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

Edited by Michael Chimney

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SUMMARY

The construction and operation of large freshwater treatment wetlands, known as the Everglades Stormwater Treatment Areas (STAs), are mandated by the Everglades Forever Act (EFA; Section 373.4592, Florida Statutes) and are an integral part of state and federal efforts to preserve the remaining Everglades ecosystem. These wetlands (STA-1 East [STA-1E], STA-1 West [STA-1W], STA-2, STA-3/4, and STA-5/6) are located south of Lake Okeechobee (**Figure 5B-1**) and are designed to reduce total phosphorus (TP) concentration in surface water runoff prior to discharging this water into the Everglades Protection Area (EPA). The Everglades STAs are operated by the South Florida Water Management District (SFWMD or District) and currently encompass 62,000 total acres (ac) of treatment area permitted to operate, which includes the expanded treatment areas of STA-1W, STA-2, and STA-5/6. This chapter[2] and its appendices (Appendices 5B-1 through 5B-4 of this volume) summarize short-term and long-term Everglades STA treatment performance and document any environmental conditions that may have adversely affected treatment performance, the status of these facilities, and operational challenges during Water Year 2021 (WY2021; May 1, 2020–April 30, 2021). An analysis of annual Everglades STA

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[2] Chapter 5B is an annual report on the condition and performance of the Everglades STA treatment facilities. It combines a report of routine operations, construction activities, vegetation maintenance, and effects of extreme weather conditions or other unusual events. The primary target readers for the chapter are regulatory personnel and various other STA stakeholders. The reported values are linked to other documents, including Restoration Strategies documents, permits, consent orders, operation plans, weekly reports to stakeholders, and electronic programs that are used to track and manage the Everglades STAs. To preserve the continuity of understanding with the stakeholders and agreement with these documents and electronic programs, results reported in Chapter 5B include a mixture of International System of Units (SI) and non-SI units. Non-SI units used in this chapter include wetland surface area as acres (ac), flow rate as cubic feet per second (cfs), water volume as acre-feet (ac-ft), and TP mass as metric tons (t). Conversion factors to express these values in SI units are as follows: 1 ac = 0.40469 hectare or 4,046.9 square meters; 1 cfs = 0.02832 cubic meters per second; 1 ac-ft = 1,233.5 cubic meters; and 1 t = 1,000 kilograms.

treatment performance relative to compliance with the Everglades STA operating permit is reported in Volume III, Appendix 3-1. A status update on implementing the *Everglades Protection Area Tributary Basins Long-Term Plan for Achieving Water Quality Goals* (Long-Term Plan; Burns & McDonnell 2003) is covered in Appendix 5B-2 of this volume. This chapter also reports on facility status and operational issues, including relevant maintenance activities, vegetation conditions, and wildlife issues. Research activities conducted as part of the Restoration Strategies *Science Plan for the Everglades Stormwater Treatment Areas* (Science Plan; SFWMD 2013) are presented in Chapter 5C of this volume. More information about the Everglades STAs is available on the District's website: https://www.sfwmd.gov/our-work/wq-stas.

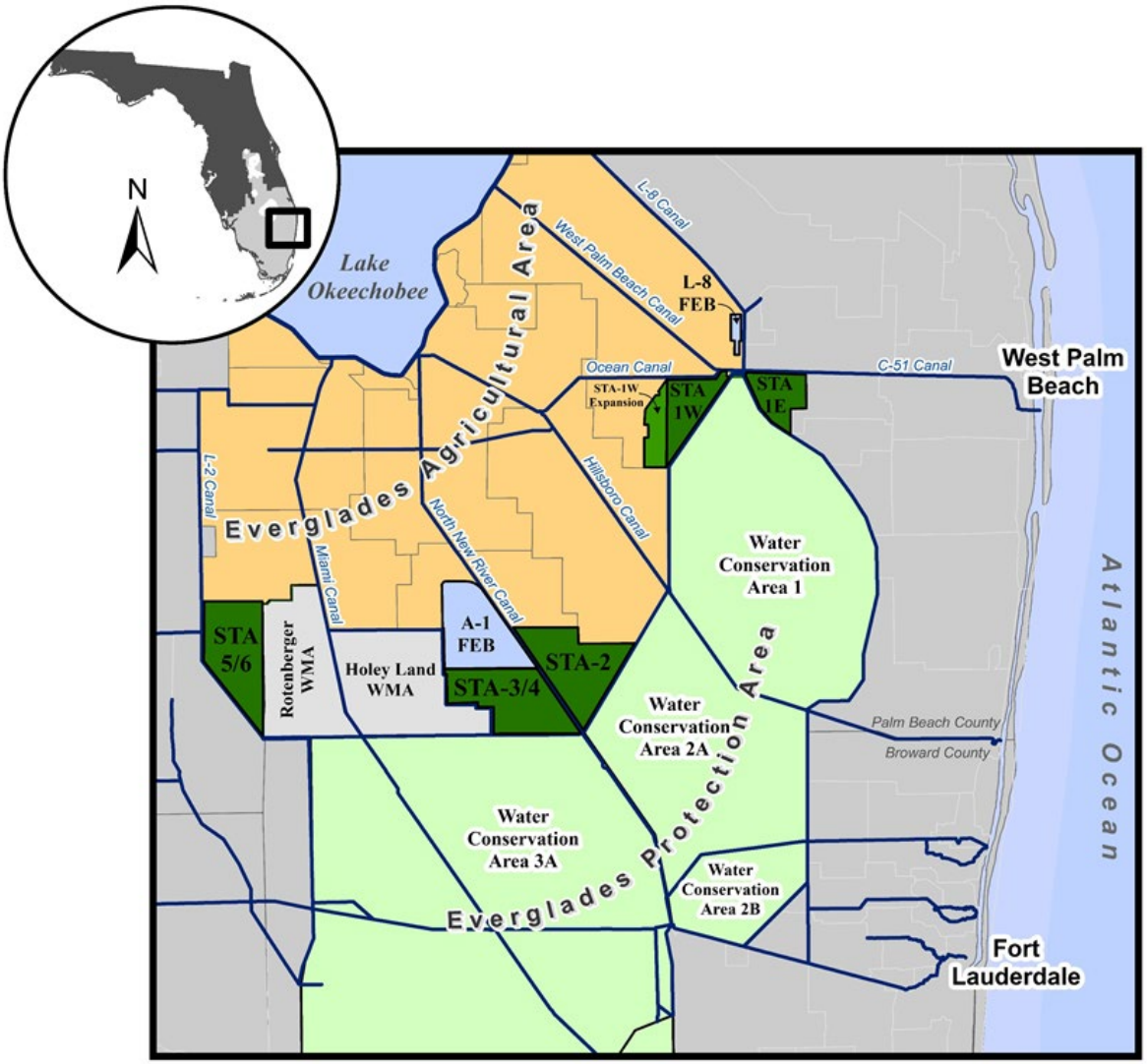


Figure 5B-1. Location of the Everglades STAs (STA-1E, STA-1W, STA-2, STA-3/4, and STA-5/6), STA-1W Expansion Area, and flow equalization basins (FEBs; A-1 and L-8) in relation to Lake Okeechobee, the EPA, and other landscape features of South Florida. (Note: WMA – Wildlife Management Area.)

A summary of findings for the STAs for WY2021 is as follows:

- Over the past 27 years, the Everglades STAs have treated approximately 24.2 million acre-feet (ac-ft) of water (~ 7.9 trillion gallons) and retained 3,089 metric tons (t) of TP with a 77% TP load reduction. The overall outflow flow-weighted mean (FWM) TP concentration from these treatment wetlands during this period has been 30 micrograms per liter (µg/L). STA-3/4, over its 18-year operational history, has treated the most water (~ 7.9 million ac-ft), retained the most TP load (844 t), achieved the highest percent TP load retained (85%), and discharged water at the lowest outflow FWM TP concentration (15 µg/L) of all the Everglades STAs.
- In WY2021, the Everglades STAs combined treated approximately 1.6 million ac-ft of water and retained 207 t of TP, which equated to a 78% TP load reduction and produced an outflow FWM TP concentration of 28 µg/L. Approximately 162,000 ac-ft of the inflow volume in this water year came from Lake Okeechobee, of which 147,000 ac-ft were regulatory releases, while 15,000 ac-ft were delivered as supplemental water to maintain cell water levels at target stages in all of the Everglades STAs.
- The outflow FWM TP concentrations from individual Everglades STAs in WY2021 were 37, 38, 21, 12, and 80 µg/L in STA-1E, STA-1W, STA-2, STA-3/4, and STA-5/6, respectively. The percent inflow TP load retained this water year ranged from 67% (STA-5/6) to 84% (STA-3/4). The consistently good annual treatment performance in STA-3/4 can be attributed, in part, to this STA having one of the lowest inflow TP concentrations over its period of record (POR; 101 µg/L).
- All flow-ways in STA-1W and STA-5/6 were operational throughout WY2021. However, most of the flow-ways in these STAs were online with restrictions for at least part of the water year for various reasons including protection of nesting birds, vegetation maintenance, structure repairs, or construction activities. Conversely, flow-ways in STA-1E (Western Flow-way), STA-2 (Flow-way 2) and STA-3/4 (Eastern Flow-way) were offline for part of the water year due to vegetation management or construction activities.
- Cells 6-3 and 6-5 (Flow-ways 7 and 8) in STA-5/6 were declared by the District to be in dry-out condition during part of WY2021. Most of the other cells in STA-5/6 partially dried out this water year, but not to the extent that they were declared to be in dryout condition. Cell 5 and 7 of the Western Flow-way in STA-1E, Cell 3 of the Eastern Flow-way in STA-1W, and Cell 1A of the Eastern Flow-way in STA-3/4 were allowed to dry out for a portion of the water year to accommodate construction and/or vegetation maintenance activities. Supplemental water from Lake Okeechobee was delivered to all of the Everglades STAs to maintain cell hydration to the extent practicable during the water year.
- Eighty-one black-necked stilt (*Himantopus mexicanus*) nests were observed within the Everglades STAs during WY2021. Operational priorities were adjusted in the STAs to avoid disturbing any active nests. No Florida burrowing owls (*Athene cunicularia floridana*) were observed in any of the Everglades STAs during this water year. Additionally, no snail kite (*Rostrhamus sociabilis plumbeus*) nests were observed in the Everglades STAs during WY2021.

INTRODUCTION

A major component of Everglades restoration efforts, the Everglades STAs are freshwater treatment wetlands built and operated to reduce TP concentration in surface runoff prior to these waters entering the EPA. The STAs were constructed primarily on former agricultural lands and retain nutrients through plant and microbial uptake, particulate settling, chemical sorption, and ultimately accretion of plant and microbial biomass to the sediments. This chapter describes the treatment performance and status of the five Everglades STAs: STA-1E, STA-1W, STA-2, STA-3/4, and STA-5/6 (**Figure 5B-1** and Appendix 5B-1 of this volume) and the operational challenges related to maintaining treatment performance in them. The District operates and maintains all the Everglades STAs.

Varying in size, configuration, and length of operation, the Everglades STAs are divided into "cells" by interior levees to form "flow-ways" (i.e., cells arranged in series) within the STAs (see STA maps in Appendix 5B-1 of this volume). Water flows through these systems via water control structures, i.e., pump stations, gated spillways, weirs, and culverts. The Everglades STAs are part of the District's regional flood control system and inflow is primarily from basin runoff. The Everglades STAs were constructed in a phased approach; the first prototype STA, the Everglades Nutrient Removal Project, became operational in 1994. The Everglades STAs currently have a combined treatment area of 62,000 ac. Construction of the A-1 Flow Equalization Basin (FEB) was completed in WY2016 adding approximately 60,000 ac-ft of water storage capacity upstream of STA-3/4 and STA-2. Construction of the L-8 FEB was completed in July 2017, which added approximately 45,000 ac-ft of water storage capacity upstream of STA-1E and STA-1W. The District increased the treatment area of STA-1W by 4,266 ac with the construction of the STA-1W Expansion Area #1 as part of the *Restoration Strategies Regional Water Quality Plan* (SFWMD 2012; see also Chapter 5A and Appendix 5B-2 of this volume).

Aquatic plants in the Everglades STAs are categorized based on their growth habit: emergent aquatic vegetation (EAV), submerged aquatic vegetation (SAV), or rooted and non-rooted floating aquatic vegetation (FAV). While all STA cells to varying degrees contain a mixture of these vegetation types, cells are classified based on their target vegetation community, i.e., either EAV or a mixed-marsh community containing both EAV and SAV (EAV/SAV)[3]. Periphyton, the community of attached algae and other microorganisms growing on substrates in aquatic systems, is ubiquitous throughout the STAs. The periphyton community plays an important role in nutrient cycling within wetlands (Kadlec and Wallace 2009).

Reduction in TP concentration and load has varied temporally within each Everglades STA and spatially among STAs and may be influenced by factors such as antecedent land use, soil type, cell topography, condition of the vegetation community, nutrient and hydraulic loading, hydropattern (continuously flooded versus periodic dryout), maintenance activities, and regional flood control operations in response to storm events. The District attempts to maximize Everglades STA treatment performance by balancing TP loading to these wetlands through adaptive management that prioritizes the distribution of water delivered to individual STAs and among flow-ways within each STA. These decisions are based on a weekly evaluation of interior stage (i.e., water levels), outflow TP concentrations, previous hydraulic and TP loading, vegetation condition, maintenance/rehabilitation activities, and any operational restrictions.

[3] The District does not include FAV as a target vegetation type in the Everglades STAs because as FAV coverage expands it can displace existing beds of SAV and EAV. This is not a desirable outcome, although the District has planted rooted FAV in portions of cells that have been too deep to support emergent vegetation. Cells previously referred to as "SAV" or "SAV-dominant" have been managed in recent years to contain a mixed-marsh vegetation community. This management approach has been implemented for a variety of reasons including protection of SAV during major storms, promoting improved flow patterns by adding EAV in areas prone to hydraulic short-circuits, and providing treatment resilience through plant species diversity. These cells are now referred to more accurately as "EAV/SAV" cells.

This chapter reports on Everglades STA treatment performance, facility status and operational issues, relevant maintenance activities, vegetation conditions, and wildlife issues. Discussion of implementation of the Long-Term Plan is provided in Appendix 5B-2 of this volume. Supporting information on protected birds and SAV coverage in the STAs is presented in Appendices 5B-3 and 5B-4 of this volume, respectively. Details on the District's Restoration Strategies Program and Science Plan are provided in Chapters 5A and 5C of this volume, respectively. Details on monitoring for TP and other water quality parameters mandated by the operating permit for the Everglades STAs are presented in Volume III, Appendix 3-1.

FLOW-WAY OPERATIONAL STATUS

Optimizing the short-term and long-term operation of the Everglades STAs and individual flow-ways is critical in achieving and sustaining the desired treatment performance of these wetlands. The District has established a management system that includes weekly review of individual flow-way treatment performance and condition, and discussions to prioritize operation of available flow-ways. Operation of a STA flow-way may be suspended entirely (operational status: offline [OFF]) in response to environmental conditions that may reduce phosphorus (P) uptake, to allow for construction activities, or to allow the completion of critical rehabilitation activities. Operation of a flow-way may also be flow- or stage-restricted (operational status: online with restrictions [ONR]) for a number of reasons, such as to protect recently planted vegetation or to avoid negative impacts to nests of bird species protected under the Migratory Bird Treaty Act or the Endangered Species Act, to facilitate construction or vegetation rehabilitation activities, or to conduct controlled research studies. Flow-ways designated as ONR would be in full operation mode only during emergencies, such as large storm events. During small- or moderately-sized storms, stormwater may be partially or entirely routed to other STAs or flow-ways for treatment.

STA REFURBISHMENT PROJECTS

In WY2020, the District initiated construction on a suite of STA refurbishment projects that are being completed in addition to the projects included in the *Restoration Strategies Regional Water Quality Plan* (see SFWMD 2012 for details[4] and Appendix 5B-2 and Chapter 5A of this volume for an overview and status updates for plan projects). The STA refurbishment projects will improve the hydraulics, vegetation conditions, and treatment performance of the existing STAs. They are being completed as a proactive measure to ensure the facilities are poised to achieve compliance with the water quality based effluent limit (WQBEL)[5] once all the Restoration Strategies projects are complete.

ADJUSTMENT OF TREATMENT AREA VALUES

The treatment area[6] in each Everglades STA was used to calculate the hydraulic loading rate (HLR), P loading rate (PLR), and P removal rate values (see **Table 5B-1** in the *Overview of POR and WY2021* section). Treatment areas are adjusted, if needed, using the **Equation 1** based on the fractional period of operation for each STA flow-way during the water year. Flow-ways are considered to be available for operation at all times except for those days when their operational status was designated as OFF. The total

[4] The Restoration Strategies Projects are efforts mandated under Consent Orders associated with the District's operating permit for the Everglades STAs. The STA Refurbishment Projects are separate work efforts that the District has undertaken voluntarily.

[5] The District's operating permit for the Everglades STAs established a WQBEL for TP concentration in STA discharge that mandates: (1) the annual FWM outflow TP concentration from each STA shall not exceed 19 µg/L in any water year and (2) the annual FWM outflow TP concentration from each STA shall not exceed 13 µg/L in more than three out of five water years on a rolling basis (State of Florida 2017). The first year of the first five years of compliance is WY2027 assuming that the last milestone is completed on December 31, 2025. For more information of the operating permit, please see Appendix 3-1 in Volume III of this report.

[6] The wetted surface area of the Everglades STAs is referred to as "treatment area" in this chapter and is synonymous with "effective treatment area" used elsewhere in this volume and in other District publications to describe the same wetted surface area.

treatment area of an Everglades STA during the water year is the summed treatment areas of its individual flow-ways.

$$Adjusted\ Flowway\ Treatment\ Area = Total\ Flowway\ Area \times \frac{\#\ days\ in\ operation}{\#\ days\ in\ year} \quad (1)$$

CALCULATION OF ANNUAL LOADS AND FWM CONCENTATIONS

Annual TP loads and FWM TP concentrations were calculated based on daily TP concentrations interpolated from weekly measurements (sample size [n] = 52) of surface water inflow to and outflow from the Everglades STAs over the entire water year as follows:

$$TP\ Load = \sum_{1}^{n}(C_iV_i + C_{i+1}V_{i+1} + \ldots\ C_{i+n}V_{i+n}) \quad (2)$$

$$FWM\ \text{TP}\ Concentration = TP\ Load \Big/ \sum_{1}^{n}(V_i + V_{i+1} + \ldots\ V_{i+n}) \quad (3)$$

where

C_i = TP concentration for the ith day during the water year
V_i = Water volume for the ith day during the water year.

All calculations were performed using the District's Nutrient Load Program application.

Water is collected by both grab sampling and with flow-proportioned autosamplers at designated Everglades STA inflow and outflow locations. Autosamplers are triggered based on real-time flow measurements at these sites, and all aliquots collected during the week are composited into a single collection vessel. TP concentrations are calculated preferentially using the autosampler data; grab sample data are used as a backup only on the rare occasion when autosampler data are not available at a site.

VEGETATION MANAGEMENT

Vegetation management in the Everglades STAs includes planting select species, primarily giant bulrush (*Schoenoplectus californicus*), alligator flag (*Thalia geniculata*), and American lotus (*Nelumbo lutea*) and inoculations of SAV, such as southern naiad (*Najas guadalupensis*), spiny naiad (*Najas marina*), eelgrass (*Vallisneria americana)*, Illinois pondweed (*Potamogeton illinoensis*), and muskgrass (*Chara* spp.). In EAV/SAV cells, giant bulrush and alligator flag are planted either in linear strips (i.e., "vegetation strips") or as irregular shaped patches to eliminate hydraulic short-circuits, buffer other plant species from uprooting caused by high wind and discharge events, or provide plant cover at locations where the water is too deep for sustained growth of cattail (*Typha latifolia* and *T. domingensis*). Alligator flag and American lotus are also planted to secure unstable sediments, stabilize EAV in areas prone to sediment delamination[7], and minimize the effects of FAV damage in areas where SAV and cattail are difficult to establish. The compartmentalization of EAV/SAV cells with vegetation strips also is thought to provide functional redundancy in nutrient uptake needed to sustain treatment performance in the event of SAV loss[8]. In

[7] The term "delamination" refers to the separation of a layer of surficial soil from the underlying subsoil. This separated layer of soil often floats on the water surface and may or may not have EAV rooted within it.

[8] Based on lessons learned from managing and operating the Everglades STAs, the District has allowed EAV cover to expand outside of the vegetation strips to create a mixed-marsh vegetation community in EAV/ SAV cells where periodic large-scale loss of SAV cover has occurred previously. The expansion of EAV in these cells is monitored and controlled as necessary based on cell treatment performance.

EAV/SAV cells, the most desired SAV species are muskgrass, Illinois pondweed, southern naiad, and spiny naiad. In EAV cells, the most desired species are cattail[9], giant bulrush, alligator flag, and sawgrass (*Cladium jamaicense*). Other desirable native species that thrive in certain areas of the Everglades STAs are arrowhead (*Sagittaria latifolia*), duck potato (*S. lancifolia*), pickerel weed (*Pontederia cordata*), and spikerush (*Eleocharis* spp.). Another species commonly found in the STAs is hydrilla (*Hydrilla verticillata*), which thrives in areas of high water column TP concentrations. Despite hydrilla's ability to remove P, it is not a desired SAV species due to its tendency for sudden population crashes and that it is a highly invasive non-native species. Hydrilla was present in some cells of STA-1E, STA-3/4, and STA-5/6 during WY2021.

Vegetation management in the Everglades STAs also involves herbicide applications and manual removal to control undesired FAV, SAV, and emergent herbaceous and woody species[10]. Herbicides are used only to the extent needed to encourage the growth of desired plant communities when undesired species are removed. Controlling non-rooted FAV, such as water lettuce (*Pistia stratiotes*) and water hyacinth (*Eichhornia crassipes*), is necessary because these species can form dense beds that shade out SAV species underneath. Dense FAV also can hinder the maintenance and growth of existing EAV beds, damage newly planted vegetation, and impede the even distribution of flow through cells creating hydraulic short-circuits. Woody species, such as primrose willow (*Ludwigia* spp.), are controlled because they tend to displace cattail and do not provide the same level of P removal as cattail or sawgrass. Trees and large shrubs also can encourage bird nesting and rookery formation, which can adversely impact STA operations and serve as nutrient inputs. The District uses United States Environmental Protection Agency-registered herbicides applied by licensed applicators at the dosages recommended by the manufacturer. None of these products bioaccumulate, all are registered for use in aquatic systems, and none are restricted-use category herbicides. While these products are toxic to plants, toxicity is negligible to non-plant organisms at the application rates used in the Everglades STAs and elsewhere throughout District lands. The District's vegetation management program is regulated by the Florida Department of Environmental Protection (FDEP) and fully complies with the STA's National Pollution Discharge Elimination System (NPDES) operating permit regulations. An accounting of herbicide application rates and quantities used, the acreage treated in each Everglades STA, and the species targeted during WY2021 is provided in Volume III, Appendix 3-1, Attachment E.

VEGETATION SURVEYS

Ground surveys are conducted by airboat within Everglades STA cells designated as EAV/SAV cells on a periodic basis to assess the areal coverage of SAV taxa. Assessments are made at a network of fixed geo-referenced sites arranged in a grid pattern within each cell. The coverage of SAV taxa at each site is evaluated based on the amount of SAV in the water column visible to an observer within the immediate vicinity of the airboat. In addition, a garden rake is dragged along the wetland bottom to collect any plant material not directly visible to the observer to ensure all taxa were detected. Surveys are conducted by scientists from the District and DB Environmental, Inc., using a 4-point ordinal scale to estimate SAV

[9] Cattail in the Everglades STAs can be both a desirable and an undesirable species depending on the situation. In general, cattail is a desired species in EAV cells. However, there are situations where the District controls (i.e., removes) cattail, e.g., when converting a cell from an EAV to an EAV/SAV community or when a stand of cattail has floated thus providing no treatment and the cell needs to be rehabilitated. The vegetation management sections in this chapter only document cattail control measures since cattail establishment and expansion normally occurs on a volunteer basis and requires no intervention by the District.

[10] Widespread harvesting often has been suggested as a way to manage vegetation in the Everglades STAs. However, harvesting is not under consideration for a number of reasons including (1) mechanical removal is very labor intensive and would be disruptive to the STAs if done on a large scale, (2) the lack of local disposal sites for the collected plant biomass and high transportation costs to reach more distant disposal locations, (3) a viable market for plant byproducts, such as conversion into biofuel, has not materialized in South Florida, and (4) harvesting removes carbon from the system that may be critical to some nutrient removal processes (e.g., nitrogen). A synthesis of the potential benefits and liabilities of harvesting wetland vegetation by Kadlec (2011) influenced SFWMD's decision not to pursue harvesting in the STAs.

coverage: *None* = no plants observed, *Low* = 1 to 33% coverage, *Medium* = 34 to 66% coverage, and *High* > 66% coverage. Coverage assessments were made for each SAV taxon and for all SAV taxa taken together.

SAV taxa coverage maps for individual cells presented in previous South Florida Environmental Reports (SFERs) have been replaced with stacked-bar plots of SAV frequency of occurrence over the POR for each cell (Appendix 5B-4, Figures 1 through 21). These figures provide a comparison of every survey conducted within a cell to illustrate temporal trends in the SAV community and provide historical context for the latest SAV survey data. Frequency of SAV occurrence is calculated from the number of survey sites in a cell at which a SAV taxon was present divided by the overall number of survey sites. For example, if a taxon was present at every survey site in a cell, its frequency of occurrence would be 1.0, whereas if the taxon was present at only one-half of the sites, its frequency of occurrence would be 0.5. When the frequencies of occurrence for each taxon from a cell survey are plotted as a stacked bar, the stacked bar represents the "overall SAV occurrence" (i.e., summation of all taxa) in the cell and can exceed a value of 1 on the plot's y-axis. For example, if each of three taxa occurred at one-half of a cell's survey sites (i.e., each taxon had a frequency of occurrence = 0.5), the stacked bar of all taxa frequencies for this survey would extend to 1.5 on the y-axis. Because multiple SAV taxa were usually present at multiple sites during cell surveys, stacked bars often exceed a value of 1 on the plot's y-axis. Changes in taxa occurrence and composition of the SAV community over the POR were inferred from examination of the stacked bar plots.

Low-altitude helicopter surveys of the Everglades STAs are conducted on a monthly basis to qualitatively assess the condition of the EAV, SAV, and FAV communities. This information is used primarily to guide vegetation maintenance and restoration activities (e.g., the need to treat encroaching FAV or the planting of EAV in areas with sparse coverage), supplement the ground SAV surveys as needed, and track any notable changes in the vegetation that occurred during the water year.

DRYOUT

One of the challenges in managing the Everglades STAs is dealing with periodic dryout. During the dry season in South Florida (approximately October to May), and particularly during prolonged droughts when supplemental water from Lake Okeechobee is not available, portions of or entire cells can dry out. This is especially problematic for cells that have a higher ground elevation than surrounding areas (resulting in water loss through seepage) and cells that are not capable of receiving supplemental water from Lake Okeechobee to keep them hydrated. Dryout is known to affect STA treatment performance and the health of SAV and EAV communities, as well as encourage nesting of protected avian species that can result in conflicts with the operation of flow-ways. Dry conditions promote the rapid oxidation of soil organic matter and subsequent reflooding results in outflow TP concentration spikes due to the flux of mineralized soil P into the water column (Martin et al. 1996, DeBusk and Reddy 2003, Bostic and White 2007). The impact of dryout on outflow TP concentrations from the STAs is influenced by factors such as the spatial extent and duration of dry conditions, soil characteristics, type of vegetation, and the lag time between reflooding and cell discharge following the dryout. Operational experience indicates that brief dryout periods in peat-based STA cells usually do not result in large outflow TP concentration spikes, likely due to the ability of the peat material to retain water within the soil matrix. However, in areas where the substrate has a higher mineral content, such as the soil found in some of the cells in STA-5/6, the upper soil column dries out much faster upon loss of surface water and is prone to fluxing soil P upon rewetting. Another contributing factor to the intensity of soil P flux is the duration of the dryout. The impact of annual cycles of dryout and reflooding on treatment performance in Cells 6-3 and 6-5 of STA-5/6 is discussed in Chapter 5 of the *2010 South Florida Environmental Report – Volume I* (see pages 5-100 to 5-105 in Pietro et al. 2010).

While prolonged dryout conditions in EAV/SAV cells can be detrimental to the SAV plant community, dryout in EAV cells for short periods[11] does not appear to have negative impacts and may benefit the plants.

[11] In general, a "short" period can be up to several weeks in duration, but the exact length of time can vary depending on the soil's ability to retain moisture.

For example, managed water level drawdowns have been effective in encouraging recruitment of cattail in STA-3/4. Extended periods of dryout, however, have visibly affected EAV communities causing die-off of wetland vegetation and invasion of terrestrial plant species. When dried cells are rehydrated, EAV generally recovers more quickly than SAV.

The District began implementing the *South Florida Water Management District Everglades Stormwater Treatment Areas (STAs) Drought Contingency Plan* in 2008 to minimize dryout during periods of drought (SFWMD 2015). These procedures were updated in *Water Shortage Suggested Operating Procedures – Stormwater Treatment Areas* (SFWMD 2020). When dry conditions are anticipated, the plan provides guidance regarding raising cell target stages before the end of the wet season to increase storage volume in mixed-marsh EAV/SAV cells, the use of temporary pumps to deliver water to the Everglades STAs from nearby sources when available, and the delivery of supplemental water, when available, from Lake Okeechobee to the Everglades STAs. The plan prioritizes hydration of EAV/SAV cells over EAV cells to minimize impact to the SAV community and sets the minimum target stages in EAV and EAV/SAV cells during drought conditions at 15 to 30 centimeters (cm; ~ 6 to 12 inches) below and 15 cm above the average ground elevation, respectively, to maintain the vegetation community in a healthy condition. FEBs located adjacent to STA-1E and STA-1W (L-8 FEB) and STA-2 and STA-3/4 (A-1 FEB) (**Figure 5B-1**), and the future C-139 FEB that will be adjacent to STA-5/6, are anticipated to increase the supply of water available to the STAs during the dry season. In addition, the capacity of the FEBs to store stormwater runoff at the start of the wet season may allow the District to hold water longer in the STAs before they need to accept more runoff and discharge from reflooded flow-ways that have dried out. This may allow time for the P flux from these rehydrated soils to be re-assimilated before water is released.

Stage in the Everglades STAs during dry conditions when there is little to no basin runoff can recede to levels where there is no hydraulic connection between water at the inflow and outflow structures and any remaining pools of water in the marsh. When this occurs, the District declares the affected flow-ways to be in a "dryout condition" and notifies FDEP that permit-mandated water quality sampling is suspended until water levels increase and reestablish the connection between the structures and the marsh. In addition, a portion of one or more cells in an Everglades STA with higher ground elevation can dry out but not to the extent that the District declares these cells to be in a dryout condition[12]. Note that days when flow-ways are declared to be in dry-out condition or experience only partial dryout are classified as being "online" and available for operation when calculating adjusted treatment areas.

STORM IMPACTS

Treatment performance in the Everglades STAs can be degraded by large storms events through several mechanisms, whether these storms are tropical cyclones (tropical storms and hurricanes) or simply prolonged periods of heavy rainfall. First, heavy rainfall can substantially increase the volume of runoff coming from a drainage basin. In response to increased runoff, inflow pump stations may operate at or near full capacity for extended periods, which increases water velocities thereby reducing the hydraulic residence time within these wetlands. Second, prolonged heavy pumping also can increase water depths to the point where water levels overtop the vegetation reducing treatment and increasing plant stress. Third, the TP concentration in basin runoff can increase markedly both during and after large storms. Fourth, high wind speeds can damage the vegetation community, thereby reducing the wetland's ability to retain TP. Fifth, wave action generated by high wind speeds can scour the bottom sediments and mix dissolved and particulate P up into the water column. Any of these factors if severe enough, whether singly or in combination, can cause an increase in Everglades STA annual outflow FWM TP concentrations. The Everglades STAs experienced no major impacts from storm events in WY2021.

[12] The STAs are not completely flat; ground elevation can vary up to several feet within an STA. As a result, soil at higher elevations can be exposed (i.e., dry out) during the dry season when there is little inflow from basin runoff while soil at lower elevations can remain flooded. Cells so affected are characterized as having partially dried out.

MIGRATORY BIRD AND SNAIL KITE NESTING

The District, in cooperation with the United States Fish and Wildlife Service (USFWS), finalized the *Avian Protection Plan for Black-necked Stilts and Burrowing Owls Nesting in the Everglades Agricultural Area Stormwater Treatment Areas* (APP) in 2008 for the Everglades STAs (Pandion Systems 2008). The black-necked stilt (*Himantopus mexicanus*) and Florida burrowing owl (*Athene cunicularia floridana*) are protected species under the Migratory Bird Treaty Act of 1918. Additional protected status has been given to the Florida burrowing owl since it also is listed as a threatened species by the State of Florida. In accordance with the APP, the District conducts surveys within the Everglades STA cells for nests of these two bird species during their nesting seasons. The APP provides the District with a framework to modify Everglades STA operations to minimize potential impacts to active nests of either species. This is accomplished by diverting water around cells or regulating inflow to these cells to avoid raising water levels and flooding nests[13]. Although the District is committed to mortality reduction measures, there may be situations where bird mortality is unavoidable as the District fulfills its flood control and water quality treatment responsibilities. Specifically, the District during storm events seeks to minimize sending untreated water directly to the Everglades Water Conservation Areas (WCAs). Operation of the Everglades STAs at these times may result in the inadvertent taking of migratory birds or nests. Standardized black-necked stilt nesting surveys were conducted in all the STAs during the 2020 and 2021 nesting seasons[14] following protocols outlined in the APP. The number of black-necked stilts, a ground-nesting species, attracted to the Everglades STAs each year, is largely a function of available nesting habitat, which can vary from year to year. This species prefers mudflats and shallow water for nesting. Low water levels in the Everglades STAs can expose areas of these wetlands suitable for nesting. To the extent practicable, the District attempts to keep the Everglades STAs at target stage during the spring to discourage nesting. However, keeping the Everglades STAs flooded is subject to the availability of water in the basin, which is a function of rainfall patterns and the need to maintain low water levels to accommodate construction activities inside the STAs. In addition, EAV coverage in many treatment cells has increased as the STAs have matured. This has resulted in limiting the amount of habitat that black-necked stilts find suitable for nesting even when water levels are low. Survey results are summarized in each STA section of this chapter and reported in more detail in Appendix 5B-3 of this volume.

In addition to the District's nest surveys for black-necked stilts and Florida burrowing owls, the University of Florida conducts nest surveys each year in the Everglades STAs for the snail kite (*Rostrhamus sociabilis plumbeus*), which has federal status as an endangered species. USFWS is consulted and the District follows a set of voluntary guidelines (SFWMD 2016) on modifying construction, maintenance activities, and STA operations to avoid disturbing any active nests. Survey results for these bird species are summarized in each STA section of this chapter and reported in more detail in Appendix 5B-3 of this volume.

[13] The District is not required to alleviate flooding in cells with nests that is due to direct rainfall onto the Everglades STAs. The District, to the extent practicable, maintains the Everglades STAs at a stage that is sufficient to keep all cells completely flooded, especially during the dry season. This dissuades black-necked stilts from using the Everglades STAs as nesting areas. In cases where black-necked stilts have nested in the Everglades STAs, the District maintains inflow to the affected cells at a restricted stage to prevent any further cell dry out, which would attract more nesting birds.

[14] Survey results for the 2020 and 2021 nesting seasons are reported in this chapter even though the 2020 season began before the start of WY2020 and the 2021 nesting season continued after the end of WY2021.

OVERVIEW OF POR AND WY2021

OVERVIEW OF TREATMENT PERFORMANCE

The Everglades STAs combined, over their 27 years of operation, have treated approximately 24.2 million ac-ft of water (~7.9 trillion gallons) and retained 3,089 t of TP or 77% of the TP load that entered these facilities (4,014 t). The marked increase in the combined inflow water and TP loads to the Everglades STAs that began after WY2001 reflected an increase in treatment capacity as additional STAs were built and came online (**Figure 5B-2**). The POR inflow FWM TP concentration for all the Everglades STAs through WY2021 is 134 µg/L, while the POR outflow FWM TP concentration is 30 µg/L (**Table 5B-1**).

All the Everglades STAs combined received approximately 1.6 million ac-ft of inflow during WY2021 (**Table 5B-1**). Of this inflow water volume, approximately 162,000 ac-ft were Lake Okeechobee releases directed to the STAs; 147,000 ac-ft were regulatory releases, while 15,000 ac-ft were delivered as supplemental water to maintain water levels at target stages in all Everglades STAs.

The Everglades STAs combined received 266 t of inflow TP load during WY2021 and retained 207 t of this mass (**Table 5B-1**), which equated to a 78% load reduction. The overall annual inflow to outflow FWM TP concentrations this water year decreased from 134 to 28 µg/L, respectively. The annual percent TP load retained has ranged from the lowest retention (63%) in WY2003 to the highest (86%) in WY2016 and has been greater than or equal to 77% in each year since WY2008.

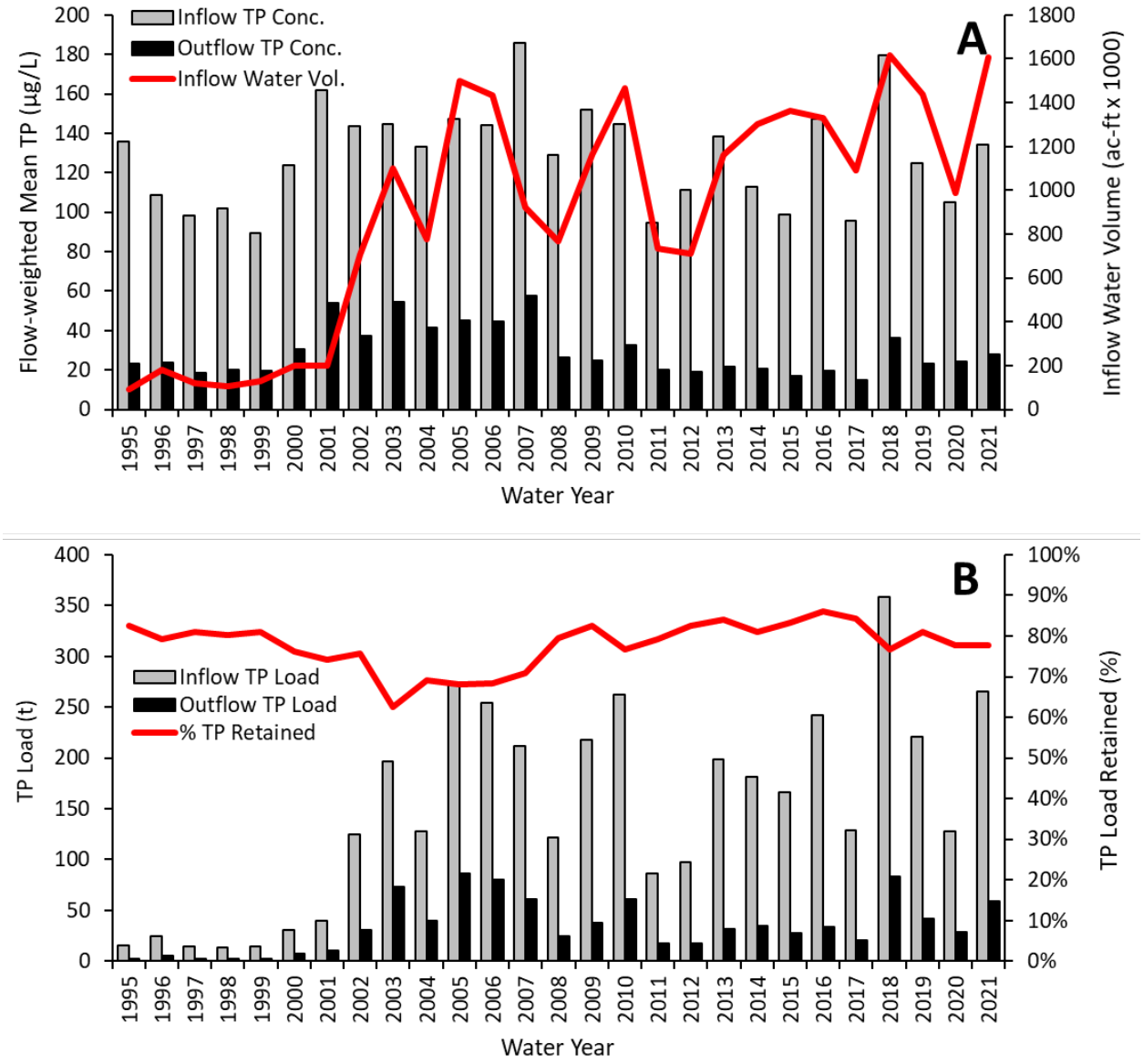


Figure 5B-2. POR time series in all the Everglades STAs combined for (A) annual inflow and outflow FMW TP concentrations (Conc.) with corresponding inflow water volumes (Vol.) and (B) annual inflow and outflow TP loads with the percent TP load retained.

Table 5B-1. Summary of treatment performance in each Everglades STA and all STAs combined for WY2021 and the POR.

Parameter (Unit [a])	STA-1E	STA-1W	STA-2	STA-3/4	STA-5/6	All STAs
Treatment Area (ac)	4,994	10,810	15,495	16,327	14,338	61,964
Adjusted Treatment Area (ac) [b]	3,021	10,810	14,910	15,245	14,338	58,323
WY2021 Inflow						
Inflow Water Volume (ac-ft)	323,000	192,000	440,000	521,000	130,000	1,606,000
Inflow TP Load (t)	55	60	55	51	45	266
FWM Inflow TP Concentration (µg/L)	138	254	100	80	281	134
Hydraulic Loading Rate (cm/d)	8.9	1.5	2.5	2.9	0.8	2.3
Phosphorus Loading Rate ($g/m^2/yr$)	4.5	1.4	0.9	0.8	0.8	1.1
WY2021 Outflow						
Outflow Water Volume (ac-ft)	284,000	216,000	502,000	539,000	152,000	1,694,000
Outflow TP Load (t)	13	10	13	8	15	59
FWM Outflow TP Concentration (µg/L)	37	38	21	12	80	28
TP Retained (t)	42	50	42	43	30	207
TP Removal Rate ($g/m^2/yr$)	3.4	1.1	0.7	0.7	0.5	0.9
TP Load Retained (%)	76%	83%	76%	84%	67%	78%
POR						
Start Date	September 2004 [c]	October 1993 [d]	June 1999	October 2003	December 1997	
Inflow Water Volume (ac-ft)	2,187,000	4,741,000	6,235,000	7,949,000	3,085,000	24,198,000
TP Inflow Load (t)	447	1,059	778	994	735	4,014
FWM Inflow TP (µg/L)	166	181	101	101	193	134
Outflow Water Volume (ac-ft)	2,044,000	4,885,000	6,680,000	8,162,000	2,864,000	24,635,000
TP Outflow Load (t)	97	272	178	151	228	925
FWM Outflow TP Concentration (µg/L)	38	45	22	15	64	30
TP Retained (t)	351	788	600	844	507	3,089
% TP Retained	78%	74%	77%	85%	69%	77%

a. Conversion factors: 1 ac = 0.40469 hectares or 4,046.9 square meters; 1 ac-ft = 1,233.5 cubic meters; 1 metric ton (t) = 1,000 kilograms; and 1 centimeter per day (cm/d) = 0.39370 inches per day. Note: $g/m^2/yr$ – grams per square meter per year.

b. Adjusted treatment area is time and area weighted to exclude any cells that were off-line; refer to **Table 5B-2**.

c. STA-1E was operated in WY2005 for emergency flood control purposes and to establish wetland vegetation; it became fully operational in WY2006.

d. Flow-through operations in STA-1W did not begin until August 1994.

Among all the Everglades STAs, STA-3/4 again had the lowest annual outflow FWM TP concentration in WY2021 (12 µg/L), while annual outflow FWM TP concentrations in the other Everglades STAs ranged from 21 to 80 µg/L (**Table 5B-1**). STA-3/4 received the largest inflow water volume (520,000 ac-ft) and STA-1W the largest inflow TP load (60 t) this water year, while STA-5/6 received both the smallest inflow water volume (130,000 ac-ft) and TP load (45 t) (**Figure 5B-3**). Minimum and maximum HLRs during WY2021 were 0.8 centimeters per day (cm/d) in STA-5/6 and 8.9 cm/d in STA-1E; HLRs in the other Everglades STAs ranged from 1.5 to 2.9 cm/d (**Figure 5B-3**). The PLRs ranged from 0.8 to 1.4 grams per square meter per year ($g/m^2/yr$) in STA-1W, STA-2, STA-3/4, and STA-5/6, while STA-1E had a PLR of 4.5 $g/m^2/yr$.

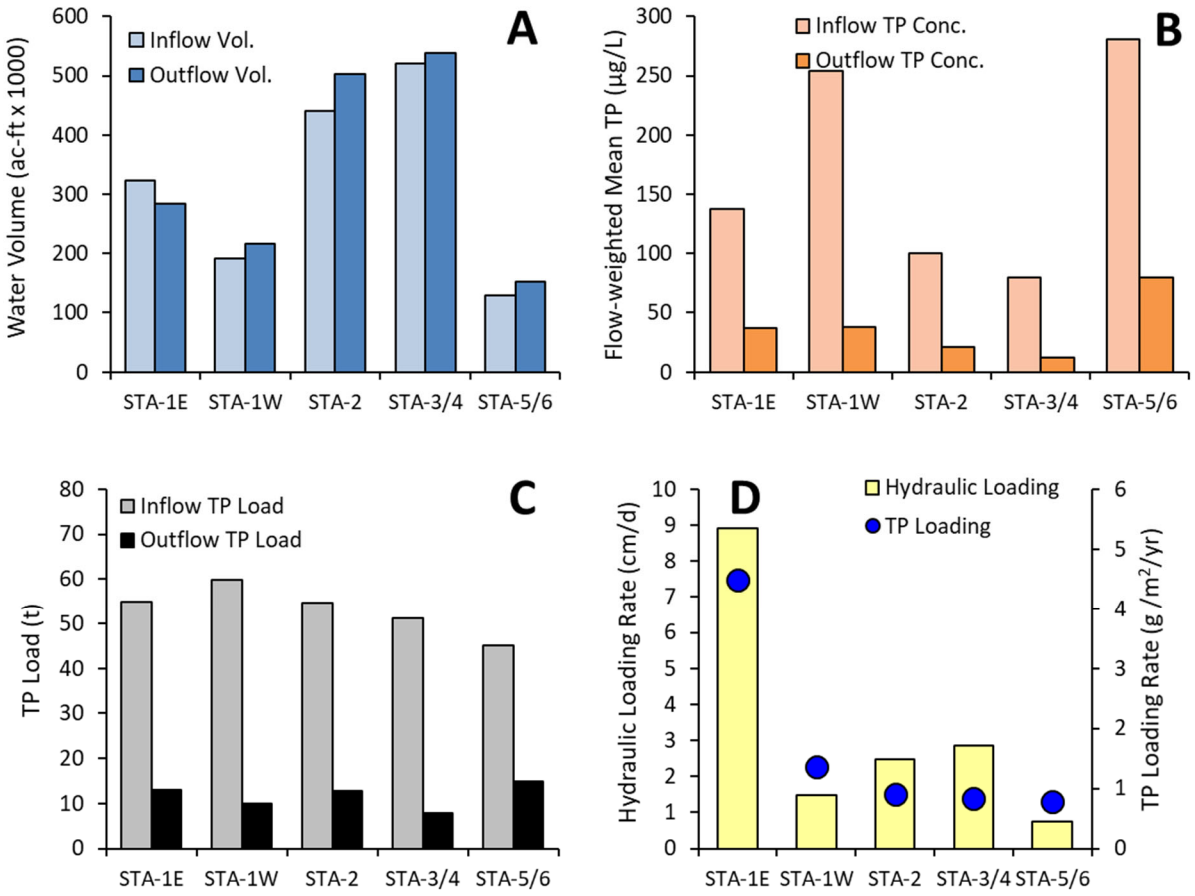


Figure 5B-3. Comparison of (A) inflow and outflow water volumes (Vol.), (B) inflow and outflow FWM TP concentrations (Conc.), (C) inflow and outflow TP loads, and (D) hydraulic and TP loading rates in the Everglades STAs during WY2021.

OVERVIEW OF FACILITY STATUS AND OPERATIONAL ISSUES

The calculated treatment area of STA-1E, STA-2, and STA-3/4 was adjusted in WY2021 because one or more of their flow-ways were taken offline during part or all of the water year (**Table 5B-2**). In addition, other flow-ways in the Everglades STAs were ONR for at least a portion of WY2021. Details of the operational status of each flow-way are provided in the individual STA sections that follow.

Table 5B-2. Operational status of Everglades STA flow-ways during WY2021.

STA	Flow-way	Treatment Area (ac [a])	Operational Status [b]	Comments [c, d]	% Time Online
STA-1E	Entire STA	4,994			61
	Eastern	1,082	No restrictions in WY2021		100
	Central	1,939	ONR: 05/2020 to 06/2020 ONR: 05/2020 to 04/2021 ONR: 01/2021 to 04/2021	BNS nesting Vegetation rehabilitation Vegetation management	100
	Western	1,973	ONR: 05/2020 to 06/2020 OFF: 05/2020 to 04/2021	BNS nesting RSP: Cells 5 and 7 earth work	0
STA-1W	Entire STA	10,810			100
	Eastern	2,171	ONR: 11/2020 to 02/2021 ONR: 02/2021 to 04/2021	RSP: STA-1W discharge canal plug construction Refurbishments construction	100
	Western	1,369	ONR: 11/2020 to 02/2021 ONR: 02/2021 to 04/2021	RSP: STA-1W discharge canal plug construction Refurbishments construction	100
	Northern	4,956	ONR: 05/2020 to 11/2020 ONR: 11/2020 to 02/2021 ONR: 02/2021 to 04/2021	RSP: STA-1W Expansion Area #1 start-up RSP: STA-1W discharge canal plug construction Refurbishments construction	100
	Cell 7	1,201	ONR: 11/2020 to 02/2021	RSP: STA-1W discharge canal plug construction	100
	Cell 8	1,113	ONR: 05/2020 to 06/2020 ONR: 11/2020 to 02/2021 ONR: 04/2021	BNS nesting RSP: STA-1W discharge canal plug construction BNS nesting	100
STA-2	Entire STA	15,945			96
	#1	1,840	ONR: 05/2020 ONR: 12/2020 to 1/2021	Vegetation management Vegetation management	100
	#2	2,373	ONR: 05/2020 OFF: 11/2020 to 02/2021 ONR: 02/2021 to 04/2021	Vegetation management Refurbishments construction Refurbishments construction	75
	#3	2,296	ONR: 05/2020 to 04/2021 ONR: 12/2020 to 03/2021 ONR: 02/2021 to 03/2021	Vegetation rehabilitation Vegetation management Refurbishments construction	100
	#4	5,990	ONR: 05/2020 to 04/2021	Vegetation management	100
	#5	2,995	ONR: 12/2020 to 03/2021	Vegetation management	100
STA-3/4	Entire STA	16,327			93
	Eastern	6,476	ONR: 05/2020 to 03/2021 ONR: 06/2020 to 03/2021 OFF: 03/2021 to 04/2021	Vegetation rehabilitation Vegetation management Vegetation rehabilitation/cell drawdown	83
	Central	5,349	ONR: 05/2020 to 04/2021 ONR: 06/2020 to 04/2021	Vegetation rehabilitation Vegetation management	100
	Western	4,502	ONR: 05/2020 to 04/2021	Vegetation management	100
STA-5/6	Entire STA	13,685			100
	#1	2,418	ONR: 05/2020 to 06/2020	BNS nesting	100
	#2	2,068	ONR: 05/2020 to 04/2021	Flow restrictions following RSP	100
	#3	1,922	ONR: 05/2020 to 04/2021	Flow restrictions following RSP	100
	#4	1,871	ONR: 05/2020 to 06/2020	BNS nesting	100
	#5	2,642	No restrictions in WY2021		100
	#6	1,900	ONR: 05/2020 to 06/2020	BNS nesting	100
	#7	621	DO: 04/2021		100
	#8	242	DO: 04/2021		100

a. Conversion factor: 1 acre = 0.40469 hectares or 4,046.9 square meters.

b. DO – District declared dryout; OFF – offline; and ONR – online with restrictions.

c. BNS – black-necked stilt; EDC – East Distribution Cell; RSP – Restoration Strategies project; SK – snail kite; and WDC – West Distribution Cell.

d. STA operations and maintenance activities modified during WY2021 due to bird nesting are detailed in Appendix 5B-3 of this volume.

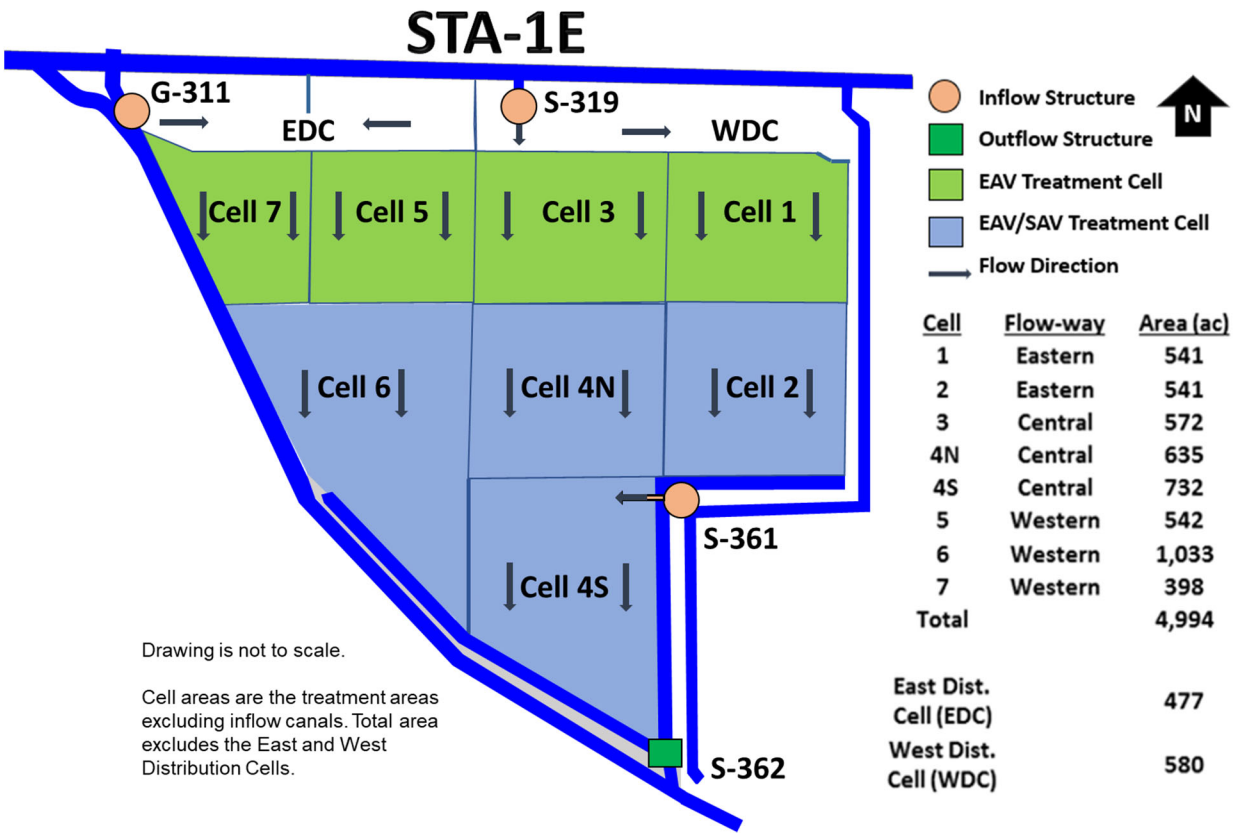
During the 2020 and 2021 nesting seasons, 81 black-necked stilt nests were observed across all the Everglades STAs while no active Florida burrowing owl nor snail kite nests were detected. Operational priorities were adjusted in the Everglades STAs as needed to avoid disturbing active nests; all such adjustments are discussed in Appendix 5B-3.

STA-1E

STA-1E is located in Palm Beach County approximately 32 kilometers (km; ~ 20 miles) west of West Palm Beach, south of State Road 80 and the C-51 canal, adjacent to the northeast boundary of the Arthur R. Marshall Loxahatchee National Wildlife Refuge (LNWR), and directly east of the STA-1 Inflow and Distribution Works (referred to as the STA-1 Inflow Basin) (**Figure 5B-1**). This facility was flooded in WY2005 to establish wetland vegetation. STA-1E provides a total treatment area of 4,994 ac arranged into three parallel treatment trains, or flow-ways, that contain eight cells (Piccone et al. 2019; **Figure 5B-4**). The East and West distribution cells are not considered part of the STA-1E treatment area. STA-1E receives inflow primarily from the C-51 West basin and smaller water volumes from the L-8 and S-5A basins, Lake Okeechobee releases, and the Rustic Ranches subdivision (see Figure 1 in Appendix 5B-2). In WY2007, STA-1E started receiving runoff from Wellington Acme Basin B. During the dry season, supplemental water is delivered from Lake Okeechobee when available to maintain hydration in priority cells, such as cells containing SAV. 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

A number of issues have affected STA-1E operations over its POR, including high hydraulic loadings during large storm events (particularly Hurricane Wilma in October 2005, an unnamed storm in February 2006, Tropical Storm Isaac in August 2012, multiple large rainfall events in June 2017, and Hurricane Irma in September 2017), the repair of internal water control structures by the United States Army Corps of Engineers (USACE), uneven ground topography that results in excessively deep water and hydraulic short-circuiting (particularly in Cells 5 and 7 of the Western Flow-way, see below), dryout of cells during droughts, and vegetation die-off (i.e., the gradual decline of cattail in Cell 7 over time, the mass uprooting of hydrilla in Cell 6 during a high flow event in WY2010, and the complete removal of SAV in Cell 4S from herbivory by the exotic island applesnail [*Pomacea* maculata] in July 2013). Recently, there was damage from the water level draw-down initiated prior to Tropical Strom Eta in 2020 and adverse impacts from floating cattail tussocks (i.e., hydraulic short circuits) and expansion of willow (*Salix* spp.) and FAV coverage in some cells.



Cell	Flow-way	Area (ac)
1	Eastern	541
2	Eastern	541
3	Central	572
4N	Central	635
4S	Central	732
5	Western	542
6	Western	1,033
7	Western	398
Total		4,994
East Dist. Cell (EDC)		477
West Dist. Cell (WDC)		580

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

STA TREATMENT PERFORMANCE

Over its 17-year POR, STA-1E has treated approximately 2.2 million ac-ft of water and retained 351 t of TP or 78% of the inflow TP load (447 t) (**Table 5B-1**). The POR inflow FWM TP concentration to this facility is 166 µg/L, while the corresponding outflow FWM TP concentration is 38 µg/L.

STA-1E received its largest inflow water volume in WY2021 (323,000 ac-ft) (**Figure 5B-5**), which was 56% greater than second largest inflow water volume received in WY2016 (207,000 ac-ft)[14]. Approximately 25,000 ac-ft of this water year's inflow water volume were Lake Okeechobee releases directed to STA-1E via the S-319 and G-311 structures; 23,000 ac-ft were regulatory releases, while 1,400 ac-ft were delivered as supplemental water to maintain the vegetation communities in the STA. Lake Okeechobee water was received in all months this water year except June and July 2020.

STA-1E retained 76% of the inflow TP load this water year (42 of 55 t; **Table 5B-1**). Annual inflow and outflow FWM TP concentrations were 138 and 37 µg/L, respectively, while the HLR and PLR were 8.9 cm/d and 4.5 g/m^2/yr, respectively. This year's HLR and PLR were, by far, the highest loading rates experienced in STA-1E over its POR[15]. Percent TP retention in this STA has been fairly consistent since WY2011 (**Figure 5B-5**).

[15] Controlling water levels to accommodate construction activities in STA-1W reduced the volume of inflow to this facility in WY2021. A portion of the flow that normally would have gone to STA-1W was directed to STA-1E instead, which, in large measure, accounted for the large increases in inflow water volume, HLR, and PLR in STA-1E this water year.

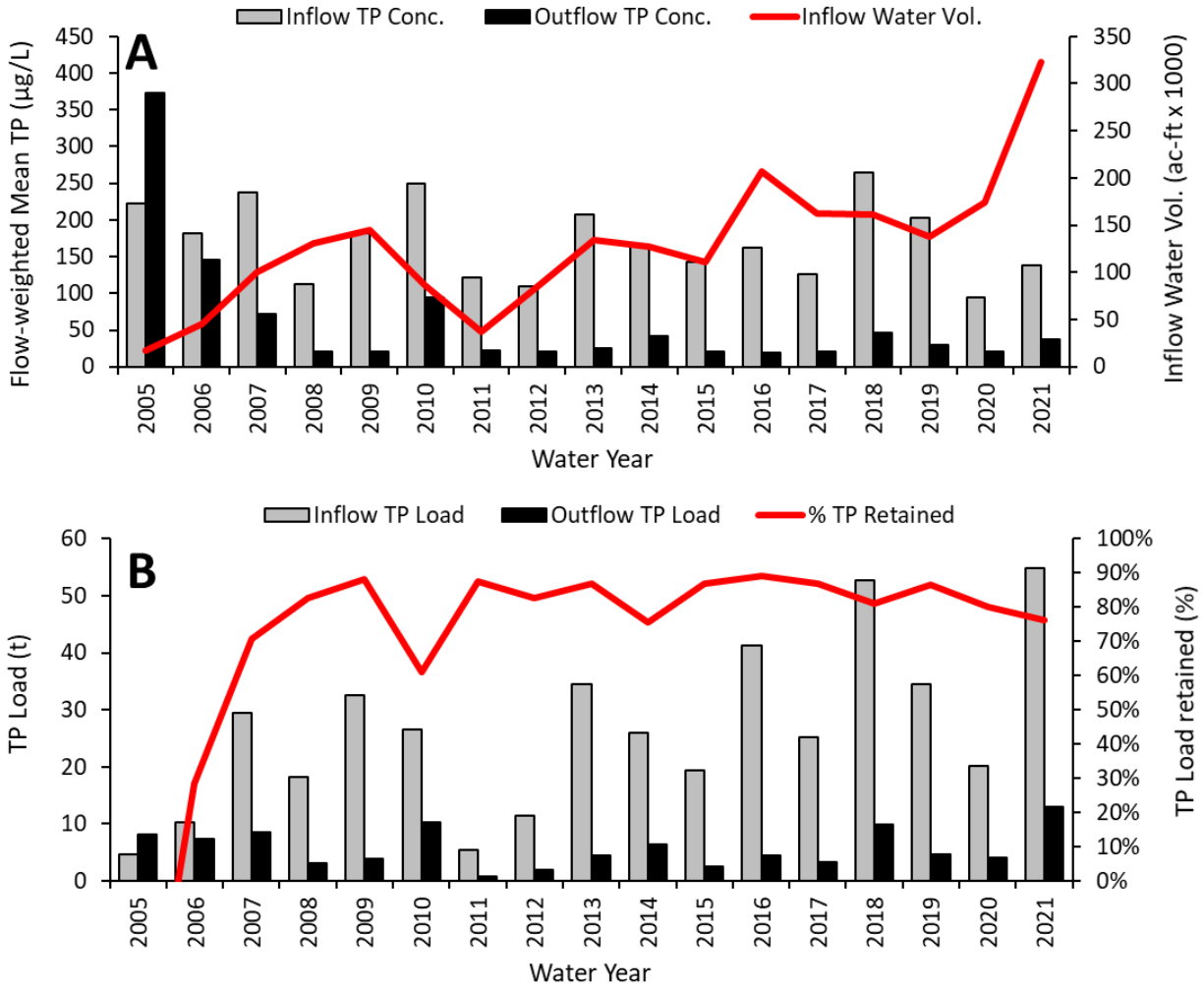


Figure 5B-5. POR time series for STA-1E for (A) annual inflow and outflow FWM TP concentrations (Conc.) with corresponding inflow water volumes (Vol.) and (B) annual inflow and outflow TP loads with the percent TP load retained.

FACILITY STATUS AND OPERATIONAL ISSUES

The Eastern and Central flow-ways of STA-1E were operational throughout WY2021 (**Table 5B-2**). The Western Flow-way was OFF throughout WY2021 for a Restoration Strategies project to fill and regrade Cells 5 and 7 to even out their ground elevations with the surrounding cell. The Central Flow-way was ONR during portions of the water year for vegetation management/rehabilitation activities and black-necked stilt nesting. The Western Flow-way also was ONR for part of WY2021 due to black-necked stilt nesting.

Refurbishment Project

A STA-1E refurbishment project completed in WY2021 consisted of degrading remnant farm roads and filling the adjacent remnant farm ditches in Cell 6 that were causing hydraulic short-circuiting in some areas and blocked flow in other portions of the cell. The material from the degraded farm roads was left within the cell in a manner that will not impede flow, and no import or export of material occurred during construction.

Dryout

Cells 5 and 7 of the Western Flow-way in STA-1E dried out this water year as these cells were OFF for STA-1E Restoration Strategies projects. All other STA-1E cells were hydrated during WY2021.

Migratory Bird and Snail Kite Nesting

Black-necked stilt nests were observed in the STA-1E Western Distribution Cell and Cells 4N, 5, 6 and 7 during May 2020. A stilt nest was later observed in Cell 5 in June 2020. No snail kite nests, nor Florida burrowing owls, were found in STA-1E this water year. Additional information on nesting survey results and STA-1E operational and maintenance adjustments made to protect bird nests during WY2021 is presented in Appendix 5B-3 of this volume.

VEGETATION MANAGEMENT

Vegetation management in STA-1E during WY2021 was focused on controlling FAV and preparing impacted cells for future rehabilitation efforts. Approximately 63 and 237 ac of FAV were treated in the Western and Eastern distribution cells, respectively, to prevent damage to water control structures from encroaching FAV and prevent FAV from entering the STA. We also manually removed over an acre of floating tussocks from these structures that was hindering their operation. In the Eastern Flow-way, 170 and 187 ac of FAV were treated in Cells 1 and 2, respectively. In the Central Flow-way, efforts to control the expansion of undesirable vegetation included the following treatments: 240 ac of primrose willow and 75 ac of FAV in Cell 3; 248 ac of cattail mixed with FAV and 174 ac of FAV in Cell 4N; and 242 ac of FAV in Cell 4S. In the Western Flow-way, 8 ac of FAV in Cell 6 and 2 ac of FAV in the outflow canal of Cell 7 were treated. Despite Cells 5 and 7 Cell being OFF for the entire water year with no inflow, Cell 6 received enough seepage to keep much of it wet and maintain viable SAV beds that will help the recovery of treatment performance when this flow-way returns to operation. A small population (approximately 2 ac) of a new invasive SAV species, Indian swampweed (*Hygrophila polysperma*), was discovered in the inflow canal adjacent to the Cell 4S boat ramp and was treated to prevent its spread.

VEGETATION SURVEYS

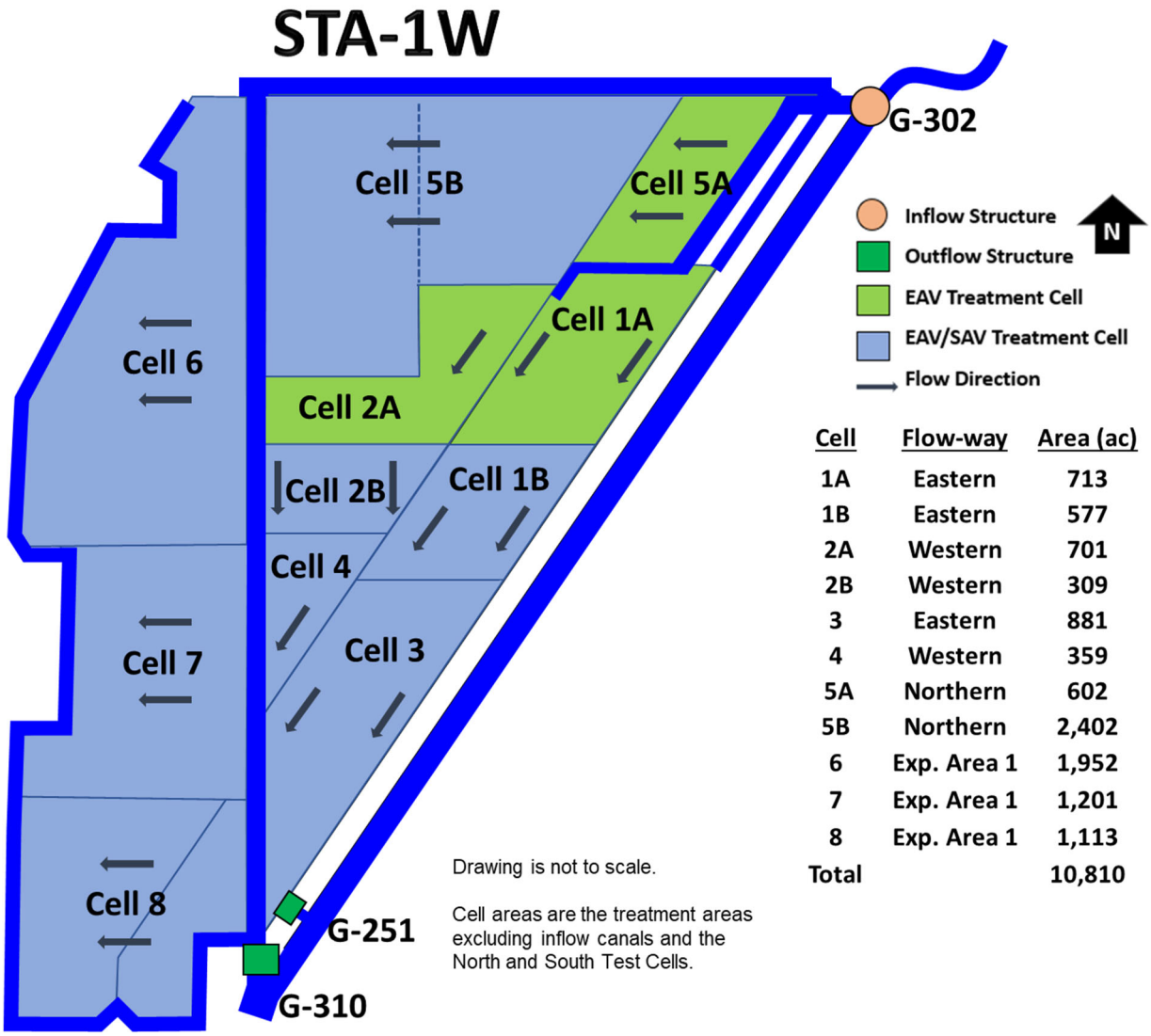
Ground surveys were conducted during the following months in WY2021 to map SAV areal coverage in STA-1E: October 2020 and March 2021 in Cells 4N, October 2020 and April 2021 in Cell 4S, and March 2021 in Cell 6 (Appendix 5B-4, Figures 1 through 3). Cell 6 could not be accessed during the wet season due to construction for a Restoration Strategies project within the Western Flow-way. No SAV was found at 62% of the survey sites, low SAV coverage at 24% of sites, medium SAV coverage at 6% of survey sites, and high SAV coverage at 8% of sites. The following SAV taxa were identified in STA-1E this water year: coontail (*Ceratophyllum demersum*), bladderwort (*Utricularia* sp.), hydrilla, muskgrass, southern naiad, and spiny naiad. Coontail was the dominant taxon in Cell 4N, muskgrass was dominant in Cell 4S, and bladderwort was dominant in Cell 6. Southern naiad, hydrilla, and spiny naiad were present in lesser quantities relative to the dominant taxa. Overall, SAV occurrence in all cells of STA-1E has declined compared to WY2020, most notably in Cell 6, which was OFF for a Restoration Strategies project. There has been a pronounced decline in SAV occurrence in Cells 4N and 6 over their PORs.

STA-1W

STA-1W, which began operation in 1994 as the Everglades Nutrient Removal (ENR) Project, is located in Palm Beach County northwest of LNWR (**Figure 5B-1** and Figure 1 in Appendix 5B-2 of this volume). This STA encompasses 10,810 ac of treatment area arranged into three flow-ways with 11 treatment cells (Piccone et al. 2019; **Figure 5B-6**). The Eastern and Western flow-ways comprised the ENR Project, and the Northern Flow-way was added to the facility in 1999. Compartmentalization of former Cells 1 and 2 was completed in 2007 with the construction of two new interior levees that created Cells 1A, 1B, 2A, and 2B. Construction of an additional interior levee completed in 2015 completely separated inflow to the Western Flow-way from inflow entering the Eastern Flow-way. The treatment area of STA-1W was further expanded by 4,266 ac when construction of Expansion Area #1 (Cells 6, 7, and 8) was completed in late 2018. These new cells were flooded for most of WY2020 to initiate wetland plant colonization and were used to treat runoff at the end of this water year. Cell 6 is part of the Northern Flow-way. However, because Cells 7 and 8 can receive water from both the Eastern and Western Flow-ways, they are not considered to be part of an either flow-way. This STA receives inflow primarily from the S-5A drainage basin and East Beach Water Control District, as well as Lake Okeechobee releases (see Figure 1 in Appendix 5B-2). During the dry season, supplemental water is delivered from Lake Okeechobee, when available, to maintain hydration in cells containing SAV. The cell/flow-way nomenclature for STA-1W is as follows:

- Eastern Flow-way = Cells 1A, 1B, and 3
- Western Flow-way = Cells 2A, 2B, and 4
- Northern Flow-way = Cells 5A, 5B, and 6
- Cells 7 and 8 in the Expansion Area #1

Over its operational history, STA-1W has been affected by extreme weather events (regional droughts and large storms), maintenance activities that included water level drawdowns and construction, high hydraulic and nutrient loadings, and poor cattail establishment. Major rehabilitation activities were implemented in STA-1W between 2005 and 2007 to reestablish the vegetation communities that were damaged by hydraulic overloading in previous water years and restore treatment performance to all cells. Stage in the Eastern Flow-way was lowered in WY2016 and following water years as part of a major vegetation rehabilitation effort that included planting depth-tolerant species such as giant bulrush and alligator flag.



Cell	Flow-way	Area (ac)
1A	Eastern	713
1B	Eastern	577
2A	Western	701
2B	Western	309
3	Eastern	881
4	Western	359
5A	Northern	602
5B	Northern	2,402
6	Exp. Area 1	1,952
7	Exp. Area 1	1,201
8	Exp. Area 1	1,113
Total		10,810

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

STA TREATMENT PERFORMANCE

Over its 27-year POR, STA-1W has treated approximately 4.7 million ac-ft of water and retained 788 t of TP or 74% of the inflow TP load (1,059 t; **Table 5B-1**). The POR inflow FWM TP concentration is 181 µg/L, while the POR outflow FWM TP concentration is 45 µg/L.

STA-1W treated approximately 192,000 ac-ft of runoff in WY2021 (**Table 5B-1**). Of this inflow water volume, approximately 7,800 ac-ft were Lake Okeechobee releases directed to STA-1W via G-302, 6,300 ac-ft were regulatory releases, and 1,400 ac-ft were delivered as supplemental water to maintain the vegetation communities in the STA. Lake Okeechobee water was received from May through October 2020 and in April 2021.

STA-1W had inflow and outflow FWM TP concentrations of 254 and 38 µg/L, respectively, this water year (**Table 5B-1**). STA-1W retained 50 t of TP or 83% of the inflow TP load (60 t) and had an HLR and a PLR of 1.5 cm/d and 1.4 g/m^2/yr, respectively. Treatment performance in STA-1W has recovered from the dramatic decline that occurred from WY2002 through WY2006 when the facility was hydraulically overloaded (**Figure 5B-7**). The percent TP load retained in STA-1W has been 80% or greater in each water year since WY2009, which is comparable to the level of treatment performance experienced prior to WY2001.

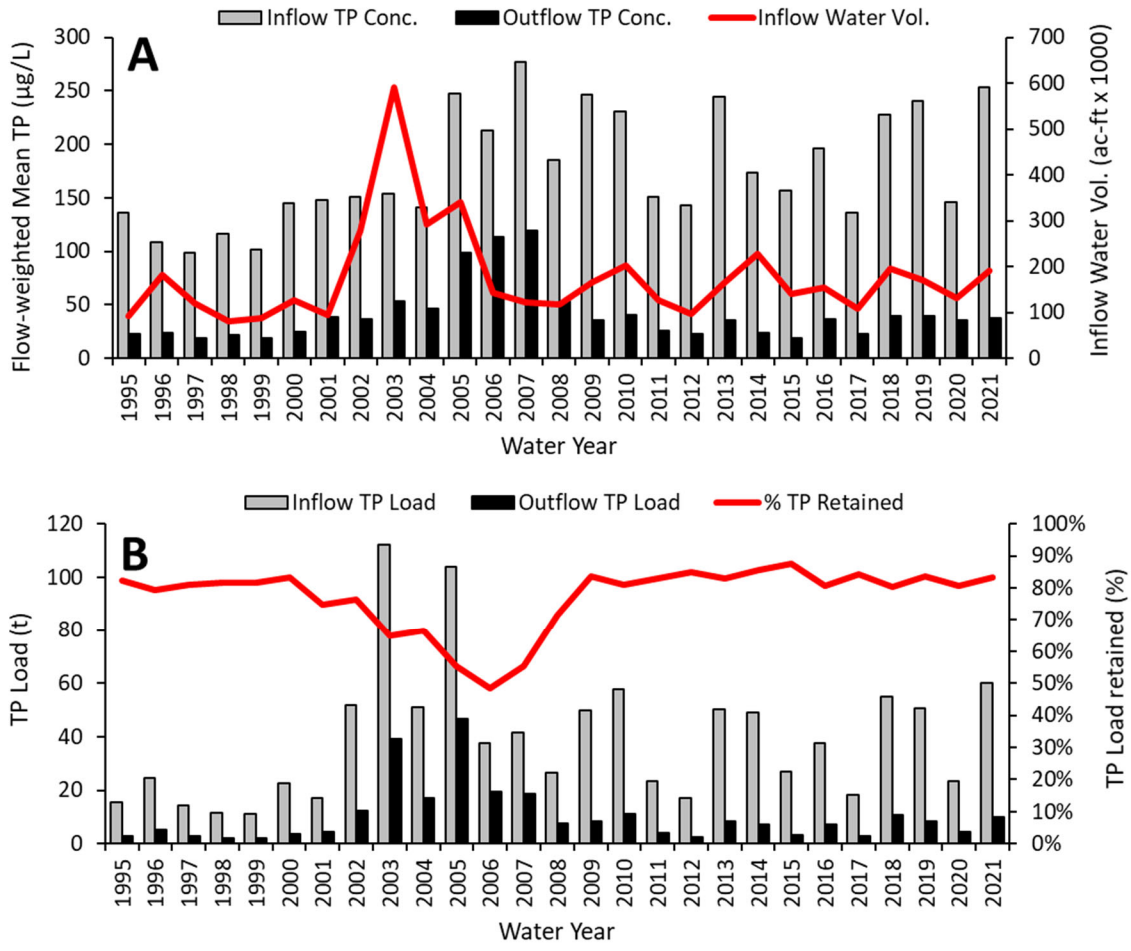


Figure 5B-7. POR time series for STA-1W for (A) annual inflow and outflow FWM TP concentrations (Conc.) with corresponding inflow water volumes (Vol.) and (B) annual inflow and outflow TP loads with the percent TP load retained.

FACILITY STATUS AND OPERATIONAL ISSUES

All STA-1W flow-ways were operational throughout WY2021 (**Table 5B-2**). All flow-ways and Cells 7 and 8 were ONR for portions of the water year due to the construction and removal of earthen plugs in the STA-1W discharge canal, STA refurbishment projects, or activities related to the start of flow-through operation in the STA-1W Expansion Area #1. Cell 8 also was ONR during a portion of the year for black-necked stilt nesting. Cells 7 and 8 underwent a period of reverse flow in September and October 2020 before the earthen plug was installed in the old discharge canal and normal flow-through operations began. During reverse flow, water was sent through the Northern Flow-way, released from Cell 6 via G-730 into the new discharge canal, then directed back into Cell 7 via its G-732 discharge structure and Cell 8 via its G-734 discharge structure. Water then traveled eastward to the Cell 7 and 8 inflow structures where it was sent into the old STA-1W discharge canal for final release into WCA-1 via the G-310 and G-251 pump stations.

Refurbishment Projects

STA-1W refurbishment projects include construction work in all three flow-ways to address poor hydraulics and topographic issues that adversely affect vegetation condition and treatment performance of the cells. The project also includes removal of some features from the original ENR Project that have deteriorated over time or are obsolete and no longer needed for operation of the STA. All refurbishment work is scheduled to be completed by late WY2022.

The refurbishment work in Cell 5B/2A consists of reconfiguring the levee along the southwest portion of Cell 5B and the north portion of Cell 2A (**Figure 5B-6**). The levee's irregular geometry (the levee makes two abrupt 90 degree turns along its length, the first to the south and the second to the west and is referred to as the "dog-leg" levee) results in the southwest portion of Cell 5B having poor hydraulics and sparse SAV growth that affects treatment performance of the cell. The existing dog-leg levee will be removed, and a new straight one-mile levee will be constructed to make Cell 5B more rectangular and improve flow patterns in the cell. In addition, a 1.5-mile remnant farm ditch within Cell 5B that runs parallel to flow will be filled to remove the hydraulic short-circuit created by this feature. Since Cell 2A shares the same dog-leg levee as Cell 5B, reconfiguring the levee will add 400 ac to Cell 2A creating a rectangular shaped cell that also will improve flow distribution. The existing Cell 2A inflow distribution canal will be extended to the west for about one mile adjacent to the new levee.

The refurbishment work in Cell 3 consists of regrading the southernmost 100-ac portion of the cell and filling three finger canals that were constructed as part of the ENR Project to convey water to the G-251 outflow pump station. These finger canals are no longer needed as a result of new flow patterns within the cell following completion of the STA-1W Expansion Area #1 construction.

The refurbishment work in Cell 2B/4 consists of removing the G-254 levee and its deteriorated culverts. These structures were part of the ENR Project, which no longer serve a purpose due to new flow patterns in the Western Flow-way following completion of the STA-1W Expansion Area #1 construction.

Dryout

The southern portion of Cell 3 of the Eastern Flow-way in STA-1W was allowed to dry out this water year to accommodate work on the STA Refurbishment projects. All other cells in STA-1W were hydrated during WY2021.

Migratory Bird and Snail Kite Nesting

Black-necked stilts nests were observed in STA-1W Cell 8 in May 2020 and again in Cells 4, 5B, and 8 during April 2021. No snail kite nests, nor Florida burrowing owls, were found in STA-1W this water

year. Additional information on nesting survey results and STA-1W operational and maintenance adjustments made to protect bird nests during WY2021 is presented in Appendix 5B-3 of this volume.

VEGETATION MANAGEMENT

Vegetation management in STA-1W during WY2021 focused on treating FAV to protect earlier rehabilitation efforts and to support ongoing construction activities in the STA. In the Eastern Flow-way, FAV treatments in Cells 1A and 1B totaled 471 and 319 ac, respectively; 3 ac of floating cattail also were removed from water control structures to facilitate flow into Cell 3. In Cell 3, 123 ac of water lettuce, 2 ac of Brazilian peppertree (*Schinus terebinthifolius*), and less than 1 ac of floating tussocks were treated throughout the cell and less than 1 ac of floating cattail was removed from water control structures. Bulrush was planted and southern naiad inoculated in deeper areas of Cell 1A in which EAV recruitment has been unsuccessful. Soil delamination and tussock formation were problems in the deeper portions of Cell 1B where prior cattail plantings have failed; 11 ac of pickerelweed (*Pontederia cordata*) were planted to help stabilize the soil in these areas. In addition, approximately 2 ac of bulrush were planted along the inflow canal in Cell 3.

In the Western Flow-way, 34 ac of FAV were treated in Cell 2A. In Cell 2B, 22 ac of yellow pondlily (*Nuphar lutea*) were treated along with 4 ac of non-rooted FAV; in addition, 2 ac of cattail were sprayed and manually removed from water control structures to facilitate operations. Areal coverage of yellow pondlily had expanded into Cell 4 and 120 ac were treated to protect existing SAV beds; bulrush was planted to provide sites for harvesting material needed for future vegetation rehabilitation efforts.

In the Northern Flow-way, a combination of vegetation-restriction boom malfunctions and high FAV inflow loads necessitated treating 746 ac of FAV in Cell 5A and another 663 ac in Cell 5B. Eleven 11 ac of bulrush were planted in Cell 5A to reduce hydraulic short circuiting and provide a barrier to the spread of FAV. In Cell 5B, 35 ac of bulrush, 16 ac of pickerelweed, and 14 ac of spikerush were planted to provide sites for future plant harvesting.

Vegetation management in the STA-1W Expansion Area #1 this water year was geared towards controlling the coverage of undesired species, reducing the impact of hydraulic short circuits using EAV, and assisting with the grow-in of the SAV community. Six ac of Carolina mosquitofern (*Azolla caroliniana*) were treated in Cell 6. EAV planting and SAV inoculation efforts included placing 68 ac of bulrush and 4 ac of muskgrass in Cell 6, 20 ac of bulrush in Cell 7, and 32 ac of bulrush and 11 ac of sawgrass in Cell 8.

VEGETATION SURVEYS

Ground surveys were conducted during the following months in WY2021 to map SAV areal coverage in STA-1W: all cells were surveyed in October 2020, and Cells 3 and 5B also were surveyed in March 2021 (Appendix 5B-4, Figures 4 through 8). Most cells could not be accessed during the dry season due to ongoing STA-1W refurbishment projects. Because SAV is still colonizing Cells 6, 7, and 8 of the STA-1W Expansion Area #1, and thus had limited coverage, SAV occurrence data are not included in this year's SFER but will be in future reports. No SAV was found at 42% of the survey sites, low SAV coverage at 26% of survey sites, medium SAV coverage at 21% of survey sites, and high SAV coverage at 11% of survey sites. The following SAV taxa were identified in STA-1W this water year: coontail, muskgrass, southern naiad, spiny naiad, and bladderwort. Coontail was the dominant SAV taxon in Cells 1B, 2B, and 4 this water year, while muskgrass was dominant in Cells 3 and 5B. Southern naiad, spiny naiad and bladderwort were present in lesser quantities relative to the dominant taxa. SAV occurrence this water year declined to varying degrees in Cells 3 and 4 compared to WY2020. There has been a progressive decline in SAV occurrence in Cells 2B, 4, and 5B during the latter part of their PORs. The SAV community in Cell 2B has shifted from being dominated by muskgrass throughout most of its POR to dominance by coontail in recent years.

STA-2

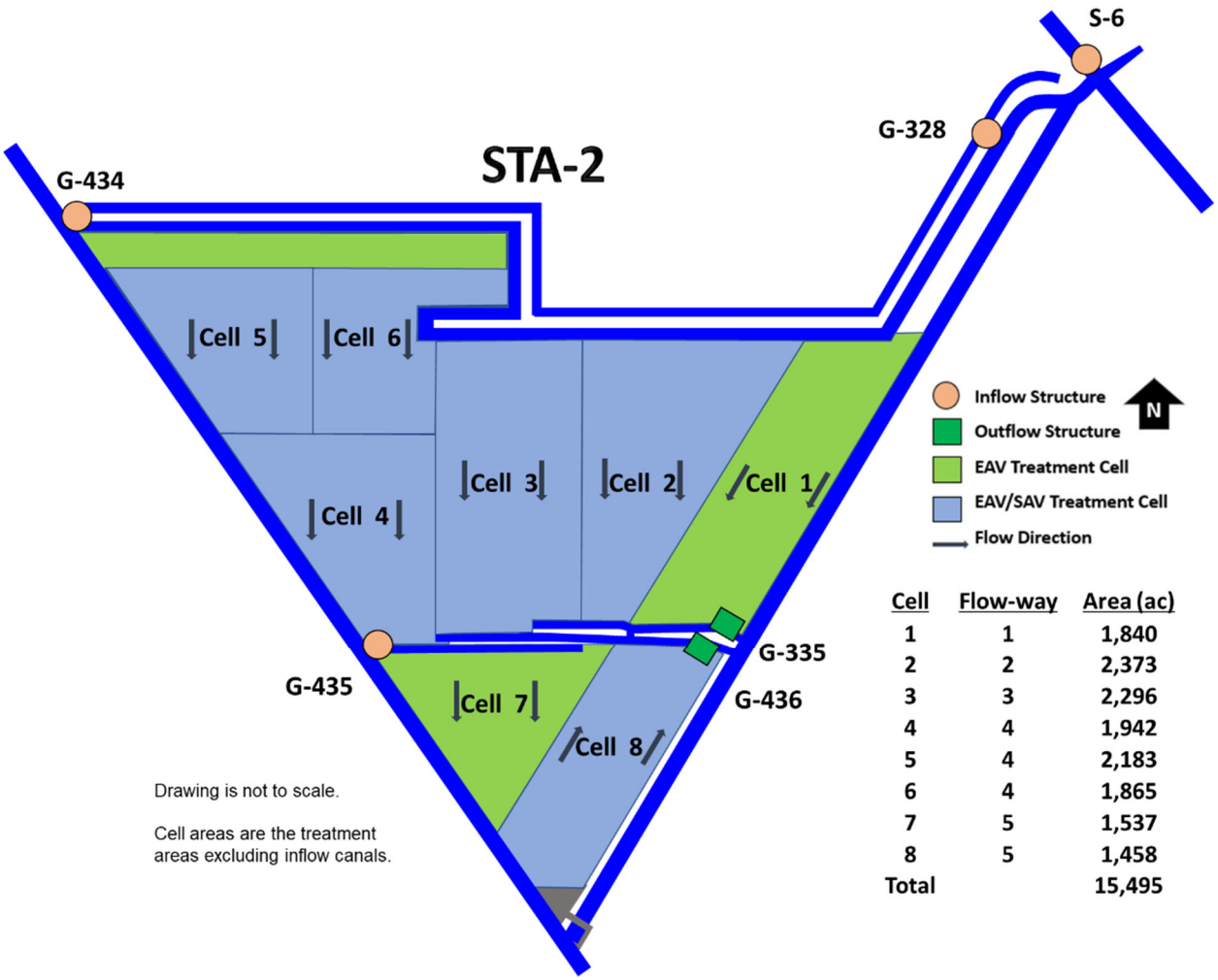
STA-2 is located in Palm Beach County immediately west of WCA-2A (**Figure 5B-1** and Figure 1 in Appendix 5B-2 of this volume). STA-2 originally consisted of three treatment cells (Cells 1, 2, and 3) that began operation in 2000. This facility was expanded with the construction of Cell 4, which was flow capable in December 2006. Cell 4 then went OFF in WY2010 during the construction of Cells 5, 6, 7, and 8, which were completed by WY2013. STA-2 now has five flow-ways with eight cells that have a total treatment area of 15,495 ac (Piccone et al. 2019; **Figure 5B-8**). STA-2 receives agricultural runoff from three Everglades Agricultural Area (EAA) basins; runoff primarily comes from the S-6 and a portion of the S-2 basins but also can come from the S-7 basin and the remaining portion of the S-2 basin. STA-2 also receives runoff from the East Shore Water Control District, the Closter Farms Drainage System, and a portion of the S-5A basin (see Figure 1 in Appendix 5B-2). During the dry season, supplemental water is delivered from Lake Okeechobee, when available, to maintain hydration in cells containing SAV.

The flow-way nomenclature for STA-2 is as follows:

- Flow-way 1 = Cell 1
- Flow-way 2 = Cell 2
- Flow-way 3 = Cell 3
- Flow-way 4 = Cells 4, 5, and 6
- Flow-way 5 = Cells 7 and 8

The A-1 FEB (Figure 5B-1), a 15,000-ac aboveground storage reservoir and a critical component of the Restoration Strategies Regional Water Quality Plan (SFWMD 2012), was completed and started operation in WY2016. STA-2 began receiving outflows from this facility in November 2015. The primary purpose of the A-1 FEB is to temporarily store stormwater runoff and thereby attenuate peak inflows to STA-2 to help improve its treatment performance. Secondarily, the A-1 FEB may provide a source of water during the dry season and reduce the frequency of dryout conditions in STA-2. For additional information on the A-1 FEB, see the following section on STA-3/4 and Volume III, Appendix 3-3.

Like the other STAs, STA-2 has been affected by regional droughts and large storm events over its POR. For example, Cells 1 and 2 have dried out, either partially or entirely, during past droughts when the supply of supplemental water was limited.



Cell	Flow-way	Area (ac)
1	1	1,840
2	2	2,373
3	3	2,296
4	4	1,942
5	4	2,183
6	4	1,865
7	5	1,537
8	5	1,458
Total		15,495

Figure 5B-8. Simplified schematic of STA-2 showing major inflow and outflow water control structures, the treatment area of each cell, flow direction, and dominant/target vegetation types. Treatment areas do not include pump stations, levees, roads, or other upland areas. A detailed structure map of STA-2 is provided in Appendix 5B-1 of this volume.

STA TREATMENT PERFORMANCE

Over its 20-year POR, STA-2 has treated approximately 6.2 million ac-ft of water and retained 600 t of TP or 77% of the inflow TP load (778 t) that entered this facility (**Table 5B-1**). The POR inflow FWM TP concentration to this facility is 101 µg/L, while the POR outflow FWM TP concentration is 22 µg/L.

STA-2 treated approximately 441,000 ac-ft of runoff in WY2021 (**Figure 5B-9**). Of the inflow water volume this water year, approximately 72,000 ac-ft were Lake Okeechobee releases directed to STA-2 via S-6, G-434, and G-435, virtually all of which were regulatory releases, while only 314 ac-ft were delivered as supplemental water to maintain the vegetation communities in STA-2. Lake Okeechobee water was received in all months this water year except July and August 2020.

STA-2 had inflow and outflow FWM TP concentrations of 100 and 21 µg/L, respectively, this water year (**Table 5B-1**). The facility retained 42 t of TP, or 76% of the inflow TP load (55 t), and had an HLR and a PLR of 2.5 cm/d and 0.9 g/m^2/yr, respectively. The treatment performance of STA-2, as measured by the percent TP load retained, has been fairly consistent over its POR (~ 75 to 84%; **Figure 5B-9**).

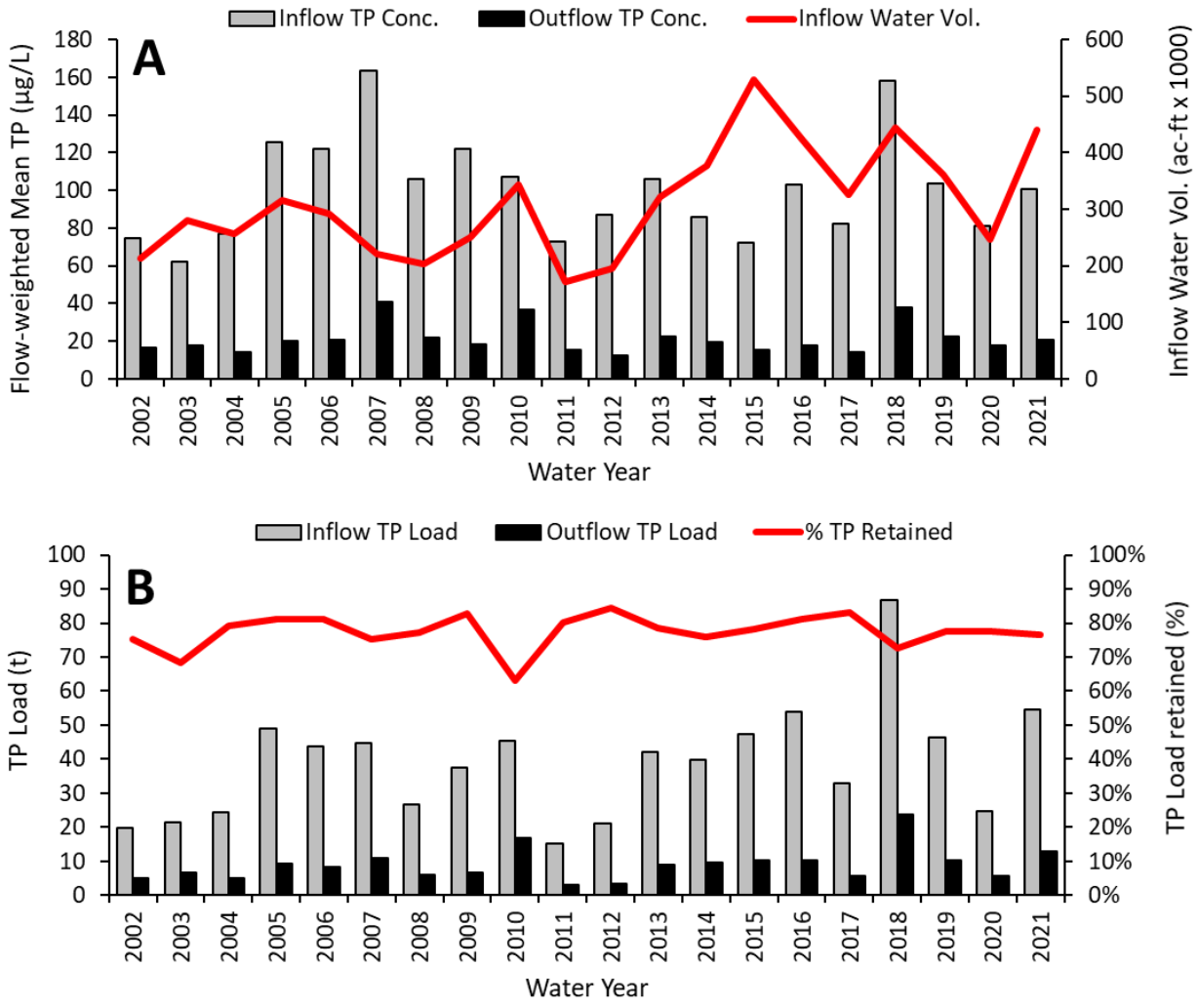


Figure 5B-9. POR time series for STA-2 for (A) annual inflow and outflow FWM TP concentrations (Conc.) with corresponding inflow water volumes (Vol.) and (B) annual inflow and outflow TP loads with the percent TP load retained.

FACILITY STATUS AND OPERATIONAL ISSUES

Flow-ways 1, 3, 4, and 5 of STA-2 were operational throughout WY2021, while Flow-way 2 was OFF from November 2020 through February 2021 for STA refurbishments construction (**Table 5B-2**). All flow-ways were ONR during portions of the year for vegetation management/rehabilitation activities. Flow-ways 2 and 3 were also ONR for a portion of the water year for STA refurbishment projects.

Refurbishment Projects

STA-2 refurbishment projects consist of earthwork in Flow-ways 2 and 3 (Cells 2 and 3) to address poor vegetation recruitment and reduced treatment performance caused by hydraulic short-circuits and uneven topography. All refurbishment work is scheduled to be completed by the middle of WY2023.

The northwest 500-ac corner of STA-2 Cell 2 has a lower ground elevation than the rest of the cell and has remained largely unvegetated since operation of this STA began due to deep water conditions. This area will be filled to raise its ground elevation to more closely align it with the surrounding cell ground

elevation and enable EAV to become established. The northeast portion of Cell 2 contains a ridge of high ground immediately south of the inflow culverts that blocks flow producing an uneven flow distribution in the cell. This area is being graded to match the final elevation of the filled northwest area, which will create conditions favorable for EAV growth and more uniform hydraulics as flow is conveyed from north to south in the cell. The Cell 2 refurbishment work also includes reinforcing deteriorated earthen plugs in the east borrow canal which will help reduce short-circuiting along the east side of the cell.

The refurbishment work in Cell 3 consists of placing cuts in the remnant elevated farm roads that were left in place during the construction of STA-2. These roads obstruct flow and create hydraulic short-circuits. Numerous cuts were made through the five east-west oriented roads and the two north-south oriented roads to promote better flow distribution across the cell and improve treatment performance. An approximate 0.5-mile portion of one remnant road was completely degraded to promote better flow through the northern portion of the EAV area along the east side of Cell 3. The Cell 3 refurbishment work also includes reinforcing the deteriorated earthen plugs in the borrow canal that runs along the east side of the cell.

Dryout

All cells in STA-2 were hydrated during WY2021.

Migratory Bird and Snail Kite Nesting

No black-necked stilt nests, snail kite nests, nor Florida burrowing owls were found in STA-2 this water year. Additional information on nesting survey results and STA-2 operational and maintenance adjustments made to protect bird nests during WY2021 is presented in Appendix 5B-3 of this volume.

VEGETATION MANAGEMENT

Vegetation management in STA-2 during WY2021 was primarily focused on rehabilitating Flow-ways 3 and 4 through planting EAV to supplement or replace damaged cattail stands, repairing open-water trails in Cell 3 created by boat traffic that promoted hydraulic short circuits, controlling woody vegetation on and adjacent to canal banks, and treating FAV in the STA-2 inflow canals and within the STA. Nine ac of FAV were treated in Cell 1, 43 ac in Cell 2, 147 ac in Cell 3, and 170 ac in Cell 5; 125 ac of floating tussocks were treated in Cell 6. We planted 13 ac of bulrush and 33 ac of alligator flag upstream and downstream of the cuts made in the remnant elevated farm roads in Cell 3 and inoculated the cell with Illinois pondweed. SAV and EAV were harvested from Cell 4 and distributed to other cells. A small population of Indian swampweed in the STA-2 inflow canal was treated to prevent it from invading the STA.

VEGETATION SURVEYS

Ground surveys were conducted during the following months in WY2021 to map SAV areal coverage in STA-2: August 2020 and April 2021 in Cell 3, September 2020 and April 2021 in Cells 4 and 5, October 2020 and April 2021 in Cell 6, and September 2020 and March 2021 in Cell 8 (Appendix 5B-4, Figures 9 through 13). Note that approximately one-third of sites in Cell 6 were not surveyed this water year to avoid disturbing ongoing vegetation management activities. No SAV was found at 52% of survey sites, low SAV coverage at 13% of survey sites, medium SAV coverage at 14% of survey sites, and high SAV coverage at 21% of sites. The following SAV taxa were identified in STA-2 this water year: muskgrass, spiny naiad, southern naiad, Illinois pondweed, bladderwort, and coontail. Spiny naiad and muskgrass were the co-dominant SAV taxa observed in Cell 3, while muskgrass was dominant in Cells 4, 5, and 6. Cell 8 contained a diverse community where southern naiad, muskgrass, and bladderwort were the most prevalent taxa. Illinois pondweed and coontail were found in lesser quantities relative to the dominant taxa. Overall, SAV occurrence increased to varying degrees in STA-2 compared to WY2020 with the changes most pronounced in Cell 3, which is recovering from the adverse impacts of Hurricane Irma in

2017, and in muskgrass beds throughout the STA. There has been a progressive decline in SAV occurrence in Cells 4 and 5 over their PORs.

STA-3/4

STA-3/4 is located in Palm Beach County northeast of the Holey Land Wildlife Management Area and north of WCA-3A (**Figure 5B-1** and Figure 1 in Appendix 5B-2 of this volume). This STA became operational in WY2004 and a new interior levee was constructed in WY2006 to subdivide Cell 3 into Cells 3A and 3B. STA-3/4 is comprised of six treatment cells arranged into three flow-ways with a total treatment area of 16,327 ac (Piccone et al. 2019; **Figure 5B-10**). A 445-ac section of Cell 2B is the site of the District's STA-3/4 Periphyton-based Stormwater Treatment Area (PSTA) Project. The STA-3/4 PSTA Project has been described in past SFERs (see Zamorano et al. 2018). STA-3/4 treats stormwater runoff from the S-2/S-7, S-3/S-8, S-236, and C-139 basins, South Shore Drainage District, and South Florida Conservancy District, and releases from Lake Okeechobee (see Figure 1 in Appendix 5B-2). During the dry season, A-1 FEB releases and/or supplemental water can be delivered from Lake Okeechobee, when available, to maintain hydration in cells containing SAV. The flow-way nomenclature for STA-3/4 is as follows:

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

The A-1 FEB (Figure 5B-10) is a 15,000-ac aboveground storage reservoir located immediately north of STA-3/4, and a critical component of the Restoration Strategies Regional Water Quality Plan (SFWMD 2012). This facility was completed and started operation in WY2016. STA-3/4 began receiving outflows from the reservoir in November 2015. The primary purpose of the A-1 FEB is to temporarily store stormwater runoff and thereby attenuate peak inflows to STA-3/4 to help improve its treatment performance. Secondarily, the A-1 FEB may provide a source of water during the dry season and reduce the frequency of dryout conditions in STA-3/4. See Volume III, Appendix 3-3 for additional information on the A-1 FEB.

Similar to the other Everglades STAs, STA-3/4 has been affected by extreme weather events such as regional droughts and large storms. High hydraulic loads during and following storms have resulted in excessively deep water for extended periods in cells at the top of the flow-ways. Chronic deep-water conditions have stressed the cattail populations in Cells 1A and 2A causing widespread mortality, especially at the inflow regions of these cells, and subsequent invasion of less desired species, such as non-rooted FAV. In WY2021, a water-level drawdown of Cell 1A was initiated to address the poor EAV condition due to chronically high water levels.

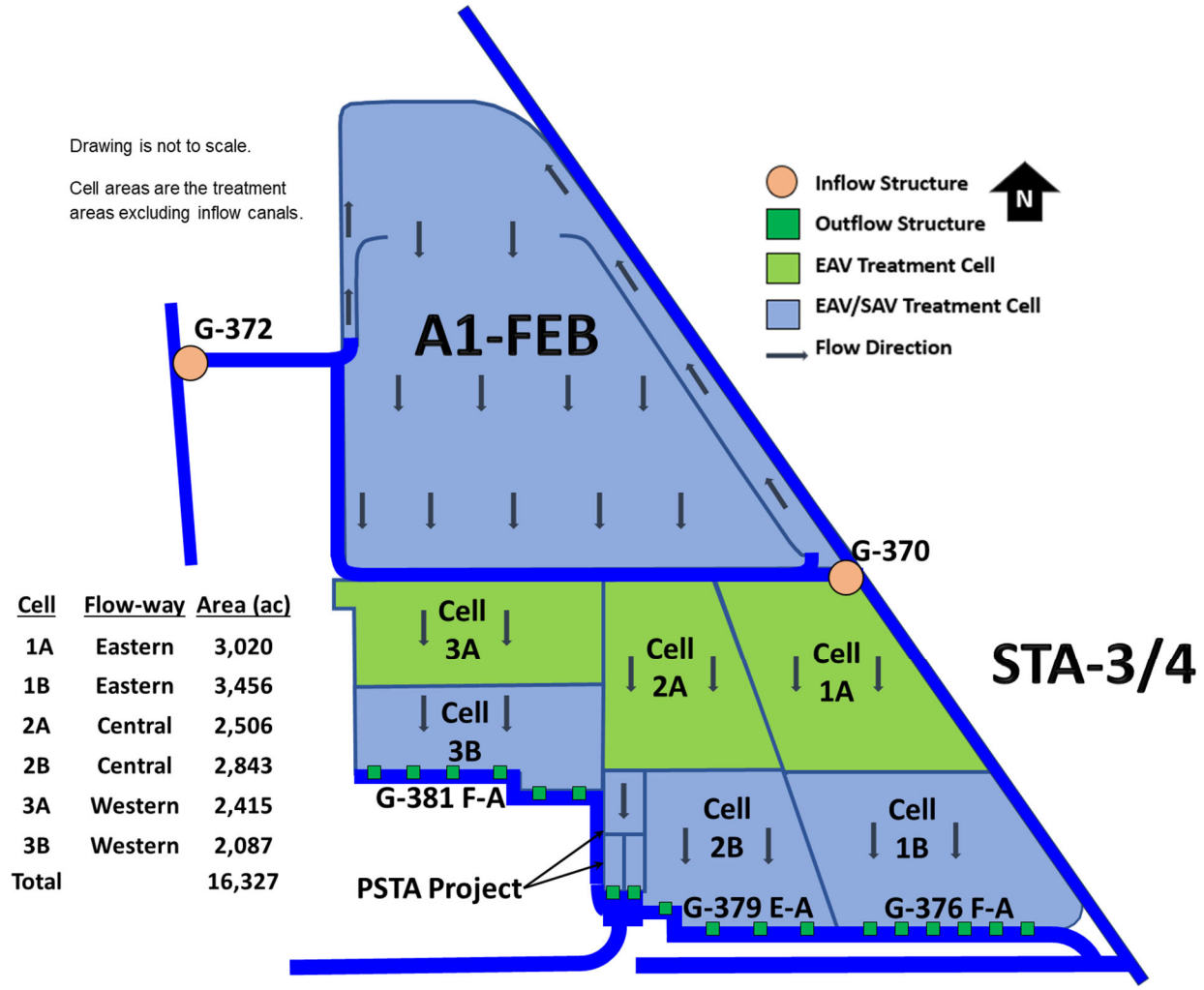


Figure 5B-10. Simplified schematic of STA-3/4 and the A-1 FEB showing major inflow and outflow water control structures, treatment area of each cell, flow direction, and dominant/target vegetation types. Treatment areas do not include pump stations, levees, roads, or other upland areas. Detailed structure maps of STA-3/4 and the A-1 FEB are provided in Appendix 5B-1 of this volume.

STA TREATMENT PERFORMANCE

STA-3/4, over its 18-year POR, has treated the largest volume of water (7.9 million ac-ft) and retained the most TP mass (844 out of 994 t) with the greatest treatment efficiency, based on its percent inflow TP load retained (85%), of all the Everglades STAs (**Table 5B-1**). The POR inflow FWM TP concentration for STA-3/4 is 101 µg/L, while the POR outflow FWM TP concentration is 15 µg/L, which is the lowest POR outflow TP concentration among all the Everglades STAs. Based on these metrics, STA-3/4 has been the best performing Everglades STA. The good POR treatment performance of STA-3/4 is attributed, in part, to its relatively low POR inflow TP concentration compared to the other Everglades STAs (see **Table 5B-1**). Past SFER reports have documented moderate regression relationships between annual or POR outflow TP concentration with inflow TP concentration. Depending on the averaging period, inflow TP concentration generally accounted for 50 to 60% of the variability in outflow TP concentration in these analyses. The remaining variability in outflow TP concentration is attributed to other biogeochemical or operational differences among the Everglades STAs (e.g., Zhao and Piccone 2020). A fuller understanding of why treatment performance varies among the Everglades STAs is one of the objectives of the ongoing Science Plan's Evaluation of Phosphorus Sources, Forms, Flux, and Transformation Processes in the

Stormwater Treatment Areas, referred to as the P Flux Study (see James et al. 2020 for more information on this study).

STA-3/4 treated approximately 521,000 ac-ft of runoff in WY2021 (**Table 5B-1**). Of this inflow water volume, approximately 47,000 ac-ft were Lake Okeechobee releases sent to the STA-3/4 – A-1 FEB complex prior to delivery south to WCA-2A and WCA-3A, 38,000 ac-ft were regulatory releases, and 9,600 ac-ft were delivered as supplemental water to maintain the vegetation communities in the STA. Lake Okeechobee water was received in all months this water year except July 2020.

STA-3/4 had an inflow FWM TP concentration of 80 µg/L and produced an outflow FWM TP concentration of 12 µg/L this water year, which is among the lowest annual outflow TP concentrations recorded in any Everglades STA to date (**Table 5B-1**). This facility retained 43 t of TP, or 84% of the inflow TP load (51 t) and had an HLR and PLR of 2.9 cm/d and 0.8 g/m^2/yr, respectively. The annual percent TP load retained in STA-3/4 has been relatively constant throughout much of its POR (~ 80 to 90%; **Figure 5B-11**).

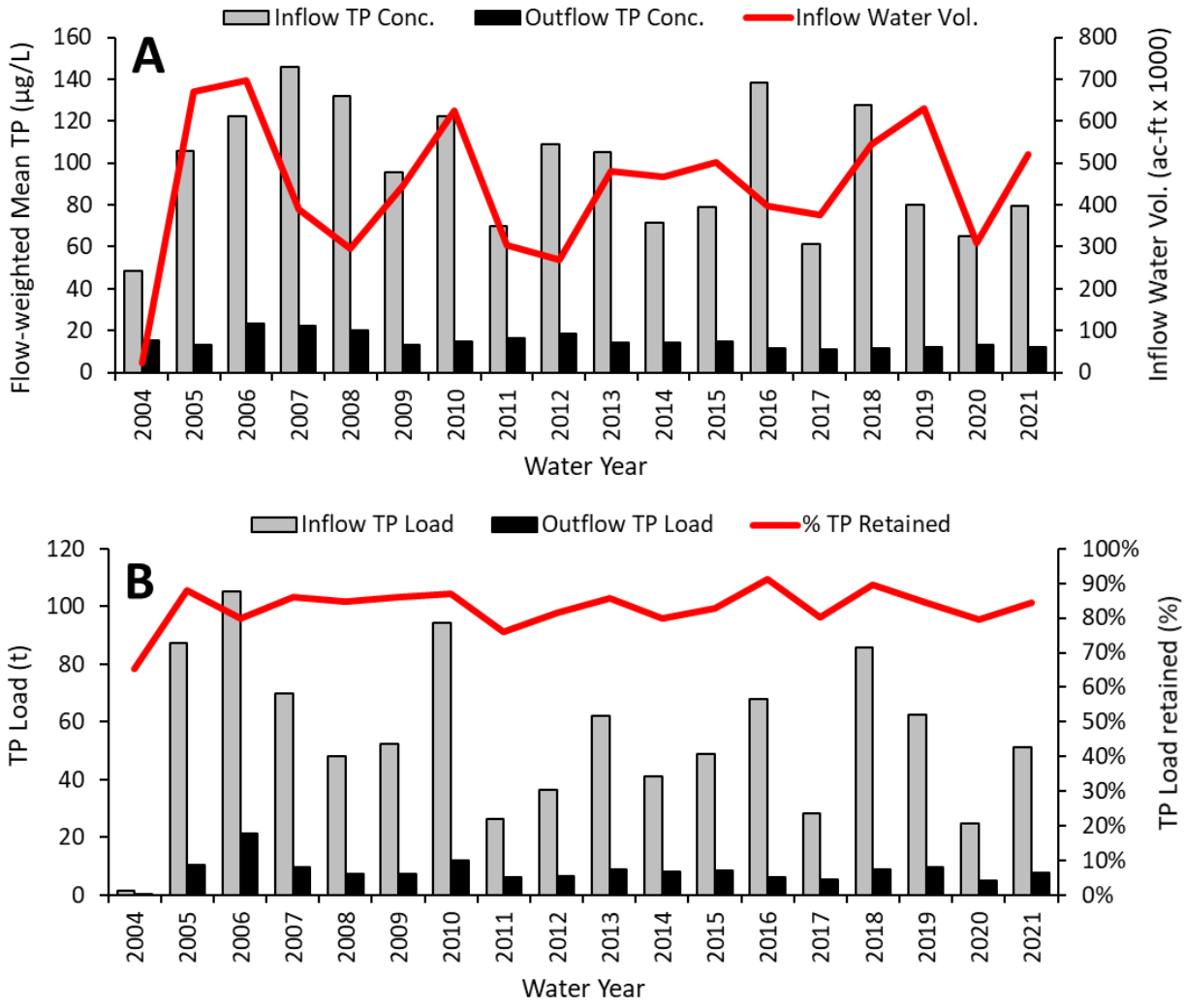


Figure 5B-11. POR time series in STA-3/4 for (A) annual inflow and outflow FWM TP concentrations (Conc.) with corresponding inflow water volumes (Vol.) and (B) annual inflow and outflow TP loads with the percent TP load retained.

FACILITY STATUS AND OPERATIONAL ISSUES

The Central and Western flow-ways of STA-3/4 were online throughout WY2021, while the Eastern Flow-way was OFF from March to April 2021 for vegetation rehabilitation (**Table 5B-2**). In addition, all flow-ways were ONR for portions of the water year for vegetation management and/or rehabilitation activities.

Refurbishment Project

An STA-3/4 refurbishment project was completed in WY2021 and consisted of installing riprap to serve as energy dissipators (i.e., flow deflectors) downstream of all 17 gated box culverts that control inflow to Cells 1A, 2A, and 3A. The culverts discharge into a spreader canal designed to distribute flow evenly across the northern end of each cell. However, after many years of high flow events, much of the EAV along the southern side of the spreader canal opposite the culverts has been displaced resulting in significant short-circuits through the vegetation. The energy dissipators are intended to reduce water velocities immediately downstream of the culverts, to promote more even flow distribution across the cells, and to allow vegetation to be restored in the short-circuits through planting efforts as well as natural recruitment. Initial vegetation plantings around the energy dissipators were completed this water year but many of the plantings did not survive due to the onset of the wet season and the need to increase flow into STA-3/4. New plantings are planned in WY2022 and beyond as needed to reinforce vegetation coverage in the inflow portion of these cells.

Dryout

Cell 1A of the Eastern Flow-way in STA-3/4 was dried out using temporary pumps during this water year for vegetation rehabilitation activities. All other cells in STA-3/4 were hydrated during WY2021.

Migratory Bird and Snail Kite Nesting

Black-necked stilt nests were observed in STA-3/4 Cell 1A in April 2021. No snail kite nests, nor Florida burrowing owls, were found in STA-3/4 this water year. Additional information on nesting survey results and STA-3/4 operational and maintenance adjustments made to protect bird nests during WY2021 is presented in Appendix 5B-3 of this volume.

VEGETATION MANAGEMENT

Vegetation management in STA-3/4 during WY2021 focused on treating FAV in the inflow canals before it could move into the STA, treating FAV and other invasive/undesirable species within EAV cells, and planting EAV to ameliorate hydraulic short circuits. A small population of Indian swampweed population was detected in the STA-3/4 inflow canal and was treated prevent its spread into the STA. The restoration of Cell 1A in the Western Flow-way was initiated with a water level drawdown using temporary pumps to help stabilize 850 ac of delaminated soil and floating cattail and treating 801 ac of FAV. This was followed by planting 17 ac of bulrush and alligator flag in this area. An additional 255 ac of FAV was treated in Cell 1B. In the Central Flow-way, 521 ac of FAV were treated in Cell 2A and approximately 1 ac of bulrush was planted at the upstream end of hydraulic short circuits. The Western Flow-way had 985 and 76 ac of FAV treated in Cells 3A and 3B, respectively.

VEGETATION SURVEYS

Ground surveys were conducted during the following months in WY2021 to map SAV areal coverage in STA-3/4: October 2020 and March 2021 in Cells 1B and 2B, and September 2020 and March 2021 in Cell 3B (Appendix 5B-4, Figures 14 through 16). Most of Cell 3B was not accessible during the dry season due to low water levels, which biased our survey results. No SAV was found at 19% of survey sites, low SAV coverage at 20% of survey sites, medium SAV coverage at 20% of survey sites, and high SAV

coverage at 41% of survey sites. The following SAV taxa were identified in STA-3/4 this water year: muskgrass, southern naiad, spiny naiad, bladderwort, coontail, and Illinois pondweed. Muskgrass was the dominant taxon in all cells, while all other taxa were observed in lesser quantities. SAV occurrence in Cells 1B and 2B this water year was similar to that observed in WY2020. There has been a progressive decline in SAV occurrence in Cell 3B during the latter part of its POR.

STA-5/6

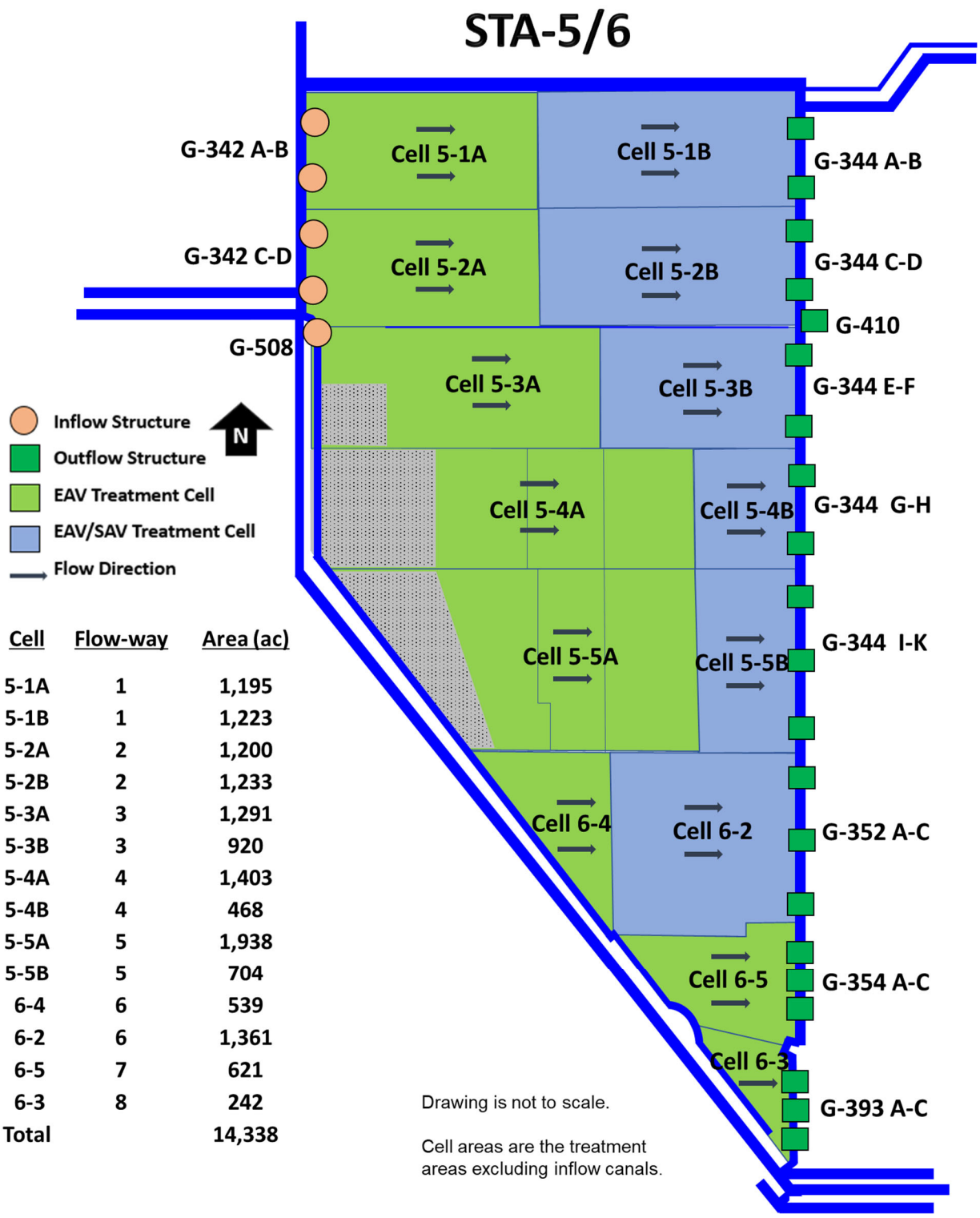
STA-5/6 is located in Hendry County and is bordered by the C-139 and C-139 Annex basins on the west and the Rotenberger Wildlife Management Area on the east (**Figure 5B-1**). This STA was created by merging what had been two separate Everglades STAs: STA-5 and STA-6. The original STA-5 (Cells 5-1A, 5-1B, 5-2A, and 5-2B) and STA-6 (Cells 6-3 and 6-5) (**Figure 5B-12**) began operation in WY2000 and WY1998, respectively. STA-5 received inflow primarily from the C-139 Basin and STA-6 treated agricultural runoff from the former United States Sugar Corporation's Southern Division Ranch, Unit 2 (see Figure 1 in Appendix 5B-2)[16]. In 2006, Cells 5-3A and 5-3B were added to STA-5 and Cell 6-2 (formerly known as Section 2) was added to STA-6. Construction of additional treatment cells was completed by 2012 on the remaining portion of the STA-5/6 complex, which has 14 cells arranged into eight flow-ways with a total treatment area of 14,338 ac (Piccone et al. 2019; **Figure 5B-12**). STA-5/6 is operated as an integrated facility to treat runoff from the C-139 Basin. Performance measures that were reported individually for STA-5 and STA-6 in past annual reports have been recalculated for the integrated STA-5/6 complex over its entire POR.

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
- Flow-way 5 = Cells 5-5A and 5-5B
- Flow-way 6 = Cells 6-4 and 6-2
- Flow-way 7 = Cell 6-5
- Flow-way 8 = Cell 6-3

As with the other Everglades STAs, STA-5/6, over its POR, has been adversely affected by high inflow TP concentrations and extreme weather events, such as regional droughts and large storms. Some of the EAV cells in this STA have dried out almost every dry season, and WY2021 was no exception. High soil P flux has followed rehydration of these cells, usually resulting in temporary spikes in outflow TP concentration.

[16] The Southern Division Ranch, Unit 2 was incorporated into STA-5/6 when the treatment area of this STA was expanded.



Cell	Flow-way	Area (ac)
5-1A	1	1,195
5-1B	1	1,223
5-2A	2	1,200
5-2B	2	1,233
5-3A	3	1,291
5-3B	3	920
5-4A	4	1,403
5-4B	4	468
5-5A	5	1,938
5-5B	5	704
6-4	6	539
6-2	6	1,361
6-5	7	621
6-3	8	242
Total		14,338

Figure 5B-12. Simplified schematic of STA-5/6 showing major inflow and outflow water control structures, treatment area of each cell, flow direction, and dominant/target vegetation types. Treatment areas do not include pump stations, levees, roads, or other upland areas. A detailed structure map of STA-5/6 is provided in Appendix 5B-1 of this volume.

STA TREATMENT PERFORMANCE

STA-5/6 over its combined 24-year POR has treated approximately 3.1 million ac-ft of water and retained 507 t of TP or 69% of the inflow TP load (735 t) (**Table 5B-1**). The POR inflow FWM TP concentration is 193 µg/L, while the POR outflow FWM TP concentration is 64 µg/L; these are the highest POR inflow and outflow concentrations of any Everglades STA. Based on these metrics, STA-5/6 has been the poorest performing STA. However, treatment performance, as measured by outflow FWM TP concentration, improved after WY2013 when this STA began operation as an integrated facility (**Figure 5B-13**).

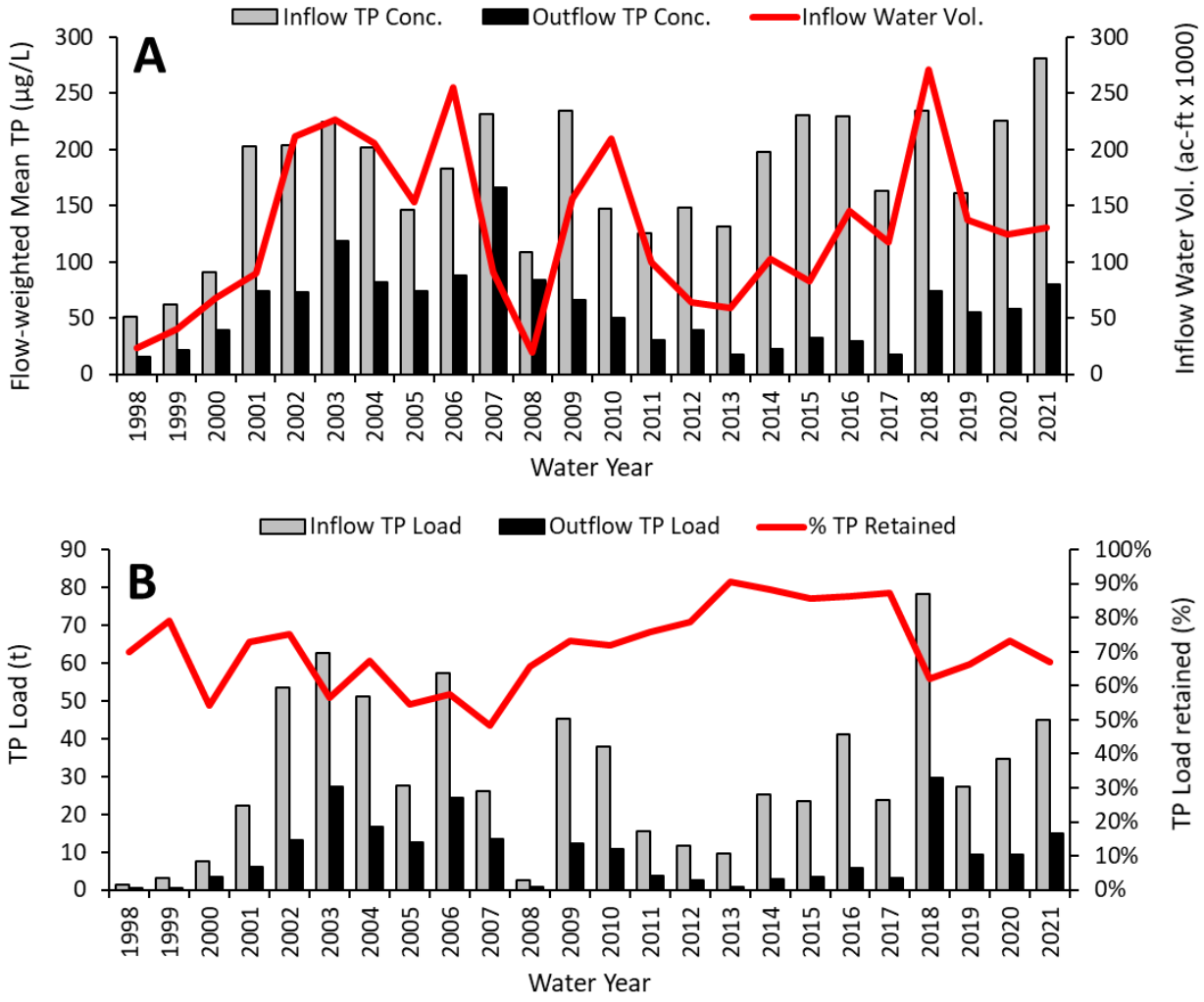


Figure 5B-13. POR time series in STA-5/6 for (A) annual inflow and outflow FWM TP concentration (Conc.) with corresponding inflow water volumes (Vol.) and (B) annual inflow and outflow TP loads with the percent -TP load retained.

STA-5/6 treated approximately 130,000 ac-ft of runoff in WY2021 (**Table 5B-1**); 2,500 ac-ft of this inflow water volume were Lake Okeechobee releases delivered as supplemental water to maintain the vegetation communities in the STA. Lake Okeechobee water was received in April 2021. Note that the STA-5/6 inflow structures cannot receive water deliveries directly from Lake Okeechobee due to the lack

of the necessary infrastructure, so supplemental water usually comes from other sources[17]. However, this year temporary pumps located at the Manley Ditch north of G-373 and just east of PC-15, were used to transfer Lake Okeechobee water from the Miami Canal into STA-5/6 via the G-349B, G-350B, and G-507 pump stations to help maintain cell hydration.

The inflow FWM TP concentration this water year was 281 µg/L while the outflow FWM TP concentration was 80 µg/L (**Table 5B-1**). STA-5/6 retained 30 t of TP, which corresponded to 67 % of the inflow TP load (45 t) and had the lowest HLR (0.8 cm/d) and PLR (0.8 $g/m^2/yr$) this water year compared to the other Everglades STAs (**Figure 5B-3**). Beginning in WY2013, STA-5/6 consistently has had some of the lowest HLRs and PLRs of all the Everglades STAs, which is attributed, in large measure, to the substantial increase in STA-5/6 treatment area once Flow-ways 3, 4, and 5 came online. The percent TP load retained in STA-5/6 from WY2013 to WY2017 (86 to 91%), was comparable with the best treatment performance observed in the other Everglades STAs during this period (**Figure 5B-13**).

FACILITY STATUS AND OPERATIONAL ISSUES

All flow-ways in STA-5/6 were online throughout WY2021 (**Table 5B-2**). Flow-ways 2 and 3 were ONR throughout WY2021 following the Restoration Strategies project to grade and lower the ground elevation of a portion of Cells 5-2A and 5-3A. Additionally, Flow-ways 1, 4, and 6 were ONR for a portion of the year due to black-necked stilt nesting.

Dryout

The District declared that dryout conditions existed in STA-5/6 Cells 6-3 and 6-5 (Flow-ways 7 and 8) from April through June 2021 and notified FDEP of these developments accordingly. Most of the other cells partially dried out this water year, but not to the extent that the District declared them to be in dryout condition.

Migratory Bird and Snail Kite Nesting

Black-necked stilt nests were observed in STA-5/6 Cells 5-1B, 5-4A, 5-4B, and 6-2 in May 2020. No snail kite nests, nor Florida burrowing owls, were found in STA-5/6 this water year. Additional information on nesting survey results and STA-5/6 operational and maintenance adjustments made to protect bird nests during WY2021 is presented in Appendix 5B-3 of this volume.

VEGETATION MANAGEMENT

Historically, STA-5/6 has had chronic problems with willow and primrose willow expansion in the EAV cells and heavy FAV influx and expansion in all cells. WY2021 was no different and the focus of vegetation management again was on reducing FAV coverage by treating the inflow canals when FAV loads were high and the following treatments within the STA: Cell 5-1A – 32 ac of FAV; Cell 5-1B – 144 ac of FAV; Cell 5-2A – 15 ac of FAV, Cell 5-2B – 6 ac of FAV and 3 ac of willow; Cell 5-3A – 31 ac of FAV; Cell 5-4A – 171 ac of FAV; Cell 5-4B – less than 1 ac of FAV; Cell 5-5A – 98 ac of FAV; Cell 5-5B – less than 1 ac of FAV; Cell 6-2 – 11 ac of FAV; Cell 6-3 – 2 ac of FAV; Cell 6-4 – 26 ac of FAV; and Cell 6 – 5 ac of FAV.

[17] When available, supplemental water, primarily from STA-3/4, can be pumped out of the STA-5/6 discharge canal and delivered via the G-350B, G-507, and G-509 pump stations into Cells 5-1B, 5-2B, 5-3B, and 5-4B to keep them flooded during dry conditions.

VEGETATION SURVEYS

Ground surveys were conducted during the following months in WY2021 to map SAV areal coverage in STA-5/6: October 2020 and April 2021 in Cell 5-1B; October 2020 in Cell 2B; and October 2020 and March 2021 in Cells 5-4B and 5-5B (Appendix 5B-4, Figures 17 through 21). Cells 5-2B and 5-3B remained ONR for Restoration Strategies projects the entire water year, which limited access to only Cell 5-2B during the wet season. No SAV was found at 60% of survey sites, low SAV coverage at 24% of sites, medium SAV coverage at 10% of survey sites, and high SAV coverage at 7% of survey sites. The following SAV taxa were identified in STA-5/6 this water year: coontail, muskgrass, hydrilla, southern naiad, bladderwort, and Illinois pondweed. Cell 5-1B contained a diverse SAV community where coontail, muskgrass, hydrilla, and southern naiad were the most prevalent taxa. Muskgrass was the dominant taxon in Cell 5-2B, while coontail was dominant in Cells 5-4B and 5-5B. The other SAV taxa were observed in lesser coverages. SAV occurrence this water year was similar in most cells compared to WY2020, except in Cell 5-5B where SAV occurrence declined. There has been a progressive decline in SAV occurrence in Cells 5-1B, 5-2B, 5-4B, and 5-5B during the latter portions of their PORs.

LITERATURE CITED

Bostic, E.M., and J.R. White. 2007. Soil phosphorus and vegetation influence on wetland phosphorus release after simulated drought. *Soil Science Society of America Journal* 71(1):238-244.

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

DeBusk, W.F., and K.R. Reddy. 2003. Nutrient and hydrology effects on soil respiration in a northern Everglades marsh. *Journal or Environmental Quality* 32:702-710.

James, R.T., C. Armstrong, J. King, K. O'Dell, T. Piccone, and O. Villapando. 2020. Chapter 5C: Restoration Strategies Science Plan. In: *2020 South Florida Environmental Report – Volume I*, South Florida Water Management District, West Palm Beach, Florida.

Kadlec, R.H. 2011. *Harvest to Remove Phosphorus*. Wetland Management Services, Chelsea, MI. April 2011.

Kadlec, R.H., and S. Wallace. 2009. *Treatment Wetlands.* CRC Press, Boca Raton, FL.

Martin, H.W., D.B. Ivanoff, D.A. Graetz, and K.R. Reddy. 1996. Water table effects on histosol drainage water carbon, nitrogen, and phosphorus. *Journal of Environmental Quality* 6:1062-1071.

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

Piccone, T., J. McBryan, H. Zhao, and Y. Yan. 2019. *2012 Updated Everglades Stormwater Treatment Area Ground Elevations, Stage-Area/Stage-Volume Relationships and Effective Treatment Areas*. Technical Publication ASB-WQTT-12-02, South Florida Water Management District, West Palm Beach, FL. Revised November 2019.

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

SFWMD. 2012. *Restoration Strategies Regional Water Quality Plan*. South Florida Water Management District, West Palm Beach, FL. April 27, 2012.

SFWMD. 2013. *Science Plan for the Everglades Stormwater Treatment Areas*. South Florida Water Management District, West Palm Beach, FL. June 2013.

SFWMD. 2015. *South Florida Water Management District Everglades Stormwater Treatment Areas (STAs) Drought Contingency Plan*. South Florida Water Management District, West Palm Beach, FL.

SFWMD. 2016. *2016 Voluntary Guidelines to Minimize Impacts to Everglade Snail Kites within Everglades Stormwater Treatment Areas*. South Florida Water Management District, West Palm Beach, FL. January 2016.

SFWMD. 2020. *Water Shortage Suggested Operating Procedures - Stormwater Treatment Areas*. South Florida Water Management District, West Palm Beach, FL.

State of Florida. 2017. *Industrial Wastewater Facility Permit # FL0778451-003-GL7A/NR for STA-1E, STA-1W, STA-2, STA-3/4 and STA-5/6*. Issuance date: September 06, 2017. Permittee: South Florida Water Management District, West Palm Beach, FL.

Zamorano, M.F., K. Grace, T. DeBusk, T. Piccone, M. Chimney, R.T. James, H. Zhao, and C. Polatel. 2018. Appendix 5C-2: Investigation of Stormwater Treatment Area 3/4 Periphyton-based Stormwater Treatment Area Performance, Design, and Operational Factors. In: *2018 South Florida Environemental Report – Volume I,* South Florida Water Management District, West Palm Beach, FL.

Zhao, H. and T. Piccone. 2020. Large-scale constructed wetlands for phosphorus removal, an effective nonpoint source pollution treatment technology. *Ecological Engineering* 145:105711.