Development of a Methodology to Assess Standards Violations in the Everglades Utilizing Secondary Data Sources

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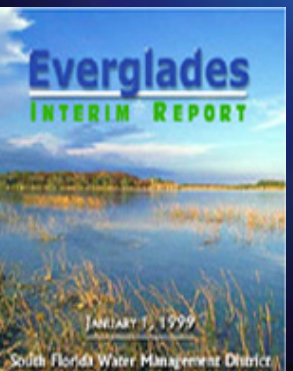
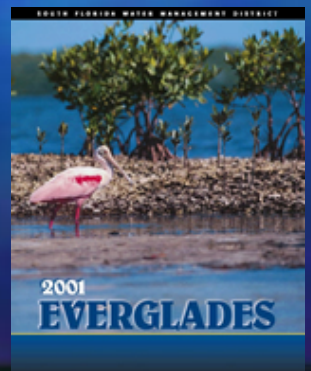
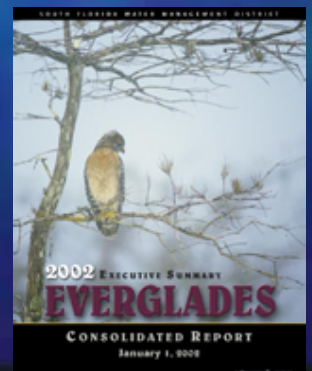
Everglades Reports

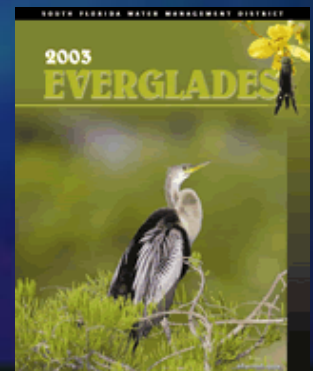
- The Everglades Forever Act (EFA) (Section 373.4592(4)(d) Florida Statutes) directed the South Florida Water Management District and Florida Department of Environmental Protection to issue an annual peer-reviewed report that summarizes all data and findings from the research and monitoring programs in the Everglades

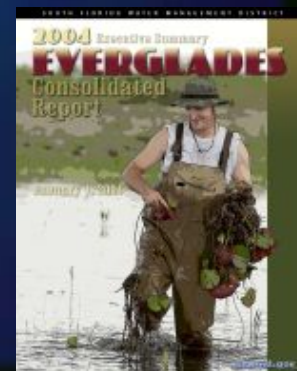
http://www.sfwmd.gov/org/ema/everglades/









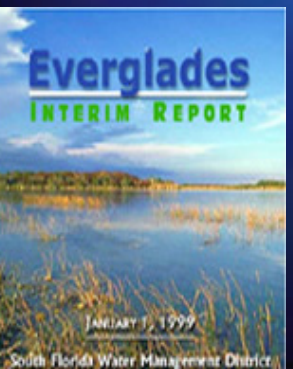


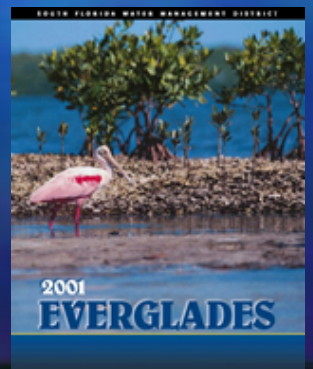
Existing Monitoring and Research Programs

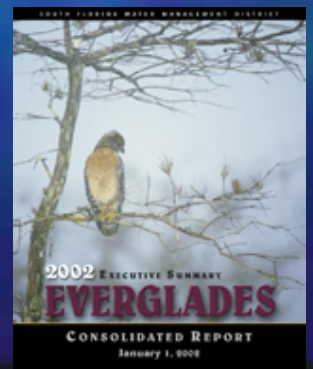
- Phosphorus criterion development
- Evaluation of existing state water quality standards applicable to the Everglades
- Ecological and hydrological needs of the Everglades
- Phosphorus reduction technologies
  - Best Management Practices
  - Storm Water Treatment Areas (Constructed wetlands)
- Permit required monitoring

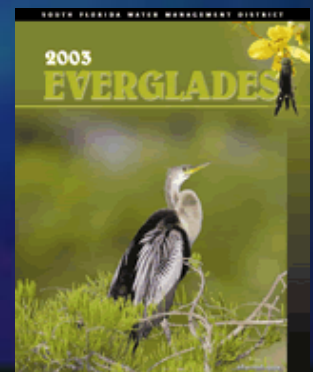
Reporting Requirements

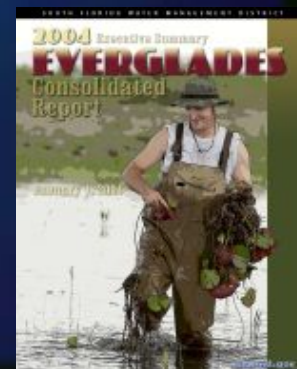
- The report shall identify water quality parameters, in addition to phosphorus, which exceed state water quality standards or are causing or contributing to adverse impacts in the Everglades Protection Area.











Water Quality Chapter Purpose and Objective

- The water quality chapter provides an assessment of water quality constituents exceeding water quality standards or causing or contributing to adverse impacts in the Everglades Protection Area (EPA).
- More specifically, the the primary purpose is to provide an overview of the status of surface water quality, relative to Class III standards, in the Everglades during the previous water year (May 1 through April 30).
- Summarize areas and times where water quality standards are not being met and indicate trends in excursions over space and time.

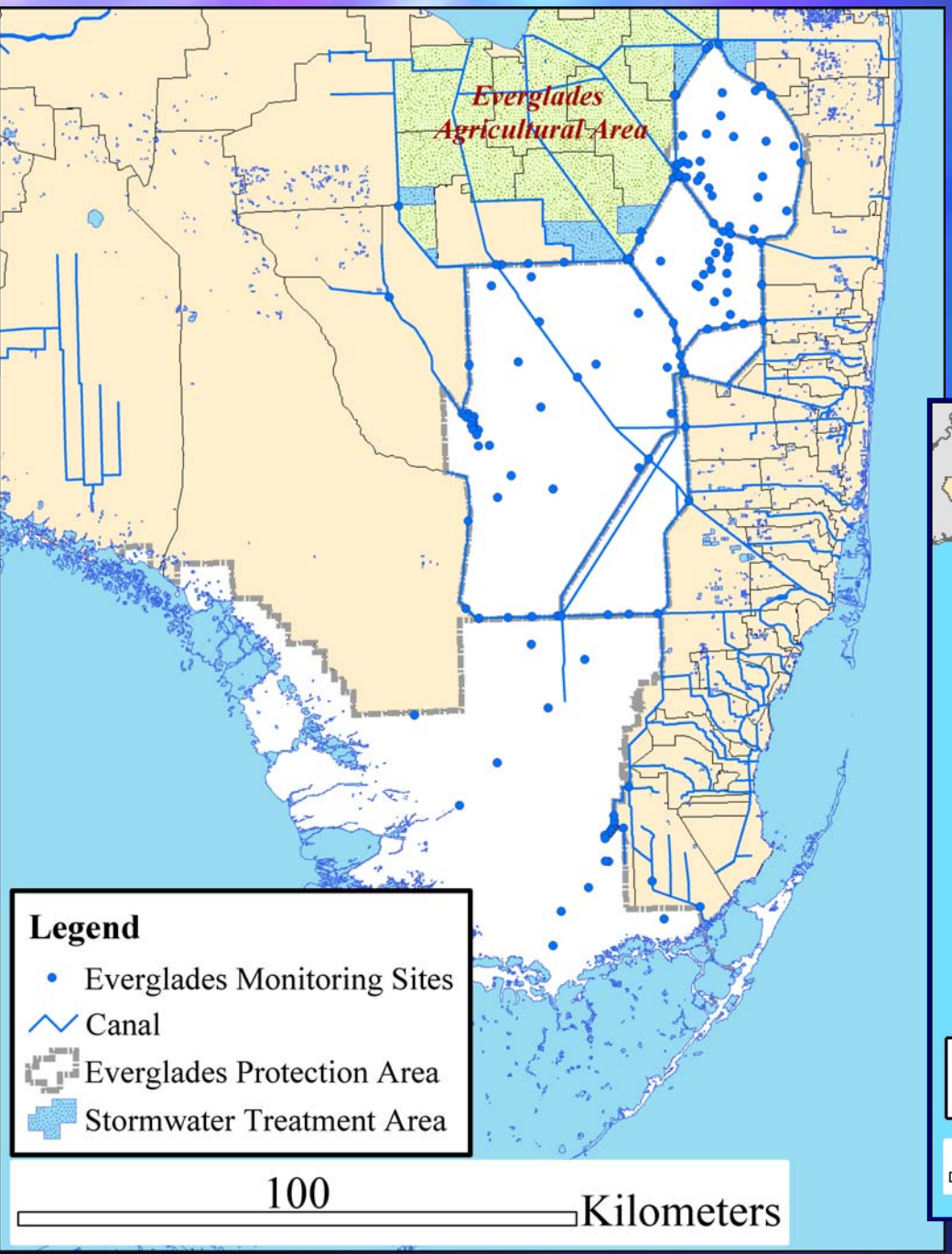
Data Sources

- There is no uniquely designed and operating Everglades monitoring program to measure compliance with ambient water quality standards
- Two SFWMD Databases
  - DBYDRO-primary water quality and hydrologic data repository
  - Everglades Systems Research Division Database
- Eleven monitoring projects or programs
  - Monthly ambient monitoring
  - Discharge (inflow and outflow)-biweekly, when flowing, and monthly otherwise
  - Research monitoring - typically monthly

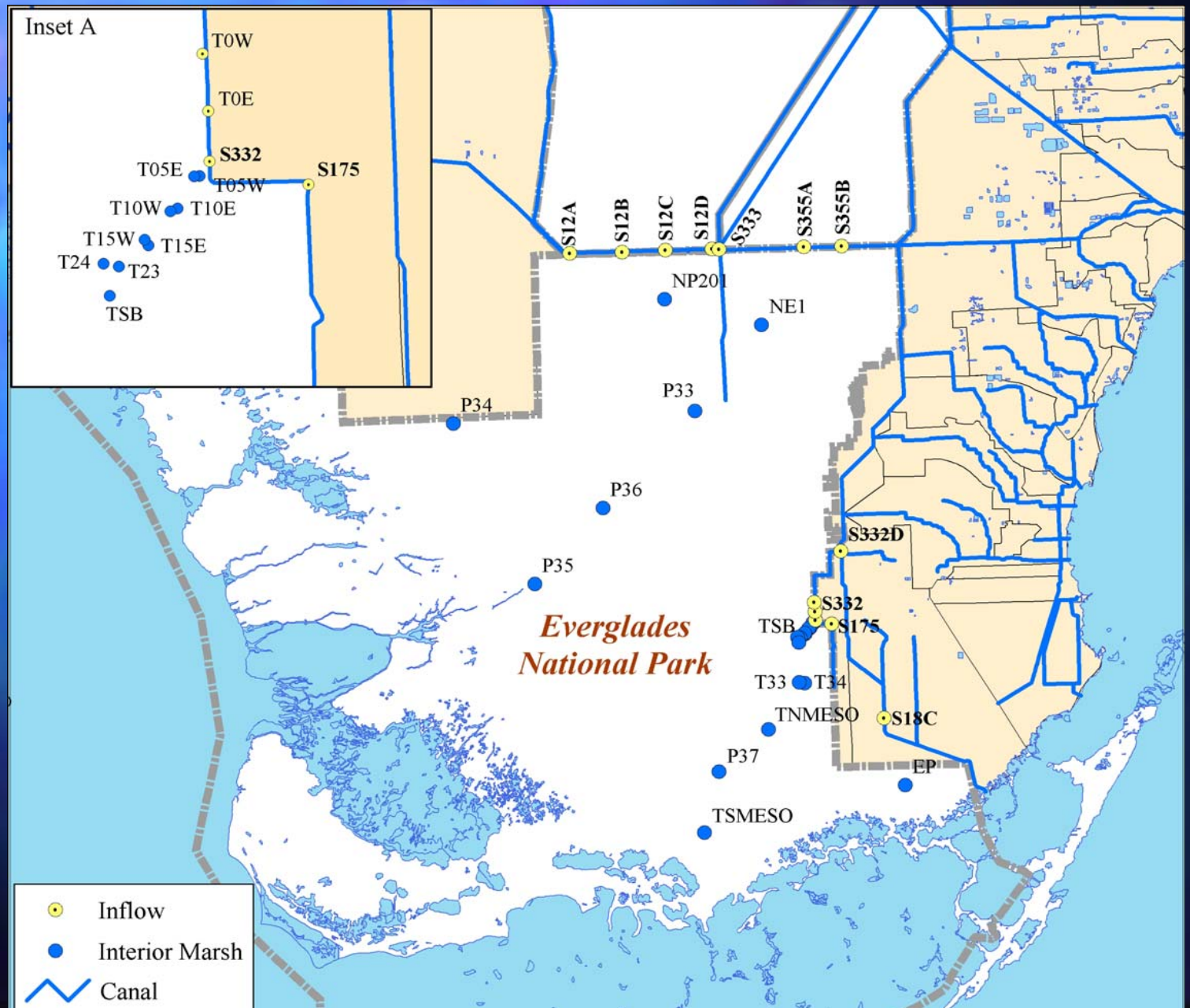
Data Sources Continued

- The water quality analysis methods were designed, in a scientifically sound manner, to use data collected for other purposes (secondary data sources or found data) to perform an assessment of standards violations (Excursion Analysis)

Everglades Water Quality Monitoring



Example Monitoring Sites at a Region Scale



Excursion Analysis Protocol

- An excursion is recorded when a reported value that is above the method detection limit exceeds the applicable numeric criteria (Chapter 62-302.530, Florida Administrate Code)
- The primary objective of the protocol is to provide a synoptic review of water quality standards compliance on a regional scale
- Used to trigger further analysis
- Serves as water quality “report card” to public and policy makers

Excursion Analysis Protocol (1999-2002)

- Prior to the 2003 Everglades Consolidated Report, the Everglades Reports utilized a raw-score approach to rank and categorize the severity of excursions from state water quality standards
- Using this raw-score method, a variable was classified as a "concern" when more than 5 percent of the measurements exceeded the applicable numeric standards

Excursion Categories for Water Quality Constituents in the Everglades (1999-2002)

Excursion Category	Conventional Constituents*	Pesticides
Concern	> 5% Excursions	Class III criterion and/or toxicity levels exceeded
Potential Concern	≤ 5% Excursions	> MDL
No Concern	No Excursions	≤ MDL

*Excludes pesticides, human health based criteria, and nutrients

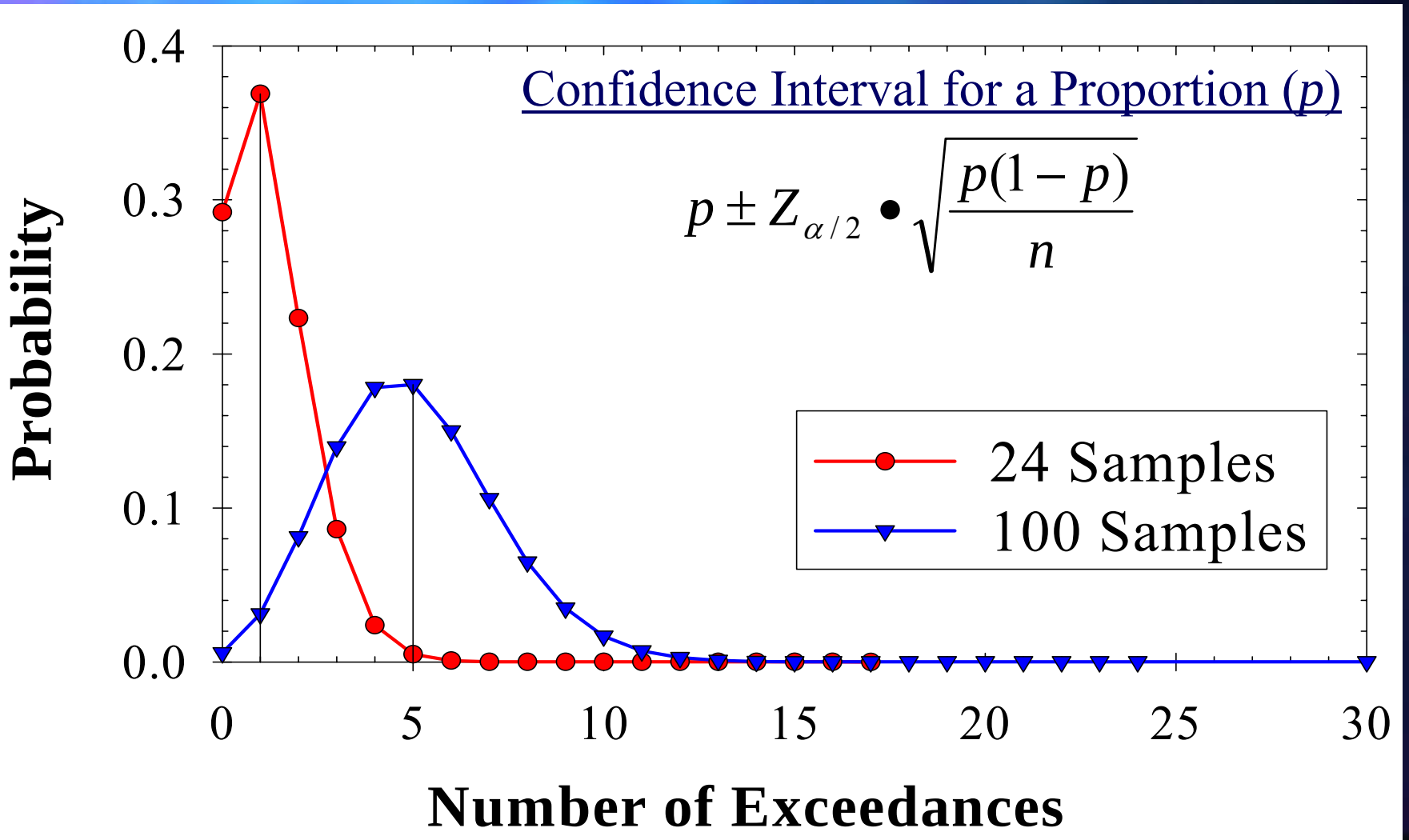
Example Excursion Results
Water Year 2001 Results (2002 Report)
(Variables classified as "No Concern" are not included)

Region	Class	Parameter	Class III Criteria	Excursion	
				Category	%
WCA2	Inflow	Conductivity (µmhos/cm)	≤1,275	PC	2.7
		DO (mg/L)	≥5	C	64.9
		Un-ionized NH_4 (mg/L)	≤0.02	PC	1.8
	Interior	Conductivity (µmhos/cm)	≤1,275	PC	4.8
		DO (mg/L)	≥5	C	82.8
		Un-ionized NH_4 (mg/L)	≤0.02	PC	1.7
	Outflow	DO (mg/L)	≥5	C	49.2
		Un-ionized NH_4 (mg/L)	≤0.02	PC	1.6
WCA3	Inflow	Conductivity (µmhos/cm)	≤1,275	PC	0.8
		DO (mg/L)	≥5	C	61.6
		Turbidity (NTU)	≤29	PC	0.7
		Un-ionized NH_4 (mg/L)	≤0.02	PC	2.5
	Interior	DO (mg/L)	≥5	C	78.4
		Turbidity (NTU)	≤29	PC	1.4
	Outflow	DO (mg/L)	≥5	C	81.4

Limitation of the Raw Score Approach

- Attempting to assess whether the **true** exceedance frequency of a variable exceeds a predetermined threshold (5%)
- Since the **true** exceedance frequency cannot be measured, it must be estimated from a set of samples (*i.e.*, a subset of the entire population) which introduces statistical uncertainty
- The degree of uncertainty in the estimate depends on the sample size (*i.e.*, smaller sizes are associated with greater uncertainty)
- The raw score approach does not consider this uncertainty

Probability of recording a given number of water quality exceedances if the true exceedance frequency is 5%

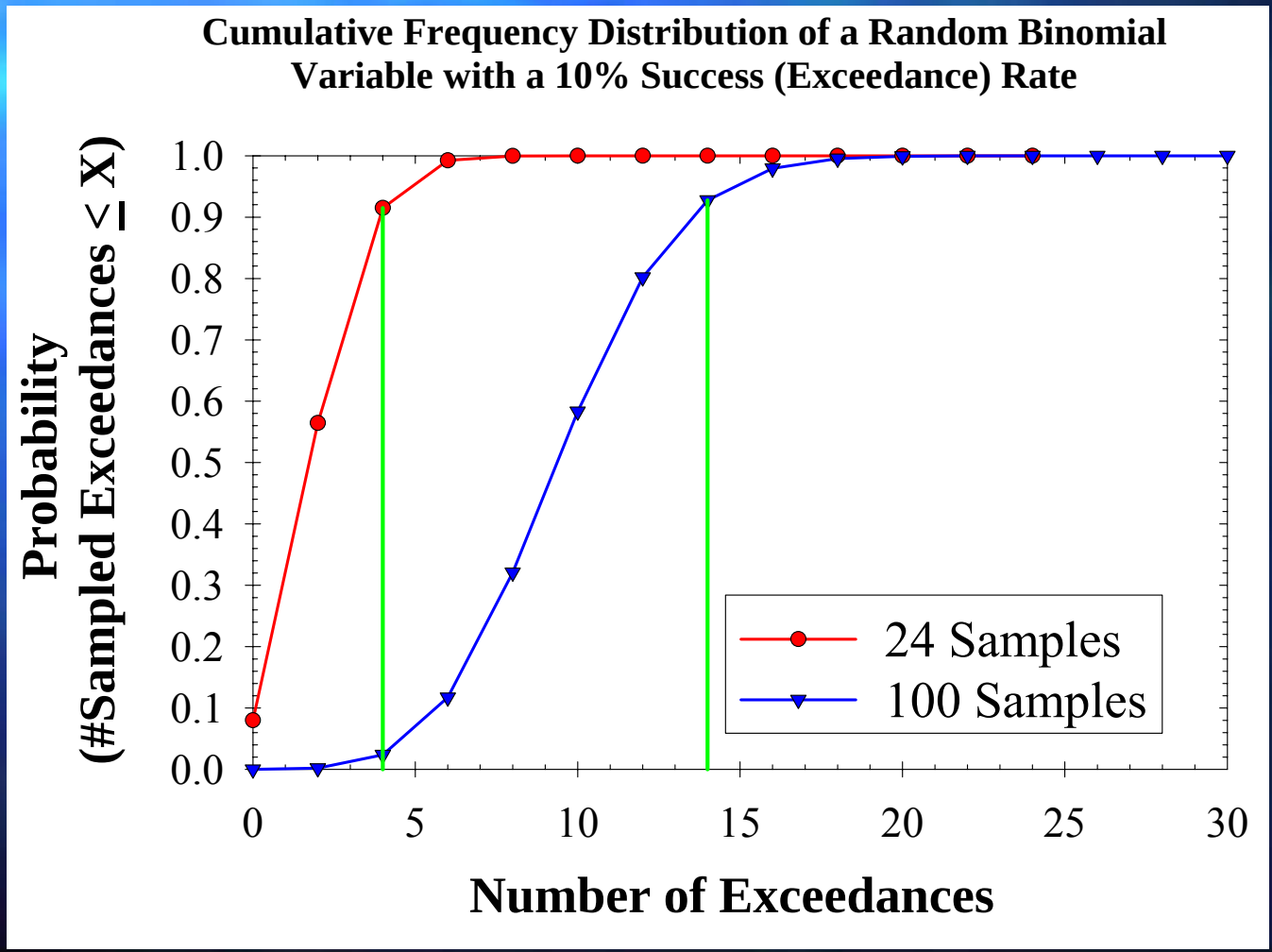


Changing Analysis Method

- Comments received from the Everglades Consolidated Report Peer Review Panel (2001 and 2002)
- Increase consistency with Florida's Impaired Waters Rule [303(d) listing and delisting protocol]
- Recent literature suggests that a binomial hypothesis test, could be used in water quality evaluations to take sample size into account (Lin *et al*., 2000; Smith *et al*., 2001; NRC, 2001)
- 5% excursion rate does not reflect more recent USEPA guidance, which recommends that a 10% rate of exceedance from applicable water quality standards be used to delineate impaired water bodies

Binomial Hypothesis Test at 90% Confidence Level

Testing the hypothesis that the probability of exceeding the standard is less than or equal to 10% (H_0: $f \leq 0.10$; H_A: $f > 0.10$)



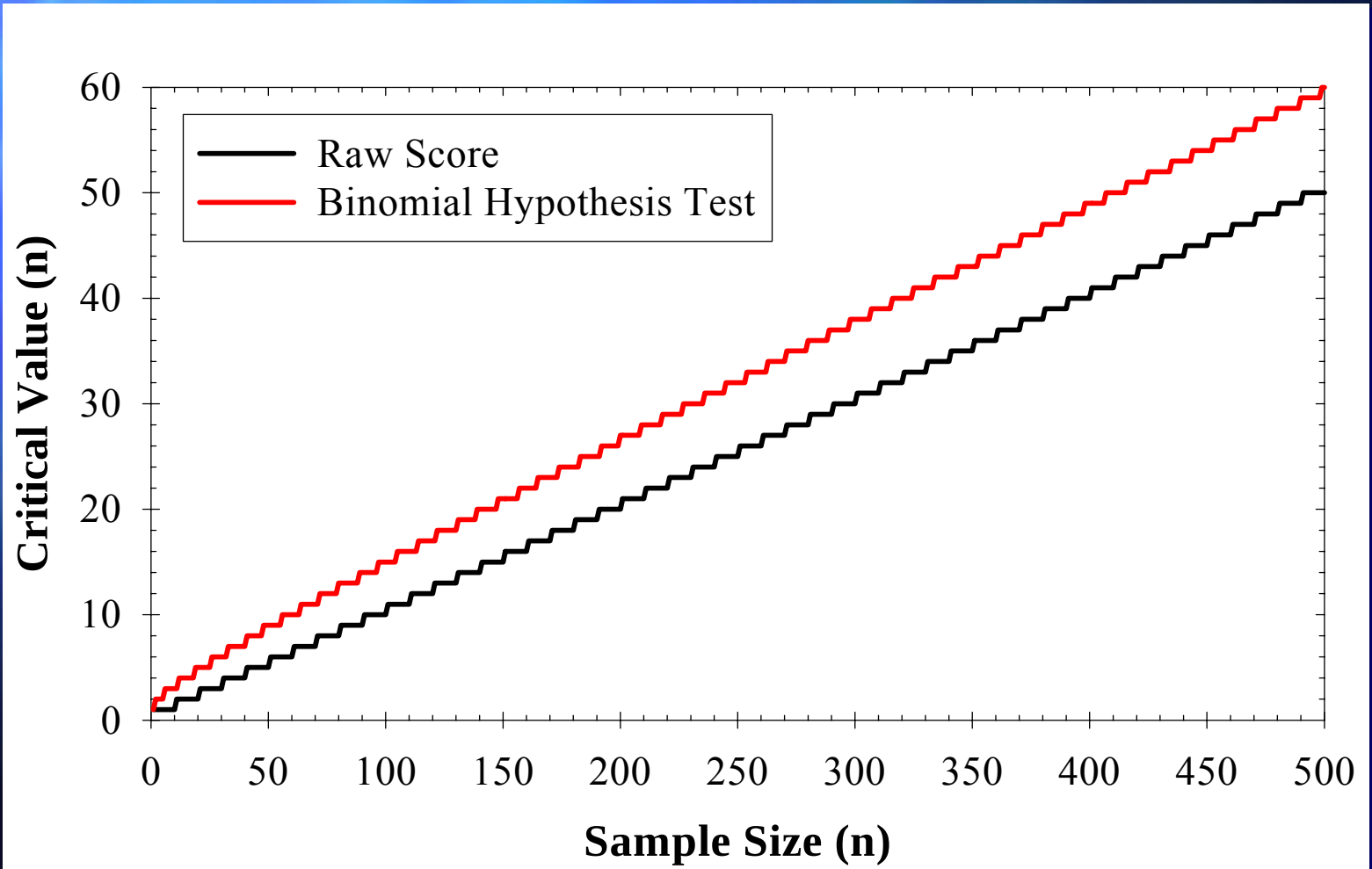
Revised Excursion Categories for Water Quality Constituents in the Everglades

Excursion frequencies were statistically tested using the binomial hypothesis test at the 90 percent confidence level for sample sizes of at least 28

Excursion Category	Conventional Constituents
Concern	> 10% Excursions
Potential Concern	> 5% and ≤ 10% Excursions
Minimal Concern	≤ 5% Excursions
No Concern	No Excursions

Exceedance Table For Binomial Test

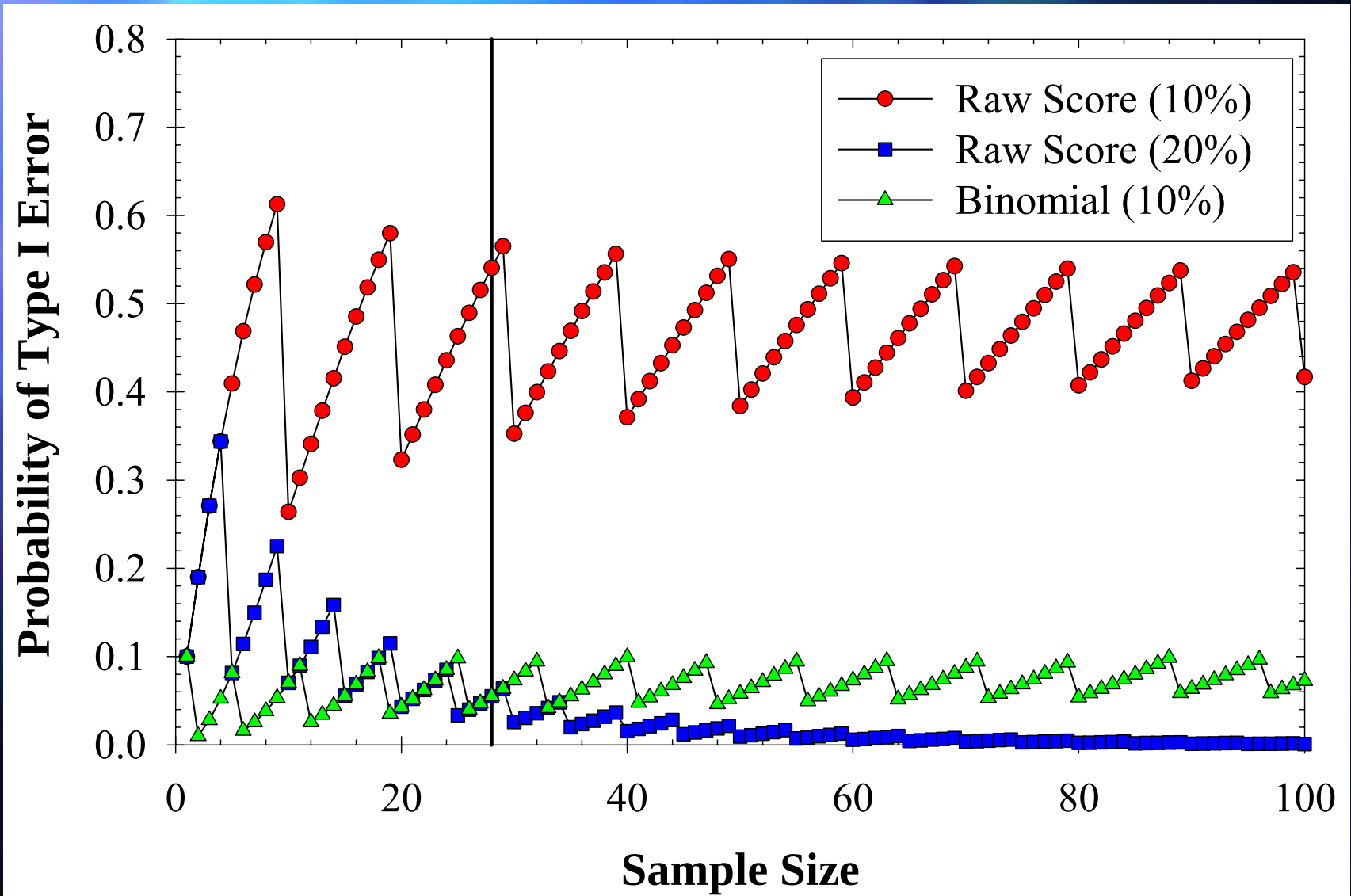
Number of exceedances required to be at least 90% confident that the true exceedance rate is greater than 10%



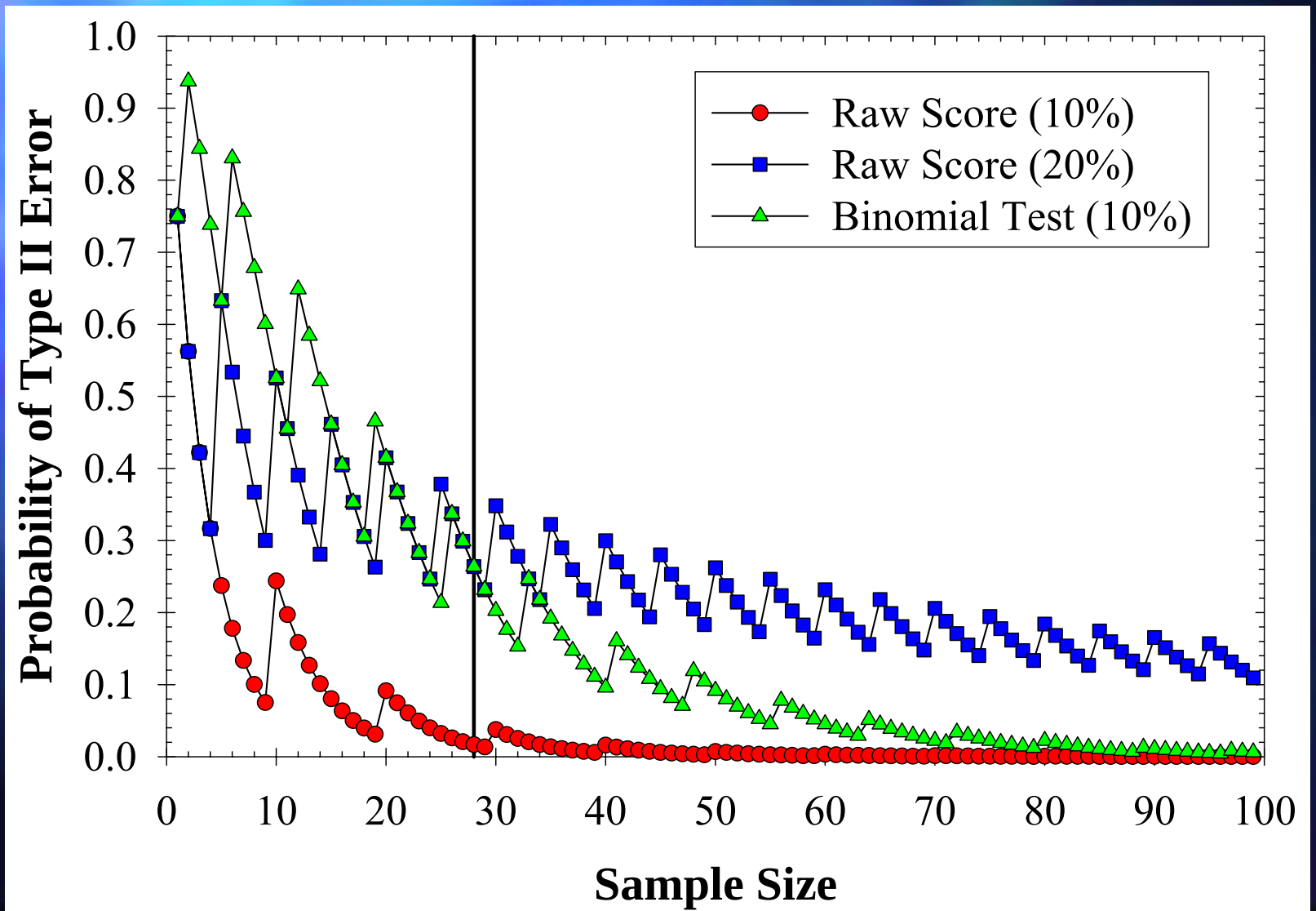
Sample Sizes Issues

- Sample size is still an important consideration in the reliability of excursion frequency estimation
  - Type I error (probability of falsely listing as a concern; false positive)
  - Type II error (probability of not listing when truly is a concern; false negative)
- As long as sample sizes are maintained at acceptable levels (>28), binomial methodologies can be utilized to better balance and manage error rates than the raw-score approach (Riggs and Aragon, 2002)

Type I Error Rates Associated with Raw Score and Binomial Methodologies True Exceedance Frequency is 10%



Type II Error Rates Associated with Raw Score and Binomial Methodologies True Exceedance Frequency is 25%



Handling Sample Sizes Less Than 28

- Using "found" data; therefore, do not have control over the number of samples collected
- Initially categorized based on raw score excursion frequency
  - >20%: Concern
  - >0% and ≤20%: Potential Concern
- Assumes that a 20% excursion frequency provides substantial reason to suspect true exceedance frequency exceeds 10%

Handling Sample Sizes Less Than 28 (Continued)

- As a means of reducing uncertainty, any variable initially identified as a concern or potential concern (using raw score) based on fewer than 28 samples was further evaluated based on longer term (five year) excursion rates using the binomial hypothesis test.
- Analysis over a longer period of record assumes that exceedance frequencies are constant among years, that is, there is no trend.

Assumption of Homogeneous Exceedance Probabilities

- Use of the either the binomial hypothesis test or raw score approach assumes a constant exceedance probability across all monitoring stations within a monitoring unit
  - Monitoring unit = a station within an area/class (e.g., WCA-2 interior, Park inflows)
- Potential problems if assumption is violated:
  - Mask a localized exceedance pattern
  - Overestimate the regional significance of a problem

Assumption of Homogeneous Exceedance Probabilities (Continued)

- The assumption of homogeneous exceedance probabilities may not hold for every water quality variable within an area as large as the Everglades.
- Subdividing each region into smaller, more homogenous sub-water bodies is a potential approach to insure adherence to this assumption.
  - However, this method does not meet the chapter's objective of providing regional summaries at the water body level (*i.e.*, Refuge, WCA-2, WCA-3, and Park).
  - Potentially reduce sample size below 28 samples
  - Homogenous sub-regions would not be consistent for all variables and may change over time.

Assumption of Homogeneous Exceedance Probabilities *Controlling Errors*

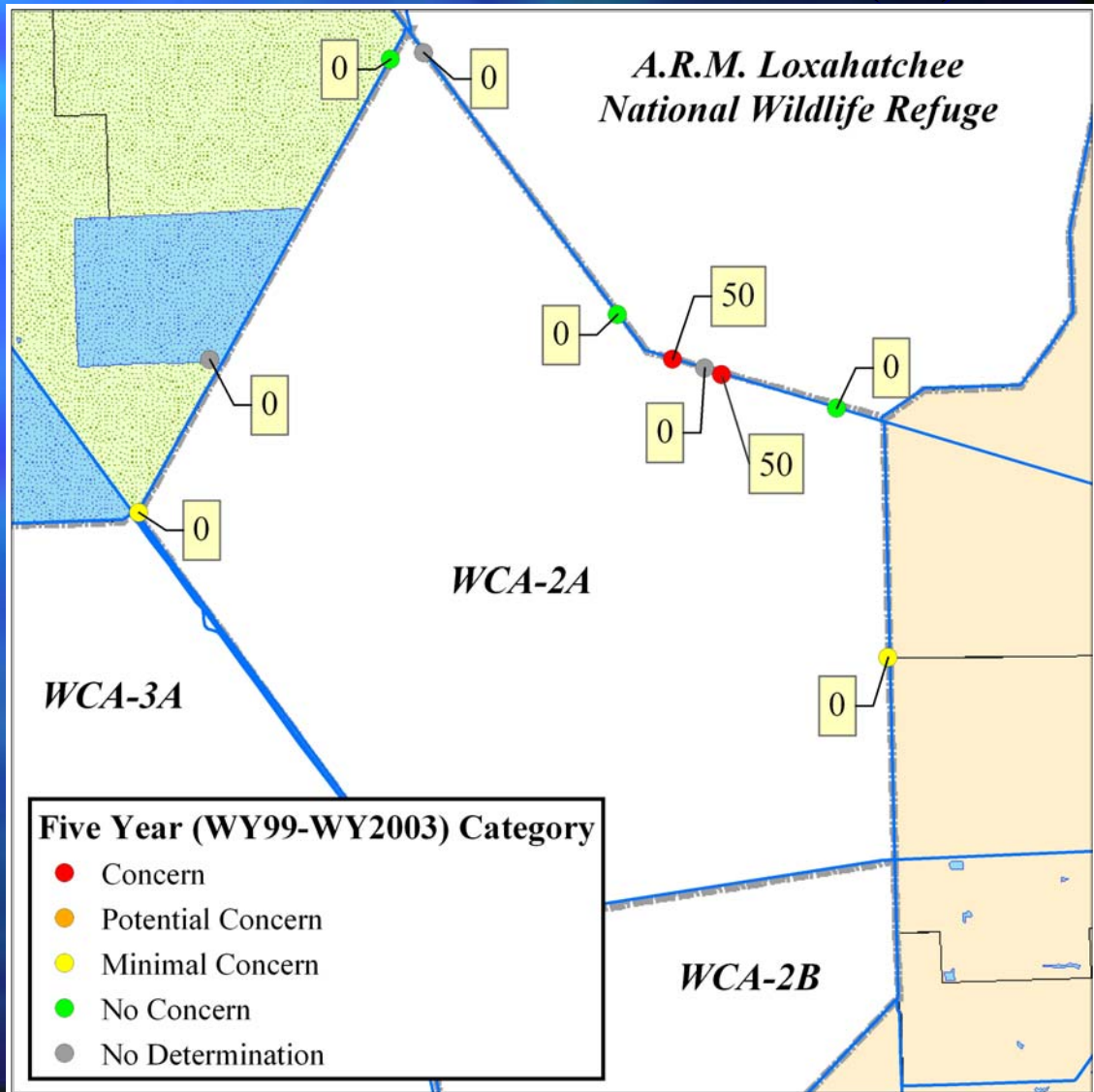
- Beginning with the 2004 report, methods to detect localized exceedance patterns within each water body were utilized to supplement the regional analyses.
- The binomial hypothesis test and excursion criterion were applied to individual station data.
- Because there are typically insufficient data (< 28 samples) over a single year, individual station analyses are based on a five year period of record.

Assumption of Homogeneous Exceedance Probabilities *Controlling Errors* (Continued)

- Use of a five year period provides sufficient data for most variables.
- No determination is made for any variable with less than 28 samples.
- If one or more monitoring stations are categorized at a higher level of concern than the region as a whole, then a localized exceedance is recorded and investigated further.

Example:
WCA-2 Inflow Un-ionized Ammonia
Labels are the Water Year 2003 Exceedance Rates (%)

- Overall exceedance rate of 11.4 ± 4.4 % (PC)
- However, exceedances were localized at just two stations
- Reviewing site-specific exceedances controls potential errors
  - Identified a localized condition
  - Un-ionized ammonia is not a WCA-2 wide issue



Example Excursion Analysis Results
Water Year 2003 Results (2004 Report)

Region	Class	Variable	Units	Class III Criteria	N	Excursion	
						%±90% C.I.	Category
WCA-2	Inflow	Alkalinity	mg/L	≥20	98	1.0 ± 1.7	MC
		Dissolved Oxygen	mg/L	≥5	139	52.5 ± 7.0	C
		Specific Conductance	µmho/cm	≤1275	140	11.4 ± 4.4	PC (C)
		Un-ionized Ammonia	mg/L	≤0.02	98	10.2 ± 5.0	PC (C)
	Interior	Dissolved Oxygen	mg/L	≥5	275	82.5 ± 3.8	C
		Specific Conductance	µmho/cm	≤1275	278	20.9 ± 4.0	C
	Outflow	Dissolved Oxygen	mg/L	≥5	50	44 ± 11.5	C
		pH	Units	≥6.0, ≤8.5	57	1.8 ± 2.9	MC
		Specific Conductance	µmho/cm	≤1275	57	1.8 ± 2.9	MC
WCA-3	Inflow	Dissolved Oxygen	mg/L	≥5	306	47.7 ± 4.7	C
		pH	Units	≥6.0, ≤8.5	318	1.6 ± 1.1	MC
		Specific Conductance	µmho/cm	≤1275	315	0.6 ± 0.73	MC
		Un-ionized Ammonia	mg/L	≤0.02	194	0.5 ± 0.9	MC
	Interior	Dissolved Oxygen	mg/L	≥5	319	87.1 ± 3.1	C
	Outflow	Dissolved Oxygen	mg/L	≥5	194	83 ± 4.4	C

Excursion Analysis Summary

- The primary objective of the Everglades Water Quality Chapter is to provide a synoptic review of water quality criteria attainment on a regional scale
- The excursion analysis protocol achieves the objective of summarizing water quality criteria attainment on a regional scale
- Provides an easy to understand “report card” on water quality for the public, policy makers, and elected officials.
- The protocol has been modified over the years to better account for uncertainty and the limitations associated with using “found” data.
- Excursion analysis triggers addition evaluation for constituents identified as concerns or potential concerns
  - Spatial and temporal trends
  - Investigation into factors contributing to exceedances

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Literature Cited

Lin, P., D. Meeter and X. Niu. 2000. A Nonparametric Procedure for Listing and Delisting Impaired Waters Based on Criterion Exceedance. Technical Report submitted to the Florida Department of Protection, Tallahassee, FL.

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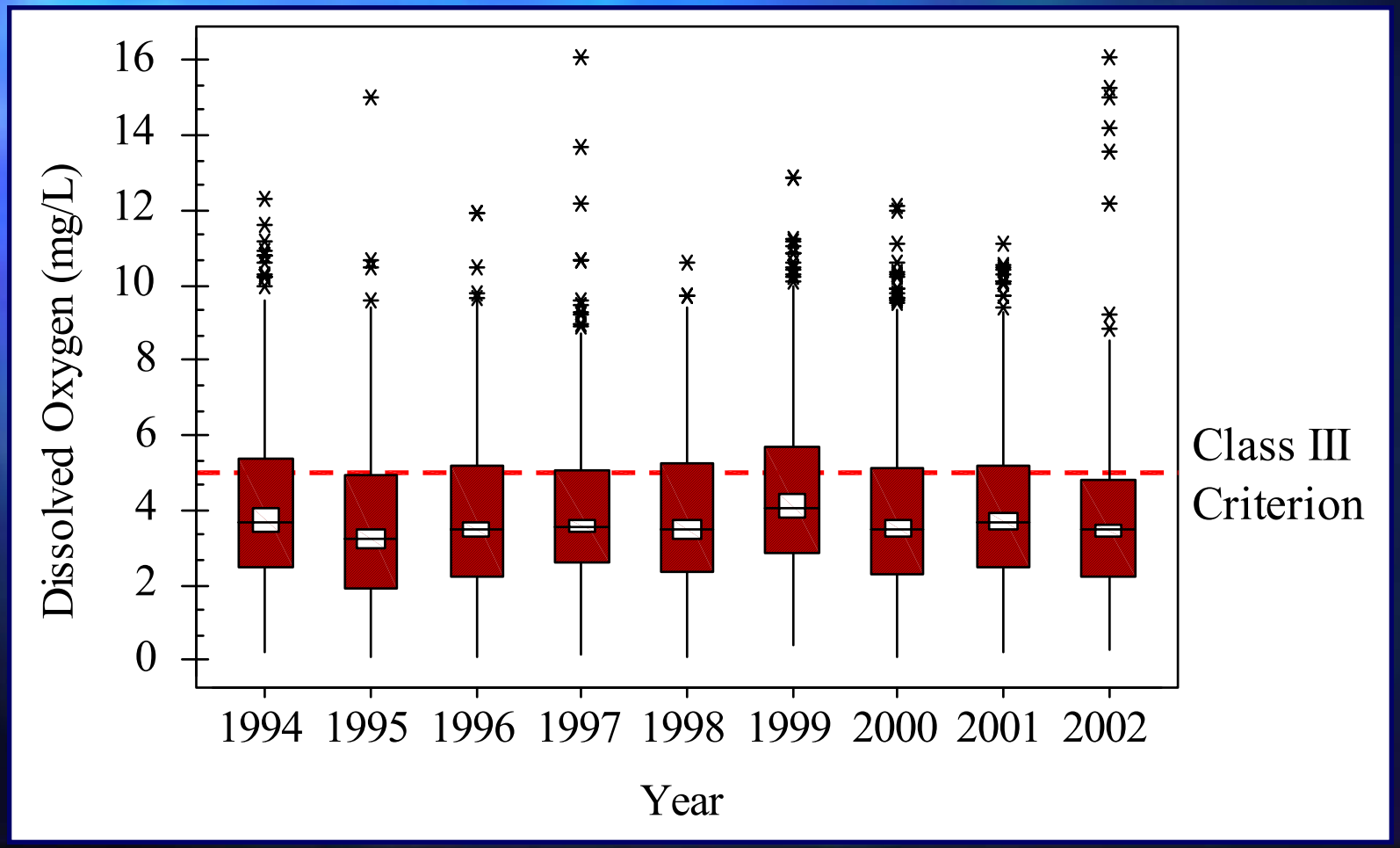
Smith, E.P., Y. Keying, C. Hughes and L. Shabman. 2001. Statistical Assessment of Violations of Water Quality Standards under Section 303(d) of the Clean Water Act. *Envir. Sci. Technol.*, 35: 606-612.

Incorporating Uncertainty into Water Quality Standards

Parameter	Units	Class I	Class II	Class III: Fresh	Class III: Marine	Class IV	Class V
(23) Conductance, Specific	Micromhos/cm	Shall not be increased more than 50% above background or to 1275, whichever is greater		Shall not be increased more than 50% above background or to 1275, whichever is greater		Shall not be increased more than 50% above background or to 1275, whichever is greater	Shall not exceed 4,000
(24) Copper	Micrograms/L See Note (3).	Cu $\leq e^{(0.8545[\ln H]-1.465)}$	$\leq$ 2.9	Cu $\leq e^{(0.8545[\ln H]-1.465)}$	$\leq$ 2.9	$\leq$ 500	$\leq$ 500
(25) Cyanide	Micrograms/L	$\leq$ 5.2	$\leq$ 1.0	$\leq$ 5.2	$\leq$ 1.0	$\leq$ 5.0	$\leq$ 5.0
(26) Definitions (see Section 62-302.200, F.A.C.)							
(27) Detergents	Milligrams/L	$\leq$ 0.5	$\leq$ 0.5	$\leq$ 0.5	$\leq$ 0.5	$\leq$ 0.5	$\leq$ 0.5
(28) 1,1-Dichloro-ethylene (1,1-di-chlorcethene)	Micrograms/L	$\leq$ 0.057 annual avg.; $\leq$ 7.0 max	$\leq$ 3.2 annual avg.	$\leq$ 3.2 annual avg.	$\leq$ 3.2 annual avg.		
(29) Dichloromethane (methylene chloride)	Micrograms/L	$\leq$ 4.65 annual avg.	$\leq$ 1,590 annual avg.	$\leq$ 1,580 annual avg.	$\leq$ 1,580 annual avg.		
(30) 2,4-Dinitrotoluene	Micrograms/L	$\leq$ 0.11 annual avg.	$\leq$ 9.1 annual avg.	$\leq$ 9.1 annual avg.	$\leq$ 9.1 annual avg.		
(31) Dissolved Oxygen	Milligrams/L	Shall not be less than 5.0. Normal daily and seasonal fluctuations above this level shall be maintained.	Shall not average less than 5.0 in a 24-hour period and shall never be less than 4.0. Normal daily and seasonal fluctuations above these levels shall be maintained.	Shall not be less than 5.0. Normal daily and seasonal fluctuations above these levels shall be maintained.	Shall not average less than 5.0 in a 24-hour period and shall never be less than 4.0. Normal daily and seasonal fluctuations above these levels shall be maintained.	Shall not average less than 4.0 in a 24-hour period and shall never be less than 3.0.	Shall not be less than 0.3, fifty percent of the time on an annual basis for flows greater than or equal to 250 cubic feet per second and shall never be less than 0.1. Normal daily and seasonal fluctuations above these levels shall be maintained.
(32) Dissolved Solids	Milligrams/L	$\leq$ 500 as a monthly avg.; $\leq$ 1,000 max					
(33) Fluorides	Milligrams/L	$\leq$ 1.5	$\leq$ 1.5	$\leq$ 10.0	$\leq$ 5.0	$\leq$ 10.0	$\leq$ 10.0
(34) "Free Froms" (see Minimum Criteria in Section 62-302.500, F.A.C.)							
(35) "General Criteria" (see Section 62-302.510, F.A.C. and individual criteria)							

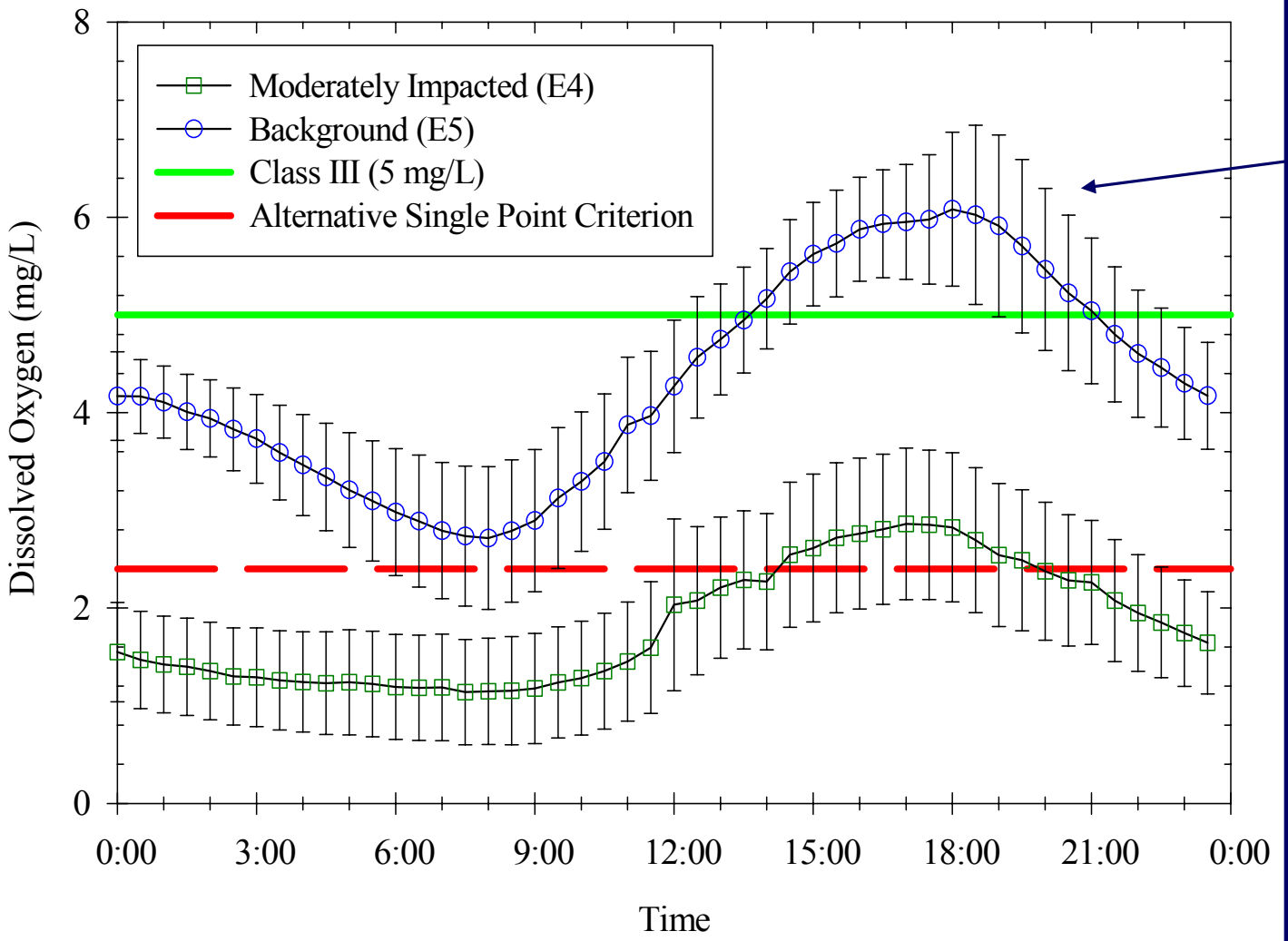
Issue: Dissolved Oxygen Concentrations Within Everglades Marshes Routinely Fall Below the State Dissolved Oxygen Water Quality Standard of 5.0 mg/L Due to Natural Diurnal Fluctuations

(Data from 50 Natural Background Sites across all areas of the Everglades)



Defining Natural Background Conditions

A New Single Point Criterion Would Not Adequately Describe Natural Diurnal Fluctuations



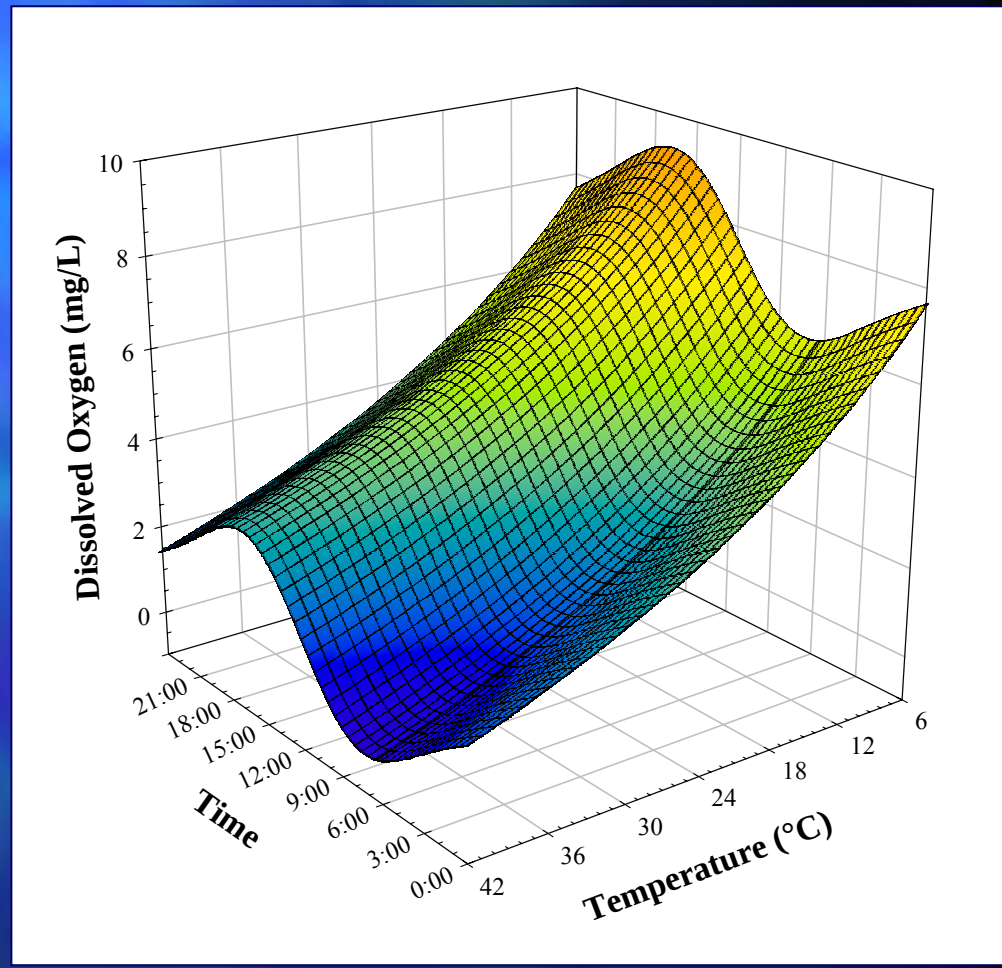
Solution: Model Background Diurnal Cycle

Solution to Dissolved Oxygen Issue

- Developed a Site Specific Alternative Criterion (SSAC) to formally recognize the natural background conditions in the Everglades marshes
- SSAC includes an Assessment Methodology
  - Utilizes feasible sampling methodology
  - Considers uncertainty
  - Considers natural variability
  - Provides defined and consistent statistical methodology
- SSAC Provides:
  - An accurate differentiation between impacted and background conditions relative to DO
  - More realistic information on ecosystem status than the existing Class III criterion

SSAC Compliance Assessment

- Limit established based on 10th percentile of background reference sites
- Calculate predicted DO for individual observations based on collection time and water temperature
- Compliance based on annual average DO levels
  - Observed annual average concentration compared to annual average predicted value
  - Provides an allowance for natural variability



Annual Assessment for An Individual Site

$$DO_{AL} = \frac{1}{n} \bullet \sum_{i=1}^{n} -3.70 - (1.50 \bullet \sin(\frac{2\pi}{1440} \bullet t_i) - 0.30 \bullet \sin(\frac{4\pi}{1440} \bullet t_i)) + \frac{1}{(0.068 + 0.00198 \bullet C_i + 5.24 \bullet 10^{-6} \bullet C_i^2)} - 1.40$$

Compare to:

$$\overline{DO} = \frac{1}{n} \bullet \sum_{i=1}^{n} x_i$$

Where:

- DO_{AL}=Annual Compliance Limit (mean predicted value)
- DO=Annual mean measured dissolved oxygen
- n=Total Number of samples collected during year
- t_i=Sample collection time of the i^{th} sample
- C_i=Water temperature (°C) of the i^{th} sample
- x_i=Measured dissolved oxygen concentration of the i^{th} sample.

DO SSAC Summary

- Provides an accurate differentiation between impacted and background conditions relative to DO
  - Impaired sites fail 83% of the time (1994-2003)
  - Highly impaired sites fail 94% of the time (1994-2003)
  - Unimpaired background sites pass 90% of the time (1994-2003)
- More realistic information on ecosystem status than the existing criterion
- Technical documentation available at: http://www.dep.state.fl.us/water/wqssp/everglades/dossac.htm