Effective Phosphorus Removal in Wetlands: Three Case Studies

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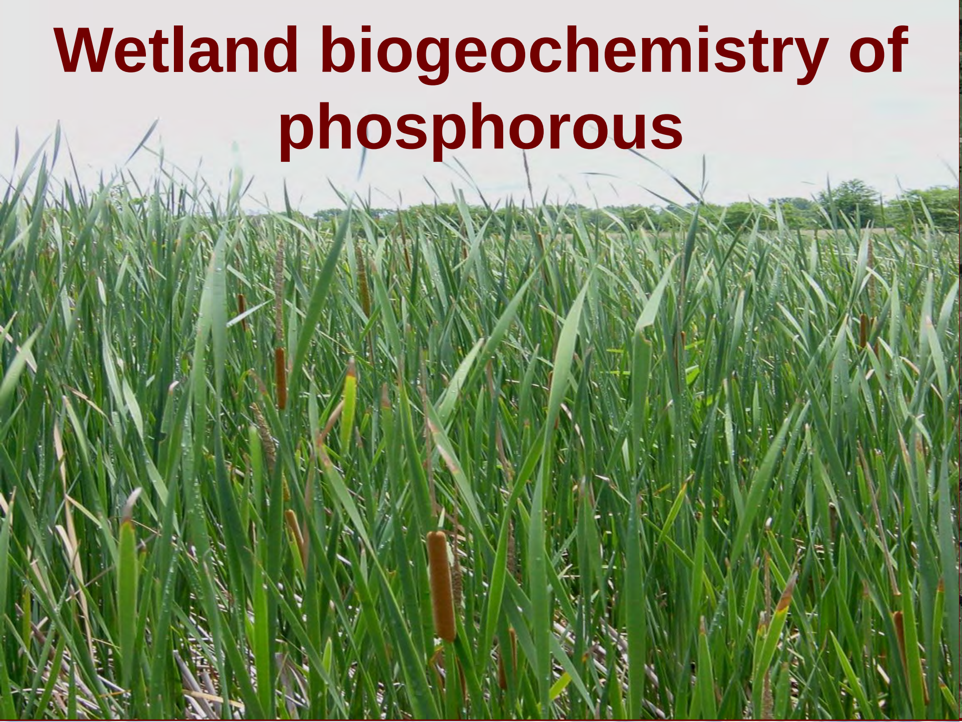

Wetland biogeochemistry of phosphorous

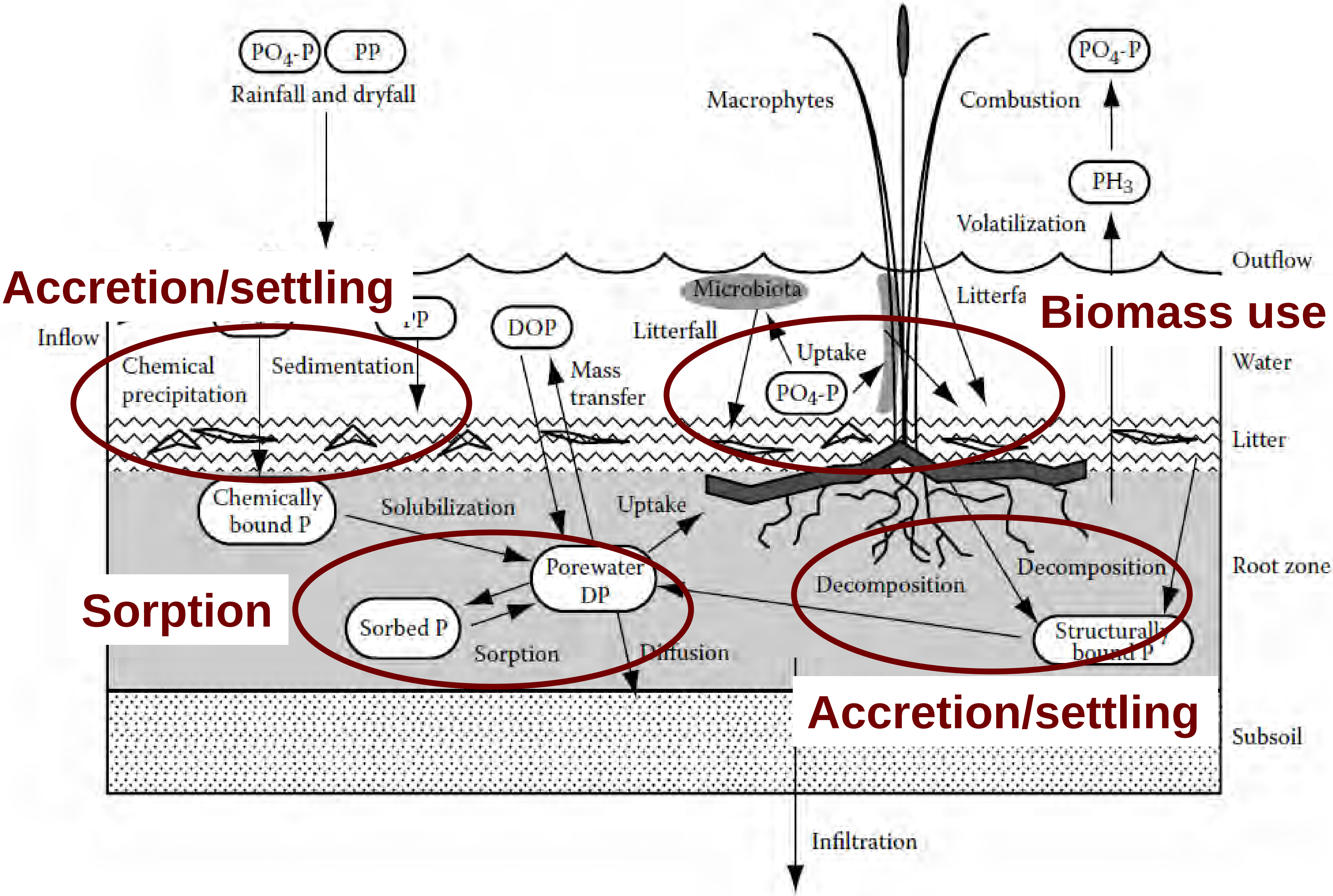

Olentangy River Wetland Research Park, Ohio


Everglades Stormwater Treatment Areas, Florida

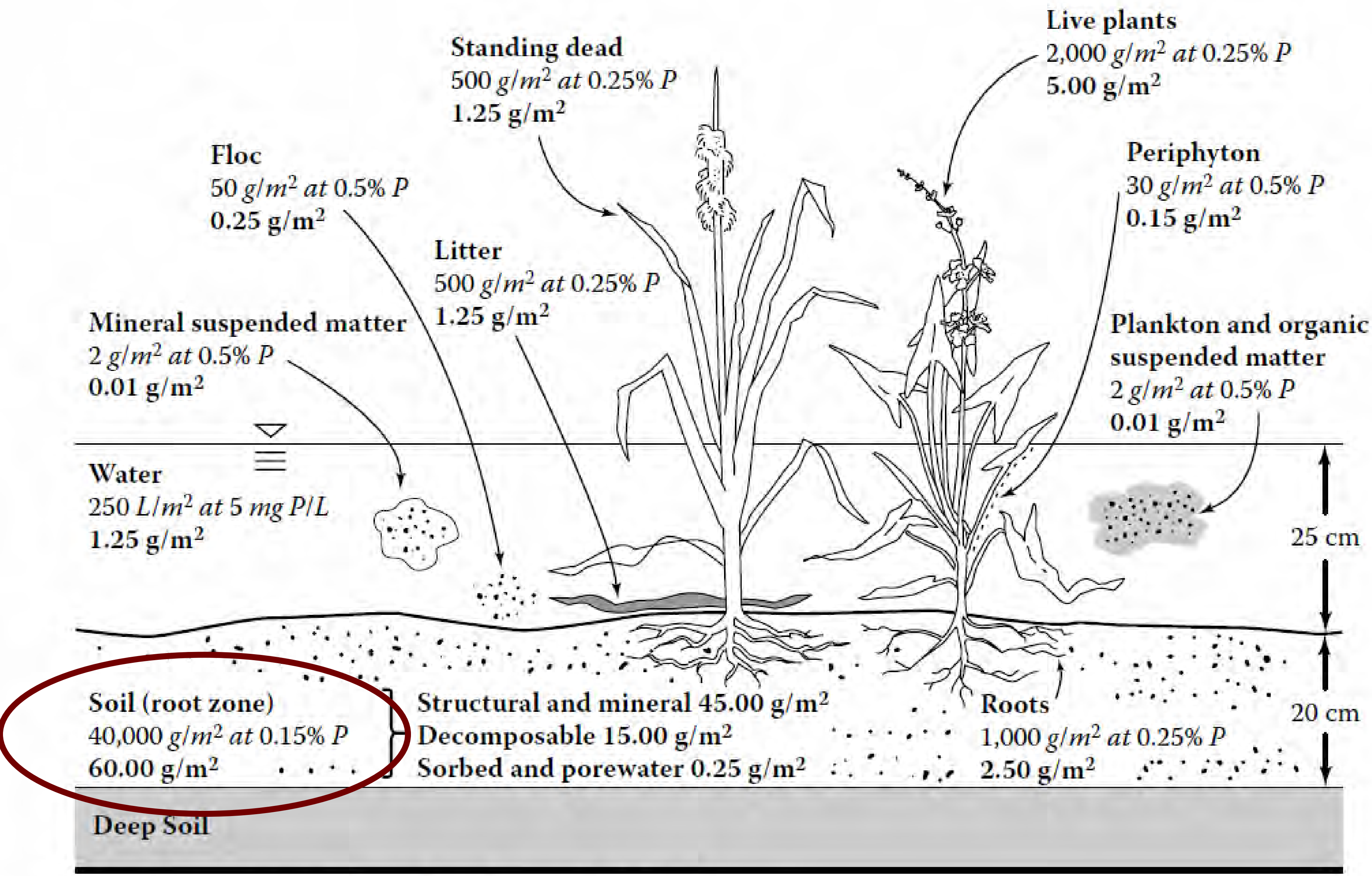

East Fork Raw Water Supply Project, Texas

Wetland biogeochemistry of phosphorous

Kadlec, R.H. and S.D. Wallace. 2009. *Treatment Wetlands*, 2nd ed. CRC Press LLC. 1016 pp.



PO4-P
PP
Rainfall and dryfall
Macrophytes
Combustion
PO4-P
PH3
Volatilization
Outflow
Accretion/settling
Microbiota
Litterfa
Biomass use
Inflow
DOP
Litterfall
Chemical precipitation
Sedimentation
Mass transfer
Uptake
PO4-P
Water
Litter
Chemically bound P
Solubilization
Uptake
Porewater DP
Root zone
Decomposition
Decomposition
Sorption
Sorbed P
Structurally bound P
Sorption
Diffusion
Accretion/settling
Subsoil
Infiltration

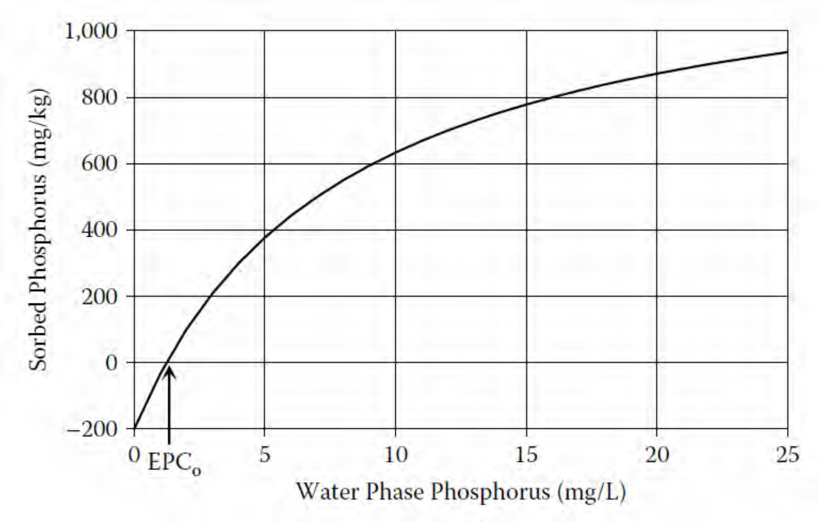


Note: Dry mass is in *italics* and standing stock is in **bold**.

Phosphorus processing

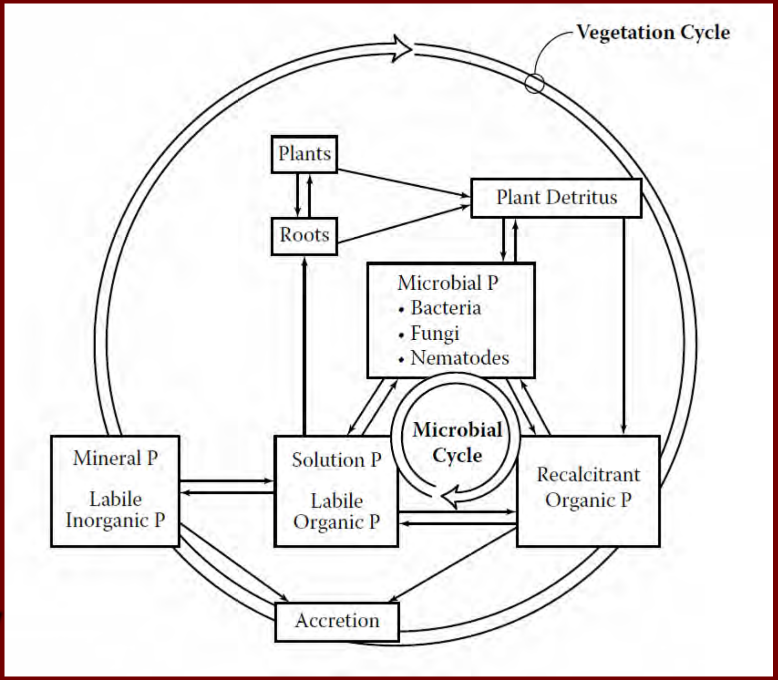
1. Sorption
   – Rapid exchange between pore water and soil particles or mineral surfaces (adsorption)
   – Penetration into solid phase (absorption)
   – Depends on Fe and Al in soil
   – Saturable process so finite P retention capacity

Langmuir model adsorption of P on wetland soil



Phosphorus processing

2. Biomass utilization
   - Microbial, algal and macrophytic components
   - "Flywheel effect" – growth, storage and release
   - Must include:
     - Phytomass
     - Biomass
     - Necromass
   - Some sediment accretion
   - Finite P retention capacity



Phosphorus processing

3. Soil accretion
   - Creation of new soils and sediments
   - Least studied aspect of P transfer
   - Burial of plant detritus of considerable importance
   - Sustainable removal

TP_{aq} (mg/L)	Accretion (cm/yr)	P burial (g m^{-2} yr^{-1})
<0.1	0.22 ± 0.1	0.18 ± 0.1
0.1<1.0	0.84 ± 0.4	0.67 ± 0.4
>1.0	1.48 ± 0.3	5.7 ± 7.0

Kadlec and Wallace (2009); n = 11

Phosphorus processing

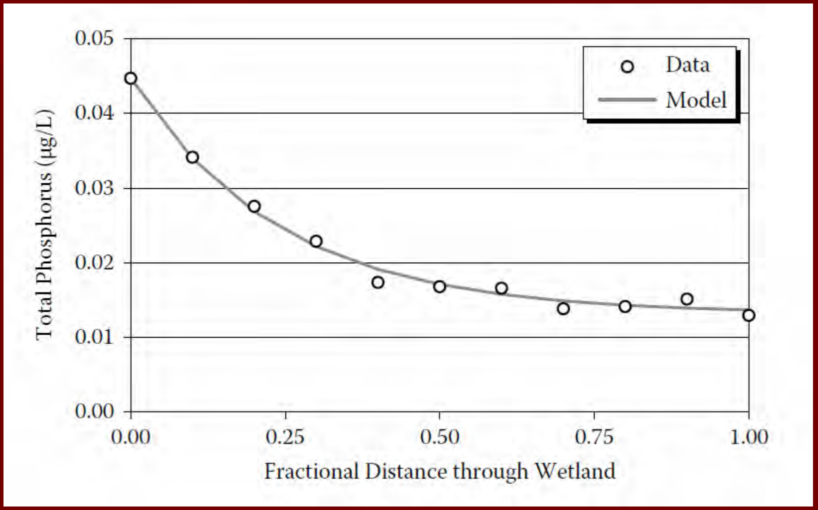
4. Particulate settling
   - Chemical precipitation (e.g., $CaHPO_4$, $FePO_4$)
   - Incoming particulate settling (mineral vs. organic particulate P)
   - Strongly reliant on source and system
   - Sustainable removal

Total P			Particulate P		
TP_{in} (mg/L)	TP_{out} (mg/L)	TP Rem. (%)	PP_{in} (mg/L)	PP_{out} (mg/L)	PP Rem. (%)
0.92	0.45	44±6	0.23	0.14	45±5

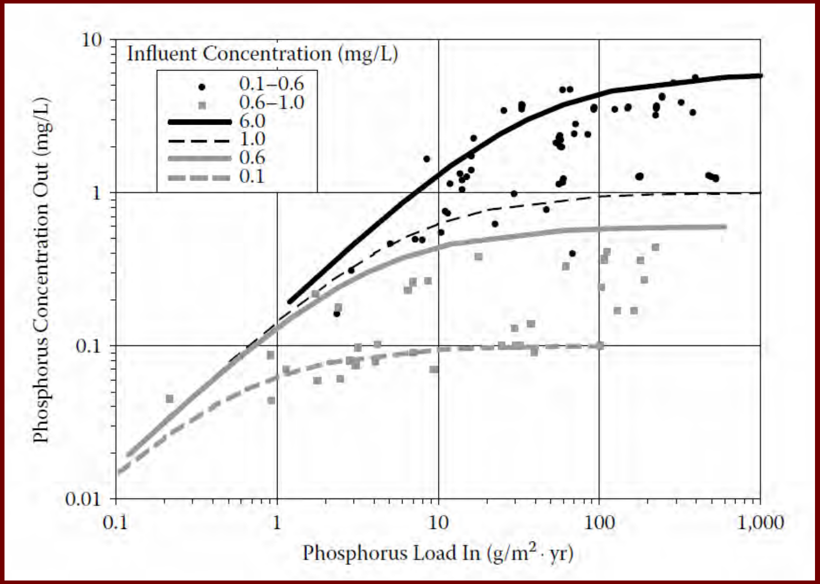
Phosphorus removal in wetlands

- Exponential decrease to "C*"

$$\frac{C_o - C^*}{C_i - C^*} = e^{\left(\frac{-k_A}{q}\right)}$$



- Documented P removal in >300 wetlands
  - $[TP_{in}]$: <20 µg/L to >100 mg/L
  - Mass removal: <0.1 to > 100 g m^{-2} yr^{-1}

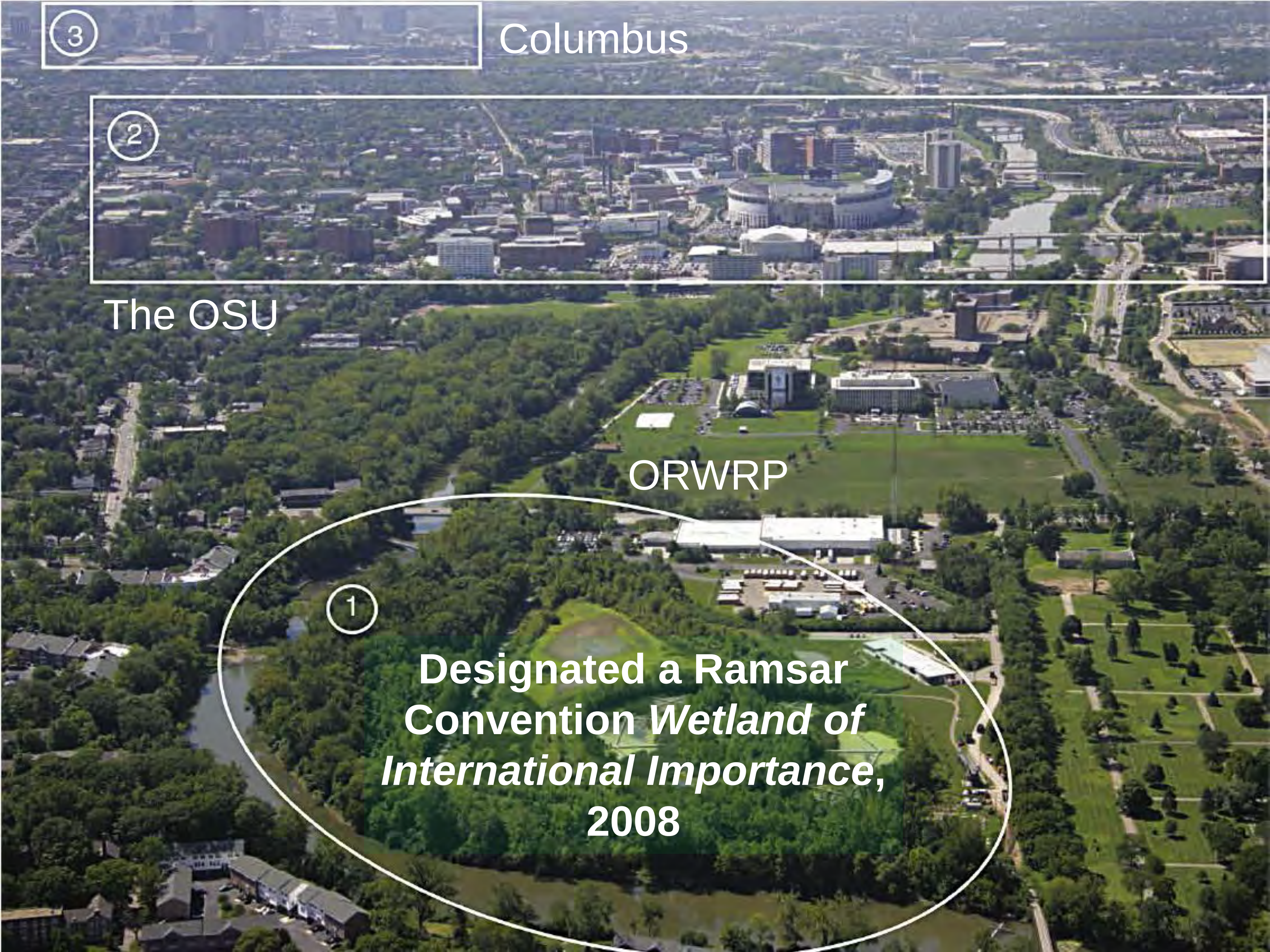


Olentangy River Wetland Research Park, Ohio

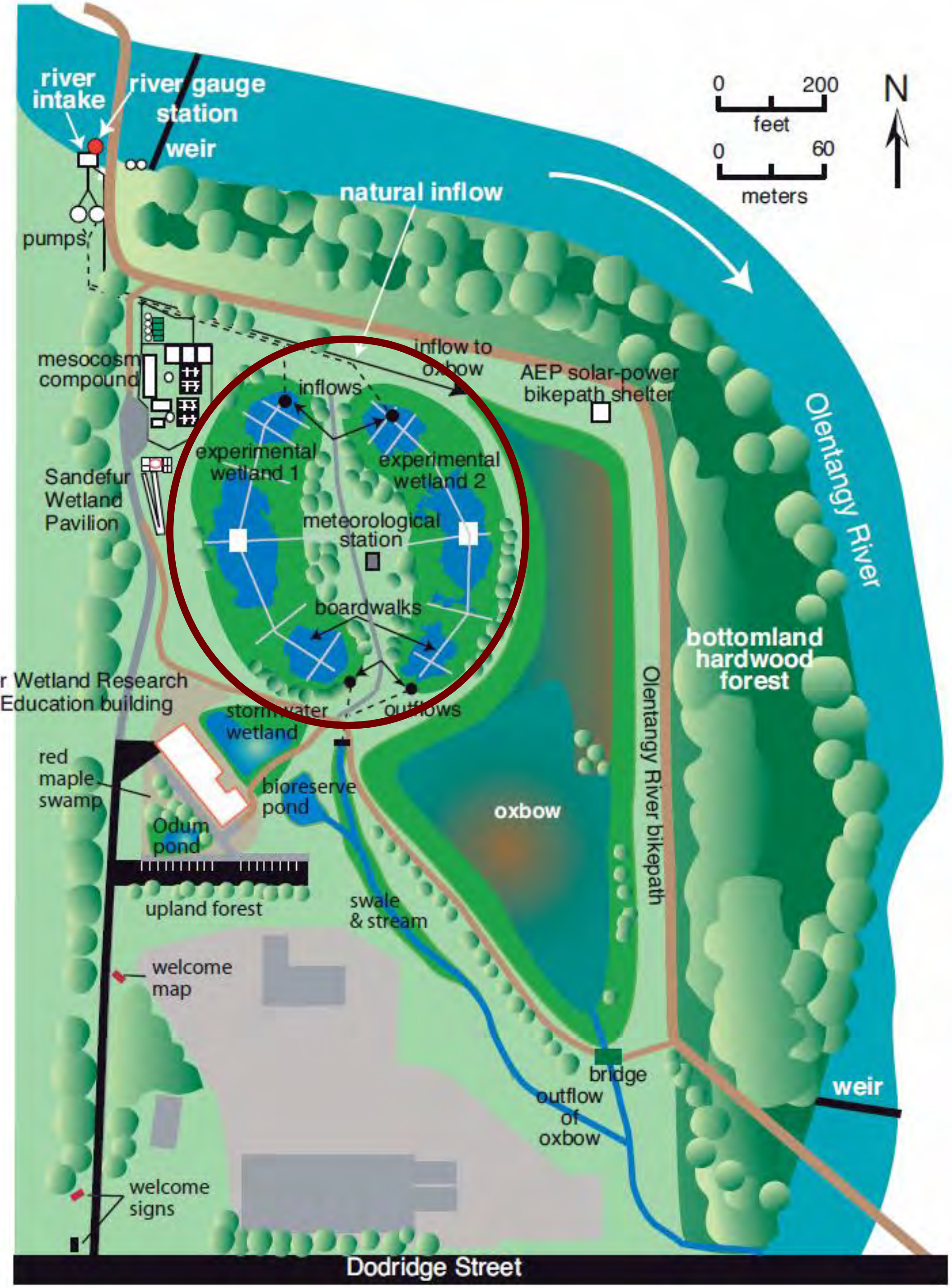
Mitsch, W.J. et al. 2014. Validation of the ecosystem services of created wetlands: Two decades of plant succession, nutrient retention, and carbon sequestration in experimental riverine marshes. *Ecological Engineering* 72: 11-24.

Olentangy River Wetland Research Park

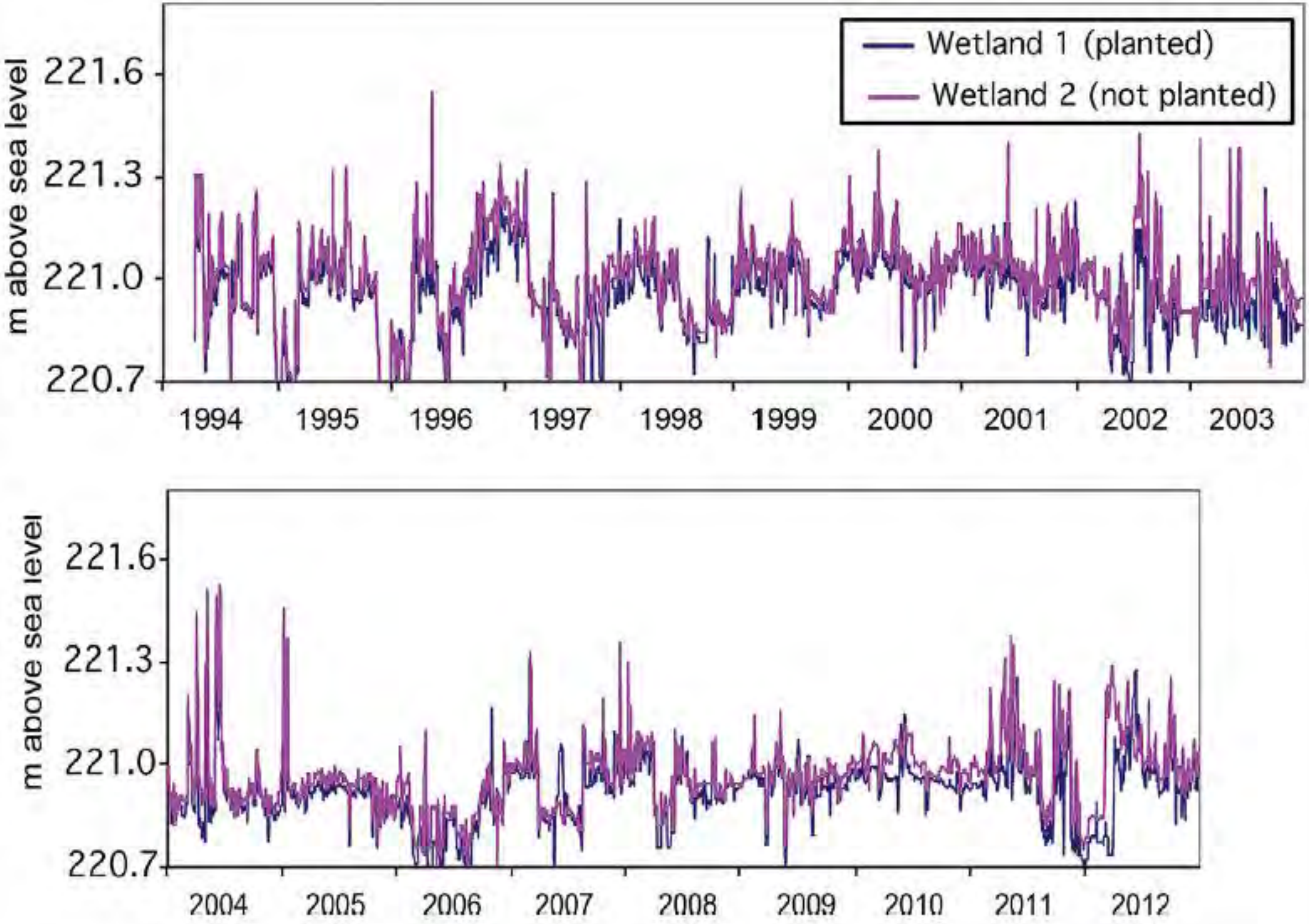
- 20-ha wetland and stream research and teaching field laboratory
- Adjacent to The Ohio State University campus
- Phase 1: Two 1-ha experimental marshes (1992-94)
- Phase 2: Research infrastructure (1994-99)
- Phase 3: Wetland building (2000-03)
- Phase 4: River restoration and ecotourism (2004-2012)


3
Columbus
2
The OSU
ORWRP
1
Designated a Ramsar Convention *Wetland of International Importance*, 2008

- Effects of introduced biodiversity on ecosystem function
- Two 1-ha wetlands with identical hydrology
  - W1: Planted with 2,400 propagules of 13 species
  - W2: Natural colonization
- 1994-

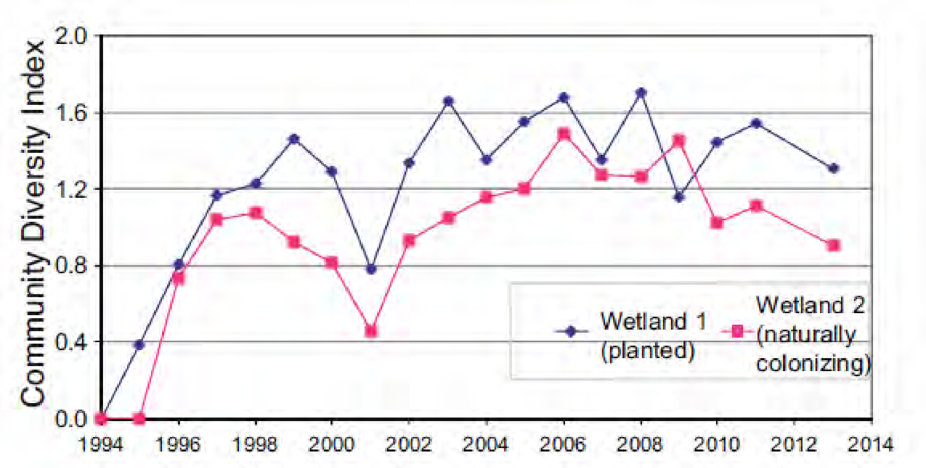


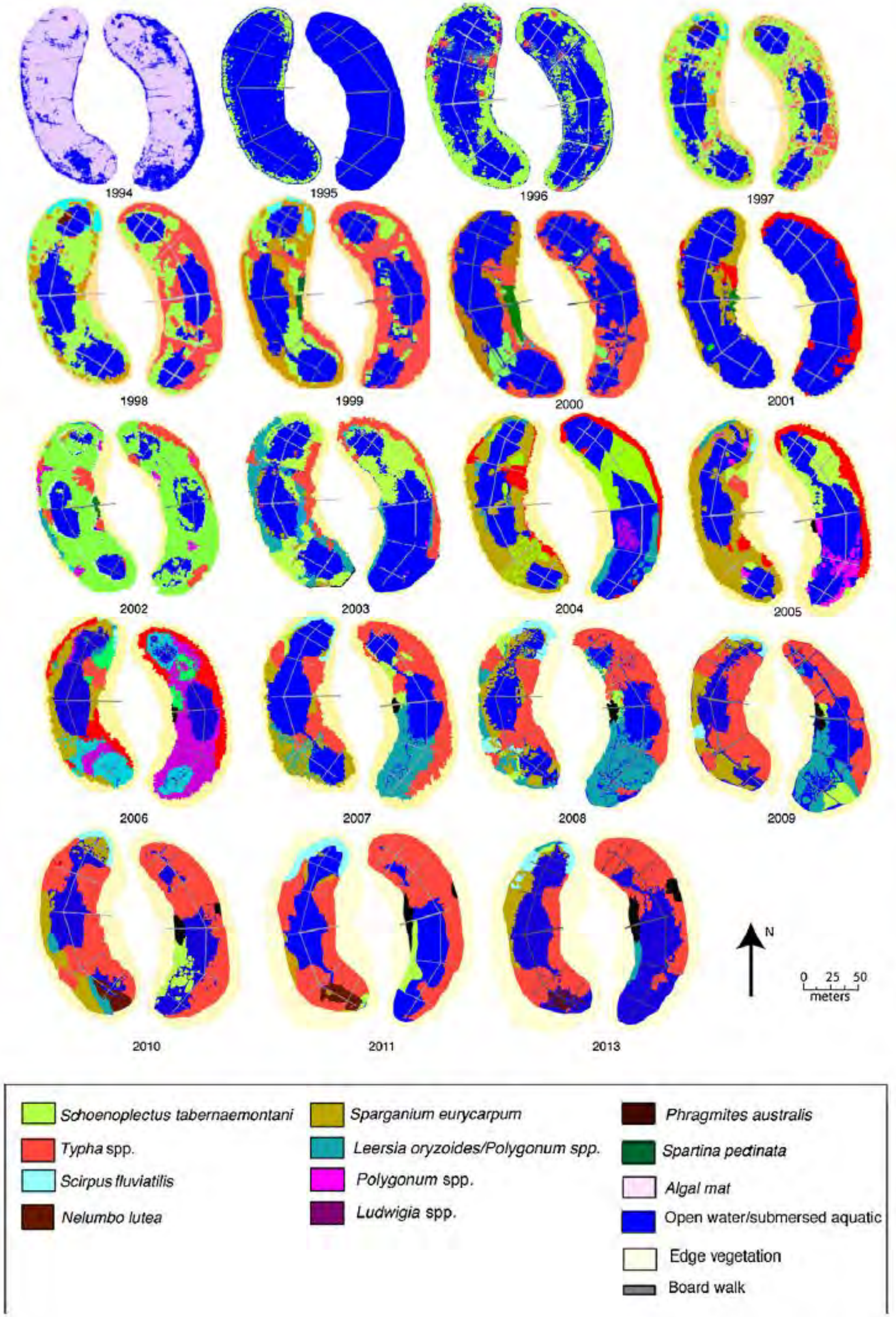
Identical hydrology



Vegetation succession

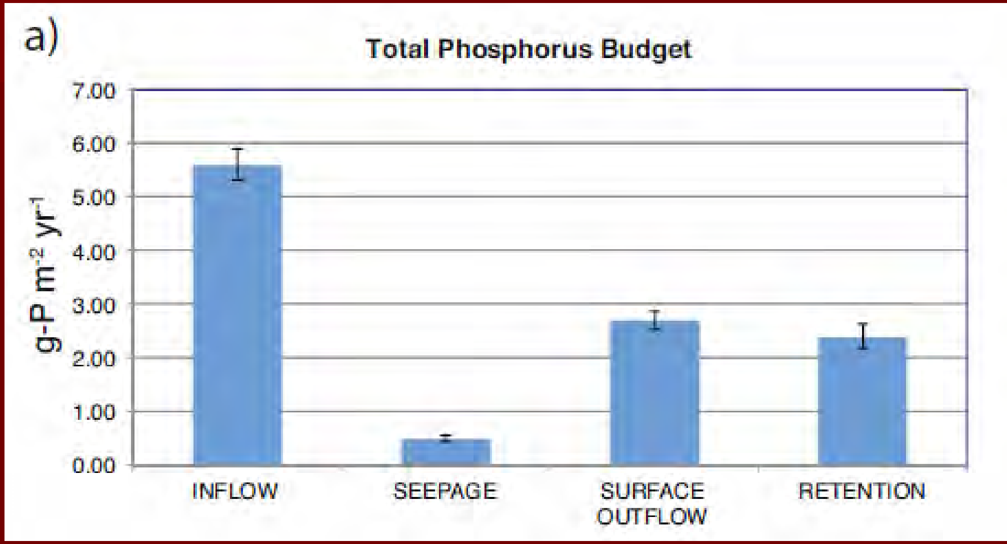
- 12 distinct communities
- W1
  - 101 species
  - 9 of 13 present
- W2
  - 97 species
  - 2 of 13 present

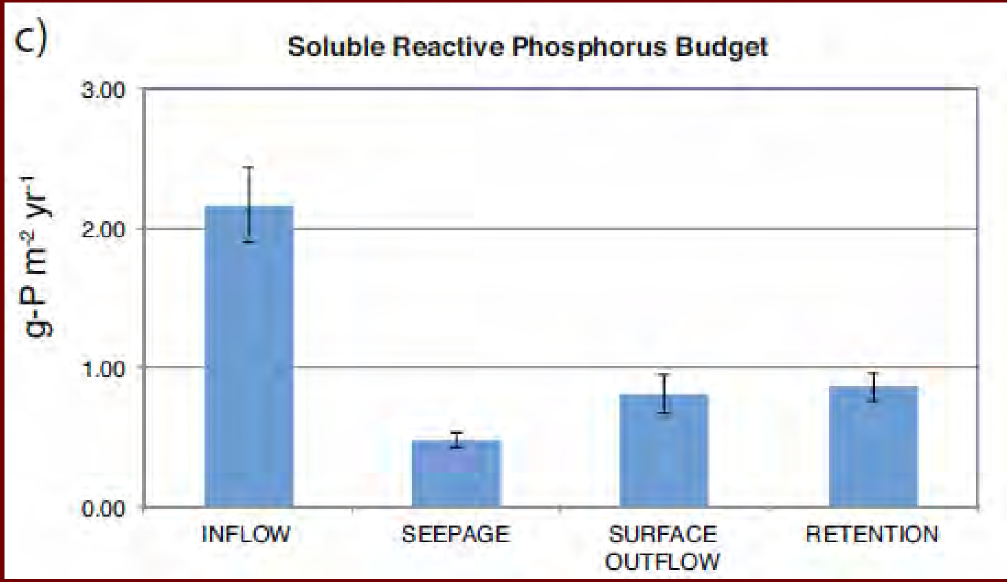




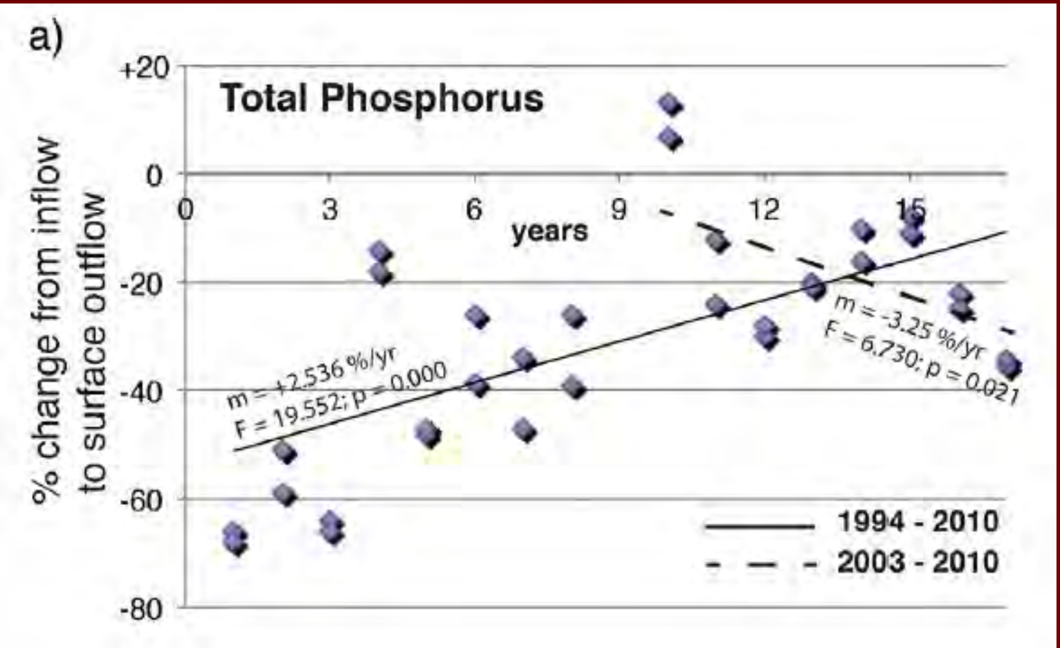
Phosphorus retention

- Total P
  - 2.40±0.23 g m^{-2} yr^{-1}
  - 42.7% by mass
- SRP
  - 0.87±0.10 g m^{-2} yr^{-1}
  - 40.3% by mass
  - 36% of TP
- W1: 44.3±4.4%
- W2: 38.8±5.3%
- $p < 0.06$





Phosphorus retention trends



- Overall, P retention decreasing over time
- But for last 6 years, trends reversed and P retention increasing over time
- Soil P accumulation
  - –W1: 3.26±0.25 g m^{-2} yr^{-1}
  - –W2: 3.49±0.25 g m^{-2} yr^{-1}

Everglades Stormwater Treatment Areas, Florida

Mitsch, W.J. et al. 2015. Protecting the Florida Everglades wetlands with wetlands: Can stormwater phosphorus be reduced to oligotrophic conditions? *Ecological Engineering* (in press) DOI: 10.1016/j.ecoleng.2014.10.006

WETLANDS WARRIOR

Professor brings expertise to environmental front line: The Everglades

BILL MITSCH WAS CONDUCTING RESEARCH AS AN environmental engineering science graduate student at the University of Florida in the early 1970s when an epiphany in Naples set him on the path to becoming one of the world's foremost experts on wetlands.

"I remember going to Corkscrew Swamp Sanctuary to study the cypress sloughs," he said. "I just said, 'Wow!' It was like being in a cathedral. I fell in love with Florida ecology. That's what turned me into a wetlands scientist, and I've been in wetlands ever since."

Thirty-seven years after earning his doctorate at UF and embarking on a teaching career largely spent at The Ohio State University, Mitsch has returned to Southwest Florida to live, teach, research and head FGCU's new Everglades Wetland Research Park in Naples. He was appointed in October as the first Juliet C. Sproul Chair for Southwest Florida Habitat Restoration and Management -- a position made possible by an endowment from Sproul, a Naples developer and philanthropist.

"I'm kind of returning to Florida," said Mitsch, 65. "The wetlands here are a big reason. If you were an oceanographer you would live near the ocean. If you're a wetland scientist, you should live here. The Florida Everglades are a great resource. A lot of good wetlands science is being done down here."

Scientists as well as undergraduate, master's and doctoral students already have begun using the facility for research on Everglades marsh and mangrove forest restoration and carbon mitigation and methane emissions in local ecosystems. As the program develops, teaching, research and outreach opportunities will grow.

The EWRP's mission and location highlight FGCU's continuing commitment to sustainability, according to Donna Price Henry, dean of the College of Arts and Sciences.

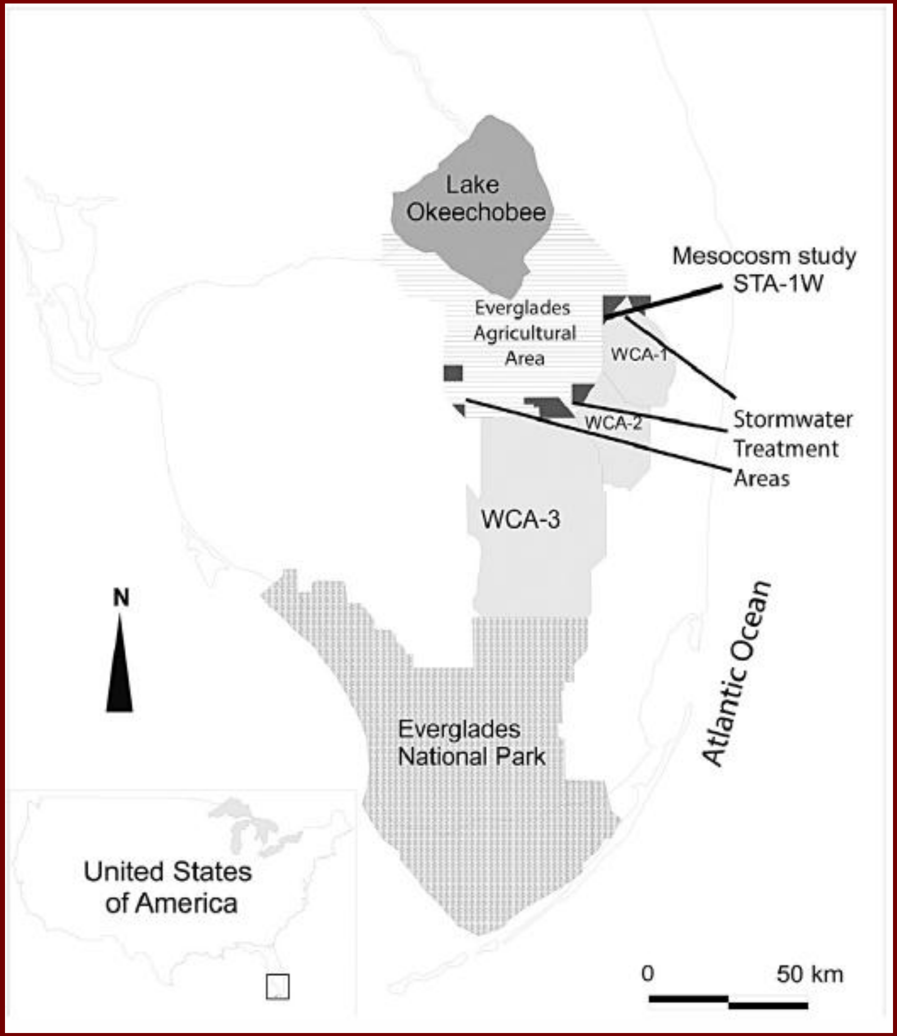
"The Greater Florida Everglades provide priceless ecosystem services for Southwest Florida, serving as the habitat for some of the richest biodiversity on the planet while protecting our coastline water quality and the economic viability of our shoreline and Gulf," she said. "Most important, our new research program is perfectly attuned to the vision set forth by FGCU when it was established 16 years ago."

By DREW STERWALD

Photo by BRIAN TIETZ

The Everglades and Phosphorus

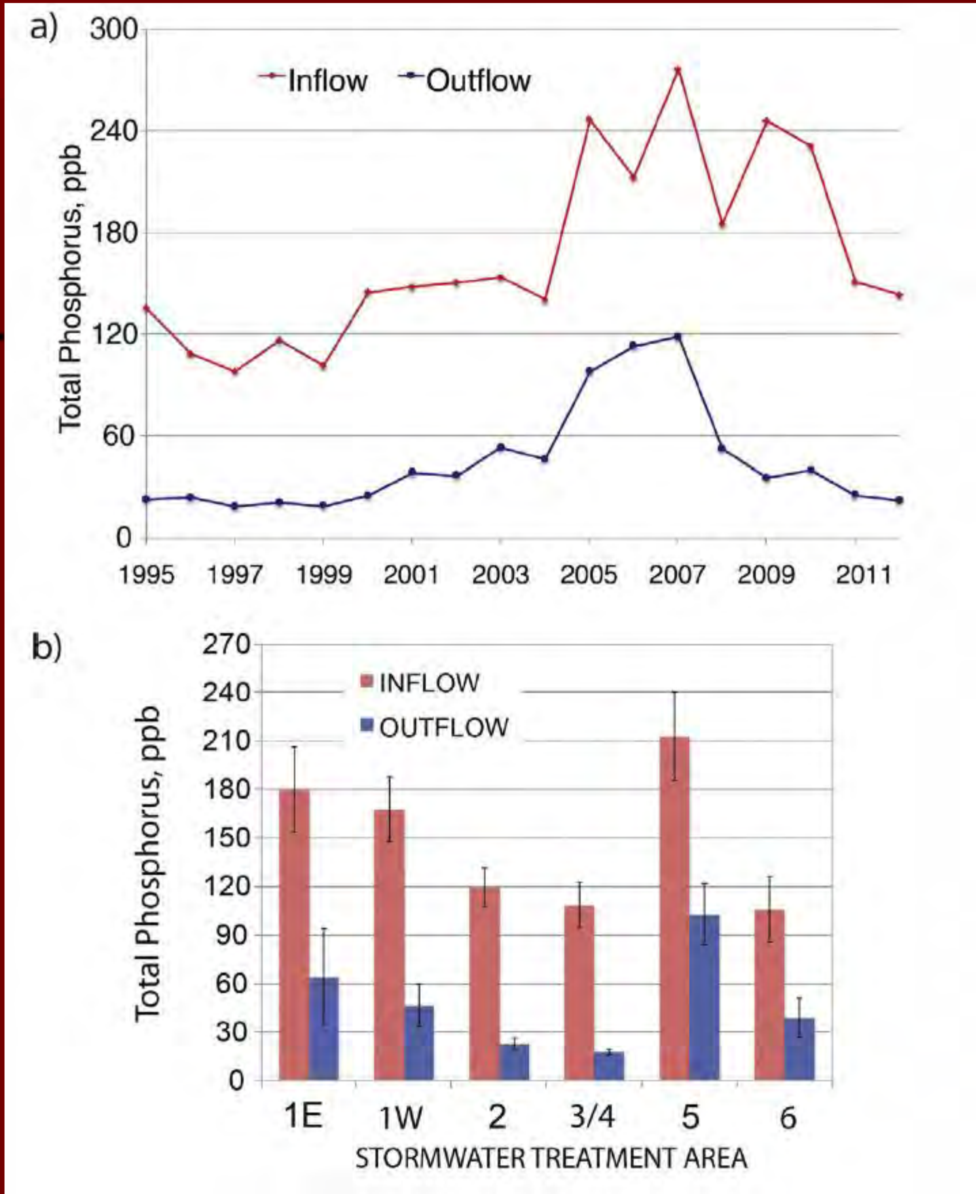
- Oligotrophic sawgrass (*Cladium jamaicense*) peatland
- → High-nutrient stormwaters from EAA
- Eutrophic cattail (*Typha latifolia/ domingensis*) community
- $[TP]_{sw}$ ~10 μg/L needed



Stormwater Treatment Areas

- Six STAs (23,000 ha) restored from farmland
- Some in operation 20 yr

- P loads reduced 73%
- Mean [TP]Δ:
  - 140 to 37 μg/L
- Significant adaptive management

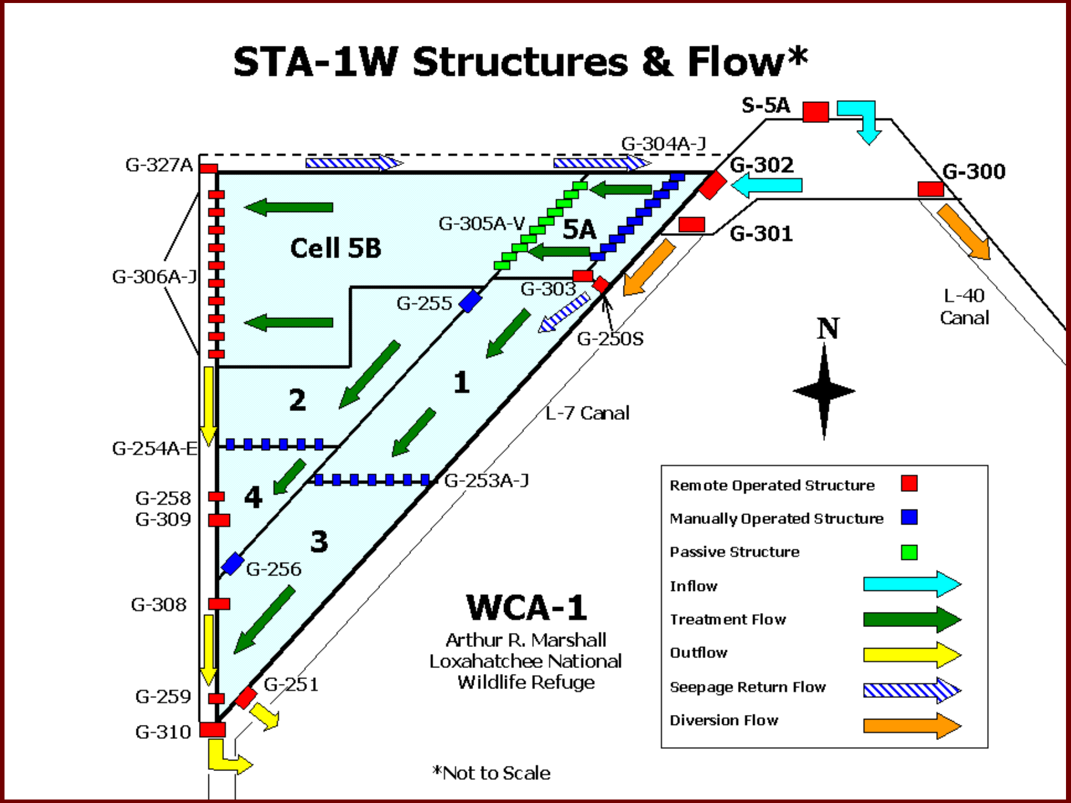


Stormwater Treatment Areas

- Mass loads <1.3 g m^{-2} yr^{-1} provided "high likelihood of achieving $[TP]_{out}$ <30 $\mu g/L$"
- For SAV wetlands and ***restored*** emergent wetlands with mass loads <2 g m^{-2} yr^{-1}, $[TP]_{out}$ = 10-20 $\mu g/L$ and >85% retention
- $1.35B spent over 17 yr; [TP] decreased by 10-58% at various locations

STA-1W Longevity

- Started 1994; 2700 ha
- 2008-2012
  - $[TP]_{in}$ = 191 μg/L
  - $[TP]_{out}$ = 35 μg/L
- Retention:
  - 82%
  - 1.25 g m^{-2} yr^{-1}
- Not consistently reached 10 μg/L threshold



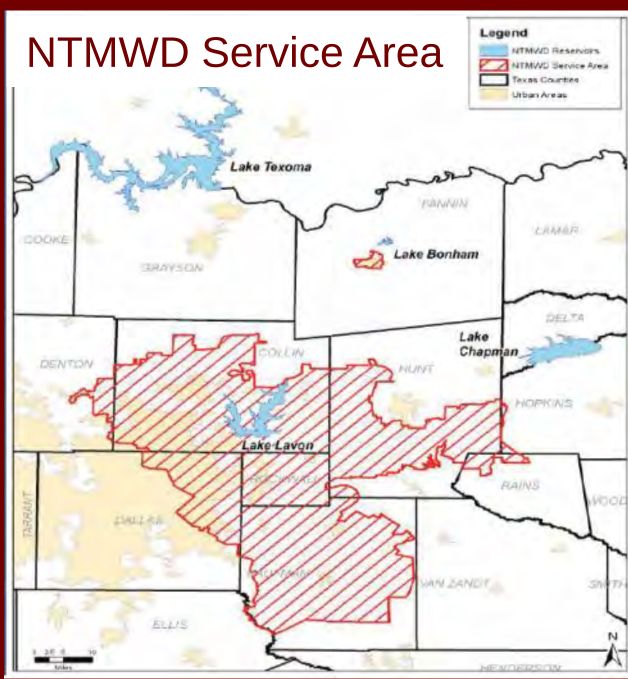
East Fork Raw Water Supply Project, Texas

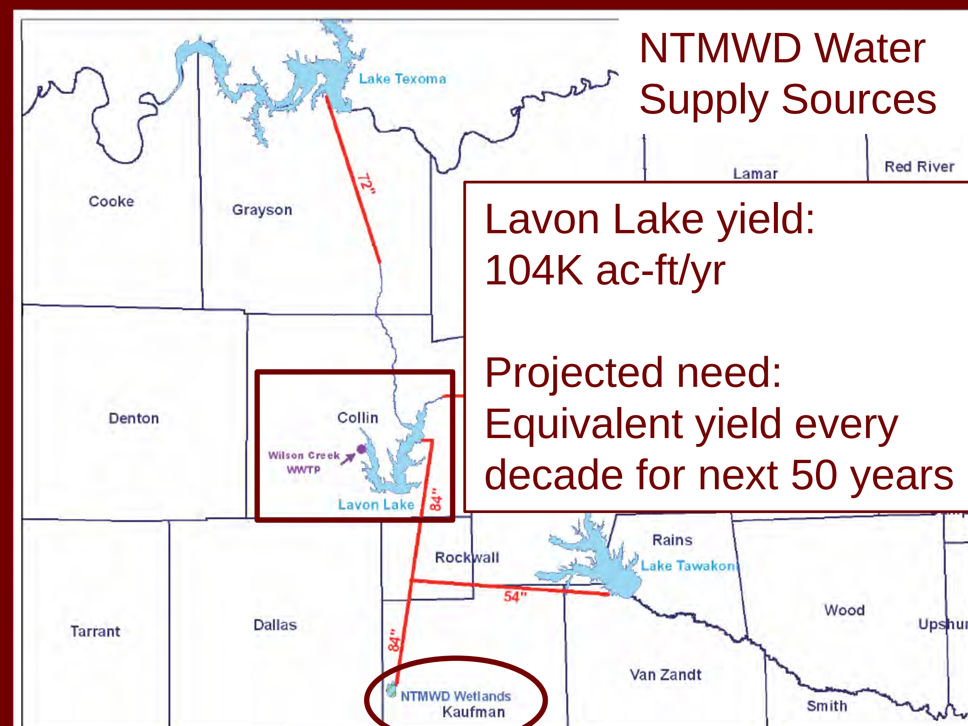
Mokry, L. 2011. North Texas Municipal Water District's East Fork Wetland: Initial Operational Issues and Performance Evaluation. 96th Ecological Society of America Annual Meeting Abstracts, COS 84-5.

Hickey, D. 2014. North Texas Municipal Water District: East Fork Raw Water Supply Project. wetlandcenter.com

East Fork Raw Water Supply Project

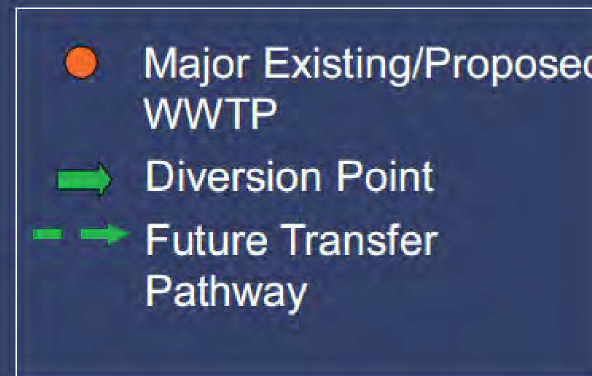
- North Texas Municipal Water District
  - 13 member cities
  - 49 customer entities





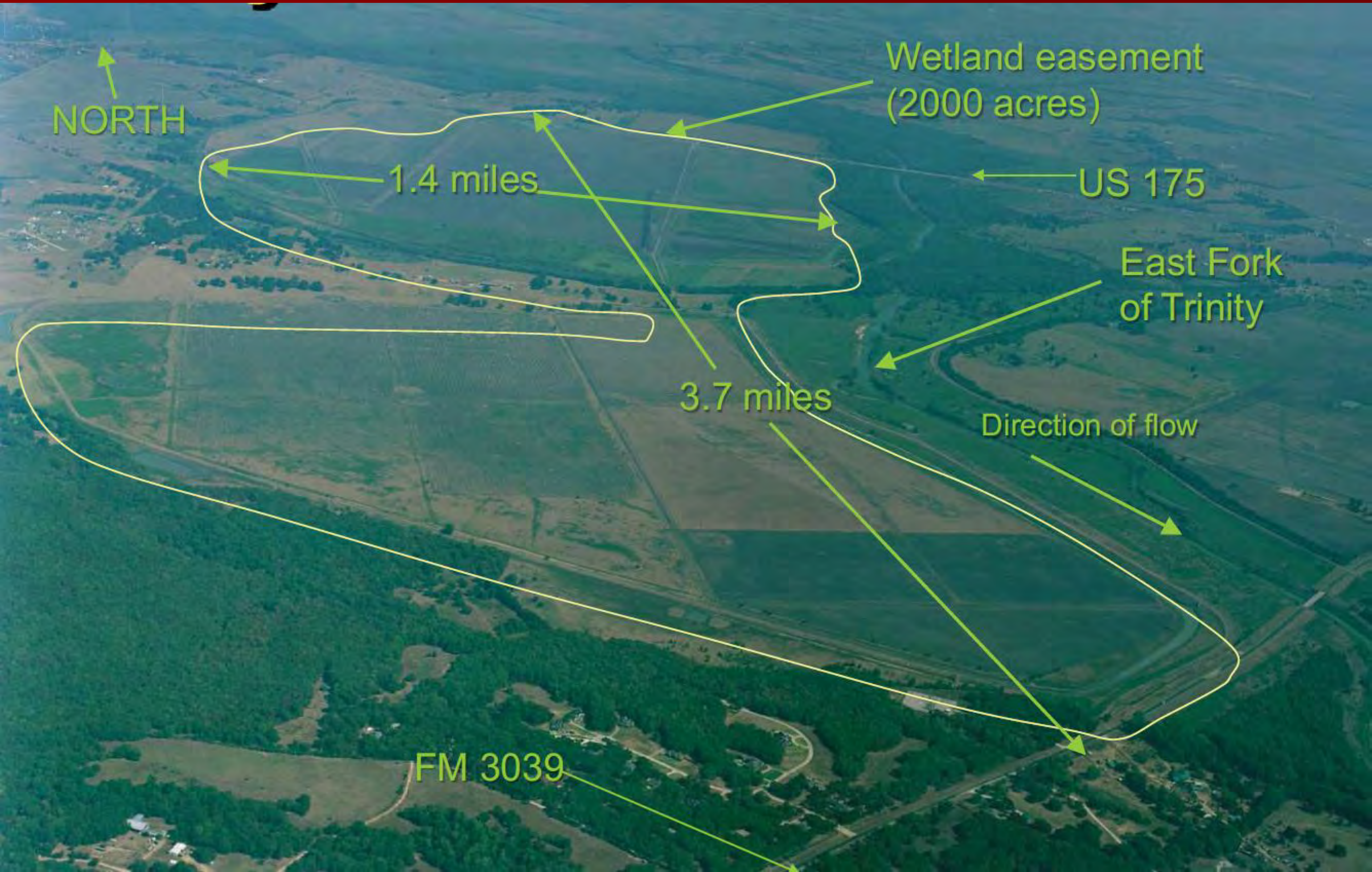
East Fork Raw Water Supply Project

- 745 ha wetland
- Polishing treatment of diverted East Fork Trinity River water
- Designed to provide 81K-102K ac-ft/yr
- Maximize supplies during drought and while Texoma supplies offline
- Completed 2009
- Estimated cost $246M

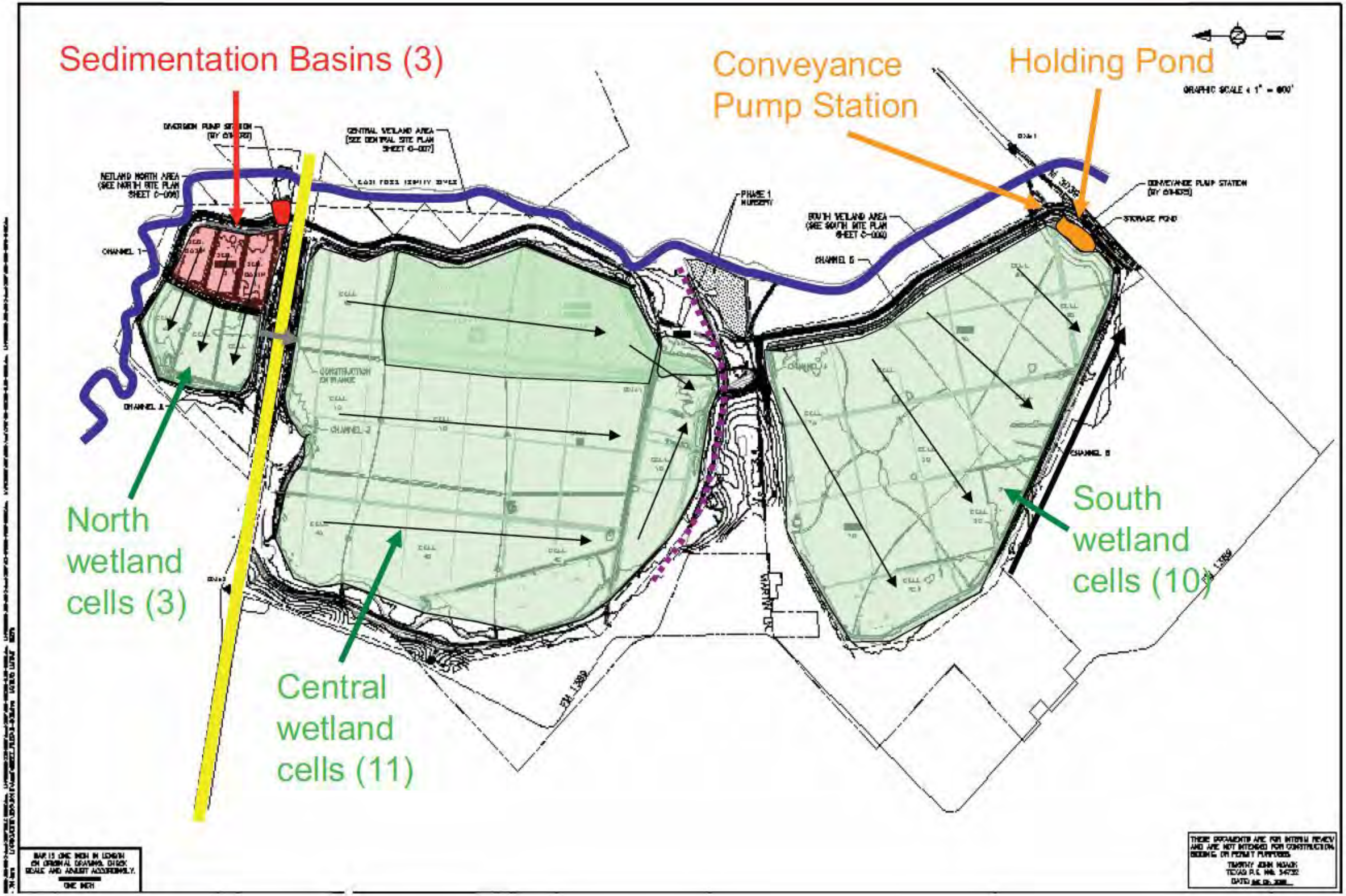


East Fork Raw Water Supply Project Schematic

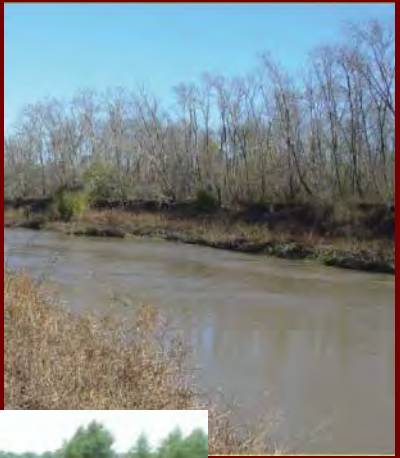
East Fork Raw Water Supply Project



East Fork Wetlands

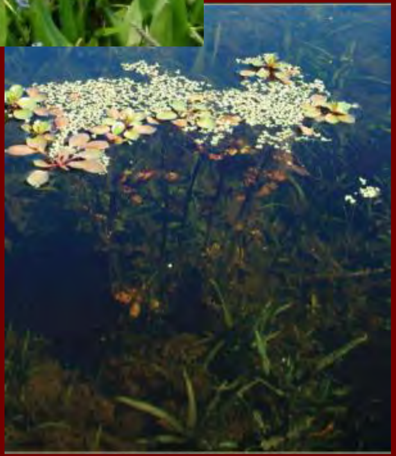


Phosphorus retention



- 20 emergent wetland species planted
- Plant diversity to achieve water quality and wildlife goals

- $[TP]_{in}$ ~2000 μg/L
- $[TP]_{out}$ ~ 300 μg/L
- Mass retention:
  - 83% → 65%



John Bunker Sands Nature Center

Provides Water and Environmental Education & Research Opportunities

Conclusions

- Wetlands are an effective tool for long-term phosphorus retention
- Multiple processes contribute to short- and long-term phosphorus dynamics
- Performance is dependent on influent loads and antecedent conditions
- Time and self-design are key

Acknowledgements

- Thank you to Steve Patterson and OCLWA

Questions?

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