



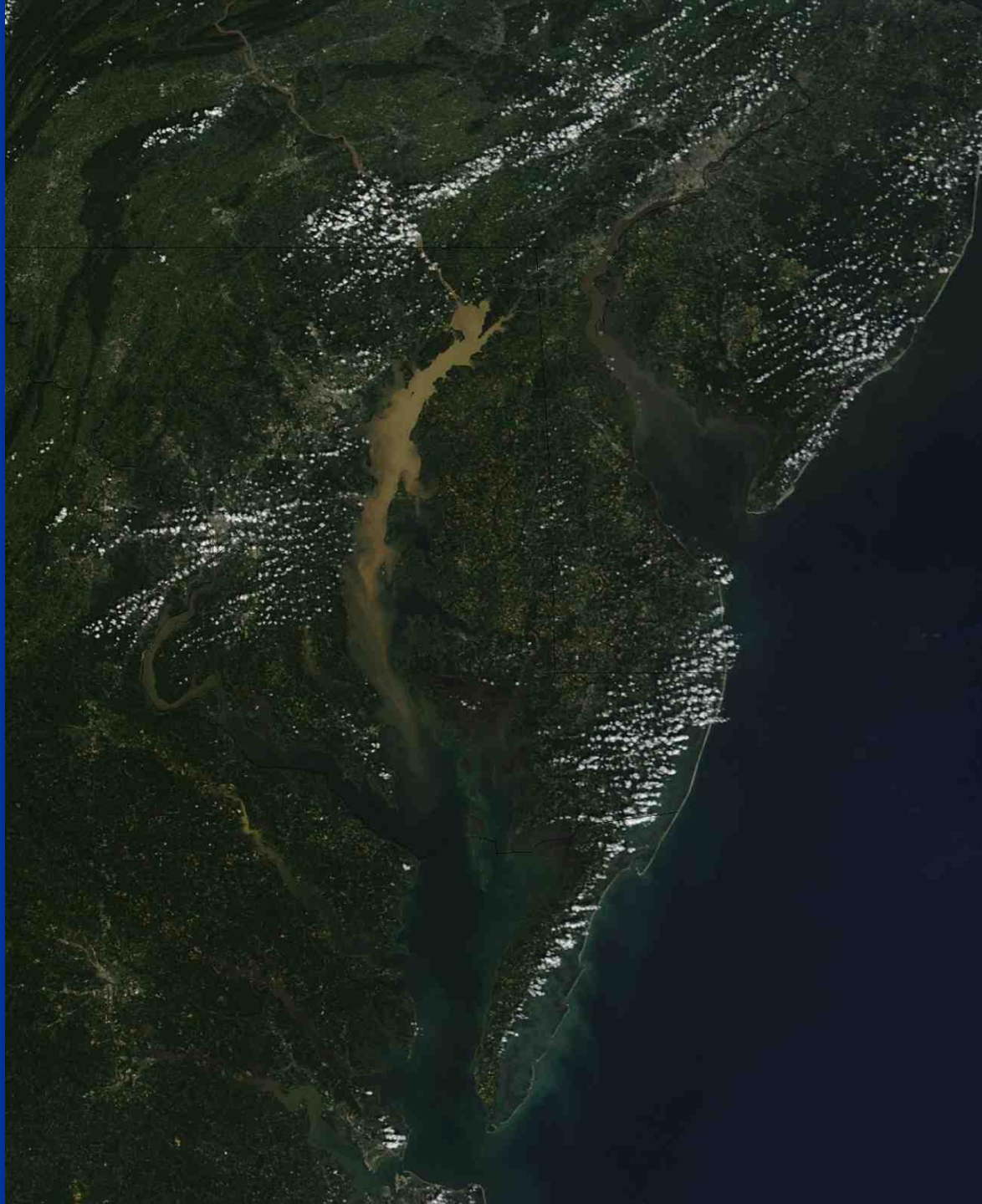
Results of data analysis on Nitrogen, Phosphorus, and Suspended Sediment fluxes from the Susquehanna River to the Bay in Tropical Storm Lee, 2011

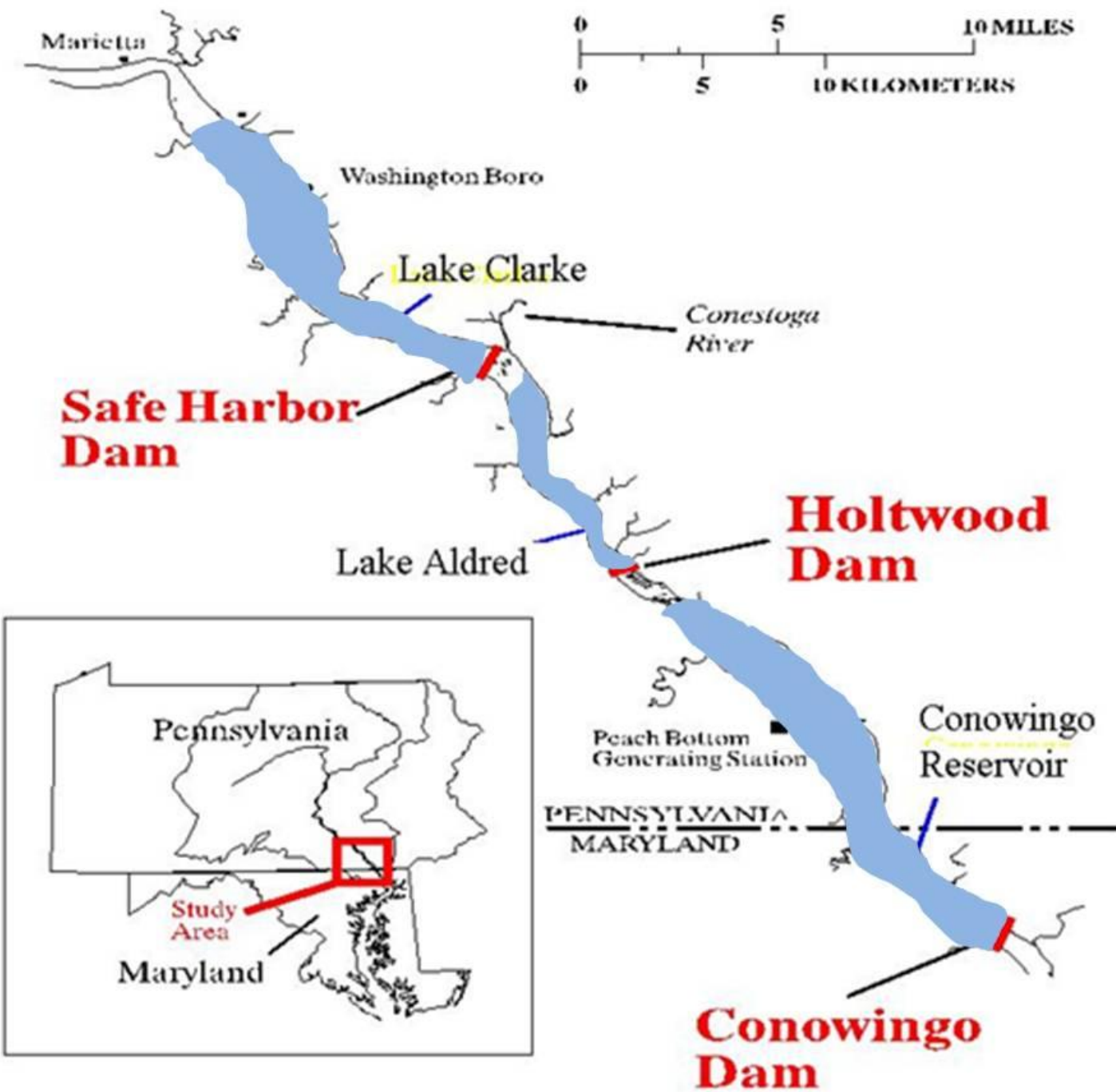
Robert M. Hirsch,
Research Hydrologist, USGS
June 19, 2012



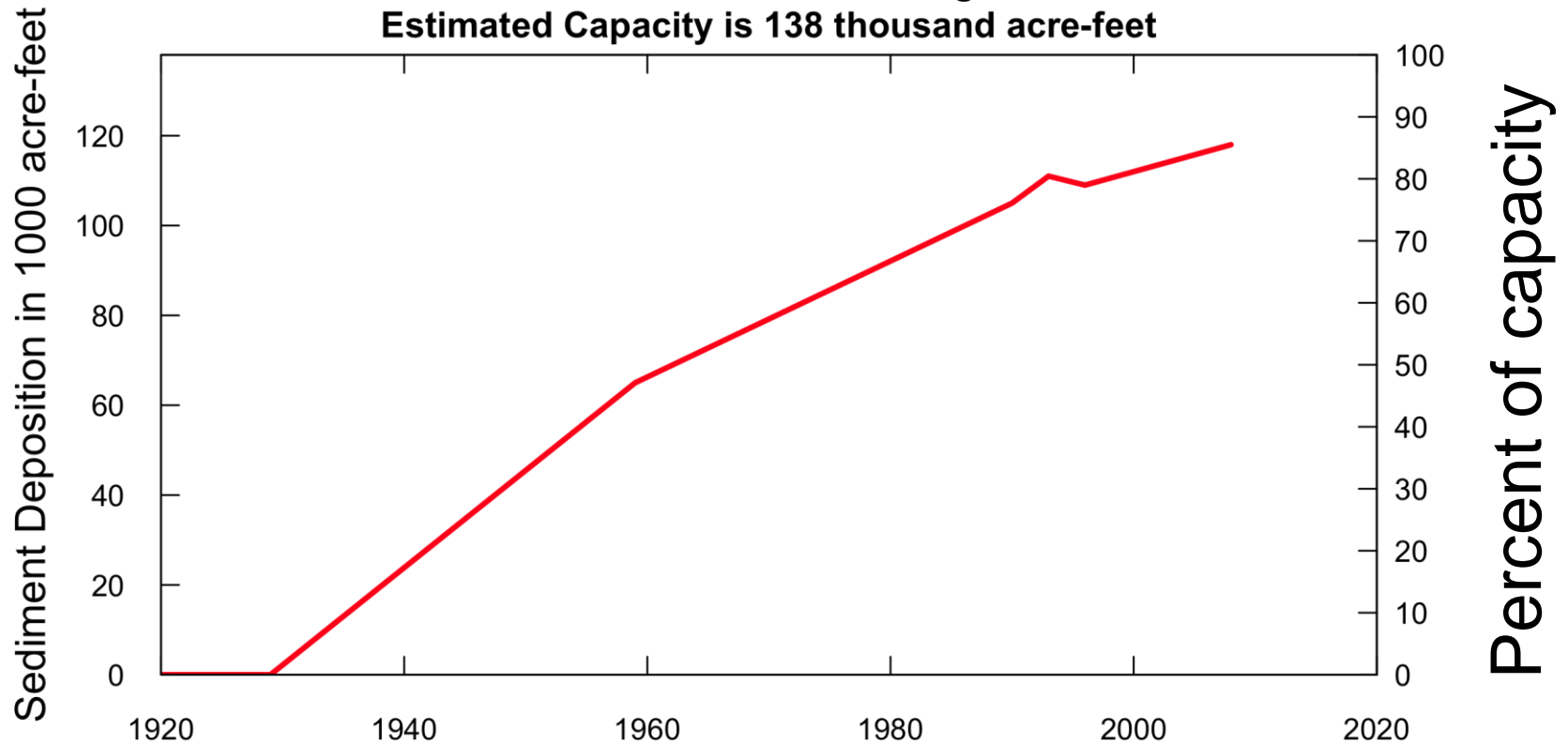
Photo credit: Wendy McPherson, USGS, September 12, 2011

**Photo credit:
NASA MODIS,
Sept. 13, 2011**





**History of Sediment Deposition
In the lower 11.5 miles of Conowingo Reservoir
Estimated Capacity is 138 thousand acre-feet**



Source: Langeland, 2009
<http://pubs.usgs.gov/sir/2009/5110/>

Predictions by Langland (1998)

Reservoirs would be “full” in 17 to 20 years

And all other things being equal

TN flux would increase 2%

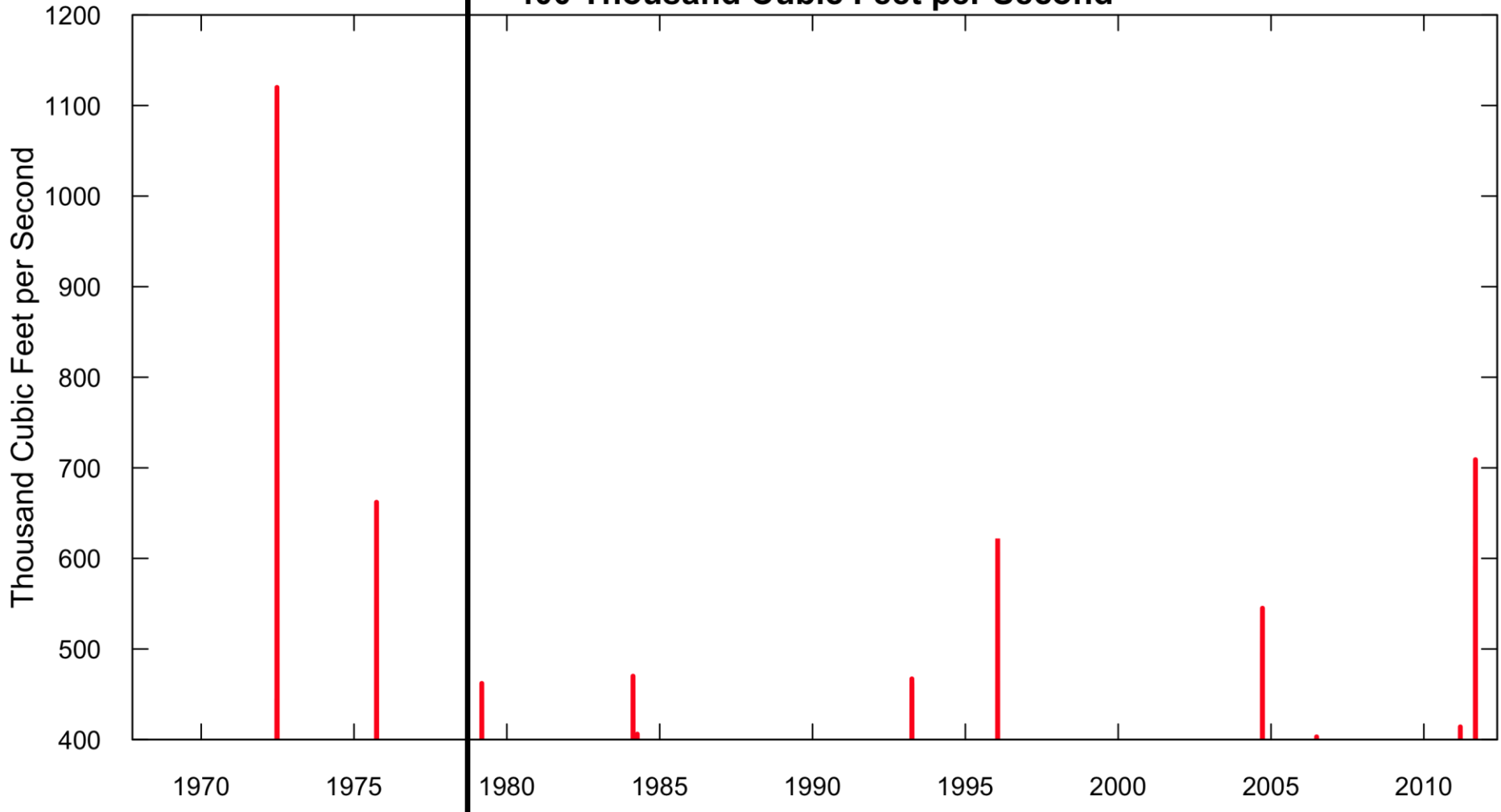
TP flux would increase 70%

SS flux would increase 250%

How unusual was the Tropical Storm Lee event?

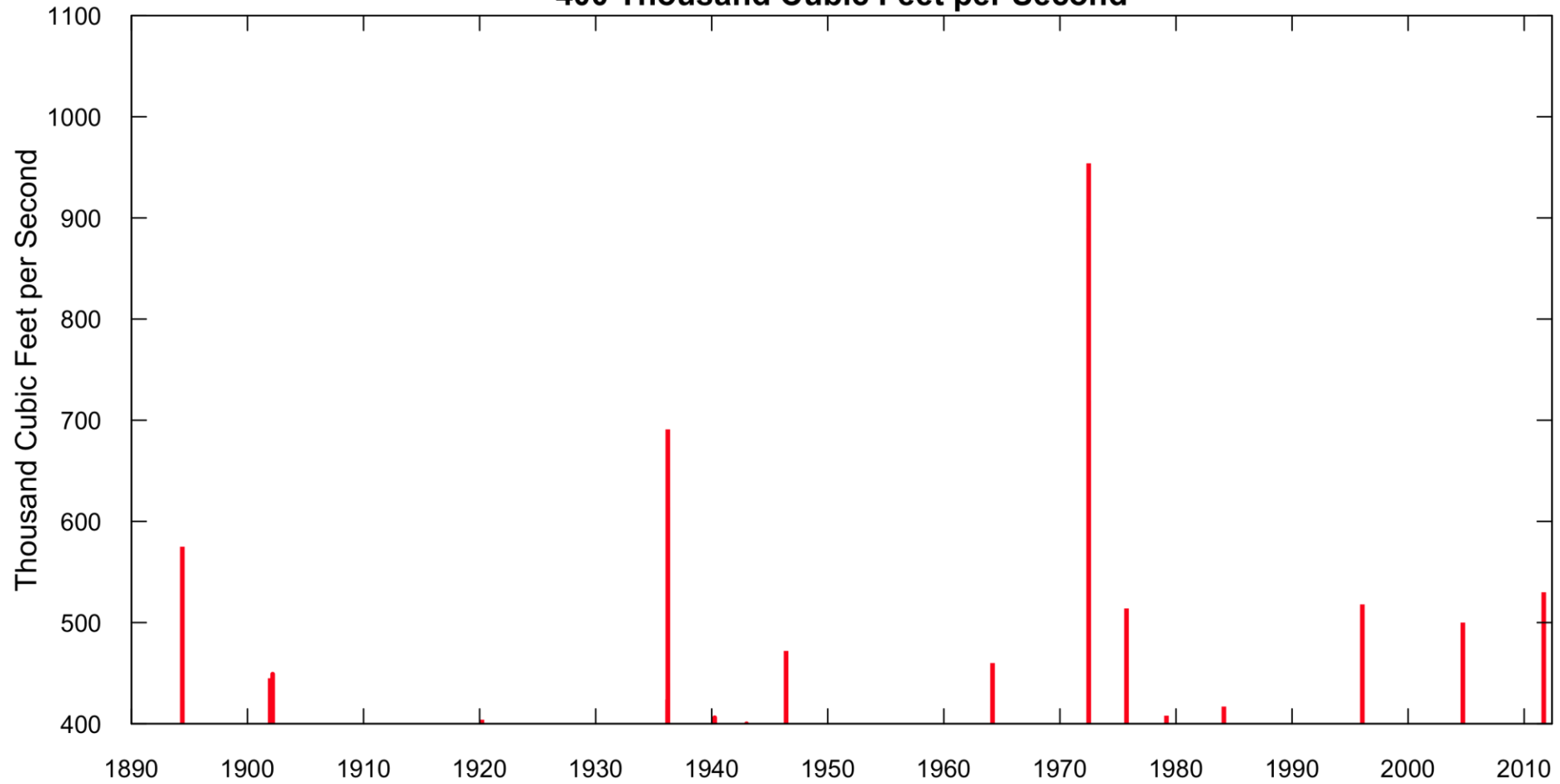
**Pre-water
quality
record**

**Susquehanna River at Conowingo, MD
Daily discharge above a threshold of
400 Thousand Cubic Feet per Second**

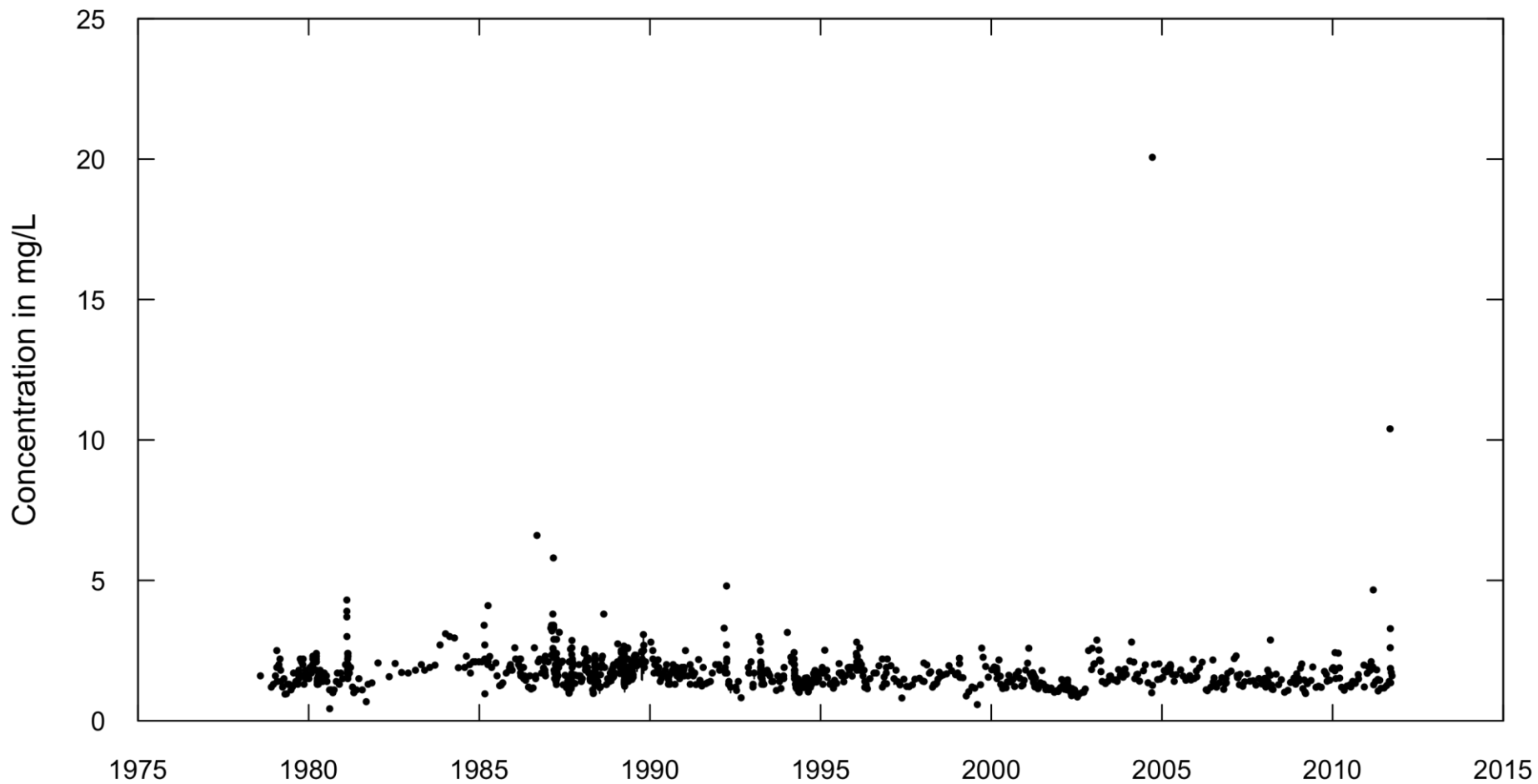


What if we look at the longer record at Harrisburg?

**Susquehanna River at Harrisburg, PA
Daily discharge above a threshold of
400 Thousand Cubic Feet per Second**

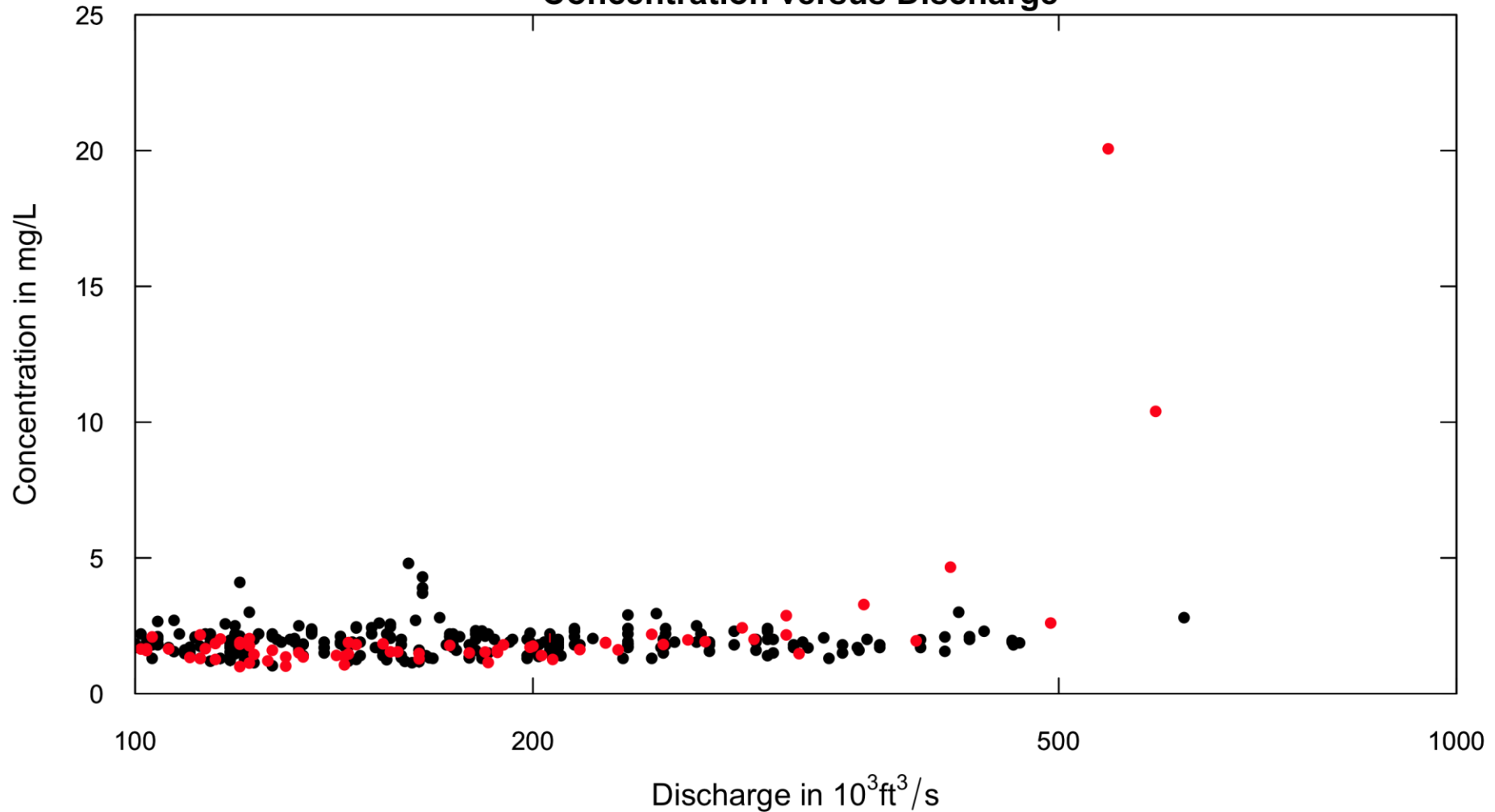


Susquehanna River at Conowingo, MD , Total Nitrogen, as N

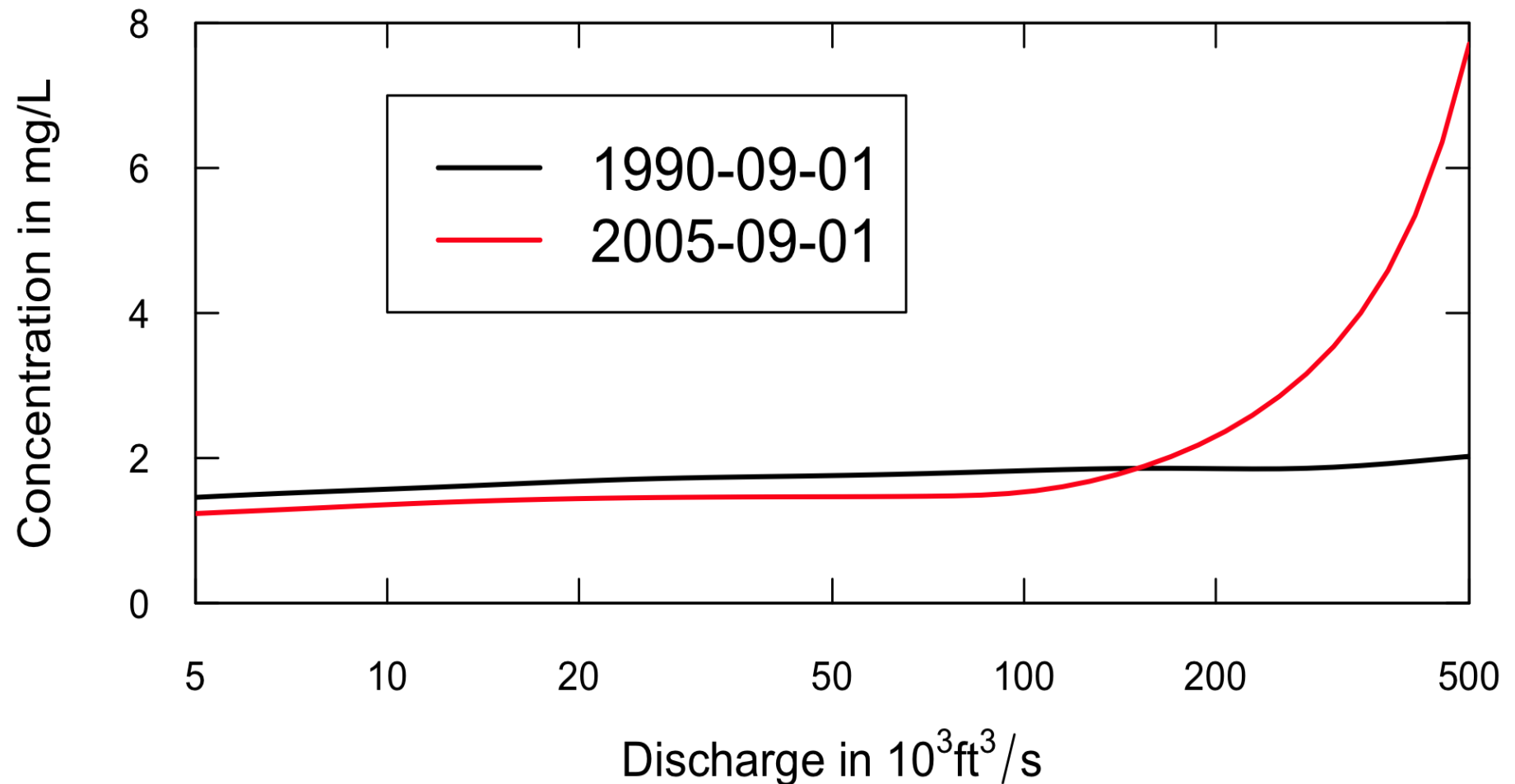


Black dots are pre-2000, Red are since 2000

Susquehanna River at Conowingo, MD
Total Nitrogen, as N
Concentration versus Discharge

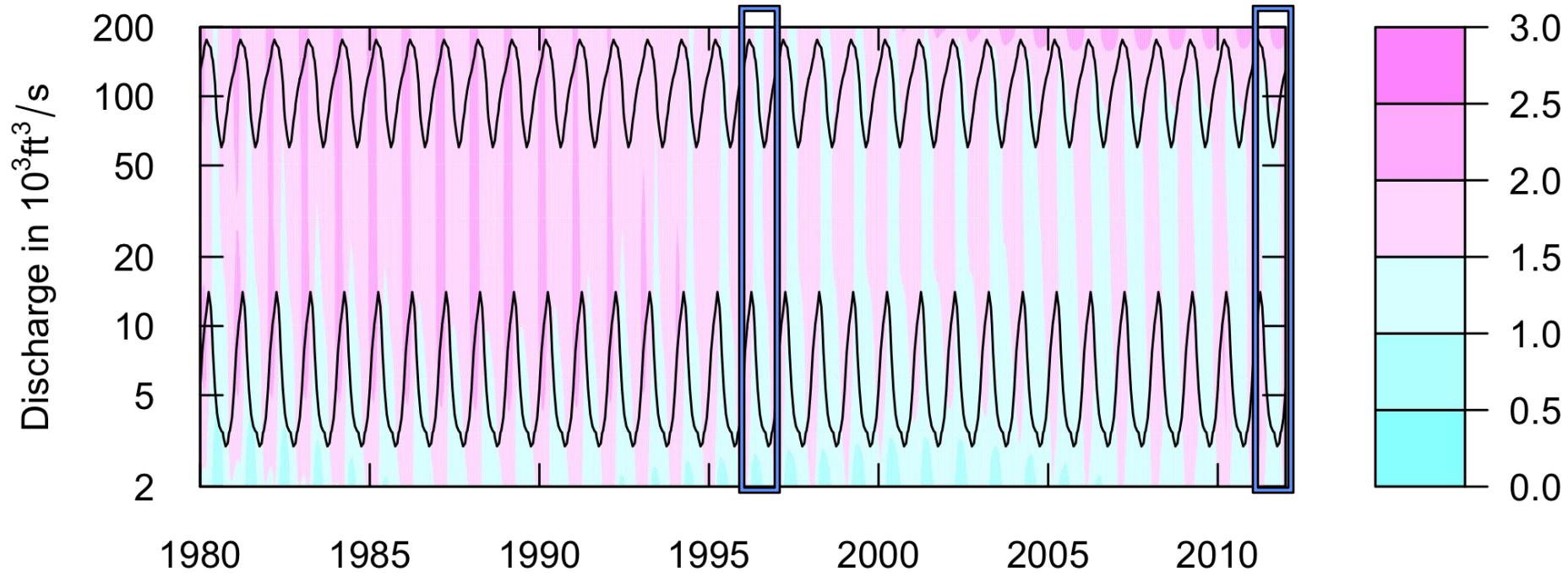


Use the WRTDS (Weighted Regressions on Time, Discharge and Season) method to describe the evolving behavior of Total Nitrogen



Evolving behavior of TN

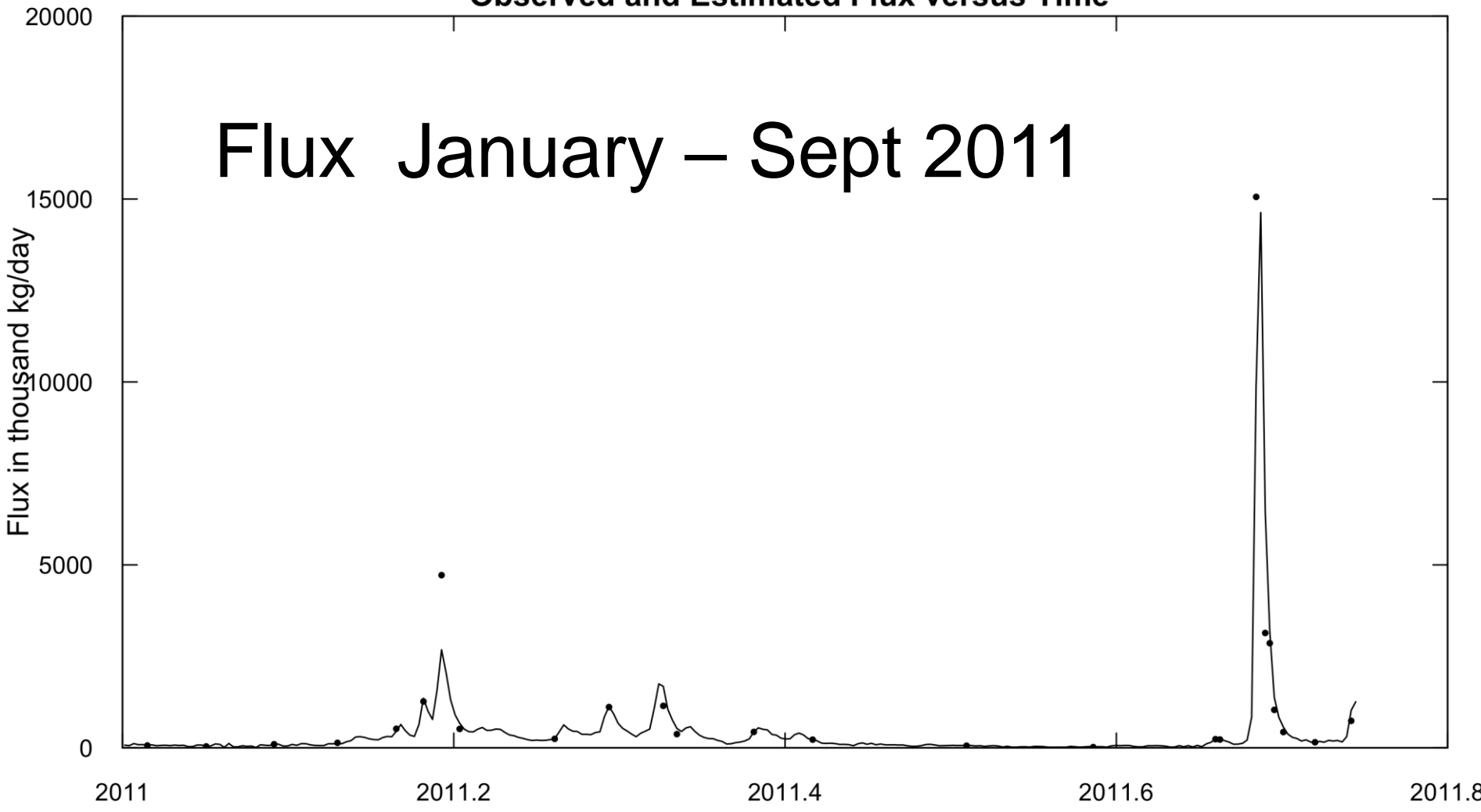
Susquehanna River at Conowingo, MD Total Nitrogen, as N
Estimated Concentration Surface in Color
Black lines are 5 and 95 flow percentiles



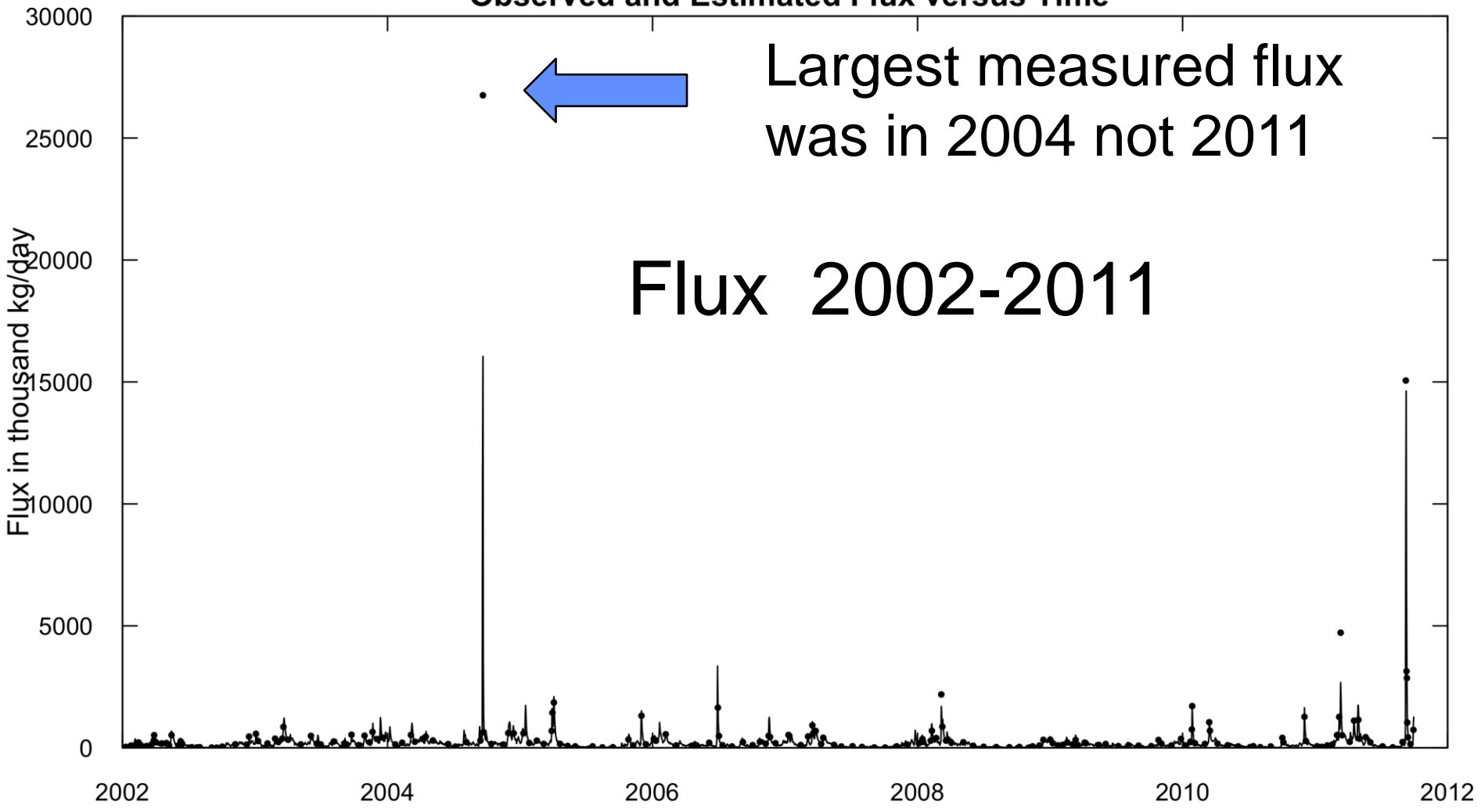
Compute the difference between two years

Susquehanna River at Conowingo, MD
Total Nitrogen, as N
Observed and Estimated Flux versus Time

Flux January – Sept 2011



Susquehanna River at Conowingo, MD
Total Nitrogen, as N
Observed and Estimated Flux versus Time



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 78,600 tons/yr
- The past 34 year average was 69,800 tons/yr

Annual Flux In 10^3 tons/yr

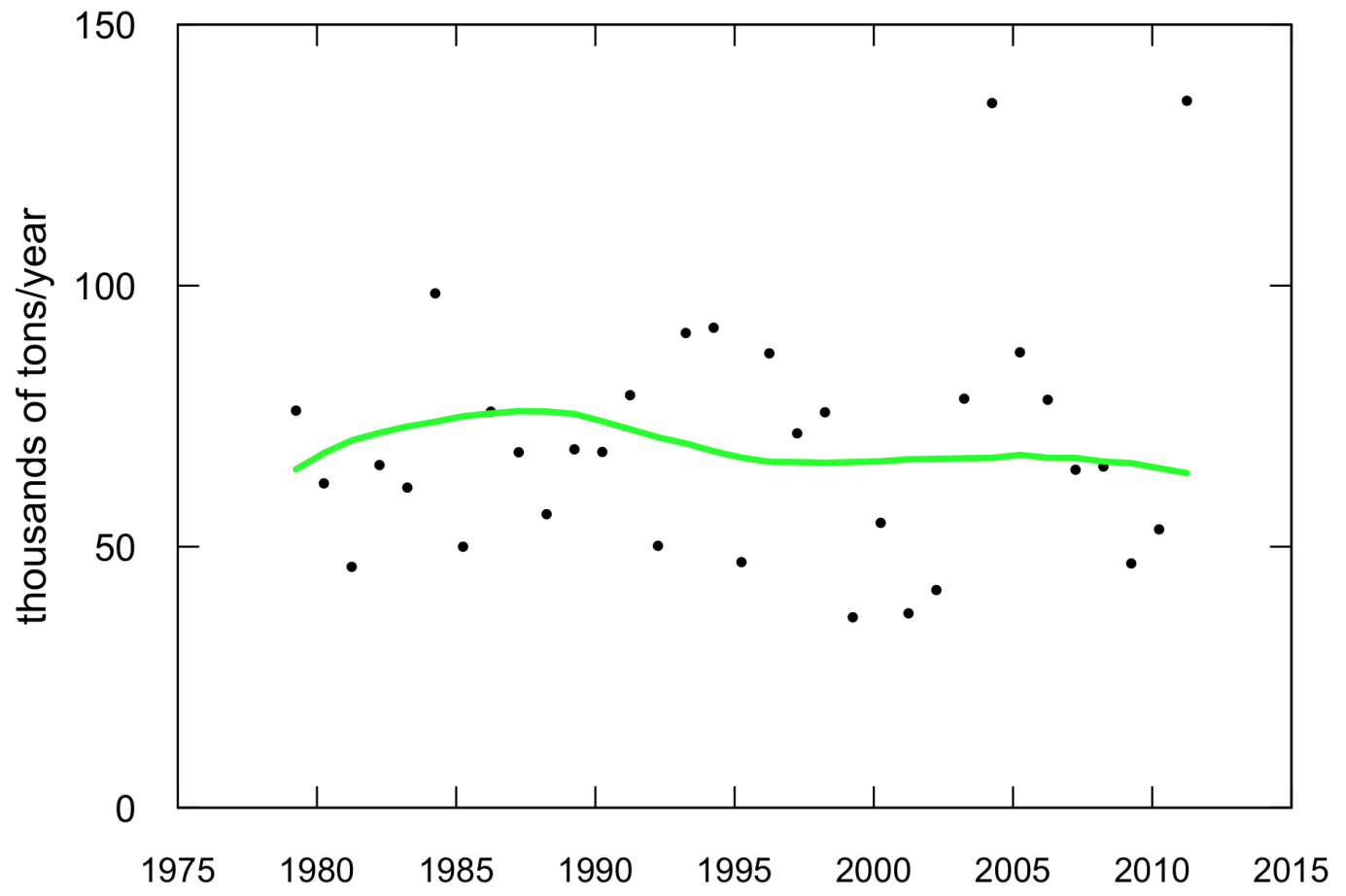
2011 = 135

2010 = 50

2004 = 135

Flow
Normalized
Flux Change
Since 1996
-3.3%

Susquehanna River at Conowingo, MD Total Nitrogen, as N
Water Year
Flux Estimates (dots) & Flow Normalized Flux (line)

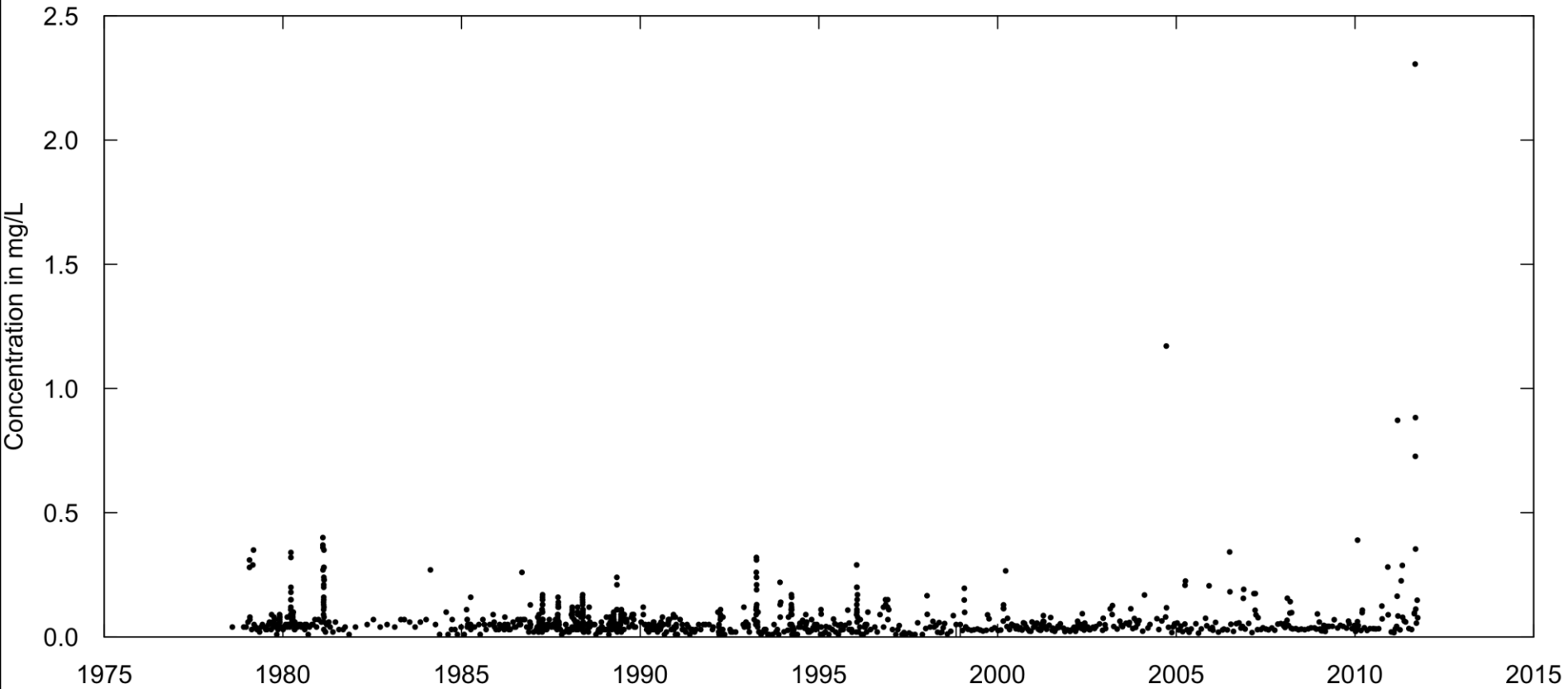


Take home messages: TN

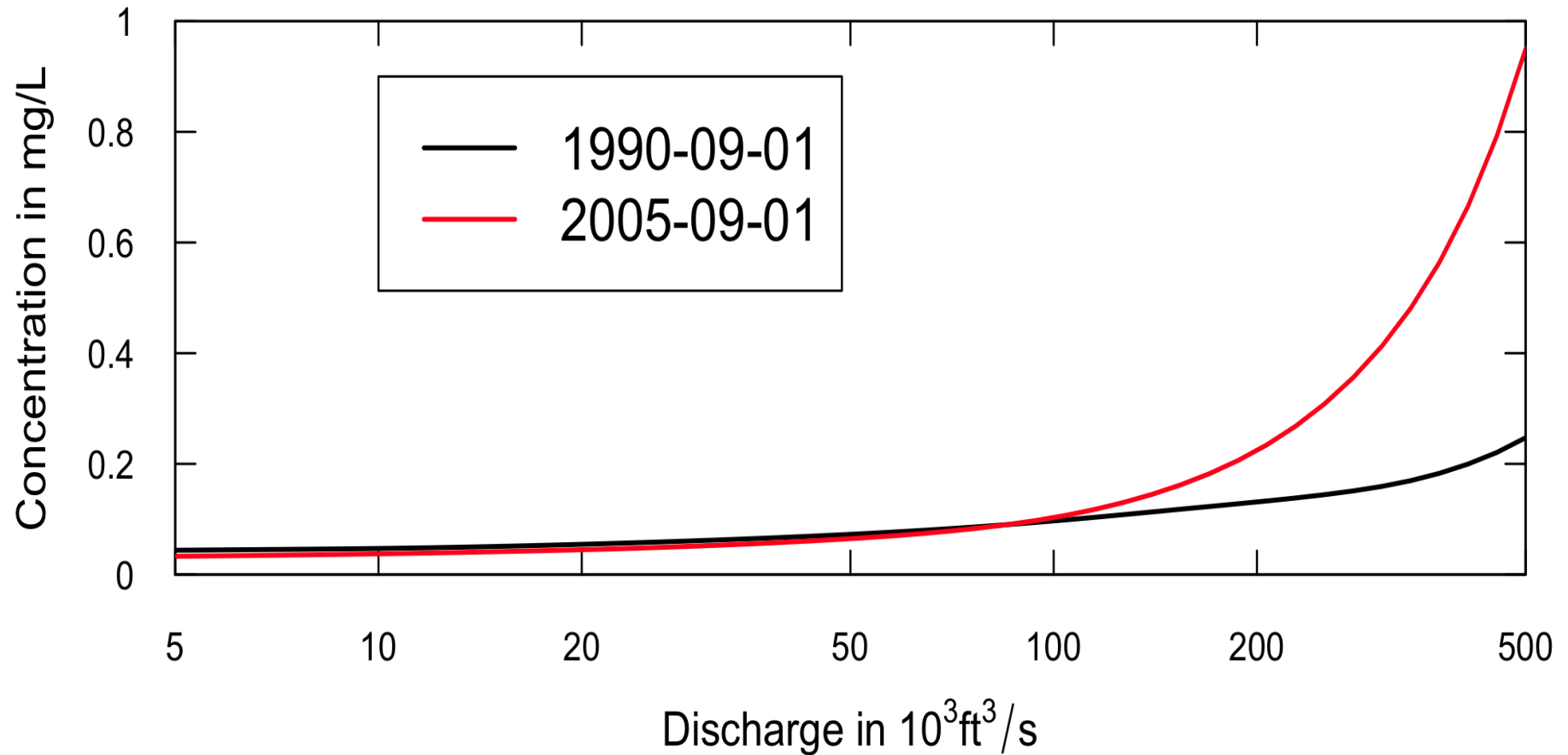
- Total Nitrogen concentrations are continuing to decline at most discharges.
- But at very high flows they are showing some increase.
- Flow-normalized flux continues to fall. Down about 16% since its high in 1987.
- Year to year variability in actual TN flux is increasing (standard deviation about double for 2002-2011 vs. 1979-2001).

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

Susquehanna River at Conowingo, MD , Total Phosphorus

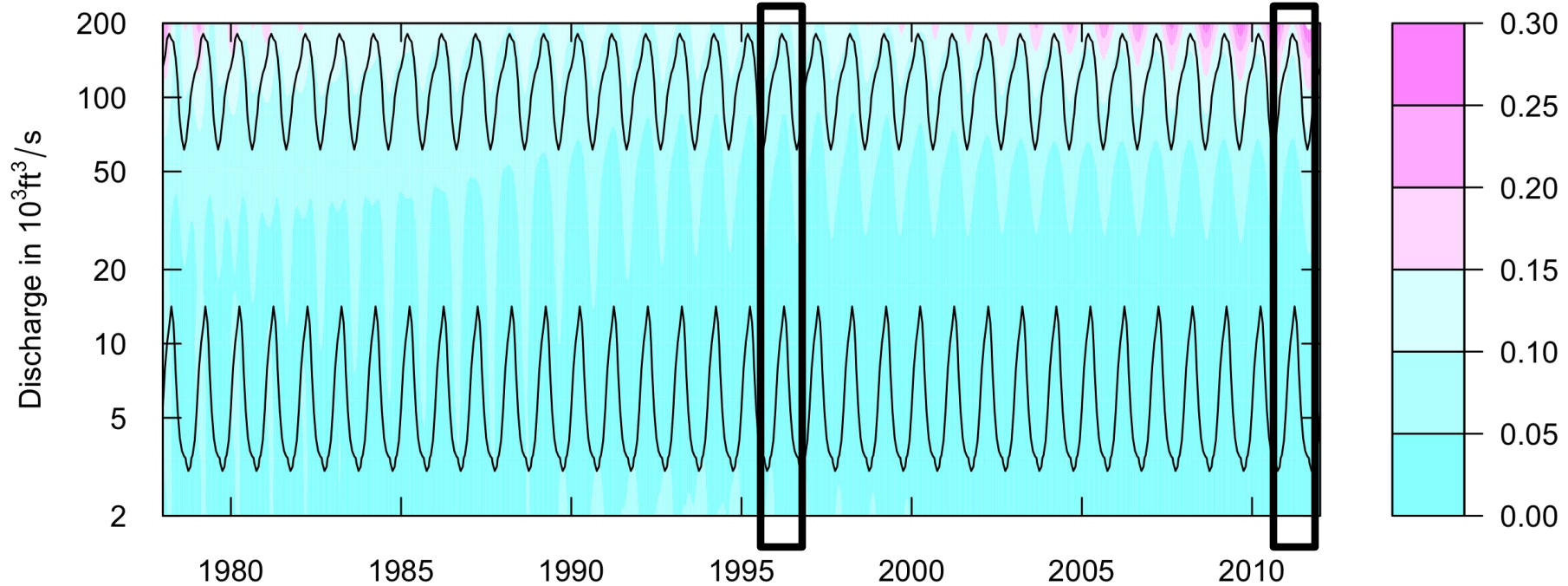


Use the WRTDS model to describe the evolving behavior of Total Phosphorus



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

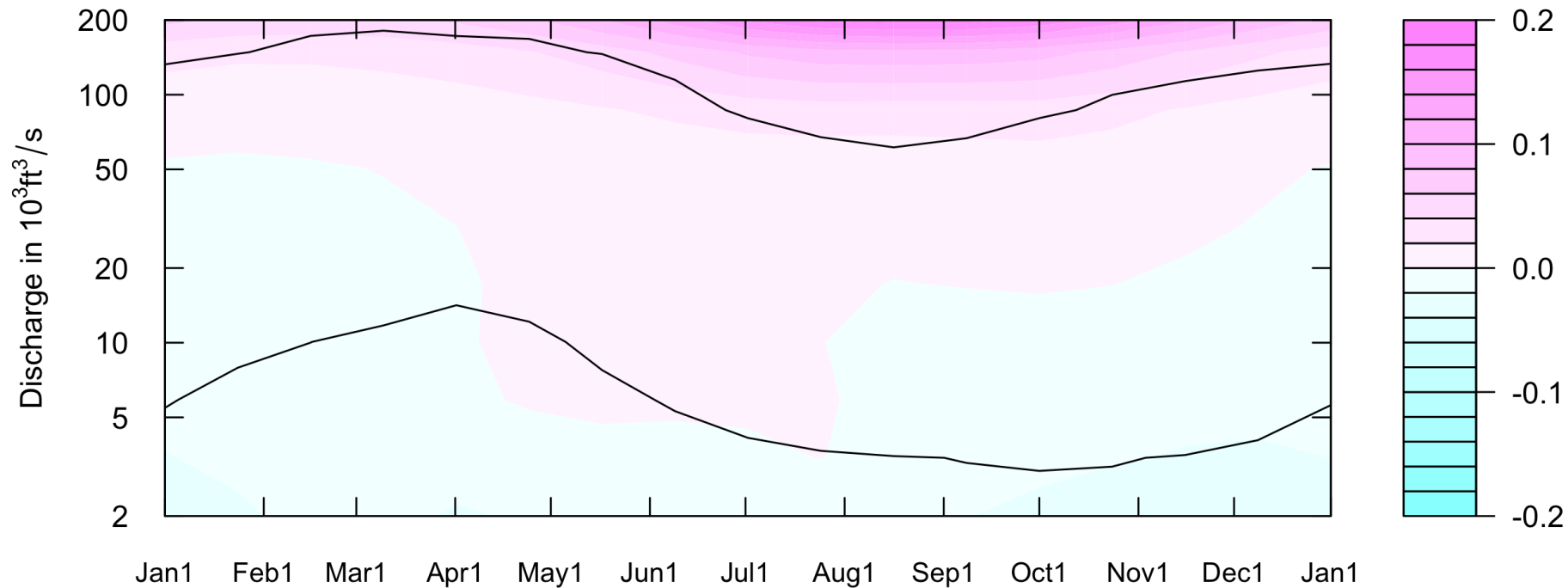
Susquehanna River at Conowingo, MD Total Phosphorus
Estimated Concentration Surface in Color
Black lines are 5 and 95 flow percentiles



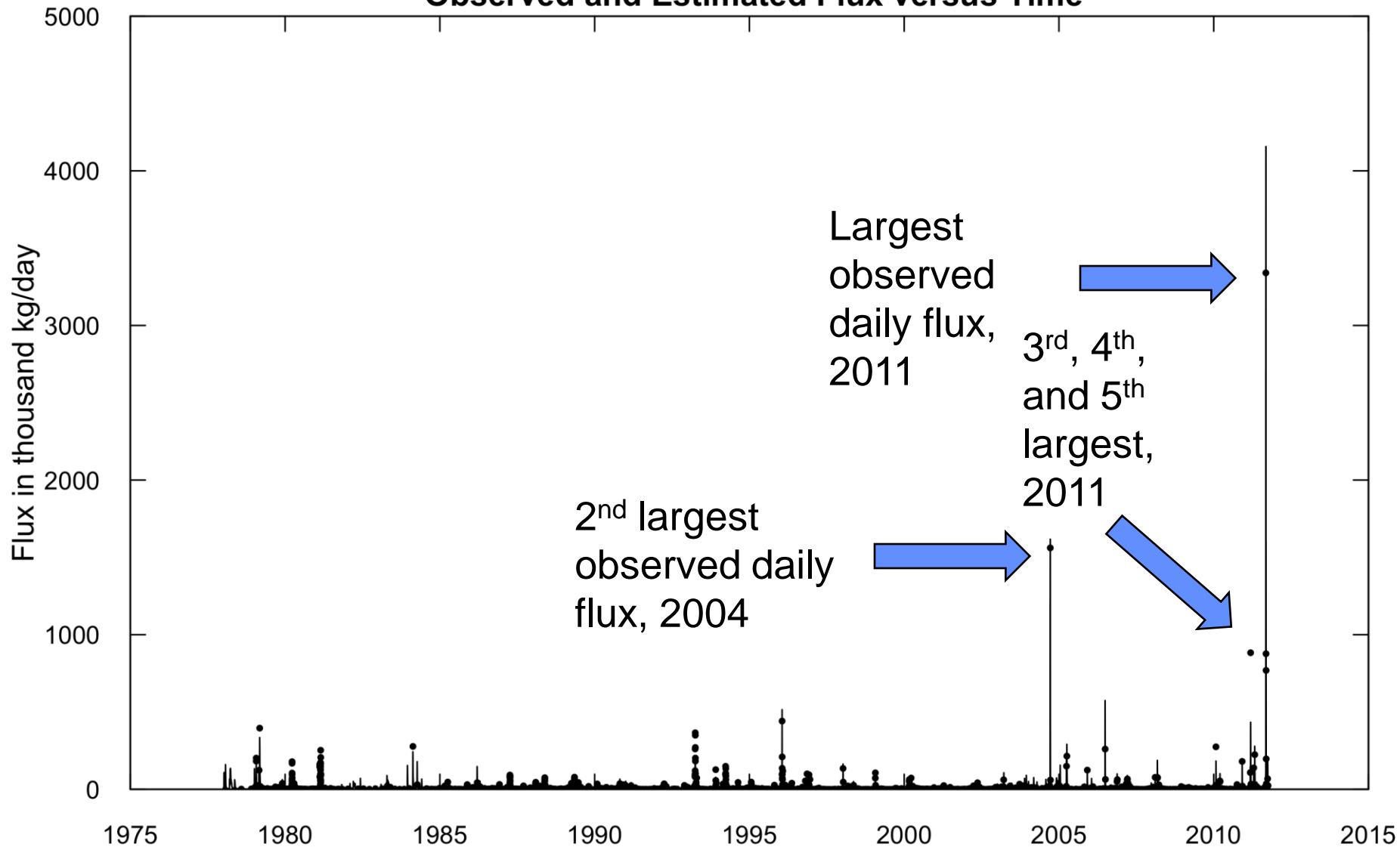
Let's compare 1996 and 2011

- 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

Susquehanna River at Conowingo, MD Total Phosphorus
Estimated Concentration change from 1996 to 2011
Black lines are 5 and 95 flow percentiles



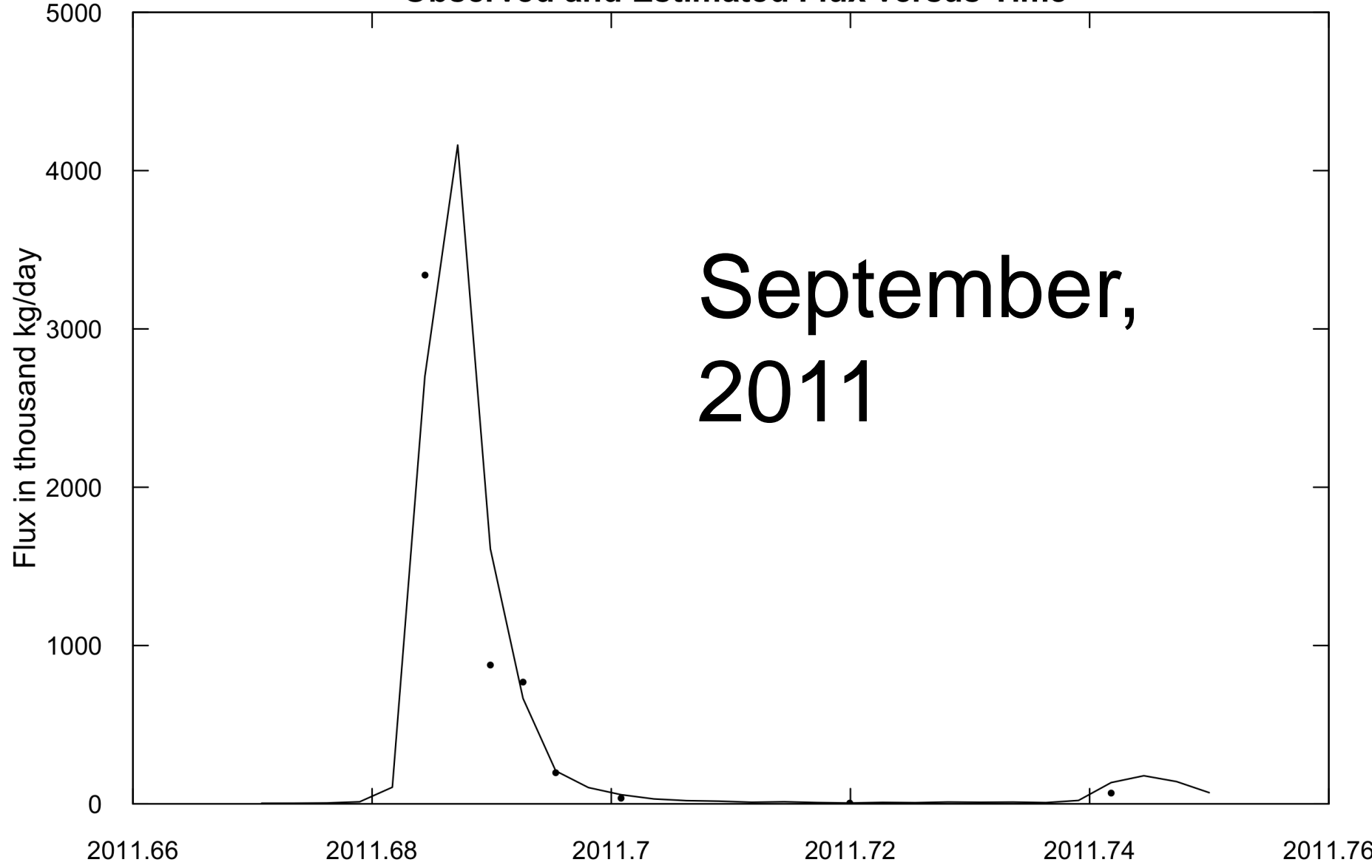
**Susquehanna River at Conowingo, MD
Total Phosphorus
Observed and Estimated Flux versus Time**



Susquehanna River at Conowingo, MD

Total Phosphorus

Observed and Estimated Flux versus Time



September,
2011

Total Phosphorus 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

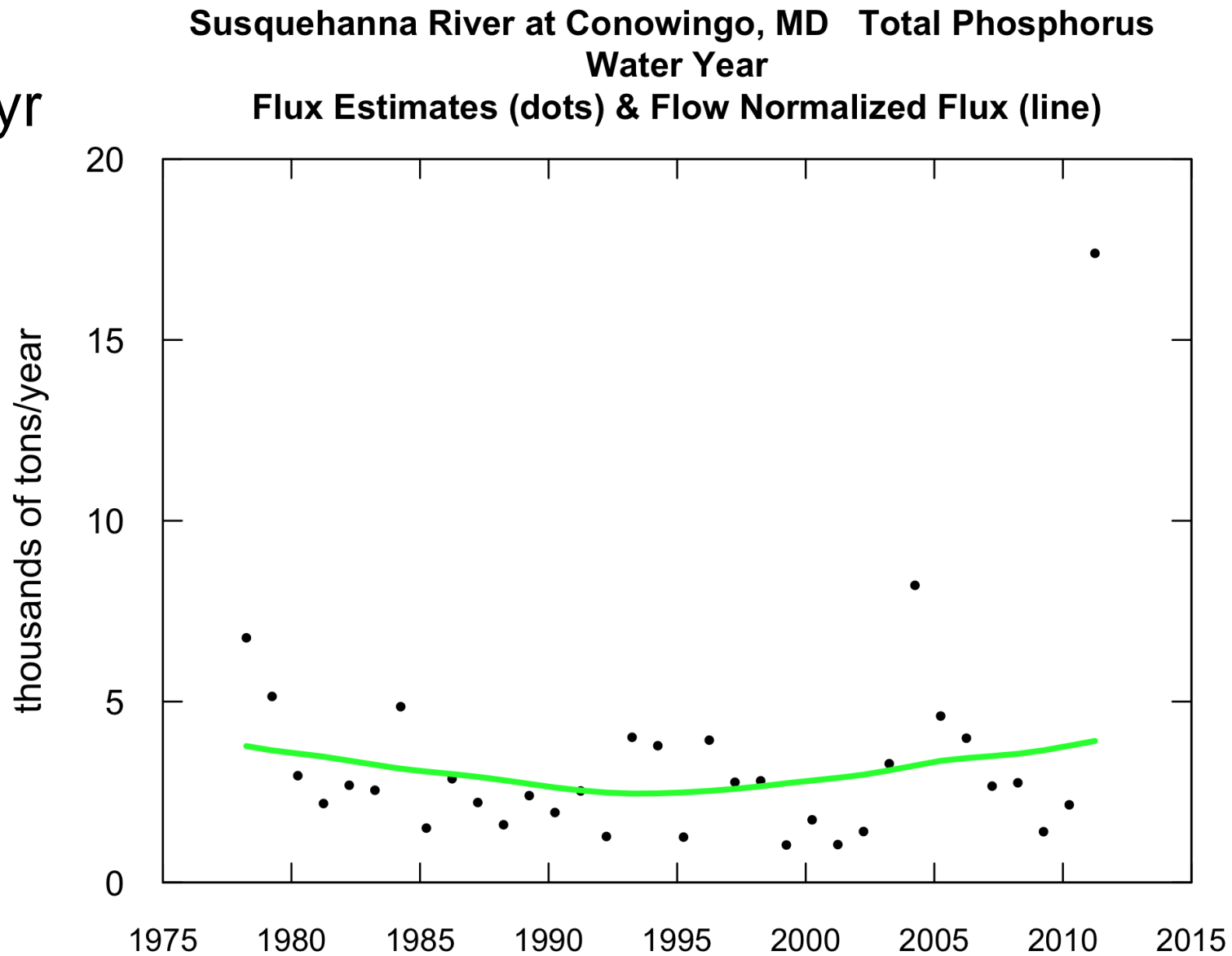
2011=17

2010= 2

2004= 8

Flow
Normalized
Flux

Up 55%
Since 1996

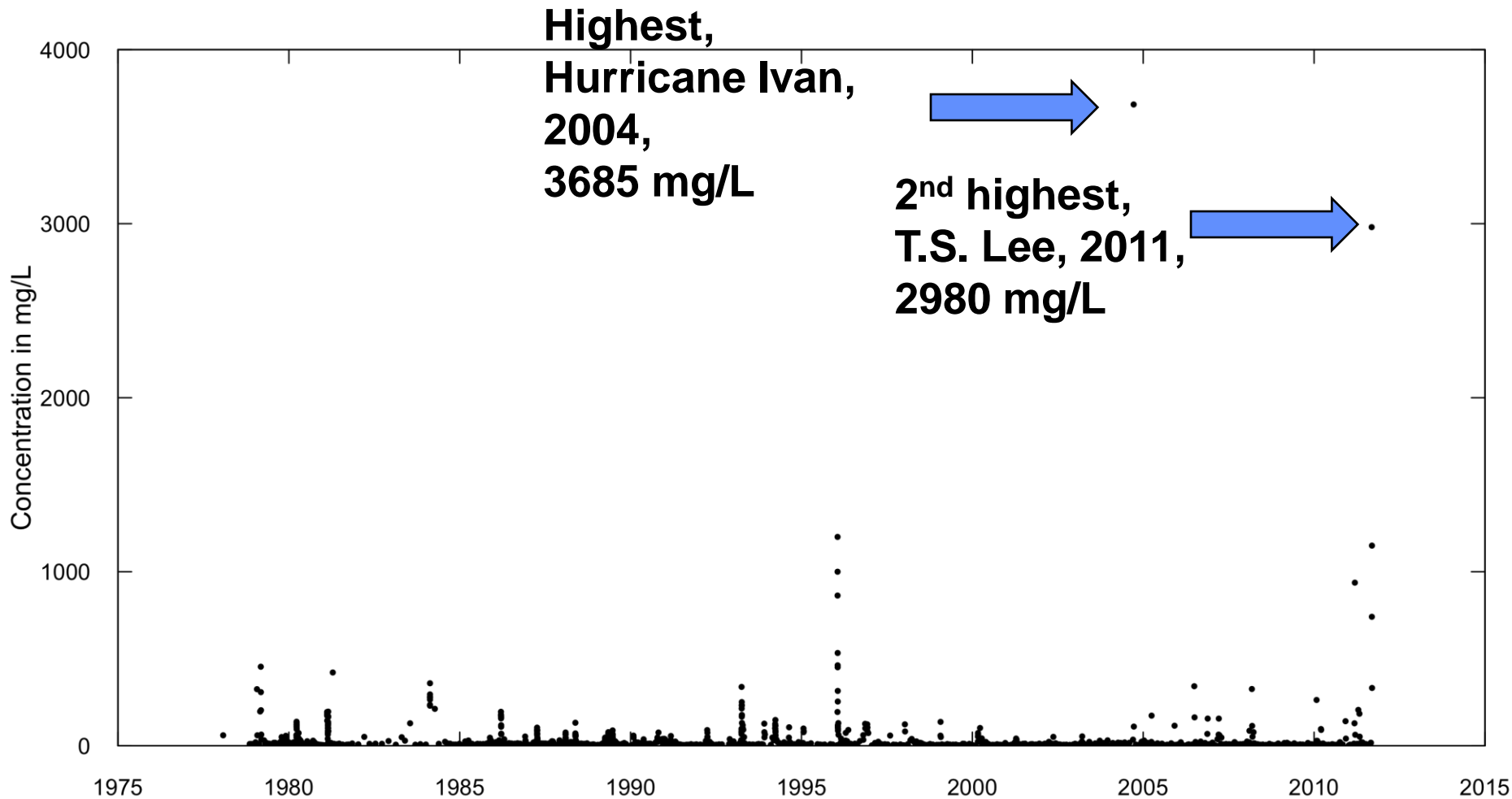


Take home messages about TP

- 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 Reservoir

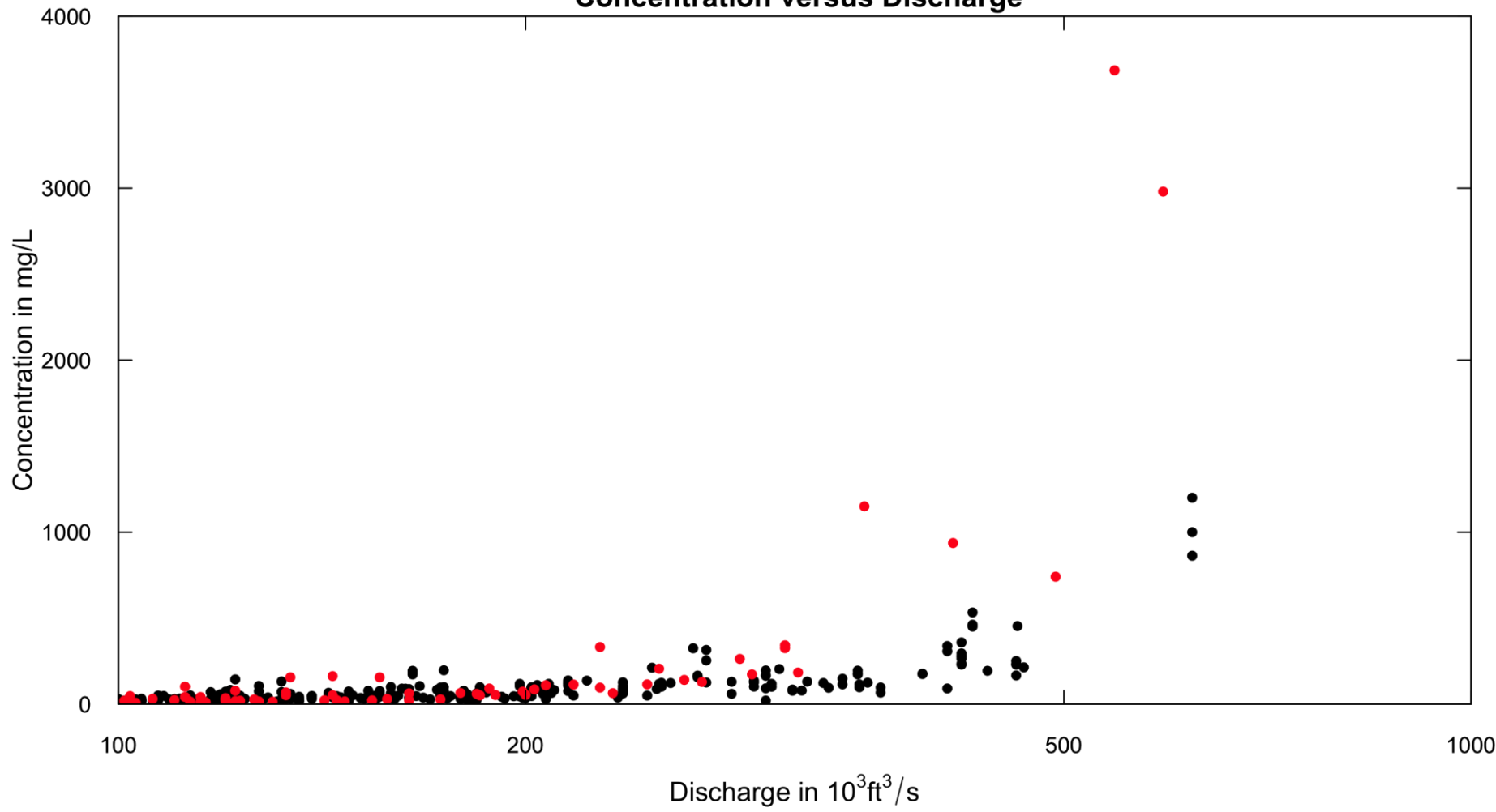
Suspended Sediment

Susquehanna River at Conowingo, MD , Suspended Sediment

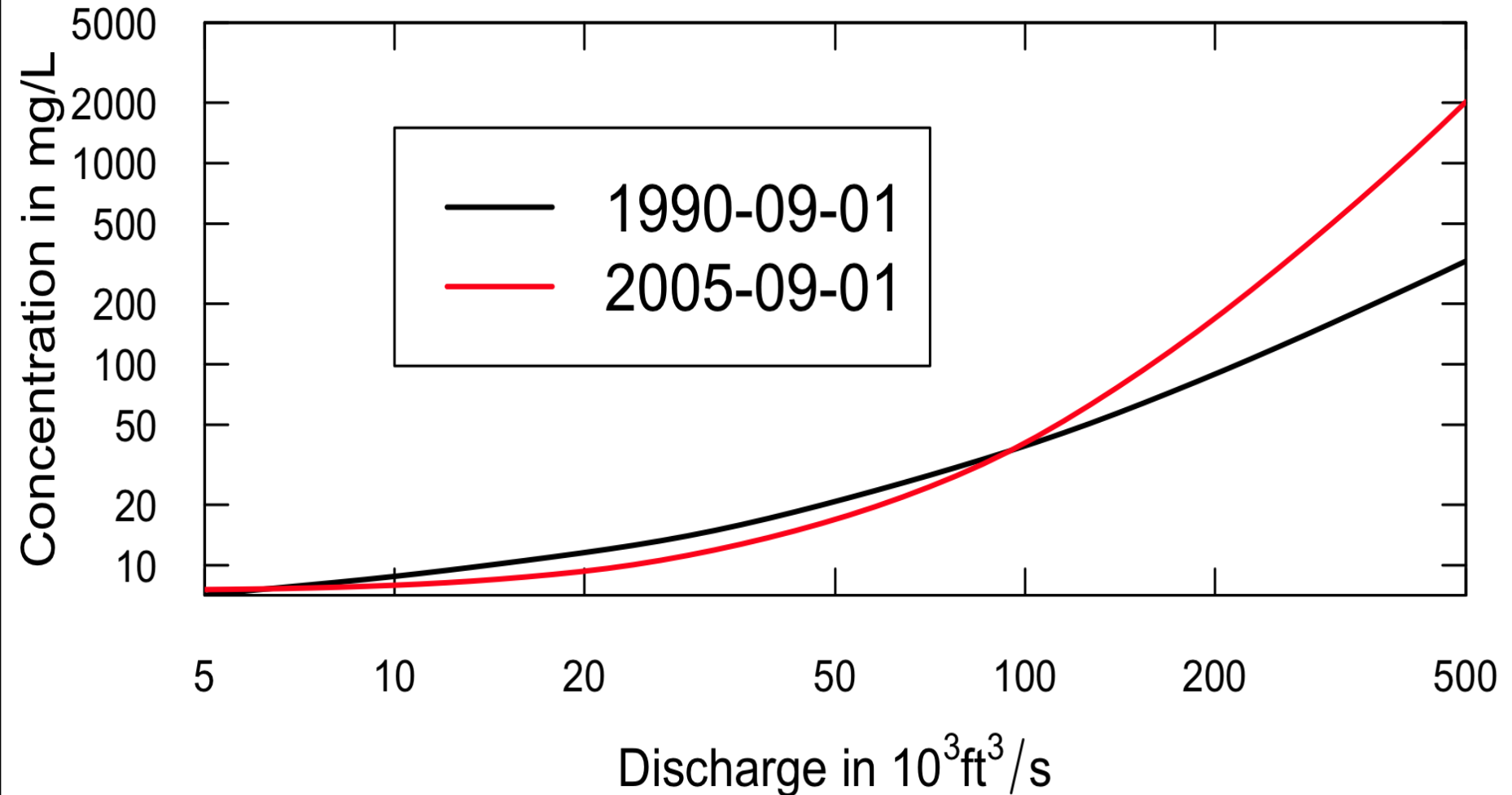


Black dots are pre-2000, Red are since 2000

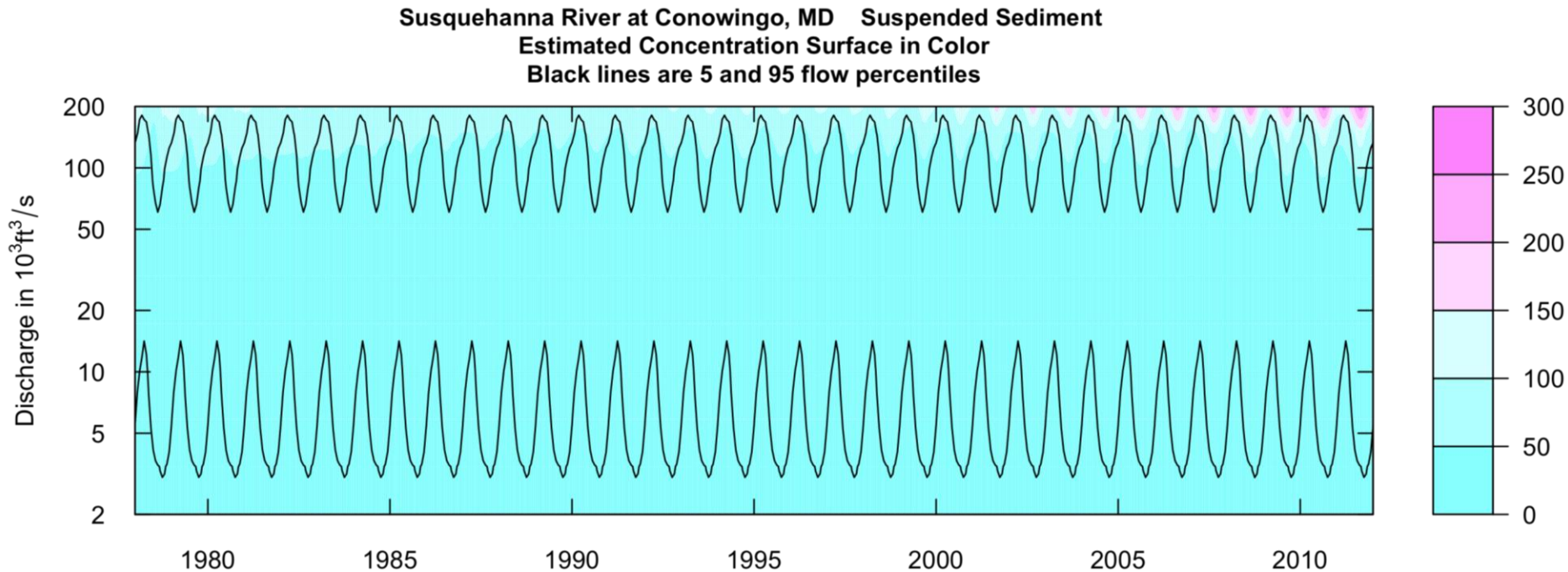
Susquehanna River at Conowingo, MD
Suspended Sediment
Concentration versus Discharge



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



Evolving behavior of Suspended Sediment

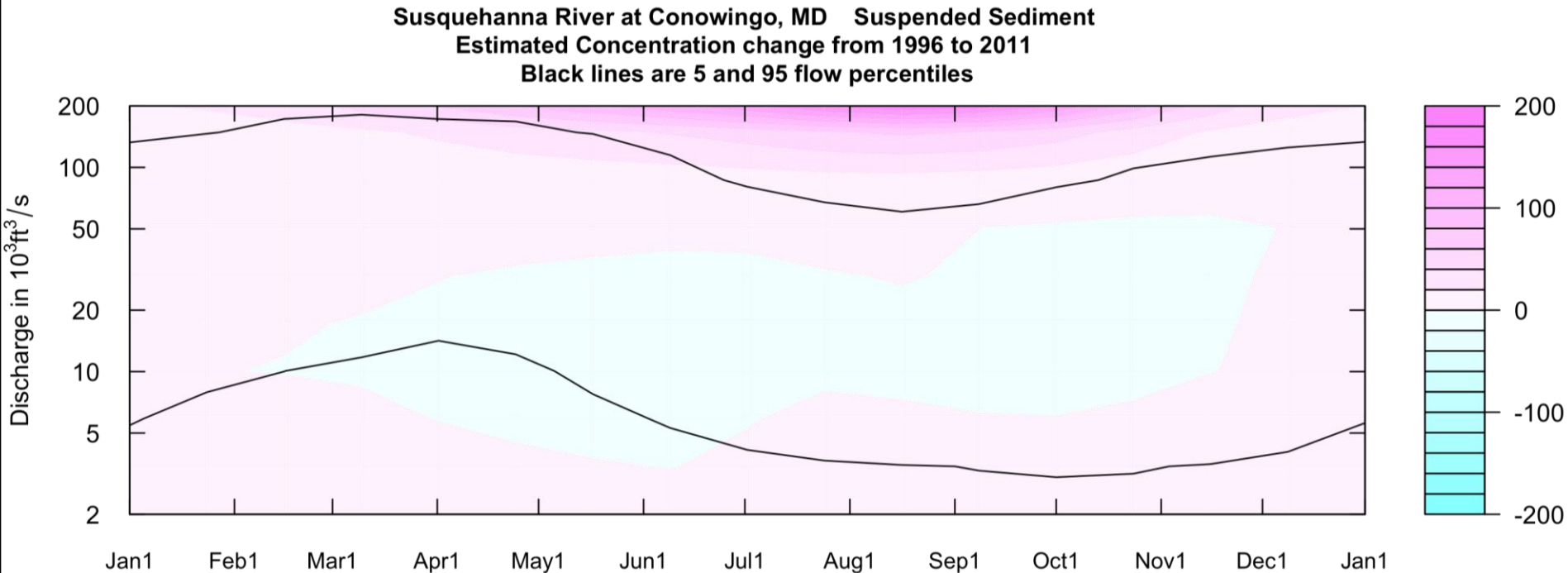


Very difficult to define:

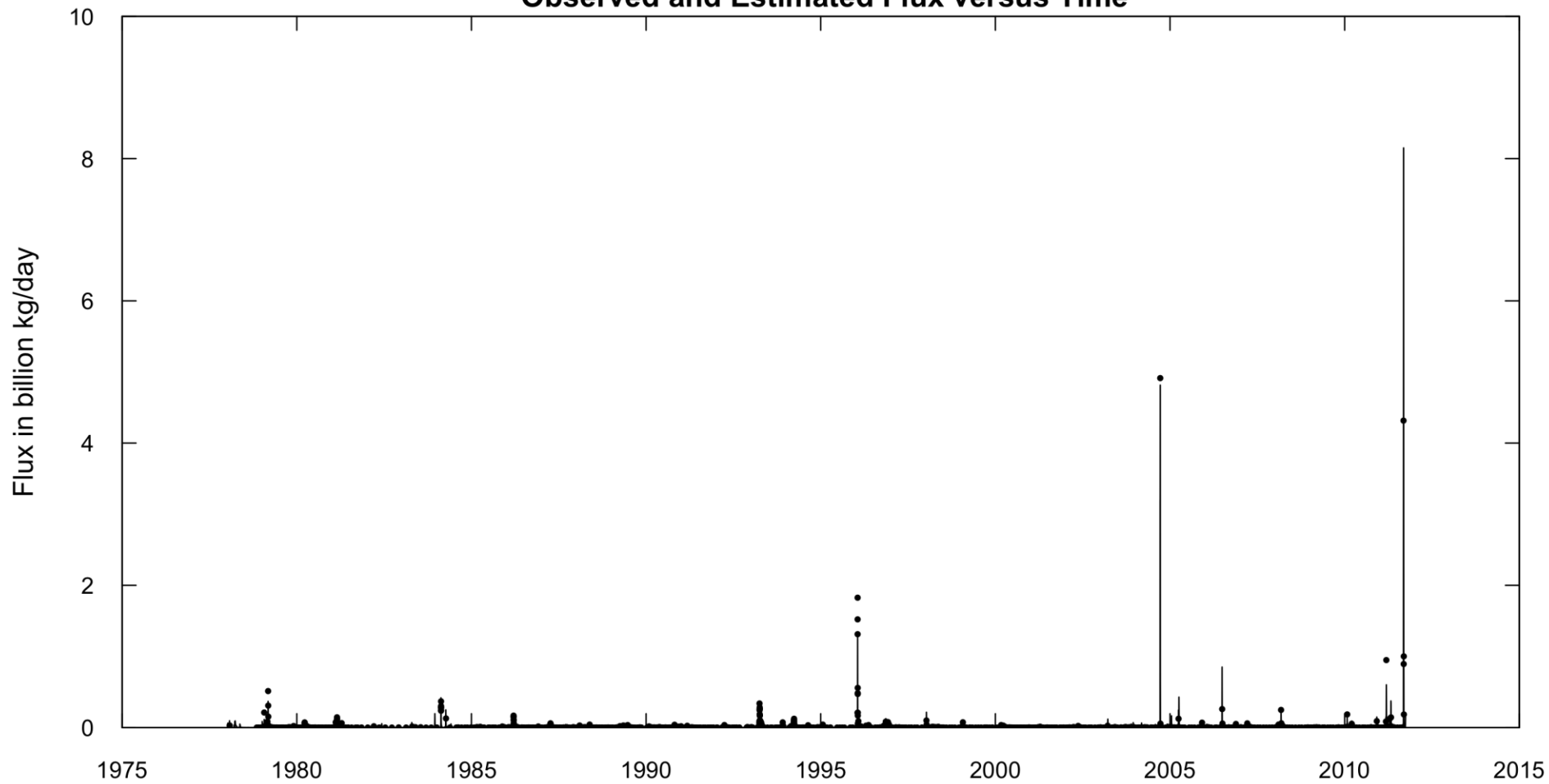
So much depends on a few rare events

Little to no change at most discharges and times of year

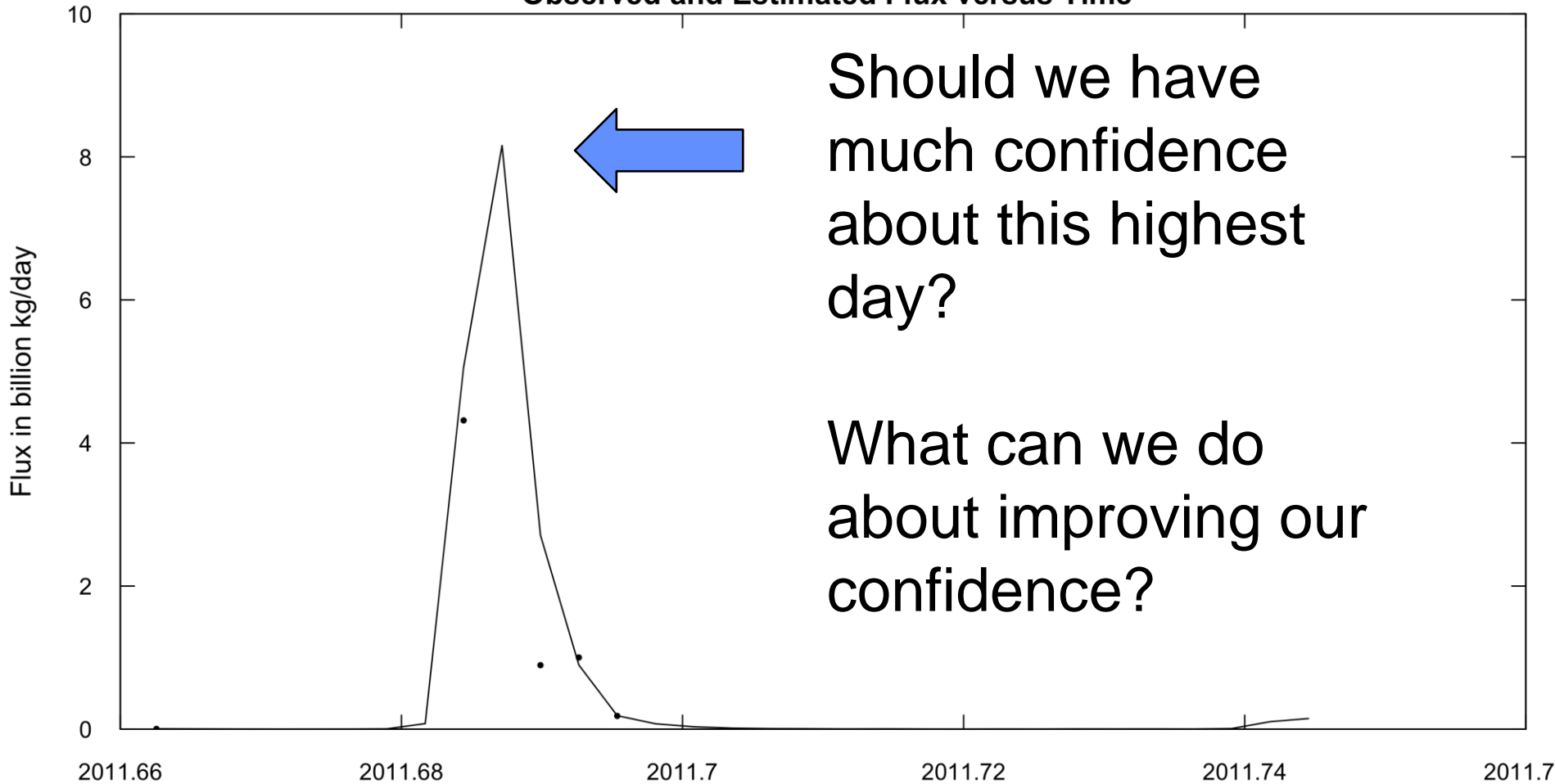
Except, large increases above 100,000 cfs



**Susquehanna River at Conowingo, MD
Suspended Sediment
Observed and Estimated Flux versus Time**



Susquehanna River at Conowingo, MD
Suspended Sediment
Observed and Estimated Flux versus Time



Should we have
much confidence
about this highest
day?

What can we do
about improving our
confidence?

Suspended sediment flux estimates using WRTDS

- T.S. Lee flux about 19 million tons
- The 2011 water year 24 million tons
- The past decade average was 4.8 million tons
- The past 34 year average was 2.5 million tons

Annual Flux in 10^6 tons/yr

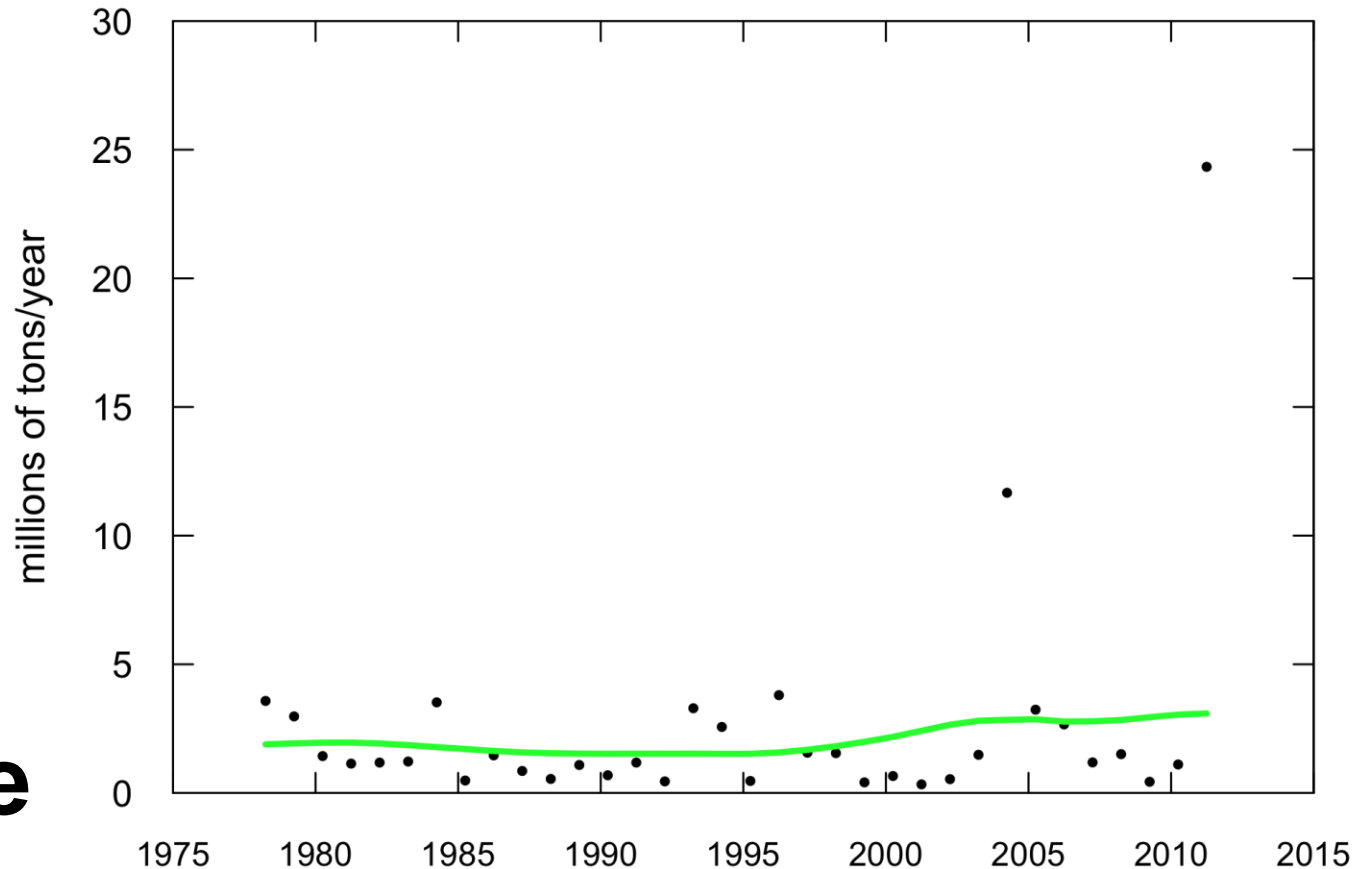
2011 = 24

2010 = 1

2004 = 12

**Flow
Normalized
Flux Change
Up 97%
Since 1996**

Susquehanna River at Conowingo, MD Suspended Sediment
Water Year
Flux Estimates (dots) & Flow Normalized Flux (line)



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's 1998 prediction of change in flux	Observed change in flux since 1996
TN	+2%	-3.3%
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 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 and SS inputs to the Bay.

Science needs

- Continued data collection upstream and downstream of reservoirs
- Improved temporal resolution of monitoring during high flow events
- Coupled mass balance analysis of inputs, change in storage, and outputs
- Measurements and simulation models of scour and deposition processes