Modeling Phosphorus Dynamics in Everglades Wetlands and Stormwater Treatment Areas

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As water with elevated phosphorus (P) moves through a wetland ecosystem, phosphorus is removed and a gradient of decreasing P concentration is produced. In the Everglades Water Conservation Areas, that gradient typically ranges from > 100 ppb near inflow points to < 8 ppb in native marsh communities. The water-column P gradient is typically accompanied by decreasing gradients of P storage in vegetation and soils. Nearly three decades of monitoring and research by the South Florida Water Management District and other organizations have conclusively established that the characteristics of the wetland ecosystems change dramatically along the gradient and that native communities are viable only at P concentrations < 10 ppb.

That same research and monitoring data have provided a basis for developing relatively simple mass-balance models to support design and optimization of ~58,000 acres of Stormwater Treatment Areas (STA's) for removing P from marsh inflows and to simulate downstream marsh responses to variations in inflow P loads. This paper describes the evolution of those models from the steady-state STA design model (1995), the Everglades Phosphorus Gradient Model (EPGM, 1996), and Dynamic Model for Stormwater Treatment Areas (DMSTA, 2002). Applications to STA and marsh monitoring data collected through 2007 provide a basis for testing previous model calibrations and evaluating STA performance relative to long-term expectations.

While DMSTA was developed primarily a design tool, it can also be used as a diagnostic tool to facilitate interpretation of real-time monitoring data. Variations in measured STA outflow concentrations and loads reflect variations in inflow volumes, inflow P loads, water depths, climate, management, P cycling within wetland communities, measurement errors, and other random factors. It is difficult to evaluate the inherent P removal performance of the wetland community in the context of data variations induced by the other factors. DMSTA attempts to factor out the effects of management (inflow distribution, depth), hydrologic variations, and climatologic variations, so that the data provide a better signal of vegetation function and long-term performance relative to design simulations and management expectations.

Findings based upon data collected through 2007 include:

- Differences between observed and predicted STA outflow concentrations and loads were generally within uncertainty envelopes established in previous DMSTA calibrations.

- Performance of individual STAs cells was reasonably consistent with simulations of designated community types (emergent vs. submergent) when allowance is made for factors not considered by the model (startup, construction, maintenance).

- Applications to marsh data indicate the potential for combining EPGM and DMSTA into a single dynamic model for simulating phosphorus storage in the water column, vegetation, and soils along gradients downstream of inflow points.

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by

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Topics

- Model Concepts & Evolution
- STA Modeling
- Marsh Modeling
- Limitations & Directions
- Data & Research Needs

Phosphorus Mass Balance Models

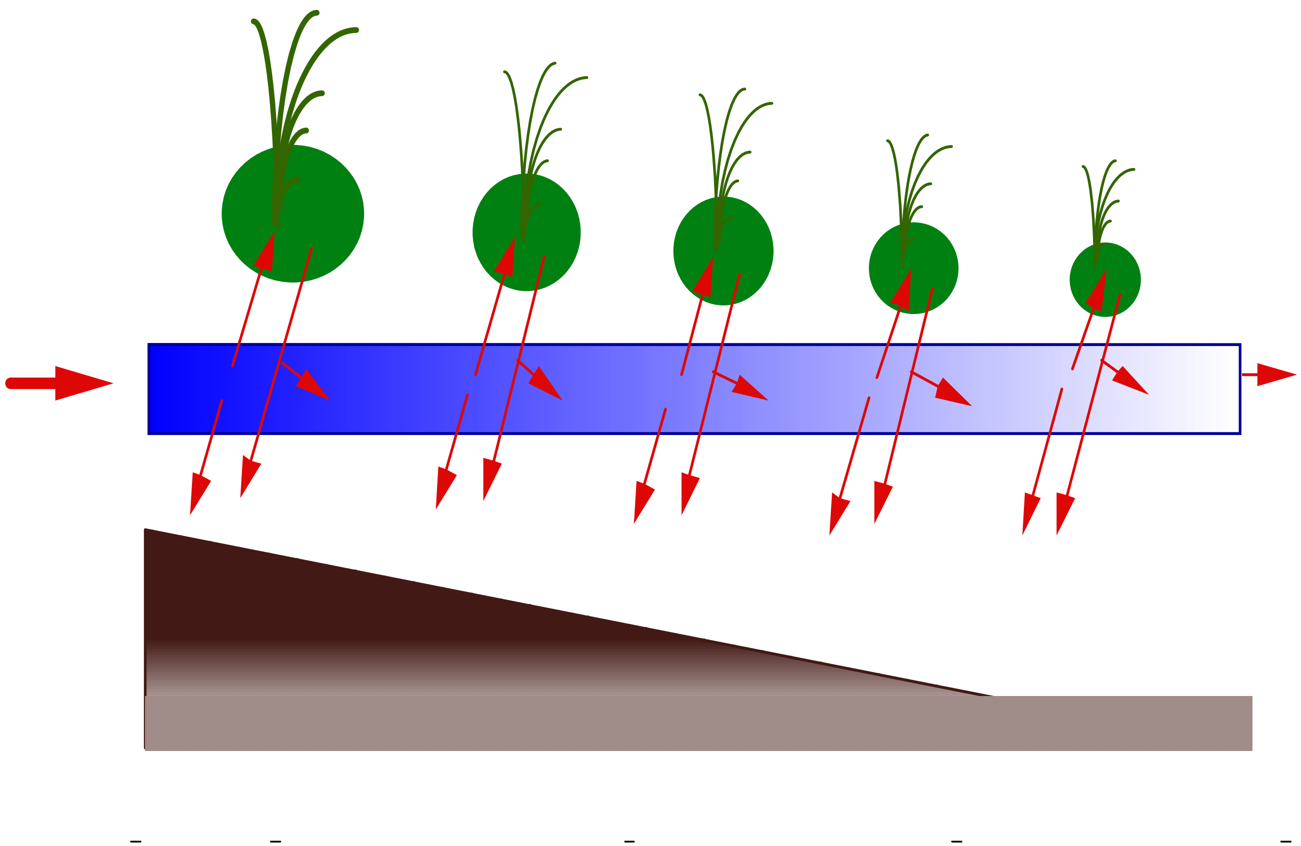
- Aggregated Variables & Processes
- Limited User Input Data
- Calibrated & Tested vs. Regional Datasets
- Testing Strategies
  - Independent Datasets or Time Periods
  - Residuals Analysis
- Applicability Limited by Data Boundaries
- Uncertainty Evaluated
- Excel / Visual Basic Platforms
- Details: wwwalker.net/dmsta   & …/epgm

Model Applications

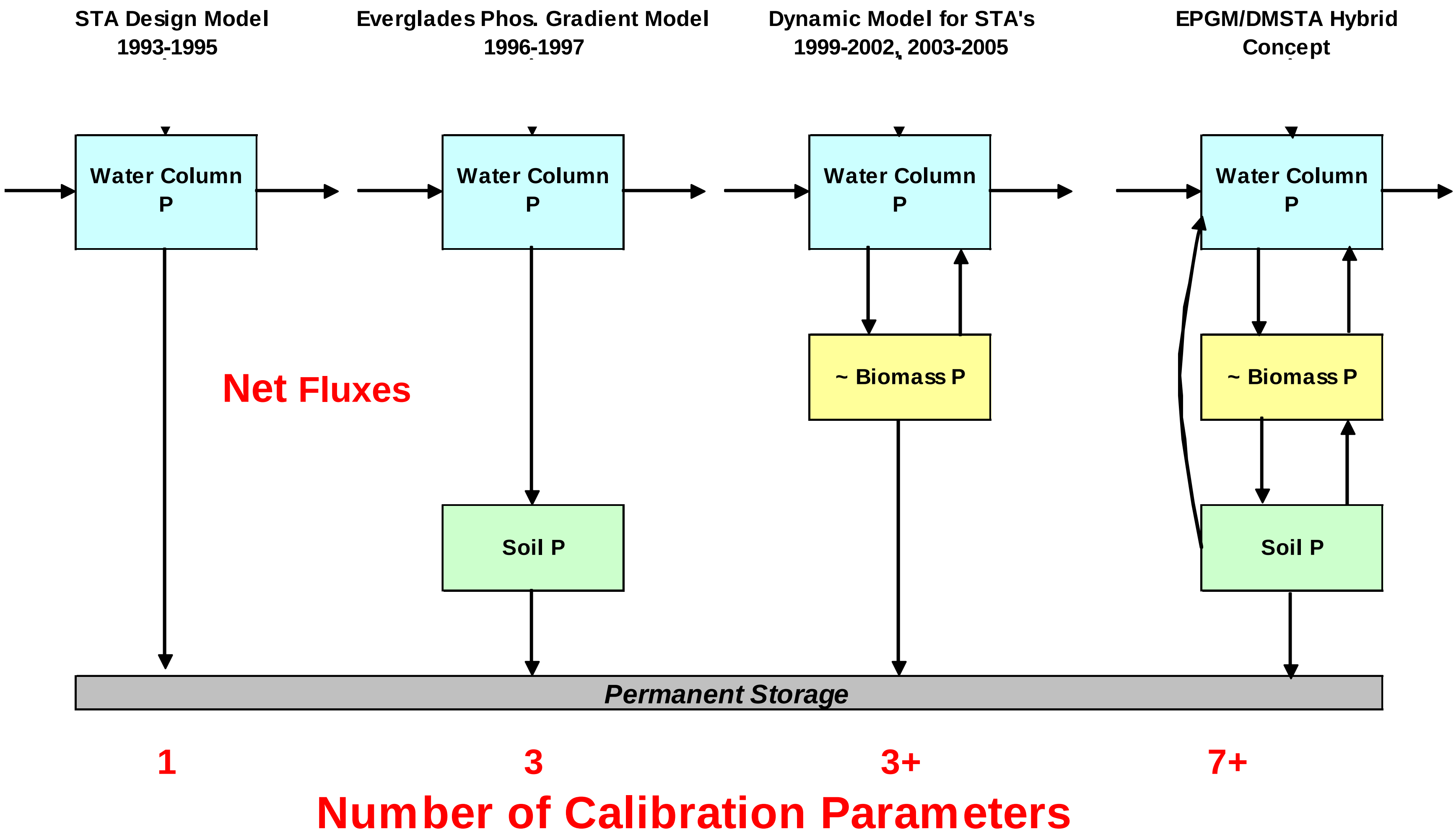
- Engineering Design
  - Design & Optimization of Stormwater Treatment Areas
  - Evaluation of Regional Water Mgt & P Control Plans
  - Consideration of BMP’s, STA’s & Reservoirs

- Adaptive Management
  - Forecasting Marsh Enrichment/Recovery
  - Benchmark for Interpreting Monitoring Data
    - STA Performance
    - Downstream Marsh Transects
  - Optimizing STA Operation (Flows, Depths, Veg.)
  - Integrating Research & Monitoring Data
  - Identifying Research Questions & Data Gaps

Marsh Phosphorus Gradient

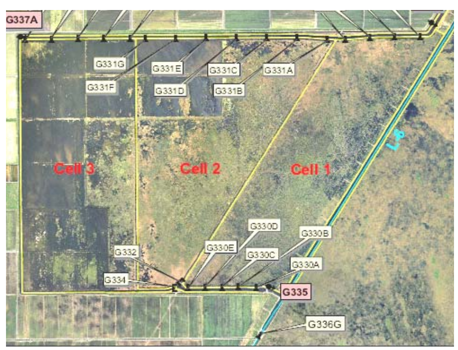


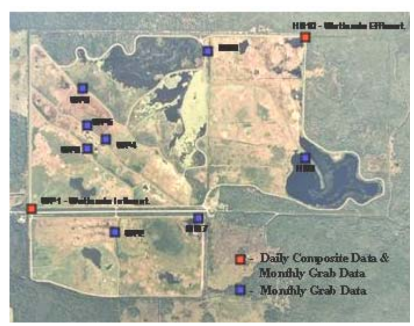
Model Evolution, 1993 - 2008



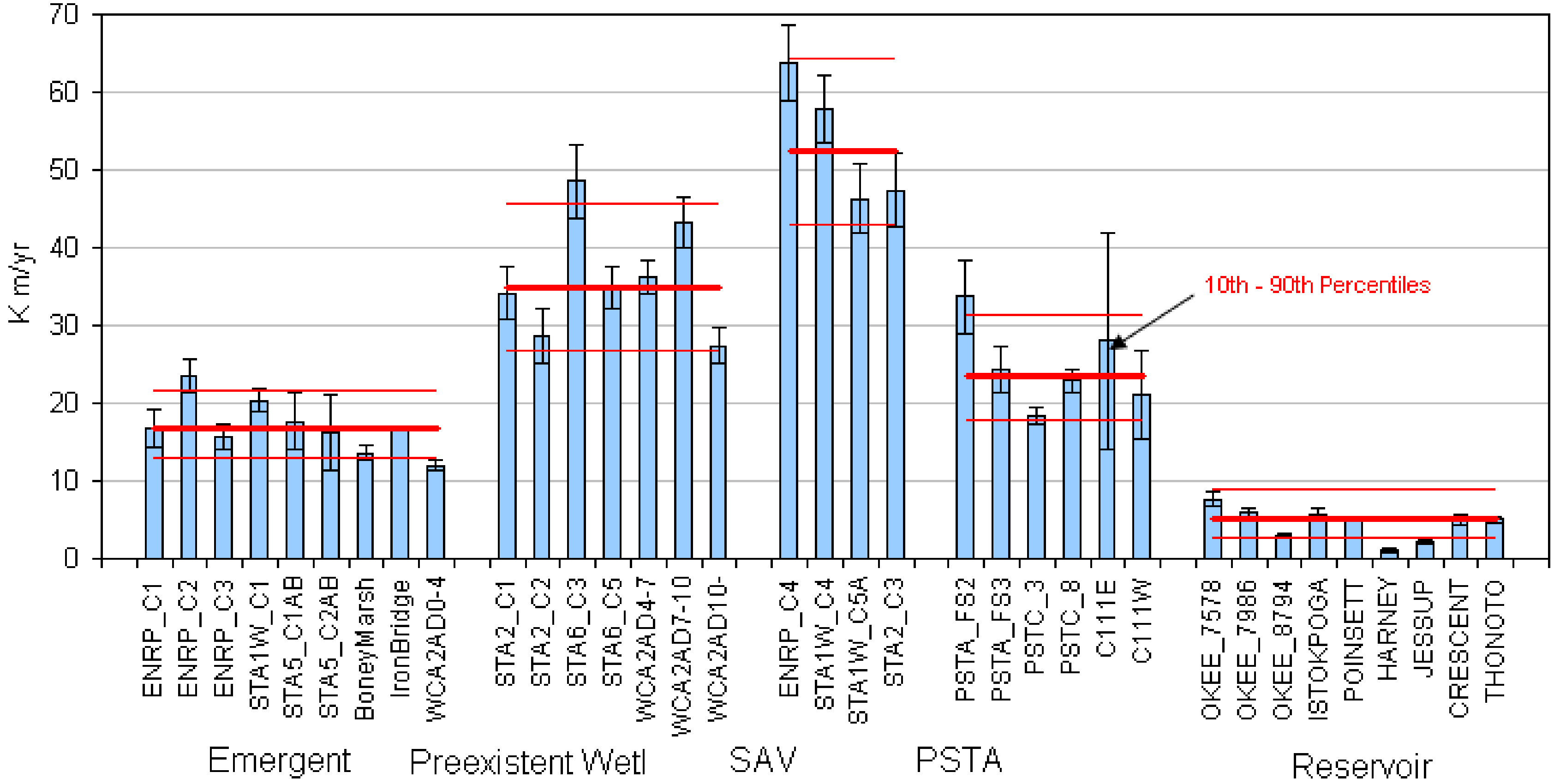
> 80 Platforms Used in Calibration & Testing

Daily Water & P Balances, .01-150 km^2, 1-30yrs

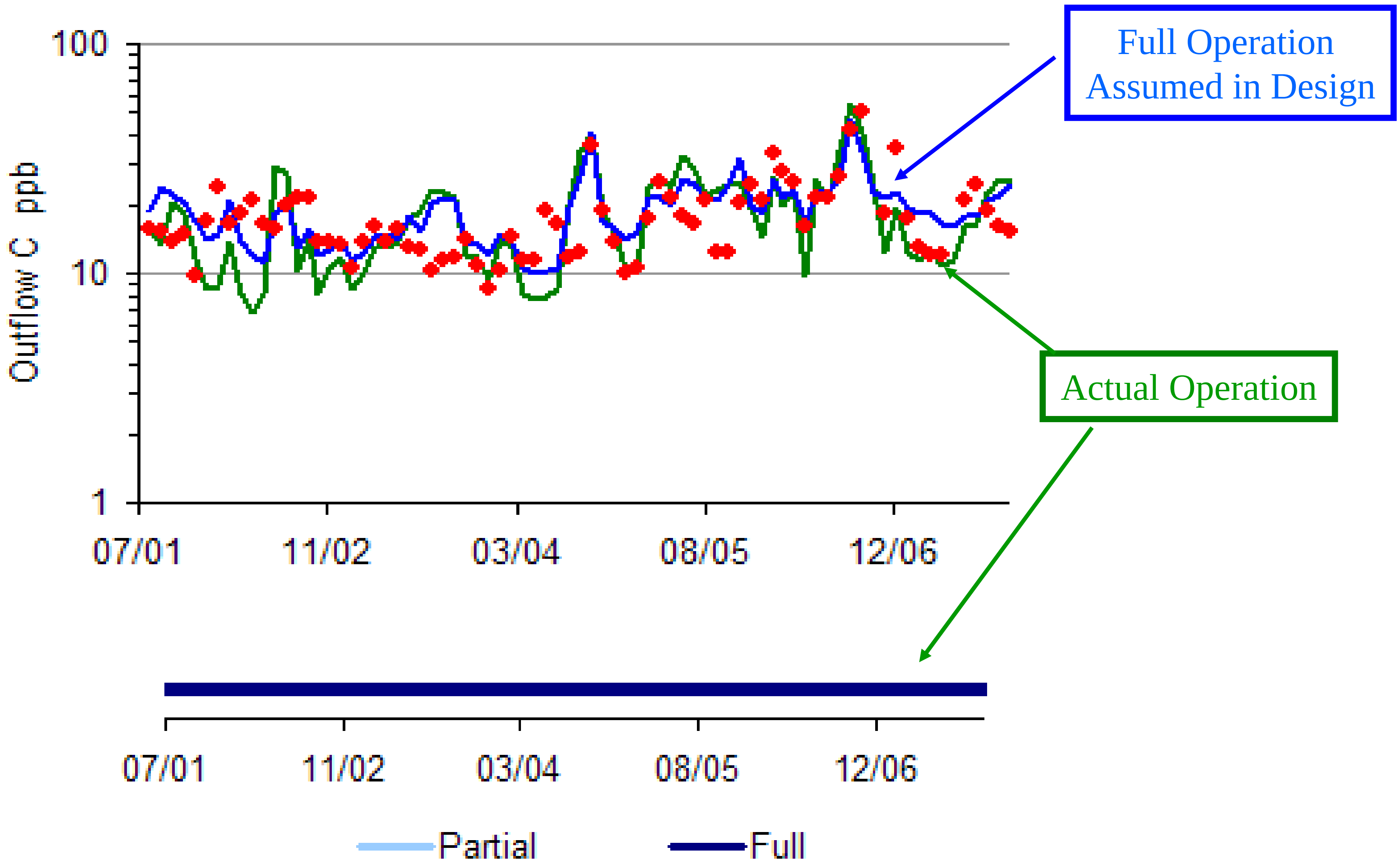




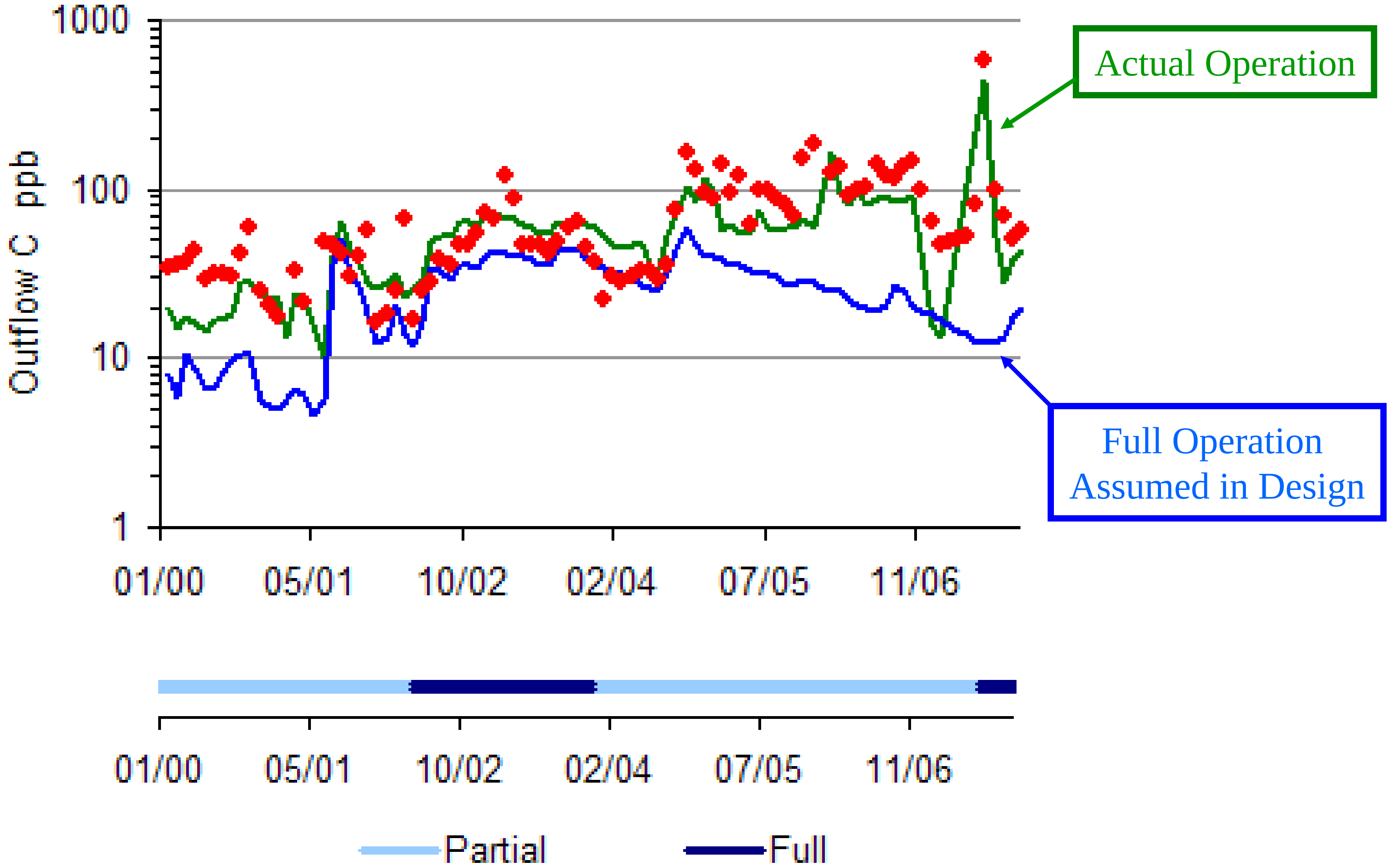
DMSTA2 – 2005
Calibrations to Five Community Types



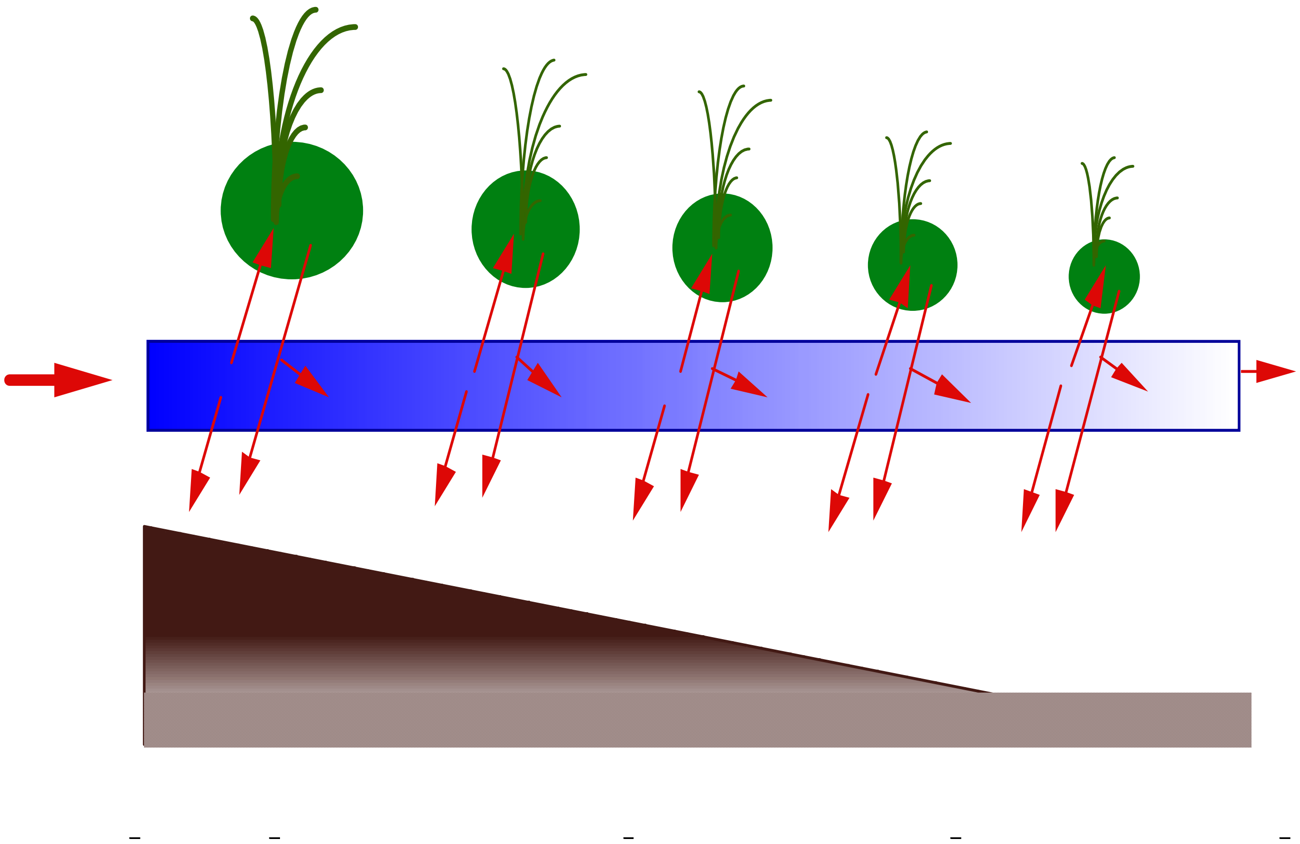
STA-2 Simulation, 2001-2007

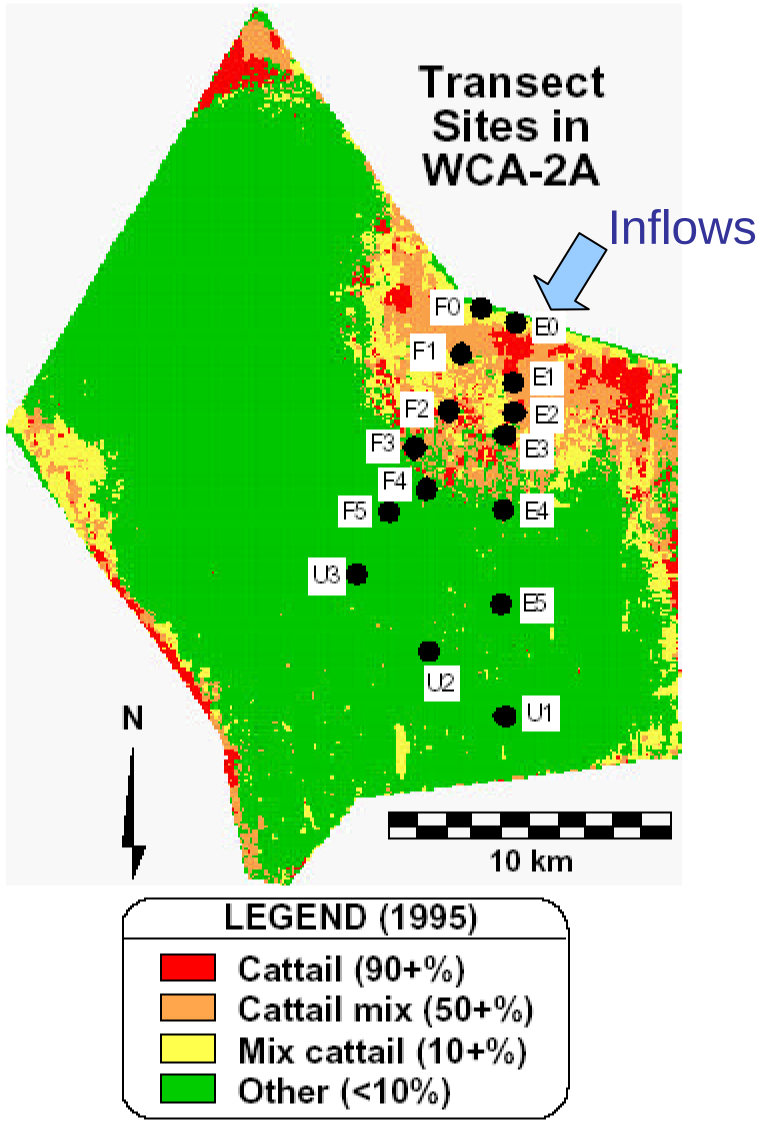


STA-1W Simulation, 2000-2007



Marsh Phosphorus Gradient





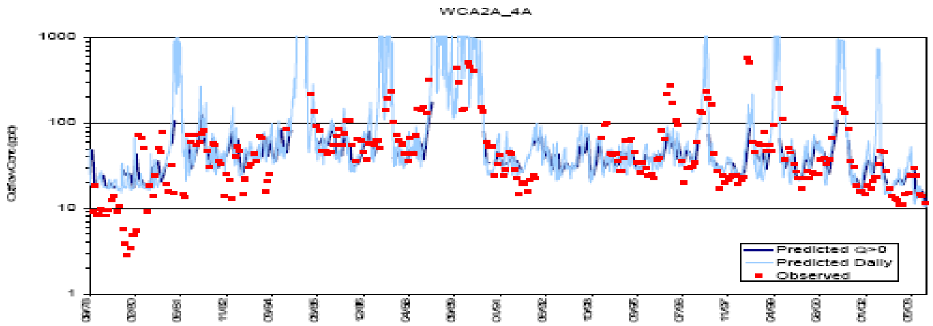
Research to Support the Derivation of the Numerical Criterion for P in the Everglades

Everglades Division
South Florida Water Management District

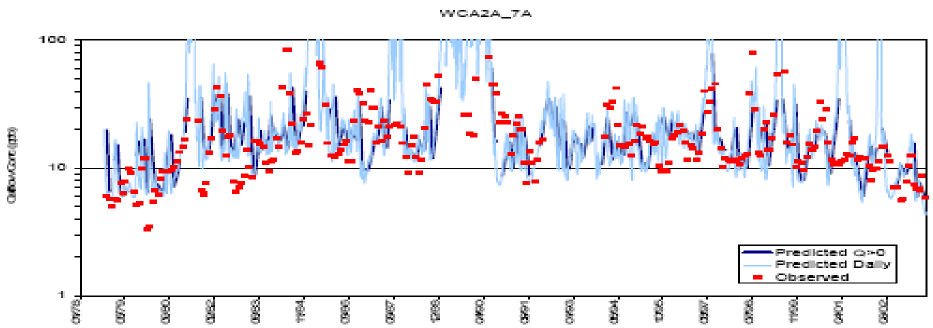
P Criterion Workshop
20-21 September 2001

WCA-2A Gradient TP Concentrations
DMSTA Simulation, 1978-2004

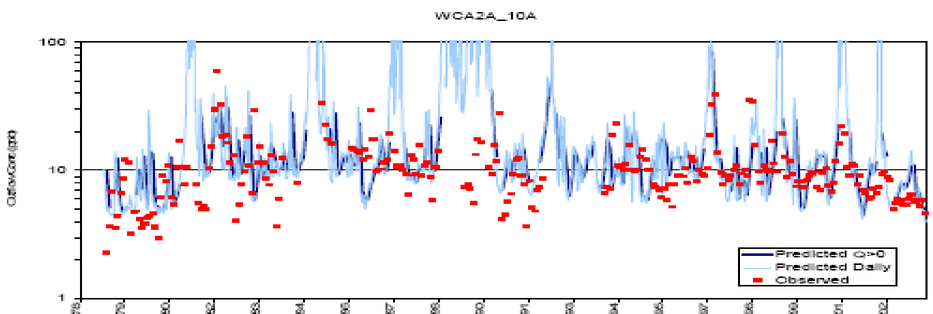
4 km



7 km

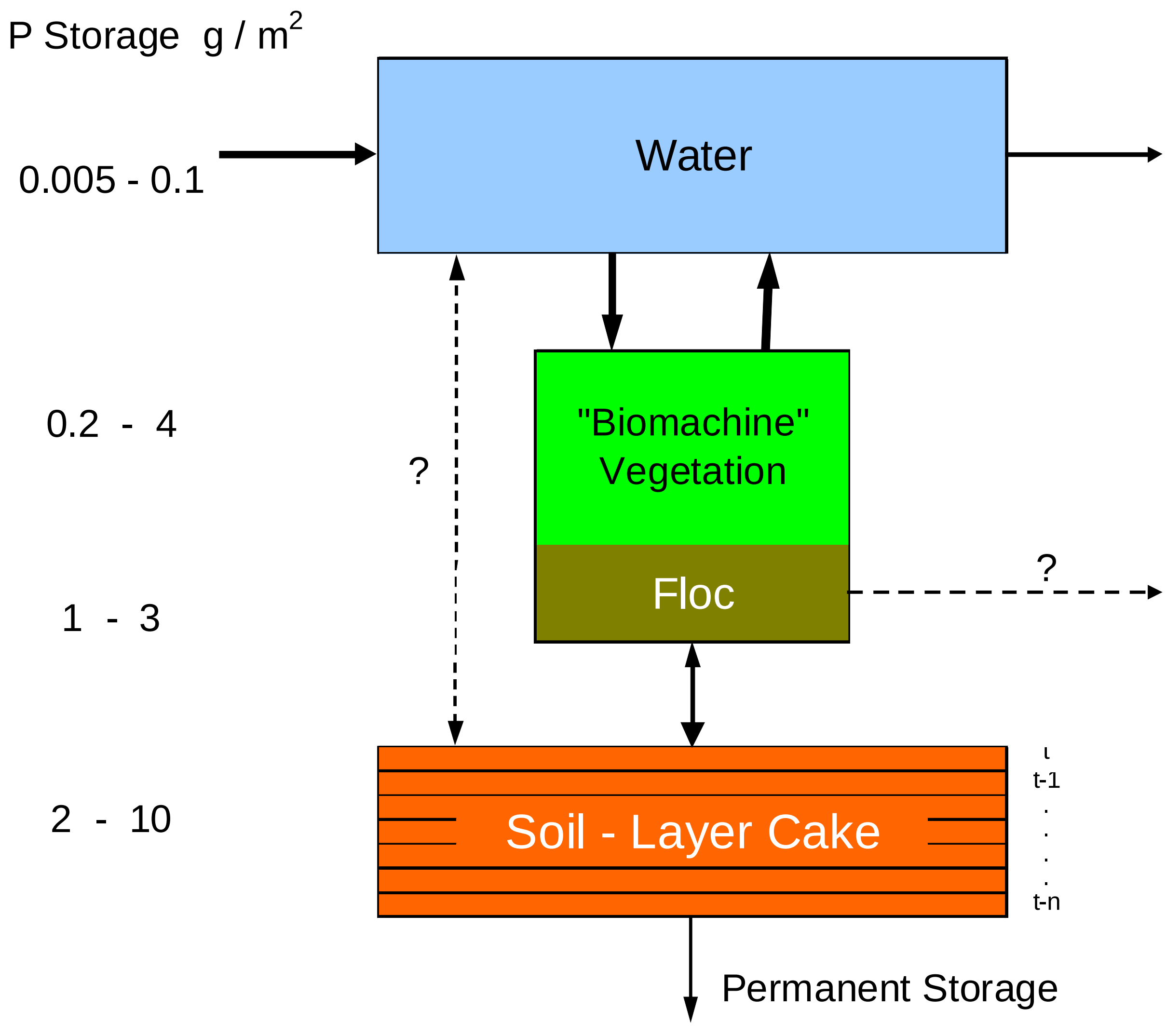


10 km



Coupled EPGM & DMSTA

Cwater = F (X , T)   Csoil = F (X , Z , T)

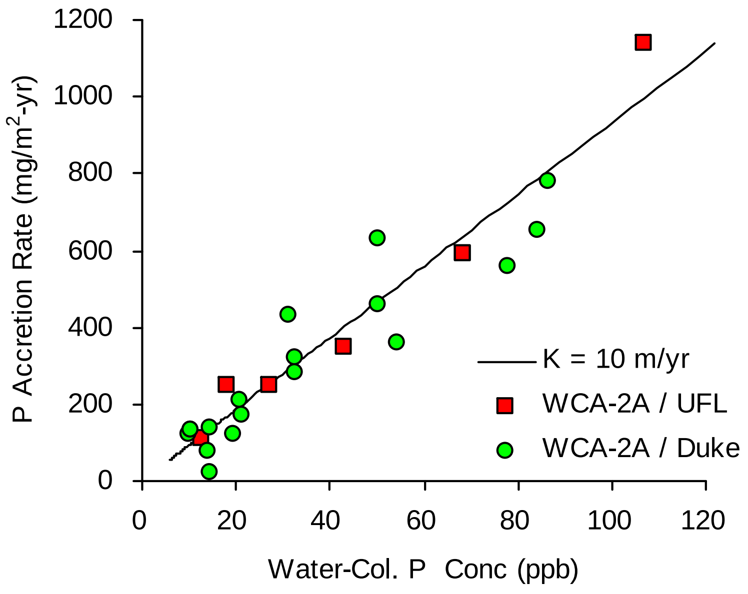


STADM & EPGM Cornerstones

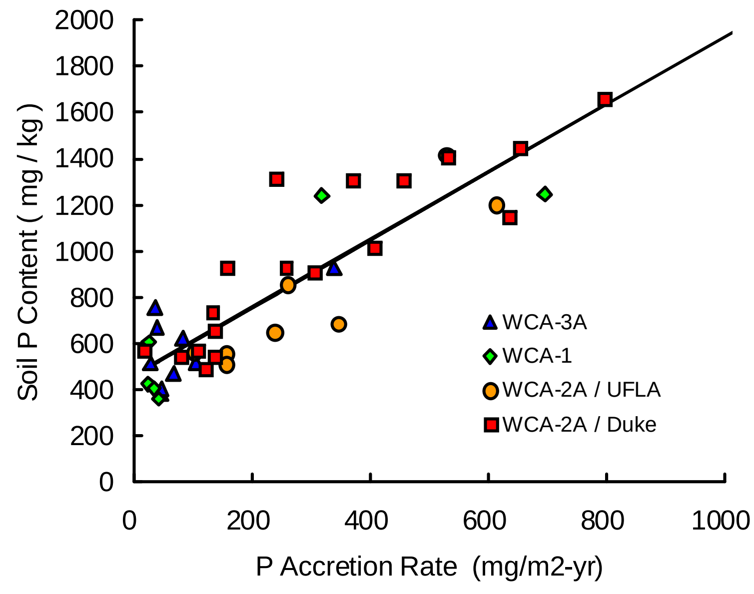
Dated Soil Cores from WCA-2A, 1991

Reflecting 26 Yrs of P Loading & Peat Accretion

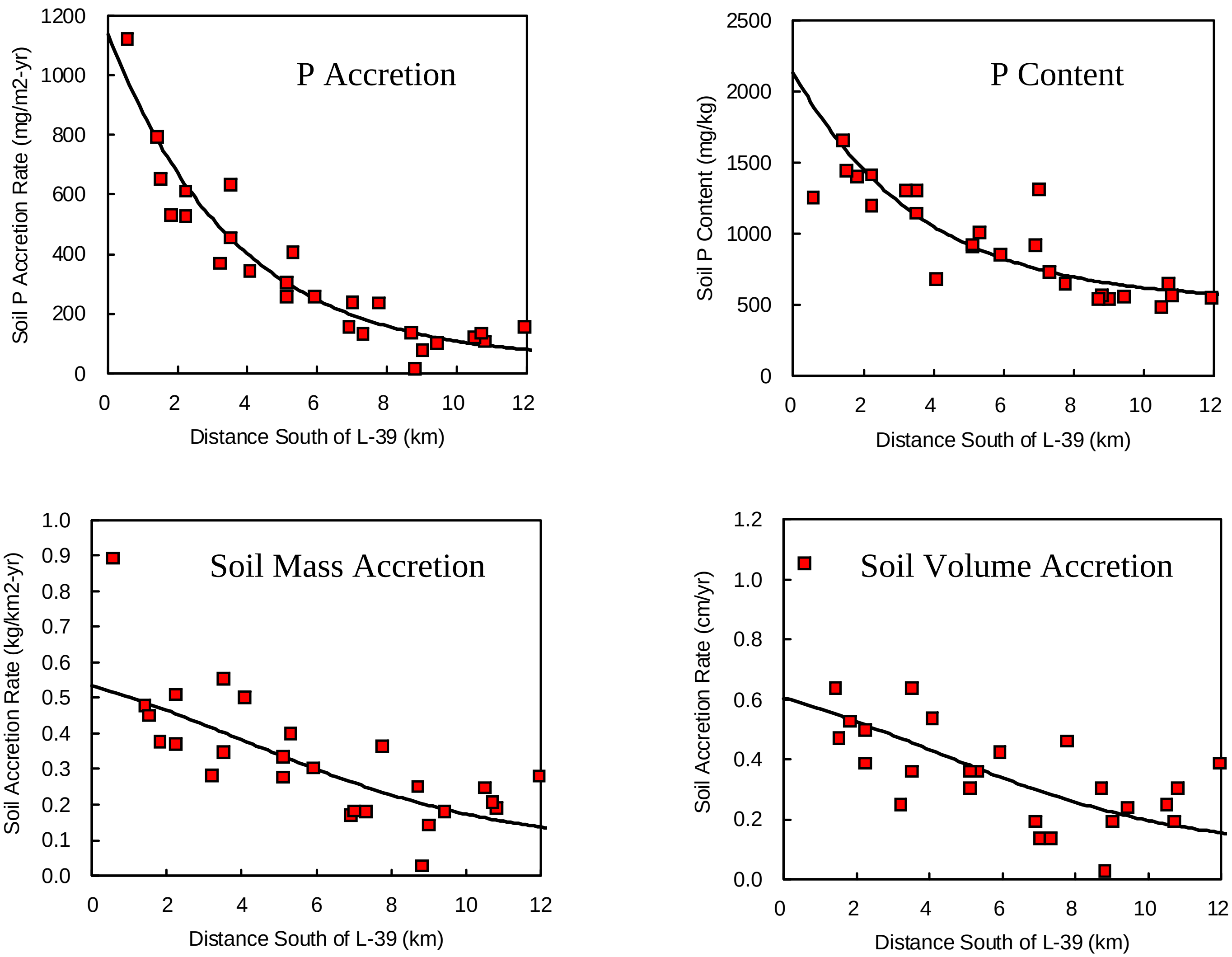
Soil P Accretion vs. Water TP



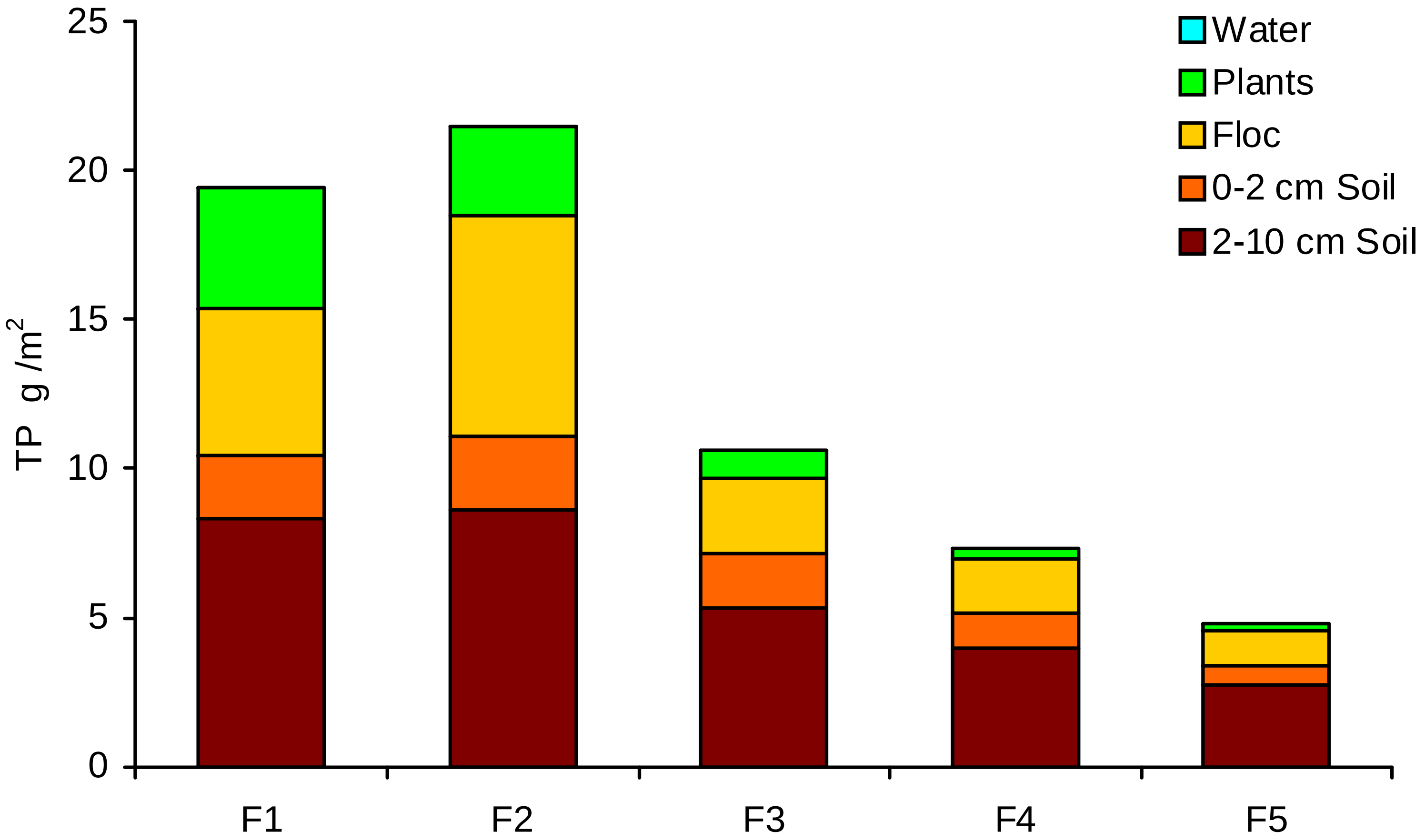
Soil P Content vs. Accretion Rate



EPGM Simulation of WCA-2A - 1991
Gradients in Soil P Content & Accretion Rates

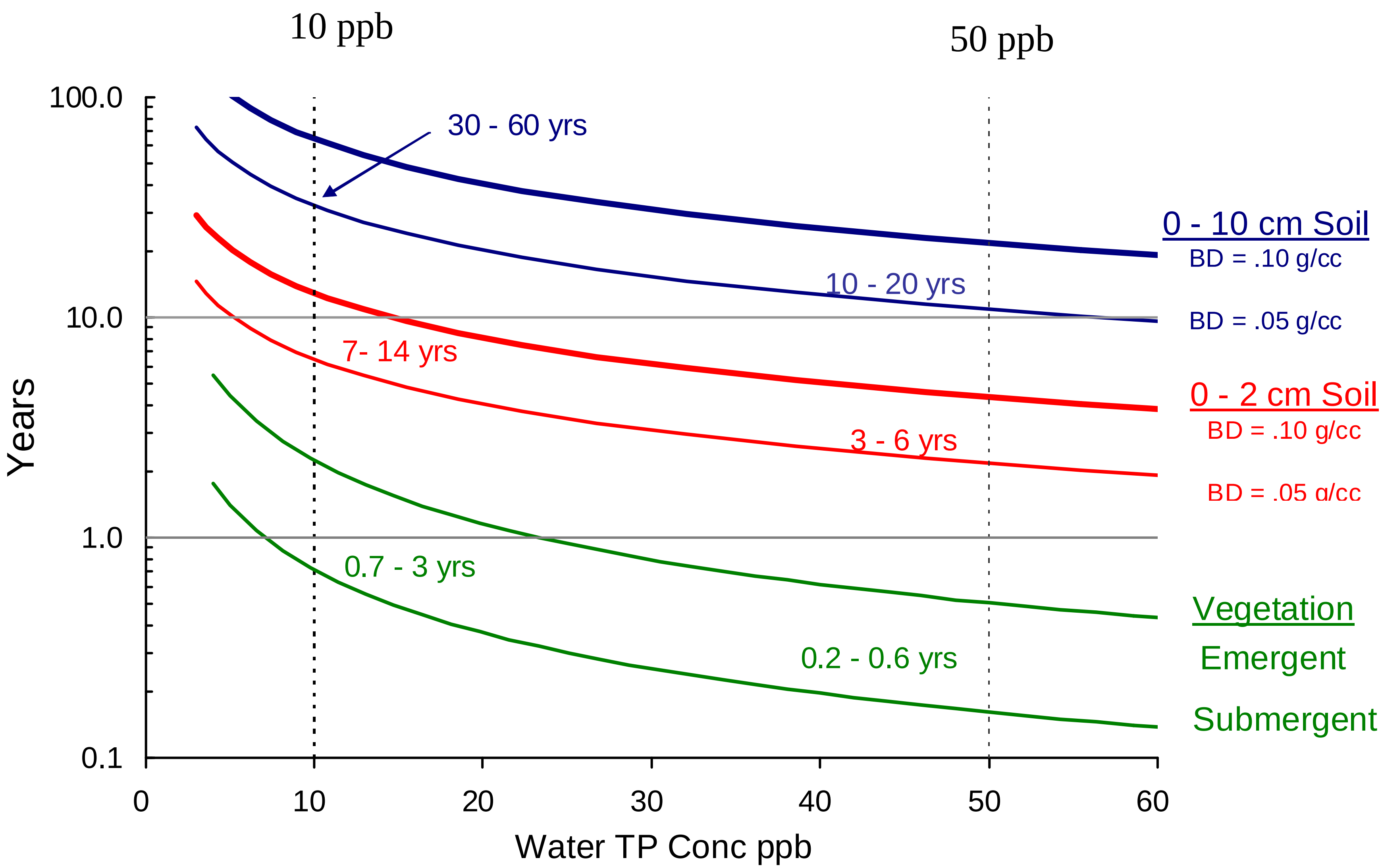


TP Storage in WCA-2A, 1996-2006

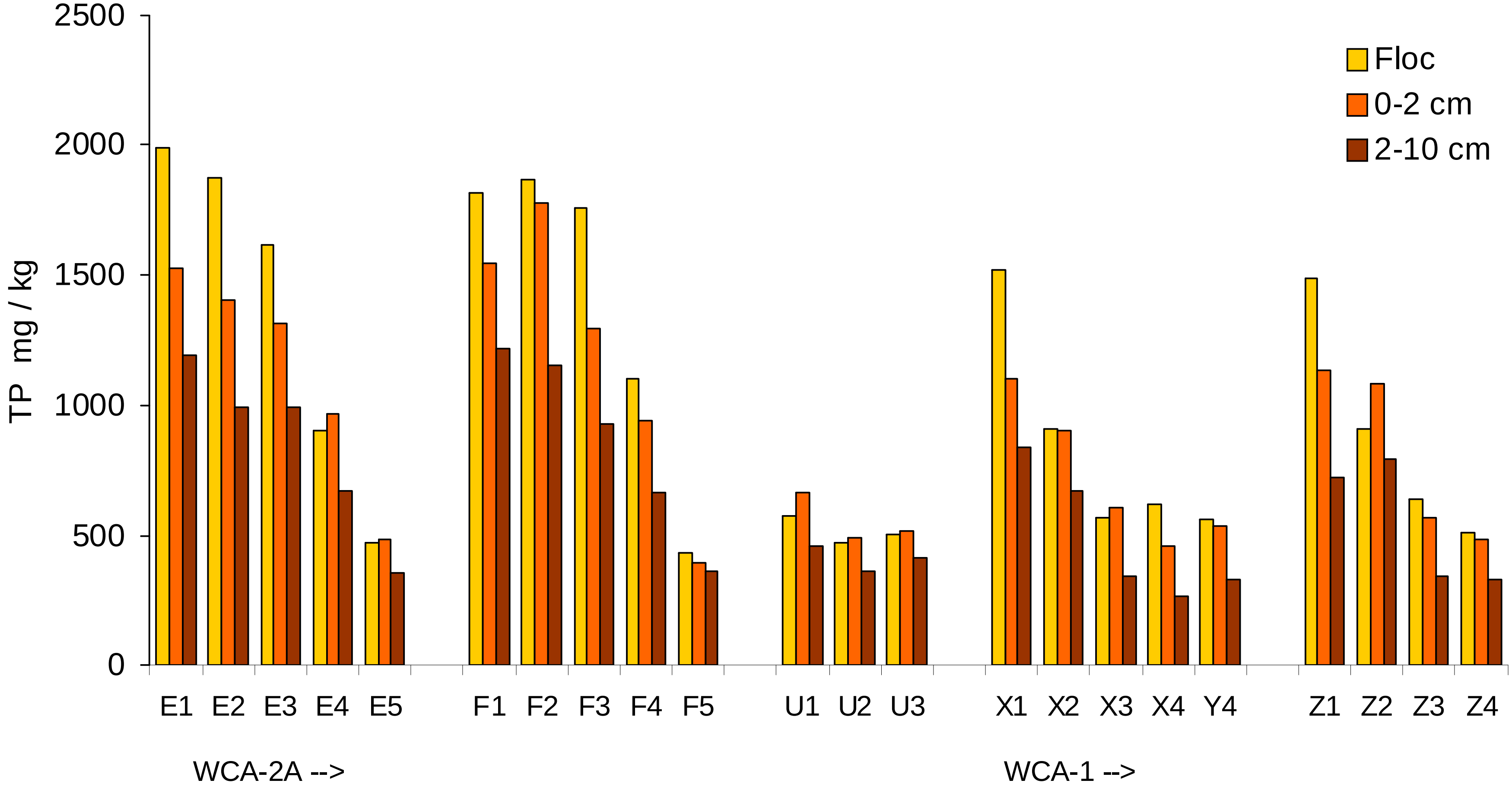


SFWMD Research Transects, 1996-2006
Plant Storage Estimated From DMSTA Calibration
TP Conc. Range ~80 to 8 ppb, Water TP Storage ~ 0.004 to 0.04 g/m^2

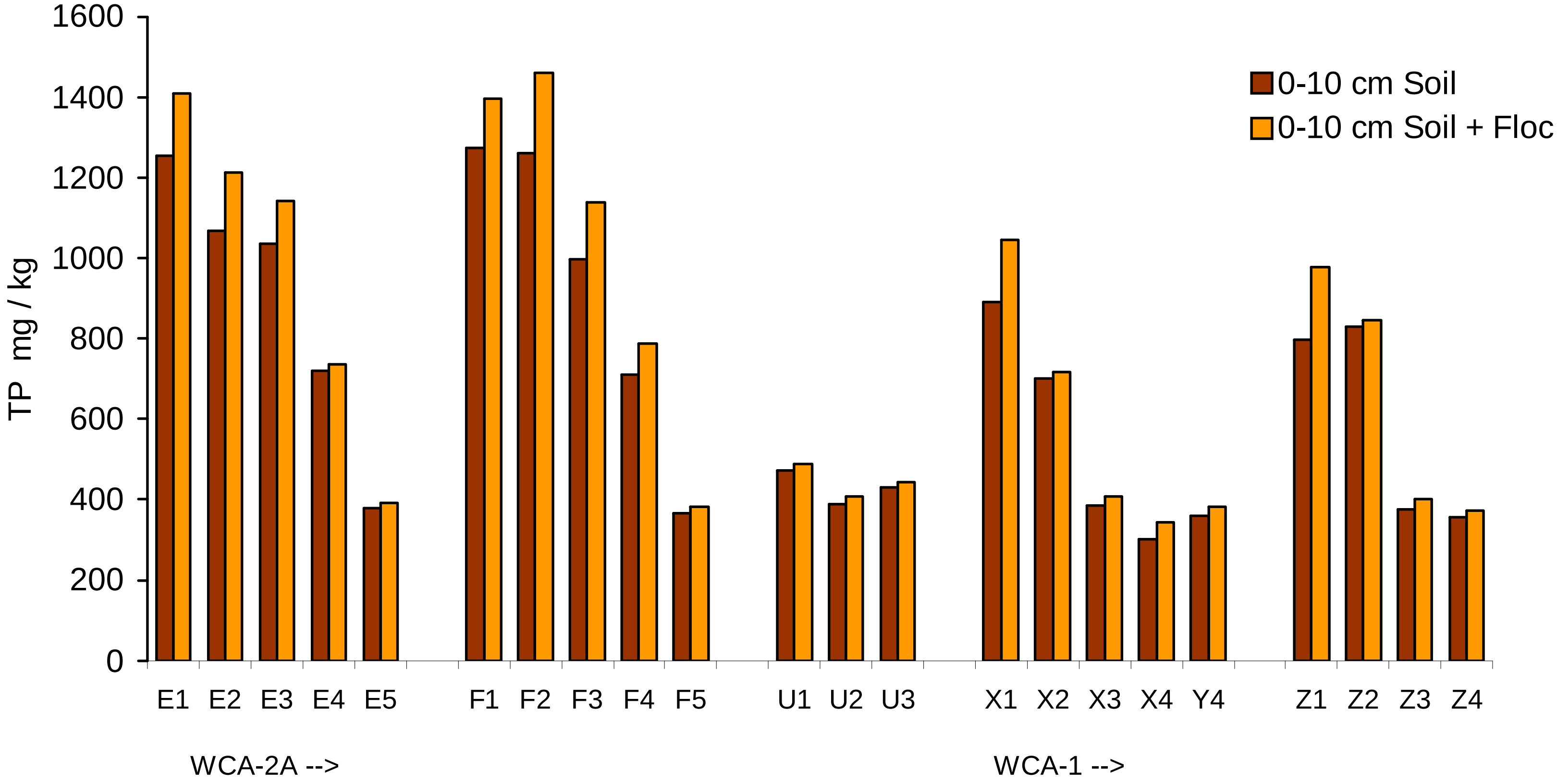
Time Scales of P Storage in Soil & Vegetation
Based upon DMSTA & EPGM Calibrations



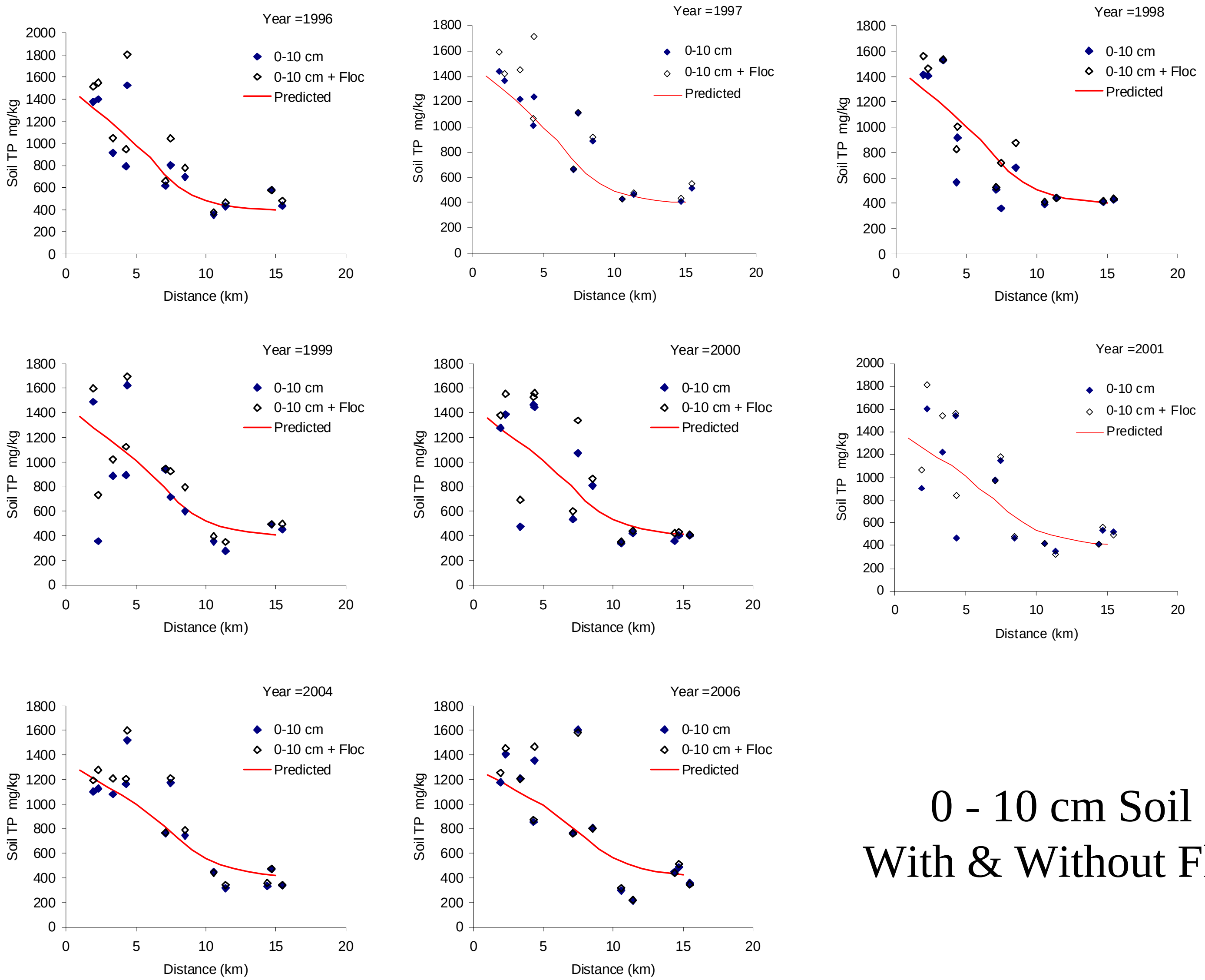
Soil P Contents vs. Depth Increments
SFWMD Research Transects, 1996-2006



Effect of Including Floc on 0-10 cm Soil TP
SFWMD Research Transects, 1996-2006

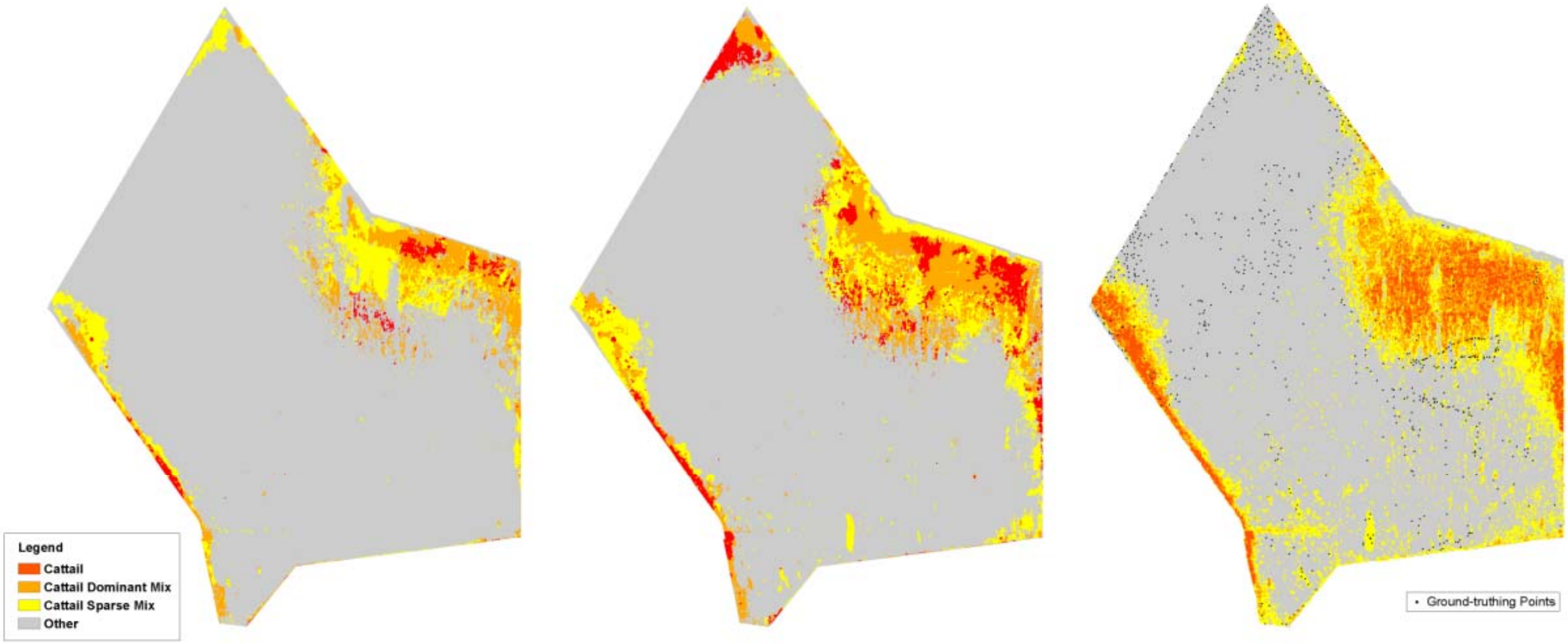


Coupled DMSTA/EPGM Simulation of Soil TP Gradients SFWMD Research Transects in WCA-2A, 1996-2006



0 - 10 cm Soil
With & Without Floc

Water Conservation Area 2A Cattail Trend Analysis 1991 - 2003



1991

1995

2003

N

Everglades Division

Time series trend analysis of cattail (Typha spp.) within Water Conservation Area 2A (WCA-2A) was performed utilizing 1:24,000 scale color infrared aerial photography captured in 1991, 1995 and 2003. Each cattail map was generated utilizing stereo photointerpretation techniques. The 1991 and 1995 cattail maps were delineated using a vector system with a minimum mapping unit of one acre. (Further discussion of 1991 and 1995 maps can be found in the February 1999 journal of Photogrammetric Engineering & Remote Sensing.) The 2003 cattail map was compiled utilizing a quarter hectare (50 x 50 meter) grid method constituting a minimum mapping unit of 0.6 acres. The quarter hectare grid was generated and superimposed over the 2003 aerial photography, resulting in 170,500 individual grid cells covering all of WCA-2A. Vegetation within each individual grid cell was observed on the aerial photography utilizing a Leica SD2000 stereo-plotter. Cattail cover was estimated for each grid cell and assigned one of four possible categories. The categories of this classification are: "cattail monotypic" (greater than or equal to 90% cattail), "cattail dominant mix" (50% - 89% cattail), "cattail sparse mix" (10% - 49% cattail), or"other" (less than 10% cattail). For ground-truthing, seven hundred and forty-two locations within WCA-2A were visited using differential GPS navigation by airboat or helicopter. These points where determined to be areas in question or "unknown" during the photointerpretation process.

Advantages of the grid system mapping include greater time and cost efficiency and the unique ability to classify vegetation within the same quarter hectare grid cells from this analysis during future mapping efforts. This allows for the past, present and future analysis of each individual quarter hectare of the entire area under study. In addition, the grid system more accurately models the overall heterogeneity of Everglades vegetation.

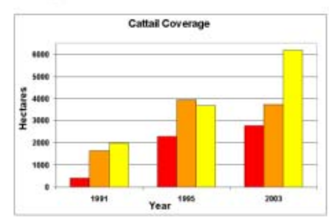
Results show that cattail continues to spread throughout WCA-2A, with monotypic cattail patches expanding throughout the eastern portion of the impoundment and along the southwestern boundary. In addition, sparse cattail continues to spread along distinct cattail-sawgrass boundaries and throughout the southern regions of WCA-2A. The rate of spread appears to be slowing down, however, when compared to the 1991-1995 period. This decrease in rate may be due to the reduction in total phosphorous load that went into the impoundment on a yearly basis during the 1995 to 2003 period. Excess nutrients, hydrologic alterations, invasive habitat availability, and fire have been shown to influence successful establishment of cattail in the Everglades. The relative importance of these factors influencing cattail coverage in WCA-2A from 1995 to 2003 still needs to be determined. One positive observation at the northern tip of WCA-2A is an actual loss of cattail. It is hypothesized that the loss of cattail in this area is due to a combination of events including fire, a reduction in phosphorous loading, and water levels with the closing of structure S10E in 1996. Structure S10E regulates water flow from the Hillsboro Canal into northern WCA-2A.

Ted Schall, Ken Rutchey, and Matt Love of the Everglades Division at the South Florida Water Management District compiled this latest 2003 cattail vegetation map. For additional information contact Ken Rutchey at (561) 682-6618 or email at krutchey@sfwmd.gov.

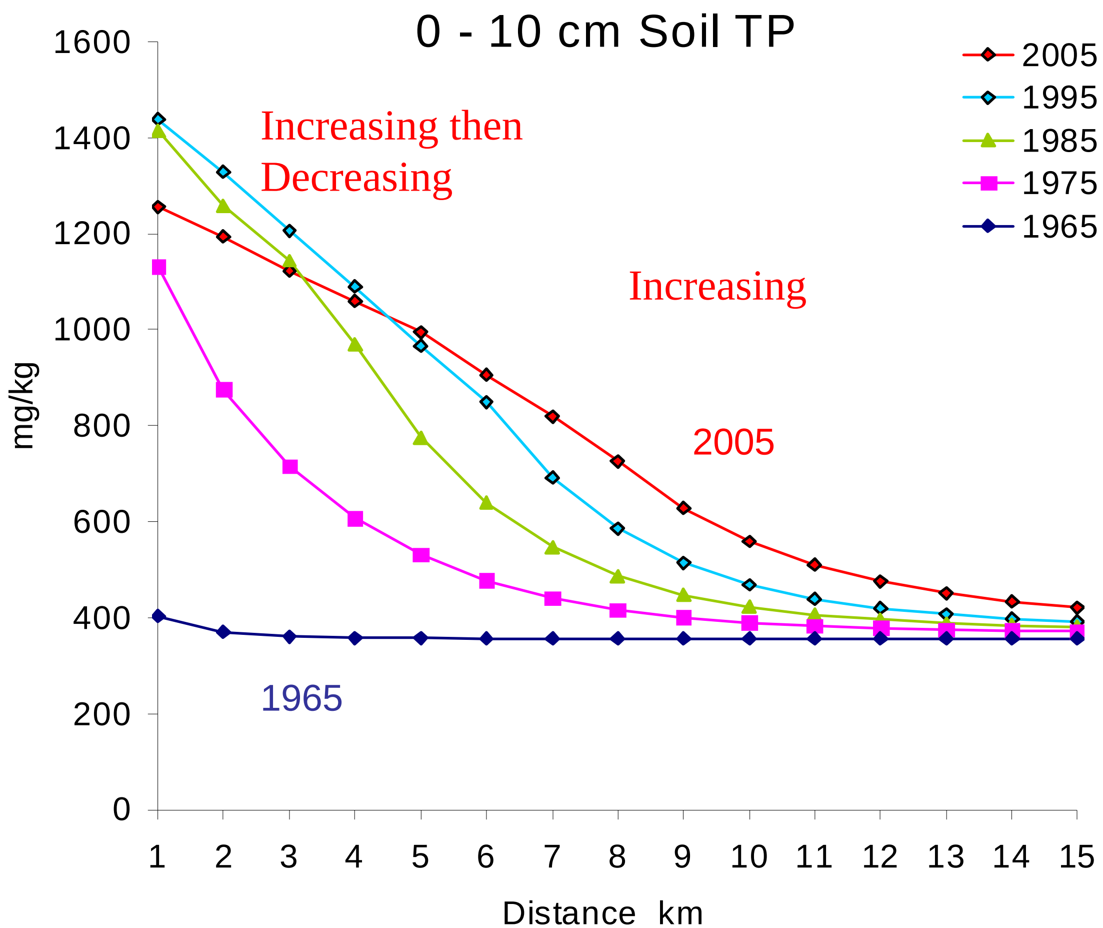
Cattail Coverage of Each Sampling Date

	Cattail	Cattail Dominant Mix	Cattail Sparse Mix	Other	Total Cattail
1991	421.6	2287.3	2760.9	36528.6	5469.8
1995	1646.3	3944.0	3721.7	32686.5	9312.0
2003	1982.5	3680.0	6191.5	30164.5	11854.0

* Coverage is in hectares

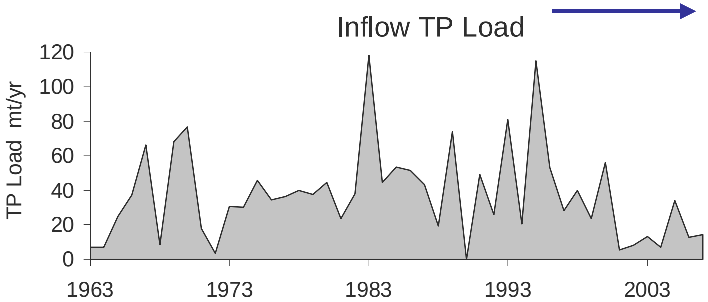


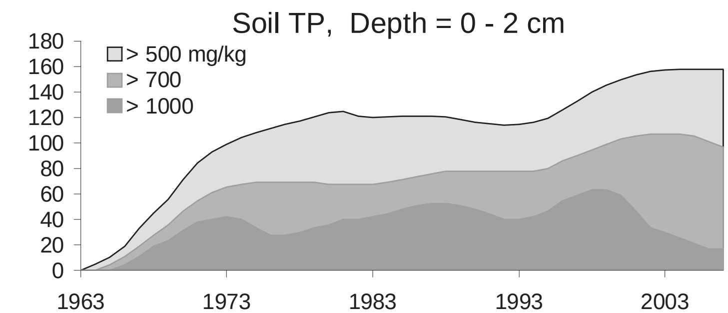
Simulated Historical P Gradients in WCA-2A, 1965-2005

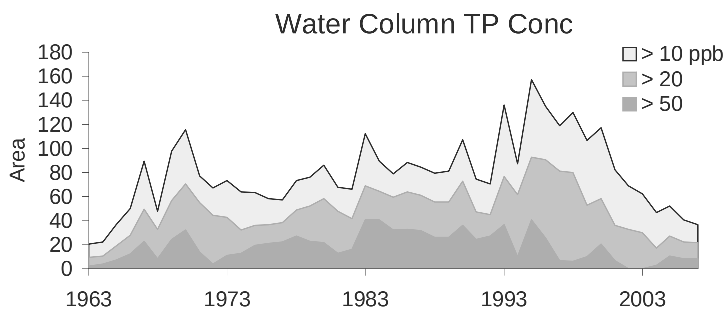


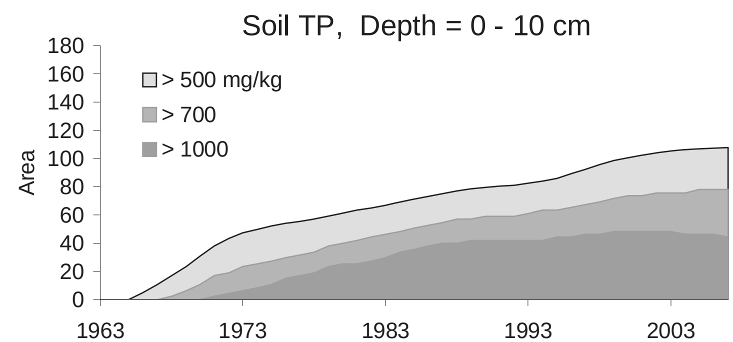
WCA-2A Simulation, 1963 - 2007
Areas Exceeding Water & Soil P Criteria

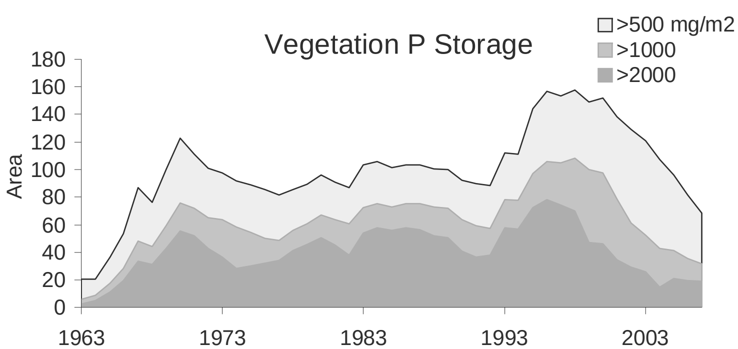
Decreasing Rainfall & P Load

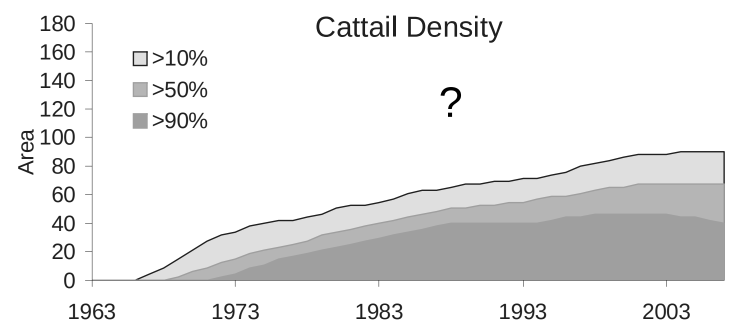




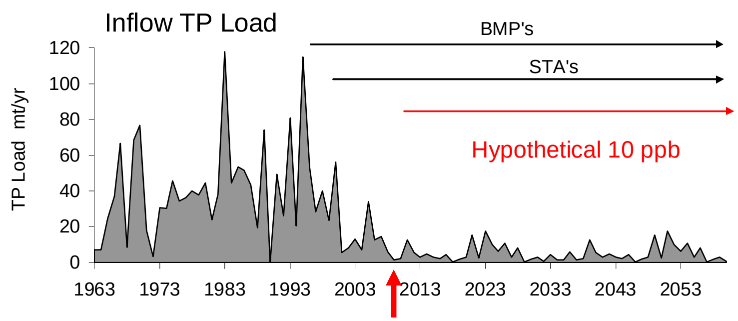


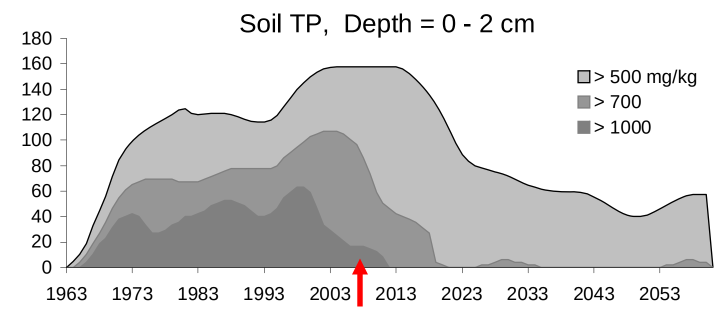


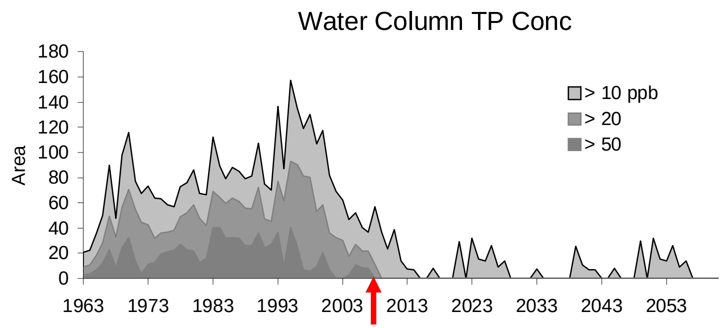


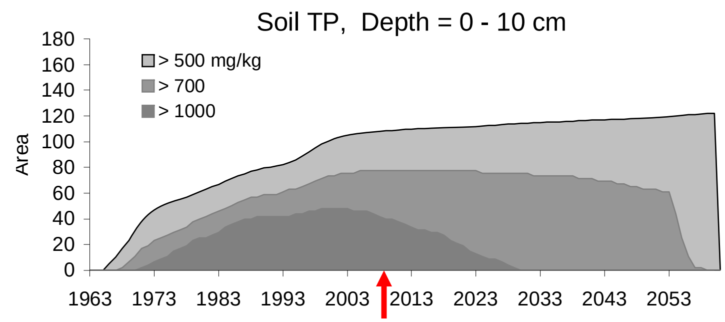


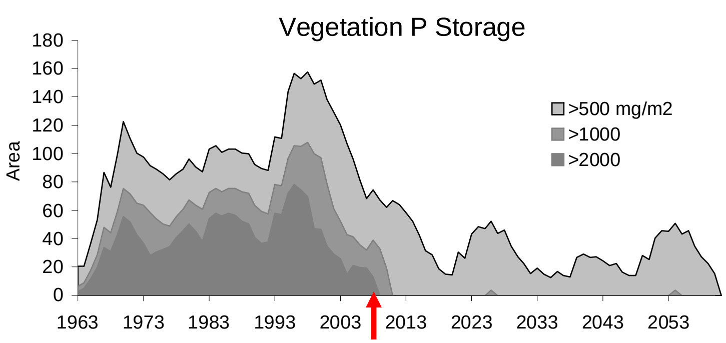
"Taking Her Out for a Spin"
100-Year Simulation of WCA-2A – Restoration Scenario
Areas Exceeding Water & Soil P Criteria

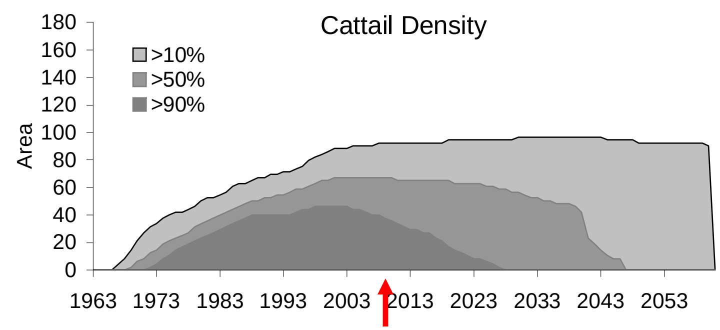












Model Explicit Factors

- Water & Mass Balance
- Inflow Volumes & Loads
- Rainfall, ET, Seepage
- Depths / Hydraulics
- Community Types
- P Uptake by Vegetation/Floc
- P Recycle from Veg/Floc
- Net P Accretion in Soils

Implicit Factors Embedded in Calibrations

- Phosphorus Speciation
- Calcium
- Topographic Variations
- Non-Ideal Flow
- Particle / Floc Transport
- STA Startup Transients
- Community Transition
- Plant Uptake from Soil
- P Release from Soil
- Vertical Transport of P within Soil

Data & Research Needs to Support Modeling

- Continue / Expand Marsh Transects
- Dated Sediment Cores
- Consistent Soil Sampling Methods vs. Yrs, Investigators, & Sites
- Soil P Criteria for Ecological Impact (Depth Interval, Speciation, Conc. Levels) to Track Restoration Progress
- The 0-10 cm / 400-500 mg/kg Criteria Reflect Historical Conditions, but are "Ambitious" Goals with Very Long Time Scales.
- Floc Characterization & Transport
- Soil P Reflux Studies
- Impact of Calcium on P Cycling Parameters
- Differences in Treatment Efficiency - Lake Okee vs. EAA Runoff
- Several others….