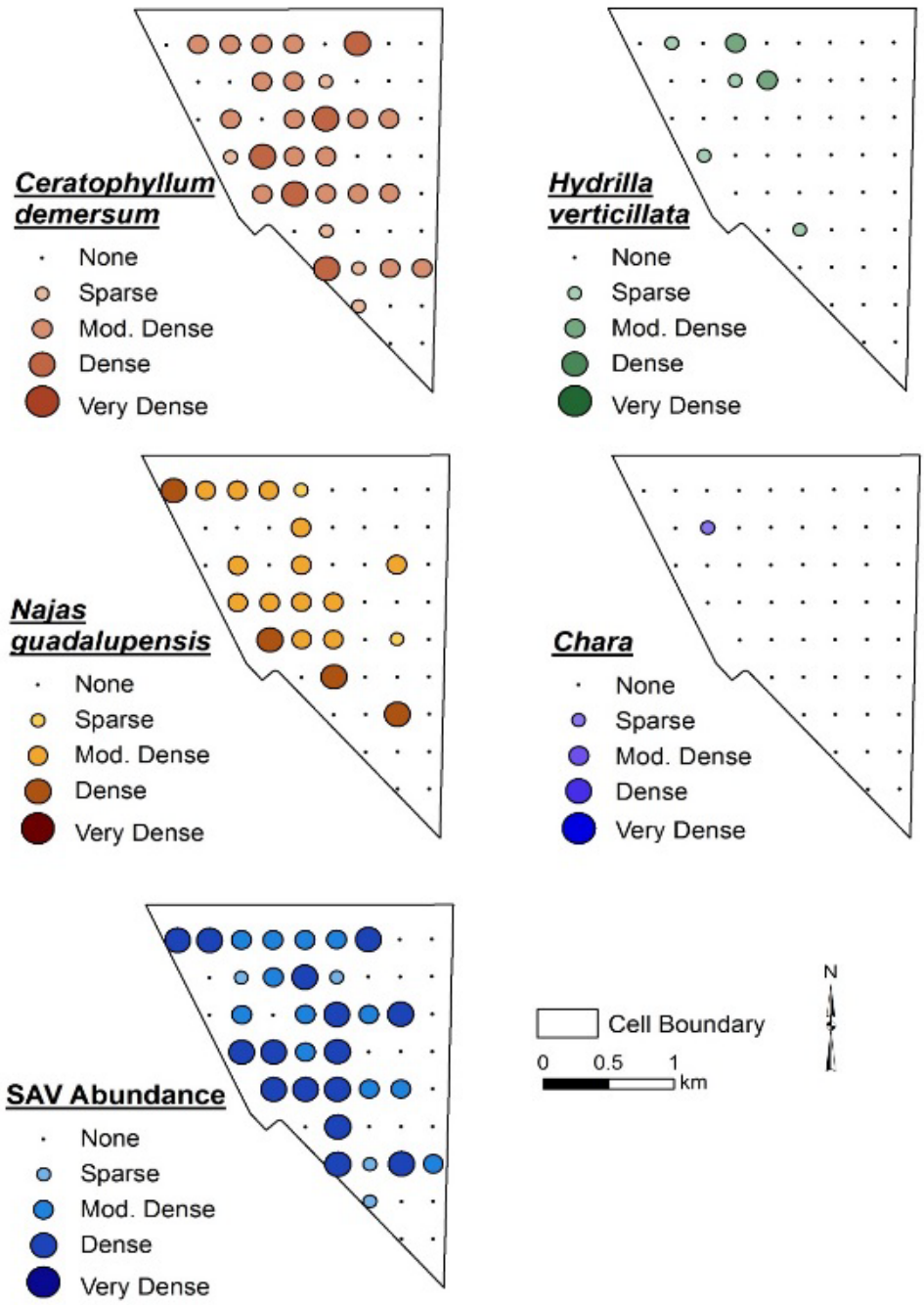


Figure 5B-13. Spatial coverage and relative abundance of coontail (*Ceratophyllum demersum*), hydrilla (*Hydrilla verticillata*), southern naiad (*Najas guadalupensis*), muskgrass (*Chara* sp.), and all SAV species grouped together in STA-1E Cell 6 on December 22, 2014. Dots indicate locations of SAV ground survey sites.

STA-1W OVERVIEW OF PERFORMANCE AND ACTIVITIES

STA-1W is located adjacent to the northwestern boundary of WCA-1 (**Figure 5B-1**) and west of STA-1E. STA-1W was built in a phased approach with the Eastern and Western flow-ways starting operation in 1994 (referred to as the Everglades Nutrient Removal Project) and the Northern Flow-way starting operation in 1999. In 2007, divide levees were added to the Cells 1 and 2 to compartmentalize them, creating Cells 1A, 1B, 2A, and 2B. STA-1W currently encompasses 6,544 acres of effective treatment area and is arranged in three flow-ways with eight treatment cells (Piccone et al. 2014; **Figure 5B-14**; Appendix 5B-1, Figure 2).

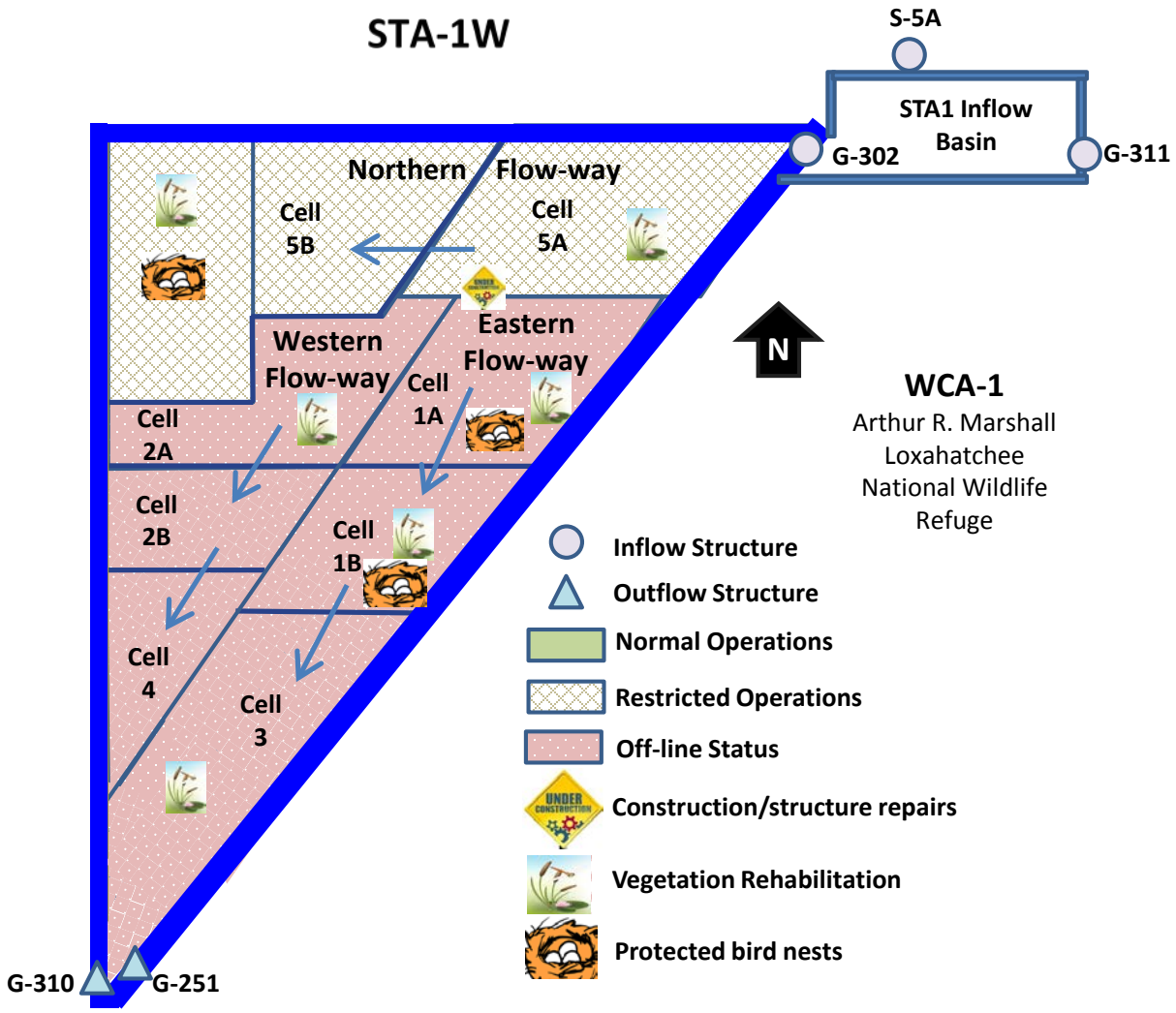


Figure 5B-14. Simplified schematic of STA-1-W showing the different factors that affected the operations of the STA which include construction or structure repairs, vegetation management activities, or the presence of protected bird nests. See **Figure 5B-15** for specific dates. A detailed structure map is provided in Appendix 5B-1, Figure 2, of this volume.

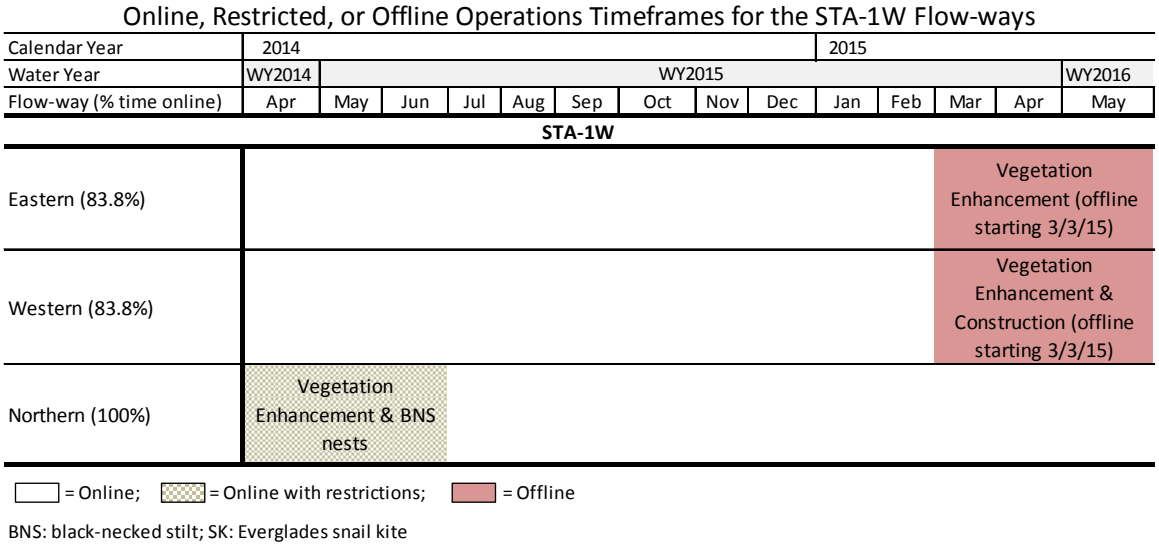


Figure 5B-15. Timeline showing the STA-1W flow-ways that were online, offline, or operated online with restrictions due to the presence of protected bird nests, vegetation management activities, or construction or infrastructure repairs.

The flow-way nomenclature for STA-1W is as follows:

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

Over its operational history, STA-1W has been affected by extreme weather events (regional droughts and large storms), enhancement activities that included water level drawdowns and construction, and high hydraulic and nutrient loadings. A series of major rehabilitation activities were implemented in STA-1W between 2005 and 2007 to reestablish the vegetation communities that were damaged by hydraulic and nutrient overloading in previous years and restore the treatment performance of all cells.

Over the POR since WY1994, STA-1W has received approximately 3.8 million ac-ft of inflow water with an average FWM TP concentration of 174 ppb (**Table 5B-1**). STA-1W has retained 72 percent of the inflow TP load with an average outflow FWM TP concentration of 47 ppb. In WY2015, all of the flow-ways were under normal operations from July 2014 to February 2015. The Northern Flow-way was operated under restricted flow conditions from April to June 2014 and the Eastern and Western flow-ways were taken offline in March 2015 for vegetation rehabilitation in the Eastern Flow-way[8]. Operational challenges in WY2015 included the presence of black-necked stilt nests and vegetation enhancement activities.

[8] Prior to the construction of the STA-1W Western Flow-way independent flow-way, the Eastern and Western Flow-ways shared the same inflow structure, so when the Eastern Flow-way was taken offline, the Western Flow-way was also taken offline.

STA-1W Facility Status and Operations

A timeline summarizing the status of each flow-way in STA-1W is presented in **Figure 5B-15**. The Northern Flow-way was operated online with restrictions for part of WY2015 due to the presence of black-necked stilt nests and vegetation enhancement activities (**Figures 5B-14** and **5B-15**). The Eastern and Western flow-ways were taken offline starting March 3, 2015, for vegetation rehabilitation activities in the Eastern Flow-way. For a short period from April 17 to April 27 (during the period when the Eastern and Western flow-ways were off-line), back-siphon operation at the G-310 outflow pump station was performed to supply water from WCA-1 to Cells 4, 2A, and 2B to avoid dry-out. Structure maintenance activities in STA-1W in WY2015 included S-5A pump station hardening repairs and the G-302 headwater sensor repair.

During WY2015, STA-1W received moderate amounts of Lake Okeechobee regulatory releases for treatment prior to delivery to WCA-1 (see discussion about this later in this section). Regulatory releases to STA-1W were suspended during the period of January 2015 to early February 2015 due to high turbidity levels in the releases. The delivery of regulatory releases to STA-1W was limited starting from March 2015 through the end of the water year due to the offline status of the Eastern and Western flow-ways.

Construction to change the way water is delivered to the Western Flow-way occurred in WY2015. Historically, inflow to the Western Flow-way was first routed into Cell 1A before going through the inflow structure to Cell 2A. In order to improve the ability to manage and operate the Eastern and Western flow-ways, the District initiated a project to provide the Western Flow-way with an independent inflow route. This was accomplished by isolating the existing inflow canal for the Western Flow-way from Cell 1A (**Figure 5B-16**). Construction of the STA-1W Independent Western Flow-way Project began in April 2015 was completed in June 2015. The flow-way was returned to normal operation in July 2015.

Figure 5B-16. Construction of the STA-1W Independent Western Flow-way, which will allow water flow to be sent directly to the Western Flow-way instead of being routed through the Eastern Flow-way (photo by SFWMD).

STA-1W Performance

In WY2015, STA-1W received approximately a third less inflow flow volume and TP load compared to WY2014 (38 and 45 percent, respectively), which is also less than the POR (WY1995–WY2014) (**Figure 5B-17**). Inflow FWM TP concentration (157 ppb) and loading rates (HLR 2.0 cm/d and PLR 1.1 g/m^2/yr) in WY2015 were also less compared to WY2014 (HLR 2.9 cm/d and PLR 1.8 g/m2/yr) and the POR (HLR 2.8 cm/d and PLR 1.8 g/m2/yr). Despite restricted flow operations for each flow-way, 87 percent of the inflow TP load was retained and the outflow FWM TP concentration in WY2015 (19 ppb) was the lowest concentration since WY1998.

Among the flow-ways for WY2015, inflow FWM TP concentrations were highest for the Eastern Flow-way (168 ppb) and similar for the Western and Northern flow-ways (142 and 144 ppb, respectively). The outflow FWM TP concentrations for all the flow-ways were the lowest over the POR. ranging from 16 ppb for the Eastern Flow-way to 18 ppb for the Western Flow-way.

The lowest outflow concentration at the STA and individual flow-way level to date is likely due to the relatively low loading rates, including the absence of major storm events during WY2015. This performance occurred however at a time when there were restrictions in flow-way operation, poor vegetation in Cells 1A, 2A, and 5A throughout the water year, as well as loss of SAV in Cells 1B and 4 during part of the year. Details of vegetation condition and enhancements are discussed later in this section. Further enhancements discussed in this chapter, e.g. independent flow-way for the Western Flow-way, and planting of emergent vegetation, are expected to result in further improvement of STA-1W performance.

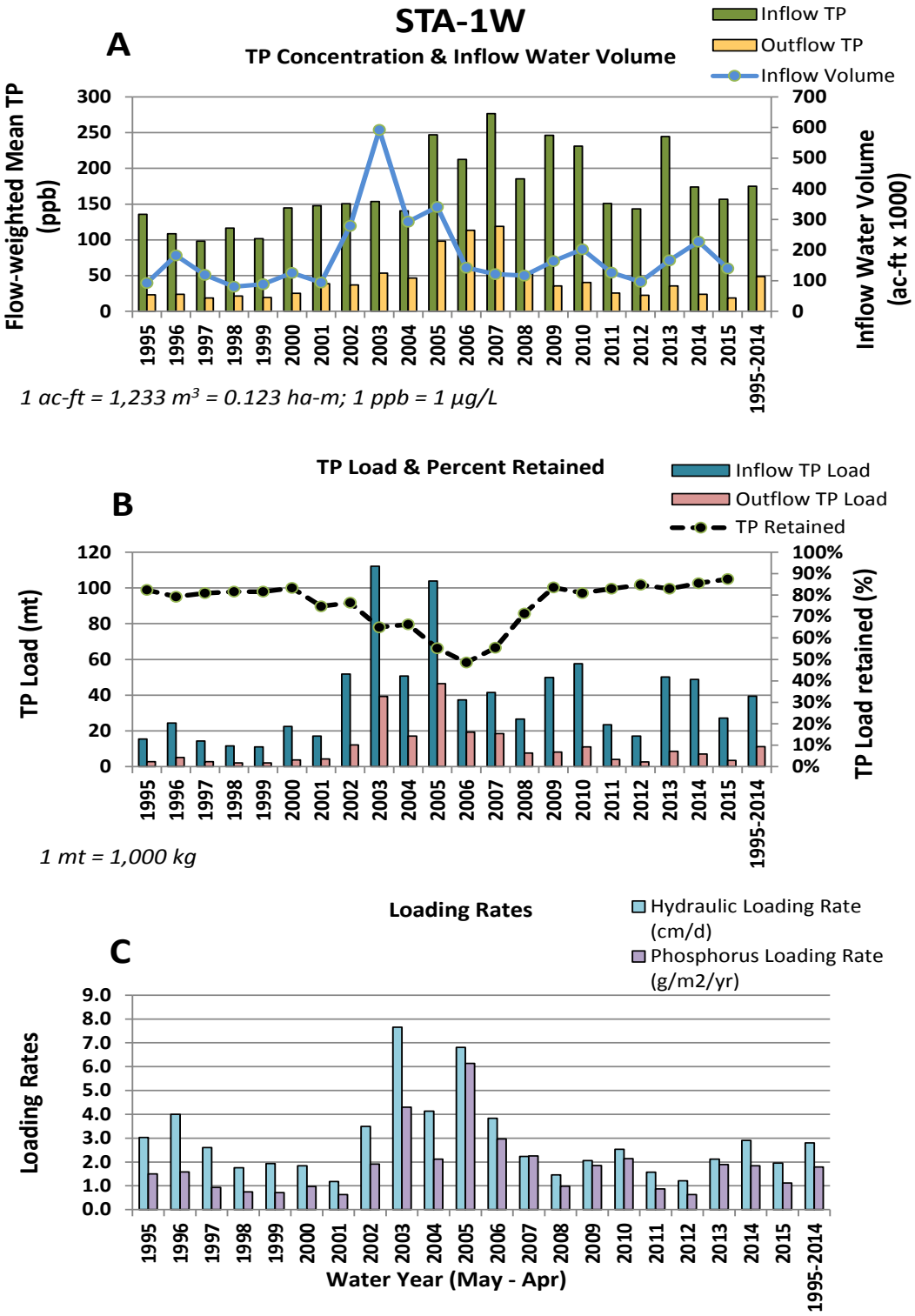


Figure 5B-17. Annual time series in STA-1W over POR of (A) inflow and outflow FWM TP concentrations and inflow water volume, (B) annual inflow and outflow TP loads and percent TP load retained, and (C) annual inflow HLR and PLR.

Lake Okeechobee Regulatory Releases to STA-1W

Approximately 50,786 ac-ft of lake water were treated in STA-1W in WY2015 (**Table 5B-2**). As in STA-1E, delivery of regulatory releases from Lake Okeechobee into STA-1W was also suspended beginning around December 19, 2014, due to high turbidity levels in the water coming from the lake (Appendix 5B-4 of this volume). As mentioned earlier, median turbidity at S-5A, the primary inflow pump station that conveys water to STA-1E and STA-1W, was 20 NTUs. There were no turbidity measurements at G-302. However, TSS data for the G-302 structure (STA inflow) indicates highest TSS between November and December 2014, but the median value for WY2015 was comparable with the previous five years (**Figure 5B-18**). TSS values measured at the STA outflow structure G-310 were all less than the MDL, indicating effective reduction in TSS and turbidity within the STA.

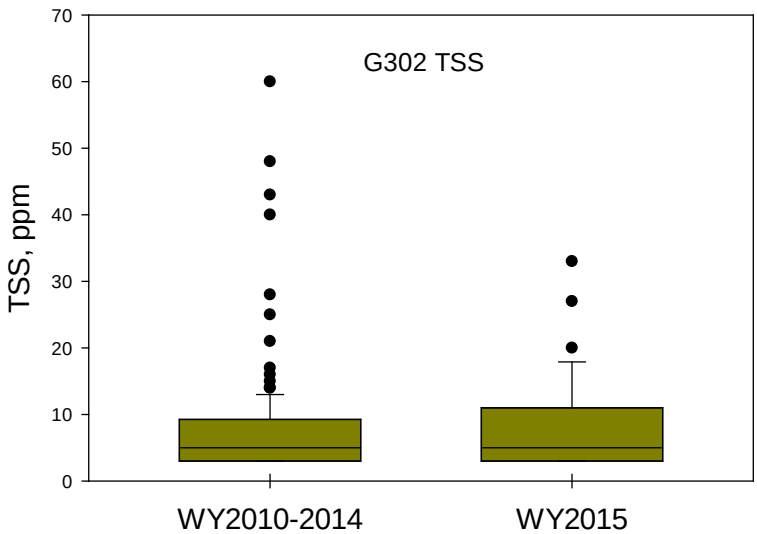


Figure 5B-18. Comparison of total suspended solids (TSS) values measured at the STA-1W inflow gated structure G-302, between WY2015 and the preceding five water years (WY2010–WY2014).

There were no notable changes in TP concentration at the outflow structures of the individual flow-ways or at the STA outflow structures (G-310 and G-251) during the timeframe that lake regulatory releases were delivered to the STA (**Figure 5B-19**). Construction and vegetation rehabilitation activities in the Eastern and Western flow-ways also limited the amount of lake water that could be delivered to STA-1W during WY2015.

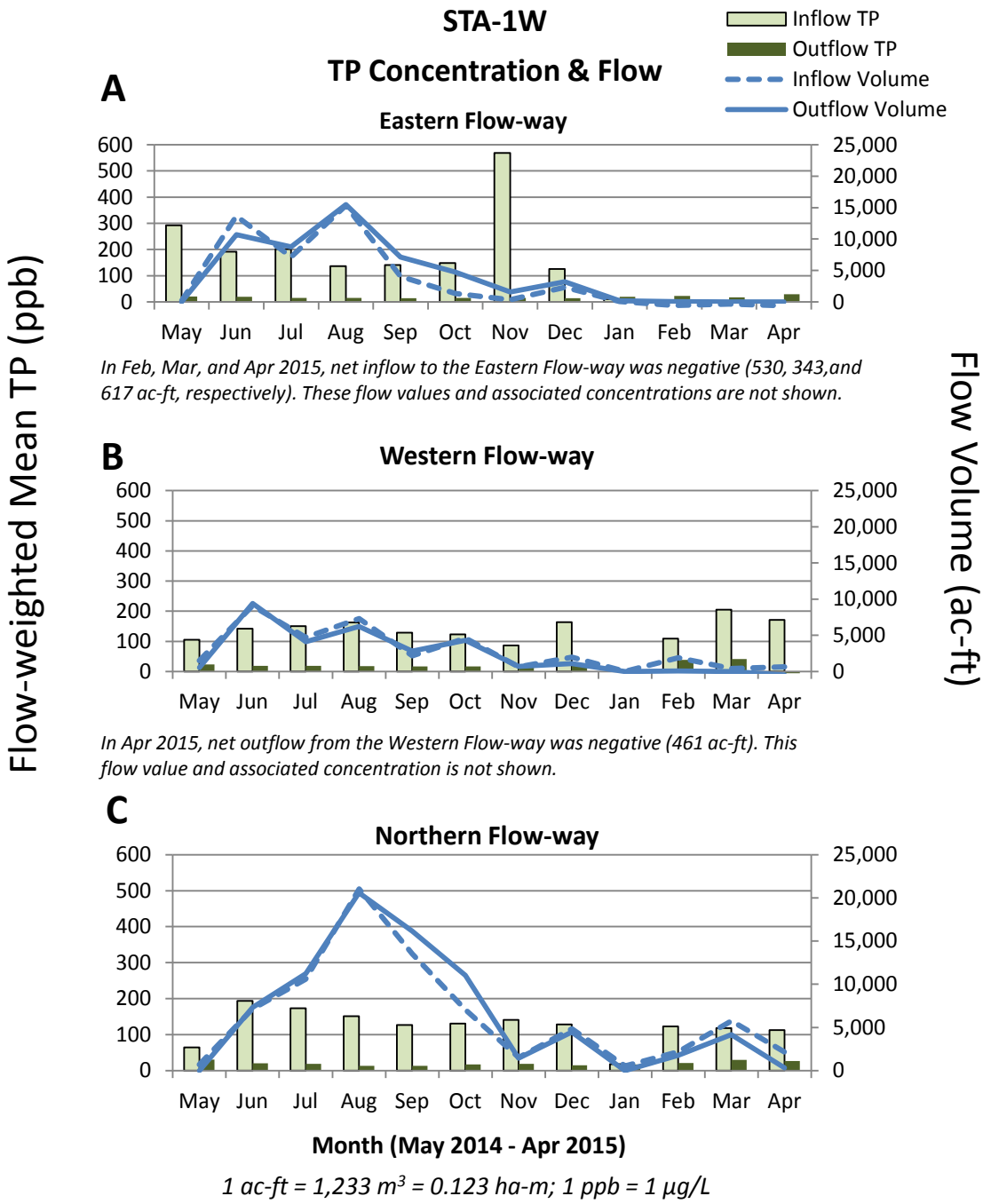


Figure 5B-19. Monthly time series for the STA-1W flow-ways of inflow and outflow FWM TP concentrations and water volume for (A) the Eastern Flow-way, (B) the Western Flow-way, and (C) the Northern Flow-way in WY2015. Although it is unintentional and infrequent, negative (reverse) flows can occur at gated culverts, as observed in the Eastern and Western flow-ways some of the months during WY2015.

STA-1W Vegetation

Enhancements and Maintenance Activities

During WY2015, various vegetation maintenance and enhancements were performed in STA-1W including herbicide treatment of FAV in Cells 1A, 1B, 2A, 5A, and 5B and cattail treatment in the south central area of Cell 3, fire flag and giant bulrush planting in Cells 5B, and major vegetation rehabilitation activities in Cell 1A, which includes drawdown and planting (**Table 5B-4**). Declines in SAV coverage were observed in January 2015 in Cells 1B and 4 with regrowth observed three months later in March 2015.

Table 5B-4. Vegetation management and enhancement activities conducted in STA-1W in WY2015.

Flow-way/Cell	Activities
Eastern Flow-way/Cell 1A	Major rehabilitation activities were initiated. Aerial and ground (airboat) herbicide treatments of 800 ac of floating pennywort, primrose willow, and floating cattail tussocks. The treated area was then planted with alligator flag and giant bulrush and the water level lowered to allow for recruitment of cattail seedlings.
Eastern Flow-way/Cell 1B	A vegetation strip was planted across the northern end of the cell.
Eastern Flow-way/Cell 3	Herbicide treatments were applied to eliminate cattail encroachment.
Western Flow-way/Cell 2A	Water levels were lowered to encourage cattail recruitment.
Western Flow-way/Cell 4	Herbicide treatments were applied to eliminate cattail encroachment.
Northern Flow-way/Cell 5A	Frequent herbicide treatments were needed to control water lettuce (*Pistia stratiotes*), water hyacinth, and pennywort (320 ac).
Northern Flow-way/Cell 5B	An SAV inoculation occurred in May 2014. Alligator flag and giant bulrush were planted to begin establishing a buffer of emergent vegetation along the eastern end of the cell. Frequent herbicide treatments were needed to control water lettuce, water hyacinth and pennywort (750 ac).

Qualitative Assessment of STA-1W Vegetation Coverage (Helicopter Surveys)

In the Eastern Flow-way, thin cattail stands and floating mats of smartweed (*Polygonum densiflorum*) were observed in Cell 1A (**Figure 5B-14**; Appendix 5B-1, Figure 2). Expansion of the unvegetated areas along short-circuit areas and in the north-central portion of the cell were noted. Cell 1A (Eastern Flow-way) was taken offline in March 2015 for major rehabilitation activities. In Cell 1B, SAV coverage at the beginning of WY2015 was moderate and increased throughout the year. By the end of WY2015, SAV coverage estimated from aerial assessments was considered to be good. In Cell 3, SAV coverage at the beginning of the water year was moderate and increased substantially throughout the year. There were no significant declines in SAV coverage observed.

The Western Flow-way was noted to have a significant impairment, in terms of vegetation condition. Cattail density in Cell 2A was poor and a large portion of the cell had floating mats and primrose willow coverage. The coverage of cattail progressively declined due to expansion of

pennywort mats. This flow-way was also taken off-line when rehabilitation efforts started in Cell 1A (as noted previously, this was prior to construction of the Independent Western Flow-way route). By the end of the water year, cattail coverage was still sparse with no EAV cover in approximately 80 percent of the area. In Cell 2B, a substantial decline in SAV, which was primarily muskgrass, was observed in January 2015. SAV became reestablished within two months and improved toward the end of WY2015. Similar loss in SAV coverage was also noted in Cell 4, which had excellent SAV coverage until January 2015 when it lost SAV cover in 70 percent of the cell area. Improvements in SAV coverage were noted in March 2015 and by the end of the water year, the cell was considered to be only 20 percent impaired.

In the Northern Flow-way, Cell 5A was considered to be 75–85 percent impaired throughout WY2015 due to a lack of cattail coverage attributed to extensive floating mats of smartweed. In Cell 5B, SAV coverage was excellent in the northern half of the cell but sparse in the southwest quadrant throughout the year.

STA-1W Vegetation Coverage Estimates Based on Aerial Imagery

Estimated coverage of EAV[9] in the treatment cells based on the aerial photographs show that there was an increase in net coverage in all the cells in 2014 relative to 2013. The increase in EAV coverage from 2013 and 2014 was doubled for Cells 2B, 4, and 5B, where coverage increased from 7 to 42 percent in Cell 2B, and increased from 12 to 36 and 28 percent for Cells 4 and 5B, respectively (Appendix 5B-7).

Qualitative Ground Surveys for SAV Condition in STA-1W Cell 5B

An SAV survey of STA-1W Cell 5B was conducted on January 30, 2015. Dense SAV areas extending from the middle to the north western region of the cell was covered with southern naiad and muskgrass (**Figure 5B-20**). Large areas located to the east and south of the cell had very low to no SAV coverage, confirming the observations from the helicopter assessments. Other species such as coontail and spiny naiad were also found in localized areas and in lower densities (**Figure 5B-20**). The cell also contains EAV, mostly in the form of vegetation strips to help protect the SAV from strong winds or strong flows or sporadically distributed throughout the cell. During this survey, recently planted bulrush and fire flag were observed near the northeastern portion of the cell.

The areas lacking SAV coverage to the east were covered with dense mats of FAV, primarily pennywort, water hyacinth, and small patches of water lettuce. The southern region of the cell was comprised of cattail and grass patches interspersed with large open areas covered with filamentous algae (**Figure 5B-21**). In addition, heavy floc and easily resuspended material was also found throughout the cell but primarily within the open areas (**Figure 5B-21**).

[9] It is often impossible to distinguish actual SAV coverage in the aerial images; therefore, some portion of areas mapped as SAV in the STAs may include open water without plants.

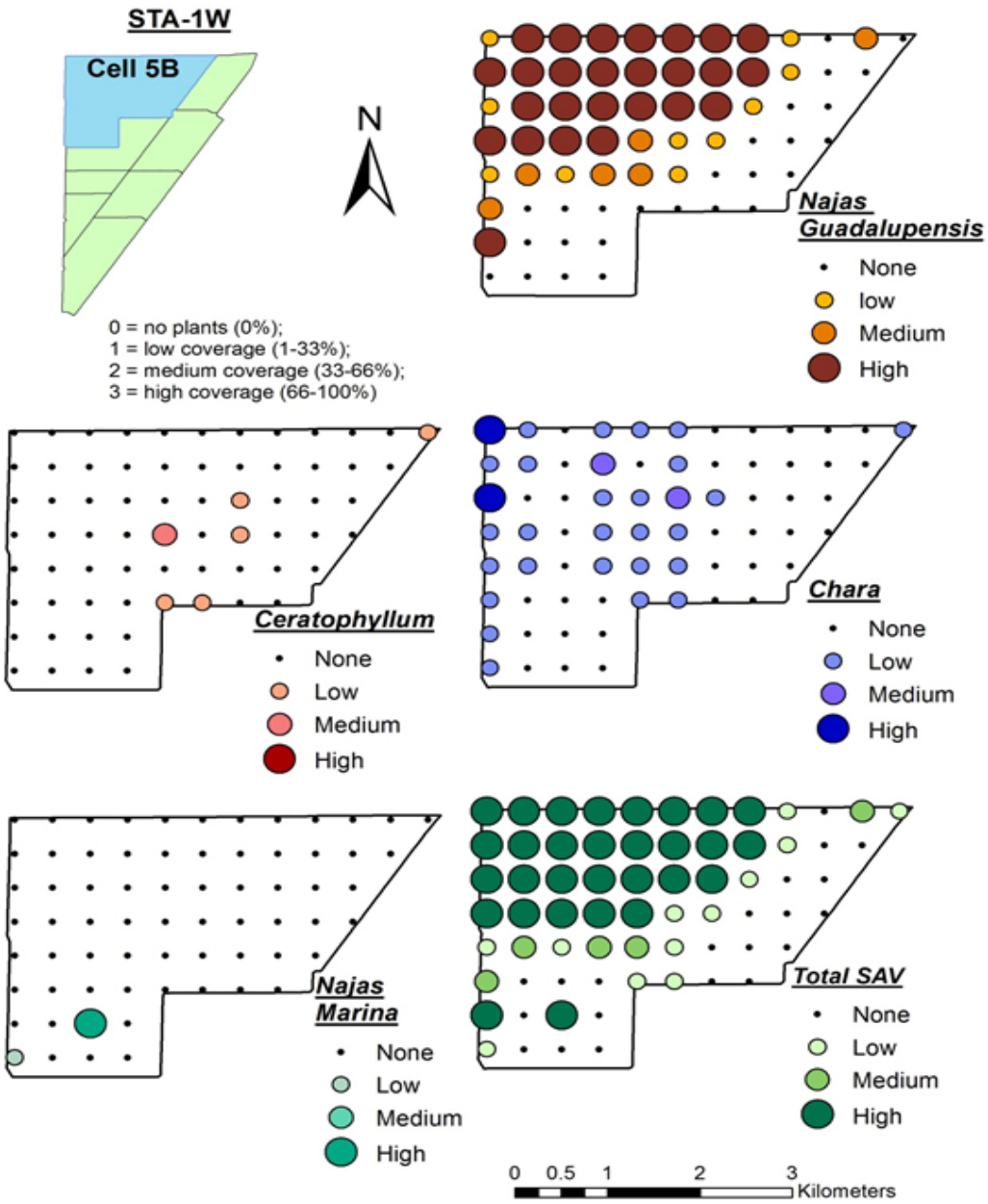


Figure 5B-20. SAV ground survey results depicting the spatial coverage and relative coverage of southern naiad and spiny naiad (*Najas guadalupensis* and *N. marina*, respectively), coontail (*Ceratophyllum demersum*), muskgrass (*Chara*, spp.), and all SAV species grouped together in STA-1W Cell 5B on January 30, 2015. Dots indicate location of SAV ground survey sites. Coverage of FAV or EAV, which may also have been present in the cell, is not shown on the map.

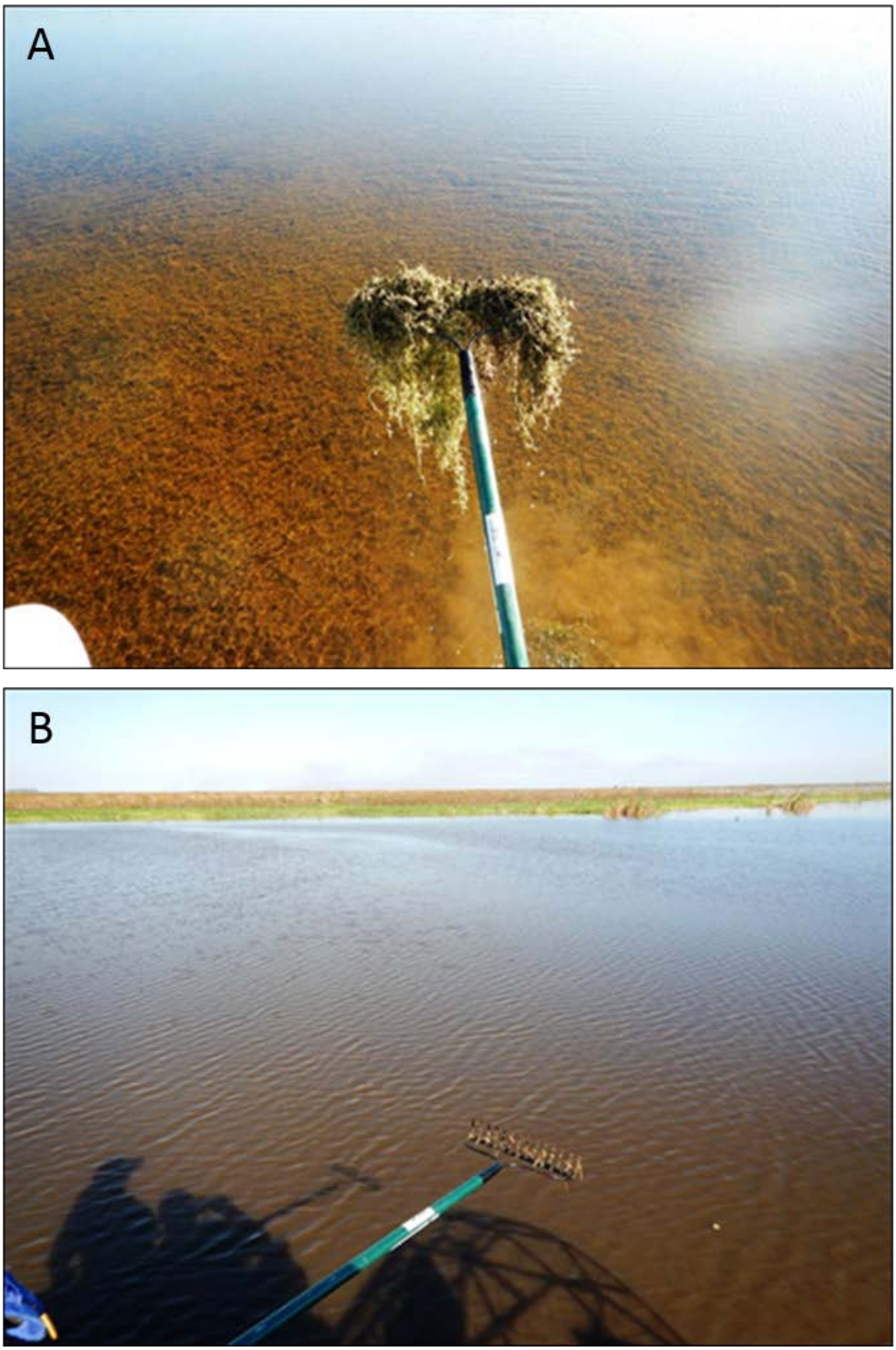


Figure 5B-21. Pictures taken during the vegetation survey conducted in STA-1W Cell 5B showing (A) dense beds of southern naiad and (B) open water areas without SAV and heavy floc material (photos by SFWMD).

STA-2 OVERVIEW OF PERFORMANCE AND ACTIVITIES

STA-2 is located in western Palm Beach County immediately west of WCA-2A (**Figure 5B-1**). STA-2, which began operation in 2000, originally consisted of three treatment flow-ways (Flow-ways 1, 2, and 3). This facility was expanded with the construction of Cell 4, which was flow capable by December 2006; and Cells 5, 6, 7, and 8, which were constructed later, creating Flow-ways 4 and 5. These new flow-ways were flow capable in WY2013. Currently, STA-2 has eight treatment cells arranged in five flow-ways with a total effective treatment area of 15,495 acres (Piccone et al. 2014; **Figure 5B-22**; Appendix 5B-1, Figure 3).

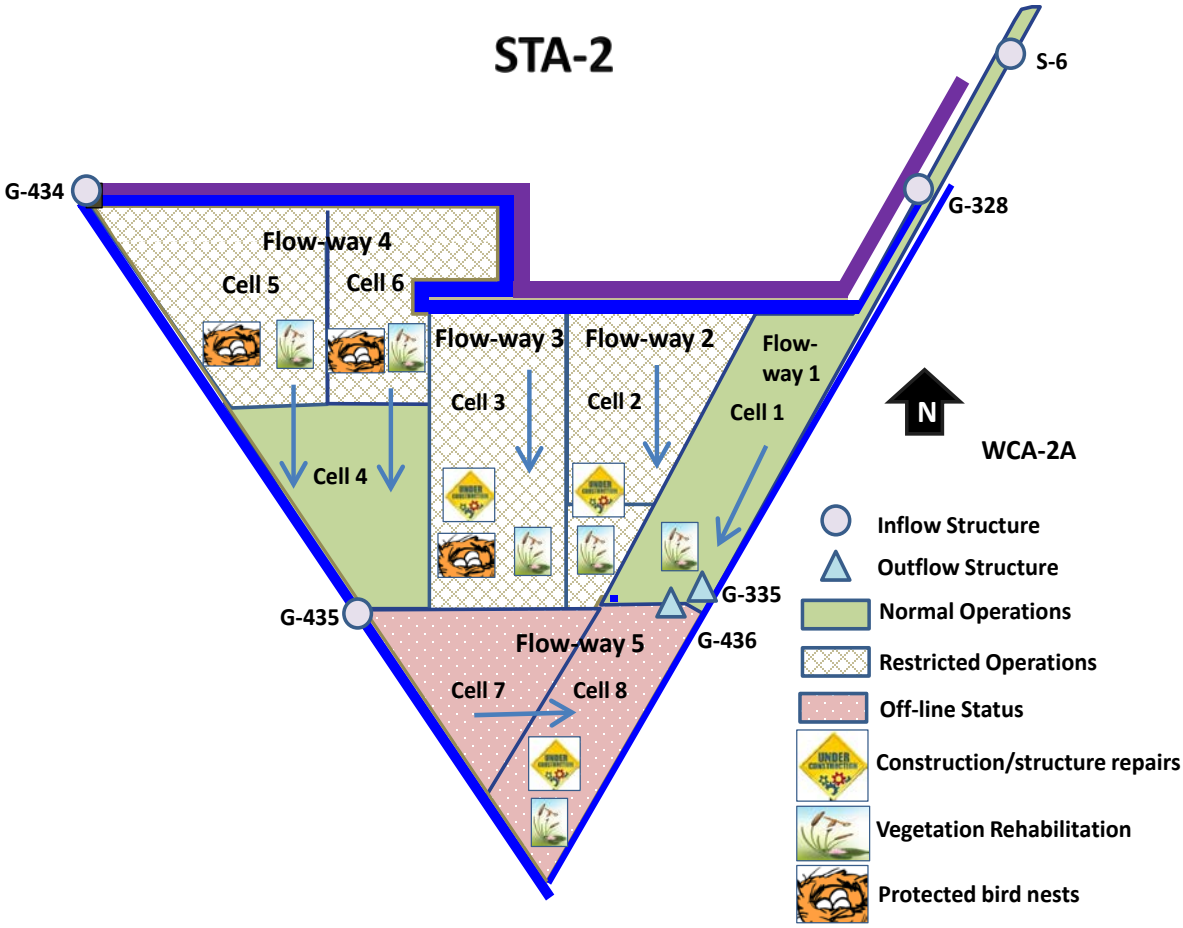


Figure 5B-22. Simplified schematic of STA-2 showing the different factors that affected the operations of the STA, which include construction or structure repairs, vegetation management activities, or the presence of protected bird nests. See **Figure 5B-23** for specific dates. A detailed structure map is provided in Appendix 5B-1, Figure 3, of this volume.

Over the POR including WY2015, STA-2 has performed relatively well compared with the other STAs, with an annual average of 21 ppb FWM TP concentration at the outflow and TP load retention of 77 percent (**Table 5B-1**). This STA has received approximately four million ac-ft of inflow water with an average TP concentration of 97 ppb and a total of 479 mt of TP load.

One feature of STA-2 thought partly responsible for its good treatment performance is that all of Cell 1 and part of Cell 2 were never farmed prior to these areas becoming part of the STA. The hypothesis is that there is reduced P flux from the unfarmed soils to the water column, which leads to lower outflow TP concentrations particularly from Cell 1. Beginning in WY2009, the vegetation community in approximately 300 ac at the southern end of Cell 2 was converted from cattail to SAV to improve treatment performance. Outflow TP concentrations from Cell 2 have generally improved over time, however the impact of this performance may not be apparent in the overall STA performance because multiple factors affect overall STA performance, including the fact that in WY2015 new flow-ways were undergoing startup and were in the vegetation grow-in phase. In more recent years, the overall STA-2 performance trend has improved as the new flow-ways have stabilized and are providing additional effective treatment area. Like the other STAs, STA-2 has been affected by regional droughts and storm events over its POR. The District seeks to improve operation of the STAs to minimize impacts from such events. For example, Cells 1 and 2 have dried out, either partially or entirely, during past droughts when the supply of supplemental water was limited. Starting in WY2011, as a proactive measure, stage throughout STA-2 were increased slightly in advance of the dry season, which has helped minimize dry out.

STA-2 Facility Status and Operations

In WY2015, Flow-ways 1 and 2 were operated under normal flow conditions for the entire water year. Flow-ways 3 and 4 were operated periodically online with restrictions, and Flow-way 5 was offline the beginning of the water year from April to August 2014. Operational challenges include grading and startup operations in Cell 8, structure repairs, vegetation enhancement activities, and presence of black-necked stilt nests (**Figure 5B-22**).

A timeline summarizing the status of each flow-way in STA-2 is presented in **Figure 5B-23**. Flow-ways 1 and 2 were operated under normal operations throughout WY2015, Flow-way 3 was operated online with restrictions from May to June 2014 for vegetation enhancement and presence of black-necked stilt nests and from October to December 2014 for vegetation enhancements, Flow-way 4 was operated online with restrictions from May to June 2014 and April 2015 due to the presence of black-necked stilt nests, and Flow-way 5 was off-line starting from December 10, 2013, for grading activities in a portion of Cell 8 upstream of the discharge structure. As of July 1, 2014, the Cell 8 grading work was complete, and Flow-way 5 remained offline for vegetation grow-in until being returned to online status on August 6, 2014. Structure maintenance activities in STA-2 during WY2015 included Cell 2 inflow structure (G-331A, C, F, and G) tailwater sensor repairs and the G-333D (Cell 3) gate sensor replacement (Appendix 5B-1, Figure 3).

During WY2015, STA-2 treated water from Lake Okeechobee regulatory releases prior to delivery to WCA-2 (**Table 5B-2**). Approximately 252,655 ac-ft of regulatory releases were treated in WY2015, which is the highest annual regulatory release volume treated in STA-2 over the POR.

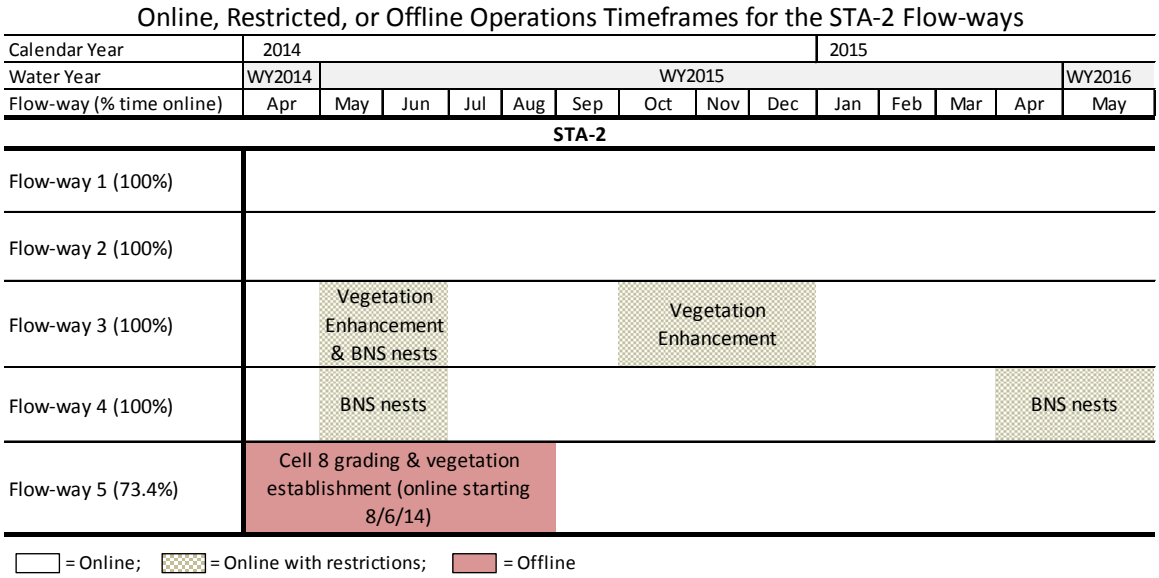


Figure 5B-23. Timeline showing the STA-2 flow-ways that were online, offline, or operated online with restrictions due to the presence of protected bird nests, vegetation management activities, construction or infrastructure repairs. [Note: BNS – black-necked stilt.]

STA-2 Performance

In WY2015, STA-2 received an annual inflow FWM TP concentration of 72 ppb, approximately 14 ppb less compared to WY2014 and 29 percent less than the POR average (**Table 5B-1** and **Figure 5B-24**). The PLR in WY2015 was about equal to the PLR in WY2014 (0.8 and 0.7 g/m^2/yr, respectively) and the HLR (3.0 cm/d) was about 36 percent higher compared to WY2014 (and equal to the POR average). Despite restricted flow operations for three of the five flow-ways, 78 percent of the inflow TP load was retained and the outflow FWM TP concentration was 16 ppb, which is 3 ppb less than in WY2014. The lowest outflow concentration at STA level to date can likely be attributed to the lower loading rates, particularly due to absence of extreme events such as storms and drought during WY2015.

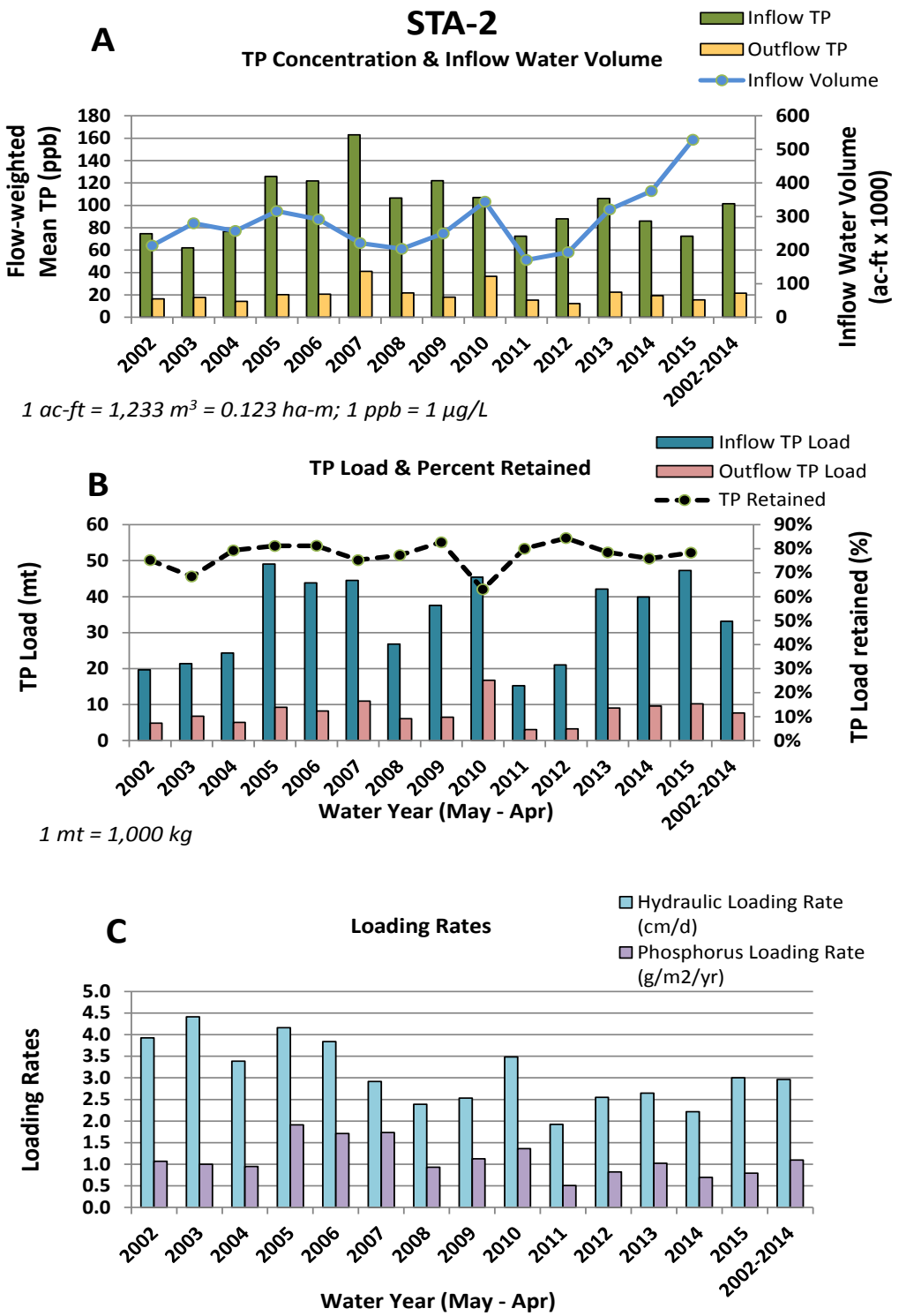


Figure 5B-24. Annual time series in STA-2 over POR of (A) inflow and outflow FWM TP concentrations and inflow water volume, (B) annual inflow and outflow TP loads and percent TP load retained, and (C) annual inflow HLR and PLR.

Lake Okeechobee Regulatory Releases to STA-2

In WY2015, STA-2 treated approximately 252,655 ac-ft of Lake Okeechobee regulatory releases (**Table 5B-2**). Lake water is delivered to STA-2 by releases from lake structure S-351 to the STA-2 inflow structures, S-6, G-434, and G-435 pump stations (**Figure 5B-1**). STA-2 received lake releases beginning in WY2014; however, the volume of lake releases increased in WY2015 between August 2014 and the end of the water year (**Table 5B-2**). The quality of water released from S-351 is generally better than from S-352 or CULV10A due to the presence of littoral areas on the southern portion of the lake (Appendix 5B-4 of this volume). Average turbidity at S-351 during the water year was 10 NTUs. Slightly elevated turbidity was also observed during some days in January and February 2015, at which time lake releases into SAV cells were suspended or reduced to minimize impacts to the SAV.

This portion of the chapter summarizes the trend in P concentration, P loading, and calcium (Ca) before, during, and after the period of lake releases. STA-2 was selected as a monitoring site for these parameters for the following reasons: (1) the investigation of an observed increase in TP and SRP concentrations in STA-2 Cell 1 during the period of lake releases, (2) STA-2 has received ~50 percent of total lake releases into the STAs in WY2015, (3) STA-2 provides a parallel comparison among the different vegetation configuration (Cell 1– emergent vegetation, Cell 2 – mixed emergent + submerged, Cell 3 – submerged, and Flow-way 4 – sequential emergent then submerged), and (4) there is an ongoing separate scientific study in STA-2, one of the Restoration Strategies Science Plan studies, which also aims to determine and report the long-term influence of Ca on P removal and cycling.

Total Phosphorus Concentration and Loading in STA-2 Flow-ways

In WY2015, the mean TP concentration at S-351 (Lake Okeechobee structure) was 84 ppb. The annual inflow FWM TP concentration at STA-2 inflow pump stations (S6 and G434) was 73 ppb, and for the individual flow-ways (Flow-ways 1 to 4), the inflow concentrations were 78, 81, 89, 58, and 25 ppb, respectively (**Figure 5B-25**). The low inflow concentrations entering Flow-way 5 (25 ppb) were likely influenced by seepage from STA-3/4, and were unrelated to lake releases. The Flow-ways 1 through 4 inflow TP concentrations were generally within the same range or lower than the period of record inflow concentrations for STA-2, suggesting that the lake water TP concentration itself was not detrimental to this STA. However, due to the large volume of lake water that was sent to the individual flow-ways, particularly to Flow-ways 1, 2, 3, and 4, the PLR increased during the water year (**Figure 5B-26**). The 365-day rolling PLR for the entire STA doubled, from 0.4 $g/m^2/yr$ in the beginning of the water year to 0.8 $g/m^2/yr$ at the end of the water year. The greatest increase in PLR was in Flow-ways 1 and 2, which reached 2.0 and 1.6 $g/m^2/yr$, respectively, by the end of the water year.

HLR and PLR have been shown to directly influence STA performance (Chen et al. 2015, Juston and DeBusk 2006, Dunne et al. 2012). This was likely the case in STA-2, particularly in Flow-ways 1 and 2, which had the highest loading rates and higher outflow TP concentrations in March and April 2015 (**Figures 5B-25** and **5B-26**).

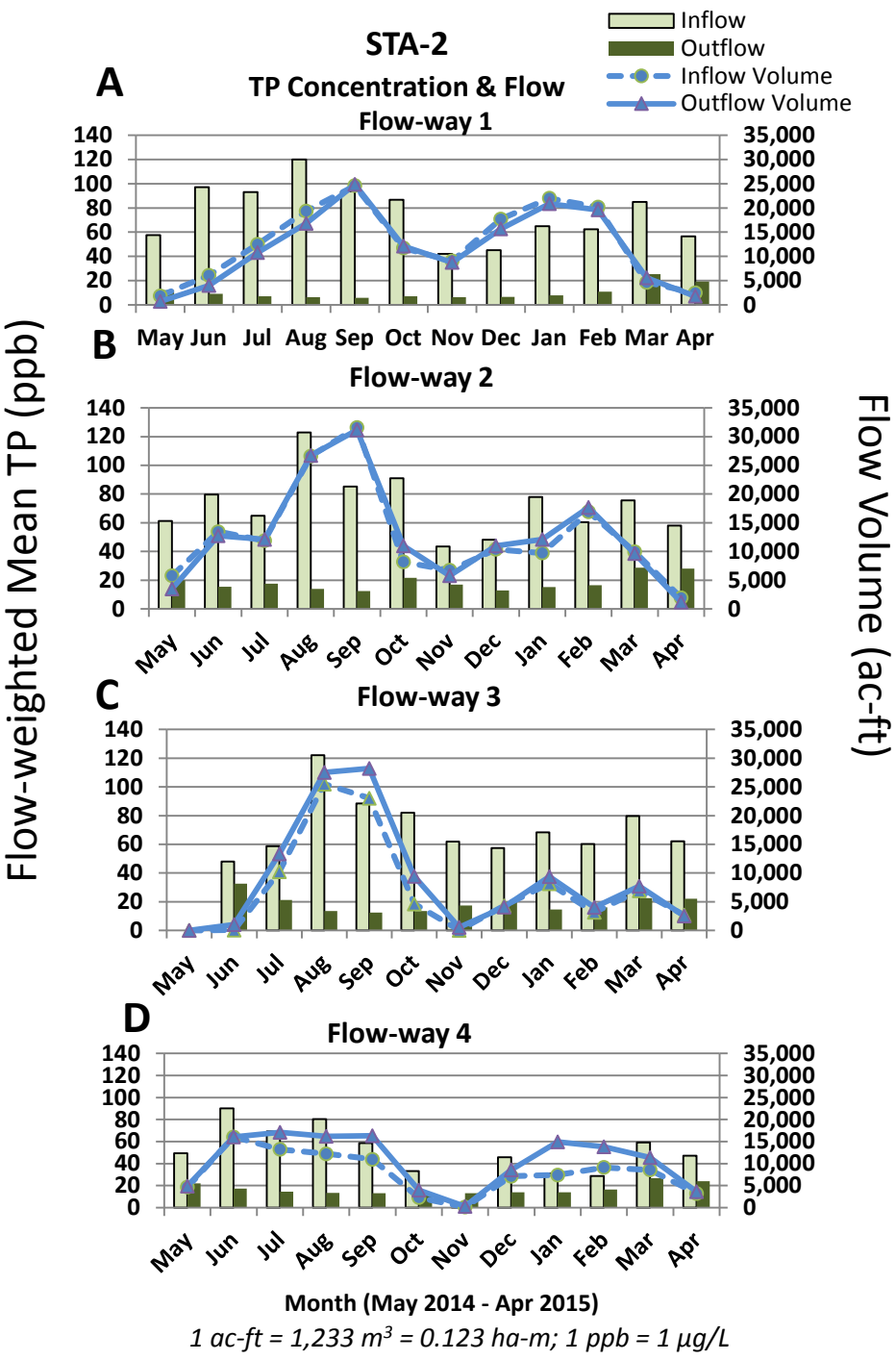


Figure 5B-25. Monthly time series for the STA-2 flow-ways inflow and outflow FWM TP concentrations and water volume for (A) Flow-way 1, (B) Flow-way 2, (C) Flow-way 3, and (D) Flow-way 4 in WY2015.

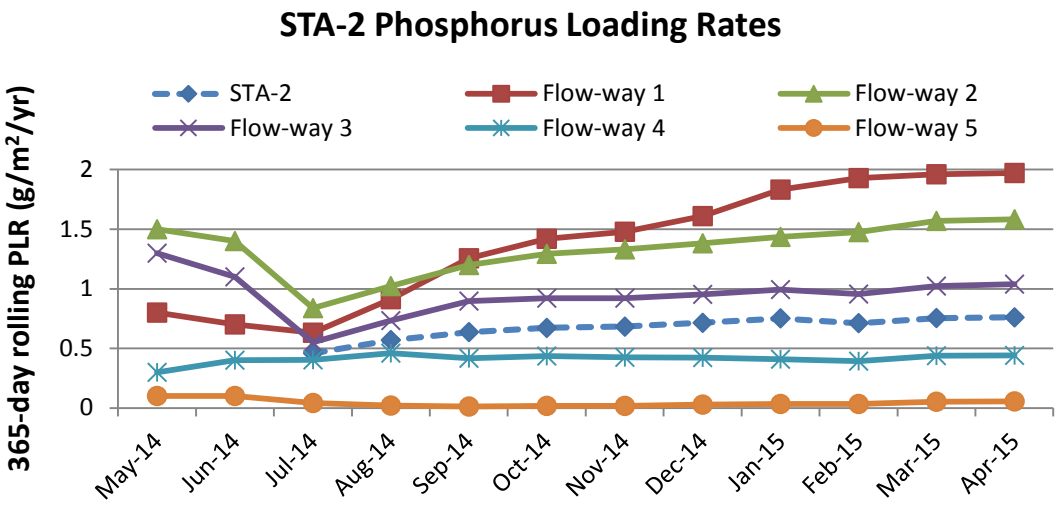


Figure 5B-26. 365-day rolling PLRs in STA-2 and individual flow-ways, calculated for each month in WY2015. Each data point is based on loading for 365-days from the specified date.

Inflow to Outflow Phosphorus Gradient in STA-2 Flow-way 1

Coupled with high temporal resolution inflow/outflow data, less frequent, high-spatial resolution internal transects were established in STA-2 Flow-way 1. Internal water quality sampling, along the inflow to outflow transects within Flow-way 1, was performed in September 2014 and March 2015, one month and six months after the increased lake releases. Average flows for each event were 712 and 160 ac-ft per day, respectively. These results are compared to a similar event that occurred in February 2014 (flow of 327 ac-ft per day) prior to the lake releases. Monitoring transects were collected at geo-referenced locations oriented perpendicular to the direction of flow. Samples collected along each transect were either composited in the field prior to analyses (to provide one sample per transect for analysis) or collected as individual grab samples (**Figure 5B-27)**. These samples were analyzed for TP, total dissolved P (TDP), and soluble reactive P (SRP). Dissolved organic P (DOP) and particulate P (PP) were calculated using the following relationships: (1) DOP = TDP – SRP, and (2) PP = TP – TDP.

During all the sampling events, there were noticeable increases in TP concentrations immediately downstream of the inflow structure likely due to internal loading from P-enriched sediment or floc accrued over time, including accrued floc from lake releases (**Figure 5B-28).** Concentrations generally decreased toward the outflow region of the flow-way. Based on the September 2014 sampling event, the concentrations increased from 75 ppb (at the inflow structure) to 100 ppb or greater between the B and E transect locations. Water column TP concentrations peaked at 127 ppb along the D transect, but declined rapidly at the mid-region of the flow-way, and resulted in an outflow TP concentration of 5 ppb. In the March 2015 sampling event, the internal TP concentration profile increased from 85 ppb (inflow) to above 100 ppb from the B transect to the H transect, suggesting an expanded area of high P flux compared to the September 2014 sampling event. The maximum TP concentration was also much higher at 224 ppb at the F transect and the outflow TP concentration was relatively higher at 37 ppb.

Compared to the February 2014 sampling event, both the September 2014 and March 2015 sampling results indicate higher maximum TP flux within the cell and a moving front of the spatial

extent of the elevated P flux along the flow-way. In February 2014, at the maximum TP concentration inside the flow-way was 117 ppb along the C transect (**Figures 5B-28**) and the outflow concentration was 7 ppb. Additional sampling will be performed in WY2016 to continue monitoring the wetland in terms of P reduction performance.

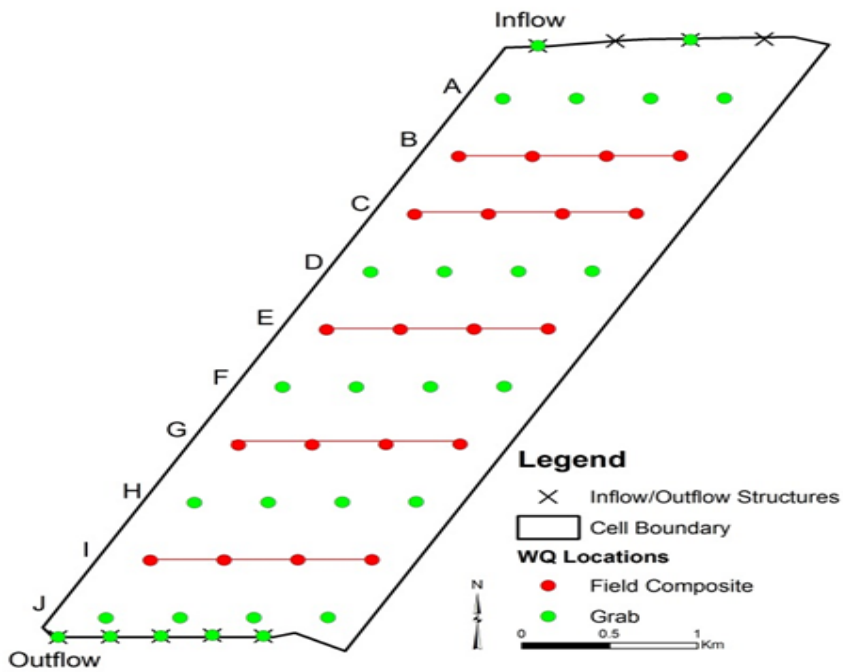


Figure 5B-27. Internal water quality monitoring transects and stations in STA-2 Flow-way 1.

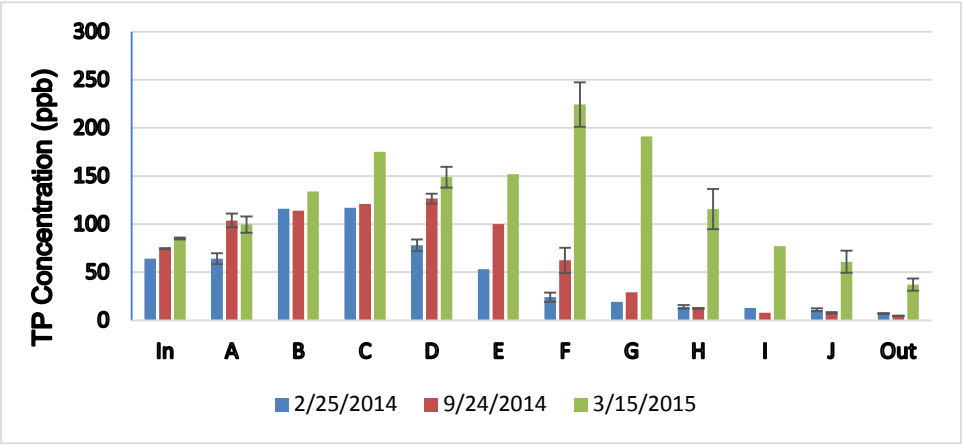


Figure 5B-28. TP concentrations gradients along STA-2 Flow-way 1 in February 2014, September 2014, and March 2015. Data points represent mean values (± standard error) for stations along each internal monitoring transect. (1 ppb = 1 µg/L)

Phosphorus Speciation in STA-2 Flow-ways

SRP, which is the most bioavailable form of P, comprised between 40 and 70 percent of inflow TP in STA-2. In a well performing STA flow-way, SRP is removed rapidly within the inflow region, leaving primarily PP and DOP along the remainder of the flow-way. An analysis of WY2015 outflow data indicates that SRP was generally less than or slightly above the laboratory MDL at flow-way outflows. However, SRP concentrations were detected during March 2015 at the Flow-way 1 outflow (13 and 17 ppb), Flow-way 2 outflow (15, 17, and 9 ppb), and at G-335 (6–23 ppb), which is one of the two STA outflow pump stations. These elevated SRP levels correspond to the unusually high TP values observed in Flow-ways 1 and 2 in the same month.

Similar to the spatial trend observed for TP in Flow-way 1, modest increases in water column SRP concentrations were also observed in this flow-way within the inflow region of the wetland in February and September 2014 (**Figures 5B-29**). The highest observed SRP concentration in February and September 2014 was below 60 ppb. In March 2015, the spatial extent of elevated SRP was markedly greater, with a pronounced peak just downstream of the mid-point of the flow-way (154 ppb). The observed SRP increases were likely a result of P release from the accrued soil and floc, as well as from decomposing litter. Reduced flows during the March 2015 sampling event may have also influenced the difference in spatial SRP profile compared to the previous two sampling events.

Compared to the February 2014 data, PP data in WY2015 indicates a decline in PP removal, with little to no removal in March 2015 (**Figure 5B-29**). In all sampling dates, PP generally increased from the inflow location, indicating PP release from the wetland, but declined to less than detection levels upstream of the outflow structure in February and September 2014. In March 2015, after the wetland had received a significant volume of lake releases, PP increased to as high as 40 ppb and was still at detectable levels at the outflow structures.

A similar trend was observed for DOP, based on the internal transect sampling events (**Figure 5B-29**). In February and September 2014, there was a general increase in DOP immediately downstream of the inflow structure, reaching as high as 50 ppb, but the concentrations eventually got reduced to less than the laboratory practical quantitation levels (< 8 ppb) before reaching the outflow structures. Based on March 2014 data, there was a net increase in DOP concentration within the flow-way, and remaining at detectable levels (17 ppb) at the outflow structures.

These results, along with TP data, indicates P release was occurring within the flow-way, likely due to increased P loading into the cell.

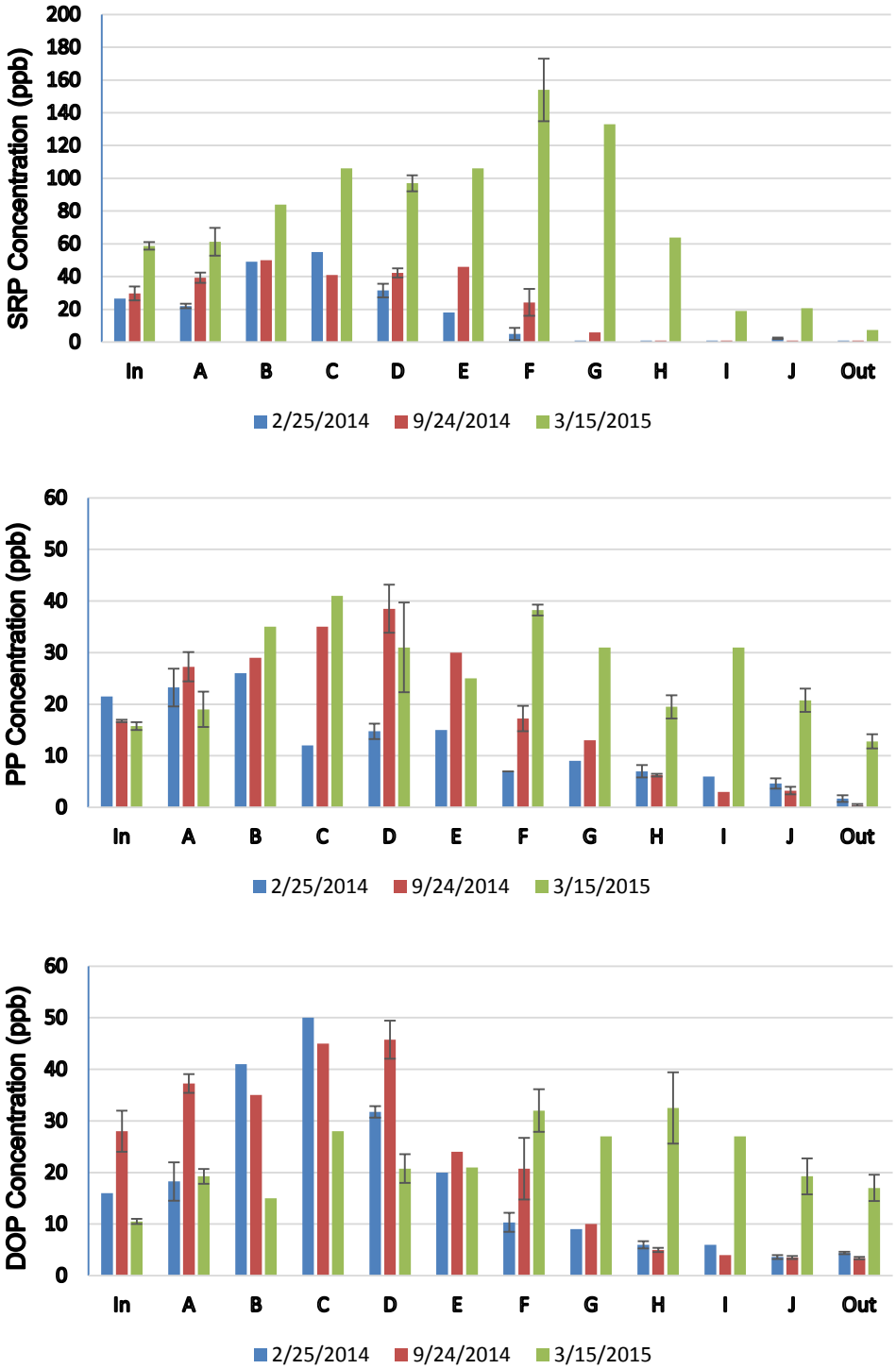


Figure 5B-29. SRP (top panel), PP (middle panel), and DOP (bottom panel) concentrations gradients along STA-2 Flow-way 1 in February 2014, September 2014, and March 2015. Data points represent mean values ± standard error for stations along each internal monitoring transect. [Note: 1 ppb = 1 µg/L.]

Trend in Calcium Concentrations in STA-2 Flow-ways

P co-precipitation with Ca is an important mechanism in the reduction of SRP in the STAs, therefore, reduction in Ca levels may result in corresponding decrease in SRP uptake. The following discussion summarizes the trend in Ca levels in STA-2 during the water year.

Concentration of Ca decreased by approximately 38 percent at the STA-2 inflow structures during the period as a direct result of lake releases. In WY2015, the mean Ca concentration measured at S-352 and CULV10A lake structures was 43 ppm, which is approximately half of the Ca levels found in Everglades Agricultural Area basin runoff (Diaz et al. 1994, Ivanoff et al. 2012).

In Flow-ways 1 and 2, the mean inflow Ca concentrations between May and October 2014 were 91 and 93 ppm, respectively, which decreased to a mean of 56 and 55 ppm, respectively, in November 2014 to the end of the water year (**Figure 5B-30**). The trend in outflow concentrations in STA-2 Flow-ways 1 and 2, with primarily emergent vegetation (Flow-way 2 has SAV at the southern region), generally followed the inflow concentration trend with minimal removal prior to November 2014. In the second half of the water year, when inflow Ca concentrations declined due to lake releases, outflow Ca concentration exceeded inflow concentration, which may suggest a release of Ca within the flow-way during this time period, from either the floc, detrital material, or both.

In Flow-way 3, which is primarily SAV, the trends in Ca inflow concentrations are similar to Flow-ways 1 and 2, but Ca reduction was more prominent, with 33 percent reduction between the inflow and outflow structures during May to October 2014, and less than a 10 percent reduction for the remainder of the water year (**Figure 5B-30**). In Flow-way 4, inflow Ca concentration also decreased (31 percent) between the two periods (May to October 2014 and November 2014 to April 2015). During the period from May to October 2014, there was approximately 43 percent reduction in Ca between the inflow and outflow structures, which occurred evenly between the front end cells (Cells 5 and 6) and back end cell (Cell 4). There was less than 10 percent reduction in Ca concentration between the inflow and outflow structures of Flow-way 4 from November 2014 to the end of the water year.

A correlation analysis (not included here) of Ca and SRP data for WY 2015 did not show any significant relationship, primarily due to the effects of other various factors such as internal flux and loading. This is consistent with previous attempts to characterize relationships between Ca and reductions in TP and SRP in the STAs that have proven inconclusive with conflicting trends due to the influence of other significant variables. A study is underway to investigate the long-term influence of Ca levels on P cycling and reduction in the cattail-dominated and SAV-dominated treatment areas; the study involves sampling at shorter-term interval (every four hours for TP and every week for Ca and SRP during controlled flow events) and in more sites within the wetlands.

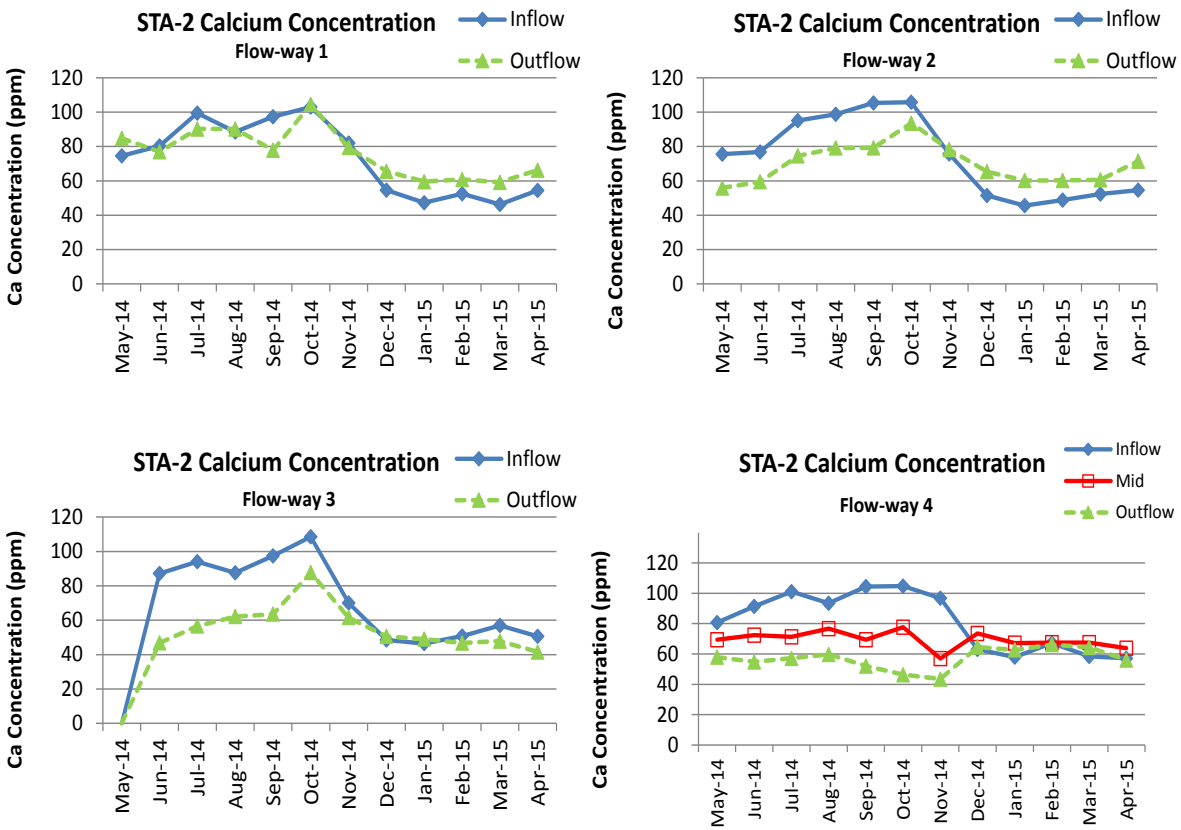


Figure 5B-30. FWM Ca concentrations at the inflow and outflow structures of Flow-ways 1, 2, 3, and 4 of STA-2. [Note: 1 ppm = 1 mg/L.]

STA-2 Vegetation

Enhancements and Maintenance Activities

Various vegetation management and enhancements were performed in STA-2 during WY2015 including herbicide treatment of FAV and cattail encroachment, SAV inoculations, and vegetation planting to alleviate hydraulic short-circuiting and create vegetation strips within SAV cells (**Table 5B-5**).

Table 5B-5. Vegetation management and enhancement activities conducted in STA-2 in WY2015.

Flow-way/Cell	Activities
Flow-way 1	There were no vegetation management activities or enhancements conducted in Flow-way 1
Flow-way 2	Herbicide treatment to control cattail in the southern region of the cell (~275 ac within the SAV conversion area)
Flow-way 3	Hydraulic short-circuits in the northern third of the flow-way were planted with alligator flag and giant bulrush and a new strip of giant bulrush was established in the southern end of this flow-way.
Flow-way 4/Cell 4	Aerial herbicide treatment of 75 ac of cattail encroachment in the southern portion of Cell 4 was completed March 2015.
Flow-way 4/Cells 5 & 6	Incremental conversion from EAV to SAV started and those areas were inoculated in May 2014 with southern naiad. Approximately 250 ac of cattail in Cell 6 were treated by aerial herbicide application in March 2015 as part of the second phase of the incremental SAV conversion in that cell.
Flow-way 5/Cells 7 & 8	In Cell 8, conversion of the northern 230 ac of the cell was initiated in WY2014 and extensive beds of muskgrass were observed. An SAV inoculation was conducted during the period of November 2014 to January 2015, when naiad was harvested from Flow-way 2 and planted in Cell 8. Aerial herbicide treatments were applied to 450 ac of cattail in Cell 8 for the second phase of incremental conversions of EAV to SAV.

Qualitative Assessment of Vegetation Coverage in STA-2 (Helicopter Surveys)

In Flow-way 1, the EAV coverage was considered to be excellent throughout the water year until the end of WY2015 (April 2015) when thinning cattail stands were observed in the northern part and southernmost region of the flow-way. Increased coverage of FAV was also observed at this time in the northern part of the flow-way.

In Flow-way 2, coverage of SAV in the southern portion of the flow-way was excellent and EAV coverage throughout the remainder of the flow-way was considered to be good. A more detailed discussion of the conversion to SAV for the southern region of this flow-way is discussed later in this section. A deep region in the northwestern corner of the flow-way remained unvegetated throughout the year. Flow-way 3 had a good SAV and EAV coverage in the beginning of WY2015 and further improved, based on the September 2014 survey.

In Flow-way 4, approximately 70 percent of Cell 4 had SAV cover, which improved throughout the water year until a 25 percent decline was observed in April 2015. In Cells 5 and 6, incremental conversion from EAV to SAV started in WY2014 and during the water year, scattered beds of SAV were observed throughout the conversion areas. Starting in September 2014, patches of cattails in both Cell 5 and 6 dislodged from the sediment and the cells were considered to be 15 percent impaired through the end of the water year.

Establishment of desired EAV and SAV species in Flow-way 5 was successful, with excellent EAV coverage in Cell 7 and excellent coverage of SAV in Cell 8. In Cell 8, conversion of the

northern 230 ac of the cell, which was initiated in WY2014, was successful with establishment of extensive beds of muskgrass.

Qualitative Ground Surveys for STA-2 Cell 3 SAV and EAV Conditions

Based on a survey conducted on August 26, 2014, STA-2 Flow-way 3 had abundant SAV coverage throughout the cell (**Figure 5B-32**). A combination of hydrilla, coontail, and southern naiad dominated the inflow region, while the middle and outflow regions were dominated by muskgrass with small areas of dense pondweed (*Potamogeton*, spp.), spiny naiad, and southern naiad. A survey conducted on March 18, 2015, indicated similar distribution of species found in the previous ground survey, but with a slight decline of plant density across the entire flow-way (**Figure 5B-33**).

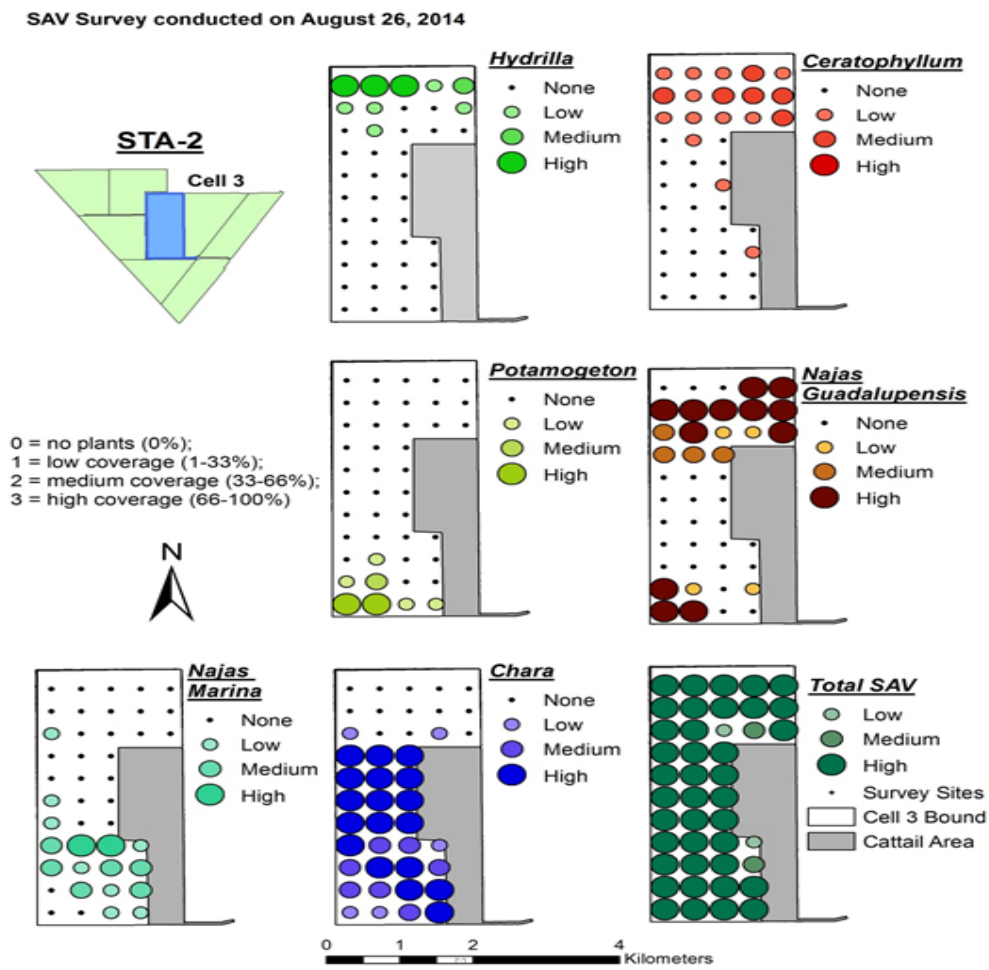


Figure 5B-32. SAV ground survey results depicting the spatial coverage and relative coverage of southern naiad (*Najas guadalupensis*), spiny naiad (*Najas marina*), coontail (*Ceratophyllum demersum*), muskgrass (*Chara*, spp.), pondweed (*Potamogeton*, spp.), hydrilla (*Hydrilla verticillata*), and all SAV species grouped together in STA-2 Cell 3 on August 26, 2014. Dots indicate location of SAV ground survey sites. Coverage of FAV or EAV, which may also have been present in the cell, is not shown on the map.

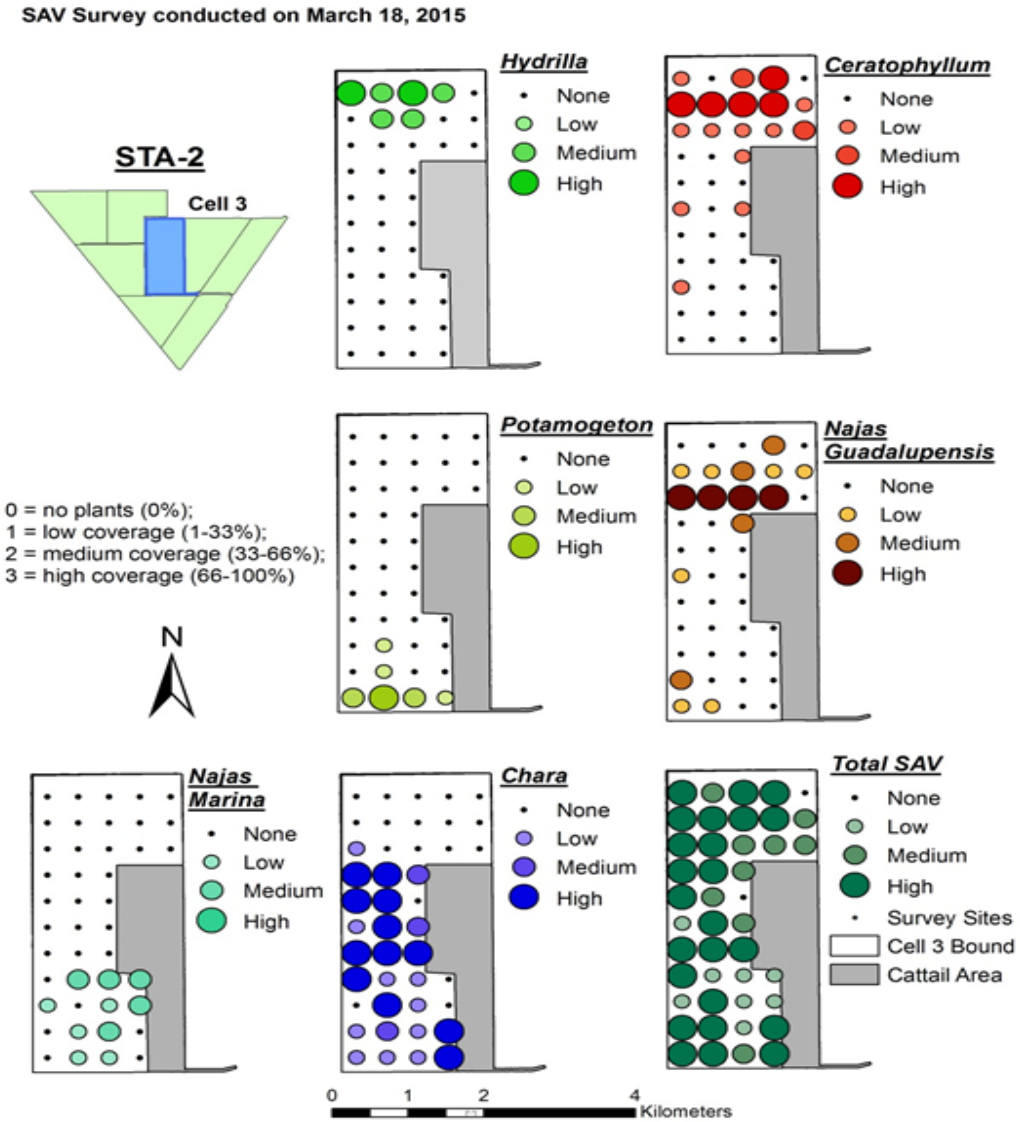


Figure 5B-33. Submerged aquatic vegetation (SAV) ground survey results depicting the spatial coverage and relative coverage of southern naiad (*Najas guadalupensis*), spiny naiad (*Najas marina*), coontail (*Ceratophyllum demersum*), muskgrass (*Chara*, spp.), pondweed (*Potamogeton*, spp.), hydrilla (*Hydrilla demersum*), and all SAV species grouped together in STA-2 Cell 3 on September 19, 2013. Dots indicate location of SAV ground survey sites. Coverage of FAV or EAV, which may also have been present in the cell, is not shown on the map.

Ground Surveys for SAV and EAV Conditions in STA-2 Cells 5 and 4

A field survey of the vegetation in STA-2 Cell 4 was conducted on August 19, 2014, to evaluate establishment of SAV in this relatively new cell, as well as to determine if there are any visible stress in vegetation as a result of Lake Okeechobee releases. At the time of the survey, the cell showed significant SAV coverage throughout (**Figure 5B-34**). No signs of SAV or EAV stress were observed.

Figure 5B-34. Dense muskgrass mats, pondweed, and southern naiad found in the mid-western region of Cell 4 (photo by SFWMD).

A survey of Cell 5 also conducted on August 18, 2014, indicated low to moderate SAV density coverage in the inoculated area in the southeastern region of the cell. Muskgrass and spiny naiad appeared to dominate this area although dense mats of hydrilla were found primarily near the inflow region. Bladderwort (*Utricularia*, spp.) was moderately distributed throughout the cell (**Figure 5B-35**). The middle region of the cell remained populated by dense cattail stands with sparse willow trees (**Figure 5B-35**). Overall, the cattail community appeared healthy in the untreated region, with the exception of the northeastern area in which uprooted cattail plants were floating.

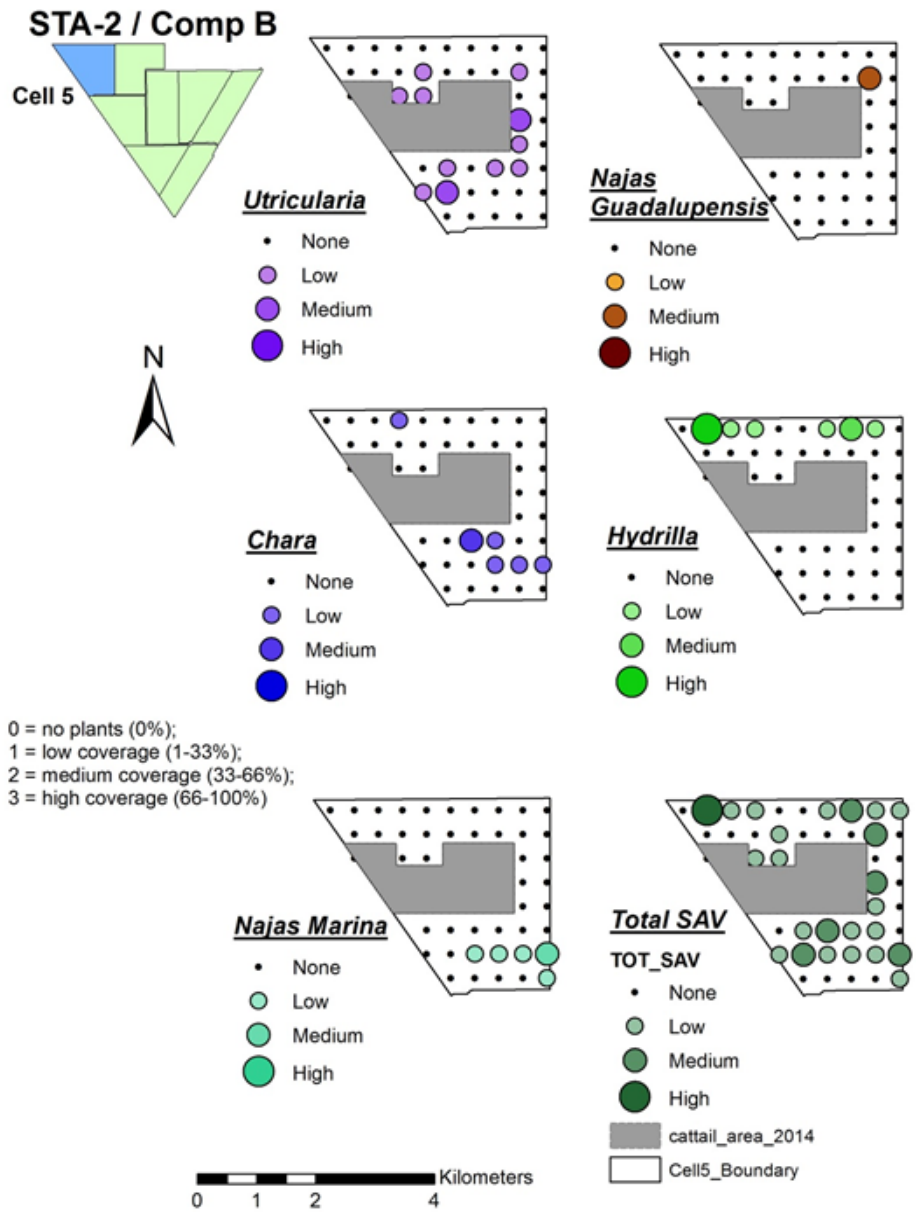


Figure 5B-35. SAV ground survey results depicting the spatial coverage and relative coverage of hydrilla (*Hydrilla verticillata*), southern naiad (*Naja guadalupensis*), spiny naiad (*Naja marina*), muskgrass (*Chara* sp.), bladderwort (*Utricularia* spp.), and all SAV species grouped together in STA-2 Cell 5 on August 18, 2014. Dots indicate location of SAV ground survey sites. Coverage of FAV or EAV, which may also have been present in the cell, is not shown on the map.

STA-2 Flow-way 2 Vegetation Conversion

STA-2 Flow-way 2, has historically been dominated by EAV consisting primarily of cattail and patches of sawgrass with the exception of a deep area in the northwestern portion of the cell that consists of SAV (predominantly hydrilla) or open water conditions. The Everglades Protection Area Tributary Basins Long-term Plan for Achieving Water Quality Goals (Burns and McDonnell 2003) included compartmentalization of this cell, i.e. with a divide levee, and conversion of the downstream portion to SAV in an effort to further improve P removal performance. Based on the outstanding performance of the neighboring flow-way (Flow-way 1) and the relatively good performance of Flow-way 2, it was decided to postpone any physical compartmentalization of this flow-way. Instead, in April 2009, approximately 300 ac of the existing cattail in the southern region of the cell was treated with herbicide to initiate a phased vegetation conversion from EAV to SAV (**Figure 5B-36**). In July 2010, the area was aerially inoculated with SAV (primarily muskgrass and southern naiad) obtained from the adjacent Flow-way 3. By June 2011, small beds of muskgrass had established in the western region. To accelerate the establishment of SAV, an additional inoculation with southern naiad and coontail was conducted at nine internal sites on July 2011. Additional herbicide treatments to the conversion area were conducted to reduce cattail encroachment (Volume III, Appendix 3-1, Attachment E). This report summarizes the trend in establishment of SAV since April 2009.

Methods

SAV surveys were initially conducted at 12 stations to assess SAV establishment in the conversion area. In October 2012, 21 additional monitoring stations were added for a total of 33 stations (**Figure 5B-36**). The SAV coverage was estimated using a semi-quantitative method in which species present at a site were assigned a relative abundance class from low (1 to 33 percent coverage, sparse), medium (33 to 66 percent coverage), and high (66 to 100 percent coverage, very dense). Relative abundance class by date was calculated for each species. In addition, water quality was monitored at internal transect locations from inflow to outflow to cover conversion and non-conversion areas. Soil accrual was also estimated by measuring the depth of unconsolidated floc material at each site using a coring device.

Results and Discussion

In August 2010, initial assessment of inoculated areas showed a gradual establishment and expansion of muskgrass (**Figure 5B-37**). Subsequent surveys indicated an increased abundance of muskgrass and southern naiad. In November 2011, following the second inoculation, newly introduced coontail remained present in most sites, but was absent by June 2012. Subsequent surveys showed good coverage of SAV primarily muskgrass and southern naiad, despite a marked decline in April 2013 (**Figure 5B-37**). A survey on April 2014, found dense SAV widespread throughout the conversion area. However, a survey on March 2015 indicated a significant reduction of SAV density and coverage in most of the conversion area.

Prior to conversion, the unconsolidated floc layer consisted primarily of decomposed emergent vegetation material measuring an average depth of 7 ± 2 centimeters (cm). By January 2012, the floc depth has increased to 20 ± 6 cm, indicating an accrual of 13 cm, which includes the decomposed cattail material, silt transported from upstream region, and residue from SAV and periphyton. Based on April 2014 and March 2015 measurements, soil accrual has slowed down with little change in average floc depth (**Figure 5B-38**).

Following a drought period and immediately after the first aerial spraying, surface water samples, collected on May 27, 2009, showed elevated TP concentration throughout the cell with higher concentrations in the EAV area (**Figure 5B-39**). After this event, subsequent sampling indicated a marked decline in P concentrations with more stable concentrations at the conversion

area (**Figure 5B-39)**. The initial increase in P concentrations was likely from the combined effects of soil oxidation from dryout and decomposing EAV in the conversion area after reflooding.

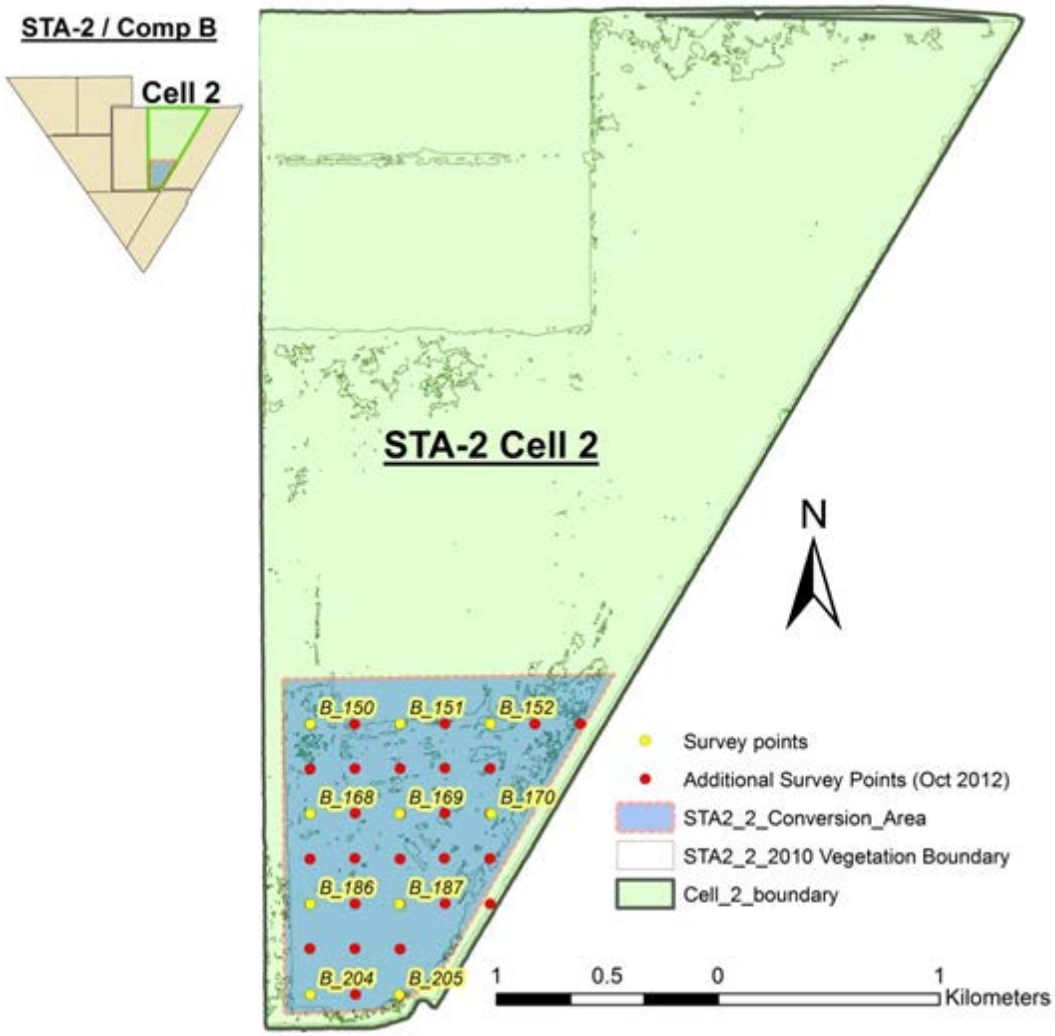


Figure 5B-36. Location of SAV and sediment survey sites within the STA-2 Cell 2 conversion area.

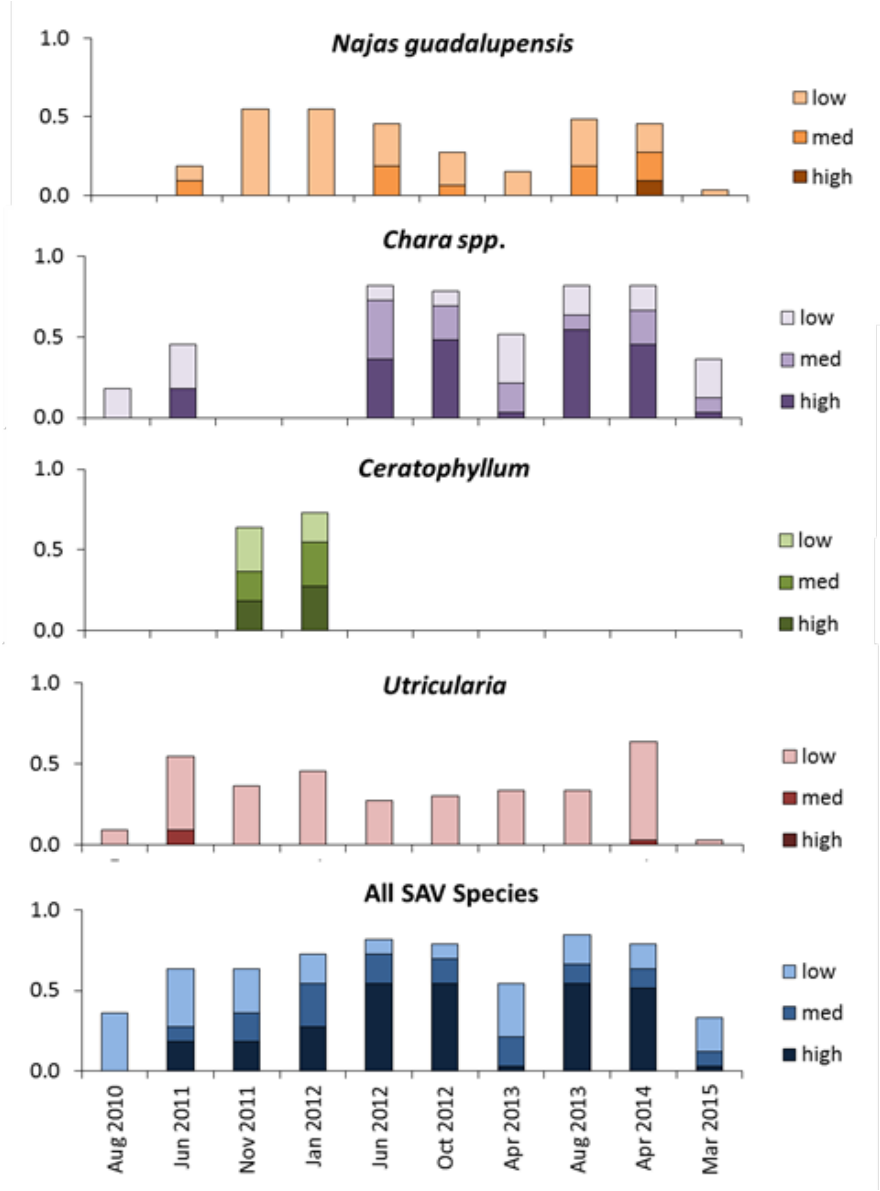


Figure 5B-37. Frequency of SAV species relative abundance in the STA-2 Cell 2 conversion area from August 2010 through April 2014 for southern naiad (*Najas guadalupensis*), muskgrass (*Chara*, spp.), coontail (*Ceratophyllum demersum*), and bladderwort (*Utricularia* spp.).

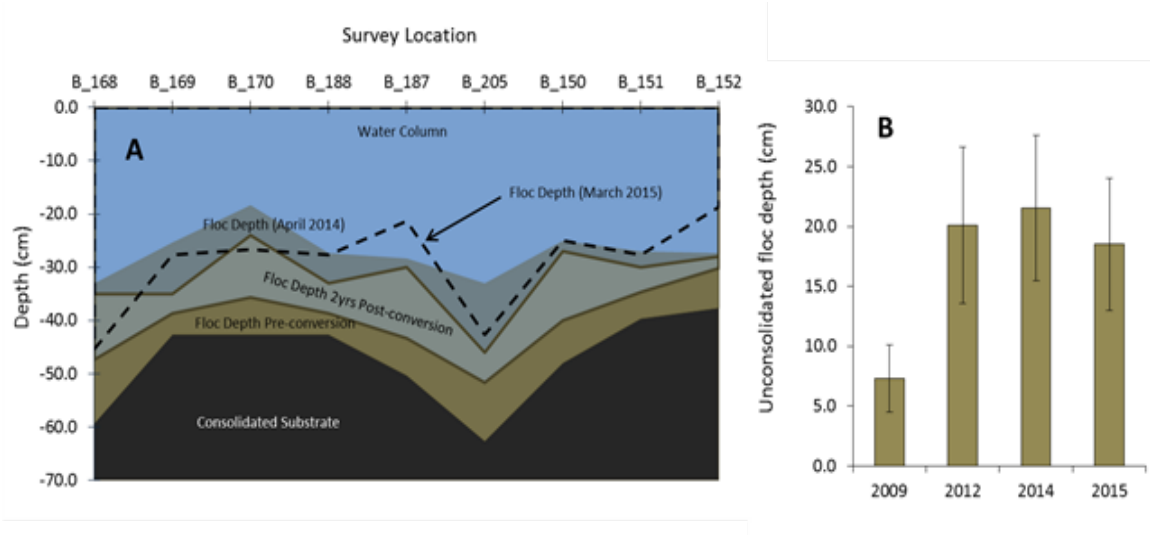


Figure 5B-38. (A) Temporal changes in unconsolidated floc depth within the conversion area in the south region of STA-2 Cell 2 and (B) mean ± standard deviation floc depths from all sites within the conversion area measured in 2009, 2012, 2014, and 2015.

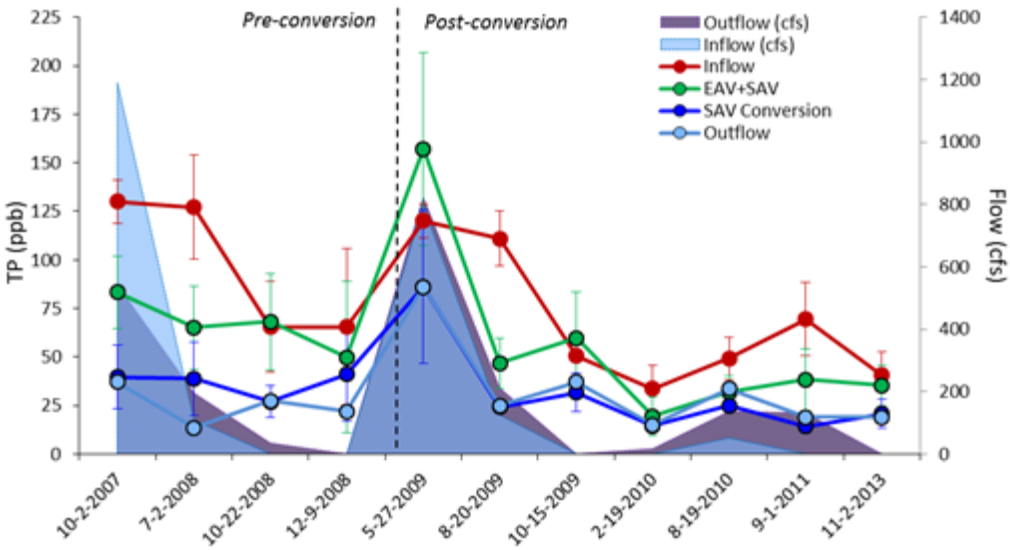


Figure 5B-39. Temporal trend in water column mean TP concentration from inflow to outflow in STA-2 Cell 2 during pre- and post-conversion showing flow and no flow conditions at the time of sampling. Error bars represent ± standard deviation of the mean for grab samples collected at inflow (n = 2), EAV and SAV areas (n = 4–16), SAV conversion area (n = 5–8), and the outflow.

STA-3/4 OVERVIEW OF PERFORMANCE AND ACTIVITIES

STA-3/4 is located east of the Holey Land Wildlife Management Area and north of WCA-3A (**Figure 5B-1**). STA-3/4 became operational in WY2004. In WY2006, a divide levee was constructed in Cell 3, creating Cells 3A and 3B. STA-3/4 is comprised of six treatment cells arranged in three flow-ways with a total effective treatment area of 16,327 acres (Piccone et al. 2014; **Figure 5B-40**; Appendix 5B-1, Figure 4). The District's STA-3/4 PSTA Project is located in a 445-acre section in the southwestern portion of Cell 2B.

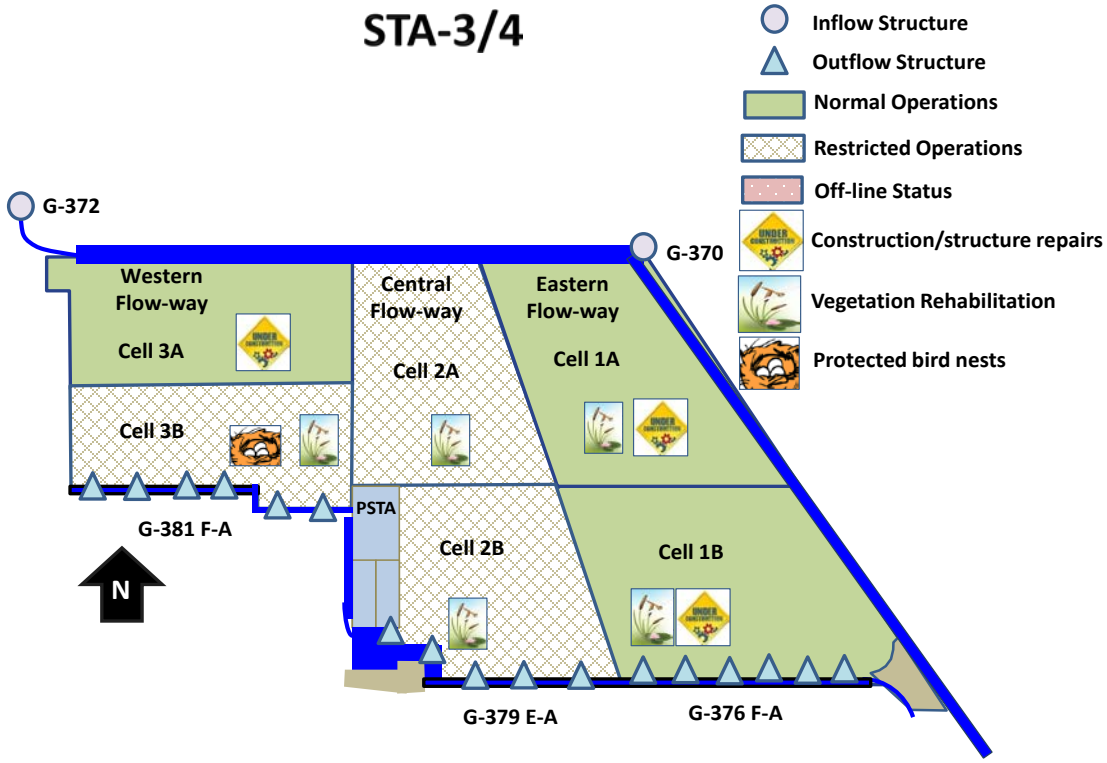


Figure 5B-40. Simplified schematic of STA-3/4 showing the different factors that affected the operations of the STA, which include construction or structure repairs, vegetation management activities, or the presence of protected bird nests. See **Figure 5B-41** for specific dates. A detailed structure map is provided in Appendix 5B-1, Figure 4, of this volume.

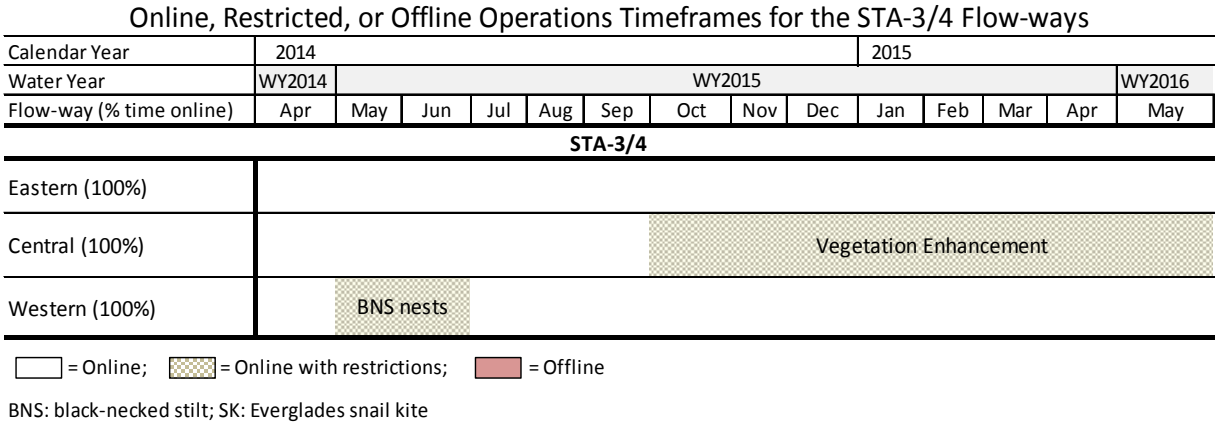


Figure 5B-41. Timeline showing the STA-3/4 flow-ways that were online, offline, or operated online with restrictions due to the presence of protected bird nests, vegetation management activities, or construction or infrastructure repairs.

The flow-way nomenclature for STA-3/4 is as follows:

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

Over its POR since WY2004 and including WY2015, STA-3/4 retained the greatest percentage of inflow TP load (84 percent) and achieved the lowest average outflow FWM TP concentration (17 ppb) compared to the other STAs. This STA has received over 5.2 million ac-ft of inflow with an average FWM TP concentration of 106 ppb and a total of 674 mt of TP (**Table 5B-1**). Although STA-3/4 has been affected by extreme weather events (regional droughts and large storms), receiving high hydraulic loads during and following large storms, annual outflow FWM TP concentrations were never greater than 23 ppb (WY2006 and WY2007) and were as low as 13 ppb (WY2009). High flows during large storms generally resulted in excessively deep water for extended periods in cells at the front end of the flow-ways. Persistent deep water conditions stressed the cattail populations in Cells 1A and 2A causing widespread mortality, especially at the inflow regions of these cells. Vegetation enhancement activities have focused on rehabilitating these areas by planting giant bulrush and lowering water levels in the dry season to encourage cattail regrowth. Phased incremental conversions from EAV to SAV communities have occurred in Cells 1B, 2B, and 3B over the POR.

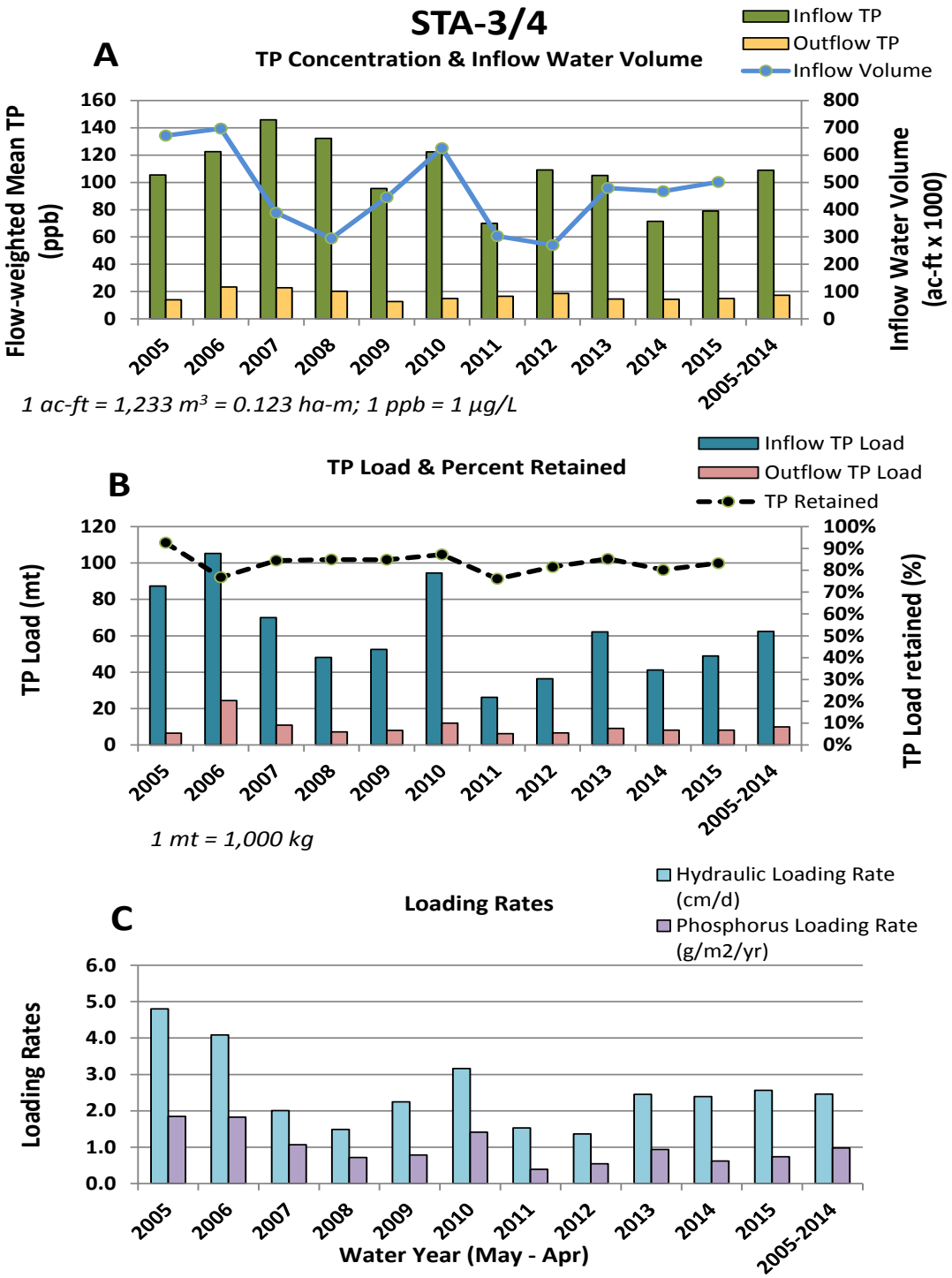


Figure 5B-42. Annual time series in STA-3/4 over POR of (A) inflow and outflow FWM TP concentrations and inflow water volume, (B) annual inflow and outflow TP loads and percent TP load retained, and (C) annual inflow HLR and PLR.

STA-3/4 Facility Status and Operations

In WY2015, operational challenges included vegetation enhancement activities and presence of black-necked stilt nests. A timeline summarizing the status of each flow-way in STA-3/4 is presented in **Figure 5B-41**. All flow-ways in STA-3/4 were operational in WY2015. For the entire water year, the Eastern Flow-way was operated under normal flow conditions. Except the period in the wet season from April through September 2014, the Central Flow-way was operated online with restrictions due to vegetation enhancement activities. The Western Flow-way was also operated online with restrictions during May–June 2014 when stages were restricted in Cell 3B to protect black-necked stilt nests. New monitoring platform construction and sensor replacements for structures G-374B, G-374E, G-376B, and G-376E were initiated in February 2015 and were ongoing as of July 2015 (Appendix 5B-1, Figure 4). Structure maintenance activities in STA-3/4 this year also included G-380E headwater and tailwater sensors and stilling well replacement.

In WY2015, Lake Okeechobee regulatory releases were sent south through STA-3/4 for treatment prior to delivery to the WCA when conditions allowed (**Table 5B-2**). The releases were suspended for some short periods during the wet season to provide flood control. Approximately 227,129 ac-ft of regulatory releases were treated in this STA during WY2015. This annual regulatory release volume is the highest during the entire STA-3/4 operation period.

As required by the WCA-3A regulation schedule, a replacement of an equivalent volume of water was delivered to WCA-3A for water supply for south Dade County. To supply water to the WCA-3A via WCA-2, Lake Okeechobee water was delivered to the north end of the WCA-3A through the diversion structure G-373 without routing the water through the STAs to avoid significant losses in water volume. This water supply operation started on May 28 and ended on June 9, 2014.

A dry season flow test was conducted in the Western Flow-way to evaluate the impact of continuous flow to the STAs during the dry season. The flow began the week of November 12, 2014, and ended on May 22, 2015. The results from these field studies will be used to support the modeling efforts to optimize operation of FEBs and STAs (Chapter 5C of this Volume).

STA-3/4 Performance

In WY2015, STA-3/4 received slightly higher inflow flow volume and FWM TP concentrations compared to WY2014 (**Figure 5B-42**) as well as inflow TP loads. The HLR and PLR rates (2.6 cm/d and 0.7 $g/m^2/yr$, respectively) were similar to WY2014 (2.4 cm/d and 0.6 $g/m^2/yr$, respectively) and the POR (2.4 cm/d and 0.9 $g/m^2/yr$, respectively). In WY2015, 83 percent of the inflow TP load was retained and the inflow FWM TP concentration (79 ppb) was reduced to 15 ppb at the outflow, which is the lowest outflow TP concentration among the STAs. The moderate HLRs, relatively low PLRs, dense cattail communities, thick EAV vegetation strips in Cells 1B, 2B, and 3B, and the absence of extreme storm events are factors that likely influenced the low outflow concentration at the STA level.

Lake Okeechobee Regulatory Releases to STA-3/4

In WY2015, STA-3/4 also received Lake Okeechobee releases and an evaluation of P and Ca trends is presented in this section. Approximately 227,129 ac-ft of Lake Okeechobee water was treated in STA-3/4 in WY2015; this volume includes regulatory releases, water supply deliveries, and a dry season continuous flow test in the Western Flow-way. Lake water was delivered primarily via lake structure S-354 to STA-3/4 inflow pump station G-372. In some instances, lake water was also sent from S-351 to STA-3/4 inflow pump station G-370. STA-3/4 received lake regulatory releases beginning in WY2014; the bulk of lake releases were from August 2014 through the end of the water year. The quality of lake water from S-354 and S-351 is generally better than from

S-352 or CULV10A due to the presence of littoral areas on the south and western portions of the lake, therefore turbidity was not problematic with regards to lake releases into STA-3/4 during WY2015 (Appendix 5B-4). In addition, the EAV cells were effective in reducing turbidity prior to water delivery into the SAV cells.

Dry Season Flow Test in the STA-3/4 Western Flow-way

A dry season flow test was conducted in the Western Flow-way beginning November 2014 and continued past the end of the water year, therefore the majority of the lake releases into STA-3/4 was treated in this flow-way. The Eastern and Central Flow-ways received less flows due to relatively poorer vegetation condition in the EAV cells (compared to the Western Flow-way) and vegetation rehabilitation efforts in the Central Flow-way during the dry season. The purpose of the dry season flow test was to evaluate an STA receiving low to moderate flows expected to be typical with the implementation of the A-1 FEB and the Central Everglades Planning Project. The target flows during this test was 260 cfs at 24-hour per day pumping. **Table 5B-6** shows the monthly flows during the entire water year. Results for WY2015 (outflow TP concentration, HLR, PLR, P concentration reduction, and P load reduction), including the months of the dry season flow tests, are presented below. (**Figure 5B-43**). Vegetation condition was also monitored in STA-3/4 Cells 3A and 3B.

Table 5B-6. Daily average and minimum/maximum flows in the Western Flow-way of STA-3/4. This flow-way was subjected to a dry season flow test to evaluate performance and vegetation conditions. The target daily average flow rate during this test period was 260 cfs.

Month and Year	Mean Daily Flows (cfs)	Minimum Flows (cfs)	Maximum Daily Flows (cfs)
May 2014	95	0	495
June 2014	235	0	721
July 2014	362	0	984
August 2014	554	0	1,309
September 2014	620	189	1,416
October 2014	153	0	778
November 2014	224	0	587
December 2014	249	0	410
January 2015	242	4	255
February 2015	271	222	505
March 2015	325	159	551
April 2015	265	113	633

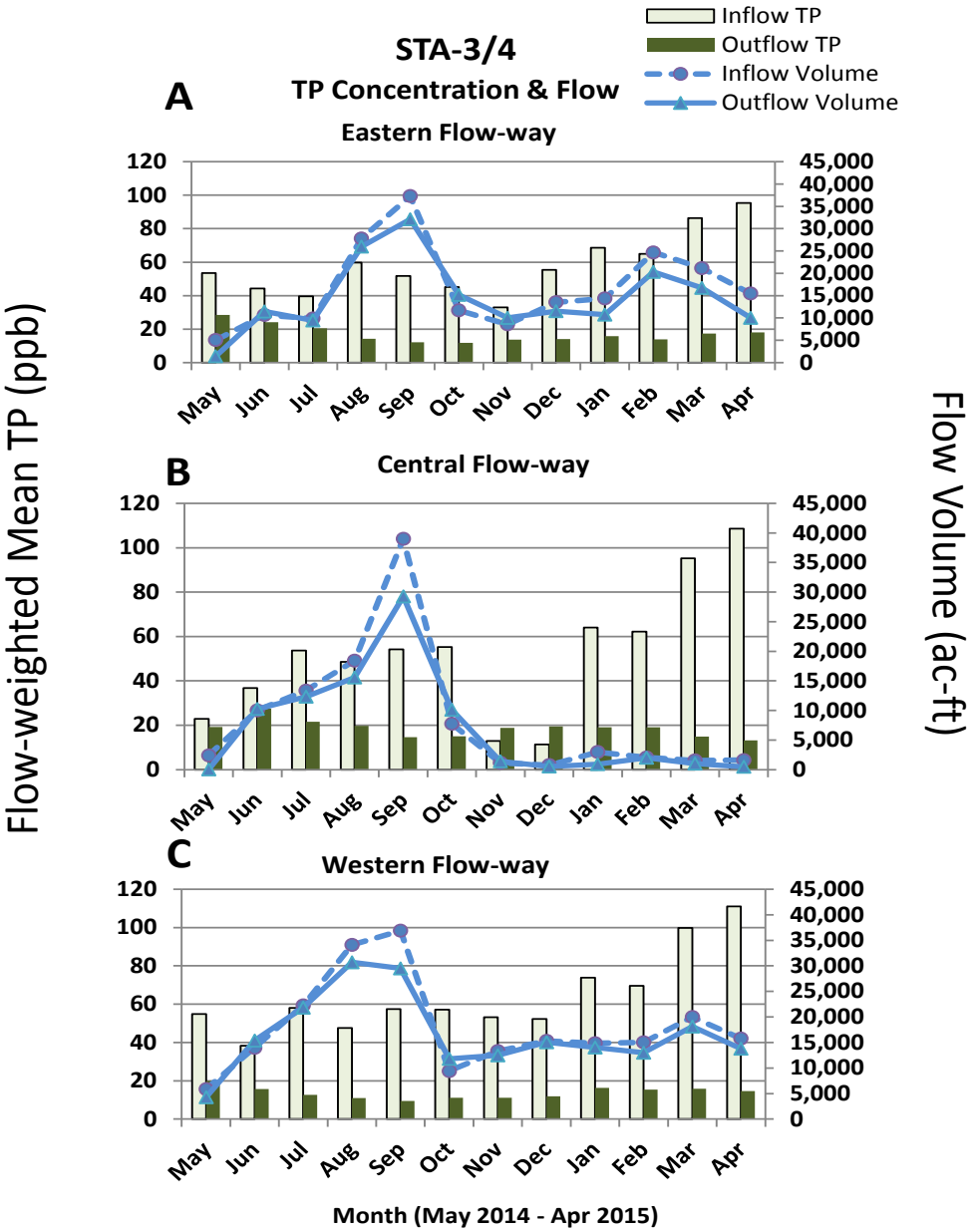


Figure 5B-43. Monthly time series for the STA-3/4 flow-ways inflow and outflow FWM TP concentrations and water volume for (A) the Eastern Flow-way, (B) the Western Flow-way, and (C) the Northern Flow-way in WY2015.

STA-3/4 Phosphorus Loading Rate

The PLR for the entire STA increased slightly from 0.61 g/m^2/yr in the beginning of WY2015 to 0.74 g/m^2/yr at the end of the water year (**Figure 5B-44**). The Western Flow-way had the greatest increase in PLR, since it received the highest amount of flows compared to the other two flow-ways. The highest 365-day rolling PLR experienced by the Western Flow-way was 0.94 g/m^2/yr, which is less than for STA-2 Flow-ways 1 and 2. Less dramatic increases in 365-day rolling PLR were also observed in the Eastern Flow-way, which reached a maximum of 0.57 g/m^2/yr. A decrease was observed in the Central Flow-way in the beginning of the water year and remained at less than 0.4 g/m^2/yr due to restricted flows into the cell for vegetation rehabilitation.

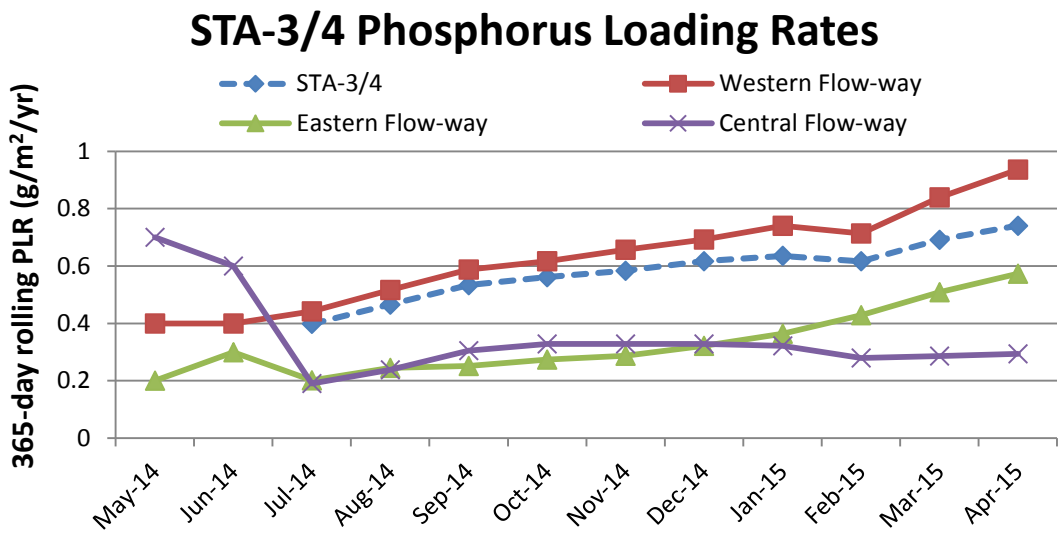


Figure 5B-44. 365-day rolling PLR in STA-3/4 and individual flow-ways, calculated in each month in WY2015. Each data point was based on loading for 365-days from the specified date.

STA-3/4 Total Phosphorus Concentration

Results show an increasing trend in STA and flow-way inflow TP concentrations between November 2014 and April 2015, reaching a maximum of 111 ppb by the end of the water year (**Figure 5B-45**). Similarly, mid-levee TP concentrations correspondingly increased during this time period, reaching 33 ppb by the end of the water year, which was approximately 20 ppb higher than in November 2014. Outflow TP was 11 ppb in November 2014 and increased to 14 ppb in April 2015 but this may be due to the fact that Cell 3B experienced a complete loss of SAV vegetation, which was primarily muskgrass, since the beginning of the water year. The cause of the SAV loss remains unknown, however the healthy EAV strips in this cell appeared to provide effective treatment in spite of the lack of SAV.

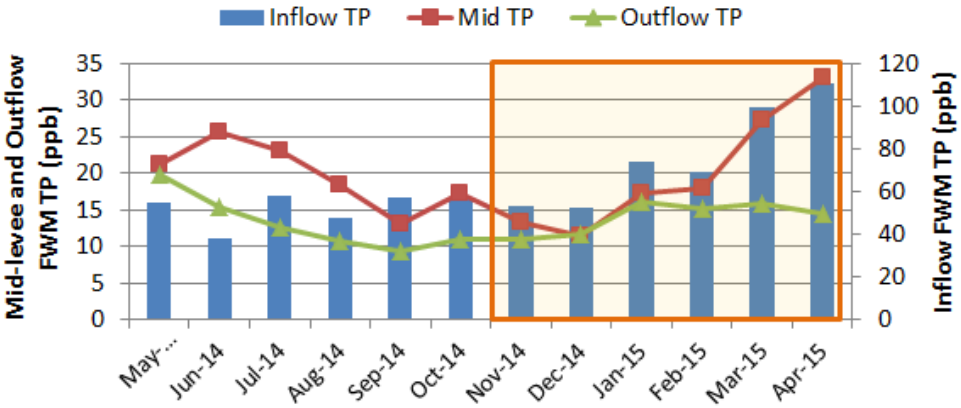


Figure 5B-45. Inflow, mid-levee, and outflow FWM TP concentrations in the Western Flow-way of STA-3/4.

Trend in STA-3/4 Calcium and Soluble Reactive Phosphorus Concentration

As the dry season lake releases into each of the flow-ways continued, the levels of Ca in the surface water decreased (**Figure 5B-46**) compared to the pre-lake release period. Between May and October 2014, inflow FWM Ca concentration averaged at 90 ppm, while between November 2014 and April 2015, the average concentration was 54 ppb for the three flow-ways. This indicates Ca decreases began as the wet season was ending, and most of the inflows to the STA were from lake releases. The temporal trend in Ca concentration along each flow-way was very similar. There was little to no removal early in the water year, then an increase in Ca concentration at the mid-levee and outflow structures, compared to inflow concentrations, was observed at varying times, indicating Ca release from within the cell. This is similar to what was observed in the STA-2 flow-ways although the occurrence in the STA-2 flow-ways was more consistent (beginning in November 2014). In the Eastern Flow-way of STA-3/4, the increase of Ca within the EAV cell started in December 2014, while in the Central and Western flow-ways, this increase started in September and October, respectively. As mentioned earlier, the increase in Ca relative to the inflow may be a result of particulate resuspension and/or hydrolysis resulting in Ca release from sediment particles. In addition, the lack of SAV in Cell 3B likely resulted in reduced Ca uptake.

SRP concentrations at the STA inflow (G-372) and flow-way inflow (G-380) were highly variable during the water year, with a mean of 25 ± 4 and 27 ± 4 ppb (**Figure 5B-47**). At the flow-way inflow, the weekly minimum was 2 ppb and the maximum was 96 ppb (April 2015). Highest concentrations were observed in the latter part of the water year. At the mid-levee structures, SRP concentrations correspondingly increased during the latter part of the water year, beginning around January 2015, with the highest levels (12–32 ppb) occurring between March and April 2015. This coincides with the observed increase in TP in this flow-way. Outflow concentrations at the G-381 structures were mostly at or below the detection limit of 2 ppb, except for approximately 10 instances at various times in the water year when SRP was at 4 ppb at either G-381B or G-381 E.

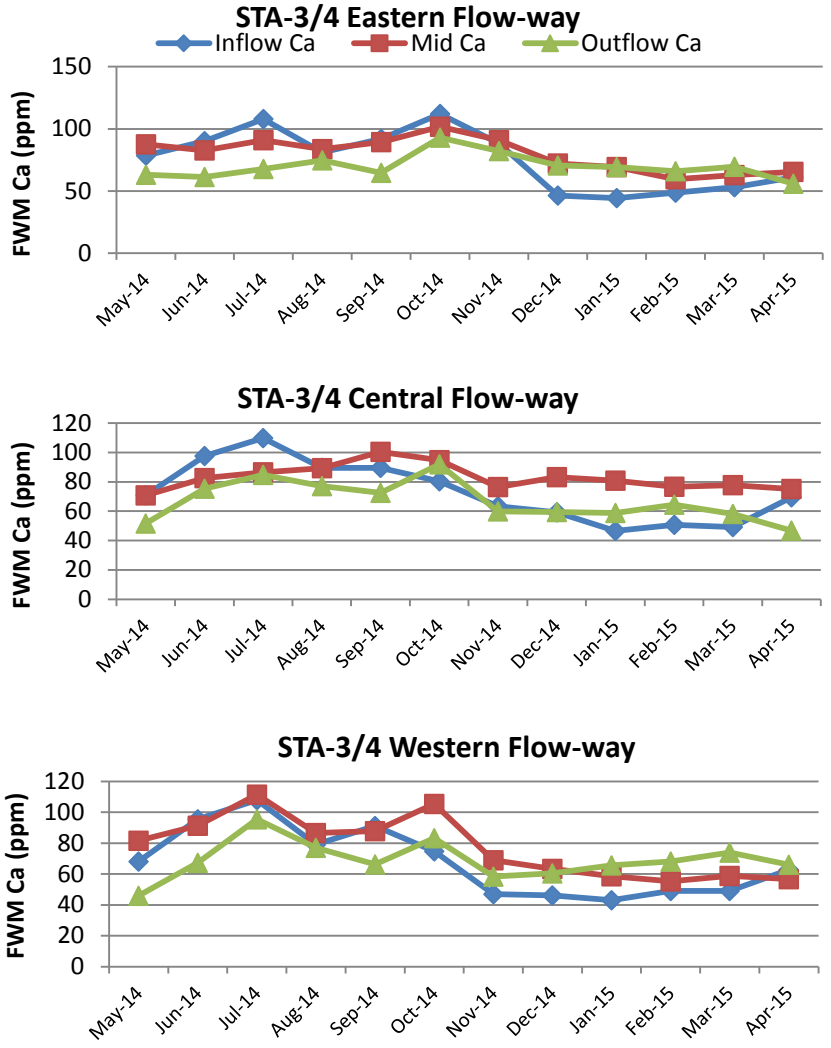


Figure 5B-46. FWM Ca concentrations at the inflow, mid, and outflow structures of Eastern, Central, and Western flow-ways of STA-3/4.

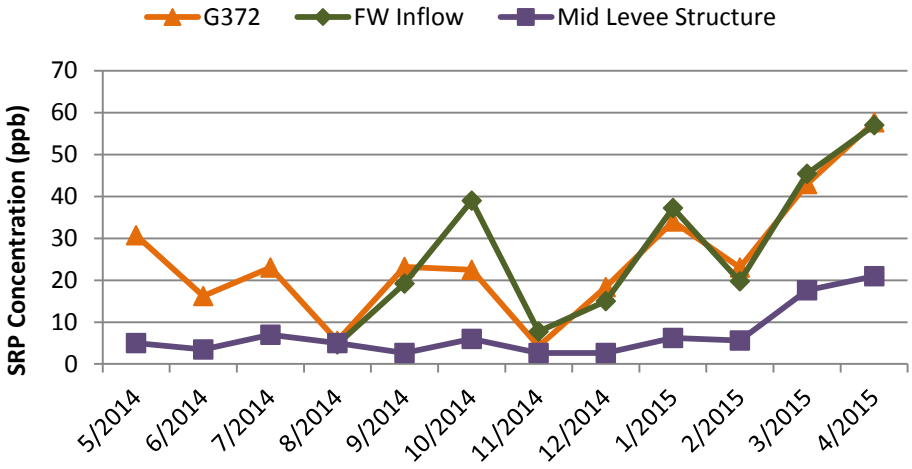


Figure 5B-47. Weekly SRP concentrations at the STA inflow (G-372), flow-way inflow (FW Inflow; G-380), and mid-levee structures (G-384B and E) of the Western Flow-way of STA-3/4 in WY2015.

STA-3/4 Vegetation Condition during the Dry Season Lake Releases

Historically, STAs received a majority of their inflows and associated increased water depths during the wet season, while the dry season was associated with lower inflows and reduced water depths, generally thought to be beneficial to vegetation health (particularly EAV). Vegetation health is monitored to determine if increased flows have any effects on the STA vegetation condition. Twenty sites at the inflow region of Cell 3A and 10 sites at the inflow region of Cell 2A were selected and monitored every 6 to 8 weeks (**Figures 5B-48** and **5B-49**). The cattail condition in STA-3/4 Cell 3A was closely monitored because the cell received continuous lake releases in WY2015. Lake releases continued in WY2016 although not in the same continuous manner that was implemented in WY2015. As a comparison, vegetation health was also monitored in STA-3/4 Cell 2A because the cell did not receive the dry season flows in WY2015. Vegetation monitoring included visual observation to look for cattail stress indicators such as mortality, floating cattail plants, floating cattail islands (tussocks), or weakened root system. In addition, biomass and soil samples were collected in March–June 2015 for baseline information. Additional biomass and soil samples will be collected in WY2016 and an evaluation of the findings will be presented in future SFERs.

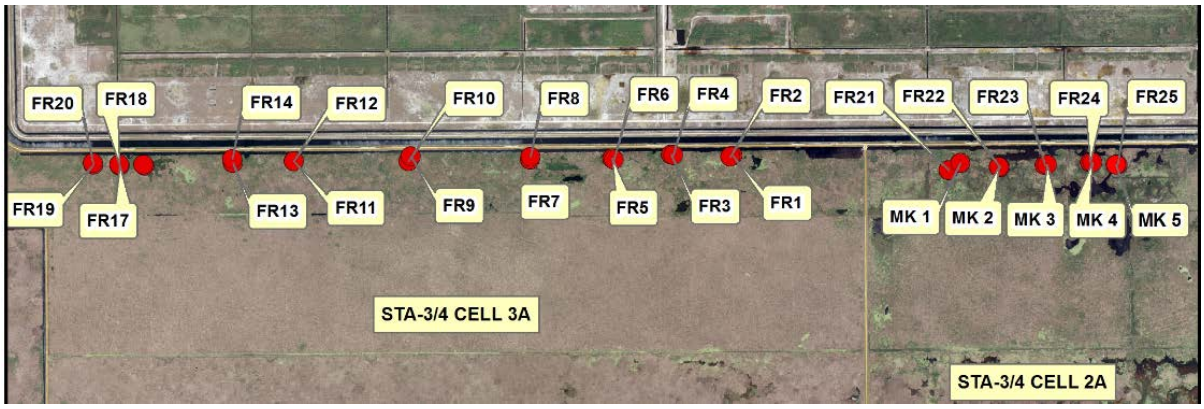


Figure 5B-48. Vegetation monitoring sites in STA-3/4 Cell 3A, which received continuous lake releases. Additional sites were selected in STA-3/4 Cell 2A for comparison; Cell 2A did not receive continuous lake flows.

Figure 5B-49. Scientists surveying cattail condition in one of the monitoring plots in STA-3/4 Cell 3A to determine potential effects of continuous dry season Lake Okeechobee releases on STA vegetation. (Photos by the SFWMD, 2015.)

STA-3/4 Vegetation

Vegetation enhancements were performed in STA-3/4 throughout WY2015, including planting in the non-vegetated areas in the upstream end of Cell 2A and a short-circuit at the outflow of the Cell 2B, SAV inoculations in the unvegetated portions of Cells 1B and 2B, and herbicide treatment of FAV and cattail encroachment (**Table 5B-7**). Targeted herbicide application is used to aid in maintaining the preferred vegetation communities for optimal P removal treatment. For example, in SAV cells, cattail is not entirely eliminated but is maintained in the form of EAV strips to help protect the SAV during high winds and/or flow events.

Table 5B-7. Vegetation management and enhancement activities conducted in STA-3/4 in WY2015.

Flow-way/Cell	Activities
Eastern Flow-way/Cell 1B	Herbicide treatments to eliminate cattail encroachment in SAV communities. SAV inoculation of southern naiad and spiny naiad (*Najas marina*) in open water areas throughout the cell.
Central Flow-way/Cell 2A	30 ac of alligator flag and giant bulrush were planted in non-vegetated areas in the upstream end of the cell. Herbicide treatment to prevent FAV (water lettuce, water hyacinth, and pennywort) from impacting establishment of planted alligator flag and giant bulrush.
Central Flow-way/Cell 2B	Alligator flag and giant bulrush were planted in a hydraulic short-circuit in the downstream end of the cell. SAV inoculation of southern naiad and spiny naiad in open water areas throughout the cell.
Western Flow-way/Cell 3B	Herbicide treatments to eliminate cattail encroachment in SAV communities.

Qualitative Assessment of STA-3/4 Vegetation Coverage (Helicopter Surveys)

In the Eastern Flow-way, EAV coverage in WY2015 was considered to be good in Cell 1A and increased cover of FAV was observed. It was noted that the plantings of giant bulrush in WY2014 failed to block the short circuits along the eastern and western portions of the cell. In Cell 1B, a majority of the cell lost SAV coverage since the beginning of WY2015. The cell was inoculated with SAV and, scattered beds of muskgrass and southern naiad reestablished throughout the year until February 2015 when a decline in SAV cover was observed. Similar losses of SAV communities were also observed in STA-1W. Coverage of SAV increased slightly toward the end of the water year, however, approximately 50 percent of the cell lacked SAV cover

In the Central Flow-way, giant bulrush and alligator flag were planted in unvegetated areas in Cell 2A throughout the year and thin EAV cover was observed in the northern portion of the cell. Similar to the vegetation conditions in Cell 1B, SAV cover in Cell 2B was sparse the beginning of WY2015 with a majority of the cell lacking SAV cover. The northern end of the cell was inoculated in June 2014 and extensive beds of southern and spiny naiad reestablished throughout the year until loss of SAV cover was observed in March 2015. SAV coverage improved toward the end of the water year.

In the Western Flow-way, EAV cover in WY2015 was considered to be excellent in Cell 3A although breaches in coverage in the eastern and central portion of the cell were observed later in the water year (March 2015) downstream of two inflow structures. Similar to the other two SAV cells, Cell 3B also lost SAV cover in most of the cell in the beginning of WY2015. Throughout the year, SAV cover increased until late February 2015 when SAV coverage declined again leaving approximately half of the cell without SAV cover.

Qualitative Submerged Aquatic Vegetation Surveys in STA-3/4 Western Flow-way (Cell 3B)

SAV surveys were performed in Cell 3B of the Western Flow-way of STA-3/4 on August 20, 2013, and February 18, 2015 (**Figures 5B-50** and **5B-51**). Moderately dense to very dense SAV beds were observed at all locations in August 2014 (**Figure 5B-50**). SAV coverage and density were both lower during the February 2015 event than in August 2014 (**Figure 5B-51**). Although the dominant SAV in this cell is muskgrass, other SAV species, in particular spiny naiad and bladderwart, were beginning to become more prevalent.

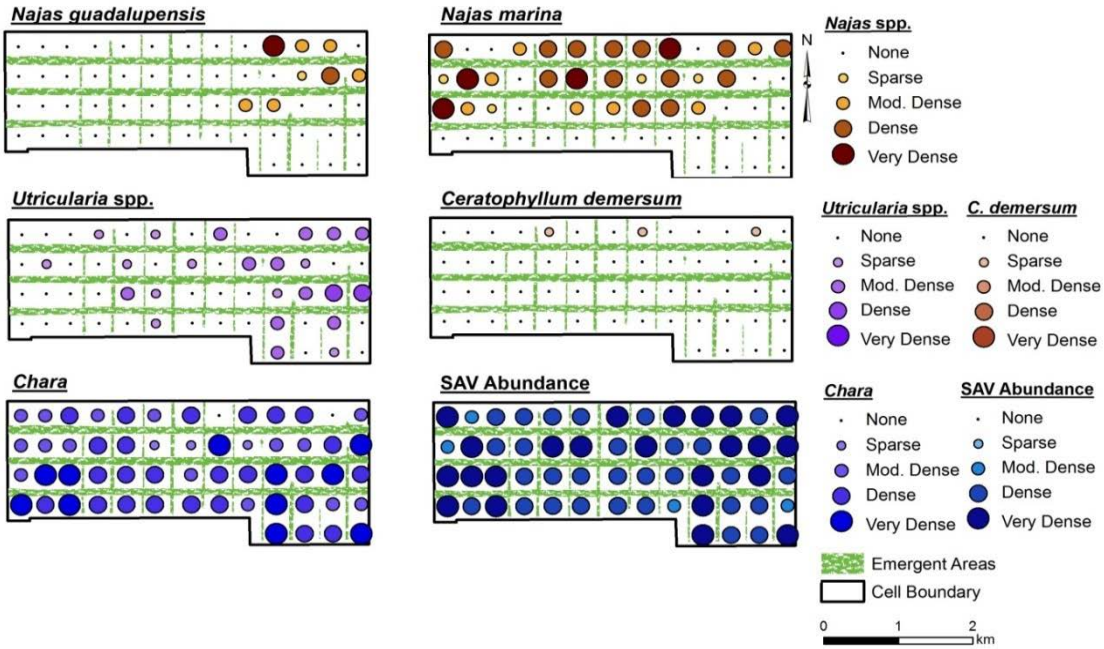


Figure 5B-50. SAV ground survey results depicting the spatial coverage and relative abundance of southern naiad and spiny naiad (*Najas* spp.), bladderwort (*Utricularia* spp.), coontail (*Ceratophyllum demersum*), muskgrass (*Chara* spp.), and all SAV species grouped together in STA-3/4 Cell 3B on August 20, 2014. Dots indicate locations of SAV ground survey sites. Coverage of FAV, which may also have been present in the cell, is not shown on the map.

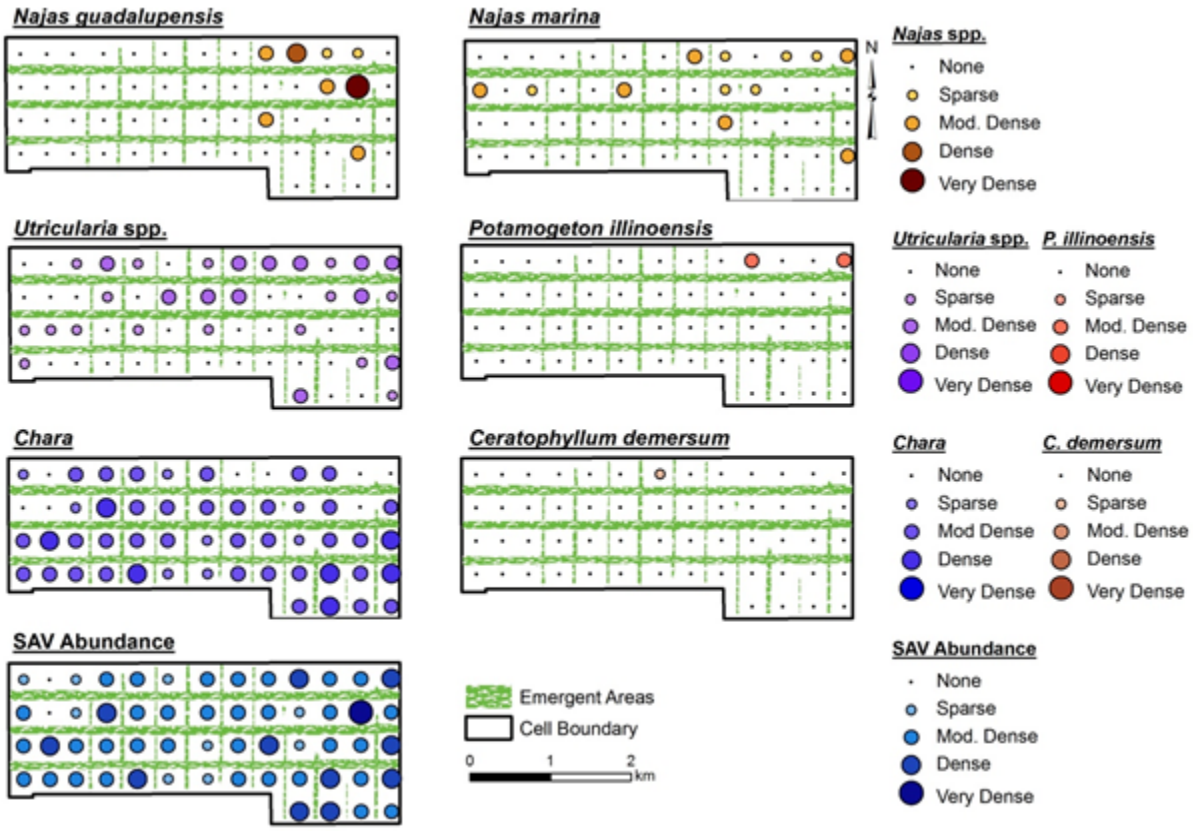


Figure 5B-51. SAV ground survey results depicting the spatial coverage and relative abundance of southern naiad and spiny naiad (*Najas*, spp.), bladderwort (*Utricularia*, spp.), coontail (*Ceratophyllum demersum*), muskgrass (*Chara*, spp.), and all SAV species grouped together in STA-3/4 Cell 3B on February 18, 2015. Dots indicate locations of SAV ground survey sites. Coverage of FAV, which may also have been present in the cell, is not shown on the map.

STA-5/6 Overview of Performance and Activities

STA-5/6 is located to the west of STA-3/4 and bordered on the east by the Rotenberger Wildlife Management Area (**Figure 5B-1**). The original STA-5 (Flow-ways 1 and 2) began operating in 2000 (**Figure 5B-52**; Appendix 5B-1, Figure 5). The original STA-6, which consisted of Cells 6-3 and 6-5, began operation in 1997 and treated agricultural runoff from the United States Sugar Corporation's Southern Division Ranch, Unit 2. After Unit 2 was purchased for restoration purposes and farming operations ended, this area became known as Compartment C. In 2006, Section 2 (now Cell 6-2) was added to STA-6, and a third flow-way (Flow-way 3) was added to STA-5 on a portion of Compartment C. In 2012, construction of treatment facilities was completed on the remaining portion of Compartment C. The STA-5/6 complex, consisting of the former STA-5, Compartment C, and the former STA-6, has 14 treatment cells arranged in eight flow-ways with a total effective treatment area of 13,685 ac (Piccone et al., 2014, **Figure 5B-52**). This STA is operated as an integrated facility to treat runoff from the C-139 Basin. The analysis of treatment performance is based on past and present operation of the integrated facility. Performance measures for STA-5 and STA-6 that were reported individually in past annual reports have been recalculated as STA-5/6.

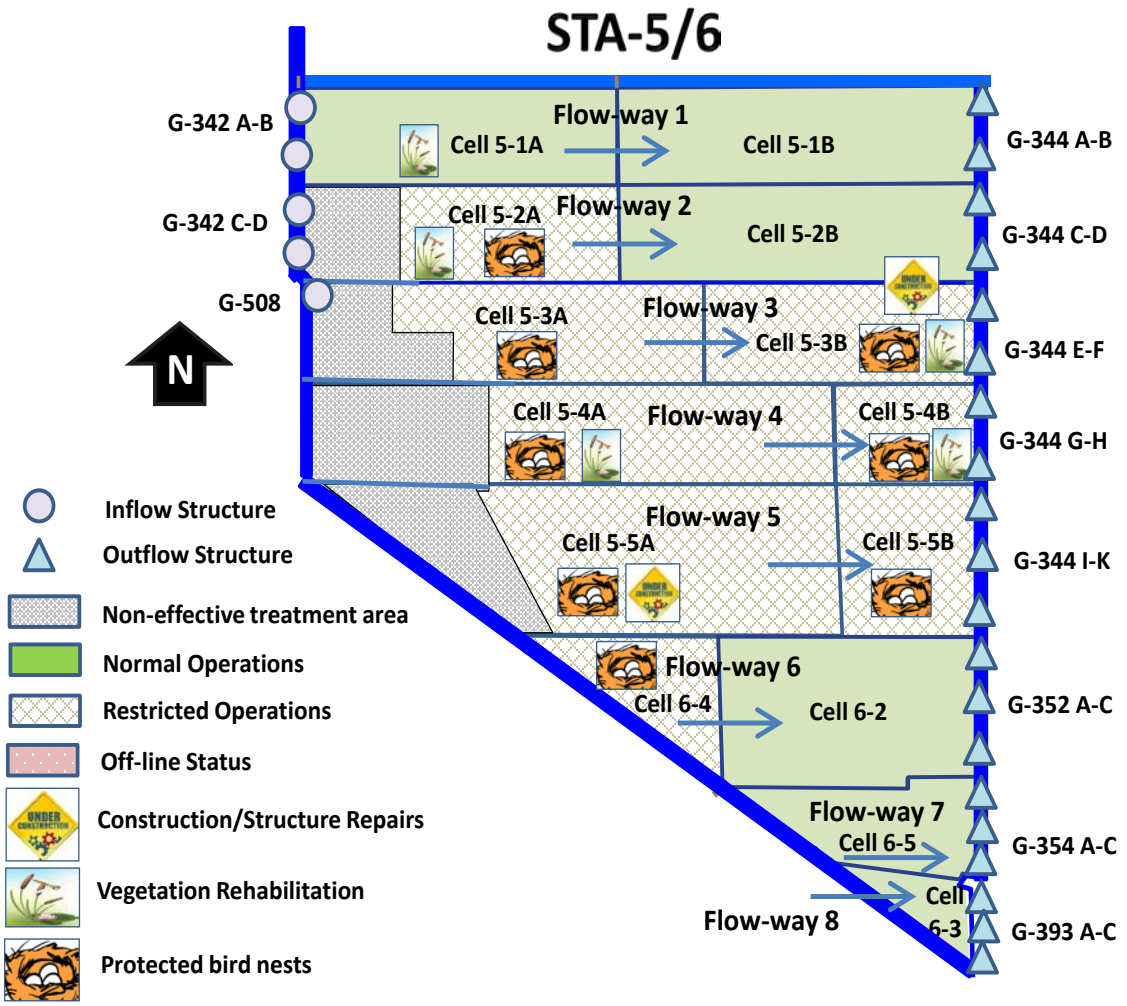


Figure 5B-52. Simplified schematic of STA-5/6 showing the different factors that affected the operations of the STA, which include construction or structure repairs, vegetation management activities, or the presence of protected bird nests. See **Figure 5B-53** for specific dates. A detailed structure map is provided in Appendix 5B-1, Figure 5, of this volume.

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

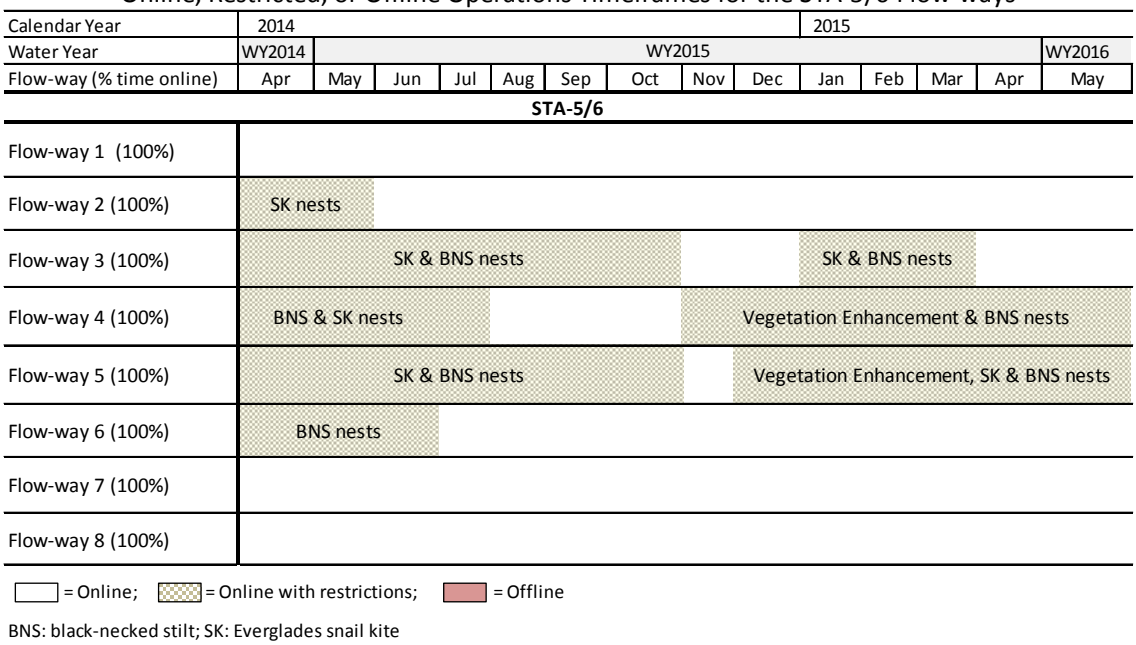
- Flow-way 1 = Cells 5-1A and 5-1B (former STA-5 Northern Flow-way)
- Flow-way 2 = Cells 5-2A and 5-2B (former STA-5 Central Flow-way)
- Flow-way 3 = Cells 5-3A and 5-3B (former STA-5 Southern Flow-way)
- Flow-way 4 = Cells 5-4A and 5-4B (new cells in Compartment C)
- Flow-way 5 = Cells 5-5A and 5-5B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

Since 1997 and including WY2015, STA-5/6 has received approximately 2.2 million ac-ft of inflow water with an average inflow FWM TP concentration of 182 ppb, the highest average inflow concentration compared to the other STAs (**Table 5B-1**). STA-5/6 also has the highest POR outflow FWM TP concentration (69 ppb) and retained the least amount of inflow TP load (68 percent) compared to the other STAs. Over its period of operation, STA-5/6 has been affected by high inflow TP concentrations and extreme weather events (regional droughts and large storms). Inflows to STA-5/6 are irregular due to the nature of the tributary basin's water management practices (i.e., the farmers hold onto their water as long as possible but during the wet season, when their canals and impoundments are full, they start releasing water). Some cells in this STA are routinely subjected to dryout and subsequent temporary increases in TP upon rehydration. In 2009, Cell 5-1A underwent rehabilitation to alleviate short-circuiting and higher ground elevation areas on the west end were leveled. Numerous vegetation enhancements have been implemented in Cell 5-1A and in the SAV cells. As a result, outflow TP concentrations have notably improved starting in WY2009. As in previous year's dry seasons, seasonal low flow volumes into STA-5/6 resulted in dryouts of multiple cells in WY2015.

STA-5/6 Facility Status and Operations

Challenges in WY2015 include presence of protected bird nests, dryout conditions in some of the flow-ways, and vegetation management activities (**Figure 5B-52**). All flow-ways were in operational condition throughout WY2015, although there were very little flows into most of the flow-ways. A timeline summarizing the status of each flow-way in STA-5/6 is presented in **Figure 5B-53**. During WY2015, Flow-ways 1, 7, and 8 were operated under normal flow conditions while the remaining five flow-ways were operated online with restrictions due to presence of bird nests or vegetation enhancement activities. Flow-ways 6, 7, and 8 were in dryout conditions the beginning of the water year, from April 10 to June 24, 2014. Repairs to the G-715 gated structure and the tailwater sensor at G-342L were initiated toward the end of WY2015.

Online, Restricted, or Offline Operations Timeframes for the STA-5/6 Flow-ways



BNS: black-necked stilt; SK: Everglades snail kite

Figure 5B-53. Timeline showing the STA-5/6 flow-ways that were online, offline, or operated online with restrictions due to the presence of protected bird nests, vegetation management activities, or construction or infrastructure repairs.

A minimal volume of Lake Okeechobee water (~800 ac-ft) was delivered to STA-5/6 in WY2015 for hydration of SAV cells. These flows were via the small hydration pump stations located along the eastern boundary of the STA, via G-507, G-349B, and G-350B (Appendix 5B-1, Figure 4). Lake Okeechobee regulatory releases were not discharged to this STA due to lack of infrastructure to convey water from the lake to the designated inflow structures.

STA-5/6 Performance

In WY2015, STA-5/6 received approximately 20 percent less inflow volume and six percent less TP load compared to WY2014 (**Figure 5B-54**). The HLR and PLR were relatively low, 0.5 cm/d and 0.4 $g/m^2/yr$, respectively, compared to the POR. Although the loads and flows to STA-5/6 were low, inflow FWM TP concentration in WY2015 was 33 ppb higher (230 ppb) and the outflow FWM TP concentration (32 ppb) was 9 ppb higher than in WY2014. Dryouts in many of the cells (**Figure 5B-55**), loss of vegetation, and higher inflow concentrations are likely contributors to the observed elevated outflow TP concentration in WY2015. Spikes in TP concentrations have occurred following rehydration of previously dried cells (Chimney 2014). At the beginning of WY2015, Flow-ways 1 through 5 received relatively small amount of flows and had less than 0.5-foot average water depths[10] and dry condition in most of the cell at the beginning and toward the end of the water year. Flow-ways 6, 7, and 8 did not receive any flows and were in dryout conditions until the end of June 2014 (**Figures 5B-55** and **5B-56**). Substantial flows to all the flow-ways lasted four months during July to October 2014.

The inflow FWM TP concentrations to the flow-ways during WY2015 ranged from 16 ppb in Flow-way 2 up to 496 ppb for Flow-way 5 (**Figure 5B-56**). The outflow FWM TP concentrations were highest for Flow-ways 6, 7, and 8 (72, 118, and 129 ppb, respectively) following rehydration after dryout conditions and flow-through operations in July. The elevated outflow FWM TP concentrations for Flow-ways 6, 7, and 8 started to decline in August and, by October, monthly FWM TP concentrations were 31, 23, and 19 ppb, respectively. The outflow FWM TP concentrations for the remaining flow-ways by October ranged from 19 to 30 ppb. Additionally, flow-through operations for all the flow-ways in WY2015 lasted for only part of the year. Unlike the other STAs, STA-5/6 was not able to receive inflows from the Lake Okeechobee regulatory releases due to infrastructure constraints, but a small volume of lake releases (approximately 808 ac-ft) was delivered to STA-5/6 to provide water to the SAV cells.

[10]Daily average water depths were estimated by taking the average of the daily average stage reading downstream of the inflow structures and upstream of the outflow structures and subtracting the average ground elevation listed in Piccone et al. 2014.

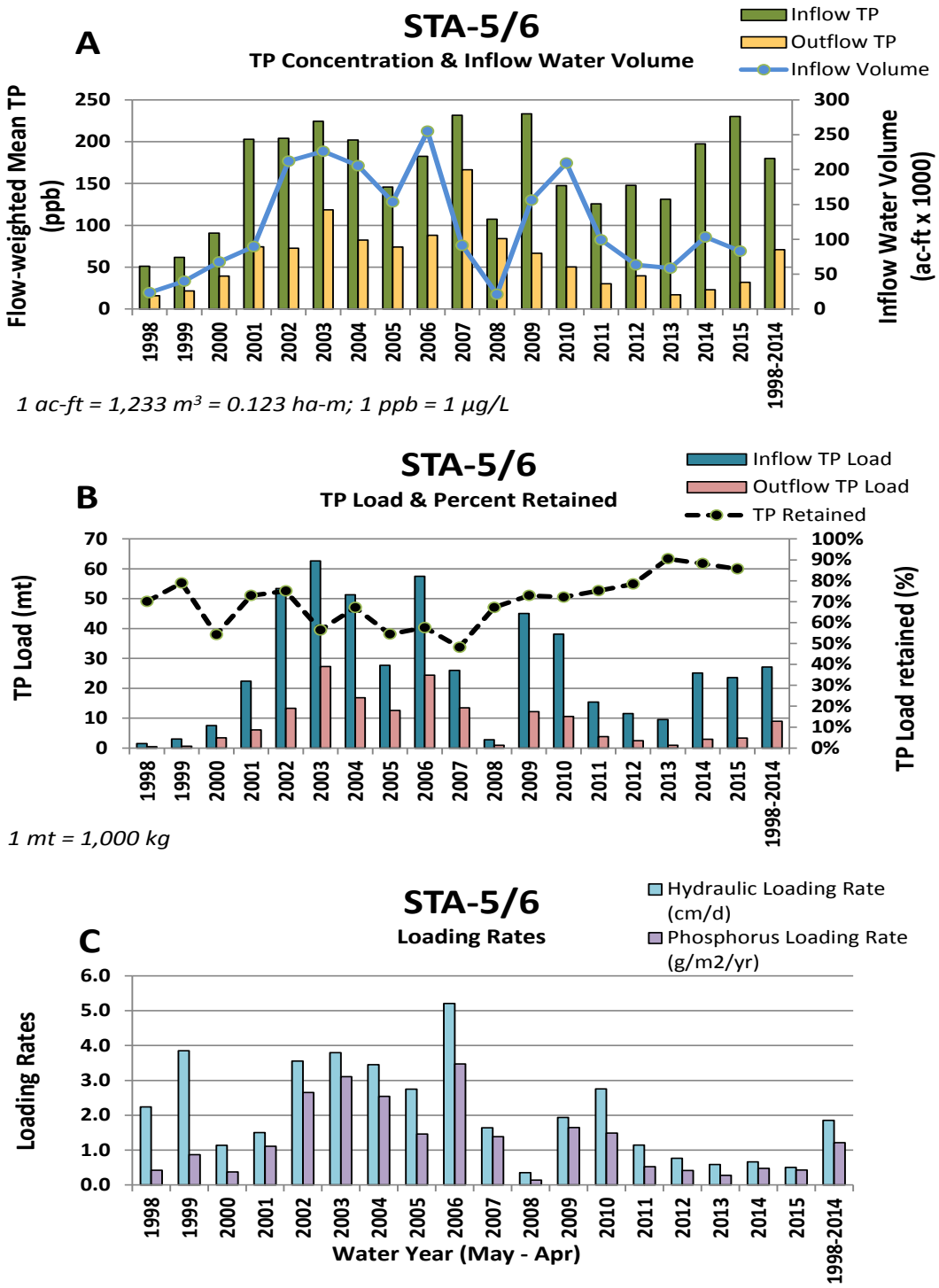
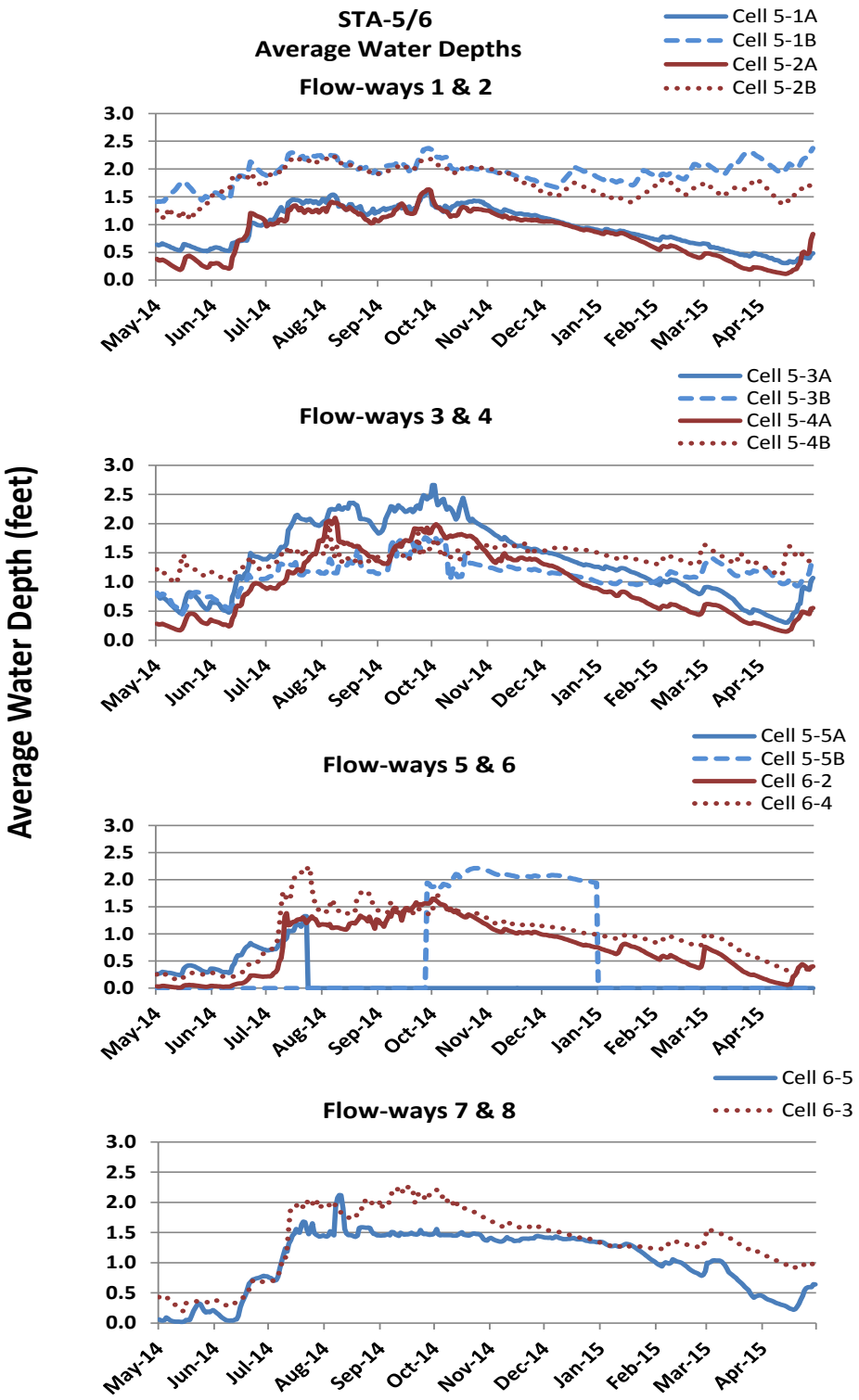
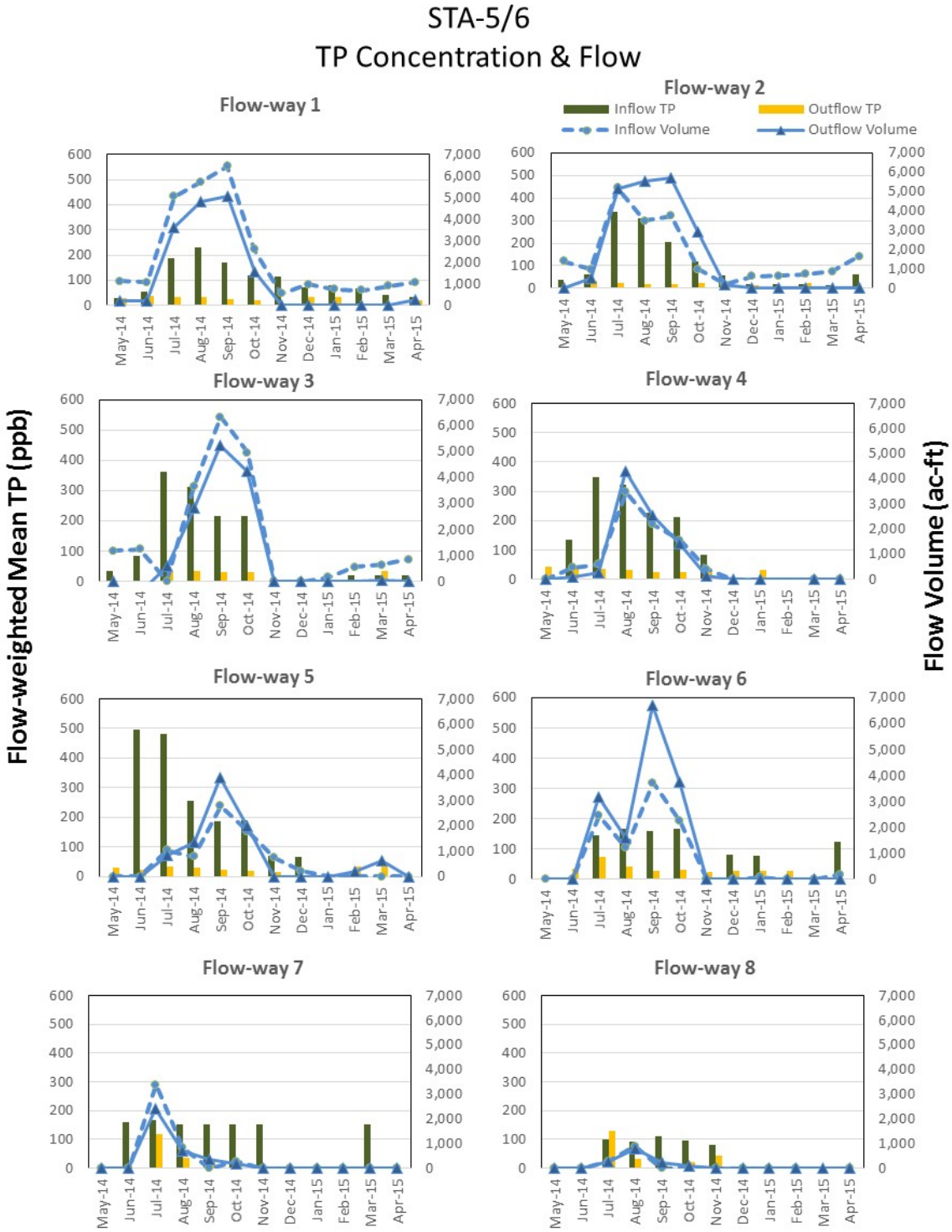


Figure 5B-54. Annual time series in STA-5/6 over POR of (A) inflow and outflow FWM TP concentrations and inflow water volume, (B) annual inflow and outflow TP loads and percent TP load retained, and (C) annual inflow HLR and PLR.



1 foot = 0.3 m

Figure 5B-55. Monthly average water depths for the STA-5/6 flow-ways in WY2015.



1 ac-ft = 1,233 m^3 = 0.123 ha-m; 1 ppb = 1 µg/L

Figure 5B-56. Monthly inflow and outflow flow volume and FWM TP concentrations for the STA-5/6 flow-ways in WY2015.

STA-5/6 Vegetation

Vegetation enhancements which were performed in STA-5/6 during WY2015 include herbicide treatments of primrose willow and FAV, EAV planting in the non-vegetated areas, and creation or fortification of new or existing vegetation strips (**Table 5B-8**). Control of FAV, such as water lettuce or hyacinth, was mainly conducted in the vicinity of water control structures (including pump stations and culverts) to prevent flow obstruction. FAV was also controlled when it negatively impacted coverage of other desired vegetation, such as SAV.

Table 5B-8. Vegetation management and enhancement activities in the STA-5/6 flow-ways.

Flow-way/Cell	Activities
Flow-way 1/Cells 1A and 1B	Aerial herbicide treatment to eliminate willow and primrose willow in Cell 1A. Repeated ground treatments to control water lettuce and water hyacinth (225 ac) in Cell 1B.
Flow-way 2/Cells 2A and 2B	Aerial herbicide treatment to eliminated willow and primrose willow in Cell 2A. Repeated ground treatments to control water lettuce and water hyacinth (320 ac) in Cell 2B.
Flow-way 3/Cell 3B	Giant bulrush and alligator flag were planted to repair gaps in EAV strips near the outflow.
Flow-way4/Cell 4A	Aerial and ground (i.e., airboat) herbicide applications to eliminate 50 ac of undesirable vegetation in a non-vegetated area in the middle compartment and 1,000 ac of water lettuce, which was interfering with establishment of rooted EAV.
Flow-way4/Cell 4B	Giant bulrush and alligator flag were planted to repair gaps in EAV strips near the outflow and across the middle of the cell

Qualitative Assessment of STA-5/6 Vegetation Coverage (Helicopter Surveys)

In Flow-ways 1 and 2, willow and regrowth of previously treated willow and primrose willow was observed in Cells 1A and 2A. Loss of SAV was observed in Cells 1B and 2B, with more than 60 percent or more of the cells without vegetation, at the beginning of WY2015. Coverage increased throughout the year except in February 2015 when a significant decline in SAV was observed.

In Flow-way 3, dense beds of SAV were observed in the eastern portion of the Cell 3A but other areas of the cell lacked EAV cover. On-going vegetation conversion from EAV to SAV in Cell 3B and an inoculation was precluded by the presence of snail kite nests.

In Flow-way 4, Cell 4A lacked EAV coverage in more than half of the cell, although dense beds of SAV established along the eastern and central regions of the cell. Cattail coverage increased slightly during the winter. In Cell 4B, the distribution of SAV was sparse throughout the cell. Similar vegetation conditions were found in Flow-way 5, with lack of EAV cover in most of Cell 5A, but coverage improved slightly during the water year. In Cell 5B, which underwent a vegetation conversion from EAV to SAV in WY2014, SAV was absent during most of the water year, but slight improvement in coverage (approximately 50 percent of the cell) was observed at the end of the water year.

Flow-way 6, Cell 6-4 also lacked EAV cover throughout the year. For Cell 6-5 and in Flow-ways 7 and 8, EAV coverage was good to excellent for the entire water year.

Qualitative Submerged Aquatic Vegetation Surveys in STA-5/6

There were no SAV ground surveys conducted in STA-5/6 in WY2015.

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