Lake Frances
How Much Alum is Enough?

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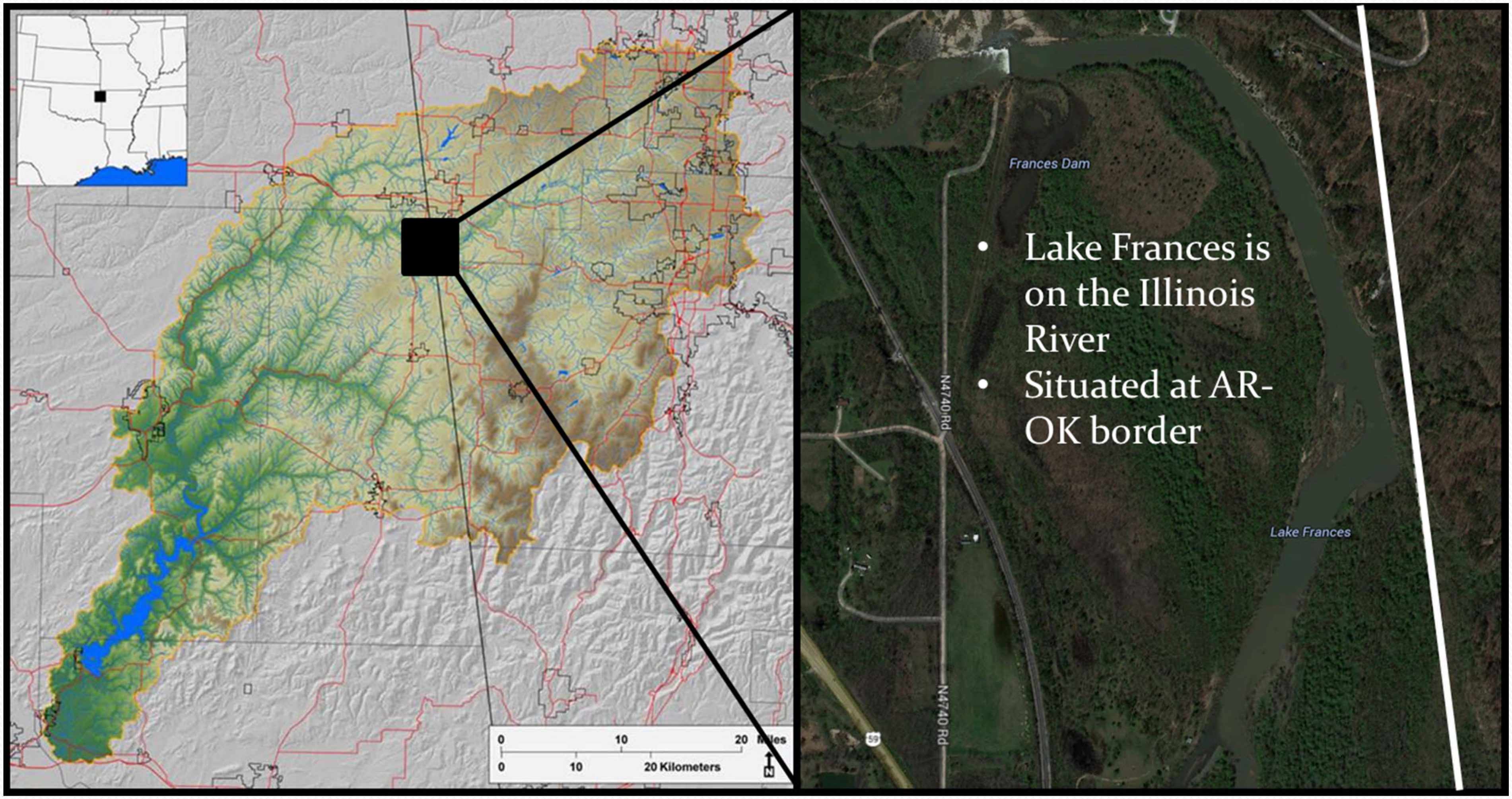
Study Site



- Lake Frances is on the Illinois River
- Situated at AR-OK border

Background

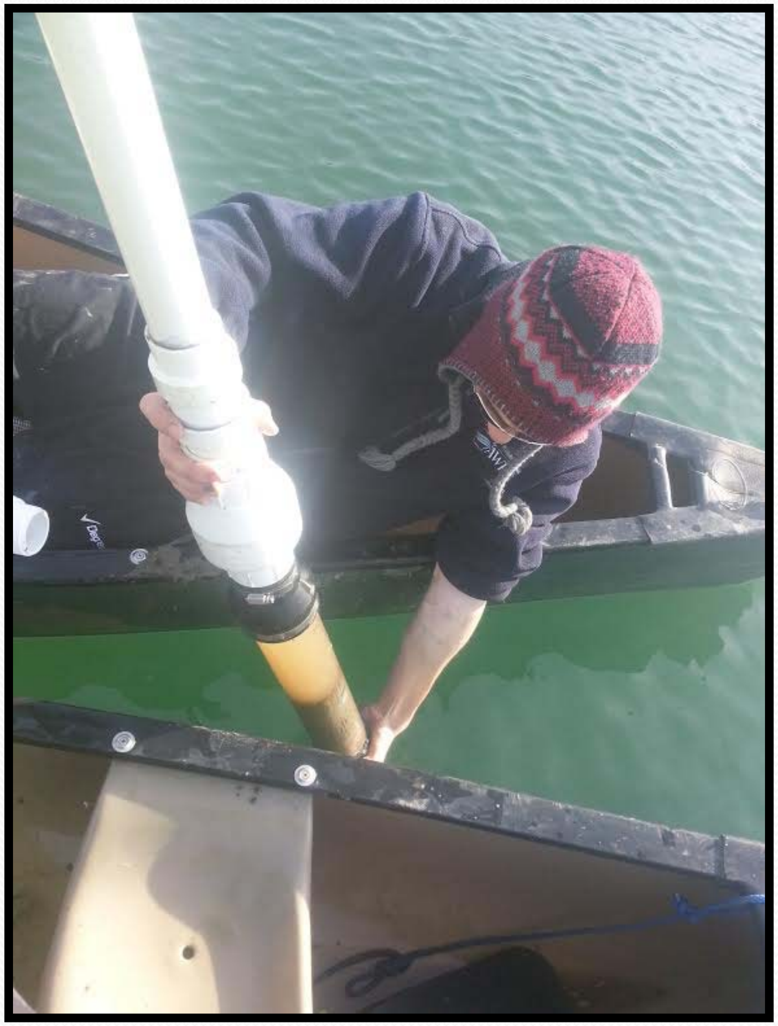
- Oklahoma Scenic Rivers like the Illinois River have a total phosphorus (TP) criterion of 0.037 mg L^{-1}
- Previous study showed high potential for phosphorus (P) release from sediment
  - Average P flux of 3.6 and 15.5 mg-P m^{-2} d^{-1} under aerobic and anaerobic conditions, respectively (Haggard and Soerens, 2006)
- These release rates are high relative to that measured in regional reservoirs:
  - Lake Eucha: 1.03 and 4.40 mg-P m^{-2} d^{-1} under aerobic and anaerobic conditions, respectively (Haggard et al, 2005)
  - Lake Wister: 0.94 and 2.41 mg-P m^{-2} d^{-1} under aerobic and anaerobic conditions, respectively (Haggard and Scott, 2011)
  - Beaver Lake: 0.15 and 1.77 mg-p m^{-2} d^{-1} under aerobic and anaerobic conditions, respectively (in the Transition Zone) (Sen et al, 2007)

What Needs to be Answered?

- Is P release still occurring?
- Is the P contribution significant?
- Can we do something about it?
  - Conventional treatments include:
    - Chemical: for example, alum ($Al_2(SO_4)_3 \cdot 18\ H_2O$) application
    - Physical: for example, sediment dredging
- If we want to do something about it, what exactly should we do?

Field Methods

- Collect Cores
  - Want approximately 20 cm of sediment
  - Adjust to 1 L of overlying water at lab
- Stopper both ends
- Cores collected near dam
  - ~6 m deep
  - ~0.6 m sediment depth

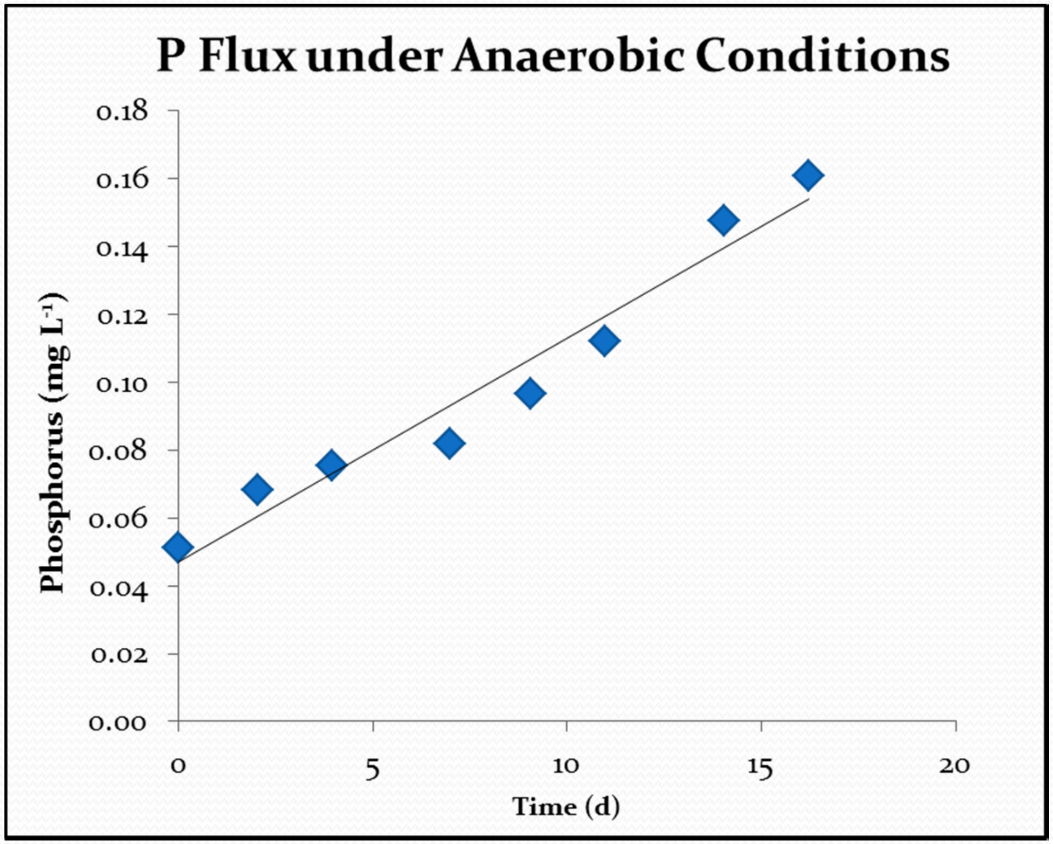


Lab Methods

- Incubate under aerobic and anaerobic conditions
    - Anaerobic conditions create redox potential necessary for accelerated P release
- Monitor P concentration for 15 days
- Determine P flux (mg-P m^{-2} d^{-1})
- Treat with various amounts of alum
- Continue incubation for another 15 days
- Monitor P concentration
- Determine P flux with alum treatment

Determining Flux

- Example plot of P vs time
- Calculate slope, divide by surface area for flux
  - The surface area of the sediment-water interface



Treatment
What Questions Need to be Answered?

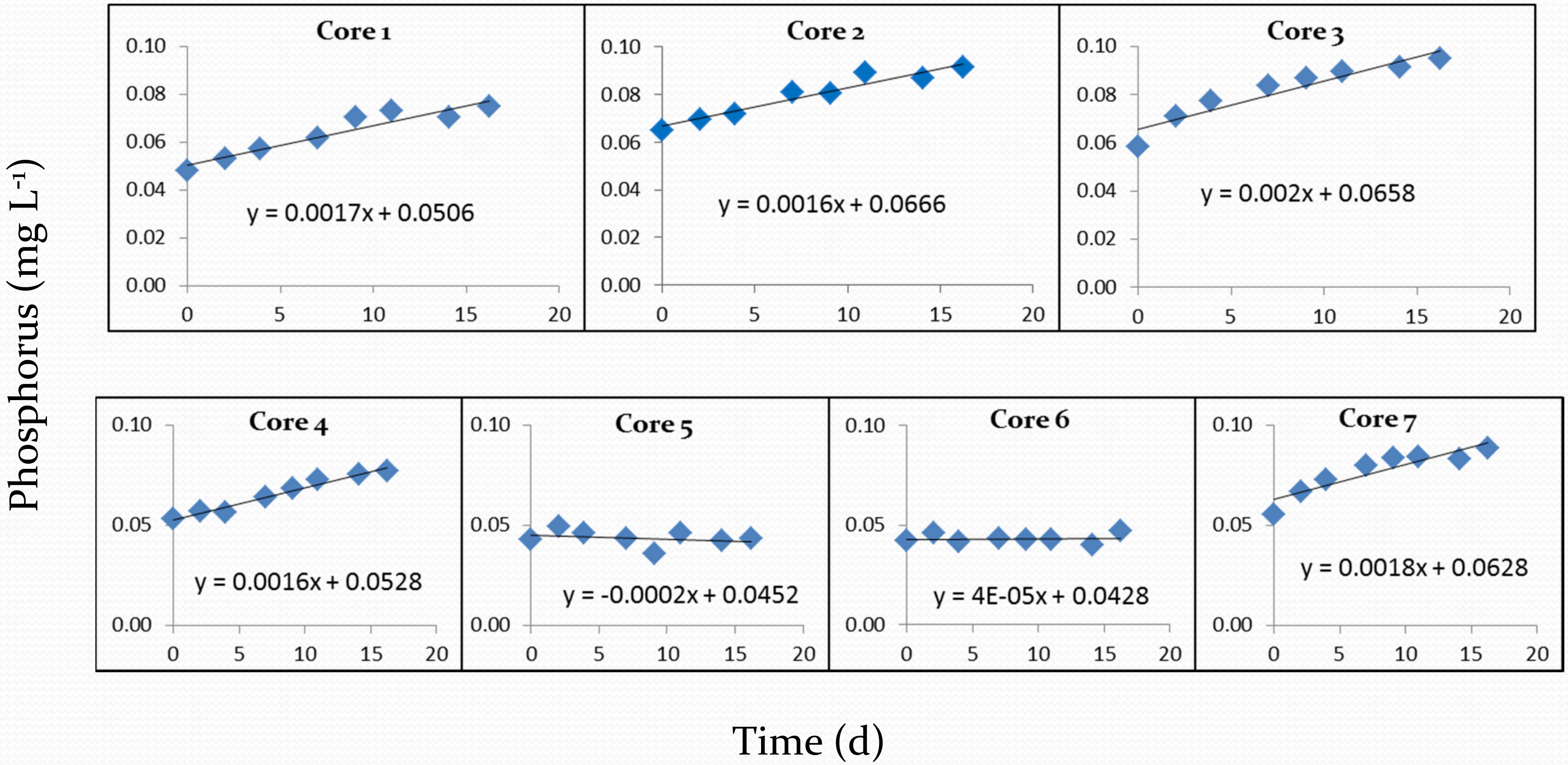
- Alum addition
  - Treatment dose determined by P flux.
  - What alum dose is the best treatment option?
    - Test a range of doses
    - Look at initial P sequestration
    - Look at long term P flux mitigation
- Important notes
  - 2 mols Al per mol alum
  - 18 mols H_2O per mol alum

Adding Alum

- When alum is added to water, it forms a floc
- As the floc settles, it removes dissolved P from the water column
- This floc forms a sediment "cap" which can continue to capture dissolved P as it is released

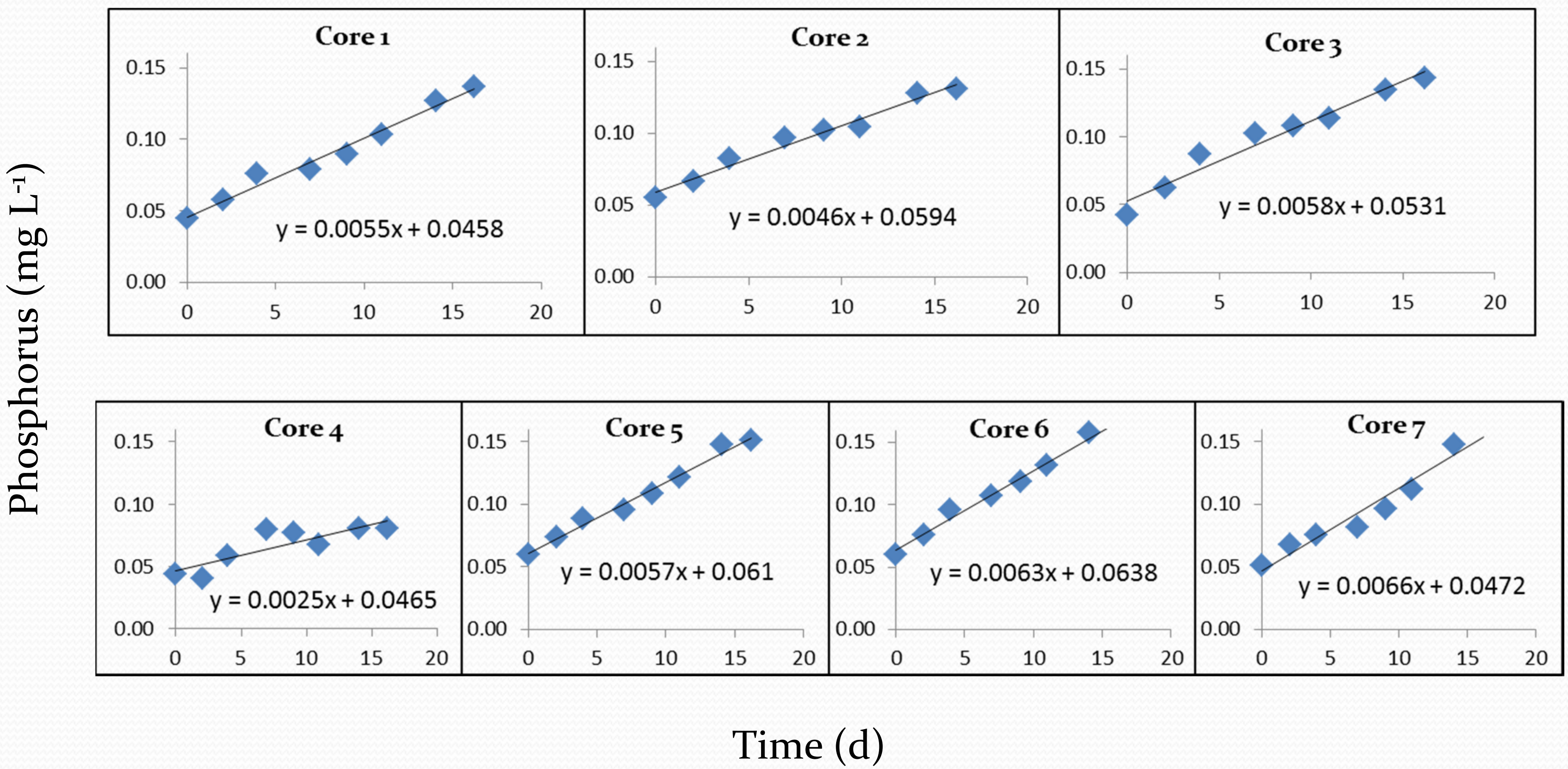
Treatments Tested	
Areal Basis (g-alum m^{-2})	Concentration (mg-Al L^{-1})
0	0
6.7	2.5
13.5	5
26.9	10
53.8	20
108	40
269	100

Results
Aerobic Flux Before Alum

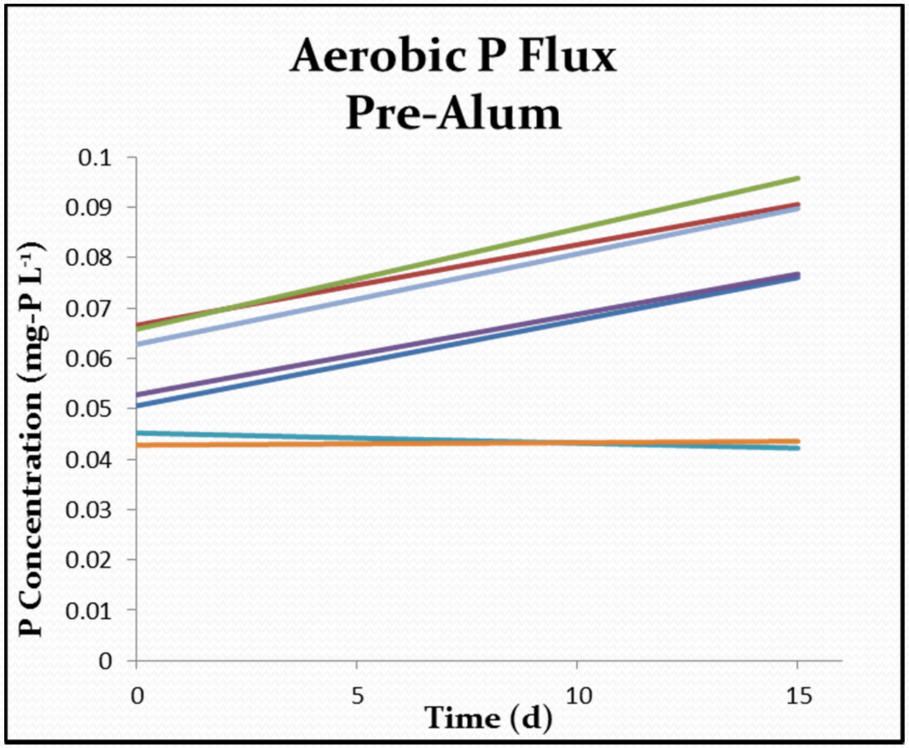


Results

Anaerobic Flux Before Alum

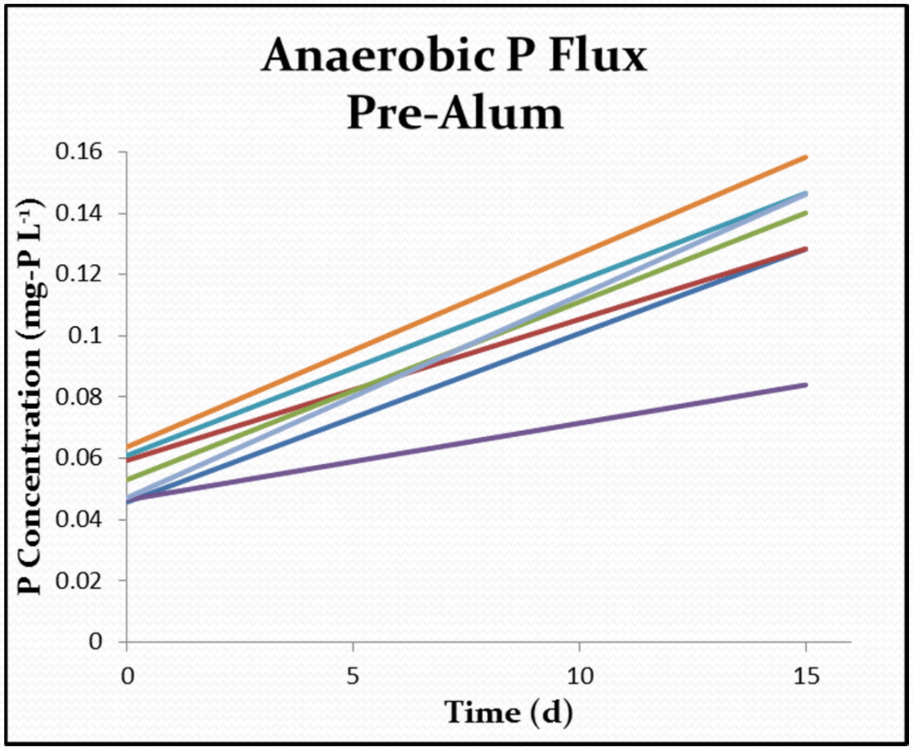


So, is P Release Still Occurring?



Core	P Flux (mg-P m^{-2} d^{-1})
1	0.37
2	0.35
3	0.44
4	0.35
5	-0.04
6	0.01
7	0.39
Average	0.27

So, is P Release Still Occurring?

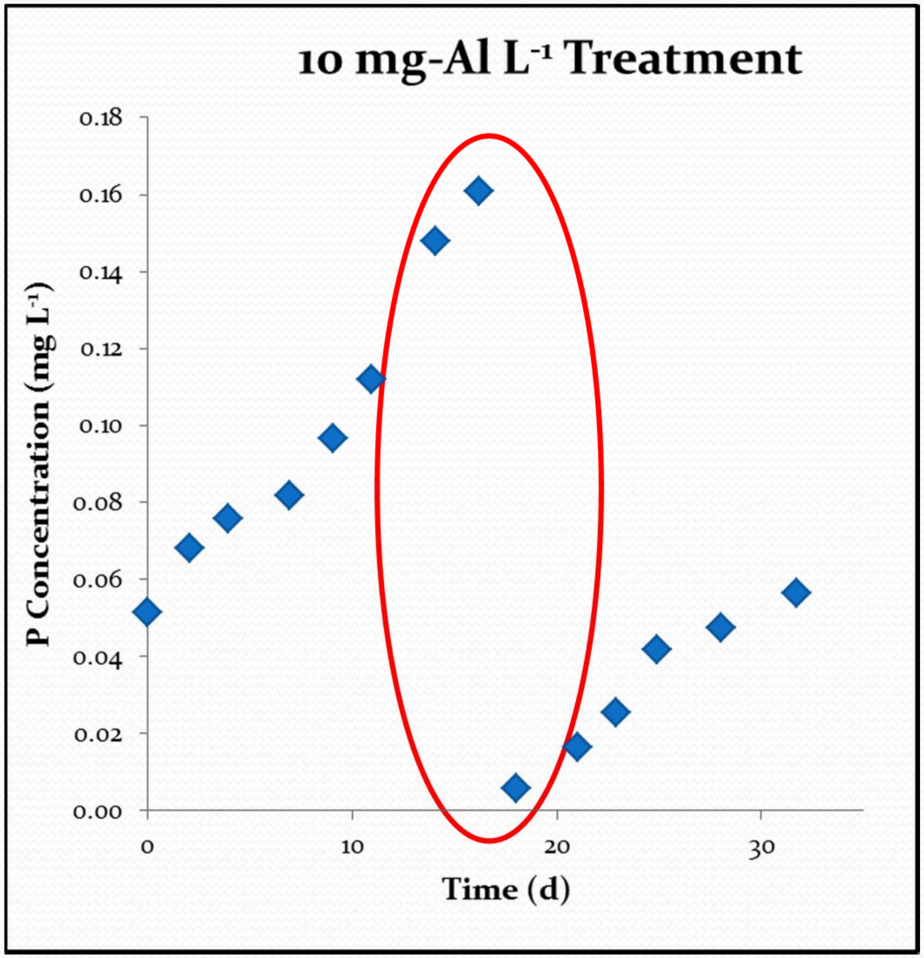


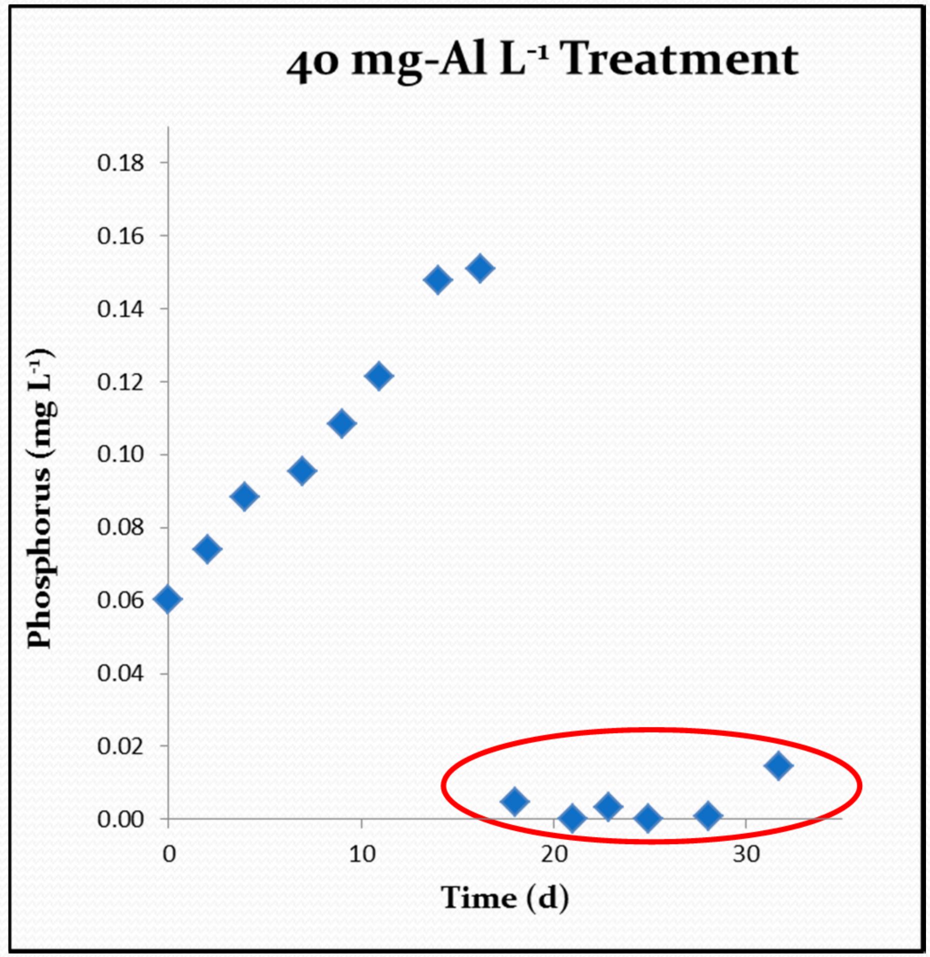
Core	P Flux (mg-P m^{-2} d^{-1})
1	1.20
2	1.00
3	1.27
4	0.56
5	1.24
6	1.37
7	1.44
Average	1.15

Is This P Release Significant?

- Average P flux under aerobic (0.27 mg m^{-2} d^{-1}) and anaerobic (1.15 mg m^{-2} d^{-1}) conditions are less now
  - Previously 3.6 mg m^{-2} d^{-1} under aerobic conditions
  - Previously 15.5 mg m^{-2} d^{-1} under anaerobic conditions
  - Haggard and Soerens (2006)
- But, even under aerobic conditions, P release occurs until equilibrium interactions take effect around 0.10 mg-P L^{-1}
- If water in the Illinois River enters Lake Frances at 0.037 mg-P L^{-1}, P release will occur!

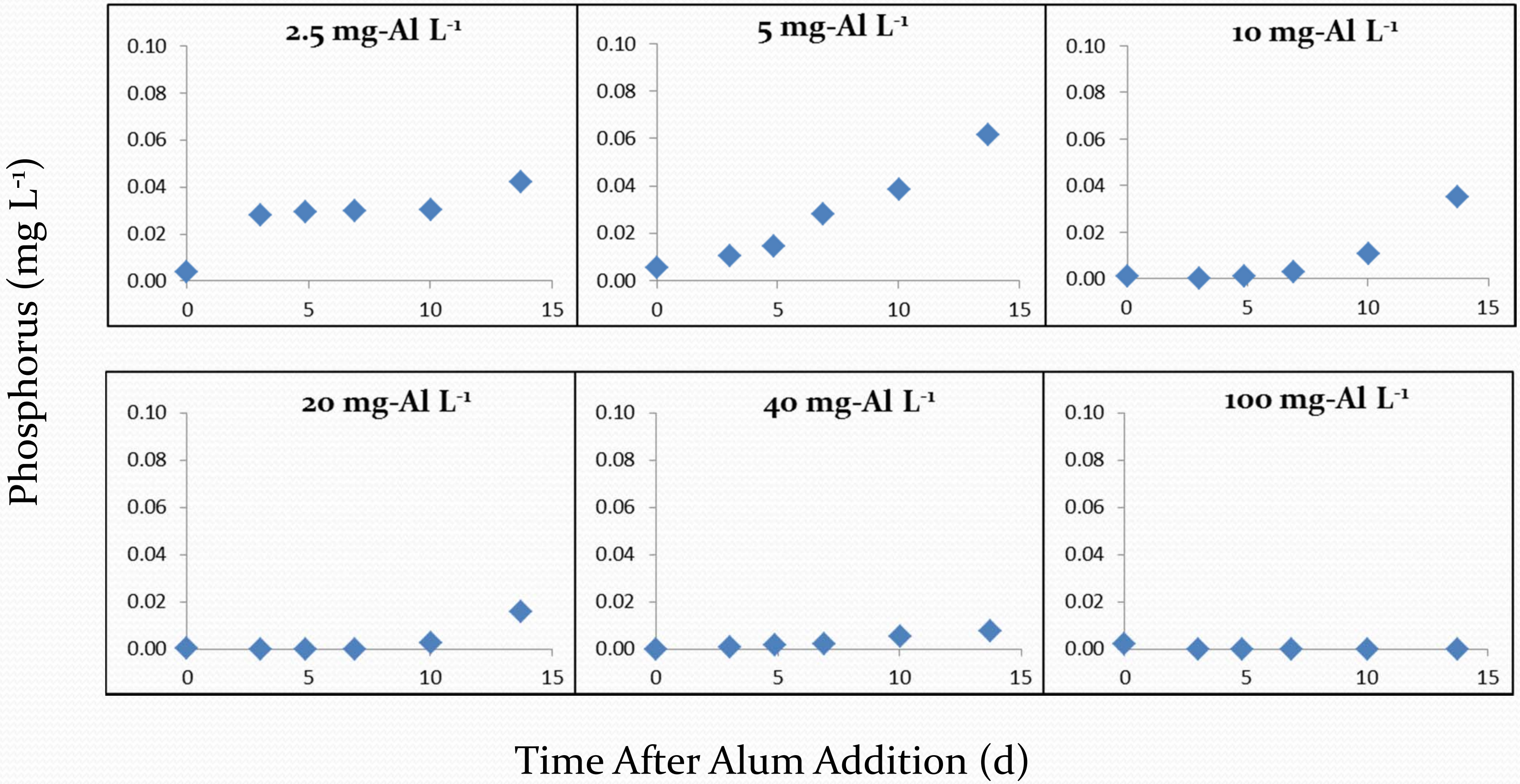
Alum Addition at a Glance



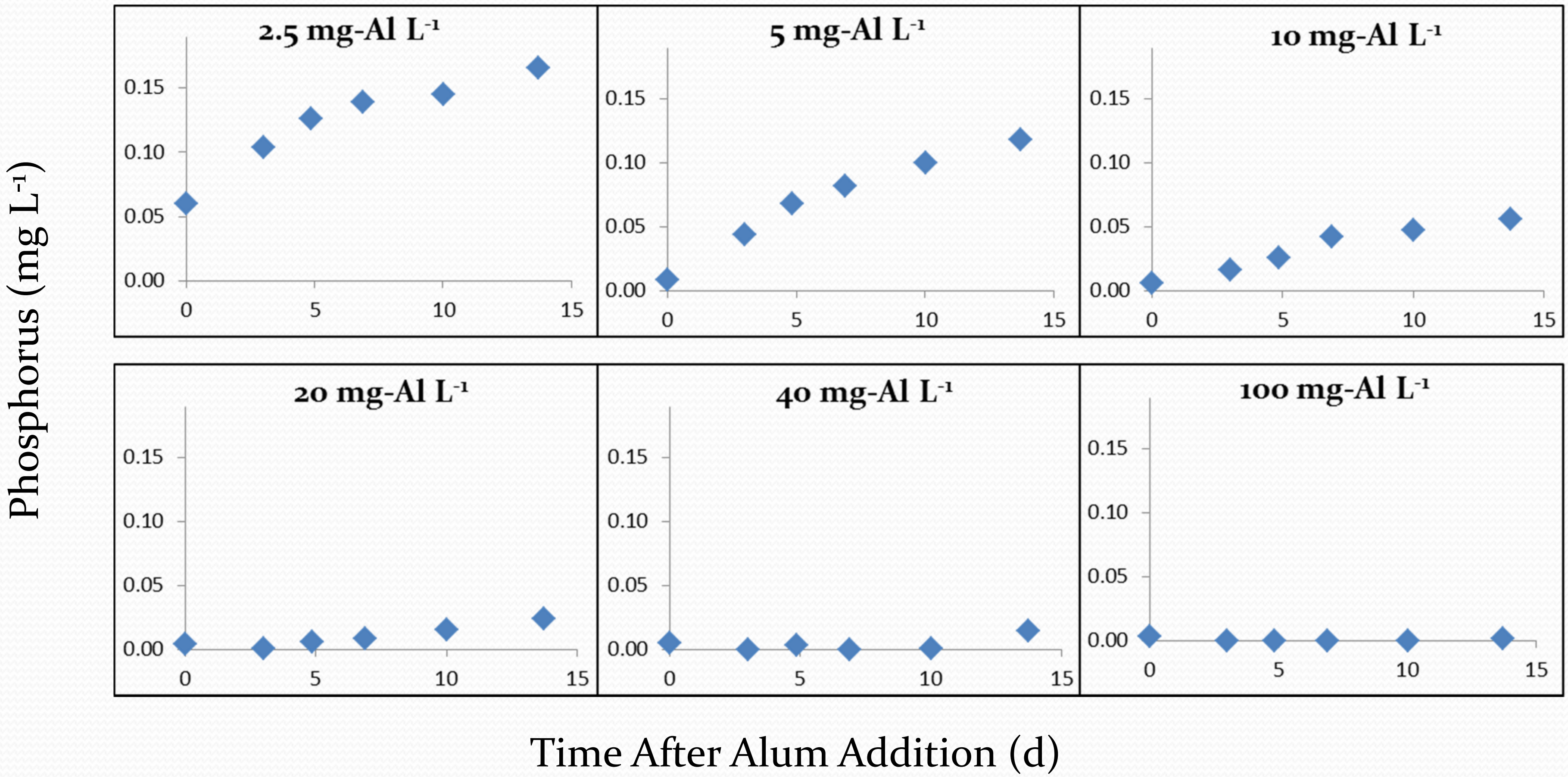


Results

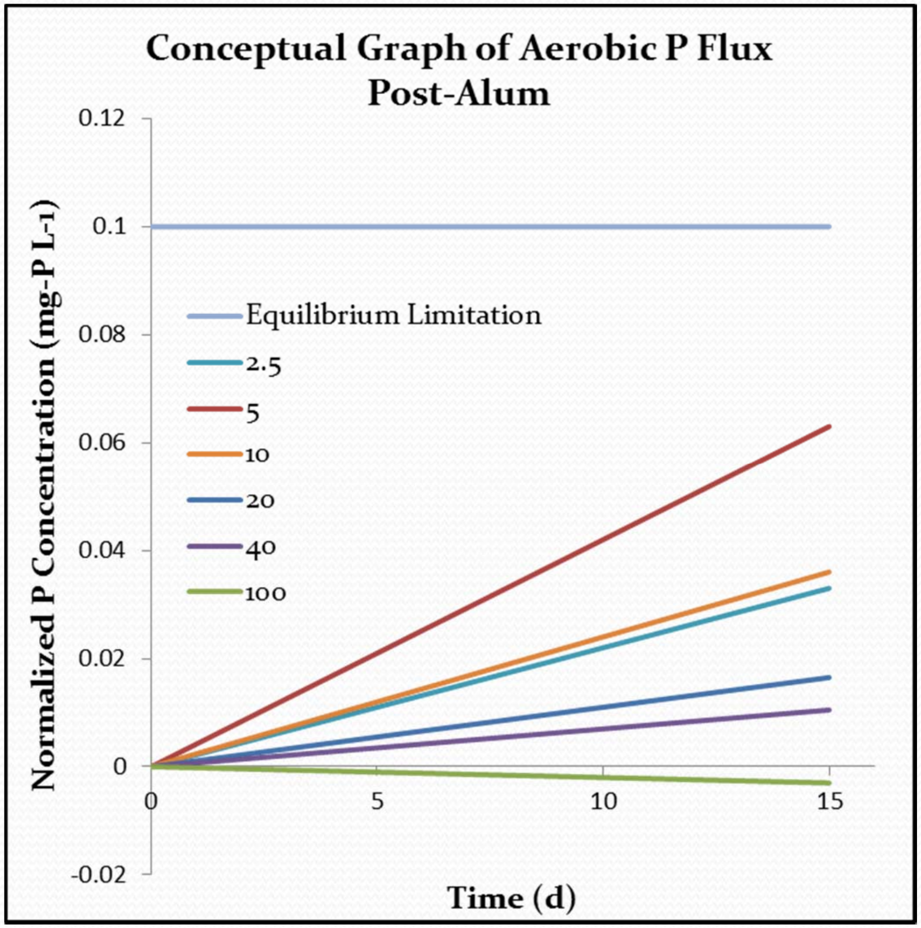
Aerobic Flux with Alum



Results
Anaerobic Flux with Alum

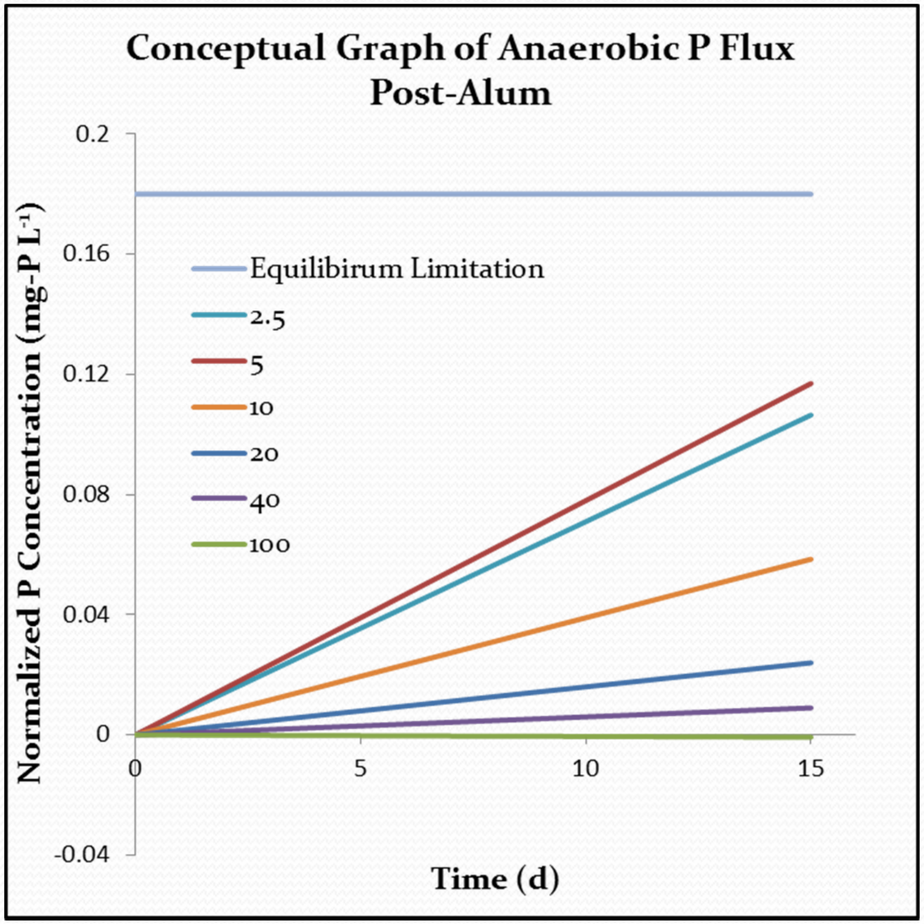


So, Can We Do Something About It?



Treatment (mg-Al L^{-1})	P Flux (mg-P m^{-2} d^{-1})
2.5	0.48
5	0.92
10	0.52
20	0.24
40	0.15
100	-0.04

So, Can We Do Something About It?

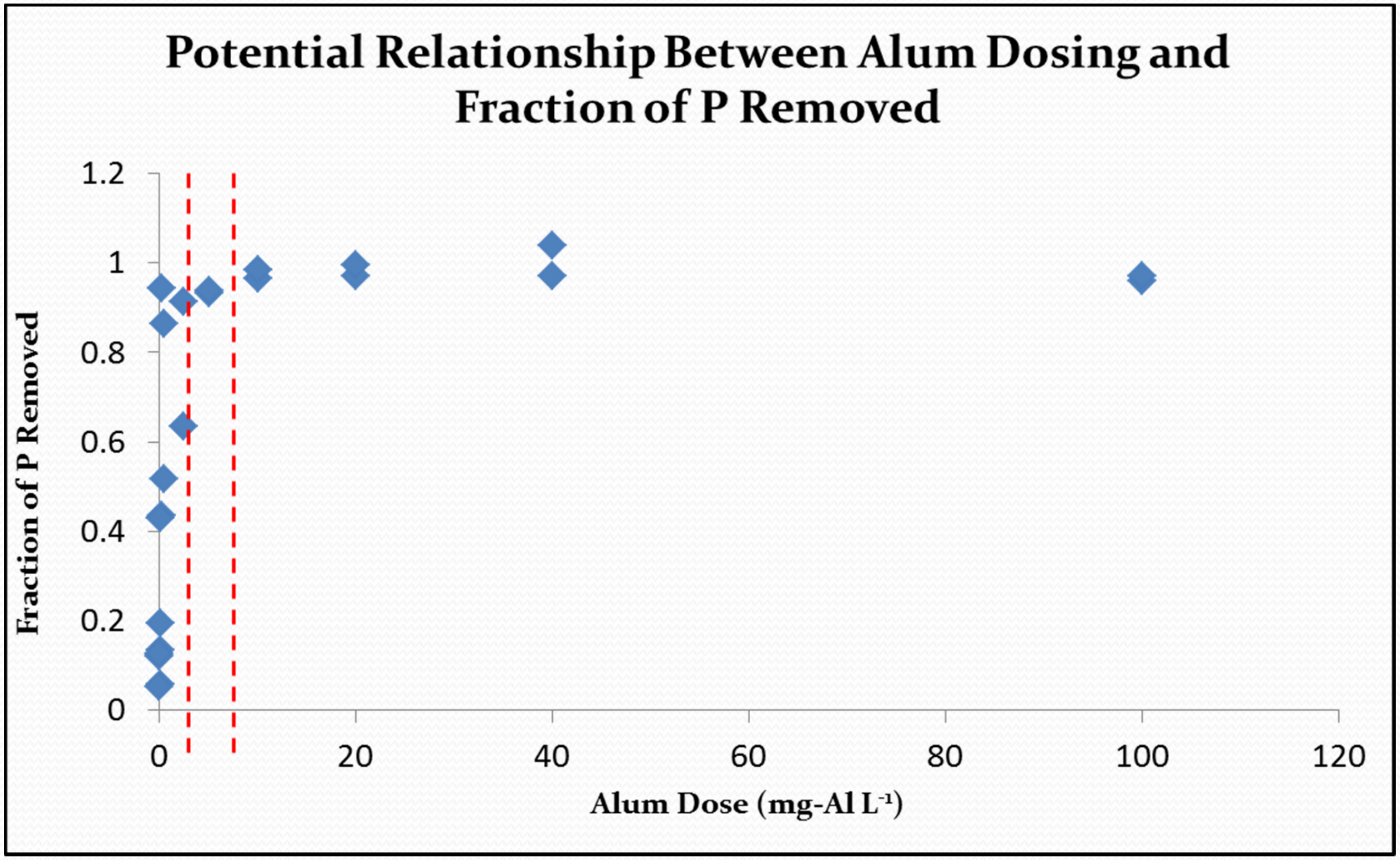


Treatment (mg-Al L^{-1})	P Flux (mg-P m^{-2} d^{-1})
2.5	1.55
5	1.70
10	0.85
20	0.35
40	0.13
100	-0.01

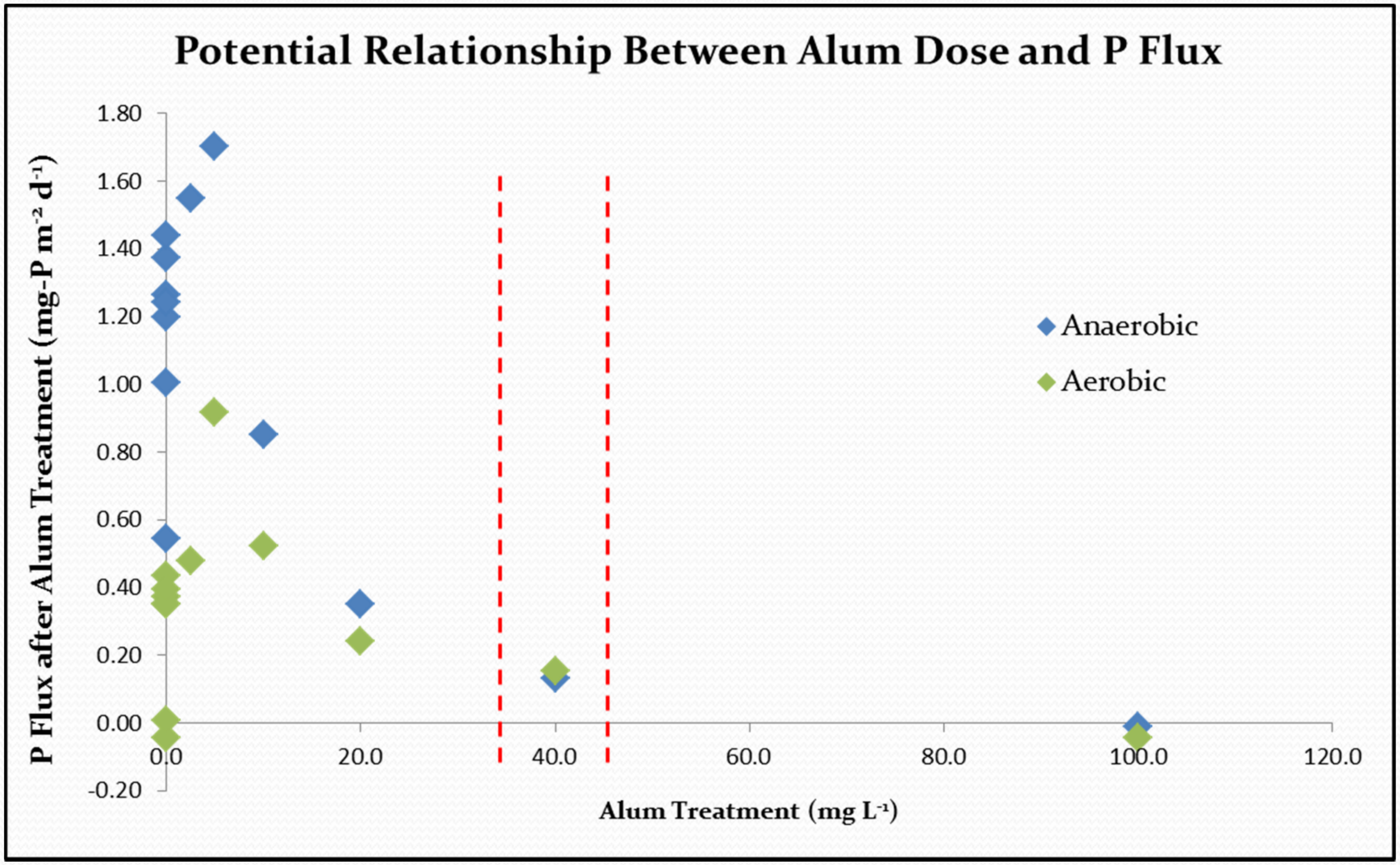
What to do with Results?

- There are 2 measures of success, depending on your desired effect:
  - How much dissolved P was removed from the water column?
  - Was P flux mitigated?

Results
P Removal by Alum



Results
P Flux Mitigation by Alum



So, What Exactly Should We Do?

- For a one-time treatment of P in the water column of Lake Frances: dose Alum at 2.5 – 5 mg-Al L^{-1}
- For long term sediment treatment at Lake Frances: dose Alum at approximately 108 g-alum m^{-2} (40 mg-Al L^{-1})

Did We Answer All of Our Questions?

- Is P release still occurring?
  - Yes
- Is the P contribution significant?
  - Yes
- Can we do something about it?
  - Yes
- If we want to do something about it, what exactly should we do?
  - 2.5 – 5 mg-Al L^{-1} for treatment of the water column
  - Around 108 g-alum m^{-2} (40 mg-Al L^{-1}) for long term P flux mitigation

Acknowledgements

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Questions?