Observations about the changing behavior of the Susquehanna River at Conowingo, Maryland

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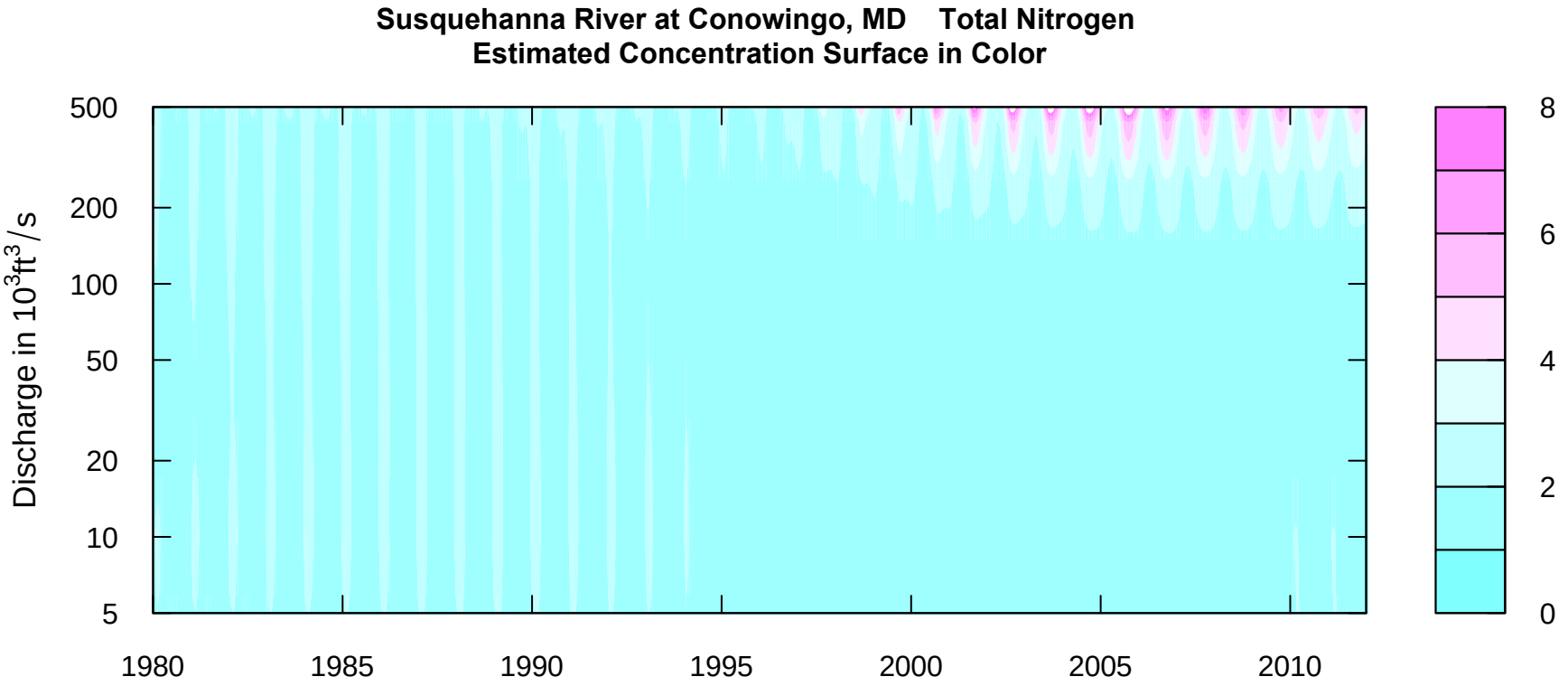
USGS
science for a changing world

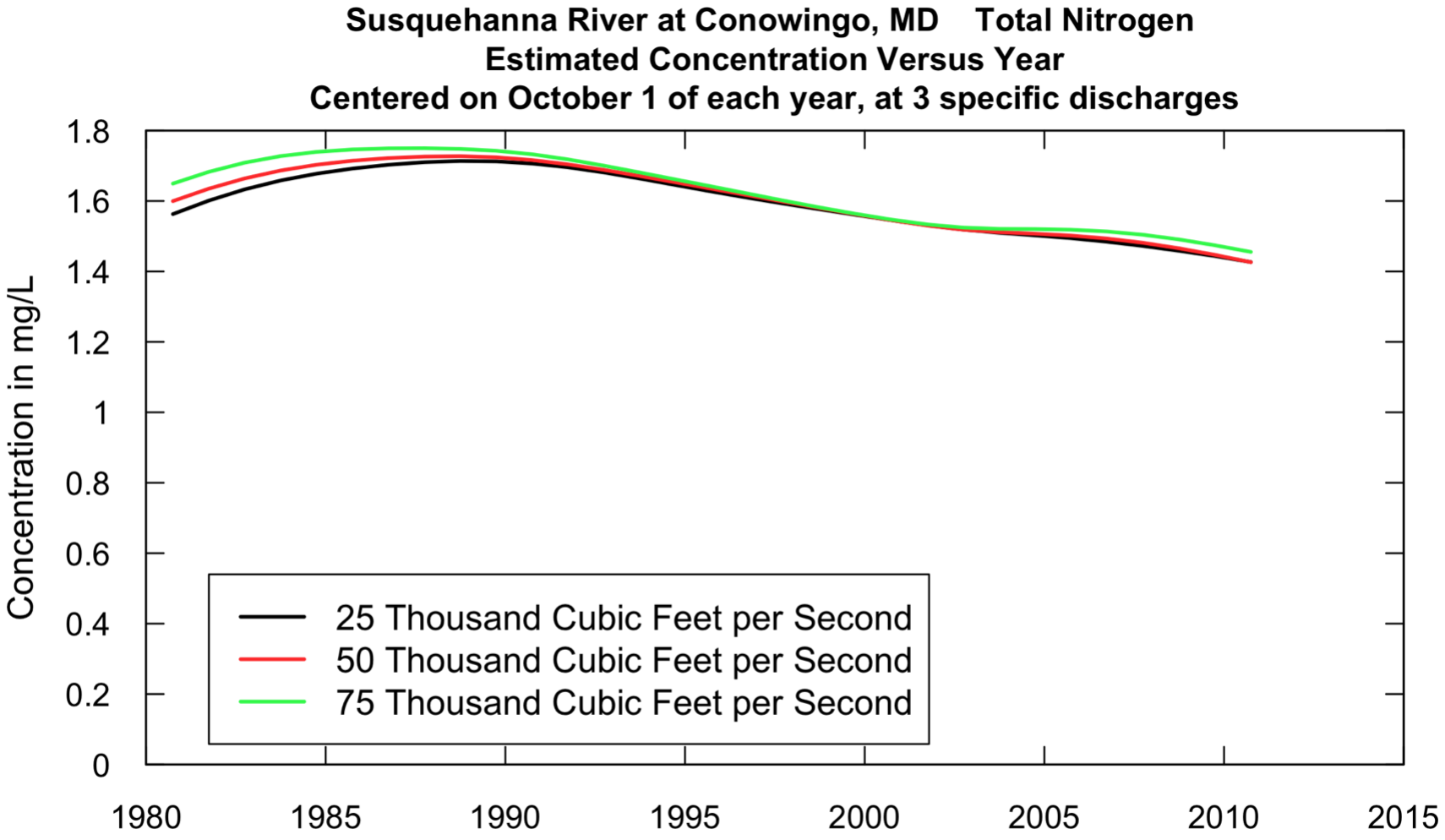
Take away messages

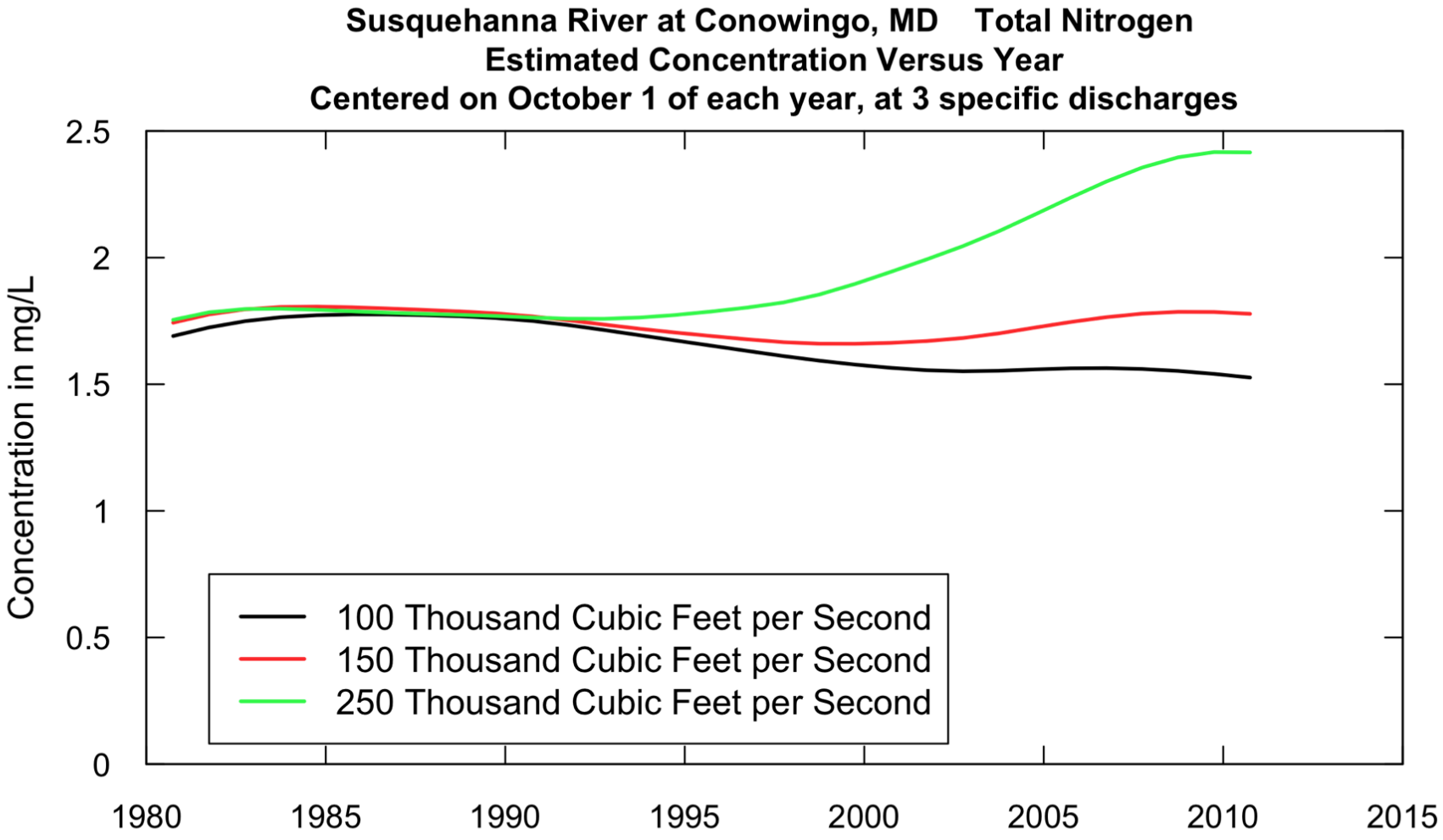
- **Conowingo Reservoir is a BMP. It is a trap for N, P, and SS that is rapidly declining in effectiveness.**
- **The decline probably started around 1996, but only became obvious in 2011.**
- **Discussions of when it will "fill" are meaningless.**
- **Two things are happening**
  - **Deposition changes: less deposition of particulate N, P and of SS at moderately high flows (above about 75,000 cfs)**
  - **Scour changes: more scour for a given discharge above about 400,000 cfs, and perhaps a somewhat lower threshold of scour**
- **For the Bay: the loss of deposition may be more important than increase in scour.**
- **WRTDS is my tool for describing the change to date**

Using WRTDS, (weighted regressions on time, discharge and season):

This is the fitted “surface” for total nitrogen:
It is the expected value of concentration as a function of time and discharge: what is it telling us?

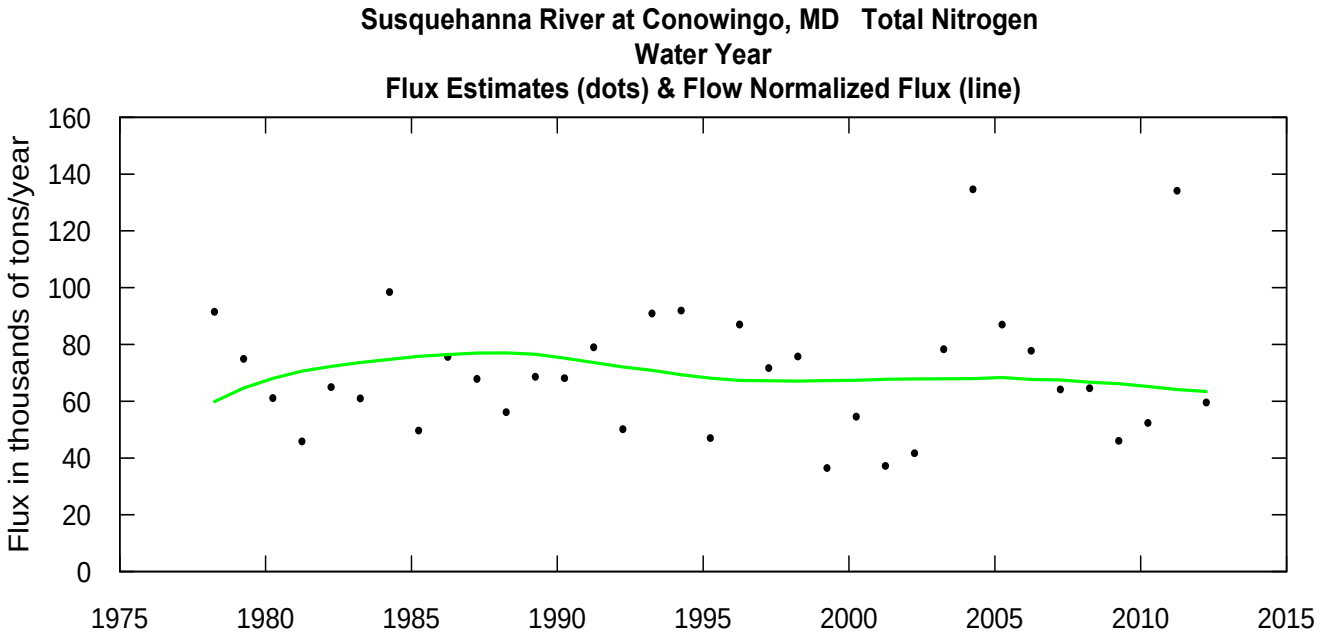



Susquehanna River at Conowingo, MD Total Nitrogen
Estimated Concentration Versus Year
Centered on October 1 of each year, at 3 specific discharges
Concentration in mg/L
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1980
1985
1990
1995
2000
2005
2010
2015
25 Thousand Cubic Feet per Second
50 Thousand Cubic Feet per Second
75 Thousand Cubic Feet per Second


Susquehanna River at Conowingo, MD Total Nitrogen
Estimated Concentration Versus Year
Centered on October 1 of each year, at 3 specific discharges
Concentration in mg/L
2.5
2
1.5
1
0.5
0
1980
1985
1990
1995
2000
2005
2010
2015
100 Thousand Cubic Feet per Second
150 Thousand Cubic Feet per Second
250 Thousand Cubic Feet per Second

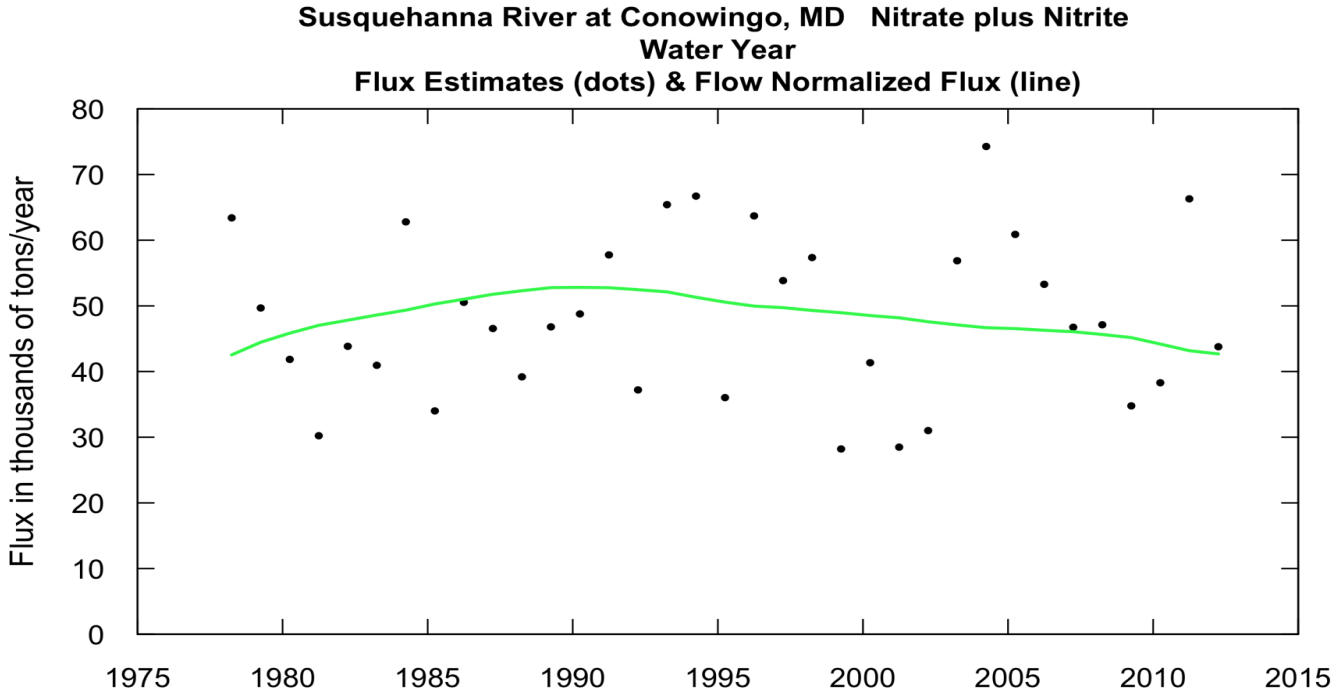
Change in Total Nitrogen flux for 1996- 2012 is a decrease of about

3.9 10^3tons/yr

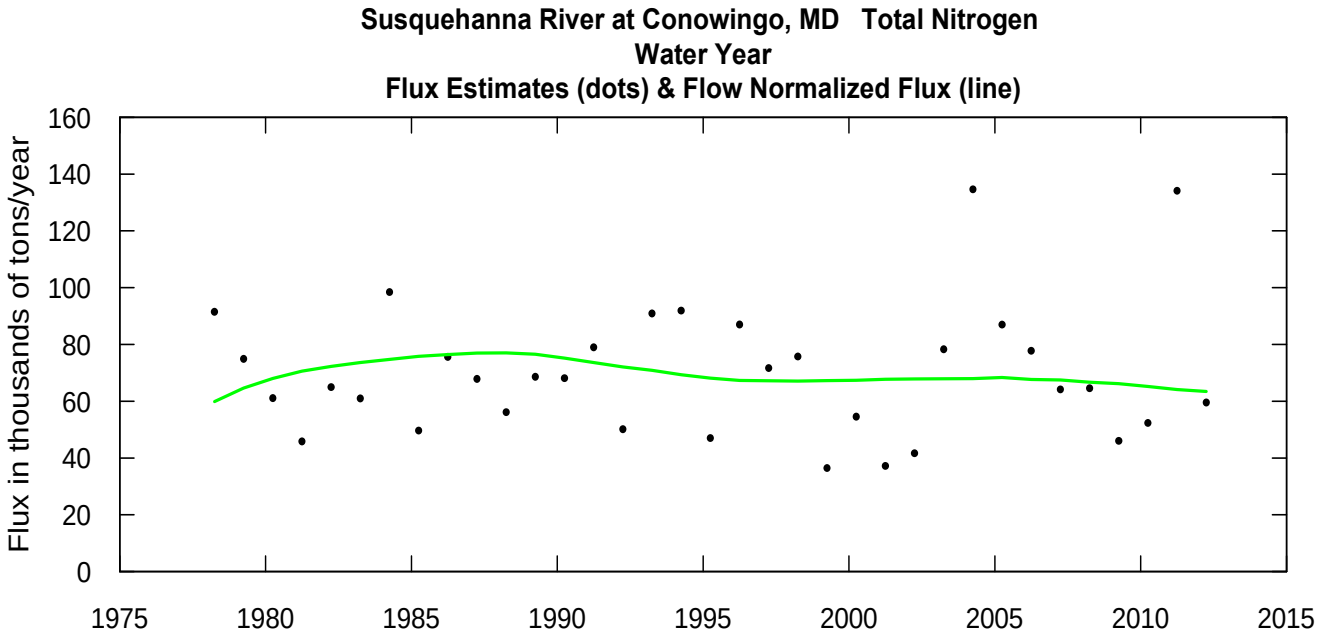


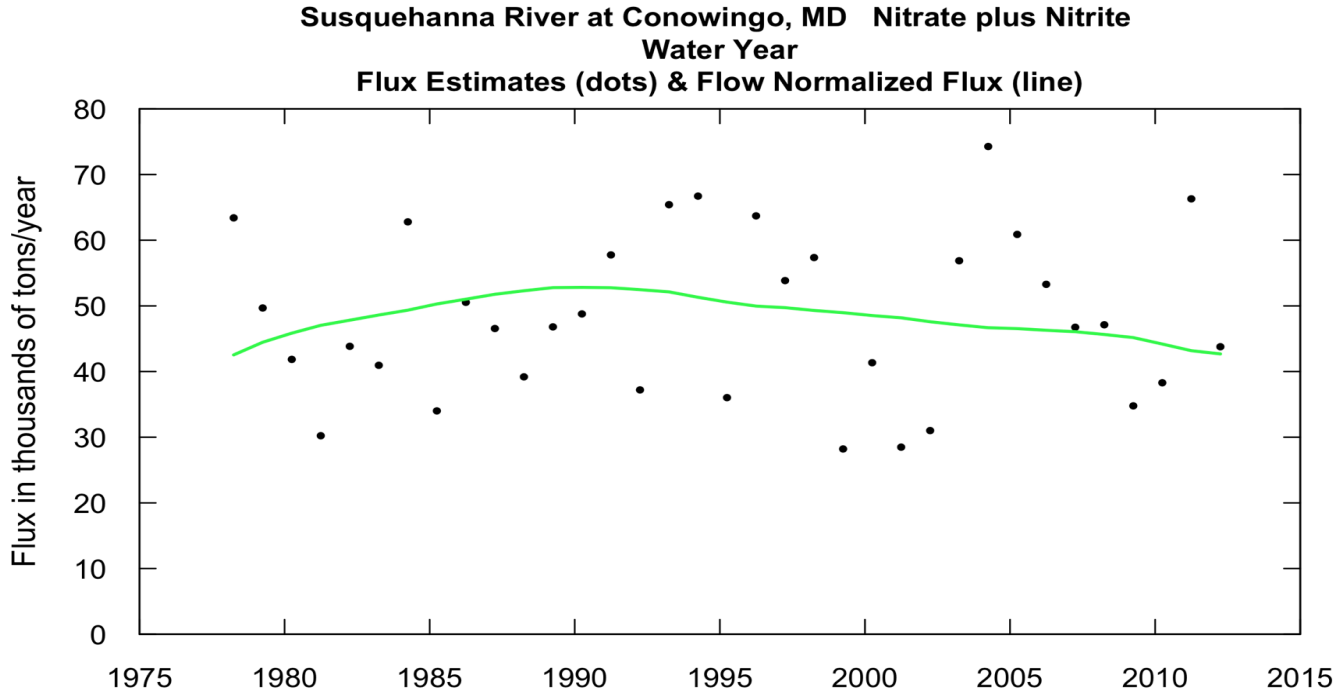
Change in NO2 + NO3 (the dissolved N) for 1996-2012 is a decrease of about

7.3 10^3tons/yr

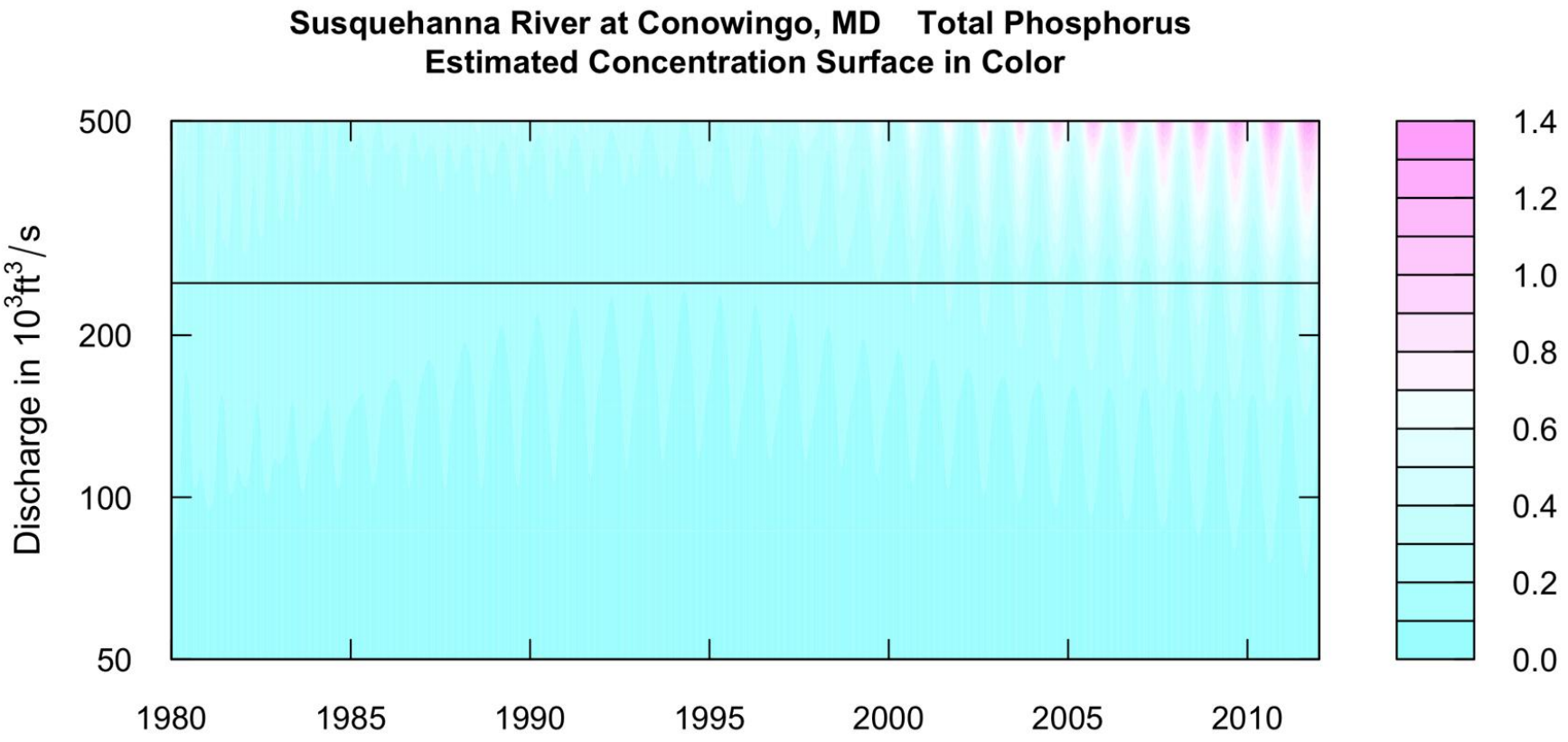


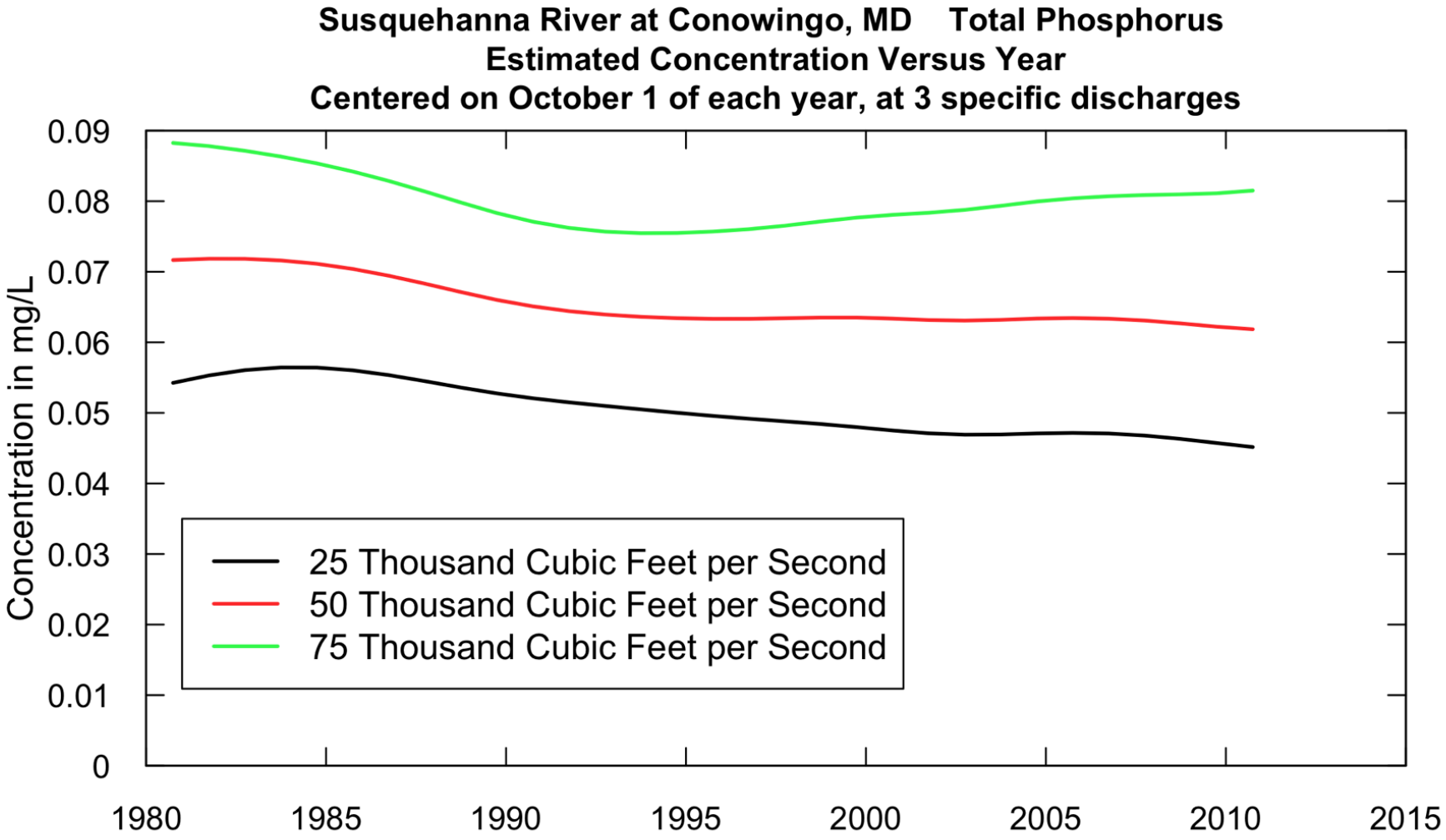
This suggests that particulate nitrate has increased about:
3.4 10^3 tons/yr

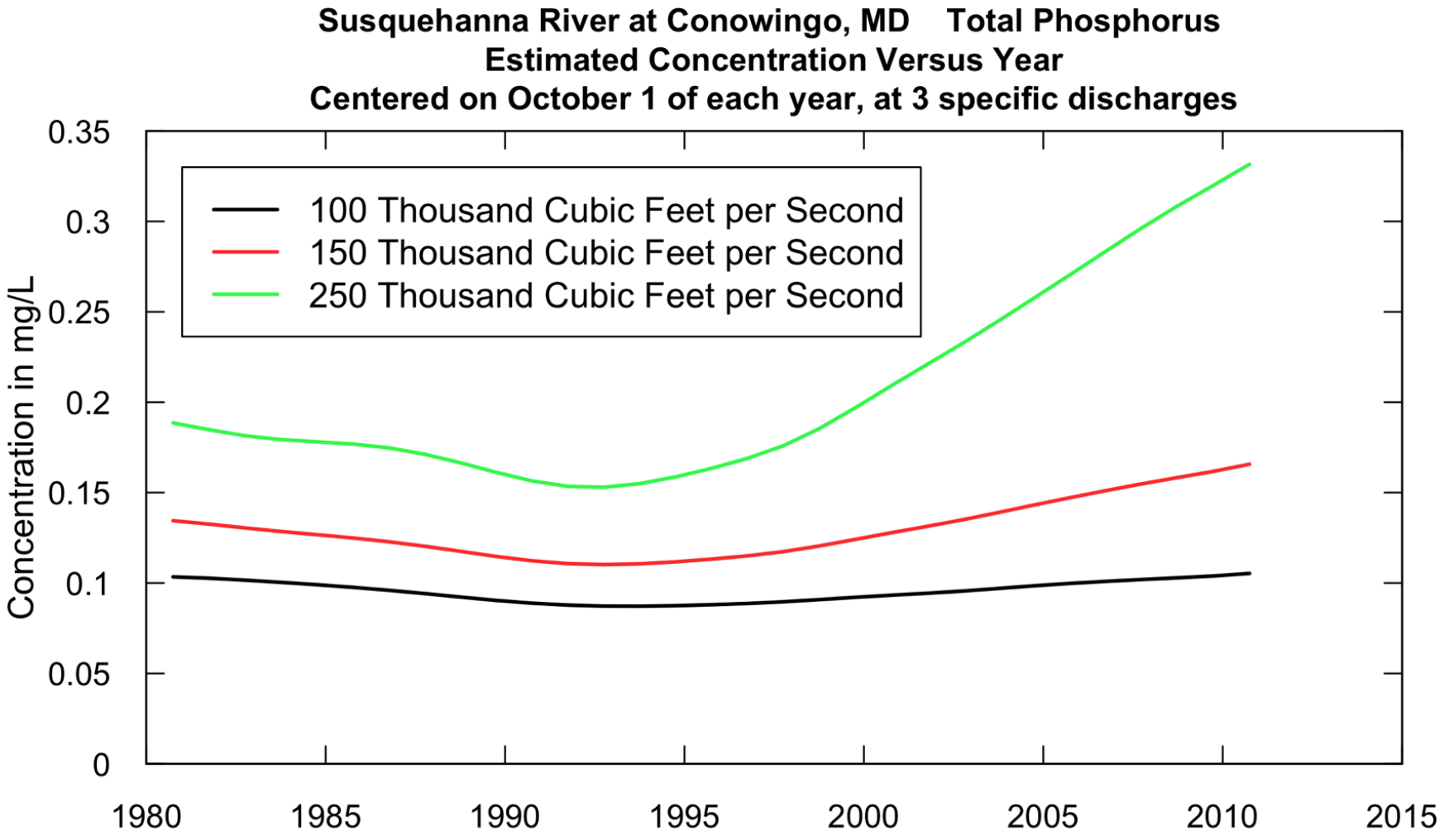


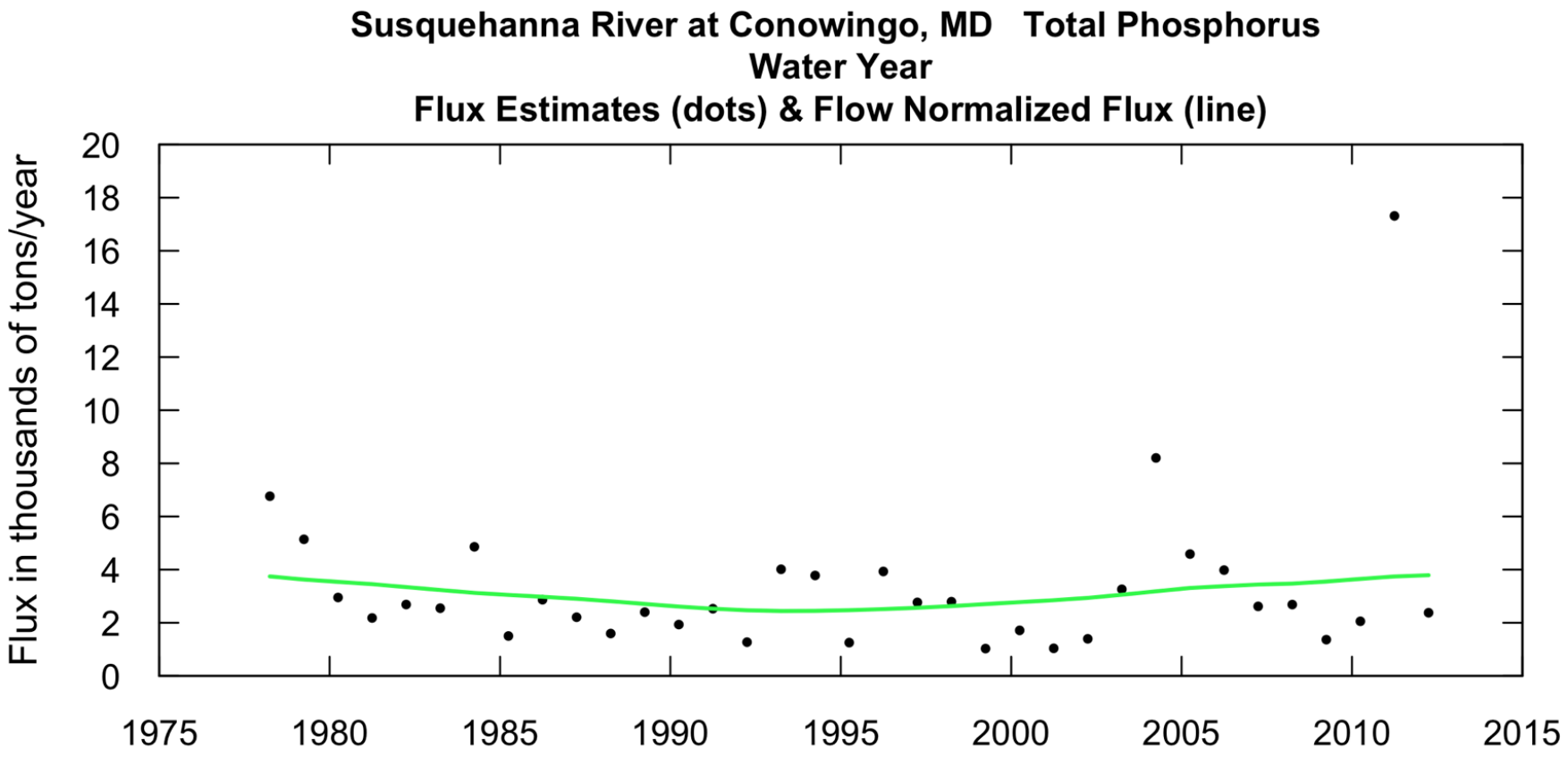


	Change: 1996-2012 Total		Change: 1996-2012 Dissolved fraction		Particulate as % of total	
	%	10^3 tons/yr	%	10^3 tons/yr	1996	2012
Nitrogen	-6%	-3.9	-15%	-7.3	26%	33%


Susquehanna River at Conowingo, MD Total Phosphorus
Estimated Concentration Surface in Color
Discharge in $10^3 ft^3/s$
500
200
100
50
1980
1985
1990
1995
2000
2005
2010
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0


Susquehanna River at Conowingo, MD Total Phosphorus
Estimated Concentration Versus Year
Centered on October 1 of each year, at 3 specific discharges
Concentration in mg/L
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1980
1985
1990
1995
2000
2005
2010
2015
25 Thousand Cubic Feet per Second
50 Thousand Cubic Feet per Second
75 Thousand Cubic Feet per Second


Susquehanna River at Conowingo, MD Total Phosphorus
Estimated Concentration Versus Year
Centered on October 1 of each year, at 3 specific discharges
100 Thousand Cubic Feet per Second
150 Thousand Cubic Feet per Second
250 Thousand Cubic Feet per Second
Concentration in mg/L
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1980
1985
1990
1995
2000
2005
2010
2015

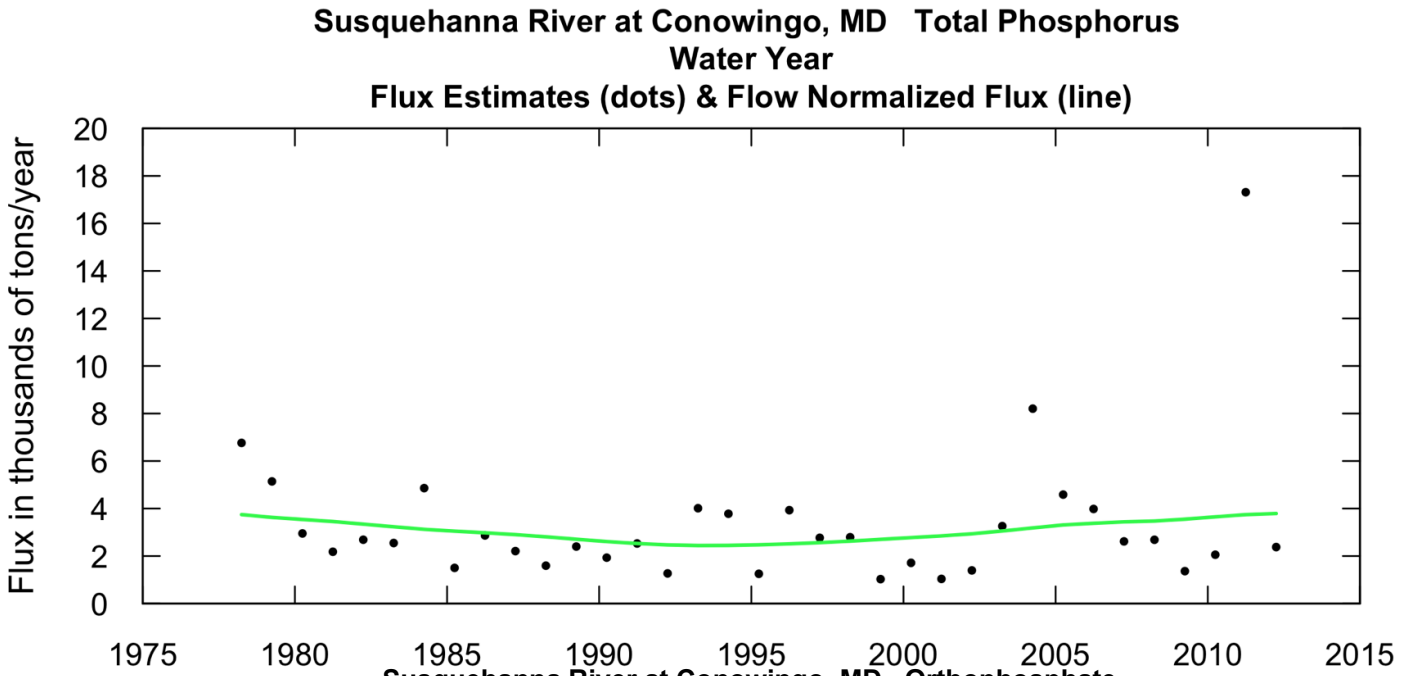


Although concentration only increased 8% from 1996 to 2012, flux increased by 51%

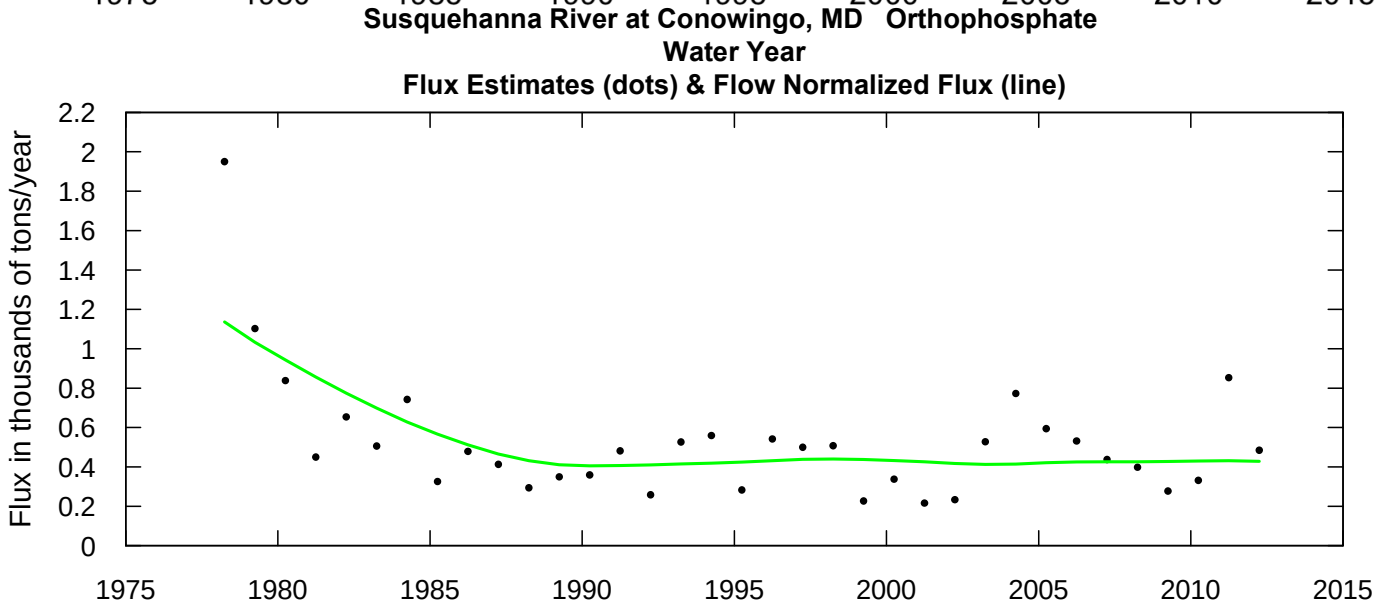
How much of the change in TP flux is at Q>400,000 cfs?

- Using my WRTDS model, compare 1996 to 2012
- I estimate that about 41% of the increase is at Q>400,000 (we see that about 1.7 days per year)
- I estimate that about 59% of the increase is at Q between 75,000 and 400,000 cfs (we see these about 48 days per year)

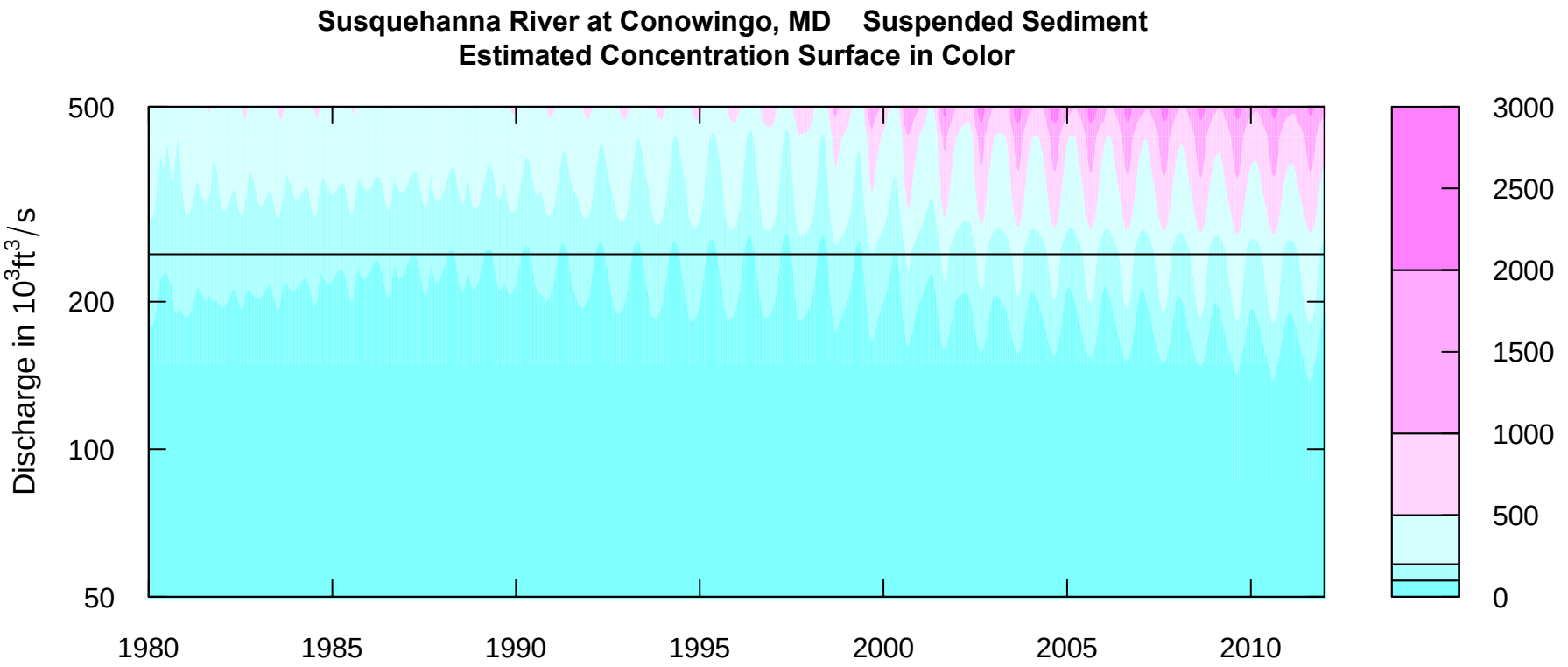
Total P up 51%
for 1996 - 2012



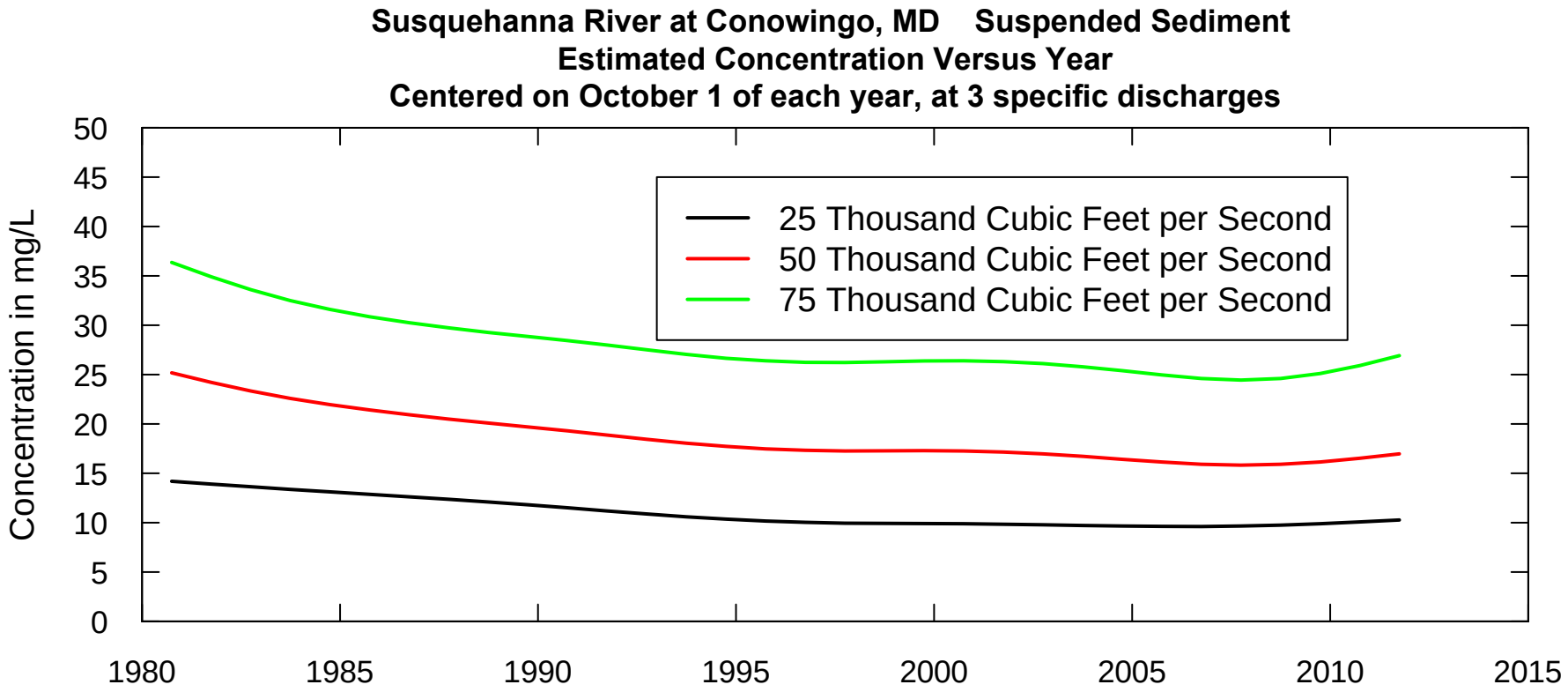
Dissolved P
virtually level,
down 0.7% for
1996 - 2012

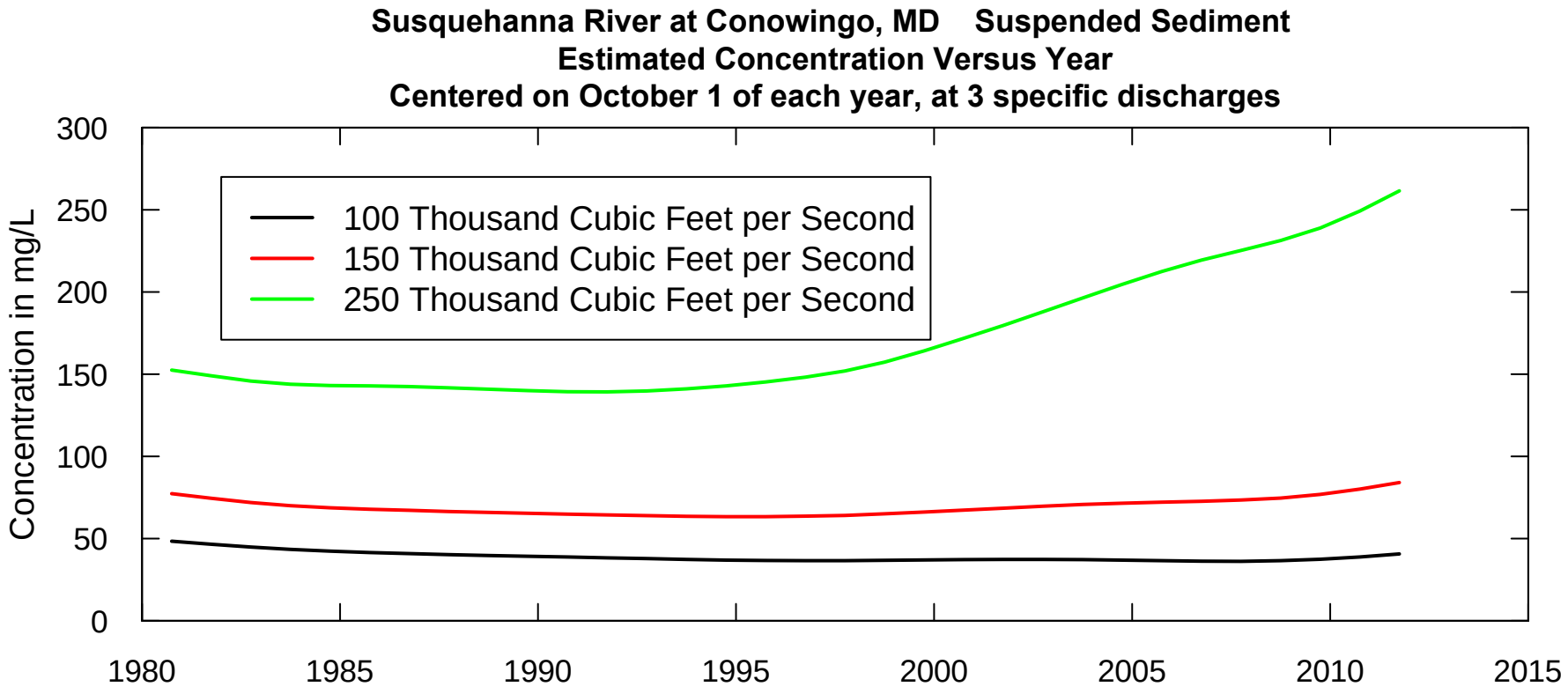


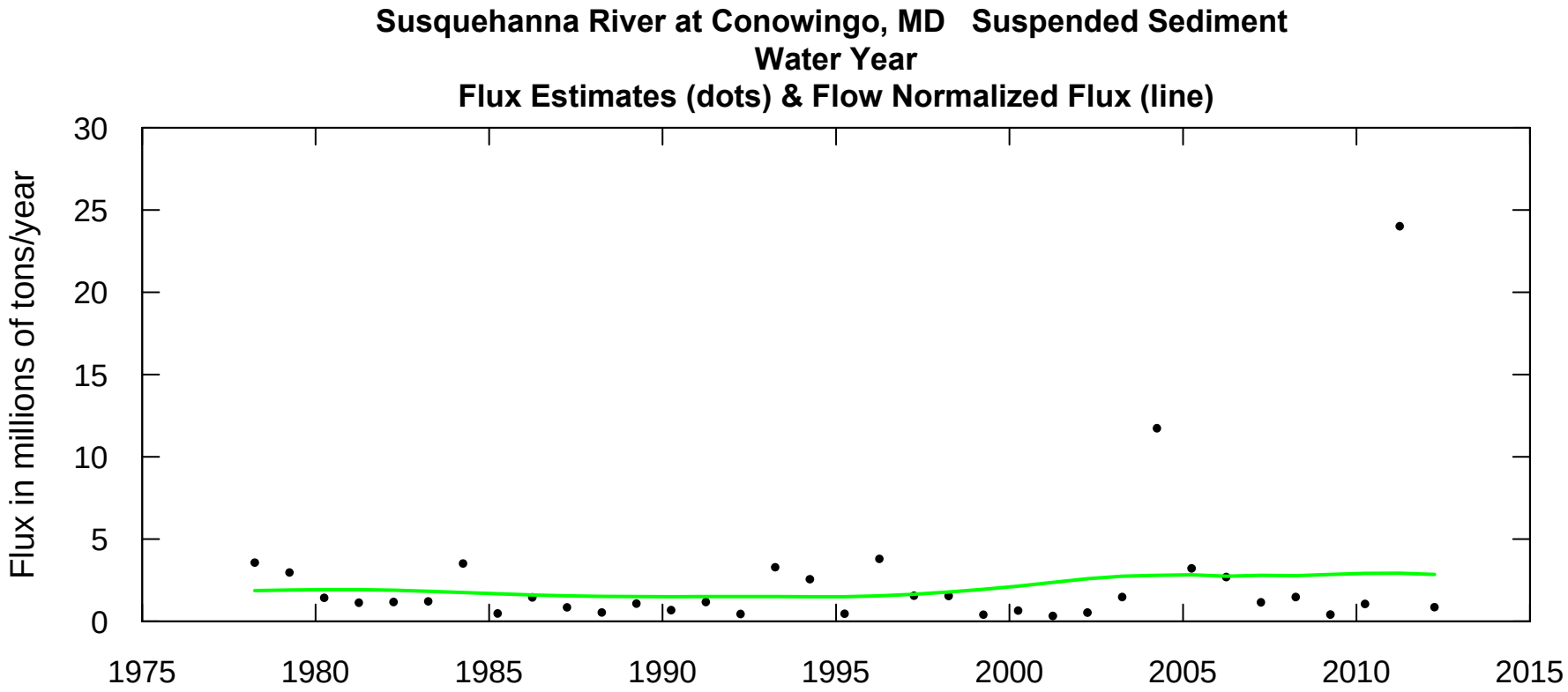
	Change: 1996-2012 Total		Change: 1996-2012 Dissolved fraction		Particulate as % of total	
	%	10^3 tons/yr	%	10^3 tons/yr	1996	2012
Nitrogen	-6%	-3.9	-15%	-7.3	26%	33%
Phosphorus	+51%	+1.3	-0.7%	-0.0	83%	89%



Note: three lowest classes are: 0 – 100 mg/L, 100 – 200 mg/L, 200-500 mg/L


Susquehanna River at Conowingo, MD Suspended Sediment
Estimated Concentration Versus Year
Centered on October 1 of each year, at 3 specific discharges
Concentration in mg/L
50
45
40
35
30
25
20
15
10
5
0
1980
1985
1990
1995
2000
2005
2010
2015
25 Thousand Cubic Feet per Second
50 Thousand Cubic Feet per Second
75 Thousand Cubic Feet per Second


Susquehanna River at Conowingo, MD Suspended Sediment
Estimated Concentration Versus Year
Centered on October 1 of each year, at 3 specific discharges
Concentration in mg/L
300
250
200
150
100
50
0
1980
1985
1990
1995
2000
2005
2010
2015
100 Thousand Cubic Feet per Second
150 Thousand Cubic Feet per Second
250 Thousand Cubic Feet per Second



From 1996 to 2012, Flow-Normalized Flux has increased 84%.

Rising from about 1.55 million tons/yr to about 2.85 million tons/yr
An increase of about 1.3 million tons/yr

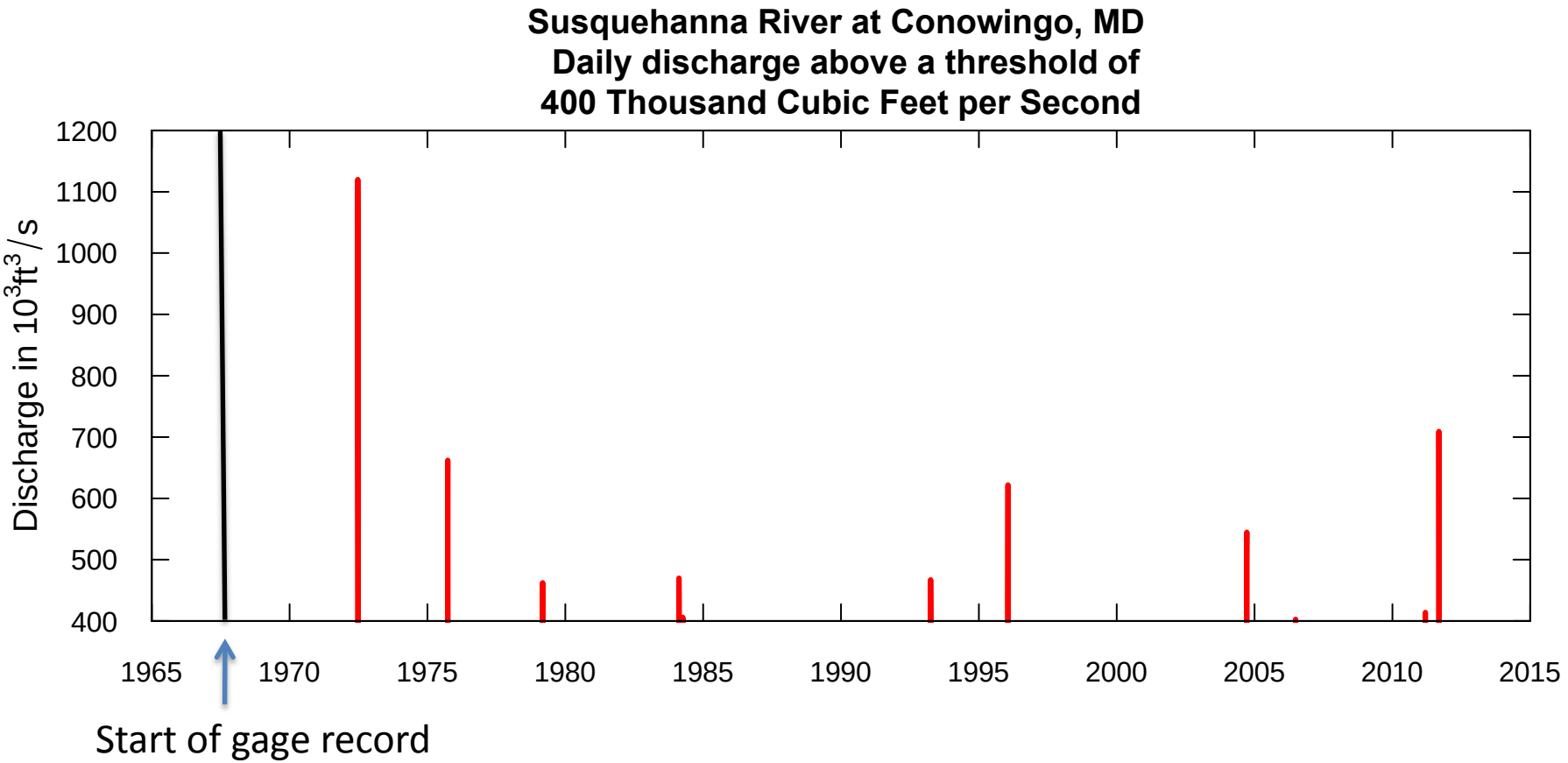
	Change: 1996-2012 Total		Change: 1996-2012 Dissolved fraction		Particulate as % of total	
	%	10^3 tons/yr	%	10^3 tons/yr	1996	2012
Nitrogen	-6%	-3.9	-15%	-7.3	26%	33%
Phosphorus	+51%	+1.3	-0.7%	-0.0	83%	89%
Sediment	+84%	+1300				

Alternative Hypothesis:
Maybe the change is about high-flow events getting more frequent over time

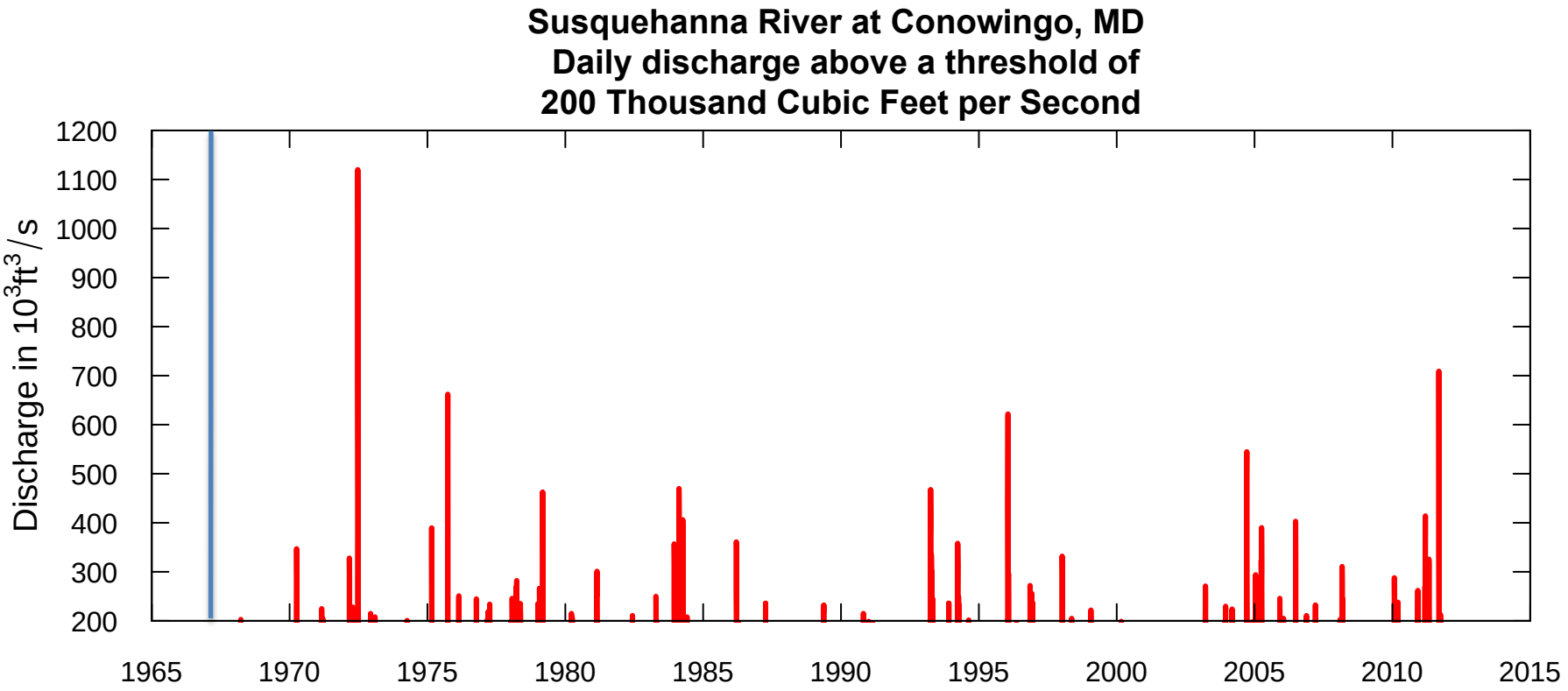
- **There is a theory that floods are getting bigger (or more frequent) because of enhanced greenhouse forcing of the global climate.**

- **Maybe so, but, lets be skeptical and look at the data.**

Look at the full streamflow record at Conowingo, starting in 1967.



The fact is, floods tend to cluster. It is very hard make a case for a real trend in floods

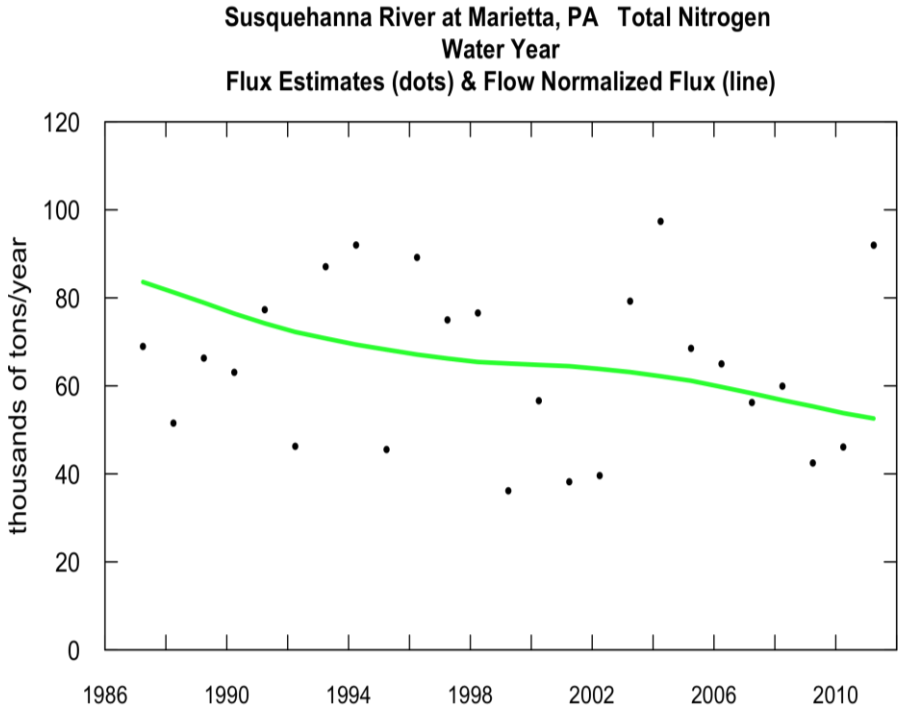


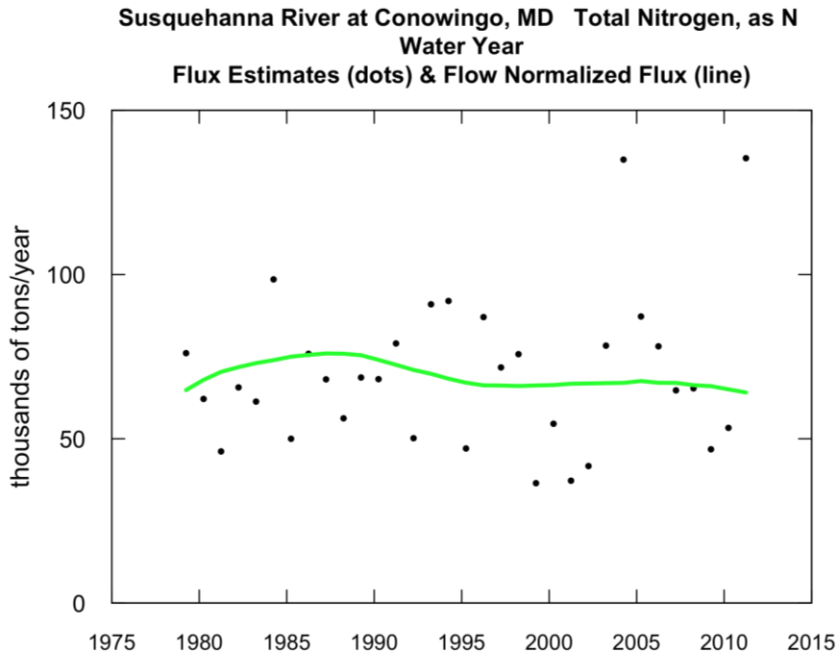
Think of flood events as natural experiments that allow us to gain insight on how the system operates.

Another alternative hypothesis

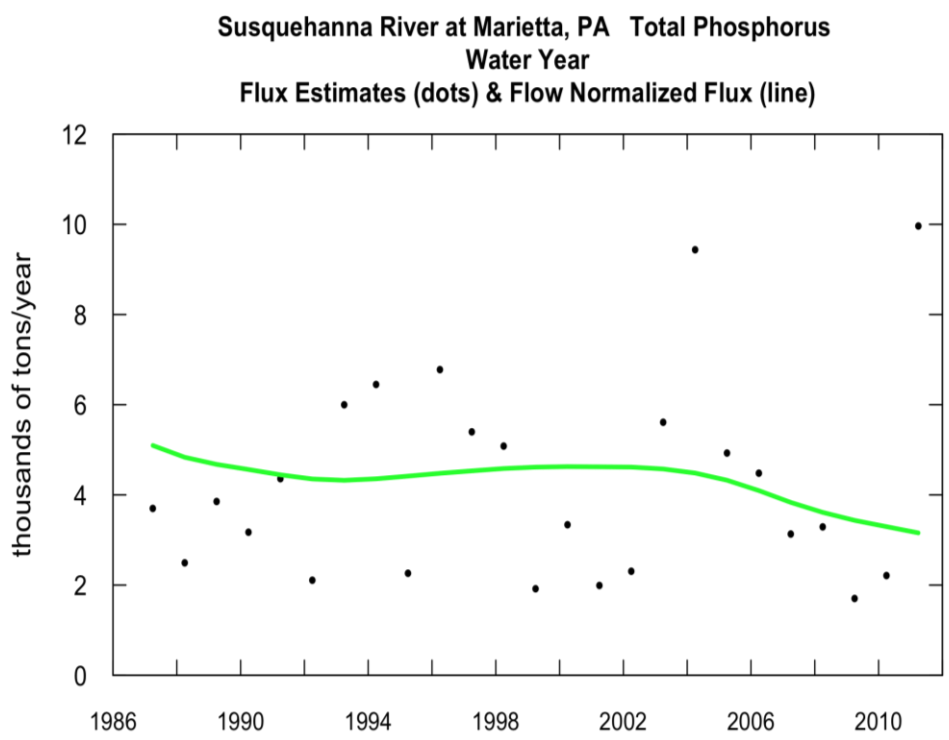
- These trends in SS and TP at Conowingo are just a reflection of what is going on upstream in the Susquehanna watershed.
- So, what can we say about the trends upstream of the reservoirs?
- This is being addressed by Qian Zhang and Bill Ball at Johns Hopkins University.
- I have some preliminary results.

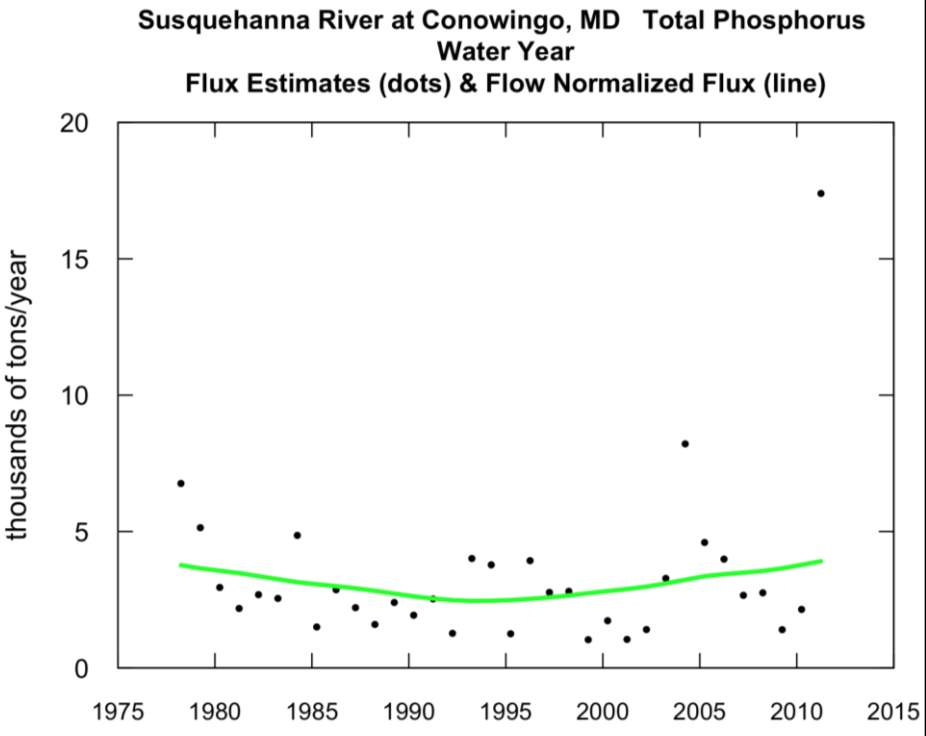
Total Nitrogen: Marietta and Conowingo



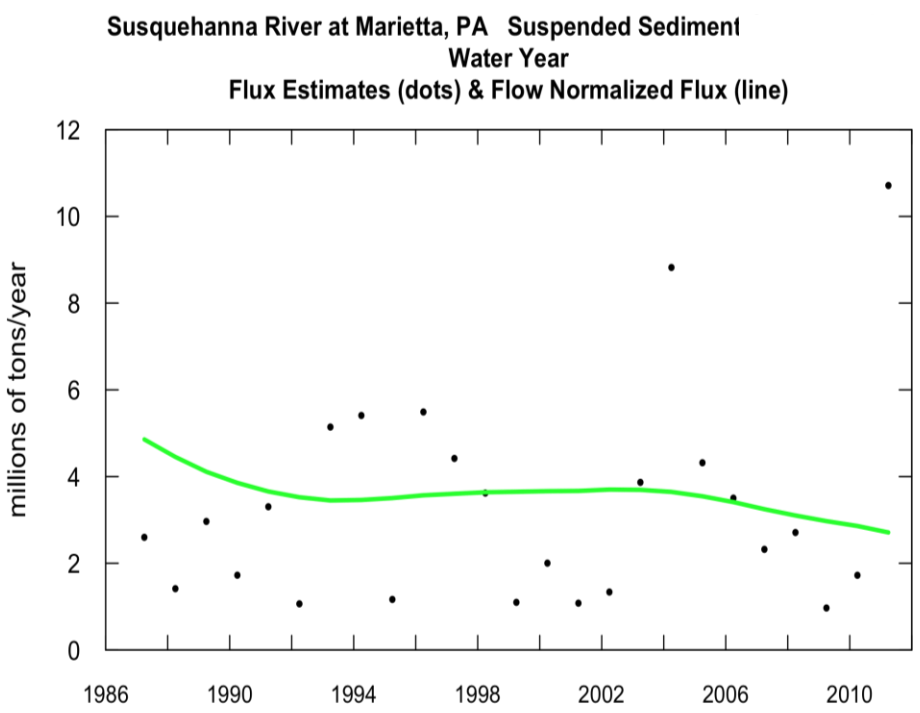


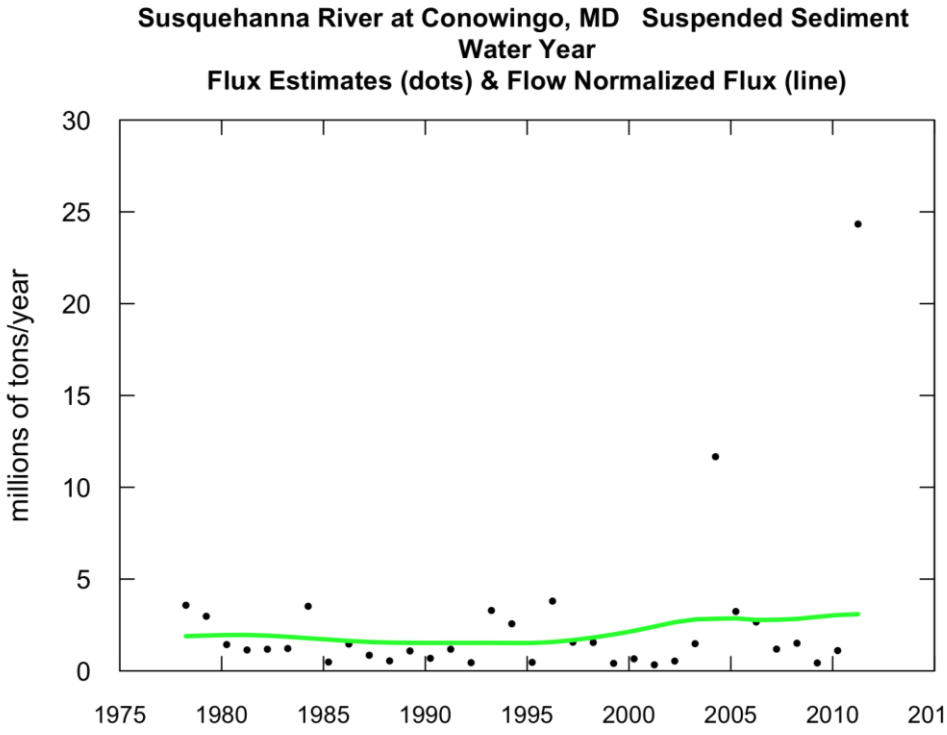
Total Phosphorus: Marietta and Conowingo





Suspended Sediment: Marietta and Conowingo





My 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) and greater amount of scour for a given discharge.**
- **This also leads to a decrease in the amount of deposition at moderately high discharge.**
- **For most of the last 80 years, output has been less than input. Ultimately, average output must equal average input.**
- **Unless there is a dramatic decrease in the inputs, the outputs of particulate N and P, and of SS must rise. That can be through natural mechanisms or by engineering measures to remove it.**

Two things happen as the reservoir fills

- **The ability of the dam to trap particulates (N, P, and SS) at moderately high discharges will continue to decrease, resulting in greater fluxes to the Bay on about 45 days per year on average.**

- **The propensity to scour will continue to increase causing a somewhat higher frequency of scour events and a larger amount of scour when it happens. This is a large amount of N, P, and SS, but it only happens about 1.5 days per year on average.**

Science needs

- **Continued data collection upstream and downstream of reservoirs**
- **Improved temporal resolution of monitoring during high flow events to improved mass balances of N, P, and SS.**
- **Reservoir models must simulate both the increase in scour and the decrease in deposition**
- **Ecosystem models must consider the changing frequency distribution of inputs (not just scour events).**