



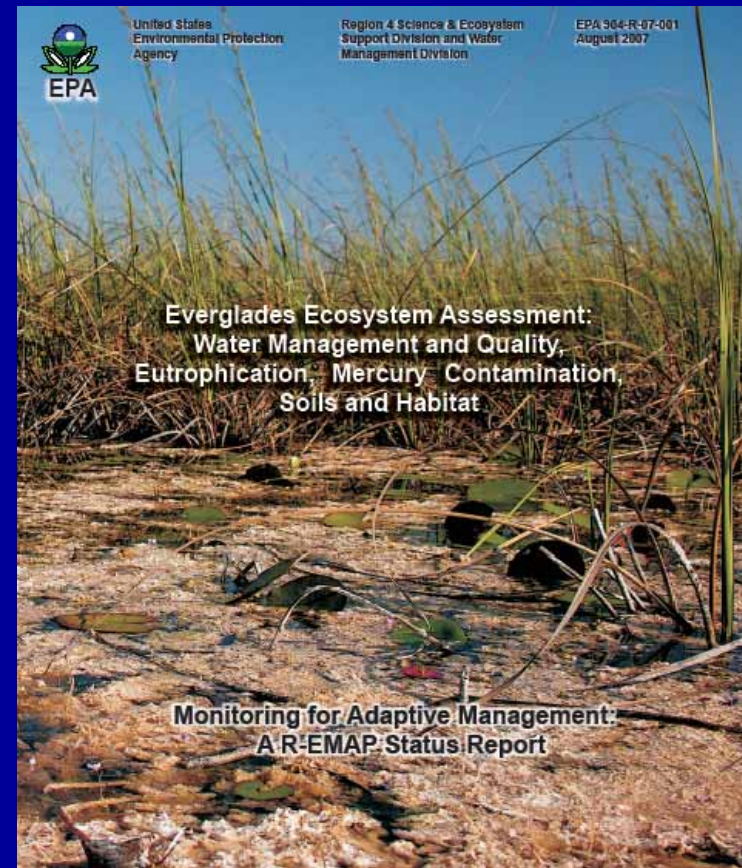
# R-EMAP: Phosphorus and sulfur landscape patterns and temporal trends

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Scheidt and Kalla 2007. <http://www.epa.gov/region4/sesd/reports/epa904r07001.html>

# R-EMAP Sampling 1993-2005

EMAP probability-based  
design

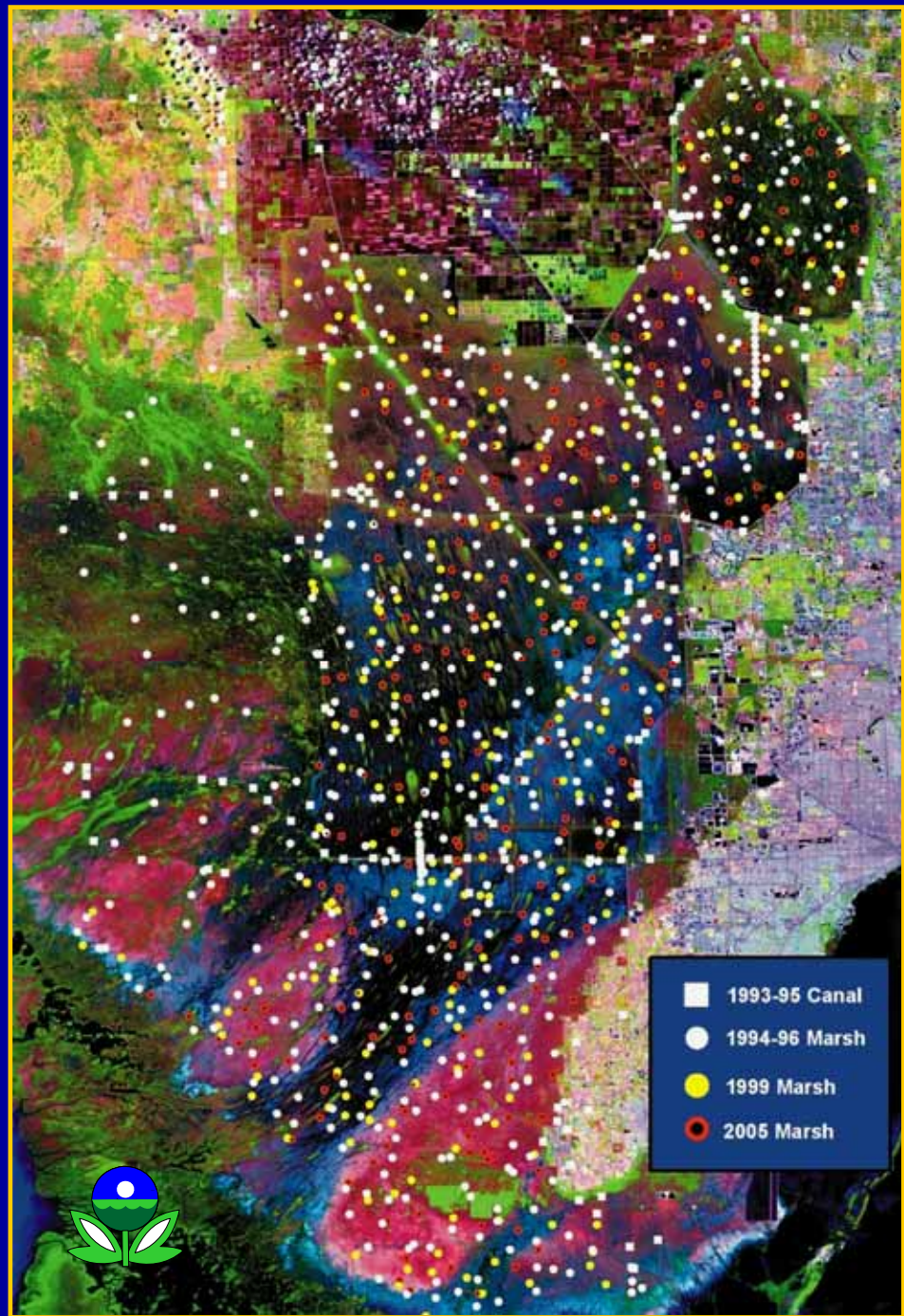
Canal = 1993-95

Marsh = 1995-96; 1999; 2005

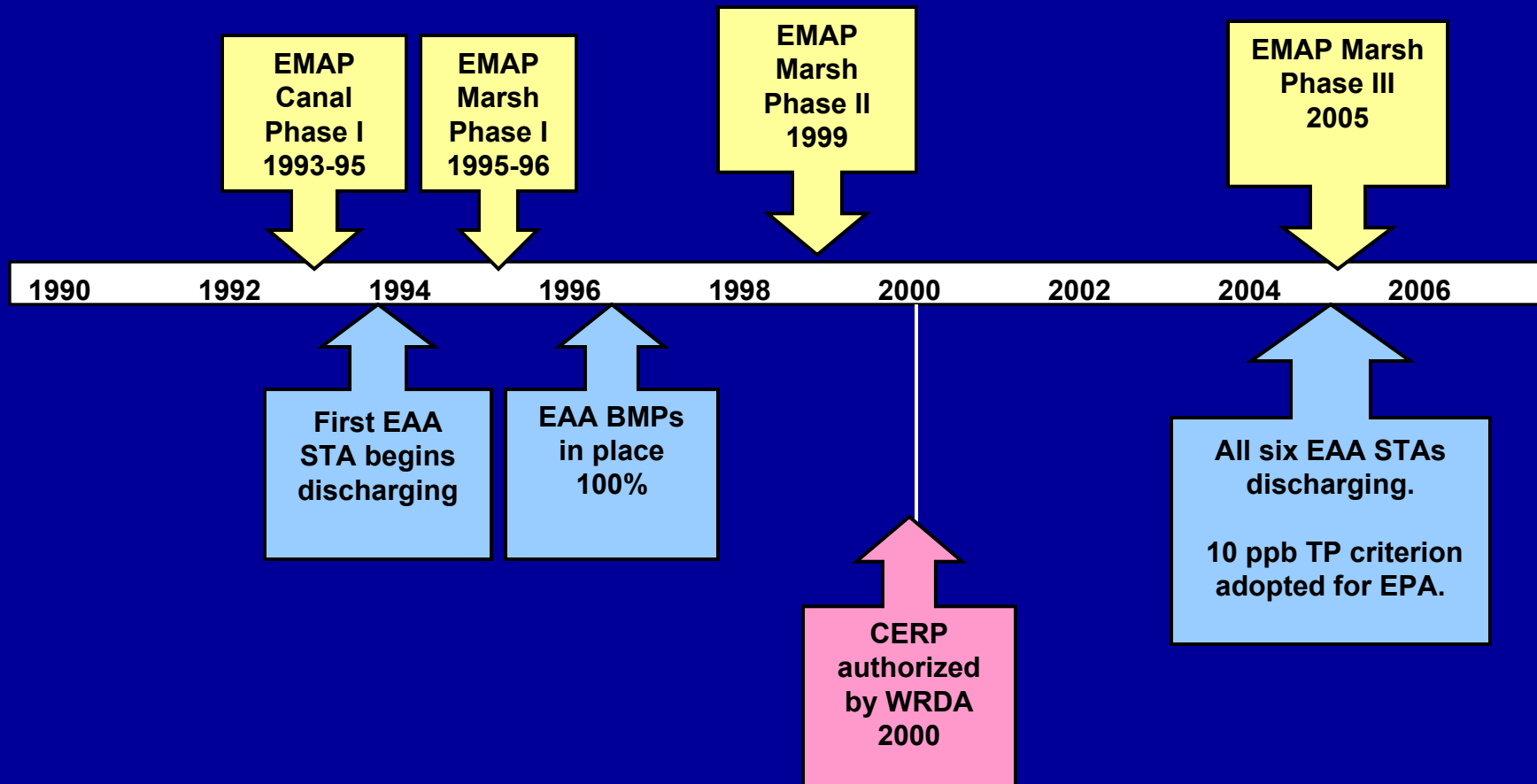
1145 Distinct Sample Sites,  
990 marsh sites

~ biogeochemistry  
(~100,000 data values);  
periphyton; macrophytes;  
community ecology

~\$6M investment to date;  
CERP > \$11 billion



# R-EMAP program timeline & restoration milestones



**PHOSPHORUS**

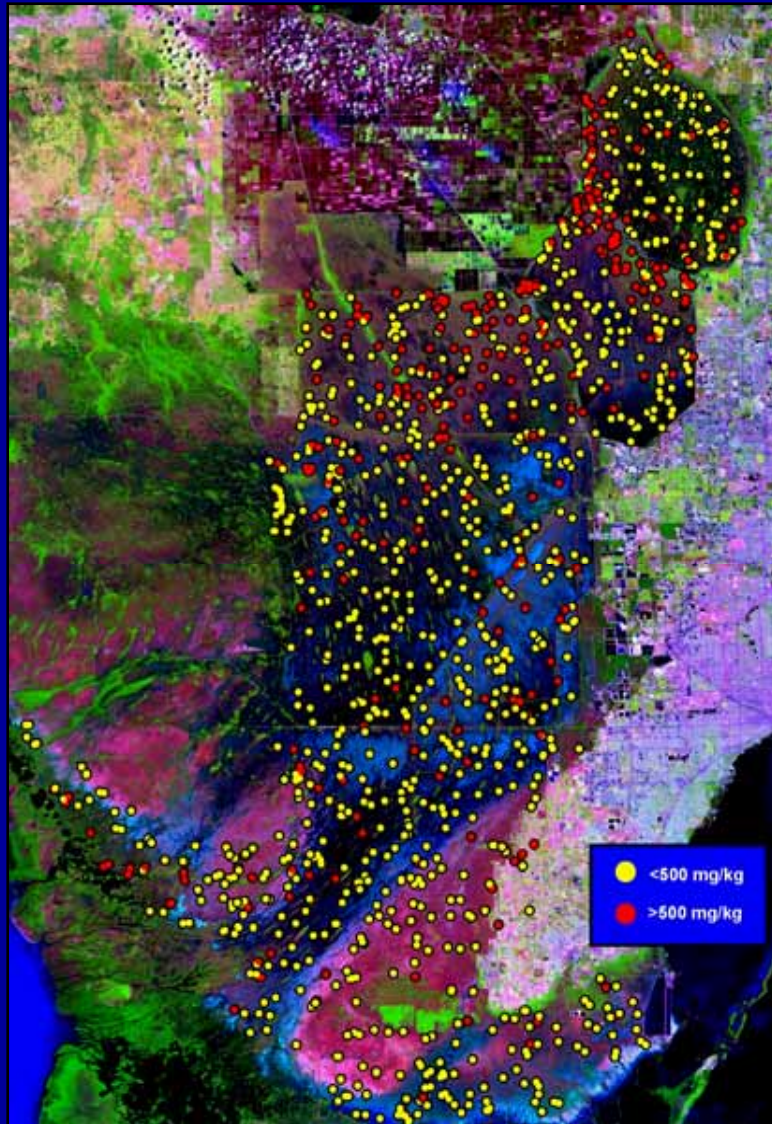
# Soil sampling



- 3 inch inner diameter clear polycarbonate core
- 0 – 10 cm soil
- Separate soil, floc, benthic periphyton
- Triplicate cores at all sites



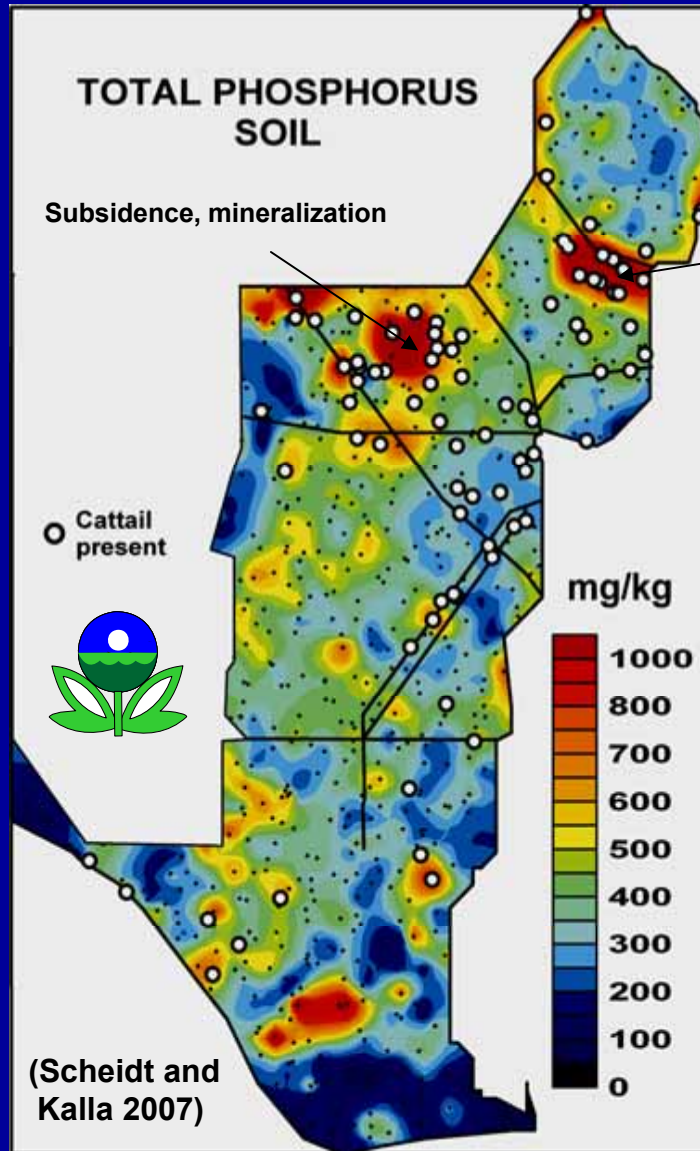
# Total Phosphorus in Soil 2003-2005



- **N = 1270**
  - USEPA R-EMAP
  - UF/SFWMD Everglades Soil Mapping Project
  - STA 404 permit transects
- **Florida definition of P-impacted for Everglades: >500 mg/kg, 0–10 cm**

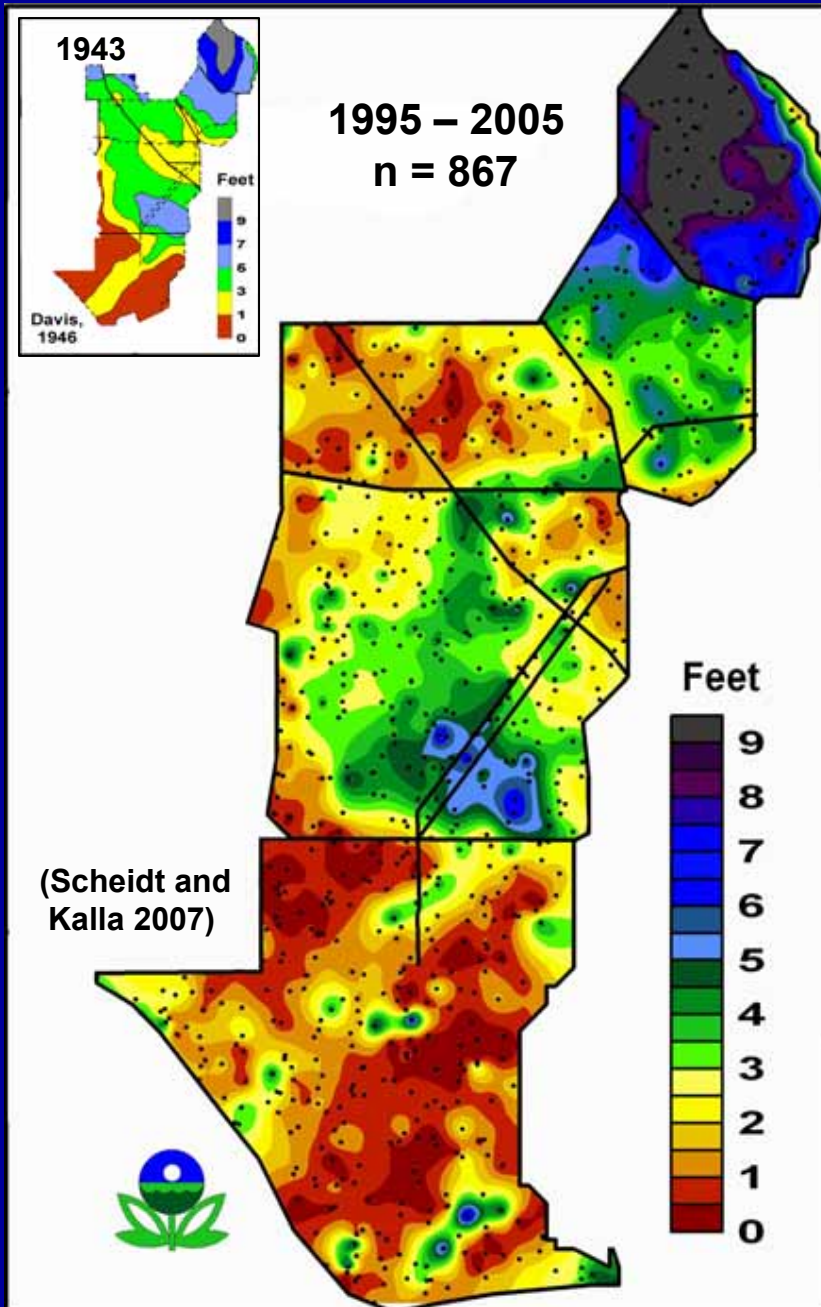


# Total Phosphorus in Soil



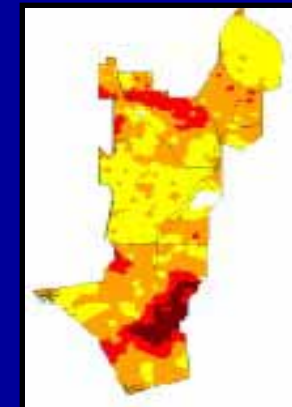
Anthropogenic eutrophication

- Cattail present at 19 % of stations in 2005



## R-EMAP Soil Thickness

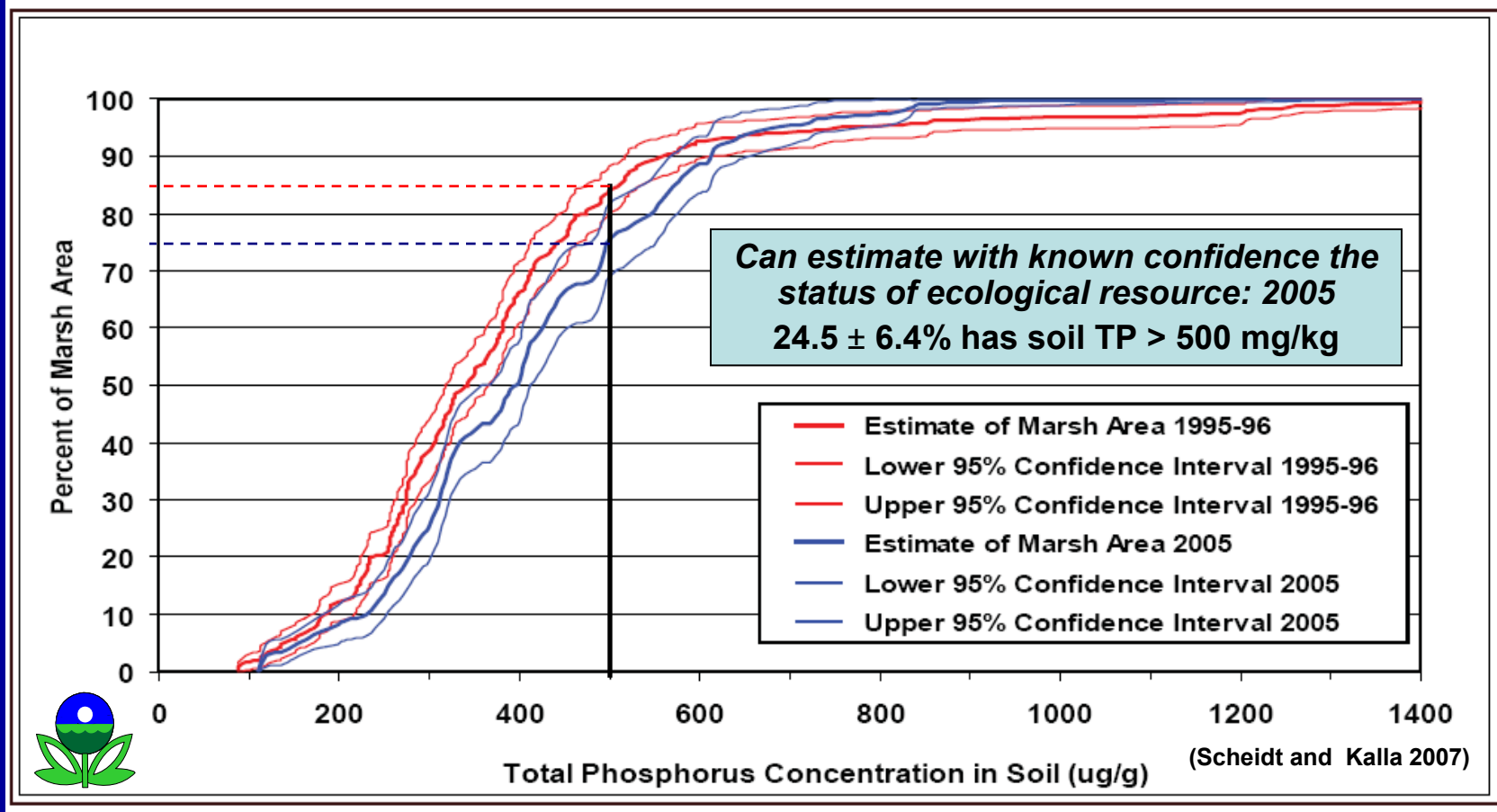
- 867 sample sites
- Only database since the 1940s
- ~ 25.1% +/- 2.0% of the EPA has soil < 1 foot, 36.1% +/- 2.1% > 3 feet.
- Median 2.3 feet
- **From 1946 to 1996 northern WCA3A lost 39% to 69% of its soil.**
- **Soil subsidence associated with dry conditions, decreasing organic content, vegetation change.**
- No change since 1995/96
- Peat fire risk (SFWMD 2002):





# Total Phosphorus in Soil

## Wet Season 1995/96 vs. 2005



# R-EMAP Findings in the EPA

- **Soil Phosphorus**
  - 1995-96 impacted area
    - 16.3 ( $\pm 4.1\%$ ) > 500 mg/kg FAC
    - 33.7 ( $\pm 5.4\%$ ) > 400 mg/kg CERP restoration goal.
  - 2005 impacted area
    - 24.5 ( $\pm 6.4\%$ ) > 500 mg/kg FAC
    - 49.3 ( $\pm 7.1\%$ ) > 400 mg/kg CERP goal

# Increasing Soil Phosphorus

- EPA 2005 soil TP distribution (median 390 mg/kg) > 1995-96 TP distribution (median 343 mg/kg). Significant increase.
  - [P < 0.05, Wald, mean Eigenvalue, Satterthwaite]
- WCA 2 1990 vs. 1998
  - (UF/SFWMD Grunwald et al. 2004)
- WCA 3 1992 vs. 2003
  - (UF/SFWMD Bruland et al. 2007)
- WCA1 WCA2 1989 vs. 1999
  - (FIU Childers et al. 2003)

WY05-07 geomean inflow TP ug/L (SFER 2008)

**ECP Basins:**

**STA-1E**

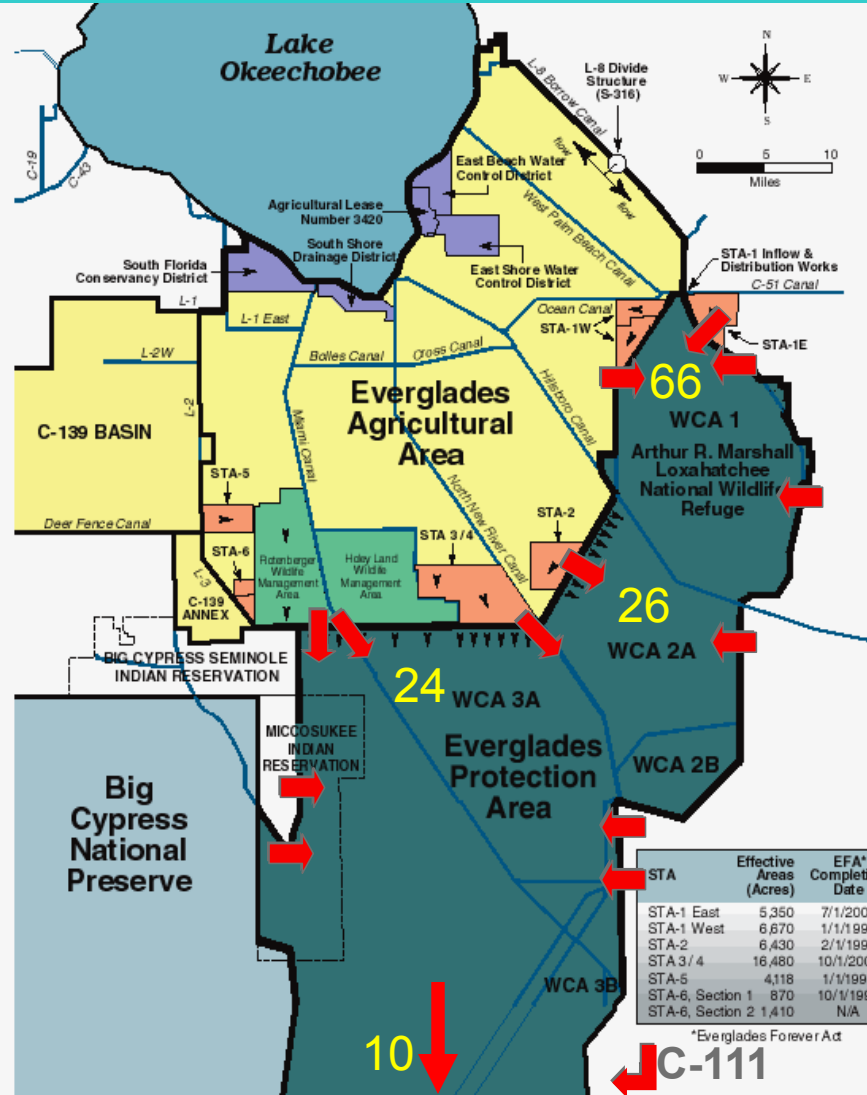
**STA-1W  
(incl. L-8)**

**STA-2**

**STA-3/4**

**STA-5**

**STA-6**



**ESP Basins:**

**ACME Basin  
"B"**

**North Springs  
Improvement  
District**

**North New  
River Canal  
(G-123)**

**C-11 West**

**L-28**

**Feeder Canal**

## Excess P into the Everglades

- WY 06: 63% TP from EAA removed
  - STAs retained 177 mt
  - EAA BMPs retained 117 mt
- 169 mt TP discharged into WCAs 1, 2, and 3
- If discharges equivalent to 10 ppb: 42 mt
- Excess TP  $169 - 42 = 127$  mt

**SULFUR**

# Sulfur Enrichment in the Everglades

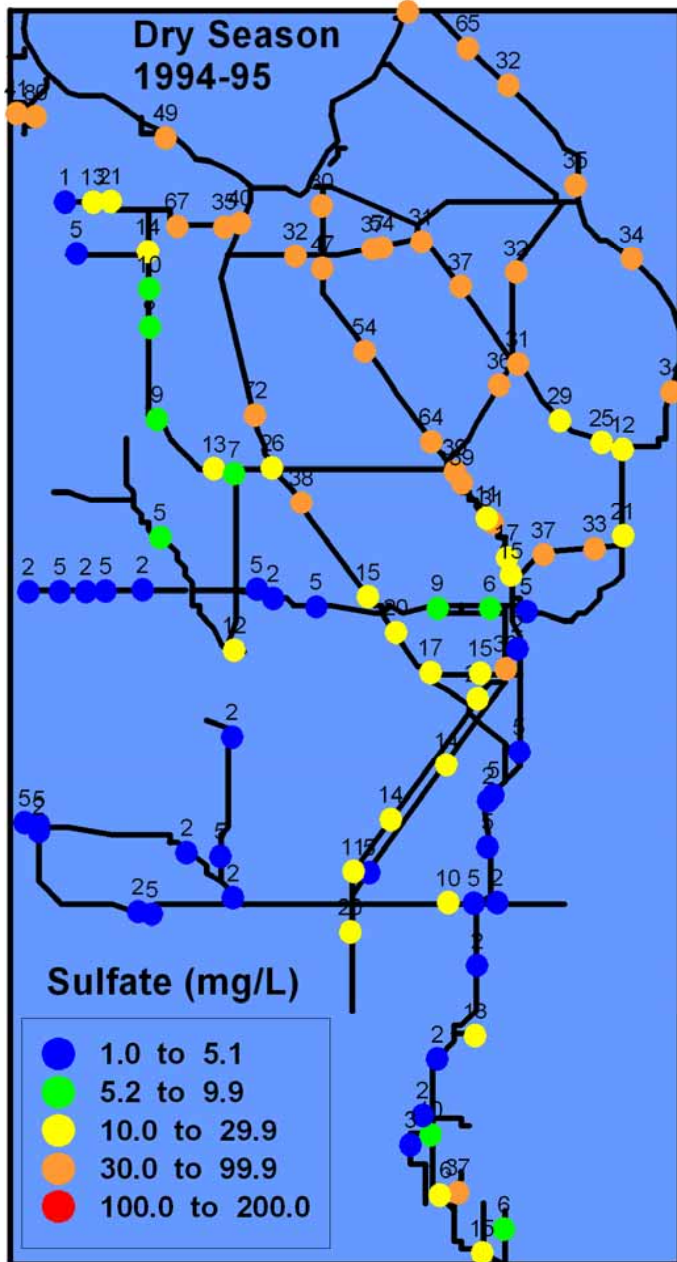
- **No numeric quality criteria in Florida, but FAC requires that substances “*which injure, are chronically toxic to, or produce adverse physiological or behavioral response in humans, plants or animals – none shall be present.*”**
- **Sulfate → sulfide when anaerobic**
- **Sulfide toxic to plants**
- **Some sulfate enhances mercury methylation. Excess sulfate, sulfide inhibit**
- **Sulfur can mobilize phosphorus**
- **Mineralization can impact Refuge soft water biota such as periphyton**

# Sulfur Enrichment in the Everglades

- Surface water sulfate varies spatially depending upon proximity to EAA and the relative contribution of rain water, stormwater and groundwater.
- Sulfate in stormwater discharges into Everglades up to 500 x marsh background. Seasonal.



# R-EMAP Canal Sulfate 1993-95

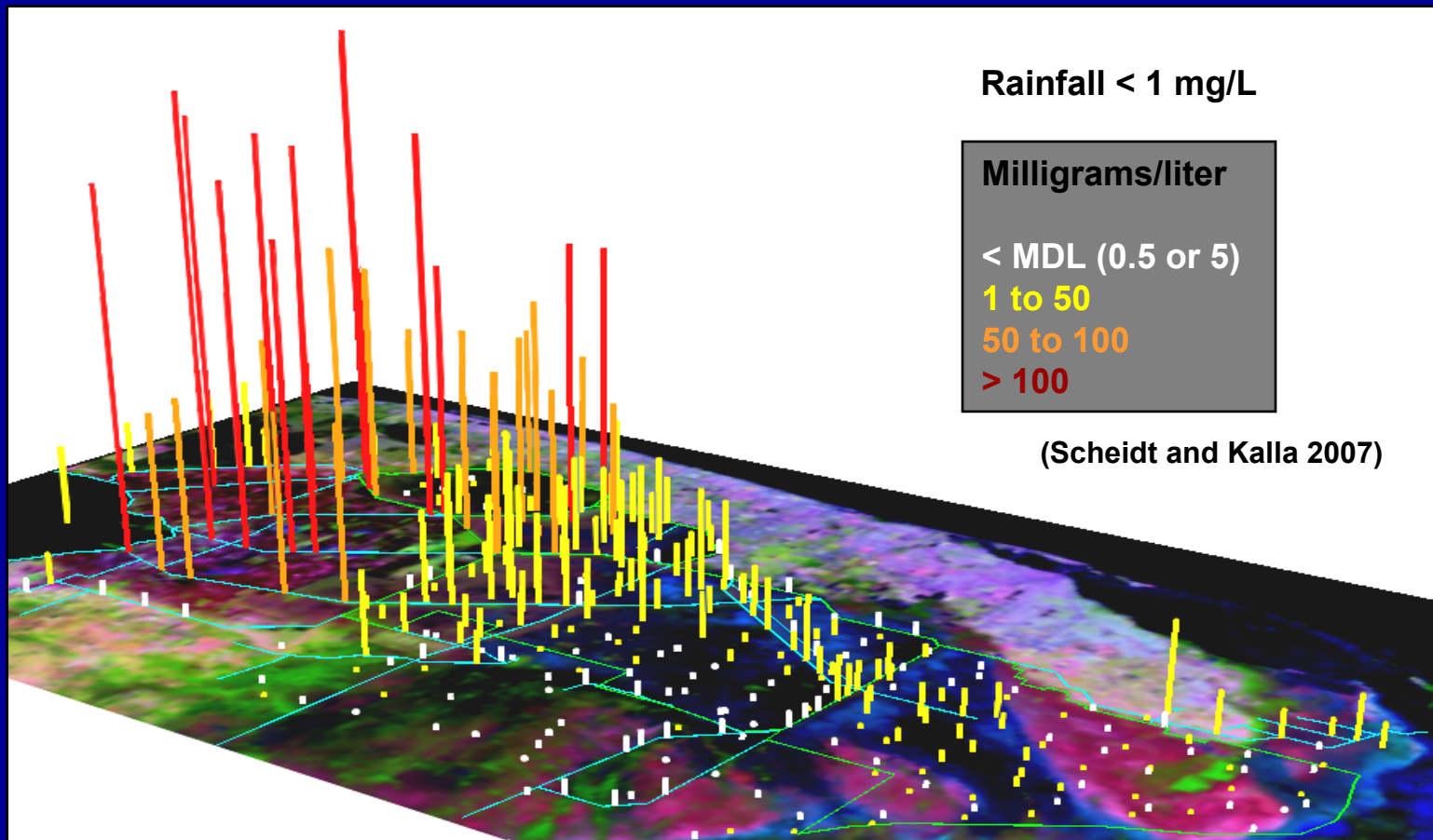


- Random probability-based locations
- Seasonality, gradients.
  - Eastern EAA highest
- Conductivity, C, P have similar pattern

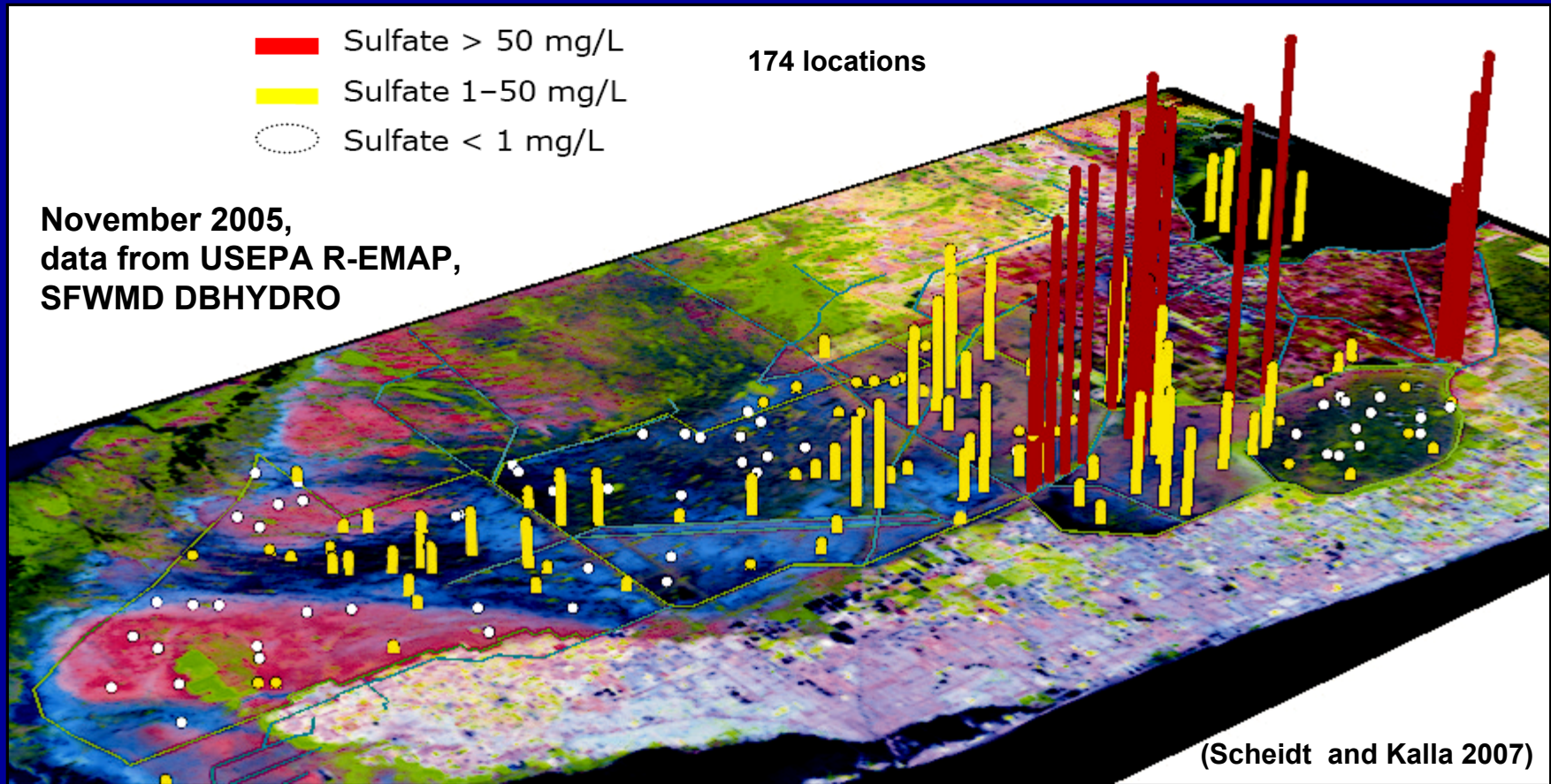


# Surface Water Sulfate 1993-96

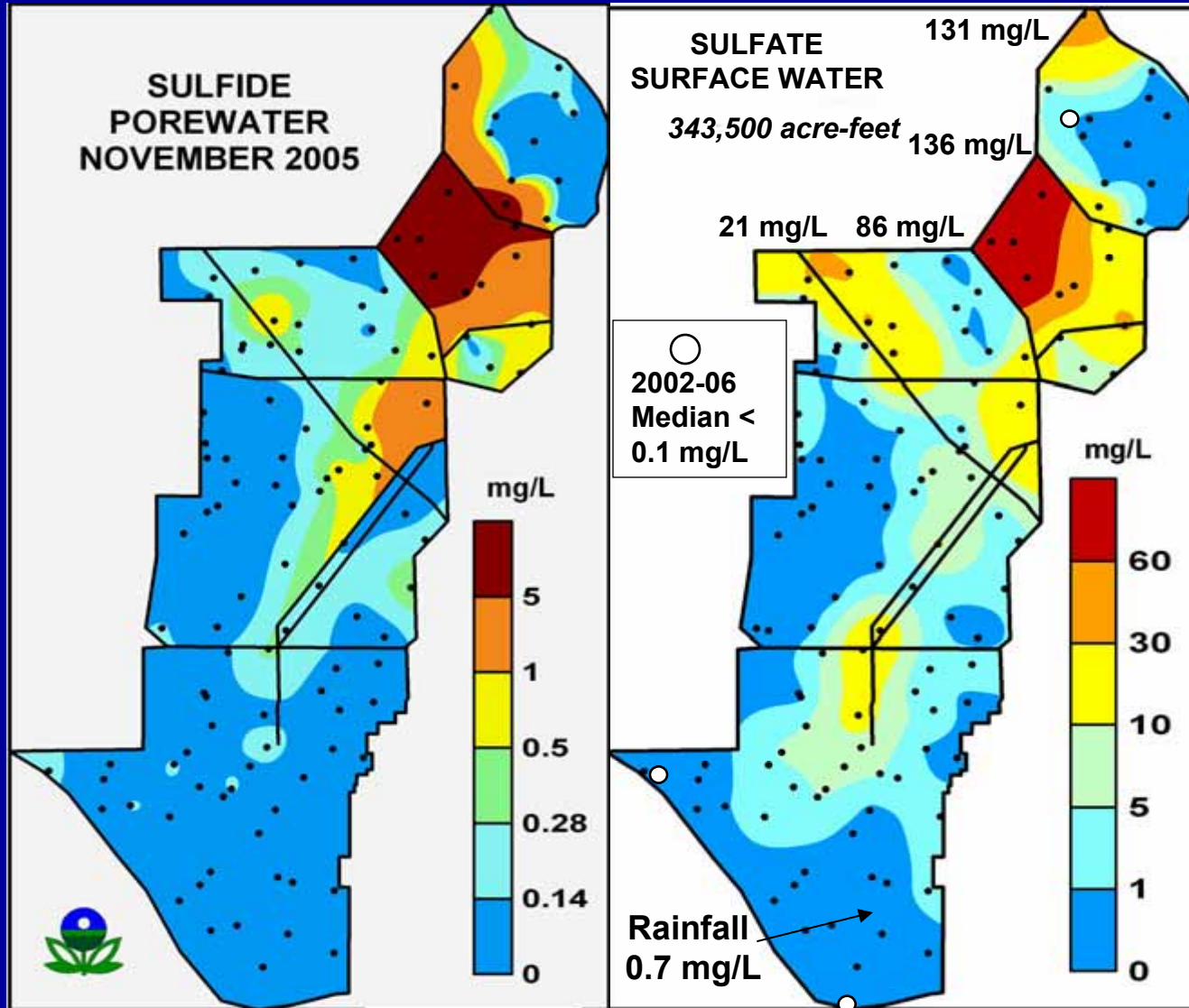
Wet Season



# Surface Water Sulfate 2005 Wet Season

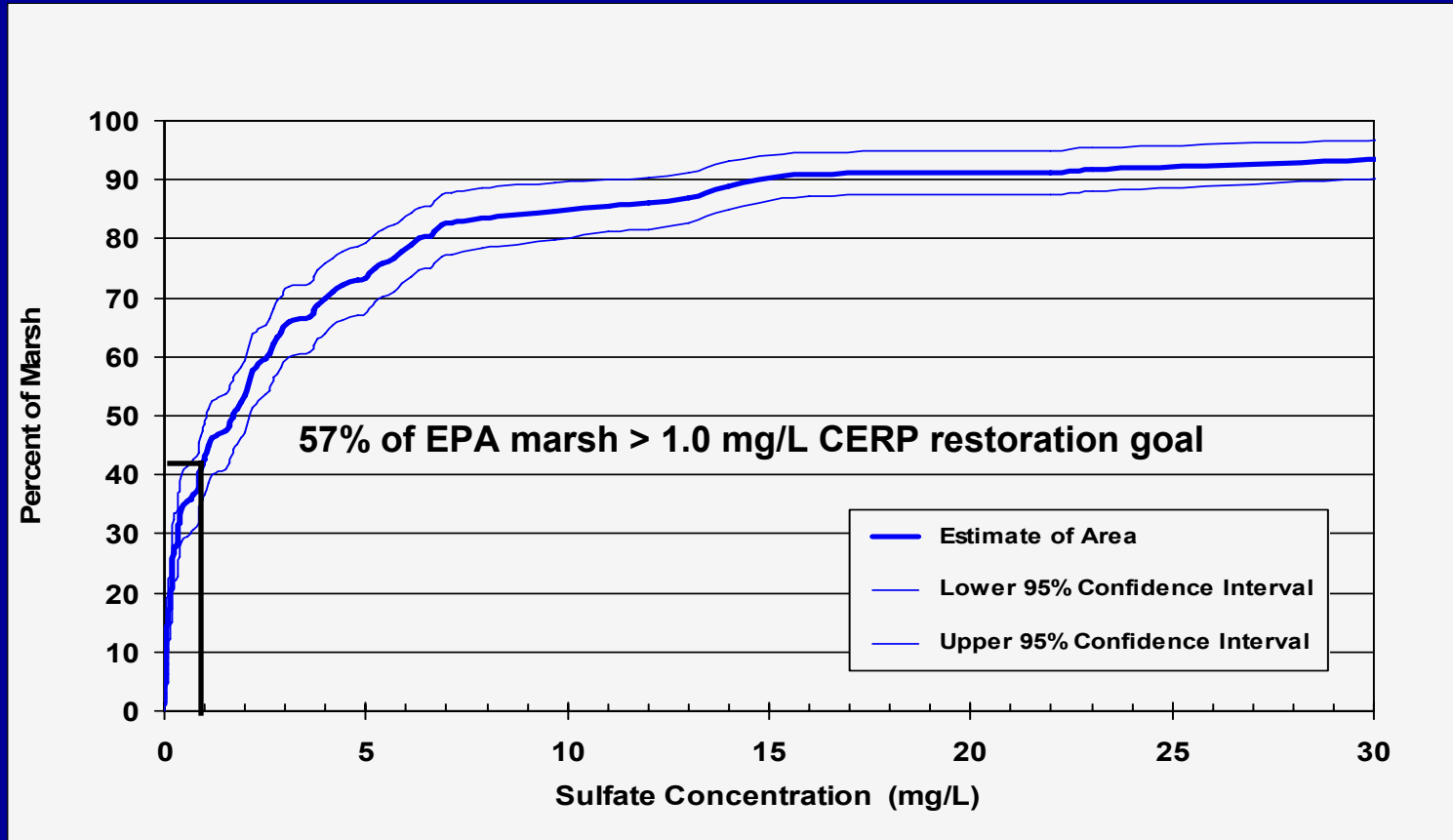


# Sulfide - Sulfate November 2005



(Scheidt and Kalla 2007)

# Surface Water Sulfate 2005 Wet Season



## Surface water sulfate

- 2005:  $57.3 \pm 6.0\%$  of EPA exceeded 1.0 mg/L CERP restoration goal. Background  $< 0.2$  mg/L.
- 1995:  $66.1 \pm 7.0\%$  exceeded 1.0 mg/L. Significant drop.
- Less stormwater. Stormwater inflow in 60 days prior to 2005 sampling 1/2 1995 sampling.

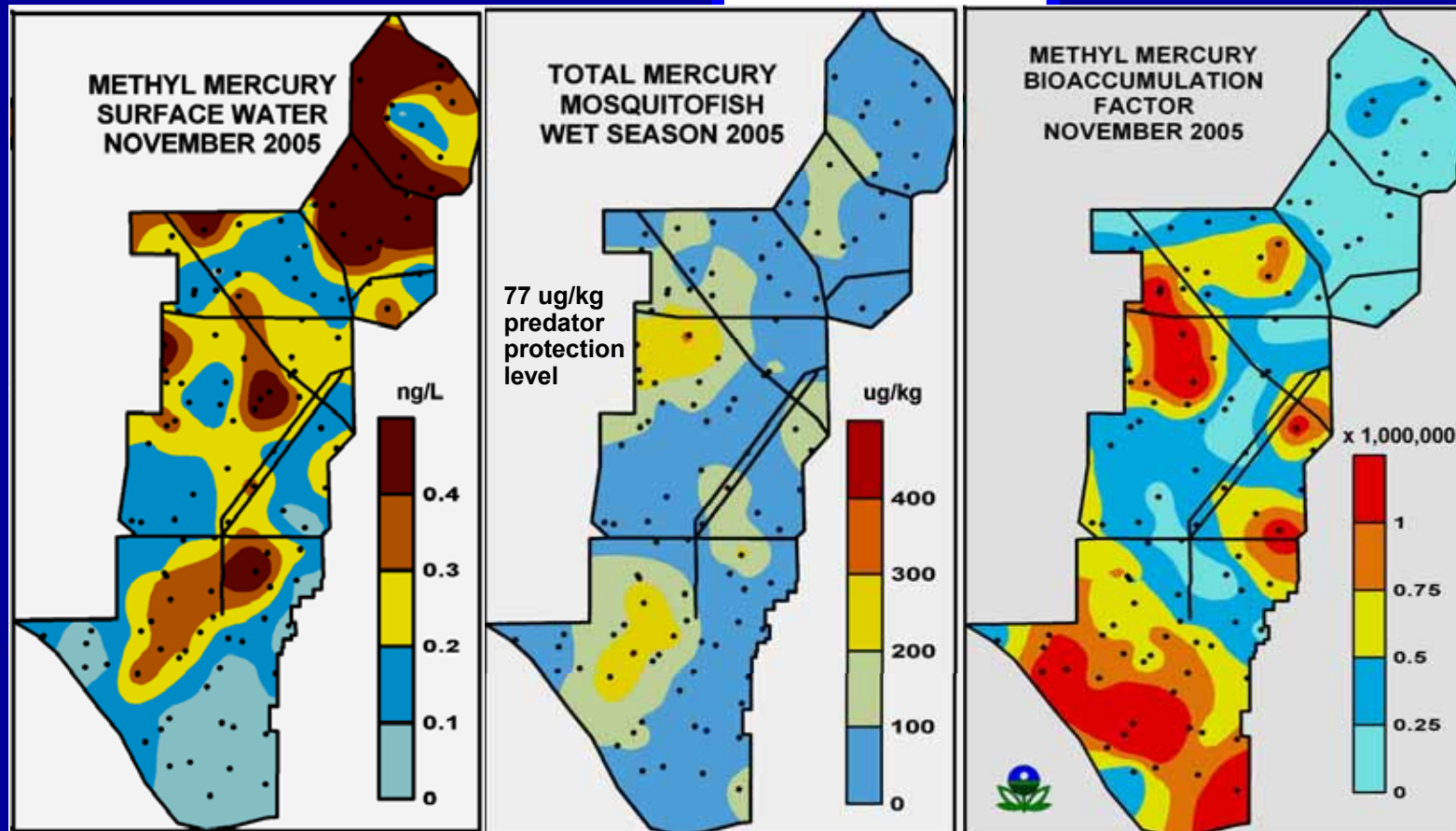
# Mercury, 2005 Wet Season

## WARNING

The Florida Department of Health and Rehabilitative Services has issued a health advisory urging limited consumption of largemouth bass and warmouth caught in certain portions of the Everglades due to excessive accumulation of the element mercury.

- Fish caught in Arthur R. Marshall Loxahatchee National Wildlife Refuge (Water Conservation Area 1) should not be eaten more than once per week by adults and not more than once per month by children under 15 and pregnant women.

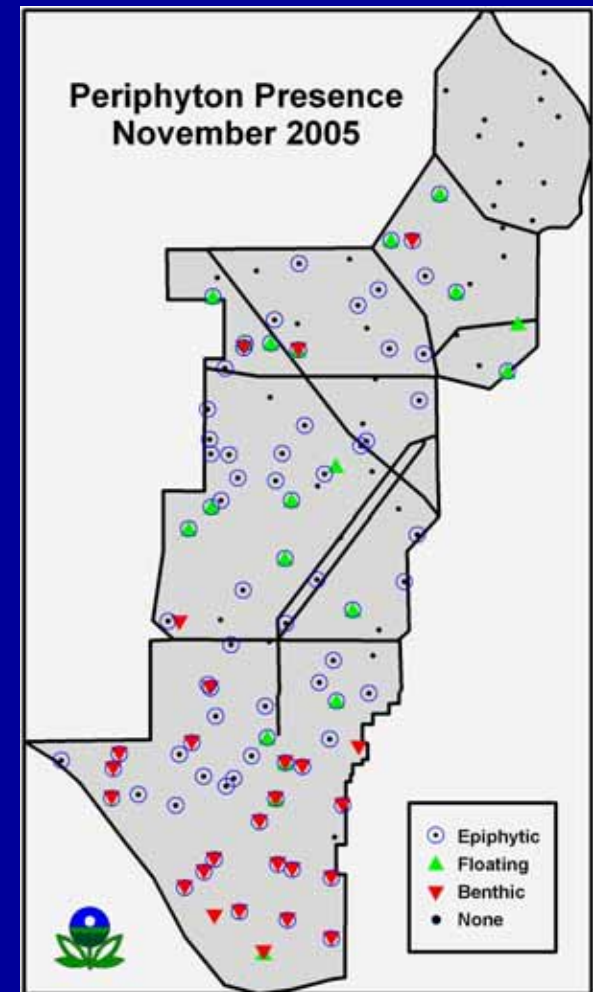
- Fish caught in Water Conservation Areas 2a and 3 should not be eaten at all.



# Sulfur: Pearson Correlation Coefficients

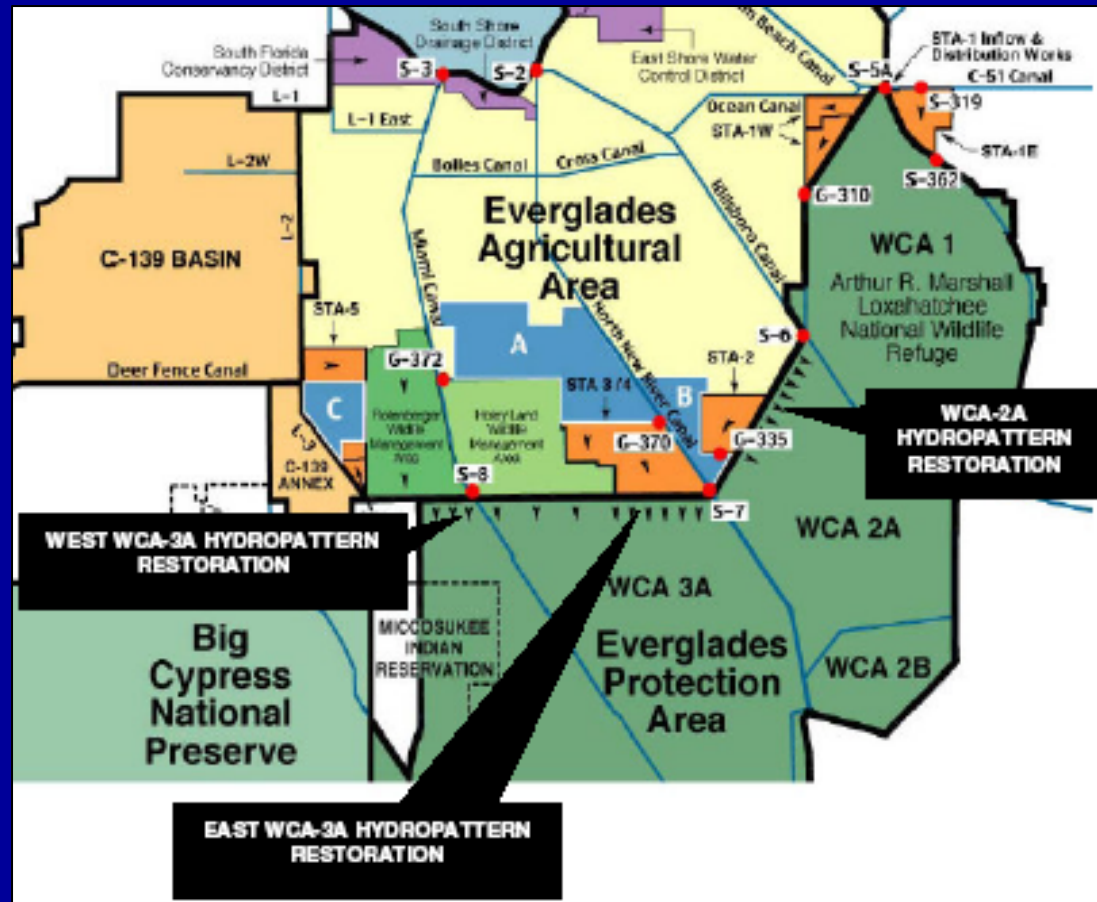
$p < 0.0006$

- **SW sulfate**
  - SW MeHg (0.65)
  - BAF (-0.47); MeHg Peri B (0.87)
- **PW sulfide**
  - SW THg (0.51), MeHg (0.61), SW Sulfate (0.77); PW sulfate (0.81)
  - BAF (-0.63); MeHg Peri B (0.80), THg Peri E (0.88); THg Peri B (0.68)



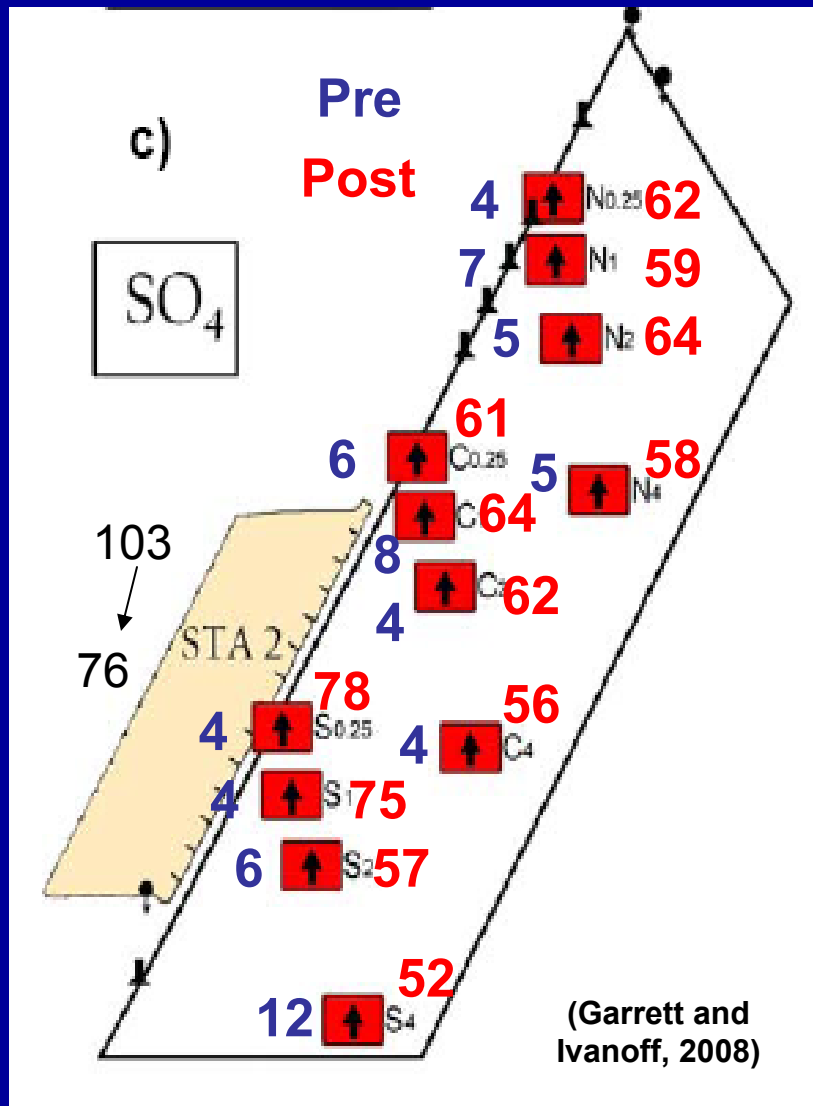


# WCA 2 Hydropattern restoration



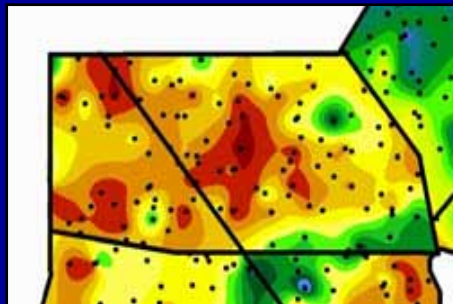
(CH2MHILL, Inc and Goforth, Inc 2008)

# Sulfate & WCA 2 Hydropattern Restoration



- WCA2 Pre (1998-2001) vs. post (2001-2006) hydroperiod restoration discharge
- Significant increase ( $p < 0.05$ ) at all sampling locations. [4 – 12 mg/L vs. 52 – 78 mg/L]
- Farthest site 6 miles.
- CERP restoration goal 1 mg/L
- STAs remove little sulfate
- Ecological effects?
- Risks vs. benefits:
  - Hydropattern restoration vs. TP vs. S enrichment vs. Hg

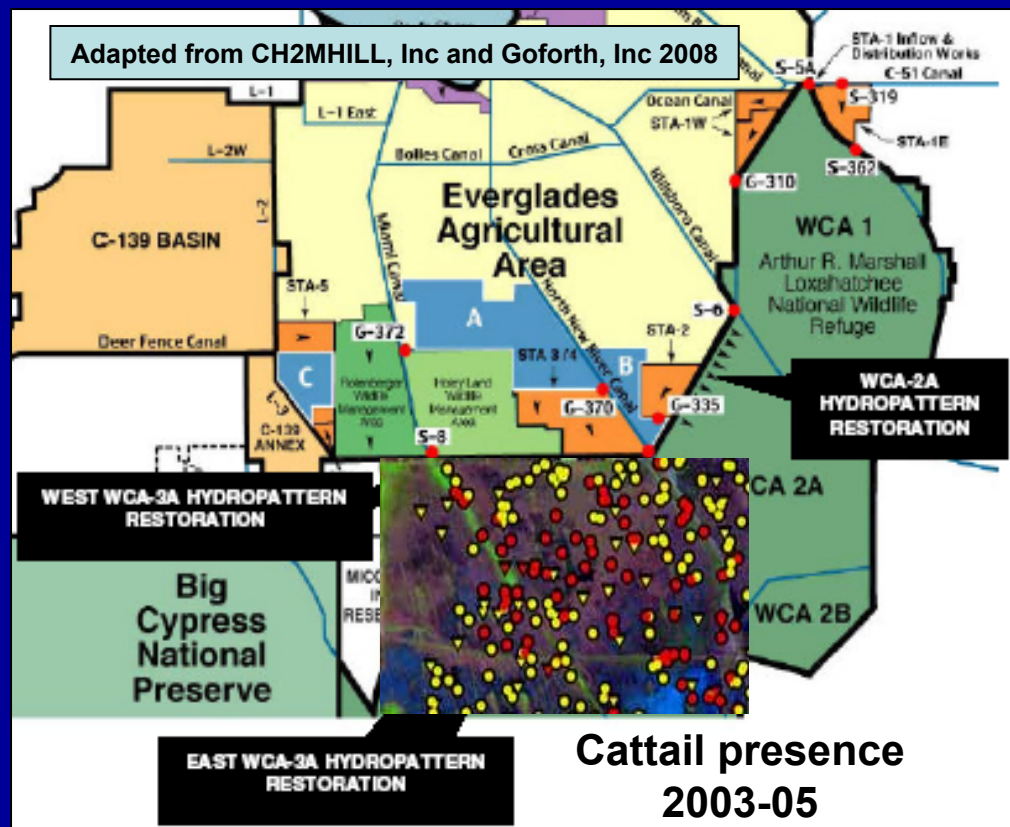
# WCA 3A Hydropattern Restoration



Soil Thickness  
~ 1-2 feet



Soil TP  
> 500 mg/kg

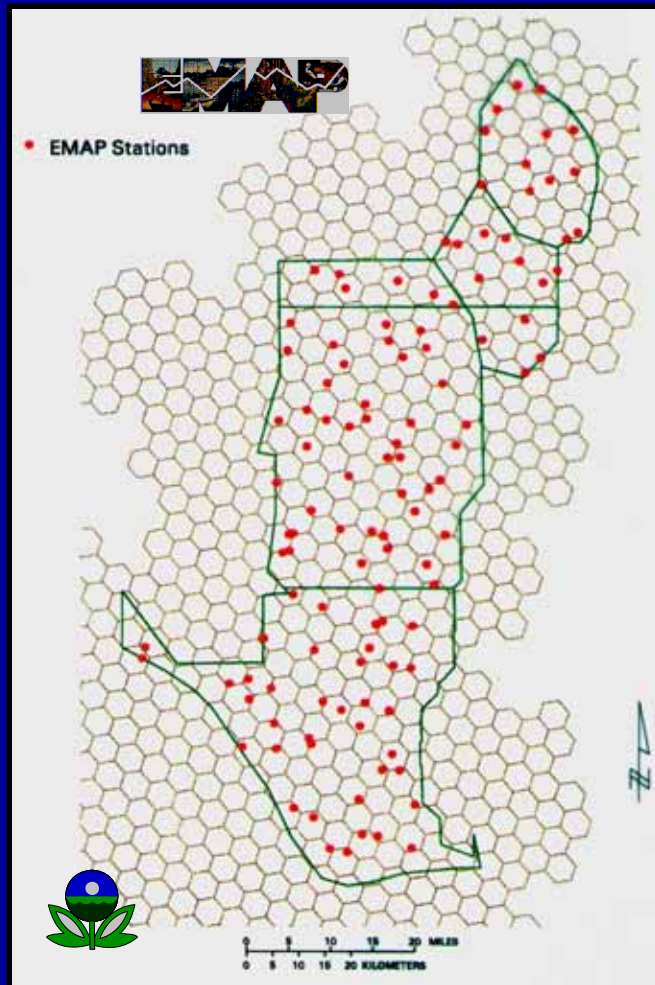


Ecological risks vs. benefits: Soil loss/fire risk vs. TP enrichment, cattail expansion, habitat decline vs. S enrichment vs. Hg

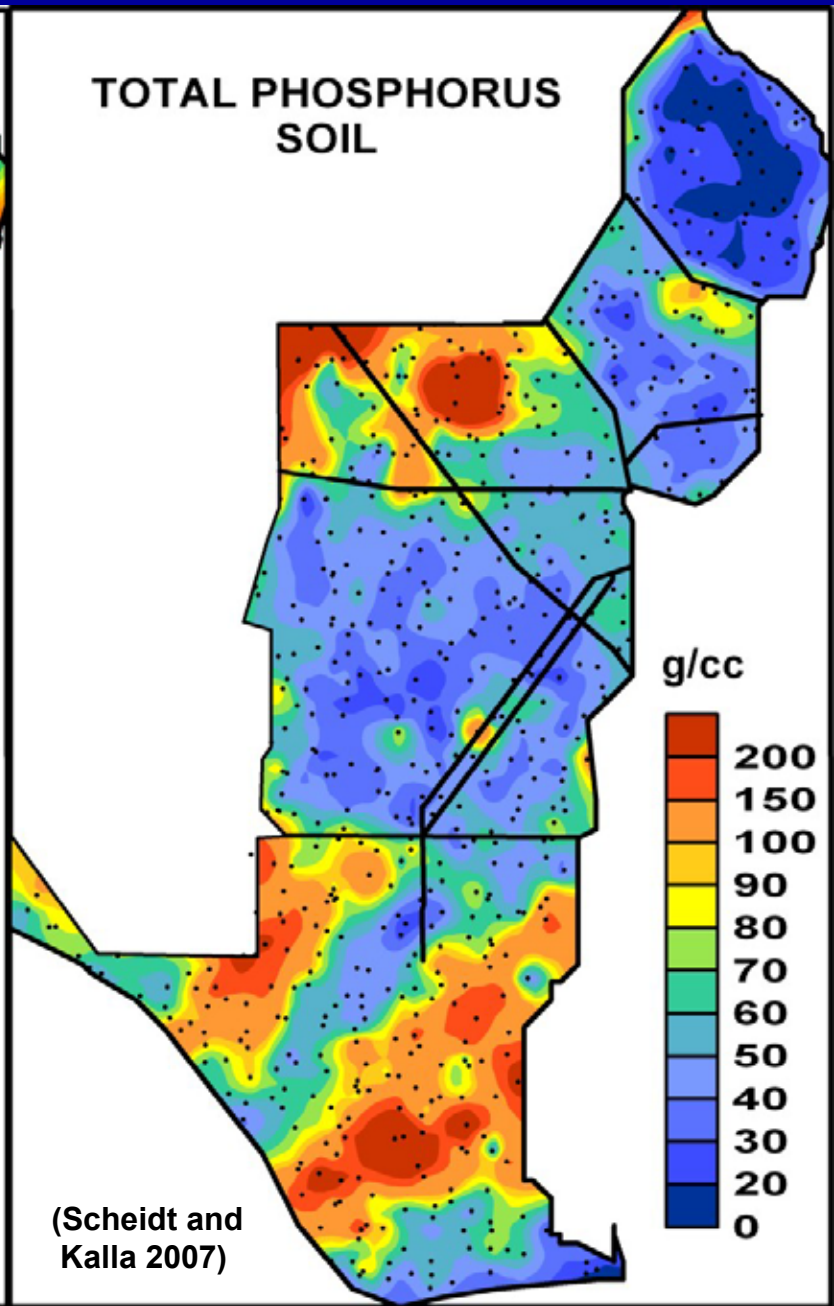
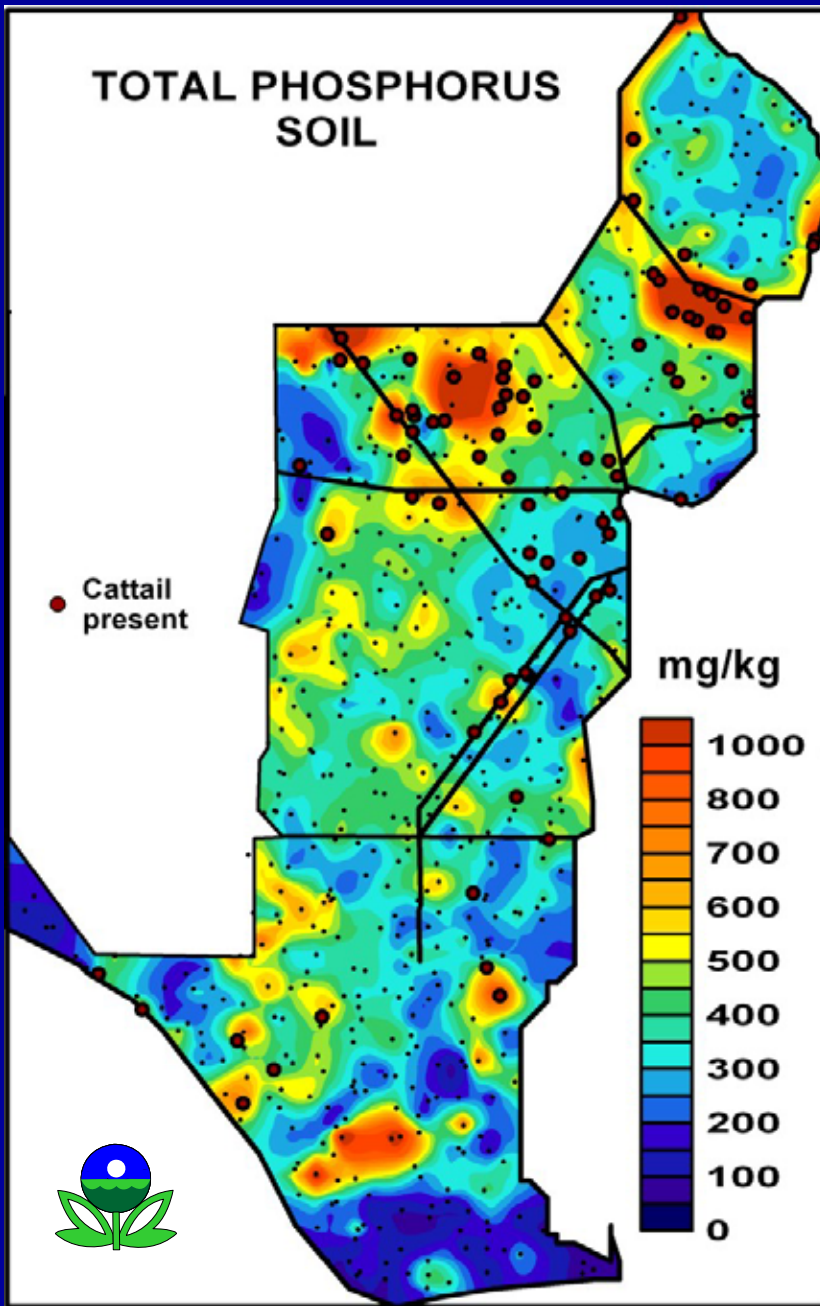
# Closing thought

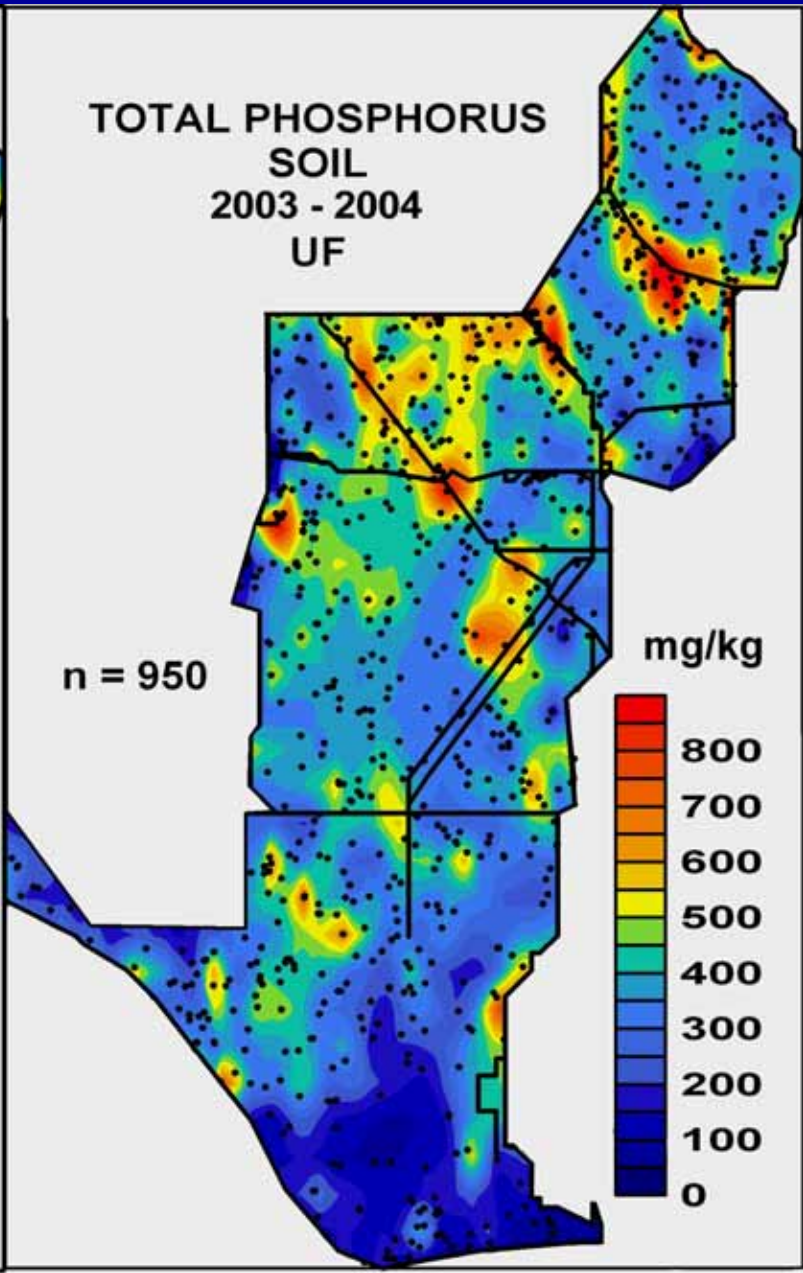
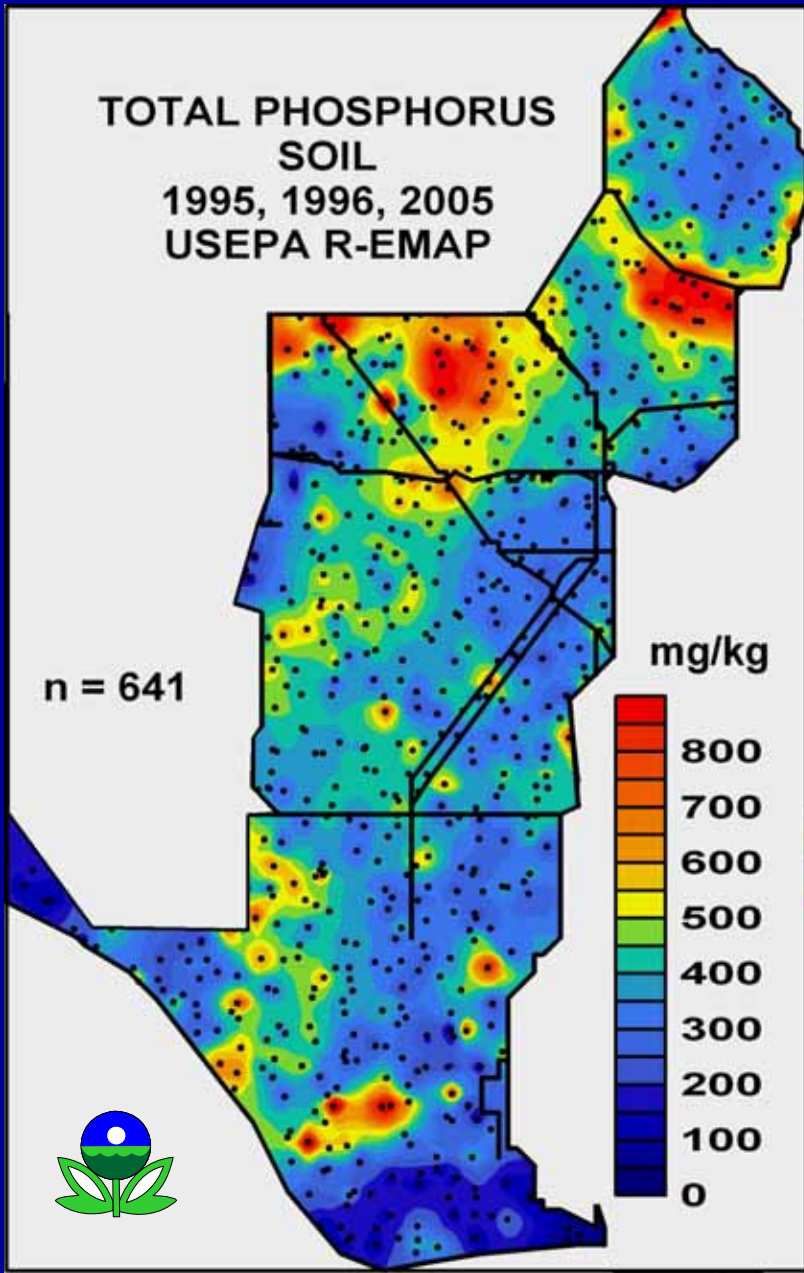
- **R-EMAP program helps satisfy CERP, EFA monitoring objectives**
  - **Baseline variability, status and trends, responses, associations.**
- **Documented 1995, 1996, 1999, 2005 condition for the entire EPA**
- **25% of EPA is P-impacted.**
- **57% of EPA has sulfate > CERP restoration goal.**
- **65% of EPA had mosquitofish Hg exceeding 77 ug/kg predator protection level**

# R-EMAP Probability-based Design



- Reviewed by National Academy of Sciences.
- Every member of a statistical population has a known chance of being selected and the samples are drawn at random.
- ***Can estimate with known confidence the status of ecological resources (% of area  $\pm$  CI, ie,  $24.5 \pm 6.4\%$  has soil TP > 500 mg/kg, 2005)***
- Only multi-media program across entire Everglades Protection Area (EPA) with probability-based design.





# R-EMAP Soil Bulk Density

