Chapter 4B: STA Optimization

The Everglades Forever Act (EFA) requires the South Florida Water Management District (District) to optimize the performance of the Stormwater Treatment Areas (STAs). The STA Optimization Research and Monitoring Program (hereafter referred to as the STA Optimization Program) consists of a number of individual efforts designed to assist the District in meeting this mandate. A description of the STA Optimization Program, its goals, its objectives, and a presentation of results from earlier STA optimization monitoring and research efforts can be found the in the *Everglades Interim Report* (Chimney and Moustafa, 1999) and in previous years' Everglades Consolidated Reports (ECRs) (Chimney et al., 2000; Nungesser et al., 2001; Jorge et al., 2002). The objective of Chapter 4B in the *2003 Everglades Consolidated Report* is to summarize new findings and analyses completed since the 2002 ECR was written, and to update ongoing studies, including STA optimization experiments conducted in the STA-1W test cells. The reader is directed to the aforementioned reports and the references within them for background information on the history and past treatment performance of the STAs. Evaluations of overall STA performance, including calculation of total phosphorus (TP) load and concentration reductions, are presented in Chapter 4A of the 2003 ECR. Chapter 4B contains evaluations of STA-1W, STA-5 and STA-6 and results from the final STA optimization experiments conducted in the STA-1 west (STA-1W) test cells.

The District has initiated a program to monitor sediment and vegetation within all the STAs that are currently in operation. In addition, installation of equipment to monitor flow and water quality conditions within the interior of the operational STAs is ongoing. The objective is to correlate differences in STA treatment performance with changes in vegetation and sediments. However, only limited data are available, to date, from these sampling efforts. A detailed analysis of STA performance has been deferred until there is sufficient information for a thorough comparison across all STAs. The following data presentations for each STA are descriptive in nature and should be regarded as preliminary.

PERFORMANCE EVALUATION OF STA-1W

DESCRIPTION OF STA-1W

STA-1W has five treatment cells organized into three separate flow-ways: east, west and north (**Figure 4B-1**). STA-1W's total area is 2,699 ha (6,670 acres). The older portion of STA-1W, operational since 1994, consists of cells 1 and 3 (east flow-way) and cells 2 and 4 (west flow-way). Cells 5A and 5B (north flow-way), which began operation in late 1999, complete STA-1W. Surface inflow to the wetlands originates at the S-5A pump station and enters STA-1W through the G-302 lift gates. Part of this flow is directed westward through culverts in the G-304 levee, the primary inflow into the north flow-way. The remainder passes through the G-303 gates into the east and west flow-ways. Water exits the north flow-way through 10 culverts in the G-306 levee and moves out of STA-1W through the G-310 pump station. Water from the east and west flow-ways exits STA-1W through the G-251 pump station. All the discharge from STA-1W is sent into Water Conservation Area 1 (WCA-1), which is part of the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge).

Besides the engineered surface inflows to STA-1W, additional inflows include seepage from WCA-1 through the L-7 levee, groundwater upwelling, and rainfall. Additional water losses include evapotranspiration (ET), groundwater recharge, and seepage into a perimeter collection canal along the STA-1W boundary. Background information and details on the water budget and hydrology of STA-1W are provided in previous years' ECRs (Chimney and Moustafa, 1999; Chimney et al., 2000; Nungesser et al., 2001; and Jorge et al., 2002).

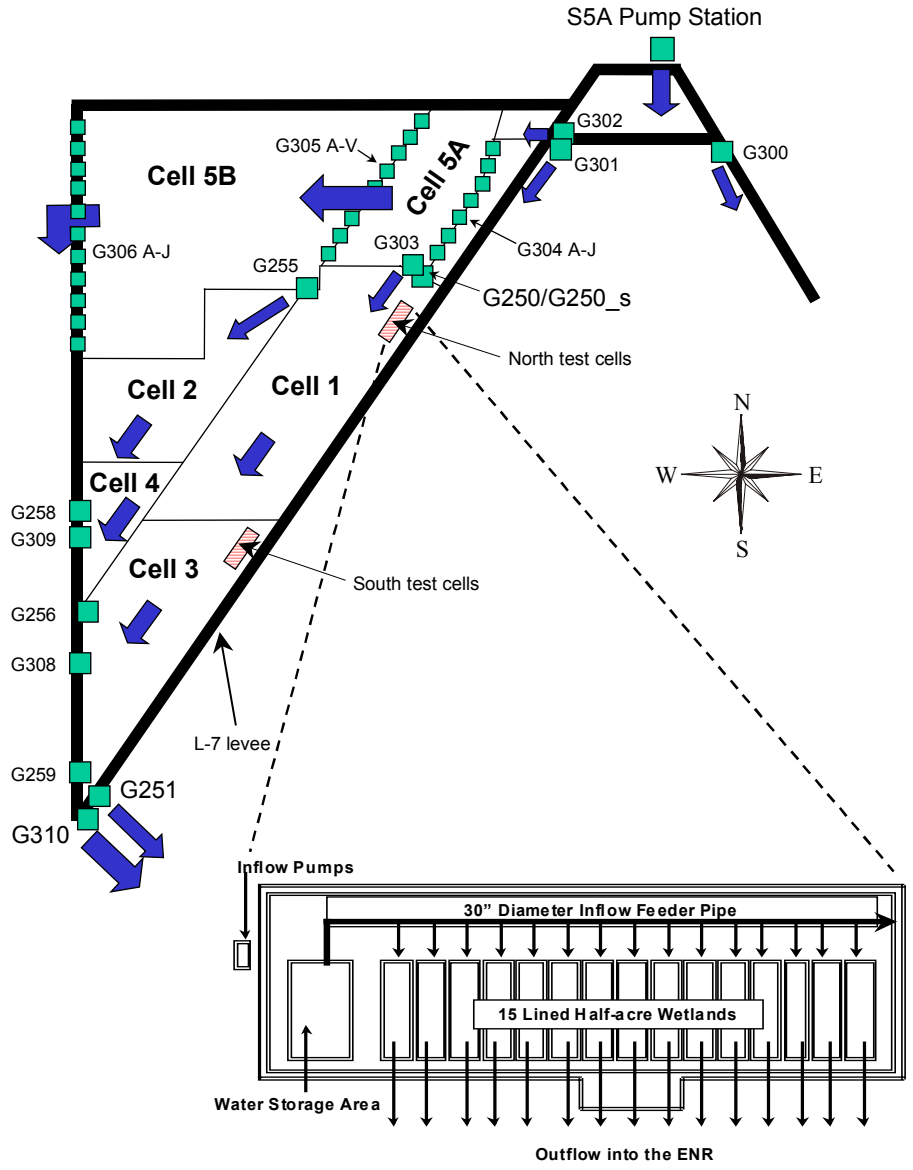

Figure 4B-1. Map of Stormwater Treatment Area 1 West showing location of test cells. Arrows indicate direction of flow through each treatment cell

DATA COLLECTION AND ANALYSIS

Previous ECRs have included separate water and TP budgets for the older portion of STA-1W (Chimney et al., 2000; Nungesser et al., 2001). The 2003 ECR presents updated budgets for these treatment cells. Though cell 5 began discharging water in the summer of 2000, delays in installing and calibrating instrumentation prevented the calculation of reliable budgets. This year's water and TP budgets, therefore, were computed for cells 1, 2, 3, and 4 only. Water and TP budgets for cell 5 will be provided in next year's ECR.

Water and TP budget calculations followed the methodology detailed in Chimney et al. (2000) and Nungesser et al. (2001). Because the hydrology of STA-1W is different from the hydrology of the Everglades Nutrient Removal Project (ENRP) (see description in Jorge et al., 2002 of infrastructure and operational changes made to the ENRP when it was incorporated into STA-1W), in this report, water and TP budgets are presented for STA-1W beginning after modifications were completed (**Appendix 4B-1**).

The addition of two water control structures (G-308 and G-309) affected the water and TP budgets for cells 3 and 4. These new gates serve as separate outflow points for these cells, complicating budget calculations. While flow data are available for both gates, outflow TP concentrations were not monitored. TP concentrations for gates G-308 and G-309 are estimated using TP data from the inflow culverts to cells 3 and 4, respectively.

RESULTS

Water Budgets

Inflow and outflow components of water budgets for STA-1W and its treatment cells during Water Year 2001−2002 (WY01−02) are summarized in **Figure 4B-2**. Individual values for the water budget components are listed in **Appendix 4B-1**. Water budgets are calculated based on water years running from May 1 through April 30 of the following calendar year.

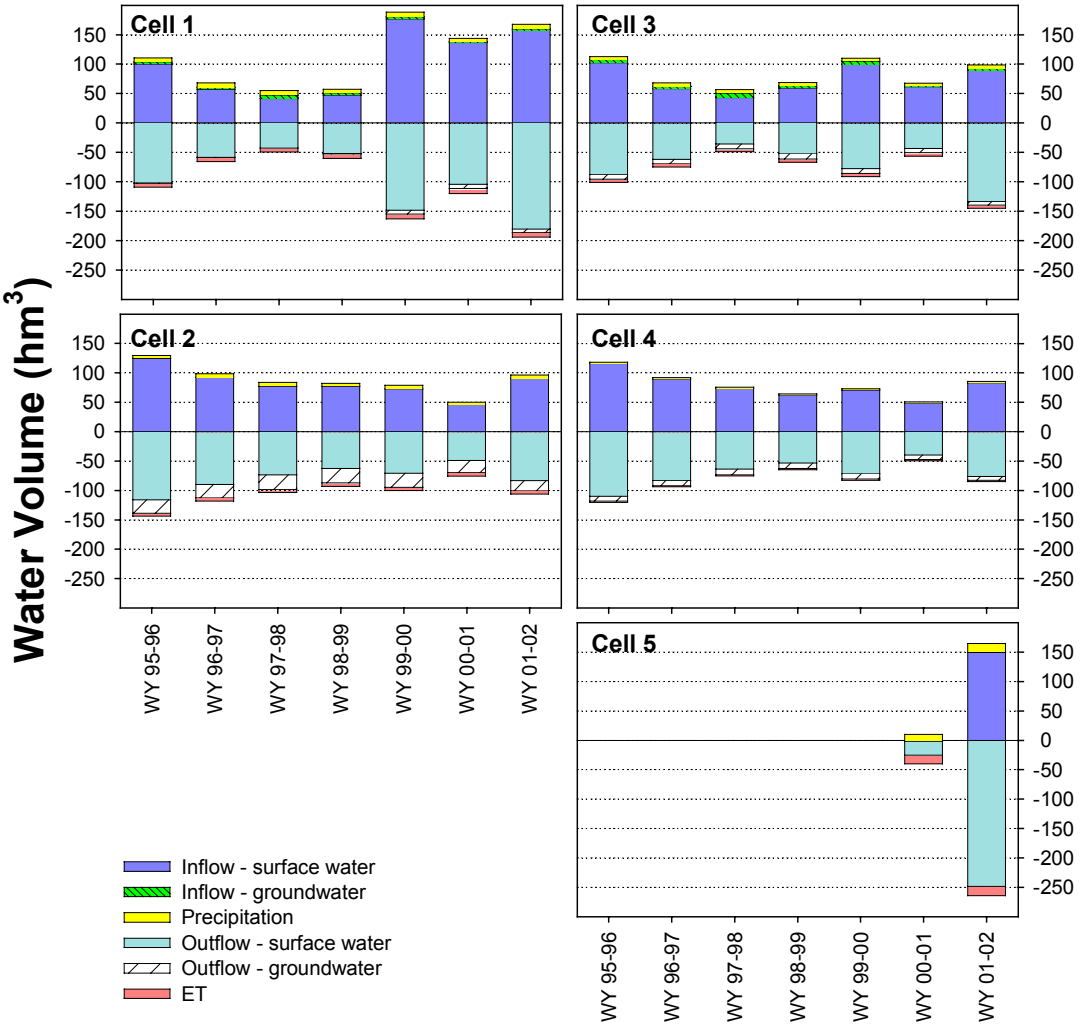

Figure 4B-2. Annual water budgets for each treatment cell in Stormwater Treatment Area 1W. Outflow components of each water budget are represented by negative water volumes. One hm^3 = 1,000,000 m^3

STA-1W

The drought ended in WY01-02, restoring a more normal hydrologic period for STA-1W than the previous water year. Surface flow through G-302 conveyed 87 percent of the inflow, rainfall conveyed 11 percent, and seepage from WCA-1 accounted for 2 percent. Eighty-eight percent of outflow from the STA moved through pump station G-310, and 2 percent moved through pump station G-251; ET was 10 percent and groundwater recharge was less than 1 percent. Total annual inflow during this water year was 334 hm^3 (1 hm^3 = 1,000,000 m^3), twice that of the prior year during the drought. The combined outflow pumping during WY01-02 was also lower than in any previous water year, representing only 90 percent of total outflow. Overall error for the STA-1W water budget has consistently remained at or below 5 percent; this year's error term remained within this range at 3.6 percent.

CELL 1

Cell 1 receives all the inflow to the east and west flow-ways of STA-1W (**Figure 4B-1)**. Eighty-five percent of this water volume entered cell 1 through gate G-303 (**Figure 4B-2**). An additional 9 percent of inflow was delivered through pump station G-250S, which recycles water captured by the seepage return canal. The remaining inflow was from rainfall (5 percent), seepage, and groundwater from WCA-1. Water entering through the pump station and the gate was routed in nearly equal proportions, either southward through cell 1 (46 percent) or westward through the G-255 levee into cell 2 (47 percent). Evapotranspiration accounted for another four percent of water leaving the treatment cell. Seepage and groundwater recharge made up the other three percent of the outflow from cell 1. As in the previous water year, the annual water budget error was larger than earlier in this treatment cell's history (−16 percent).

CELL 2

Cell 2 is the upper treatment cell in the west flow-way of STA-1W (**Figure 4B-1**). Ninety-four percent of inflow was through G-255 from cell 1 (9.1 hm^3) (**Figure 4B-2)**; the remaining 6 percent of inflow fell as rain. Flow from cell 2 through G-254 into cell 4 accounted for 79 percent of outflow. An additional 5 percent of outflow was from ET, and 16 percent was from seepage into the seepage return canal. The water budget for cell 2 continued to reflect relatively high error, averaging −11.3 percent for WY01−02, considerably less than last year's high of nearly 50 percent error in the budget.

CELL 3

Water leaving cell 1 flows into cell 3 through the G-253 levee (**Figure 4B-1**), representing 91 percent of the annual total inflow (**Figure 4B-2**). Seepage from WCA-1 and groundwater provided another 4 percent, with rainfall accounting for the remaining 5 percent. Originally, outflow from cell 3 was not measured directly as in the other treatment cells; rather, surface outflow was estimated as the difference between outflow pumped through G-251 and the outflow from cell 4. Operation of the new G-308 structure has changed internal flow-paths. The combined flow through these two structures accounted for 76 percent of outflow. ET and seepage accounted for 11 percent each, with the remaining 2 percent through groundwater recharge. The water budget error for cell 3 was high at 50 percent, probably because of error in the two outflows. Previous years' water budget errors ranged between 1 and 15 percent.

CELL 4

Surface water enters cell 4 through the G-254 levee from cell 2 (**Figure 4B-1**). This levee provided 98 percent of the inflow (**Figure 4B-2**), with the additional water as rainfall (2 percent). Outflow is more complex. The new gated structure, G-309, was used occasionally during the year, removing 23 percent of the outflow. Most outflow passed through the G-256 levee (67 percent), with additional outflow as ET (2 percent) and seepage (8 percent). Unlike the other

treatment cells, residual error in cell 4's water budget was extremely low this year: less than 1 percent.

CELL 5

Inflow enters cell 5 through the G-304 levee, travels westward and is discharged through the G-306 levee into a canal. From there, cell 5 water is pumped out of STA-1W through the G-310 pump station into WCA-1 (**Figure 4B-1**). Based on preliminary data, 91 percent of the inflow was through the G-304 levee, and 9 percent was from rainfall (**Figure 4B-2**). Most of the outflow from cell 5 was through the G-306 levee (94 percent), with an additional 6 percent from ET. The error term in the cell 5 water budget was exceptionally large (> 50 percent), indicating that there is substantial error in flow estimates for some of the water control structures. The accuracy of all monitoring instrumentation and flow equations is being rechecked. When corrected flow data are available, the cell 5 water budget will be recalculated.

Total Phosphorus Budgets

TP retention varied among treatment cells, but overall, STA-1W retained 71 percent of incoming TP for WY01−02 (see Chapter 4A). Treatment cell performance this year was generally consistent with performance in prior water years with respect to mass retention, but not for outflow concentrations, which were elevated for the third consecutive year. The treatment cells retained TP over a wide range of flow conditions and operational conditions, including high and extended low-flow periods. The greatest treatment efficiencies coincided with high flow during summer 2001, when the regional drought ended and normal rainfall conditions returned. For several months, cells 1, 2 and 3 exported, rather than retained, TP, but this pattern reversed itself over the water year. Outflow TP concentration from cell 4 has continued to increase since lows in WY97−98 and WY98−99, currently averaging 33 µg/L for WY01−02. For this water year, cells 1 through 4 retained 42,380 kg of P. Individual treatment cell TP budgets are provided in **Appendix 4B-2**.

CELL 1

For the period of record, cell 1 has retained approximately one third of all incoming TP (**Figure 4B-3**); however, during WY01−02 it has retained only 22 percent of incoming TP, totaling 3,482 kg. The cell's average TP reduction was 0.860 $g/m^2 \cdot yr$. Flow-weighted TP concentrations decreased from 95 µg/L at the inflow to 64 µg/L at the cell 1 outflow.

CELL 2

Cell 2 retained 23 percent of inflow TP (**Figure 4B-3**), 2,302 kg TP in WY01−02. TP load reduction averaged 0.492 $g/m^2 \cdot yr$. Similar to cell 1, the inflow TP concentration from all sources was 91 µg/L, decreasing to 64 µg/L at the outflow.

CELL 3

Conversion of the ENRP to STA-1W substantially altered the physical layout of cell 3 (see discussion in Jorge et al., 2000) and complicated calculation of water and TP budgets. Outflow for this cell was partially calculated as the difference between discharge from cell 4 and the G-251 pump station instead of being measured directly. When the G-308 gate operated, water was commingled from both cell 3 and the cell 4 outflow canal. The G-308 gate operated during most months of WY01−02. In addition, TP concentrations were estimated rather than measured at G-308. These factors contributed to the large uncertainty in the cell 3 TP budget.

CELL 4

Cell 4, which is managed for Submerged Aquatic Vegetation (SAV), continued its high overall TP retention of 51 percent (2,896 kg TP) for this water year (**Figure 4B-3**). TP load reduction averaged 1.971 g/m^2·yr, considerably higher than cells 1 and 2. However, cell 4 outflow concentrations have increased over the last three years and were double in WY01–02 compared to its optimal performance period from WY97–98 to WY98–99. WY01–02 flow-weighted TP concentrations decreased from 66 µg/L at the inflow to 33 µg/L at the cell 4 outflow. Outflow concentrations were 27 µg/L in WY00–01and 27 µg/L in WY99–00. The reasons for these increased outflow concentrations are unclear and are being investigated.

CELL 5

Calculating a TP budget for cell 5 requires a good water budget. When the water budget issues in this cell are resolved, a TP budget for cell 5 will be produced.

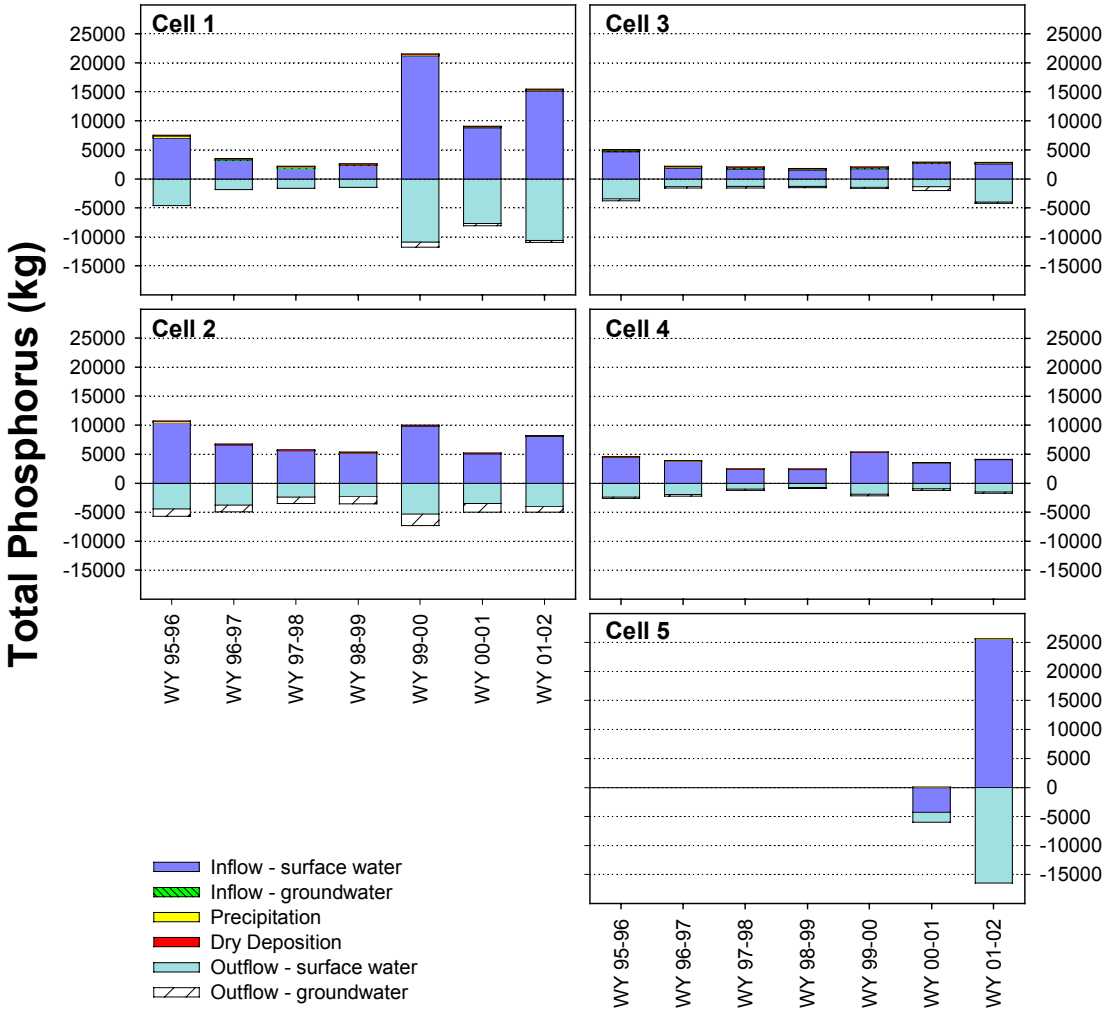

Figure 4B-3. Annual TP budgets for each treatment cell in Stormwater Treatment Area 1 West. Outflow components of each TP budget are represented by negative values

FUTURE MONITORING

The District recognizes that uncertainty in some of the water and TP budgets for STA-1W is unacceptably high. To remedy this situation, the District will re-survey the headwater and tailwater elevations for G-302, G-303, G-308, G-309 and all water control structures within cell 5 (**Figure 4A-1**). These new elevation data will be used to verify stage measurements and flow equations associated with these structures and, where appropriate, correct flow data. In addition, the District will install autosamplers at G-302, G-304, G-306, G-308 and G-309 to collect time- or flow-proportioned samples to improve estimates of TP concentrations at these structures. Future ECRs will include water and TP budgets for all five treatment cells in STA-1W.

STA-1W TEST CELL RESEARCH

DATA COLLECTION AND ANALYSIS

The District is conducting research in the STA-1W test cells to evaluate the impact that hydrology has on wetland performance as part of the STA Optimization Program. These experiments involve hydraulic manipulations, such as maintaining steady flows and depths for a prescribed period, that cannot be duplicated in the STAs because the timing and delivery of water to the STAs is a function of rainfall events and subsequent flood control discharges from the drainage basin and cannot be controlled to the degree needed for experimentation.

The test cells are small, rectangular 0.2-ha wetlands that are hydrologically isolated from each other. The test cells are arranged into two groups of 15 units: one group is located in cell 1 (north site) and the other in cell 3 (south site) of STA-1W (**Figure 4B-1**). Ten test cells are being used for this research: six at the north site and four at the south site. Vegetation in the test cells consists primarily of dense stands of cattail (*Typha* spp.) mixed with incidental populations of submerged aquatic vegetation (SAV) and periphyton. The District elected to perform this research in cattail-dominated systems that developed voluntarily because it is anticipated that this community type will also dominate the STAs. A more complete description of the test cells, and the design of the individual experiments being conducted in them, is provided in previous ECRs (Chimney et al., 2000; Nungesser et al., 2001). The status of STA optimization experiments scheduled for the test cells is provided in **Table 4B-1**. Findings from hydraulic loading rate (HLR) experiments that concluded in WY00–01 are described in the 2002 ECR (Jorge et al., 2002). The treatment efficacy of wetlands dominated by SAV and periphyton is being evaluated in other District-sponsored research projects (see Chapter 4C). While there is always some concern in extrapolating results from small- to full-scale systems, the test cells were used to address hydraulic issues, such as changing depth and loading rates, that could not easily be studied in the larger STAs. It is generally accepted that these factors scale well within the test cells and that the influence of wetland-edge effects was minimal. However, velocity does not scale and was substantially lower in the test cells compared to the STAs. Scaling issues in the test cells are addressed in more detail in Jorge et al. (2000).

Table 4B-1. Start dates, duration, experimental regime, mean hydraulic loading rates and nominal depths for STA optimization experiments conducted in the STA-1W test cells. Two control test cells at both the north and south sites were held at a constant HLR of 2.3 cm/d and a nominal depth of 0.6 m for all experiments. Test cells were operated in one of the following configurations: low HLR/low-depth→-high-depth or high HLR/pulsed flow

Exp. #	North Test Cells	South Test Cells	Exp. Regime	HLR (cm/d)		Nominal Depth (m)
				Low	High	
1	05/20/99 (98 days)	11/02/99 (104 days)	HLR	1.2	4.8	0.6
2	09/01/99 (106 days)	02/14/00 (105 days)	HLR	0.1	10.4	0.6
3	02/14/00 (105 days)	07/05/00 (105 days)	HLR	0.3	18.5	0.6
4	10/04/00 (180 days)	10/18/00 (177 days)	Pulsed	0.05 - 5.1		0.6
5	10/04/00 (180 days)	10/18/00 (177 days)	Depth	2.6		0.2
6	07/24/01 (180 days)	04/13/01 (188 days)	Pulsed	0.3 - 15.3		0.6
7	07/24/01 (180 days)	04/13/01 (188 days)	Depth	2.6		1.2

One series of experiments, concluded in WY01–02, was designed to document the effect that water depth has on TP removal (**Table 4B-1**). All test cells used in these experiments were operated initially at an HLR of 2.6 cm/d and a depth of 0.6 m to provide baseline performance data. These starting conditions were within the range of the STA conceptual design criteria ($1.6 \leq$ HLR ≤ 3.0 cm/d; 0.2 m $\leq$ operating depth ≤ 1.4 m; Burns and McDonnell, 1994) and operating guidelines currently used for the STAs. Two test cells at each location acted as controls and were maintained at the initial HLR throughout the experiments (NTC-05, NTC-10, STC-01 and STC-15). Two north cells (NTC-07 and NTC-08) and one south cell (STC-01) were used for water depth experiments (nominal low depth = 0.15 m; high depth = 1.2 m) and were operated at a constant HLR of 2.6 cm/d, resulting in nominal hydraulic retention times (HRTs) of 5.5d and 45.7d for the low- and high-depth experiments, respectively. Because the low-depth experiments, which had the shorter HRT, were performed before the high-depth experiments with a longer HRT, there was no concern that the effects of one experiment could influence those of the next due to extended HRTs. Actual depths were recorded throughout the study every 10 m along a centerline transect from inlet to outlet. At constant HLR, depth is proportionately related to the HRT, i.e., decreasing the depth decreases the HRT, and increasing the depth increases the HRT. To determine actual HRTs, lithium (Li) tracer experiments were conducted in five test cells for each of the low- and high-depth experiments.

Pulsed-HLR experiments were conducted in the remaining STA optimization test cells and were run concurrently with the depth experiments described above (**Table 4B-1**). The pulsing scheme that was employed consisted of changing HLR biweekly over a range of 0.05 to 15.27 cm/d, while the depth was held at 0.6 m. Holding the depth constant while pulsing the HLR results in varied HRTs, which in part simulated the operation of an STA. The inflow pattern developed for this experiment was based on a 10-year period of record (1978 to 1988) for the STA-2 basin (this was the same data set used for simulations performed as part of the supplemental technology standard of comparison; see Chapter 4C). The pulsing experiments were conducted for one calendar year, from October 2000 through September 2001, and included both

wet and dry seasons. The wet season in South Florida generally runs from May through October, and the dry season runs from November through April. During these experiments the effects of pulsing were investigated under both a high- and a low-HLR regime. The low-pulsed HLR regime ran from October 2000 through April 2001, and then increased from May 2001 through the end of October 2001. During the low-pulsed HLR period, HLR ranged from 0.05 to 5.1 cm/d; HLR ranged from 0.3 to 15.3 cm/d for the high-pulsed HLR period.

The length of the pulsed HLR and depth experiments (177 to 188 days) was increased over the earlier HLR experiments (98 to 105 days) to address concerns raised about HRTs (see discussion in Jorge et al., 2000). There were "stabilization" periods, ranging from 37 to 142 days, between the end of the HLR experiments and the start of the pulsed HLR and depth experiments in all but one of the test cells.

The statistical significance of differences between outflow TP concentrations from control versus experimental test cells was evaluated using a non-parametric median test. The level of significance (α) for all tests was 0.5.

RESULTS

The pulsed HLR and the low- and high-depth experiments were concluded in WY01–02 (**Table 4B-1**). These experiments addressed two questions central to the STA Optimization Program: (1) what are the impacts of prolonged low or high depth on treatment performance of the STAs, such as that which might occur during extremely dry or wet periods, and (2) what are the effects of pulsed inflow on treatment performance? The reader is cautioned that results from these experiments can only be extrapolated to full-scale wetlands with the same type of vegetation, i.e., cattail-dominated communities, and are subject to the scaling artifacts inherent in all small-scale ecological experiments summarized in Jorge et al. (2002).

Low-depth Experiments

The mean water depth at the north site was 0.28 m (NTC-07) and 0.31 m (NTC-08) for the low-depth cells and 0.79 m (NTC-05) and 0.86 m (NTC-10) for the control cells, which was higher than nominal depths calculated from mean water stage and the design bottom elevation. This resulted in actual mean HRT calculated from tracer studies of 9.5 days for the low-depth cells and 36 days for the control cells. At the south site, measured depths more closely matched nominal depths, with means of 0.15 m for the low-depth cell (STC-02) and 0.6 m for the control cell (STC-01), respectively. Correspondingly, mean HRTs at the south site were four days and 28 days for the low-depth and control cells, respectively.

The mean inflow TP concentration at the north site was 45 µg/L, almost twice that of the mean TP inflow of 19 µg/L at the south site. The north control cells reduced the inflow TP concentration by about 55 percent, while the south control cells experienced only a 6-percent reduction.

Lowering water depth to a nominal 0.15 m resulted in a slight improvement in TP removal at the north site but resulted in markedly poorer TP removal performance in the south site compared to the respective controls. The median outflow TP concentrations at the north control and low-depth test cells (20 versus 15 µg/L, respectively) were significantly different. In the south, median outflow TP concentration for the low-depth cell (32 µg/L) also was significantly greater than the control cells (18 µg/L).

High-depth Experiments

The actual mean water depth at the north site was 1.29 m (NTC-07) and 1.31 m (NTC-08) for the high-depth cells and 0.79 m (NTC-05) and 0.86 m (NTC-10) for the control cells, which are higher than the nominal depths calculated from mean water stage and design bottom elevation. This resulted in actual mean HRT calculated from tracer studies of 55 days for the high-depth cells and 36 days for the controls at the north site. At the south site, measured depths more closely matched nominal depths, with means of 1.2 m for the high-depth (STC-02) and 0.6 m for the control cell (STC-01). Correspondingly, mean HRTs at the south site were 50 days and 28 days for the high-depth and control cells, respectively.

During the high-depth experiments, mean inflow TP concentration at the north site was 77 µg/L, slightly more than twice as high as the south site (35 µg/L). During the experiment the north control cells reduced inflow TP concentration by about 66 percent, while the south site controls had a mean TP concentration reduction of only 12 percent.

Increasing water depth in the north site had no significant effect on TP reduction; median outflow TP concentrations were 26 and 25 µg/L for the control and high-depth test cells, respectively. However, during the first seven weeks of this study the high-depth system had outflow TP concentrations that generally exceeded those of the control systems.

At the south site, the median outflow TP concentration from the control test cells (31 µg/L) was significantly less than outflow from the high-depth test cells (49 µg/L). Outflow TP concentrations from the controls often exceeded their inflow concentrations during this experiment. The mean outflow TP concentration for the high-depth system was 110 µg/L, which far exceeded the mean inflow TP concentration. However, the outflow mean was strongly influenced by high outflow TP concentrations during the first seven weeks of the experiment. Following this period, the outflow TP concentration of the high-depth cell decreased and remained relatively stable, with a mean concentration of 41 µg/L for the remainder of the experiment.

Pulsed-HLR Experiments

The overall mean HLR to the pulsed test cells at both the north and south sites was 3.4 cm/d. This was higher than in the HLR in the controls (2.6 cm/d) and STA design criteria (1.6 to 3.0 cm/d; Burns and McDonnell, 1994). To mimic increased flows expected during the wet season, the HLR during this period was varied from 0.7 to 18.5 cm/d, with a mean of 5.4 cm/d. The mean HLR during the dry season part of the study was 1.4 cm/d and ranged from 0 to 4.8 cm/d (**Figure 4B-4**). The inflow TP concentration correlates to the wet and dry season experienced in South Florida, with increased TP concentrations measured during the wet season.

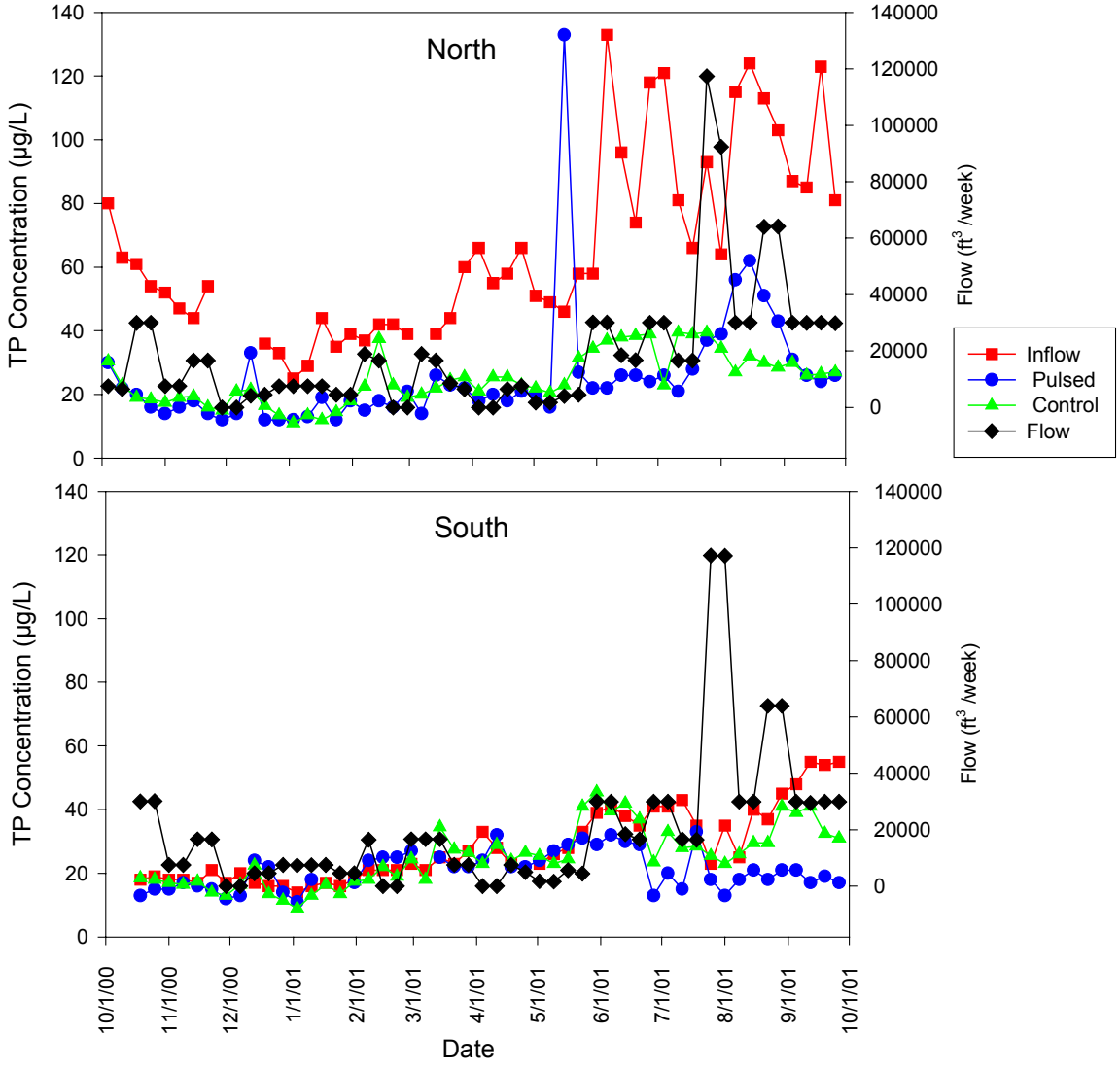

Figure 4B-4. Inflow, pulsed outflow and control outflow TP concentrations for the pulsed-HLR experiments at the north and south test cells located in STA-1W (October 4, 2000 through October 3, 2001)

The mean inflow TP concentrations at the north and south sites during this experiment (October 2000 to October 2001) were 66 and 28 µg/L, respectively. However, mean TP inflow concentrations at both sites were lower during the dry season than during the wet season (**Figure 4B-5)**.

Generally, TP outflow concentrations for the pulsed-HLR and control test cells at the north site were below inflow TP concentrations, with means of 40 and 25 µg/L, respectively **(Figure 4B-5)**. While mean TP outflow concentrations for controls and experimental test cells were greater during the wet-season pulsing regime than during the dry season, mean TP concentration reduction was greater in the wet season due to increased inflow TP concentration during this period. Differences between median outflow TP concentrations for the control and pulsed-HLR cells were significant during both the dry season (20 versus 29 µg/L, respectively) and the wet season (32 versus 39 µg/L, respectively).

At the south site, mean outflow TP concentration from the pulsed cell was 20 µg/L, slightly lower than the control cell mean (26 µg/L). The mean outflow TP concentration from both systems was less than the mean inflow TP concentration (**Figure 4B-5**). As at the north site, the mean outflow TP concentration was higher during the wet season than the dry season, though the percent reduction increased due to increased inflow TP concentrations. Differences between median outflow TP concentrations for the control and pulsed-HLR cell were not significant during the dry season (20 versus 21 µg/L, respectively) but were statistically significant during the wet season (34 versus 21 µg/L, respectively).

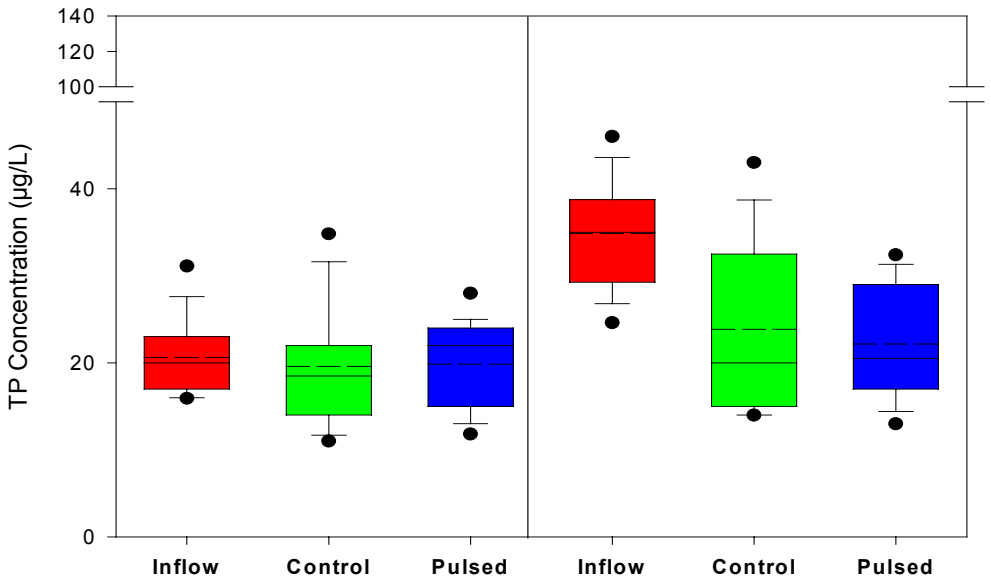

Figure 4B-5. Inflow, control outflow and pulsed outflow during dry- and wet-season pulsing regimes for north and south sites. HLR ranged from 0 to 4.8 for the dry season and 0.72 to 18.5 for the wet season

Hydraulic Tracer Studies

Uneven flow distribution through a treatment wetland, i.e., short-circuiting, can result in hydraulic inefficiency and may reduce the system's ability to remove nutrients and other constituents (Reed et al., 1995; Persson et al., 1999). Hydraulic tracer studies are the most effective means to quantify the degree of wetland short-circuiting. District staff conducted a number of tracer studies using lithium (Li) in five STA optimization test cells between May 2000 and August 2000 as part of the HLR experiments (**Table 4B-1**). These data were reported in Jorge, et al. (2002). Staff subsequently conducted 11 additional tracer studies in six of the STA optimization test cells between March 2001 and February 2002 as part of the water depth experiments described above. The results of these recent tracer studies are described below. Tracer spikes were prepared by diluting Li chloride brine solution (78,457 mg/L as Li) to an approximate concentration of 350 µg Li/L. The tracer spike was added to each test cell over a period of two to three minutes by pouring it into the inlet distribution system. Automated samplers were deployed at the outlet of each test cell and were programmed to collect 250-mL samples at varying time intervals beginning with the introduction of the tracer. Samples were preserved with nitric acid (pH ≤ 2). Test cell outflow was measured as described in Chimney et al. (2000).

The tracer study data were interpreted following the gamma distribution method summarized by Kadlec (2001). Each hydraulic tracer study was typically run for a period three times the nominal HRT to ensure adequate recovery of the Li spike. The mean HRT for the 11 studies ranged from a low of 4.2d for STC-02, operated at 0.15 m, to a high of 55.7 d for NTC-07, operated at 1.2 m (**Tables 4B-2** and **4B-3**). The residence time distribution (RTD) curves fell into two general groups. Five of the studies had an N greater than 4.0, while the remaining six studies had an N of less than 3.0 (**Figure 4B-6**). With the exception of one study, the test cells with emergent plant communities and a depth greater than 0.7 m exhibited better plug-flow hydraulics than test cells less than 0.6 m deep.

Table 4B-2. Summary of lithium tracer studies performed at the STA optimization test cells located within STA-1W, cells 1 and 3. Tracer tests were performed during the low-depth experiments from March 1, 2001 to June 30, 2001

	North Test Cells			South Test Cells		
Parameter	Control	Low-depth	Low-depth	Control	Control	Low-depth
Test cell ID	NTC-05	NTC-07	NTC-08	STC-01	STC-15	STC-02
Mean volume (m^3)	1,961	646	719	1,423	1,906	340
Mean flow (m^3/d)	57.4	60.8	59.6	61.1	61.4	63.6
Mean HLR (cm/d)	2.6	2.6	2.6	2.6	2.6	2.6
Mean depth (cm)	78.7	28.2	31.4	58.9	76.6	15
Nominal HRT (d)	34.2	10.6	12.1	23.3	31.0	5.3
Mean HRT, τ (d)	34.9	9.9	9.1	28.1	38.1	4.2
Number of tanks (N)	4.61	2.3	2.6	1.6	1.9	2.8
Mass recovery (%)	46.5	76.4	62.8	19.7	32.2	83.7
Hydraulic efficiency (%)	102	93	76	121	123	79

Table 4B-3. Summary of lithium tracer studies performed at the STA Optimization test cells located within STA-1W, cells 1 and 3. Tracer tests were performed during the high-depth experiments from November 2, 2001 to February 24, 2002.

	North Test Cells			South Test Cells	
Parameter	**Control**	**High-depth**	**High-depth**	**Control**	**High-depth**
Test cell ID	NTC-05	NTC-07	NTC-08	STC-01	STC-02
Mean volume (m^3)	1,961	3,013	3,495	1,314	3,153
Mean flow (m^3/d)	69.7	69.6	70.2	66.7	67.4
Mean HLR (cm/d)	2.6	2.6	2.6	2.6	2.6
Mean depth (cm)	78.7	129.3	131.4	54.8	120
Nominal HRT (d)	28.2	43.2	49.8	19.7	46.8
Mean HRT, τ (d)	49.7	55.7	55.1	21.9	50
Number of tanks (N)	4.6	5.8	4.5	2.4	4.8
Mass recovery (%)	58	61.6	58.1	5.8	68.3
Hydraulic efficiency (%)	177	129	111	111	107

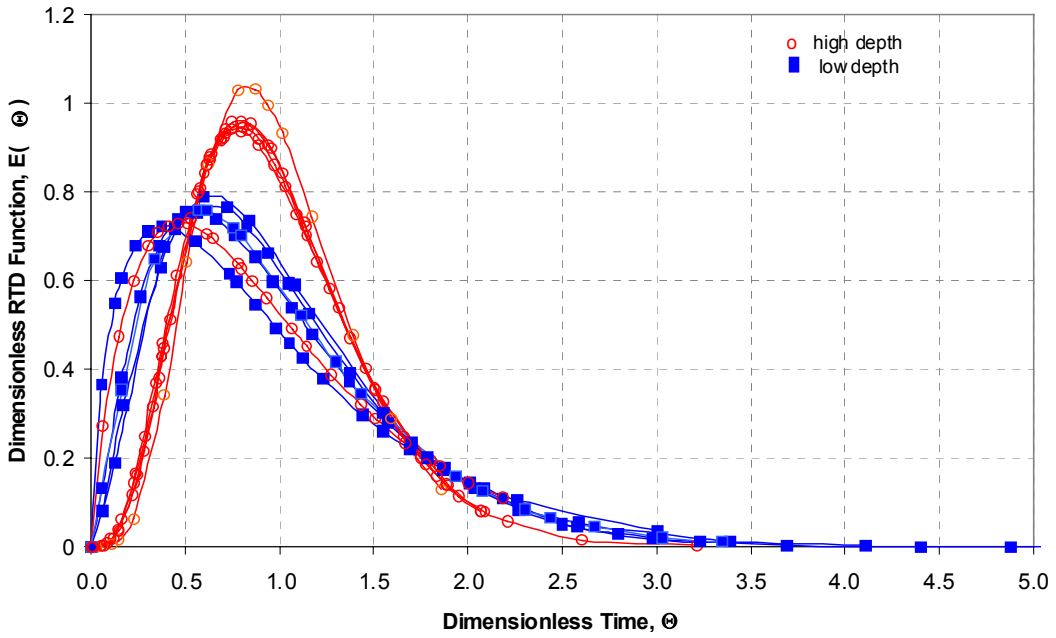

Figure 4B-6. Residence time distributions for the north and south test cells generated using the gamma distribution method. Tracer data were collected during the high- and low-depth STA optimization experiments from March 1, 2001 to February 24, 2002. Blue solid squares denote cell depth higher than 70 cm, and red open circles denote cell depths less than 60 cm

The mean HRT, based on the tracer data for NTC-05, was about the same as the nominal HRT computed using the HLR, indicating that this system did not have many dead zones or substantial short circuits (Levenspiel, 1999). However, the three low-depth test cells (NTC-07, NTC-08, and STC-02) had mean tracer HRTs that were less than the calculated nominal HRT, indicating possible dead zones within the system. The two south control test cells (STC-01 and STC-15) had mean tracer HRTs greater than the calculated nominal HRT. Tracer HRTs greater than the nominal HRT indicate that either the tracer moved through only a portion of the wetland (i.e., short circuiting) or the average bottom elevation was inaccurate, leading to an incorrect volume estimate (Kadlec, 1994).

Tracer recovery ranged from a low of 20 to a high of 84 percent of the Li introduced into the test cells (**Tables 4B-2** and **4B-3**). Low tracer recovery is indicative of seepage loss or decay/adsorption/absorption of the tracer material. However, the test cells are fully lined and Li is thought to be a conservative material not subject to environmental degradation. One explanation for the low tracer recoveries is that some of the Li became entrained in the sediment and was not flushed through the wetland (R. Kadlec, personal communication). Lithium is denser than water, and it is possible that the method of introduction, i.e., pouring directly into the test cell influent, may have resulted in some Li sinking to the sediment at the base of the inlet distribution trough. If this were true, then it should follow that the shallower test cells would have entrained more Li compared to deeper test cells. However, the three low-depth systems (NTC-07, NTC-08 and STC-02) had the highest tracer recoveries. Additionally, in conjunction with the Li tracer study, the District participated with DB Environmental, Inc. in a comparative study of rhodamine WT dye and bromide to determine if either of these materials could be used as a tracer in cattail-dominated wetlands. Two control test cells, NTC-05 and STC-01, were used in these trials. Both rhodamine WT and bromide were added as dilute solutions in the same manner described above for Li. At NTC-05, 23 percent and 16 percent of the bromide and rhodamine WT, respectively, were recovered, less than the recovery of Li. At the STC-01, bromide recovery was only slightly better than Li (23 percent), while 41 percent of the rhodamine WT was recovered. Differences in recovery efficiency of the three tracer materials were judged to be inconclusive. However, regardless of the mass recovered, the results of the mean tracer HRT and tank-in-series calculations are relatively similar; the trend was the same with NTC-05, but not with STC-01, tending toward plug-flow hydraulics.

MANAGEMENT IMPLICATIONS

Increasing or decreasing the depth in the test cells at a constant HLR had only a slightly positive effect on TP removal in the north test cells. Neither increasing nor decreasing the HRT by more than half in this experiment had the same effect as during the HLR experiment, where a marked increase in mean TP outflow concentration compared to controls was noted when HRTs were lowered to less than 11 days, but not when HRT was increased (Jorge et al., 2002). The main differences between experiments were that the depth was changed and the mass TP load was constant on an areal basis. During the HLR experiment the areal TP load was greatly modified in both directions. Additionally, during the low- and high-depth experiments the overall mean inflow TP concentration was 45 µg/L, which is less than half the mean TP inflow concentration of 100 µg/L during the HLR experiment. Therefore, in front-end emergent STA cells it appears that change in depth, within the range examined in these experiments, is not an operational constraint because loading rate is the greater determining factor for system performance.

Conversely, increasing or decreasing the depth while maintaining the HLR at the south site had negative effects on TP removal performance compared to the control systems. During both the HLR and depth experiments the test cells exhibited little or no TP removal capabilities due to the extremely low inflow TP concentrations at this site. Therefore, it appears that cells dominated by emergent vegetation may not be efficient in TP removal when functioning as the last "polishing" cell in a treatment train.

While pulsing in both the north and south site test cells during the dry season resulted in slightly greater lowering of TP removal compared to controls during the wet season, pulsing overall did not have a substantially negative effect on TP removal performance from these wetland systems.

FUTURE MONITORING

Monitoring of the control test cells is continuing, but no new research experiments for the STA optimization test cells are currently planned. Forecasts of STA performance based on this work must be verified against actual STA performance data. It should be noted, however, that the unifying principle behind all these experiments was to examine wetland response at the extremes of STA operating conditions. Verification will be possible only when the STAs experience extreme hydrologic conditions. Comparisons between predicted and actual STA performance are ongoing.

PERFORMANCE EVALUATION OF STA-2

Instrumentation to monitor flow and water quality conditions is currently being installed at interior sites within STA-2. The District has initiated sediment, vegetation and grab-sample water quality collection within each treatment cell. Analyses of these data will be presented in the 2004 ECR. Refer to Chapter 4A of this report for information regarding STA-2 permit requirements.

PERFORMANCE EVALUATION OF STA-5

STA-5 encompasses an area of 1,975 ha (4,880 ac), with an effective treatment area of 1,663 ha (4,109 ac). The STA is located in Hendry County east of the L-2 borrow canal and west of the Rotenberger Wildlife Management Area (**Figure 1-1**) and is divided into parallel north and south flow-ways with two treatment cells each (**Figure 4A-12**). The north and south flow-ways are equal in size, encompassing about 832 ha (2,055 ac) each. The front 156 ha (385 ac) of each flow-way is not flooded. Therefore, cells 1A and 2A have an effective treatment area of just 338 ha (835 ac).

Cells 1B and 2B are larger. Each cell has an effective treatment area of 494 ha (1,220 ac). Refer to the STA-5 Operation Plan (SFWMD, 2000b) and both the 2001 and 2002 ECR for a detailed description of STA-5 operations. Chapter 4A of the 2003 ECR discusses current performance data.

STA-5 has dried out several times during its operational history in response to droughts. The most recent dryout occurred during the severe drought in South Florida from December 2000 until June 2001, when all cells in STA-5 except cell 1B went dry for 50 days. Cell 1B was kept flooded during this period by use of a temporary inflow pump to sustain its SAV community. The

District initiated a six-month monitoring study of STA-5 in June 2001 to evaluate changes in the plant community and water quality in response to dryouts.

DATA COLLECTION AND ANALYSIS

As part of the STA Optimization Program the District initiated monitoring of cell-to-cell P reduction, sediment nutrient content and plant community species' composition/abundance in STA-5. In addition, the worst drought in South Florida's recorded history ended in 2002, and the District initiated a study to evaluate nutrient release from dried STA-5 soils upon reflooding. The 2003 ECR presents preliminary results of these monitoring efforts. Evaluations of overall TP removal performance, including calculation of TP load and concentration reductions, are presented in the 2003 ECR in Chapter 4A.

METHODS

Weekly flow-weighted composite water samples were collected and analyzed for TP from inflow structures G-342A through D and from outflow structures G-344A through D for permit requirements (see Chapter 4A). Biweekly grab samples were collected from these same structures and were analyzed for soluble reactive P (SRP), total dissolved P (TDP), nitrate+nitrite nitrogen (NO_x-N), ammonia nitrogen (NH_4-N), total Kjeldahl nitrogen (TKN), total dissolved Kjeldahl nitrogen (TDKN), chloride (Cl), sulfate (SO_4), alkalinity, pH, dissolved oxygen (DO), conductivity and temperature. Additionally, in April 2002 the District installed autosamplers at two water control structures (G-343B and G-343F) located between the upper and lower treatment cells in the north and south flow-ways.

Beginning in June 2001, 12 sites in each treatment cell (48 total sites) were monitored semi-annually to assess plant community composition and regrowth following the drought. At each site, percent cover and species composition were recorded within a 1-m^2 plot. Samples of the dominant species from a 0.25-m^2 quadrant were collected at or near each vegetation survey site and were analyzed for TP, total carbon (TC), total nitrogen (TN) and dry-weight content. Additionally, soil and water depth were measured at each site with a calibrated metal rod and a meter stick, respectively. Nominal water depth within each cell in STA-5 was calculated by subtracting the mean cell bottom elevation from the mean stage recorded at the inflow, outflow and middle levees.

Daily average flow at pumps G-349A, G-349B, G-350A and G-350B was computed using pump rating curves calibrated to differences in headwater and tailwater stage. Daily average flow through culverts G-342A through D and G-344A through D was computed using combination culvert/orifice equations for each structure based on gate opening and headwater/tailwater stage data.

RESULTS

Hydraulic Performance

Mean nominal water depths for WY01–02 were 0.53 m and 0.41 m for the north and south flow-ways, respectively. These depths were greater than mean depths in WY00–01, especially in the south flow-way (cells 2A and 2B), which was not kept hydrated during the drought. Except for cell 2A, mean depths based on field measurements in each cell were equal to or greater than

the nominal depth, with differences ranging from about 1 cm to 15 cm, due mainly to the influence of deep zones that exist in the eastern portion of cells 1A and 1B.

Average annual inflow during WY01–02 for both flow-ways was approximately 101 hm^3/yr, which was slightly more than the design flow of 96.7 hm^3/yr but was less than the estimated flow of 128.4 hm^3/yr that accounted for the additional water from the Deer Fence Canal. Outflow from the north flow-way was 62 hm^3/yr greater than the south flow-way. Monthly inflows ranged from zero flow during the dry season to approximately 22 hm^3/mo during the wet season. During WY01–02 about 90 percent of the flow occurred between May and December 2001, indicating the highly pulsed nature of water delivery to this wetland (**Figure 4B-7**).

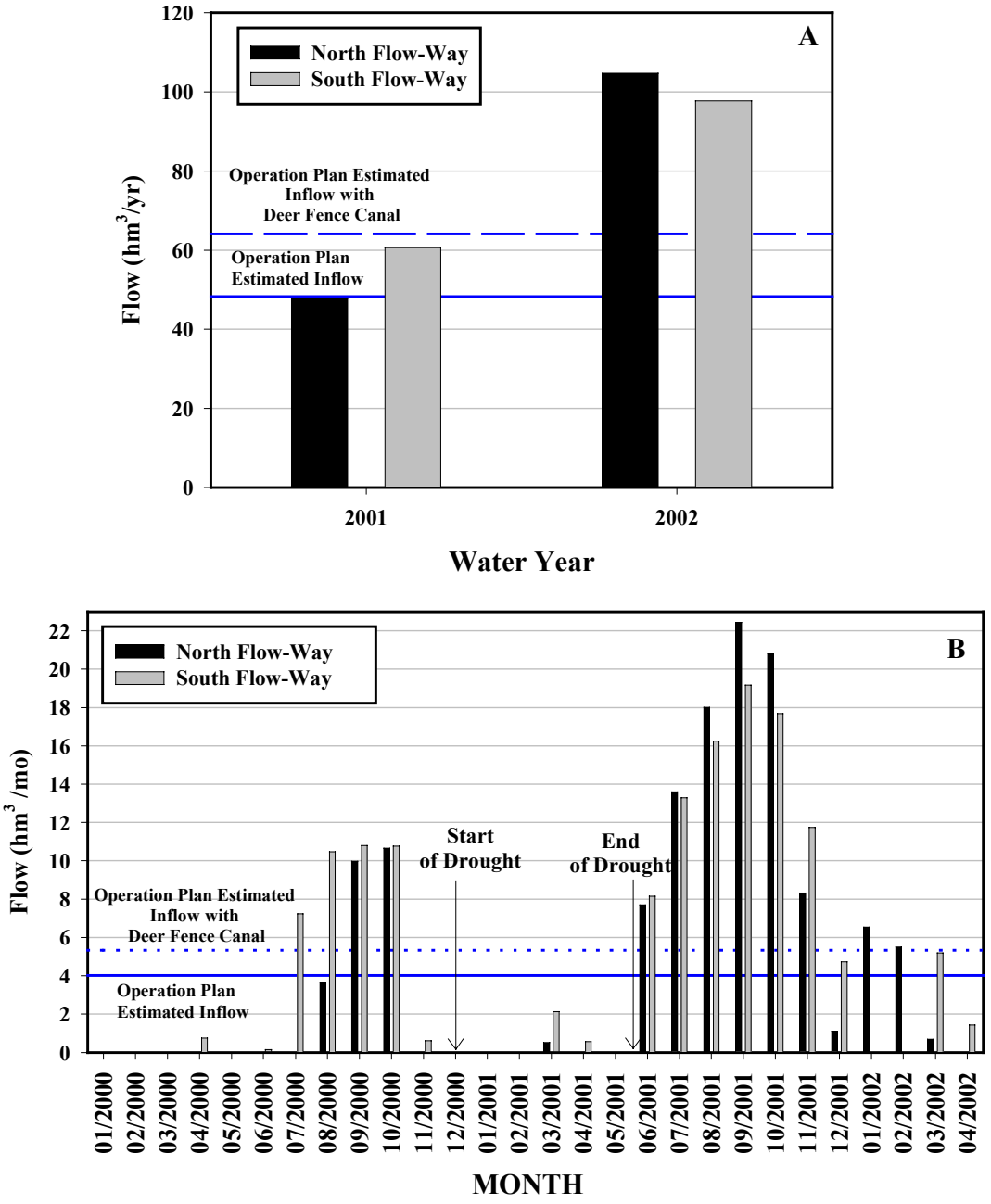

Figure 4B-7. Inflow into the northern and southern flow paths in STA-5 for WY00-01 and WY01-02. Yearly operational inflows expressed as monthly values are for reference only and do not reflect design assumptions

Treatment Performance

Mean inflow TP concentration to STA-5 for WY01–02 was 163 µg/L; mean inflow TP concentrations to the south and north flow-ways were 175 and 150 µg/L, respectively (**Table 4B-4**). This difference was primarily due to additional water that the south flow-way received from the Deer Fence Canal, which had higher inflow SRP (109 µg/L) compared to the north flow-way (85 µg/L). However, both north and south flow-ways had increased TP concentrations relative to WY00–01. The difference in inflow concentrations was attributable to an increase in inflow SRP concentrations during WY01–02 over WY00–01.

Table 4B-4. Mean inflow and outflow phosphorus concentrations in grab samples collected from the north and south flow-ways in STA-5 for water years 2000-2001 and 2001-2002[a, b]

		P Concentrations (µg/L)							
	Location	WY00-01				WY01-02			
		SRP	PP	DOP	TP	SRP	PP	DOP	TP
North Flow-way	Inflow	47 (0.04)	52 (0.07)	14 (0.01)	113 (0.09)	85 (0.07)	51 (0.03)	14 (0.01)	150 (0.08)
	Outflow	34 (0.06)	106 (0.09)	28 (0.01)	168 (0.12)	25 (0.03)	14 (0.01)	14 (0.00)	53 (0.03)
South Flow-way	Inflow	73 (0.05)	49 (0.04)	14 (0.00)	136 (0.07)	109 (0.08)	53 (0.06)	13 0.01)	175 (0.11)
	Outflow	52 (0.06)	65 (0.06)	22 (0.01)	139 (0.09)	63 (0.04)	18 (0.02)	12 (0.01)	93 (0.04)
STA-5	Inflow	60 (0.05)	51 (0.06)	14 (0.01)	125 (0.08)	97 (0.07)	52 (0.04)	14 (0.01)	163 (0.10)
	Outflow	43 (0.06)	86 (0.07)	25 (0.01)	154 (0.11)	44 (0.03)	16 (0.02)	13 (0.01)	73 (0.04)

[a]District water years extend from May 01 through April 30 of the next calendar year.

[b]Standard deviations are in parenthesis.

During WY01–02 the north flow-way had a markedly lower mean outflow TP concentration than the south flow-way, with concentrations of 53 and 93 µg/L, respectively (**Table 4B-4**). Total P reduction was greater in the northern treatment cells than the south flow-way, with reductions of 65 and 47 percent, respectively. Additionally, despite the increased TP inflow concentrations the individual cell performance during WY01–02 was an improvement over WY00–01. During WY00–01, mean TP outflow concentrations from the north flow-way exceeded mean inflow TP concentrations, while the south flow-way achieved no net TP concentration reduction. In WY00–01, both flow-ways reduced SRP concentrations, but outflow DOP and PP levels exceeded corresponding inflow concentrations.

Inflow TP mass was higher for the south flow-way compared to the north flow-way during WY00–01 and WY01–02; the mass of TP delivered to both flow-ways was markedly higher in WY01–02 than in WY00–01 (**Table 4B-5**). Total P retention in the north flow-way was less than that of the south flow-way during WY00–01 and WY01–02, but the north flow-way reflected a

substantial improvement in TP retention from WY00–01 to WY01–02 despite increased P loading, with an increase in TP retention from 22 to 57 percent, respectively. South flow-way TP retention was 83 percent during WY00–01, though it decreased slightly to 79 percent during WY01–02. However, the actual mass retained by the south flow-way during WY01–02 was about 21,267 kg, which is slightly more than double the 10,070 kg TP retained by the same treatment cells during the previous water year.

Table 4B-5. Yearly inflow and outflow total phosphorus mass for the north and south flow-ways of STA-5 for water years 2000–2001 and 2001–2002[a]

Flow-Way	Location	WY00-01 (kg/yr)	WY01-02 (kg/yr)
North	Inflow	5,209	23,436
	Additional Inflows[b]	1,114	912
	Total Inflows	6,323	24,348
	Outflow	4,901	10,482
	TP Retention	22%	57%
South	Inflow	11,362	26,231
	Additional Inflows[b]	653	561
	Total Inflows	12,015	26,792
	Outflow	1,945	5,525
	TP Retention	83%	79%
Percent TP Reduction for STA-5		58%	68%

[a] District water years run from May 01 through April 30 of the next calendar year.

[b] Additional inflows include G-349A and supplemental pump (cell 1B) for the north flow-way and G-350A for the south flow-way.

The TP load into STA-5 during WY01–02 (50,228 kg) was about double the design P load (25,300 kg) and 50 percent greater than the additional P load (33,600 kg) anticipated from the Deer Fence Canal (**Table 4B-5**). The south flow-way received more than twice the P load of the north flow-way during WY00–01, with loads of 12,015 kg P and 6,323 kg P, respectively. During WY01–02, while both flow-ways were markedly over-loaded, the TP load was more equally distributed, with the north flow-way receiving 24,348 kg P and the south flow-way receiving 26,792 kg P. Additionally, most TP was delivered to STA-5 during the wet season **(Figure 4B-8**).

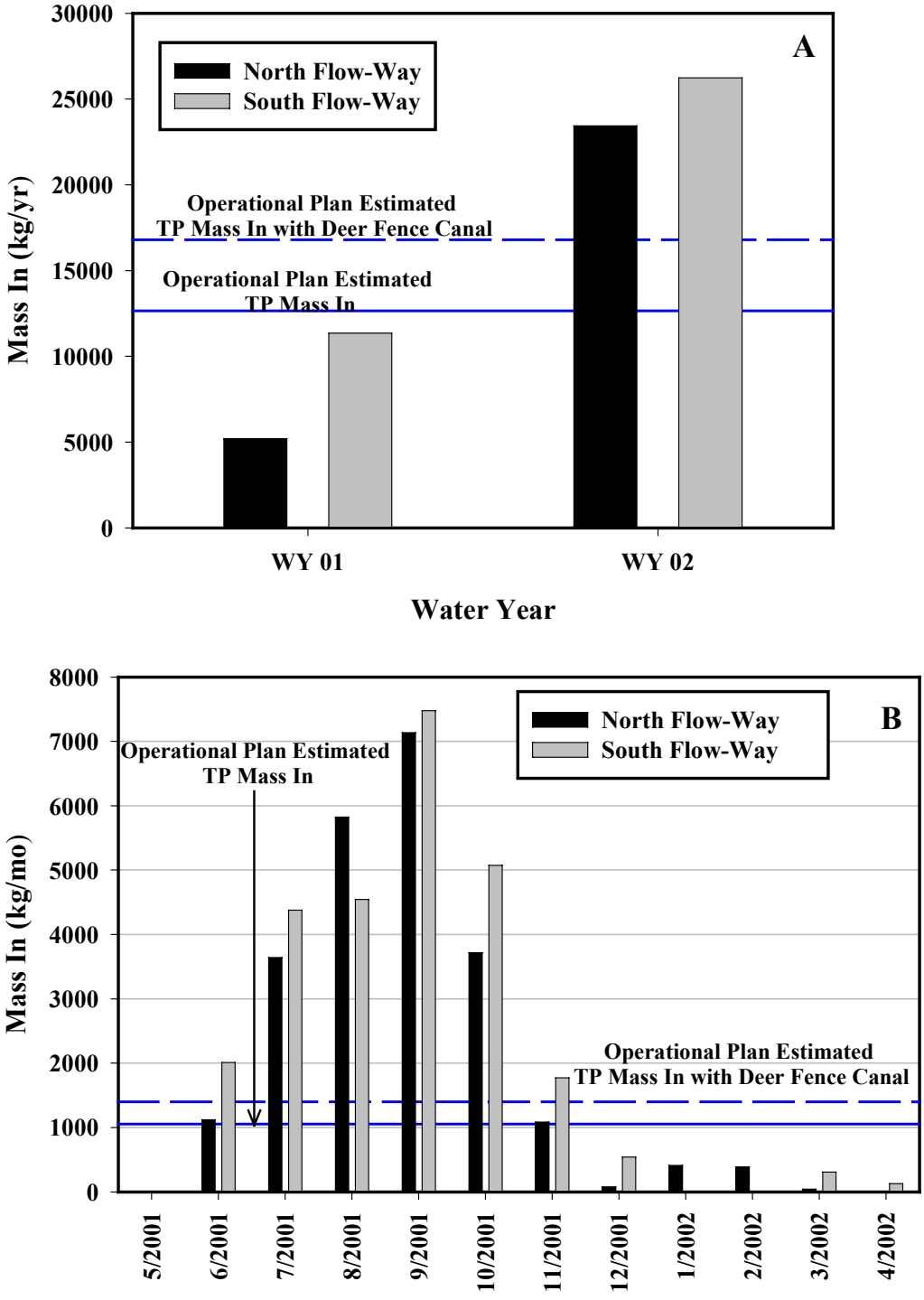

Figure 4B-8. Mass TP into the northern and southern flow paths in STA-5 for WY00-01 and WY01-02. Yearly operational inflows expressed as monthly values are for reference only and do not reflect design assumptions

Vegetation

In June 2001 the District initiated a six-month study to monitor the recovery of STA-5 vegetation following the severe drought in WY00–01. The drought in WY01–02 resulted in drier soils in cells 1A, 2A and 2B, which stressed some of the plant communities and allowed upland species, such as dog fennel (*Eupatorium compositifolium*), to invade portions of STA-5. Six months after rehydration (October 2001), cells 1A and 2B exhibited the greatest plant diversity, while cell 1B had the lowest diversity. **Table 4B-6** lists the four most common species found in each treatment cell six months after rehydration. Water lettuce (*Pistia stratiotes*) and water hyacinth (*Eichhornia crassipes*) dominated the north flow-way, while cattail and small floating aquatics, such as *Salvinia minima* and *Lemna valdivianna,* dominated the south flow-way. Additionally, hydrilla (*Hydrilla verticillata*) was found at northern sampling sites but not at the south flow-way. After the WY01–02 drought, cattail coverage increased in all cells, ranging from twice the pre-drought areal coverage in cell 2B to five times the coverage in cell 1A. In general, SAV contained the highest tissue TP, TN and TC concentrations, followed by water hyacinth, and then cattail.

Table 4B-6. Dominant vegetation based on percent cover estimates from 48 sites located in STA-5, cells 1A, 1B, 2A and 2B in October 2001

Treatment Cell	Dominant Species > 5%			
	Most Common →			Least Common
Cell 1A	*Pistia stratiotes*	*Eichhornia crassipes*	*Typha sp.*	*Hydrilla verticillata*
Cell 1B	*Pistia stratiotes*	*Eichhornia crassipes*	*Hydrilla verticillata*	*Najas guadalupensis*
Cell 2A	*Typha spp.*	*Salvinia minima Lemna valdivianna*	*Polygonum spp.*	*Pistia stratiotes*
Cell 2B	*Salvinia minima Lemna valdivianna*	*Typha spp.*	*Pistia stratiotes*	*Eichhornia crassipes*

SUMMARY

STA-5 was overloaded relative to the design annual TP load, which may explain why TP levels from the south flow-way were greater than the outflow target concentration. However, despite being overloaded both the north and south flow-ways removed more P mass during WY01–02 than during the previous year, with TP retention of 57 and 79 percent, respectively. Increased TP removal was attributed to development of the plant community in WY01–02 relative to WY00–01. During WY00–01, South Florida experienced a severe drought that coincided with the start-up growth of vegetation in STA-5. Consequently, many upland plant species invaded STA-5. Therefore, both wetland vegetation density and biomass were lower in WY00–01 than in the following year. During WY01–02 wetland vegetation recovered quickly after the drought. Within six-months of rehydration, most of the invasive upland species had died and cattail coverage increased in all cells dominated by emergents. During WY01–02, cell 1B became dominated with floating aquatics as opposed to SAV, and hydrilla had greater areal coverage than *Najas guadalupensis*.

FUTURE MONITORING

The District will continue biweekly water quality monitoring of all treatment cells in STA-5 to increase operational knowledge of this wetland and provide data in support of efforts to optimize treatment performance. The number of vegetation and soil-monitoring sites will be increased. The District is in the process of obtaining ground elevation data to prepare a topographic map of STA-5. These data will aid in reducing the error in the storage volume estimates and increase the accuracy of hydraulic models.

PERFORMANCE EVALUATION OF STA-6

STA-6 section 1 (hereafter referred to as STA-6) encompasses 352 ha (870 ac) and is located in the southwestern corner of the Everglades Agricultural Area (EAA) adjacent to the Rotenberger Wildlife Management Area (**Figure 1-1**). Inflow to STA-6 is via a pump station (G-600) that has five 2.83 m^3/s (100-cfs) pumps (**Figure 4A-18**). The pump station is owned by U.S. Sugar Corporation and is operated based on the irrigation needs of the upstream basin (a 4,209-ha area, also owned by U.S. Sugar Corporation). STA-6 is divided into two treatment cells by an interior levee. Cell 3 (99 ha) receives approximately 37 percent of total inflow through a single weir (G-603), while cell 5 (253 ha) receives the remaining inflow through two weirs (G-601 and G-602). Both treatment cells have three outflow culverts. For a detailed description of the layout and operation of STA-6, refer to the STA-6 Operation Plan (SFWMD, 2002). Current performance data are presented in Chapter 4A of the 2003 ECR.

Since STA-6 began flow-through operations in December 1997, outflow TP concentrations have averaged 19 µg/L, well below the design target of 50 µg/L, despite the fact that the hydraulic load to this wetland has been two to three times greater than anticipated. As a result, the nominal HRT for each treatment cell (cell 3 = 5.4 days; cell 5 = 8.5 days) (Huebner, 2001) was substantially less than the nominal HRT for STA-1W, which ranged from 17 to 25 days. In addition to high hydraulic loading, STA-6 has dried out for two to three months during the summer each year since it began operation. In June 2001 the District initiated a 12-month study to evaluate the potential for nutrient release from dried STA-6 soils upon reflooding.

HISTORICAL OPERATIONS AND SOIL TYPES

Prior to its conversion to an STA, U.S. Sugar Corporation used STA-6 as a stormwater detention area from 1988 to 1997. The system had one inflow pump station (G-600) that discharged water into the northwest section of cell 5 and moved in sheet-flow fashion into cell 3 through culverts in the interior levee. In 1997 the perimeter levees were heightened and the culverts in the interior levee were closed, creating two separate, parallel flow-ways. The direction of flow is now from west to east instead of the historical north-to-south direction. The soils are classified as mucks and sands. Based on sediment core data, STA-6 has markedly lower TP, TN, TC and organic content, as well as higher sediment bulk density, than the other STAs. This is indicative of a more highly mineralized sediment. The data further suggest that STA-6 soils are stable and should not readily release P into the water column. Additional details regarding the sediment data and analyses can be found in Jorge et al. (2002).

DATA COLLECTION AND ANALYSIS

As part of the STA Optimization Program, water quality and vegetation samples were collected from STA-6 to assess and optimize TP removal in this wetland. An evaluation of STA-6 performance, including calculation of TP load and concentration reductions for WY01–02, is presented in Chapter 4A of the 2003 ECR.

METHODS

Weekly flow-weighted composite water samples from the G-600 inflow structure and the G-354C and G-393B outflow structures are analyzed for TP as part of STA-6 permit requirements (see Chapter 4A). In addition, biweekly grab samples are collected from these structures and are analyzed for TP, SRP, TKN, total suspended solids (TSS), turbidity, NH_4, color, DO, conductivity, pH and temperature. Daily outflow water samples were collected for a four-week period following the annual summer dryout and were analyzed for TP concentration.

Vegetation samples were collected in November 2001 from eight 1-m^2 quadrants in cell 5 and from three 1-m^2 quadrants in cell 3. All samples were analyzed for dry weight, ash-free dry weight, TP, TN, TC, cellulose and lignin.

Duplicate 30-cm cores were collected from three locations in cell 3 using a 5.1-cm diameter corer in September 2001. These samples augmented cores collected from cell 5 in October 2000 (soil cores were not collected from cell 3 on this date because water depth was too low to allow airboat access). Cores were shipped on ice to the laboratory, where they were divided into 0-to10-cm and 10-to-30-cm sections. The duplicate cores for each depth section were combined and analyzed for bulk density, TP, TN, TC, percent moisture and loss on ignition. Additionally, the 0-to-10-cm sections were analyzed using an inorganic P fractionation scheme (White and Reddy, 2001).

Mean daily inflow at inlet weirs G-601, G-602 and G-603 and at outlet weirs G-354A through C and G-393B was computed using standard weir equations and differences in headwater and tailwater stage (Huebner, 2002). Inflow through the G-600 pump was computed using pump performance curves. Seepage was estimated using seepage coefficients, the length of the seepage boundary, and hydraulic head difference. Cell depths were computed based on stage elevations (NGVD) minus nominal cell elevations (NGVD).

RESULTS

An evaluation of annual treatment performance for STA-6 in WY01–02 can be found in Chapter 4A of the 2003 ECR.

Hydraulic Performance

Mean annual water depths in cells 3 and 5 for WY01–02 were 49.4 and 47.4 cm, respectively. Mean water depths in these cells during the wet season were 60.0 and 57.2 cm, respectively, greater than mean water depths during the dry season (**Table 4B-7**). Inflow to cell 5 during WY01–02 was 40.7 hm^3, which was substantially greater than cell 3 inflow (25.9 hm^3). Inflow HLRs were 4.4 and 7.1 cm/d for cells 5 and 3, respectively. Outflow from cell 5 during WY01–02 (35.2 hm^3) was also greater than outflow from cell 3 (17.9 hm^3). Seepage from STA-6

was 13.5 hm^3. The seepage rate in cell 5 was three times greater than in cell 3. Seepage from cell 5 was about 26 percent of surface inflow volume to this cell (Huebner, 2002).

Table 4B-7. Average water depth in STA-6 during water year 2001–2002

Treatment Cell	WY01-02 (cm)	Wet Season (cm)	Dry Season (cm)
Cell 3	49.4	60.0	41.8
Cell 5	47.4	57.2	40.4

Rehydration Response

STA-6 dried out twice in WY01–02. The first dryout began in March 2001 following a prolonged period of drought; the second dryout began in May 2001. Rainfall totaled 13.1 cm during the first dryout and 33.2 cm during the second dryout. The mean inflow TP concentration during the first rehydration period following the dryout was 149 μg/L, which was about equal to the mean inflow TP concentration of 151 μg/L during the second rehydration period. Mean outflow TP concentration was 85 μg/L during the first rehydration and 51 μg/L during the second rehydration.

Vegetation

STA-6 has an emergent plant community. Sawgrass (*Cladium jamaicense*) and willow (*Salix* spp.) are dominant in cell 3, with isolated stands of pickerelweed (*Pontederia cordata*), duck potato (*Sagittaria* spp.) and milk vine (*Mikania* sp.). Cell 5 is dominated by paragrass (*Brachiaria purpuranscens*), torpedo grass (*Panicum repens*) and switch grass (*Panicum virgatum*), with scattered areas of cattail, other emergent species, and open water with floating periphyton mats. This vegetation assemblage in STA-6 most likely developed in response to the mineral sediment, low-inflow TP concentrations and repeated dryouts.

Sediment

Mean sediment bulk densities ranged from 0.3 to 1.3 g/cm^3 (**Table 4B-8**). All sediment nutrient values were corrected for bulk density and were reported as nutrient mass per unit volume of sediment. Mean sediment TP concentrations from the top 10 cm of cell 3 (79.1 g/m^3) were less than the mean concentration of 106.8 g/m^3 in the upper sediments of cell 5 (**Table 4B-8)**. Annual sediment samples of the upper 10 cm of STA-6 will be collected and analyzed for nutrient content in an effort to quantify the system's long-term nutrient storage.

Table 4B-8. Mean nutrient concentrations in sediments collected in STA-6. Cell 5 was sampled in October 2000, and cell 3 was sampled in September 2001[a]

	0-10 cm Core Section		10-30 cm Core Section	
Parameter	**Cell 3**	**Cell 5**	**Cell 3**	**Cell 5**
Moisture (%)	71.5 (14.8)	58.8 (10.9)	44.0 (14.8)	33.0 (10.3)
Bulk Density (g/cm^3)	0.3 (0.2)	0.5 (0.2)	0.8 (0.3)	1.3 (0.3)
TP (g/m^3)	79.1 (11.7)	106.8 (24.6)	87.9 (17.5)	77.0 (25.7)
TN (g/m^3)	5.3 (2.5)	6.2 (1.8)	5.8 (2.5)	5.4 (1.4)
TC (g/m^3)	66.9 (27.0)	81.7 (22.1)	66.6 (26.1)	74.9 (22.8)
Loss on Ignition (%)	42 (26)	22 (11)	20 (15)	7 (5)

[a]Standard deviations are shown in parentheses.

SUMMARY

Seepage from STA-6 was estimated to be 19 percent of inflow. Estimated seepage from cell 5 was 26 percent of inflow, which was about twice the seepage rate calculated for cell 3 (12 percent of inflow). While cells 3 and 5 were dominated by emergent vegetation, sawgrass dominated cell 3, with little or no periphyton mats. Cell 5 was dominated by paragrass, torpedo grass and periphyton mats in the open water areas. Historically, STA-6 sediment had a higher mineral content and bulk density compared to other STAs. However, STA-6 may be accreting an upper layer of low-density peat material.

FUTURE MONITORING

The District will continue biweekly water quality monitoring of both treatment cells in STA-6 to increase operational knowledge of this wetland and provide data in support of efforts to optimize treatment performance. The District has implemented several changes to the STA-6 monitoring program. The changes include the following: (1) the installation of autosamplers at the inflow to cells 5 and 3; (2) the addition of Ca, alkalinity and TDP to the list of parameters monitored in biweekly grab samples; (3) the initiation of annual vegetation and soil monitoring within each cell; (4) the installation of shallow wells at inflow and outflow locations in both cells to measure porewater nutrients and groundwater depth during periods of inundation and dryout.