Chapter 8: Advanced Treatment Technologies for Treating Stormwater Discharges into Everglades Protection Area

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SUMMARY AND FINDINGS

The South Florida Water Management District (District) has embarked on an ambitious research program for testing the feasibility of several advanced treatment technologies (ATTs) for the removal of phosphorus from waters entering Florida's Everglades. The goal of this research program is to identify technologies that will meet the long-term water quality standards for the Everglades, as stipulated in the 1994 Everglades Forever Act (Act) (Section 373.4592, Florida Statutes).

Per the mandates of the Act, the same criteria are being used to evaluate these treatment technologies: phosphorus load reductions; phosphorus discharge concentration reductions; water quantity, distribution, and timing for the Everglades Protection Area (EPA); compliance with water quality standards; compatibility of treated water with the balance in 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, local acceptability, and marsh readiness of the outflow waters. All ATTs must be effective at basin scale, i.e., they must be able to treat the runoff generated from within the Everglades Agricultural Area (EAA) basin during storm events. The goal of the current studies is to provide information on phosphorus removal performance, estimated costs, and the ability of the technology to meet Act's requirement so that "…discharges into the 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".

It is expected that research and optimization of promising ATTs will continue at least until the P criterion and method of compliance are established by the Florida Department of Environmental Protection (Department) and the Environmental Regulatory Commission. Below, the findings to date of each ATT being investigated are summarized. However, insufficient information exists to draw definitive conclusions regarding: (1) the effects of hydrologic pulsing, system dryout, 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. Ongoing research will seek to address these issues. To date, no dedicated funding has been identified for implementation of ATTs to meet the long-term water quality standards for water going into the Everglades Protection Area.

Periphyton-based Stormwater Treatment Area (PSTA)

- Preliminary research indicates that PSTA monthly mean outflow TP concentrations ranged from 13-20 ppb.
- PSTA Phase 1 results have shown that a periphyton community can be established and sustained in post-STA water. PSTA peat-based systems are more rapidly colonized by macrophytes indicating that a limerock substrate less prone to macrophyte colonization may be necessary to support a viable PSTA system. There are additional costs involved in either placing a limerock cap or scraping the peat from a cell. Since there are substantial cost savings possible if a viable periphyton system could be created on peat, ongoing research is continuing to consider ways to make this construction approach more viable.
- Preliminary data indicates that PSTA wet sediment accretion represents about 1.5 cm/yr.

Submerged Aquatic Vegetation/Limerock (SAV/LR)

- Mean outflow TP concentrations of 15 ppb were achieved in SAV/LR in mesocosms with a hydraulic residence time of 7 days.
- During 1998-99, average outflow TP concentrations from STA-1W, Cell 4, an SAV-dominated cell, was 14 ppb.
- To date, harvesting of SAV biomass has provided no long-term enhancement of P removal performance. Additionally, short-term increases in outflow TP levels following harvest suggest that this management practice is not desirable for SAV systems designed for low-level P removal.
- SAV grown on muck substrate appears more robust than the SAV growth in either sand or limerock substrates, indicating that muck removal to expose a limerock substrate (or limerock placement over muck) does not enhance SAV growth.
- SAV colonization is possible in large-scale treatment wetlands created from farm fields. Evidence also suggests that a stable SAV community can persist longer than four years with relatively little long-term vegetation management.

Chemical Treatment/Solids Separation (CTSS)

- The CTSS treatment can produce a settled, clarifier effluent of less than 10 ppb of TP on EAA surface waters using either ferric chloride or alum as coagulants. The principal unit processes responsible for these results were chemical coagulation, flocculation and inclined plate enhanced clarification. Further investigation for full-scale implementation is warranted.

- Bioassay and algal growth potential (AGP) studies conducted on representative CTSS inflow and effluent samples demonstrated that the CTSS does not have a significant adverse impact on receiving waters. The CTSS process reduces the alkalinity, color and pH of treated waters and use of an effluent buffer cell has been suggested for incorporation in to the full-scale design for effluent conditioning.
- Residual solids produced by the CTSS process contain no hazardous constituents as defined by the toxicity characteristic leachate procedure. Full-scale conceptual designs have included recommendations for direct application of residual solids on land adjacent to the treatment facilities.
- Further research is needed to address issues such as marsh readiness and water quality after chemical treatment, residual disposal and possible system optimization and cost savings by reducing and/or recycling chemicals.
- Several vendor technologies (DensaDeg® high-rate solids contact clarification process by Infilco Degremont, Actiflo® micro-sand enhanced flocculation and settling process by Kruger, and the CoMag® technology by Micromag, a magnetite seed chemical treatment) significantly reduced outflow TP concentrations. Further evaluation would be required prior to full-scale implementation.
- Several technologies and treatment processes, including dissolved air flotation, direct in-line filtration, direct filtration and activated alumina treatment proved ineffective at reducing the TP content of the EAA stormwaters and no further testing of these technologies is recommended.

Low-Intensity Chemical Dosing (LICD)

- LICD Phase I results indicated that LICD reduced total dissolved phosphorus concentrations by 33-50 percent. However, metal bound P particles did not settle, and therefore, TP outflow concentrations exceeded 10 ppb.
- Preliminary results from LICD Phase II study indicate that with the addition of polymers and improved mixing, settling rates are improved and TP levels averaging as low as 12-28 ppb may be achieved.

Managed Wetlands Technology System (MWTS)

- Preliminary MWTS results indicate that iron and aluminum metal salt additions will reduce inflow phosphorus concentrations. During startup, phosphorus levels have been reduced from an average inflow of 95 ppb to 49-73 and 36-50 ppb for iron and aluminum salts, respectively, at the north test cells. Further reductions are anticipated after adjustments are made to dosing rates, mixing times, and hydraulic loading rates. This performance optimization may yield chemical treatment effluent with TP concentrations comparable to those of CTSS.

INTRODUCTION

The Everglades Forever Act of 1994 (Act) requires that the Florida Department of Environmental Protection (Department) and the South Florida Water Management District (District) design and conduct the Everglades Program, a series of 56 projects, including research, regulation, and construction activities to restore the Everglades. The Department is directed to initiate a rule-making to establish a numerical phosphorus criterion and review the Florida Class III Water Quality Standards and method of compliance for phosphorus (P) entering the Everglades Protection Area (EPA) by December 31, 2001 (Chapter 3). If rule-making is not completed, and a P standard is not established by the Department by December 31, 2003, the Act establishes a 10 parts per billion (ppb) default P criterion. Other responsibilities established by the Act require the Department to establish a relationship between discharge levels and water quality in the EPA, and the District and Department to use this relationship to set a limit for discharges into the EPA.

Additionally, the Act directs the District and Department to initiate research and monitoring to generate sufficient water quality data to evaluate the effectiveness of both constructed wetland treatment systems, known as stormwater treatment areas (STAs) (Chapter 6), and on-farm Best Management Practices (BMPs) (Chapter 5) for improving water quality. This information will be used to begin the selection of the most promising technologies to meet the final P standard, and will be included in the water quality plan required by the Act by December 31, 2003 (Chapter 1). The ultimate combination of approaches will also need to consider the site-specific conditions that could affect the successful implementation and performance of the treatment train.

Interim efforts of the Everglades Construction Project are centered on land acquisition and construction of six STAs. Long-term efforts are focused on identifying, demonstrating and implementing ATTs to achieve the long-term criterion to be set by the Department through its rule-making process. Because the phosphorus (P) removal goals likely will be lower than what the STAs can achieve alone, the District, Department, United States Army Corps of Engineers (USACE), and Everglades Protection District (EPD) are developing and evaluating ATTs for reducing P levels to meet a planning goal of 10 ppb. Research on ATTs began in 1997 with the Microfiltration Project (conducted by the Department), Low-Intensity Chemical Dosing (conducted initially by the Everglades Agricultural Area Environmental Protection District, currently by the Department) and a combined Chemical Treatment/Solids Separation Project (conducted by the District). In 1998, the District began work on the Submerged Aquatic Vegetation/Limerock, Managed Wetlands Treatment System, and the Periphyton Stormwater Treatment Area demonstration and research programs. Each of these treatment technologies is explained in detail in this chapter. Research and optimization of promising technologies will continue until a final phosphorus criterion and method of compliance is established by the Department and the Environmental Regulatory Commission.

IMPACTS OF SECTION 404 PERMIT

The USACE Section 404 permit contains several conditions that have significantly influenced the level of effort and schedule for the ATT program. Specifically for STA-2, because of the pristine areas within Water Conservation Area (WCA) 2A, there is a requirement that if adverse impacts should be documented, then special condition No.1(b)6 requires the District to make best efforts to implement additional water quality measures for STA-2 by the end of the fourth year of operation after first discharge. The 404 permit specifies first discharge as the date of the first flows across the degraded east L-6 Levee into WCA-2A. This could result in the requirement to implement additional water quality strategies (i.e., ATTs) by 2003, three years earlier than the implementation date of December 31, 2006 specified by the Act (Chapter 1). However, the District, with support from the Department and USACE, will reroute the discharge to minimize the impacts of STA-2 discharges to WCA-2A. In addition, special condition No. 5 requires the development of a strategy to achieve the final state water quality standard for P by January 1, 2001. This Everglades Consolidated Report is submitted to fulfill the Section 404 permit conditions referring to strategies or plans. Finally, special condition No. 7 includes a list of eight potential ATTs to be investigated for potential use in meeting the long-term water quality standards by the 15 urban and agricultural basins discharging water into the Everglades. The District, and/or its partners, is investigating all of these technologies.

ADVANCED TREATMENT TECHNOLOGIES UNDER INVESTIGATION

In 1996, the District completed a comprehensive evaluation of promising water quality treatment technologies, ranging from constructed wetlands that require fairly low maintenance to full chemical treatment for the removal of P (PEER Consultants and P.C./Brown and Caldwell, 1996). These technologies were evaluated on the basis of projected nutrient removal performance, costs and compatibility with environmental criteria. The evaluation confirmed that STAs were the best interim step toward achieving the long-term water quality and hydropattern restoration goals for the Everglades. Additionally, several ATTs were identified for further investigation on if, and how, they could be used for meeting long-term water quality standards for discharge into the Everglades.

The District, and/or its partners, has initiated demonstration studies on eight technologies required by the USACE 404 permit to further determine critical design criteria, such as performance efficacy, hydrologic operating characteristics, capital and operating costs, and identification of potential environmental impacts. Some of these have the potential of both on-farm treatment of hot spots and regional application. These technologies include the following:

- Periphyton-based STAs (PSTAs)
- Submerged Aquatic Vegetation/Limerock

- Chemical Treatment/Solid Separation (Chemical Treatment/Direct Filtration, Chemical Treatment/High-Rate Sedimentation, Chemical Treatment/Dissolved-Air Flotation, Chemical Treatment/Microfiltration)
- Low-Intensity Chemical Dosing
- Managed Wetlands.

Demonstration and research projects are ongoing at various locations within STA-1W and adjacent to STA-2. Small-scale mesocosm and pilot scale studies are located at the north (post-BMP) and south (post-STA) ATT sites at STA-1W (**Figure 8-1**). Larger scale studies are also being performed at the test cells; half-acre, lined wetlands located within Cells 1 and 3 of STA-1W. Refer to Chapter 6 of this volume and Chimney et al. (2000) for a complete description of the test cells. Additional field scale projects and studies are located in Cells 4 and 5 of STA-1W and in a 15-acre area adjacent to STA-2. Each technology has a scientific review panel, and analyses are subject to review by the Department, interested agencies, professional peers and public input.

All studies analyze water samples for a large set of parameters (Table 6-6, Chapter 6). However, phosphorus (as the nutrient of most concern) will be the focus of this chapter. Phosphorus in water exists in four main forms: dissolved inorganic, dissolved organic, particulate organic, and particulate inorganic. A complete set of definitions of phosphorus forms is provided in the Glossary.

Generally, three chemical analyses of water samples are used to characterize the forms of phosphorus in the water column: total phosphorus (TP), total dissolved phosphorus (TDP), and soluble reactive phosphorus (SRP). Total phosphorus is comprised of dissolved inorganic phosphorus (DIP), dissolved organic phosphorus (DOP), and particulate phosphorus (PP). Total dissolved phosphorus (TDP) includes only the dissolved organic and inorganic fractions. Soluble reactive phosphorus (SRP) is an operationally defined parameter that estimates dissolved inorganic phosphorus. SRP is the most readily bioavailable fraction of the phosphorus forms. From these three analyses, DOP and PP are calculated. DOP is the difference between TDP and SRP, and PP is the difference between TP and TDP.

Additionally, forms of phosphorus can also be divided into two large categories, labile and recalcitrant. Labile phosphorus is defined as the P that exists as easily assimilable forms of P (also includes forms that are easily mineralized); recalcitrant P encompasses tightly bound forms of P that are not readily bioavailable (or mineralized).

The long-term goal of the Everglades Program is to combine point source control, basin-level and regional solutions in a system-wide approach to ensure that all waters discharged into the Everglades Protection Area meet the numeric phosphorus criterion and other applicable state water quality standards by December 31, 2006. It is anticipated that conceptual engineering plans will be developed by September 2003 to provide the information for these permit applications and water quality improvement plans.

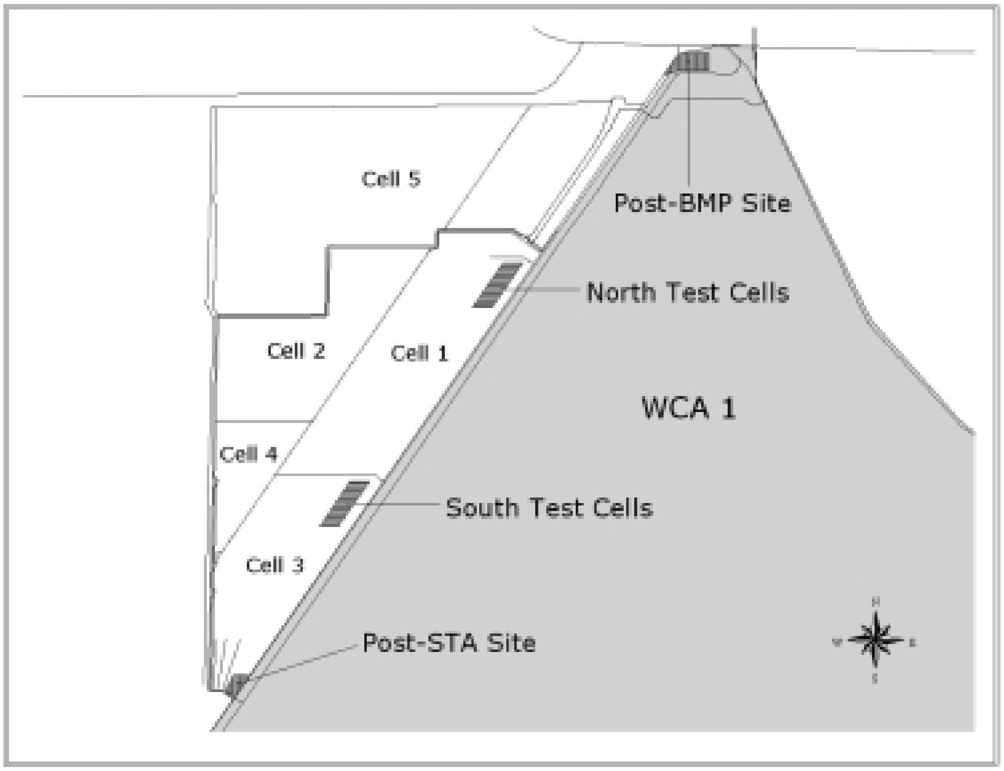

Figure 8-1. Schematic indicates the relative locations of the North and South test cells and Post- BMP and STA sampling locations.

As soon as sufficient information is obtained from the Best Management Practices (Chapter 5), STA optimization (Chapter 6), Advanced Treatment Technology research (this chapter), and the Everglades Stormwater Program regulatory action strategy (Chapter 11), the District will evaluate the feasibility of alternative water quality solutions for each of the basins that discharge into the Everglades Protection Area. These basin-specific feasibility studies will integrate information from research, regulation, and planning to determine the basin-specific optimal combination of BMPs, optimized STAs, and ATTs to meet the final water quality objectives. For planning purposes, an end-of-pipe discharge limit of 10 ppb will be assumed. See Chapters 1 and 11 for additional details on the basin-specific feasibility studies.

PERIPHYTON-BASED STORMWATER TREATMENT AREAS (PSTAs)

In this ATT, post-STA water flows over a substrate colonized primarily with calcareous periphyton (attached algae) and sparse macrophytes, the latter primarily functioning as additional substrate and a stabilizing mechanism for the algal mats. Phosphorus is removed from the water column through biological uptake, chemical adsorption, and algal mediated co-precipitation with calcium carbonate within the water column (**Figure 8-2**).

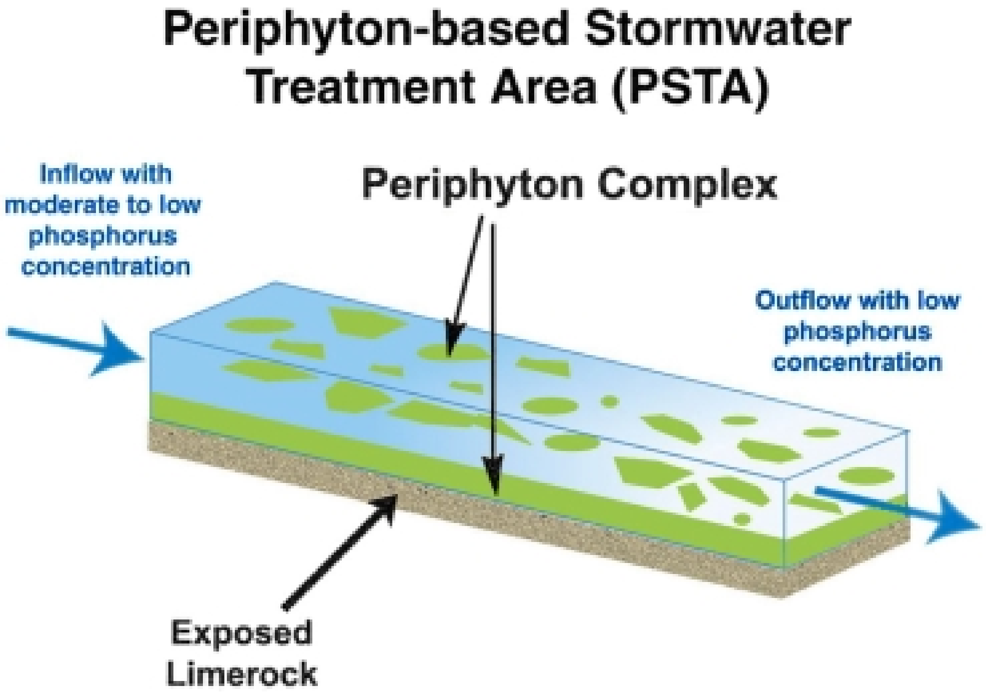

Figure 8-2. Schematic of the Periphyton-based Stormwater Treatment Area Advanced Treatment Technology.

The PSTA takes advantage of natural processes to sequester phosphorus. However, unlike the chemical treatment systems, there are no historical data on large-scale construction, operation or removal capacity of PSTA technology. Therefore, the research focus of this concept includes the long-term performance and stability of an algal-based system, the level of required maintenance, and macrophyte control needed to prevent shading of the periphyton community (SFWMD, 2000). At least two years of field-testing will be required to obtain information on the feasibility and functionality of this concept for scale-up design and operation. This section summarizes the results from the first year of mesocosm and test cell research and then describes the design for the 15-acre demonstration project currently in startup.

Current Status of PSTA Research

PSTA research has been organized into two phases. Phase 1 was a proof-of-concept study conducted from February 1999 through March 2000, and it examined many variables at the mesocosm (fiberglass tanks) and test cell (0.5 acre constructed wetlands) scales. Phase 1 included startup and operation. Phase 2 was initiated in April 2000, and will address issues related to the construction and operation of a full-scale PSTA, as it expands the proof-of-concept studies to address the effect of seasonal factors on P removal.

Twelve mesocosm treatments were studied in Phase 1. Six of these were replicated treatments that examined the effects of hydraulic loading rate (HLR), water depth, and depth-width ratios, while the remaining unreplicated treatments examined the effects of substrate, wall effects in small-scale mesocosms, and presence or absence of vegetation (**Table 8-1**) (CH2M HILL, 2000b). Additionally, three unreplicated demonstration projects in the STA-1W south test cells (**Figure 8-1**) were started during Phase 1, and examined the effects of substrate, water depth, and HLR. Results are summarized below.

Table 8-1. Phase 1 treatments for the PSTA Project small-scale mesocosms. The replicated treatments examined water depth, depth-width ratios, and hydraulic loading rate and contained both periphyton and macrophytes. The unreplicated systems demonstrated controls for substrate, macrophyte and periphyton absence, and wall effects. Treatments 1 through 10 were completed in 6m L x1m W x1m H mesocosms, while treatments 11 and 12, which examined wall effects, were completed in 6m L x 3m W x1m H mesocosms.

Treatment	***Substrate***	***Water Depth (cm)***	***HL (cm/day)***	***Depth-Width Ratios***	***Vegetation Present***
Replicate Portable Mesocosm Experiments (3 mesocosms each treatment)					
1	Peat	60	6	0.6	Yes
2	Shellrock	60	6	0.6	Yes
3	Peat	30	6	0.6	Yes
4	Shellrock	30	6	0.3	Yes
5	Shellrock	60	12	0.6	Yes
6	Shellrock	0-60	0-12	0.3	Yes
Unreplicated Portable Mesocosm Demonstrations (1 mesocosm each treatment)					
7	Sand	60	6	0.6	Yes
8	Sand	60	6	0.6	Yes
9	Peat	60	6	0.6	No
10	Shellrock	60	6	0.6	No
11	Shellrock	30	6	0.1	Yes
12	Peat	30	6	0.1	Yes

At the initiation of mesocosm experimentation, a dye study was conducted to identify any short-circuiting and to provide information for the concurrent modeling effort. Based on the results obtained, the flows in the mesocosms can be characterized as between well-mixed and plug flow in both the shallow systems (30cm) and in the deeper systems

(60cm). Flows in the test cells can be characterized as completely well mixed (CH2M HILL, 2000b).

Phase 1 concluded in March 2000. Results have been analyzed for two periods: the entire period of Phase 1 and an “operational” period. The entire Phase 1 period began with system startup and system stabilization and included startup phenomena, such as periphyton and emergent colonization and growth, as well as a probable nutrient flux from the sediment. The “operational” period represented the time of operation after system stabilization, and began approximately five months after startup (July 2000). (CH2M HILL, 2000b).

Overall, Phase 1 work has shown that periphyton community can be established on shell rock and sustained in post-STA water and, generally, the monthly mean outflow TP concentrations were less than 15 ppb and have been below 10 ppb on a periodic basis (**Figure 8-3**). Specifically, preliminary results indicate that substrate, water depth, velocity and vegetation may be parameters to be considered in the design, construction, and long-term operation of PSTA systems. The mean annual TP outflow concentration for the entire Phase 1 period ranged from 16-18 ppb in the mesocosms and 19-21 ppb in the test cells. This corresponds to removal rates 7.1 to 34.3 percent in the mesocosms and 14.6 to 31.1 percent in the test cells. SRP concentrations are at the detection limit (2 ppb) in the inflow and outflow of both the test cells and mesocosms.

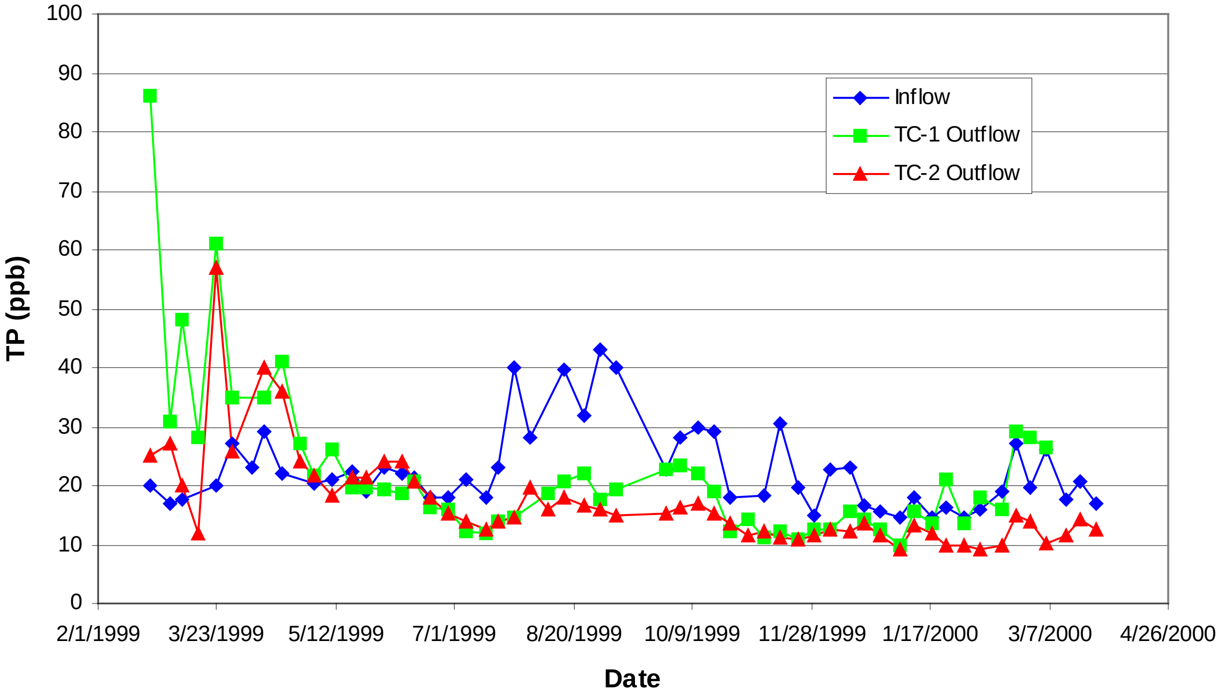

Figure 8-3. Phase 1 time series plot of total phosphorus concentrations in the PSTA test cells. The blue line with diamonds (inflow) represents the inflow concentration to all test cells, while the green line with squares (TC-1) represents the outflow from the peat-based cell and the red line with triangles (TC-2) represents the outflow from the shellrock-based cell (CH2M HILL, 2000b).

During the “operational” period, the P concentration range (and corresponding TP removal rates) were from 13 to 17 ppb (20.7 to 42.7 percent) and 13 to 18 ppb (22.3 to 43.2 percent) in the mesocosms and test cells, respectively. Generally, small phosphorus shifts from dissolved to particulate forms were seen at the outflow. TDP inflow and outflow for the mesocosms average 14 and 10 ppb, respectively. TDP inflow and outflow for the test cells average 12 and 11 ppb, respectively. Particulate phosphorus (PP) is that fraction adsorbed or absorbed on soil or sediment particles, and maybe comprised of both organic and mineral forms. This fraction is usually quantified by subtracting TDP from TP. PP inflow and outflow concentrations for the mesocosms average 6 and 8 ppb, respectively. PP inflow and outflow concentrations for the test cells average 9 and 8 ppb, respectively. The minimum monthly TP averages for all treatments ranged from 8 to 13 ppb, but these averages were not sustainable during this period of research. Considerable variation between replicates at the mesocosm scale was noted. This variation could be the results of stochastic factors, such as snail grazing and edge effects, which would not be seen in the larger scale systems. **Table 8-2** summarizes the treatment results.

Table 8-2. Phosphorus mass balance summary for Phase 1 in PSTA test cells.

Treatment		***Phase 1 -- Period of Record***				***Phase 1 -- “Operational” Period***			
		TP (ppb)		Removal		TP (ppb)		Removal	
		Inflow	Outflow	g/m^2/yr	%	Inflow	Outflow	g/m^2/yr	%
Mesocosms	1	19	16	0/08	15.7	20	14	0.19	27.5
	2	19	15	0.11	21.8	20	13	0.23	34.1
	3	22	16	0.17	28.0	25	15	0.31	38.9
	4	22	16	0.18	30.1	25	14	0.35	42.7
	5	22	17	0.31	26.8	25	17	0.56	35.0
	6	22	16	0.12	26.0	26	15	0.18	42.3
	7	22	16	0.17	29.2	25	15	0.31	40.3
	8	19	18	0.04	7.1	20	16	0.14	20.7
	9	22	18	0.14	21.0	26	20	0.19	20.8
	10	22	15	0.21	34.3	26	15	0.35	42.2
	11	22	18	0.15	24.6	25	16	0.30	36.9
	12	22	18	0.12	20.0	25	17	0.27	33.1
Test Cells	1	24	19	0.09	21.7	25	16	0.14	34.4
	2	23	16	0.12	31.1	24	13	0.17	43.2
	3	23	21	0.06	14.6	23	18	0.09	22.3

Design and construction issues are of particular importance due to the rapidly approaching deadlines established by the Everglades Forever Act, and preliminary research indicates the choice of substrate is critical in the construction of a PSTA. Three substrates were examined in the Phase 1 research: peat, limerock (shellrock) and sand, with the latter being used as a control substrate. During the first year of operation, the mesocosm and test cell peat-based systems were rapidly colonized by macrophytes planted to provide an anchoring structure (*Eleocharis* spp.), and those established on a volunteer basis (*Typha* spp.) (**Figure 8-4.**). This rapid colonization indicates that a limerock substrate less prone to macrophyte growth may be necessary to support a viable PSTA system. This effect can be achieved by either placing a limerock cap or by scraping the peat from a cell, but if a viable periphyton system could be created on peat, this step could be eliminated. Therefore, ongoing research is continuing to investigate ways to improve the performance of peat-based systems.

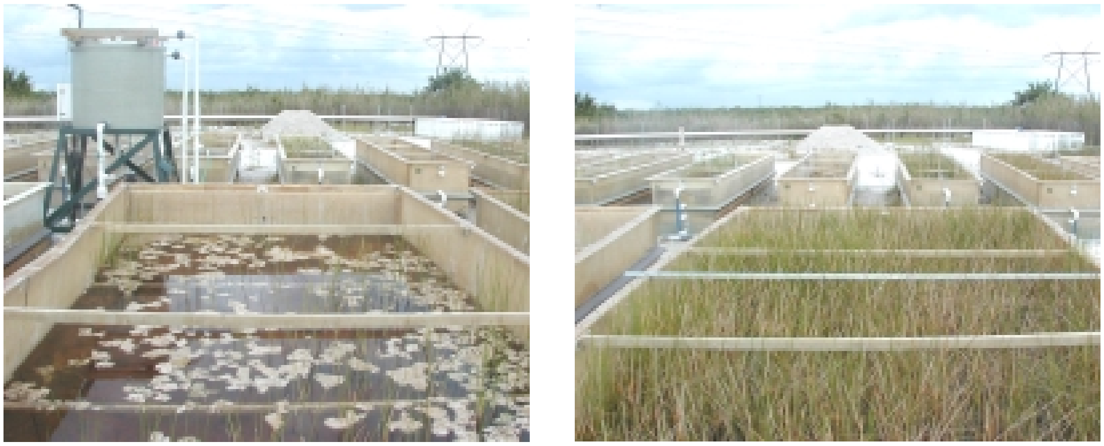

Figure 8-4. Vegetation coverage in a shell rock system (left) versus a peat based system (right). Both systems have been running for 13 months (CH2M HILL, 2000c).

Preliminary results indicate that water depth may be a critical design and operational factor in the PSTA technology. Water depths of 30 and 60 cm were used to test the feasibility of the PSTA concept for Phase 1 studies, and although phosphorus removal was not significantly different at these two depths, the periphyton developed quicker and had more biomass in the 30-cm depth systems (CH2M HILL, 2000a). Other research has shown that depth may be critical to optimizing the P removal of PSTA. The Submerged Aquatic Vegetation/Limerock Project has achieved long-term mean TP outflow concentrations of 10 ppb in periphyton systems operated at very low water depths (9 cm) over a limerock substrate (SAV/LR Shallow Raceways section in this chapter).

Long-term effectiveness of PSTAs for P removal has not yet been determined, and will be addressed at the 15-acre demonstration site, as well as in the ongoing mesocosm and test cell experiments. Preliminary results from the mesocosm and test cell experiments indicate the following:

- Long-term average outflow TP concentrations from PSTA mesocosms during the first year of operation were about 13 ppb, and monthly averages were as low as 9 ppb.

- Following the start-up period, TP removal rates generally increased during the first year of operation.
- Antecedent labile reactive P in substrates reduced performance and resulted in higher TP outflow concentrations. Batch-mode studies indicated that internal P loading mechanisms were still active even after one year of operation. In these studies, the system TP concentration ranged from 14 to 17 ppb after two months without external loadings.
- Mean outflow TP concentrations did not increase with increased TP loading rates.
- Mesocosm tanks produced lower mean TP outflow concentrations and higher settling rate constants (k) than the test cells, indicating that full-scale performance estimates generated with mesocosm data may not be scalable due to constraints on varying HLR, water depth, hydraulic residence time, edge effects, etc.
- In the nonvegetated mesocosm controls, there was increased TP outflow concentrations, but variable removal rates relative to comparable mesocosms with periphyton, demonstrating the complexity of the details related to P cycling in these PSTA test units.
- TP accretion rates are generally comparable to net TP removal rates estimated by inflow-outflow mass balances, and in these studies, wet accretion represented about 1.5 cm/yr (CH2M HILL, 2000a).

Information gained in Phase 1 was used to focus the research for continuing studies in Phase 2. Phase 2 studies commenced in April 2000 and will be reported in next year’s Everglades Consolidated Report. At the mesocosm-scale, the District extended the 30-cm depth tank research to incorporate seasonal factors into the analyses. These experiments include: a variable-depth treatment with dry out, increased velocity, limerock substrate, calcium-amended peat soils, and batch studies to examine the evapotranspiration rates and determine the background P concentration in these systems (assuming no external P loads). **Table 8-3** contains a complete list of Phase 2 treatments at the mesocosm scale.

To simulate increased velocity with the currently available mesocosms, a pump was used to recycle water from the outflow end. Recycling was one way to examine increased velocity without increasing the external hydraulic loads. (TP loading is increased minimally.) Ideally, larger systems would have been constructed to examine the velocity variable. However, time constraints (i.e., grow in and stabilization) required the use of existing mesocosms to answer velocity design variables for the construction of the field scale mesoscosms. Although recirculation did not affect the total mass balance of the system (recirculation outflow mass approximately equals recirculation inflow mass), it does affect the internal cycling in these systems. When considering the loading at an individual point within the system, analyses account for recycling.

Table 8-3. Phase 2 experimental and demonstration treatments for the small scale mesocosms.

Replicated Treatments	***Substrate***	***Water Depth (cm)***	***Velocity (cm/sec)***	***HLR (cm/day)***
Replicate Portable Mesocosm Experiments (3 mesocosms each treatment)				
13	Peat Amended with Lime	30	0.0014	6
14	Limerock	30	0.0014	6
3	Peat	30	0.0014	6
4	Shellrock	30	0.0014	6
15	Shellrock	30	0.5000	6
16	Shellrock	0-30	0.0014	6
Unreplicated Portable Mesocosm Demonstrations (1 mesocosm each treatment)				
7	Sand	30	0.0014	6
17	Pre-washed Sand	30	0.0014	6
18	No Substrate	30	0.0014	6
19	Synthetic Substrate	30	0.0014	6
11	Shellrock	30	0.0014	6
12	Peat	30	0.0014	6

At the test cells, the peat-based treatment cell has been amended with lime in an attempt to reduce release of labile P from sediments and encourage periphyton development. The second test cell is being used to test the effects of dryout on the algal community and P removal, and the third test cell remains unchanged with the exception of decreasing the depth to 30 cm.

Based on these preliminary findings [CH2M HILL, 2000b], low velocities and edge effects associated with small-scale projects may be a limiting factor for this technology. Testing the PSTA concept on a larger scale is warranted. The District is completing construction of a 15-acre (three 5-acre cells) field scale PSTA research site adjacent to STA-2. Two different construction methods, scraping down to limerock and capping the peat soils with limerock, will be studied to gain information on full-scale design, construction, and operational costs of a periphyton STA. This demonstration project will operate at two different nominal velocities (0.07 and 0.21 cm/s) that will be more representative of larger systems (**Figure 8-5**).

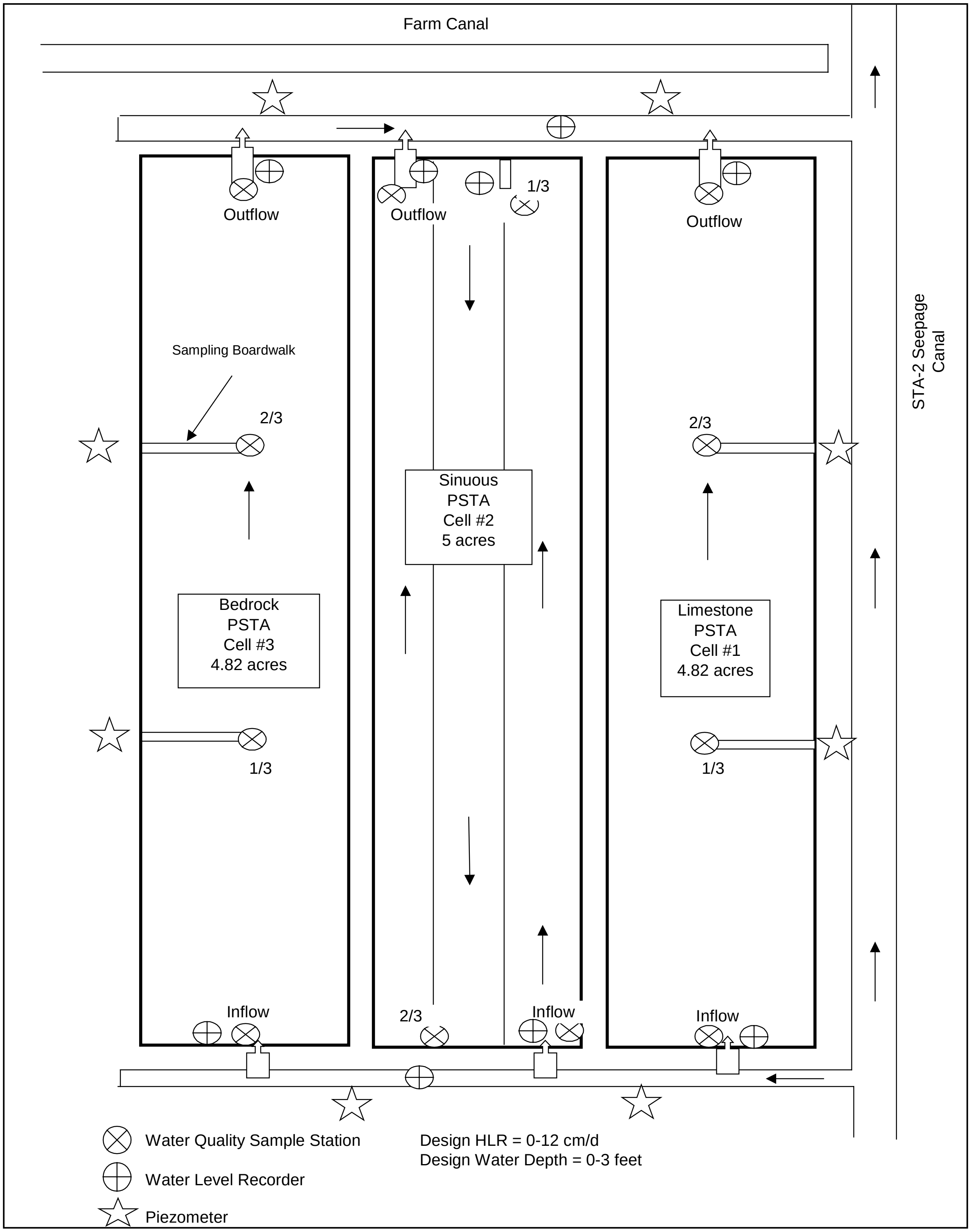

Figure 8-5. Field-scale PSTA conceptual site plan.

Other PSTA Research

The District has a contract with the Southeastern Environmental Research Center at Florida International University for research designed to further understand fundamental concepts of natural systems. Efforts underway include coordination across the different PSTA initiatives and continued research on a 10-acre site at STA-2 to study the effect of limerock as a substrate. Other work scopes, including lab work, are being defined and negotiated.

In addition, there are other ongoing PSTA research projects not under the purview of the District. They include studies conducted by the USACE and Florida International University (FIU) to study the effects of a scrape-down area in the C-111 Basin on TP concentration in the water column. Additionally, the USACE/FIU have completed construction of a flume system in STA-1E, which will determine the feasibility of using the PSTA concept in that location.

SUBMERGED AQUATIC VEGETATION/LIMEROCK

The Submerged Aquatic Vegetation/Limerock (SAV/LR) technology uses indigenous submerged plants to remove P from the water column followed by a limerock filter at the downstream end of the system. Removal of P is believed to be accomplished by plant uptake as well as by adsorption to (or co-precipitation with) calcium carbonate that precipitates from the water column due to photosynthesis-related pH elevations. The limerock filter further removes a small amount of particulate P (PP) and dissolved organic P (DOP) (**Figure 8-6**).

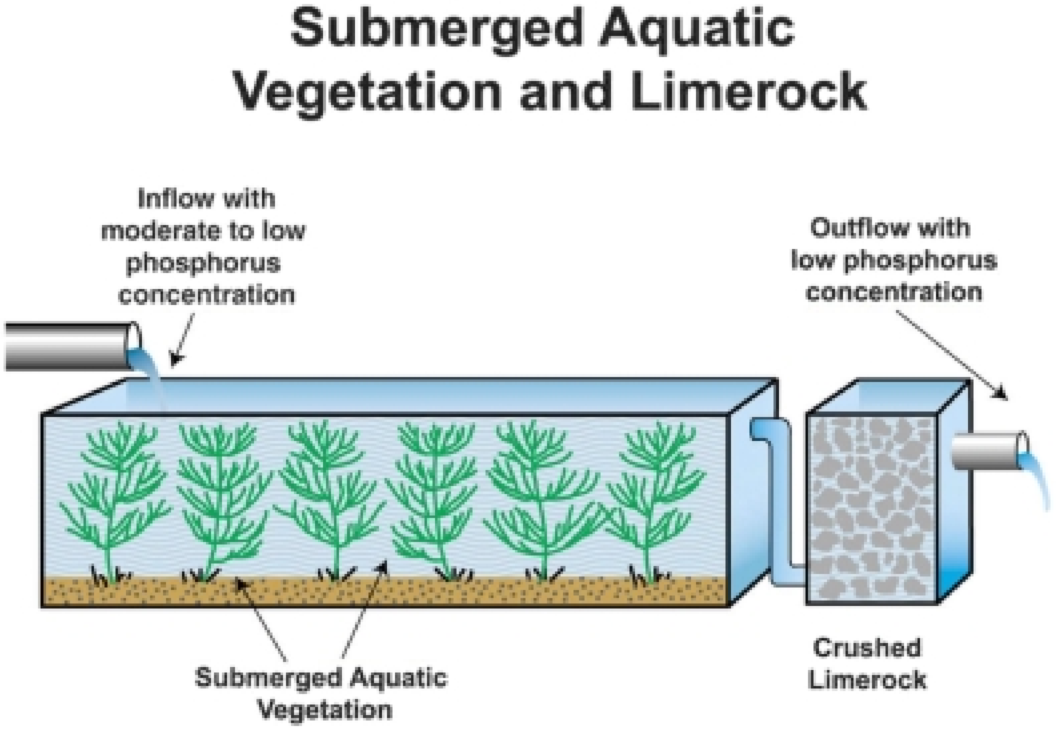

Figure 8-6. Schematic of the Submerged Aquatic Vegetation and Limerock Advanced Treatment Technology.

The SAV/LR project is divided into two phases. During Phase I of this project mesocosms were operated under constant flow conditions to evaluate P removal performance of SAV and limerock under various nominal hydraulic residence times, water depths, and harvesting regimes (DBEL, 1999). Phase 1 was concluded in April, 1999. The Phase II SAV/LR research program, also known as the Follow-on Study, addresses a number of system processes, as well as operational and management issues at various scales (DBEL, 2000a), and continues some of the experiments from Phase 1 (**Table 8-4**). USEPA Section 319(h) funding, through the Department, has been received for this project.

Table 8-4. An overview of research activities for the Phase II Submerged Aquatic Vegetation and Limerock Advanced Treatment Technology.

Topics	*Platform*	*Experiments*
Process Issues	Laboratory	Characterization of DOP and PP
	Laboratory, Microcosms	Effects of calcium concentrations, pH and alkalinity on SRP co-precipitation
	Mesocosms, Test Cells, Cell 4	Sediment characterization & stability
	Mesocosms, Cell 4	Sediment P accretion rate & mass balance
Operation Issues	Cell 5	SAV inoculation techniques
	Cell 5	Effects of liming on water color and P precipitation
	Mesocosms	SAV harvesting
	Mesocosms	Drydown/reflooding
Management Issues	Mesocosms, Cell 4	Effects of pulse-loading
	Mesocosms	Effects of fluctuating water depth
	Cell 4	Hydraulic optimization
	Mesocosms	Effects of substrate
	Mesocosms	Effects of velocity
	Filter columns/mesocosms	Evaluation of filtration materials
	Test Cells	Evaluation of limerock filter

Effects of HRT: This experiment was designed to examine the P removal performance by the SAV/LR treatment system under various nominal HRTs (1.5, 3.5 and 7.0 days). Effects were studied in fiberglass mesocosms (4.66m L x 0.79m W x 1.0m H) holding water depth constant. The inflow rate for each HRT was 1.92, 0.83 and 0.41 m^3/day, respectively. Results indicated that the vegetation and not the LR filter provided most of the P removal. Outflow TP concentrations from the 1.5, 3.5 and 7.0 day HRT SAV mesocosms averaged 53, 28 and 23 ppb during the experimental period (**Figure 8-7**). These values were further reduced in the downstream limerock filters to 40, 19 and 15 ppb, respectively. Inflow TP values to the SAV mesocosms during this period averaged 108 ppb. Increasing the HRT from 1.5 to 3.5 days markedly improved the P removal performance; however, doubling the HRT from 3.5 to 7 days had little additional effect. In both the 3.5 and 7.0-day HRT mesocosms, average SRP levels were reduced to below the detection limit (DBEL, 1999; 2000b). Most studies of treatment wetlands have shown that long HRTs typically result in better treatment performance. These data confirm that at a constant depth, higher SAV P removal performance can be achieved at longer HRTs, which offer more time for the interaction between SAV and the nutrients. Furthermore, higher SAV biomass was observed in the mesocosms with longer HRT (DBEL, 1999).

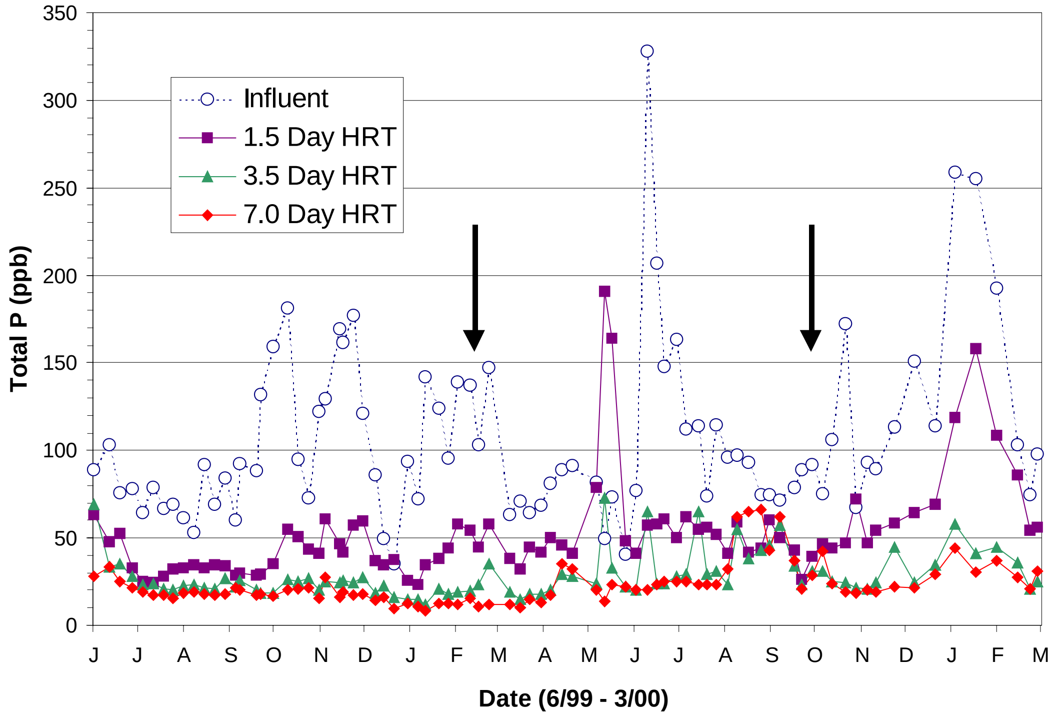

Figure 8-7. Mean total phosphorus concentrations in the inflow and outflows of triplicate mesocosms operated at 1.5, 3.5 and 7.0-day HRTs since June 1, 1998. Data from only one mesocosm of each HRT is presented for the period between February 10 and September 29, 1999 (arrows).

Effects of water depth: The SAV mesocosms (2.23m L x 0.79m W x 1.0m D for 6 tanks and 2.23m L x 0.79m W x 1.3m D for 3 tanks), operated at shallow (0.4m), moderate (0.8m) and deep (1.2m) water depths, received the same inflow of 0.17 m^3/day, which equates to a hydraulic loading rate of 10 cm/day. This resulted in nominal HRTs of 4.0, 8.1 and 12.1 days for the shallow, moderate and deep mesocosms, respectively. Results from the first year (through April 1999) of the study indicated that despite their shorter HRT, the 0.4 m depth mesocosms performed slightly better than either the moderate or deep systems (DBEL, 2000a). Subsequently, outflow TP concentrations have been equal among all depth treatments, averaging about 20 ppb, suggesting that SAV will provide effective TP removal over depths ranging from 0.4 to 1.2m (DBEL, 1999; 2000b) (**Figure 8-8**). A dye (Rhodamine WT) study was conducted to evaluate hydraulic characteristics among water depth treatments. Results indicated that the measured HRTs were within 20 percent of the nominal HRT for each water depth treatment (DBEL, 1999).

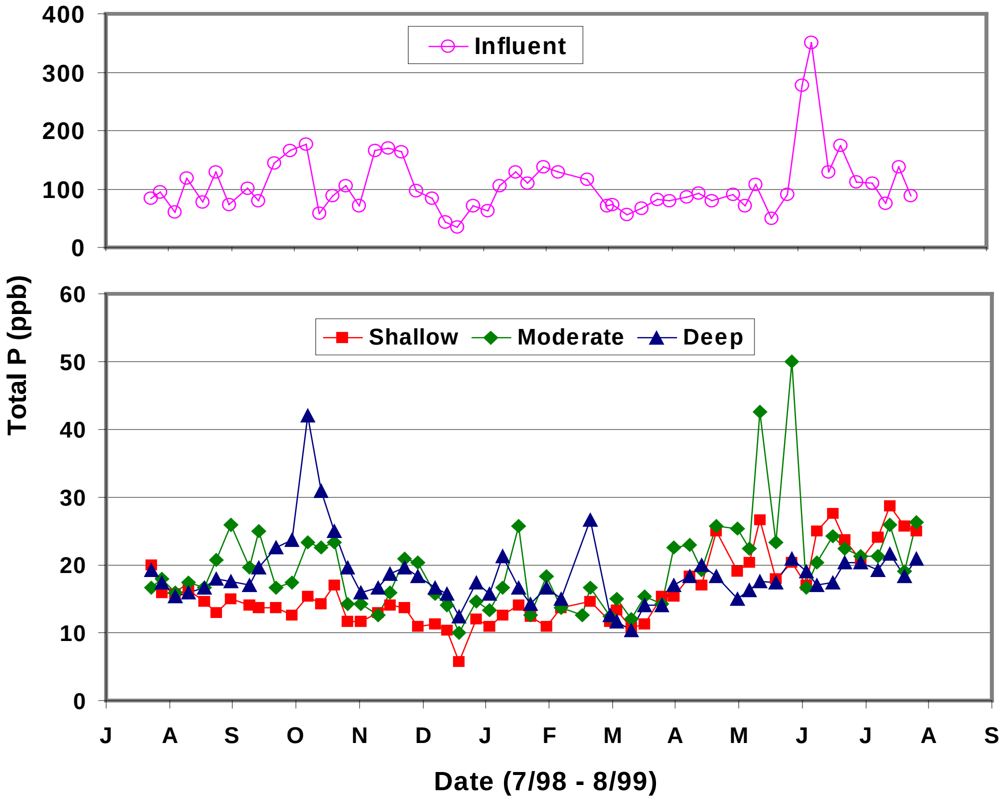

Figure 8-8. Mean total phosphorus inflow and outflow concentrations in the shallow, moderate and deep mesocosms at the post-STA site.

Effects of SAV harvesting on P removal: This experiment was designed to assess whether periodic harvesting will enhance P removal performance of SAV wetlands. Both periodically harvested and non-harvested SAV mesocosms (triplicate) were established in July 1998. The first harvest (partial removal of both SAV shoot and root biomass) was performed in September 1998. Outflow TP concentration levels were considerably higher following this harvest, but returned to pre-harvest levels after several weeks (DBEL, 1999). The second harvest (clipping and discarding the top half of the SAV) was performed on August 19, 1999, and the P removal efficiency was reduced for about 7 weeks, but returned to near pre-harvest levels by the second week in October (**Table 8-5**). To date, harvesting of SAV biomass has provided no long-term enhancement of P removal performance. Additionally, short-term increases in outflow TP levels following harvest suggest that this management practice is not desirable for SAV systems designed to remove P to low levels (~10 ppb) (DBEL, 2000b).

Table 8-5. Mean inflow and outflow TP concentrations of triplicate harvested SAV mesocosms before harvest, and during and after a “recovery” period. Harvesting was performed on August 19, 1999.

	Sampling Events	***Inflow TP (ppb)***	***Outflow TP (ppb)***	***P Removal (%)***
Pre-Harvest Period (July 1–Aug. 18, 1999)	7	98	29	70
Recovery Period (Aug. 19–Oct. 5, 1999)	7	83	84	-1
Post-Recovery Period (Oct. 6–Jan. 31, 2000)	13	144	37	74

Effects of substrate types: In this study, SAV was grown in muck, limerock and sand substrates using STA-1W outflow (post-STA) waters and small mesocosms (0.73m^2 surface area x 0.4m D). Inflow rate varied over time, ranging from 0.16 to 0.66 m^3/day. The SAV grown in the muck produced slightly lower outflow TP concentrations than SAV grown on the other substrates (**Table 8-6**). The SAV standing crop on the muck substrate appears more robust than the SAV in either the sand or limerock substrate mesocosms. Increased vegetation growth may enhance the water column P removal either directly (through plant P uptake) or indirectly (altering water chemistry). This study indicates that removing the muck to expose a limerock substrate (or limerock placement over muck) has no significant effect on post-STA SAV P removal (DBEL, 2000b).

Table 8-6. Mean inflow and outflow TP concentrations of SAV on various substrate types.

	Inflow	*Limerock*	*Muck*	*Sand*
Mean	17	14	13	15
Minimum	9	6	6	10
Maximum	30	27	21	25

Sequential SAV/LR treatment system: Because of the initial high P removal of the shallow depth SAV systems, a sequential SAV/LR treatment system was established during Fall 1998 (DBEL, 1999; 2000b). This system consisted of an SAV mesocosm operated at a 0.8m depth with a nominal HRT of 3.6 days; followed by a second mesocosm at a depth of 0.4m with a nominal HRT of 1.8 days; and ended with a limerock filter with 1 hour HRT. Both mesocosms were the same size (2.33m L x 0.79m W x 1.0m D) and had an inflow rate of 0.17m^3/day. During the first 6 months of operation (November 1998-April 1999), the average inflow TP was reduced from 130 to 24 ppb in the 0.8m mesocosm, to 11 ppb in the 0.4m mesocosm, and ultimately down to 9 ppb in the limerock filters (**Figure 8-9**). However, TP concentrations at all monitoring locations of the sequential system began to increase in May 1999, and have since been quite variable. The erratic performance of the sequential system after the first 6 months was likely due to the die-off of *Chara spp*., a macroalgae that dominated the SAV community early in the study. The causes that lead to the die-off of *Chara spp.* are not clear. However, the extremely high biomass of *Chara spp.* prior to the die-off suggests that the die-off may be the result of light limitation. Field observation indicates that the die-off occurred from the sediment-up, suggesting that the plant tissues near the sediment became light-limited, which in turn led to anoxic conditions and plant die-off.

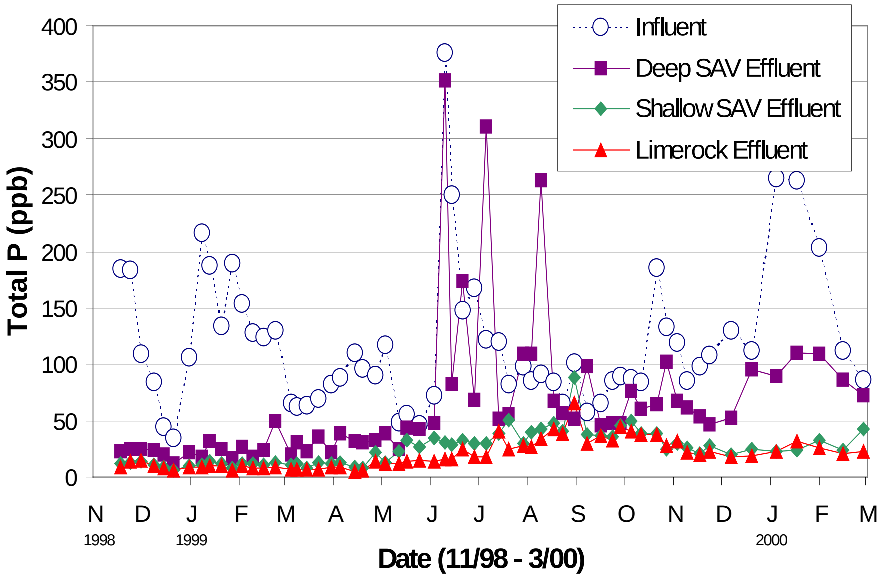

Figure 8-9. Weekly total phosphorus concentrations at four locations in the sequential system treatment train from November 18, 1998 to March 1, 2000.

Test Cell Phosphorus Removal Performance: Since Fall 1999, the north and south test cells have been subjected to wide variations in hydraulic loadings, largely to accommodate hydraulic tracer investigations and cell modifications. In December 1999, to study short-circuiting under high flow conditions, the HLR was increased to about 40 cm/d in NTC-1 for about three weeks (**Figure 8-10**). During this time, the TP outflow concentrations increased resulting in a drop in TP reduction efficiency compared to NTC-15. Additionally, this increased HLR coincided with a decrease in *Chara spp*. biomass. After three weeks, the HLR in NTC-1 was dropped to about 2 to 3 cm/d. Although the HLR of NTC-1 was less than NTC-15, the TP reduction efficiency did not improve immediately, possibly due to the lack of vegetation in the test cell.

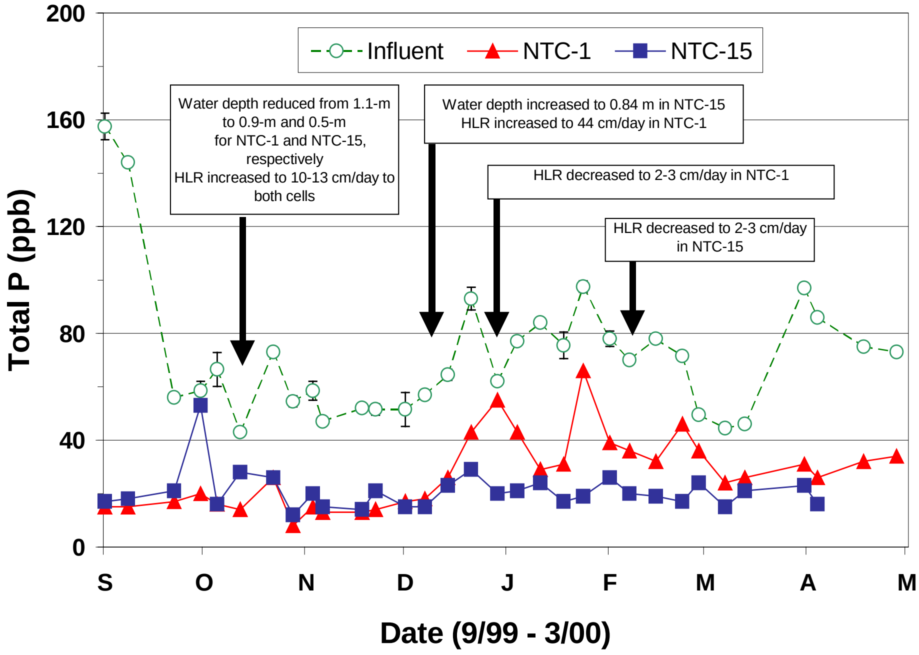

Figure 8-10. Total phosphorus concentrations in the influent and effluents of north site test cells. Error bars = ±1 s.d. Sampling was discontinued in April at NTC-15 because of draining in preparation for the installation of a limerock berm.

Both south test cells did not substantially reduce phosphorus levels (**Figure 8-11**). At that time, both cells were drained for aquatic plant control and installation of a limerock berm (STC-9 only). The poor P removal may be due to more recalcitrant forms of DOP and PP in the inflows to the south test cells, as compared to the north test cells. (DBEL, 2000e). Typical inflow values for dissolved organic phosphorus, DOP, are 17 ppb and 10 ppb for the north and the south respectively. Typical inflow values for particulate phosphorus, PP, are 48 and 11 ppb for the north and south, respectively. Outflow DOP values are 9 and 8 ppb for the north and south, respectively. Outflow PP values are 12 and 10 ppb for the north and south, respectively. The systems were drained and a limerock berm was installed in an attempt to further reduce the recalcitrant forms of phosphorus, PP and DOP, through filtration and adsorption.

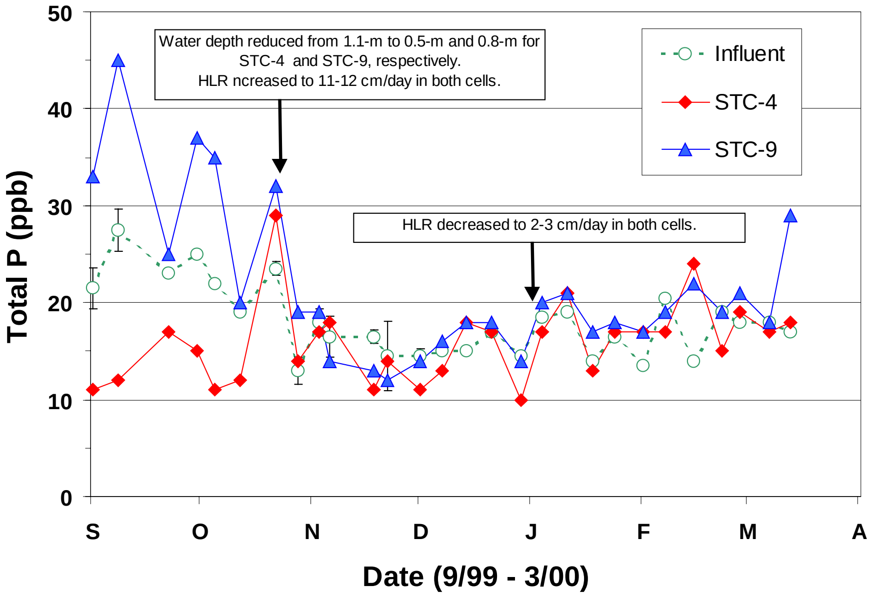

Figure 8-11. Total phosphorus concentrations in the inflow and outflow of south site test cells. Error bars = ±1 s.d.

Evaluation of STA-1W Cell 4: Since mid-1994, a stable SAV ecosystem dominated by *Ceratophyllum demersum* and *Najas guadalupensis* has been present in Cell 4 of STA-1W (346 acres) with minimal management effort. Between mid-1994 and 1999, the average HLR in Cell 4 was 15 cm/day (standard deviation=10 cm/day) and the mean water depth was 0.64 m (standard deviation = 0.13 m).

During the first three years of operation, outflow TP levels were dynamic and exhibited seasonal (winter) increases in concentration (**Figure 8-12**). However, since mid-1997, yearly mean outflow concentrations stabilized around 14 ppb. During 1999, 25 percent of measured outflow concentrations from Cell 4 were less than or equal to 10 ppb.

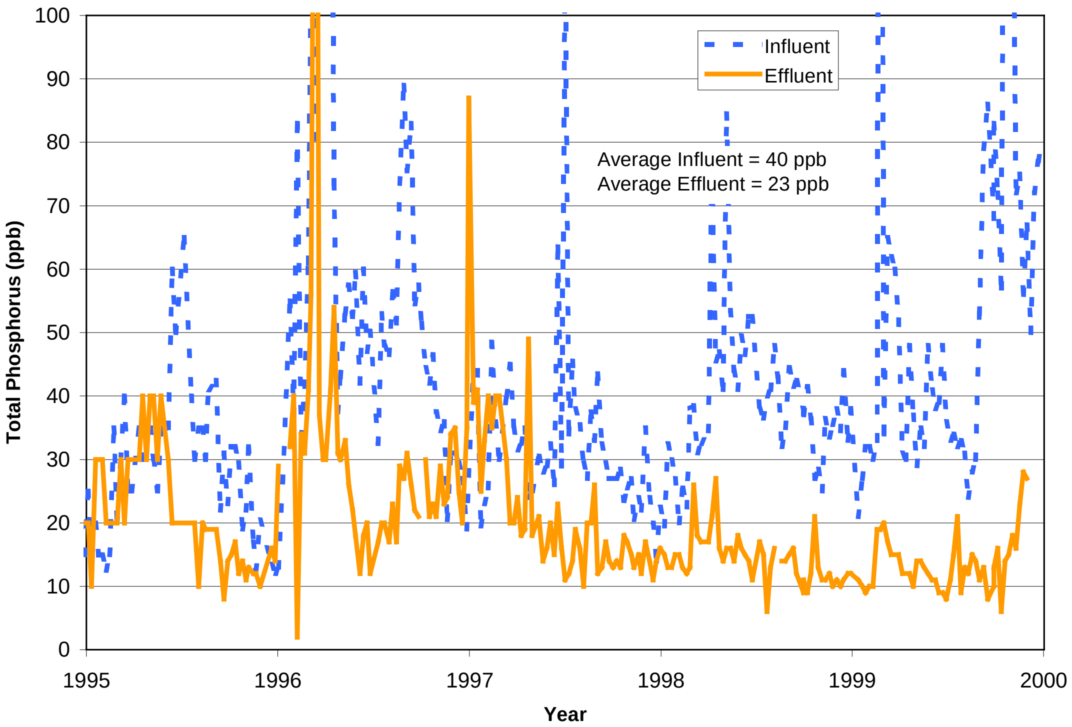

Figure 8-12. Cell 4 inflow and outflow TP concentrations from samples taken three times daily and composited weekly.

Table 8-7 summarizes Cell 4 TP removal performance on an annual basis in terms of mass removal rates, TP settling rates, and removal efficiency. During the 1998-99 calendar years when outflow concentrations averaged 14 ppb, the HLR was slightly lower than historic averages, but mass removals, settling rates, and removal efficiencies were above average values (DBEL, 2000b). The 5-year average TP settling rate of 40 m/yr is approximately 3-4 times greater than exhibited by emergent macrophyte treatment wetlands within STA-1W (Chimney et al., 2000) and elsewhere within Florida (Kadlec, 1994)

Table 8-7. Summary of Cell 4 TP removal performance.

Year	*Hydraulic Loading Rate (cm/day)*	*Inflow TP Concentration (ppb)*	*Outflow TP Concentration (ppb)*	*Mass Removal Rates ($g/m^2/yr$)*	*TP Settling Rate, k (m/yr)*	*Removal Efficiency (%)*
1995	0.16	31	21	0.7	28	26
1996	0.21	57	29	1.7	49	31
1997	0.13	33	21	0.7	26	30
1998	0.13	39	14	1.2	44	70
1999	0.11	53	14	1.9	55	61
Average	0.15	43	20	1.2	40	44

Additionally, Cell 4 has shown that SAV colonization is possible in large-scale treatment wetlands created from farm fields. The data also indicates that a stable SAV community can persist longer than 4 years with relatively little long-term vegetation management. The results from Cell 4 have proven important to the future performance optimization of the STAs.

Cell 4 Hydraulic Optimization: Despite good historical performance of Cell 4, visual observations of water flow indicate that the wetland's P removal efficiency may be compromised by internal short-circuiting and dead zones. To assess the degree of hydraulic short-circuiting, a dye study using Rhodamine-WT dye was conducted in December 1999. Analysis of the dye movement revealed that about 51 percent of the inflow water bypassed the SAV wetland and moved rapidly down deep existing borrow canal areas (DBEL, 2000c). Suggestions to improve the hydrology included plugging the short-circuiting channels, placing cuts in the spoil deposit areas, and constructing internal levees to compartmentalize the cell and redistribute the flow (DBEL, 2000d). The District is in the process of implementing these options and a second dye study will be conducted when the work is completed to assess the effectiveness of the hydraulic improvements.

Forecast Model Development: A dynamic simulation model for the SAV/LR treatment system is being developed. The model development provides a means for integrating data and concepts generated in the many multi-scale experiments in the project. The calibrated model will be used in addressing three research questions: defining the ultimate P removal potential in SAV systems, predicting system response to disturbance, and predicting long-term sustainability of SAV performance (DBEL, 2000b).

Future Research: Experiments on the effects of calcium concentration, pulse loading, fluctuating water depth, and dryout/reflooding on TP removal have been recently started, or will be initiated soon, to address several operational and maintenance issues on SAV/LR technology. The test cells are being used to determine how limerock can be integrated into the full-scale SAV treatment systems and to access the hydraulic characteristics of the LR berm. Limerock berms have been placed into two of the test cells, about three-fourths of the way down the cell flow path. The performance of these modified test cells will be compared to test cells without a berm. Additionally, the District has also started or plans to initiate several studies to provide supplemental information on long-term SAV performance and key system processes. These studies will include investigation of techniques for dissolved inorganic P removal, SAV decomposition, and sediment and water quality analyses for natural SAV systems with a history of long-term SAV dominance.

CHEMICAL TREATMENT-SOLIDS SEPARATION

The Chemical Treatment-Solids Separation (CTSS) project evaluated the feasibility of using chemical coagulation coupled with solids separation techniques (Direct Filtration, High-Rate Sedimentation, and Dissolved-Air Flotation) to remove total phosphorus (TP) from post-BMP and post-STA treated stormwater runoff from the Everglades Agricultural Area (EAA). The chemical coagulation phase involved the use of metal (iron or aluminum) salts, routinely used in municipal water treatment facilities, to precipitate P. These metal salts, combined with organic polymers, coagulate suspended precipitates and allow small particulates to be flocculated into larger, denser aggregates which are more readily settled or filtered. Solids generated from the coagulation and flocculation process are then separated from the liquid through settling and/or filtration and disposed of by land application or by transportation offsite after other dewatering techniques.

The experimental setup for this project consisted of two essentially identical conventional water treatment trains, each train rated for a maximum hydraulic loading of 12 gpm containing: two in-line static mixers, one rapid mix tank, one coagulation tank, two flocculation tanks in series, one clarifier fitted with inclined plate settlers, and three granular media rapid filters in parallel (**Figure 8-13**). The system setup allowed for chemically treated (and clarified) water to be introduced to any one or all of the filter columns of selected filter media. Various chemicals tested include alum [$Al_2(SO_4)_3 \bullet 14$ H2O], ferric-sulfate [$Fe_2(SO_4)_3$], anionic coagulant aid (A-1849 polyacrylamide also known as PAM), and hydrated lime [$CaOH_2$].

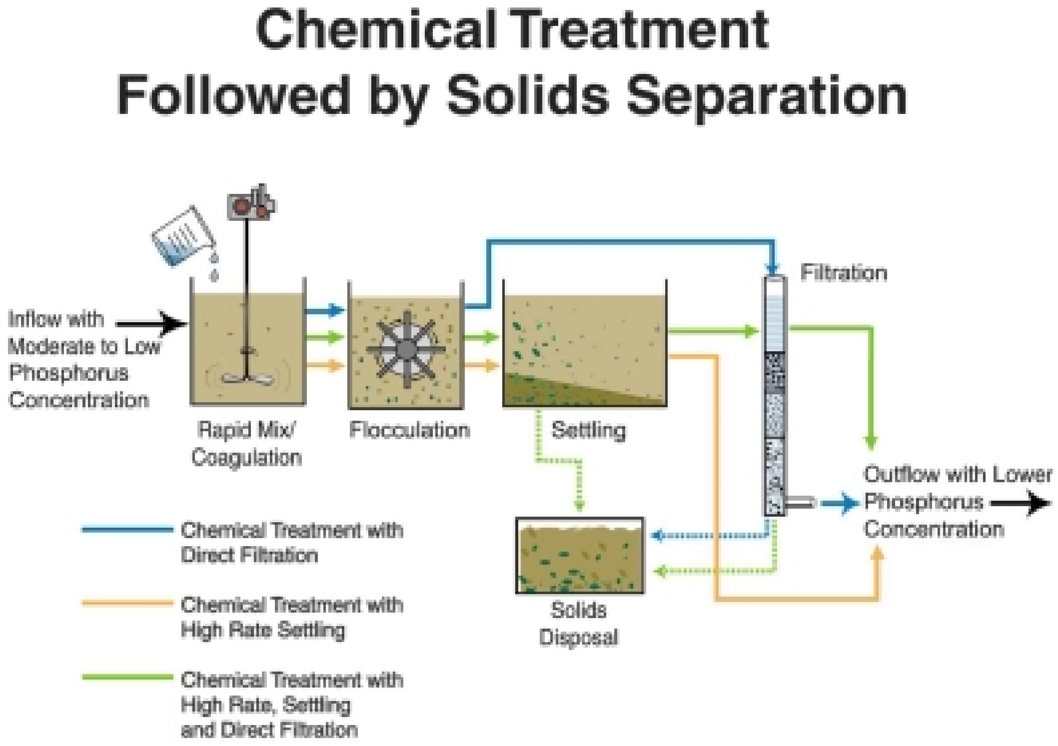

Figure 8-13. Process Schematic of the Chemical Treatment Solids Separation Advanced Treatment Technology.

The CTSS demonstration project field-testing was conducted in various stages during a seven-month period: a startup, pre-screening and screening stage at the post-STA site, followed by optimization and demonstration stages at the post-BMP and post-STA sites in parallel.

Prescreening and Screening Results: Chemical addition, coagulation, flocculation and filtration processes produced a filtered effluent containing less than 10 ppb TP during screening experiments. These successful experimental conditions were the starting point for performing additional optimization experiments. “Green Everglades” filters with dual media (anthracite and sand) and “Swiss” filters (expanded shale media) were selected for further testing because these filters displayed superior hydraulic performance (i.e., the longest run times without clogging) (HSA, 2000).

Direct (in-line) filtration was eliminated from further consideration because testing did not produce meaningful reduction in the feed water TP concentrations. In addition, no meaningful TP removal was obtained at the pilot plant during trials employing residual solids recirculation; therefore, this alternative was also eliminated from further consideration as a treatment option.

Optimization Results: During the optimization testing, a Bayesian experimental design approach (Ollos, 1997) was used to determine exact experimental conditions to be tested. Optimization testing was conducted in four unique experimental segments for sedimentation and filtration rates and coagulant and flocculant dosages with the results of earlier segments influencing the exact conditions of later experiments. The total of 138 optimization experimental results (70 at the post-BMP site and 68 at the post-STA) showed varying degrees of TP reduction. TP removal of up to 97.5 percent (from 163 to 4 ppb) was achieved at the post-BMP site. At the post-STA test site, up to 87 percent TP reduction occurred, with effluent concentrations less than 4 ppb. The "Green Everglades" filter provided marginally higher TP removal than the Swiss filter during the optimization trials.

Demonstration Results: A relatively narrow range of pilot operating conditions provided an outflow TP concentration of less than 10 ppb during optimization testing. The operating conditions recommended by the technical review team are listed in **Table 8-8**.

Table 8-8. Operating conditions of Pilot Plant during demonstration.

	Post-BMP Site	***Post-STA Site***
Feed Flow Rate, gpm	12	12
Clarifier Overflow, gpm/sqft	0.14	0.28
Filtrate Rate, gpm/sqft	4.9	9.8
Filter Media	Swiss/Green Everglades	Swiss/Green Everglades
Coagulant Type	ferric chloride	Aluminum sulfate
Coagulant Dose, mg/L as metal	40	20
Coagulation Volume, gallons	20	20
Flocculation Volume, gallons	400	400
Flocculation Blade Speed, rpm (Tank 1/Tank 2)	10/5	10/5
Flocculation HDT, minutes	33	33
Coagulation HDT, minutes	1.7	1.7
Polymer Dose (Cytec® A-130), mg/L	0.5	0.5
Clarifier Waste Rate, gpm	0.6	0.6
Inflow TP range (average), ppb	119- 260 (164)	14-26 (22)
Effluent TP range (average), ppb	4-8 (7)	4-8 (7)

Post-BMP and post-STA site demonstration trials were conducted using ferric chloride and alum coagulant, respectively, and both sites consistently produced mean outflow TP concentrations at or below 10 ppb. Inflow TP concentrations ranged from 260 to 119 ppb (average 164 ppb) in post-BMP waters and from 14 to 26 ppb (average 22 ppb) in post-STA waters. Effluent TP concentrations ranged from less than 4 to 10 ppb (average 7 ppb) in both post-BMP and post-STA waters. Total alkalinity was reduced from 129 to 38 mg/L at the post-BMP site, and from 220 to 114 mg/L at the post-STA. The mean pH was reduced from 6.8 to 6.0 at the post-BMP site and from 7.1 to 6.4 at the post-STA site. Because alum and ferric-chloride coagulants are acidic, these reductions in alkalinity and pH were expected. Addition of metallic salts to the post-BMP inflow water resulted in anticipated increases in total dissolved solids (TDS), from 308 to 358 mg/L at post-BMP sites and 581 to 587 mg/L at post-STA sites. Outflow concentrations of zinc increased relative to inflow concentrations at post-STA and BMP sites, while cobalt, copper, manganese and nickel outflow concentrations increased only at the post-BMP sites (**Table 8-9**). No statistically significant changes in concentration were observed for sodium, boron, calcium, lead, silica, molybdenum, magnesium and potassium at either site (HSA, 2000).

Mean outflow sulfate concentrations of 39 mg/L were not significantly different from mean inflow concentrations of 36 mg/L at the post-BMP site. However, at the post-STA site, where alum was the coagulant, the mean sulfate concentration increased from 50 mg/L at the inflow to 164 mg/L at the outflow.

Table 8-9. Inflow and effluent metal concentrations at the Post-BMP Test Site.

Metal	*Concentration in Feed, ppb*	*Concentration in Effluent, ppb*
Cobalt	0.7	1.5
Copper	2.1	4.4
Manganese	19	166
Nickel	1.3	5.65
Zinc	10	17

Inflow and outflow grab samples were analyzed for total and dissolved methylmercury as well as total and dissolved mercury concentrations at the post-BMP and post-STA test sites. The average concentrations of total mercury were 6.18 ng/L (inflow) and 0.31 ng/L (outflow) at the post-BMP site and 1.35 ng/L (inflow) and 0.500 (outflow) at the post-STA site. Total mercury was reduced about 95 and 63 percent at the post-BMP and post-STA sites, respectively. Dissolved mercury was reduced approximately 65 and 31 percent at the post-BMP and post-STA sites, respectively. Total methylmercury was reduced by about 63 percent at the post-BMP Site. However, at the post-STA site, the total and dissolved methylmercury concentrations were unchanged from inflow to outflow, while only dissolved methylmercury remained unchanged at both sites. Total mercury removed by CTSS accumulated in the residuals, and was equal to 81.06 ng/L at the post-BMP test site and 7.99 ng/L at the post-STA, which are lower than the Department standards for mercury in waste solids (HSA, 2000).

Due to the potential generation of methylmercury in the presence of sulfate ions, future research involving chemical treatment will be conducted using coagulants that do not contain sulfates, i.e. aluminum chloride, polyaluminum chloride and ferric chloride. The results with aluminum sulfate can reasonably be expected to be comparable to those obtained with aluminum chloride and polyaluminum chloride.

During the Demonstration phase, three of four weekly bioassay and algal growth potential (AGP) analyses performed on the CTSS inflow and outflow water (after filtration) identified no adverse biotoxicity on these indicator organisms. However, both inflow and outflow water samples collected December 7, 1999 identified a significant toxicity effect on fish, waterfleas and algal test organisms. No cause for this toxicity has been identified, but the data are still being reviewed.

Offsite disposal of solids occurred after full toxicity analyses were conducted to ensure the residuals contained levels less than the Department standards set for hazardous substances. During demonstration trials, representative samples of these residuals were collected and submitted to the Department laboratory in Tallahassee for full toxicity characteristic leachate procedure (TCLP) analyses. All the analytical results on the residual solids from post-BMP and post-STA sites were well below allowable limits for TCLP parameters, and therefore, were characterized as nonhazardous.

As part of CTSS research, several vendors provided conventional and state-of-the-art chemical technologies for evaluation. Technologies evaluated included ballasted sand enhanced settling, magnetically enhanced settling, high rate sedimentation, microfiltration, a dolomitic lime fixed film bio-reactor, and enhanced coagulation. Of these technologies, magnetic particle enhanced settling, ballasted sand enhanced settling, high rate sedimentation, and microfiltration significantly reduced TP concentrations; the rest were eliminated from further consideration due to lack of performance. Further research of the more promising technologies would be required prior to full-scale implementation.

Following the Supplemental (Advanced) Technology Standards of Comparison (STSOC) guidelines (PEER/B&C, 1999), models were run using data collected from the Demonstration phase. (STSOC is discussed later in this chapter.) Six full-scale facility scenarios were developed for both post-BMP and post-STA applications. The models used estimated flows and phosphorus loads from a 10-year period of record (POR), from 1978 to 1988, for STA-2. These facilities were designed to achieve flow weighted average effluent TP concentrations of 10 and 20 ppb TP with 0, 10 and 20 percent flow diversion (STSOC required) of the 10-year POR flow volume. Calculated flows for the resultant 12 full-scale treatment scenarios are detailed in **Table 8-10** (HSA, 2000).

Table 8-10. Supplemental (Advanced) Technology Standards of Comparison full-scale treatment scenarios.

Location	***Effluent TP***	***No Diversion (MGD)***	***10% Diversion (MGD)***	***20% Diversion (MGD)***
Post-BMP	10 ppb	380	270	200
	20 ppb	220	150	190
Post-STA	10 ppb	390	260	100
	20 ppb	140	100	80

For purposes of STSOC reporting, part of STA-2 was used as a flow equalization basin (FEB), and treatment plant sizes were determined for each POR flow diversion scenario to meet mean outflow TP concentrations of 10 and 20 ppb. Water balances were completed to determine the treatment plant sizes. The assumptions used for designing the full-scale treatment plant are summarized as follows:

- During the demonstration phase, CTSS with ferric chloride addition produced an average clarified effluent TP concentration of 6 ppb. Several of the TP concentrations were reported as below the method detection limit (4 ppb). In these instances, the detection limit value was used in all calculations. This approach results in a conservative estimate of TP outflow concentration.
- Flow equalization, chemical treatment, residual solids thickening and final buffer cell conditioning will occur within the existing footprint of STA-2.
- 6,000-acres of STA-2 will be used as a flow equalization basin (FEB) in the post-BMP scenario. The levees will not be modified and will be used to store water up to 4.5 feet (maximum design depth of STA-2).
- Bypass occurs when the FEB reaches capacity.
- Rainfall and evapotranspiration from FEB are not included in the calculations (Peer Consultants and P.C./Brown and Caldwell, 1999).
- The phosphorus removal rate was estimated as follows: 20 percent of inflow when STA-2 was used as a FEB (post-BMP), and an assumed mean outflow concentration of 65 ppb using the Walker and Kadlec model (Walker and Kadlec, 1996).
- The treatment plant will be designed to be operated so that when the water level inside the STA reaches 3.5 feet (less than 30 days/year, based on the 10-yr POR), the hydraulic loading to the system will be increased by 50 percent (peak load) of the average capacity (HSA, 2000). These operating conditions will be considered and reflected in the operation and maintenance costs of the system.
- Untreated inflow water would be blended with the CTSS outflow (assumed to be 6 ppb) to achieve the desired discharge concentration (10 to 20 ppb).
- Full-scale treatment scenarios are based on a scale-up of the CTSS pilot data using coagulation, flocculation and clarification enhanced by use of

> inclined plate settlers. A filtration process is not recommended in the scale-up scenario because TP outflow concentrations of less than 10 ppb were achieved without filtration.

The post-BMP conceptual design scenarios used 6,000 of the 6,430 acres within STA-2 for flow equalization, and the remaining 430 acres for the treatment plant works, residual solids thickening and treated water conditioning using a buffer cell. The Managed Wetlands Treatment System (later in this chapter) is working to identify conditioning provided by a wetland subsequent chemical treatment. The existing inflow STA pump station would pump the water into the FEB, and a new pump station would be installed to pump the water from the equalization basin into the treatment plant.

The post-STA conceptual design scenarios assumed an average STA outflow concentration of 65 ppb using 4,400 acres of STA-2 as a constructed wetland treatment system, a 1,500-acre basin as a flow equalization basin and 530 acres for the treatment plant works and buffer cell. The existing inflow STA pump station would pump water into the STA and a new pump station would be installed to pump the water into the FEB (HSA, 2000)

Post-BMP and post-STA waters would be pumped into concrete basin coagulators where ferric chloride or alum would be fed at an average dose of 40 mg/L as Fe. Coagulated water flows into concrete flocculation basin, where an anionic polymer is fed into the system at an average dose of 0.5 mg/L. The water is then clarified in concrete basins equipped with lamella plate settlers. The treated water would flow into a buffer cell then into a collection canal. The existing outflow STA pumping station would be used to discharge the treated water.

Residual solids are proposed to be discharged to an onsite storage lagoon for a period of three days. Supernatant overflow from the solids storage area would be returned to the FEB for treatment. Settled solids in the lagoon would be pumped to a dedicated land application facility. The estimated required area for this dedicated solids disposal area ranges from 1,150 to 1,680 acres, and is based on an annual solids loading criterion of 28 tons of dry solids per acre per year. However, additional research will be necessary to refine the accuracy of these disposal estimates.

Cost estimates for the 12 full-scale facility scenarios for CTSS treatment plants treating post-BMP and post-STA waters are under scientific and engineering peer review and will be reported next year.

LOW-INTENSITY CHEMICAL DOSING

Low Intensity Chemical Dosing (LICD) consists of the addition of small doses (less than 5.0 mg/L) of iron or aluminum salts directly to the constructed wetlands (STAs) to bind with soluble phosphorus and help precipitate the chemically bound phosphorus as well as naturally occurring particulate phosphorus. In the original concept (of LICD), no rapid mixing, flocculation or settling basins are used. The constructed wetlands act as settling basins and provide filtration to aid in the removal of the particulate phosphorus (**Figure 8-14**). This concept has been used in Belgium, along the Rhine River, and in Minnesota on lake water, although it has not been used with constructed treatment wetlands in Florida.

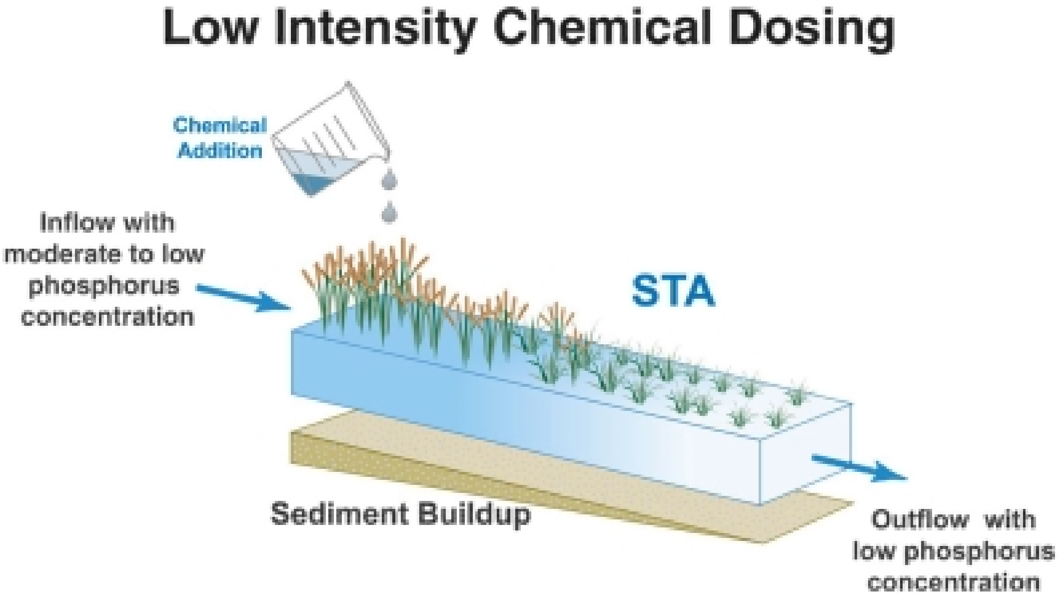

Figure 8-14. Process Schematic for Low Intensity Chemical Dosing Advanced Treatment Technology.

Current Status of Low-Intensity Chemical Dosing

The Low Intensity Chemical Dosing (LICD) project was conducted by Duke University under contract to the Department using an USEPA Section 319(h) grant. Phase I of the project has been completed in December 1999. All field and laboratory evaluations required for Phase II of the project have also been completed. The final report for Phase II of the project is being prepared. The primary goals for Phase I were to determine if LICD would reliably enhance the P removal capacity of the STAs and enable the STAs to achieve the desired threshold P concentrations, and to determine the placement of LICD within the STAs.

During the Phase I assessment, phosphorus removal through the addition of various levels of aluminum sulfate (alum) and ferric chloride were tested in laboratory (jar testing) and field scale experiments. The field scale experiments involved the application of chemicals to one of three six-foot diameter mesocosms installed in Cell 2 of the ENR. Mesocosm tests were conducted under continuous flow and batch flow modes. Results from the Phase I study (Bachand et al., 1999) indicate that mean orthophosphate concentrations were significantly reduced to levels of 5 ppb or less (**Figure 8-15).** However, a smaller reduction in TP levels was observed with concentrations in the range of 20 to 30 ppb generally being achieved. Although the concentration of TP was reduced by 33 to 50 percent, as compared to background concentrations, the concentrations achieved are much higher than the planning goal P concentration of 10 ppb. There was also some indication of a decreased community metabolism in the chemically dosed mesocosms related to decreased phosphorus availability. Decreased phosphorus availability was attributed to the conversion of orthophosphate to particulate P resulting from the metal additions. Because the particles formed were too small to settle effectively, the TP concentrations remained relatively high.

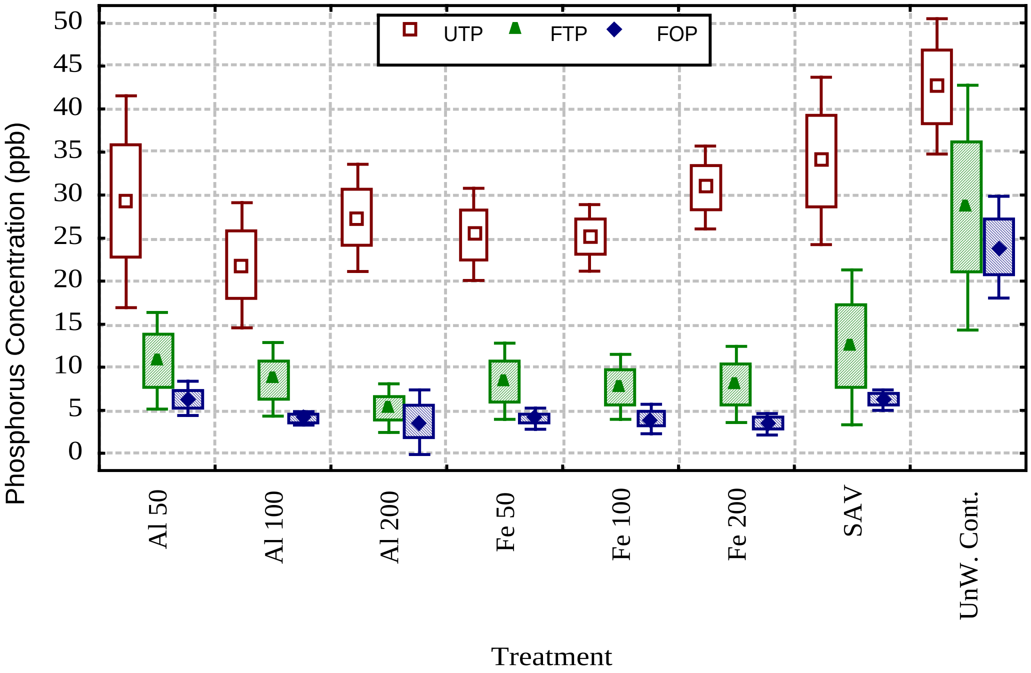

Figure 8-15. Mesocosm phosphorus concentrations for Site A, December 1998 – February 1999 (Bachand et al., 1999). From above, Unfiltered Total Phosphorus (UTP) is the same as Total Phosphorus (TP). Filtered Total Phosphorus (FTP) is the same as Total Dissolved Phosphorus (TDP). Filtered Orthophosphorus (FOP) is equivalent to Soluble Reactive Phosphorus (SRP). The inflow phosphorus levels are indicated by the Unwalled Control.

Additionally, LICD resulted in the accumulation of metal-rich sediments in the dosed mesocosms. These sediments had higher mineral content and increased phosphorus storage capacity as compared to background marsh soils. The additional P storage capacity may assist in stabilizing the P load in the sediments and prevent the release of this P into the overlying surface waters. However, it was concluded from the Phase I study that LICD is unlikely to achieve TP concentrations below 20 ppb without process development and efforts to maximize chemical use efficiency and settling of fine particulates.

The Phase II study was designed to test, among other things, improved chemical mixing regimes and the addition of polymers to aid coagulation in an effort to improve flocculation and chemical use efficiency and thereby further reduce the TP levels. Preliminary jar test data suggest that anionic polyacrylamides at very low doses (0.25 to 0.50 mg/L) dramatically improved settling rates, especially at low metal doses. Likewise, initial field data using anionic polyacrylamides at a rate of 1 mg/L suggest that total P levels ranging from 12 to 28 ppb can be achieved consistently under hydrologically isolated conditions. Since the target TP concentration of 10 ppb was not achieved, this technology may require a downstream treatment marsh to further treat the water. Since the final report for Phase II of the project has not yet been submitted, no definitive conclusions can be drawn at this time concerning the applicability of this technology under field conditions.

The metal dosage rates found to be effective during the LICD project are comparable to the chemical treatment/solids separation and managed wetlands technologies, where sludge management is required. Without sludge management, these dosage rates may result in a significant sludge accumulation in the STAs. Stability of a sludge blanket under STA flow regimes is unknown. Additionally, polymer addition represents a more engineered approach and will be duplicative of the approach taken by the other chemical ATTs. With the modifications necessary to make LICD more effective, the LICD technology has largely merged into the other chemical treatment technologies.

Future Research: The District will be conducting a flow-way demonstration project to examine extremely low doses of aluminum chloride added directly to the water column. The flow-way study will be conducted in the STA-1W test cells and will not use any polymers or enhanced mixing technologies.

MANAGED WETLANDS

In a Managed Wetland Technology System (MWTS), stormwater is mixed with chemicals to initiate flocculation and discharged into a treatment wetland prior to discharge to the Everglades Protection Area. The MWTS ATT is viewed largely as a passive system, using a pond for chemical addition, mixing and solid residual collection and removal. Potential treatment chemicals include iron and aluminum salts, and a chemical polymer as a coagulant aid. Flocculation and solids separation creates a sludge (residuals) blanket within a settling pond. The chemical treatment step occurs upstream of a constructed wetland to provide a mechanism for controlling the TP load to the wetland and to increase the performance and reliability of the overall treatment system (**Figure 8-16**).

Typically, in chemical treatment, an excess of metal ions (aluminum or iron) is supplied to precipitate the phosphorus from water column. For EAA waters, the stoichiometric ratio is on the order of 400:1. In a residuals blanket system, the flow is passed through an existing blanket providing the opportunity to use unbound metal ions, resulting in potentially less chemical usage.

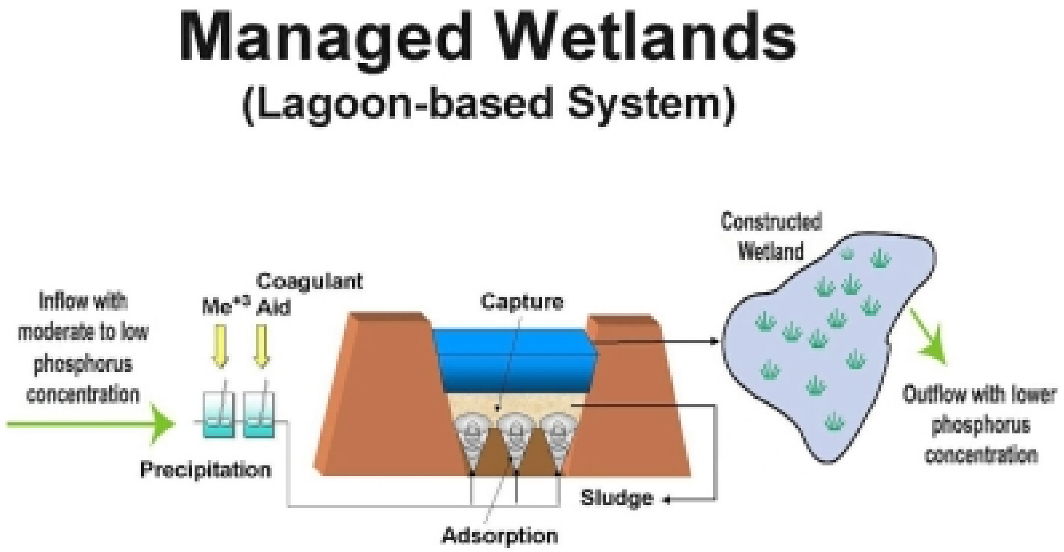

Figure 8-16. Process Schematic for Lagoon-based Managed Wetlands Treatment System Advanced Treatment Technology.

Current Status of Managed Wetlands

MWTS is proceeding in two phases. Phase 1 of the project is under way at the STA-1W test cells to determine the efficacy of this technology in cattail systems. Phase 2 is being conducted with the cooperation and participation of the Seminole Tribe of Florida at the Big Cypress Reservation, and will determine the performance of this technology when coupled to a forested (cypress) wetland. A larger scale (~100 gpm) lagoon-type chemical treatment plant, discharging to approximately four acres of cypress-dominated wetlands, is proposed. USEPA Section 319(h) funding has been received (through the Department) for the initial phase of this project, with additional funding anticipated for later phases.

Phase 1 Test Cells**:** Six test cells are dedicated to MWTS, three each at the north and south sites. Test cells are approximately 80m L x 28m W and will be operated at approximately 30 cm depth to achieve a target hydraulic loading rate of 10 cm/day. Mean TP inflow concentrations are higher at the north set than at the south set of test cells. Testing in this phase is using a nested block, paired watershed design. The nested design contains two blocks and two treatments – the two blocks of three cells each differ in inflow phosphorus concentration. Chemical treatments are being applied to three of the six cells, and three cells remain untreated.

In paired watershed analysis, a pair of water bodies is used: one where a treatment is applied, and a second that is used as a control. The use of a control water body, where no treatment is applied throughout calibration and treatment periods, allows the determination of magnitude of treatment effect (through regression analysis) without the use of experimental replication. A calibration period between the control and treatment test cells establishes the relationship between the two water bodies. Use of the control watershed during calibration and treatment periods accounts for effects of weather and climate. Initial monitoring of the test cells commenced in July 1999, ending in January 2000 (CH2M HILL, 2000).

Testing at Test Cells: Chemical treatments were commenced at the north test cells in February 2000. Chemical treatment was commenced at the south test cells in March 2000. A modification to lagoon-based MWTS concept has been applied at the STA-1W test cells. In lieu of constructing a treatment pond ahead of the test cells, a chemical treatment train similar to that of CTSS is used in the limited space available at the test cells. To simulate the sludge contact, sludge is recirculated to the top of the flow stream. To address concerns of phosphorus release of long term storage from residuals within the system, a sludge holding tank with approximately two months storage capacity is added. The key experimental and operational design features identified for testing at the STA-1W include: chemical type (coagulant), phosphorus loading rate, hydraulic loading rate in wetland cells, and the ionic conditioning provided by the wetlands. Due to the potential generation of methylmercury in the presence of sulfate ions, coagulants that do not contain sulfates i.e. aluminum chloride, polyaluminum chloride, and ferric chloride are used in MWTS.

Preliminary results from the north test cells showed that Fe and Al treatments reduced color and TDP, SRP, DOP, total nitrogen, total Kjedyl nitrogen, organic nitrogen, and total organic carbon concentrations in outflow relative to the control for inflow to the receiving wetland. Due to episodic floc overflow, TP and PP concentrations in pilot plant effluent (inflow to wetland) were not consistently lower than the inflow to the control. However, PP in the effluent was quickly removed at the head of the wetland. Treatment unit performance improved after operational adjustments in May. Due to higher TP concentration during startup, as compared to waters used in bench top tests that were used for setting dosages, some adjustments to dosing have been required. In an effort to improve flocculation, the polymer was switched from Cytec N-1986 25 percent active solids, to Cytec A130, an anionic polymer that was utilized in CTSS and LICD, both dosed at 0.5 mg/L. Adjustments to the mixing, including changing the chemical addition points and changing the mixing impellers and speeds, have been implemented. Ongoing performance optimization of the pilot units is expected to yield chemical treatment effluent with TP concentrations at or less than 10 ppb, and improved floc removal. TP and PP concentrations in wetland outflow are lower for the treatments compared to the control (CH2M HILL, 2000).

Design and Testing of a Lagoon-style Pond (Phase 2): Design of the chemical treatment pond has been completed, and construction of the lagoon-based system at the Big Cypress Reservation will begin in September 2000. Chemical treatment with polyaluminum chloride and an anionic polymer is intended as the primary method of phosphorus removal. The treatment pond will be used for solids contact, solids separation and residual solids storage. The pond will be lined with a 40-mil high-density polyethylene geomembrane and has enough solids storage volume for approximately 3 months of operation, at which time solids will be removed and trucked for disposal. Chemically treated water will flow through 2 distribution pipes running along the base of the pond. Each distribution pipe is located in a two-foot deep trench sized to hold about 3 days of precipitated solids. The distribution pipes are equally spaced and have hole patterns to provide uniform water distribution.

Once the pipe trenches fill with solids, solids contact will occur with the inlet water. Phosphorus removal occurs as water flows upward through the solids layer. A weir box at the far end of the pond will be used to set the water level in the pond and to collect treated water. Treated water will flow over the weirs and out through the discharge pipe at the base of the weir box (Burns & McDonnel Engineering, 2000).

EVALUATION AND COMPARISON OF ADVANCED TREATMENT TECHNOLOGIES

To properly evaluate the results of diverse ATT demonstration projects, it is necessary that the data obtained from all such demonstration projects be collected in a manner that allows scientifically valid comparisons to be made. To ensure that comparable information is obtained from each ATT study, the District has developed a Standard of Comparison (STSOC) that will be applied to each project. This standard is intended to be applied evenly to all technologies to provide a reasonable analysis of the potential of each technology. The STSOC provides direction to each ATT project on the data to be collected as well as the information necessary to begin the design of full-scale applications. The standard of comparison provided for the development of a database for the ATT projects and the design of an evaluation method to assess the performance of each technology.

The development of all phases of the standard of comparison has been a joint process that has included input from the District, the Department, the Everglades Technical Advisory Committee, and attendees to the Everglades Technical Workshop and the Advanced Treatment Technologies Initiative. The STSOC has evolved as follows:

Phase 1:	Formulation of conceptual approach
Phase 2:	Development of evaluation methodology, and the STSOC database
Phase 3:	Development of standardized costs
Phase 4:	Compilation and evaluation of data

In Phase 1, peer consultants prepared a concept letter report that proposed 12 evaluation concepts and a Contract Guidance Document (PEER Consultants, P.C./Brown and Caldwell, 1999). This Contract Document listed the goals and detailed the specific information on data management protocol, forms and formats that each of the Advanced Treatment Technology demonstration project research teams needed to follow during data collection. The data collection guidance document was completed in December 1997 and distributed to all the Advanced Treatment Technology demonstration project managers. The guidance document directs the collection of comparable experimental data and includes the following: identification of flow streams to be sampled: flow measurements and methodologies; analytical parameters, methods and sampling frequencies; QA/QC requirements; data formats; identification of liquid and solid-side streams to be sampled; analytical procedures for evaluating compatibility with downstream environments; the data set to be used for modeling long-term performance; and development of the conceptual design and preliminary cost templates for full-scale facilities. The contract guidance document was provided in Appendix 8-1 of the Everglades Consolidated Report 2000 (SFWMD, 2000).

In Phase 2, peer consultants developed a comprehensive evaluation methodology and STSOC database. The evaluation methodology provides a mechanism to compare different technologies on an equal basis. The STSOC database serves as a repository for storing demonstration project research data and as a comparative ATT evaluation tool. The evaluation methodology proposes five primary and five ancillary concepts, analyzed through a combination of quantitative and qualitative methods, which will be used to compare the diverse ATTs. Primary concepts include the level of P concentration reduction achieved, the level of P load reduction achieved, cost-effectiveness, evaluation of potential toxicity of the technology and implementation schedule. Ancillary concepts include the feasibility and functionality of scaled-up design and cost estimates, operational flexibility, sensitivity of technology to fires, floods, droughts and hurricanes, level of effort to manage side streams generated by the treatment process (may include potential benefits to be derived from the side streams), and other water quality issues. A database has been developed where ATT project data will be compiled for evaluation.

During Phase 3, peer consultants (Brown and Caldwell) developed the basis for estimating the cost of equipment, land and levees to be used by each demonstration project research team in developing full-scale treatment facilities. Certain items such as land, levees, pump stations, etc., will be used by most of the ATTs. To facilitate the comparison of costs, unit costs for these items have been standardized. Where practicable, the unit costs are based on actual STA construction, operation, and maintenance costs. An application of the costs has been described in a Technical Memorandum, which was distributed to all ATT demonstration project managers in September 1999.

The evaluation methodology will also include initial cost estimates and benefits (calculated as the pounds of P removed by the technology) that will be used as part of an evaluation of costs and benefits of each technology. The quantitative data will be entered into the standard of comparison database and the qualitative information will be provided by the demonstration project teams as written summaries.

During Phase 4, now underway, the District will team with independent consultants to review, update and revise the economic analysis and scale-up issues developed in Phase 3; to standardize the mathematical models being used by each of the ATTs; to compile STSOC data produced by each ATT and apply it to the STSOC database and evaluation protocol; and to select the most promising technologies with appropriate recommendations for scale up based for the STA-2 10-year period of record.

The complete STSOC final report of all the ATT projects should be available toward the end of 2001.

DEVELOP AN INTEGRATED WATER QUALITY PLAN (BMP, STA, ATT)

The Everglades Forever Act (Act) requires the development of an integrated water quality plan by December 31, 2003, which will recommend the most promising treatment train to meet the final phosphorus standard. This plan must consider the performance results from BMPs and STAs, as well as the results of the research and demonstration projects for ATTs and STA optimization. Prior to this date, the USACE Section 404 permit requires the development of a water quality strategy by January 1, 2001. The water quality strategy will be realistically limited to an evaluation of the ATTs, BMPs and STAs. Optimization research data will be available by the fall of 2000. Additional efforts will be needed to integrate all data produced by these research programs, including the phosphorus threshold research and basin specific conditions, to meet the Act’s deadline for the integrated water quality plan by 2003. Costs and benefits of each technology will also need to be determined. All supporting information and the final evaluation method will need to be incorporated into the water quality plan required by the Act.

The timelines associated with the information required for the development of the integrated water quality plan are complex (Chapter 1). The majority of the research for the ATT demonstration projects will be completed by mid-2001. In addition, there are other issues that need to be satisfactorily addressed before the integrated water quality plan can be completed. Actual phosphorus threshold values (and other water quality parameters) may not be established until December 31, 2003. The results of the Comprehensive Everglades Restoration Plan and other planning efforts need to be integrated into the plan. In addition, the relationship between discharge levels and water quality in the EPA needs to be determined. (Refer to Chapter 1 for more information on the issues associated with the Integrated Water Quality Plan.)

SELECTION AND IMPLEMENTATION OF ADVANCED TREATMENT TECHNOLOGIES

The Florida Legislature directs that the ECP and regulatory requirements associated with the Statement of Principles of July 1993 be pursued expeditiously, but with flexibility, so that ATTs may be used when available. By December 31, 2006, the Department and the District shall have taken such action as may be necessary so that water delivered to the EPA meets or exceeds state water quality standards, including the phosphorus criterion. Long-term efforts will integrate the results of ongoing research, planning and regulatory activities.

Long-term implementation (the design and construction of ATTs) will of necessity overlap the development of the integrated water quality plan (Chapter 1). Construction must begin no later than 2004. Although the evaluation criteria for ATTs will identify the most promising technologies, additional site-specific feasibility studies will likely be necessary. The ultimate combination of approaches will need to consider the site-specific conditions that will potentially affect the successful implementation and performance of the treatment train. Pilot projects of some more expensive technologies may also be desirable. Other issues for long-term implementation include land requirements and land acquisition. Funding for the long-term implementation has not yet been defined.

RESEARCH, DEVELOPMENT, AND IMPLEMENTATION COSTS

Initial cost estimates for implementation of the ATTs were provided by the Desktop Evaluation conducted by peer consultants (P.C. Brown and Caldwell) in 1996. However, these costs were extremely preliminary and were not based on data derived from tests with EAA waters. The initial estimates were also based on a number of assumptions that have since proved to be incorrect.

Through the continuation and completion of the ATT research projects described above, the District will obtain more substantial information on the costs and benefits associated with each technology. This information will be provided to the legislature in the peer- reviewed report required by the Everglades Forever Act by January 1, 2002.

The level of funding needed for long-term implementation is unclear at this time and has not been designated. Funding requirements will be contingent on the optimal combination of BMPs, STAs, and ATTs determined to achieve the long-term water quality and hydropattern goals of the Everglades restoration. Preliminary cost estimates will be developed as part of the research and demonstration studies (described above) scheduled for completion by 2002. The overall strategy for achieving water quality goals by 2006 is summarized in Chapter 1 of this report.

CHAPTER CONCLUSIONS

An enormous amount of effective research has been conducted in trying to address the uncertainties associated with removing P down to the planning target of 10 ppb. At this time preliminary findings indicate that chemical treatment can consistently deliver TP outflow concentrations of 10 ppb or less, where small-scale “green” technologies, such as SAV/LR and PSTA, may be able to achieve TP concentrations between 15 and 20 ppb. Areas for further study within ATT research include the effects of hydrologic pulsing, system dryout, water depth, and antecedent P soil concentrations on P removal and constructability.

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