Phosphorus Loading to Newnans Lake

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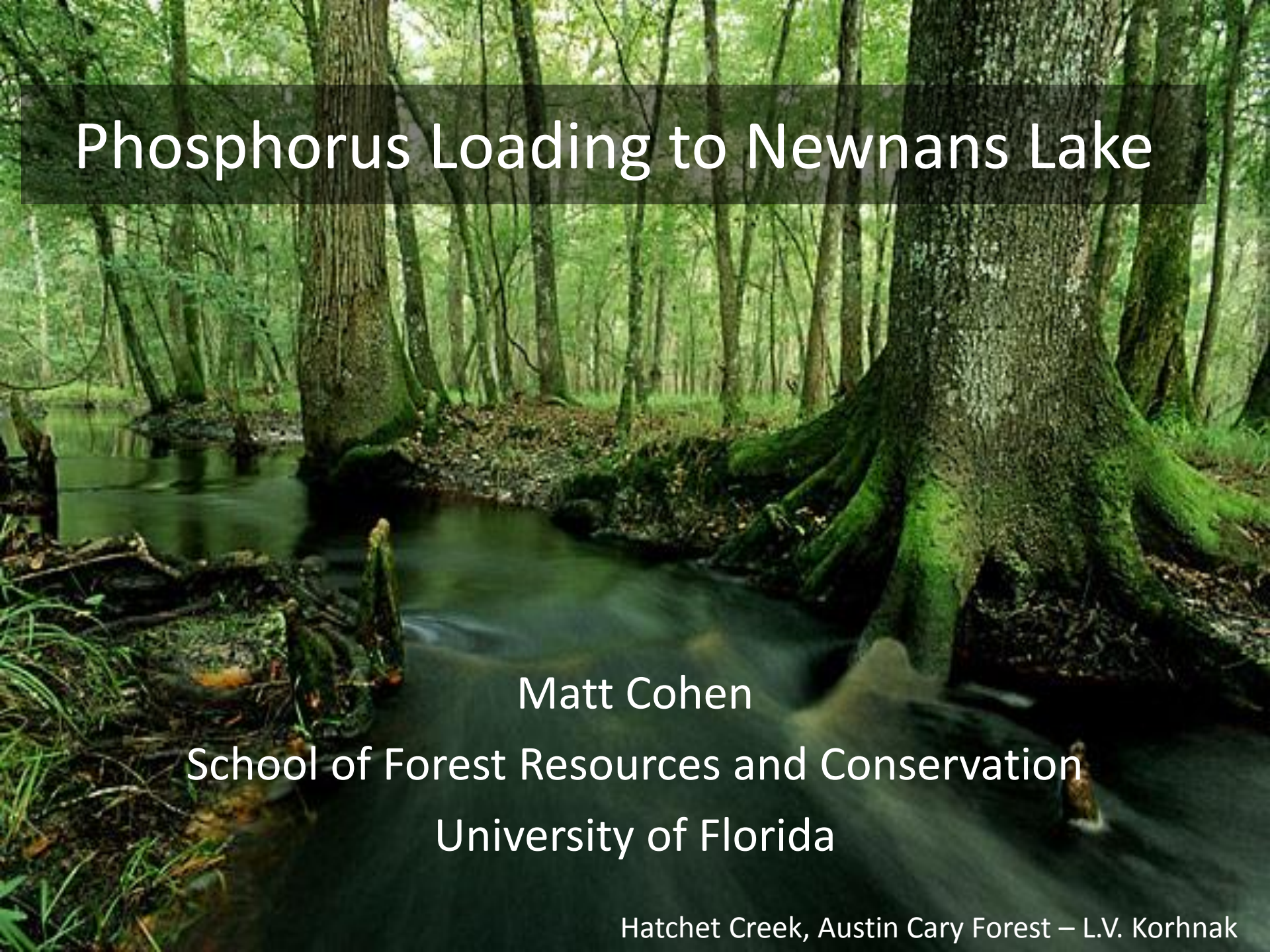
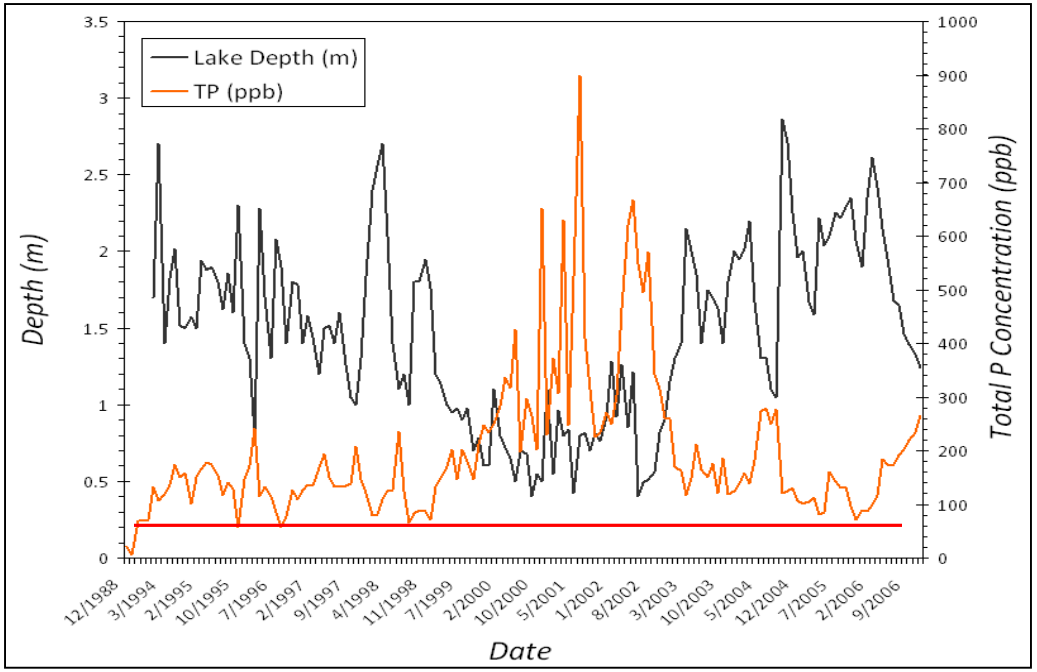
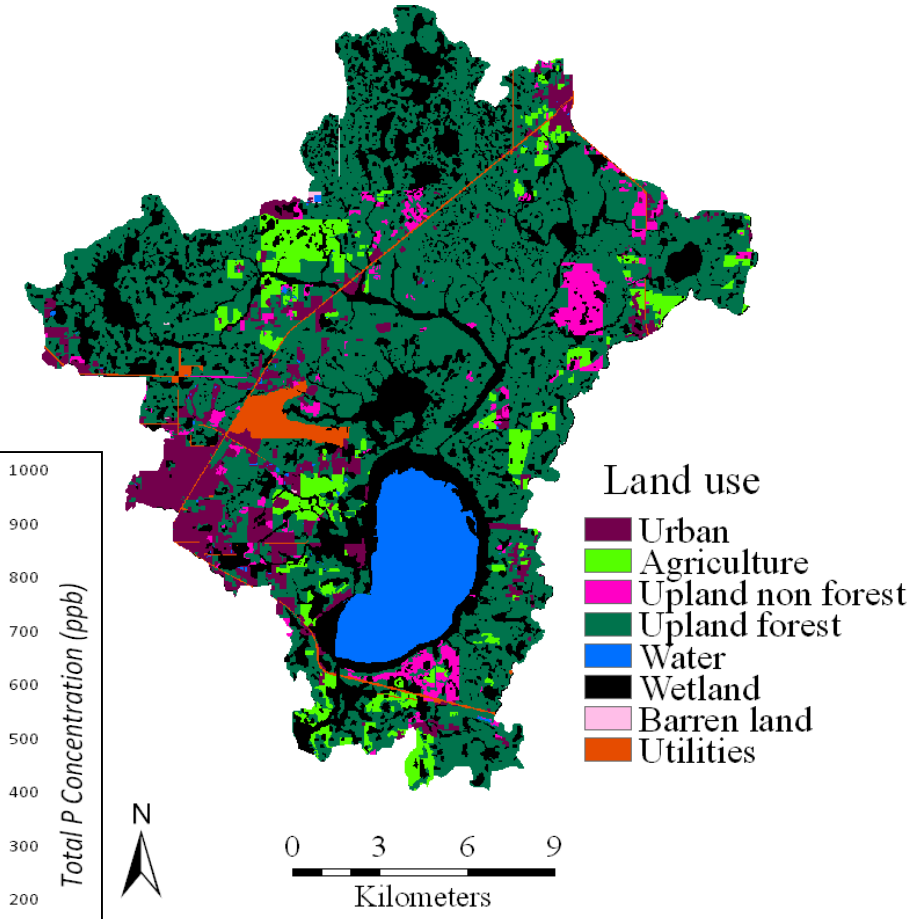


Hatchet Creek, Austin Cary Forest – L.V. Korhnak

The Newnans Lake Puzzle

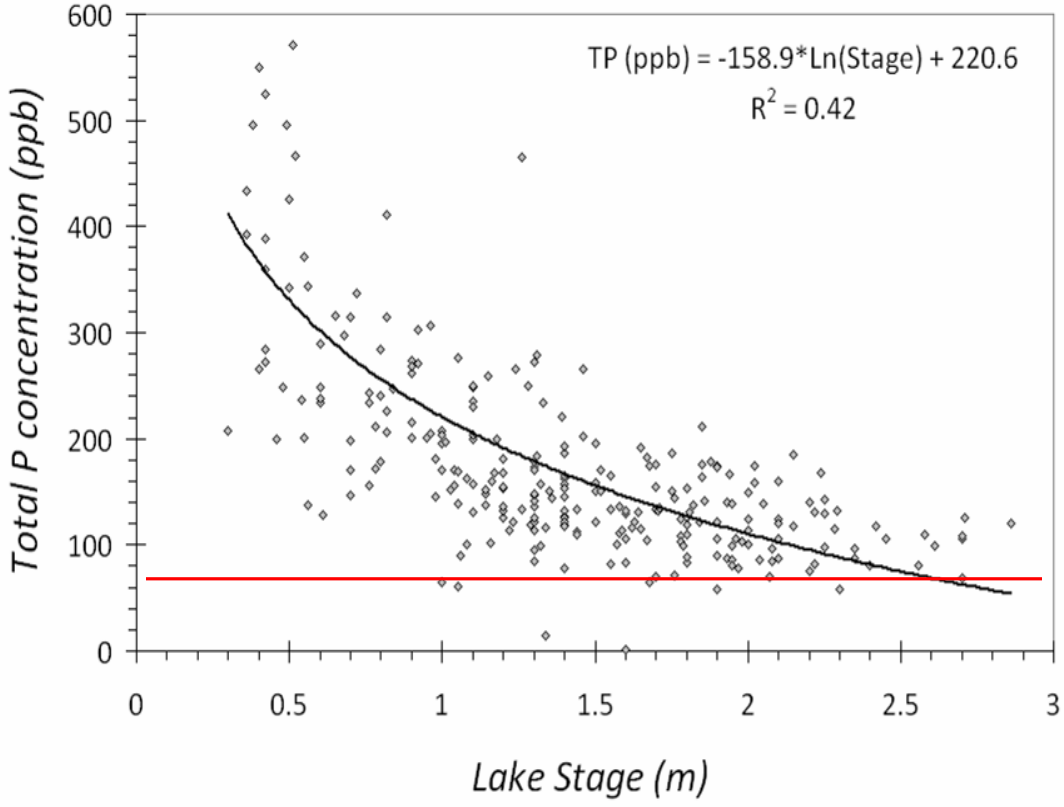
- Low intensity land use
  - 75% forests and wetlands
- Hyper-eutrophic lake
  - High P concentrations
  - Large blue-green algal blooms lead to high N concentrations
- Recent P volatility (drought)





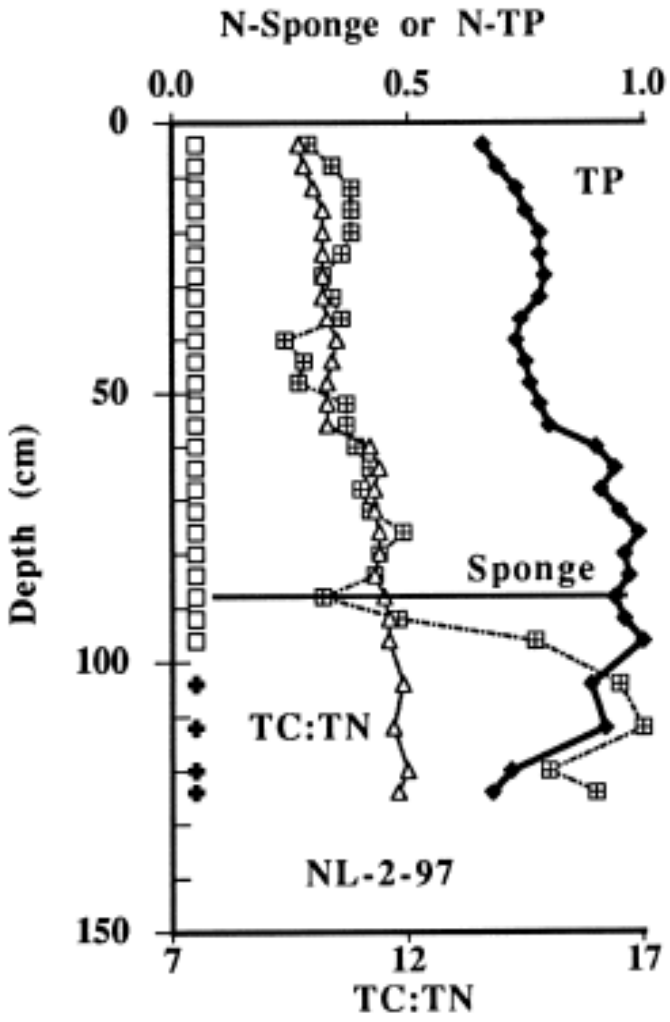
Lake Levels and Phosphorus

- Higher lake levels, lower P concentrations
- Appear to converge on ~ 100 ppb at high stage
  - Average ~ 180 ppb between 1988 and 2006
  - Lake Apopka was ~ 175 ppb from 1991 and 2000
  - Regulatory target is 68 ppb



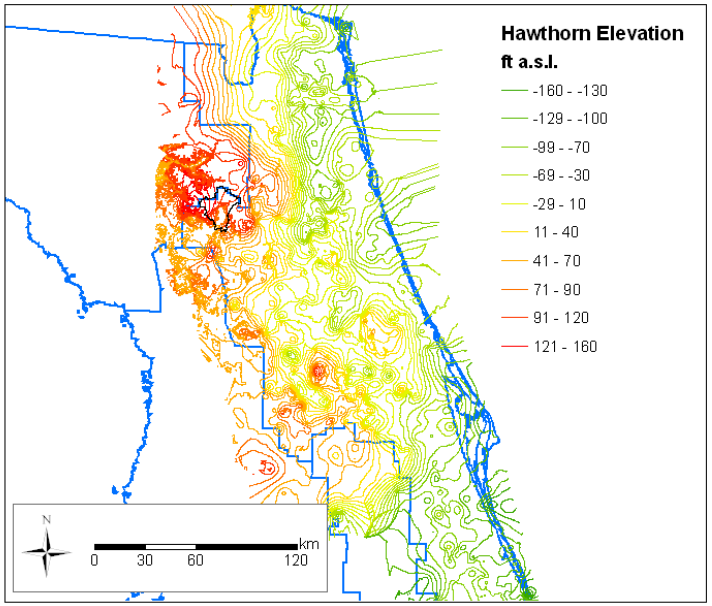
Historical P Conditions

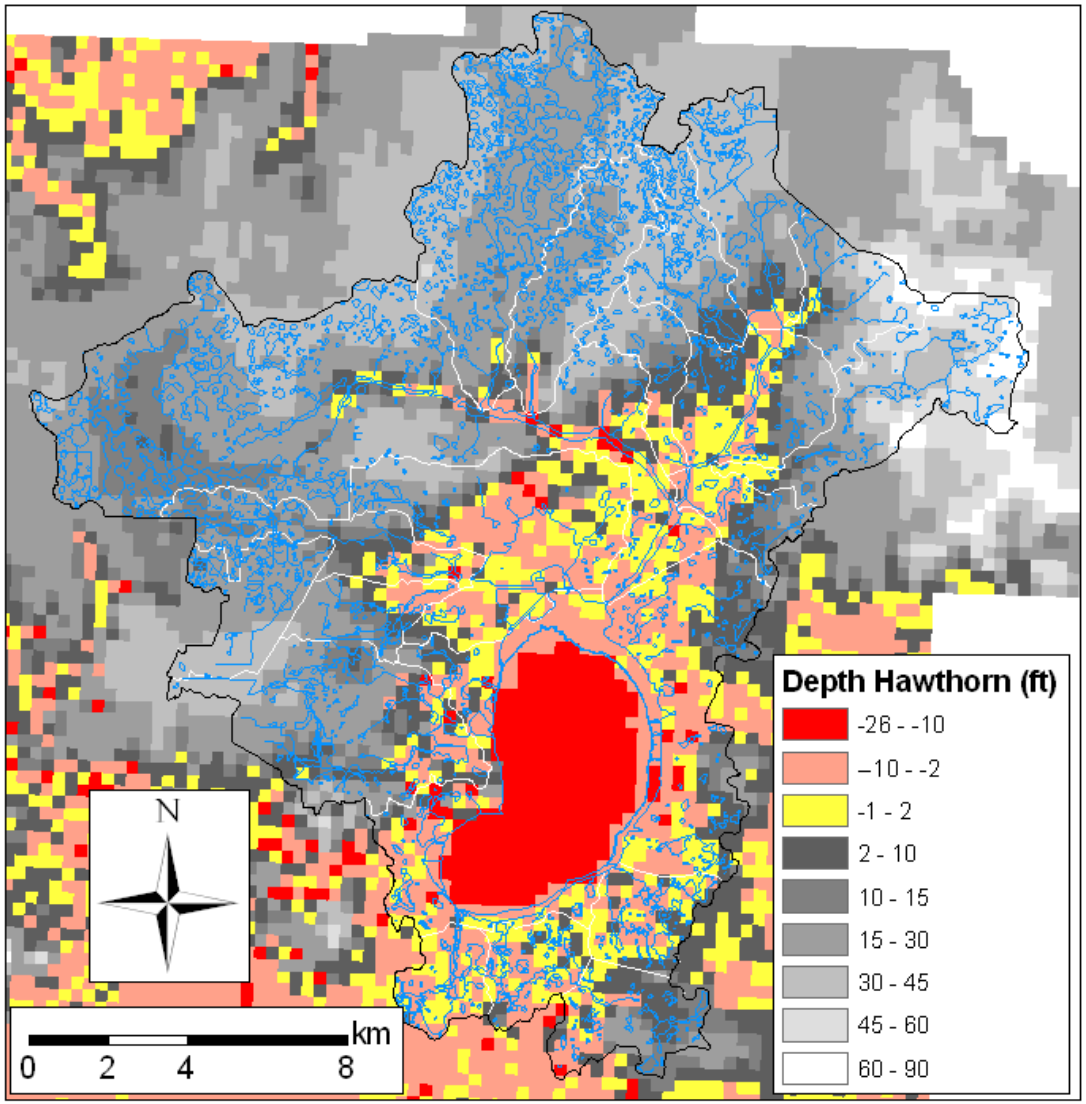
- Sediments are P enriched throughout ~ 200 years (Brenner and Whitmore 1998)
- Sediment P concentrations lowest near the sediment surface suggesting either:
  - P sedimentation was historically high, then **lower** in the years prior to sampling in the early 1990's
  - Large reservoirs of mineral P exist in the sediments, diluted by organic matter



A Note on Geologic Setting

- Hawthorn Group sediment are important P deposit
- Underlay all Northern Highland region lakes





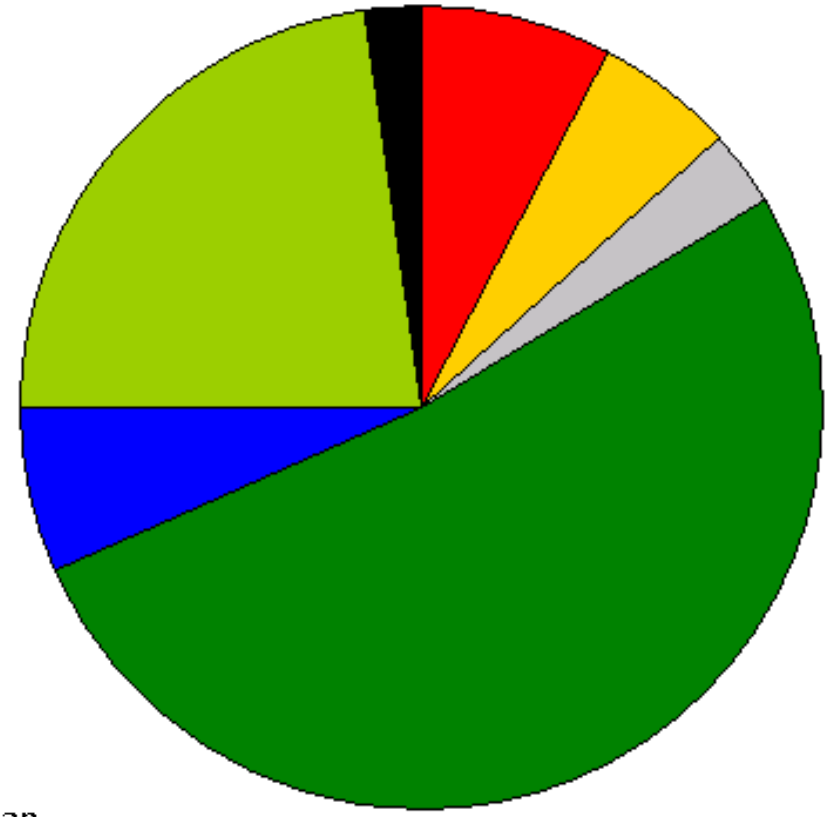
Two Central Questions

- **Is the phosphorus of anthropogenic origin?**
  1. P loading corresponds with land use intensity
  2. P and N loading vary together
  3. Geologic variables fail to explain observations
  4. P mostly in stormwater
- **Is internal P load significant?**
  1. External load fails to predict observed lake P concentrations
  2. Sediment pore water has high [P]
  3. P diffusion (or advection rates) high compared to watershed load

Question #1: **Is P Load of Anthropogenic Origin?**

Cohen et al. 2008 (SJRWMD)

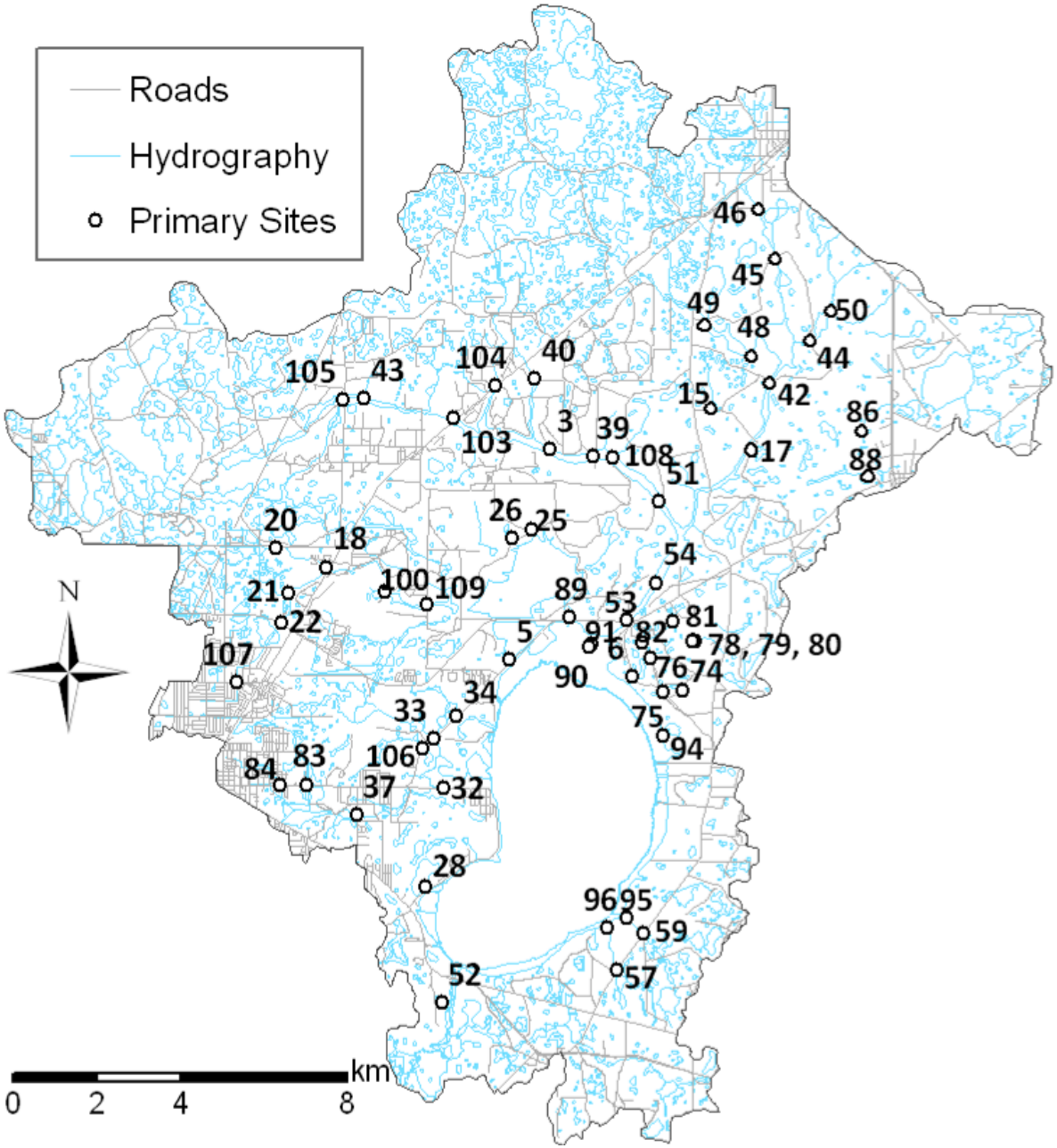
Basin Land Use



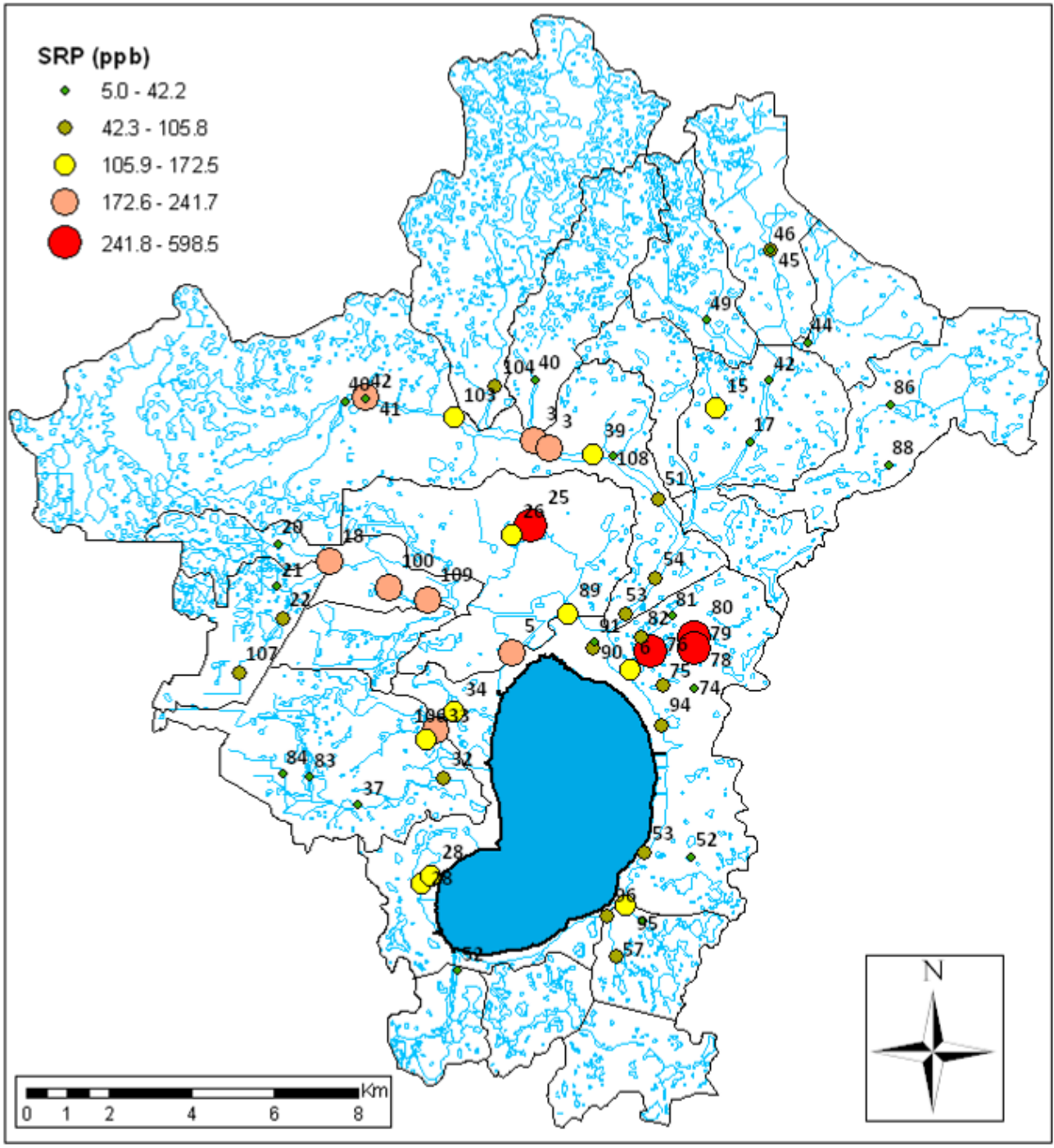
- Urban
- Agriculture
- Upland Non-Forest
- Upland Forest
- Water
- Wetland
- Barren Land
- Utilities

Landscape Development Coefficient*	Landuse Category
1	Natural System/Open Water/Wetlands
1.5 - 2	Silviculture Operations
2 - 3	Rangeland
3 - 4	Low Intensity Pasture
4 - 5	Low Intensity Row Crops
5 - 6	High Intensity Pasture
5 - 6	High Intensity Row Crops
6 - 7	High Intensity Agriculture
7 - 8	Residential
8 - 9	Industrial and Transportation
9 - 10	High Intensity Commercial

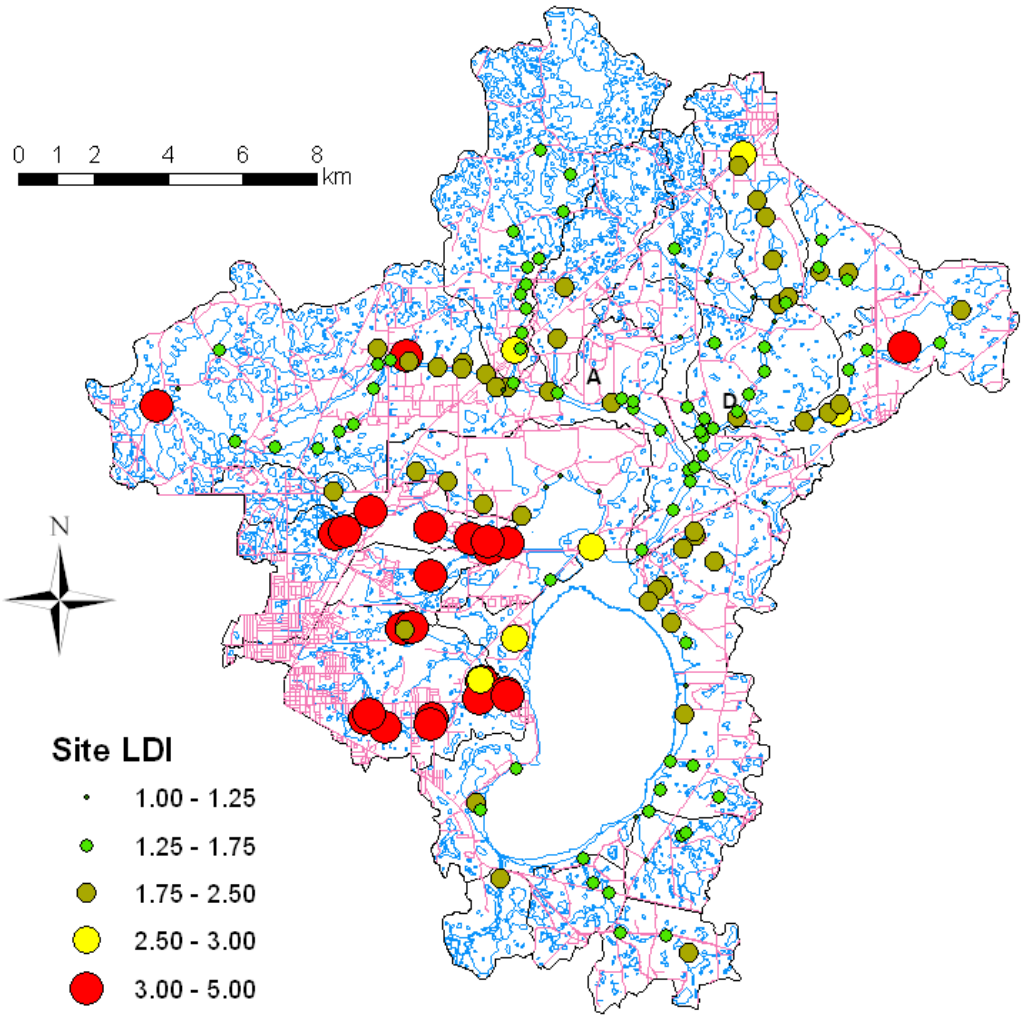
Water Quality Sampling

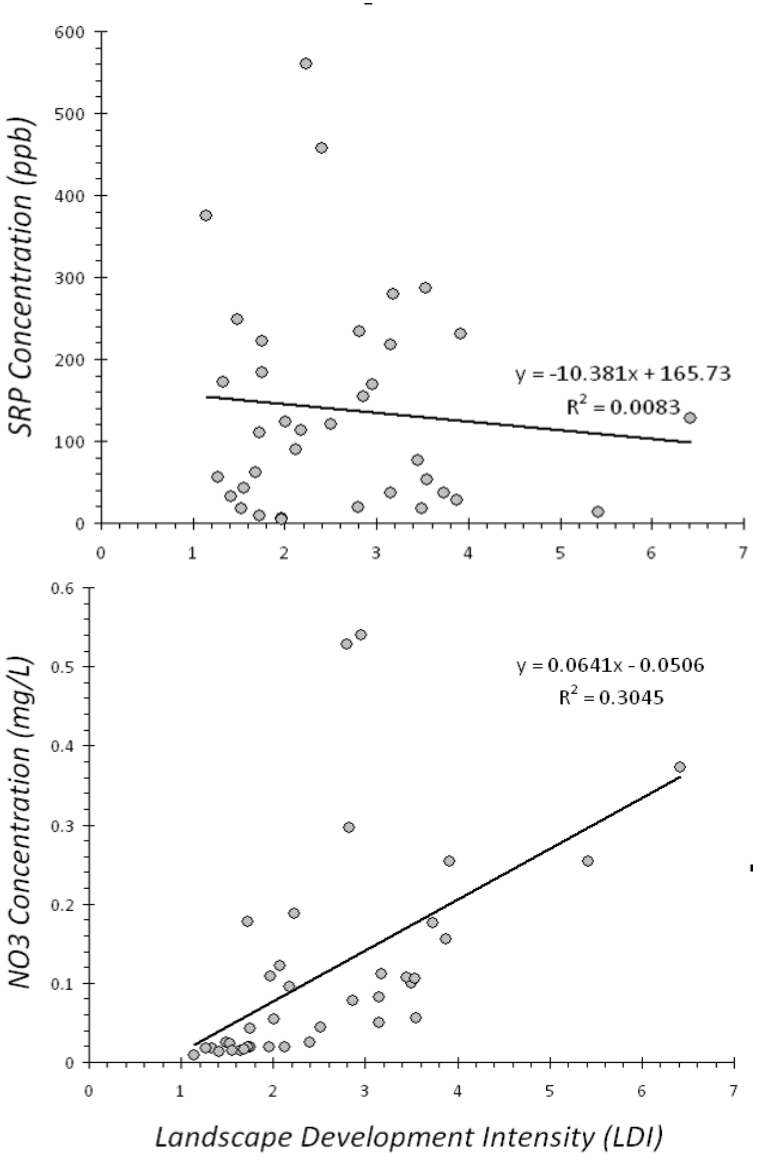


Where's the Phosphorus?

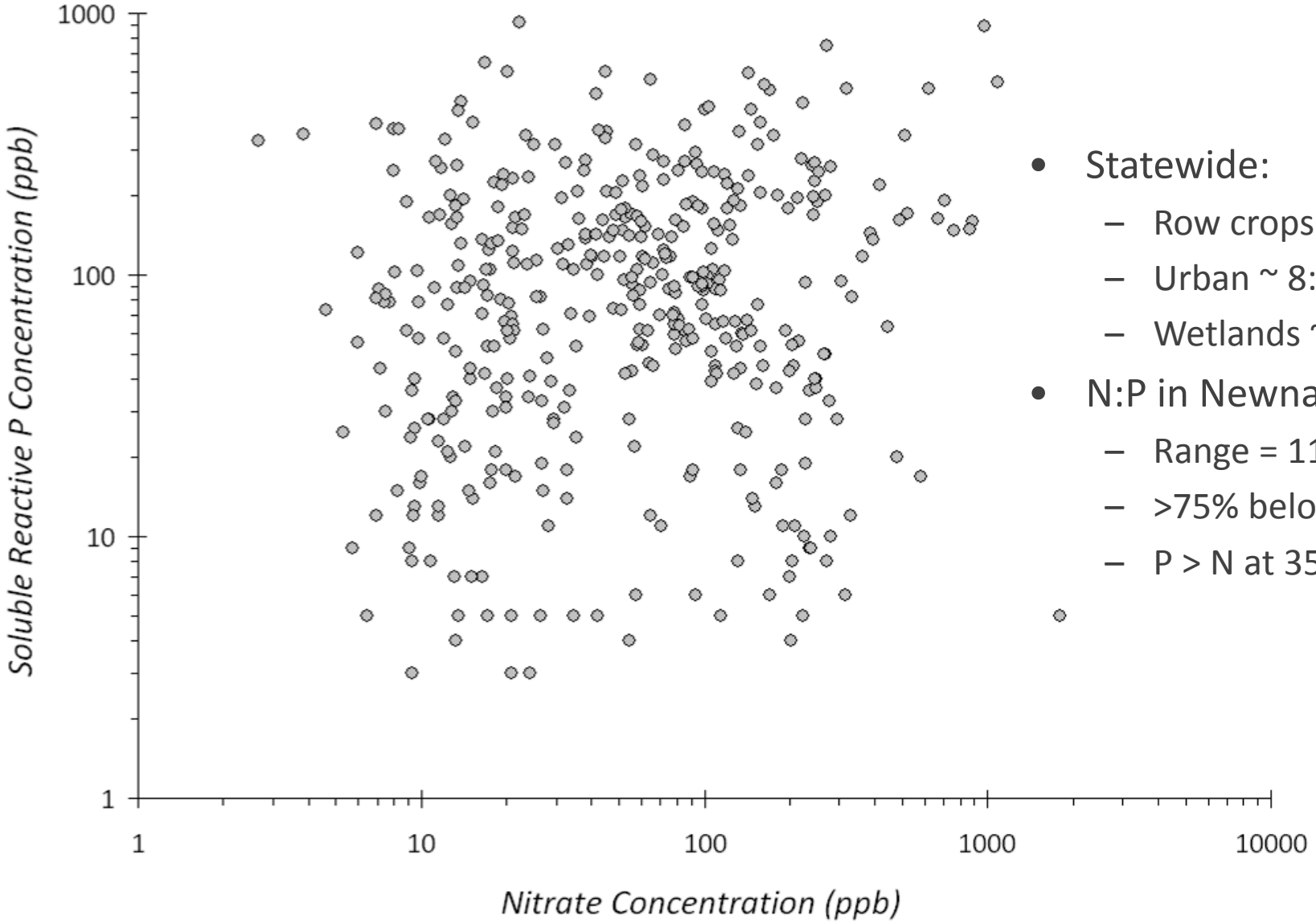


1: Landscape Intensity & Water Quality





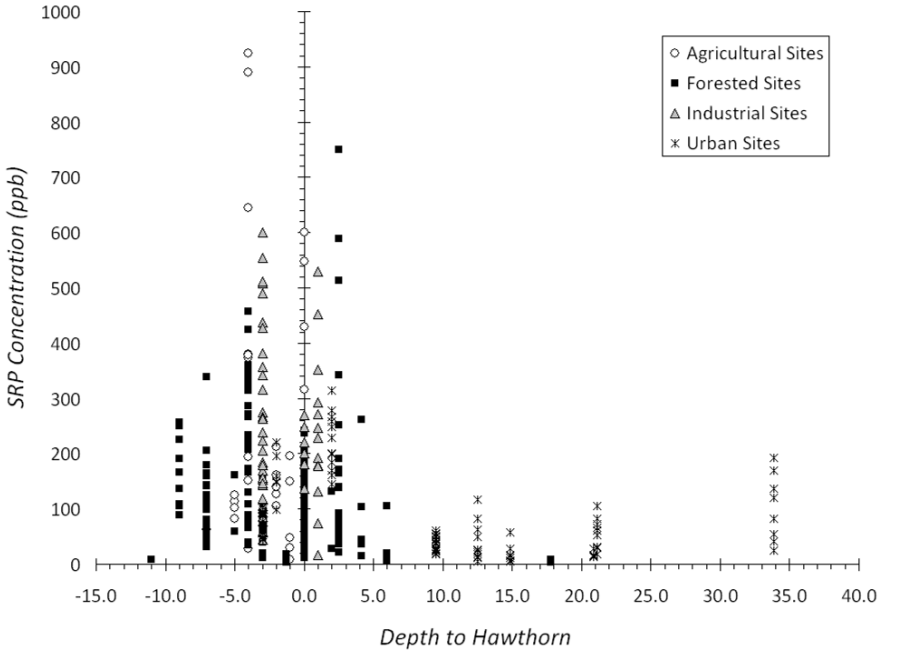
2: Nitrogen vs. Phosphorus

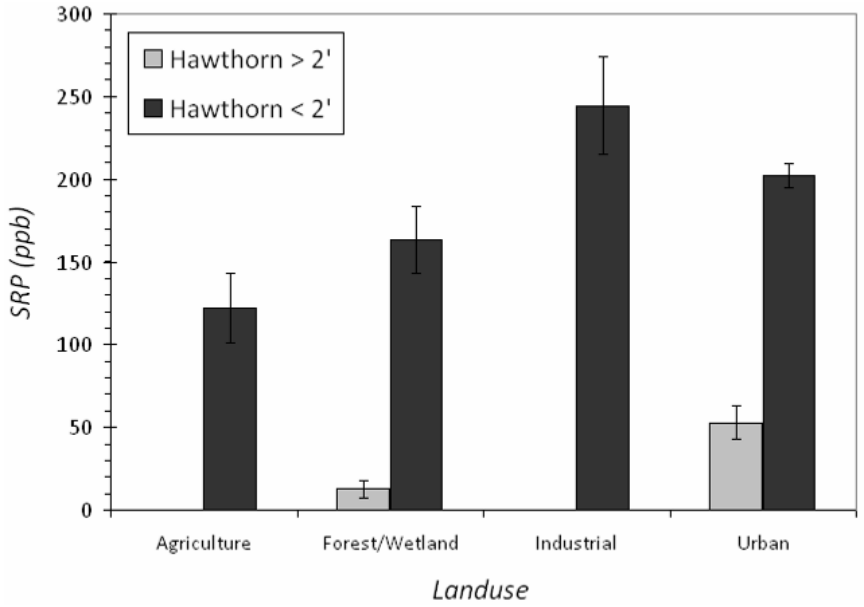


- Statewide:
  - Row crops ~ 5:1
  - Urban ~ 8:1
  - Wetlands ~ 10:1
- N:P in Newnans
  - Range = 11:1 to 0.4:1
  - >75% below 3:1
  - P > N at 35% of sites

3: One Geologic Proxies

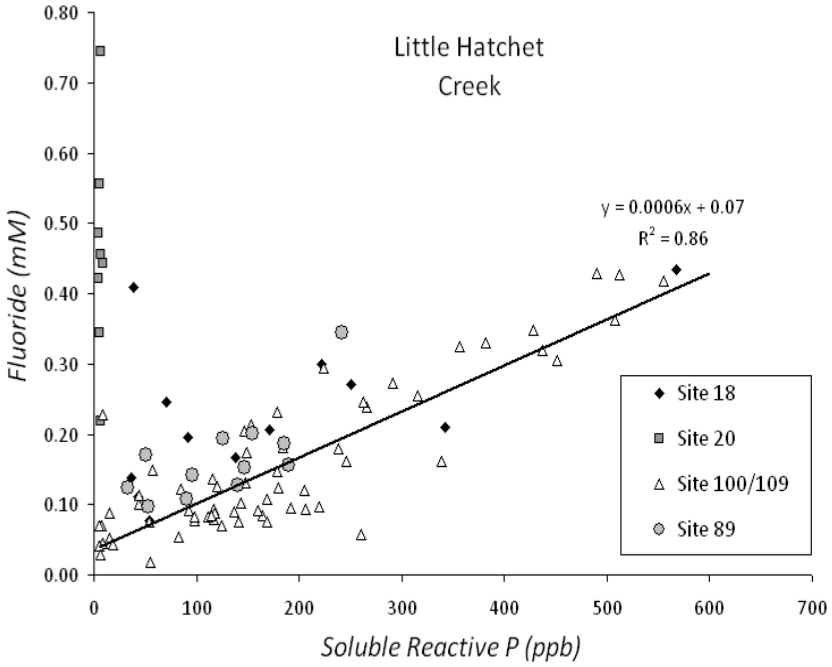
- Depth to Hawthorn predicts P conc.
  - Greater influence of geologic setting than land use
  - Without Hawthorn, patterns are more typical
    - Forestry ~ 15 ppb
    - Urban ~ 50 ppb

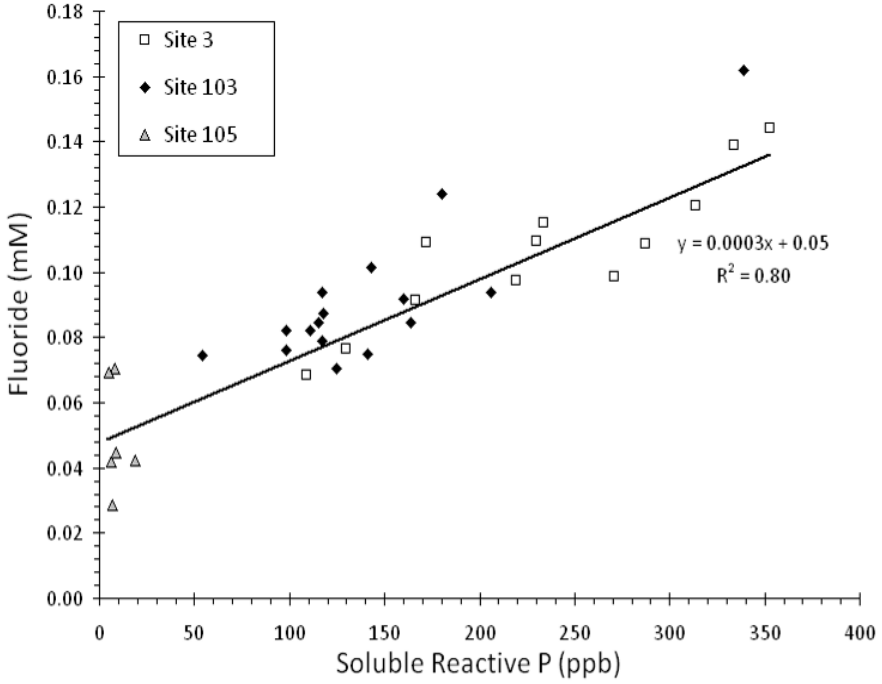




3: Another Geologic Proxy

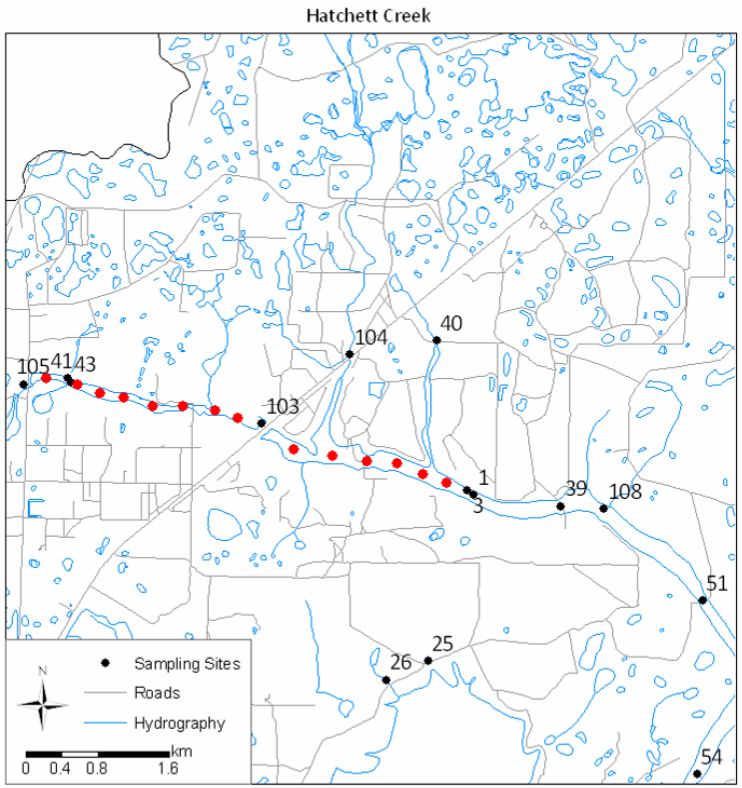
- Fluoride (F) is a by-product of apatite weathering
- Strong P vs. F relationship in Hatchet and Little Hatchet, no relationship in Lake Forest (deep Hawthorn)

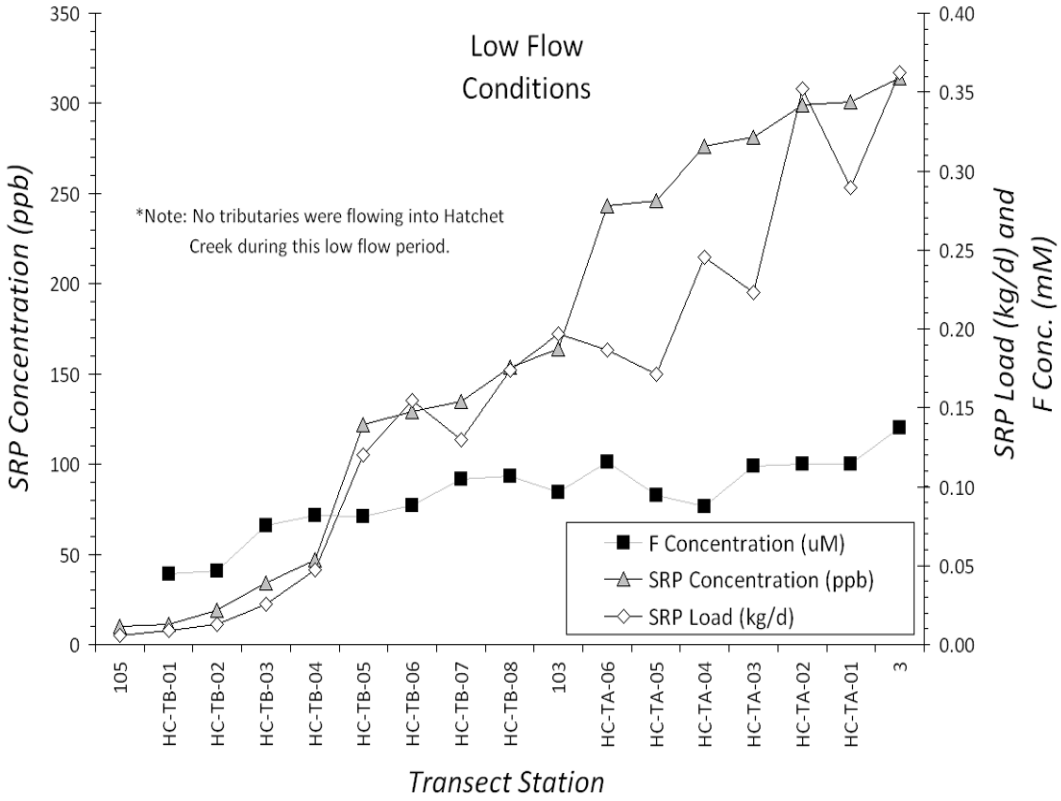




4a: Baseflow Concentrations – Hatchet Creek

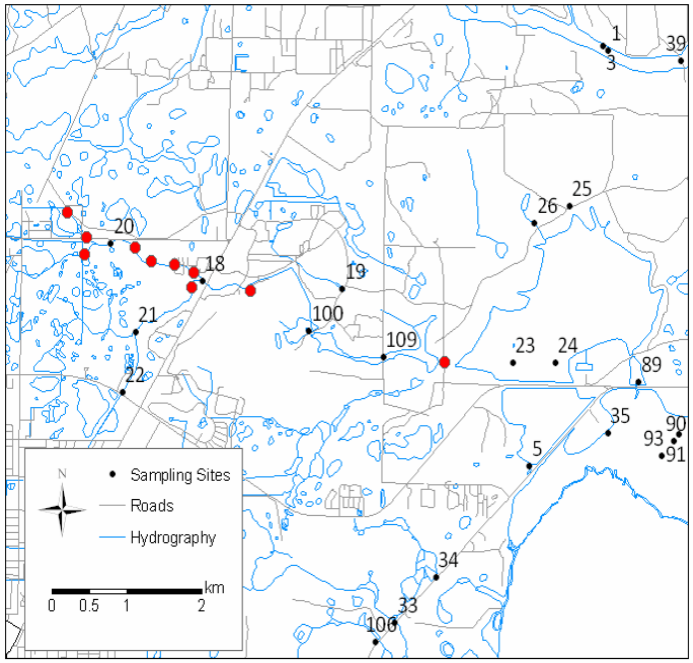
- Phosphorus enrichment occurs at baseflow
  - Seepage is highly SRP enriched (~350 ppb)
  - Indicative of intermediate aquifer (i.e. Hawthorn Formation) discharge (SC ~ 250 µS/cm)

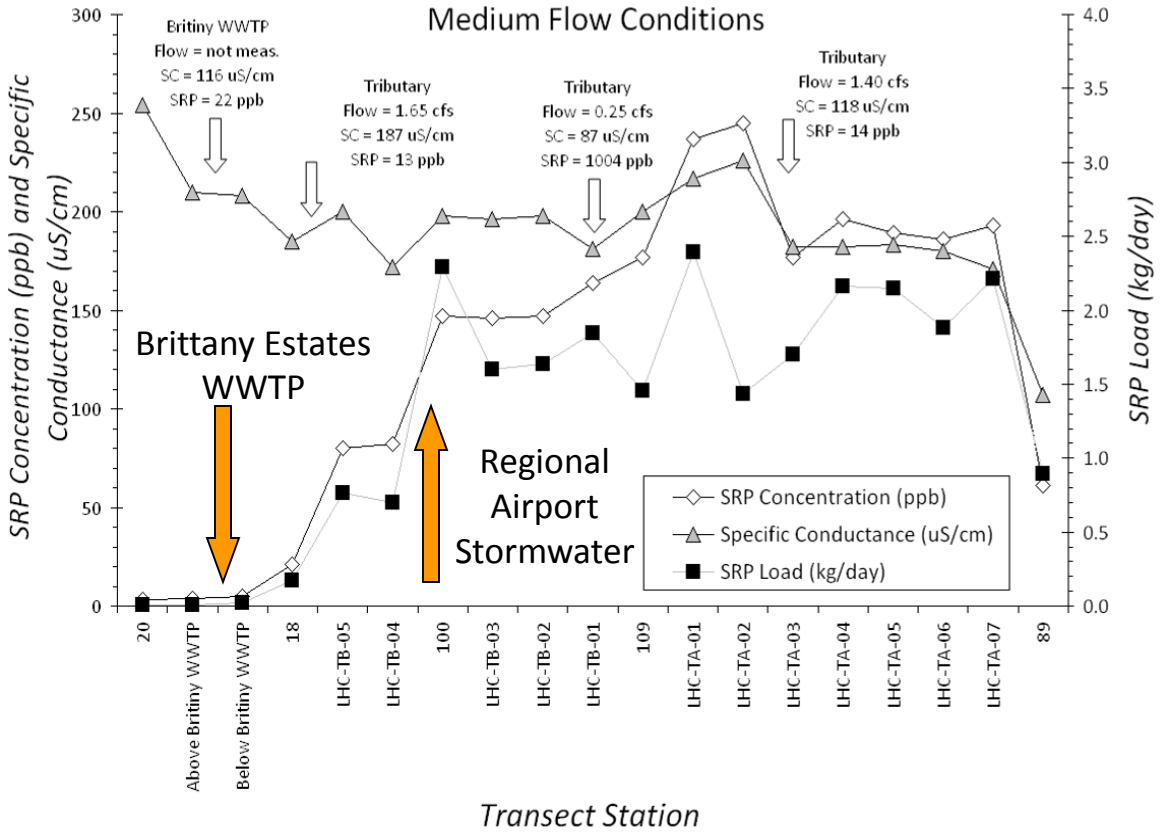




4b: SRP Concentrations – Little Hatchet Creek

- Same story
  - Flow is highly SRP enriched (~350 ppb) below airport
  - Location of increase indicates **NOT** wastewater





Question 1 Synthesis

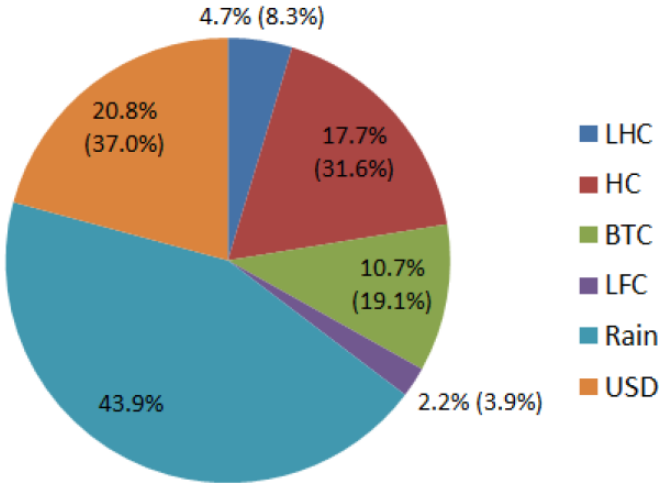
- Yes - P is principally of geologic origin
  - Land use is a poor predictor
  - N and P loads diverge
  - Geologic proxies are strong
  - High baseflow concentrations
- Implications:
  - Load reductions focus on hydrologic processes that accelerate Hawthorn erosion **especially in creek beds**

Question #2: **Is internal P Load significant?**

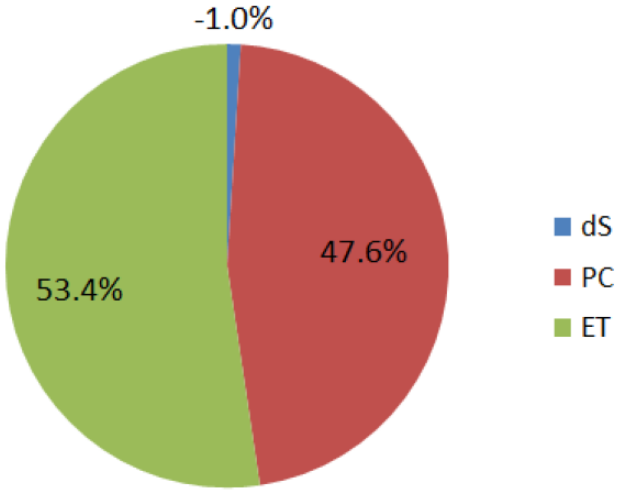
Cohen et al. 2010 (SJRWMD)

Water and Element Budgets (1998-2008)

- Empirical measurements of flows and fluxes for gaged parts of the basin (~50%)
- Extrapolation based on area-weighting for ungaged portions (~50%)



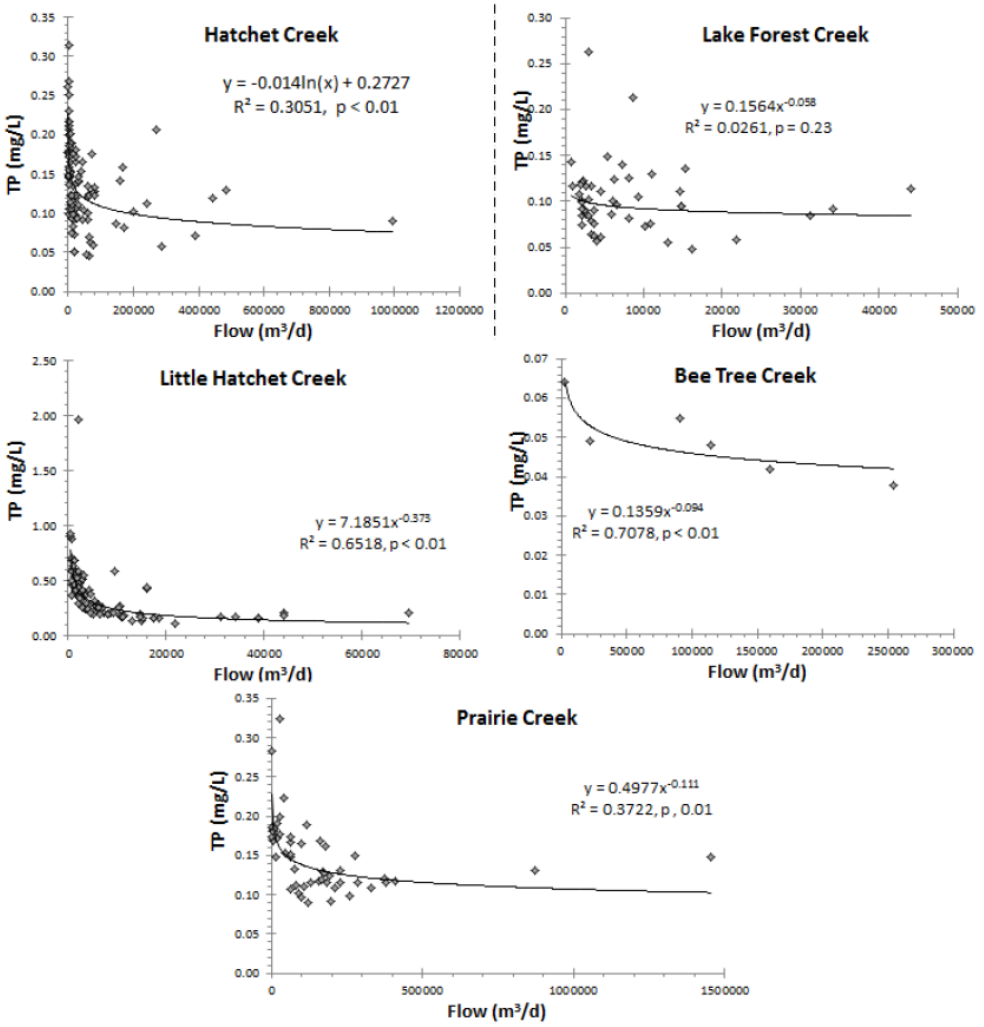
Total Water Inflow = 6.72×10^8 m^3



Total Water Outflow = 6.76×10^8 m^3

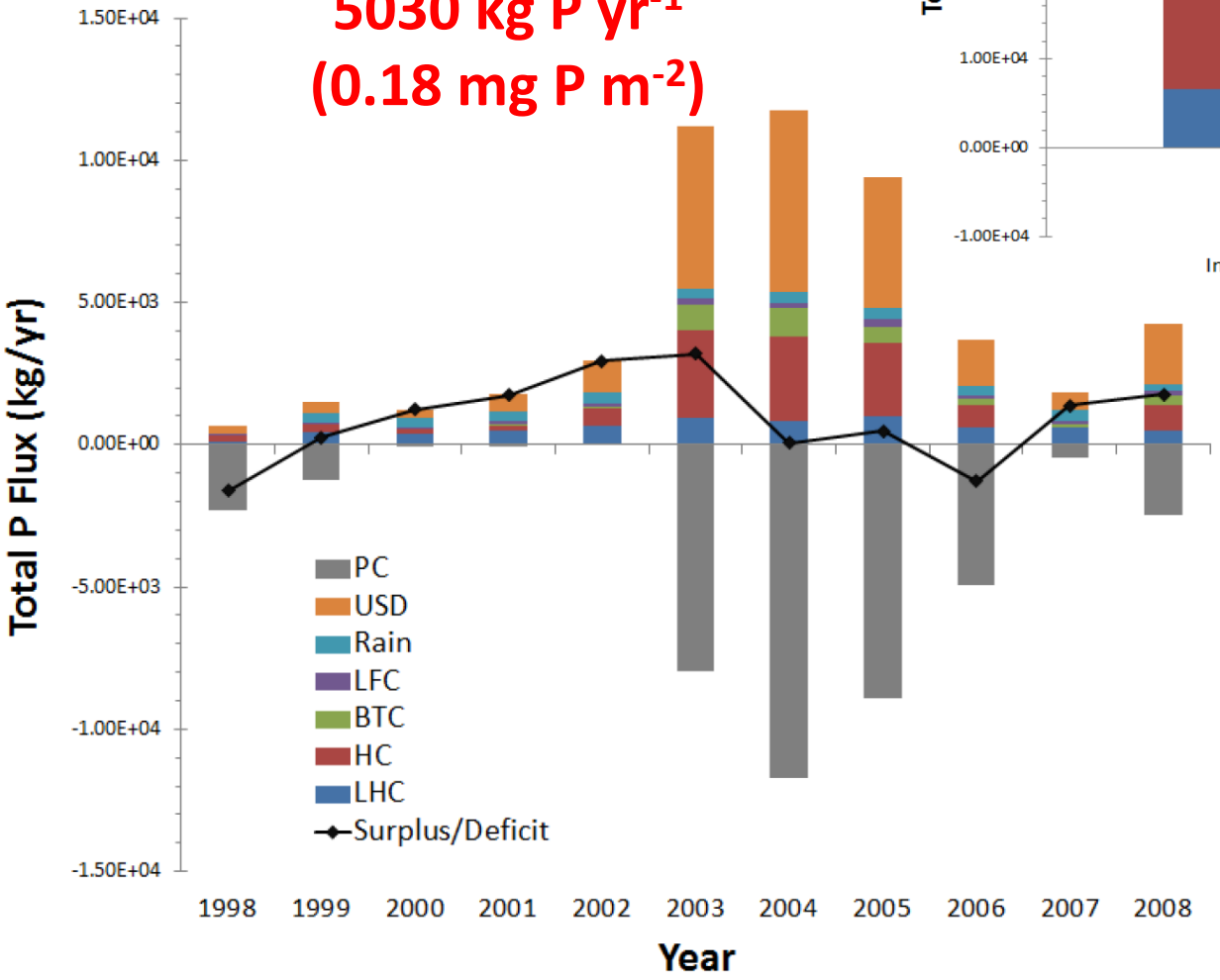
Concentration vs. Discharge Relationships

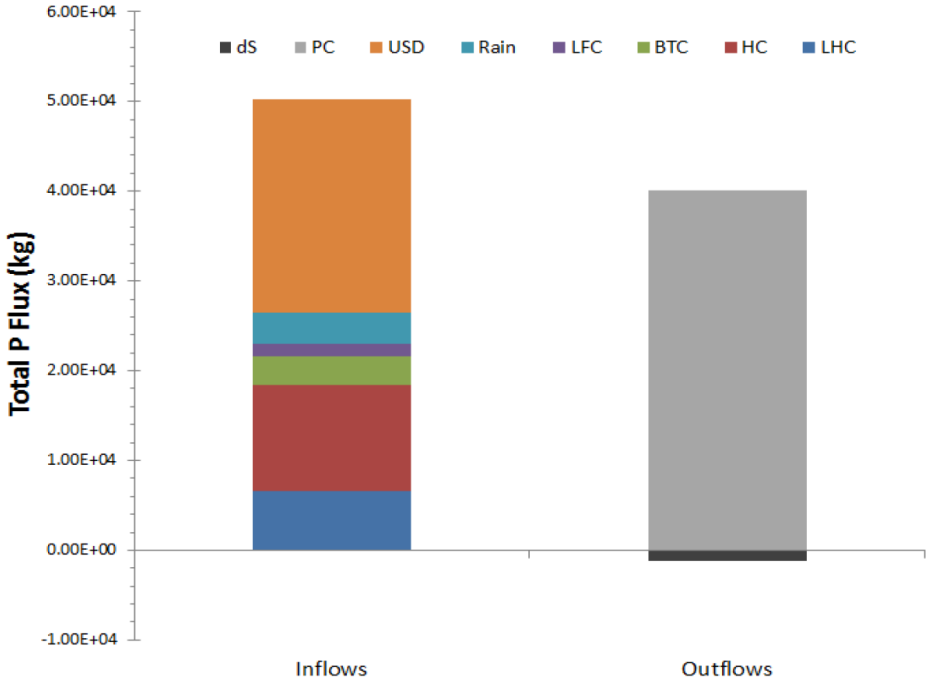
- Generic dilution
- Large catchment variation
- Apply fit to obtain P loads from daily flow



Annual and Total P Loads

Mean Annual Load = 5030 kg P yr^{-1} (0.18 mg P m^{-2})



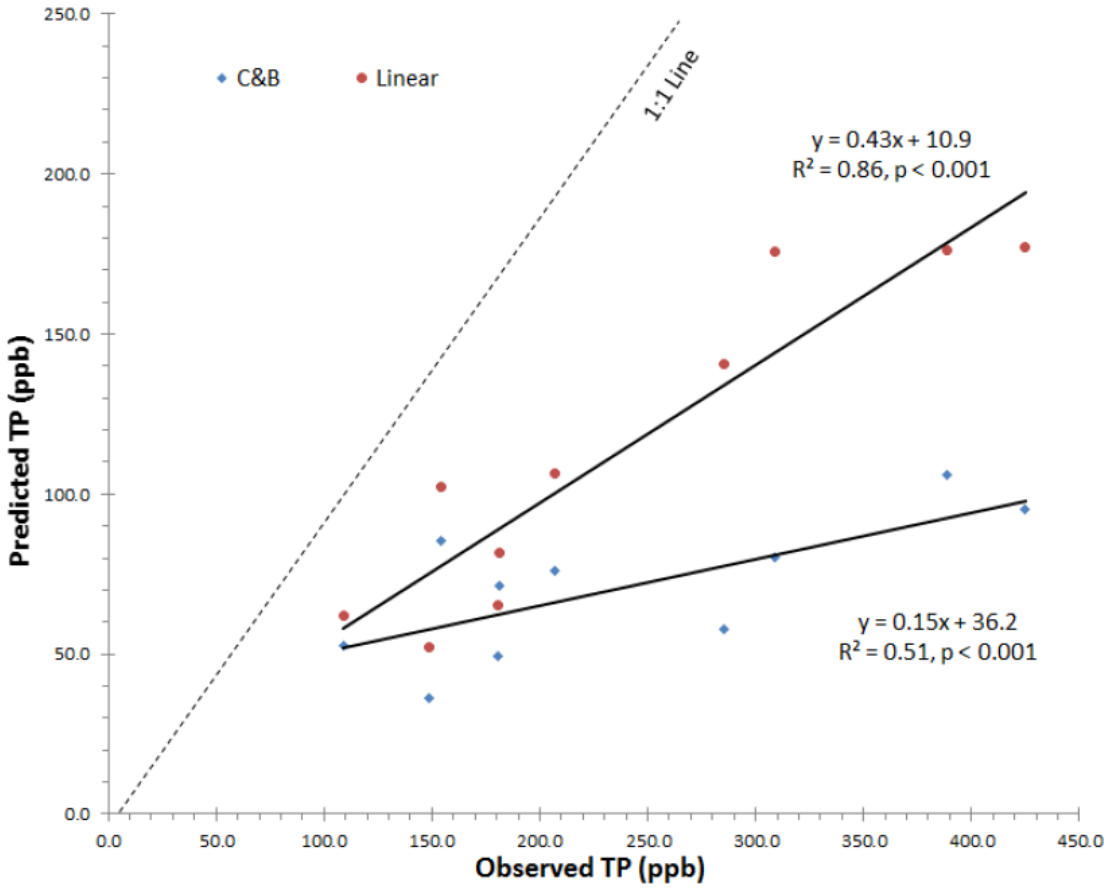


Nagid et al. (2001) found Newnans was a net P source (1998 and 1999). Over 10 years, Newnans is a <u>weak</u> net P sink (in 20% > than out)

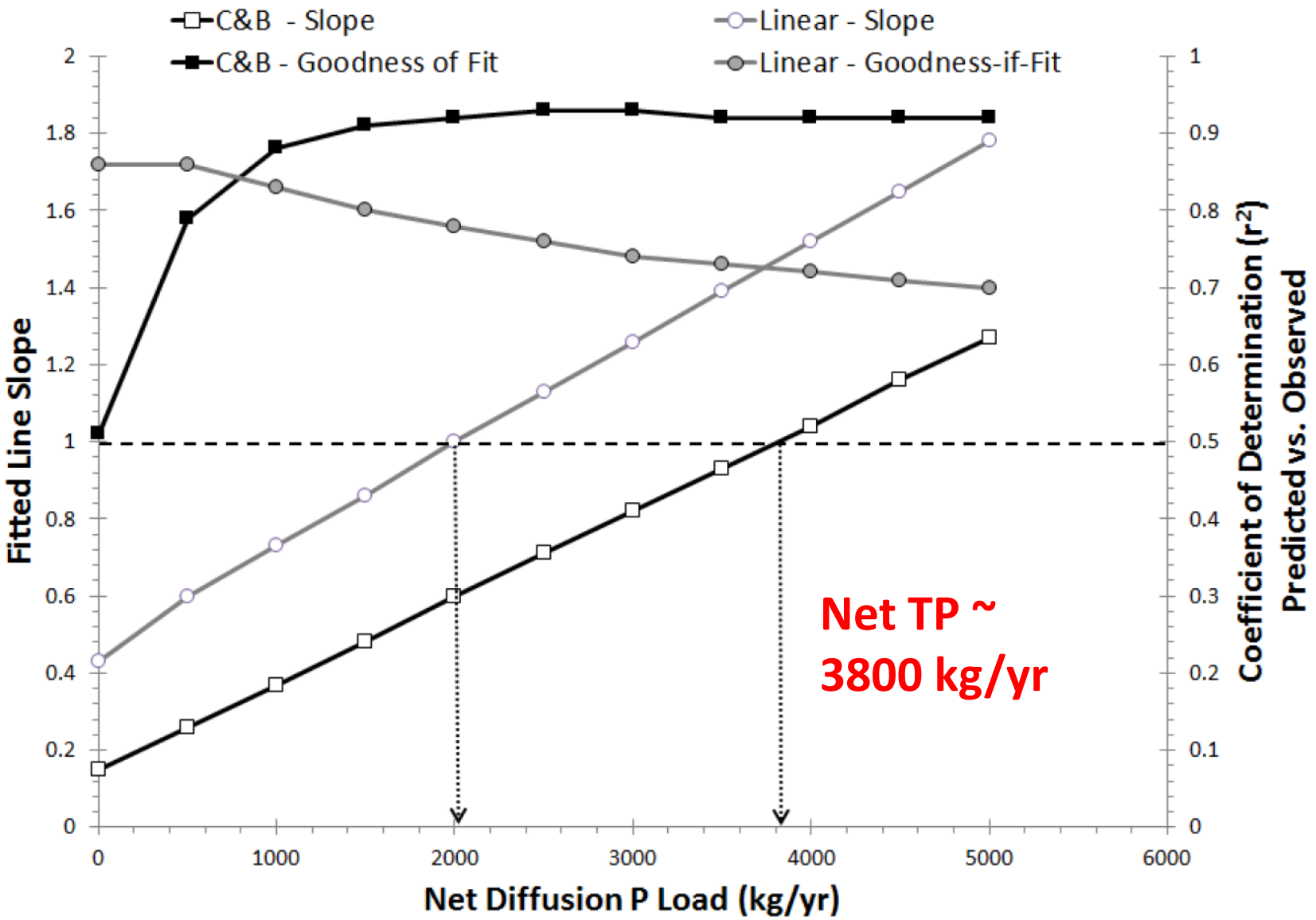
Modeled Lake TP

$$TP = \frac{L}{z(\sigma + \rho)}$$

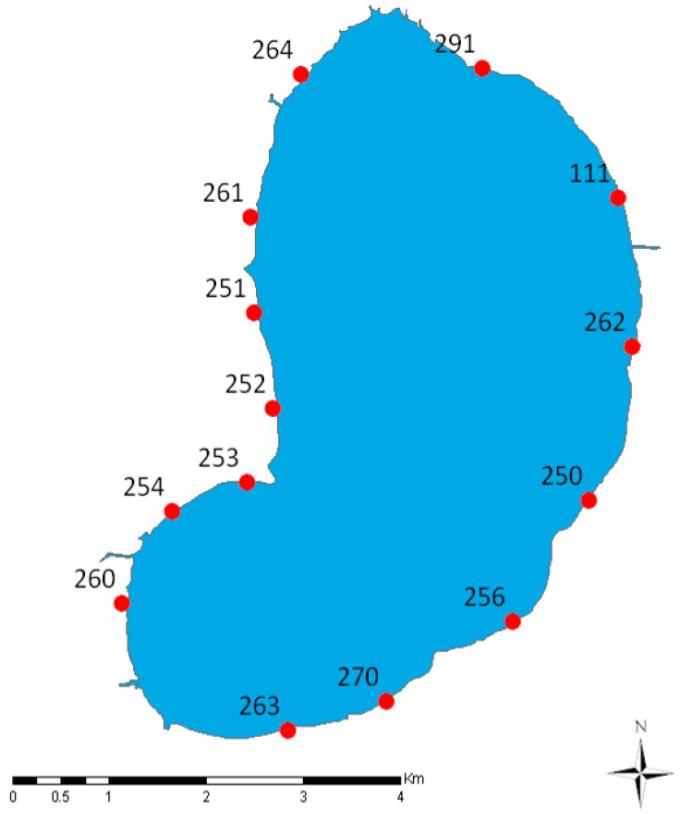
- Under-predict TP using measured loads by 85% (!)
- Implies:
  - Extremely low settling rate (σ ~ 0.17 yr^{-1}, and < 0 in some years)
  - Net "new" source of P

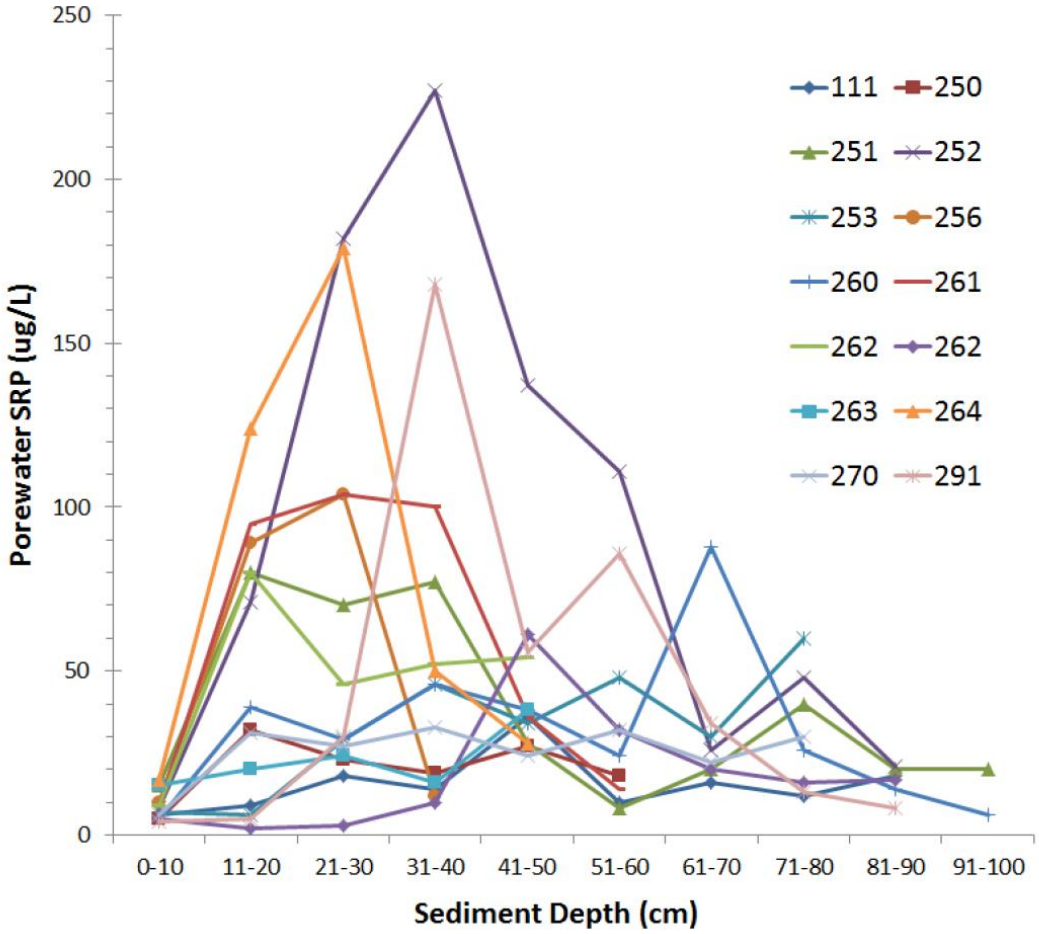


Doing Modeling Backward: How Much "New" P to Close Model



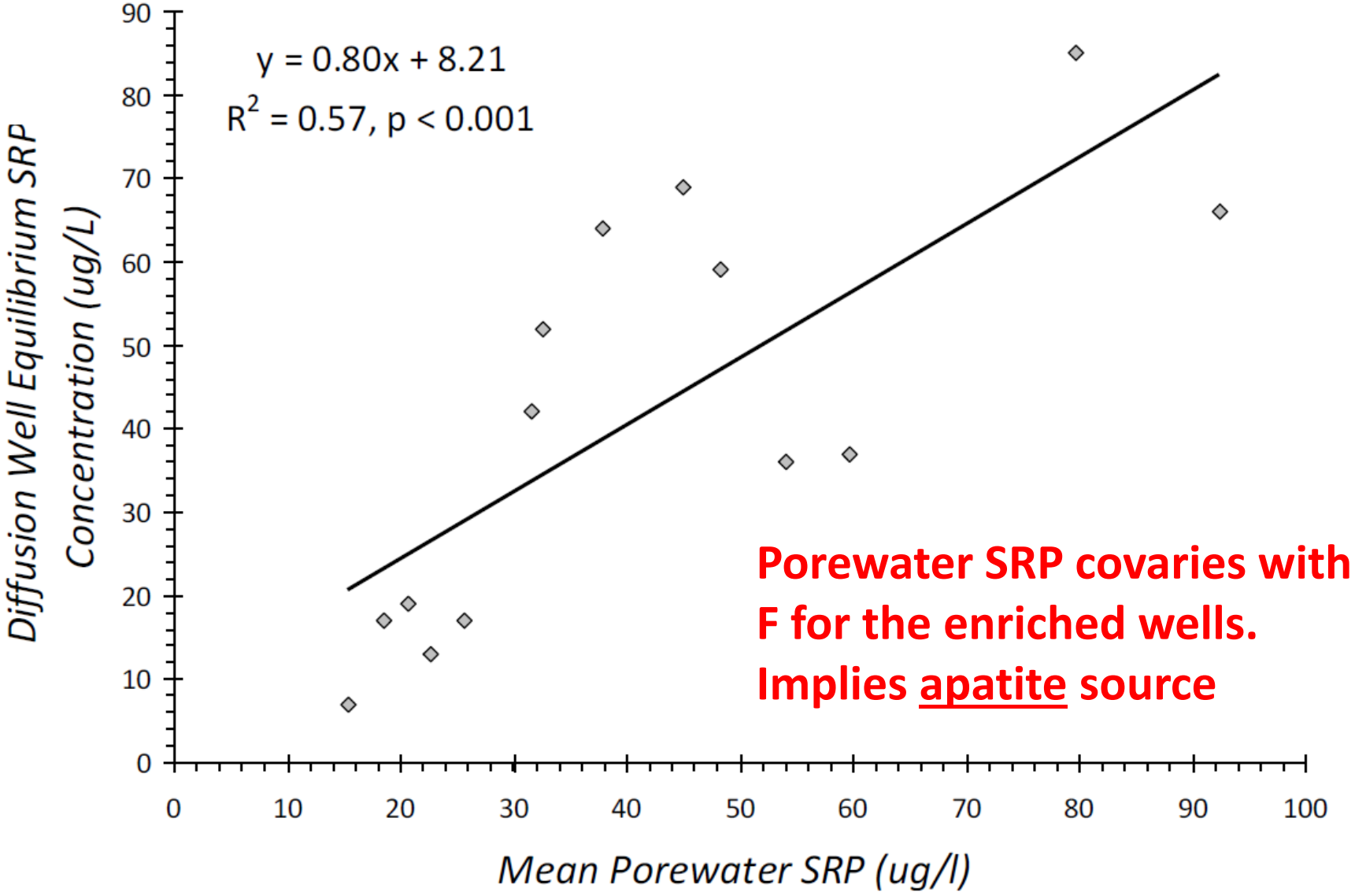
Porewater SRP (Internal Loads)





High P Concentrations in some sediments. All the porewater P is in the top 50 cm, so it's not from a deep lake bed source.

Porewater vs. Measured P Diffusion

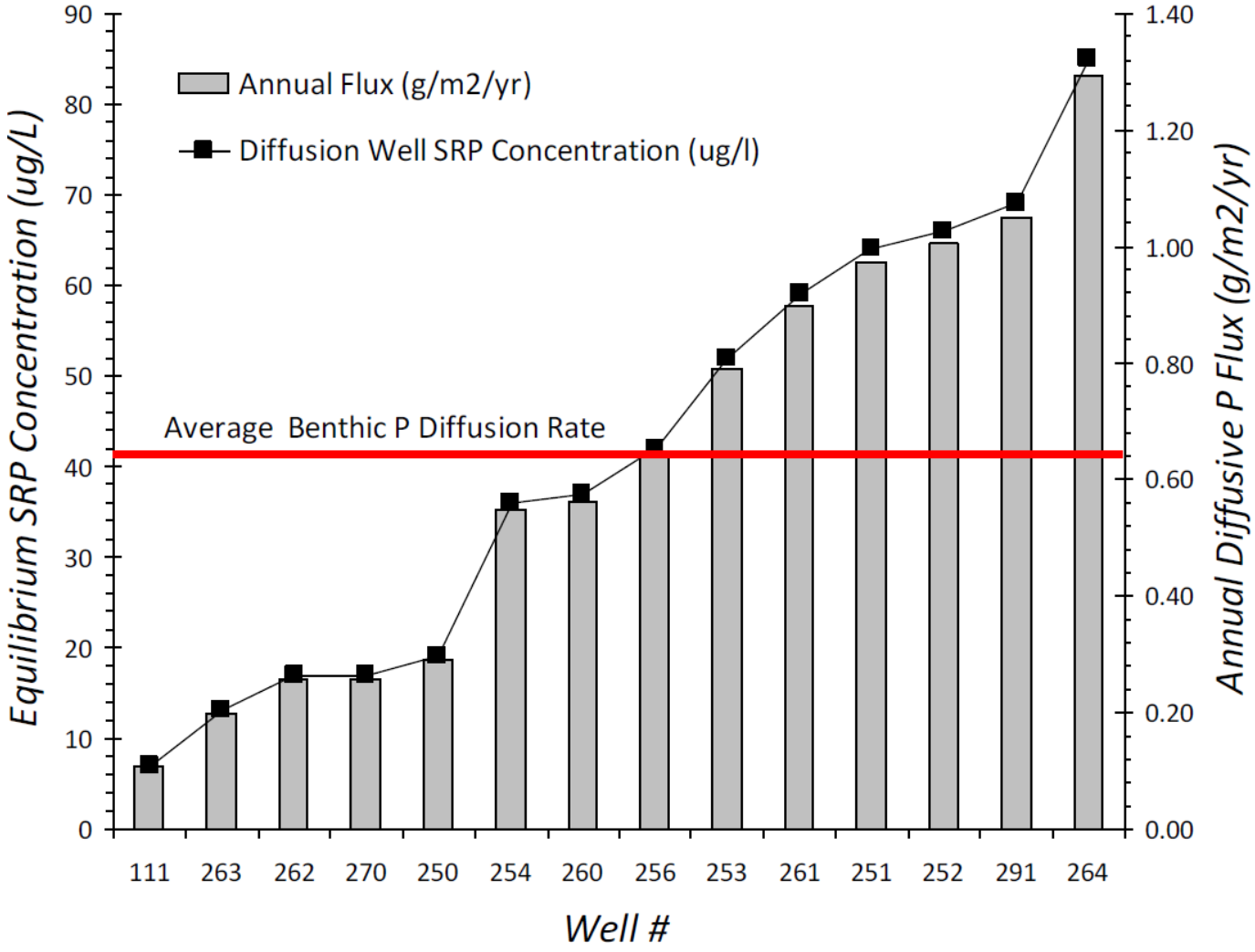


(Gross) Diffusion Rates

Gross Diffusion TP Flux ~ 16,400 kg/yr

vs.

Watershed TP flux ~5,030 kg



Net = 20% * Gross allows models to align with measurements

Question 2 Synthesis

- Newnans Lake is a **net P sink**
  - Mean empirical loading rate is ~5,000 kg/yr
- Internal load:
  - Large (gross flux is 16,000 kg/yr)
  - From the shallow sediments
  - Impacted by apatite weathering (covaries with F)
- Models cannot predict lake TP without:
  - Unreasonable assumptions about settling
  - Net P from the sediments

Overall Management Implications

- Emphasize accelerated geologic loading
  - Bed and back erosion
- Consider landscape sinks for management
  - Gumroot Swamp is P saturated (data not shown)
- Explore in-lake reduction strategies
  - Lake level management
  - Accelerating sedimentation
  - P-rich sediment removal (where are the P rich lake sediments?)


Thank You!
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