Flow impacts on P Cycling in the Everglades Ridge and Slough:

Lessons from the Decomp Physical Model

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Wetlands Biogeochemistry Symposium

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Lake Tohopekalinga in Kissimmee

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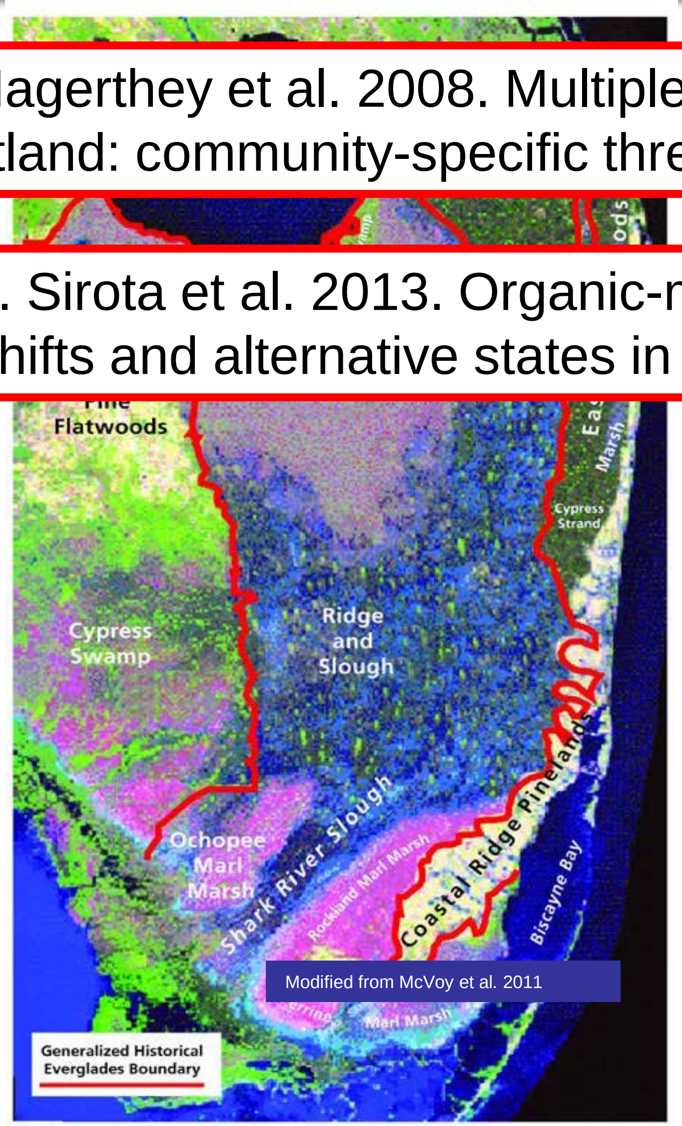
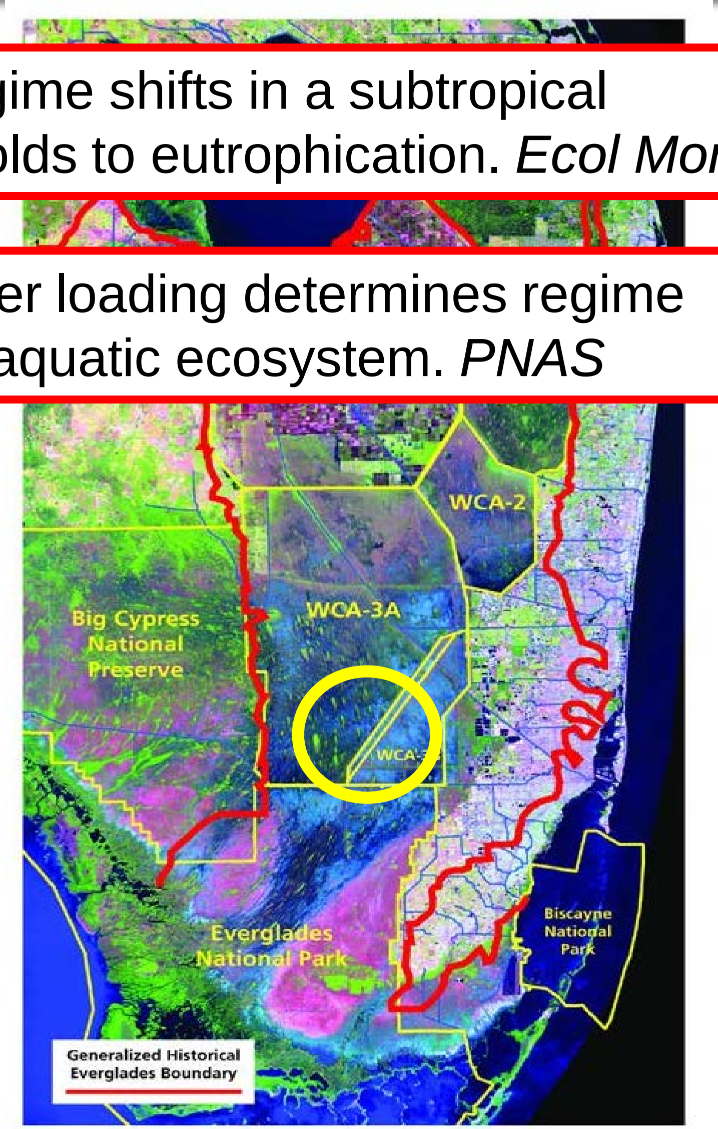
Restoring Connectivity to the Everglades Landscape

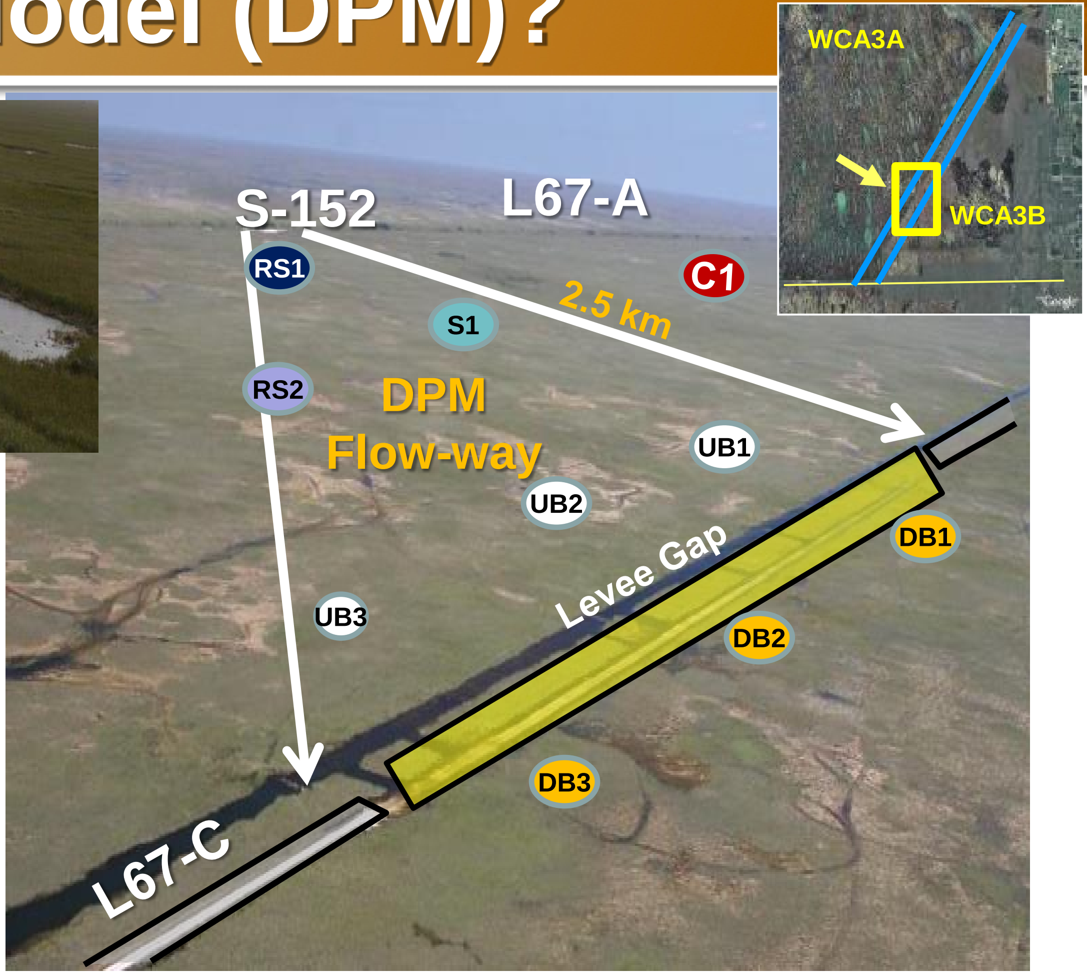
S. Hagerthey et al. 2008. Multiple regime shifts in a subtropical peatland: community-specific thresholds to eutrophication. *Ecol Mon*

J. Sirota et al. 2013. Organic-matter loading determines regime shifts and alternative states in an aquatic ecosystem. *PNAS*



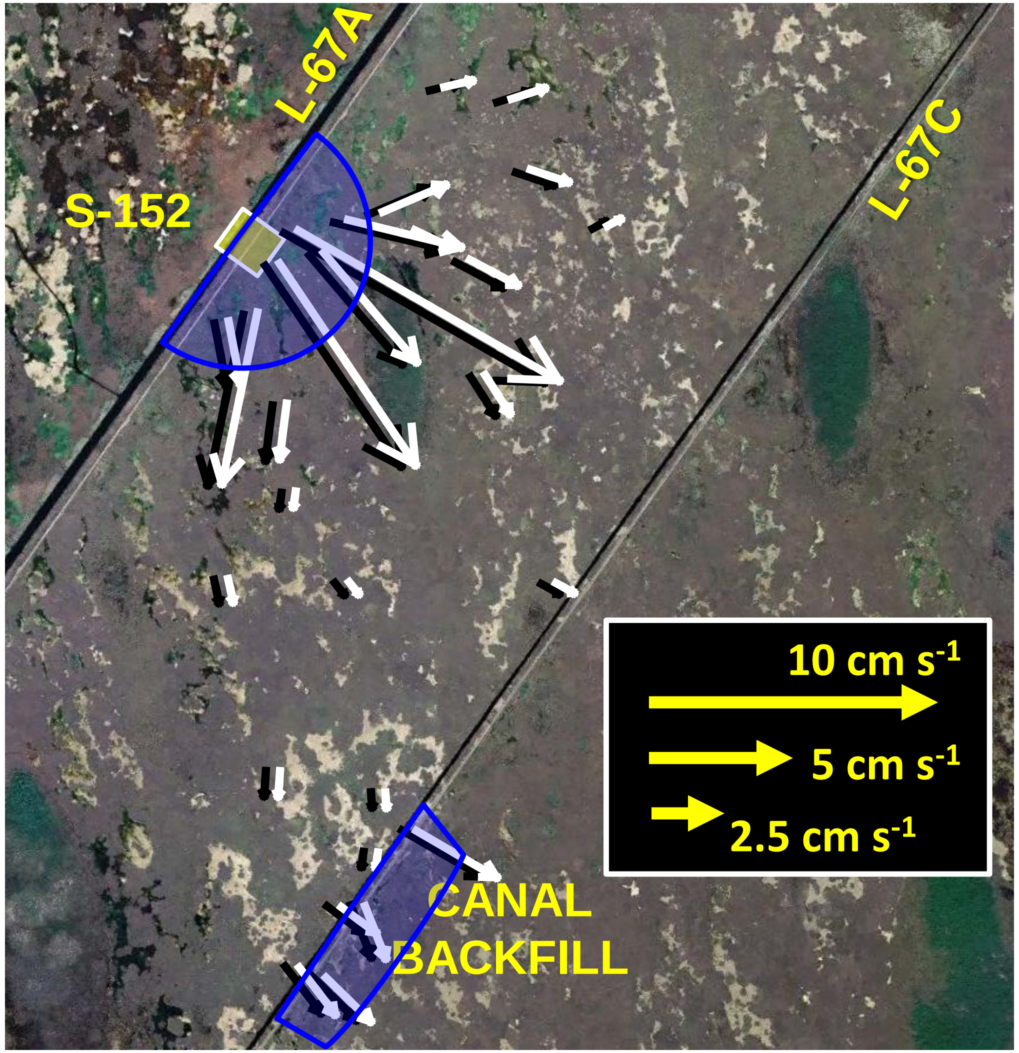


What is the Decomp Physical Model (DPM)?



- Uncertainty 1: Do high velocities (>2 cm/s) generate sediment movement needed to restore the ridge and slough topography?
- Uncertainty 2: To what extent does sheetflow alter P and OM cycling and ultimately foodwebs

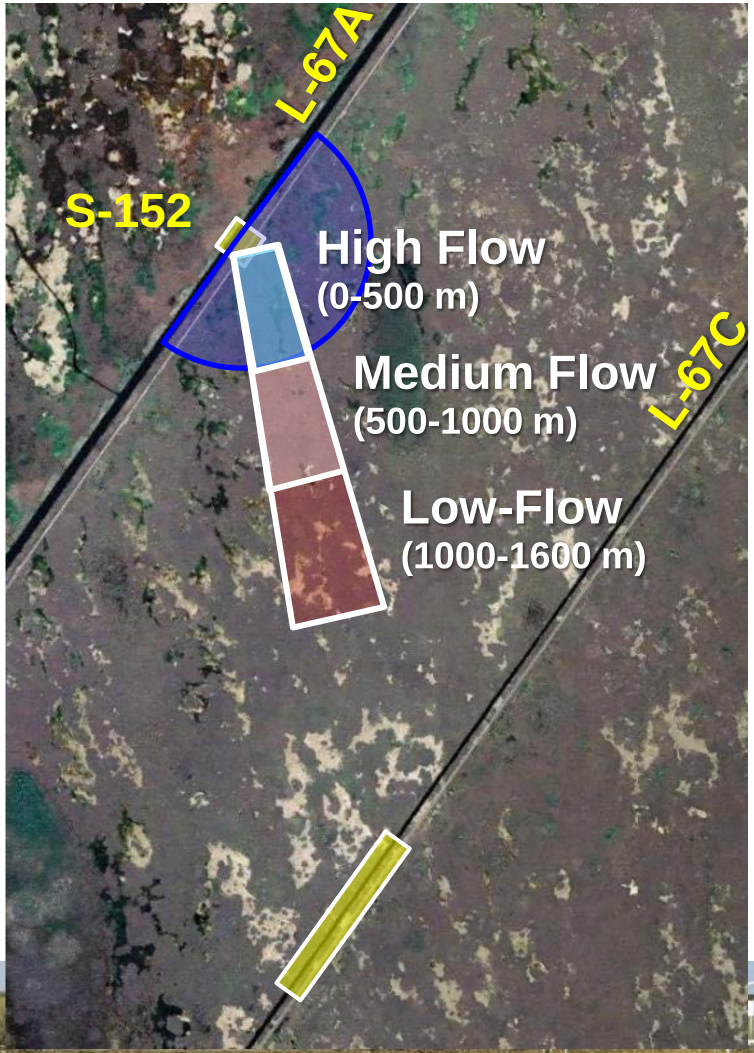
DPM Hydrologic Flow Fields



- Flows did not follow the ecologically preferred (north-south) pattern
- High flows (>2 cm s^{-1}) were limited to ~500-m from the S-152
- … and downstream of the gap

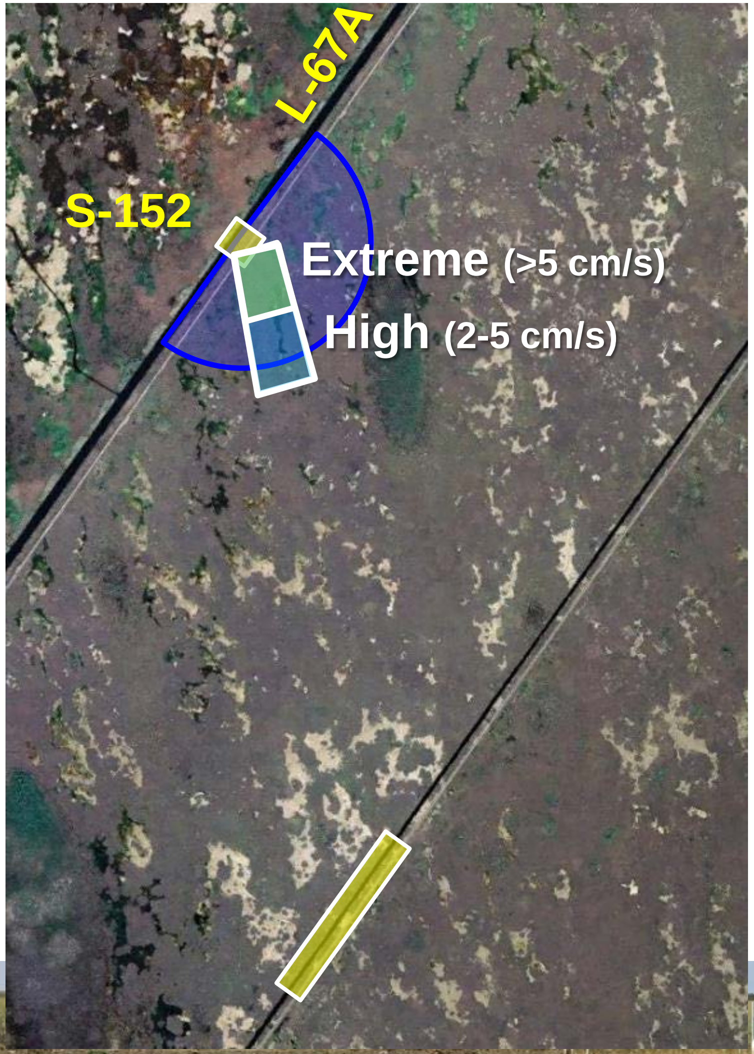
Data from E. Cline, E. Tate-Boldt, C. Hansen, S. Newman, C. Coronado-Molina, C. Saunders (SFWMD)

Objectives for DPM data synthesis: Phosphorus mass balance model



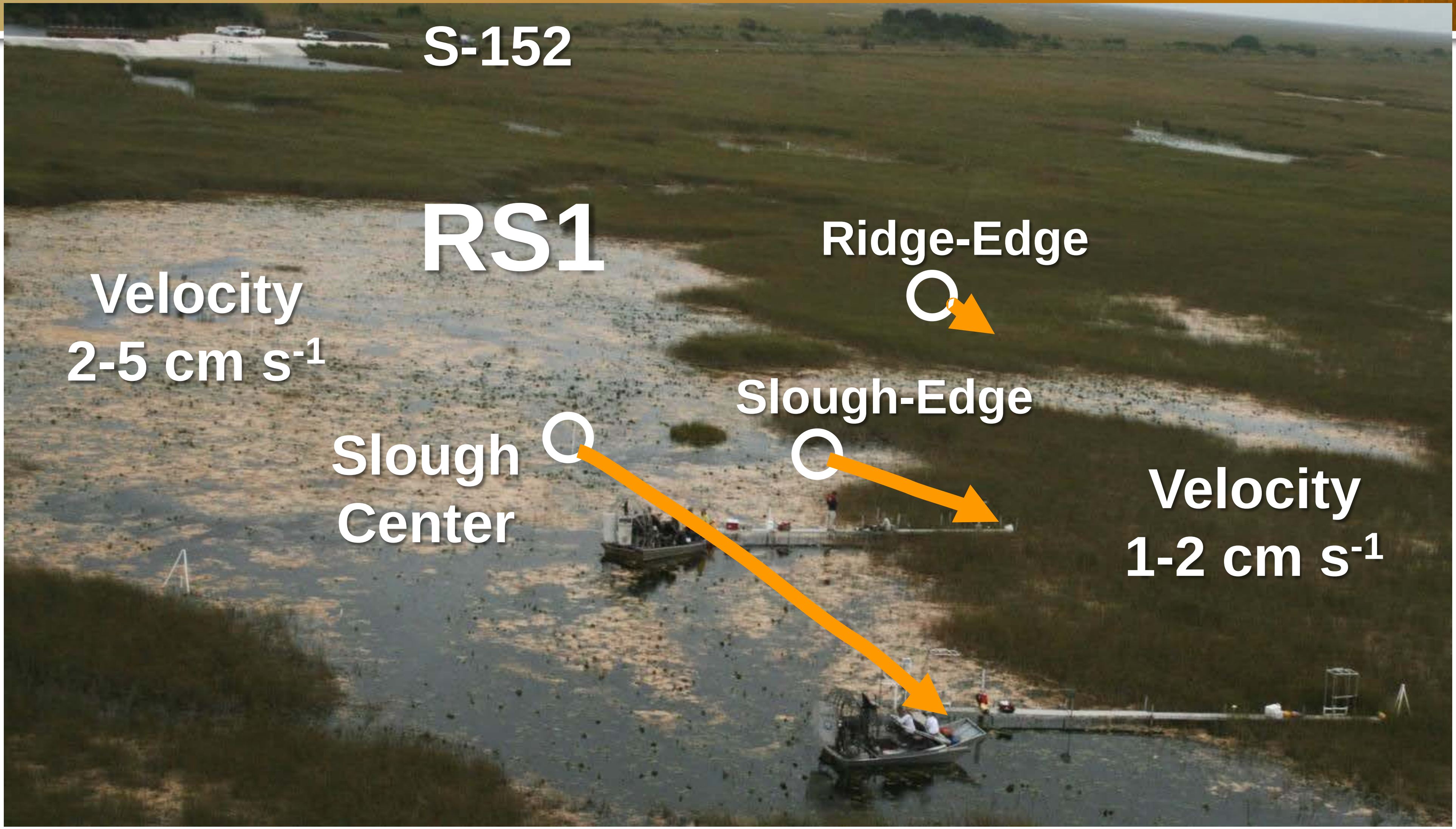
- Which flow-mediated mechanisms best explain observed ecosystem P stocks (water TP, floc P)?
- Using a "linked" mass balance, to what extent does flow impact P cycling beyond 500-m? How fast do changes migrate downstream?

Objectives for DPM data synthesis: Phosphorus mass balance model



- Which flow-mediated mechanisms best explain observed ecosystem P stocks (water TP, floc P)?
- Using a "linked" mass balance, to what extent does flow impact P cycling beyond 500-m? How fast do changes migrate downstream?
- Using a "linked" mass balance, to what extent does flow impact P cycling differently in Extreme vs High Flow Areas?

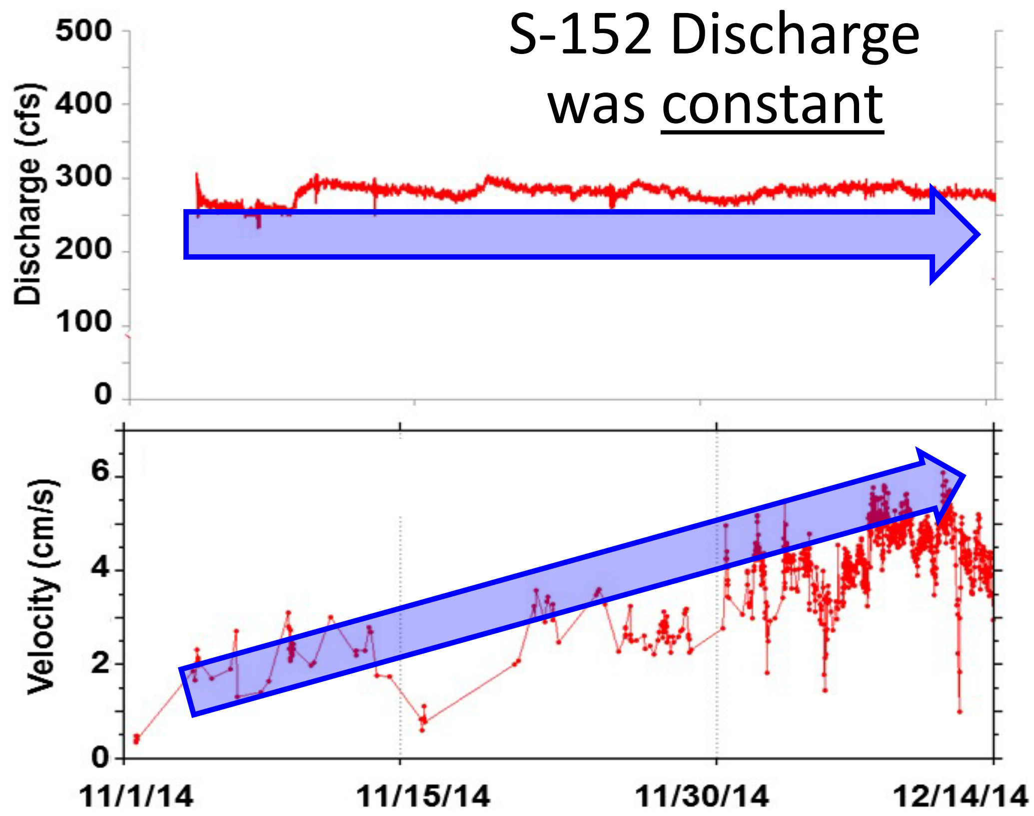
Tracking Particle Movement – Slough to Ridge



Data from E. Tate-Boldt, C. Hansen, S. Newman, C. Saunders (SFWMD)

Flow alters slough structure

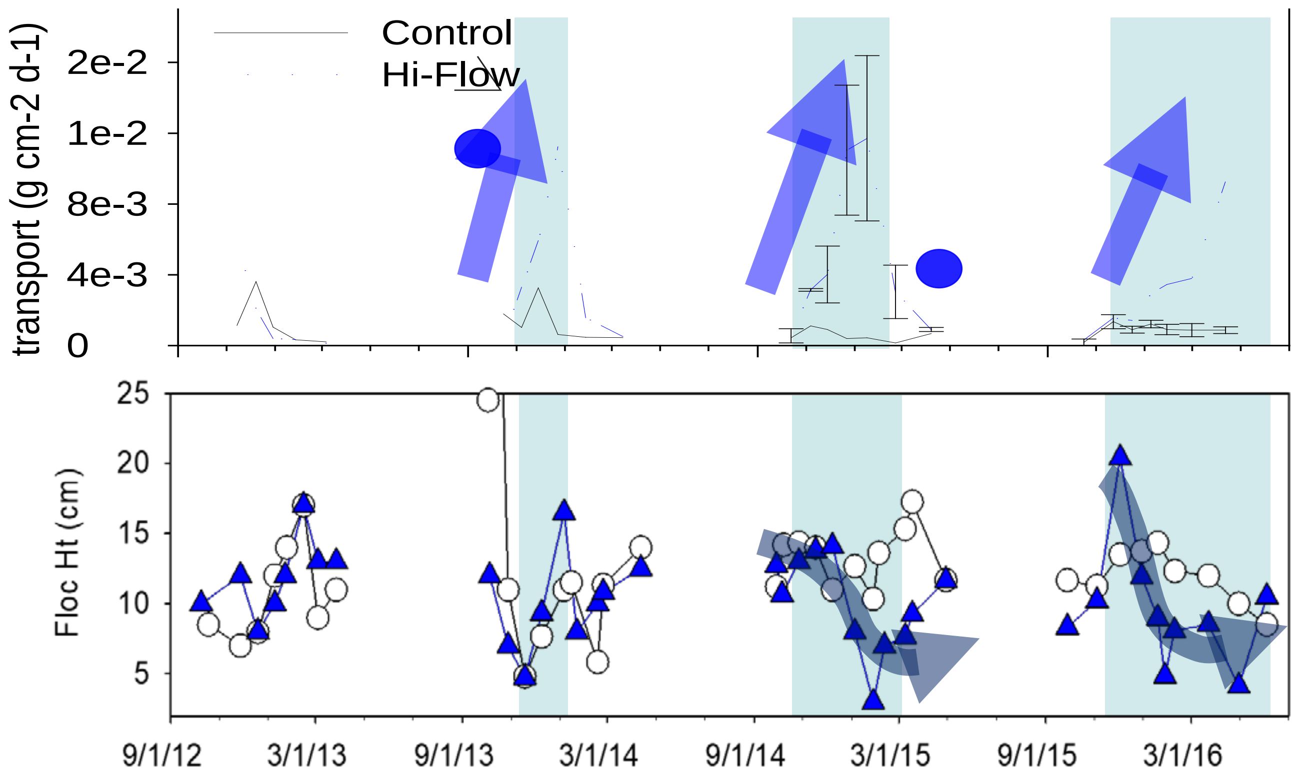
Sustained Flows Resulted in Increased Slough Velocities & Floc Transport



Slough velocities increased with sustained flow

Data from J. W. Harvey, J. Choi, M. Dickman

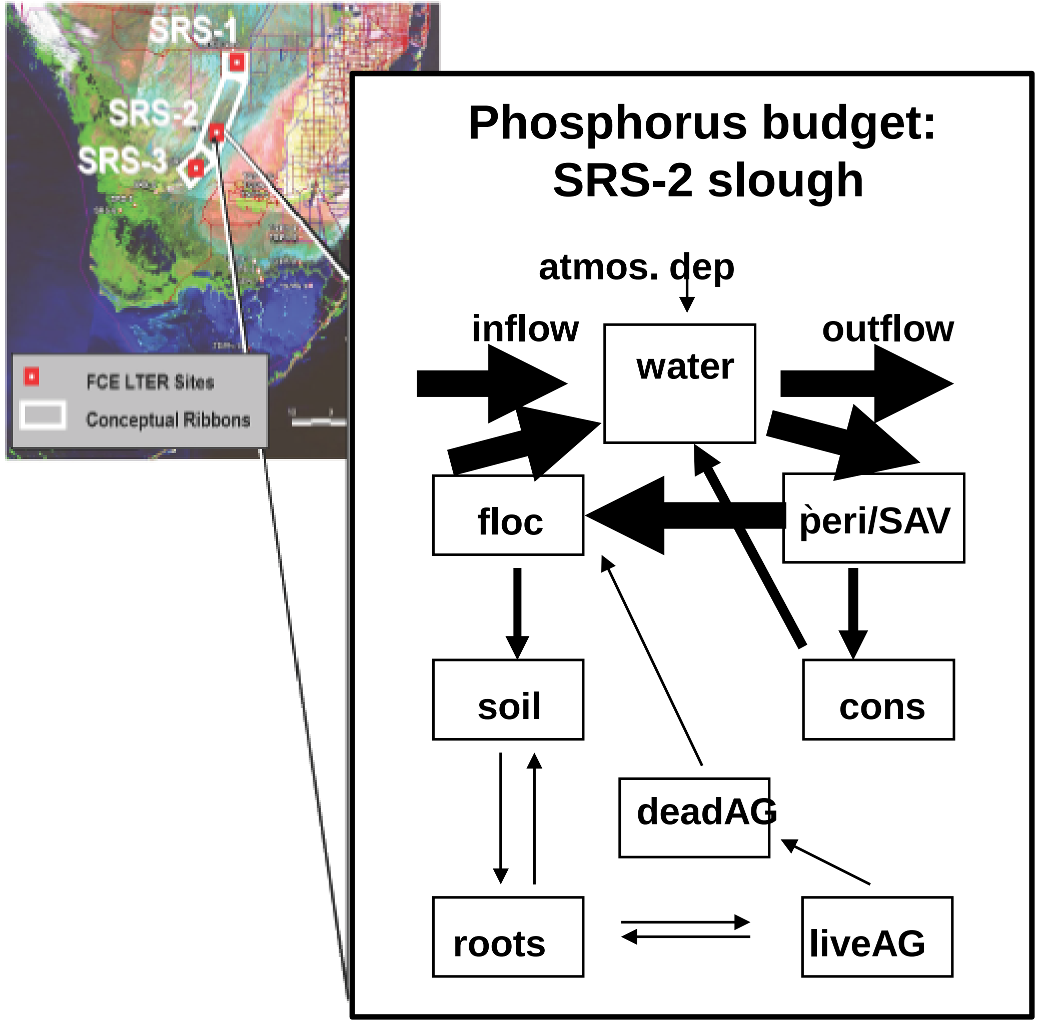
Floc transport increased with sustained flow



Floc Height decreased with sustained flow

Data from C. Saunders, E. Tate-Boldt, C. Hansen, S. Newman

Approach – P budgets of Landscape "Ribbons"



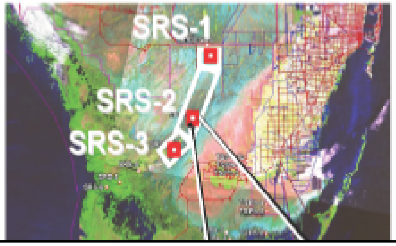
STELLA modeling software to develop P mass balance models

Based on steady state budgets by Noe & Childers (2007) for Everglades ridge & slough habitats; later applied to linked landscape "ribbons" in Shark Slough, ENP

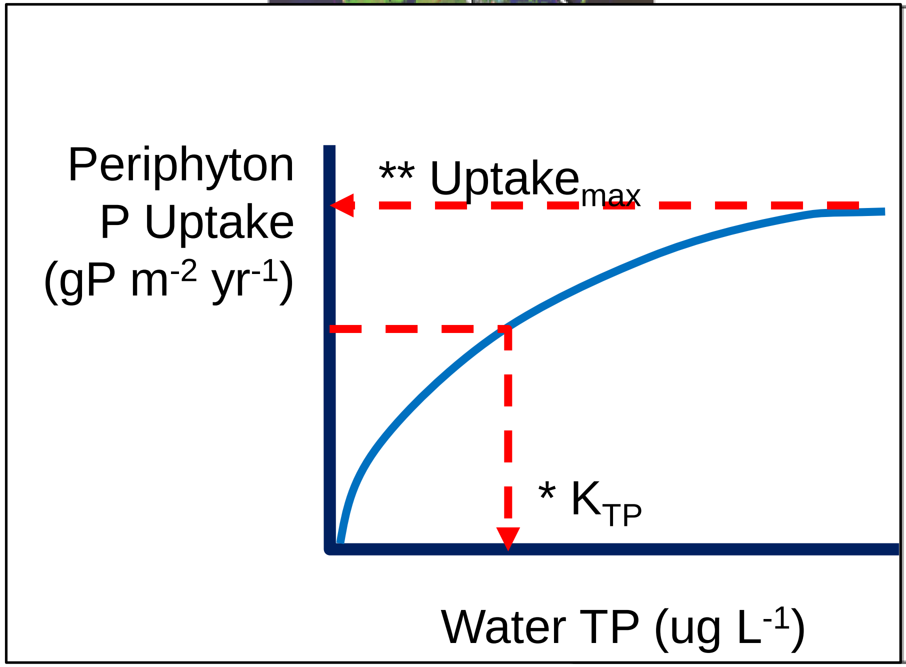
These include

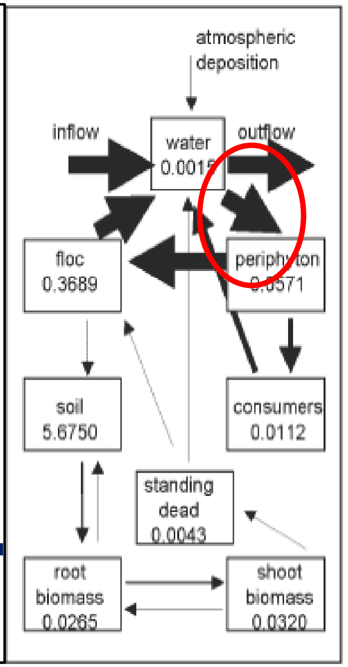
- Water column inflows, outflows
- P uptake by periphyton/SAV
- Consumption of periphyton
- Floc mineralization
- Floc – Soil – Macrophyte fluxes

Approach – P budgets of Landscape "Ribbons"



Phosphorus budget: SRS-2 slough

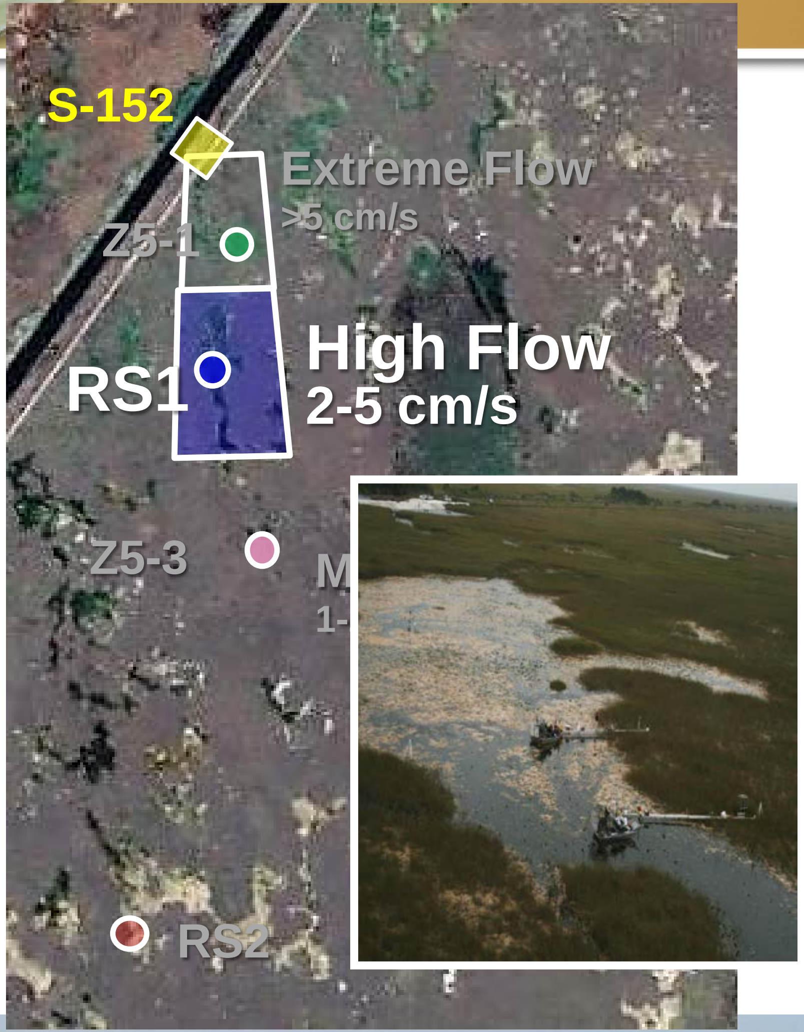




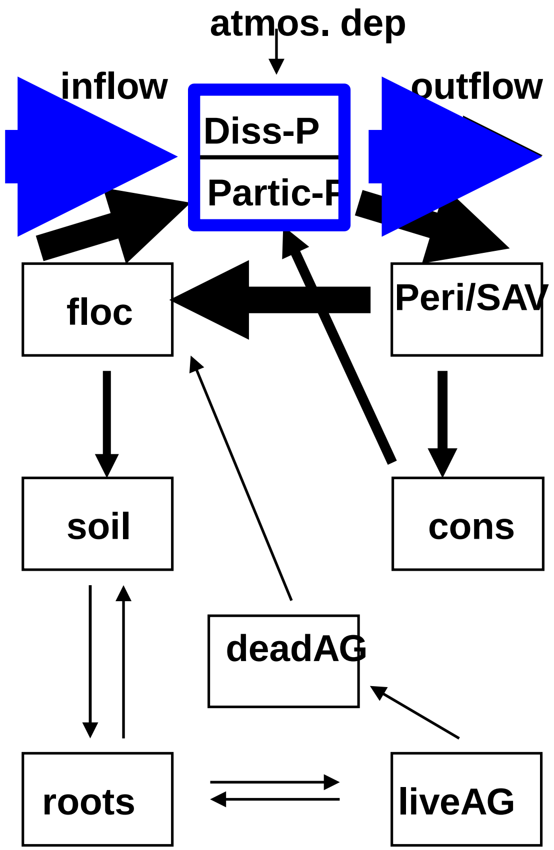
** Noe et al., 2002 & FCE LTER data
* Hwang et al., 1998

- **First order turnover rates - Noe et al., 2002; Wood, 2003; FCE LTER data; other literature**
- **Simple mechanistic equations for P-uptake and periphyton consumption**

Application – High Flow Conditions



- Increased P-load



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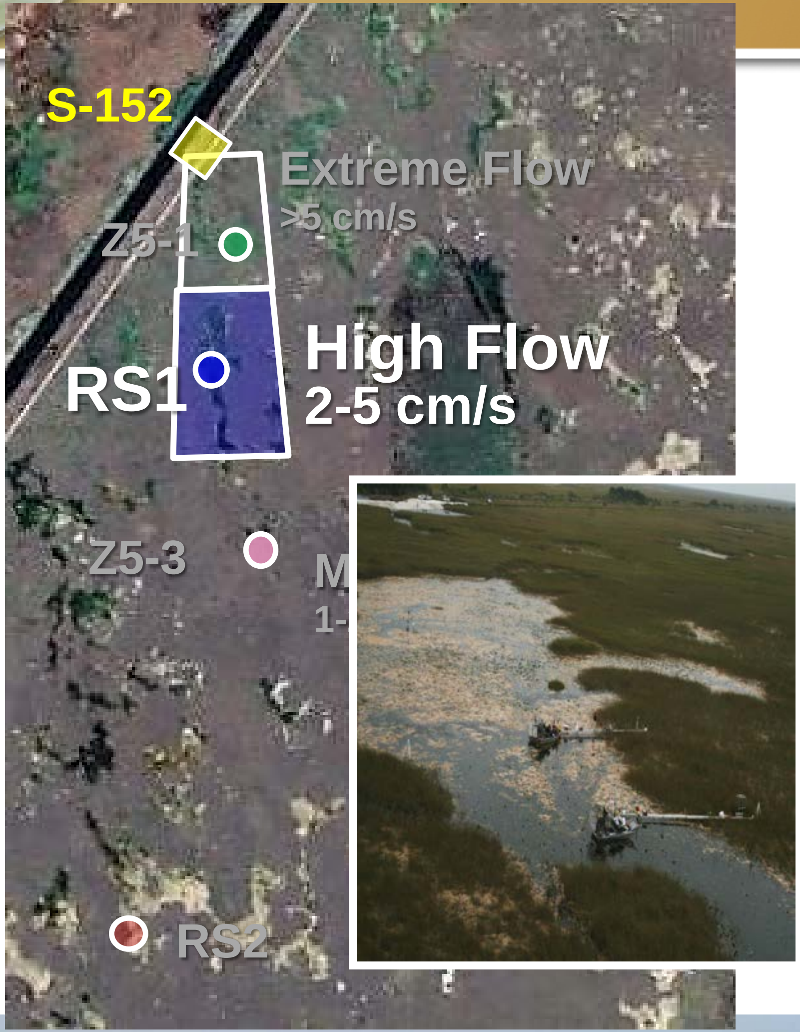
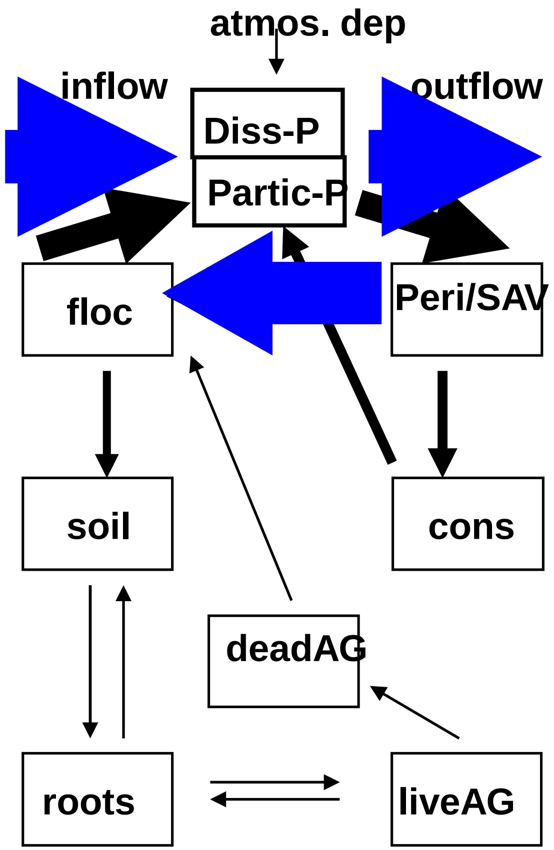


- Increased P-load
- Peri/SAV sinking (++turnover)



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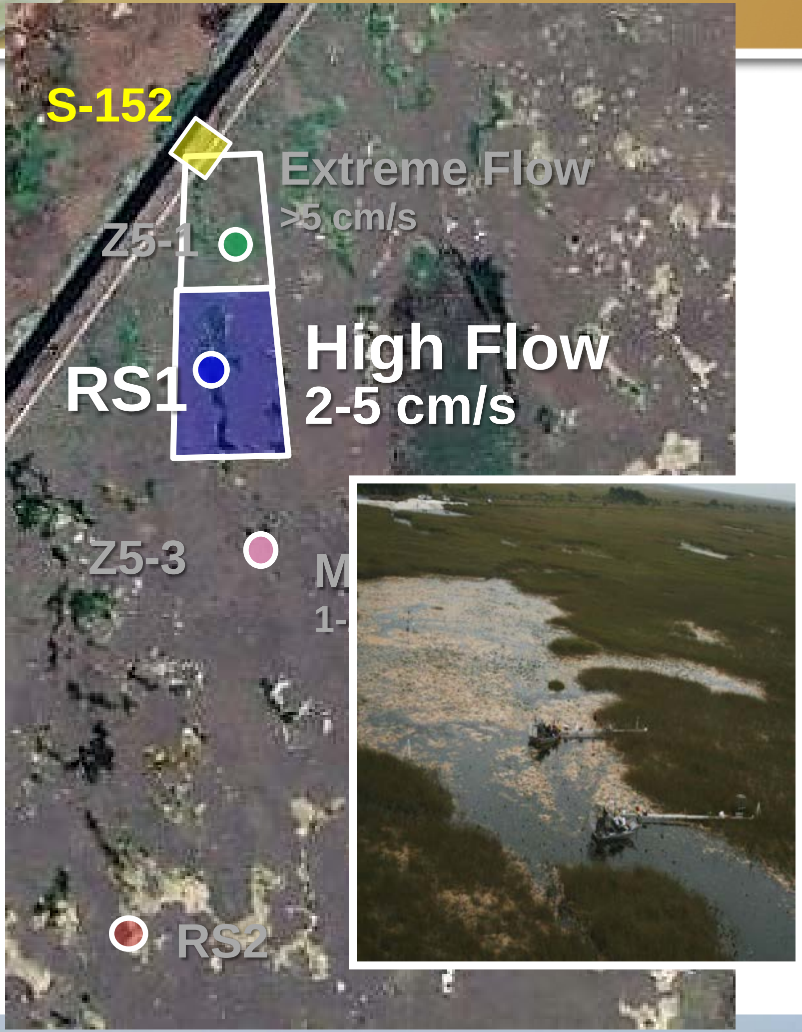
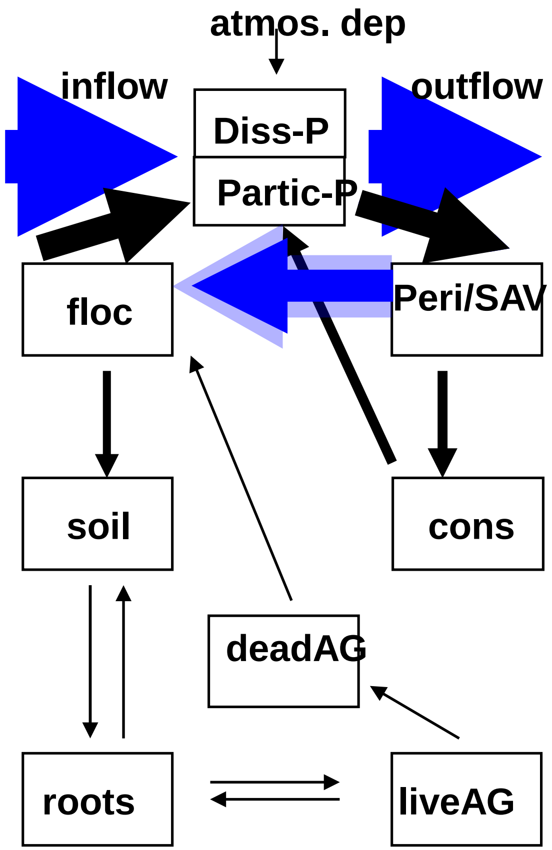


- Increased P-load
- Peri/SAV sinking (++turnover)
- Peri/SAV reduced (-uptake, +turnover)



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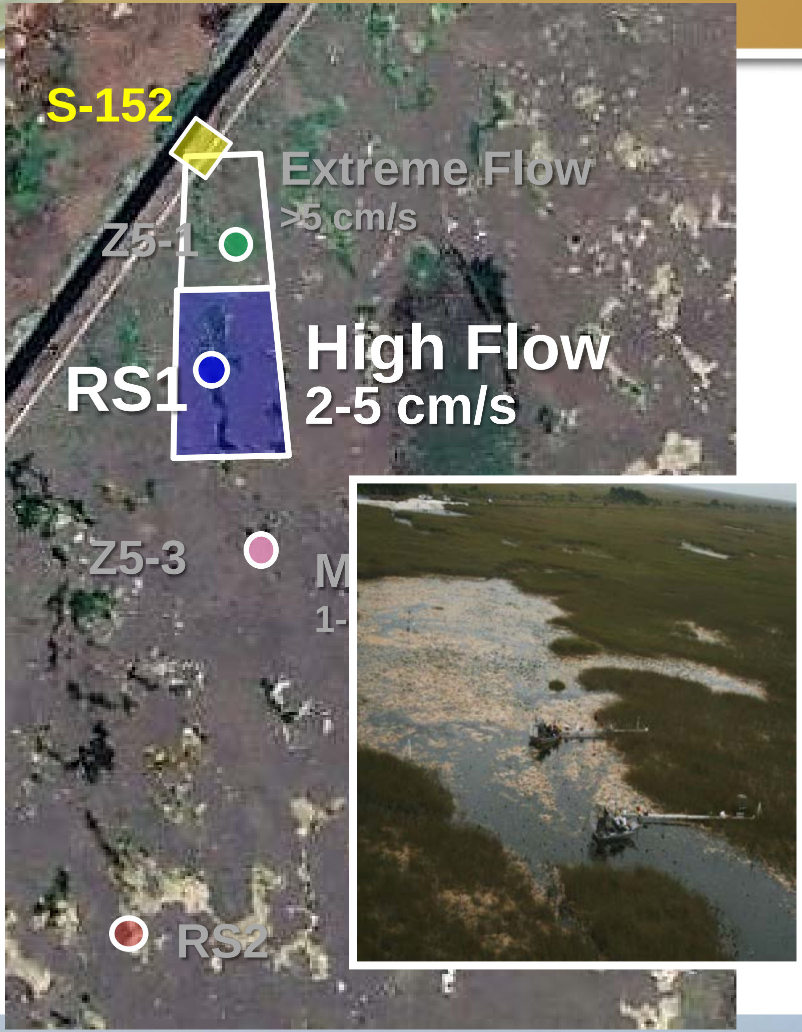
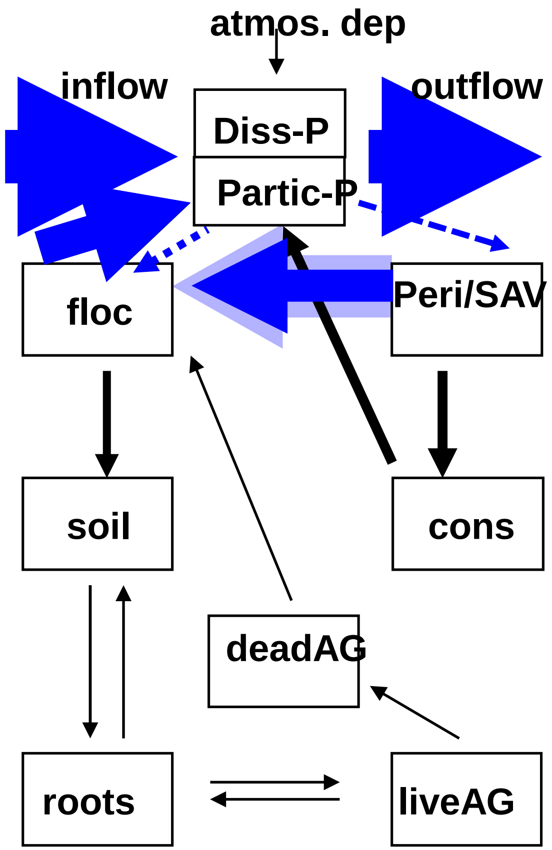


- Increased P-load
- Peri/SAV sinking (++turnover)
- Peri/SAV reduced (-uptake, +turnover)
- Floc erosion (+turnover, -settling)



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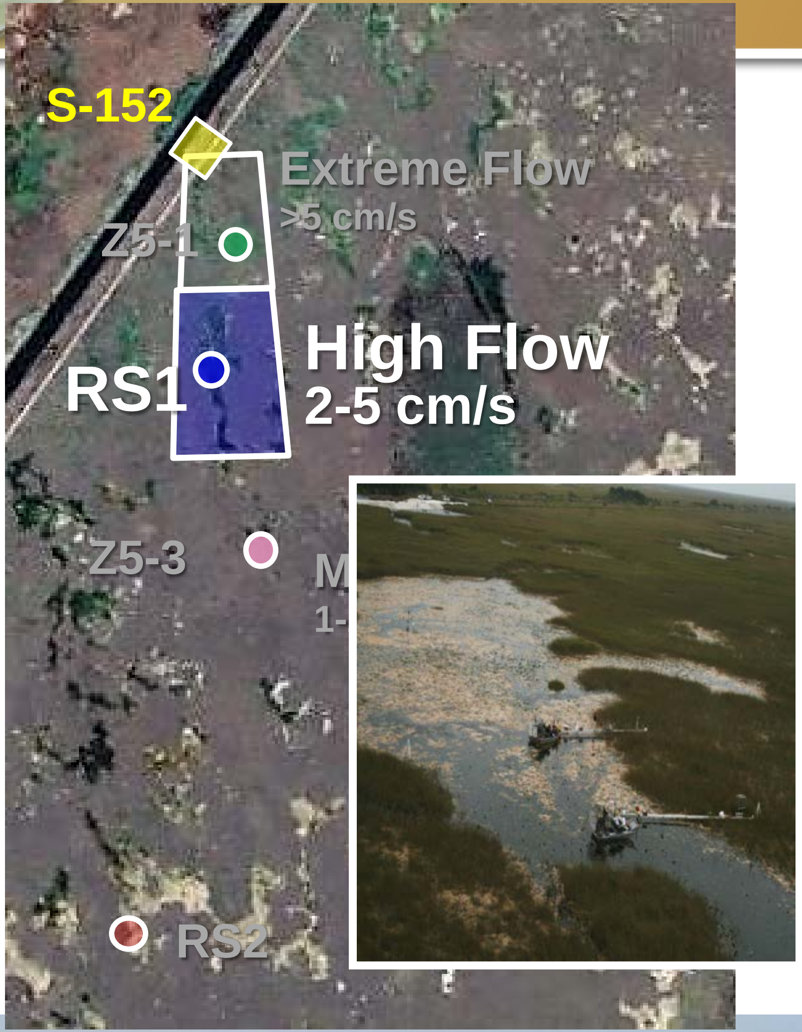
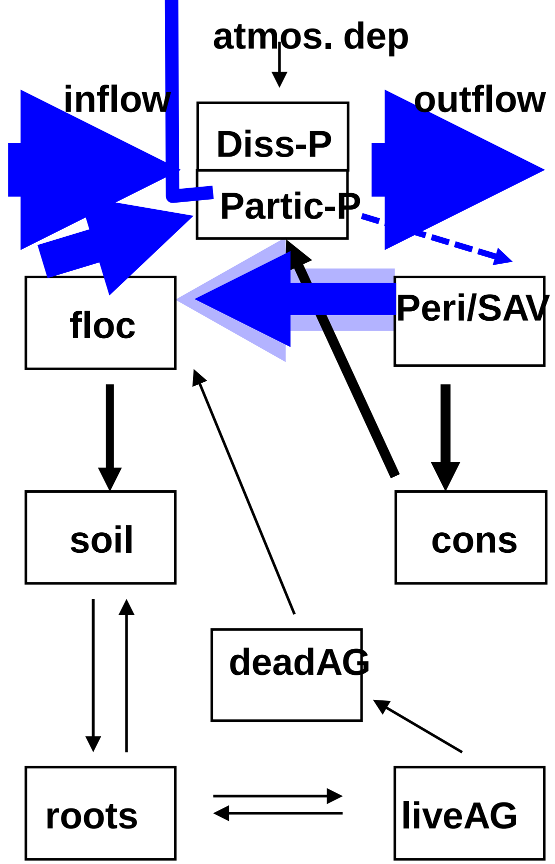
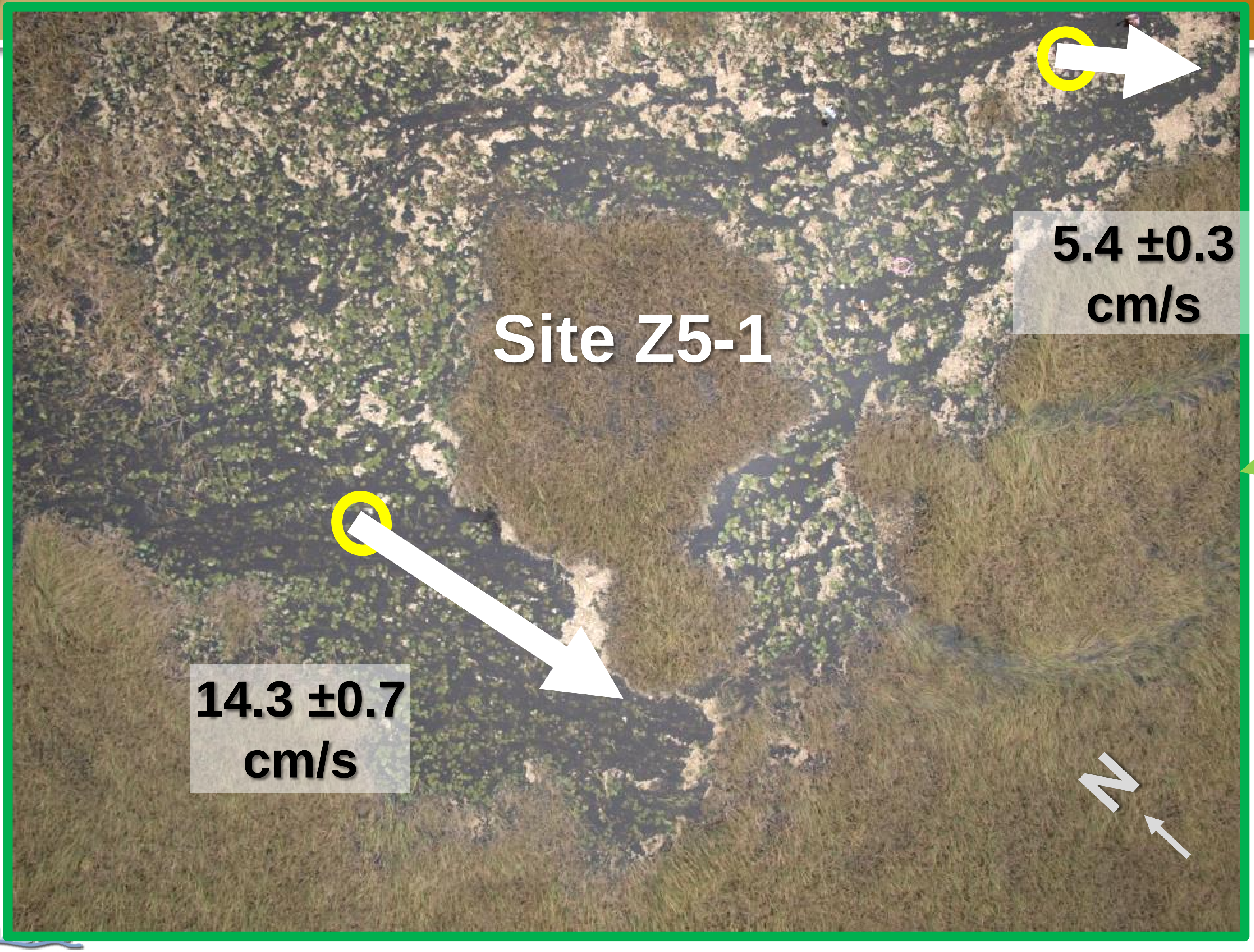


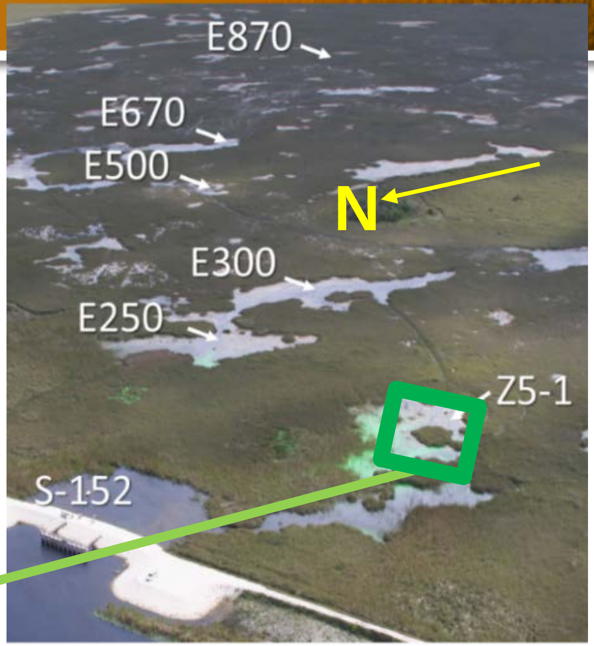
Talk to me later…

- Increased P-load
- Peri/SAV sinking (++turnover)
- Peri/SAV reduced (-uptake, +turnover)
- Floc erosion (+turnover, -settling)
- **Partic-P into ridge**



Extreme Flow – Periphyton Erosion (Nov 16, 2015)

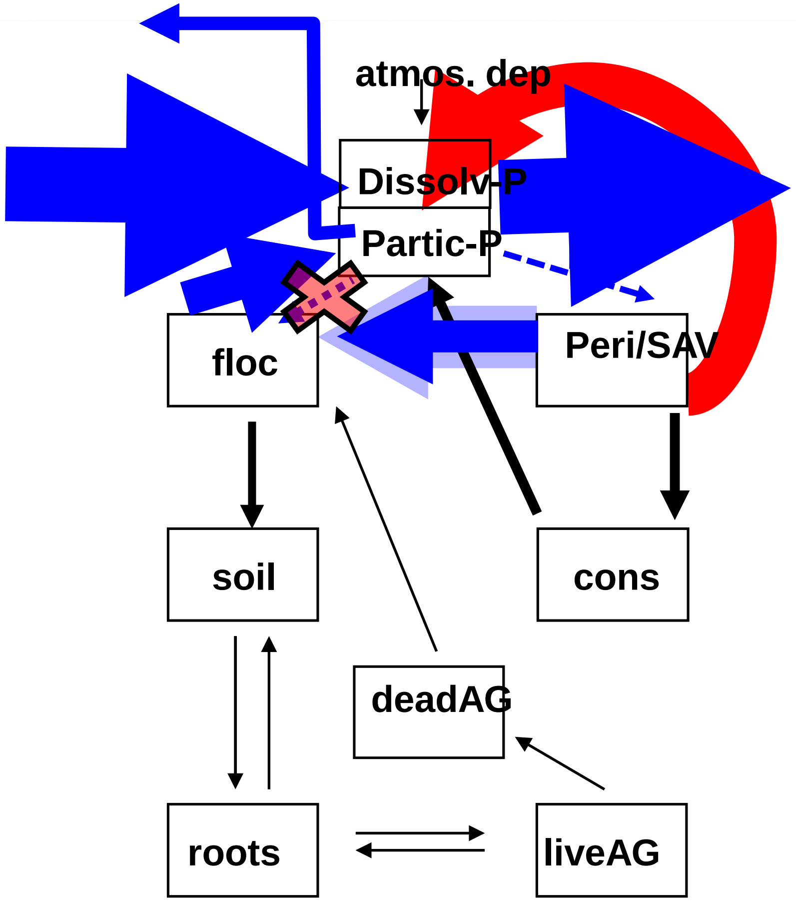




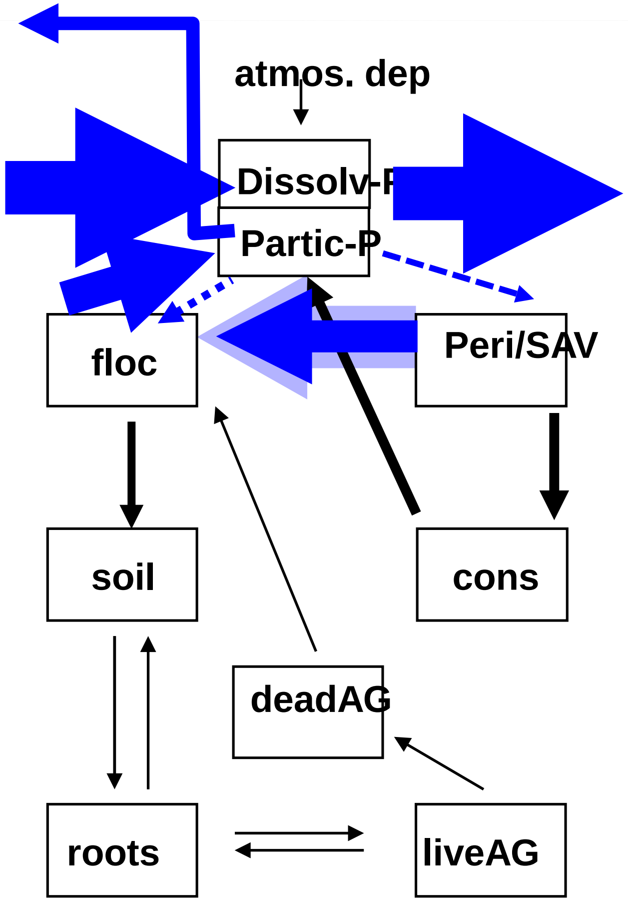
Velocity data from Sue Newman, Erik Tate-Boldt, Chris Hansen – SFWMD

Imagery from Christa Zweig - SFWMD

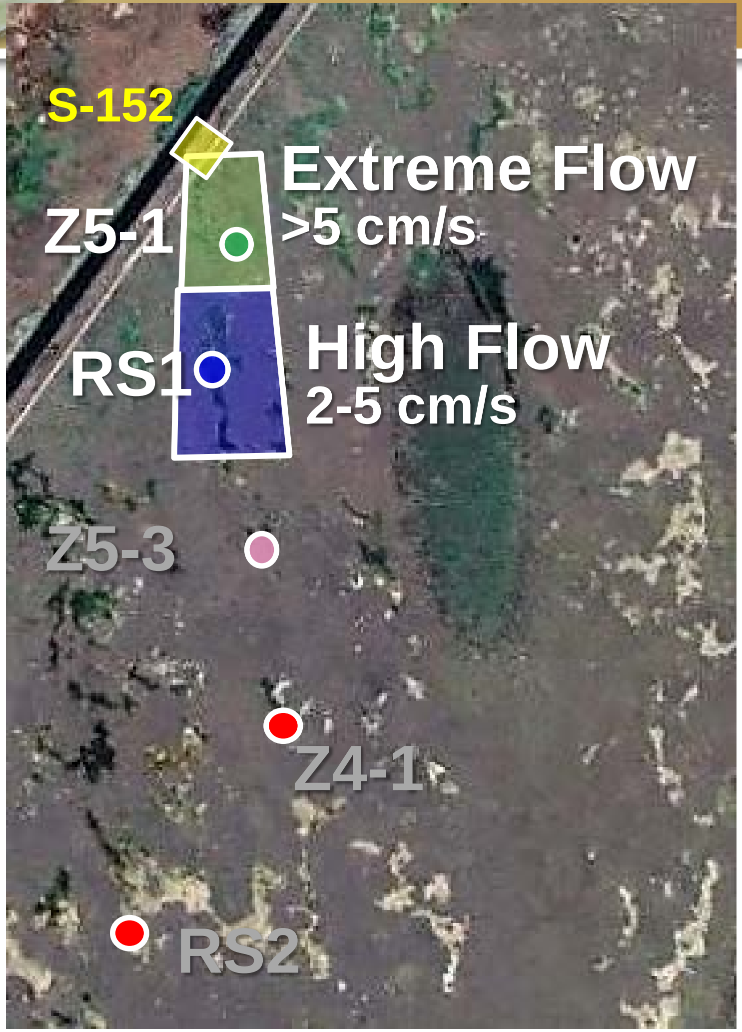
Extreme Flow



High Flow

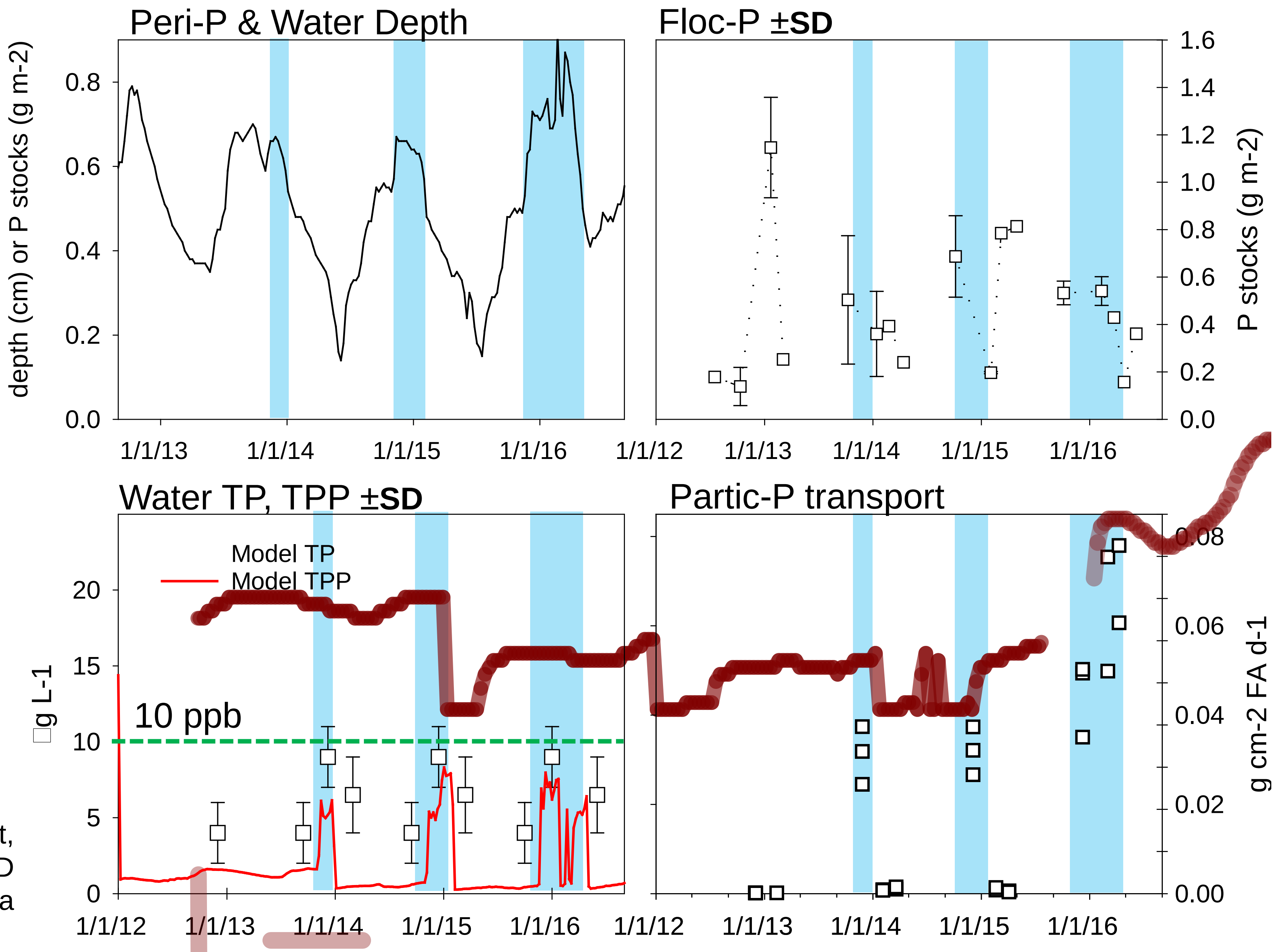


Application to DPM landscape ribbons



- Slough habitats in two 300-m landscape ribbons
  - Extreme-Flow (Z5-1), High-Flow (RS1)
- Simulation period 2012–2016
  - 2 Baseline Years
  - 3 Flow Events
- Drivers:
  - Daily water depth & velocity
  - P load for Z5-1: S152 TP
  - P load for RS1: Z5-1 Output
- Observed vs predicted time series
  - Floc P (g P m^{-2})
  - Water TP, TPP (ug/L)
  - Sediment transport (g cm^{-2} frontal area d^{-1})

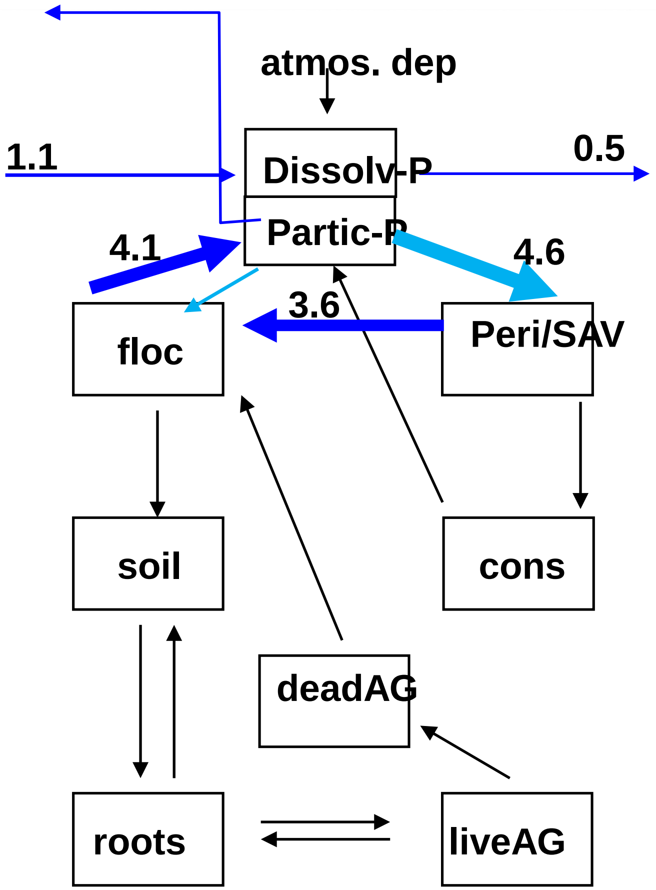
"Extreme Flow" Z5-1 Ribbon (0-300 m)



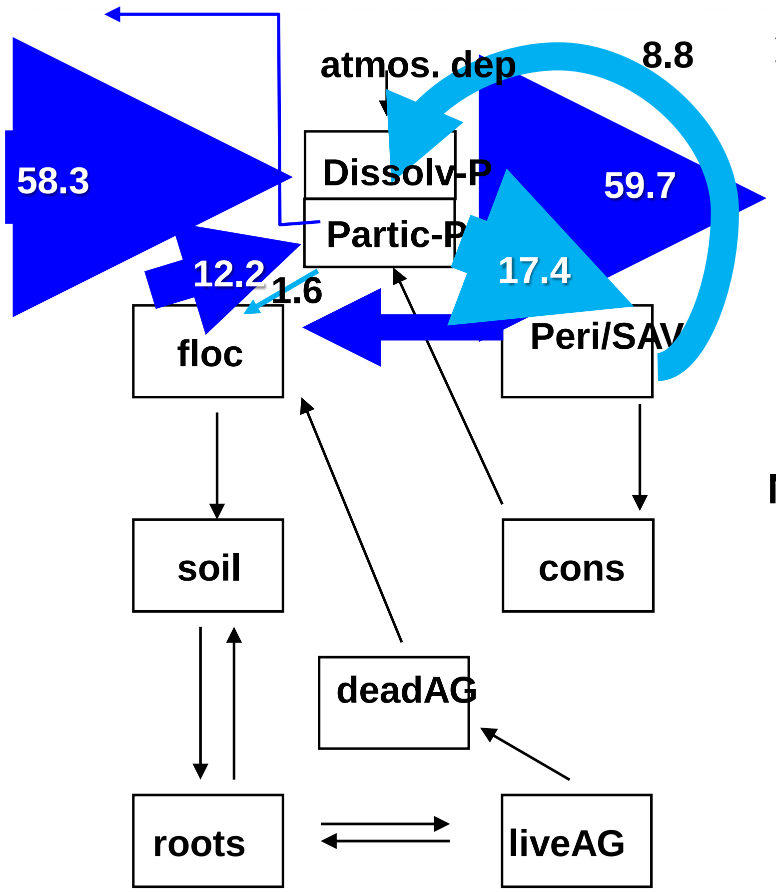
Data from Sue Newman, Erik Tate-Boldt,
Chris Hansen, C. Saunders – SFWMD
Claus Hansen - Scheda

Phosphorus Fluxes – Z5-1 ribbon (g/m2/y)

Low Flow



Extreme Flow



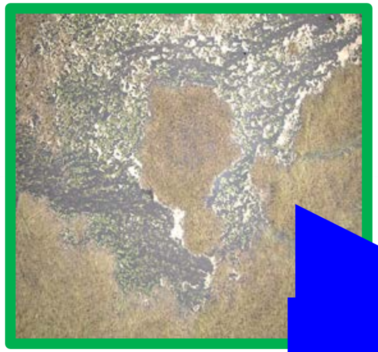
Extreme-flow mechanisms

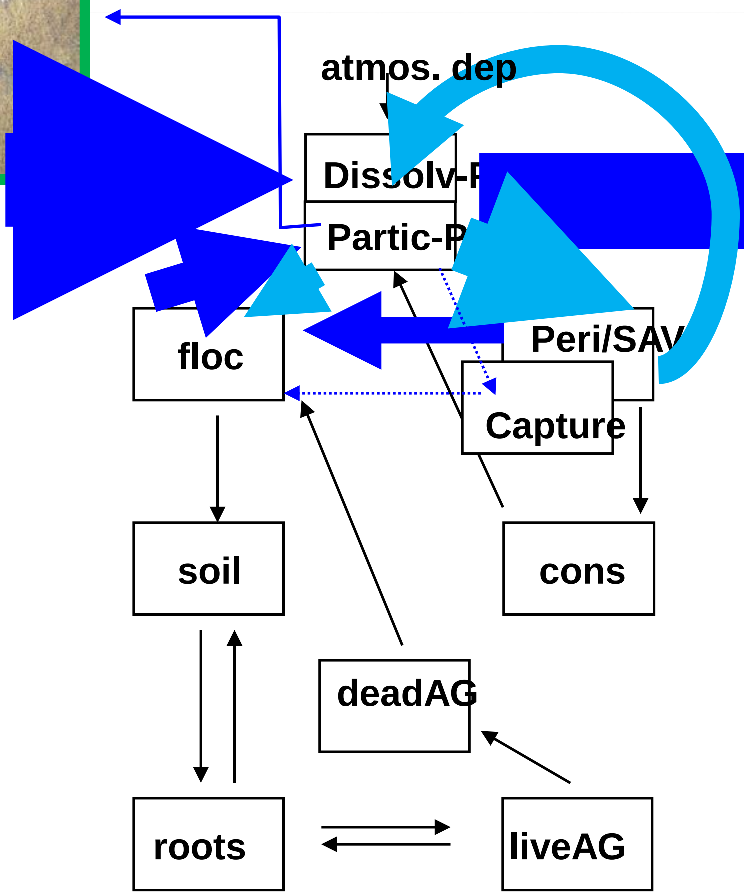
Peri/SAV reduced (~~-uptake~~, +turnover)	Uptake +385% Turnover +220%
Peri/SAV erosion	≈half of P-uptake
Floc erosion (+turnover, -~~settling~~)	Turnover +300% Settling +50%

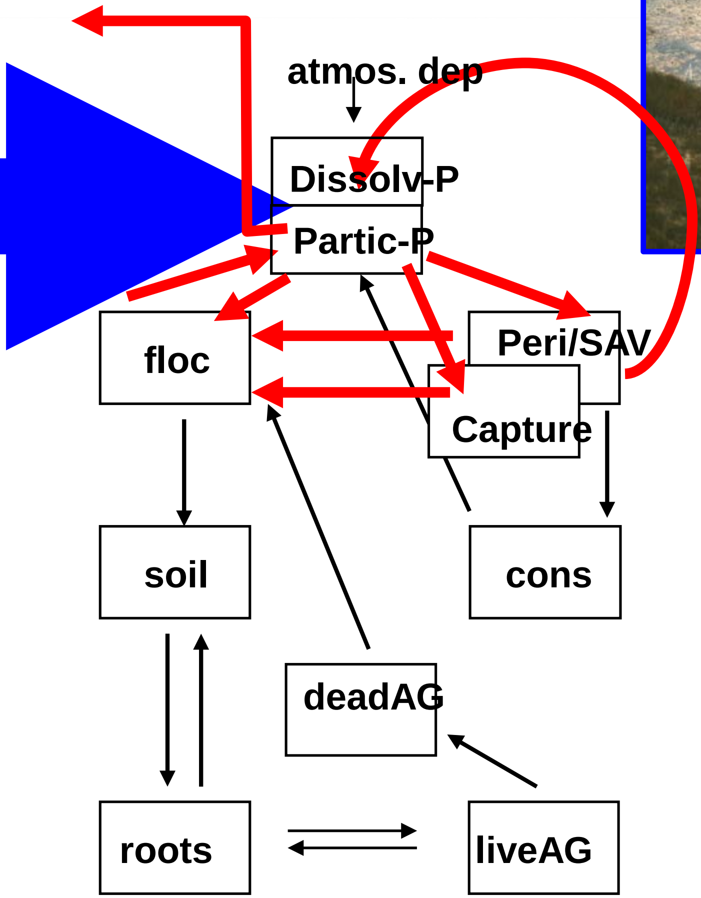
Net P source = -1.4 gP / m2 / yr

Extreme Flow

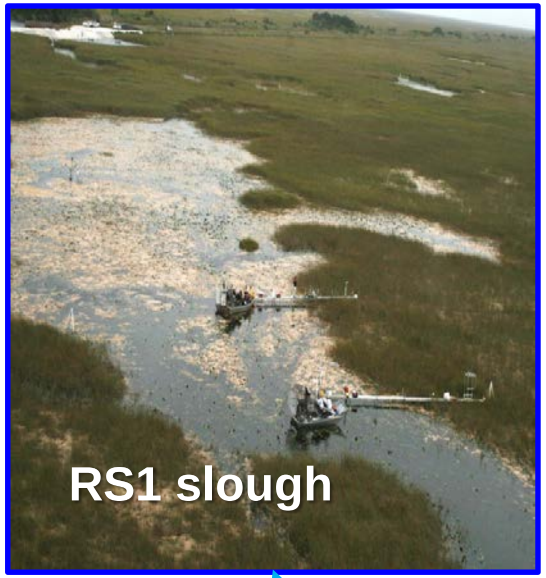
High Flow

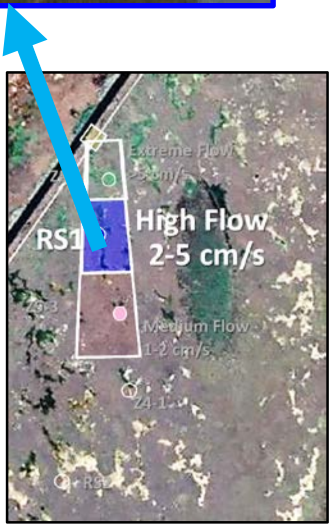




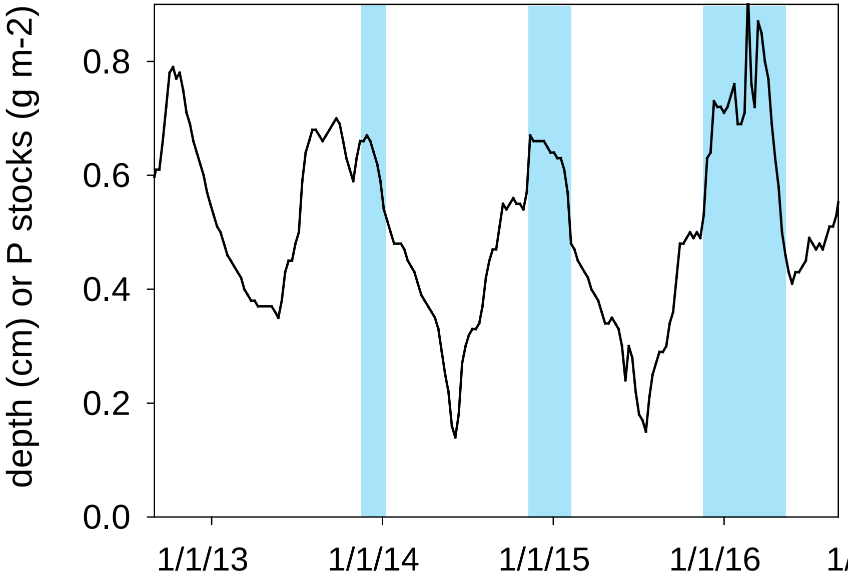


High-Flow RS1 Ribbon (300-600m)

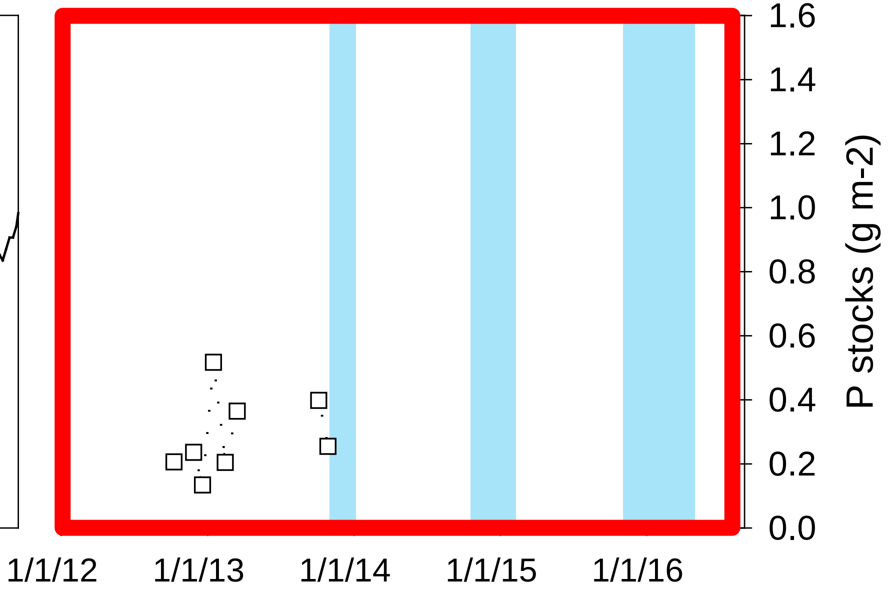




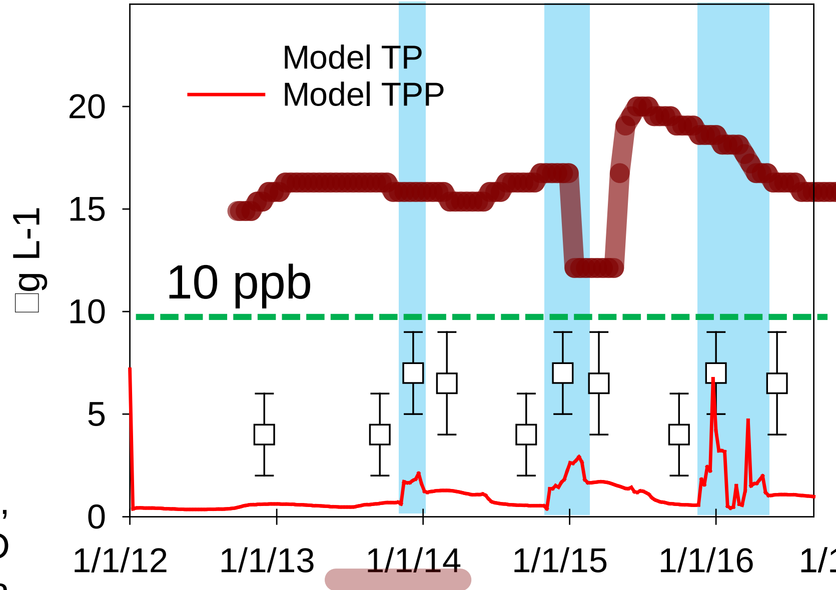
Peri-P & Water Depth



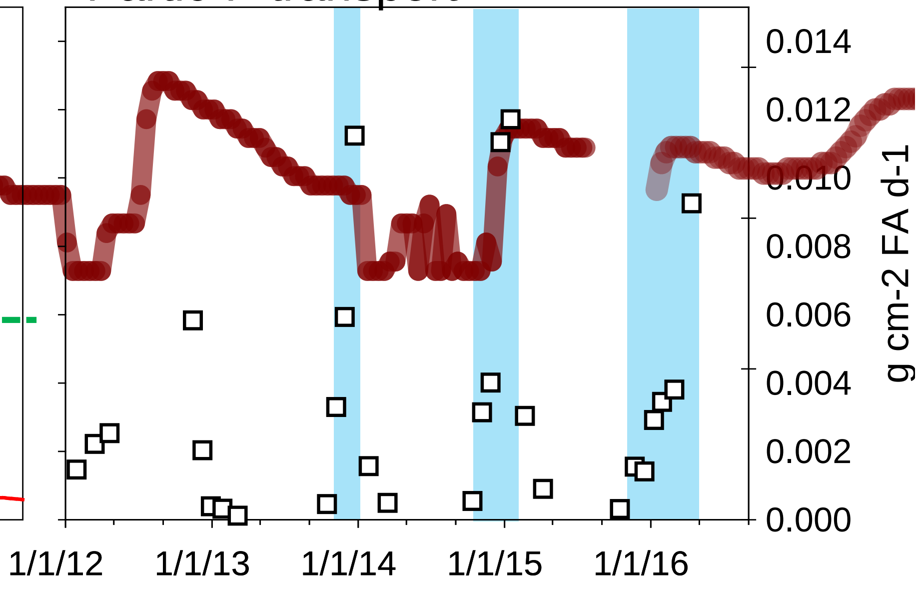
Floc-P



Water TP & TPP

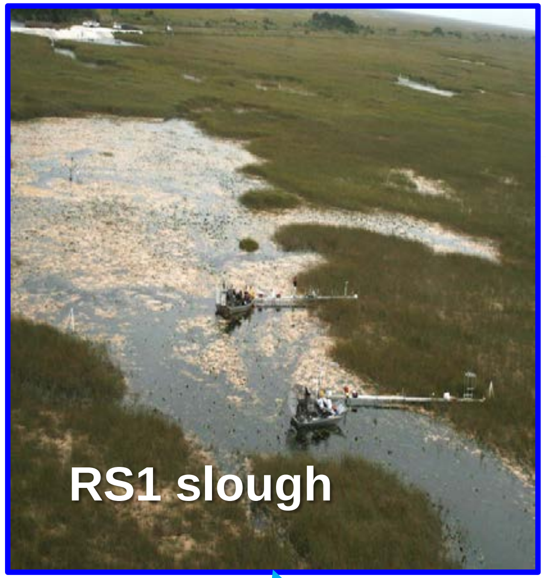


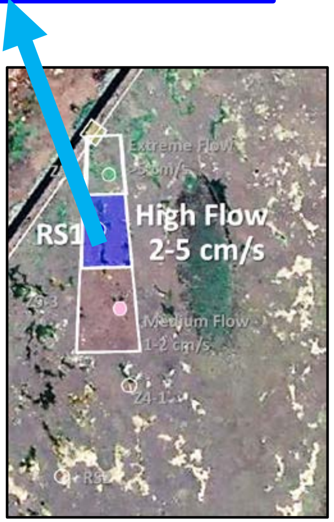
Partic-P transport



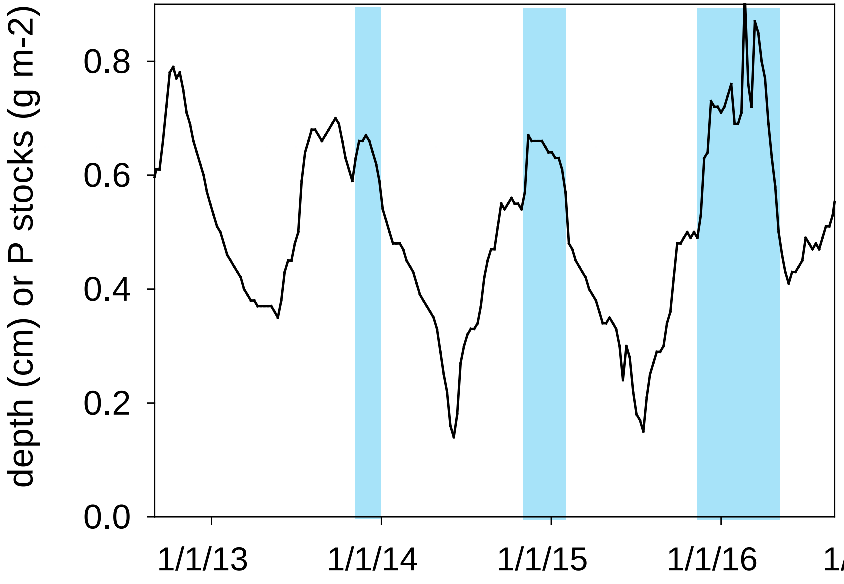
Data from Sue Newman, Erik Tate-Boldt,
Chris Hansen, C. Saunders – SFWMD
Claus Hansen - Scheda

High-Flow RS1 Ribbon (300-600m)

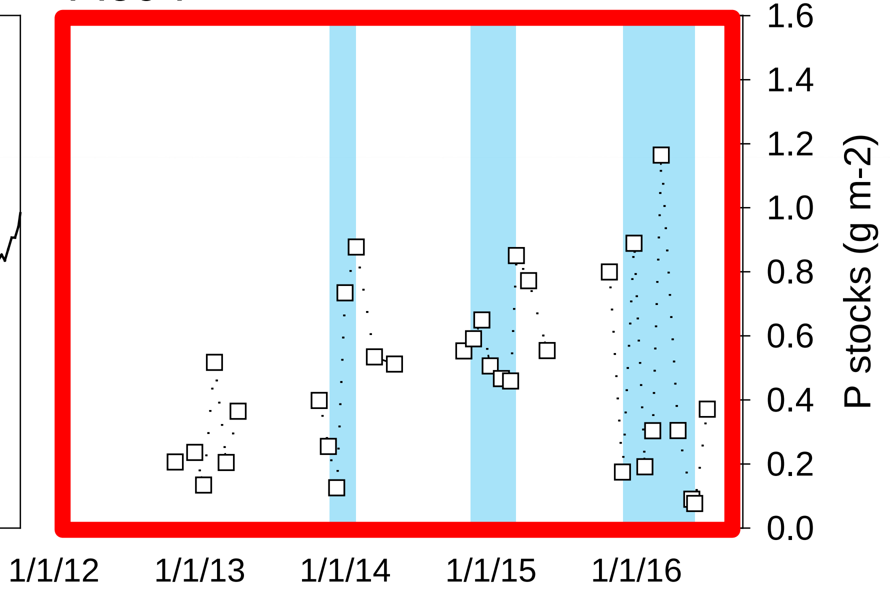




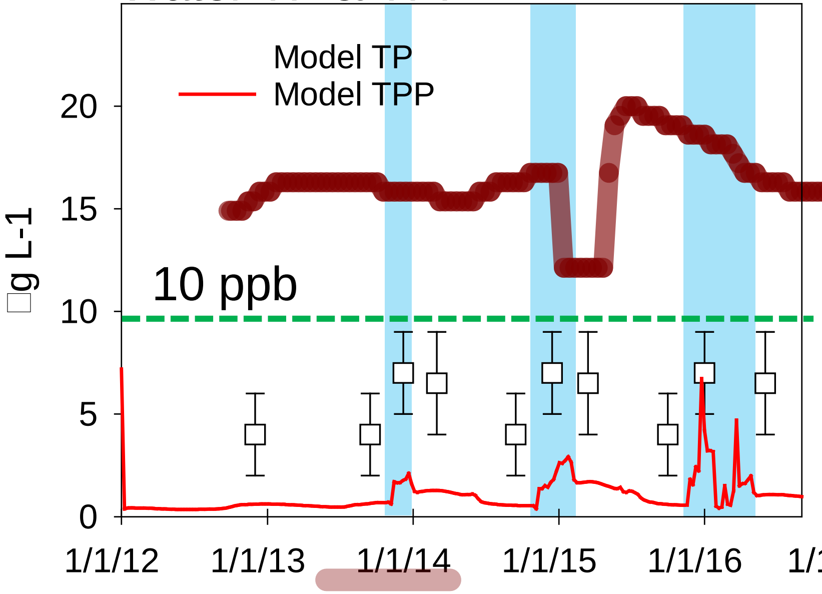
Peri-P & Water Depth



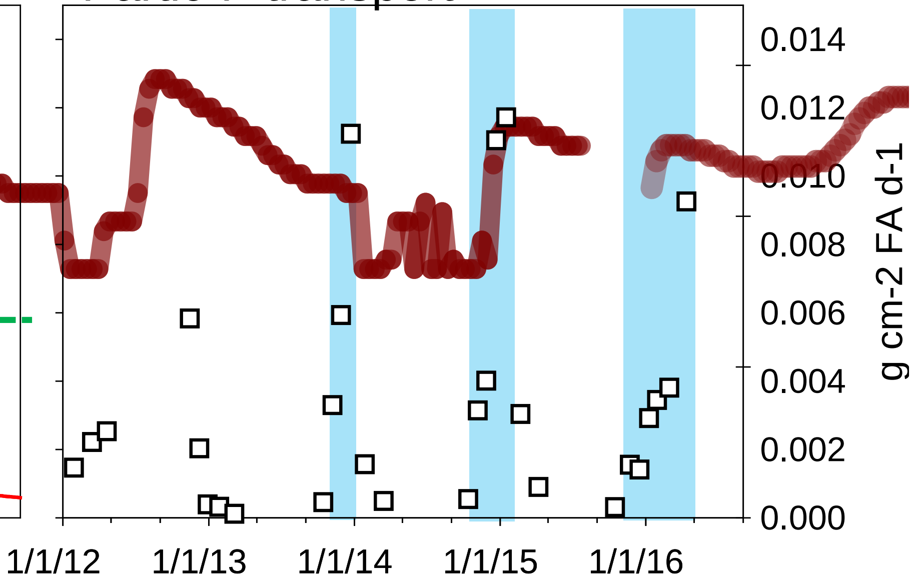
Floc-P



Water TP & TPP



Partic-P transport



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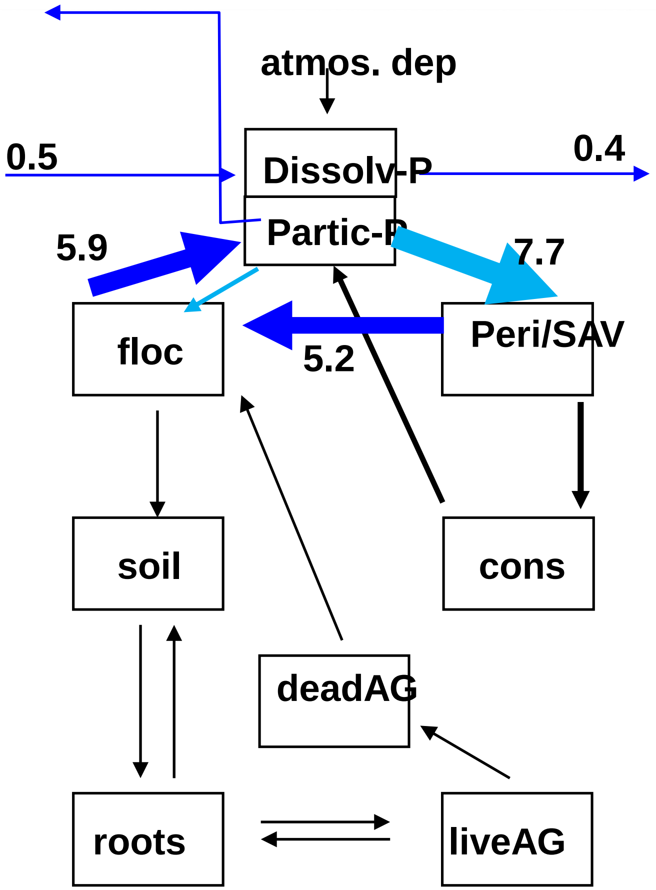
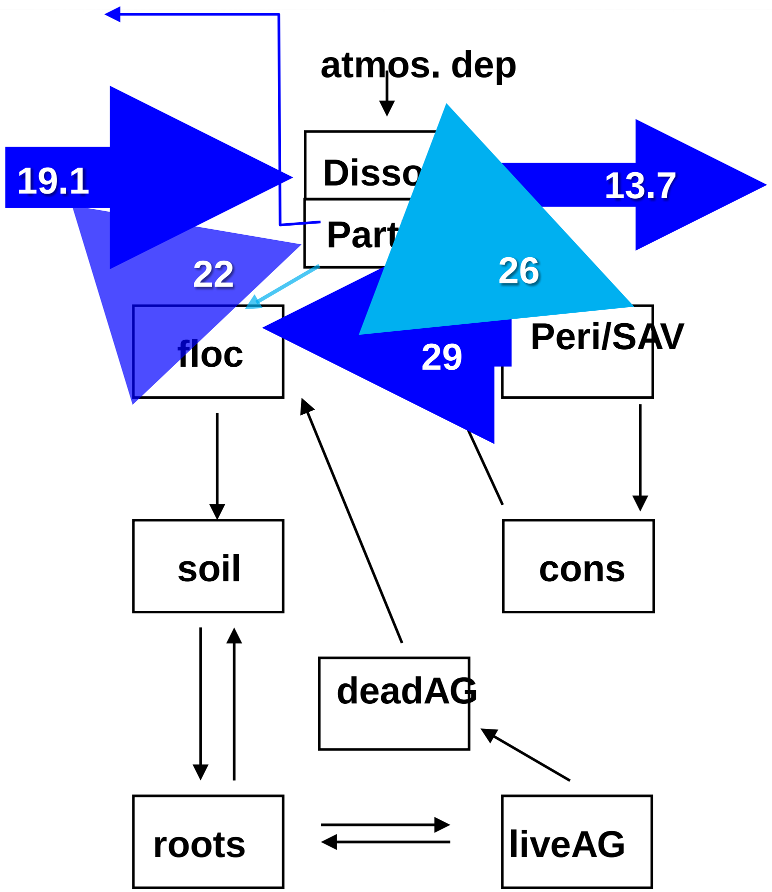
Phosphorus Fluxes – RS1 ribbon (g/m2/y)

Low Flow



High Flow



High-flow mechanisms

Peri/SAV reduced (~~-uptake~~, +turnover)

Uptake	+310%
Turnover	+470%

Floc erosion (+turnover, -settling)

Turnover	+310%
Settling	-20%

Periphyton erosion — ZERO

Net P sink = 5.4 gP / m2 / yr

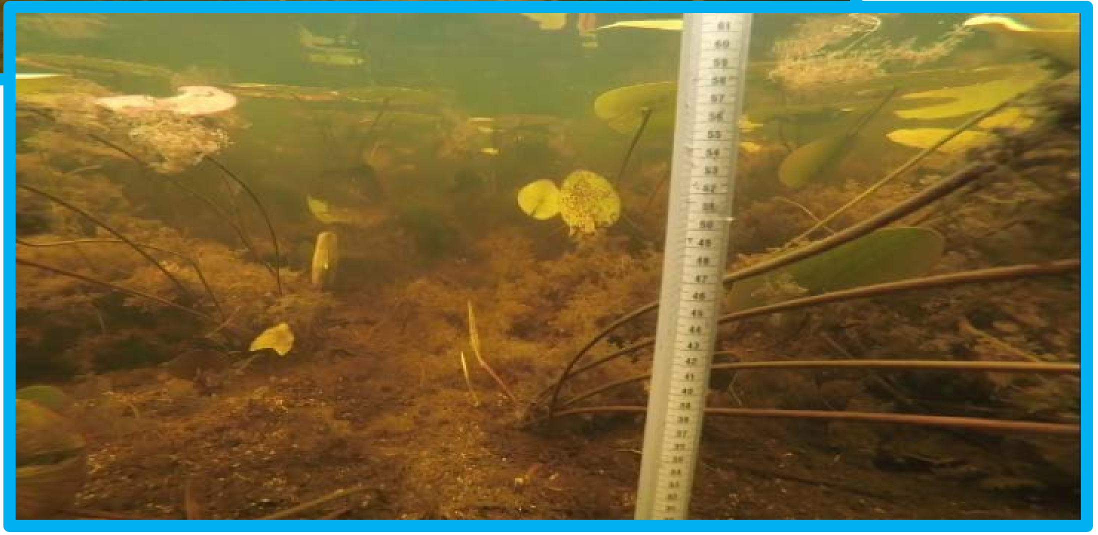
Summary: P Cycling in Extreme and High Flow

Extreme Flow (>5 cm s^{-1})

- periphyton “blow-out”
- 4x-increase Peri/SAV uptake
- P uptake << floc + peri erosion
- net P source = -1.5 g $m^{-2}yr^{-1}$

High Flow (2-5 cm s^{-1})

- periphyton sinks into floc
- 3x-increase Peri/SAV uptake
- P uptake >> floc erosion
- net P sink = +5 g $m^{-2}yr^{-1}$



DPM Science Team

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D. George

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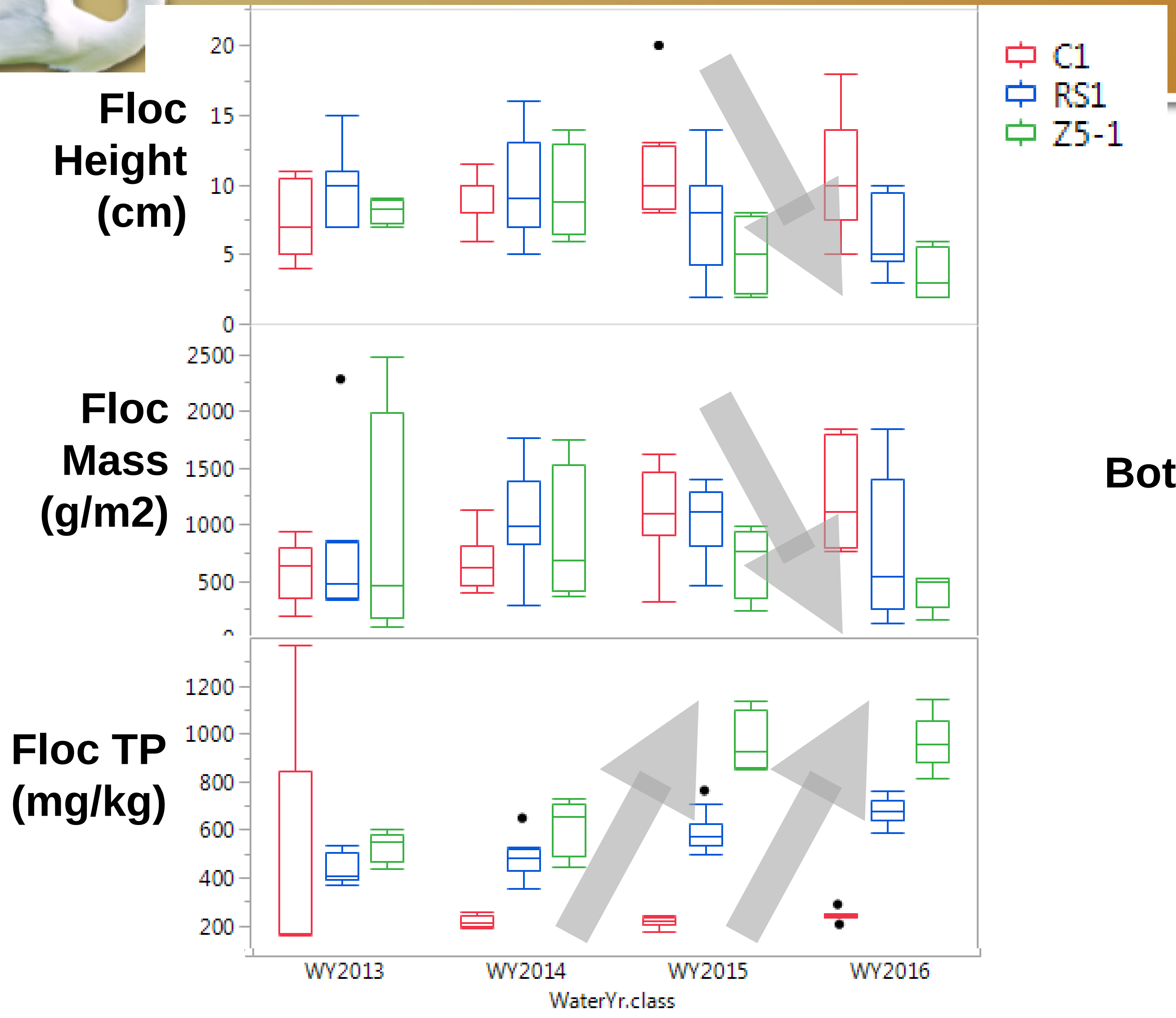
M. Bush
S. Bornhoeft
M. Ross
P. Ruiz
R. Jaffe
D. He
P. Regier
B. Jara
J. Sah

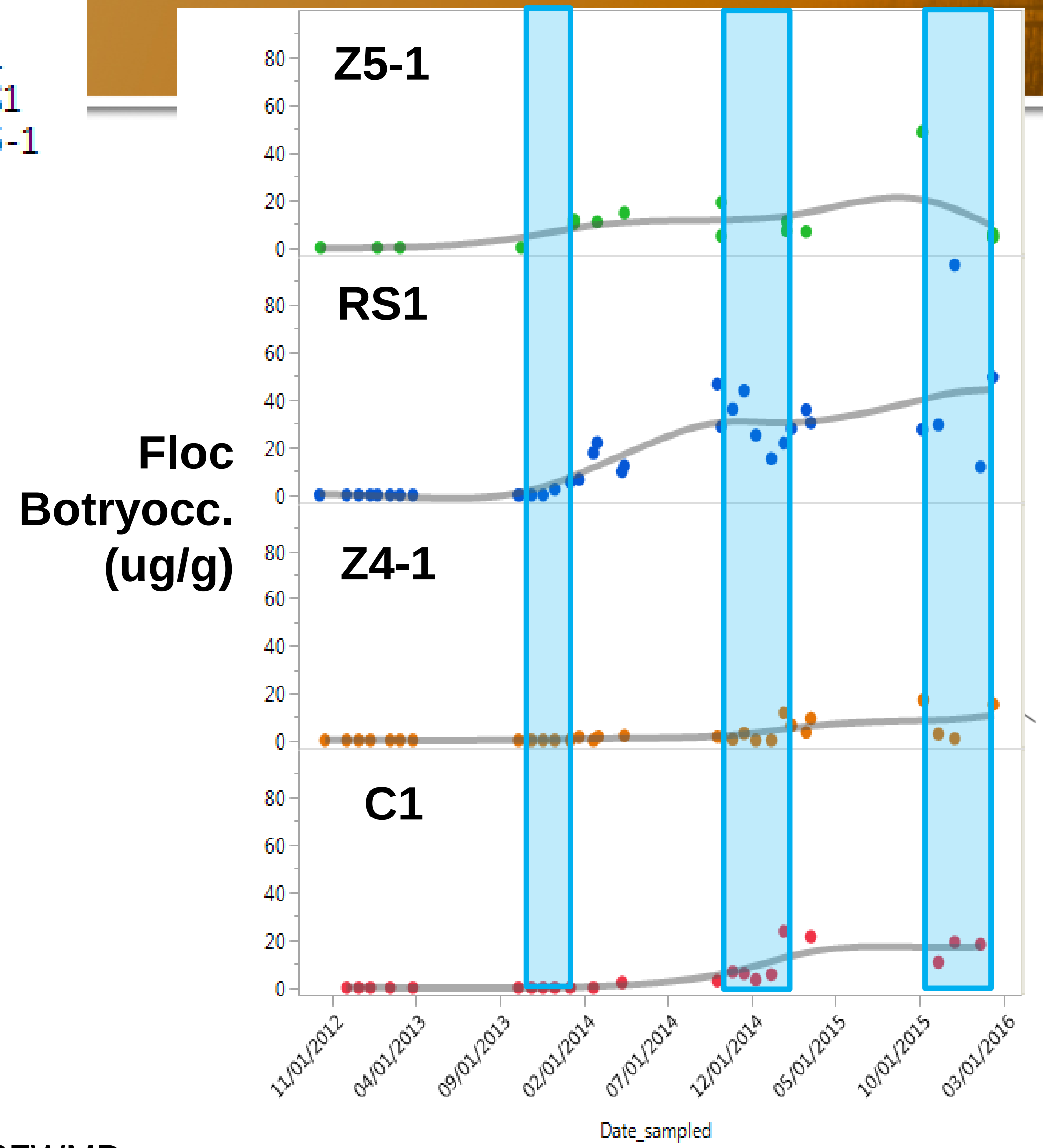
J. Harvey
B. Rosen
M. Dickman
J. Choi
J. Lewis
A. Swartz
J. Gomez
K. Skalak
L. Soderqvist

D. Ho
D. Hickman

Addenda Slides

Mechanism underlying increased P uptake?

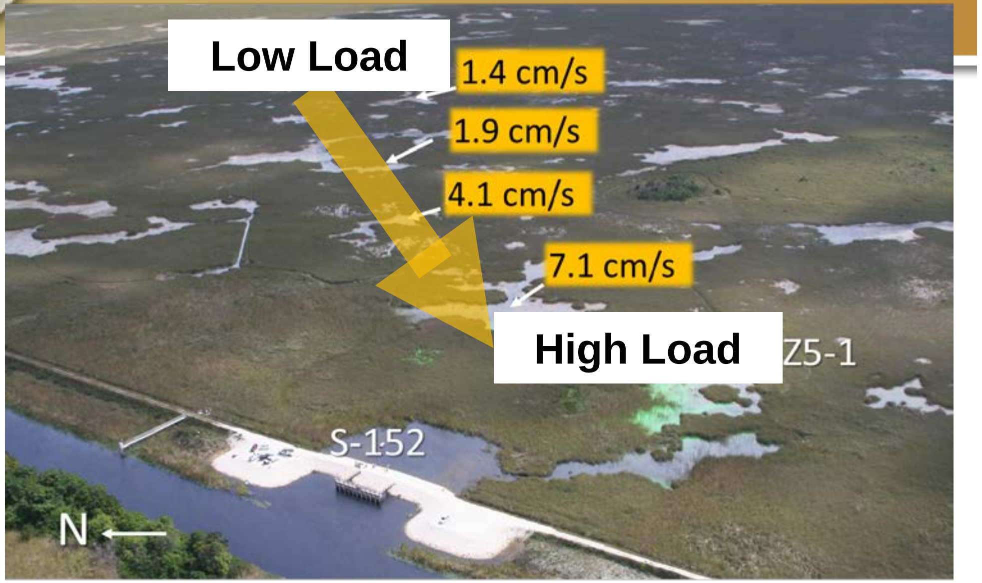


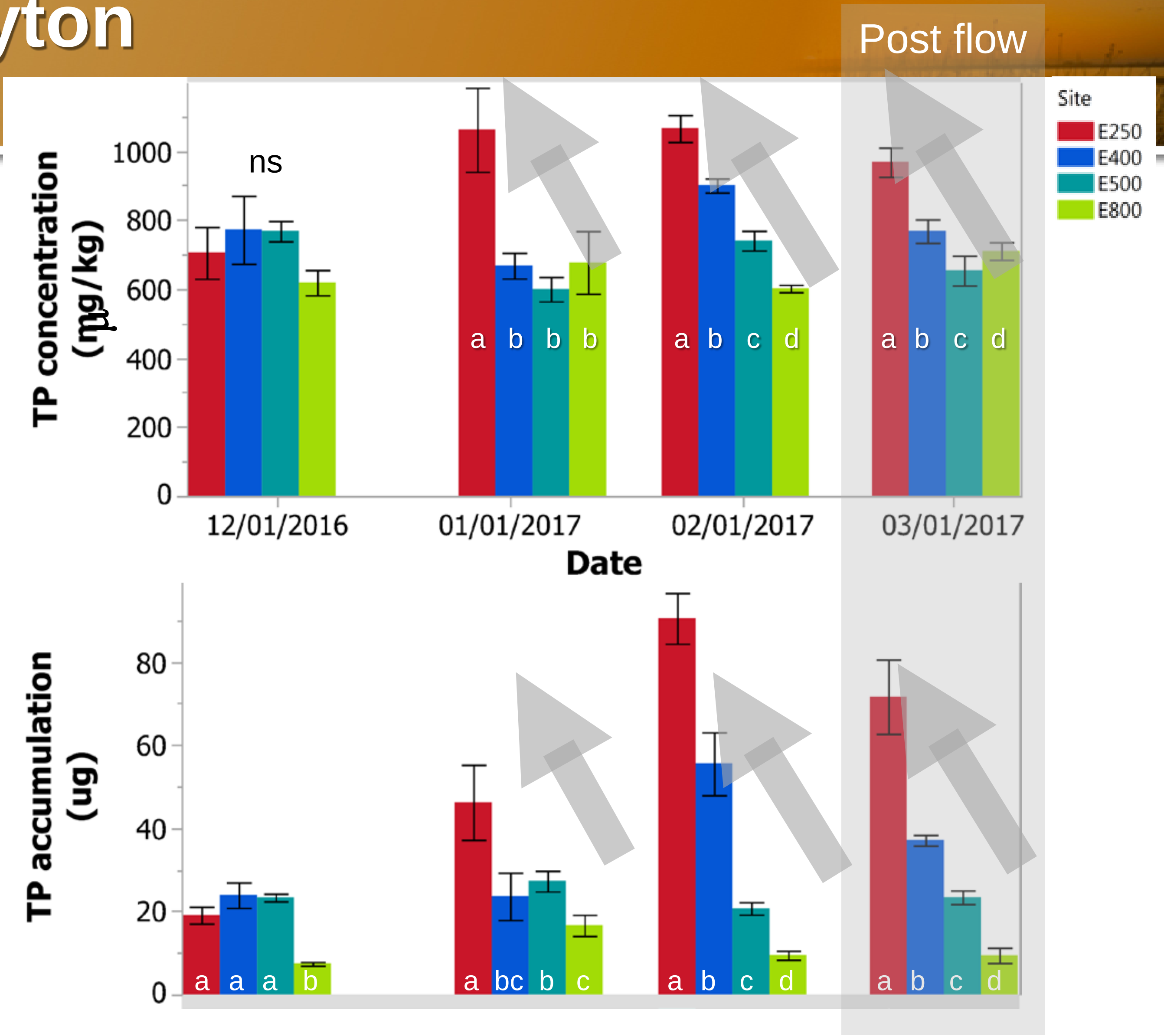


data from Erik Tate-Boldt, Chris Hansen, C. Saunders, Sue Newman – SFWMD

Biomarker data from P. Regier, R. Jaffe' - FIU

P uptake by periphyton





Implications and Next Steps

Implications of increased P cycling & storage

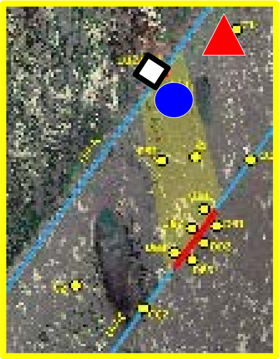
- Topography – Will increased P uptake ultimately increase P in ridges?
- Foodwebs – Will higher TP food alter fish and invertebrate populations?
- Vegetation – Will floc P eventually enrich soil TP? Change macrophytes?

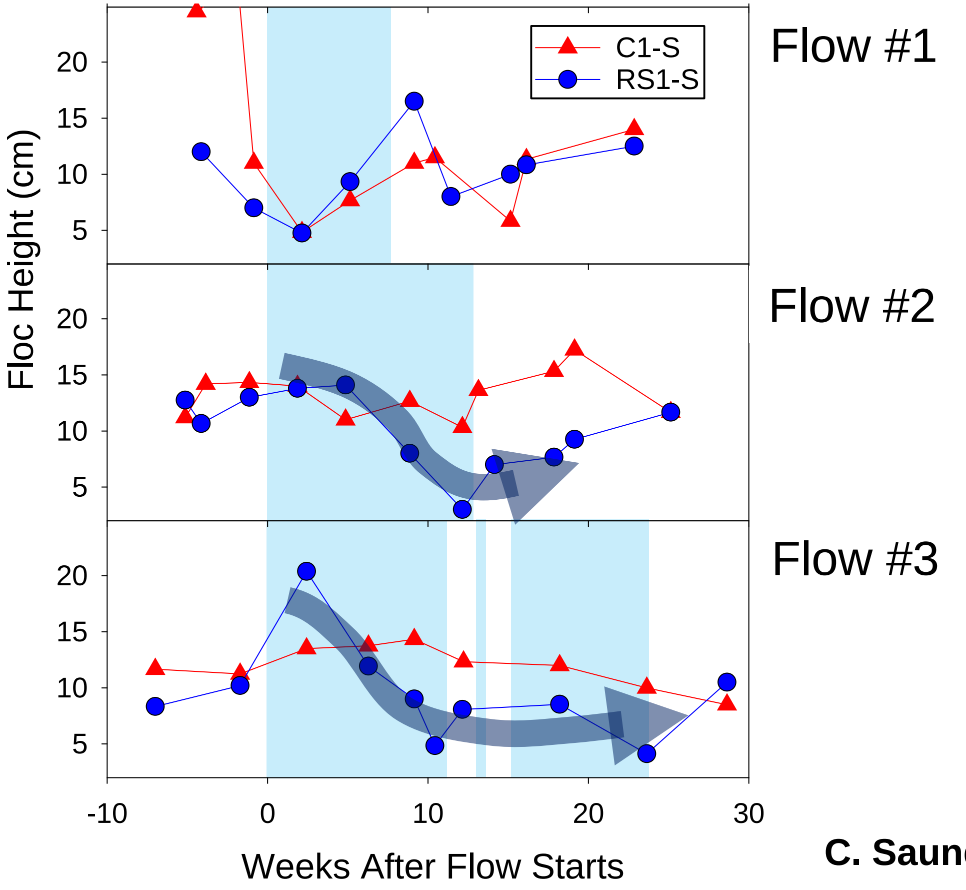
Next Steps – DPM Phase 2

- Active Marsh Improvement used to reconnect sloughs, redirect flow south
- Will we see the same responses scaled up or get a different response?

… see next talk

Sustained Flows Reduced Floc in Sloughs

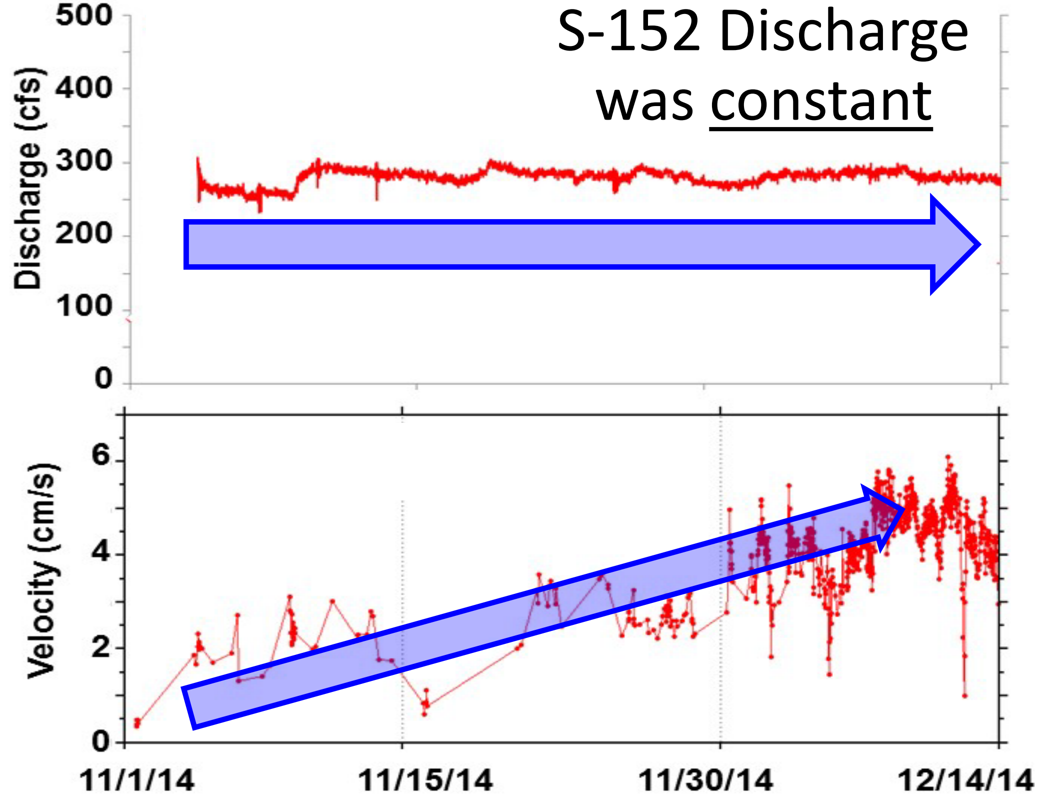




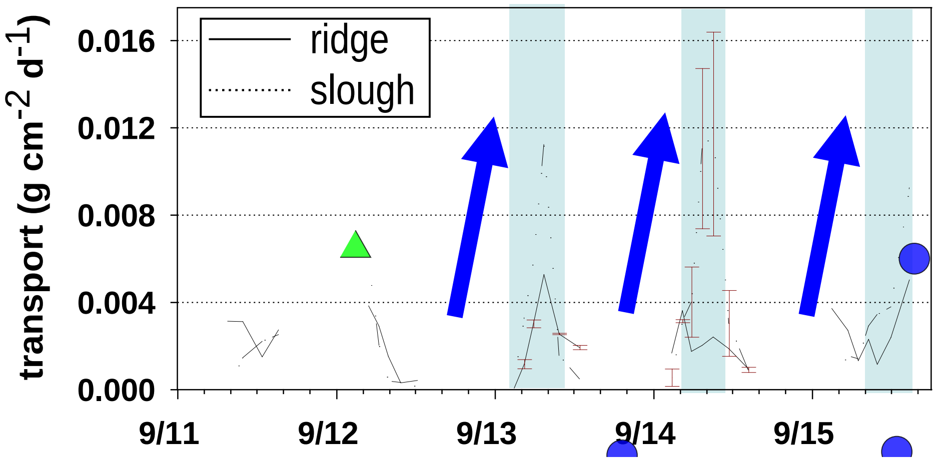
Volume of floc decreased with sustained flow

C. Saunders, E. Tate-Boldt, C. Hansen, S. Newman - SFWMD

Sustained Flows Resulted in Increased Slough Velocities & Floc Transport



Slough velocities increased with sustained flow



Floc transport increased with sustained flow

Data from C. Saunders, E. Tate-Boldt, C. Hansen, S. Newman

Data from J. W. Harvey, J. Choi, M. Dickman

Other flow observations omit

- Aquatic primary production/respiration reduced
  - Metabolism studies (E. Tate-Boldt et al., previous)

- Floc more erodible with flow
  - Benthic flume (S. Newman, M. Mann

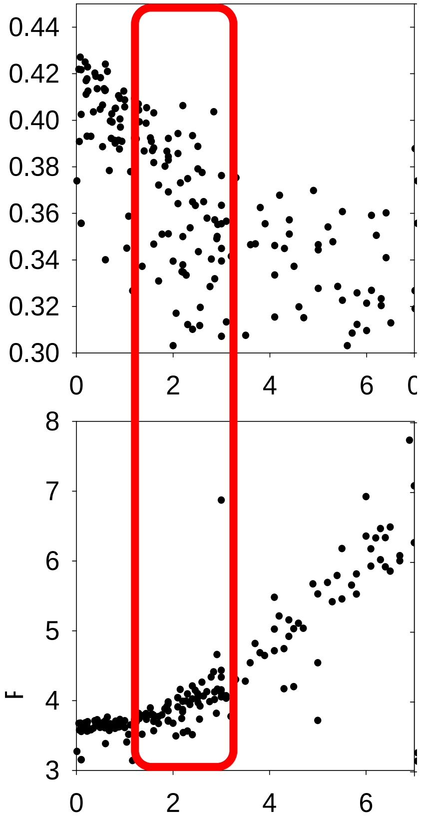
Photos from PARTRAC 2008. (Glasgow, UK)

Parameter fitting to floc-P and Water TP data:

Root Mean Squared Error (RMSE) = $\sqrt{\sum(\text{mod-obs})^2}$

RMSE FlocP (gP/m2)

RMSE WaterTP (ugP/L)



$P\text{-uptake}_{max\text{-}flow}$ (gP/m2/yr)