Chapter 4: Stormwater Treatment Areas and Advanced Treatment Technologies

Jennifer Jorge, Jana Majer Newman, Michael J. Chimney, Gary Goforth, Tim Bechtel, Guy Germain, Martha K. Nungesser, Darren Rumbold, Jose Lopez, Larry Fink, Binhe Gu, Ron Bearzotti, Drew Campbell, Christy Combs, Kathy Pietro, Nenad Iricanin and Richard Meeker

CHAPTER ORGANIZATION

As part of the restructuring of the Everglades Consolidated Report (ECR), Chapter 4 now includes all information pertinent to Stormwater Treatment Areas (STAs) that in previous versions of the ECR was provided in Chapters 4, 6, 7 and 8 (SFWMD, 2000a). The new Chapter 4 is organized into three sections, as follows:

- STA Performance and Compliance (Chapter 4A)
- STA Optimization (Chapter 4B)
- Advanced Treatment Technologies (ATTs) (Chapter 4C).

This chapter is written strictly as an update to Chapters 4, 6, 7 and 8 of last year's ECR. As in the other chapters of this Report, this chapter emphasizes information for the period May 1, 2000 through April 30, 2001.

SUMMARY AND FINDINGS

STA PERFORMANCE AND COMPLIANCE

An overview of the STA operations, vegetation, phosphorus performance and water quality compliance is presented in this section for each of the STAs. Water quality parameters addressed include nutrients, dissolved oxygen, pesticides and mercury. Appendices provide additional details of the monitoring program required by state operating permits.

STA Performance and Compliance Findings

- Four of the six STAs are fully operational and are removing phosphorus that otherwise would have gone into the Everglades Protection Area. During Water Year 2001, STA-1W, STA-5 and STA-6, Section 1 treated more than 219 cubic hectometers (177,100 acre feet) and removed more than 24 metric tons of phosphorus, for an overall 65-percent removal rate. Two cells of STA-2 were fully operational in WY2001; however, dry conditions eliminated the need for significant flow-through operations.

- Drought conditions during Water Year 2001 were responsible for lower than anticipated average inflows to the STAs. Supplemental water deliveries were required to three of the STAs to maintain minimum water levels to ensure viability of the treatment vegetation.

- The composition of the plant communities in the STAs varies among the treatment cells in the project, but is generally dominated by either cattail (*Typha sp.*) or submerged aquatic vegetation (SAV) and periphyton.

- Water quality monitoring within and downstream of the STAs demonstrated that the four STAs in operation are in full compliance with state operating permits.

- Unfiltered water concentrations of methylmercury (MeHg) and total Hg (THg = inorganic Hg + MeHg) in the inflows and outflows of STA-1W, STA-5 and STA-6 were highly variable, with occasional periods of net export. STA-6 is in the post-stabilization period of operation and appears to be removing roughly 25 percent of the THg and MeHg present in the inflow on an annual average basis.

- While STA-2, Cells 2 and 3, met their startup criteria in September and November 2000, respectively, Cell 1 still had not done so at the end of this reporting year. The District reported anomalously high levels of MeHg in interior water in STA-2, Cell 1 in October 2000. A followup study detected anomalously high levels of THg in mosquitofish, but Cell 1 dried out before sunfish sampling could commence. Nevertheless, the District inferred from the mosquitofish data that these concentrations could represent an unacceptable risk of toxic effects to fish-eating birds preferentially foraging in Cell 1. In August 2001, the District was issued a permit modification to allow Cell 1 to operate in a flow-through mode, which is expected to reduce the MeHg production and bioaccumulation rates by altering cell hydrology and surficial soil chemistry. Expanded monitoring will ensure that performance relative to this expectation is properly addressed.

- In STA-5, which is still in its stabilization period, THg concentrations in mosquitofish, sunfish and largemouth bass were highly variable at all sites and showed differences between treatment trains, but were less than those at the Everglades "hot spot" in WCA-3A. Nevertheless, levels of Hg in STA-5 fish remain at or above guidance levels developed by the USEPA and the USFWS for the protection of fish-eating wildlife.

STA OPTIMIZATION

Research into optimization of the STAs has continued over the past year. The 2000 and 2001 ECR (SFWMD, 2000a; SFWMD, 2001a) contained detailed analyses and information on the state of knowledge about the Everglades Nutrient Removal Project (ENRP) and STAs. This chapter updates ongoing research and summarizes new findings completed since last year's report.

The Everglades Forever Act (EFA) (Section 373.4592, Florida Statutes) requires the District to conduct research and monitoring programs to optimize nutrient removal performance of the STAs. Information is derived from practical experience operating the STAs and analyzing performance data, from experiments being conducted in some of the STA-1W test cells, from small-scale mesocosm experiments, from analysis of data available from other wetlands and eventually through simulation of operational scenarios using a dynamic water-quality model.

The primary focus of STA Optimization Research this year has been to assess the performance of the STA-1W treatment cells, conduct controlled experiments in the test cells, perform marsh dryout experiments in mesocosms and improve the hydraulic performance of treatment Cell 4.

- From August 1994 through April 2001, STA-1W has retained approximately 95 metric tons of TP that otherwise would have entered untreated into the Everglades. The value includes all the TP reported as having been retained by the old ENRP.
- Experiments conducted in the STA-1W test cells that received post-farm (i.e., post-Best Management Practices [BMP]) water indicated that more than a two-fold reduction in TP loading to these cattail-dominated systems did not result in outflow TP concentrations lower than levels observed in the existing STAs. The proportionate change in TP loading was equated to increasing wetland surface area by the same factor. There was no improvement in outflow TP concentrations in experiments conducted at the south test cells.
- Experiments conducted in the STA-1W north test cells found a marked decrease in TP removal when hydraulic loading rates (HLR) reached 10.4 cm d^{-1}, a level four times greater than the design average HLR for the STAs. There were no apparent differences in outflow TP concentrations in any of the high-HLR experiments conducted at the south test cells.
- The Marsh Dryout Study found that the muck soils tested always released sediment P upon reflood after a dryout. Differences in the magnitude and duration of the P flux were related to the history of P loading. Most of the P released into the water column after reflood either was in particulate or dissolved inorganic forms.
- Chemical analysis of sediment cores collected from STA-6 suggested that these soils should not readily release P into the water column upon rehydration after a dryout, and in fact may act as a nutrient sink.
- The Dynamic Model for Stormwater Treatment Areas is under development to enhance our understanding of how the STAs function, evaluate alternative long-term water-quality solutions for the Everglades Protection Area (EPA) and improve the management and design of the next generation of STAs that are part of the Comprehensive Everglades Restoration Plan.

ADVANCED TREATMENT TECHNOLOGIES

The District has embarked on an ambitious research program for testing the feasibility of several Advanced Treatment Technologies (ATTs) for the removal of TP from waters entering Florida's Everglades. The goal of this research program is to identify technologies that will meet the long-term water quality objectives for the Everglades, in accordance with the EFA. The criteria being used to evaluate these treatment technologies are also provided by the EFA: TP load reductions; TP discharge concentration reductions; distribution and timing of water delivery to the EPA; compliance with water quality standards; compatibility of treated water with natural populations of aquatic flora or fauna in the EPA; cost effectiveness; and schedule for implementation. Other evaluation criteria may include, but not be limited to, technical/scale-up feasibility, possible adverse environmental impacts and local acceptability. The goal of the current studies is to provide information on TP removal performance, estimated costs and the ability of the technology to meet the EFA's requirement so that "…discharges into the Everglades Agricultural Area (EAA) canals and the EPA prevent an imbalance in the natural populations of aquatic flora or fauna in the EPA and provide a net improvement in the areas already impacted."

Based on ATT research to date, it is clear that there are two types of treatment technologies that may be used to meet the long-term water quality requirements of the Everglades:

- *Biological Technologies*: Submerged Aquatic Vegetation (SAV) and periphyton-based Stormwater Treatment areas (PSTA)

- *Chemical Treatment Technologies:* Managed Wetlands (MW), Low Intensity Chemical Dosing (LICD), Microfiltration (MF), Chemical Treatment/Solids Separation (CTSS) and other chemical treatment-derived vendor technologies.

Refer to **Table 4C-1** for a complete summary of all ATTs researched, the scale of the experiment and future research/demonstration plans. In addition, **Table 4C-2** summarizes the best performance to date for each ATT and provides additional experimental information.

It is expected that research and optimization of promising ATTs will continue at least until the TP criterion and method of compliance are established by the Florida Department of Environmental Protection (Department) and the Environmental Regulatory Commission. The findings from each ATT project are summarized below.

Submerged Aquatic Vegetation/Limerock (SAV/LR)

The Submerged Aquatic Vegetation study during the last year has focused on key mesocosm experiments and evaluation of TP removal at the field scale. Changes in water depth had no significant effects on TP removal performance. High calcium (Ca) and alkalinity treatments were more effective in the removal of soluble reactive phosphorus (SRP) than low Ca and alkalinity treatments. Limerock or limerock berms provided slightly better TP removal than systems without these components. SAV has expanded vigorously in STA-1W, Cell 5, since inoculation, which took place in September 1999, suggesting that limited introduction of plants will enhance colonization.

Periphyton-based Stormwater Treatment Area (PSTA)

TP concentration reduction in periphyton-STA (PSTA) mesocosm experiments was inconclusive regarding the superiority of peat versus shellrock substrates. Preliminary evidence suggested that the vegetation was the major P storage compartment. The PSTA test cell research clearly showed that a peat-based periphyton system, even amended with Ca, is not as efficient at reducing P as the shellrock system.

Managed Wetlands Treatment System (MWTS)

The Managed Wetlands Treatment system (MWTS) reduced P outflow relative to the control wetlands. No redissolution of P from settled solids was detected, verifying that a pond-based treatment system sized for solids storage would provide effective P removal. Flocculent (floc) overflow occurred and was controlled by the treatment marsh. The marsh buffered hardness, aluminum (Al) and iron (Fe) concentrations as the water flowed through it. The residuals produced were found to be nonhazardous by standard testing procedures. There was no apparent bio-toxicity associated with the outflow waters.

Low Intensity Chemical Dosing (LICD)

Preliminary results of the Low Intensity Chemical Dosing (LICD) study indicated that this treatment technology was not able to improve upon TP concentration reductions of a passive cattail-marsh wetland. Additionally, results of a study performed by Duke University showed that even at high coagulant doses of about 20 mg L^{-1}, the LICD system had TP outflow concentrations of 20 to 30 µg L^{-1} and was not able to reach the planning target of 10 µg L^{-1}.

Chemical Treatment/Solids Separation (CTSS)

Given the potential major economic impact associated with Chemical Treatment and Solids Separation (CTSS) technology, additional research is needed to determine viable methods of metal salt recovery. Capital and operational costs, residuals management and water quality compatibility are the major concerns for full-scale implementation. Based on scale-up costs estimated from the pilot projects, CTSS is more cost effective with higher TP concentration inflow water, about $68/kg ($150/lb) P removed (post-BMP) versus $172/kg ($380/lb) P removed (post-STA). Based on the 10-year POR flow data used for developing the facility conceptual design, CTSS coupled with a flow-equalization basin can attenuate peak hydraulic flows and consistently produce outflow TP concentrations of 10 µg L^{-1}.

Chemical Treatment/Microfiltration

Chemical treatment combined with microfiltration for solids separation is a viable technology consistently producing outflow TP concentrations of 10 µg L^{-1}. Microfiltration without chemical addition did not produce outflow TP concentrations of 10 µg L^{-1}.

An evaluation of this technology indicated there has been a steady advancement in configuration, membrane composition, membrane technology, market conditions and availability that changed capital and operational costs considerably. As a result of these advancements, the capital and operational costs developed in 1998 were updated in 2001 showing that, costaveraged, [$85.4/Kg, $188/pound] of TP removed (post-BMP) versus [$185/Kg, $408/pound] of TP removed (post-STA).

Future Research

Research continues to address: (1) the effects of hydrologic pulsing, system dry-out, water depth and antecedent P soil concentrations on P removal; (2) constructability; (3) optimal partitioning of vegetation within treatment areas; (4) sustainability of long-term treatment; and (5) treatment effectiveness on urban stormwater. In addition to the ongoing ATT demonstration projects (descriptions of which can be found in Chapter 4C), the District and FDEP will be working together via a cooperative agreement to address the TP removal performance of sequenced biological treatment trains (emergent vegetation followed by SAV and PSTA) and the effects of pulse loading and compartmentalization. These experiments will take place at the 30 test cells located in STA 1-W. For next year's Everglades Consolidated Report, the District will have available the data from the Standard of Comparison for SAV and PSTA.

Funding

No dedicated funding has been identified for implementation of STA optimization measures, nor for the implementation of ATTs that might be necessary by year 2006 to meet long-term water quality standards for waters discharging into the EPA.