Chapter 3: Performance and Optimization Research on Agricultural Best Management Practices

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SUMMARY

Nutrient-rich discharges from the Everglades Agricultural Area (EAA) have been identified as contributors to the enrichment of the Everglades and are the primary focus of the Everglades Regulatory Program and the Everglades Construction Project. The objective of this chapter is to provide an update on the effectiveness of Best Management Practices (BMPs), as demonstrated by the implementation of the Everglades Regulatory Program and research in the EAA Basin.

Substantial efforts in BMP implementation, research and education have been directed at reducing phosphorus (P) loading from the EAA as part of the Everglades Program. These combined efforts are responsible for an appreciable reduction in the loads and concentrations of total phosphorus (TP) attributable to the EAA Basin and conveyed to the Everglades Protection Area (EPA). This chapter provides an update to the data published for previous years. The recommendations and conclusions presented this year do not vary from previous years.

The overall effectiveness of BMPs is best demonstrated by the measured phosphorus load reduction in the EAA Basin since BMPs were implemented as compared to a 10-year, pre-BMP base period. The BMP Regulatory Program in the EAA, mandated by State of Florida legislation, is one aspect of the South Florida Water Management District's (SFWMD or District) Everglades Restoration Program. The goal of the BMP regulatory program is to achieve a 25-percent reduction in phosphorus load from the EAA Basin. This reduction is determined by comparing phosphorus discharges from the District structures at the end of each 12-month water year (May 1 through April 30) to the pre-BMP base period of October 1, 1978 through September 30, 1988. The base-period phosphorus discharges are adjusted for the differences in the amount and distribution of rainfall for the current period. The rule requires the District to evaluate the data collected to assess the general trend in phosphorus load reduction, determine whether the EAA Basin is in compliance with the phosphorus load reduction requirement and publish the results annually. The EAA Basin has been in compliance since the first full year of BMP implementation (Water Year 1996).

The phosphorus load discharged from the EAA Basin for Water Year 2001 (WY01) is:

WY01 (measured with BMPs in place)	52 tons
Base Period (predicted with WY01 adjusted rainfall)	195 tons

The relative difference between the WY01 measured tonnage and the predicted base period tonnage (adjusted for rainfall) indicates a 73 percent reduction in total phosphorus load. The three-year cumulative phosphorus load reduction from the EAA is 57 percent (with a three-year cumulative concentration of 107 parts per billion [ppb]). In analyzing data trends, the three-year trend equates to a 57-percent reduction of the phosphorus load from the EAA Basin, some of which enters the Everglades. It does not account for the phosphorus loads entering the Everglades from other sources, including Lake Okeechobee releases (environmental, urban water supply and regulatory), C-139, C11 West, L-28, Feeder Canal Basin, ACME Basin B, North Springs Improvement District, North New River Canal Basin, C-111 and Stormwater Treatment Area (STA) discharges. The methodology for these calculations is discussed later in this chapter.

For WY01, the total phosphorus load to the Everglades from various sources was 103 tons, with a combined average concentration of 65 ppb. Of the 103 tons going to the Everglades, 22 tons (a portion of the 52 tons from the EAA Basin) can be directly attributable to discharges from the EAA Basin farms, cities and industry, while the remaining 81 tons is from other sources.

This chapter also includes a summary of the data from individual permittee-operated discharge structures within the EAA Basin. These data are used to determine credits toward the Everglades Agricultural Privilege Tax mandated by the Everglades Forever Act (EFA) and to determine compliance with Chapter 40E-63, Florida Administrative Code (F.A.C.), should the EAA Basin not meet the 25 percent phosphorus load reduction requirement.

In addition to the Everglades Regulatory Program, the EFA and Chapter 40E-63, F.A.C., require EAA landowners, through an organization called the EAA Everglades Protection District (EAA-EPD), to sponsor a program of BMP research, testing and implementation to identify appropriate BMPs. The latter part of this chapter summarizes ongoing research initiatives. The University of Florida EAA BMP farm-scale study, sponsored by the EAA-EPD and the Florida Department of Environmental Protection (Department), continues to demonstrate that BMPs are highly effective in reducing TP loads discharged from participating farms. In response to the research findings, the study was expanded to include the development of BMPs to control sediment and particulate P transport. Additionally, the District sponsored two research projects to develop new BMPs. One of the projects investigated the application of silicon soil amendments to control phosphorus release from organic soils. The results of this project show that the Si soil amendments have potential for use as a BMP in the EAA Basin to reduce P loading and increase crop yield, particularly in vegetable fields. Verification of these results is necessary at the field scale. The other project aimed to identify sugarcane cultivars with different phosphorus characterization levels that can be planted in the EAA Basin to reduce TP loading.

The combined efforts of the Everglades Regulatory Program in the EAA and the cooperative program of research, implementation and testing of BMPs are responsible for appreciable reductions in the load and TP concentrations attributable to the EAA Basin and conveyed to the Everglades. The EAA Basin has consistently exceeded the 25 percent load reduction requirement; however, it is anticipated that the EAA Basin TP load reductions will start to level off in coming years. It is recommended that the research, monitoring and education efforts continue in an effort to gain a better understanding of optimization techniques for BMPs and to apply "lessons learned" to other regions that discharge to the Everglades.

INTRODUCTION

A significant component of the EFA establishes both interim and long-term water quality goals to ultimately achieve restoration and protection of the Everglades. As mandated by the EFA, the long-term phosphorus (P) concentration will be set by the State of Florida Environmental Regulatory Commission based on available research, or will default to 10 parts per billion (ppb). The long-term goal is to combine point-source, basin-level and regional solutions in a system-wide approach to ensure all waters discharged to the Everglades are achieving water quality goals. The interim design goal encompasses those activities underway, the Everglades Regulatory Program and the Everglades Construction Project (ECP) to achieve an annual average P discharge concentration of 50 ppb for the final discharge from the ECP (Stormwater Treatment Area [STA] outflow). Surface water tributary sources to the ECP include the basin discharges (STA inflows) from the EAA Basin, C-139 Basin and Lake Okeechobee normal releases (environmental, water supply, regulatory).

Agriculture is the predominant land use in both the EAA and C-139 basins. Nutrient-rich water from both areas contributes to enrichment of the Everglades and is the primary focus of the Everglades Regulatory Program and the ECP. The Everglades Regulatory Program provides for the implementation of BMPs as point-source treatment upstream of the STAs. The design of the STAs is based on the EAA Basin discharges having a 25 percent reduction in P load and the C-139 Basin not exceeding the historic load as compared to the pre-BMP base period of October 1, 1978 through September 30, 1988, adjusted proportionately for rainfall.

The EAA Basin is located south of Lake Okeechobee within Eastern Hendry and Western Palm Beach counties and encompasses an area of approximately 1,122 square miles of highly productive agricultural land comprised of rich organic peat or muck soils (**Figure 3-1**). The area is considered one of Florida's most important agricultural regions. Approximately 77 percent of the area is devoted to agricultural production. The major crops in the EAA Basin include sugar cane, vegetables and sod. Rice and citrus are also grown in the EAA. The EAA Basin ultimately discharges to the Everglades through STAs-1W, 2, 6 and eventually STA-3/4, once construction is complete. The BMP Regulatory Program has been implemented in the EAA since 1992. Because of BMP implementation by EAA Basin landowners, the TP load from the EAA Basin has declined in recent years compared to the pre-BMP base period.

The C-139 Basin is located southwest of Lake Okeechobee within Eastern Hendry County and adjacent to the EAA Basin (**Figure 3-1**). The C-139 Basin ultimately discharges to the Everglades through STA-5. Amendments to Chapter 40E-63, F.A.C., are currently proposed to implement a BMP regulatory program in the C-139 Basin in accordance with the EFA. The proposed rule establishes a compliance methodology similar to that of the EAA Basin (disregarding the 25 percent load reduction criteria) to determine the annual average phosphorus load limitation for the C-139 Basin and a plan for BMP implementation to minimize P in offsite discharges. If adopted, the amendments would require landowners in the basin to obtain permits for BMP Plans and report annually to the District on the status of BMP implementation. The rule is anticipated to become effective by spring 2002. These efforts are to ensure that the C-139 Basin does not contribute substantially to nutrient loading in the Northern Everglades. Until fully implemented in the C-139 Basin, BMP effectiveness will focus solely on the EAA Basin.

The implementation of BMPs is the cornerstone for source control of P on the farms. BMPs have been implemented in the EAA Basin for six complete compliance years and have proven successful at reducing TP loading. Additionally, ongoing BMP research in the EAA Basin initiated as early as 1992 continues to show varying degrees of effectiveness in TP reduction through the implementation of combinations of water management practices, fertilizer application control practices, and particulate matter control practices. This chapter provides an update of the data for these programs.

UPDATE ON EVERGLADES REGULATORY PROGRAM

The Everglades Regulatory Program, Chapter 40E-63, F.A.C. ("Rule 40E-63"), states that lands in the EAA that release water that ultimately makes use of, connects to, releases to, or discharges to the Works of the District (WOD) within the Everglades require a permit. Rule 40E-63 permits approve a BMP Plan and a Water Quality Monitoring Plan for each sub-basin.

Currently, there are a total of 37 Everglades WOD permits, including 209 sub-basins and 304 privately-owned water control structures discharging into the District canals in the EAA encompassing an area of approximately 490,000 acres (**Figure 3-2**). The regulated area is described by rule and thus remains static. There are annual differences in the total permitted acreage, typically the result of acreage being removed from permits as acreage is converted from agricultural production to stormwater treatment areas.

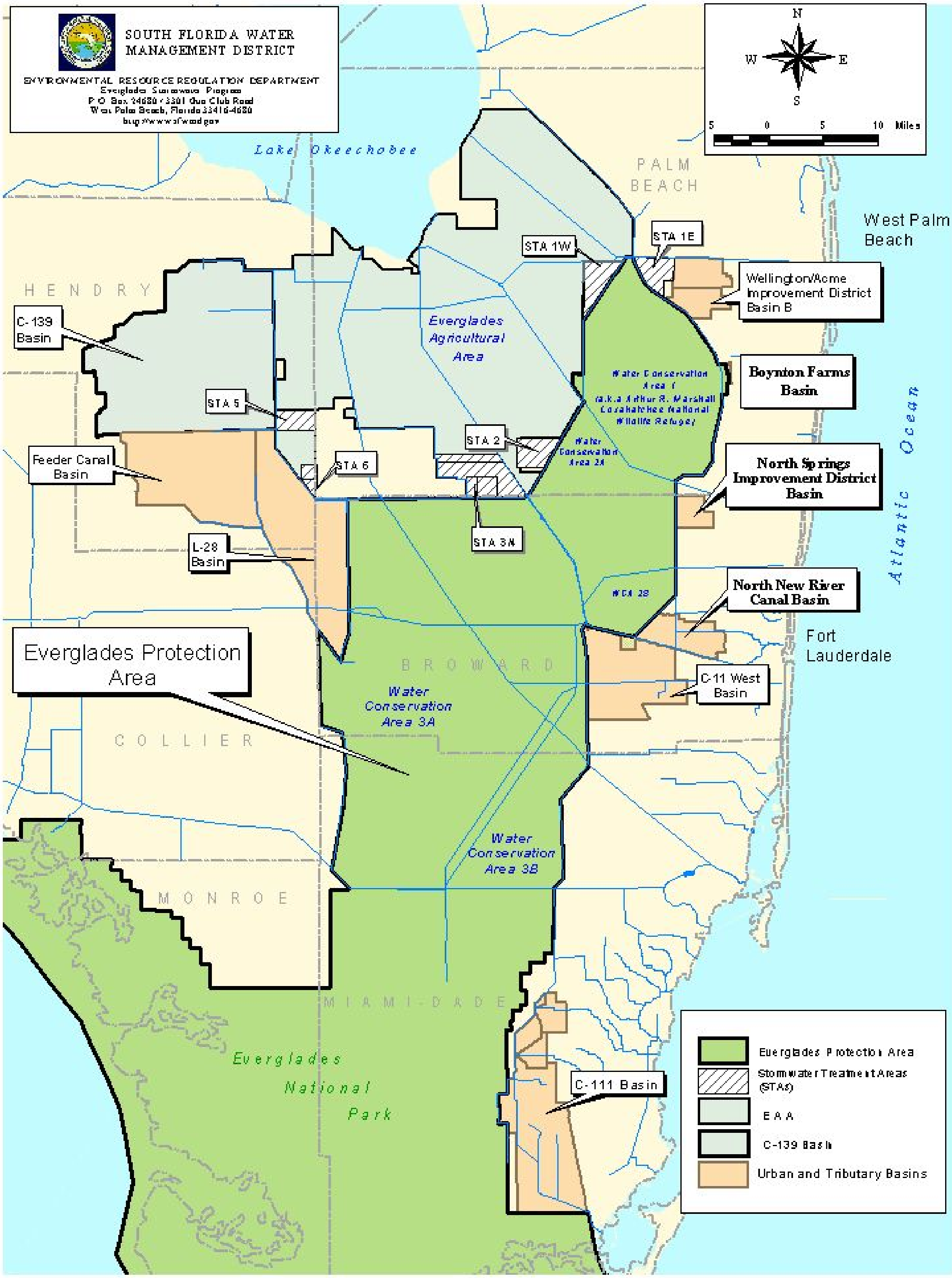


Figure 3-1. Location for Basins, Tributary to EPA

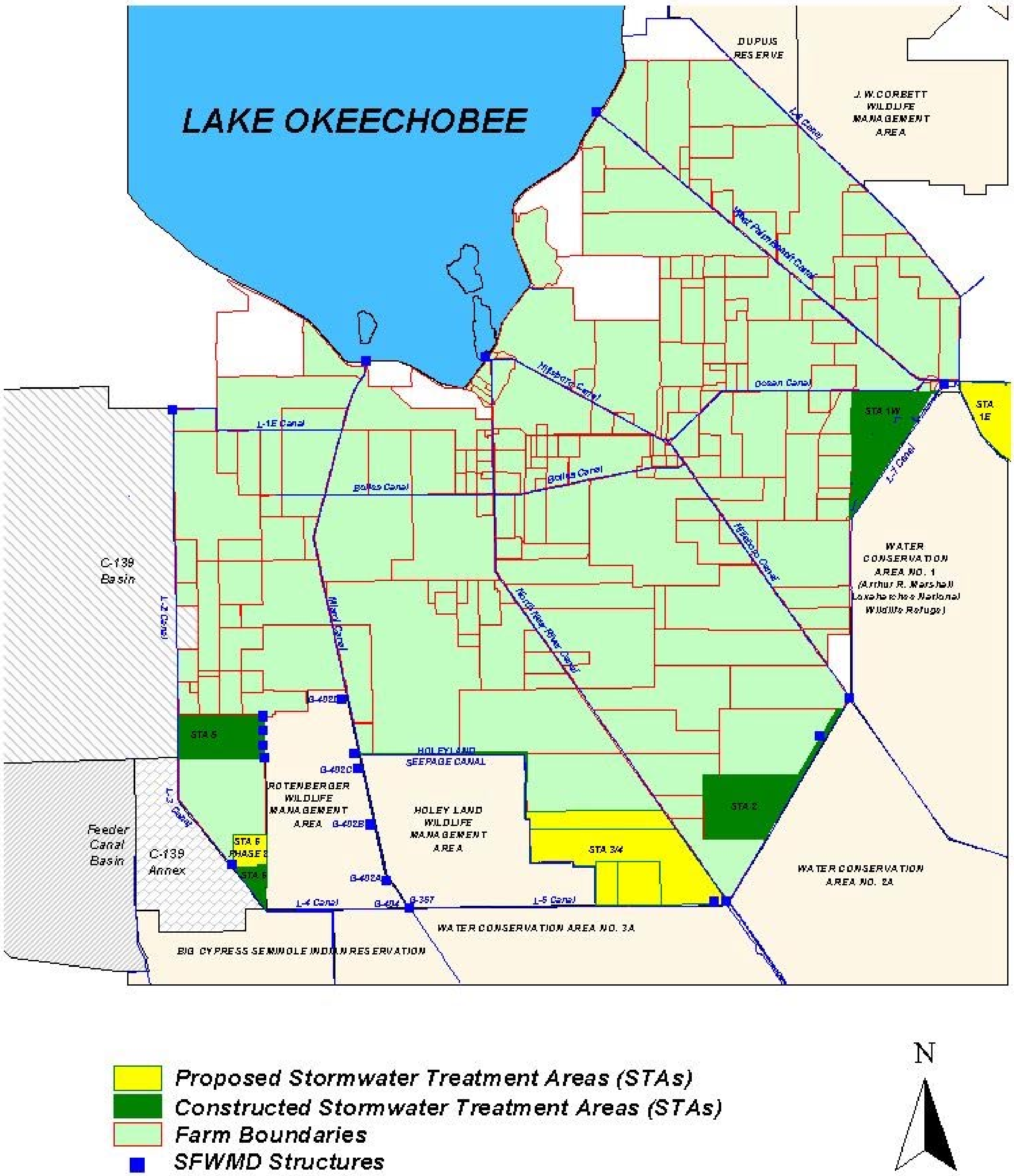


Figure 3-2. SFWMD Water Control Structures with Boundaries Defined by Rule 40E-63

BEST MANAGEMENT PRACTICE PLANS

Each EAA WOD permit approves an onsite implementation plan for BMPs ("BMP Plan"). The BMP Plan includes operational programs or physical enhancements designed to reduce P levels in discharges to the WOD. The District is responsible for ensuring that a base level of BMPs is established for each permit area and that BMP plans between different permittees are consistent and comparable. To accomplish this, a system of BMP "equivalents" was developed. The intent was to assign points to BMPs within three basic categories: water-management practices, nutrient-management practices and control of particulate matter. BMP research has been conducted within the EAA region, with positive results on relative effectiveness of BMPs. However, no specific phosphorus-reduction levels are quantified for individual BMPs. The equivalent points assigned to each BMP, shown in **Table 3-1**, are based on best professional judgment and cooperative workshops conducted between affected landowners, consultants, District staff and the general public.

Twenty-five BMP equivalents, or points, are set as the minimum target BMP plan for the EAA Basin. Utilizing the BMP-equivalents approach allows each permittee the flexibility to develop a BMP plan that is best suited for site-specific soil types, hydrology and crop conditions. For each proposed BMP, the permittee must consider how the BMP will be implemented, how the staff responsible for BMP implementation will be trained and how BMP implementation will be documented. Post-permit compliance activities include verification of the implementation of the approved BMP plans by two methods: (1) Annual submittal of BMP implementation reports by the permittee and (2) in-field visual observations and review of documentation. The goal is to conduct onsite verifications annually; however, this can vary depending on circumstances. Onsite verifications allow District staff to work with the permittees by discussing BMP strategies and optimization of current BMP practices. The BMP site verifications conducted thus far indicate permittees have implemented their respective BMP plans and are taking a proactive approach to reviewing and improving their plans where possible.

Table 3-1. Best Management Practices Summary and "BMP Equivalent" Points

BMP	PTS	DESCRIPTION
WATER MANAGEMENT PRACTICES		MINIMIZES THE VOLUME OF OFF-SITE DISCHARGES
½ Inch Water Detention 1 Inch Water Detention	5 10	Delay pumping based on rain gage measurements. Detention (in farm canals and soil profile) measured on a per event basis – rainfall vs. runoff.
Improved Infrastructure	5	Water table management plan; controlling levels in canals and field ditches using internal water control structures, fallow fields, aquatic cover crop fields, prolonged crop flood; effective irrigation and discharge plans.
Other	tbd	Properly constructed and maintained storage system; greater detention with water management plan having target water table levels and structure operating procedures; monitored water table.
NUTRIENT CONTROL PRACTICES		MINIMIZES THE MOVEMENT OF NUTRIENTS OFF-SITE * Limited Applicability
Fertilizer Application Control	2 ½	Uniform and controlled boundary fertilizer application (e.g. banding at the root zone; pneumatic controlled-edge application such as AIRMAX); calibrated application equipment; setbacks from canals.
Fertilizer Spill Prevention	2 ½	Formal spill prevention protocols (handling, transfer, education).
Soil Testing	5	Avoid excess application by determining P requirements of soil.
Plant Tissue Analysis	2 ½	Avoid excess application by determining P requirements of plant.
Split P Application*	5	Applying P proportionately at various times during the growing season. Total application not exceeding recommendation.
Slow Release P Fertilizer*	5	Applying specially treated fertilizer that breaks down slowly thus releasing P to the plant over time.
PARTICULATE MATTER AND SEDIMENT CONTROLS		MINIMIZES THE MOVEMENT OF PARTICULATE MATTER AND SEDIMENTS OFF-SITE (Each consistently implemented across the entire basin acreage.)
Any 2 Any 4 Any 6	2 ½ 5 10	• leveling fields • ditch bank berm • sediment sumps in canals • sediment sumps in field ditches • canal/ditch cleaning program • slow drainage velocity near pumps • sediment sump upstream of drainage structure • cover crops • raised culvert bottoms • stabilized ditch banks • aquatic plant management • debris barriers at outfall
PASTURE MANAGEMENT		PLAN FOR ON-FARM OPERATION AND MANAGEMENT PRACTICES
Pasture Management	5	• reduce cattle waste nutrients in discharges by "hot spot" management, i.e. plans for placement of drinking water, feed and supplements, cowpens and shade. • low cattle density
OTHER BMPs		OTHER PRACTICES PROPOSED
Urban Xeriscape	5	Use of plants that require less water and fertilizer.
Det. Pond Littoral Zone	5	Vegetative filtering area for on-site stormwater runoff.
Other BMP Proposed	tbd	BMP proposed by permittee and accepted by SFWMD.

COMPLIANCE DETERMINATION

Within the EAA Basin, monitoring is performed at two levels:

(1) EAA basin-level monitoring by the District, and

(2) Individual sub-basin or farm-level monitoring by the owner/operator of private water control structures discharging within the EAA Basin.

The primary means to determine the Rule 40E-63 program success is through District data collection and analysis of water quality monitoring conducted at the EAA Basin level. The discharge TP concentration and quantity are recorded at all inflow and outflow points, including: S-2 Complex, S-3 Complex, S-352 Complex, S-5A Complex, S-6, S-7, S-150, S-8, G-136, G-200, G-328, G-344A, G-344B, G-344C, G-344D, G-349B, G-350B, G-600, G-410, G-402A, G-402B, G-402C, G-402D, G404, G-357, EBWCD and ESWCD (**Figure 3-2**). The TP levels measured at these structures collectively determine primary compliance for all EAA WOD permits. For primary compliance, the EAA Basin must demonstrate a 25 percent reduction in load on an annual basis as compared to the pre-BMP base period.

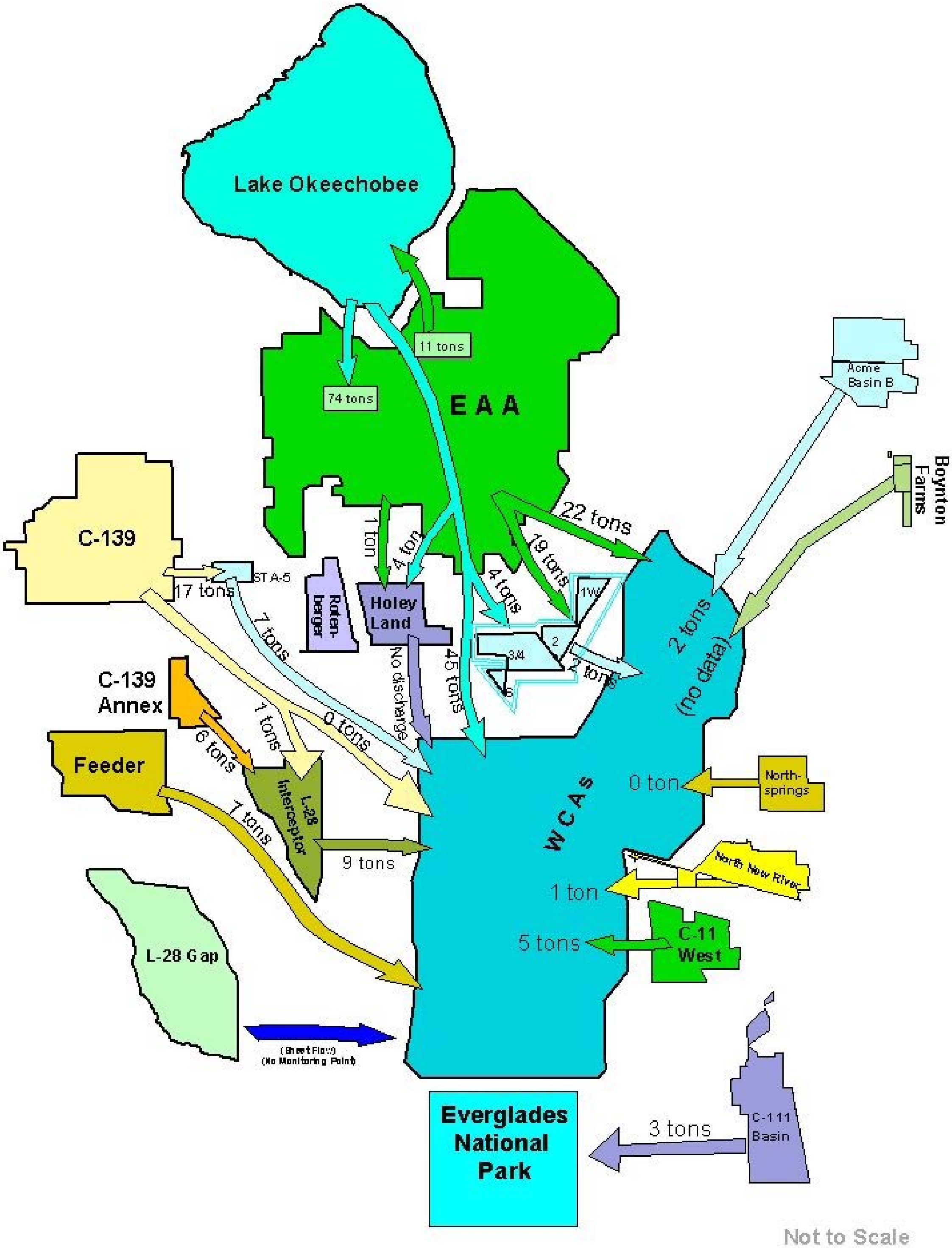
A secondary method of program compliance measurement is through individual sub-basin ("permit-level" or "farm-level") water quality monitoring conducted by the permittee. The permit-level monitoring will only be used for compliance determinations if the EAA Basin does not meet the 25 percent load reduction requirement. The permit-level data is also used to determine credits toward the Everglades Agricultural Privilege Tax mandated by the EFA (Section 373.4592(6), Florida Statutes). The permittee water quality monitoring results are not used to calculate the TP reduction at the EAA Basin level.

EAA BASIN-LEVEL MONITORING RESULTS

Since the implementation of BMPs, as required by the Everglades Regulatory Program, P load from the surface water runoff attributable to the lands from within the EAA Basin has shown a trend of reduction.

To interpret TP measurements taken at inflow and outflow pump stations and water control structures discharging from the EAA Basin (**Figure 3-2**), it is important to recognize that water leaving the EAA Basin through these structures is a combination of EAA farm and urban-generated runoff and water passing through the EAA Basin canals from external basins. Careful accounting of TP loads from various sources is required to develop accurate conclusions about TP loads originating from the EAA Basin.

The reported TP loads attributed to the farms, cities and industries within the EAA Basin should not be confused with the TP load being delivered to the Everglades. The tributary sources and flow patterns are complex. The schematic in **Figure 3-3** represents the sources and amounts of phosphorus discharged from or through the EAA Basin and other tributary sources to the Everglades for Water Year 2001. The data are discussed below.



Tons presented are metric, 1000 kg = 1 metric ton, 2205 lb = 1 metric ton

NOTE: Only STAs-1W, 5, and 6 were operational in Water Year 2001

Figure 3-3. Schematic of Total Phosphorus Inflows to WCAs from Various SFWMD Controlled Structures – WY01

The EFA specifically mandates a method to measure and calculate the annual EAA Basin export of P in surface water runoff from the EAA lands (farms, cities, and industry). These calculations are adjusted for the hydrologic variability associated with rainfall and surface water discharges over time. These adjusted equations attempt to predict what the average annual TP load would have been for the EAA Basin during the base period if the current water year's rainfall amount and monthly distribution had occurred during the base period. The calculations for the annual "percent reduction in phosphorus" are then determined simply as the relative difference between the measured annual loads and the corresponding predicted average annual base period loads.

EAA Basin Annual Phosphorus Measurements and Calculations

The first year of the 25 percent reduction compliance measurement mandated by statute occurred during Water Year 1996 (May 1995 through April 1996). TP load reduction measurements are conducted and reported annually. The EAA Basin TP loads and concentrations are determined in accordance with procedures specified in the Everglades Regulatory Program (Rule 40E-63) and the EFA. The data for all calculated years are summarized in **Table 3-2 and Figure 3-4**. The data for Water Year 2001 are summarized below.

Predicted Base Period P Loads from EAA

195 tons of P (adjusted for WY01 rainfall)

Water Year 2001 P Loads from EAA (includes farms, cities, and industry)

52 tons of P with a combined average concentration of 64 ppb
NOTE: Only a portion of this load (22 tons) goes to the Everglades.

Water Year 2001 P Loads from Other Tributary Sources to EPA

81 tons of P with a combined average concentration of 83 ppb

Of the 52 tons attributable to the EAA farms, cities and industry, 22 tons went to the Water Conservation Areas (part of the Everglades shown in **Figures 1-1** and **3-1**), 11 tons were backpumped to Lake Okeechobee by the District, 1 ton went to the Holey Land and 19 tons went to the active STAs (ultimately discharging to the Everglades). A breakdown of the 81 tons of P discharged to the Everglades from other sources is shown below and on the schematic in **Figure 3-3**. For a discussion on STA performance, please refer to Chapter 4. Any difference in reported P tonnage between chapters is a result of rounding differences and differences in calculation methodology.

- 0 tons from C-139 Basin
- 45 tons from Lake Okeechobee, passed through the EAA Basin (environmental, urban supply, and regulatory releases)
- 9 tons from L-28 Basin (pump station S-140)
- 7 tons from the Feeder Canal Basin (structure S-190)
- 5 tons from the C-11 West Basin (pump station S-9)
- 2 tons from Wellington Basin B (pump stations ACME1 and ACME2)

- 0 tons from North Springs Improvement District (pump station NSID1)
- 1 ton from North New River Canal (Pump Station G-123)
- 3 tons from C-111 Basin (S-18C, S-174, S-175, S-332 and S-332D)
- 9 tons from STA outflows

Table 3-2. Summary of EAA Basin TP Calculations Conducted in Accordance with Procedures Specified in Rule 40E-63 and the EFA

TIME →

	WY80 ↓ WY91 Pre-BMP Period	WY92 ↓ WY93 Partial BMP Implementation	WY94	WY95	WY96 ← Full BMP Implementation	WY97	WY98	WY99	WY00	WY01 →
Three-Year Cumulative Phosphorus % Load Reduction	**n/a**	**n/a**	**39%**	**36%**	**47%**	**51%**	**55%**	**44%**	**48%**	**57%**
Phosphorus Concentration (ppb)	**173 ppb** 12-year average	**166 ppb** 2-year average	**121** ← 3-year cumulative each Water Year	**130**	**109**	**106**	**100**	**107**	**114**	**107** →
% Acres Implemented with BMPs as per the Everglades BMP Program (Rule 40E-63)	0%	0% *	15%	63%	100%	100%	100%	100%	100%	100%
WY Annual Phosphorus Concentration (ppb)	173 ppb 12-year average	166 ppb 2-year average	112	116	98	100	102	124	119	64
WY Annual Calculated Phosphorus Load % Reduction	n/a	n/a	17%	31%	68%	49%	34%	49%	55%	73%
80% Confidence Interval	n/a	n/a	-26-46%	-4-54%	54-78%	32-62%	6-54%	29-64%	38-68%	62-82%

*NOTE: Lake Okeechobee SWIM BMP Program, 1992-1993, gave BMP credit for:

- Initiation of deep-well injection of domestic wastewater from Belle Glade, South Bay, and Pahokee
- Pump BMPs in S2 and S3 Basins

Table 3-3. WY80 through WY01 EAA Basin TP Measurements and Calculations.

Water Year	Observe TP (m. tons)	Predict TP (m. tons)	% TP Reduct.	Annual Rain (in)	Annual Flow (Kac-ft)	Base Period	Pre-BMP Period	LOK SWIM BMPs	Evrglds Rule BMPs
80	167	154	-9%	53.50	1162				
81	85	98	13%	35.05	550				
82	234	255	8%	46.65	781				
83	473	462	-2%	64.35	1965				
84	188	212	11%	49.83	980				
85	229	180	-27%	39.70	824				
86	197	240	18%	51.15	1059				
87	291	261	-12%	51.97	1286				
88	140	128	-9%	43.43	701				
89	183	274	33%	39.68	750				
90	121	120	-1%	40.14	552				
91	180	219	17%	50.37	707				
92	106	179	41%	47.61	908				
93	318	572	44%	61.69	1639				
94	132	160	17%	50.54	952				
95	268	388	31%	67.01	1878				
96	162	503	68%	56.86	1336				
97	122	240	49%	52.02	996				
98	161	244	34%	56.12	1276				
99	128	249	49%	43.42	833				
00	193	425	55%	57.51	1311				
01	52	195	73%	37.28	667				

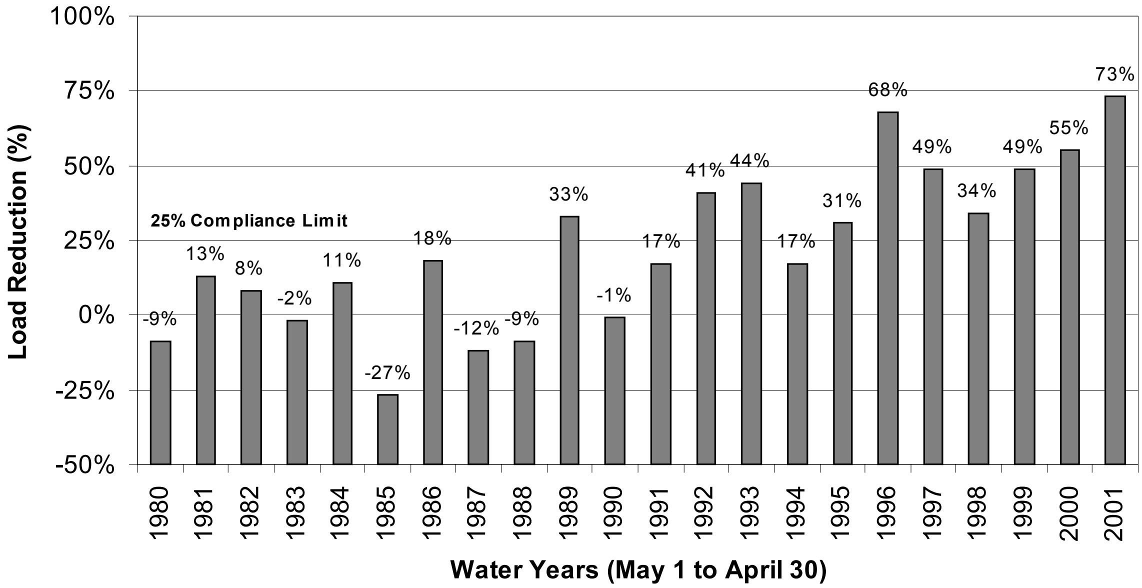


Figure 3-4. EAA Basin TP Percent Reduction

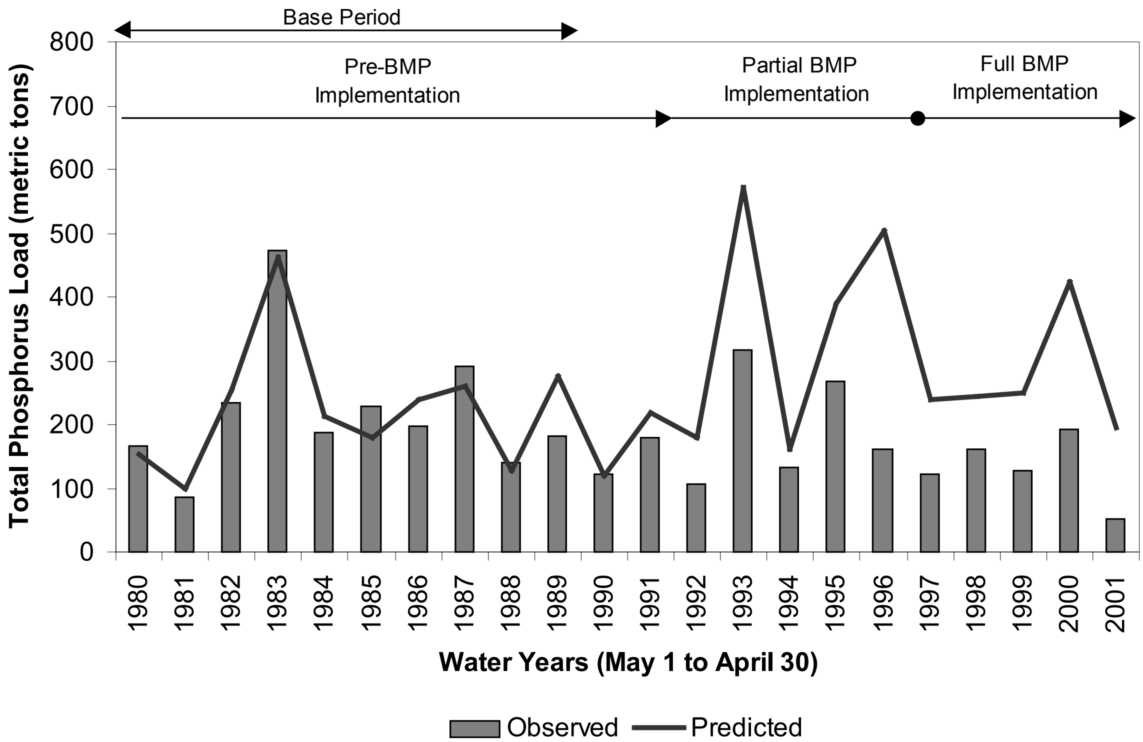


Figure 3-5. EAA Basin TP Load Calculated as Per Criteria in Rule 40E-63

WATER YEAR 2001, EAA PHOSPHORUS LOAD REDUCTION (PERCENT)

- Estimated P Load from the EAA during the Base Period Years Adjusted for WY01 Rainfall Amount and Distribution (1979-1988) 195 tons
- Actual WY01 P Load from the EAA with BMPs Implemented 53 tons
- WY01 P Load Reduction (relative difference) 73 percent
- Three-year Cumulative P Load Reduction 57 percent

WATER YEAR 2001, EAA PHOSPHORUS CONCENTRATION (PPB)

- Actual Annual Average EAA P Concentration Implementation (1979 – 1991) Prior to BMP 173 ppb
- Actual WY01 P Concentration from the EAA With BMPs Implemented 64 ppb
- Three-Year Cumulative P Concentration 107 ppb

The observed and predicted data measurements for the EAA P calculations and annual rainfall and flow measurements are presented in **Table 3-3**. The dashed vertical line indicates the period for which BMPs were not fully implemented.

The P values presented in **Figures 3-5** through **3-8** are attributable only to the EAA farms, cities and industry and do not represent the cumulative P being discharged to the Everglades from all sources. **Figure 3-5** provides a graphical perspective of the EAA Basin calculations conducted in accordance with Rule 40E-63. Each data bar represents the actual measured annual P tonnage from the EAA Basin each water year. The data line in **Figure 3-5** represents the annual phosphorus tonnage predicted by the methodology described earlier. The relative difference between the measured P tonnage (data bar) and the predicted (data line) is the percent P reduction.

As described, the annual percent reduction of P is calculated as the relative difference between the actual measured EAA Basin TP load and the predicted base period TP load (adjusted for rainfall). The annual EAA Basin percent TP reduction calculations are presented in **Figure 3-6**. The solid line shows the three-year trend of percent reduction. The ♦ symbols represent the annual measurements. An upward trend in the solid line in **Figure 3-6** denotes a reduction (improvement) in loads.

It can be difficult at times to clearly recognize any trend of P reduction from the Rule 40E-63 calculation methodology, particularly with annual base-period P levels, which vary depending on each year's timing and distribution of rainfall. **Figure 3-7** provides an alternative view of the EAA Basin annual TP loads. The approach used is to combine the TP load data from **Figure 3-5** with the percent reduction calculations **(Figure 3-6)**. The result is a normalized view of the data to assist with the recognition of data trends. The arithmetic annual average TP load during the base period is approximately 207 metric tons. Each annual EAA Basin percent reduction of TP load was multiplied by the 207 metric ton pre-BMP annual average and plotted on **Figure 3-7** (normalized annual load = 207 mtons x [1 - annual percent reduction]). It appears that there has been an overall trend of P reduction since the initial implementation of BMPs within the EAA Basin.

In addition to TP load, TP concentrations are also calculated; however, concentration levels are not directly considered in determining EAA Basin compliance. Flow-weighted concentrations allow relative comparisons between years. Annual concentrations and three-year trends presented in this report are true "annual flow-weighted" values calculated by dividing the total annual cumulative TP load by the total annual cumulative flow.

An alternative method to examine the progress being made towards the reduction of P from the ECP tributary basins is provided in **Figure 3-8**. The data in **Figure 3-8** are presented in terms of percent of water delivered to the Water Conservation Areas. The shading in **Figure 3-8** represents four P concentration ranges (where "C" represents concentration). For a discussion on the relative impacts of various concentrations, please refer to Chapter 5.

Consistent with **Figures 3-5** through **3-7**, the data are presented as three-year rolling averages for analysis of data trends. **Figure 3-8** shows progress of increasing levels of surface water runoff to the Everglades with lower P concentration levels. The solid horizontal arrows across the top of the graph show the implementation period. A dashed line indicates partial implementation of BMPs.

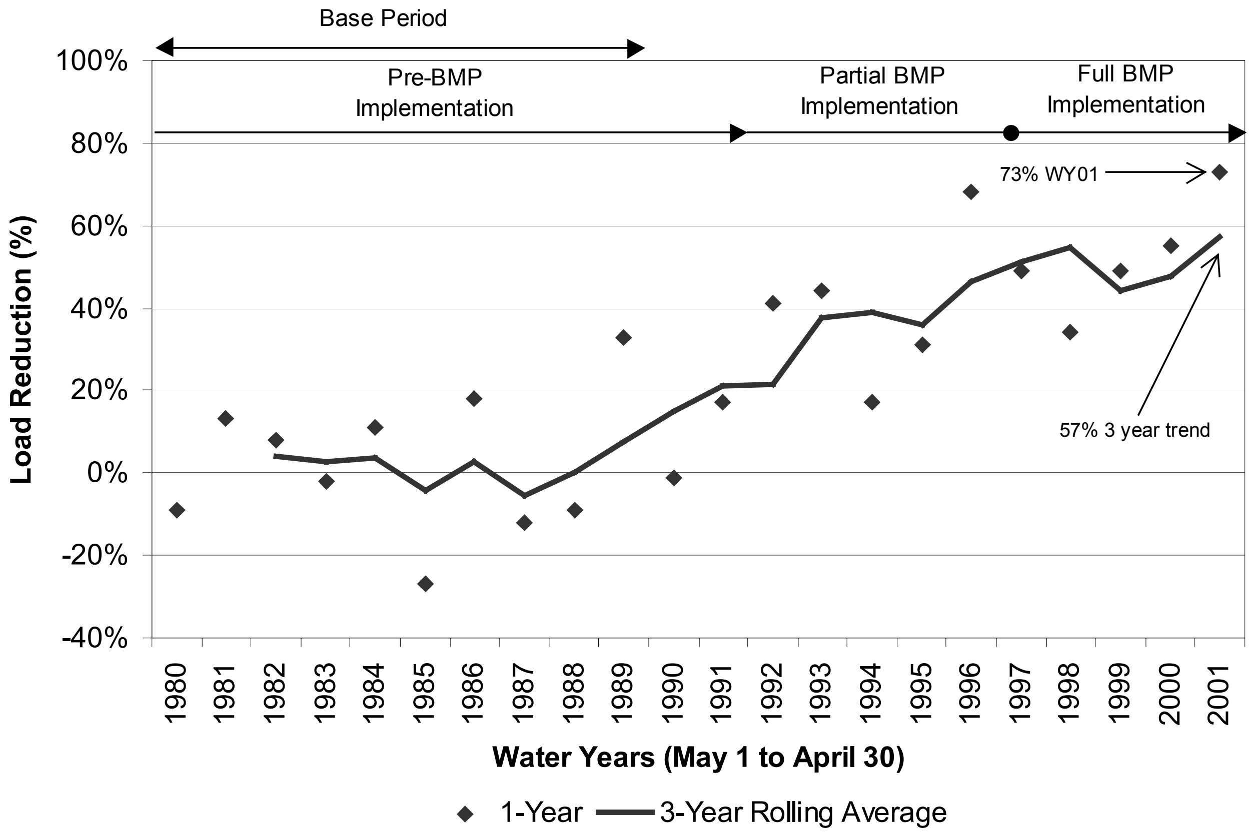


Figure 3-6. EAA Basin TP Percent Reduction Calculated as Per Criteria in Rule 40E-63

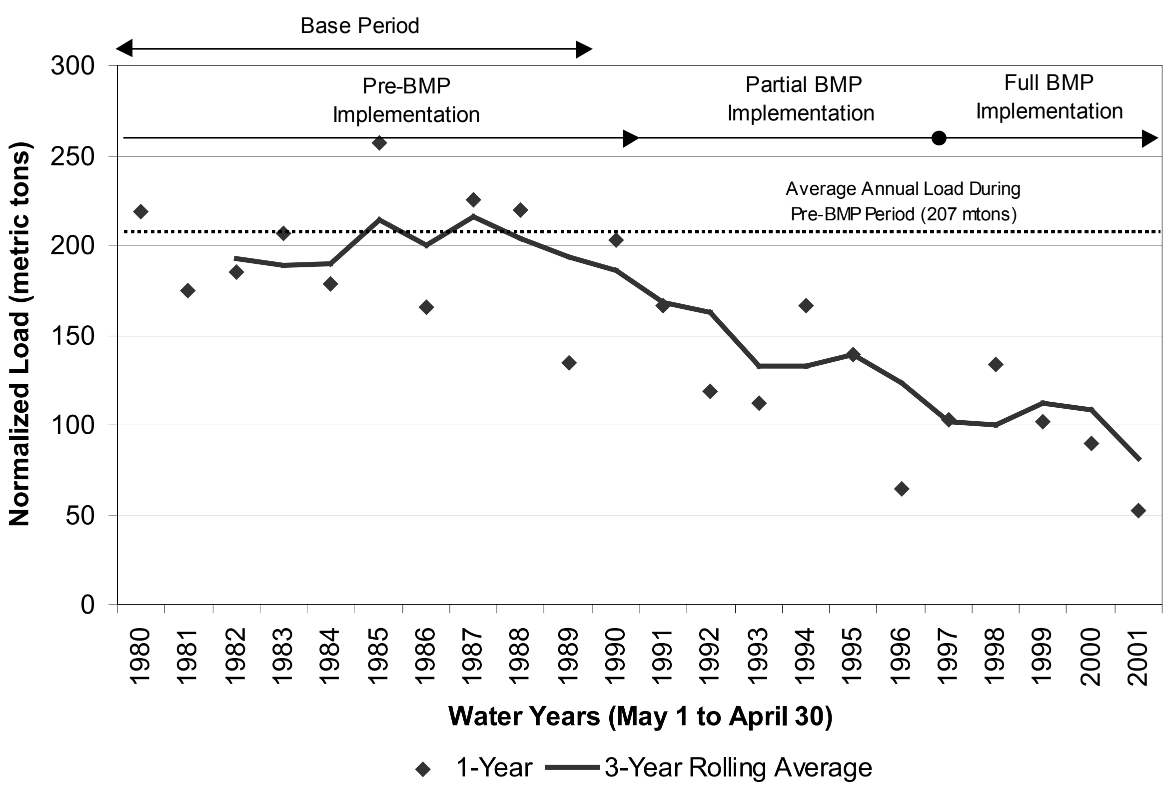


Figure 3-7. Normalized View of EAA Basin TP Loads Calculated as Per Criteria in Rule 40E-63

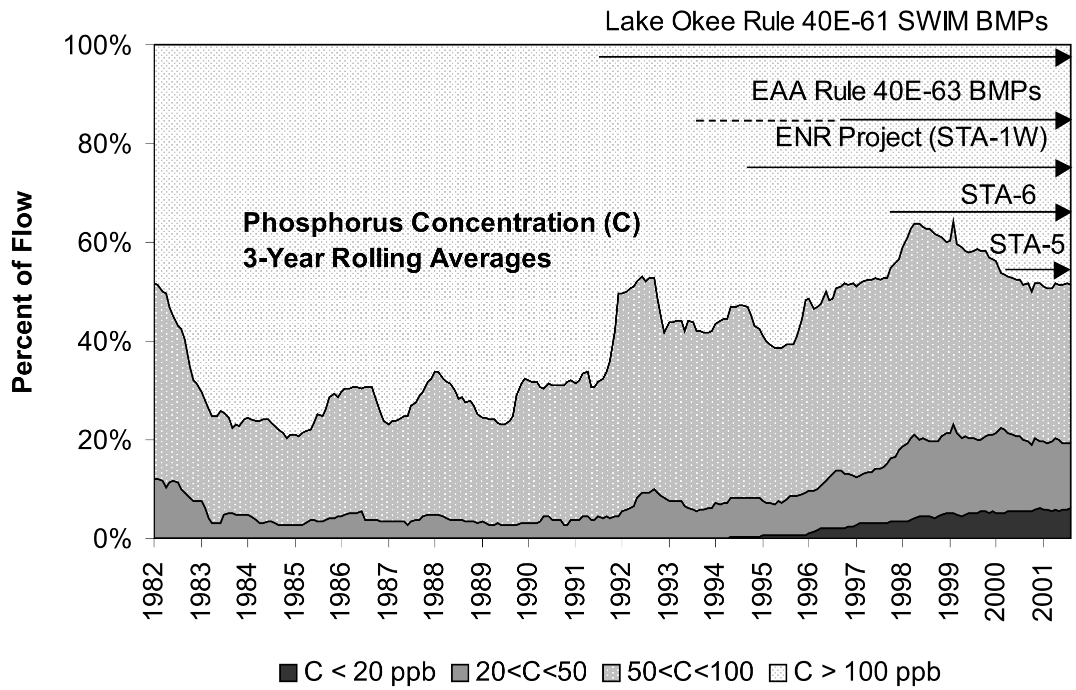


Figure 3-8. Measure of Progress toward TP Reduction to Everglades through BMPs and STAs

EAA PERMIT-LEVEL MONITORING RESULTS

In addition to the BMP Plan, each Rule 40E-63 permit is required to propose a Water Quality Monitoring Plan for individual drainage basins within the permit. The permit-level monitoring plans consist of flow measurements, collection and compositing of discharge water samples and analysis for TP. Discharges are generally quantified using site-specific calibration equations. Water quality samples are generally collected by automatic samplers and are composited for a sampling period of up to 21 days prior to being transported to a laboratory for analysis. Daily TP load is calculated by multiplying the TP concentration for the sampling period by each daily flow. Rule 40E-63 requires data to be submitted in an electronic format. All field water quality monitoring is required to be collected under a Comprehensive Quality Assurance Plan approved by the Department. In addition, any laboratory that analyzes TP for the Rule 40E-63 permit monitoring program is required to be certified by the Florida Department of Public Health for the analysis of TP in surface water.

Annual average flow-weighted TP concentrations (ppb) and load discharges (lb/ac) have been calculated from the permittee's daily water quality monitoring data reported during WY01. **Figures 3-9** and **3-10** present the spatial distributions of TP concentrations and load discharges by permit drainage basin. **Figures 3-11** and **3-12** present frequency distributions of the WY01 permittee's drainage basin TP concentrations and loads. Thus far the relationship between the EAA basin-level phosphorus reductions and the farm-level BMP plans has not been established. The EAA Basin-level data verify that the individual farms have collectively reduced phosphorus loads coincident with BMP implementation. However, the data collected to date do not establish a direct statistical relationship between the water quality from an individual EAA farm or subset of farms and the EAA Basin as a whole because of the many variables affecting phosphorus load at the farm level. Further work in this area is necessary. The permit-level data are useful for making relative comparisons between permit sub-basin or between water years for the same sub-basin. The District currently uses this relative comparison when discussing individual sub-basin performance and BMP optimization with permittees.

This on-farm, or permittee-level, water quality monitoring will only be used for compliance determination if the EAA Basin does not meet the 25 percent phosphorus load reduction requirement. The permittee water quality monitoring results are not used to calculate the phosphorus reduction at the EAA Basin level. EAA basin-level monitoring is conducted by the District at all inflow and outflow structures. In fact, the permittee-level water quality monitoring cannot be used to determine the measure of phosphorus discharged to the Everglades. The surface water discharged from any one of the given 209 defined drainage sub-basins may be withdrawn as irrigation or freeze-protection water by another farm. On an annual basis, a tremendous amount of water is recycled within the EAA prior to any discharge to the Everglades. This conclusion is based upon the fact that the average annual cumulative total volume of water discharged from the 304 permittee or farm-level pump stations is greater than the volume released from the District water control structures surrounding the EAA. The permit-level water quality monitoring does allow a relative comparison between permit basins. The WY01 permit-level TP data is presented in **Appendix 3-1**.

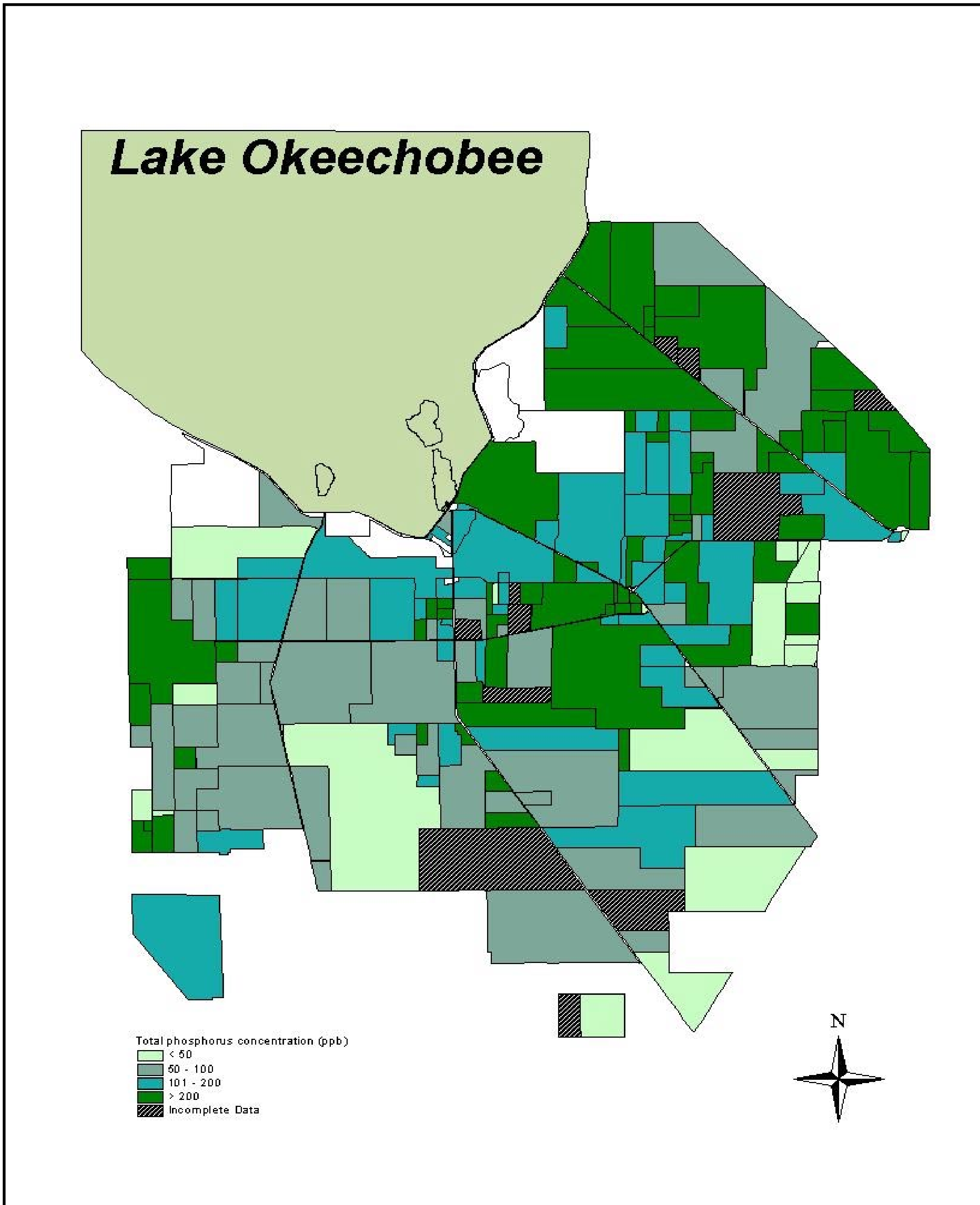


Figure 3-9. WY01 Spatial Distribution of Permit Drainage Basin TP Concentrations

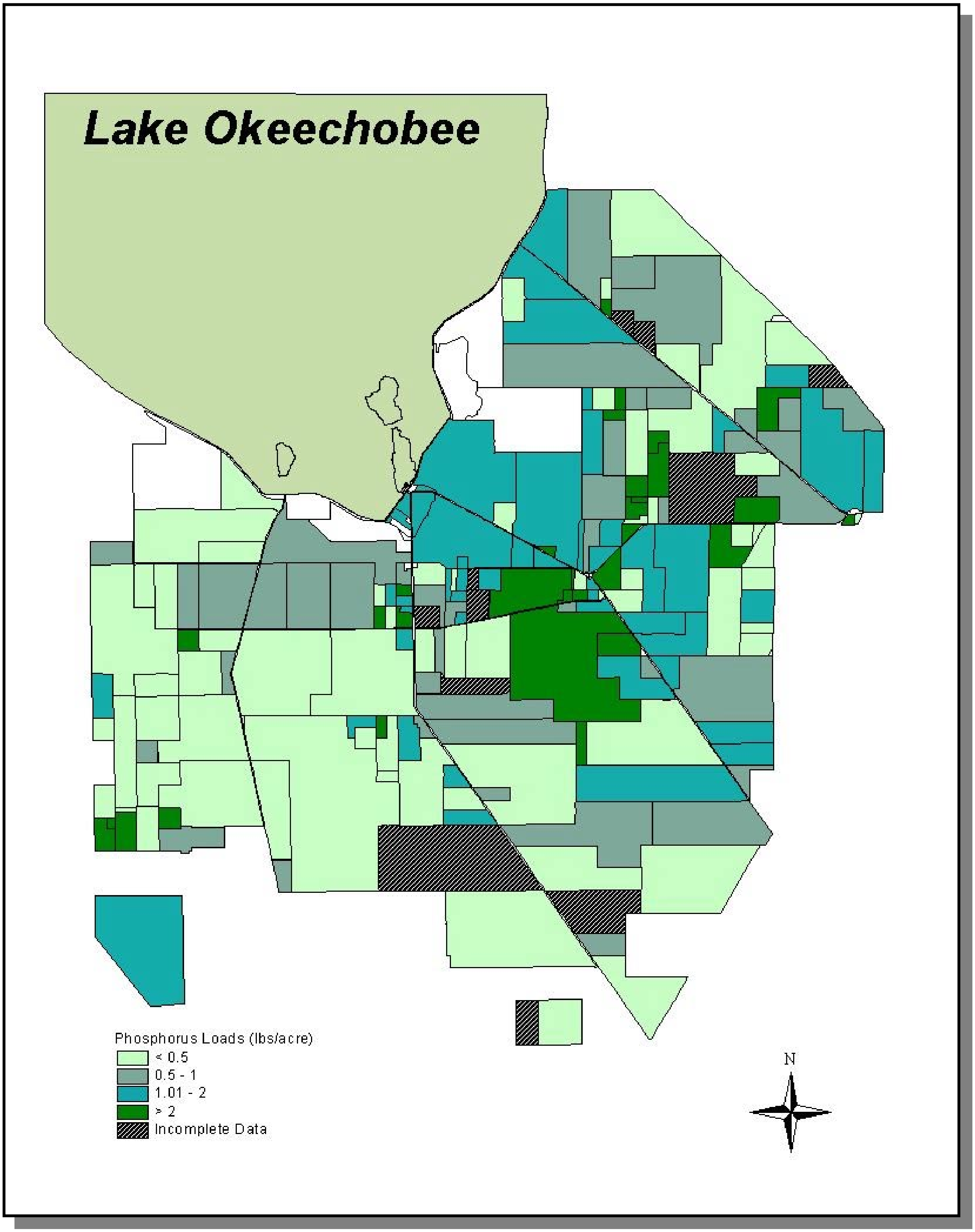


Figure 3-10. WY01 Spatial Distribution of Permit Drainage Basin TP Loads

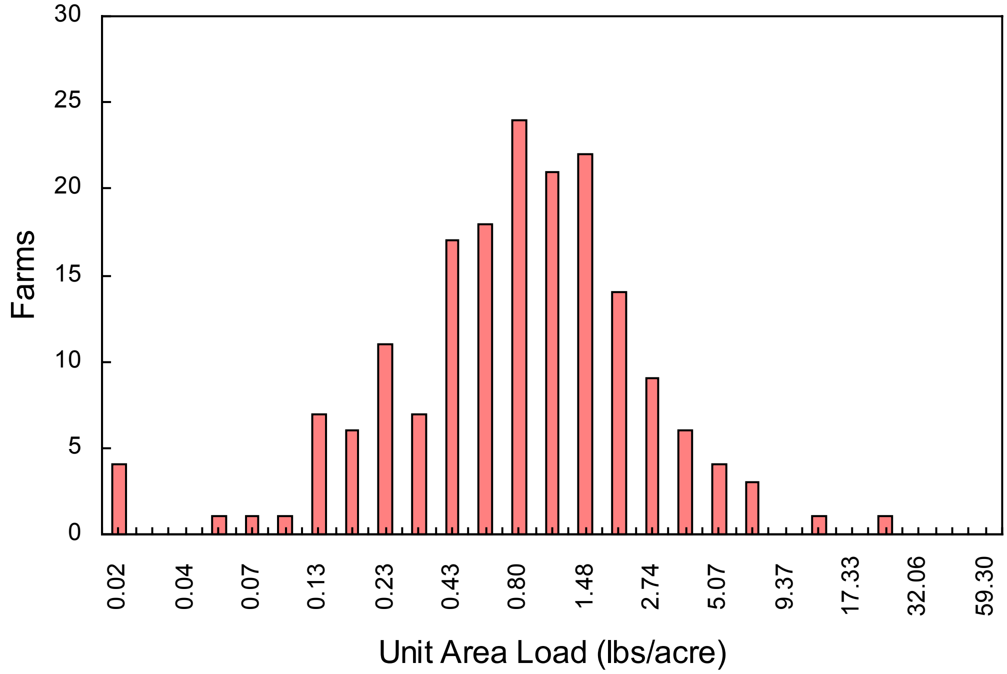


Figure 3-11. Frequency Distribution of WY01 Permittee Drainage Basin TP Concentrations

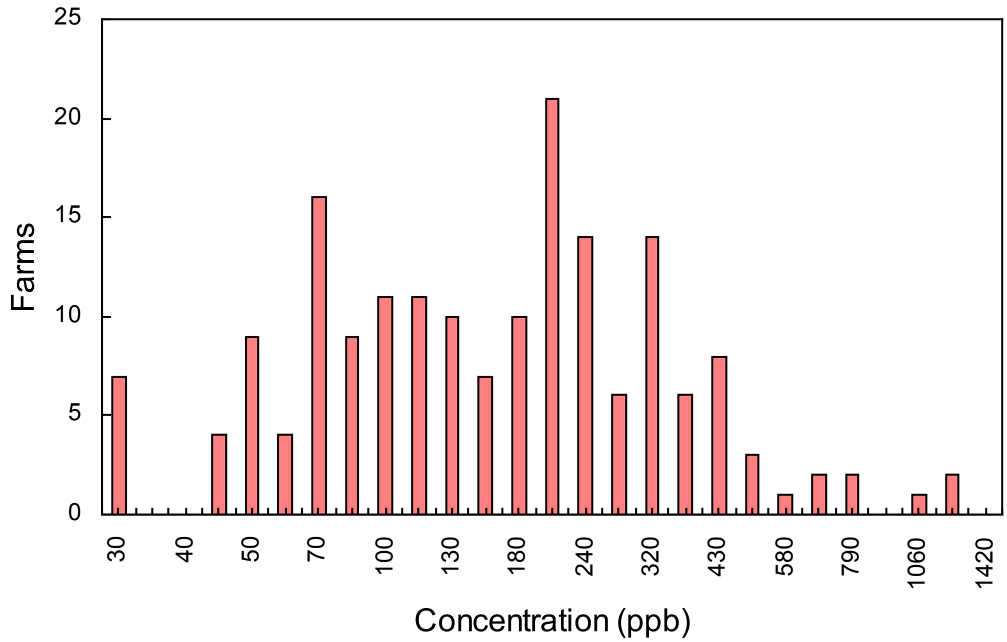


Figure 3-12. Frequency Distribution of WY01 Permittee Drainage Basin TP Load Discharged

UPDATE ON EVERGLADES BMP RESEARCH

BMP effectiveness has been demonstrated at different scales – the EAA Basin as a whole, and through individual sub-basin or farm-level research projects in the EAA Basin. In addition to BMP implementation, the EFA mandates landowners to sponsor a program of BMP research, testing, and implementation. To improve the understanding and predictability of TP relative to BMPs, research projects to quantify the effectiveness of BMPs are necessary. The following is an update on active BMP research projects in the EAA. To encourage the optimization of BMPs, as data become available, research results are provided to the industry through outreach programs sponsored by UF/IFAS, EAA-EPD, and the District.

UNIVERSITY OF FLORIDA/INSTITUTE OF FOOD AND AGRICULTURAL SCIENCE (UF/IFAS) ON-FARM RESEARCH

The research conducted by UF/IFAS represents the most comprehensive ongoing research program regarding the effectiveness of BMPs in the EAA Basin. The project was initiated in 1992. Project funding was provided primarily by the EAA-EPD, with supplemental monetary contributions from the Department and the District. Ten farms ranging in size from 320 acres to 4,600 acres have been studied in an attempt to develop and verify the effectiveness of BMPs for reducing TP loading in the EAA Basin. These farms are representative of the EAA Basin with respect to soils, crops, water and fertilizer management practices and geographic locations (**Figure 3-2**). Land use on the selected farms varies from monocultures of sugarcane and vegetables to multi-cultures of vegetables, rice, sod and sugarcane. BMPs implemented on the ten farms are described in **Table 3-4**.

To monitor BMP efficacy, all sites have been instrumented with electronic flow, water sampling and data storage instruments. Flow and TP concentrations were monitored for the baseline period from 1992 to 1994 and for the BMP period from 1995 to present. During the most recent water year, two sites (UF9201A and UF9205A) have been removed from the monitoring program due to STA development and a change in project goals. Work has progressed in annual phases. In recent phases of the project, water quality monitoring has been expanded to include the characterization of other water quality parameters, including specific conductance, atrazine and ametryn. Nine annual reports and numerous publications have been produced from this project data.

Table 3-4. Summary of BMPs implemented on 10 UF/IFAS Experiment Sites (Izuno and Rice, 2000)

Site	Farm size (acres)	Cropping system	Major BMPs
UF9200A	1280	Sugarcane monoculture	Reduced frequency of irrigation/drainage events, attenuated water table micro- management, cleaned ditches, removed sedimentary material from ditch ways, installed weed-boom in main farm canals (98), calibrated soil test
UF9201A (Discontinued)	1280	Vegetable monoculture	Routed water internally from field block to field block during planting season, allowed summer fallow flood waters to recede naturally through ET/percolation, water storage, calibrated soil test
UF9202A	320	Sugarcane monoculture	Improved drainage uniformity by installing internal booster pump, reduced off- farm discharge, minimum-tillage sugarcane planting practices, calibrated soil test
UF9203A	4608	Sugarcane/rice rotation	Installed control structures to allow for improved farm drainage and hydraulic control between internal blocks, increased farm drainage capacity, calibrated soil test
UF9204A	640	Sugarcane monoculture to sugarcane/rice rotation to sugarcane monoculture	Implemented new off-farm pumping protocol (1/95), rotated half of farm sugarcane acreage into rice (4/95) in absence of concurrent hydraulic BMP implementation, rotated melons back to fallow (10/95), calibrated soil test
UF9205A (Discontinued)	320	Sugarcane monoculture to sugarcane/vegetable mix to sugarcane monoculture	Rotated almost half of farm sugarcane acreage into corn (3/94) followed by fallow and melons (5/95) in the absence of concurrent hydraulic BMP implementation, rotated melons back to fallow (10/95) and then sugarcane (2/ 96), calibrated soil test
UF9206A&B	1754	Sugarcane/sod mix with vegetable/rice rotation	Installed control structures, blocked farm into six hydraulically isolated units, routed vegetable/rice drainage water to other areas of farm for storage and/or removal through ET/percolation, installed weed-boom in main farm canals (98), calibrated soil test
UF9207A&B	2500	Sugarcane/vegetable mix	Reduced drainage pumping chemical injection and diversion of water around farm, sediment trap/pit in main farm canal, calibrated soil test
UF9208A	262	Sugarcane monoculture	Increased on-farm retention in soil profile and open waterways, reduced drainage pumping, implemented various ditch and canal sediment control strategies, calibrated soil test
UF9209A	3072	Sugarcane monoculture	Reduced drainage pumping using strict protocols for triggering off-farm discharge, installed internal booster pump for improved drainage, calibrated soil test

Water Management BMPs to achieve drainage/irrigation uniformity are implemented at all ten farms

Effectiveness of BMPs

The TP concentration and ratio of unit area load (UAL) to rainfall (R) over the past seven consecutive years for the UF/IFAS 10 farms are presented in **Table 3-5** (WY01 data were not available at the time of this report preparation). The UAL/R ratio is one of the methods the project team used to indicate the TP load reduction with rainfall adjustment. The data indicate that for most of the farms, the UAL/R ratio was approximately 10 percent to 60 percent lower than that recorded for WY94. This demonstrates that BMPs implemented are highly effective in reducing TP loading at the farm level. However, reduction in TP concentration is not as significant for most of the sites, partly because nutrient management BMPs were partially implemented during 1994 and 1995 in the EAA (**Table 5-5**). Similar conclusions are obtained by the project team with other assessment methods.

Table 3-5 also indicates that there are significant variations in TP concentration and UAL/R ratio between farm locations and years. The variations reflect differences in BMP effectiveness with respect to farm management practices, crop rotations, and natural hydrologic conditions. The increase in UAL/R and concentration in WY99 for some of the sites is a direct result of Hurricane Georges that was predicted to hit south Florida in September 1998, resulting in significant pumping in anticipation of the event. This drainage resulted in leaching of soluble phosphorus contained in the soil profile and accelerated transport of sediment. The significant increases in the UAL/R ratio at site UF9205A reflect water management difficulties that were due to large-scale cropping system changes in the absence of water management BMPs (**Table 5-3**). Site UF9205A opted to rotate back to melons in a farming block adjacent to the discharge structure and continues to have water management problems. Site UF9206 is also a mixed-crop site. However, TP load reduction has been realized at the site with the adoption of comprehensive water management practices coupled with other BMPs. The increase in WY97 directly reflected the rotation of vegetable and rice production in blocks immediately adjacent to discharge structures. This again shows that coordination of farm-cropping patterns is critical to the success of implemented BMPs. In general, the study indicates that water management BMPs coupled with proper crop rotation practices have the greatest effects on farm drainage TP concentration and load.

Table 3-5. TP concentration and the ratio of unit area load to rainfall at the UF/IFAS experimental sites during WY94 through WY00

Site	Water Year	Baseline TP (ppb)	BMP TP (ppb)	UAL/R ratio (lb/acre/in)	percent AUA/R ratio change from WY94
UF9200A	94	234	-	0.0265	-
	95	275	-	0.0321	21.3
	96	-	241	0.0207	-21.8
	97	-	153	0.0086	-67.4
	98	-	131	0.0066	-75.2
	99	-	654	0.0766	189.3
	00		370	0.0408	54.1
UF9201A	94	743	-	0.0844	-
	95	858	-	0.1019	20.7
	96	-	616	0.0467	-44.7
	97	-	540	0.0208	-75.3
	98	-	903	0.2205	161.3
	99	-	1006	0.1750	107.3
	00		NA	NA	NA
UF9202A	94	71	-	0.0034	-
	95	51	-	0.0027	-20.1
	96	-	90	0.0075	118.4
	97	-	63	0.0035	2.5
	98	-	57	0.0036	3.7
	99	-	157	0.0094	174.1
	00		120	0.0065	88.2
UF9203A	94	181	-	0.0079	-
	95	108	-	0.0063	-20.5
	96	-	110	0.0074	-5.4
	97	-	174	0.0088	12.4
	98	-	148	0.0069	-12.0
	99	-	112	0.0045	-42.2
	00		126	0.0060	-24.0
UF9204A	94	152	-	0.0064	-
	95	211	-	0.0137	113.2
	96	-	302	0.0189	193.4
	97	-	151	0.0037	-42.1
	98	-	151	0.0068	6.0
	99	-	93	0.0042	-34.9
	00		229	0.0125	93.5
UF9205A	94	81	-	0.0073	-
	95	91	-	0.0207	184.5
	96	-	81	0.0267	267.6
	97	-	87	0.0215	195.9
	98	-	69	0.0262	260.1
	99	-	131	0.0403	454.4
	00		NA	NA	NA
UF9206A&B	94	288	-	0.0540	-
	95	273	-	0.0503	--6.8
	96	-		0.0442	-18.2

	97	-	363	0.0778	44.0
	98	-	480	0.0356	-34.2
	99	-	211	0.0408	-24.4
	00		268	0.1058	95.9
			596		
UF9207A&B	94	226	-	0.0322	-
	95	338	-	0.0599	-86.0
	96	-	338	0.0346	7.4
	97	-	244	0.0226	-29.9
	98	-	214	0.0159	-50.6
	99	-	189	0.0230	-28.5
	00		227	0.0257	-20.2
UF9208A	94	150	-	0.0040	-
	95	121	-	0.0022	-45.3
	96	-	124	0.0026	-34.4
	97	-	98	0.0023	-42.5
	98	-	59	0.0023	-43.5
	99	-	111	0.0051	28.1
	00		97	0.0072	79.4
UF9209A	94	86	-	0.0102	-
	95	85	-	0.0091	-10.2
	96	-	66	0.0060	-41.1
	97	-	78	0.0088	-13.5
	98	-	62	0.0053	-48.0
	99	-	173	0.0148	45.3
	00		75	0.0087	-14.1

Farm-level Phosphorus Budget

The UF/IFAS research program has lysimeters in fields, including 11 lysimeters for a vegetable and rice rotation system and 14 planted with sugarcane. These lysimeters are instrumented to allow for automatic tracking of drainage and irrigation, water table monitoring and water sampling. Field research efforts also include determination of P inputs as fertilizers and exports in harvested crops. The combination allows for the calculation of detailed P budgets for the two-crop systems. Preliminary results from this lysimeter study are summarized in **Table 3-6**. Averaged across all of the lysimeters, the vegetable/rice P budget (214.12 lb/acre) is about six times higher than that of sugarcane, primarily because the amount of fertilizer applied for vegetable/rice was much higher than that for sugarcane. Vegetables rotated with rice seem to be an effective strategy to efficiently use P applied in the system. Data also indicate that sugarcane fields with fertigation of vegetable/rice drainage water remain a net P sink, highlighting the importance of rerouting high phosphorus-laden water within a farm as a BMP.

Table 3-6. Summary of lysimeter TP budget for the period of December 1997 through September 2000.

Crop System	Irrigation/ Rainfall	Fertigation	Fertilizer	Crop Harvest	Drainage	Other	P budget
Lettuce/Rice			*lb P/acre*				
Lettuce --Flooded fallow – Lettuce	1.38	0	402.32	-55.67	-113.78	0	234.25
Lettuce –Rice (1 harvest) – Flooded fallow – Lettuce	1.71	0	402.32	-82.35	-107.95	-1.40	209.33
Lettuce –Rice (2 harvests) – Flooded fallow – Lettuce	1.65	0	402.32	-93.51	-109.65	-2.01	198.80
Sugarcane							
Water table 18-24 inches below soil surface	1.17	0	61.19	-18.55	-6.41	0	37.39
Water table 14-20 inches below soil surface	1.15	0	61.19	-19.40	-8.52	0	34.42
Water table 14-20 inches below soil surface with limited fertigation (rice drainage water)	1.14	0.54	61.19	-20.19	-7.49	0	35.18
Water table 14-20 inches below soil surface with fertigation (rice drainage water)	1.14	23.68	61.19	-21.72	-20.14	0	44.15

Note: 1. A negative value indicates a net P export.
2. "Other" represents estimates of rice yield lost to birds.

BMP DEVELOPMENT

Sediment and Particulate Phosphorus Control

Last year's chapter evaluated the effectiveness of individual BMPs at the field level and identified the need for research for BMP development (Wan et. al., 2001). One of the research areas identified is the need for effective and economical sediment control BMPs to manage aquatic macrophyte growth in farm ditches and canals and control particulate P transport. The UF/IFAS research program includes an ongoing effort to develop BMPs dealing with particulate P transport. The BMP study considered in the research focuses on using inter-event periods for aquatic weeds to uptake P and then hydraulically redistributing the plants and settled detritus. Potential BMPs may include isolation of aquatic weeds from pumping stations using weed booms, physical cultivation and harvesting of the plants to extract soluble P from the water and hydraulic removal of the flocculated top sediment in the canal bed. Their effectiveness will be reported as data become available. The District is looking for opportunities to jointly fund research for sediment and particulate control BMP development.

Soil Amendment and Biological Control

Two BMP development projects that have been funded by the District are close to completion. The first project, conducted by UF/IFAS, studied the effectiveness of applying silicon (Si) soil amendments to control P release from organic soils. A final report, titled "Minimizing phosphorus and organic carbon leaching from organic soils with silicon amendments," was submitted to the District. The second project aims at identifying commercial high-yield sugarcane varieties that can take up more P or need less P fertilizer so they can be strategically planted in the EAA Basin to reduce TP loading. This is a cooperative research program between the District and the United States Department of Agriculture (USDA) Agricultural Research Services. One of the project deliverables is a report titled "Leaf phosphorus of sugarcane genotype selected for high yields in Florida." Major results from these two reports are summarized below.

The Si soil amendment project is a laboratory study using soil samples taken from the EAA and Si-rich industrial byproducts, including Recmix and Tennessee slag. Both are commercially available in Florida and can be used as Si fertilizer in the EAA. Phosphorous sorption/desorption isotherm curves developed for soils mixed with these Si soil amendments showed significant improvement of P sorption capacity of organic soils in the EAA Basin. This is primarily because the Si soil amendment contained a significant amount of calcium and magnesium and a limited amount of iron and aluminum. In addition, the Si added to the soil may undergo a series of physical and chemical interactions with organic materials and P in EAA Histisols, which may improve P availability and reduce loss of fine organic particles. A greenhouse experiment in the project using EAA Basin soil samples mixed with Recmix and Tennessee slag at the rate of 0, 4 and 10 tons/ha was also conducted to determine the effects of Si soil amendments on plant growth and P leaching. Lettuce, a popular vegetable grown in the EAA Basin, was used as the test plant. The results showed that during a two-month period, the applied Si soil amendments reduced TP leaching by about 25 to 40 percent at the application rate of 4 tons/ha. This reduction is particularly pronounced for dissolved P. It also showed that Si soil amendments had positive effects on lettuce growth because of the beneficial effects of Si as a nutrient. Approximately a 30-percent increase in lettuce production was realized in this study. The implication of the project is that these Si soil amendments are a potential BMP for use in the EAA Basin to reduce TP loading and increase yield. This will be particularly effective in vegetable fields where the soil is heavily fertilized with P. While the effectiveness and the procedures of this practice need to be verified at the field scale, application of the tested Si soil amendment at a rate of about four tons/ha is not likely to be necessary on an annual basis.

The sugarcane genetics project was conducted to characterize levels of leaf P at three fertilization rates for 24 sugarcane genotypes previously selected for high cane and sugar yield in the EAA Basin. The study involved planting of these varieties at four locations within the EAA Basin and analyzing leaf samples from the plant cane through the second ratoon crops at each location. Statistical analyses of the obtained data identified high and low leaf TP concentrations within each group. This characteristic was generally repeatable across P fertilization rates, locations, crops and sampling dates. The results showed that four widely used cultivars, including CP 80-1743, CP 80-1827 and CP 84-1198, had high leaf TP concentrations and it was estimated these cultivars would remove from 2.9 to 3.8 kg/ha more P than other cultivars. Widely used cultivars with low leaf TP were CP 72-2086, CP 78-1628 and CP 88-1762. These high/low P cultivars could be strategically planted in the EAA Basin to reduce TP loading at no additional cost to growers.

These research findings are a critical element in optimizing the effectiveness of site-specific BMPs. Through outreach-type programs, research results are made available to permittees so they may effectively apply BMPs to their site-specific circumstances.

FINDINGS AND FUTURE DIRECTIONS

The overall effectiveness of BMPs is best demonstrated by the measured TP load reduction in the EAA Basin since BMPs were implemented, as compared to a 10-year, pre-BMP base period. BMP effectiveness is further supported by ongoing BMP research in the EAA Basin. The goal of the EAA Everglades Regulatory Program is a 25-percent annual TP reduction from the EAA Basin as compared to the base period. Water Year 2001 represents the sixth year that the EAA Basin has been in compliance with the required TP load reduction. The WY01-adjusted TP load, assuming that BMPs were not implemented, was 195 tons. The measured TP load was 53 tons, resulting in a 73-percent reduction. The overall trend over several years has shown a significant reduction in TP load with the implementation of BMPs. The annual TP concentration showed a similar trend with the recent three-year average of 107 ppb, compared to the 173 ppb during the pre-BMP period.

The basin-level reductions are generally supported by the UF/IFAS 10-farm research. However, variations between farms and years are significant, as indicated by the results of both the farm-level monitoring conducted by permittees and the UF/IFAS 10-farm research.

Recent data continue to support the ongoing pursuit of past recommendations. That is, through continued research, monitoring and education efforts, water quality improvements can be made by applying new information to existing situations and by applying “lessons learned” to other regions that discharge to the Everglades. Future BMP work should continue to be directed at:

1. Optimizing the effectiveness of existing BMPs
2. Identifying other potential BMPs and their applicability to specific areas
3. Determining the relationship between the EAA Basin-level phosphorus reductions and the farm-level BMP plans.

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