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Methodology for Testing Compliance of the Everglades Protection Project with Phosphorus Load Reductions Required by the State/Federal Settlement Agreement

prepared for

U.S. Department of Interior

by

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Introduction

Technical representatives of the Federal Government and South Florida Water Management District met at Loxahatchee National Wildlife Refuge in June 1995 to discuss methods for testing compliance of the Everglades Protection Project prescribed by the 1994 Everglades Forever Act with phosphorus load reductions required by the 1991 State/Federal Settlement Agreement. A consensus was reached on basic assumptions and methodology. This report describes the structure and calibration of the proposed methodology. Refinements to account for expected year-to-year variability in performance and for extreme hydrologic conditions are also developed. Further refinements can be developed in response to comments provided by the Everglades Technical Oversight Committee, which will be responsible for implementing the test and for interpreting results.

Assumptions

The compliance test is designed to reflect requirements of the Settlement Agreement, while accounting for the expanded scope of the Everglades Protection Project. Basic assumptions are as follows:

1. The Settlement Agreement requires average load reductions of approximately 80% to the Water Conservation Areas (WCA's) and 85% to Loxahatchee National Wildlife Refuge (Refuge), relative to

loads which were discharged through the Everglades Agricultural Area (EAA) pump stations (S5A, S6, S7/S150, & S8) during the October 1978 -September 1988 base period.

2. The Settlement Agreement requires that flow reductions attributed to Best Management Practices (BMP's) in the EAA be offset (BMP makeup water). It is assumed that the required BMP makeup water will be routed to Stormwater Treatment Areas (STA's) for treatment before being discharged to the WCA's.

3. The Everglades Protection Project provides diversion and treatment of additional flows which were not included in the Settlement Agreement (C139, C51W, 298 Districts, Lake Regulatory). These additional flows will not be considered in testing compliance with the Settlement Agreement load-reduction requirements.

4. Technical aspects of the plan to implement the Settlement Agreement (STA water and phosphorus balances) are documented in Appendix F of the Everglades SWIM Plan.

Methodology

If the plans were identical and if the longterm-average loads from each STA could be directly measured, the following equation could be used to test compliance:

$$\text{Load Reduction} = 100\% \left(1 - \text{Future Load} / \text{Base Period Load} \right) \quad (1)$$

The Future Load would reflect outflows from the STA's (treated runoff + treated makeup water) and any bypass of untreated runoff around the STA's. The Base Period Load would reflect WCA inflows through the major EAA pump stations (S5A, S6, S7/S150, & S8). To be consistent with design calculations, bypasses for urban water supply (generally from Lake Okeechobee) would be excluded from the Future and Base Period Loads.

Equation(1) cannot be used directly to test compliance for the following reasons:

1. The Everglades Protection Project treats flows which were not considered in the Settlement Agreement. The formula must be modified to consider only loads treated by the Settlement Agreement.

2. Because of normal hydrologic and sampling variability, the load reduction measured in any year(s) may be greater than or less than the longterm-average load reduction required by the Settlement

Agreement. The formula must be modified to account for expected temporal variability in performance.

To account for differences in the treated flows, an equation of the following form is proposed:

$$\text{Load Reduction} = 100\% \left(1 - Q_f C_f / Q_b C_b \right) \quad (2)$$

where,

Q_f = Future average inflow to WCA's (or Refuge), from design calculations

= Treated Runoff + Treated Makeup Water + Bypassed Runoff

C_f = Future flow-weighted-mean inflow concentration (measured)

Q_b = Average inflow for the 1979-1988 base period, excluding bypasses for urban water supply

C_b = Flow-weighted-mean inflow concentration for base period

Values for Q_f, Q_b, and C_b are fixed at average values specified in design calculations for the Settlement Agreement STA configuration. In this way, calculated load reductions will only consider flows treated by the Settlement Agreement. Values for C_f will be derived from future monitoring of STA outflows and bypassed flows. The formula reflects longterm-average mass balances and load reductions using design flow values. A method to account for year-to-year variability is developed in a subsequent section.

Table 1 lists flow and phosphorus balances for the Settlement Agreement STA configuration, as documented in Appendix F of the Everglades SWIM Plan. These figures are used to calibrate the methodology. Because of refinements to the historical flow and load data sets which were developed during and after 1991, the figures differ slightly from those which were used earlier in developing the Settlement Agreement and later in developing the Everglades Protection Project. Calibration using alternative data sets would influence the calculated load reductions by less than 2%.

Formula for Refuge Load Reduction

To calculate load reductions for the Refuge, terms are defined as follows:

Q_f = S5A Treated Runoff + S5A Makeup Water + Bypassed Runoff
= 210.8 + 54.5 + 0.0 = 265.2 kac-ft/yr

Q_b = Average Refuge inflow for base period
S5A + S6 = 437.1 kac-ft/yr

C_b = Flow-weighted-mean inflow concentration for base period, combined S5A + S6 = 187.1 ppb

Substituting in the fixed quantities for Q_f, Q_b, and C_b, equation (2) reduces to:

$$\text{Refuge Load Reduction} = 100\% \left(1 - C_f / 308.3 \right) \quad (3)$$

In any future year, the flow-weighted-mean outflow concentration for inflows to the Refuge will be computed as follows:

$$C_f = \Sigma_i \, q_i \, c_i \, / \, \Sigma_i \, q_i \quad (4)$$

where,

Σ_i = sum over STA's 1E & 1W

q_i = measured annual outflow volume for STA i (kac-ft/yr)

c_i = measured annual flow-weighted-mean outflow conc. for STA i (ppb)

Any bypassed runoff (direct discharges to Refuge, excluding urban water supply) would be considered part of the STA outflows for the purpose of computing the Refuge inflow concentration.

The computed load reduction for the Refuge is a linear function of Refuge inflow concentration, as tabulated below:

C_f (ppb):	30	40	50	60	70
Load Reduction: (%)	90%	87%	84%	81%	77%

If the STA's produce exactly 50 ppb without bypass, the computed load reduction would be 84%. The required load reduction of approximately 85% corresponds to a longterm-average STA outflow concentration of approximately 46 ppb.

Formula for WCA Load Reduction

To calculate load reductions for the Water Conservation Areas, terms are defined as follows:

Q_f = Treated Runoff + BMP Makeup Water + Bypassed Runoff
= 680.3 + 176.1 + 0.0 = 856.4 kac-ft/yr

Q_b = Average WCA inflow for base period,
S5A + S6 + S7/S150 + S8 = 950.3 kac-ft/yr

C_b = Flow-weighted-mean inflow concentration for base period,
combined S5A, S6, S7/S150, S8 = 165.4 ppb

Substituting in the fixed quantities for Q_f, Q_b, and C_b, equation (2) reduces to:

$$\text{WCA Load Reduction} = 100\% \left(1 - C_f / 183.5 \right) \quad (5)$$

In any future year, the flow-weighted-mean inflow concentration to the WCA's will be computed from monitoring data as follows:

$$C_f = \Sigma_i \, q_i \, c_i \, / \, \Sigma_i \, q_i \quad (6)$$

where,

Σ_i = sum over STA's 1E, 1W, 2, 34, & 6

q_i = measured annual outflow volume for STA i (kac-ft/yr)

c_i = measured annual flow-weighted-mean outflow conc. for STA i (ppb)

Any bypassed runoff (direct discharges to WCA's, excluding urban water supply) would be considered part of the STA outflows for the purpose of computing the WCA inflow concentration. Note that STA-5 is excluded from these calculations because it will treat flows not considered in the Settlement Agreement.

The computed load reduction is a linear function of WCA inflow concentration, as tabulated below:

C_f (ppb):	30	40	50	60	70
Load Reduction: (%)	84%	78%	73%	67%	62%

If the STA's produce exactly 50 ppb without bypass, the computed load reduction

would be 73%. The required load reduction of approximately 80% corresponds to a longterm-average STA outflow concentration of approximately 37 ppb.

Achievability

The above compliance tests for load reduction (>80% for WCA's and >85% for Refuge) are equivalent tc compliance tests for STA outflow concentration (<37 and <46 ppb, respectively). These concentrations are below the 50 ppb target for STA's designed under the Everglades Protection Project. Given certain conservative assumptions in the design calculations, however, these levels appear to be achievable with the current STA designs. Conservative assumptions include:

1. The STA's have been designed assuming a BMP phosphorus load reduction of 25%. The Everglades Forever Act provides significant financial incentives for achieving load reductions ranging from 30% in 1993 to 45% in 2005. The observed average load reduction for the most recent four years of monitoring (1992-1995) was 36%. BMP's were only partially implemented during this period.

2. The STA's have been designed assuming a phosphorus settling rate of 10.2 meters/yr (Walker,1995a). Derived from WCA-2A peat data, the 90% confidence interval for this value is 8.9 to 11.6 meters/yr. This estimate is the average over a 26-year period which included droughts. Water-column data collected between 1976 and 1981, when the marsh was continuously flooded, indicate an average settling rate of 13.0 m/yr (90% confidence interval = 11.3 to 14.8 m/yr). Water-column data collected during intervals between 1976 and 1991 when water levels were within the STA design operating range indicate an average settling rate of 12.2 m/year (90% c.i. = 11.0 to 13.5 m/yr). Performance data from wetland treatment systems indicate an average settling rate of 12 m/yr (Kadlec, 1995). Recent monitoring data from WCA-2A transects and performance data from the Everglades Nutrient Removal Project (ENRP) during its first year of operation both indicate settling rates exceeding 15 m/yr (Walker, 1995b).

3. The STA's have been designed assuming a rainfall phosphorus concentration of 50 ppb. This is based upon the average historical concentration in bulk rainfall samples collected with little control over contamination. When samples containing insects and bird feces are excluded, SFWMD Rainfall phosphorus data from the ENP Research Center indicate a bulk concentration of 14 ppb (wet + dry deposition) (Walker,1989). Analysis of historical SFWMD atmospheric deposition data from other stations indicates a high correlation between wet or

dry deposition rates and visible evidence of contamination. When samples with more than a 20% probability of contamination are excluded, an average bulk concentration of 17 ppb is indicated (Walker, 1992). Recent data collected by the National Atmospheric Deposition Program using more elaborate techniques indicate average bulk concentrations ranging from 2 to 17 ppb at 5 Florida locations (Dolske, 1994).

Mass-balance calculations can be used to predict the effects of variations in the above parameters on the performance of the Everglades Protection Project and on the load reductions calculated using the above formulae. These calculations are similar to those used in the STA conceptual designs (Burns & McDonnell, 1994). Results for two sets of parameters are summarized below:

Parameter Set	Design	Alternative
Settling Rate (m/yr)	10.2	12.2
BMP Load Reduction (%)	25%	36%
Rainfall P. (ppb)	50	30
Predicted Load Reductions		
Refuge (eq. 3)	84%	89%
WCA's (eq. 5)	73%	81%

Based upon the above discussion, the alternative parameter set still contains conservative values. Based upon these results, the required load reductions of 85% for the Refuge and 80% for the WCA's appear to be achievable with the plan prescribed by the Everglades Forever Act.

Year-to-Year Variability

The compliance formulae reflect longterm-average mass balances. Because of normal hydrologic and sampling variability, the load reduction measured in any year(s) may be greater than or less than the longterm-average load reduction required by the Settlement Agreement. The formula must be modified to account for expected temporal variability in inflows and performance. A variety of parametric or non-parametric statistical methods could be used to estimate the probability of compliance with longterm objectives, given monitoring data from specific year(s).

A simple, coin-toss model follows that used in the EAA Regulatory Rule (40E-63) for testing compliance of phosphorus loads measured in three consecutive years with load-reduction targets. If the actual longterm-average load reduction equals the target and if data from consecutive years are serially independent, the probability of failing the test in consecutive years is as follows:

	B			
no. of consecutive failures	1	2	3	4
probability formula	p	p^2	p^3	p^4
probability (p = .500)	50%	25%	13%	6%
probability (p = .444)	44%	20%	9%	4%

The test requires an assumed value for p, the probability of failing the test in any year when the longterm-average load reduction equals the target. For a symmetrical distribution of annual values (p = .5), the model describes successive coin tosses. Since the compliance formulae are linear in concentration, the probability of failing the test in any year is equal to the probability that the annual flow-weighted-mean STA outflow concentration exceeds the longterm-average outflow concentration. Direct calibration of p would require longterm monitoring data from operating STA's. In the absence of such data, EAA runoff time series (reflecting temporal variation in STA inflows) provides a limited basis for calibration. Table 2 lists EAA annual runoff, load, and flow-weighted-mean concentration for the 9-year base period used in developing the EAA Regulatory Rule. The yearly flow-weighted-mean concentration in EAA runoff exceeded the longterm flow-weighted-mean (175 ppb) in 4 out of 9 years (p = .444).

For p values between .444 and .5, the probability of failing the annual test in three consecutive years would range from 9% to 13% and the probability of failing the test in four consecutive years would range from 4% to 6%. The p estimate could be refined as longterm STA monitoring data are accumulated. Failure in 3 or 4 consecutive years could be taken to indicate that compliance with longterm load-reduction requirements is unlikely. Adoption of a May-April water year for compliance testing is recommended to provide consistency with the EAA Regulatory Rule.

Extreme Hydrologic Conditions

Under both the Settlement Agreement and the Everglades Forever Act, STA configurations have been designed using flow and phosphorus load data for the 1979-1988 period. The STA's have been designed to treat runoff experienced during this period without bypassing any flows directly to the Water Conservation Areas and without requiring special flow allocations to maintain wet conditions in the STA's during drought periods. Consideration should be given to whether the compliance test should be modified to account for extreme hydrologic conditions which were not encountered during the base period.

Both wet and dry extremes are of potential concern. On the high end, extreme storm events may require hydraulic bypass over relatively short time scales (days to weeks). Prolonged wet periods may cause the assimilative capacity of the STA's to be exceeded, even if no hydraulic bypass is necessary. On the low end, extreme droughts not experienced in the base period may require allocation and delivery of additional flow to maintain wet conditions and prevent mobilization of phosphorus stored in STA soils. If additional flow is not available for maintaining STA water levels, STA performance may be negatively impacted.

EAA rainfall data (Table 2) provide a frame of reference for interpreting future hydrologic conditions in relation to the 1979-1988 base period. Potential screening criteria based upon yearly rainfall include the following:

1. In testing EAA compliance with the EAA Regulatory Rule (40E-63), years when the "adjusted rainfall" (Table 2) exceeds the maximum value in the base period (63.8 inches) are excluded. The adjusted rainfall statistic is directly correlated with EAA phosphorus load during the base period. This criterion may also be appropriate for excluding data from the load-reduction compliance tests. This would tend to exclude extremely wet years when the assimilative capacity of the STA's may be exceeded.

2. The lowest EAA annual rainfall experienced during the base period was 35.1 inches. If lower rainfall is encountered in the future, it is assumed that an effort will be made to allocate additional water, as needed to maintain wet conditions in the STA's. If additional water is not available during extreme drought years and if STA performance is hindered as a result, it may not be appropriate to use data from such years in testing compliance.

As an alternative, exclusion based upon hydrologic criteria may be optional (e.g., exclude extreme years only if they would otherwise fail the compliance test). Additional hydrologic criteria employing shorter time steps (daily vs. annual) may be appropriate to accommodate STA bypass flows resulting from extreme storm events. Bypass flows are not anticipated under base-period hydrologic conditions. Unless they result from extreme storm events not experienced in the base period, any bypass flows which occur in the future would be combined with the STA outflows in calculating annual flow-weighted-mean concentrations for use in compliance testing.

Summary

The following statements summarize the basic elements of the compliance test developed above:

1. Compliance will be tested in each water year (May-April) using monitoring data from STA outflows and bypass flows (untreated runoff discharged directly to the Refuge or WCA's). The calculations will exclude flows bypassed for urban water-supply purposes.

2. Compliance with the 85% load reduction requirement for Loxahatchee National Wildlife Refuge will be assumed unless the annual load reduction calculated according to equation (3) is less than 85% in three or more consecutive water years.

3. Compliance with the 80% load reduction requirement for the WCA's will be assumed unless the annual load reduction calculated according to equation (5) is less than 80% in three or more consecutive water years.

4. Compliance will not be tested in water years when the EAA adjusted rainfall, as defined in SFMWD Rule 40E-63, exceeds 63.8 inches. Compliance will not be tested in water years when the EAA rainfall is less then 35.1 inches, if sufficient supplemental flows are not available to maintain wet conditions in the STA's. If a year is excluded based upon these criteria, results from adjacent years will be treated as consecutive in testing compliance.

5. Unless they result from extreme storm events not experienced in the 1979-1988 base period, bypass flows (discharge of untreated runoff directly to the Refuge or WCA's) will be combined with the STA outflows in calculating annual flow-weighted-mean concentrations for use in compliance testing. Further analyses and discussions are required to define such events.

6. The compliance tests will be conducted and interpreted by the Technical Oversight Committee. The tests are designed to identify periods when it is unlikely that numerical load-reduction targets are being met. The tests do not account for the fact that targets themselves are described as "approximate" in the Settlement Agreement. Test results should therefore be subject to further interpretation by the TOC to determine whether performance is consistent with the Settlement Agreement.

References

Burns and McDonnell, Inc., "Everglades Protection Project, Conceptual Design", Report to South Florida Water Management District, February 1994.

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Walker, W.W., "Design Basis for Everglades Stormwater Treatment Areas", Water Resources Bulletin, Volume 31, No. 4, pp. 671-685, August 1995a.

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Table 1
STA Flow & Mass Balances for Settlement Agreement

Variable	Units	STA-1	STA-2	STA-3	STA-4	Total	Source - Appendix F
EAA Basin		5A	S6	S7/S150	S8		
Effective Area	acres	12185	4540	4705	11170	32600	Table 5, p. F-11
Base Period Total Flow	kac-ft/yr	312.8	155.7	275.6	311.3	1055.4	Table 3, p. F-5
Water Supply Bypass	kac-ft/yr	7.9	23.5	33.2	40.5	105.2	Table 3, p. F-5
Base Period Adjusted Inflow *	kac-ft/yr	305.0	132.1	242.4	270.8	950.3	Calculated
Land Converted to STA's	kac-ft/yr	31.6	4.9	8.9	26.8	72.2	Table 3, p. F-5
BMP Flow Reduction *	kac-ft/yr	54.5	25.1	47.0	49.5	176.1	Calculated
STA Inflow	kac-ft/yr	218.9	102.2	186.5	194.6	702.1	Table 3, p. F-5
Precipitation on STA's	kac-ft/yr	45.6	17.0	17.6	41.8	122.0	Calc. @ 1.14 m/yr
ET from STA's	kac-ft/yr	53.7	20.0	20.7	49.2	143.7	Calc. @ 1.34 m/yr
STA Outflow *	kac-ft/yr	210.8	99.1	183.3	187.1	680.3	Calculated
Base Period Total Load	mtons/yr	77.0	28.0	33.0	67.0	205.0	Table 4, p. F-6
Water Supply Bypass	mtons/yr	1.0	3.1	4.2	2.7	11.0	Table 4, p. F-6
Base Period Adjusted Load	mtons/yr	76.0	24.9	28.8	84.3	194.0	Calculated
Land Converted to STA's	mtons/yr	7.7	1.0	1.0	5.6	15.3	Table 4, p. F-5
BMP Load Reduction	mtons/yr	17.3	5.9	6.8	14.7	44.8	Calculated
STA Inflow	mtons/yr	51.0	18.0	21.0	44.0	134.0	Table 4, p. F-5
STA Outflow	mtons/yr	13.0	6.1	11.3	11.5	42.0	Calculated @ 50 ppb
Base Period Adj. Inflow Conc. *	ppb	202.0	152.6	96.2	192.4	165.4	Calculated

Data Source: Tables 3, 4 & 5 of Appendix F, Everglades SWIM Plan
STA Outflows do not include makeup water
* Values used in Calibrating Load Reduction Equations

Table 2
EAA Runoff and Rainfall Time Series

Water Year	Flow kac-ft/yr	Total P Load mtons	Flow-Wtd. Conc. ppb	Rainfall Total Inches	Rainfall CV	Rainfall Skewness	Adjusted Rainfall Inches
80	1162	167	117	53.5	0.599	1.413	43.5
81	550	85	126	35.1	0.729	0.306	37.2
82	781	234	243 *	46.7	0.941	1.817	51.8
83	1965	473	195 *	64.4	0.667	0.332	63.8
84	980	188	155	49.8	0.656	0.369	48.6
85	824	229	225 *	39.7	0.794	0.162	45.9
86	1058	197	151	51.2	0.686	0.487	50.7
87	1286	293	185 *	52.0	0.764	1.085	52.2
88	701	140	162	43.4	0.649	0.635	40.8
Mean	1034	223	175	48.4	0.721	0.734	48.3
Minimum	550	85	117	35.1	0.599	0.162	37.2
Maximum	1965	473	243	64.4	0.941	1.817	63.8

Water Years Ending April 30

* Yearly Flow-weighted-Mean Conc. > Longterm Flow-Weighted Mean Conc.

Adjusted Rainfall (EAA Regulatory Rule) = Total Rain x Exp [1.053 (CV - 0.7205) - 0.117 (Skew - 0.7339)]
CV & Skew computed from monthly rainfall totals

Methodology for Testing Compliance of the Everglades Protection Project with Phosphorus Load Reductions Required by the State/Federal Settlement Agreement

W. Walker for U.S. Dept. of Interior

September 27, 1995

--> Plan Comparisons

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Comparison of STA, Refuge, & WCA Inflows

	Everglades Protection Project			Settlement Agreement (a)		
	Flow kac-ft/yr	Load mtons/yr	Conc ppb	Flow kac-ft/yr	Load mtons/yr	Conc ppb
Inflows to STA's						
EAA	667	139.2	169	702	134.0	155
Western Basin (C139)	98	28.7	238	0	0.0	
L8	0	0.0		included with EAA (historical only)		
C51W	105	24.1	185	included with EAA (historical only)		
Lake Regulatory	258	22.7	71	included with EAA (historical only)		
298 Districts	25	6.1	199	0	0.0	
Total	1152	220.8	155	702	134.0	155
Inflows to Refuge						
Base Period	473	105.6	181	437	100.9	187
STA Inflows	268	67.1	203	219	51.0	189
STA Outflows	271	16.7	50	211	13.0	50
BMP Makeup (c)	52	3.2	50	54	3.4	50
Total Future	324	19.9	50	265	16.4	50
% Reduction (b)	31% 21	81% 78	72%	39%	84%	73%
% Reduction (c)	43%	84%	72%	52%	87%	73%
Inflows to WCA's						
Base Period	1058	231.5	177	950	194.0	165
STA Inflows	1152	220.8	155	702	134.0	155
STA Outflow	1163	72.0	50	680	42.0	50
BMP Makeup	172	10.6	50	176	10.9	50
Total Future	1335	82.6	50	856	52.9	50
% Reduction (b)	-26% 30	64% 633	72%	10%	73%	70%
% Reduction (c)	-10%	69%	72%	28%	78%	70%

a - Settlement Agreement As Represented in Appendix F of SWIM Plan
b,c - Reductions Calculated with (b) and without (c) BMP Makeup Water

Assumptions of Compliance Methodology

1 SA Requires Load Reductions Relative to 1979-1988: from EAA
~85% for Refuge
~80% for Water Conservation Areas

2 SA Requires That Flow Reductions Resulting From BMP's Be Offset (BMP Makeup Water): - Flows ok.

a Makeup Water Will be Routed to STA's for Treatment Before Being Discharged to the WCA's. - NOT in conceptual design; in fact STAs were not sized w/ BMP water. Performance of STAs not based on BMP water

b Flows & Loads Associated with Makeup Water Will Be Considered in Testing Compliance. NO ← DEP & District disagree.

3 EPP Provides Diversion and Treatment of Additional Flows Not Included in SA (C139, C51W, 298 Districts, Lake Reg.) These Flows Will Not Be Considered in Testing Compliance.

4 Flows & Loads Bypassed for Urban Water Supply Will Not Be Considered in Testing Compliance.

5 Untreated Discharges to WCA's (STA Bypass) Will Be Considered in Testing Compliance Unless They Result from Hydrologic Conditions ~~Not~~ in excess of that Experienced in 1979-1988. } Storm Q > Historic Storm Q; $Q_{storm} > Q_{design}$ available capacity of STA

6 SA Technical Aspects Are Documented in Appendix F of the Everglades SWIM Plan.

Derivation of Compliance Equation for Load Reduction

$$\text{Load Reduction} = 1 - \frac{\text{Future Load}}{\text{Base Load}}$$

NOT A REAL NUMBER.

$$\text{Load} = \text{Flow} \times \text{Concentration}$$

$$\text{Load Reduction} = 1 - \frac{\text{Future Flow} \times \text{Future Conc}}{\text{Base Flow} \times \text{Base Conc}}$$

Evaluation of Terms

Base Flow	Fixed at Average Value Used in STA Design Calculations From Historical Flow Data, 1979-1988
Base Conc	Fixed at Average Value Specified in STA Design Calculations From Historical Flow & Concentration Data, 1979-1988
Future Flow	HELLO! Fixed at Average Value Predicted in STA Design Calculations Average for 1979-1988 Hydrologic Conditions
Future Conc	Future Measured Flow-Weighted-Mean Concentration STA Outflows (Including Makeup Water) STA Bypass Flows (Untreated Runoff)

- Exclude flows not treated - S.A.

Load Reduction Formula For Refuge

Calibration (from SWIM Plan, Appendix F)

Base Period Flow =	437.1	kac-ft/yr
Base Period Conc =	187.1	ppb
Future Flow =	265.2	kac-ft/yr

From App. F + 5A make-up water

$$\text{Load Reduction} = 1 - \frac{265.2 \times \text{Future Conc}}{437.1 \times 187.1}$$

$$\text{Load Reduction} = 1 - \frac{\text{Future Conc}}{308.3}$$

Future Conc = Measured Flow-Weighted-Mean Concentration
Outflows from STA-1E & STA-1W
Bypassed (Untreated) Runoff

Future Conc.	Load Reduction	
20	94 %	
25	92 %	
30	90 %	
35	89 %	
40	87 %	
45	85 %	
46	**85 %**	**<---- SA Requirement**
50	84 %	**Longterm Average**
55	82 %	
60	81 %	
65	79 %	
70	77 %	

Load Reduction Formula For WCA's

Calibration (from SWIM Plan, Appendix F)

Base Period Flow =	950.3	kac-ft/yr
Base Period Conc =	165.4	ppb
Future Flow =	856.4	kac-ft/yr

$$\text{Load Reduction} = 1 - \frac{856.4 \times \text{Future Conc}}{950.3 \times 165.4}$$

$$\text{Load Reduction} = 1 - \frac{\text{Future Conc}}{183.5}$$

Future Conc = Measured Flow-Weighted-Mean Concentration
Outflows from STAs 1E, 1W, 2, 34, 6
Bypassed (Untreated) Runoff

Future Conc.	Load Reduction	
20	89 %	
25	86 %	
30	84 %	
35	81 %	
37	**80 %**	**<---- SA Requirement Longterm Average**
40	78 %	
45	75 %	
50	73 %	
55	70 %	
60	67 %	
65	65 %	
70	62 %	

Achievability

Longterm-Average STA Outflow Concs. Required for Compliance:

	Load Reduction	STA Outflow Concentration
Refuge	85%	46 ppb
WCA's	80%	37 ppb

WHOA!

Load reductions were not considered in Technical Mediation

Required Concs < 50 ppb STA Design Basis

Conservative Aspects of STA Design Calculations:

--> BMP Load Reduction = 25%

EPP Targets 30% to 45%
Measured Reduction 1992-1995 = 36%
BMP's Not Fully Implemented

ADJUSTED FOR HYDROLOGIC VARIABILITY

--> P Settling Rate in STA's = 10.2 m/yr

Based upon WCA-2A Peat
Influenced by Drought (Not Expected in STA's)
Uncertainty in Peat Estimate 8.9 - 11.6 m/yr
WCA-2A Water Column (Wet Only) 11.0 - 13.5 m/yr
WCA-2A WC 1994-1995 > 15 m/yr
ENR First Year > 15 m/yr
Treatment Wetland Avg ~ 12 m/yr

[redacted] stabilization period to be considered

--> Rainfall Phosphorus Concentration = 50 ppb

Based Upon Bulk Rainfall Samples
Not Controlled for Contamination
SFWMD ENR Research Center ~ 14 ppb
SFWMD Samples < 20% Contamination Prob. ~ 17 ppb
Recent NADP Florida Data < 17 ppb

Everglades Protection Project

WCA Phosphorus Load Reductions (%)
Settlement Agreement Requirement ~ 80 %

BMP Load Reduction %

P Settling Rate (m/yr)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0%	19	28	36	42	48	54	59	63	67	70	73	76	78	80	82	84	85	87	88
5%	22	31	38	45	50	56	60	64	68	71	74	77	79	81	83	84	86	87	89
10%	26	34	41	47	52	57	62	66	69	72	75	78	80	82	83	85	87	88	89
15%	29	36	43	49	54	59	63	67	70	73	76	78	81	82	84	86	87	88	89
20%	32	39	46	51	56	61	65	69	72	75	77	79	81	83	85	86	88	89	90
25%	35	42	48	54	58	63	67	70	73	76	78	80	82	84	85	87	88	89	90
30%	38	45	51	56	60	65	68	71	74	77	79	81	83	85	86	87	89	90	91
35%	41	48	53	58	62	66	70	73	76	78	80	82	84	85	87	88	89	90	91
40%	45	50	56	60	64	68	71	74	77	79	81	83	85	86	88	89	90	91	92
45%	48	53	58	63	66	70	73	76	78	80	82	84	86	87	88	89	90	91	92
50%	51	56	61	65	68	72	75	77	79	81	83	85	86	88	89	90	91	92	92
55%	54	59	63	67	70	73	76	79	81	83	84	86	87	88	90	90	91	92	93
60%	57	62	66	69	72	75	78	80	82	84	85	87	88	89	90	91	92	93	93
65%	60	65	68	72	74	77	79	81	83	85	86	88	89	90	91	92	92	93	94
70%	64	67	71	74	76	79	81	83	85	86	87	89	90	91	92	92	93	94	94

STA Outflow Concentration (ppb)

BMP Load Reduction %

P Settling Rate (m/yr)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0%	148	132	118	106	95	85	76	68	61	55	50	45	40	36	33	30	27	24	22
5%	142	127	114	102	91	82	73	66	59	53	48	43	39	35	32	28	26	23	21
10%	136	122	109	98	87	78	70	63	57	51	46	41	37	34	30	27	25	22	20
15%	131	117	104	93	84	75	67	60	54	49	44	40	36	32	29	26	24	22	19
20%	125	112	100	89	80	72	64	58	52	47	42	38	34	31	28	25	23	21	19
25%	119	106	95	85	76	68	61	55	50	45	40	36	33	29	27	24	22	20	18
30%	113	101	91	81	73	65	58	53	47	42	38	34	31	28	25	23	21	19	17
35%	107	96	86	77	69	62	56	50	45	40	36	33	30	27	24	22	20	18	16
40%	102	91	81	73	65	59	53	47	43	38	34	31	28	25	23	21	19	17	15
45%	96	86	77	69	62	55	50	45	40	36	33	29	27	24	22	20	18	16	15
50%	90	81	72	65	58	52	47	42	38	34	31	28	25	23	20	19	17	15	14
55%	84	75	67	60	54	49	44	39	35	32	29	26	24	21	19	17	16	14	13
60%	78	70	63	56	51	45	41	37	33	30	27	24	22	20	18	16	15	13	12
65%	73	65	58	52	47	42	38	34	31	28	25	23	20	19	17	15	14	13	11
70%	67	60	54	48	43	39	35	32	28	26	23	21	19	17	16	14	13	12	11

Rainfall P Conc = 30 ppb

Everglades Protection Project

Refuge Phosphorus Load Reductions (%)
Settlement Agreement Requirement ~ 85 %

BMP Load Reduction %

P Settling Rate (m/yr)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0%	38	47	54	60	65	70	74	77	80	83	85	87	89	90	92	93	94	94	95
5%	41	49	56	62	67	71	75	78	81	84	86	88	89	91	92	93	94	95	95
10%	43	51	57	63	68	72	76	79	82	84	86	88	90	91	92	93	94	95	95
15%	45	53	59	64	69	73	77	80	83	85	87	89	90	91	92	93	94	95	96
20%	48	55	61	66	71	74	78	81	83	86	87	89	90	92	93	94	94	95	96
25%	50	57	62	67	72	76	79	82	84	86	88	90	91	92	93	94	95	95	96
30%	52	59	64	69	73	77	80	82	85	87	88	90	91	92	93	94	95	96	96
35%	55	61	66	70	74	78	81	83	85	87	89	90	92	93	94	94	95	96	96
40%	57	63	68	72	76	79	82	84	86	88	90	91	92	93	94	95	95	96	96
45%	59	65	69	73	77	80	83	85	87	89	90	91	92	93	94	95	96	96	97
50%	62	67	71	75	78	81	84	86	88	89	91	92	93	94	95	95	96	96	97
55%	64	69	73	76	80	82	85	87	88	90	91	92	93	94	95	95	96	96	97
60%	66	71	75	78	81	83	85	87	89	90	92	93	94	94	95	96	96	97	97
65%	69	73	76	79	82	84	86	88	90	91	92	93	94	95	95	96	96	97	97
70%	71	75	78	81	83	86	87	89	90	92	93	94	94	95	96	96	97	97	97

STA Outflow Concentration (ppb)

BMP Load Reduction %

P Settling Rate (m/yr)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0%	190	165	142	123	107	92	80	69	60	52	45	39	34	30	26	23	20	17	15
5%	183	158	137	119	103	89	77	67	58	50	44	38	33	29	25	22	19	17	14
10%	176	152	132	114	99	86	74	64	56	48	42	37	32	28	24	21	18	16	14
15%	169	146	126	109	95	82	71	62	54	47	40	35	31	27	23	20	18	15	14
20%	161	140	121	105	91	79	68	59	51	45	39	34	29	26	22	19	17	15	13
25%	154	134	116	100	87	75	65	57	49	43	37	32	28	25	21	19	16	14	13
30%	147	127	110	96	83	72	62	54	47	41	36	31	27	23	21	18	16	14	12
35%	140	121	105	91	79	68	59	52	45	39	34	30	26	22	20	17	15	13	12
40%	133	115	100	86	75	65	57	49	43	37	32	28	25	21	19	16	14	13	11
45%	125	109	94	82	71	62	54	47	40	35	31	27	23	20	18	16	14	12	11
50%	118	102	89	77	67	58	51	44	38	33	29	25	22	19	17	15	13	11	10
55%	111	96	84	73	63	55	48	41	36	31	27	24	21	18	16	14	12	11	10
60%	104	90	78	68	59	51	45	39	34	30	26	23	20	17	15	13	12	10	9
65%	97	84	73	63	55	48	42	36	32	28	24	21	19	16	14	13	11	10	9
70%	89	78	68	59	51	45	39	34	30	26	23	20	17	15	13	12	10	9	8

Rainfall P Conc = 30 ppb

STA Design & Construction Issues

1 STA Area for Treating Makeup Water Was Not Allocated by SA or EPP. Makeup Water Loads (@ 70 ppb) ~8% of Design Loads for (EPP STA's 1W, 1E, 2, 34, & 6).

2 Both the SA & EPP were designed to treat EAA Runoff Discharged to WCA's in 1979-1988. As a Result of the Interim Action Plan, the Percentage of EAA Runoff Discharged to the WCA's (vs. Lake) Has Increased from an Average of 86% in Base Period to >96% in Last 5 Years. STA Area for Treating IAP Diversions Was Not Allocated by the SA or EPP. IAP loads ~12% of Design Loads.

3 The STA Design Basis Requires Sheet Flow (~ WCA-2A). Potential Influences of Short-Circuiting and Topographic Variations Have Not Been Adequately Addressed in the STA General Designs. This Will Decrease Effective Areas and Reduce Treatment Efficiencies.

Potential Influences on STA Performance

Factor	STA Outflow Conc	WCA Load Reduction
Makeup Water Loads	+4 ppb	-2%
IAP Loads	+6 ppb	-3%
Hydraulic Inefficiencies (Kadlec)	+8 to +15 ppb	-4 to -7 %
Total	+18 to +25 pp	-9 to -12%

68-75 ppb

Year-to-Year Variability

Load Reductions Required by Settlement Agreement:

a Longterm-Average (e.g. 10-yr)

b "Approximate" 80 % +/- (SOMETHING)

Future Reductions Measured on a Yearly Basis (May-April)

Compliance Test to Account for Expected Year-to-Year Variability

Ra = Actual Longterm Average Load Reduction

Ry = Yearly Average Load Reduction

p = Probability That Ry < Ra in Any Year
- 0.5 for symmetrical distribution of annual values
- 0.444 for EAA runoff time series

Probability of Failing Test in n Consecutive Years if Ra = Target:

n	p = 0.5	p = 0.444
1	50%	44%
2	25%	20%
3	13%	9%
4	6%	4%

Conclusions:

-> Compliance Unlikely if Failure Occurs in 3 or 4 Consecutive Years

-> Test Does Not Account for "Approximate"

Extreme Hydrologic Conditions

STA's Designed to Handle 1979-1988 Hydrology

"Extreme" = Conditions Not Encountered in 1979-1988

Potential Impacts of Extreme Conditions:

1 Extreme Wet Periods May Exceed STA Hydraulic Capacity, Causing Bypass of Untreated Runoff to WCA's

2 Extreme Wet Years May Exceed STA Assimilative Capacity

3 Extreme Dry Years May Hinder Performance, If Additional Flows Are Not Available to Maintain STA Water Levels.

Possible Adjustments to Compliance Test:

1 Bypassed Flows Resulting from Extreme Wet Periods Will Not Be Considered in Calculating WCA or Refuge Inflow Concentrations. Otherwise, Bypassed Flows Will Be Considered, Along Wlth STA Outflows.

2 If EAA Adjusted Annual Rainfall Exceeds 63.8 Inches (Maximum In Base Period), Year Will Not Be Not Counted in Compliance Test.

3 If EAA Total Annual Rainfall Is Less Than 35.1 Inches (Minimum In Base Period), and Additional Flows are Not Available to Maintain STA Water Levels, Year Will Not Be Counted in Compliance Test.

4 If a Year is Excluded Based Upon 2 or 3, Adjacent Years Will Be Considered Consecutive for Testing Compliance.

5 Exclude Years Based Upon 2 or 3 Only If The Yearly Load Reduction is < 80% for the WCA's or < 85% for the Refuge.