Evaluation Of An Alternative Method For Assessing Compliance With The Load Reduction Expectations Of The Settlement Agreement

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EXECUTIVE SUMMARY

The modified Settlement Agreement establishes the expected performance of the Best Management Practices (BMPs) and STAs in Appendix C:

> The control program is designed to achieve approximately an 80% reduction in phosphorus loads from the Everglades Agricultural Area (EAA) to the Everglades Protection Area (EPA) by October 1, 2003 and greater than an 85% reduction in phosphorus loads to the Refuge by December 31, 2006, relative to the average annual loads measured in Water Years 1979 through 1988.

In 2004 the Technical Oversight Committee (TOC) adopted a concentration-based methodology to assess compliance with the "approximately 80%" and "greater than 85%" total phosphorus (TP) load reduction expectations. That method established compliance with the load reduction expectations if STA discharges achieved an average annual concentration limit of less than or equal to 76 ppb, with at least 1 of 3 years at 50 ppb.

An alternative method for assessing the load reduction expectations was developed and is presented herein. This method uses actual **load reductions**, as opposed to the current concentration-based method being used by the TOC. The results of this alternative assessment methodology indicate that both the 80% and 85% load reduction expectations were met for the 5-year period May 1, 2001 through April 30, 2006 (WY2002-2006), at the 90% confidence level. The effective date for the 85% load reduction from the EAA to the Refuge is December 31, 2006, so this assessment covering years prior to December 31, 2006 should be considered as demonstrative only.

SECTION 1. 1979 – 1988 BASE PERIOD FLOWS AND LOADS TO THE EVERGLADES PROTECTION AREA

The historic flows and loads to the Everglades Protection Area (EPA) for the Base Period through S-5A, S-6, S-7, S-150 and S-8 from all sources are presented in **Table 1** and **Figure 1** (from 1992 Everglades SWIM Plan Appendices B and F; SFWMD 1992**)**. Beginning in 1992 with the development of the EAA BMP rule development, a May – April water year was adopted to better coincide with the regional wet and dry seasons. Base Period loads to the EPA are presented for the May **–** April Water Year in **Appendix A.**

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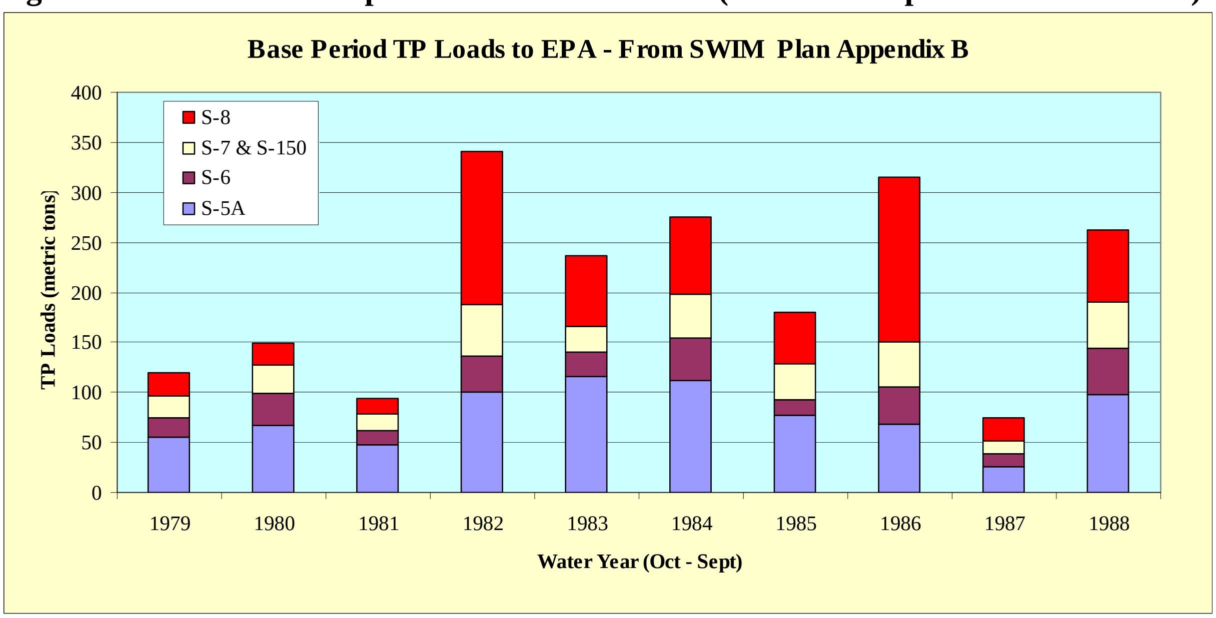
[2] Technical assistance with the EAA load reductions provided by Douglas Pescatore and Stuart van Horn of the South Florida Water Management District. Additional technical review provided by Steven Hill, Shi Xue, and Nenad Iricanin of the South Florida Water Management District, and Frank Nearhoof, Ken Weaver and Garry Payne of the Florida Department of Environmental Protection.

Table 1. Base Period Phosphorus Loads to the EPA Through (October – September Water Year; from SWIM Plan App. B). mtons = metric tons

Oct- Sept WY	S-5A (mtons)	S-6 (mtons)	S-7 + S-150 (mtons)	S-8 (mtons)	Total to EPA (mtons)	Total to Refuge (mtons)
1979	55.80	18.72	22.19	23.15	119.86	74.52
1980	67.48	32.10	27.71	21.50	148.79	99.58
1981	46.99	14.86	16.40	15.24	93.49	61.85
1982	99.76	36.26	51.32	152.88	340.22	136.02
1983	115.31	25.12	25.88	70.98	237.29	140.43
1984	112.39	41.47	44.21	76.92	274.99	153.86
1985	77.47	15.13	36.63	50.61	179.84	92.60
1986	68.64	36.47	45.53	164.99	315.63	105.11
1987	25.93	12.02	13.07	23.21	74.23	37.95
1988	97.46	46.56	46.14	72.56	262.72	144.02
Average	76.72	27.87	32.91	67.20	204.7	104.6

Figure 1. Base Period Phosphorus Loads to the EPA (October – September Water Year)



SECTION 2. LOAD REDUCTION ASSUMPTIONS IN APPENDIX C OF THE SETTLEMENT AGREEMENT

As described in Appendix C, the phosphorus control program of the Settlement Agreement was designed to achieve approximately an 80% reduction in phosphorus loads from the EAA to the EPA and greater than an 85% reduction in phosphorus loads from the EAA to the Refuge relative to average annual loads measured in Water Years 1979 through 1988. Several key assumptions were made in deriving the load reduction expectations:

- Loads associated with low-flow water supply deliveries from Lake Okeechobee were excluded from these calculations because they "do not impact WCA marshes.".
- EAA flows would be reduced by a maximum of 20% due to BMP implementation (an assumption that has proven incorrect, as the actual BMP reduction is close to zero)[3].
- EAA flows and loads would be reduced by an average of 6% to reflect conversion in land use from agriculture to STA[4].
- EAA loads would be reduced by 25% due to BMP implementation.
- The STA would reduce TP loads by 70%.

Additional assumptions were made for the 85% load reduction to the Refuge:

- Diversion of S-6 flows and loads away from the Refuge, and
- For the S-5A Basin, EAA flows and loads would be reduced by an average of 10.1% to reflect conversion in land use from agriculture to STA (see SWIM Plan Appendix F, SFWMD 1992).

Load Reductions From the EAA to the EPA

The 1992 Everglades SWIM Plan describes how the EAA load reductions were developed by applying the above assumptions to the Base Period data, using the Oct. – Sept. water year:

Table 2. Anticipated Reductions to the Base Period Loads to the EPA.

Load Reduction Component	To EPA (mtons/yr)
Reduction to exclude water supply loads	10.90
Reduction for land use conversion	15.30
25% reduction due to EAA BMPs	44.63
70% reduction due to STAs	93.72
Total load reduction	164.5

[3] While the Settlement Agreement requires replacement of water reduced by BMP implementation, there was no allowance in the load reduction expectations for the TP loads associated with this replacement water, consistent with the intent that only loads from the EAA are to be counted in assessment of this expectation.

[4] This percentage was updated to 7.5% in the 1992 SWIM Plan based on improved estimates of basin and STA areas (SFWMD 1992).

These assumptions yield a long-term average reduction in loads from the EAA of 164.5 metric tons/yr, or approximately 80.4%. Relative to average annual loads measured in October – September Water Years 1979 through 1988, an 80% reduction would be approximately 163.8 metric tons/yr. This is a long-term average, i.e., averaged over 10 years, that does not account for annual variability of the individual components.

Load Reductions From the EAA to the Refuge

For the Refuge, using the 1992 Everglades SWIM Plan data and the October – September Water Year, the above assumptions, plus diversion of S-6, yield a long-term average reduction in loads from the EAA of 89.3 metric tons/yr, or approximately 85.4%:

Table 3. Adjustments to the Base Period Loads to the Refuge.

Load Reduction Component	To Refuge (mtons/yr)
Reduction due to diversion of S-6	27.87
Reduction to exclude water supply loads	0.96
Reduction for land use conversion	7.70
25% reduction due to EAA BMPs	17.02
70% reduction due to STAs	35.73
Total load reduction	89.3

Relative to average annual loads measured in October – September Water Years 1979 through 1988, an 85% reduction would be approximately 88.9 metric tons/yr. This is a long-term average, i.e., averaged over a 10-year period, that does not account for annual variability of the individual components.

SECTION 3. ASSESSMENT OF THE LOAD REDUCTION EXPECTATIONS

The Settlement Agreement provides no guidance on

- how to assess these long-term load reduction expectations, e.g.,
    - frequency of assessment,
    - how to incorporate annual variability,
    - round-off protocol, e.g., round to the nearest 0.1 metric ton or whole metric ton,
    - how to account for impacts of hurricanes and other factors outside the control of the Settling Parties.
- how to modify the expectations due to
    - revisions to regional flow patterns and discharge locations made after the Settlement Agreement was executed, or
    - inaccurate assumptions.

In 2004 the TOC adopted a concentration-based methodology to assess compliance with the 80% and 85% load reduction expectations. This method established compliance with the load reduction expectations if STA discharges achieved an average annual concentration limit of less than or equal to 76 ppb, with at least 1 in 3 consecutive years at or below 50 ppb.

At the May 25, 2004 TOC meeting, four areas of the TOC-adopted methodology were identified as requiring refinement:

1. clarification of “low-flow water supply deliveries”
2. clarification of “extreme hydrological events”
3. revision of the annual phosphorus limit (presently at 76 ppb)
4. recognition that applicability of the current TOC-adopted methodology is contingent on flows through the STAs being within the range contemplated in the design of STAs 1E, 1W, 2, 3/4, and 6 consistent with the amended Settlement Agreement[5]

In addition, two related issues were identified that should be clarified:

5. Which 12-month period should be used for compliance?
6. When to consider “low-flow water supply deliveries” and “extreme hydrological events”?

Also in 2005, Frank Nearhoof (Florida Department of Environmental Protection) presented to the TOC a refinement of the current methodology that addressed most of these issues and was to be implemented in the STA-1E operations permit, however, the TOC did not take any action on that methodology.

The following section describes one alternative to the current assessment methodology.

[5] STA-5 is excluded from this assessment as it does not treat flows “from the EAA.”

SECTION 4. ALTERNATIVE METHOD FOR ASSESSING COMPLIANCE WITH THE LOAD REDUCTION EXPECTATIONS

Load Reduction From the EAA to the EPA

Relative to average annual loads measured in October – September Water Years 1979 through 1988, an 80% reduction in loads from the EAA to the EPA would be approximately **163.8 metric tons/yr with a 90% confidence interval of ± 39.3 metric tons/yr**. Beginning in 1992 with the development of the EAA BMP rule development, a May – April water year was adopted to better coincide with the regional wet and dry seasons. The EAA BMP Program (Rule 40E-63, Florida Administrative Code) estimates the TP load reductions attributable to the EAA BMPs using the May – April Water Year. Details on the calculation of EAA load reductions are provided in the annual South Florida Environmental Report and in Rule 40E-63, F.A.C. (Adorisio et al. 2007; Rule 40E-63, F.A.C.). The annual load reduction for EAA-wide flows going south can be calculated by excluding loads discharged to Lake Okeechobee from the EAA. Therefore, the reduction in loads from the EAA to the EPA can be calculated as

1. the load reduction due to EAA BMPs, and
2. estimating the EAA load reduction through the STAs

The annual EAA load reductions to the EPA for WY2002-2006 are presented in **Tables 4** and **5** and **Figures 2 and 3**. The annual reduction in loads from the EAA to the STAs and EPA was estimated by multiplying the load reduction calculated by the EAA BMP Rule by the percentage of EAA loads that went to the STAs and EPA, i.e., excluding EAA loads that were discharged to Lake Okeechobee. The 5-year average load reduction for WY2002-2006 was estimated as 200.4 metric tons/yr, far exceeding the 10-year Base Period average load reduction expectation of 163.8 metric tons/yr. Since the WY2002-2006 mean load reduction is greater than the mean load reduction of the Base Period, a statistical comparison of the two means is not necessary to demonstrate that the expected load reduction was achieved[6]. Also, since STA-1E was designed to capture and treat a portion of the EAA basin, the EAA load reduction would have been even higher had STA-1E, constructed by the Corps of Engineers, been in operation beginning July 2, 2002, as required by the Settlement Agreement.

Table 4. Summary of EAA Load Reduction Calculations for WY2002-2006.

May - April Water Year	Observed Load from the EAA (mtons)	Predicted Load from the EAA (per Rule 40E-63, F.A.C.) (mtons)	Load Reduced from the EAA due to BMPs (mtons)	Percentage of EAA Loads to the STAs and EPA (see Note)	Reduction in Loads from the EAA to the STAs and EPA (mtons)	Total Load to the STAs (see Table 5 for details) (mtons)	Percentage of Load from the EAA to the STAs (%)	Total Load Reduced by the STAs (mtons)	Loads from the EAA Reduced by the STAs (mtons)	Total Loads Reduced from the EAA to the EPA (mtons)
2002	101.2	226.9	125.7	58%	73.3	125.7	60%	95.5	56.9	130.2
2003	80.8	125.0	44.2	99%	43.9	199.0	30%	125.2	38.0	81.9
2004	82.3	229.0	146.7	100%	146.4	127.9	57%	88.3	49.9	196.4
2005	182.3	444.0	261.7	98%	256.3	272.9	63%	185.9	116.5	372.8
2006	152.6	270.3	117.7	96%	112.7	257.2	62%	175.3	107.9	220.6
Average	119.8	259.0	139.2	91%	126.5	196.5	55%	134.1	73.8	200.4

Excludes load reduction in water discharged to Lake Okeechobee

[6] With the null hypothesis being the difference in the two mean load reductions is zero, if the null hypothesis is accepted at the 90% confidence level, then the difference in the means is zero and the expected load reduction is achieved. If the null hypothesis is rejected, then the WY2002-2006 mean load reduction is significantly greater than the expected load reduction, and again, the expectation is achieved.

Table 5. WY2002-2006 EAA Load Reductions Within the STAs.

STA		May - April Water Year 2002	2003	2004	2005	2006	Total	Average
STA-1E	Load in (mtons)	0	0	0	4.85	12.12	16.97	8.49
	% EAA				0%	44%	31%	31%
	Load removed (mtons)				-3.22	4.82	1.60	0.80
	EAA Load removed (mtons)				0	2	2.12	1.06
	% Removal				-66%	40%	9%	9%
STA-1W	Load in (mtons)	51.77	112.17	50.73	103.87	37.41	355.96	71.19
	% EAA	95%	32%	82%	67%	72%	63%	63%
	Load removed (mtons)	39.57	72.94	33.66	57.34	18.15	221.65	44.33
	EAA Load removed (mtons)	37.54	23.30	27.50	38.60	13.13	140.07	28.01
	% Removal	76%	65%	66%	55%	49%	62%	62%
STA-2	Load in (mtons)	20.31	23.40	24.28	49.12	44.04	161.14	32.23
	% EAA	100%	62%	97%	83%	98%	88%	88%
	Load removed (mtons)	15.44	16.76	19.25	39.89	35.80	127.15	25.43
	EAA Load removed (mtons)	15.39	10.44	18.67	33.01	35.17	112.68	22.54
	% Removal	76%	72%	79%	81%	81%	79%	79%
STA-3/4	Load in (mtons)	0	0	1.41	87.37	105.38	194.15	38.83
	% EAA			100%	55%	64%	60%	60%
	Load removed (mtons)			0.86	76.96	82.86	160.68	53.56
	EAA Load removed (mtons)			0.86	42.13	53.10	96.09	32.03
	% Removal			61%	88%	79%	83%	138%
STA-5	Load in (mtons)	49.12	58.09	48.08	24.42	53.03	232.74	46.55
	% EAA	0%	0%	0%	0%	0%	0%	0%
	Load removed (mtons)	36.55	31.21	31.67	12.22	29.33	140.99	28.20
	EAA Load removed (mtons)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	% Removal	74%	54%	66%	50%	55%	61%	61%
STA-6	Load in (mtons)	4.54	5.36	3.42	3.26	5.18	21.76	4.35
	% EAA	100%	100%	100%	100%	100%	100%	100%
	Load removed (mtons)	3.97	4.31	2.91	2.74	4.34	18.27	3.65
	EAA Load removed (mtons)	3.97	4.31	2.91	2.74	4.34	18.27	3.65
	% Removal	88%	80%	85%	84%	84%	84%	84%
Total	Load in (mtons)	125.73	199.02	127.92	272.89	257.16	982.72	196.54
	% EAA	60%	30%	57%	63%	62%	55%	55%
	Load removed (mtons)	95.53	125.23	88.35	185.93	175.30	670.34	134.07
	EAA Load removed (mtons)	56.91	38.05	49.94	116.47	107.86	369.23	73.85
	% Removal	76%	63%	69%	68%	68%	68%	68%

Figure 2. Estimated Load Reduction From the EAA to the EPA (WY2002 – 2006)

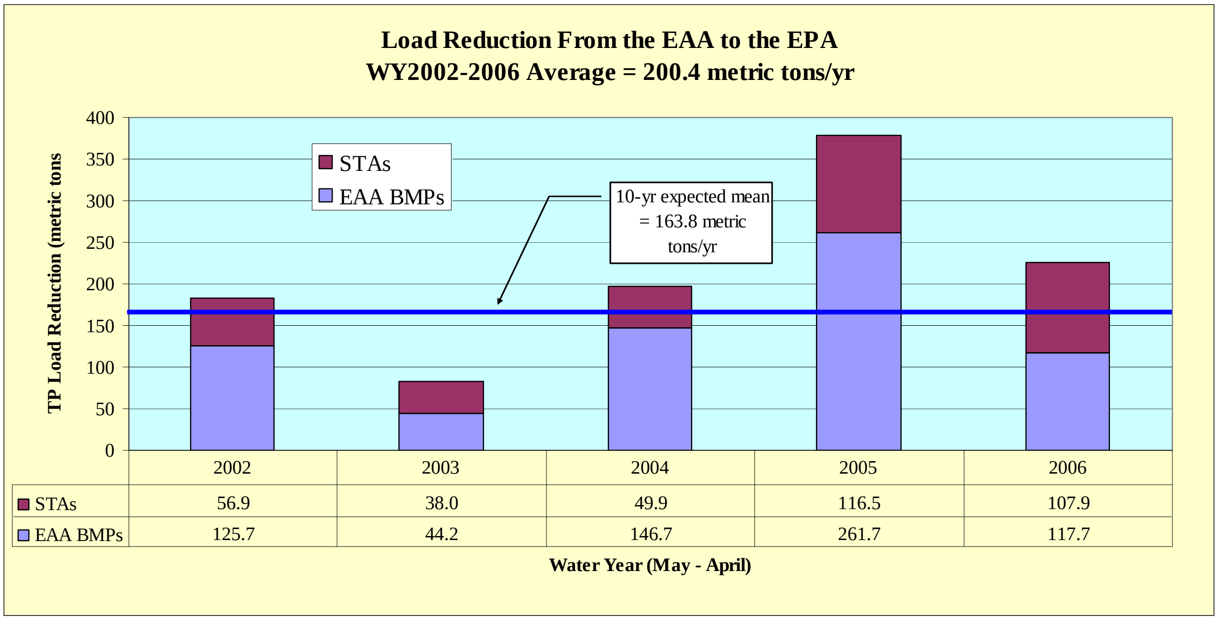
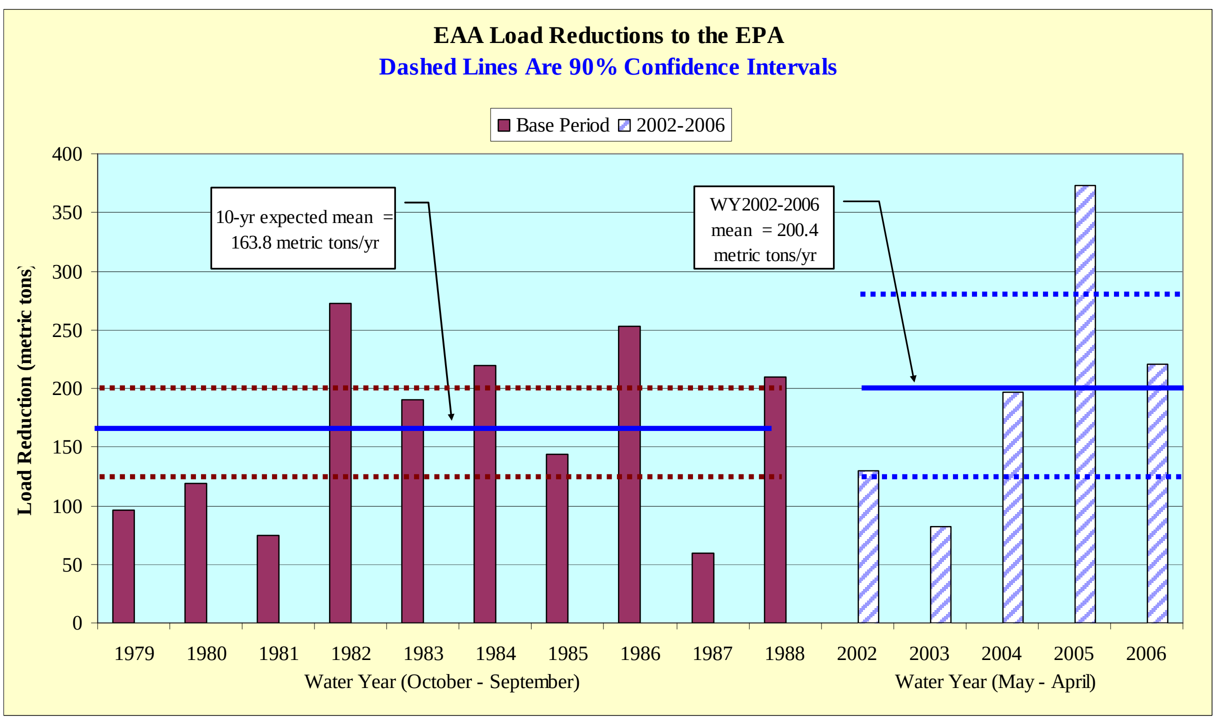


Figure 3. Comparison of Anticipated Load Reductions From the EAA to the EPA with WY2002-2006.



Load Reduction From the EAA to the Refuge

The existing EAA Basin load reduction algorithm is described in detail in Rule 40E-63, F.A.C. and is based on a regression equation between Base Period EAA rainfall and EAA TP loads. While EAA-wide load reductions are published annually, individual sub-basin load reduction values have not been calculated. However, Appendix A4 to Rule 40E-63 describes the algorithm to calculate farm scale load reductions as a function of area, and that algorithm was modified for application at the S-5A Sub-basin level (F.A.C. 40E-63, Appendix 4A) as follows:

Predicted Load = Geometric Mean of Base Period Load * Load Adjustment Factor * Area / $\text{Area}_{\text{Base Period}}$

Load Adjustment Factor = $(R_{am} / R_a)^{2.868}$

$R_a = \exp [X + 1.053 (C-C_m) - 0.1170 (S-S_m)]$

where,

R_a = Adjusted sub-basin rainfall in current year (inches)

X = natural logarithm of rainfall

C = coefficient of variation of monthly rainfall

S = skewness of monthly rainfall

m = subscript denoting average value of rainfall statistic in Base Period for EAA Sub-basin (C_m = 0.7636, S_m = 0.9999)

R_{am} = base period log-mean adjusted rainfall for EAA Sub-basin = 50.31 inches for S-5A Sub-basin

Applying the algorithm to the S-5A sub-basin rainfall for WY2002-2006 yielded an average load reduction of 21.4 metric tons per year attributable to BMPs in the S-5A sub-basin (see **Table 6**). A potential water quality impact of the WY2005 and WY2006 hurricanes is suggested in **Table 6**, with a significant decrease in the estimated load reduction during WY2006 compared to the previous years. Combining the S-5A Sub-basin load reductions with the STA load reductions from **Table 5** and the S-6 diversions[7], yields a 5-year average annual EAA load reduction to the Refuge for WY2002-2006 of 77.3 metric tons/yr (see **Table 7 and Figure 5)**. Since STA-1E was designed to capture and treat a portion of the EAA basin, the EAA load reduction would have been even higher had STA-1E, constructed by the Corps of Engineers, been in operation beginning July 2, 2002, as required by the Settlement Agreement.

[7] S-6 was diverted in WY2002.

Table 6. Summary of S-5A Sub-basin Load Reduction Calculations.

Water Year (May - April)	S-5A Sub-basin Area (acres)	S-5A Sub-basin Load (mtons)	S-5A Sub-basin Flow (AF)	S-5A Sub-basin Rainfall (inches)	S-5A Sub-basin Rainfall Coeff. Of Variation	S-5A Sub-basin Rainfall Skewness	S-5A Sub-basin Adjusted Rainfall (inches)	S-5A Sub-basin Load Adjustment Factor	S-5A Sub-basin Predicted Load (mtons)	Difference Between Predicted and Measured Loads (mtons)
1980	121,831	63.227	276,377	53.21	0.653	1.614	44.08	1.46	92.38	29.15
1981	121,831	34.811	169,680	40.00	0.866	0.988	44.61	1.41	49.15	14.34
1982	121,831	65.082	198,103	48.29	0.957	1.816	53.80	0.83	53.70	-11.38
1983	121,831	146.851	458,731	62.95	0.556	0.214	55.48	0.76	110.90	-35.95
1984	121,831	52.447	230,384	56.39	0.729	0.609	56.91	0.70	36.82	-15.62
1985	121,831	67.695	223,376	42.52	0.876	0.774	49.14	1.07	72.40	4.71
1986	121,831	57.308	273,352	53.13	0.695	0.312	53.55	0.84	47.93	-9.38
1987	121,831	40.891	262,681	52.77	0.698	1.238	47.89	1.15	47.10	6.21
1988	121,831	40.735	224,015	47.47	0.843	1.433	49.05	1.08	43.82	3.09
2002	114,140	30.549	257,496	52.09	0.728	0.509	53.15	0.85	63.31	32.76
2003	114,140	38.821	291,826	50.27	0.650	0.735	46.00	1.29	41.84	3.02
2004	114,140	37.034	259,286	50.17	0.825	1.040	53.27	0.85	63.73	26.70
2005	114,140	86.569	332,410	56.66	1.003	1.414	69.43	0.40	136.27	49.71
2006	114,140	44.535	180,159	42.93	0.696	-0.029	45.08	1.37	39.48	-5.05
WY1980-1988 Ave.	121,831	63.228	257,411	50.75	0.7636	1.000	50.50	1.03	57.74	-1.65
WY2002-2006 Ave.	114,140	47.501	264,235	50.43	0.780	0.734	53.39	0.95	61.89	21.43

Notes:
1. Sub-basin area, flows and TP loads came from the SFWMD Everglades Regulation Division.
2. All rainfall values and statistics came from the EAA Model per Rule 40E-63
3. The Base Period average predicted load is reported as a geometric mean consistent with Appendix A4 of Rule 40E-63.

Table 7. Estimated Load Reduction from the EAA to the Refuge.

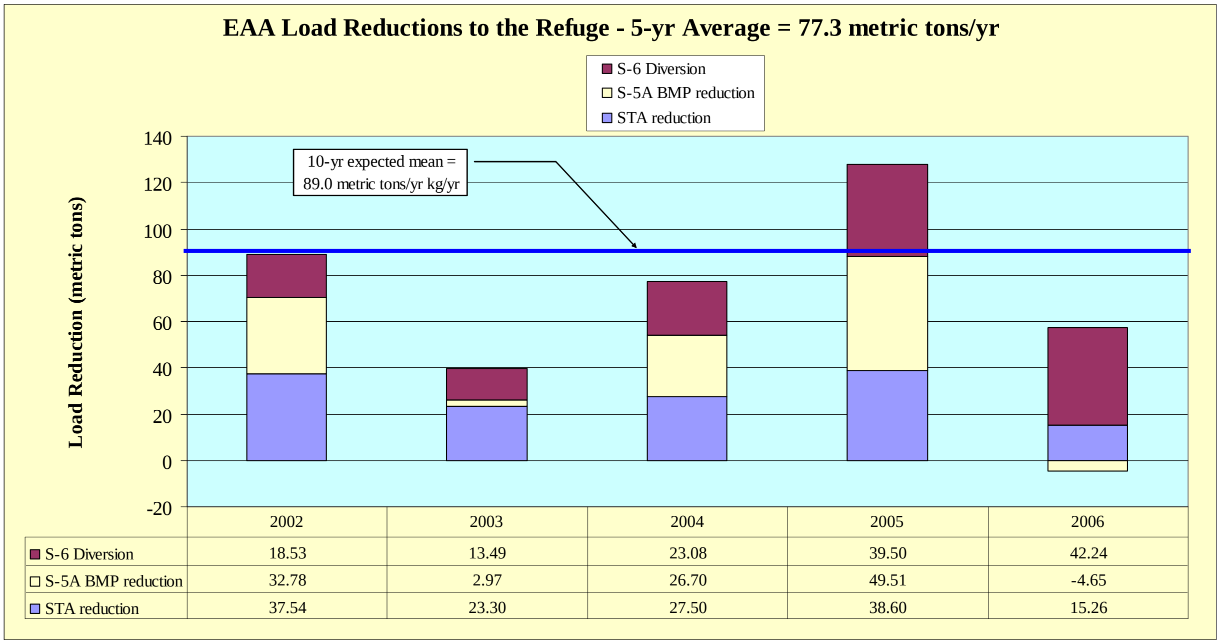
WY	EAA Load Reduction Within STA-1W and STA-1E (see Table 5) (mtons)	Loads in S-6 Discharge (mtons)	EAA Portion of S-6 Loads (%)	EAA Loads Reduced By S-6 diversion (mtons)	Observed Load from S-5A Basin (mtons)	Predicted Load from S-5A Basin (mtons)	EAA Load Reduction Due to BMPs in S-5A Basin (see Note) (mtons)	Total EAA Reduction to Refuge (mtons)
2002	37.54	18.59	100%	18.53	30.53	63.31	32.78	88.85
2003	23.30	21.66	62%	13.49	38.87	41.84	2.97	39.75
2004	27.50	23.80	97%	23.08	37.04	63.73	26.70	77.28
2005	38.60	47.74	83%	39.50	86.77	136.27	49.51	127.60
2006	15.26	42.99	98%	42.24	44.53	39.48	-4.65	52.84
Average	28.44	30.96	88%	27.37	47.55	68.93	21.46	77.3

Excludes load reduction in water discharged to Lake Okeechobee (3.54 mt in WY2006)

To assess achievement of the "greater than 85% load reduction" expectation, a one-tailed Student's t-test was used to compare the observed load reduction with an **85.1% reduction** of the Base Period mean. An 85.1% reduction in loads measured in the 1979-1988 Base Period would be approximately **89.0 metric tons/yr with a 90% confidence interval of ± 17.2 metric tons/yr**, as shown in **Figure 6**. Results from the t-test indicated that the mean load reduction from the EAA to the Refuge for WY2002-2006[8] (77.3 metric tons/yr) is not significantly different from an 85.1% reduction of the 10-year Base Period (89.0 metric tons/yr) at the 90% confidence level, and hence, the "greater than 85% load reduction" expectation was achieved. The detailed results of the t-test are shown in **Table 8**. A similar successful result was achieved when using the May-April Water Year for the Base Period (see **Appendix A**). This preliminary comparison is made for the 5-year period of WY2002-2006, even though the effective date of the 85% load reduction is December 31, 2006, and this assessment covering years prior to December 31, 2006, should be considered as demonstrative only.

[8] The effective date for the 85% load reduction from the EAA to the Refuge is December 31, 2006, so this assessment covering previous years should be considered as demonstrative only.

Figure 5. Estimated EAA Load Reduction to the Refuge (Water Years 2002 – 2006)



	2002	2003	2004	2005	2006
S-6 Diversion	18.53	13.49	23.08	39.50	42.24
S-5A BMP reduction	32.78	2.97	26.70	49.51	-4.65
STA reduction	37.54	23.30	27.50	38.60	15.26

Figure 6. Comparison of Anticipated Load Reductions From the EAA to the Refuge with WY2002-2006.

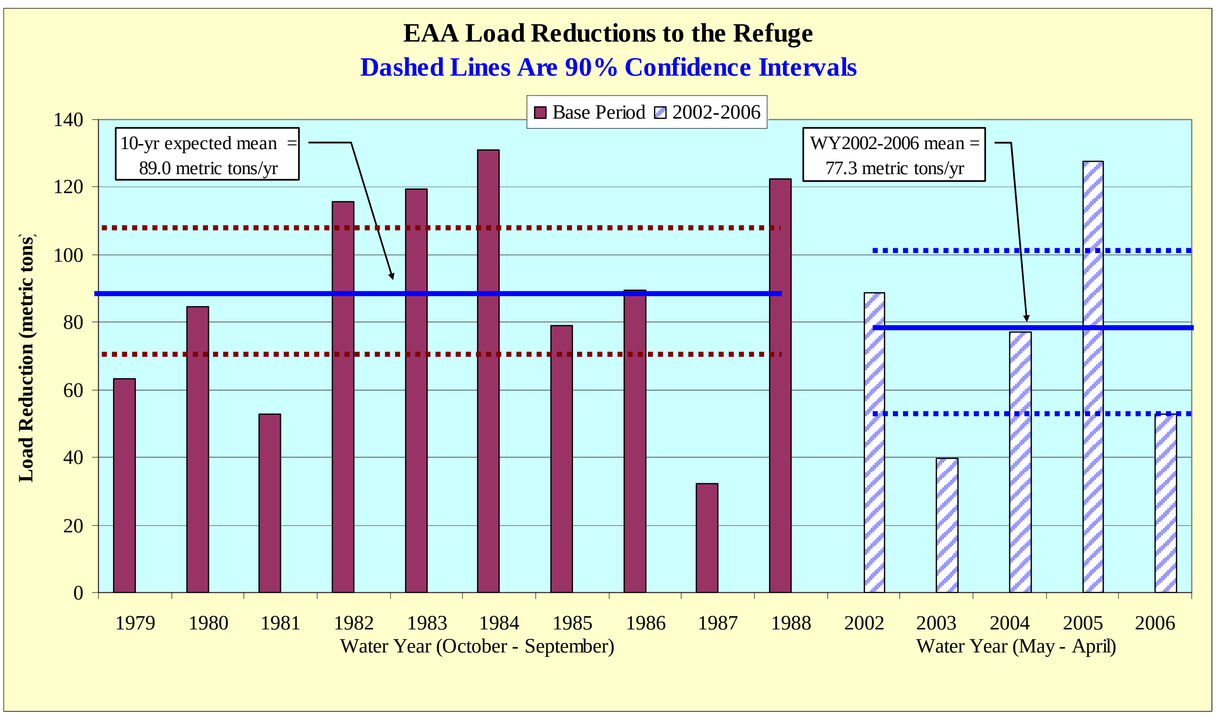


Table 8. Results of t-test Comparing 85.1% Reduction of Base Period Loads to WY2002-2006 (load reductions presented in metric tons/yr)

F-Test Two-Sample for Variances

	85.1% Reduction of Base Period	*2002-2006*
Mean	89.0	77.3
Variance	1,094	1168
Observations	10	5
df	9	4
F	0.937	
P(F<=f) one-tail	0.427	
F Critical one-tail	0.275	
P(F<=f) two-tail	0.853	

P(F<=f) two-tail > 0.1, so use equal variance t-test

t-Test: Two-Sample Assuming Equal Variances

	85.1% Reduction of Base Period	*2002-2006*
Mean	89.0	77.3
Variance	1,094	1,168
Observations	10	5
Pooled Variance	1,117	
Hypothesized Mean Difference	0	
df	13	
t Stat	0.6416	
P(T<=t) one-tail	0.2661	
t Critical one-tail	1.3502	
P(T<=t) two-tail	0.5323	
t Critical two-tail	1.7709	

P(T<=t) one-tail > 0.1, so hypothesis that difference in means is equal to 0 passes at 90% confidence level, and the difference in means is not significant

Although statistical tests based on the t-distribution are fairly robust to minor departures from normality, an assessment of the assumption that the underlying load reduction data are normally distributed was performed. A normal probability plot for both the Base Period expected load reductions (85.1%) and actual WY2002-2006 load reductions is presented in **Figure 7**. Using the method described in the Engineering Statistics Handbook of the National Institute for Standards and Technology (NIST 2007), the load reductions were plotted as a function of the corresponding normal order statistic medians which are defined as:

$$N_{(i)} = G(U_{(i)})$$

where U(i) are the uniform order statistic medians (defined below), and
G is the percent point function of the normal distribution.

The uniform order statistic medians are defined as:

$$m_{(i)} = 1 - m_{(n)} \text{ for } i = 1$$
$$m_{(i)} = (i - 0.3175)/(n + 0.365) \text{ for } i = 2, 3, ..., n-1$$
$$m_{(i)} = 0.5(1/n) \text{ for } i = n$$

The percent point function is the inverse of the cumulative distribution function (probability that the load reduction is less than or equal to some value). That is, given a probability (in this case the uniform order statistic median), the percent point function is the corresponding load reduction of the cumulative distribution function. The resulting calculations for both the Base Period and WY2002-2006 load reductions are presented in **Tables 9** and **10**.

Figure 7. Normal Probability Plot of Load Reductions (load reductions presented in metric tons/yr)

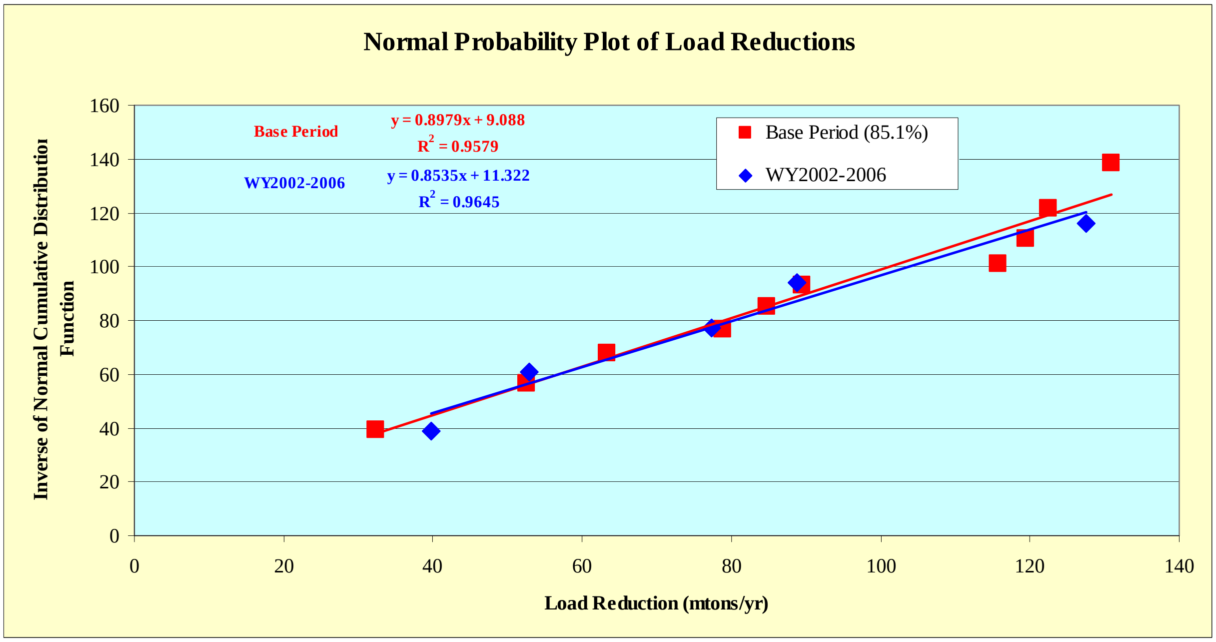


Table 9. Calculations Used in Assessing Normality of Base Period Load Reductions (load reductions in metric tons/yr)

Sorted Rank	Sorted 85.1% Load Reductions	Uniform Order Statistic Medians	Normal Percent Point Function
1	32.30	0.067	39.44
2	52.63	0.162	56.43
3	63.42	0.259	67.61
4	78.80	0.355	76.74
5	84.74	0.452	85.00
6	89.45	0.548	93.02
7	115.75	0.645	101.28
8	119.51	0.741	110.41
9	122.56	0.838	121.59
10	130.93	0.933	138.58

Table 10. Calculations Used in Assessing Normality of WY2002-2006 Load Reductions (load reductions in metric tons/yr)

Sorted Rank	Sorted WY2002-2006 Load Reductions	Uniform Order Statistic Medians	Normal Percent Point Function
1	39.75	0.129	38.68
2	52.84	0.314	60.67
3	77.28	0.500	77.27
4	88.85	0.686	93.86
5	127.60	0.871	115.85

Regression lines were fitted to the load reduction points and added to **Figure 7** as reference lines. The further the points vary from the regression line, the greater the indication of departures from normality. The correlation coefficient of the points on the normal probability plot were then compared to a table of critical values to provide a formal test of the hypothesis that the data come from a normal distribution (NIST 2007). For the Base Period, the correlation coefficient was 0.979, which was higher than the critical value of 0.917 for a sample size of 10 and a significance level of 0.05, indicating that we cannot reject the null hypothesis that the data came from a population with a normal distribution. For the WY2002-2006 load reductions, the correlation coefficient was 0.982, which was higher than the critical value of 0.879 for a sample size of 5 and a significance level of 0.05, indicating that we cannot reject the null hypothesis that the data came from a population with a normal distribution.

Perceived Weakness of Proposed Approach. The use of a Student's t-test can be criticized as a weak statistical test when comparing the means of two populations with small sample sizes and large variability[9]. However, those are the constraints of the situation at hand – comparing a long-term (i.e., 10-yr) average expectation against the short-term performance of regional phosphorus control programs in light of extremely variable meteorological and hydrologic conditions. This approach is considered more desirable than waiting until an equivalent 10 year period of data are available after the effective dates. As more annual performance data are generated over time, the sample size will increase, and the strength of the method will increase.

Outstanding TOC Issues. Regarding the issues raised at the May 25, 2004, TOC meeting:

1. clarification of "low-flow water supply deliveries" – this method looks at just loads "from the EAA" as indicated in the Settlement Agreement, so it is not necessary to track "low-flow water supply deliveries". The discussion of "low-flow water supply deliveries" in Appendix C was simply a description of how the 80%/85% expectations were achieved, and is not relevant to assessing loads "from the EAA".

2. clarification of "extreme hydrological events" – although this method looks at just loads "from the EAA" as indicated in the Settlement Agreement, it is still necessary to track "extreme hydrological events", as the effects of the hurricanes on WY2005-WY2006 performance indicates the influence of factors outside the control of the Parties can have. The May 2005 paper by Nearhoof et al. contains reasonable measures, including

    - STA bypasses resulting from extreme hydrological events shall not be combined with the STA outflows in calculating annual flow-weighted mean concentrations for use in testing compliance. Extreme hydrological events shall be defined as 7-day or 30-day flow volumes or rainfall depths that exceed the values experienced in basins tributary to an STA during the period of record used for design of that STA.

[9] To evaluate the lower bounds of load reductions that would pass this test, the estimated load reductions were rescaled to yield an average load reduction of 67.1 metric tons per year. Application of the t-test resulted in rejection of the null hypothesis that the calculated difference in the means is 0 at the 90% confidence level, i.e., the load reduction expectation would not be met.

- The District's operating philosophy is to avoid untreated bypass if possible, hence, bypass may not occur despite extreme hydrologic events. While this philosophy minimizes phosphorus loads to the Everglades, STA performance could suffer. To account for this, an additional assessment will be made if the above steps do not yield compliance. If the inflow volume or rainfall depth is greater than the corresponding baseline period for the 7-day, or 30-day durations, the District will determine the cumulative effect on the STA performance of this extreme hydrologic event.
- Performance impacts of extreme hydrologic events occurring in the previous water years, if relevant, will be considered by the District in addition to those extreme hydrologic events occurring in the current water year.

3. revision of the annual phosphorus limit (presently at 76 ppb) – this method is load-based and does not rely on a concentration limit.

4. recognition that applicability of the current TOC-adopted methodology is contingent on flows through the STAs being within the range contemplated in the design of STAs 1E, 1W, 2, 3/4, and 6 consistent with the amended Settlement Agreement) – As this method tracks actual load reductions from the EAA, there is no restriction on the use of this method.

5. Which 12-month period should be used for compliance? - This method uses the May – April Water Year, consistent with the EAA BMP Program, current State reporting requirements, and the State water quality Standard for Phosphorus for the Everglades.

6. When to consider "low-flow water supply deliveries" and "extreme hydrological events"? This method looks at just loads "from the EAA" as indicated in the Settlement Agreement, so it is not necessary to track "low-flow water supply deliveries". However, it is still necessary to track "extreme hydrological events", as the effects of the hurricanes on WY2005-WY2006 performance indicates the influence of factors outside the control of the Parties can have. See No. 2 above.

REFERENCES

Adorisio, C., C. Bedregal, J. Gomez, J. Madden, C. Miessau, D. Pescatore, P. Sievers, S. Van Horn, T. van Veen and J. Vega. 2007. Phosphorus Source Controls for the Basins Tributary to the Everglades Protection Area Chapter 4 in South Florida Environmental Report, South Florida Water Management District, March 1, 2007 (in press).

Florida Administrative Code, Rule 40E-63, Everglades Program, Rules of the South Florida Water Management District, January 2002.

Nearhoof, F., K. Weaver, G. Goforth and S. Xue. Test for Determining Achievement of 50 Part Per Billion Phosphorus Initial TBEL For Everglades Stormwater Treatment Areas, May 2005.

NIST 2007. SEMATECH e-Handbook of Statistical Methods, http://www.itl.nist.gov/div898/handbook/, February 2007.

SFWMD 1992. Surface Water Improvement and Management Plan for the Everglades, Appendices B and F, March 13, 1992.

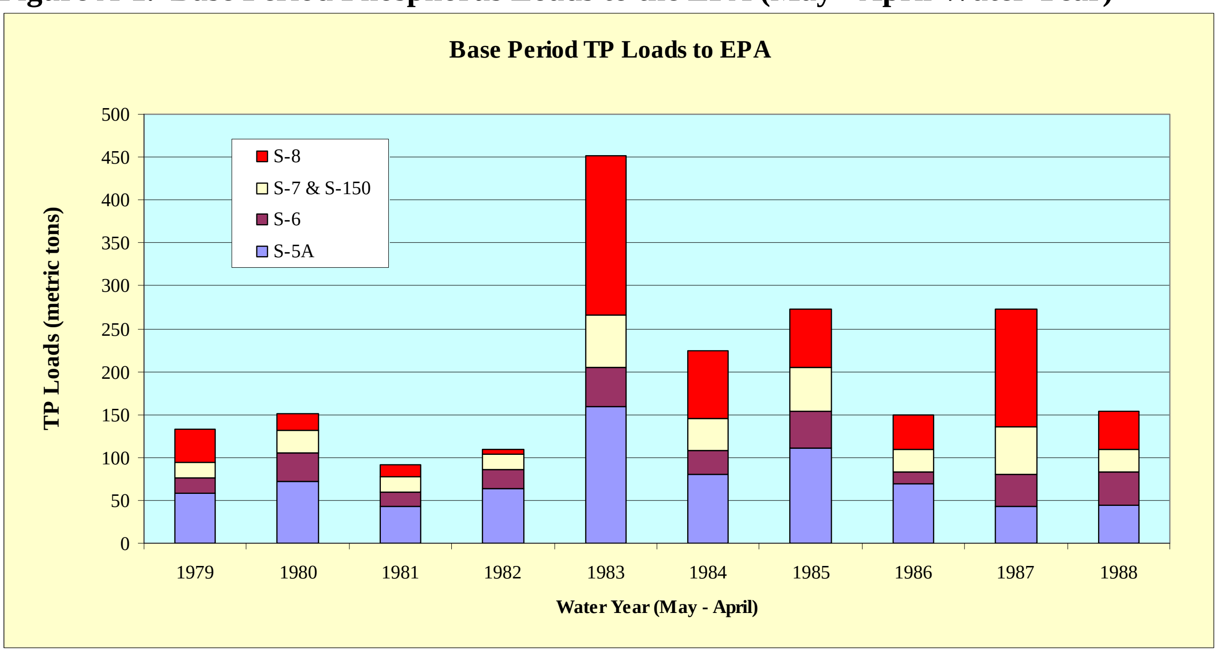
Appendix A. Load Reduction Assessment Based on a May – April Water Year

Beginning in 1992 with the development of the EAA BMP rule development, a May – April water year was applied to Everglades data to better coincide with the regional wet and dry seasons. Base Period loads to the EPA are presented in the May – April Water Year in **Table A-1** and **Figure A-1.**

Table A-1. Base Period Phosphorus Loads to the EPA (May - April Water Year)

May - April WY	TP Loads S-5A (mtons)	S-6 (mtons)	S-7 + S-150 (mtons)	S-8 (mtons)	Total Loads to EPA (mtons)	Total Loads to Refuge (mtons)	80% Reduction to EPA (mtons)	85% Reduction to Refuge (mtons)
1979	57.59	18.66	18.52	38.78	133.56	76.25	106.84	64.81
1980	72.59	32.82	25.93	19.38	150.72	105.41	120.58	89.60
1981	42.45	17.10	17.64	14.68	91.86	59.55	73.49	50.61
1982	63.43	22.21	17.74	6.67	110.05	85.64	88.04	72.79
1983	159.42	45.92	60.57	185.25	451.17	205.34	360.93	174.54
1984	80.35	28.17	36.62	79.65	224.79	108.52	179.83	92.24
1985	110.19	44.10	50.67	68.35	273.31	154.29	218.65	131.15
1986	68.98	14.35	25.53	40.86	149.72	83.33	119.77	70.83
1987	42.50	37.87	55.19	137.74	273.30	80.38	218.64	68.32
1988	44.82	38.16	25.78	45.14	153.90	82.98	123.12	70.53
Average	**742.33**	**299.36**	**334.18**	**636.50**	**201.2**	**104.2**	**161.0**	**88.5**

Figure A-1. Base Period Phosphorus Loads to the EPA (May - April Water Year)



Relative to average annual loads measured in May-April Water Years 1979 through 1988, an 80% reduction from the EAA to the EPA would be **approximately 161.0 metric tons/yr**. Relative to average annual loads measured in May-April Water Years 1979 through 1988, a "greater than 85% reduction" from the EAA to the Refuge would be **greater than 88.5 metric tons/yr**. For the purpose of this analysis, 85.1% is taken to meet the expectation of "greater than 85%"

Assessment of Load Reduction From the EAA to the EPA

The 80% load reduction expectation was achieved if the Base Period data are calculated using a May – April Water Year, in that the WY2002-2006 load reduction of 200.4 metric tons/yr is greater than the expected load reduction of 161.0 metric tons/yr.

Assessment of Load Reduction From the EAA to the Refuge

The "greater than 85% load reduction" expectation (i.e., 85.1%) was met if the Base Period data are calculated using a May – April Water Year, in that the means are not significantly different at the 90% confidence level, as demonstrated in Table A-2.

Table A-2. Results of t-test Using May-April Water Year (load reductions are in metric tons/yr)

F-Test Two-Sample for Variances

	85.1% Reduction of Base Period	*2002-2006*
Mean	88.6	77.3
Variance	1,395	1168
Observations	10	5
df	9	4
F	1.194	
P(F<=f) one-tail	0.465	
F Critical one-tail	5.999	
P(F<=f) two-tail	0.931	

P(F<=f) two-tail > 0.1, so use equal variance t-test

t-Test: Two-Sample Assuming Equal Variances

	85.1% Reduction of Base Period	*2002-2006*
Mean	88.6	77.3
Variance	1,395	1,168
Observations	10	5
Pooled Variance	1,325	
Hypothesized Mean Difference	0	
df	13	
t Stat	0.5709	
P(T<=t) one-tail	0.2889	
t Critical one-tail	1.3502	
P(T<=t) two-tail	0.5778	
t Critical two-tail	1.7709	

P(T<=t) one-tail > 0.1, so hypothesis that difference in means is equal to 0 passes at 90% confidence level, and the difference in means is not significant