Integrated Surface Water - Groundwater - Phosphorus Model to Evaluate Changes in Land Management in Agricultural Basins North of the Everglades

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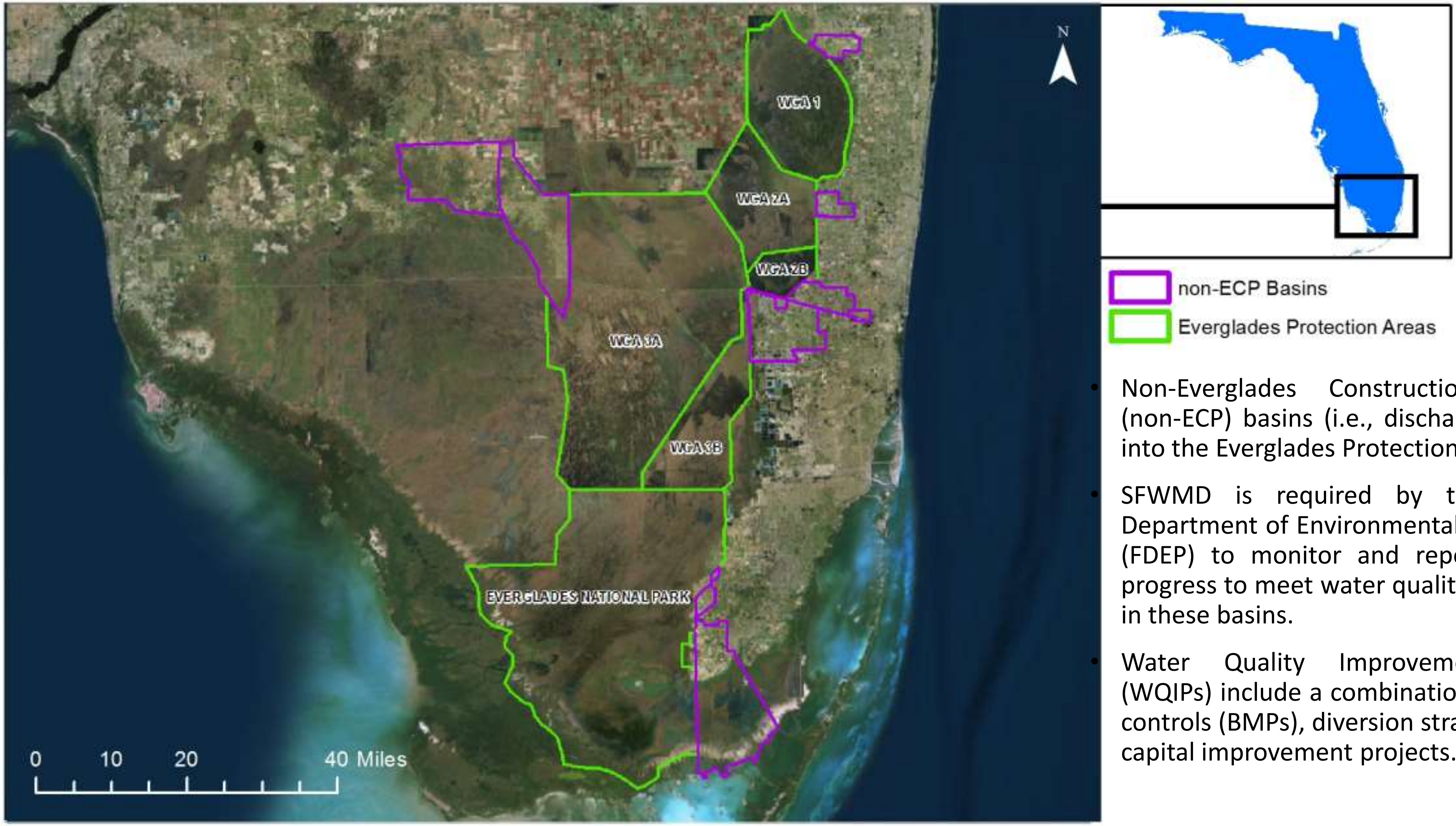
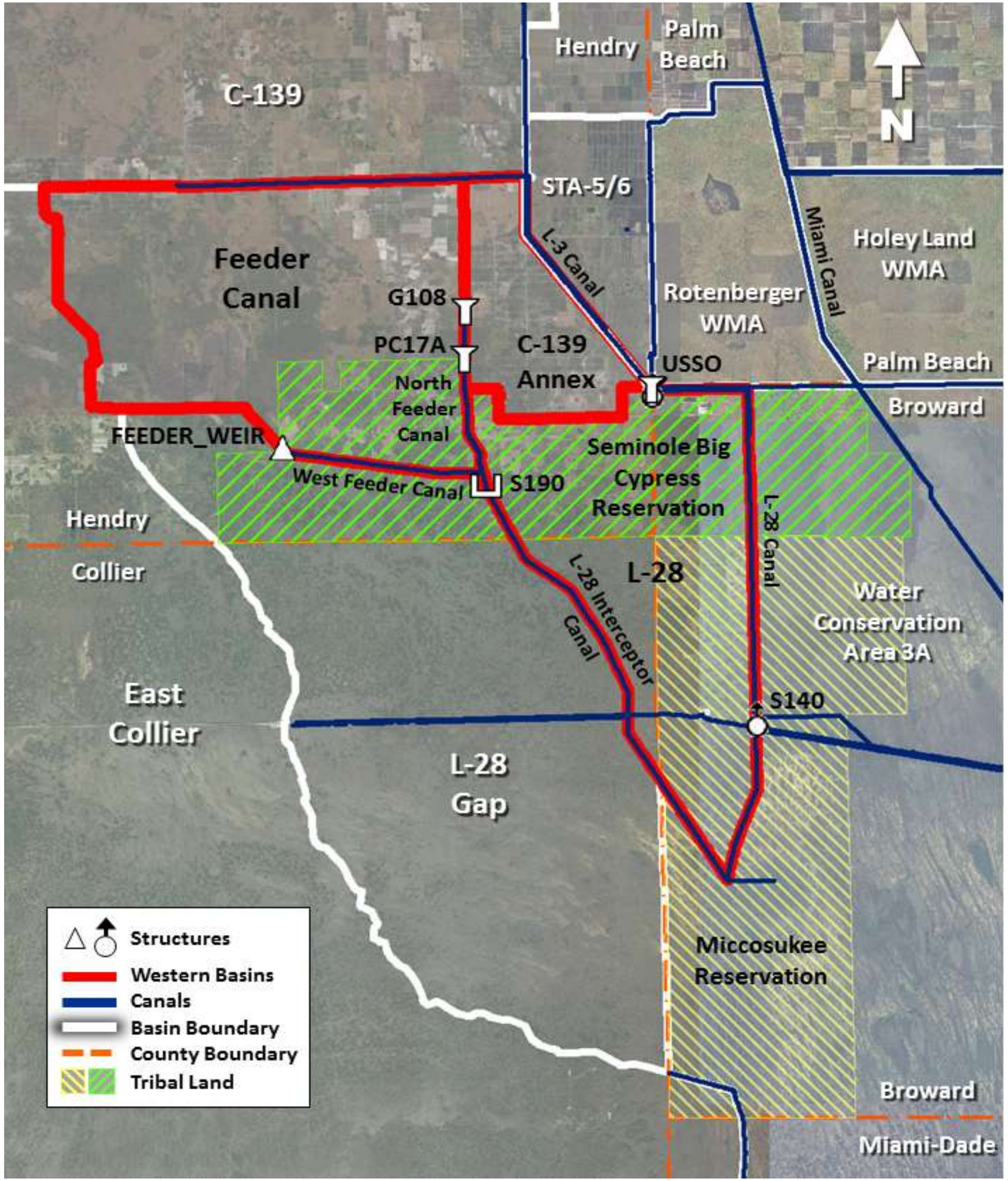
Background



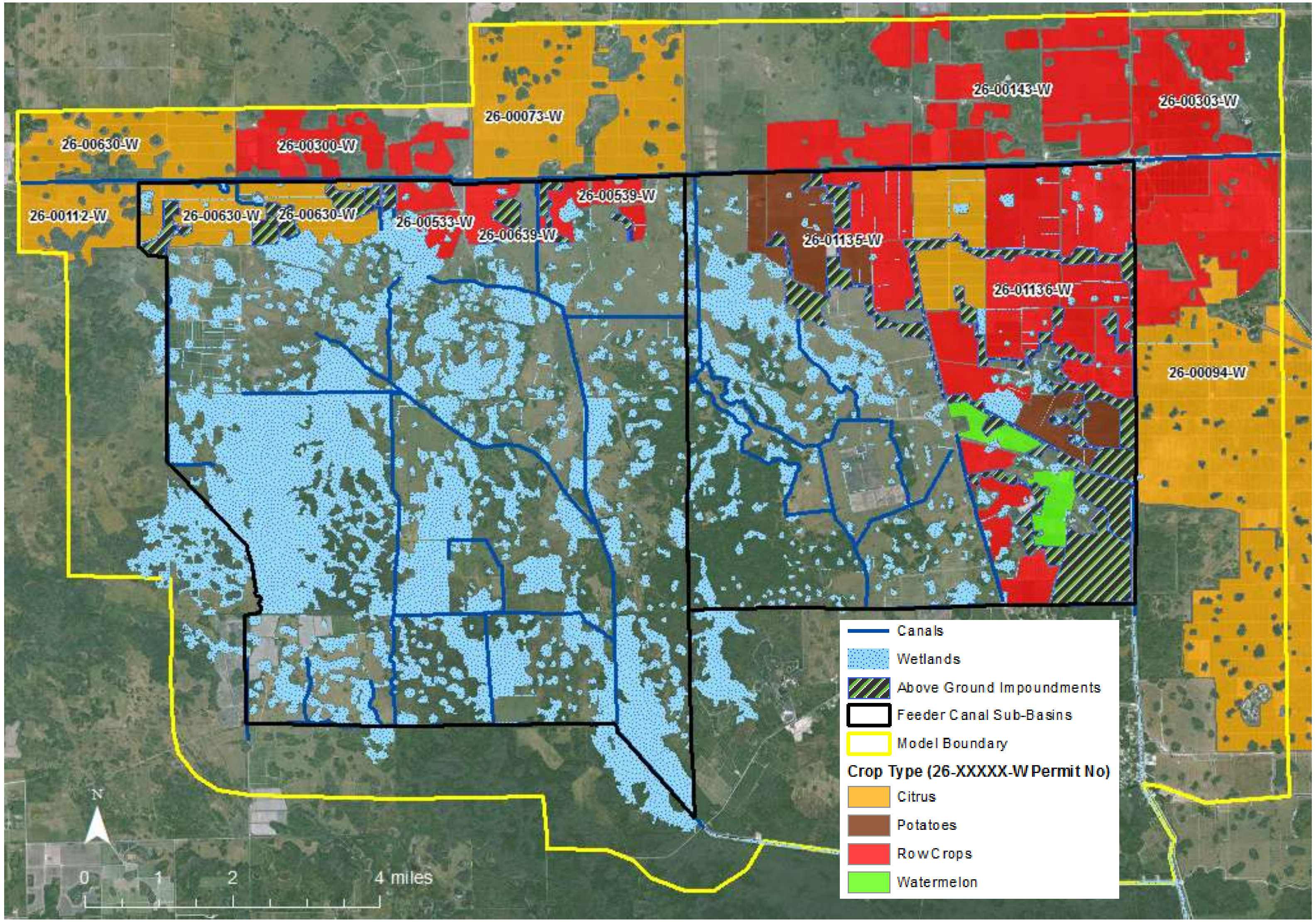
- Non-Everglades Construction Project (non-ECP) basins (i.e., discharge directly into the Everglades Protection Area.
- SFWMD is required by the Florida Department of Environmental Protection (FDEP) to monitor and report on the progress to meet water quality standards in these basins.
- Water Quality Improvement Plans (WQIPs) include a combination of source controls (BMPs), diversion strategies, and capital improvement projects.

Project Objectives

- Western Basins Water Resources Evaluation (WBWRE) to update and expand water quality management measures in the Northern Reach and support the development of a Comprehensive Basin Watershed Management Plan.
- The Northern Reach: North and West Feeder Canal and C-139 Annex.
- The S-190 and S-140 structures have contributed on average 9.0 and 6.7 metric tons of annual total phosphorus (TP), respectively, to WCA-3A since 2006.
- The TP FWMC in 2015 for the PC-17A, WWEIR, and USSO structures were 228, 47, and 139 µg/L, respectively.
- Long-Term Plan Goal: TP FWMC of **50 µg/L**.



Land Use and Water Use



WFCB: 31,850 ac

Land Use	Area (ac)
Above Ground Impoundments	662
Active Agricultural Fields	2,925
Non-AGI Wetlands	12,301

NFCB: 23,080 ac

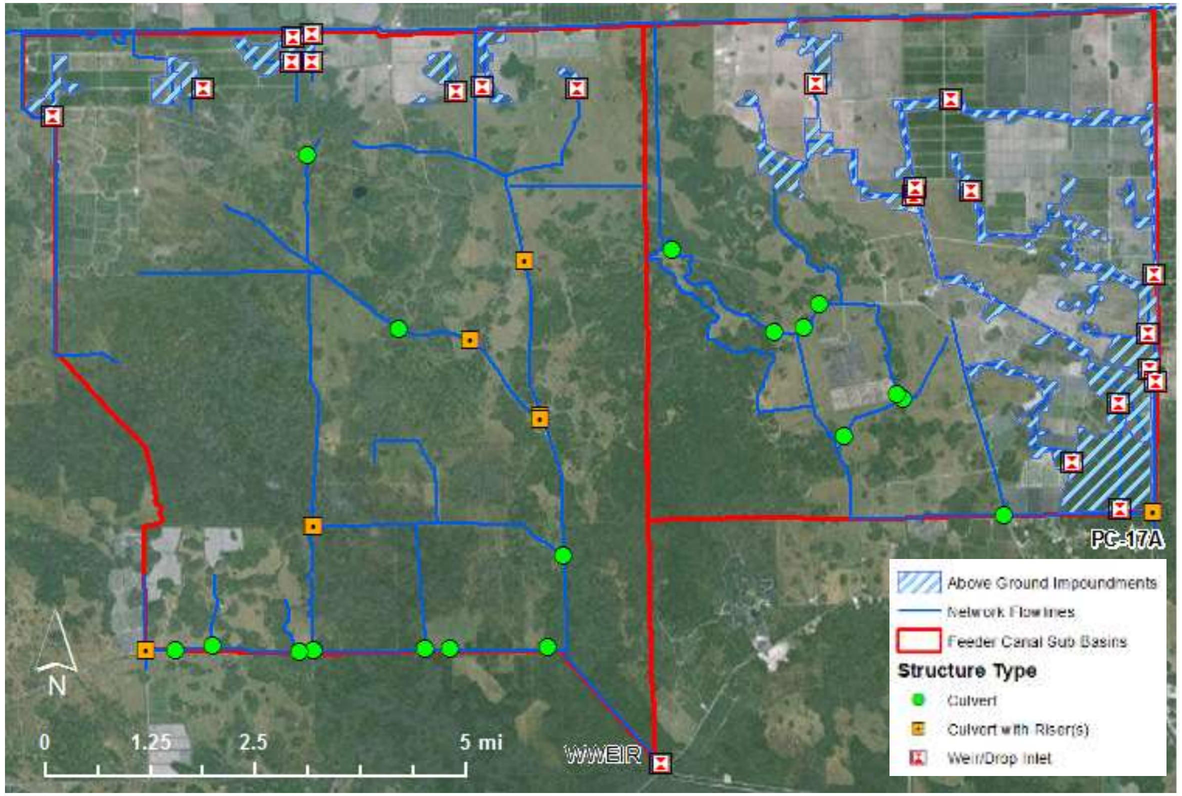
Land Use	Area (ac)
Above Ground Impoundments	2,727
Active Agricultural Fields	8,461
Non-AGI Wetlands	2,850

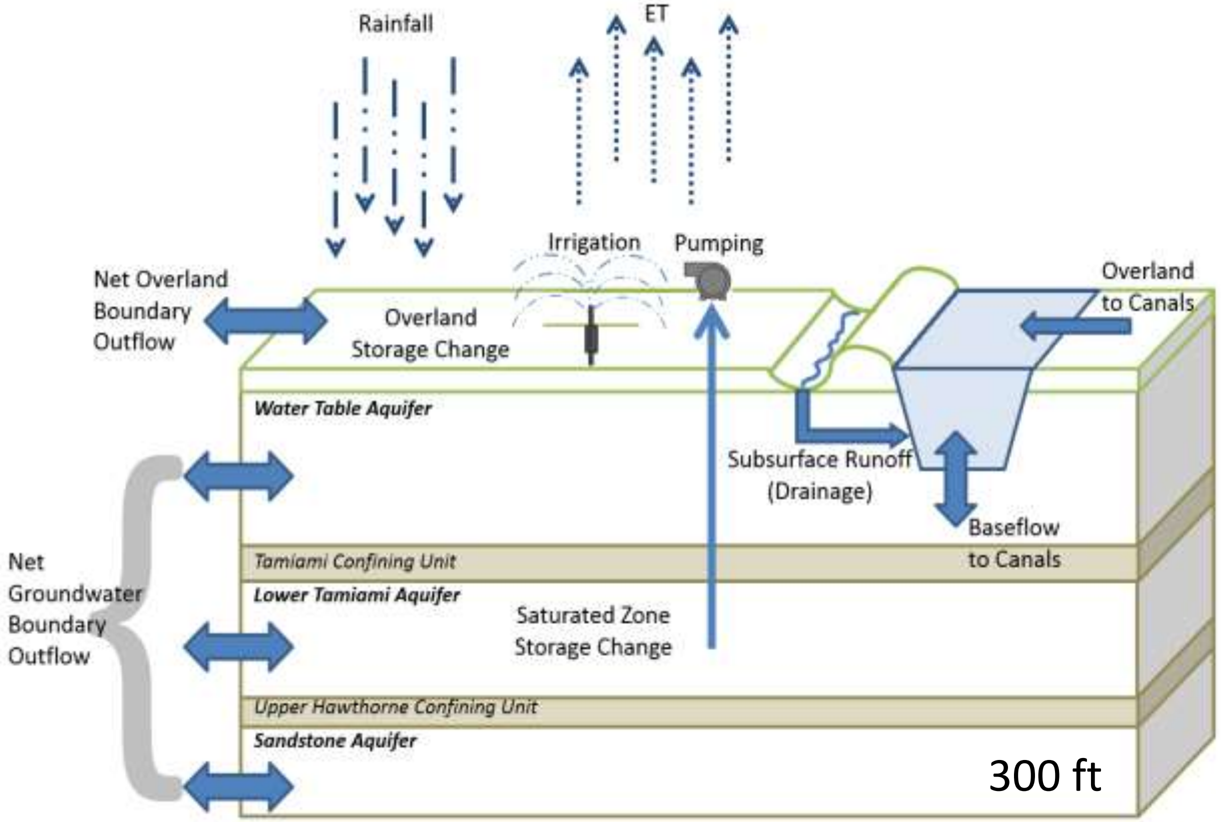
The remaining areas are mostly woodland, improved and unimproved pastures and non-active fields.

Reported water use in 2013: 236 MG in WFCB and 6,366 MG in NFCB.

Model SW/GW Components (MIKE 11/MIKE SHE)

- Radar-based rainfall and satellite-based RET.
- Sheetflow in undisturbed lands/wetlands.
- Network of canals and AGIs with hydraulic structures.
- Agricultural excess drainage.
- 3 aquifers and 2 confining units.
- Groundwater abstractions and irrigation.

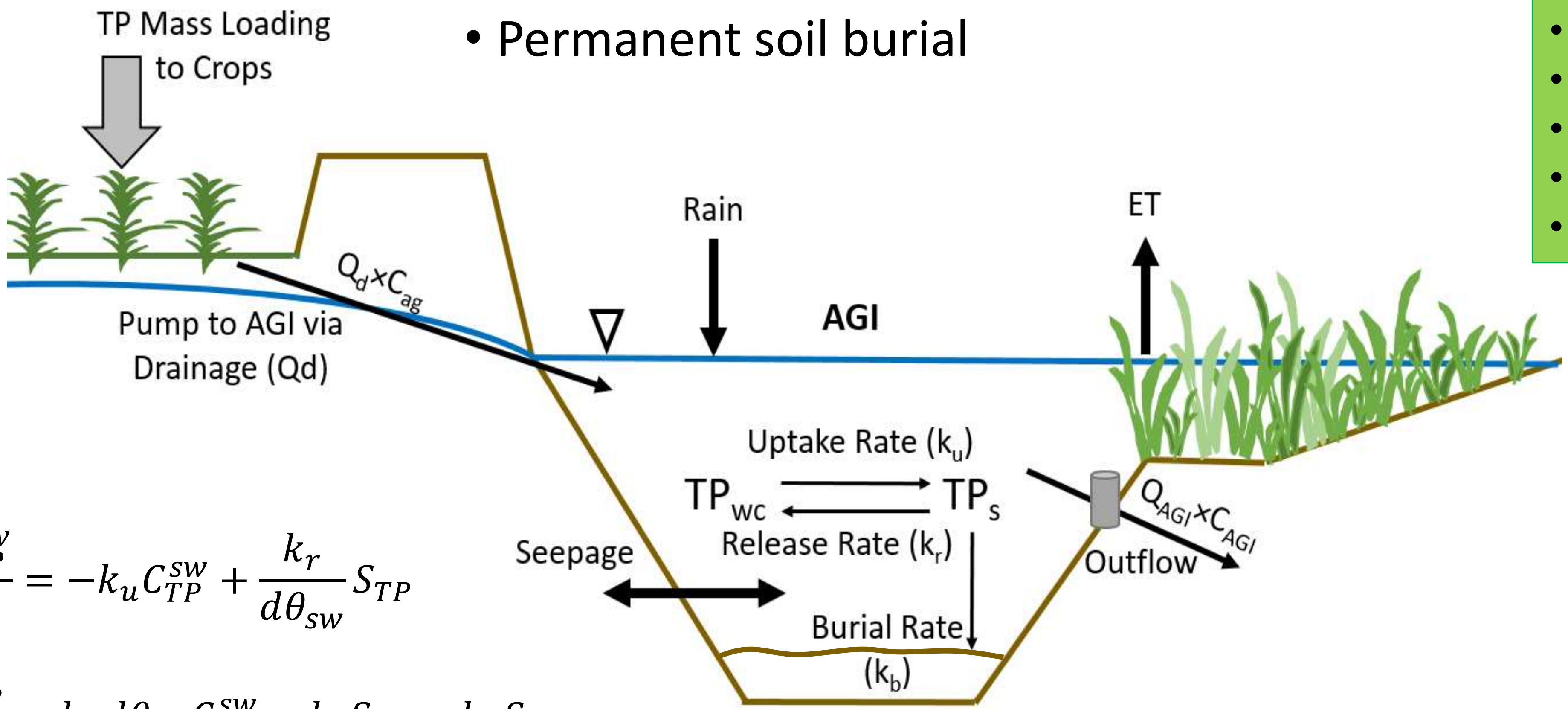




Phosphorus Conceptual Model

P components are lumped into 3 storages:

- Water column
- Soil/plant dynamic
- Permanent soil burial



DMSTA Calibrations

- Emergent
- PEW
- SAV
- PSTA
- Reservoir

$$\frac{dC_{TP}^{sw}}{dt} = -k_u C_{TP}^{sw} + \frac{k_r}{d\theta_{sw}} S_{TP}$$

$$\frac{dS_{TP}}{dt} = k_u d\theta_{sw} C_{TP}^{sw} - k_r S_{TP} - k_b S_{TP}$$

Paudel et al., 2011
Walker and Kadlec 2005

Coupling Phosphorus Processes, Transport and Hydrodynamics

The solute transport equation is coupled with transformative processes to calculate concentration.

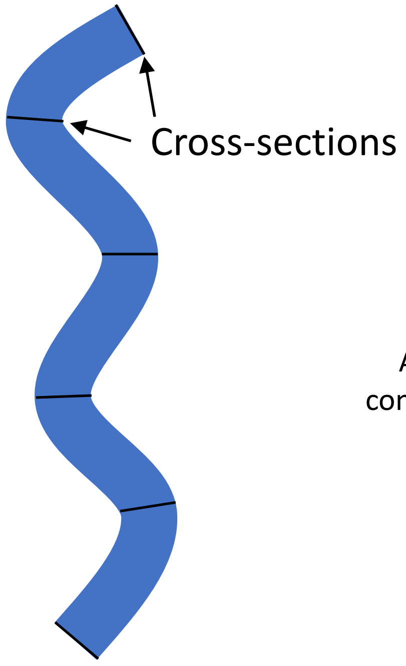
$$\frac{\partial c}{\partial t} = AD_c + P_c$$

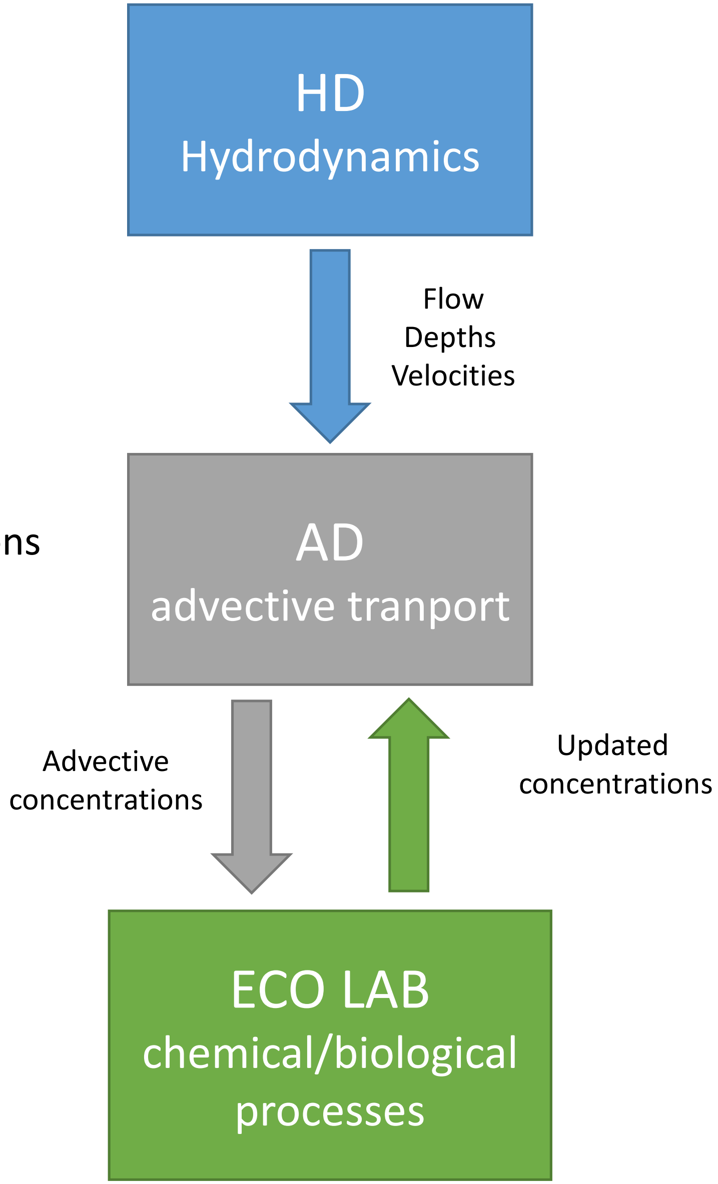
AD_c = the rate of change in concentration due to advection and dispersion

P_c = the transformative processes (phosphorus model)

$$\frac{\partial C}{\partial t} = -U\frac{\partial C}{\partial x} + D\frac{\partial^2 C}{\partial x^2} - \lambda C + C_2 q$$

C = concentration [ML^{-3}];
t = time [T];
U = flow velocity [LT^{-1}];
x =distance [L]; D =dispersion coefficient [L^2T^{-1}];
λ =first-order rate coefficient [T^{-1}];
C_2 = source/sink concentration; and q = lateral inflow





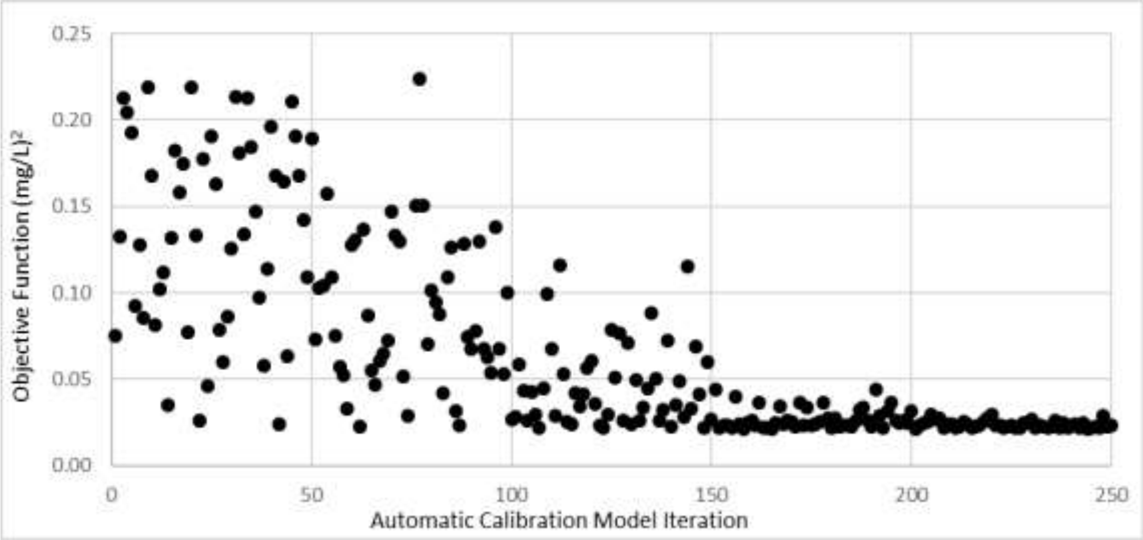
DHI, 2016

Model Calibration Approach

- Manual calibration, data analysis
- Semi-automatic, automatic calibration
- Sensitivity analysis
- Land use based distributions

Parameter	Δ Value	Δ Stage RMSE (ft)				Δ Flow RMSE (cfs)	
		Surface Water		Grounwater		WW Q	PC17A Q
		WW HW	PC17A HW	HES-28S	HES-28D		
OL Manning's n	× 2	0.0	0.0	0.0	0.0	2.3	2.0
OL-SZ leakage coefficient	× 10	0.0	0.1	0.2	0.3	7.1	4.7
OL detention storage	÷ 2	0.0	0.01	0.0	0.0	7.7	0.9
Canal Manning's n	× 2	0.0	0.0	0.0	0.0	0.3	0.5
Canal-aquifer leakage coefficient	× 2	0.0	0.8	0.2	0.1	8.7	94.4
	÷ 5	0.0	0.0	0.3	0.0	10.0	4.8
Moisture content at saturation (Θ_{SAT})	+0.05	0.1	0.1	0.2	0.0	2.9	2.2
Water Table Aquifer Kh	× 5	0.0	0.0	0.2	0.0	8.3	3.1
Water Table Aquifer Kv	× 5	0.0	0.0	0.0	0.0	0.1	0.1
Tamiami Confining Unit K	× 5	0.0	0.1	0.1	0.6	2.3	6.8
Lower Tamiami Aquifer Kh	× 5	0.0	0.0	0.0	0.1	0.4	0.1
Lower Tamiami Aquifer Kv	× 5	0.0	0.0	0.0	0.0	0.2	0.0

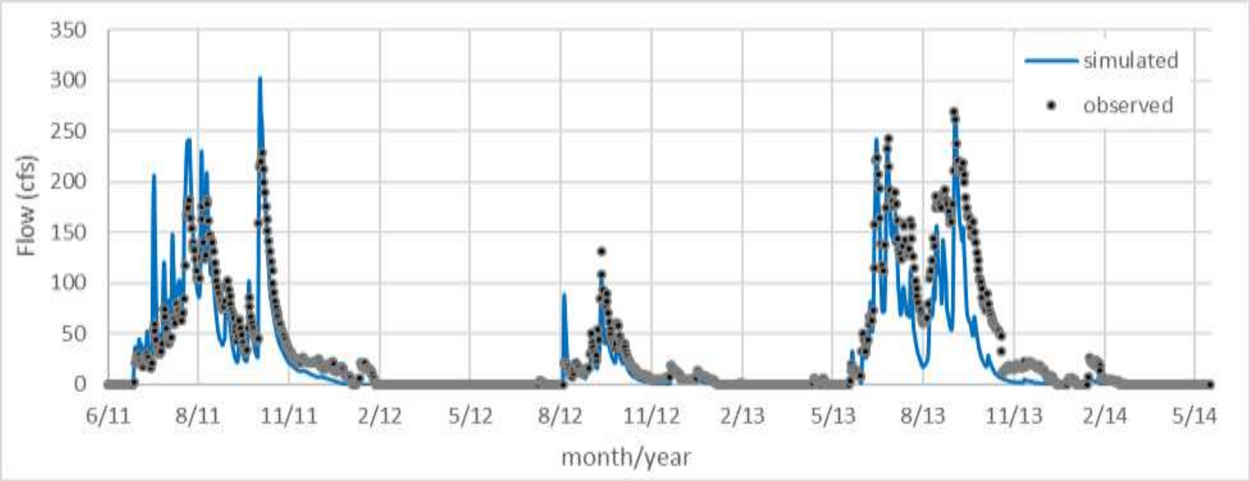
Parameter	Unit	Initial value	Lower value	Upper value	25% increase	Scaled Sensitivity Coefficients	
						Peak (µg/l)	RMSE (µg/l)
K_u (uptake rate)	1/d	0.2	0.1	0.5	0.25	-161	44
K_r (release rate)	1/d	0.002	0.001	0.008	0.0025	185	-46
K_b (burial rate)	1/d	0.001	0.0005	0.0015	0.00125	-9	2
Θ (Water content)	fraction	0.7	0.5	0.9	0.875	-19	5
C_L (load concentration)	µg/l	1000	500	1,500	1,250	79	-24



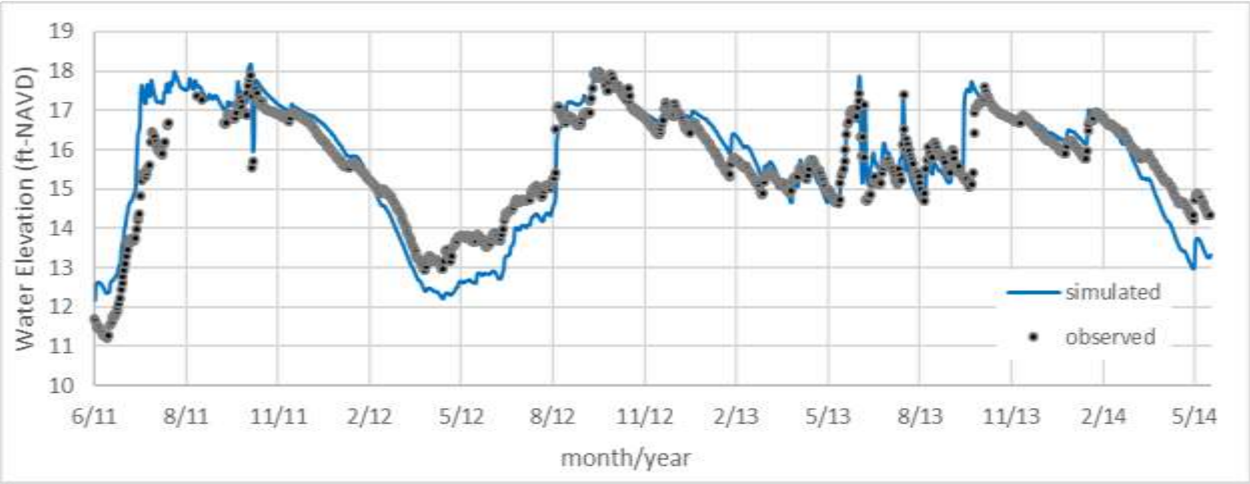
AGI	K_u (1/day)
PT_D3	0.05
PT_D2	0.08
PT_D2A	0.12
PT_D12	0.37
PT_D1011	0.16
PT_D9	0.39
PT_D5678	0.16
PT_D1	0.09
PT_D4	0.07
PT_D13	0.09
DET_D	0.28

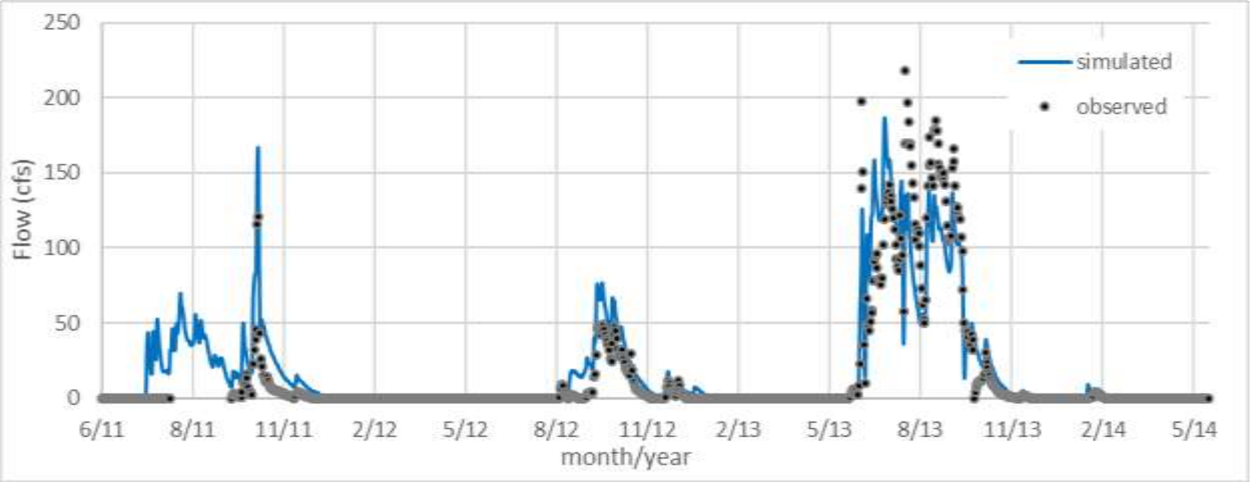
Simulated versus Observed Stages and Flow at Basin Outlets

West Feeder Canal Basin (WWEIR)



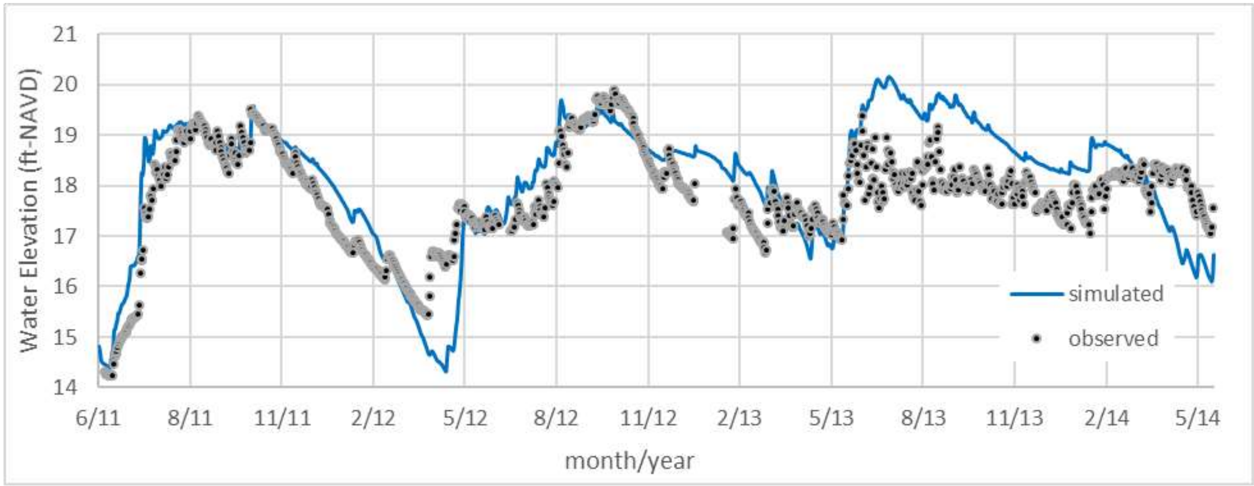
North Feeder Canal Basin (PC-17A)



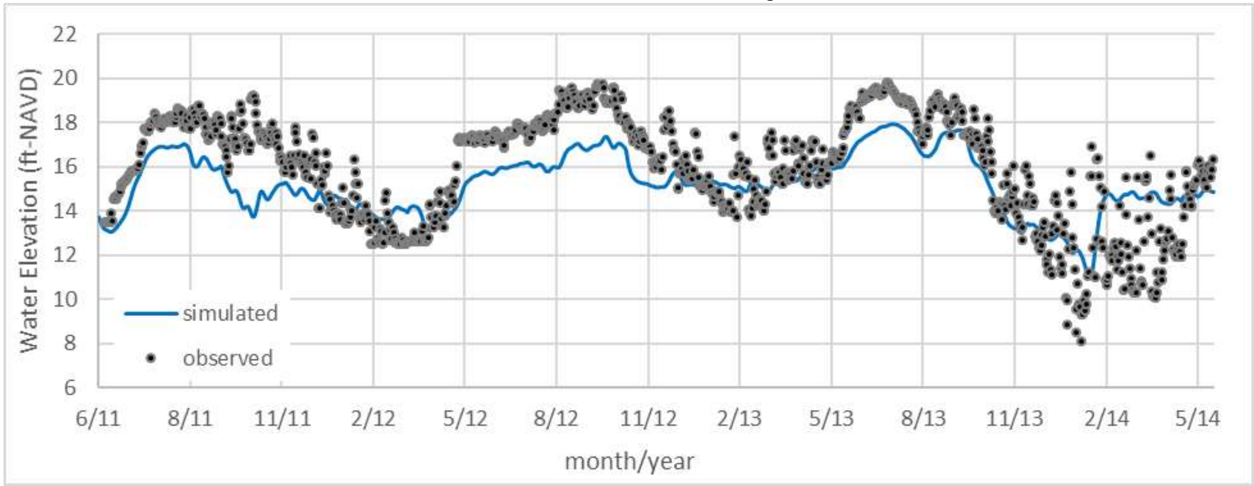


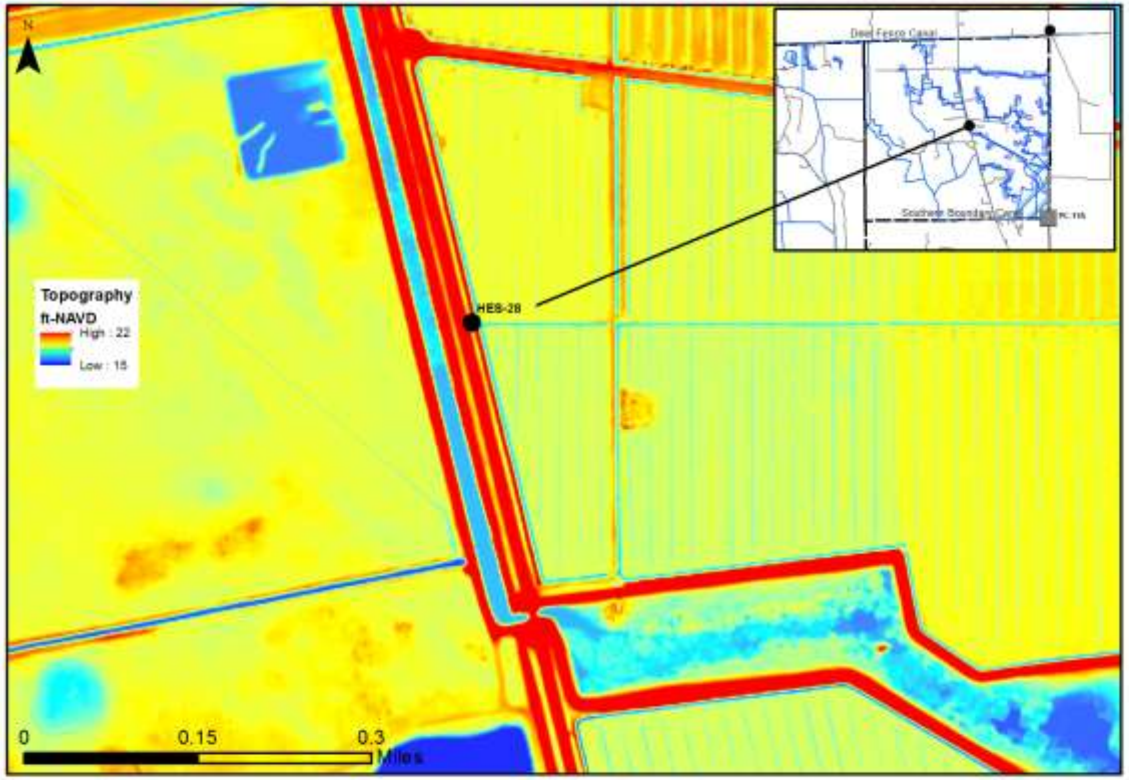
Simulated versus Observed Groundwater Elevations

Water Table Aquifer



Lower Tamiami Aquifer

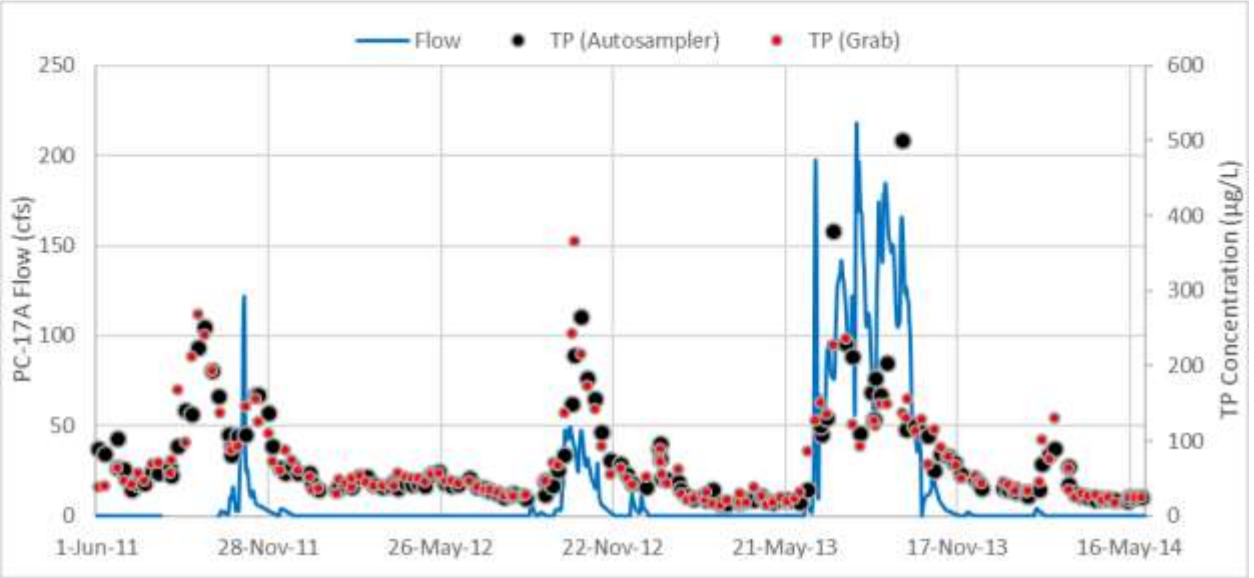




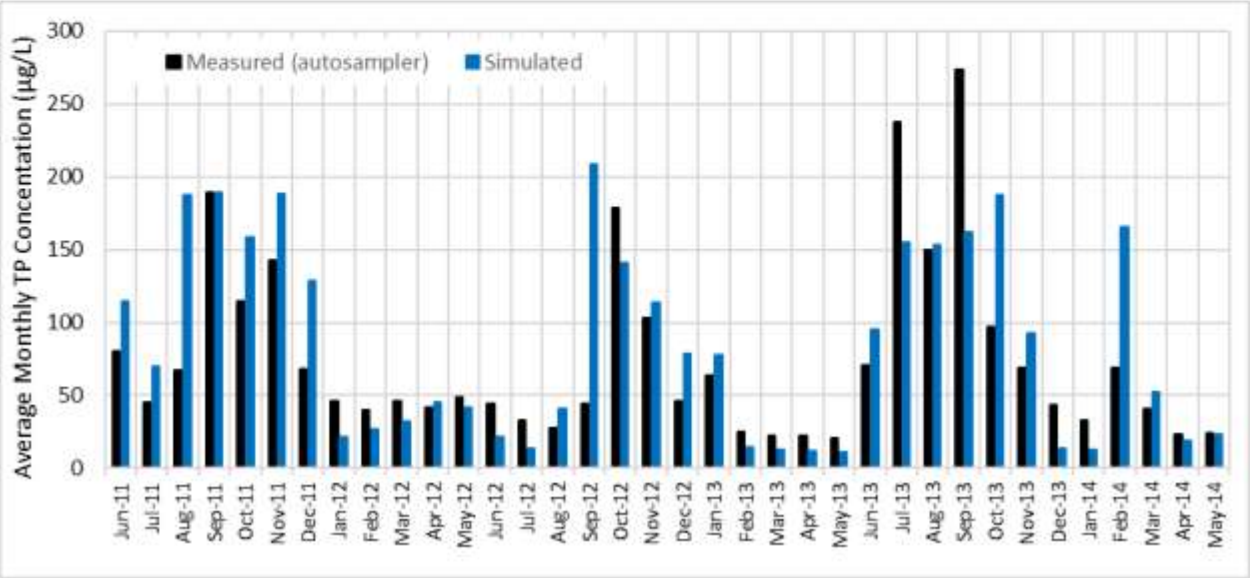
Phosphorus Model Calibration – PC-17A (NFCB)

- Strong Q - P relationship in the measured data.
- Calibrated uptake rates in the low range indicate AGI system has a low treatment efficiency (short circuiting, vegetation, soils).
- Optimal release rates: low values resulted in a low RMSE, while high values resulted in a low peak error. Possibly a function of sediment resuspension (e.g., flow velocity).

Measured Data



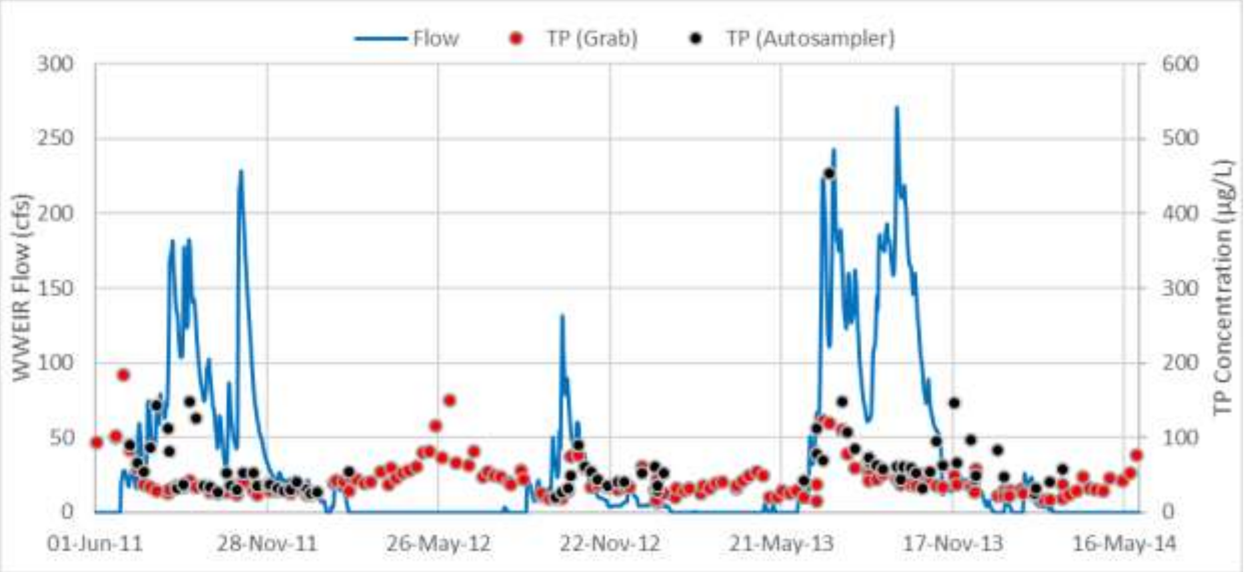
Simulated Versus Measured Data

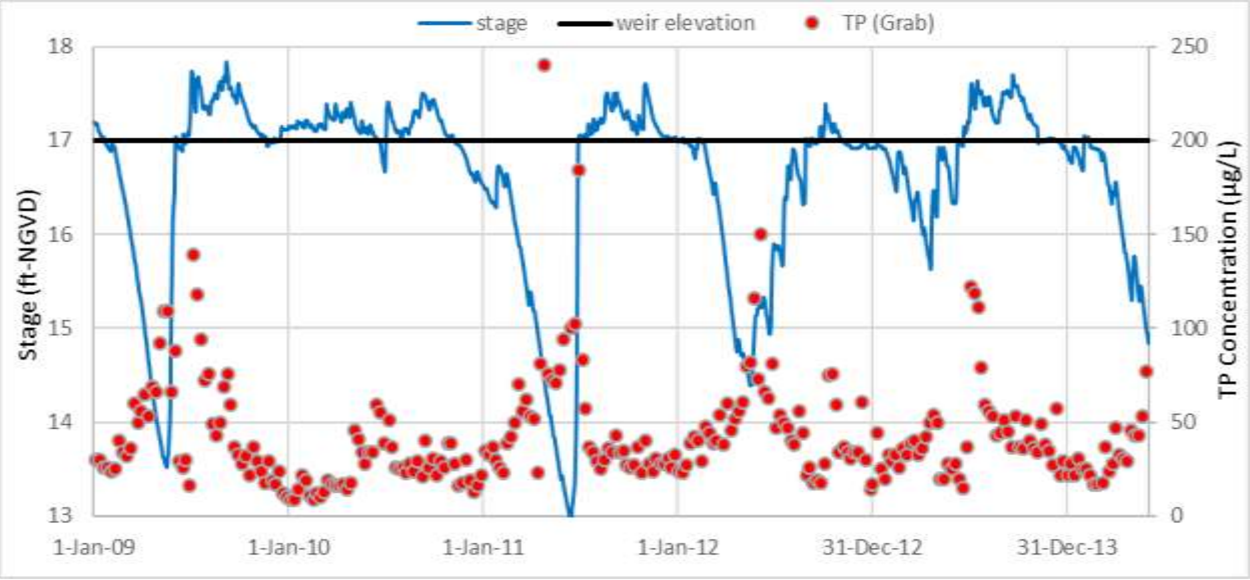


Phosphorus Model Calibration – WWEIR (WFCB)

- Poor Q - P relationship in the measured data.
- Concentrations increase when stages decrease.
- Lower concentrations in the basin due to less intensive agriculture and some AGIs discharge to wetlands.
- Legacy P maybe more critical than active agriculture runoff P.

Measured Data





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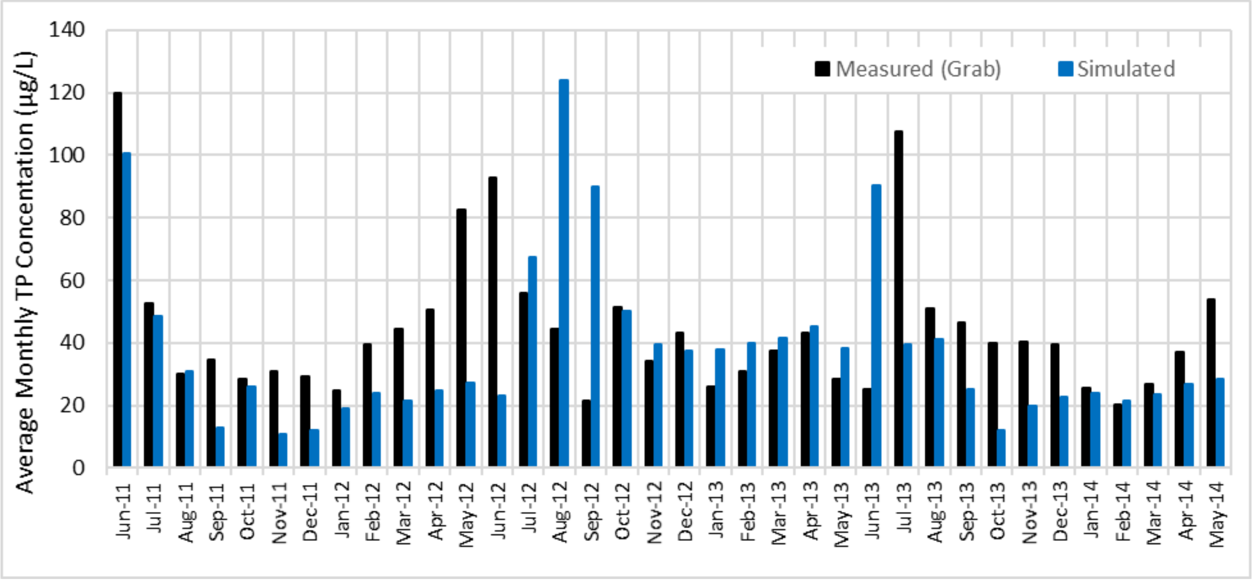
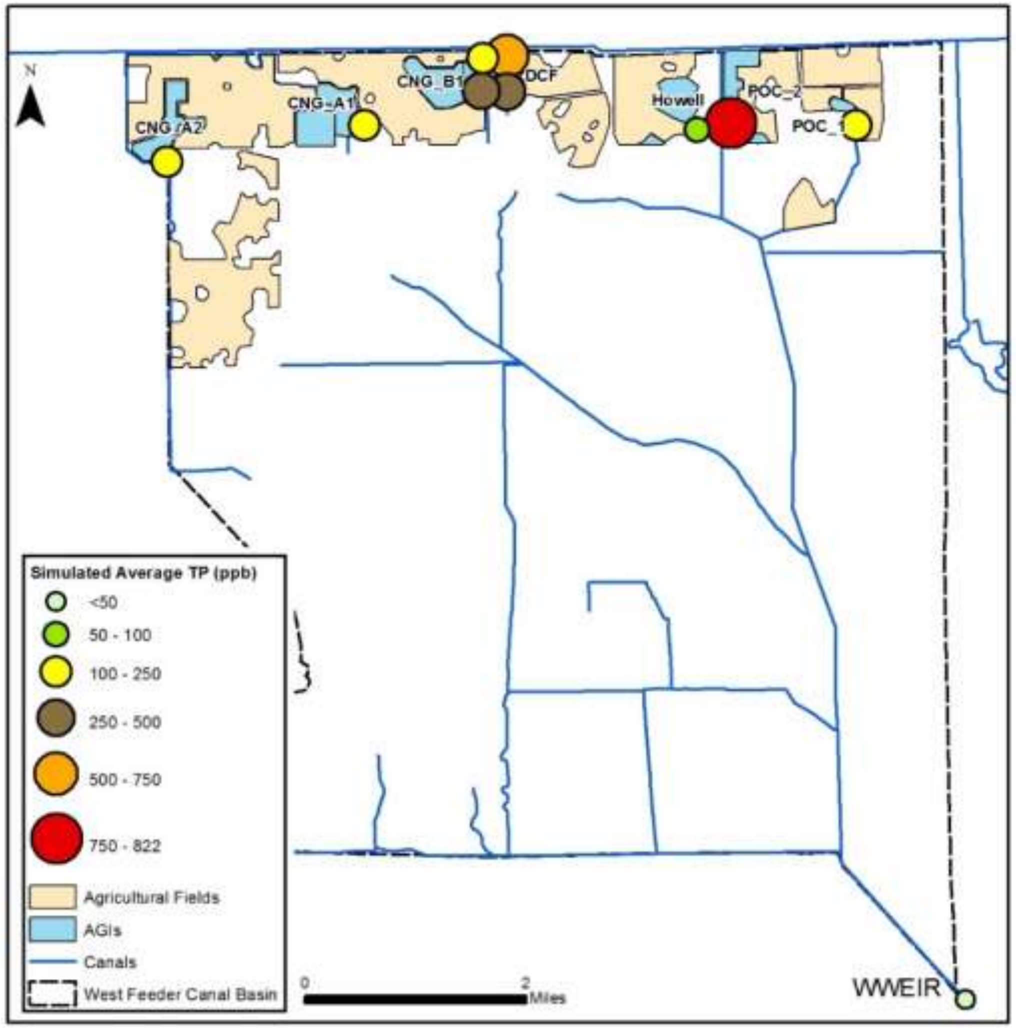
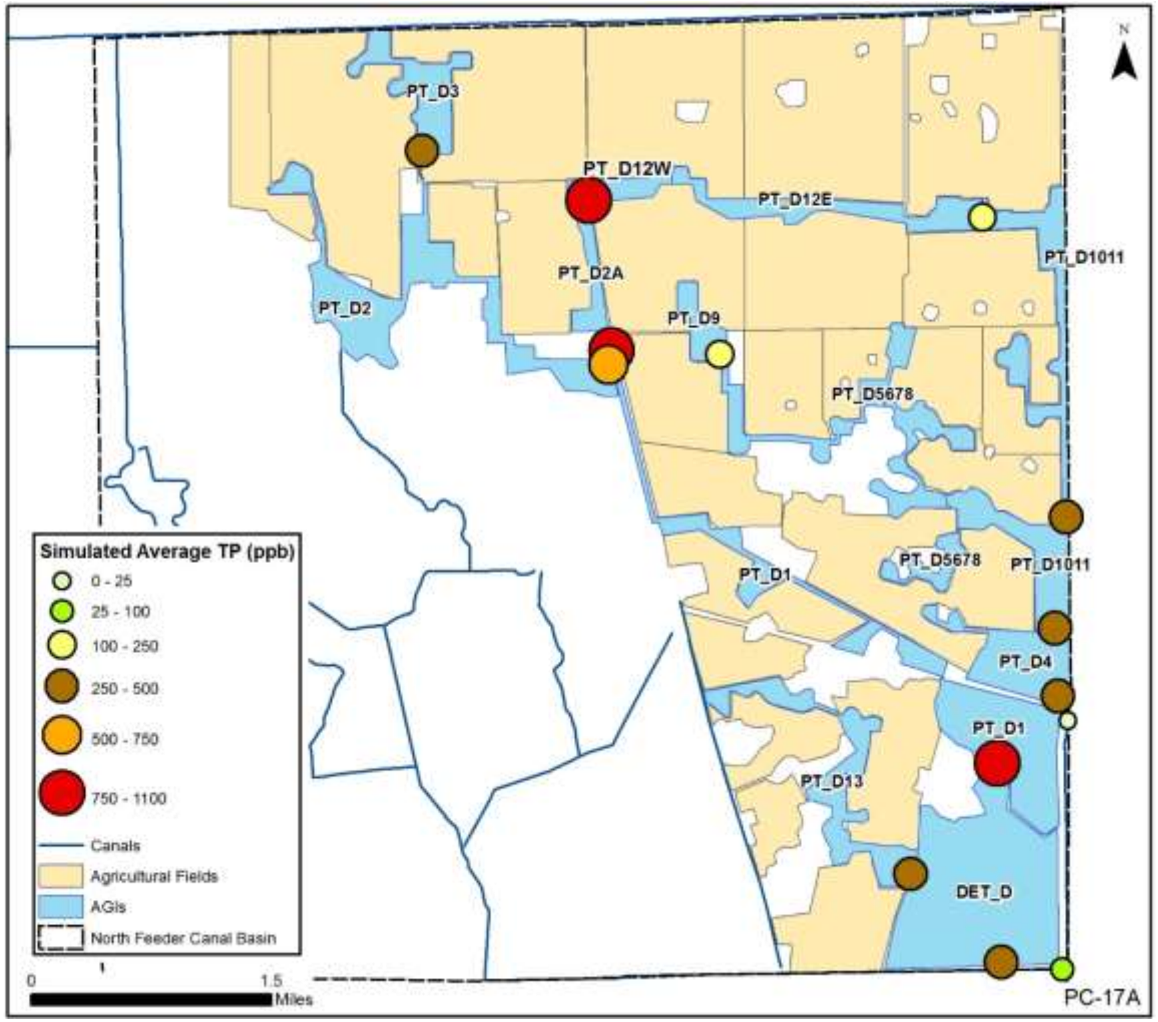


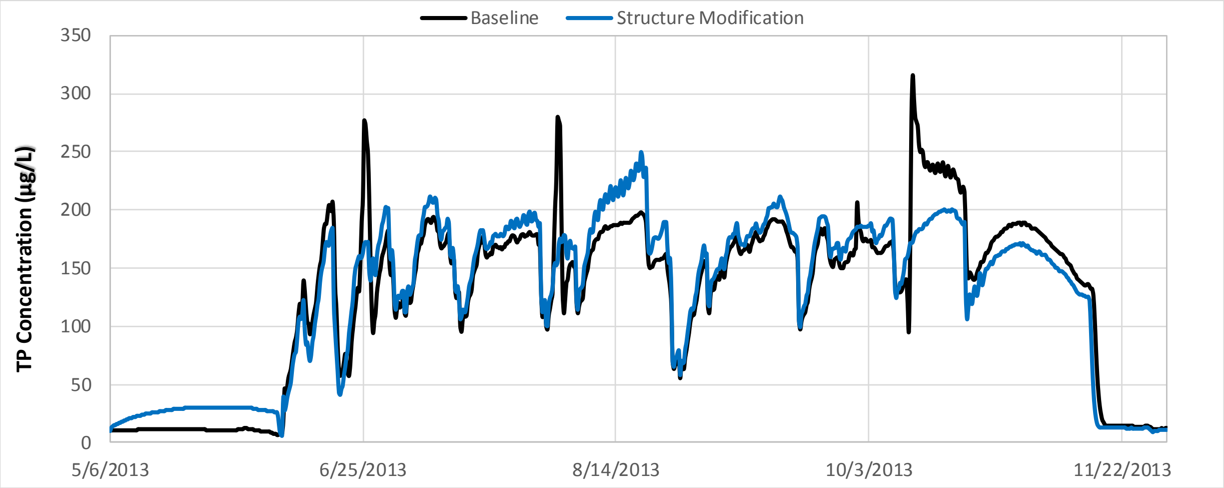
Simulated Phosphorus at the AGI Outlet Structures

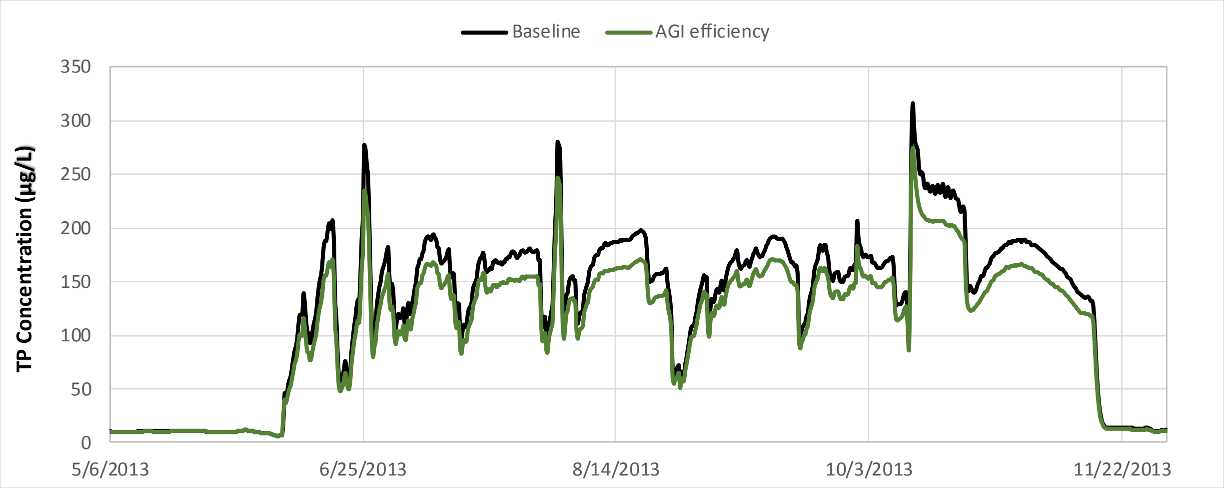




Hypothetical Scenarios

1. Outflow structure modification (PC-17A as a fixed weir)
2. AGI treatment efficiency (uptake rate) – DET D (600 acres)





TP Concentrations (µg/L)

Scenario	Maximum	Mean
Baseline	316	127
1	249	130
2	275	112

Conclusions and Recommendations

- In Everglades basins, integrated hydrological processes are important simulating the transport of nutrients.
- Empirical lumped-parameter approaches to simulate the P cycle are a practical alternative to complex, highly parameterized models. But need to be calibrated.
- Moreover, complexity can easily be added to the model by adding more compartments and linkages to additional processes.
- Data needs:
  - Measure AGI water budgets (Inflows, Rainfall, ET, Seepage)
  - AGI hydraulic retention times and treatment efficiencies
  - Agricultural loads
  - Expand monitoring system with high frequency measurements:
    - Surface water stages and flow in key upstream locations
    - Distributed groundwater measurements
    - Dissolved and particulate phosphorus in key surface water locations and groundwater
- Even with very limited data we can draw hypotheses about the system through the model calibration process.