Annual Phosphorus Loss Estimator (APLE) Model Sensitivity Analysis

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A Review of Agricultural P-dynamics in the Chesapeake Bay Watershed Model

A Workgroup Report from the Chesapeake Bay Program Scientific and Technical Advisory Committee

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Objectives

• To implement APLE 2.4 in our suite of models
• To estimate APLE model sensitivity to change in phosphorus inputs in the Chesapeake Bay Watershed
• To decide Phase 6-PQUAL phosphorus sensitivities
APLE 2.4 Implementation
According to Vadas (2013), for poorly drained soils, annual runoff may be 30-40% of total annual precipitation. For well drained soils, annual runoff may be only 5-10% of annual precipitation.
APLE Total Dissolved Phosphorus - High-till with manure (hwm)
Edge of Field (lbs/acre)

**APLE**

**Surface Outflow**
- Mean: 0.2 lbs/acre
  - 0.02 - 0.15
  - 0.16 - 0.29
  - 0.30 - 0.53
  - 0.54 - 1.06

**APLE**

**Surface + Interflow**
- Mean: 0.6 lbs/acre
  - 0.12 - 0.45
  - 0.46 - 0.78
  - 0.79 - 1.37
  - 1.38 - 3.59
Bradford PA – high till with manure

**HSPF Inputs**

- **PRECIP**
- **Surface + Interflow**
- **Surface Outflow**
- **SEDLOSS**
- **Linear (PRECIP)**
- **Linear (SEDLOSS)**

**Scenario Builder Inputs**

- **MANURE_TP**
- **FERT_TP**
- **UPTAKE_LBAC**
Bradford PA – high till with manure

**Fertilizer Dissolved P**

- APLE Surface
- APLE Surface + Interflow

**Soil Dissolved P**

- APLE Surface
- APLE Surface + Interflow

**Manure Dissolved P**

- APLE Surface
- APLE Surface + Interflow

**MEHLICH P**

- APLE Surface
- APLE Surface + Interflow
Somerset MD – high till with manure
Somerset MD – high till with manure

Fertilizer Dissolved P

Soil Dissolved P

Manure Dissolved P

MEHLICH P
Total Phosphorus Export - High-till with manure (lbs/acre)

**P5.3.2**
EOS - No BMPs
- 1.3 - 2.1 lbs/acre
- 2.2 - 3.0 lbs/acre
- 3.1 - 4.8 lbs/acre
- 4.9 - 8.9 lbs/acre

Mean: 2.1 lbs/acre

**APLE**
Surface + Interflow
- 0.6 - 6.7 lbs/acre
- 6.8 - 13.1 lbs/acre
- 13.2 - 25.3 lbs/acre
- 25.4 - 47.2 lbs/acre

Mean: 9.4 lbs/acre

**APLE + Transport Factors**
Surface + Interflow
- 0.2 - 1.6 lbs/acre
- 1.7 - 3.1 lbs/acre
- 3.2 - 5.9 lbs/acre
- 6.0 - 17.2 lbs/acre

Mean: 2.0 lbs/acre

Frequency Distributions:
- P5.3.2 EOS - No BMPs
- APLE Surface + Interflow
- APLE + Transport Factors Surface + Interflow
Bradford PA – high till with manure

APLE WITH SURFACE OUTFLOW
- Sediment P Loss: 11.0, 98%
- Soil Diss P: 0.2, 2%
- Manure Diss P: 0.02, 0.2%
- Fertilizer Diss P: 0.03, 0.3%

APLE WITH SURFACE + INTERFLOW
- Sediment P Loss: 11.0, 95%
- Soil Diss P: 0.4, 4%
- Manure Diss P: 0.05, 0.5%
- Fertilizer Diss P: 0.10, 1%

APLE WITH SURFACE + INTERFLOW + TRANSPORT FACTORS
- Sediment P Loss: 1.5, 71%
- Soil Diss P: 0.4, 21%
- Manure Diss P: 0.05, 3%
- Fertilizer Diss P: 0.10, 5%

Transport Factors
Somerset MD – high till with manure

**APLE WITH SURFACE OUTFLOW**

- Sediment P Loss: 8.2, 89%
- Soil Diss P: 0.31, 3.3%
- Manure Diss P: 0.7, 8%
- Fertilizer Diss P: 0.01, 0.1%

**APLE WITH SURFACE + INTERFLOW**

- Sediment P Loss: 8.1, 69%
- Soil Diss P: 2.3, 19%
- Manure Diss P: 1.26, 10.8%
- Fertilizer Diss P: 0.07, 1%

**APLE WITH SURFACE + INTERFLOW + TRANSPORT FACTORS**

- Sediment P Loss: 2.3, 56%
- Soil Diss P: 1.26, 32%
- Manure Diss P: 0.4, 10%
- Fertilizer Diss P: 0.07, 2%

**Transport Factors**

Graph showing transport factors with increasing values.
Sediment P Loss percent of Total Phosphorus Export - High-till with manure

Sediment transport factors
sedhwm
- 0.00 - 0.11
- 0.12 - 0.20
- 0.21 - 0.35
- 0.36 - 1.00

APLE
Soil P Loss / Total P Loss
- 19% - 55%
- 56% - 79%
- 80% - 91%
- 92% - 99%

APLE + Transport Factors
Soil P Loss / Total P Loss
- 3% - 32%
- 33% - 57%
- 58% - 76%
- 77% - 99%

Frequency Distribution

Frequency Distribution

Frequency Distribution
APLE Model Sensitivity Analysis
APLE Model Sensitivity due to Change in Inputs

- Base scenario 1992-2005
- High till with manure, low till and pasture
- Fertilizer, Manure, Uptake, Precipitation, Runoff, Sediment, Mehlich
- -60% -30% 0% +30% +60% (4)
- All land segments (~300)
Relative Sensitivity

\[ S_r = \left( \frac{O - O_b}{I - I_b} \right) \frac{I_b}{O_b} \]

Where:
- \( O \) = model output
- \( I \) = model input
- \( b \) = subscript represents the input and output value of the base scenario

<table>
<thead>
<tr>
<th>Relative Sensitivity</th>
<th>( S_r )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insensitive</td>
<td>( S_r &lt;</td>
</tr>
<tr>
<td>Slightly sensitive</td>
<td>(</td>
</tr>
<tr>
<td>Moderately sensitive</td>
<td>(</td>
</tr>
<tr>
<td>Sensitive</td>
<td>(</td>
</tr>
<tr>
<td>Extremely sensitive</td>
<td>( S_r \geq</td>
</tr>
</tbody>
</table>

APLE Model Sensitivity due to Change in Fertilizer Input

Relative Sensitivity

- Insensitive: \( Sr < |0.01| \)
- Slightly sensitive: \( |0.01| \leq Sr < |0.10| \)
- Moderately sensitive: \( |0.10| \leq Sr < |1.00| \)
- Sensitive: \( |1.00| \leq Sr < |2.00| \)
- Extremely sensitive: \( Sr \geq |2.00| \)

Graph: Scatter plot with linear regression line, equation: \( y = 0.015x + 0.004 \), and \( R^2 = 0.854 \).
APLE Model Sensitivity due to Change in Manure Input

Relative Sensitivity

- Insensitive: \( Sr < 0.01 \)
- Slightly sensitive: \( |0.01| \leq Sr < 0.10 \)
- Moderately sensitive: \( |0.10| \leq Sr < 1.00 \)
- Sensitive: \( |1.00| \leq Sr < 2.00 \)
- Extremely sensitive: \( Sr \geq 2.00 \)

\[ y = 0.026x + 0.001 \]
\[ R^2 = 0.924 \]
APLE Model Sensitivity due to Change in Uptake Input

Relative Sensitivity

- Insensitive: \( Sr < |0.01| \)
- Slightly sensitive: \(|0.01| \leq Sr < |0.10| \)
- Moderately sensitive: \(|0.10| \leq Sr < |1.00| \)
- Sensitive: \(|1.00| \leq Sr < |2.00| \)
- Extremely sensitive: \( Sr \geq |2.00| \)

Graph:
- Delta Output vs Delta Uptake (pound/acre)
- Probability vs Relative Sensitivity

Equation:
- \( y = -0.012x + 0.007 \)
- \( R^2 = 0.851 \)
APLE Model Sensitivity due to Change in Runoff Input

Relative Sensitivity

- Insensitive: $Sr < |0.01|$  
- Slightly sensitive: $|0.01| \leq Sr < |0.10|$  
- Moderately sensitive: $|0.10| \leq Sr < |1.00|$  
- Sensitive: $|1.00| \leq Sr < |2.00|$  
- Extremely sensitive: $Sr \geq |2.00|$  

$y = 0.070x + 0.026$  
$R^2 = 0.788$
APLE Model Sensitivity due to Change in Sediment Input

Relative Sensitivity

- Insensitive: $Sr < |0.01|$
- Slightly sensitive: $|0.01| \leq Sr < |0.10|$
- Moderately sensitive: $|0.10| \leq Sr < |1.00|$
- Sensitive: $|1.00| \leq Sr < |2.00|$
- Extremely sensitive: $Sr \geq |2.00|$

Graph:
- $y = 0.179x - 0.014$
- $R^2 = 0.806$

Scatter plot with regression line:
- Delta Output (pound/acre) vs. Delta Input (ton/acre)
- Probability vs. Relative Sensitivity
APLE Model Sensitivity due to Change in Mehlich Input

Relative Sensitivity

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Sr Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insensitive</td>
<td>Sr &lt;</td>
</tr>
<tr>
<td>Slightly sensitive</td>
<td></td>
</tr>
<tr>
<td>Moderately sensitive</td>
<td></td>
</tr>
<tr>
<td>Sensitive</td>
<td></td>
</tr>
<tr>
<td>Extremely sensitive</td>
<td>Sr ≥</td>
</tr>
</tbody>
</table>

Regression:

\[ y = 0.016x - 0.038 \]

\[ R^2 = 0.748 \]
## APLE Model Sensitivity Analysis Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Slope</th>
<th>( R^2 )</th>
<th>Mean ( Sr )</th>
<th>Median ( Sr )</th>
<th>Max ( Sr )</th>
<th>Min ( Sr )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mehlich</td>
<td>0.016</td>
<td>0.748</td>
<td>0.674</td>
<td>0.685</td>
<td>0.914</td>
<td>0.230</td>
</tr>
<tr>
<td>Sediment</td>
<td>0.179</td>
<td>0.806</td>
<td>0.549</td>
<td>0.598</td>
<td>0.938</td>
<td>0.036</td>
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<tr>
<td>Manure</td>
<td>0.026</td>
<td>0.924</td>
<td>0.457</td>
<td>0.404</td>
<td>1.554</td>
<td>0.044</td>
</tr>
<tr>
<td>Runoff</td>
<td>0.070</td>
<td>0.788</td>
<td>0.455</td>
<td>0.396</td>
<td>3.055</td>
<td>0.027</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>0.015</td>
<td>0.854</td>
<td>0.247</td>
<td>0.229</td>
<td>0.740</td>
<td>0.034</td>
</tr>
<tr>
<td>Uptake</td>
<td>-0.012</td>
<td>0.851</td>
<td>0.184</td>
<td>0.165</td>
<td>0.502</td>
<td>0.042</td>
</tr>
</tbody>
</table>

APLE is more sensitive to mehlich, sediment, manure, and runoff than to fertilizer and uptake.
Next

• Include new soil P data

• Phosphorus sensitivities are provisional and we’ll continue exploring APLE.