Comparison of two Regression-Based Approaches for Determining Nutrient and Sediment Loads and Trends in the Chesapeake Bay Watershed

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Conclusions

- The USGS has a new method for quantifying trends in nutrient and sediment loads.
- The new trend in load information:
  - Improves the relevancy of the information we provide to our local, state, and federal partners
  - Enhances the existing information for trend in concentration
  - Greatest reductions in loads is associated with dissolved constituents (Nitrate and Orthophosphorus)
  - Trends in TN, TP, and SED loads are primarily indicating change that is minimal or degrading
- Trend in load and trend in concentration together provide a more complete understanding of how changes in watershed characteristics (e.g. land use) and the implementation of BMPs influence resulting water-quality conditions.

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Paradigm Shift for Trend Reporting

- Historically, long-term changes in riverine water-quality conditions were represented as a trend in concentration.
- We now have the analytical ability to represent long-term changes in water-quality conditions as both trends in concentration and load.
- This shift allows for a more holistic view of changes in water-quality conditions and better aligns with nutrient and sediment reduction goals.

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Trend in Concentration vs. Trend in Load

- Trend in concentration provides information on how BMPs have influenced in-stream concentrations at a given point.
  - Great information for local water quality condition
  - Determined based on patterns in the majority of observed water-quality data (often low to intermediate Q); most influenced by baseflow, groundwater, and point-source inputs

- Trend in load *(concentration x discharge)* provides information on how BMPs have influenced the downstream transport of nutrients and sediment.
  - Relevant for managers trying to reduce the mass delivered to the tidal portions of the Bay (TMDL)
  - Determined based on patterns in the highest load samples (~10 percent of the observations); most influenced by wet-weather inputs (nonpoint sources)

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Trends in Flow-Adjusted Concentration

Example: Total nitrogen for the period 1985 to 2011

ESTIMATOR is the approach used to determine trends in flow-adjusted concentration across nontidal network.

Problem with the trend in flow-adjusted concentration is that it has been/is commonly used as a surrogate for trend in load.

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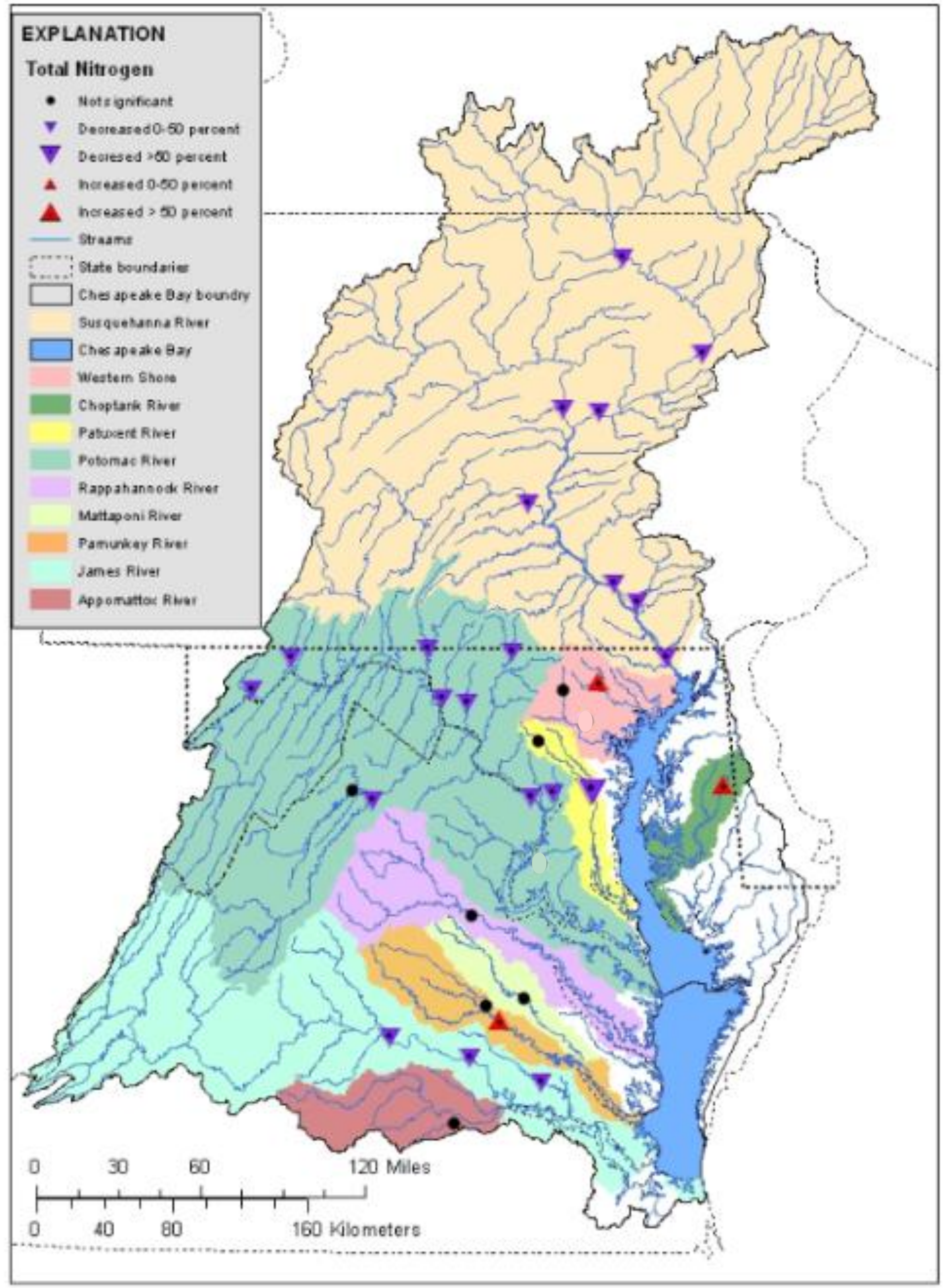
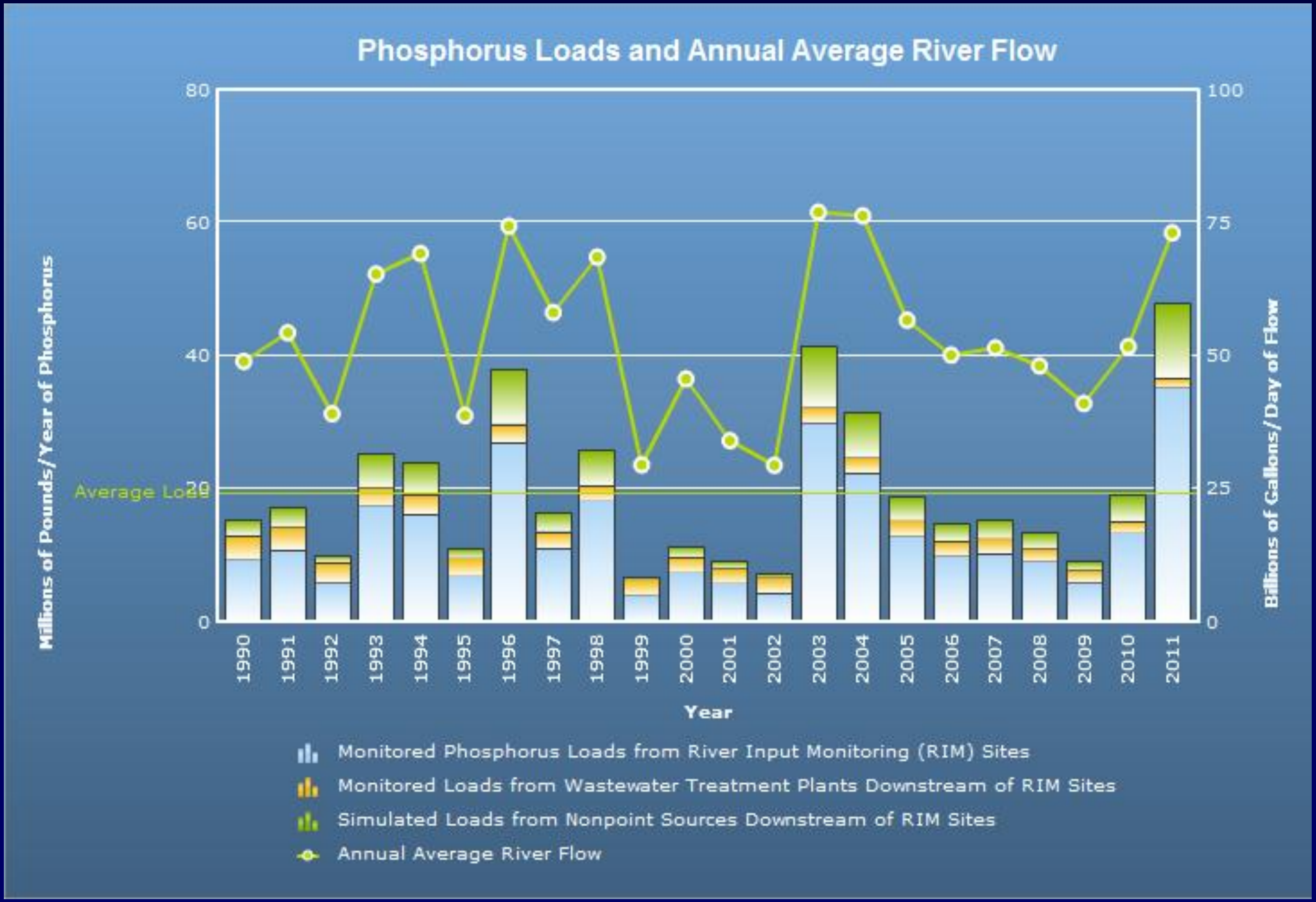


Flow-adjusted trends for total nitrogen for 31 sites in the Chesapeake Bay Watershed, 1985-2011.

MANAGEMENT CONCERNS

- Can we report a measure of trend in ANNUAL LOAD of nutrients and sediment delivered to the Chesapeake Bay that is indicative of changes in the watershed (e.g. BMPs, land conversion, …) and not influenced by random year-to-year variations in streamflow?



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Chesapeake Bay: River Input Monitoring Stations

Stations:

- Susquehanna
- Potomac
- James
- Rappahannock
- Appomattox
- Pamunkey
- Mattaponi
- Patuxent
- Choptank

Why these stations:

- Greater than 75% of the land area
- Vast majority of the total discharge from the nontidal areas passes these stations
- Robust datasets: nearly 30 years of monitoring with total observations ranging from 600 to 1,400

Constituents:

- Total Nitrogen
- Nitrate
- Total Phosphorus
- Orthophosphorus
- Suspended Sediment

Therefore 9RIM * 5 Constituents = 45 possible analytical combinations

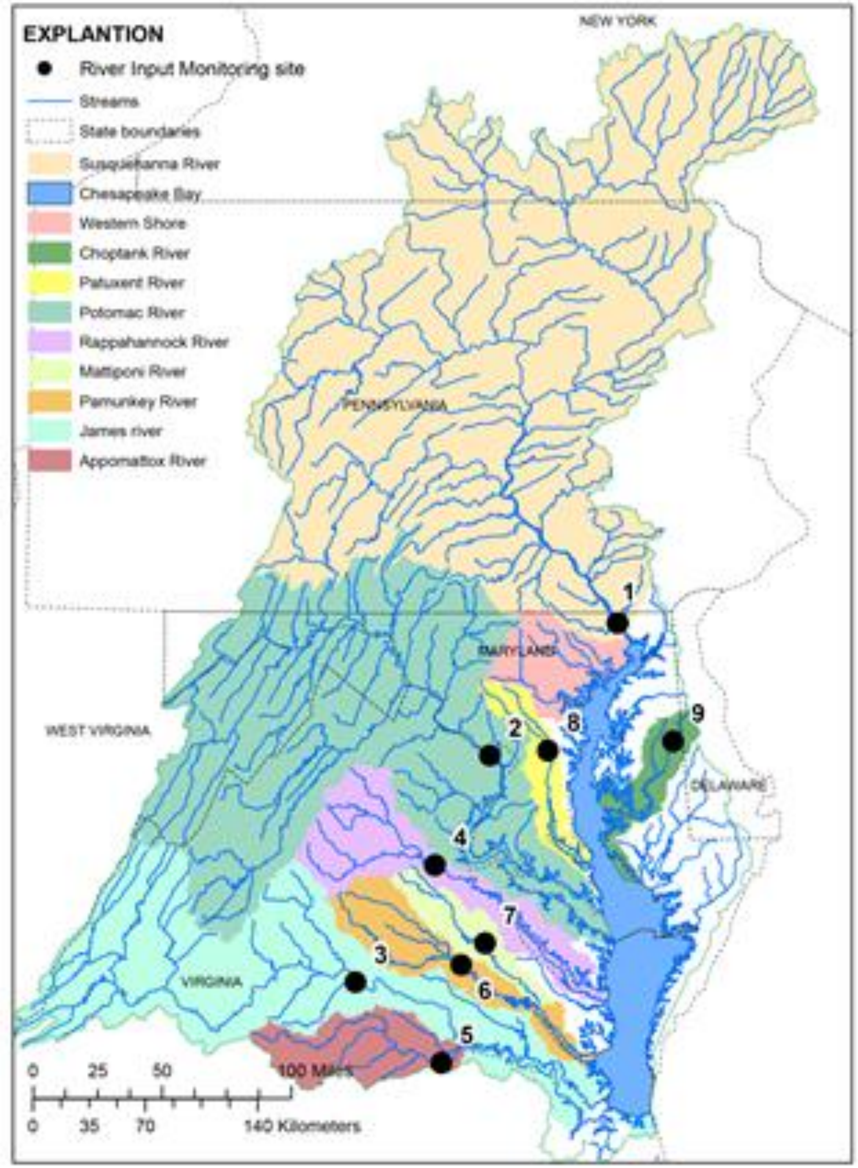

Figure 1. Map showing the location of the 9 River Input Monitoring (RIM) stations in the Chesapeake Bay watershed.

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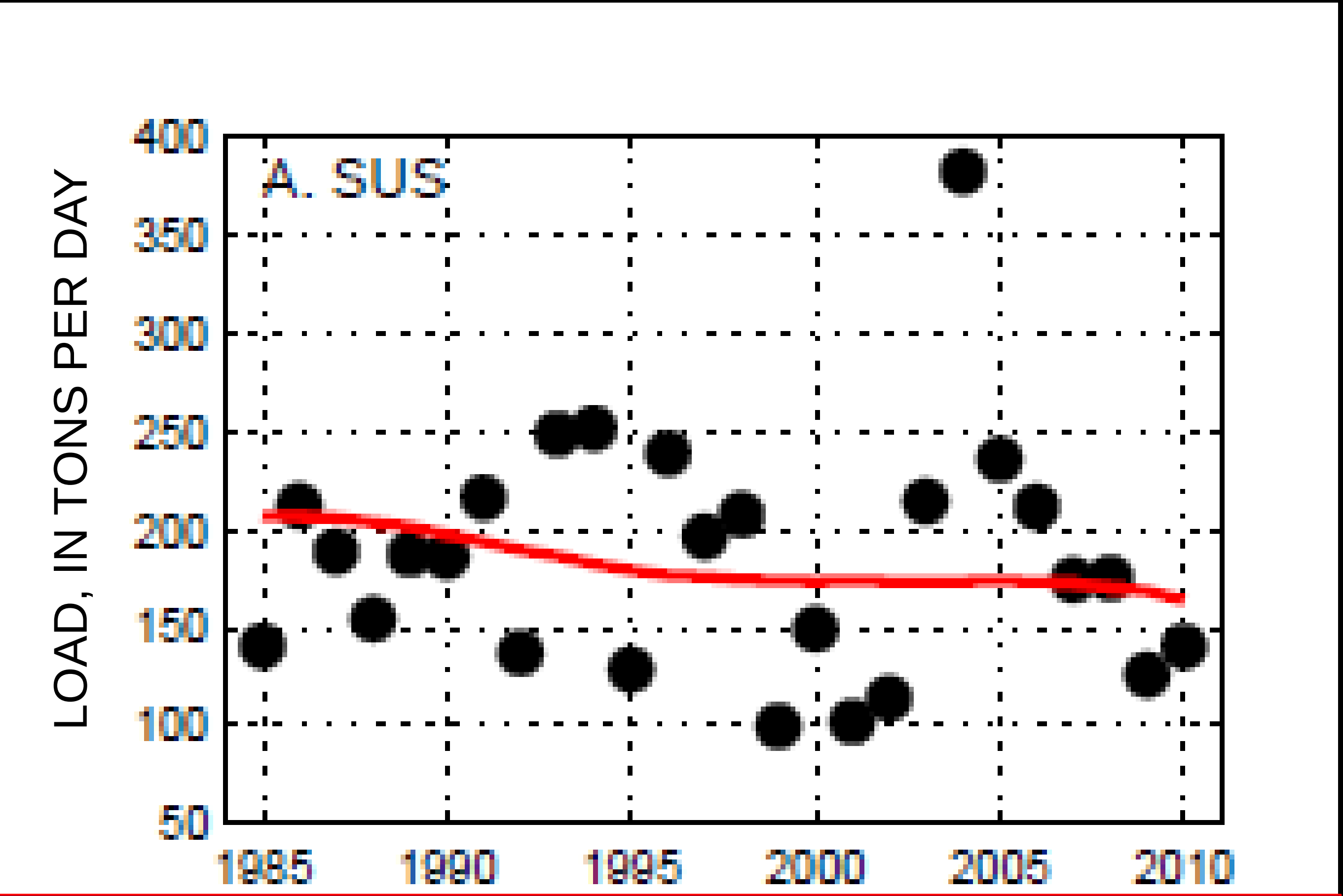
Trends in Total Nitrogen Annual Load

Total Nitrogen Load: Susquehanna (RIM)

- Influence of year-to-year variation in flow

With WRTDS, we now can communicate how annual loads have changed once the year-to-year variation in Q has been removed



Trend in load for:
1985 to 2010 = Total reduction of 21%
2001 to 2010 = Total reduction of 5.8%

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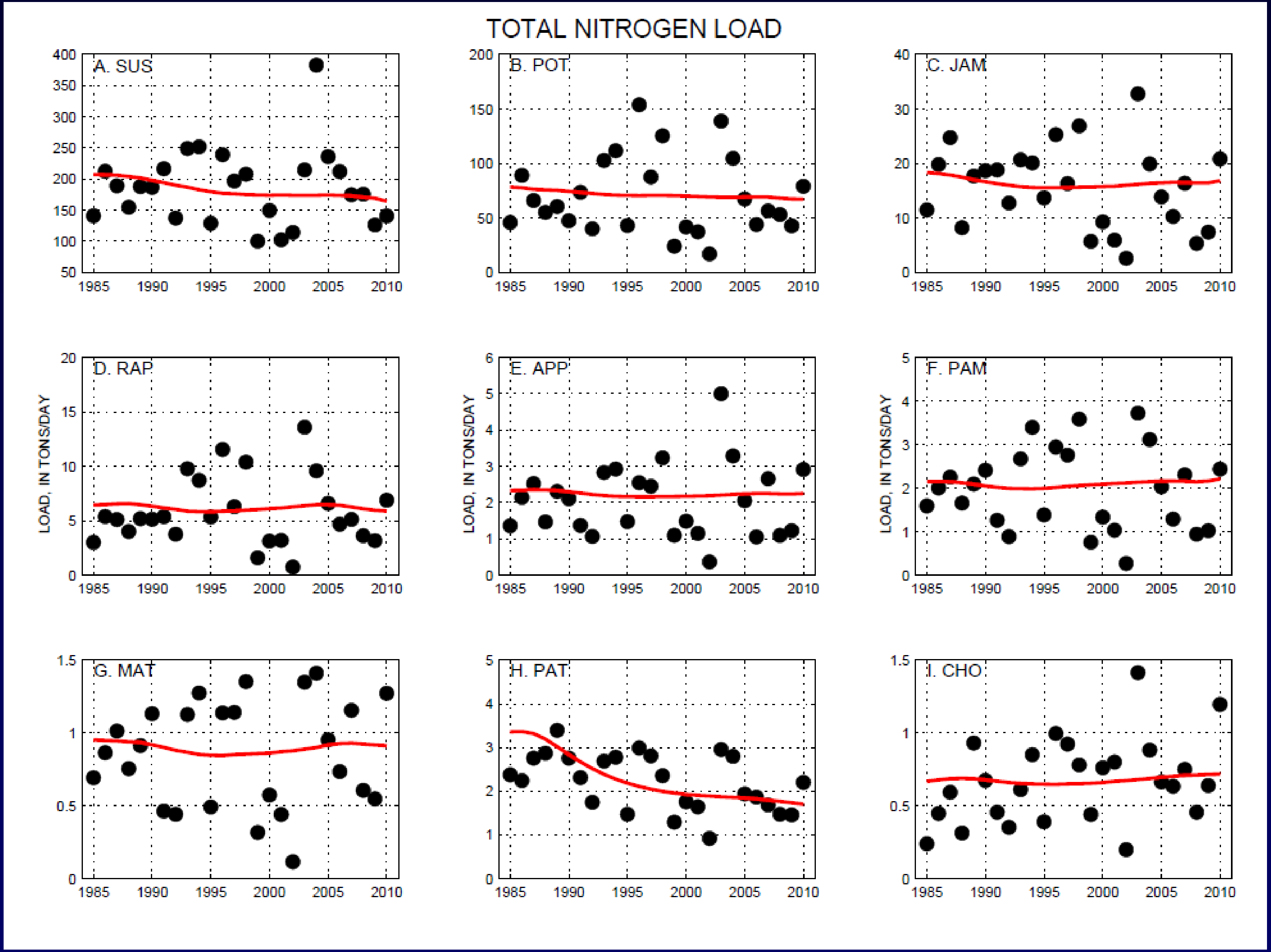
Black Dots = Annual Load Red Line = Flow Normalized Load

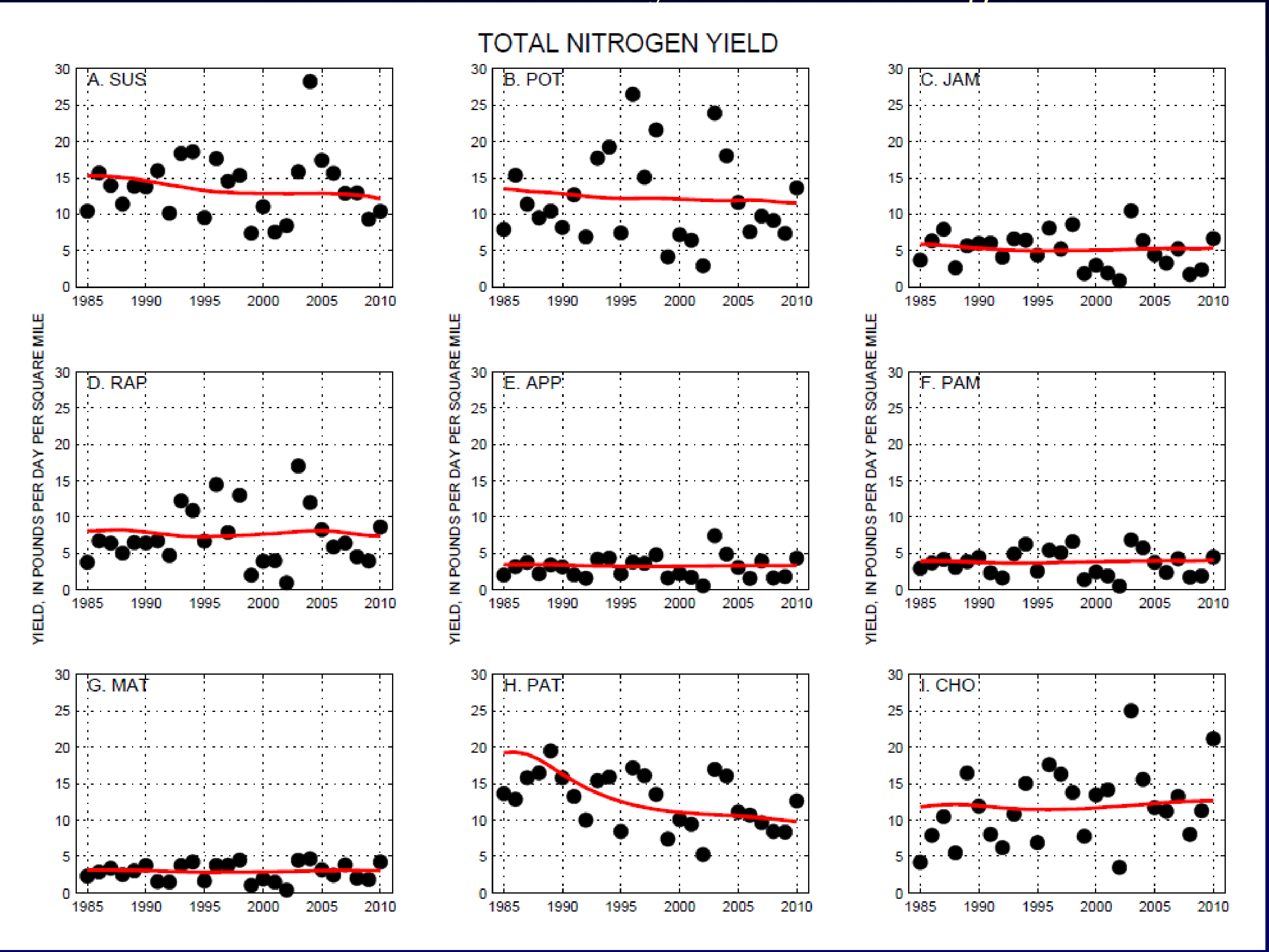
Trends in Total Nitrogen Load



Black Dots = Annual Load Red Line = Flow Normalized Load

Trends in Total Nitrogen Yield

Yield = Load divided by the Basin Drainage Area



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Black Dots = Annual Yield Red Line = Flow Normalized Yield

Trends in Nitrogen Loads

Station	Long-Term Trend (1985-2010)	
	Nitrate	Total Nitrogen
Susquehanna	Improving	Improving
Potomac	Improving	Improving
James	Improving	Minimal
Rappahannock	Improving	Minimal
Appomattox	Improving	Minimal
Pamunkey	Minimal	Minimal
Mattaponi	Minimal	Minimal
Patuxent	Improving	Improving
Choptank	Degrading	Minimal

Minimal Trend = total change less than or equal to |10%|

Improving Trend = total load reduction greater than 10%

Degrading Trend = total load increase greater than 10%

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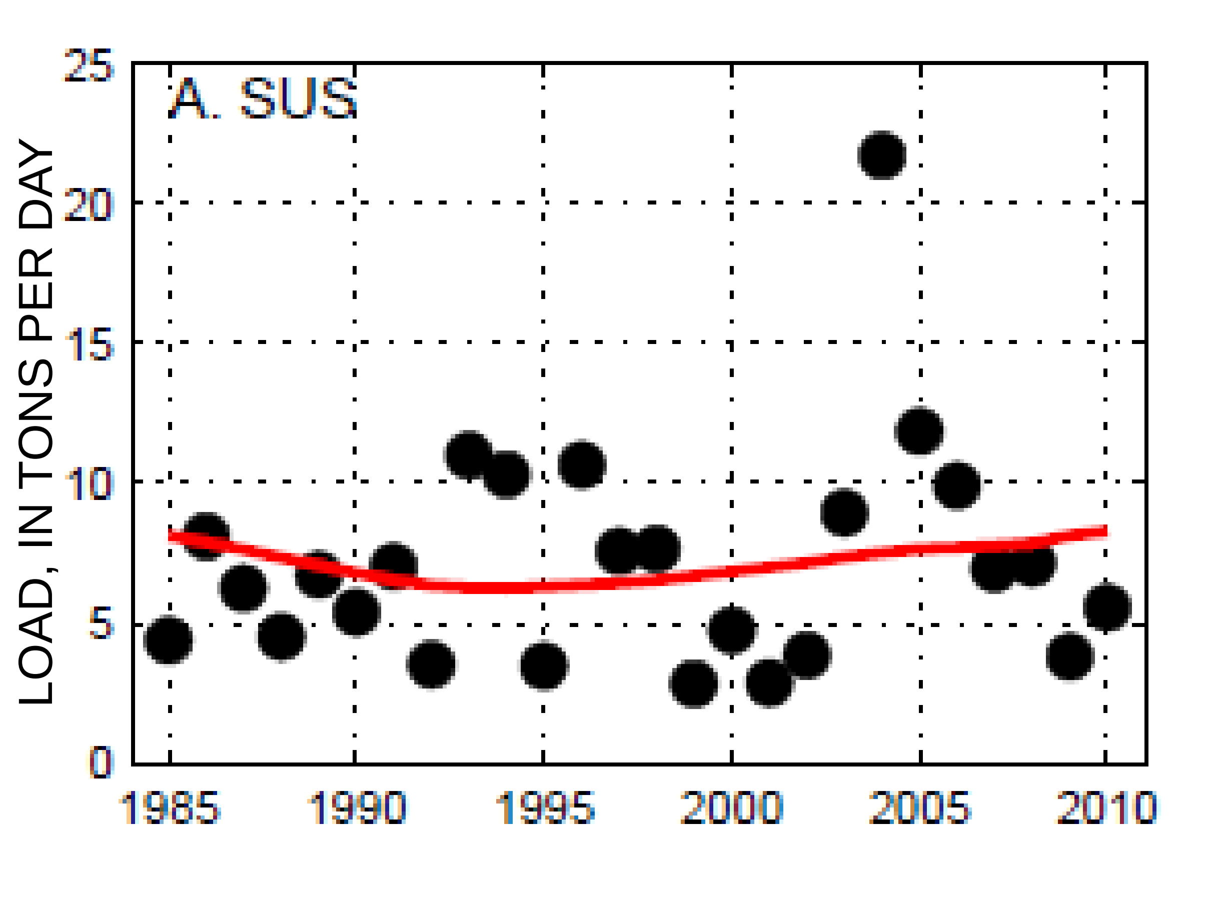
Trends in Annual Phosphorus Load



Total Phosphorus Load: Susquehanna (RIM)

- Influence of year-to-year variation in flow

Trend in load for:
1985 to 2010 = Total increase of 1.8%
2001 to 2010 = Total increase of 18%

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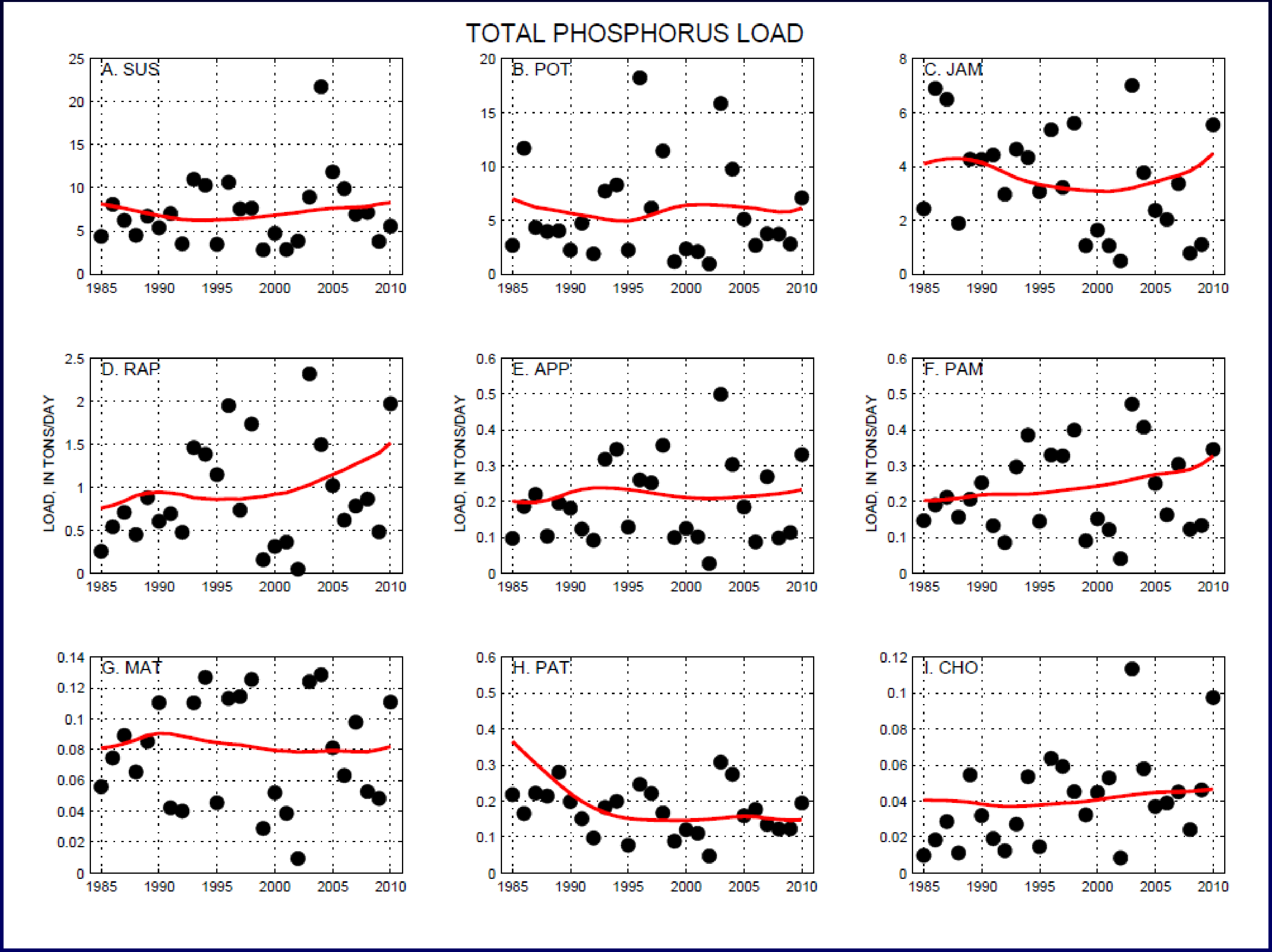
Black Circles = Annual Load   Red Line = Flow Normalized Load

Trends in Total Phosphorus Load



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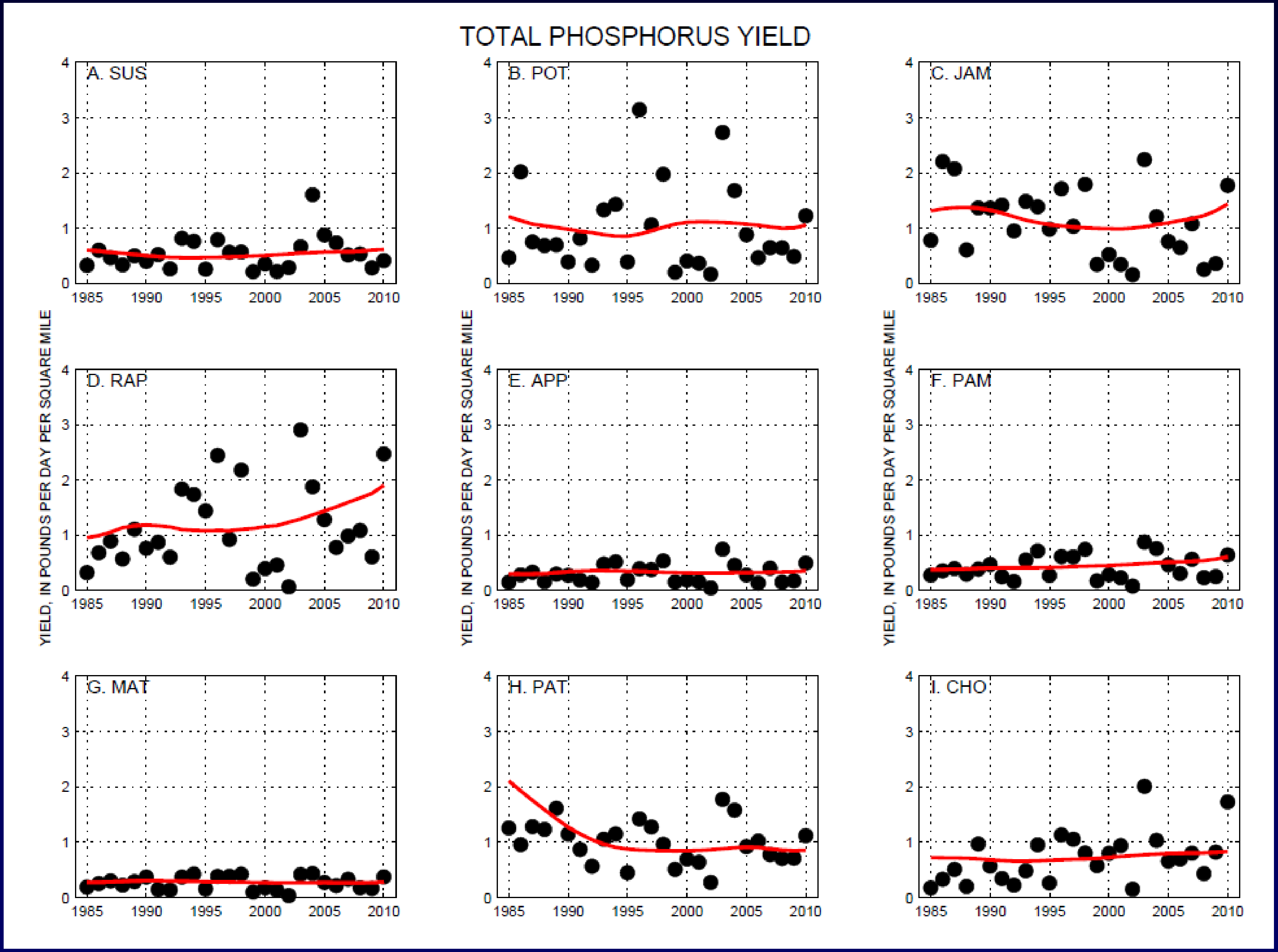
Black Dots = Annual Load Red Line = Flow Normalized Load

Trends in Total Phosphorus Yield

Yield = Load divided by the Basin Drainage Area



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Black Dots = Annual Yield Red Line = Flow Normalized Yield

Trends in Phosphorus Loads

Station	Long-Term Trend (1985-2010)	
	Ortho-phosphorus	Total Phosphorus
Susquehanna	Improving	Minimal
Potomac	Improving	Improving
James	Improving	Minimal
Rappahannock	Improving	Degrading
Appomattox	Improving	Degrading
Pamunkey	Improving	Degrading
Mattaponi	Improving	Minimal
Patuxent	Improving	Improving
Choptank	Degrading	Degrading

Minimal Trend = total change less than or equal to |10%|

Improving Trend = total load reduction greater than 10%

Degrading Trend = total load increase greater than 10%

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Trends in Suspended Sediment Load

Station	Long-Term Trend (1985-2010)	Short-Term Trend (2001-2010)
Susquehanna	Degrading	Degrading
Potomac	Degrading	Degrading
James	Not Available	Degrading
Rappahannock	Not Available	Minimal
Appomattox	Not Available	Minimal
Pamunkey	Not Available	Degrading
Mattaponi	Not Available	Improving
Patuxent	Improving	Degrading
Choptank	Improving	Degrading

Minimal Trend = total change less than or equal to |10%|

Improving Trend = total load reduction greater than 10%

Degrading Trend = total load increase greater than 10%

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Interpreting Trend in Load Results

How do these “new” trend in loads compare to the “historical” trend in concentrations?

What does it mean when the trend in load and the trend in concentration are in different directions?

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Trend in Concentration vs. Trend in Load: All 9 Chesapeake Bay RIM Stations

TIME PERIOD	TRENDS IN SAME DIRECTION	TRENDS IN OPPOSITE DIRECTIONS	RIM Stations
TOTAL NITROGEN			
1985 to 2010	9	0	
2001 to 2010	9	0	
TOTAL PHOSPHORUS			
1985 to 2010	7	2	JAM/MAT
2001 to 2010	6	3	JAM/PAM/PAT
SUSPENDED SEDIMENT			
1985 to 2010	2	2	SUS/POT
2001 to 2010	9	0	

Trend in Concentration vs. Trend in Load

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Trends Agree

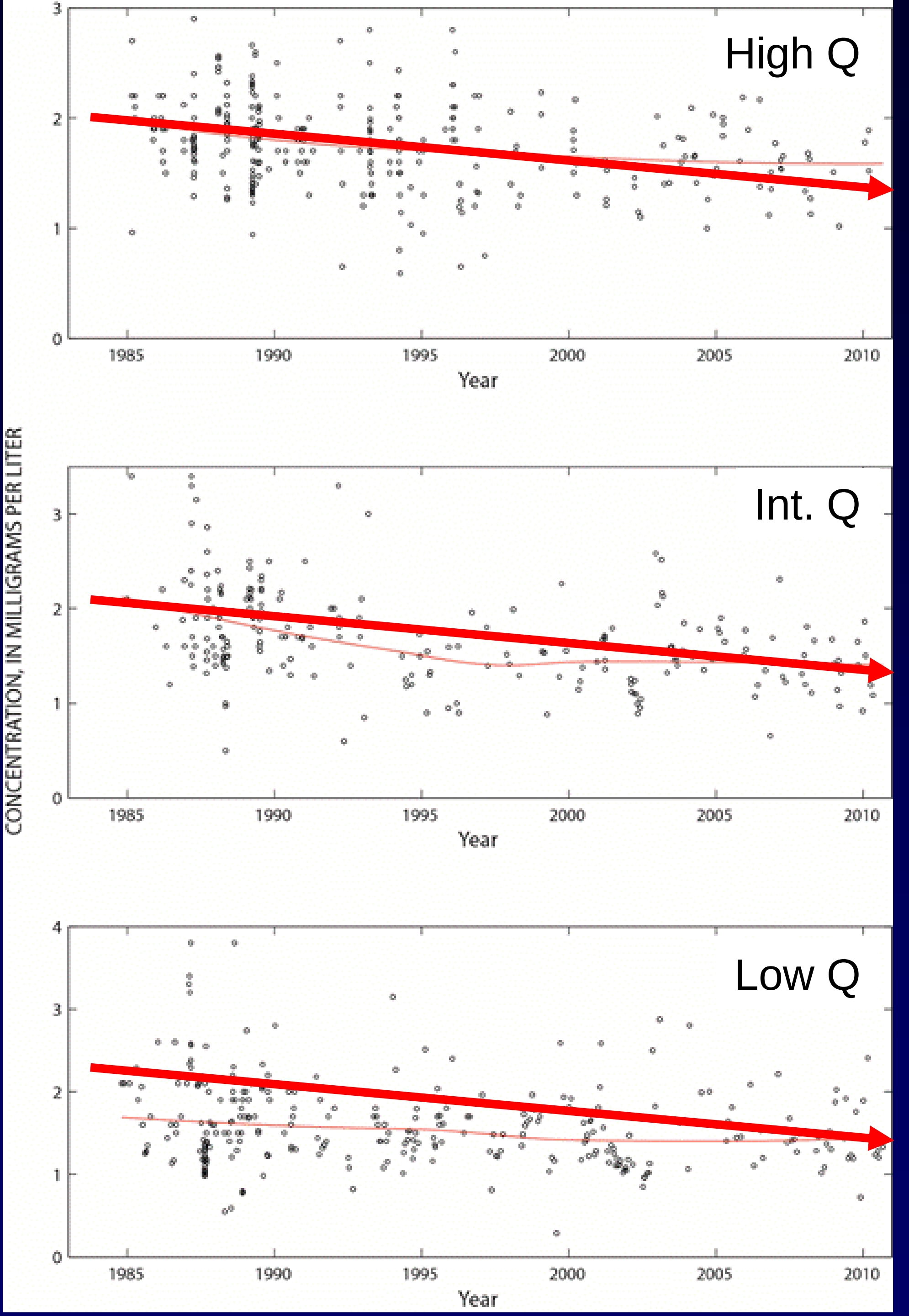
Example where trend in concentration and trend in load are in the same direction (Susquehanna Nitrate)

Categorize water-quality observations based on 3 discharge conditions:

- High
- Intermediate
- Low

ESTIMATOR trend in concentration indicates improving conditions (total reduction of approx. 16%)

WRTDS trend in load indicates improving conditions (total reduction of approx. 16%)



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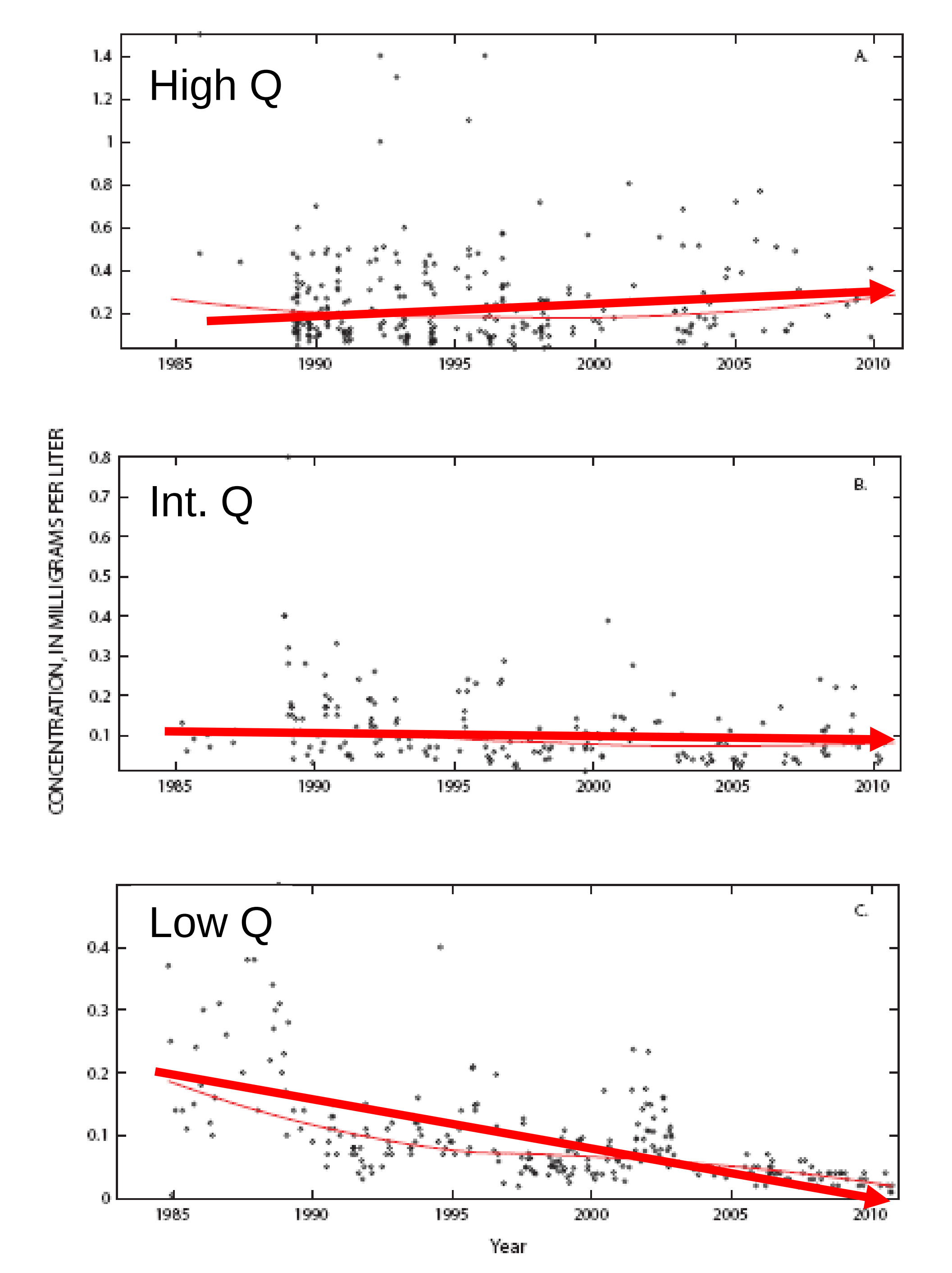
Trends Disagree

Example where trend in concentration and trend in load are in opposite direction (James River Total Phosphorus)

ESTIMATOR trend in concentration indicates improving conditions (total reduction of approx. 60%)

WRTDS trend in load indicates degrading conditions (total increase of 10%)



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Assessing Changes in Water-Quality Condition

- The new trend in load information:
  - Improves the relevancy of the information we provide to our local, state, and federal partners
  - Enhances the existing information for trend in concentration

- Trend in load and trend in concentration together provide a more complete understanding of how changes in watershed characteristics (e.g. land use) and the implementation of BMPs influence resulting water-quality conditions.

Communication

- Present trend in load results to cooperators and CBP partners (VA, PA, MD and DE, WV, COG, EPA, NRCS, CB WQ GIT, CB Comm…)
- Report is available: http://pubs.usgs.gov/sir/2012/5244
- USGS Science Summary of trend results: http://chesapeake.usgs.gov/sciencesummary-enhancedstatistical.html
- Bay Journal (January/February 2013) "Technique reveals total loads, trends of nutrients entering Bay"

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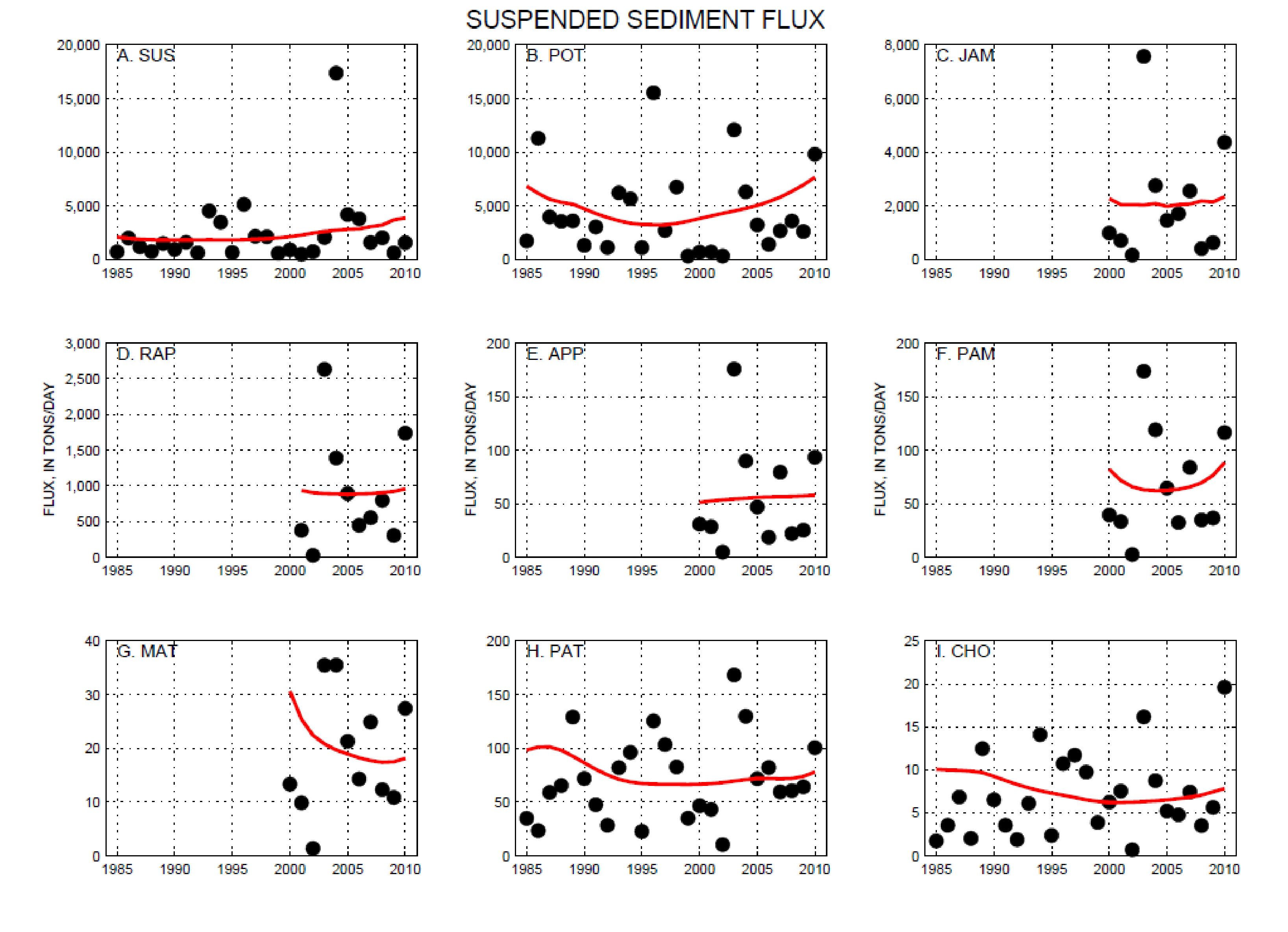
Questions and Discussion

Trends in Suspended Sediment Load



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Black Dots = Annual Load   Red Line = Flow Normalized Load