Chapter 5: Effectiveness of Best Management Practices

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Summary

A significant component of the South Florida Water Management District (District) Everglades restoration efforts is to improve the quality of water entering the Everglades Protection Area (EPA). Phosphorus (P) has been identified as the nutrient most responsible for the changes occurring in the downstream natural areas (**Chapter 3**). Best Management Practices (BMPs) are operational or structural improvements implemented at the source that reduce the amount of P being discharged into the District's water management system and subsequently discharged to the EPA. Agricultural and urban Best Management Practices are the source-control cornerstones to improving water quality entering the EPA, because Everglades Agricultural Area (EAA) basin runoff has been identified as the highest P load contributor to the EPA. As a consequence of this P loading, a substantial amount of BMP research, implementation and education has occurred. The objective of this chapter is to summarize past and current BMP research, implementation and education programs and to characterize their association with P discharges from the EAA Basin.

A literature search identified thirty-three references on BMP research, implementation, and education. They were reviewed and multiple references from the same project were combined into a single "BMP initiative." Sixteen such documented initiatives were identified between 1979 and 1997 addressing BMPs in the EAA Basin. The initiatives address water, fertilizer, sediment, and pasture management, as well as urban practices and chemical treatments.

The sixteen initiatives can be categorized into 12 BMP research projects, one regulatory initiative, and three educational programs. Three of the twelve research initiatives were performed at limited scales involving water, fertilizer, and sediment management. Four other research initiatives address similar BMPs but only at a farm, or sub-basin, scale. The remaining five research initiatives may lead to the development or identification of future BMPs. Water, fertilizer, sediment, and pasture management, as well as urban, BMPs have been implemented basin-wide through the regulatory initiatives (Rules 40E-61 and 40E-63 of the Florida Administrative Code). Three additional initiatives were undertaken to educate agricultural and urban communities within the EAA on BMP implementation and how to document effectiveness.

Research, implementation, and education on BMPs have been underway since 1985 to reduce P loading from the EAA. These research activities have been funded by at least ten private and public entities. The potential of selected BMPs to reduce total P discharge from agricultural areas was first apparent from District sponsored plot scale field studies initiated in 1985. Limited water and fertilizer management practices were among the first BMPs tested. The plot scale studies demonstrated that these particular BMPs were effective in reducing P export from the EAA organic soils. Subsequently, on-going

farm scale studies initiated in 1992 also show varying degrees of effectiveness in reducing P runoff from the implementation of combinations of water, fertilizer and sediment management practices.

The most significant measure of the effectiveness of BMPs to date is the collective EAA Basin P reduction measurements resulting from the implementation of the Everglades BMP Regulatory Program. Due to BMP implementation through the Everglades BMP Regulatory Program, the total P load from the EAA has declined in recent years compared to loads measured during a 10-year pre-BMP period (Water Years 1979 through 1988). Over the last three years, cumulative measured P loads attributable to the EAA have been reduced by 55 percent as compared to the calculated load that would have occurred during the pre-BMP period (adjusted for hydrologic variability). The pre-BMP period load calculations are a result of a complex regression equation developed from actual measured loads during the pre-BMP period.

Best management practices implemented to date have been documented to be effective at the farm level. Research data and the Everglades BMP Regulatory Program demonstrate appreciable reductions in the load and concentration of total P conveyed to the EPA attributable to the EAA. This reduction in load and concentration of total P conveyed to the EPA is an effect of BMP implementation. Experience and information is being gained on the performance of existing BMPs, and may allow improvements in effectiveness. Recent research initiatives on processes such as suspended particulate transport by water and wind, and crop variety experiments may also facilitate additional load reductions. Further declines in P load and concentration are probable.

Background

The 1994 Everglades Forever Act (Act) provides for Everglades restoration through research, land acquisition, construction, and regulation. The Everglades Program Management Plan (SFWMD/DEP, 1997) describes action plans to carry out the provisions of the Act (see **Chapters 1** and **12**). One of the seven primary elements of the Everglades Program is research and monitoring to evaluate the ecological and hydrologic needs of the EPA. The Act mandates that the effectiveness of BMPs for reducing P loads be assessed, and possible impacts associated with water-quality parameters other than P be identified and reduced.

The District developed a database in 1996 to capture data on existing BMP research (including District sponsored BMP research that began in 1985). Data from BMP research projects being conducted by private companies, the Everglades Agricultural Area Environmental Protection District (EAA-EPD), the District, and various other federal and state agencies is compiled in the database as it becomes available.

The Act also requires that the District conduct research in cooperation with the EAA landowners to identify water quality parameters that are not being significantly improved by either the Stormwater Treatment Areas (STAs) or BMPs, and to identify further BMP strategies needed to address these parameters. As a result of research in this area, the Florida Department of Environmental Protection (DEP) and the District in 1996 identified specific conductance, particulate P, ametryn, and atrazine as additional constituents of concern. The District amended Rules 40E-61 and 40E-63 in 1997 to define and implement a comprehensive program of research, testing and implementation of BMPs for all other applicable water quality parameters (initially for the four previously mentioned). The EAA-EPD is sponsoring this

University of Florida/Institute of Food and Agricultural Sciences (U of FL/IFAS) farm-scale research. Annual review of data, including a public workshop, will determine if the current research is meeting the overall objective of the Rules and the program will be adjusted accordingly.

Research and monitoring associated with evaluating the ecological and hydrological needs of the EPA, STA optimization, and BMP effectiveness is targeted for completion no later than December 31, 2001. Results from this research and monitoring will allow DEP to propose a P criterion in the EPA, and to evaluate existing state water quality standards and classifications applicable to the EAA canals (see **Chapters 12**).

Study Approach

This chapter represents an interim status report on BMP effectiveness in the EAA. The objective of this chapter is to summarize past and current BMP research, implementation, and education programs and characterize their association with P discharges from the EAA Basin. To accomplish this objective District staff (1) developed a statement of work describing the purpose and outlining tasks, (2) selected a contractor to assist the District and provide a third-party perspective, and (3) incorporated elements of the contractor's final work product into this document.

The statement of work consisted of four elements:

1. A literature search was performed to identify relevant reference material published between May 1979 and December 1997;
2. Reports deemed pertinent to evaluating the effectiveness of on-farm BMPs were selected for further review;
3. The documents were reviewed, combined into a single “BMP Initiative” when appropriate (multiple references for the same project), and then summarized; and
4. A chronology of the summarized initiatives was prepared and incorporated into a time series of total P load and concentration in water discharged from the EAA.

HydroScience Water Resource Consultants, Ltd. in association with ENTEL Environmental Companies, Inc. provided a BMP effectiveness status report for the District under Contract No. C-E9605 (January - May 1998).

Representatives of the District, DEP and the contractor's project team met to discuss the statement of work, an initial list of reference material prepared by the District, and organization of the final report. A list of pertinent reference material was finalized and summaries for the identified initiatives prepared. A chart, which illustrated the chronology of BMP-related research projects, implementation/regulatory programs, and education projects, was developed. This chart associated the BMP programs chronology with trends in P load and concentration. A comprehensive report was then prepared that included the aforementioned products, described the work performed, and documented findings. Elements of the final work product from the District's Contract No. C-E9605 has been incorporated into this chapter.

The criteria considered for including a BMP study or program in the review process were that the program or study:

- Was conducted or initiated during the period May 1979 to December 1997;
- Was performed in, or addresses, the Everglades Agricultural Area;
- Presents findings that were, or potentially may be, implemented as BMPs; and
- Documents or contains data and/or analyses that are available for review.

Numerous sources were searched for publications pertaining to water quality and best management practices in the EAA. More than 70 such publications are available for review at the District's main library and the Everglades Regulation Division library. A number of publications also were reviewed at the U of FL/IFAS library in Belle Glade, although copies of these references pertinent to this study are on file at the District libraries. Remote-access, computerized searches were performed using Telnet on the Florida universities Library User Information System and search engines LYCOS, HotBot, and AltaVista on the Internet. Reference materials, which met the criteria described above, was reviewed and is summarized in this chapter.

The literature search identified thirty-three references. They were reviewed and multiple references from the same project were combined into a single "BMP initiative." **Table 5-1** lists select information for each initiative including the BMPs addressed, extent and period of implementation, and review-summary index number. The research, implementation, and education initiatives address water, fertilizer, sediment, and pasture management, as well as urban practices and chemical treatments. Four references address an initiative to implement and monitor two regulatory programs. Four references describe 3 education initiatives. The remaining 25 references describe 12 research initiatives, 7 of which included published results that have led to basin-wide or farm-level BMP implementation, and 5 which may provide results to develop future BMPs. This process resulted in sixteen summarized BMP initiatives. At least 10 private and/or public entities participated in the BMP research projects since 1985.

A summary of each of the sixteen BMP initiatives was developed. These are provided as an Appendix (**Appendix 5**) to this report. Fifteen categories of information are provided in each initiative summary:

- **Summary Reference No.:** Sequence number cross-referenced to **Table 5-1** and **Figure 5-10**.
- **Citation No.:** Bibliographic-sequence number cross-referenced to the **Literature Cited** section of the report that identifies the source of information summarized.
- **Project Type:** Denoted by "Program Implementation" in which BMPs are implemented through a referenced program, "Research" from which study results have resulted in, or may likely result in, a BMP; and "Education" which demonstrates BMP implementation.
- **Title:** Short description of the project, program, or initiative.
- **Author / Affiliation:** Lead author(s) identified in referenced citations.
- **Agency / Funding Source:** Entity(ies) identified as contributing funding to the research effort or program development.

Table 5-1. Initiatives undertaken between 1979 and 1997 to address Best Management Practices in the Everglades Agricultural Area.

Initiative	Best Management Practice*								
Summary No.***	Water Mgmt	Fertilizer Mgmt	Sediment Mgmt	Pasture Mgmt	Chemical Trtmt	Urban	Extent** of Implementation	Program / Study	Implementation Period
1	I	I	I	I		I	Basin	Rule 40E-61, F.A.C. Rule 40E-63, F.A.C.	1989 - present 1992 - present
2	R	R					Precursor	Plot Scale BMP Testing (limited BMPs)	1985 - 1991
3	R						Precursor	Water Management Study	1990 - 1991
4			R				Precursor	Sediment Control Research	1992 - 1995
5	R						Farm	Modified Pump Practices	1991 - 1994
6			R				Farm	Sediment Control Demonstration	1993 - 1995
7	R --	R --	-- R				Farm Potential	Farm Scale BMP Implementation	1992 - present
8			R				Farm	Sediment Trapping in Rock Pit	1997 - present
9	E	E	E				Basin	Procedural Guide to BMPs	1993 - present
10	E	E	E				Farm	BMP Workbook and Training	1993 - present
11	E	E	E	E		E	Farm	BMP Demonstration and Education	1996 - present
12					R		Potential	Reduction by Precipitation and Coagulation	1992
13		R					Potential	Leaf Phosphorus Variability	1992 - 1995
14					R		Potential	Chemical Dosing and Vegetative Treatment	1992 - 1996
15	R						Potential	Sugarcane Water Tolerance	1996 - present
16			R				Potential	Wind Erosion BMP Evaluation Tool	1997 - present

*Key: I = BMP implemented through referenced program
R = BMP research project
E = BMP education project or program

**Key: Basin = Basin-wide extent of implementation
Precursor = Work that led to implemented BMPs
Farm = Farm-level extent of implementation
Potential = Work that may lead to future BMPs

***Reference number for narrative descriptions of initiatives in **Appendix 5**.

- **Research Funding:** Estimated amount of funds (by source) contributed and/or budgeted between May 1979 and September 1998 for BMP-related research. Does not include in-kind support or services, which have been provided by private entities on several initiatives. Information that was unavailable or could not be verified by a mail survey is identified as "Not Available."
- **Objective:** Description of what the initiative planned or plans to accomplish.
- **Period of Implementation:** The period of time during which the initiative was performed.

- **Study / Program Area:** Denoted by "Basin Scale" for work addressing the entire Everglades Agricultural Area, "Plot Scale" for work performed on small acreage areas, and "Farm Scale" for work on sub-basin sized areas that are significantly larger than plots.
- **BMPs Addressed:** Denoted by practices that address water management, fertilizer management, sediment management, pasture management, chemical treatment, and urban management.
- **Research / Program Design:** Description of the approach used to perform the initiative.
- **Major Findings:** Description of key results published for the initiative.
- **Extent of BMP Implementation:** Denoted by "Basin-Wide" for BMPs implemented throughout the Everglades Agricultural Area, "Precursor" for small-scale research studies that provided information on BMPs that were then implemented basin-wide, "Farm Level" for BMP research and implementation on some farms within the EAA, and "Potential Precursor" for small-scale research studies that may provide information resulting in future BMPs.
- **Summary:** Assessment of the contribution an initiative has made to an understanding of BMPs and their effect on the load and concentration of P discharged from the EAA to the Everglades Protection Area.

BMP Initiatives

Research, implementation, and education BMP projects intended to reduce the discharge of total P from the EAA have been underway since the first initiative began in 1985. Nine of the 16 initiatives had begun by 1992. Though each BMP initiative is listed in **Table 5-1** and summarized in **Appendix 5**, the relative significance and limitations of some initiatives will be discussed in more detail in this section.

Table 5-2 is a listing of all the BMP initiatives and their estimated or reported percent P load reductions for each individual BMP or combination of BMPs at the farm or basin level. Limited BMP performance information that has been derived directly from data analysis is currently available. On-going farm scale research, basin scale implementation and education programs are somewhat limited in being able to describe individual BMP performance since similar combinations of BMPs have been implemented basin wide through Rule 40E-63, Everglades BMP Regulatory Program.

Three substantial initiatives are described below: **A. Plot Scale BMP Testing**; **B. Everglades BMP Regulatory Program, Rule 40E-63**; and **C. Farm Scale BMP Research**.

A. Plot Scale BMP Testing

(**Appendix 5: Summary Reference No. 2**)

The ability of selected BMPs to reduce total P discharge from agricultural areas was first shown from plot scale field studies initiated in 1985. This plot scale research was sponsored by the District and contracted to the U of FL/IFAS. Project funding was provided primarily by the District with substantial monetary and in-kind contributions from Fruit and Vegetable Growers Association and the Florida Sugar Cane League. Four specific conditions were tested on 1.4-acre plots: (1) sugarcane vs. drained fallow

Table 5-2. Best Management Practice initiatives' total P load reduction findings or estimates.

Type of Initiative	Initiative	Banding at a reduced rate vs. Broadcast	Calibrated Soil Test	Prevention of misplaced fertilizer	Split Application and Slow Release fertilizer	Slow vs. Fast drainage	Minimizing water table fluctuations	Retention of drainage	Rice vs. Flooding fallow	Use of aquatic cover crops	Sediment Control	Sugarcane Genetics	Chemical Treatment	Pasture Management	Urban	Collective BMPs (no separation of types)
Implementation	Rule 40E-61, F.A.C. Rule 40E-63, F.A.C.	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	55% (Basin)
Research	Plot Scale BMP Testing (does not include sediment BMPs)	15%				30%			38%							*20-60% (Basin)
	Water Management Study							57%								
	Sediment Control Research Plot and Demonstration										17-68%					
	Modified Pump Practices							^								
	Sediment Control Demonstration										^					
	Farm Scale BMP Implementation	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -					4-40% (Farm)
	Sediment Trapping in Rock Pit										^					
	Reduction by Precipitation and Coagulation												^			
	Leaf Phosphorus Variability											^				
	Chemical Dosing and Vegetative Treatment												^			
	Sugarcane Water Tolerance											^				
	Wind Erosion Evaluation Tool										^					
Education	Procedural Guide to BMPs (includes sediment BMPs)	*0-40%	*0-25%	*0-15%	*0-10%		*0-50%	*15-90%		*5-20%	*5-50%					*20-60% (Basin)
	BMP Workbook and Training															^
	BMP Demonstration and Education															^

KEY: * Percent total P load reduction was based upon professional judgment estimation - not directly substantiated with data
^ Research or educational program was not conducted in such a manner to determine % total P load reduction
- - Individual BMP percent total P load reductions have not been or may not be possible to determine from data since combinations of BMPs have been implemented

fields; (2) broadcast fertilization on cabbage crop vs. banding at a reduced rate; (3) fast vs. slow drainage rates for sugarcane; and (4) rice vs. flooding fallow following vegetable production. Three of the four conditions tested were identified as BMPs (drainage rate for sugarcane – reduce pumped volumes while removing water quickly and uniformly, banding fertilization on cabbage, and off-season rice production) that reduced total P loads. No reduction in total P load was observed for the fourth tested condition that compared drainage from sugarcane and continuously fallow plots. Although effectiveness was demonstrated for a few specific BMPs at the plot scale, the study clearly indicated at its conclusion in 1991 the need for additional research to characterize impacts of BMP implementation at the farm scale. It was estimated, using best professional judgment that from 20 to 60 percent (%) TP reductions can be achieved from pre-BMP (without BMPs) levels at the basin level, and drainage rate and volume BMPs could be responsible for about a 20% loading reduction. These original basin reduction estimates did not include the effectiveness to be gained from sediment control BMPs.

After the conclusion of the plot scale study, farm-scale BMP research was initiated in 1992 on water and fertilizer management strategies (primarily sponsored by the EAA-EPD). Prior to gaining any BMP performance information from these farm scale projects, the District was required to begin the implementation of Rule 40E-63, Everglades BMP Regulatory Program.

B. Everglades BMP Regulatory Program, Rule 40E-63

(**Appendix 5: Summary Reference No. 1**)

(Note: This section provides a limited summary of the Everglades BMP Regulatory Program. For additional information, the District's Everglades Regulation Division publishes an annual status report which provides in greater detail an explanation of the program's various components and data evaluation. For a copy, contact the District's Regulation Department, 3301 Gun Club Road, West Palm Beach, FL 33406.)

Background

In 1987 the state enacted the Surface Water Improvement and Management, or SWIM Act. The SWIM Act required Florida's water management districts to develop plans that contain strategies to either protect undisturbed "natural" water bodies or restore impacted areas. The Everglades SWIM plan development was the fourth such endeavor undertaken by the District. In 1991 the Florida legislature passed the Everglades Protection Act which further defined the scope of the Everglades SWIM Plan. The Everglades Protection Act was revised during the 1994 Florida legislative session. The resulting act, renamed the Everglades Forever Act (EFA), replaced the Everglades SWIM Plan and mandated a specific Everglades Program (see **Chapters 1** and **12**).

The Everglades Program is based upon a comprehensive approach to restoration and protection by proposing strategies for improving water quantity, timing, and distribution deliveries (hydroperiod), water quality in tributary water, and the removal and long-term management of exotic species. The Everglades Program is arguably the most publicly discussed and debated effort the District has undertaken in recent years. One of the most fundamental issues surrounding the Everglades restoration initiative, is the extent to which the Everglades' impacts are due to changes in hydroperiod versus changes in water quality. Although this discussion continues (see **Chapters 2** and **3**), the District has proceeded with efforts intended to begin improving tributary hydroperiod and water quality. One such undertaking is the Everglades Best Management Practices (BMP) Program. The Everglades BMP Program is a regulatory

permitting effort. BMP implementation programs are the cornerstone of the overall Everglades restoration initiative because they address issues at the source rather than downstream.

The largest tributary to the Everglades is the EAA. The EAA is 718,400 acres of highly productive agricultural land comprised of rich organic (muck) soils, located between Lake Okeechobee to the north and the Everglades to the south. Draining the area now known as the EAA began as a federal government project during the early 1900's in an effort to promote agricultural development and urban settlement of the sparsely populated south Florida peninsula. Today, 553,000 acres within the EAA are tributary to the northern Everglades; drainage from the remaining 165,400 acres discharges north into Lake Okeechobee. The EAA is comprised of approximately 505,000 acres of agricultural production: 82% sugar cane, 9% vegetables, 6% sod, 2% livestock, 1% rice and other crops. The remaining 48,000 acres (9%) are urban areas, roadways, canals and levees, and other land uses.

The central drainage system for this region consists of five major canals and eleven large pump stations and water control complexes operated by the District (**Figure 5-1**). Landowner water management is controlled by over 300 privately owned and operated water control structures, which range from gated culverts to 200,000 gpm pump stations, and are authorized to connect to the District's primary canals. The private water control structures serve approximately 220 drainage basins (ranging from 27 to 22,900 acres) which primarily include farms but also contain municipalities, residential, commercial, and industrial properties.

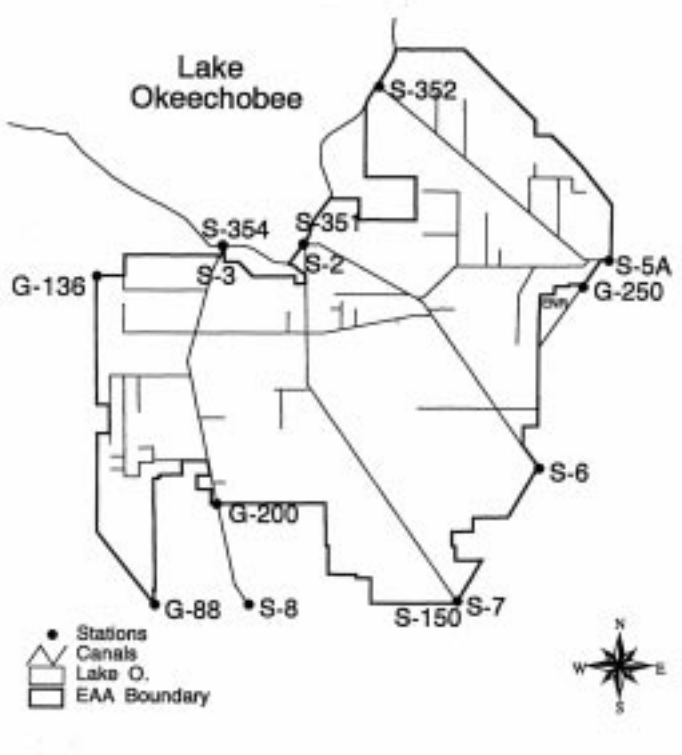

Figure 5-1. District water control structures within the 40E-63 boundaries

During 1991 and 1992 the District developed the Everglades BMP Regulatory Program for the EAA as directed by the Everglades Protection Act. The BMP program was developed through a series of public workshops and round-table discussions. The two year effort resulted in Chapter 40E-63, Florida Administrative Code (F.A.C.) which describes the intent, requirements, and compliance components of the Everglades BMP Regulatory Program.

Program Implementation

The goal of the BMP Regulatory Program is a 25% annual total P reduction from the EAA as compared to a pre-BMP implementation base period, October 1, 1978 – September 30, 1988 (complete Water Years 80 – 88). This chapter contains information from Water Years 1997 and what has been

determined thus far for 1998 (May 1, 1997 – April 30, 1998). Water Years 1996, 1997, and 1998 represent the first three years that all lands within the EAA were required to have BMPs fully implemented. P load in the runoff attributable to the EAA has shown a three-year trend reduction of 55%.

Each landowner has submitted a plan of on-site BMPs to reduce P leaving their property. Typical BMP plans incorporate improved practices of fertilizer application, improved water management including detention, and control of soil erosion. The BMP program includes follow-up verification of the approved BMP plans on two levels: (1) Annual BMP implementation report and (2) BMP field verification. Annual reports summarize the initial implementation of BMPs and the on-going maintenance and documentation. BMP field verifications are conducted to ensure that the BMPs as approved by permit and reported in the annual BMP reports have been implemented. Site verifications allow District staff to work with the landowners by discussing BMP strategies and communicating areas of concern (if any). The BMP site verifications conducted thus far indicate that the permittees have implemented their respective BMP plans and are taking a proactive approach to reviewing and improving their plans where possible. One hundred and sixty-four BMP site verifications were conducted through Water Year 1997, and totaled 427,542 acres.

The Everglades BMP Program for the EAA is unique in that its goal is to achieve a 25 percent reduction in P for the entire EAA Basin as a whole -- not for each individual internal drainage basin. The District will determine if a 25 percent overall reduction has occurred by comparing P discharges for any 12-month period with a pre-BMP period of record. The first annual compliance period was May 1, 1995 through April 30, 1996. Additional discussion on the annual compliance computation is presented within the District's Everglades BMP Program annual status reports (Everglades Regulation Division).

In the event that the 25% annual basin reductions are not met, additional drainage basin BMPs will be required for specific landowner drainage basins. During the 40E-63 rule development process, much discussion was spent on the determination of which landowner drainage basins would implement additional BMPs if the 25% basin compliance was not met. The District initially proposed that all drainage basins would be treated equally – jointly sharing the credit for reductions as well as jointly sharing the responsibilities for not meeting the basin 25% reduction target. Several landowners represented at the rule development workshops preferred to be able to demonstrate P levels discharged from individual properties. In doing so, it was felt that basins that were contributing the highest P levels to the Everglades should be identified, and thus targeted to implement additional BMPs (in contrast to requiring all areas to comply with this requirement). As a result, Rule 40E-63, F.A.C., requires water quality monitoring to be conducted at each landowner drainage basin. However, this water quality monitoring will only be used for individual permit compliance if the basin 25% reduction target is not achieved. In the event that the 25% reduction target is not achieved, the landowner drainage basins with the highest measured unit area P discharged (lbs/acre) would be identified and targeted for implementation of additional BMPs. This phased approach would continue until the EAA Basin again meets the annual 25% P reduction target level.

Permitting

Rule 40E-63 states that owners/operators of the private water control structures and owners/lessees of land served by the structures within the EAA were to apply for permits. Rule 40E-63 required each permit application to contain (a) a BMP plan and (b) a water quality monitoring plan. The minimum requirements and review process for these plans are discussed below. Rule 40E-63 set several milestones as follows:

1991 - 1992	Rule Development
January 1, 1993	Begin Early Baseline water quality monitoring
July 1993	Governing Board final actions on permit applications
Winter 1994	Begin Non-Early Baseline water quality monitoring
January 1, 1994	Required BMP implementation for Early Baseline Farms
January 1, 1995	Required BMP implementation for Non-Early Baseline Farms
May 1, 1995-April 1, 1996	First annual 25% basin reduction compliance determination

Part of each permit application, as mentioned above, requires the landowner to submit a proposed plan of on-site BMPs. Acceptable BMPs include operational programs or physical enhancements designed to reduce P leaving their property.

The District was faced with the tasks of (a) establishing a base level of BMPs for each permit area and (b) ensuring consistency with BMP plans between different landowners. To accomplish both of these tasks a system of BMP “equivalents” was developed. The intent was to assign “points” to BMPs within three basic categories: fertilizer techniques, water management, and sediment control (**Table 5-3**). At the time, some limited BMP research has been conducted within the EAA region, however no specific P reduction levels had been quantified for individual BMPs. The BMP list and points assigned to each BMP were based almost solely upon best professional judgment of District’s Everglades Regulation Division staff.

Twenty-five BMP equivalents or points were set as the minimum target BMP level. Utilizing the BMP equivalents approach allowed flexibility of each landowner to develop a BMP plan which was best suited for site specific geographic and crop conditions. **Table 5-4** compares "BMP equivalent” plans for four different landowner permit basins, showing the flexibility of this approach. Even though each basin had different land uses, soil types, and drainage capacities, point-equivalent BMP plans were successfully developed and accepted.

Rule 40E-63 water quality monitoring is being conducted at two levels:

1. EAA Basin-level by the District.
2. Landowner-level permit monitoring of private water control structures within the EAA.

The primary means to determine the Rule 40E-63 program success is through District collection and analysis of water quality monitoring conducted at the EAA Basin-level. Total phosphorus (TP) and flow measurements are recorded at District pump stations and water control complexes: S-2, S-3, S-352, S-5A, S-6, S-7, S-150, S-8, G-88, G-136, G-200, and G-250 (**Figure 5-1**). The P levels measured at these District structures collectively determine primary compliance for all permits. The results of the EAA Basin-level monitoring is presented and discussed later in this section.

A secondary method of program compliance measurement is through permittee-level water quality monitoring conducted at the individual drainage basins. Permit applications were required to contain individual water quality monitoring plans. **However, the permittee-level monitoring will only be used if the EAA Basin does not meet the 25% reduction requirement. The permittee water quality monitoring results are not used to calculate the P reduction at the EAA Basin-level. The EAA Basin-level monitoring is conducted by the District at District structures.**

Table 5-3. Best Management Practices summary and "BMP Equivalent" points.

BMP	PTS	DESCRIPTION
WATER DETENTION ½ Inch Detained 1 Inch Detained	 5 10	• increased detention in canals, field ditches, soil profile, fallow fields, aquatic cover crop fields, prolonged crop flood; • measured on an annual average basis – rainfall vs. runoff
FERTILIZER APPLICATION CONTROL	2 ½	Uniform and controlled boundary fertilizer application (e.g. direct application to plant roots by banding or side-dressing; pneumatic controlled-edge application such as AIRMAX)
FERTILIZER CONTENT CONTROLS		
Fertilizer Spill Prevention	2 ½	• formal spill prevention protocols (handling and transfer) • side-throw broadcast spreading near ditch banks
Soil Testing	5	avoid excess application by determining P levels needed
Plant Tissue Analysis	2 ½	avoid excess application by determining P levels needed
Split P Application	5	apply small P portions at various times during the growing season vs. entire application at beginning to prevent excess P from washing into canals (rarely used on cane in EAA)
Slow Release P Fertilizer	5	avoid flushing excess P from soil by using specially treated fertilizer which breaks down slowly thus releasing P to the plant over time (rarely used in EAA)
SEDIMENT CONTROLS		EACH SEDIMENT CONTROL MUST BE CONSISTENTLY IMPLEMENTED OVER THE ENTIRE ACREAGE
Any 2 Any 4 Any 6	2 ½ 5 10	• leveling fields • ditch bank berm • sediment sump in canal • strong canal cleaning program • field ditch drainage sump • slow field ditch drainage near pumps • sump upstream of drainage pump intake • cover crops • raised culvert bottoms • veg. on ditch banks • other BMP
OTHER Pasture Management	5	reduce cattle waste nutrients in surface water runoff by "hot spot" fencing, provide watering holes, low cattle density, shade, pasture rotation, feed & supplement rotation, etc.
Improved Infrastructure	5	uniform drainage by increased on-farm control structures
Urban Xeriscape	5	lower runoff & P by using plants that require less of each
Det. Pond Littoral Zone	5	vegetative filtering area for property stormwater runoff
Other BMP Proposed	TBD	proposed by permittee and accepted by SFWMD

Table 5-4. Example of “BMP Equivalent” plans for four different landowner basins.

BASIN ‘A’ (Sugar Cane, deep soils)	
BMP	Points
Water Detention – 1 ½ inch	15
Fertilizer -- Soil Testing	2 ½
Fertilizer -- Spill & Misapplication Prevention Program	2 ½
Fertilizer – Banding	5
TOTAL	25

BASIN 'B' (Sugar Cane & Vegetables, medium soils)	
BMP	**Points**
Water Detention -- 1 inch	10
Fertilizer -- Soil Testing	2 ½
Fertilizer -- Spill & Misapplication Prevention Program	2 ½
Fertilizer – Pneumatic	5
Sediment Controls -- any 4	5
TOTAL	25

BASIN 'C' (Sod, medium soils)	
BMP	Points
Water Detention -- 1 inch	10
Fertilizer -- Soil Testing	2 ½
Fertilizer -- Spill & Misapplication Prevention Program	2 ½
Sediment Controls – any 6	10
TOTAL	25

BASIN 'D' (Citrus, shallow soils)	
BMP	Points
Water Detention -- ? inch	5
Fertilizer -- Soil Testing	2 ½
Fertilizer -- Spill & Misapplication Prevention Program	2 ½
Sediment Controls -- any 4	5
Other -- Improved Infrastructure	5
Other -- Low volume drip irrigation	5
TOTAL	25

The permit-level monitoring plans consist of flow measurements, collection and composite of discharge water samples, and analysis for TP within a maximum time frame. The landowner has options for flow measurement determination as discussed further within the District's Everglades BMP Program annual status reports (Everglades Restoration Division). Calibrated flow measurements require certification by a registered professional engineer and review and acceptance by the District. Exceptions to a certified pump calibration were allowed for small landowners (less than 320 acres). These landowners were allowed to use the pump manufacturer's rated capacity and operation time log to estimate flow.

Water quality samples are required to be collected by automatic samplers. Exceptions to automatic samplers were allowed for small landowners (less than 320 acres). These landowners are allowed to take daily grab samples over a three-week composite period. All field water quality monitoring is required to be collected under a Comprehensive Quality Assurance Plan approved by the Florida Department of Environmental Protection (DEP). In addition, any laboratory which analyzes TP for the permit monitoring program is required to be certified by the Florida Department of Health and Rehabilitative Services (HRS) for the analysis of TP.

Post Permit BMP Activities

Figures 5-2 through 5-7 represent the spatial distribution of landowner implemented BMPs. These distributions show how clearly that most of the drainage basins in the EAA have selected the same individual BMPs to fulfill the BMP plan minimum 25 point criteria. Although there are many specific BMPs as listed in **Table 5-3** of this chapter, **Figures 5-2 through 5-7** group the BMPs by six major types:

- Basic fertilizer BMP (soil testing and spill prevention programs).
- Advanced fertilizer BMPs (controlled application {banding, pneumatic} split applications, slow release fertilizer).
- Rainfall detention (various amounts – $^1/_2$, 1 inch).
- Sediment controls.
- Urban practices (e.g. NPDES).
- Pasture management.

After the BMP permit plans are approved, Rule 40E-63 requires follow-up post-permit verification of the approved BMP plans on two levels: 1) BMP implementation reports and 2) BMP field verification. Annual BMP implementation reports are required by Rule 40E-63 to be submitted to the District; they are to summarize not only the initial implementation of BMPs, but ongoing BMP maintenance and documentation.

District Everglades Regulation Section staff conduct BMP site verifications on an eighteen month rotational basis to allow examination of BMPs implemented in both wet and dry seasons. Field verification procedures begin with generating a database driven BMP checklist specific to the permit drainage basin. The checklist consists of all BMPs selected by the permittee to be implemented. The checklist is mailed to the permittee prior to the verification to assist the landowner in preparing his documentation for the inspection. The verifications involve a combination of visual field observations and a review of office records. During the office review the District staff focuses on records that document soil test results, fertilizer recommendations and applications, BMP training of farm personnel, pump logs and any other

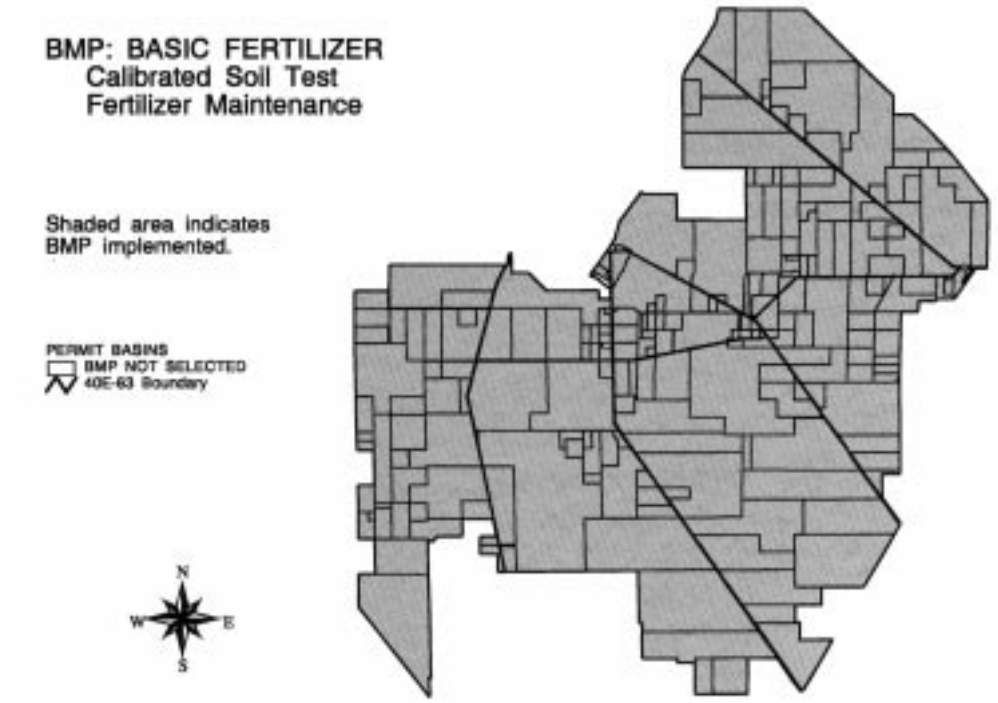

Figure 5-2. Location of Basic Fertilizer Best Management Practices in the EAA.

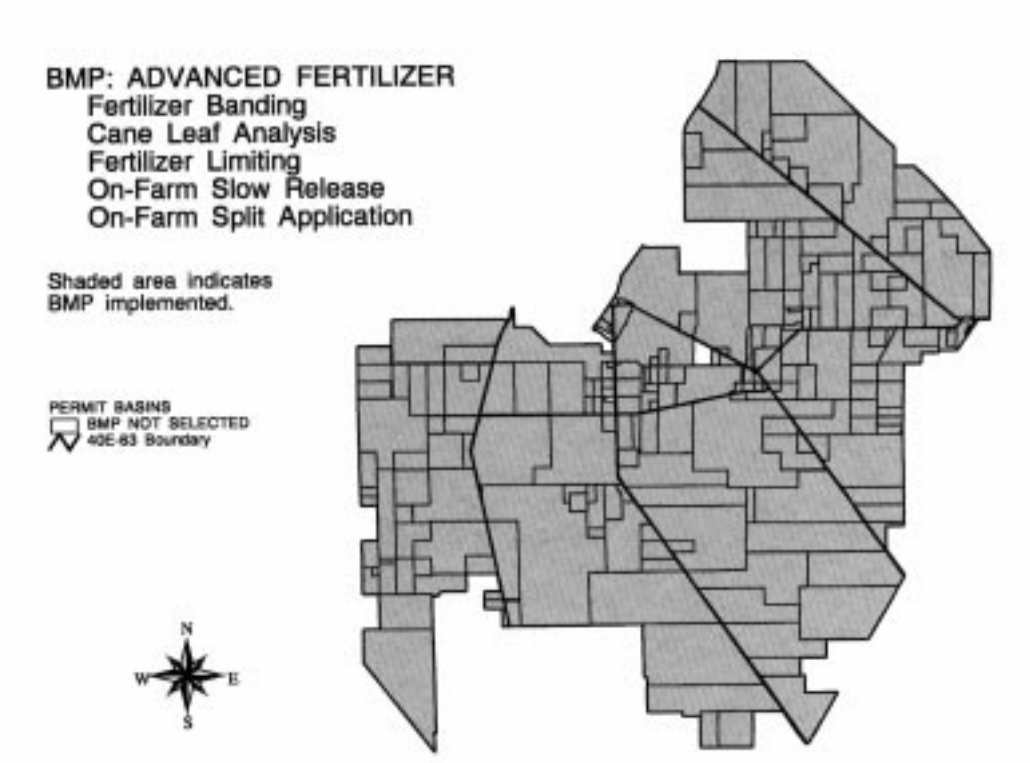

Figure 5-3. Location of Advanced Fertilizer Best Management Practices in the EAA.

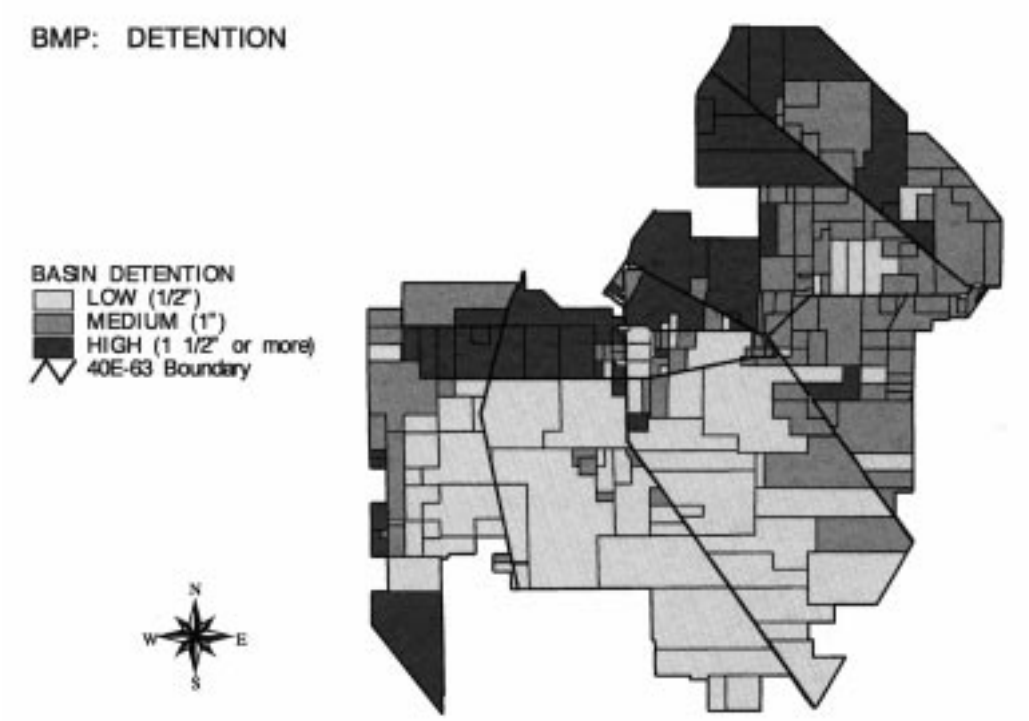

Figure 5-4. Location of Detention Best Management Practices in the EAA.

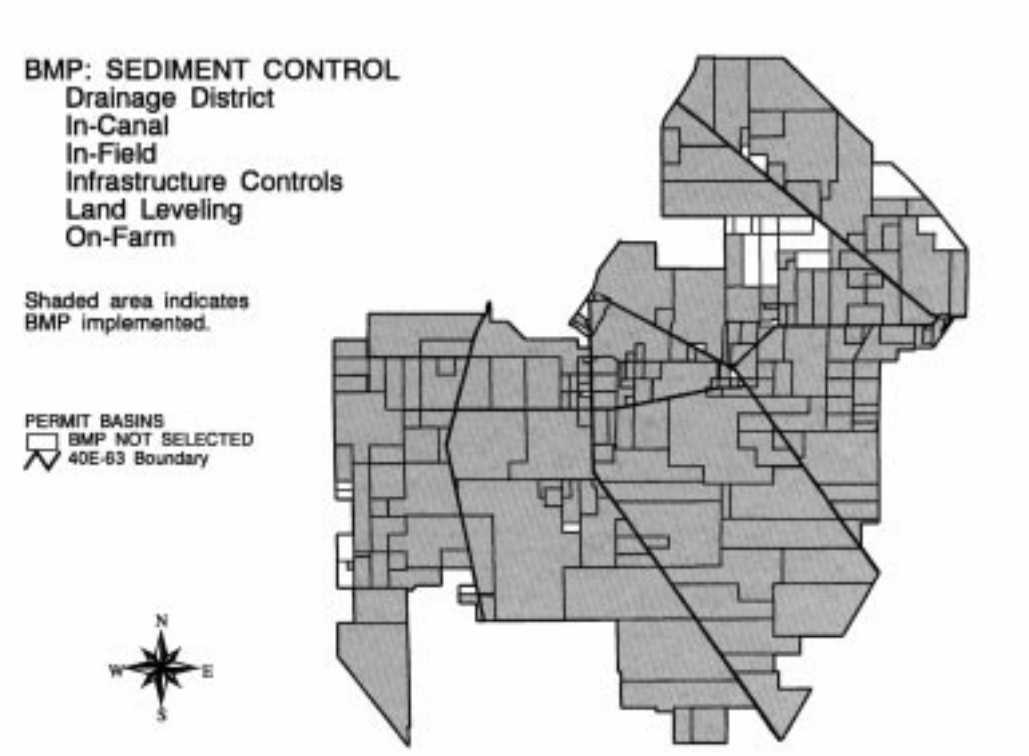

Figure 5-5. Location of Sediment Control Best Management Practices in the EAA.

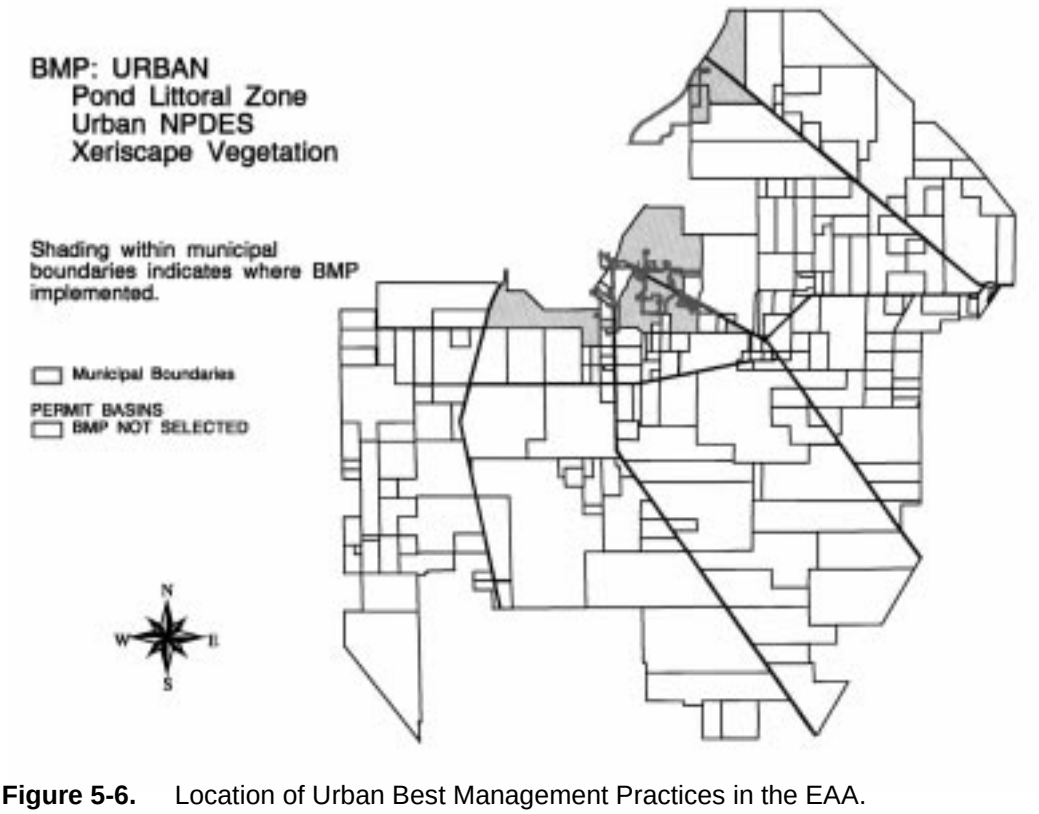

Figure 5-6. Location of Urban Best Management Practices in the EAA.

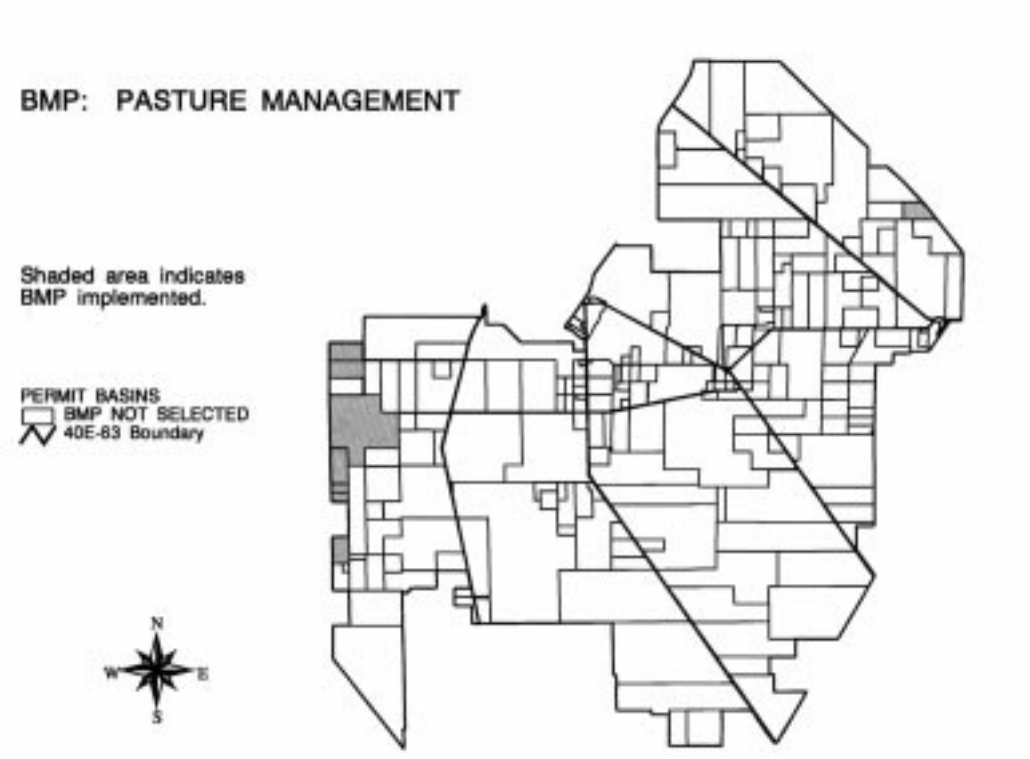

Figure 5-7. Location of Pasture Management Best Management Practices in the EAA.

material that supports BMP implementation. While in the field, District staff note any visual evidence that the selected BMPs have been implemented. This evidence may range from spoil on canal banks indicating canal cleaning was performed, fertilizer banding or land leveling equipment operating, and maintenance of vegetation on ditch banks to reduce sedimentation, to any other observable evidence that supports BMP implementation.

The verifications are a "spot-check" of the landowner's implemented BMPs. This spot check is a snapshot in time of how and when BMPs were implemented for that particular field and land use. The District knows which types of BMP have been chosen by the landowner for each particular land use and location so a verification can be conducted. However, the interpretation of a BMP by one landowner may be drastically different than that of a neighboring landowner. Data on how specifically each BMP was implemented and operated on each field over the history of the program does not exist and is therefore unavailable to the District. Pre-BMP data is also not available to the District for the 200+ drainage basins within the EAA.

Site verifications allow District staff to work with the permittees by discussing BMP strategies and communicating areas of concern (if any). The BMP site verifications conducted thus far indicate that the permittees have implemented their respective BMP plans and are taking a proactive approach to reviewing and improving their plans where possible. At the farm level, neither implementation of additional BMPs nor examination and enhancement of existing BMPs are required until basin level compliance fails to be met.

Permit or Farm-Level Phosphorus Data

Annual average flow-weighted total P concentrations (parts per billion, ppb) and P load exports (pounds per acre, lbs/ac) have been calculated from the daily permit water quality monitoring data reported during WY97. **Figures 5-8 and 5-9** present the spatial distributions of P concentrations and P load discharges by permit drainage basin.

This on-farm or permittee-level water quality monitoring will only be used if the EAA Basin does not meet the 25% reduction requirement. The permittee water quality monitoring results are not used to calculate the P reduction at the EAA Basin-level. The EAA Basin-level monitoring is conducted by the District at District structures. In fact, the permittee-level water quality monitoring cannot be used to determine the measure of P discharged to the Everglades. The surface water discharged from any one of the given 219 defined drainage basins may be withdrawn as irrigation or freeze protection water by another farm. On an annual basis, there exists a tremendous amount of recycling of water 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 300+ permittee or farm-level pump stations is approximately twice the volume released from the SFWMD water control structures surrounding the EAA. The permit-level water quality monitoring does have a utility of allowing relative comparison between permit basins.

EAA Basin-wide BMP implementation was mandated to begin in 1994 and was required to be completed on all land areas by January 1995 (Rule 40E-63). Prior to this period (1990-1993) an increasing percentage of landowners had implemented various BMPs because they were practical and/or for the purpose of conducting demonstrations to investigate their performance.

To date, very little BMP research has quantified specific P load reductions for individual BMPs. The P discharge compliance data (multiple BMPs implemented) submitted by growers in combination with

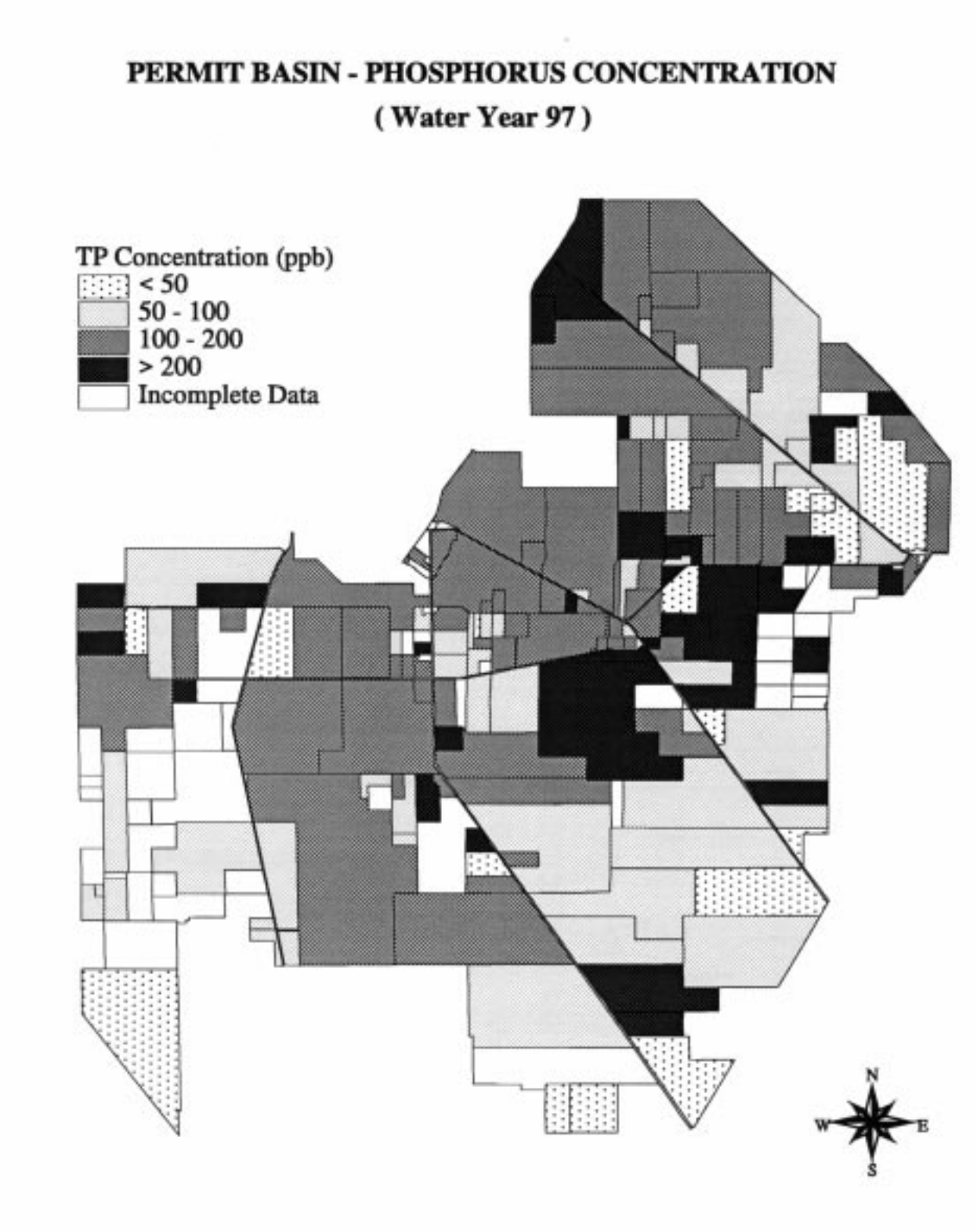

Figure 5-8. WY97 Spatial distribution of permit drainage basin phosphorus concentrations.

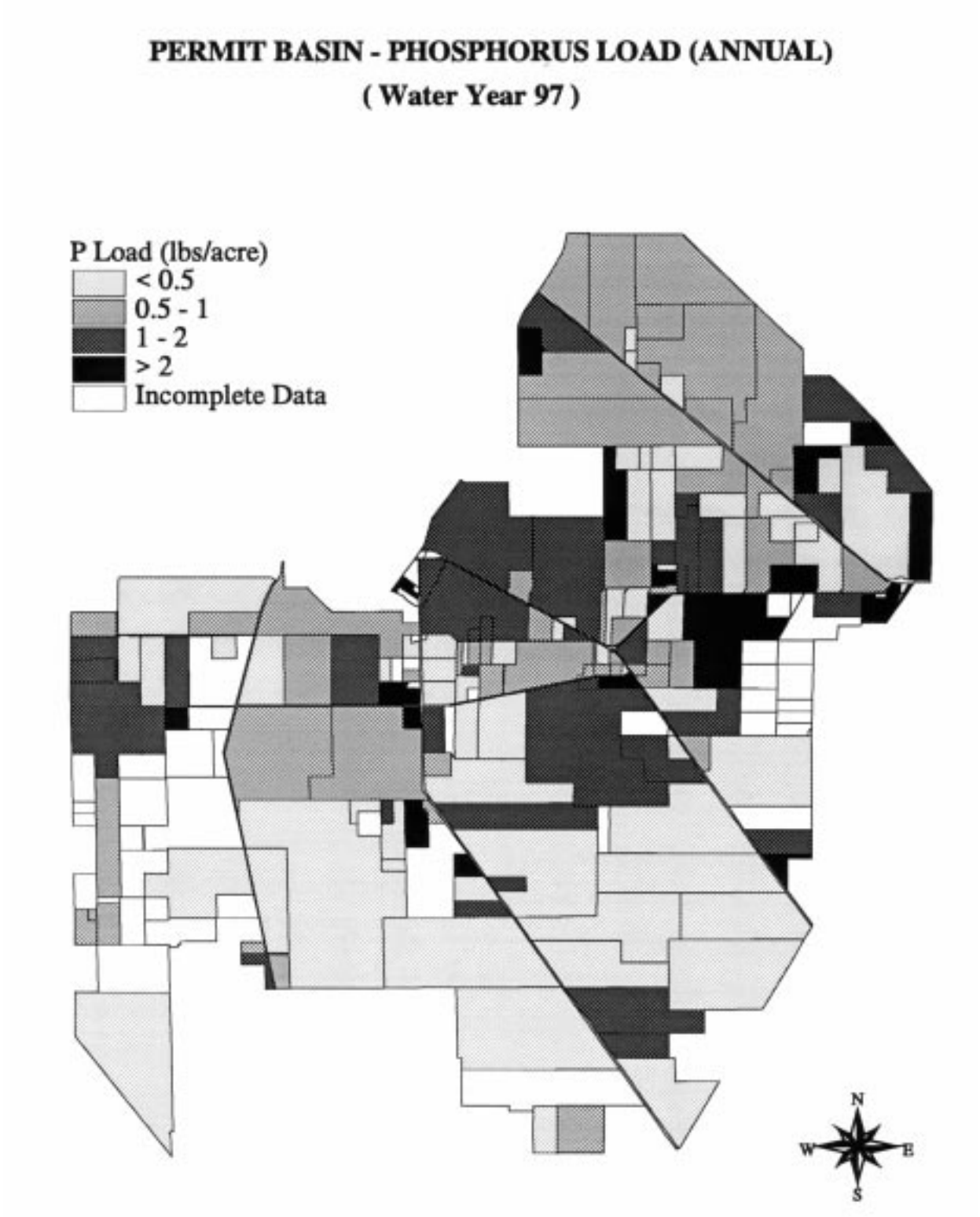

Figure 5-9. WY97 Spatial distribution of permit drainage basin total phosphorus loads.

the limited spatial variation in site-specific BMP information, makes verifying the "25-point" rating system and characterizing the utility of the compliance data virtually impossible at this point in time. Since the basin has out performed the original 25% target goal reduction, explaining individual BMP performance is not a compliance requirement within Rule 40E-63, F.A.C. The compliance water quality and BMP information could be used to identify drainage basins that do not appear to be performing as well as other similar basins. With this in mind, assisting permittees that **voluntarily** would like to investigate the lesser BMP performances on their properties appears to offer potential for further reductions.

The P contributions from the urban areas within the EAA has not been investigated. A significant amount of research has been conducted over the years on urban BMPs, though not specifically within the EAA Basin. The District plans to initiate cooperative research in these areas which may result in the selection and implementation of additional urban BMPs. Further basin reductions could also result from this work.

EAA Basin-Level Phosphorus Reduction Calculations

The Everglades Forever Act mandates a specific method to measure and calculate the annual EAA export of P in surface water runoff from the EAA lands (farms, cities, and industry). Calculating a single year's P reduction requires more than simply comparing the average annual amount from the 10-year base period to a current year's value. Because rainfall and surface-water discharges vary with time and location throughout South Florida, an adjustment for these variations is made in the calculations. These hydrologic variabilities could be large enough to mask the measured effectiveness of the BMPs in reducing P loads. In a dry year, for example, the TP discharged from the EAA may be very low, which leads to the question of whether this is because of the BMPs or less rain? The hydrologic adjustment attempts -- to the greatest extent practicable -- to factor out annual rainfall variations so a direct comparison can be made between any current year's P load and that of the pre-BMP base period.

Methodology was developed during the 1991-1992 rulemaking effort to develop the Everglades Regulatory Program (Chapter 40E-63, F.A.C.) and is described in greater detail in the District's Everglades BMP Program annual status reports (Everglades Regulation Division, District). Entities represented at the workshops included state and federal agencies, agricultural industry, environmental organizations, Native American nations of Florida, and interested members of the general public.

In brief, the methodology compares the current year's measured P load in runoff that is attributable to the EAA farms, cities, and industry with BMPs in place, with a statistical prediction of what the P load would have been without the BMPs in place if the annual rainfall and distribution measured for a *current* year had occurred during pre-BMP base period. The statistical prediction equation (r^2=0.91) was developed using the EAA measured loads during a 10-year pre-BMP period. The annual P percentage reduction is computed by comparing the *current* year's TP load with the *predicted* average annual load for what the base period would have been had the current year's rainfall pattern occurred during the pre-BMP base period.

Water Years 1996, 1997, and 1998 represent the first three years during which all lands within the EAA were required to have BMPs fully implemented. P load in the runoff attributable to the EAA has shown a cumulative three-year reduction of 55% (**Figure 5-10**).

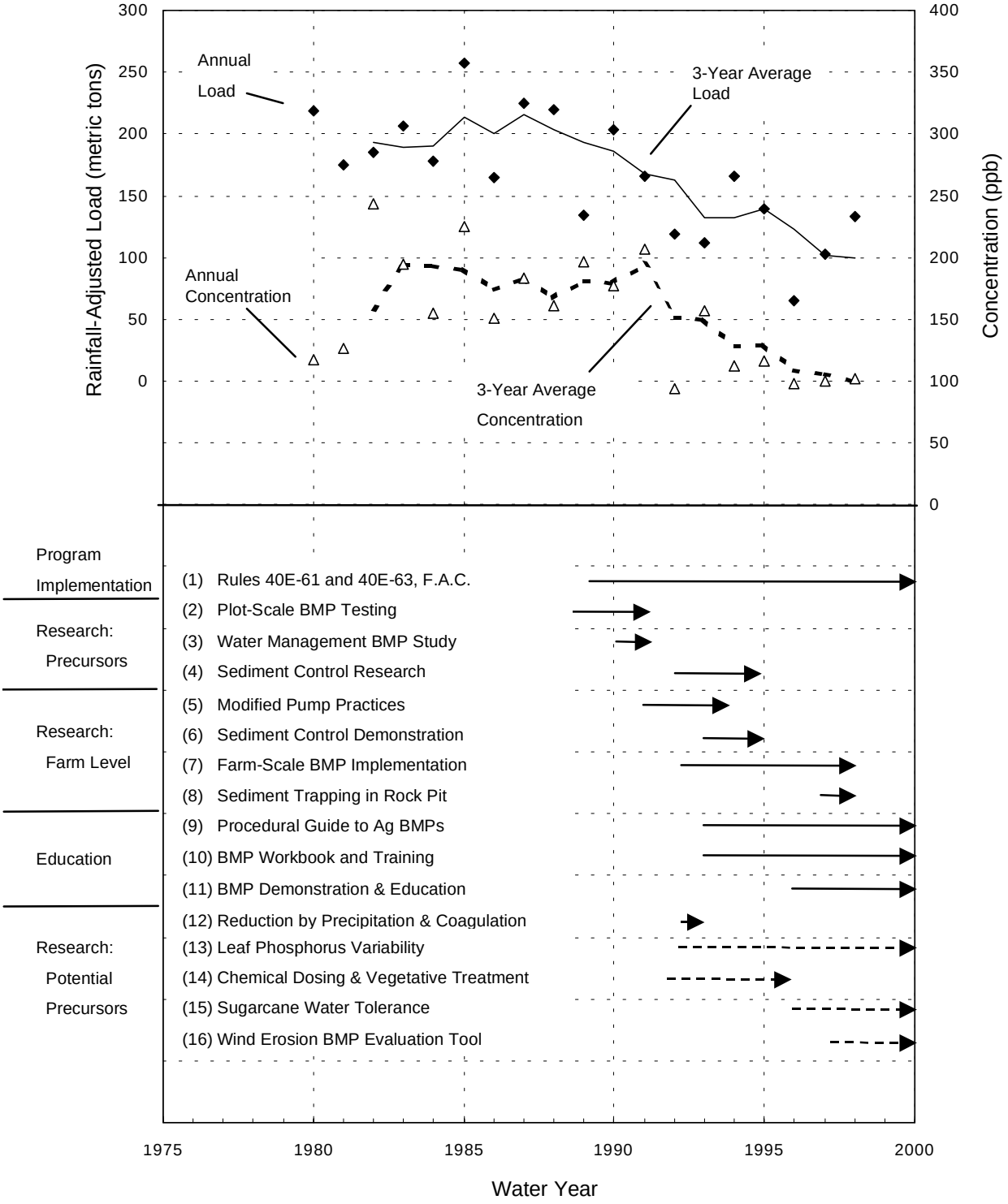

Figure 5-10. Chronologies of BMP initiatives and TP load and concentration.

The trend of P load reduction represents a decrease of P from the combined surface water runoff attributable to the EAA farms, cities, and industry. **The calculation does not equate to a 55% reduction of the total P in surface water entering the WCAs from the District operated pump stations and water control structures located at the EAA southern boundary.** The sum total of P entering the WCAs through the District operated pumps and gates within the EAA originates from the combination of EAA surface water runoff, Lake Okeechobee environmental and urban water supply releases, C-139 Basin surface water runoff, and stormwater treatment area (see **Chapter 4**).

Further, the annual flow-weighted P concentrations attributable to the EAA (total load divided by total flow) shows a similar reduction trend; **173 ppb pre-BMPs as compared to the recent 3-year average 105 ppb with BMPs (Figure 5-10).**

C. Farm Scale BMP Research

(**Appendix 5: Summary Reference No. 7**)

In 1992, after the conclusion of the plot scale study and after the initiation of the Everglades BMP Regulatory Program, farm scale BMP research began on water and fertilizer management strategies. Note that plot scale and demonstration studies on sediment control BMPs were also initiated in 1992 by United States Sugar Corporation (**Appendix 5: Summary Reference No. 4**). The ability of a combination of selected BMPs to reduce TP discharge from agricultural areas has been shown from these farm-scale studies. This farm-scale research was sponsored primarily by the EAA-Environmental Protection District and contracted to the U of FL/IFAS. Project funding was provided primarily by the EAA-EPD with supplemental monetary contributions from the Florida DEP (Environmental Protection Agency 319 Funds) and the District.

Objective

The objectives of the farm scale research have evolved over time. The study was initiated in 1992 and has continued to this date. Originally the project's focus was to measure baseline and post-BMP implementation P loads from different types and sizes of farms (ten farms ranging in size from 320 to 4,500 acres), and to evaluate P load response to weather. During more recent phases of the project the scope of work has been expanded to include the evaluation of particulate P transport and the characterization of other water-quality parameters, notably particulate P, specific conductance, atrazine and ametryn.

Project Design

Work has progressed in annual phases. Crop production on the selected plots varies from monocultures of sugarcane and vegetables to multicultures of vegetables, rice, sod and sugarcane. Consideration was taken to insure proper implementation and maintenance of BMPs, not only to address the BMPs effectiveness, but also to prevent crop damage and/or loss that may result. Baseline TP concentrations, absolute loads, unit area loads and net loads are developed for the ten plots over a period of several years. During Phases I and II, monitoring systems were installed and BMPs were implemented. Hydraulic BMPs alter hydraulics and drainage practices for irrigation/drainage systems and were implemented first at four research plots because of these far-ranging effects. EAAMOD, a parametric water- and P-transport model of subsurface flow, was reviewed and modified for hydraulic conditions in the EAA. During Phase III, a particulate P transport study was conducted by sampling several matrices including discharge water, suspended solids, surficial sediments, bed sediment, aquatic weeds and detritus.

The particulate transport study continued during Phase IV with the formulation of sediment-control BMPs. An unsteady, open-channel flow model (DUFLOW) was modified to allow input of subsurface drainage, and used to simulate water and particulate transport. During Phase V, two distinct philosophies emerged regarding the implementation of BMPs under prevailing hydraulic conditions. The first focuses on small rainfall events during which off-farm pumping may be considered as optional. The second focuses on the few major events, that contribute the majority of the TP loading. By Phase VI the hydraulic BMPs were implemented in combination with crop rotation, fertilizer management and sediment management at several test plots. Research was initiated in late 1997 to characterize other water-quality constituents pursuant to requirements of Part III, Chapter 40E-63, F.A.C. In-situ monitoring is conducted at all sites using a Hydrolab Datasonde 3, multi-parameter water-quality probe to measure temperature, dissolved oxygen, pH, conductivity, and turbidity. EAAMOD-Field version 13.0 was released. During Phase VII, EAAMOD-Farm (incorporation of EAAMOD-Field into DUFLOW) will be calibrated using project data. Lysimeter studies will begin at a project site to study: (1) the effects of higher water tables on three different sugarcane varieties; (2) the effects of growing rice in rotation with vegetables on soils, crops, fertilizer requirements and P balances; (3) the effects of storing rice and fallow field drainage water on sugarcane and sugarcane fertility; and (4) the feasbility of using high P water as fertigation.

Major Findings

Phase I - The highest P concentrations were documented at two research farm sites located in the northeast section of the EAA. These findings emphasize the influence of soil type and rainfall intensity and volume on P concentrations.

Phase II - Pump calibrations vary widely based on different methods and different persons using the same method. Baseline P-loading data documented major differences between stations. Little difference was observed in P concentrations between time and flow-weighted composite samplers; however, grab samples and incomplete composite samples yield major discrepancies that can affect calculated P loads.

Phase III - Baseline TP concentrations and unit-area loadings appear to be strongly dependent on geographic location, crop rotation and water-management strategy. The indices calculated for the BMP sites indicate that TP loads were reduced by 4 to 40%. Changes in pumping volumes resulted in both increased and decreased P loading at different farms; as such, the hydraulic BMPs need to be fine-tuned. Different crops appear to be either a net sink for, or source of, P; however, water management appears to affect this observation.

Phase IV - Preliminary results of the particulate transport study indicate that the majority of particulate P discharged during pumping originates from indigenous aquatic growth. The DUFLOW modeling clearly demonstrated the potential benefits of reducing main-channel velocities and erodible mass, and illustrated that sediment traps may have only a short-term effectiveness.

Phase V - Water table depth increased from 21 inches prior to BMP implementation to 18 inches in 1996, with a concurrent reduction of P loading that is attributed, at least partly, to reduction in pumping.

Phase VI - Major reductions in TP are reported at the farm level through the implementation of BMPs. The research results for new BMPs focusing on particulate transport and water management show the potential for greater TP loading reduction.

Phase VII – Comparison of P load to rainfall volume ratios for farms and the EAA Basin show that that farm values are consistently higher, but the water year trends for each parameter appear to closely follow the District's basin figures. Farm monitoring can yield an excellent indication of what is occurring at the EAA Basin level.

Summary of Farm-Scale Research

This research represents the most comprehensive, on-going research program regarding the effectiveness of BMPs in the EAA. It is expected that results will be used to update the U of FL/IFAS BMP procedural guide's (Circular 1177) estimates of individual BMP P reduction potential. Although studies have progressed from the plot to farm scale, the ability to extrapolate results to basin-wide projections of effectiveness has not been demonstrated. Distributed-parameter, physics-based models such as EAAMOD and DUFLOW are cumbersome to apply at the farm scale and may be impractical to apply basin-wide. However, they have contributed to an emerging understanding of dissolved- and particulate-P source, distribution and transport. This knowledge should facilitate the development of more effective on-farm sediment-management BMPs, and help to explain the cumulative effect of farm-level BMPs on P discharge from the EAA Basin.

From the previous descriptions of some of the on-going BMP initiatives, it is evident that existing BMPs are continuously being refined as experience and information is gained from implementation and research.

Relationship of BMP Initiatives to Trends in Basin TP Load and Concentration Data

Data collected by the District are used to characterize the load and concentration of TP attributable to the EAA and conveyed to the EPA. The basin load and concentration data measured and adjusted in compliance with Rule 40E-63, F.A.C. and the Act for all the water years of record is contained in the District's annual Everglades BMP Program reports. The complex mathematical equations, and basin tributary sources and flow patterns are described completely in the reports.

The load and concentration of total P discharged from the EAA has declined in recent years compared to a 10-year pre-BMP period (Water Years 80 through 88). Over the last three years, cumulative P loads from the EAA have been reduced by 55 percent as compared to the calculated load, that would have occurred during the pre-BMP period had the last three year's rainfall occurred during the pre-BMP period (adjustment for hydrologic variability). The pre-BMP load calculations are a result of a complex regression equation developed from actual measured loads. Monitoring records describe an apparent trend of declining load and concentration beginning about 1992, nearly concurrently with the heightened activity regarding BMPs (**Figure 5-10**). The 3-year trend lines in **Figure 5-10** facilitate describing longer-term trends and tend to smooth the year-to-year variability.

Notable reductions in load and concentration are apparent since water year 1989, which the end of the pre-BMP period used to characterize the affect of rainfall on TP loads. The Everglades BMP program (Chapter 40E-63, F.A.C.) required load-reduction compliance monitoring to begin in water year 1996. The first three years of required BMP implementation resulted in a 55% reduction in cumulative P compared to the pre-BMP period.

Other Water Quality Parameters of Concern

The Act requires that the District conduct research in cooperation with the EAA landowners to identify water quality parameters that are not being significantly improved by either the STAs or BMPs, and to identify further BMP strategies needed to address these parameters. As a result of research in this area, in 1996, DEP and the District identified specific conductance, particulate P, Ametryn, and Atrazine as additional constituents of concern. The District amended Rules 40E-61 and 40E-63 in 1997 to define and implement a comprehensive program of research, testing and implementation of BMPs for all other water quality parameters (initially for the four previously mentioned). The EAA-EPD is the primary sponsor of this University of Florida/Institute of Food and Agricultural Sciences farm-scale research. Annual review of data, including a public workshop, will occur to determine if the current research is meeting the overall objective of the Rules. If changes are deemed to be necessary, the program will be adjusted accordingly.

New BMP Initiatives and Recommendations

Existing BMPs continue to be refined. Nevertheless, research initiatives, which may provide results that identify new BMPs, previously referred to as potential precursors (defined under Extent of BMP Implementation on Page 6), are also underway. Further basin P reductions may be possible from the identification and implementation of additional refined BMPs.

The research initiatives potentially identifying new BMPs are discussed briefly below.

- Defining the particulate P transport process and particulate characteristics. A significant amount of P being discharged into the District's system is in the particulate form. Understanding the transport process and particulate characteristics may identify modified or new sediment control BMPs, which could result in further basin P reductions.
- Develop wind erosion, sediment transport method. Develop a method that can be used to evaluate BMPs that address sediment transport by wind erosion and effectively predict loss of soils typical of the EAA.
- Sugarcane variety experiments. 1.) Identify varieties of sugarcane which utilize P more efficiently, thereby, potentially reducing the amount of P applied and/or available for transport off-site. 2.) Identify sugarcane varieties that are more tolerant of higher water levels thus reducing soil oxidation (a process that releases P into runoff).

These on-going research initiatives have potential to reveal new BMPs that could result in further basin load reductions. U.S. Environmental Protection Agency/DEP, EAA-EPD, District, U.S. Department of Agriculture Natural Resources Conservation Service and Agricultural Research Service, and private companies are participating in these efforts.

The District is also in the process of augmenting the water quality data and limited BMP information available for the C-139 Basin. The C-139 Basin has discharged some of the highest P

concentrations to the EPA and is the next largest contributing basin of P load to the EPA after the EAA. Some BMPs implemented and under investigation in the EAA may be applicable to the C-139 Basin. However, land uses and soil types are different from the EAA so BMP knowledge, experience, and results may not be directly transferable to the C-139 Basin. BMP research would provide site-specific information.

The new BMP initiatives (previously discussed) that are already under way have a potential to improve the water quality of runoff from the EAA and C-139 Basins. Review of the past and present BMP initiatives have identified additional areas that may be worth investigating. These areas were already mentioned in this chapter but are being repeated under this section as observations/recommendations.

- Gain an understanding of the cumulative effect of farm-level BMP plans on basin-wide P discharge. Small scale, physics-based research regarding transport is helping to explain the association but the models are cumbersome to apply at the farm scale (**Appendix 5: Summary Reference No. 7**). The development and application of a basin-wide transport model may be impractical.
- A relative comparison of compliance data submitted by growers regarding water and P discharges and BMPs may be useful for identifying and assisting voluntary landowners with improving their BMP plan performance.
- There is a need to further evaluate how the observed trend in basin-wide P load is associated with variations in the volume of water discharged from the basin and in-source concentrations. Even though the EAA Basin recycles a significant amount of water, this may help to characterize the basin-wide effectiveness of water management BMPs considered in the Everglades BMP Regulatory Program.
- Continued investigation of how antecedent rainfall conditions, timing of management practices and type of rainfall events relate to water quality could lead to additional adjustments in water management practices, though it is not clear what further reductions are attainable.
- Investigate the urban area P contributions to the basin and identify and implement urban BMPs as appropriate.

Conclusions

Best management practices implemented to date have been shown to reduce P export at the farm level. Research data and the Everglades BMP Regulatory Program demonstrate appreciable reductions in the load and concentration of TP conveyed to the EPA from the EAA. This reduction in load and concentration of total P is attributable to BMP implementation.

Further declines in P load and concentration are probable as experience and information continue to be gained from the implementation of existing BMPs, and from recent research initiatives regarding processes such as suspended particulate transport by water and wind, and crop variety experiments.

Because the measurements for water year 1997 represent only the third *full* water year of required best management practices (BMP) implementation throughout the EAA, it is too early to predict the long-

term reductions of P to the Everglades that may be the result of BMPs. As the number of annual calculations increase, the staff will have increased confidence to quantify a specific level of long-term phosphorus reduction in the runoff attributable to BMPs. However, given the encouraging preliminary BMP program measurements and the performance of the initial District stormwater treatment areas (ENR Project), **there is increased confidence that the Everglades Forever Act's interim goal of achieving 50 ppb phosphorus concentration through the combination of existing landowner BMPs and downstream stormwater treatment areas will be met.**

Costs Associated with BMP Research

Research funding has been contributed by a least ten private and public entities. The various participants in the reviewed research initiatives were contacted to report the amount of funds expended. The funding listed pertains only to the BMP research cost component; it does not include the costs associated with implementation and maintenance of the practices. Refer to **Table 5-5** provided by the participating parties. The total research funding listed for all parties to date is over $8 Million. Many of the existing research projects are anticipated to continue through 2001.

Findings on the Effectiveness of Agricultural BMPs

- Sixteen initiatives between 1979 and 1997 provided information to support the Everglades Agricultural Area BMP program.
- BMP implementation has resulted in loading reductions in full compliance with the 25% mandated in the Act. The cumulative load of phosphorus discharged from the Everglades Agricultural Area over the last three years is 55% lower than the load that would have occurred without BMPs.
- The documented reduction in phosphorus conveyed to the EPA from the Everglades Agricultural Area, compared to that recorded from 1979 to 1988, is attributable to implementation of the Everglades BMP Regulatory Program, as well as research and educational programs.
- Through continuing research, monitoring and refinement, further declines in phosphorus load and concentration from the Everglades Agricultural Area are probable.

Table 5-5. Research initiatives & estimated amount of funds expended.

Research Initiative Period of Study Lead Researchers	Summary No.	Funding Source	Total Research Funding (approx.)
Agricultural BMPs for P Loading in the EAA - Plot Scale 1985 - 1991 Izuno, Bottcher, and others (UF-IFAS)	**2**	South Florida Water Management District	$1.52 Million
		Florida Sugar Cane League	Not Available
		Florida Fruit & Vegetable Growers Assoc.	Not Available
Water Management Study of Wetherald I and Mott No. 1 Plantations 1990 – 1991 Environmental Services & Permitting	**3**	United States Sugar Corporation	Not Available
Phosphorus Reduction and Sediment BMP Research 1992 – 1995 H. Andreis (United States Sugar Corporation)	**4**	United States Sugar Corporation	Not Available
Phosphorus Reduction and Modified Pumping Practices 1991 – 1994 Hutcheon Engineers	**5**	Florida Sugar Cane League	Not Available
Sediment Control Demonstration Project 1993 – 1995 Hutcheon Engineers	**6**	EAA-Environmental Protection District	$260,478
Implementation and Verification of BMPs for Reducing Phosphorus Loading & Other Water Quality Parameters - Farm Scale 1992 – present Izuno, Rice and others (UF-IFAS)	**7**	EAA-Environmental Protection District	$4.16 Million
		DEP/US EPA Chapter 319 (WM631)	$765,000
		South Florida Water Management District (C-E8616)	$50,000
EAA Sediments and Effectiveness of Soil Sediment Trapping in Rock Pit Diversions 1997 – present Izuno & Rice (UF-IFAS)	**8**	DEP/US EPA Chapter 319 (WM572)	$211,635
		EAA-Environmental Protection District	$50,000
Reduction of Phosphorus Concentrations by Precipitation, Coagulation & Sedimentation 1992 Anderson & Ceric (UF-IFAS) & Hutcheon Engineers	**12**	Florida Sugar Cane League	Not Available
Variability of Leaf Phosphorus Among Sugarcane Genotypes Grown on Everglades Histosols 1992 – 1995 Glaz (USDA-ARS); Deren & Snyder (UF-IFAS)	**13**	USDA Agricultural Research Service	$115,000
		UF-IFAS	$75,000
		Florida Sugar Cane League	Not Available
		Florida Crystals	Not Available
Nutrient Management System – Chemical Dosing & Vegetative Treatment 1992 – 1996 Bion Technologies	**14**	Sugar Cane Growers Cooperative	$187,000
Researching the Water Tolerance of Sugarcane 1996 – present Glaz (USDA-ARS)	**15**	USDA Agricultural Research Service	$730,000
		United States Sugar Corporation	Not Available
		Florida Sugar Cane League	Not Available
Wind Erosion BMP Evaluation Tool for the EAA 1997 - present USDA Natural Resources Conservation Service	**16**	South Florida Water Management District (C-8511)	$25,000
		USDA Natural Resources Conservation Service	$25,000

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