Nitrogen, Phosphorus, and Suspended Sediment fluxes from the Susquehanna River to the Bay in Tropical Storm Lee, 2011 – results and implications

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Photo credit:
NASA MODIS,
Sept. 13, 2011

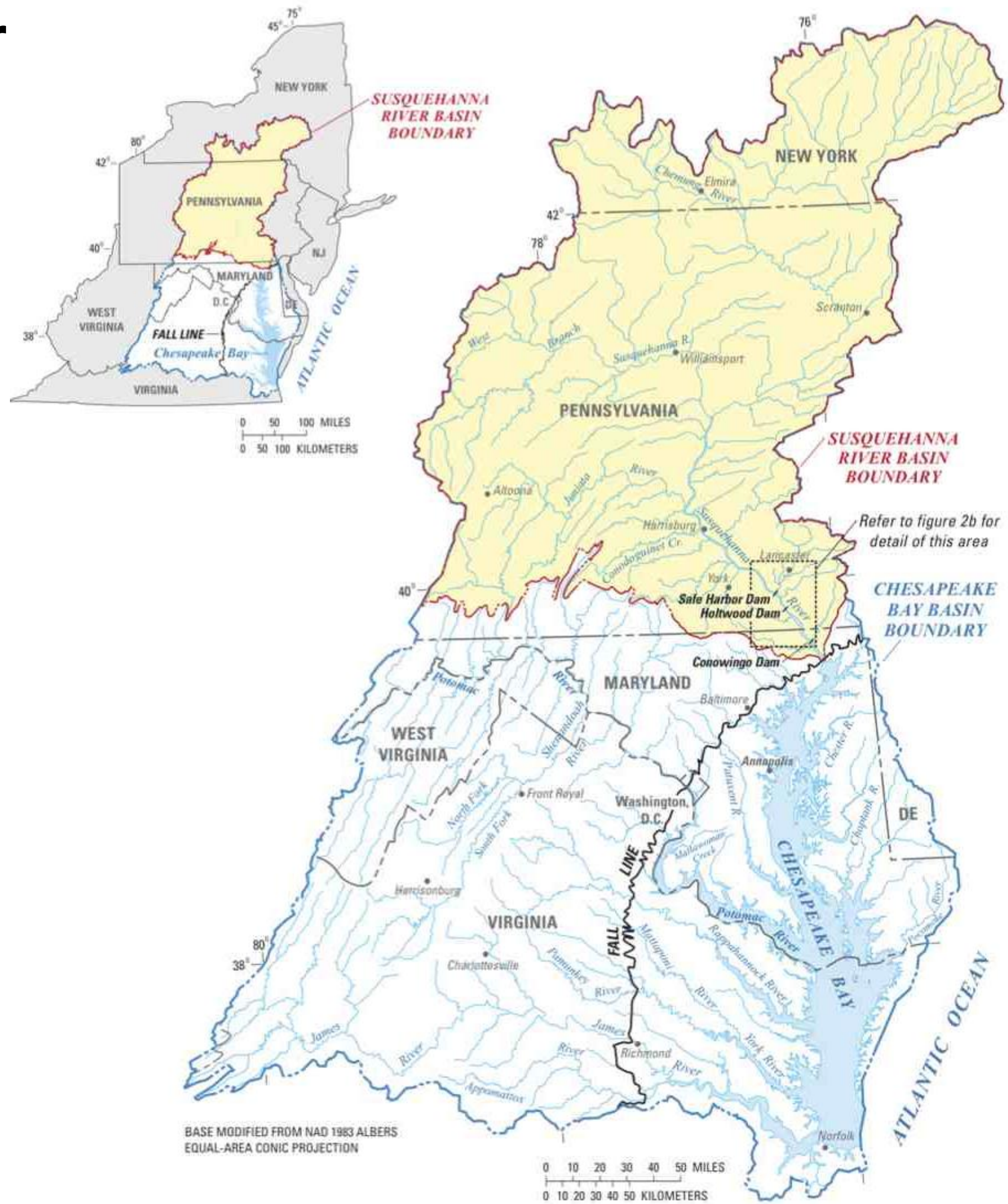
Susquehanna River As a % of Chesapeake Bay inputs

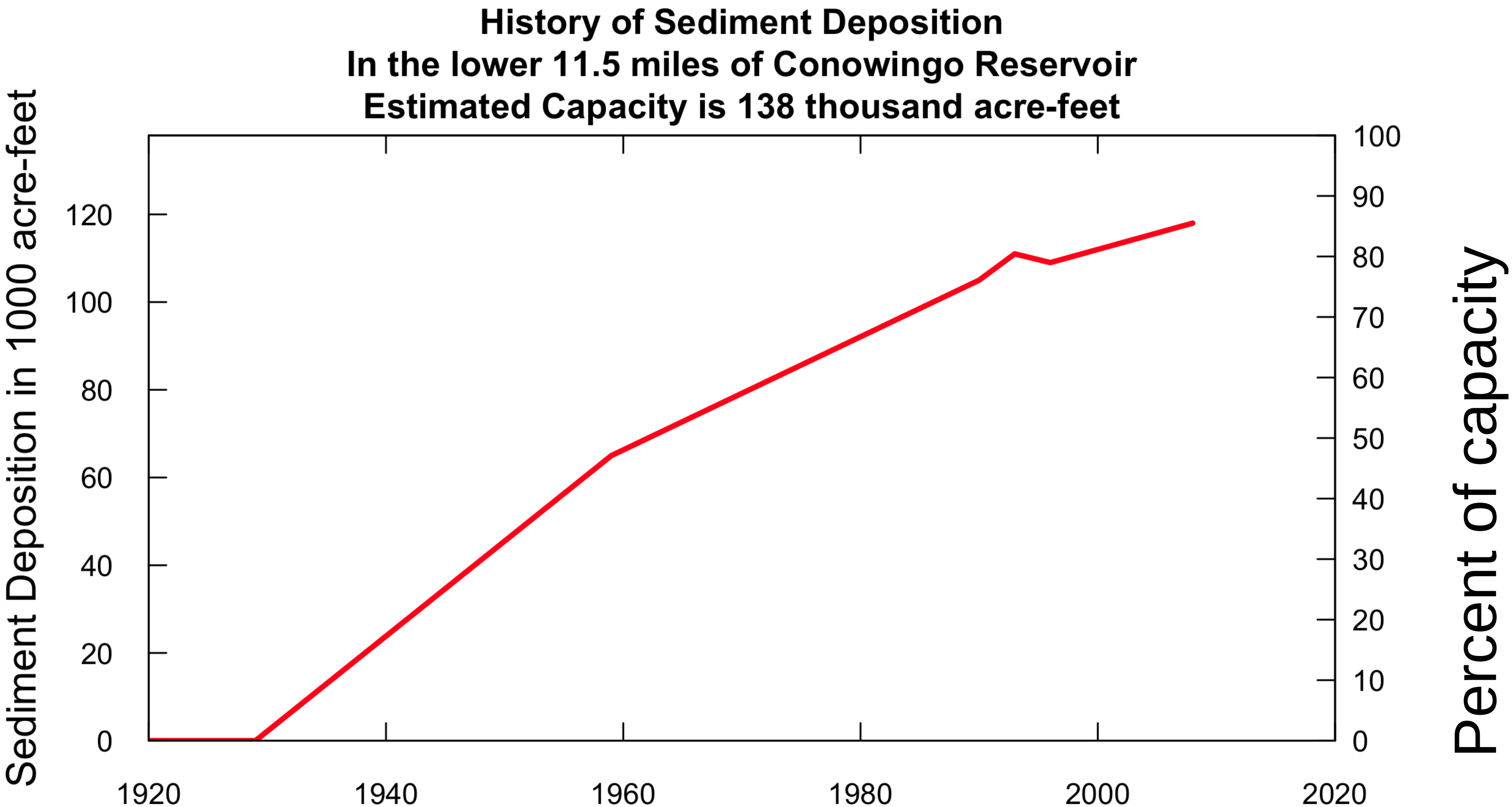
47% of freshwater

41% of nitrogen

25% of phosphorus

27% of sediment





Source: Langland, 2009
http://pubs.usgs.gov/sir/2009/5110/

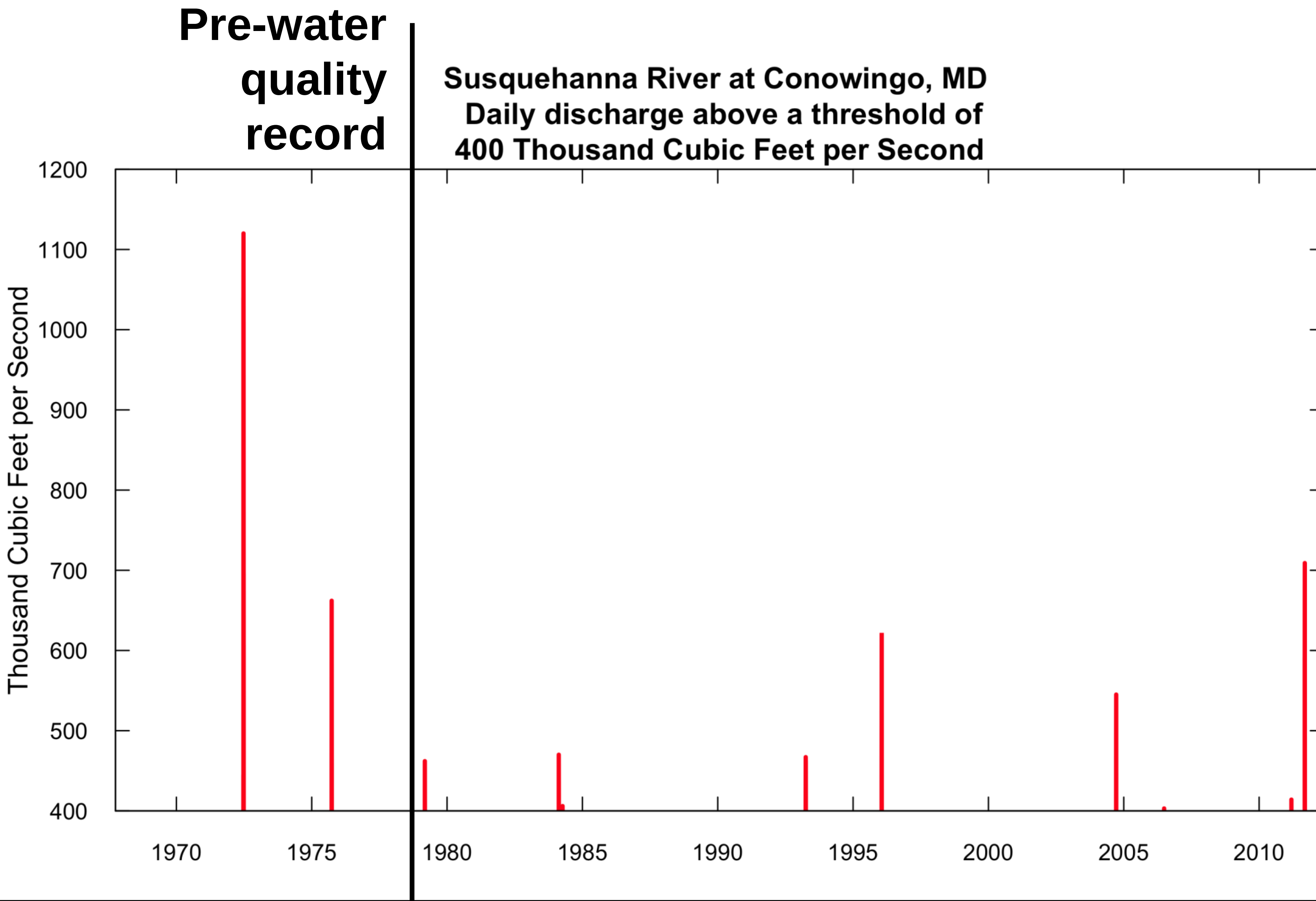
Predictions by Langland and Hainly (1997)

Reservoirs would be “full” in 17 to 20 years

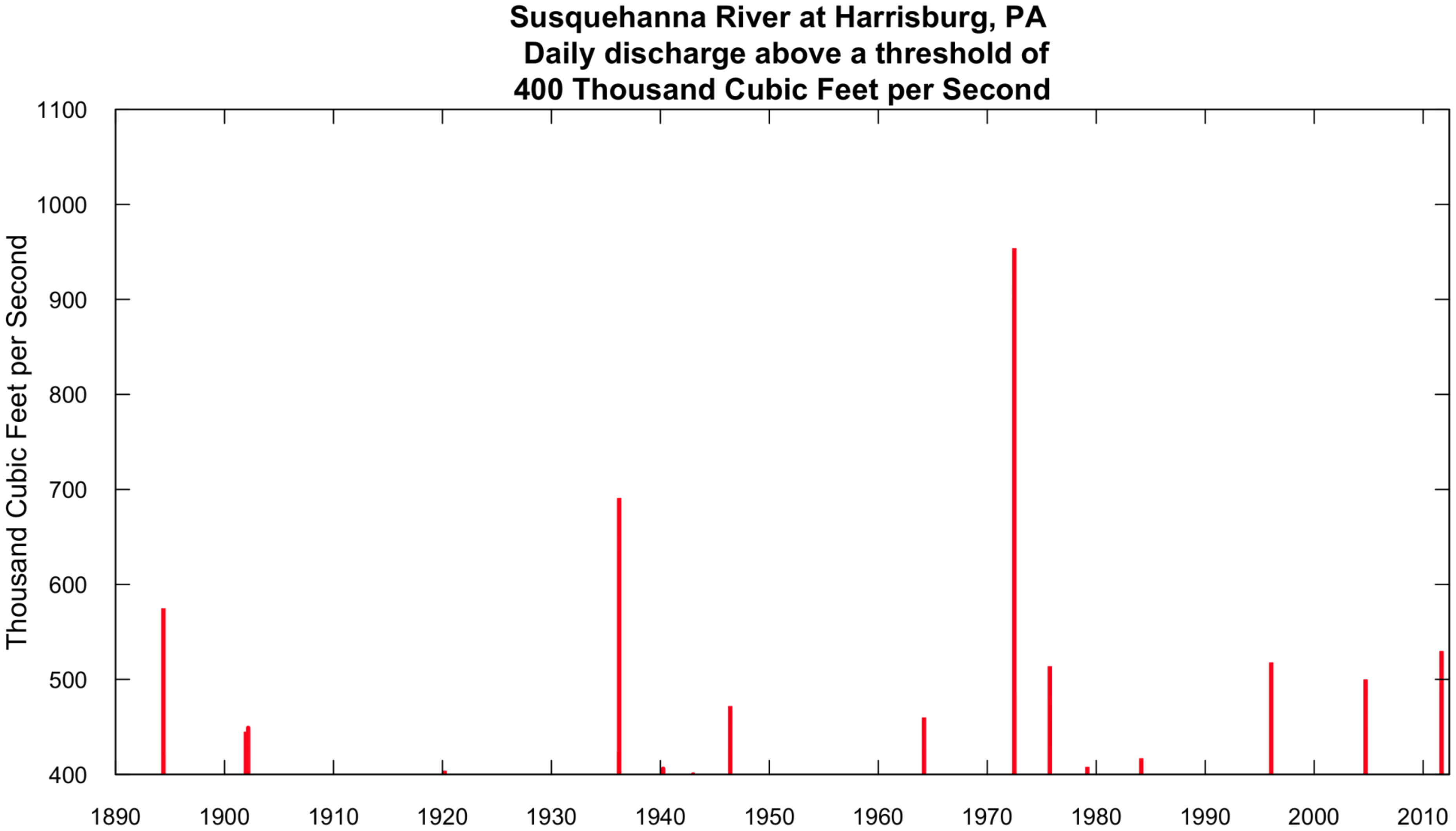
And all other things being equal

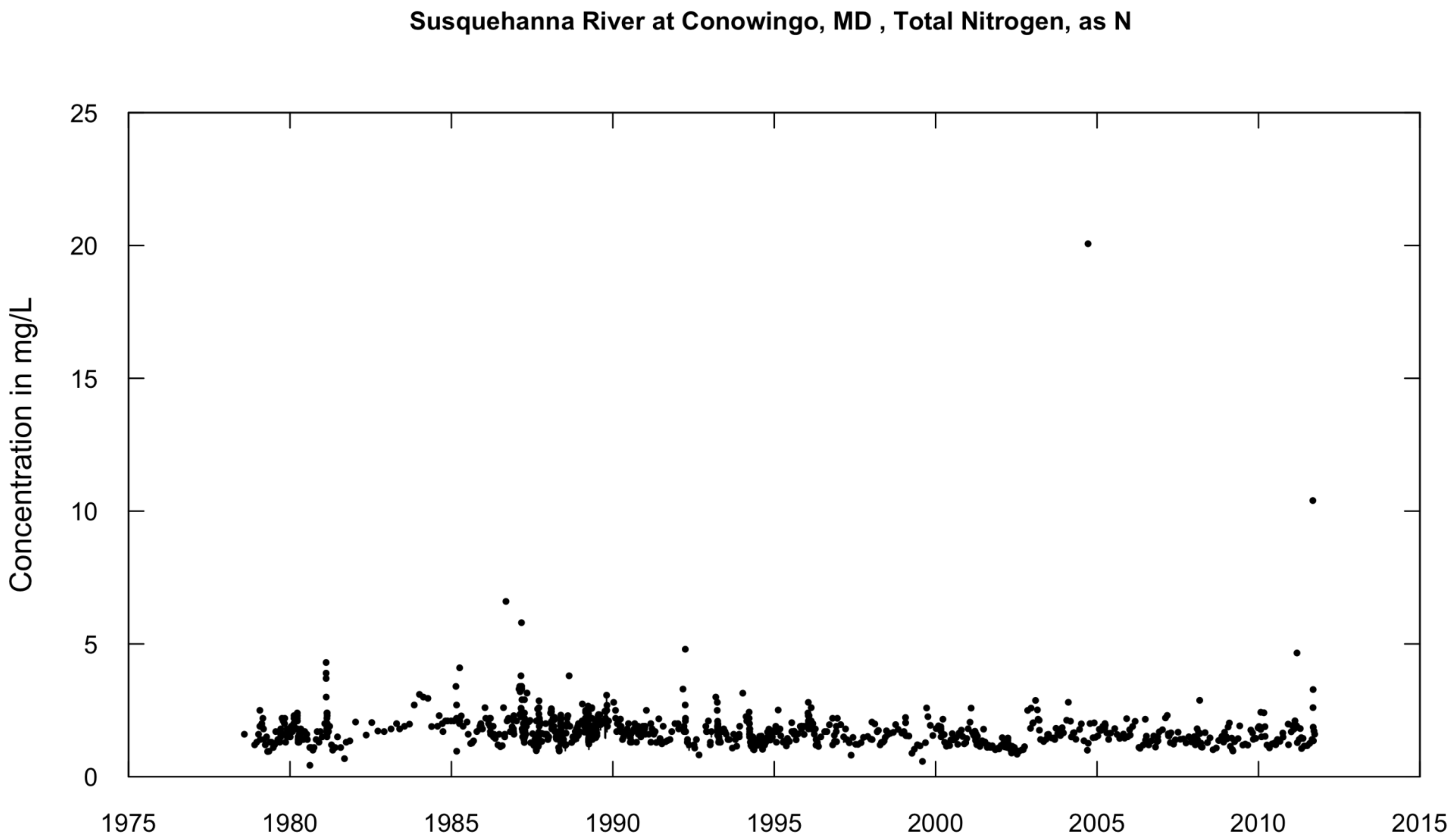
TN flux would increase 2%
TP flux would increase 70%
SS flux would increase 250%

How unusual was the Tropical Storm Lee event?



What if we look at the longer record at Harrisburg?

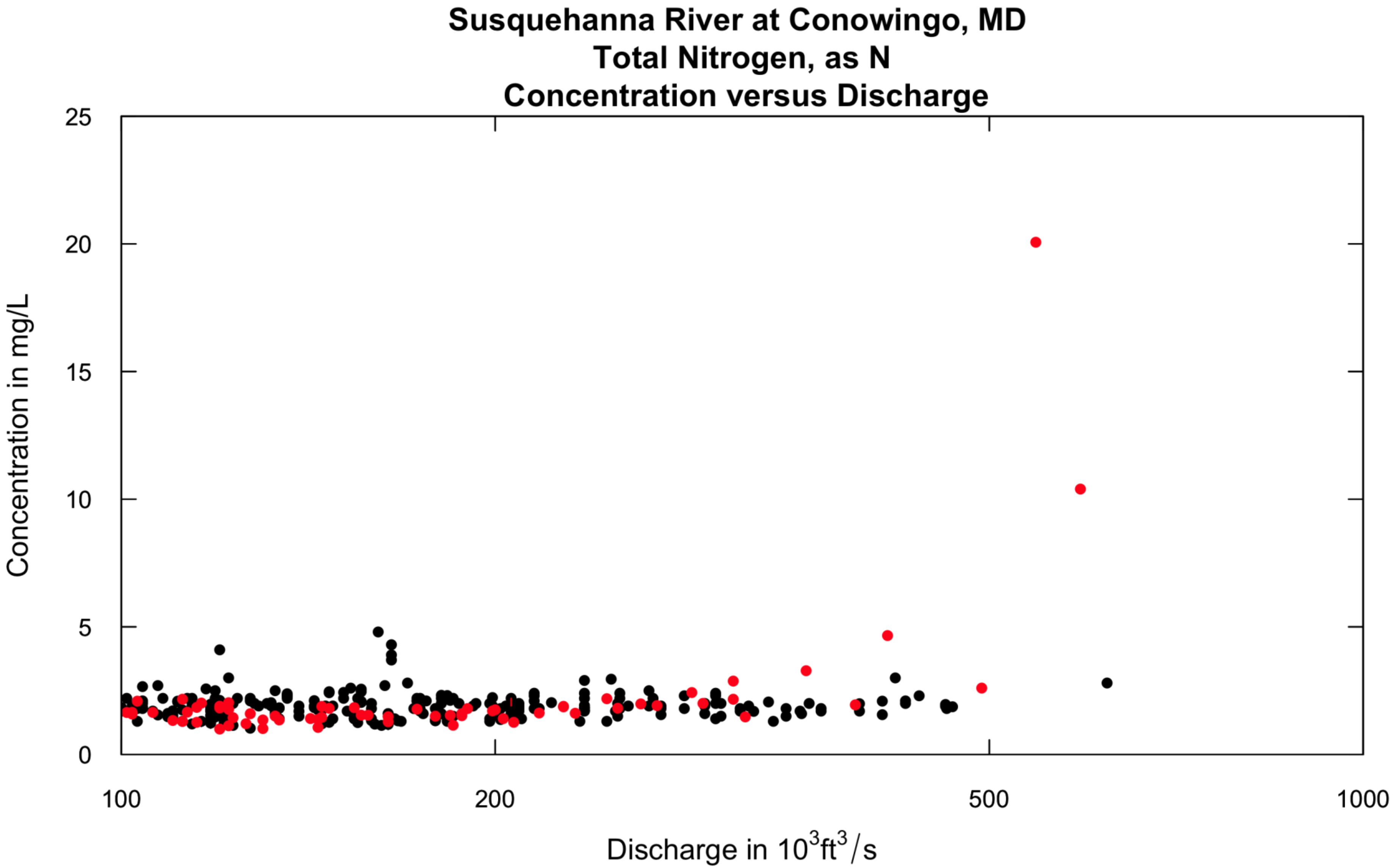




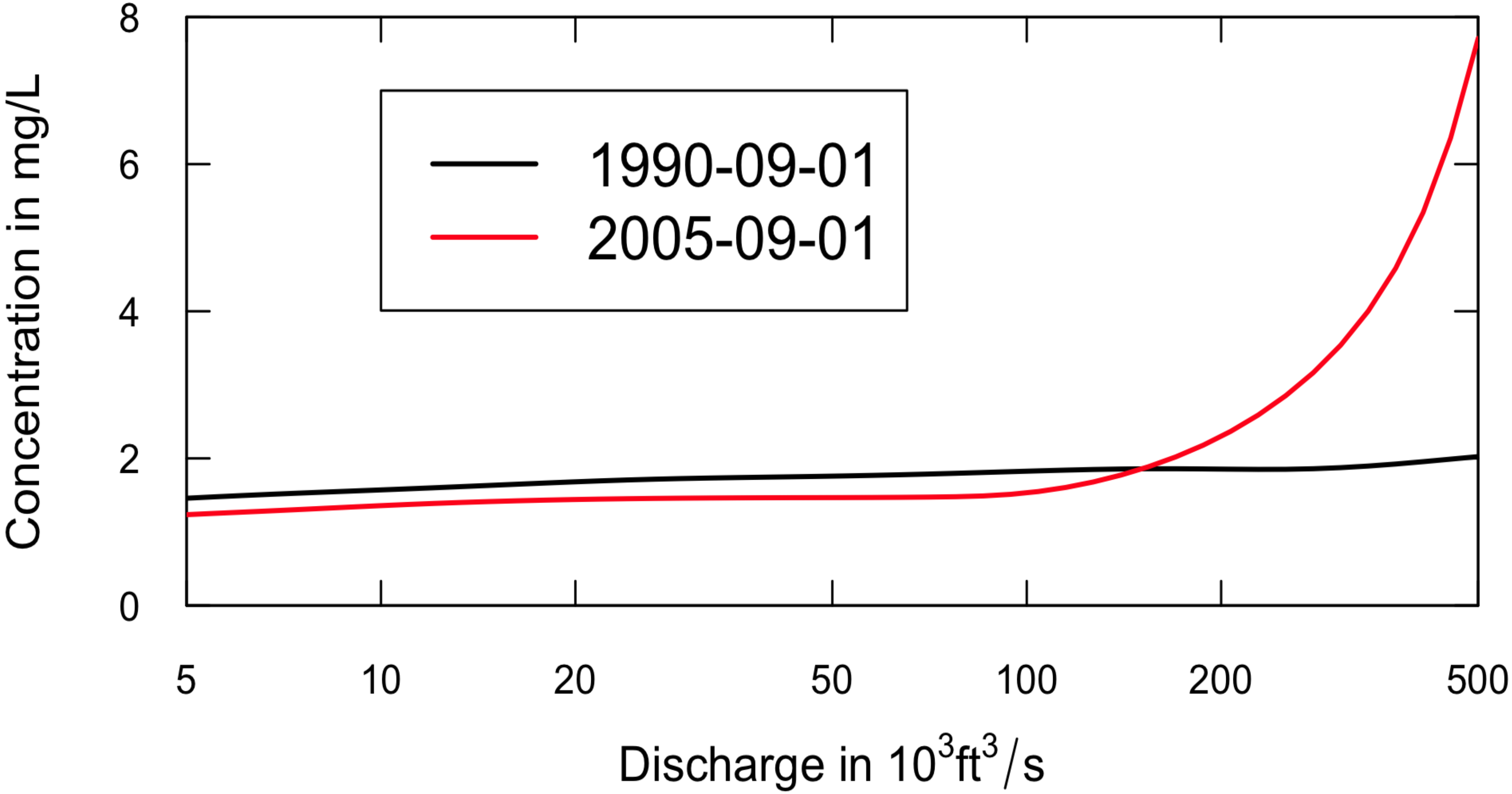
Susquehanna River at Conowingo, MD , Total Nitrogen, as N
Concentration in mg/L
0
5
10
15
20
25
1975
1980
1985
1990
1995
2000
2005
2010
2015

USGS

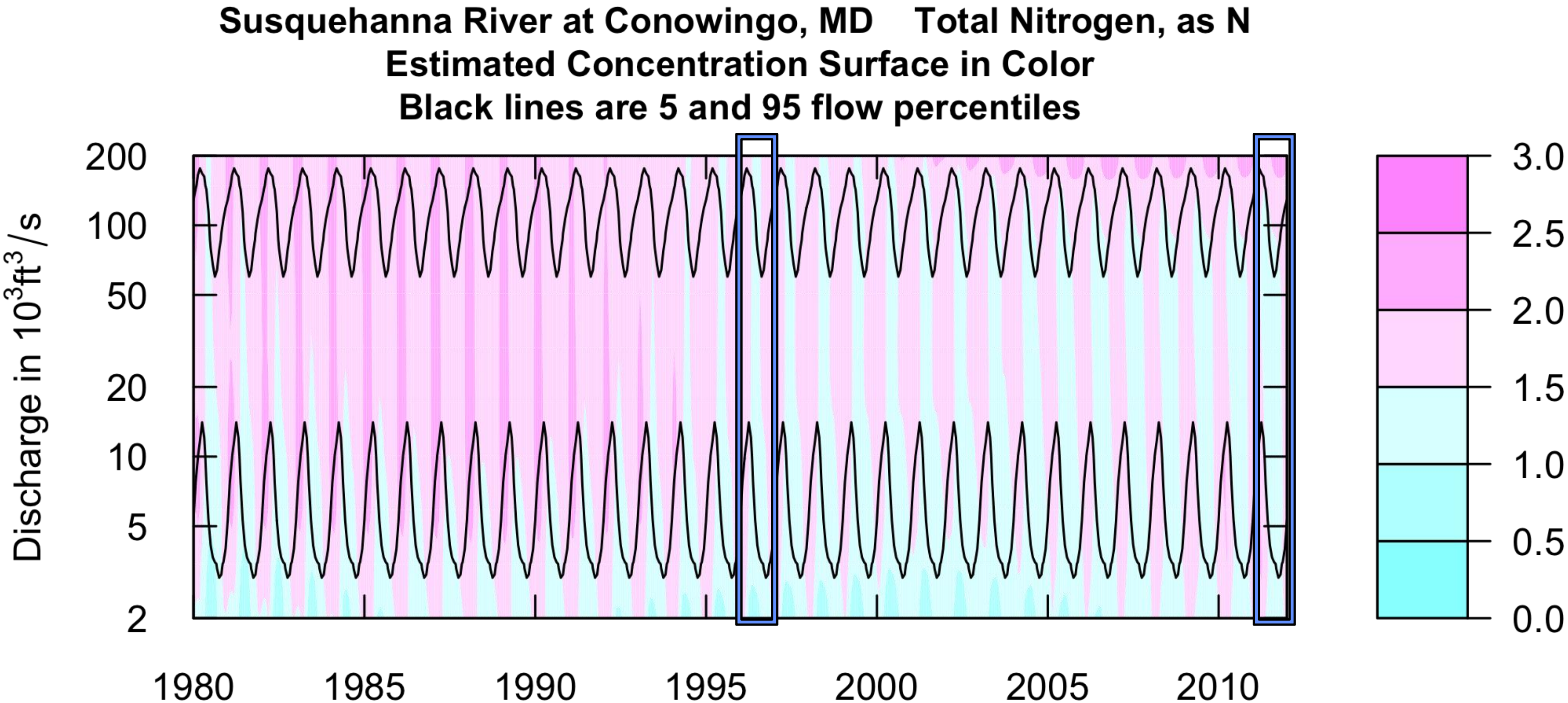
Black dots are pre-2000, Red are since 2000



Use the WRTDS (Weighted Regressions on Time, Discharge and Season) method to describe the evolving behavior of Total Nitrogen

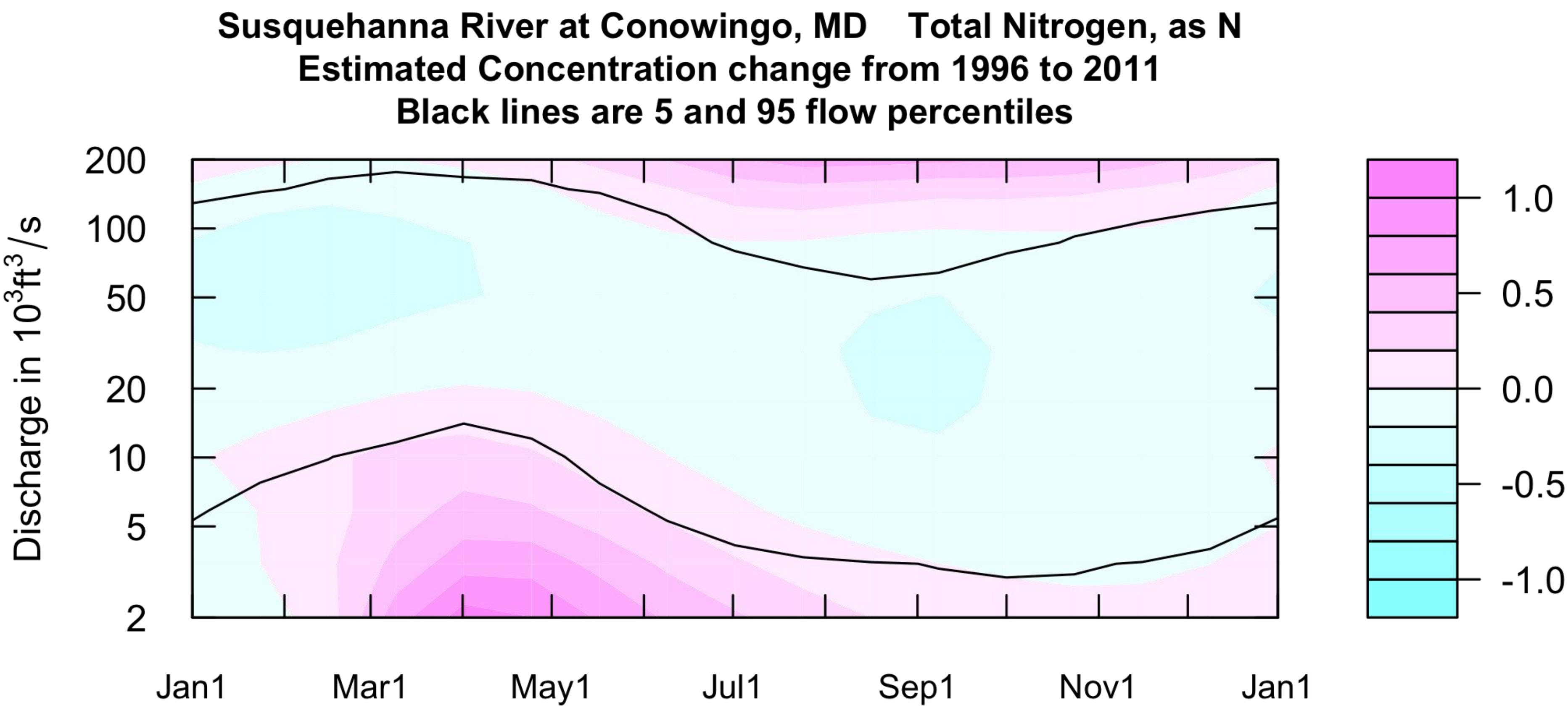


Evolving behavior of TN



Compute the difference between two years

- Decreased concentrations at almost all flows and seasons
- Biggest decrease between about 40,000 and 100,000 cfs
- Biggest decreases in Winter and early Summer
- Slight indication of increase at very low flow in Spring
- and at very high flow in Tropical Storm season



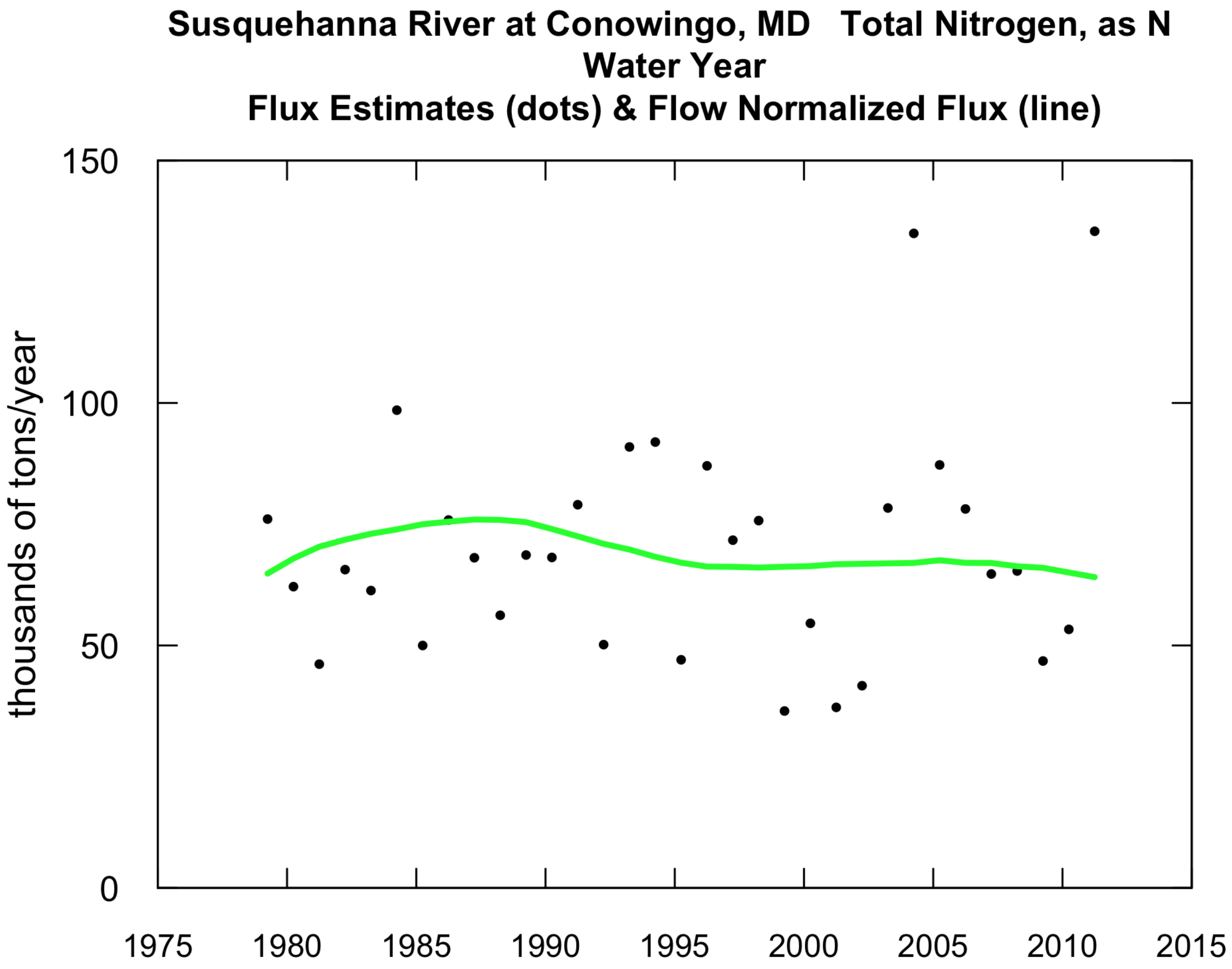
Total Nitrogen flux estimates using WRTDS

- T.S. Lee flux about 42,000 tons
- The 2011 water year 135,000 tons
- The past decade average was 79,000 tons/yr
- The past 34 year average was 71,000 tons/yr

Annual Flux
In 10^3 tons/yr

2011 = 135
2010 = 50
2004 = 135

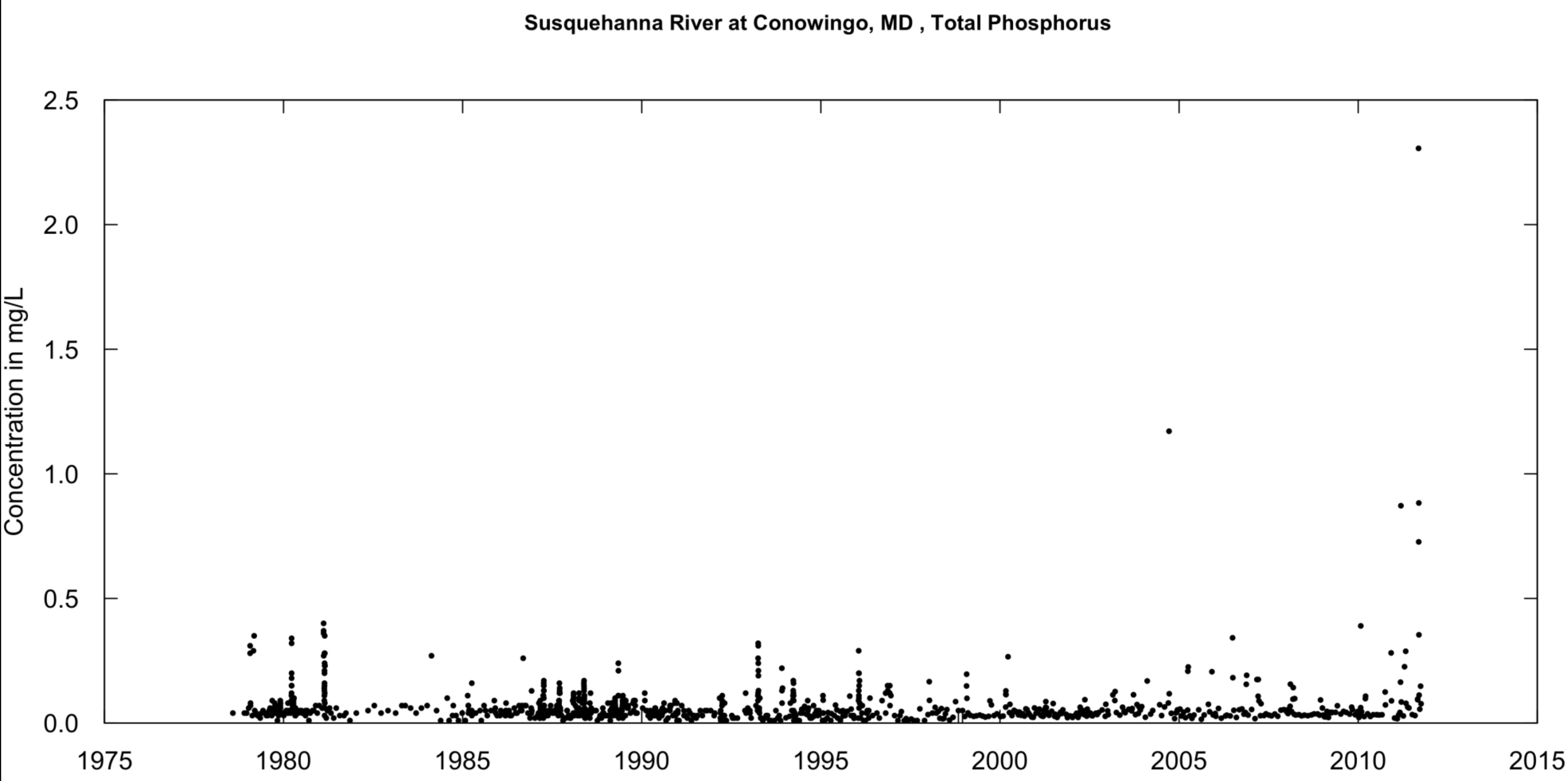
Flow
Normalized
Flux Change
Since 1996
-3.2%



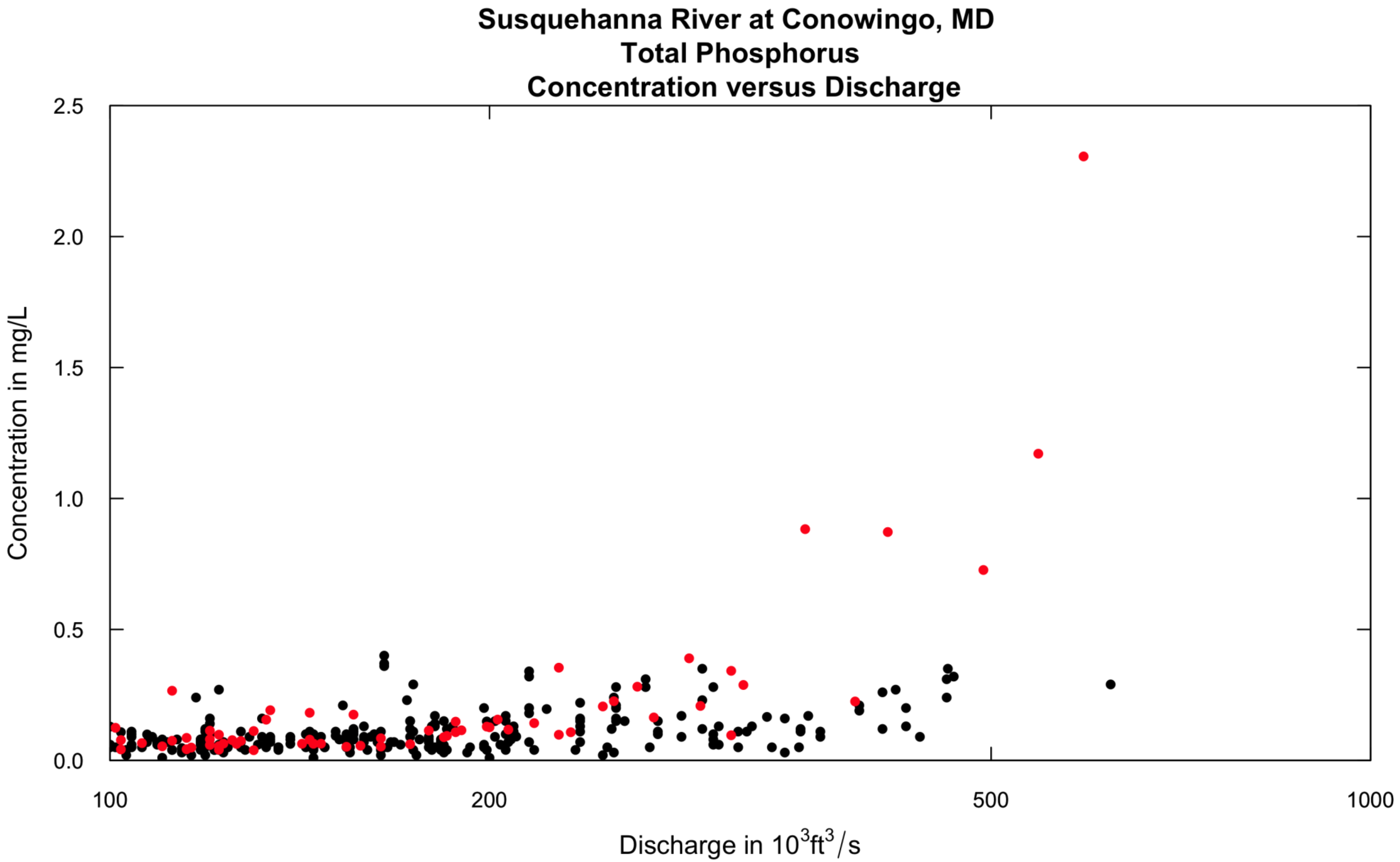
Take home messages: TN

- Total Nitrogen concentrations are continuing to decline at most discharges.
- But at very high flows they are showing some increase.
- Flow-normalized flux continues to fall. Down about 16% since its high in 1987.
- Year to year variability in actual TN flux is increasing (standard deviation about double for 2002-2011 vs. 1978-2001).

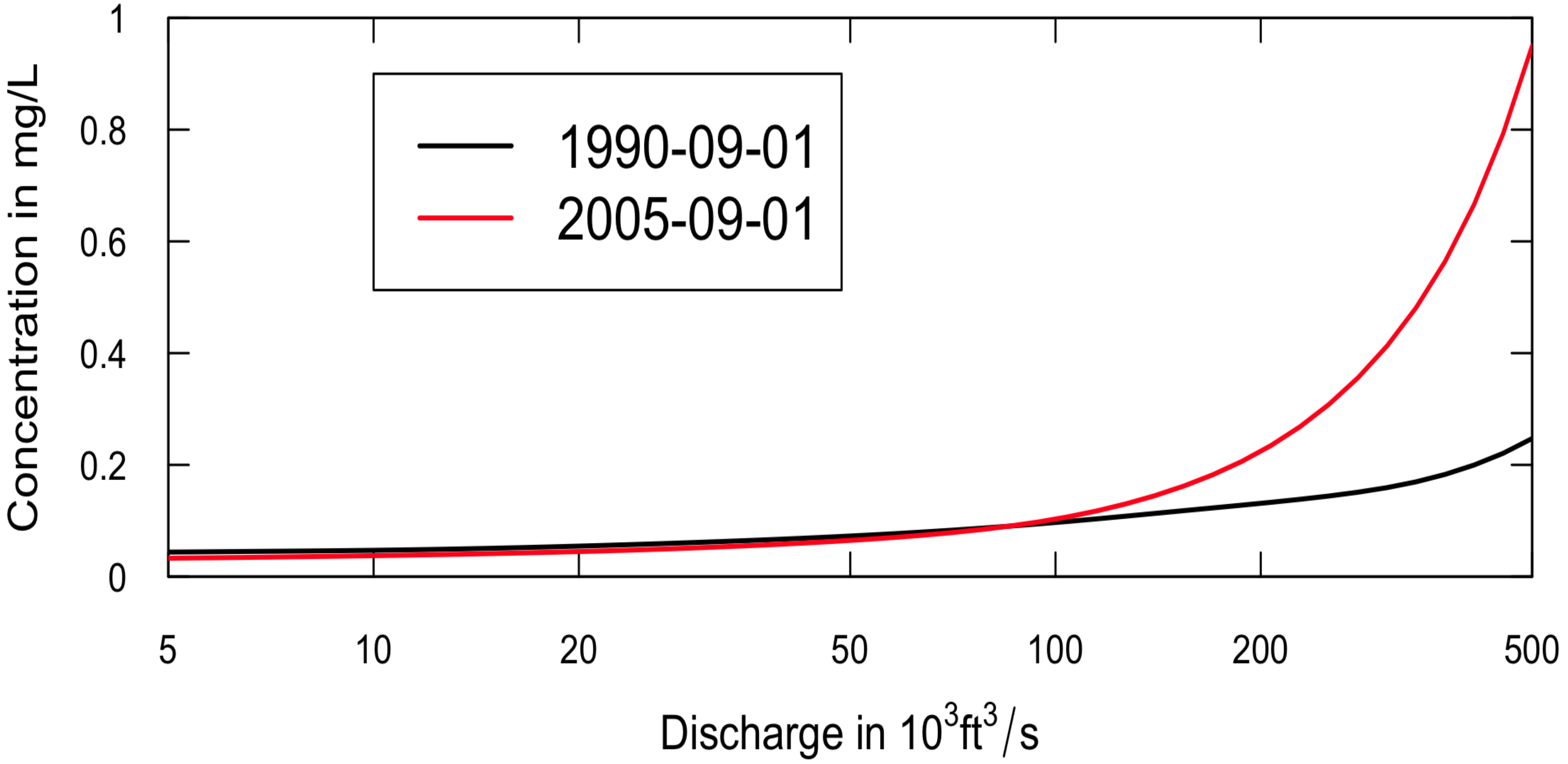
Let's look at the full history of Total Phosphorus data collected from the USGS RIM station at Conowingo Dam



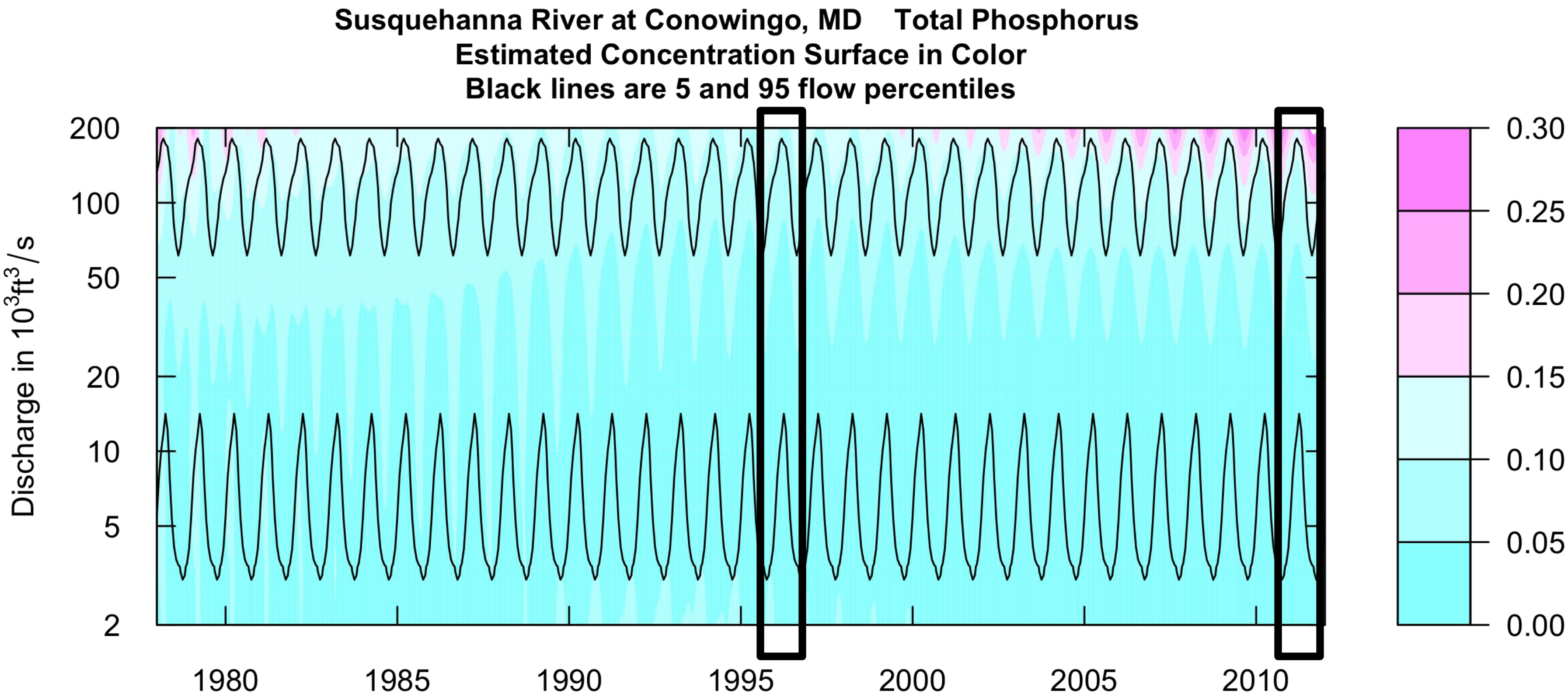
Black dots are pre-2000, Red are since 2000



Use the WRTDS model to describe the evolving behavior of Total Phosphorus

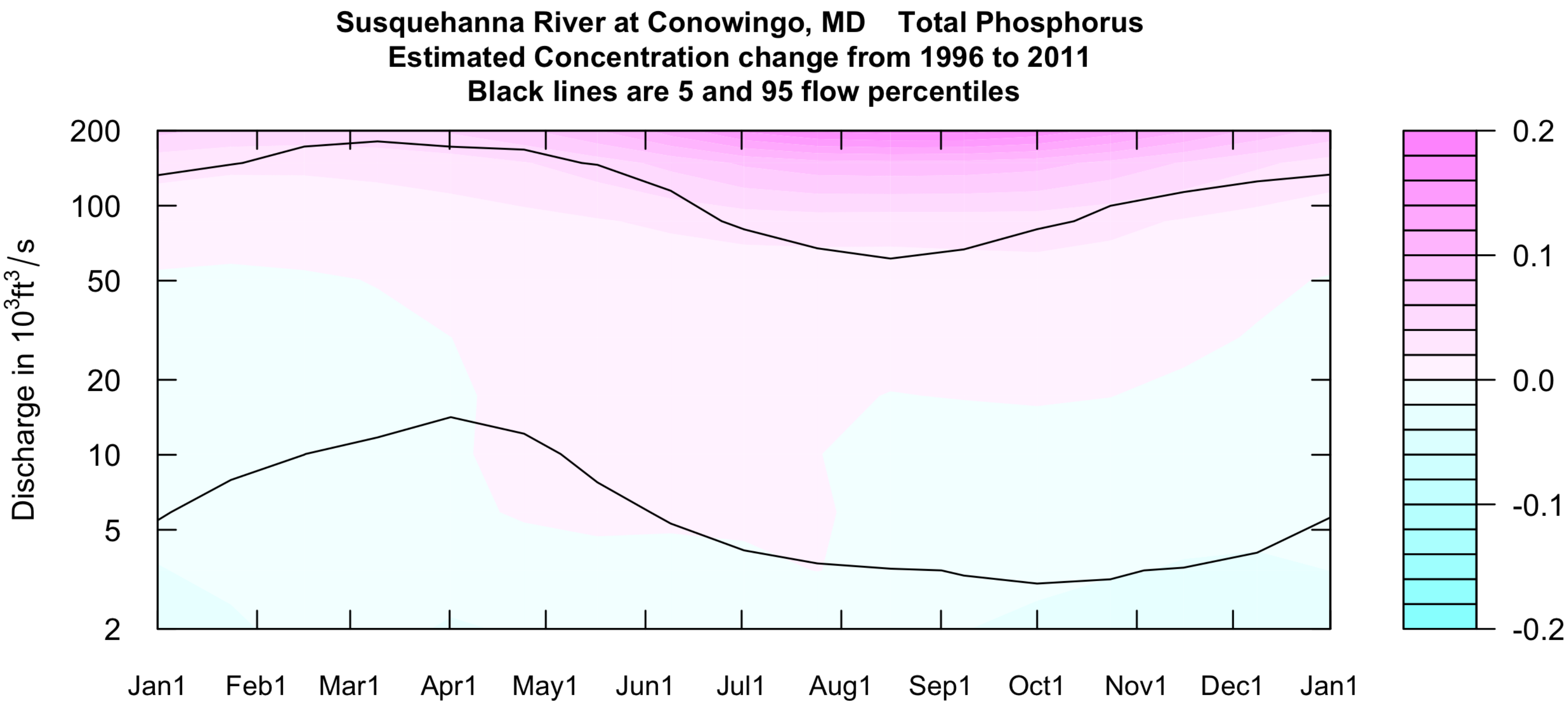


The changing behavior of Total Phosphorus concentrations at Conowingo over the 34-year monitoring period



Let’s compare 1996 and 2011

- **Increases at high discharge, all seasons but particularly the tropical storm season**
- **Small increases at moderate discharges April – July**
- **Small decreases at moderate to low discharges other parts of the year**



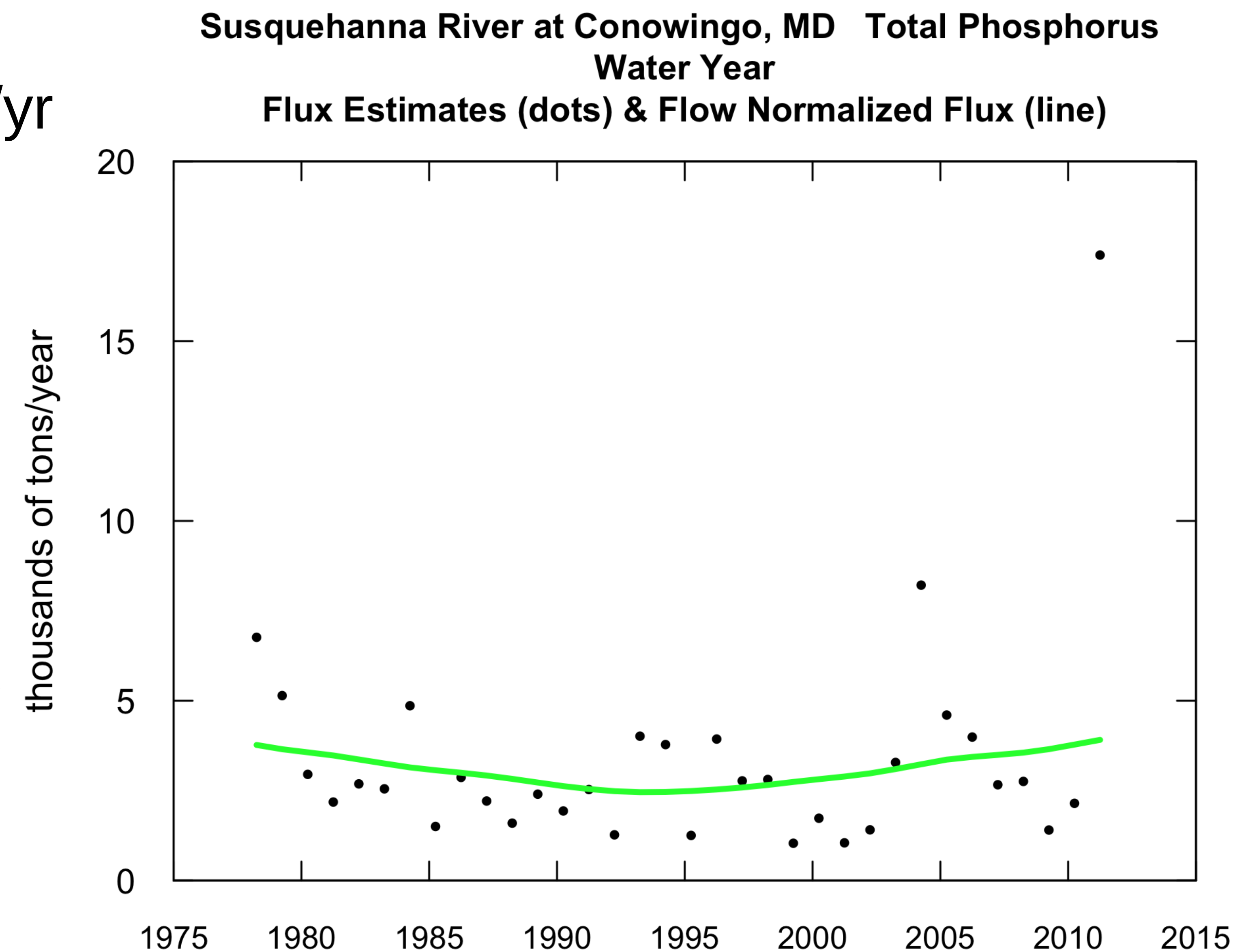
Total Phoshporus flux estimates using WRTDS

- T.S. Lee flux about 10,600 tons
- The 2011 water year 17,400 tons
- The past decade average was 4,800 tons/yr
- The past 34 year average was 3,300 tons/yr

Annual
Flux
In 10^3 tons/yr

2011=17
2010= 2
2004= 8

Flow
Normalized
Flux
Up 55%
Since 1996



Take home messages about TP

- Concentrations are relatively stable at moderate and low flows
- But at very high flows they have increased greatly in the past 15 years
- Flux continues to rise – and is becoming more and more episodic
- These changes almost certainly are related to the decreasing capacity of Conowingo Reservior

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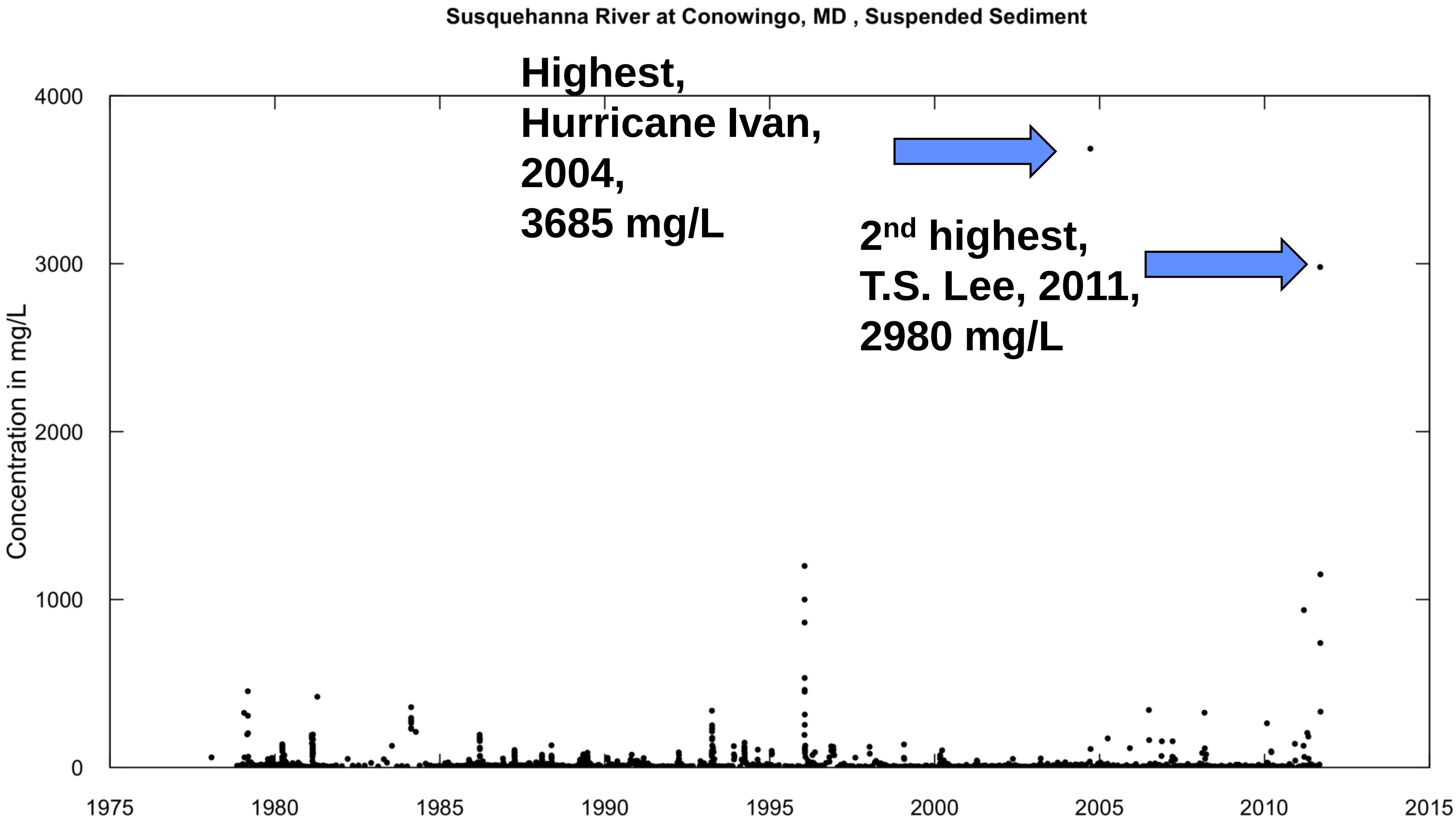
Suspended Sediment



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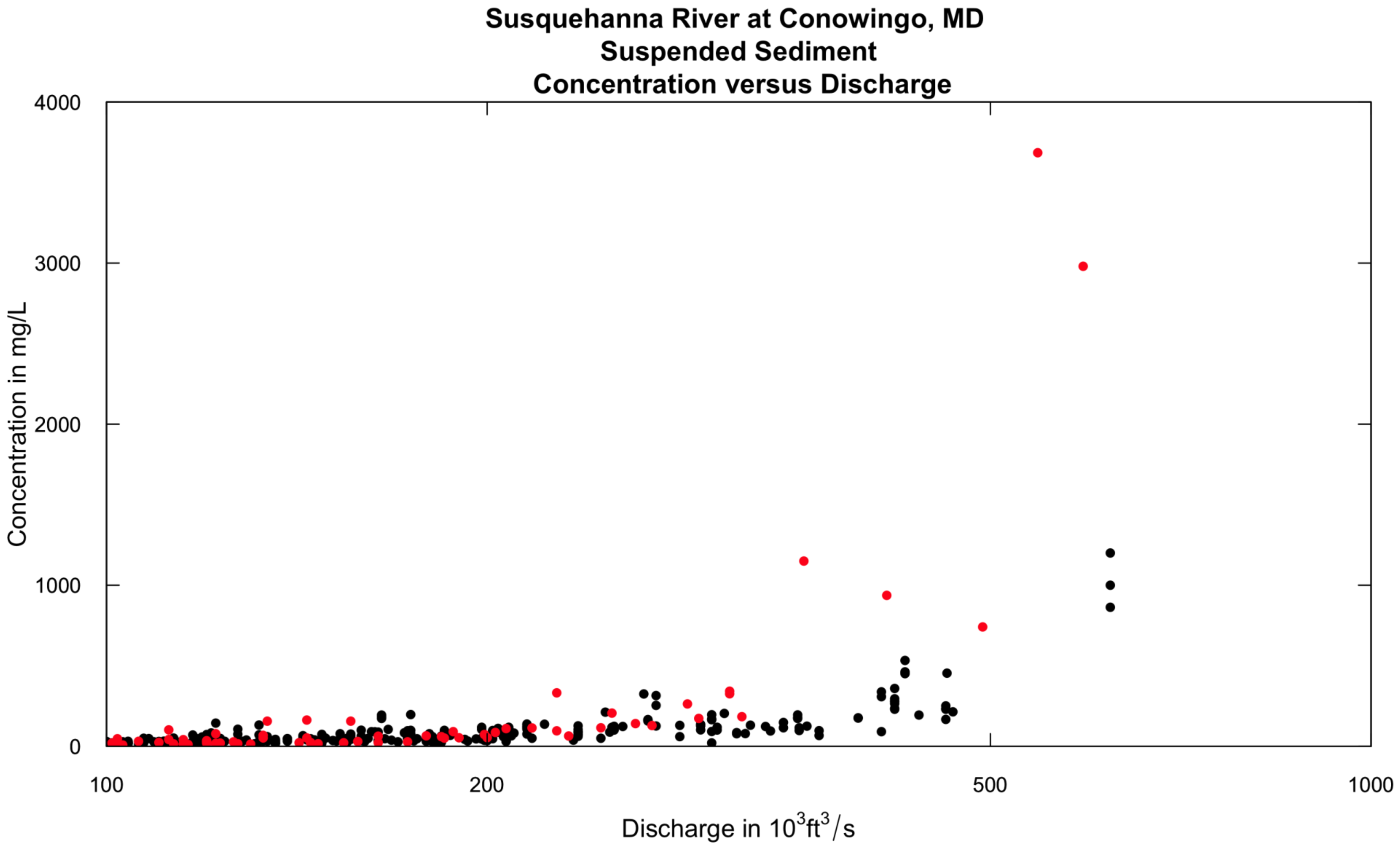
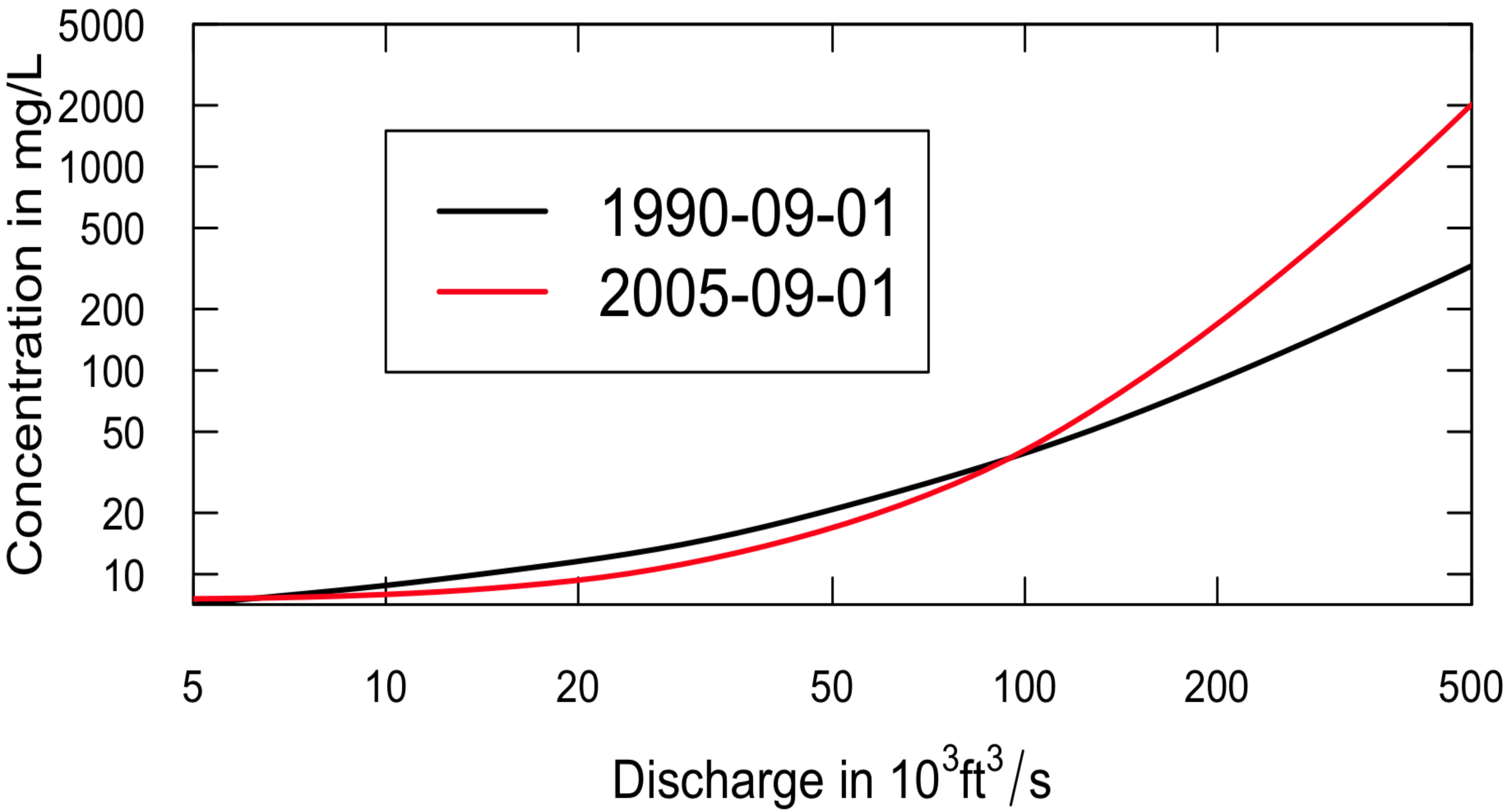
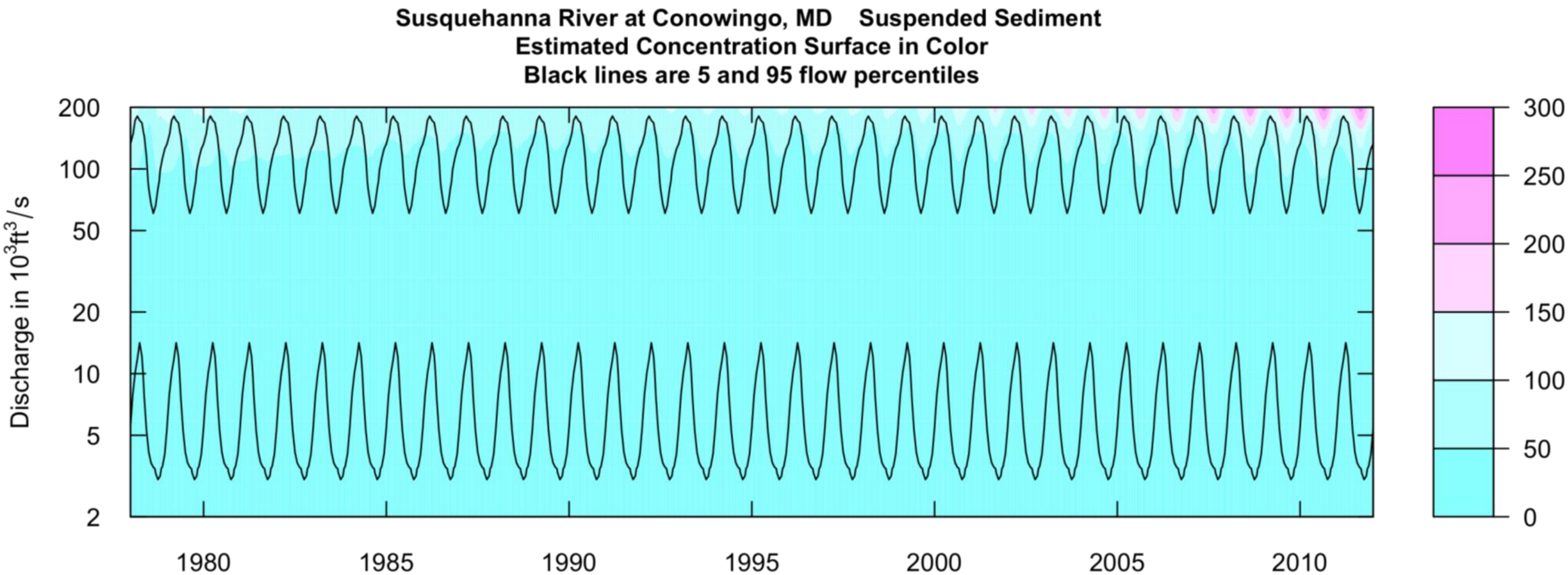


Use the WRTDS model to describe the evolving behavior of suspended sediment (note log scale on vertical axis)



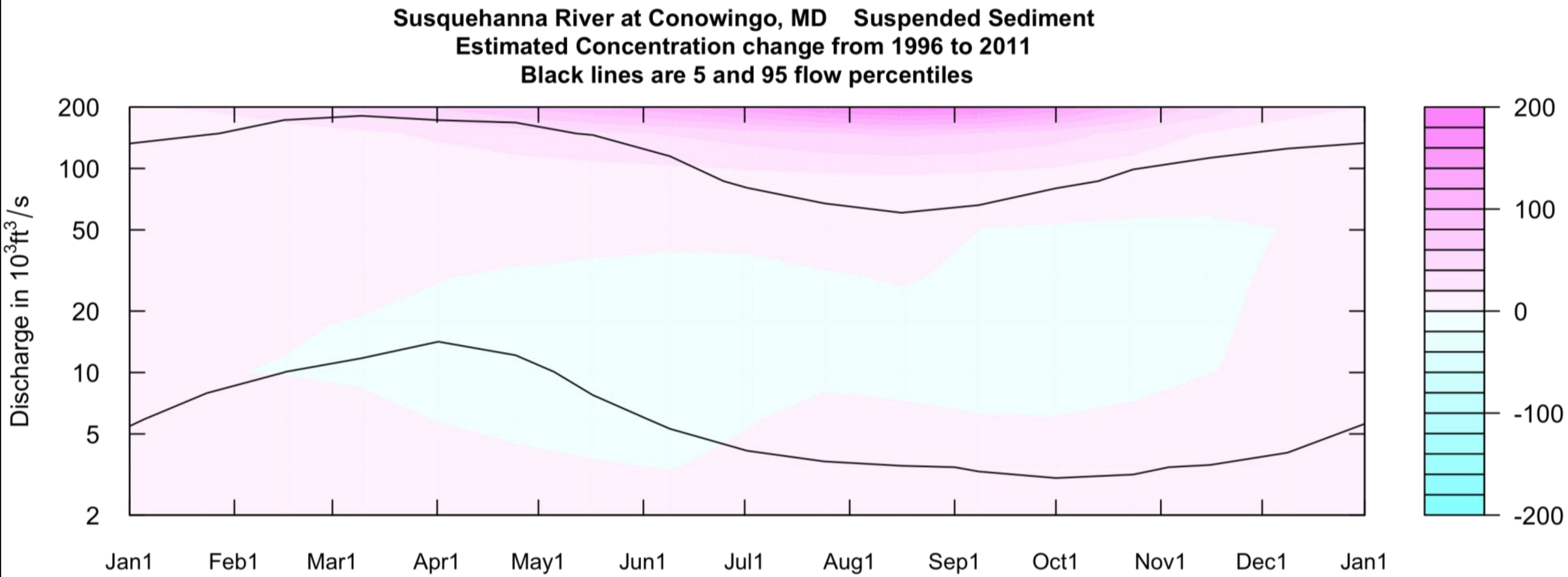
Evolving behavior of Suspended Sediment



Very difficult to define:
So much depends on a few rare events

Little to no change at most discharges and times of year

Except, large increases above 100,000 cfs



Suspended sediment flux estimates using WRTDS

- T.S. Lee flux about 19.0 million tons
- The 2011 water year 24.3 million tons
- The past decade average was 4.8 million tons
- The past 34 year average was 2.5 million tons

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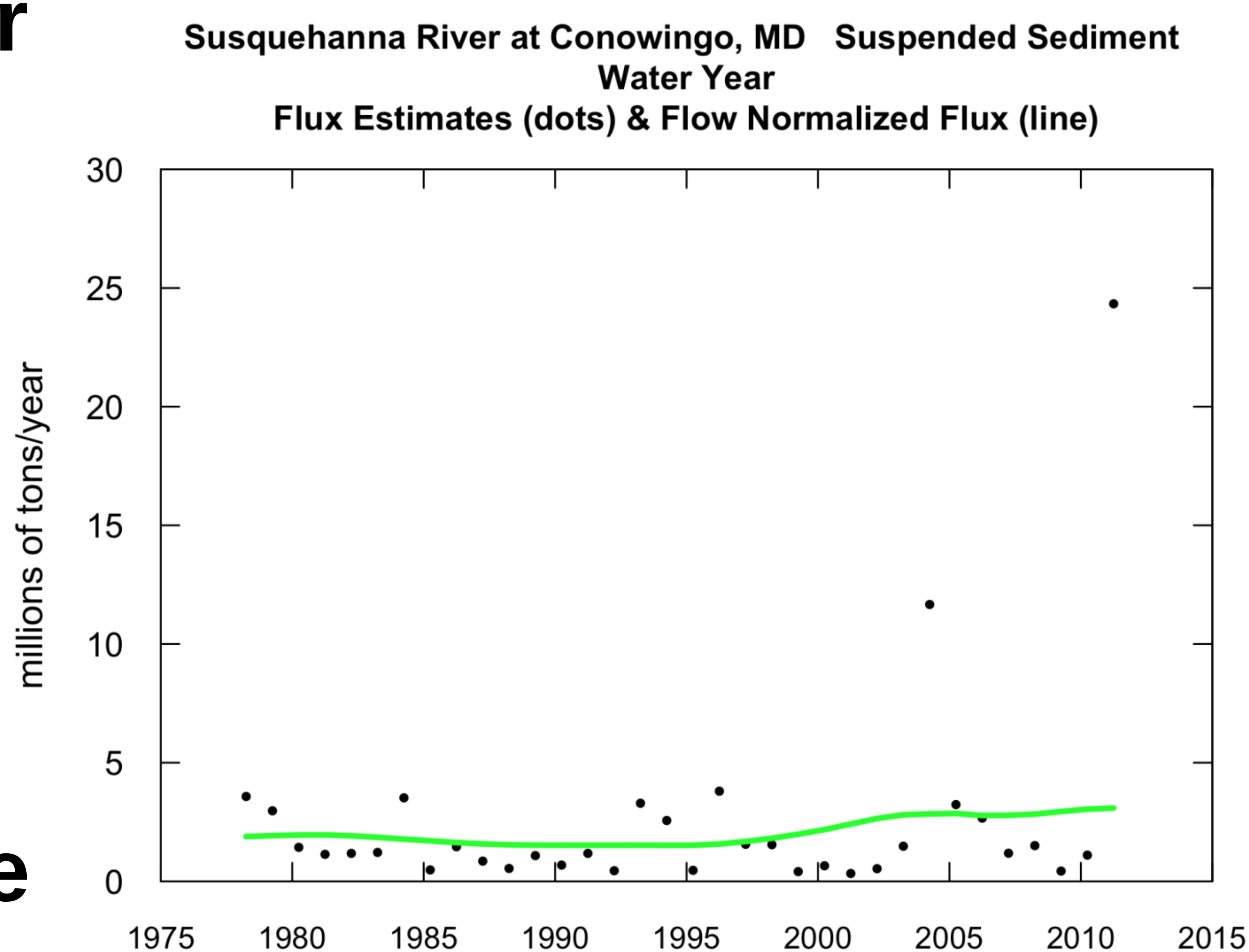
Annual Flux in10^6 tons/yr

2011 = 24
2010 = 1
2004 = 12

Flow Normalized Flux Change Up 97% Since 1996



Take away message for Suspended Sediment

- Flow-normalized flux is rising very steeply

- Variability increasing

	T.S. Lee as a % of 2011	T.S. Lee as a % of last decade	T.S. Lee as a % of full record
Time	2%	0.2%	0.06%
Flow	12%	1.8%	0.6%
Total Nitrogen			
Total Phosphorus			
Suspended Sediment			

	T.S. Lee as a % of 2011	T.S. Lee as a % of last decade	T.S. Lee as a % of full record
Time	2%	0.2%	0.06%
Flow	12%	1.8%	0.6%
Total Nitrogen	31%	5%	1.8%
Total Phosphorus			
Suspended Sediment			

	T.S. Lee as a % of 2011	T.S. Lee as a % of last decade	T.S. Lee as a % of full record
Time	2%	0.2%	0.06%
Flow	12%	1.8%	0.6%
Total Nitrogen	31%	5%	1.8%
Total Phosphorus	61%	22%	9%
Suspended Sediment			

	T.S. Lee as a % of 2011	T.S. Lee as a % of last decade	T.S. Lee as a % of full record
Time	2%	0.2%	0.06%
Flow	12%	1.8%	0.6%
Total Nitrogen	31%	5%	1.8%
Total Phosphorus	61%	22%	9%
Suspended Sediment	78%	39%	22%

Hypothesis:

- As the reservoirs fill, for any given discharge, there is less cross-sectional area, resulting in greater velocity
- This leads to a decrease in the scour threshold (more frequent scour)
- This also leads to a decrease in the amount of deposition at lower discharges

Prediction: Without dredging, reservoir output must equal input

	Langland and Hainley's 1997 prediction of change in flux	Observed change in flux since 1996
TN	+2%	-3.2%
TP	+70%	+55%
SS	+250%	+97%

What does this all mean for the Bay?

- Trapping of TP and SS is decreasing. Scour is becoming more frequent and larger
- Increasing role of high flow events for TN, TP, and SS inputs to the Bay.
- “Filling” is asymptotic and stochastic. We are well into the transition to “full.”
- Over the coming decades, the state of the reservoirs may be the main driver of TP & SS inputs from the Susquehanna.

Science needs

- Continued data collection upstream and downstream of reservoirs
- Improved temporal resolution of monitoring during high flow events
- Temporal analysis of inputs and outputs leading to improved estimates of deposition and scour
- Measurements and simulation models of scour and deposition processes

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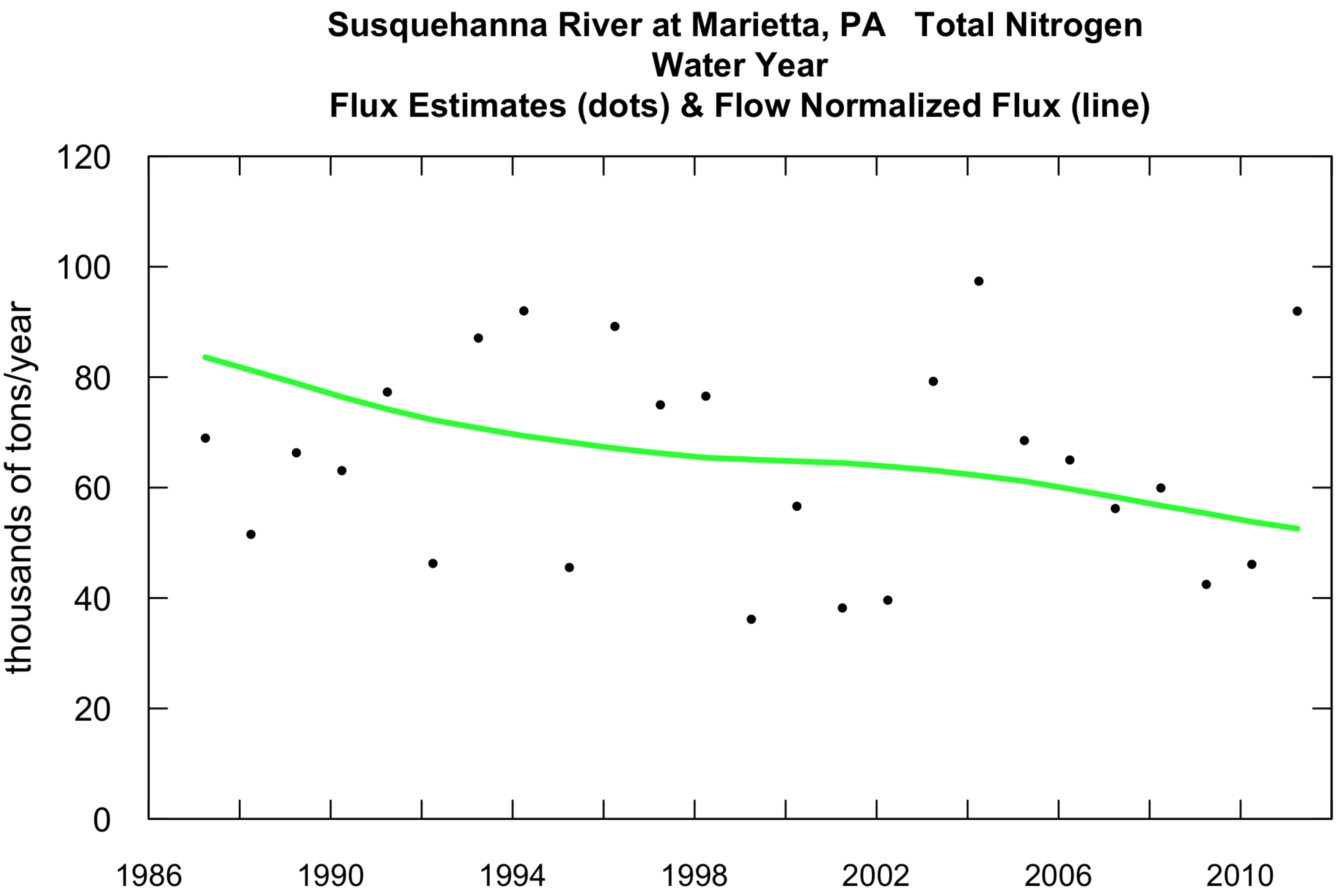
Next phase of work, already underway



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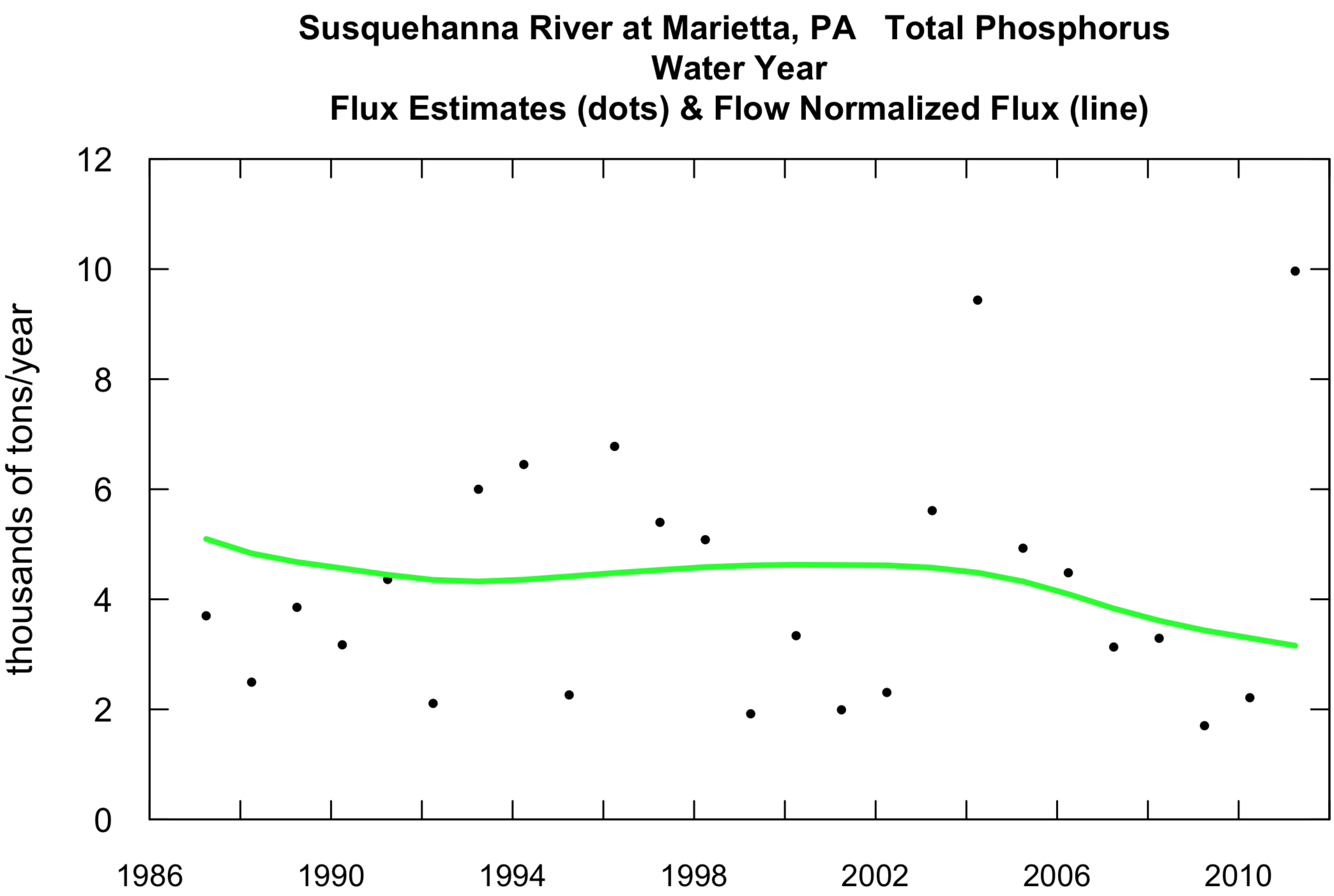

Next phase of work, already underway