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

Douglas L. Moyer, Robert M. Hirsch, and Kenneth E. Hyer
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.
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.
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 \((\text{concentration} \times \text{discharge})\) 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)
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.
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?
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
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%

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

- Black Dots = Annual Yield
- Red Line = Flow Normalized Yield
## Trends in Nitrogen Loads

<table>
<thead>
<tr>
<th>Station</th>
<th>Long-Term Trend (1985-2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nitrate</td>
</tr>
<tr>
<td>Susquehanna</td>
<td>Improving</td>
</tr>
<tr>
<td>Potomac</td>
<td>Improving</td>
</tr>
<tr>
<td>James</td>
<td>Improving</td>
</tr>
<tr>
<td>Rappahannock</td>
<td>Improving</td>
</tr>
<tr>
<td>Appomattox</td>
<td>Improving</td>
</tr>
<tr>
<td>Pamunkey</td>
<td>Minimal</td>
</tr>
<tr>
<td>Mattaponi</td>
<td>Minimal</td>
</tr>
<tr>
<td>Patuxent</td>
<td>Improving</td>
</tr>
<tr>
<td>Choptank</td>
<td>Degrading</td>
</tr>
</tbody>
</table>

- **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%.

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

Total Phosphorus Load: Susquehanna (RIM)
- Influence of year-to-year variation in flow

Black Circles = Annual Load    Red Line = Flow Normalized Load
Trends in Total Phosphorus Load

Black Dots = Annual Load     Red Line = Flow Normalized Load
Trends in Total Phosphorus Yield

Yield = Load divided by the Basin Drainage Area
## Trends in Phosphorus Loads

<table>
<thead>
<tr>
<th>Station</th>
<th>Long-Term Trend (1985-2010)</th>
<th>Ortho-phosphorus</th>
<th>Total Phosphorus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Susquehanna</td>
<td>Improve</td>
<td>Minimal</td>
<td></td>
</tr>
<tr>
<td>Potomac</td>
<td>Improve</td>
<td>Improving</td>
<td></td>
</tr>
<tr>
<td>James</td>
<td>Improve</td>
<td>Minimal</td>
<td></td>
</tr>
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<td>Improve</td>
<td>Degrading</td>
<td></td>
</tr>
<tr>
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<td>Improve</td>
<td>Degrading</td>
<td></td>
</tr>
<tr>
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<td>Improve</td>
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<td></td>
</tr>
<tr>
<td>Mattaponi</td>
<td>Improve</td>
<td>Minimal</td>
<td></td>
</tr>
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<td></td>
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# Trends in Suspended Sediment Load

<table>
<thead>
<tr>
<th>Station</th>
<th>Long-Term Trend (1985-2010)</th>
<th>Short-Term Trend (2001-2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Susquehanna</td>
<td>Degrading</td>
<td>Degrading</td>
</tr>
<tr>
<td>Potomac</td>
<td>Degrading</td>
<td>Degrading</td>
</tr>
<tr>
<td>James</td>
<td>Not Available</td>
<td>Degrading</td>
</tr>
<tr>
<td>Rappahannock</td>
<td>Not Available</td>
<td>Minimal</td>
</tr>
<tr>
<td>Appomattox</td>
<td>Not Available</td>
<td>Minimal</td>
</tr>
<tr>
<td>Pamunkey</td>
<td>Not Available</td>
<td>Degrading</td>
</tr>
<tr>
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</tr>
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<td>Improving</td>
<td>Degrading</td>
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</tbody>
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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?
<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>TRENDS IN SAME DIRECTION</th>
<th>TRENDS IN OPPOSITE DIRECTIONS</th>
<th>RIM Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL NITROGEN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1985 to 2010</td>
<td>9</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2001 to 2010</td>
<td>9</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>TOTAL PHOSPHORUS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1985 to 2010</td>
<td>7</td>
<td>2</td>
<td>JAM/MAT</td>
</tr>
<tr>
<td>2001 to 2010</td>
<td>6</td>
<td>3</td>
<td>JAM/PAM/PAT</td>
</tr>
<tr>
<td>SUSPENDED SEDIMENT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1985 to 2010</td>
<td>2</td>
<td>2</td>
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Trend in Concentration vs. Trend in Load

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- Great information for local water quality condition
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**Trend in load** 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)
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%)
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%)
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”
Questions and Discussion
Trends in Suspended Sediment Load

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