Understanding Nutrients in the Chesapeake Bay Watershed and Implications for Management and Restoration – the EASTERN SHORE

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A summary of U.S. Geological Survey Circular 1406, expected release: January 2015

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Outline

• Sources of nitrogen and phosphorus to the landscape
• Movement of nitrogen and phosphorus from upland source areas to groundwater and streams
• Explaining trends in groundwater and streams
• Response times and management implications
• Inputs* of nitrogen and phosphorus to the Eastern Shore are more intensive, on average, than to the remainder of the Chesapeake Bay watershed.

*inputs from:
- Fertilizer and manure
- Direct fixation by crops
- Undifferentiated urban
- Atmospheric
- Point sources
- Mineral sources
Sources of nitrogen and phosphorus to the landscape

Sources

- Fertilizer applications of nitrogen and phosphorus increased substantially from the 1940s through the 1970s, but have since stabilized or decreased.

- Poultry production has increased by more than 100x since the early 20th century.

[Graph showing the increase in fertilizer applications and broiler sales from 1910 to 2010]

[Broiler data are from U.S. Department of Agriculture, 2009. Estimates prior to 1950 are for total chickens or broilers raised. Fertilizer inputs are from Alexander and Smith, 1990, Battaglin and Goolsby, 1995, and Mid-Atlantic Water Program, 2012.]
Inputs of nitrogen and phosphorus to cropland have generally exceeded removal in crops for several decades.
• Water is the dominant mechanism for nitrogen and phosphorus transport from uplands to streams.
• Changes in stream chemistry with increasing flow reflect different dominant processes transporting nitrogen and phosphorus.
Fate and Transport

- Nitrate can be lost from soils and groundwater to the atmosphere through denitrification.
- Denitrification is most common in areas with abundant organic matter and little dissolved oxygen.
Fate and Transport

- Groundwater ages in the surficial aquifer range from 1 to more than 50 years with a median of between 20 and 30 years (Sanford et al., 2012).

- Several decades may be required for nitrate transport through groundwater to streams.

- Phosphorus transport over the land surface is intermittent.
Nitrogen Trends

- Because of the time required for groundwater flow, increasing nitrate in groundwater reflects increasing applications in the past.

- Increasing nitrogen in the Choptank River reflects continued increasing nitrate in groundwater contributions (Hirsch et al., 2010).

[Graphs and charts showing nitrogen trends and recharge periods.]

Phosphorus Trends

- Increasing phosphorus coincident with decreasing suspended sediment in the Choptank River suggests (possibly):
  - Greater phosphorus on sediment grains (on average)
  - Increasing dissolved phosphorus transport
  - Either of these conditions may result from increasing phosphorus saturation in soils.
Response Times and Management Implications

- Limiting infiltration of nitrate to the water table could reduce nitrate relatively quickly in shallow groundwater.
- Cover crops
- Precision applications
- Increasing denitrification
- Practices intended to limit runoff and erosion may promote the movement of nitrate to groundwater.

Data from K. Staver (U of Md); see also Staver and Brinsfield, 1998. Sanford and Pope, 2013
Decades will be required before significant reductions of loads to the bay are realized.

A 13 percent reduction in nitrogen load to groundwater will be required to maintain loads to the bay at 2012 levels.

Even a 40 percent reduction in loads to groundwater will not cause a 25 percent reduction in loads to the bay until at least 2050.

Data from K. Staver (U of Md); see also Staver and Brinsfield, 1998; Sanford and Pope, 2013.
Determining Nutrient Loads and Long-Term Trends

CONCENTRATION \times STREAMFLOW = LOAD (FLUX)

CHOPTANK RIVER NEAR GREENSBORO, MD
Total Nitrogen

CHOPTANK RIVER NEAR GREENSBORO, MD
Daily Discharge

CHOPTANK RIVER NEAR GREENSBORO, MD
Water Year
Flux Estimates (dots) & Flow Normalized Flux (line)

Choptank River near Greensboro, MD

Nitrogen:
- Total nitrogen decreases for 1st decade followed (-11%) by gradual increase in load (16 %)
- Nitrate loads increasing for 3 decades (34 percent)
- perhaps some flattening of nitrate in recent years)
- Nitrate changed from 49% to 64% of total nitrogen loads

Phosphorus:
- Total phosphorus decreases (-9%) in 1st decade followed by increase in load (34% net)
- Dissolved orthophosphate increased 134% in 3 decades
- orthophosphate grows from 19% to 33% of Total phosphorus flux
Summary

• The Eastern Shore contributes disproportionately large loads of nitrogen and phosphorus to Chesapeake Bay.

• Nutrient loads from the Eastern Shore to the bay continue to increase due to a long history of applications in excess of crop needs and resulting storage of nitrogen in groundwater and phosphorus in soils.

• Even if current management practices are effective at limiting nutrients on the landscape or movement to water resources, decades will be required before full reductions are realized in loads to the bay.