Hampton Roads Regional Stormwater Monitoring

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The Problem:

Prior to this study, data describing urban stormwater nutrient and sediment loading rates within the Virginia Coastal Plain were lacking

Without locally relevant data, does the current Chesapeake Bay Watershed Model accurately predict loading rates in this region

Program Objectives:

1. Collect high-quality data representative of the region
2. Use those data to compute annual nutrient and sediment loads
3. Investigate the mechanisms influencing nutrient and sediment loads in the region; specifically, the role of hydrology, land use, speciation, and Physiographic Province

A comprehensive summary of the first 5-years (2016 -2020) of monitoring was the subject of a recent USGS report

USGS

Prepared in cooperation with the Hampton Roads Planning District Commission

Stormwater Quantity and Quality in Selected Urban Watersheds in Hampton Roads, Virginia, 2016–2020

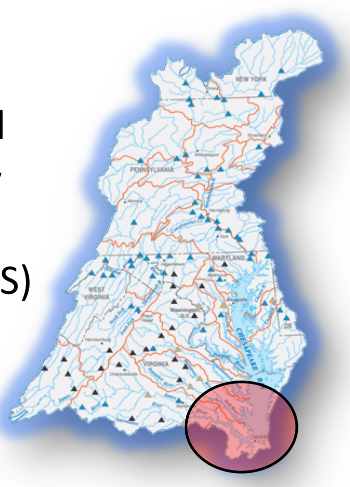
Scientific Investigations Report 2022–5111

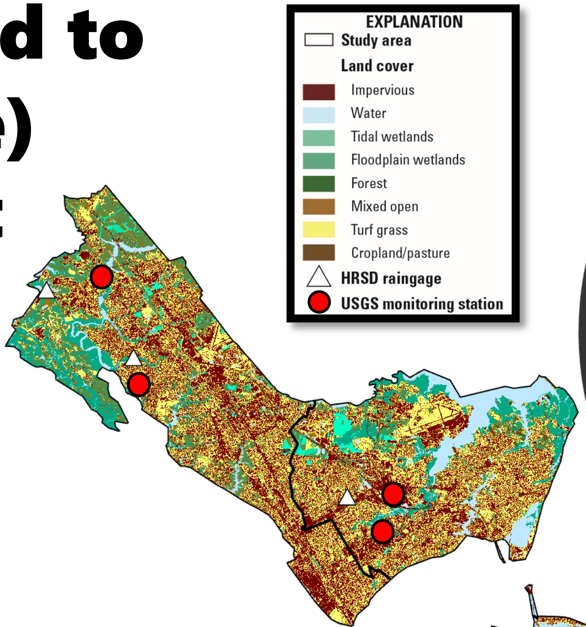
U.S. Department of the Interior
U.S. Geological Survey

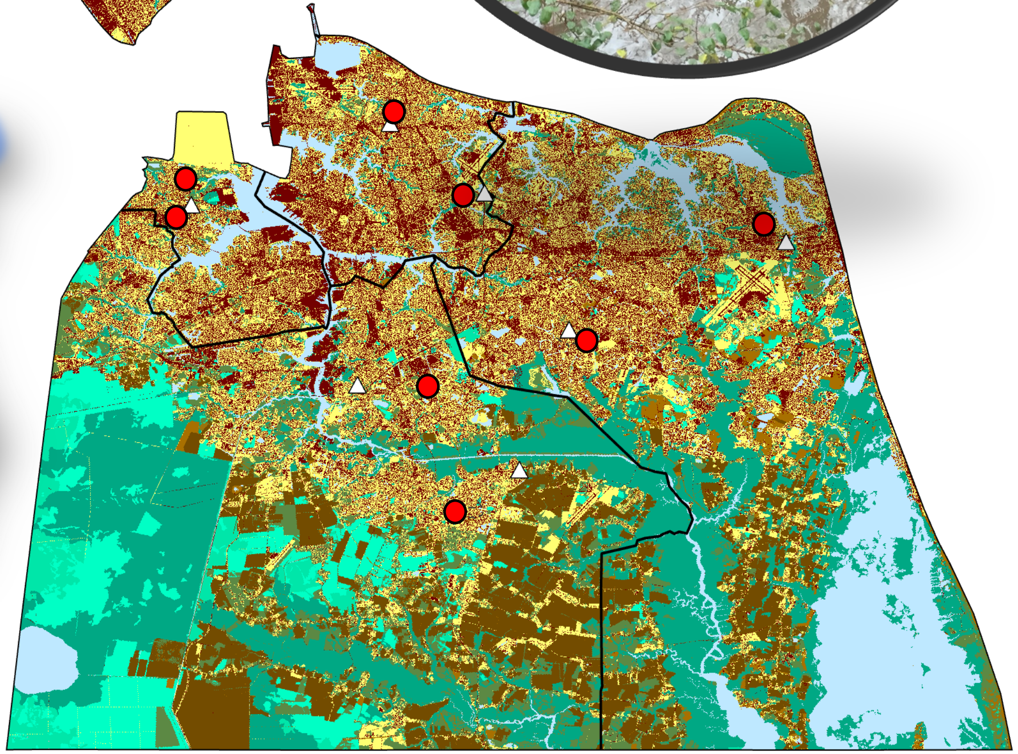
Porter, 2022

The monitoring network is designed to compute high-frequency (5-minute) estimates of nutrient and sediment loads

- 12 stormwater monitoring stations have been operated since late 2015
- Study watersheds range in size from 30 to 275 acres with imperviousness ranging from 36 to 80%
- Study watersheds (i.e., sewersheds) are not natural drainage areas, but rather shaped by the stormwater infrastructure
- Each represents a nearly homogeneous land use type of either commercial, high-density residential, or single-family residential
- High-frequency measurements of streamflow and water-quality parameters are collected
    - Nitrogen (N), phosphorus (P), and total suspended solids (S) concentrations are analyzed from monthly and storm targeted samples (~3,100 samples to date)
- **These data were used to develop station-constituent specific models for the computation of nutrient and sediment loads**





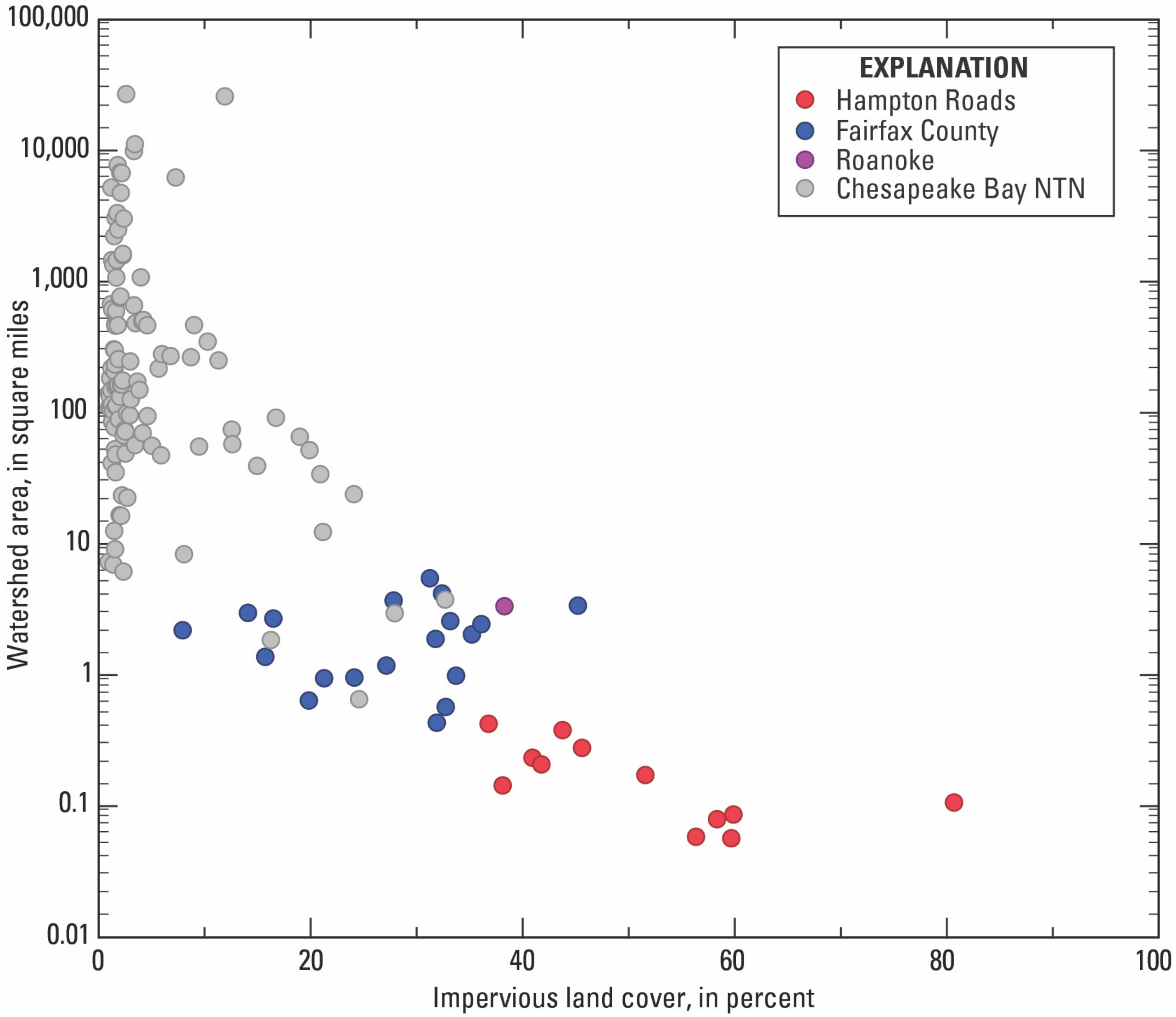


Knowledge Generation:
A snapshot of how monitoring small urban watersheds helps fill a knowledge gap

Watershed area and land cover can affect the sources, transport, and storage of nutrients and sediment

"Larger watersheds typically have smaller sediment yields due to spatial averaging of erosion or fluvial trapping sediments" (Smith and Wilcock, 2015; Donovan and others, 2015, Noe and others, 2017)

"As the percent catchment impervious surface cover (ISC) increases to 10–20%, runoff increases twofold; 35–50% ISC increases runoff threefold; and 75–100% ISC increases surface runoff more than fivefold over forested catchments" (Arnold & Gibbons 1996; Paul and Meyer, 2001).



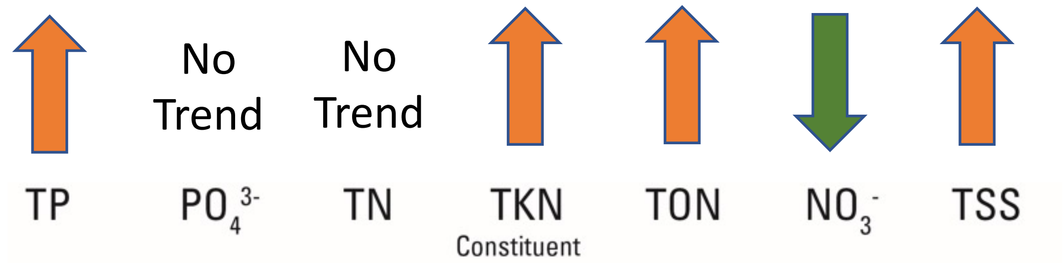
Annual nitrogen, phosphorus, and sediment loads have been computed for water years 2016 through 2022

Model Calibration

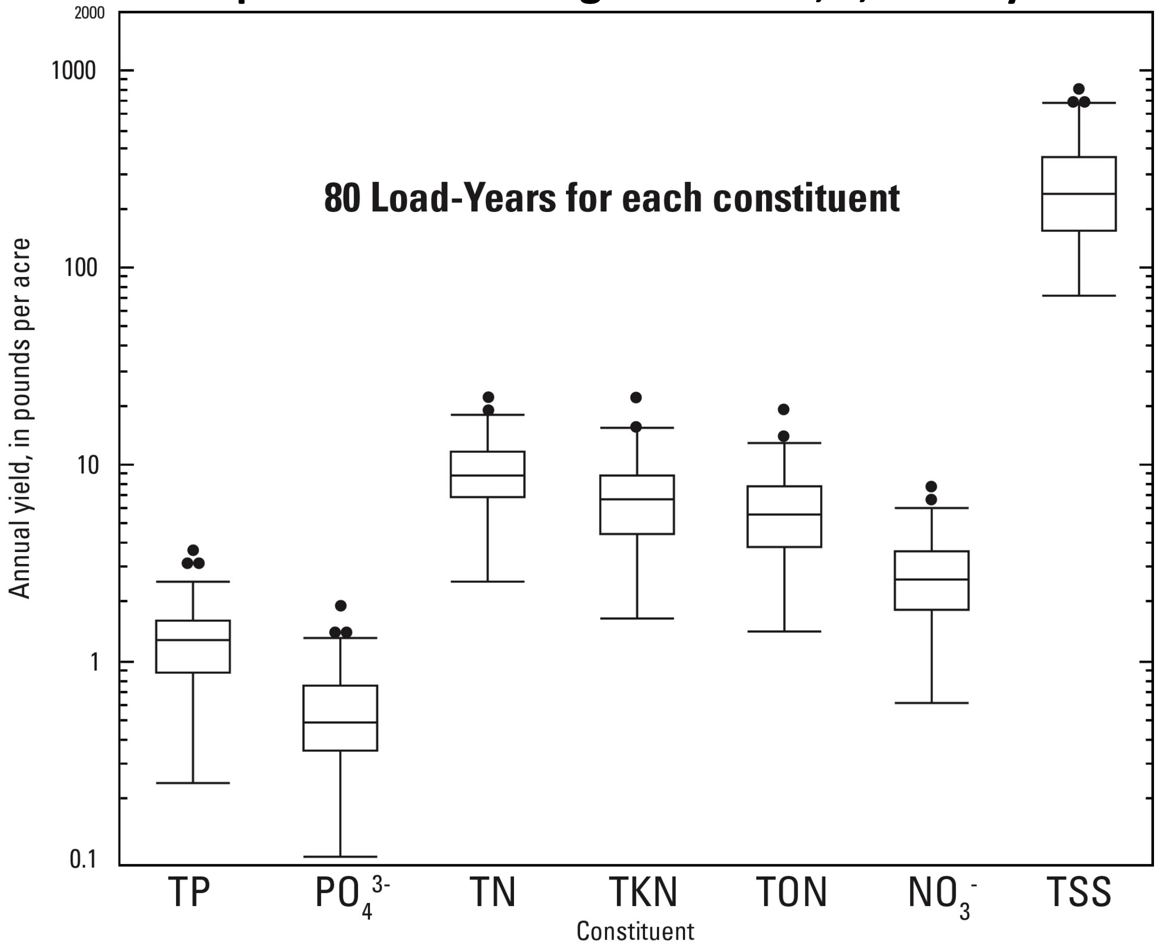
These stations represent the urban coastal plain – can their average be used as a calibration knob in the watershed model for this and similar regions?

Comparison of Trends

Preliminary trends in **flow-adjusted** annual yields were computed for all constituents – the length of the study period is not yet sufficient for a formal analysis of trends



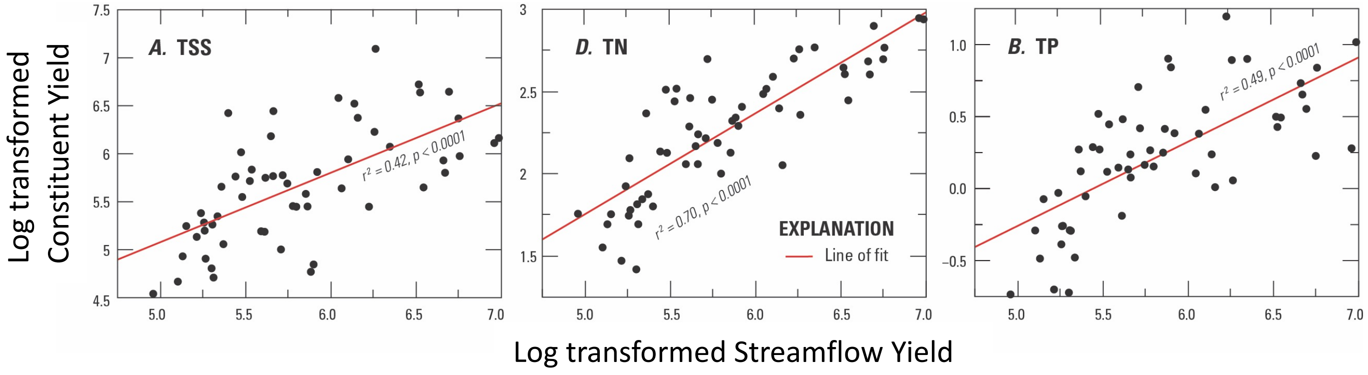
Hampton Roads average annual N, P, and S yields

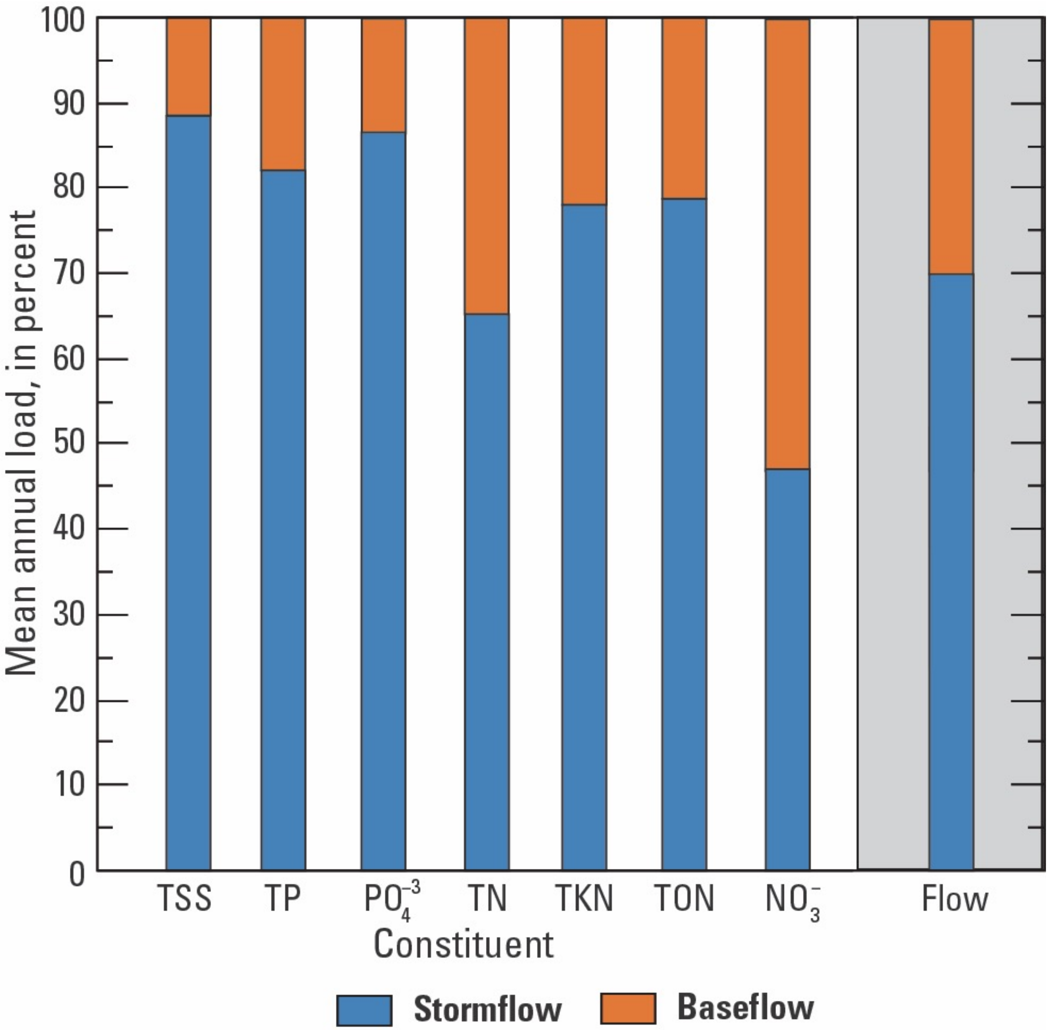


TP = total phosphorus, PO43- = orthophosphate TN = total nitrogen, TKN = total Kjeldahl nitrogen,

TON = total organic nitrogen, NO3- = nitrate plus nitrite, TSS = total suspended solids

Delivery mechanism: loads were primarily transported by overland runoff rather than groundwater





Do land use and land cover attributes affect the transport of nitrogen, phosphorus, or sediment?

<u>Impervious cover:</u>
Commercial – 67%
High-density Residential – 53%
Single-family Residential – 42%

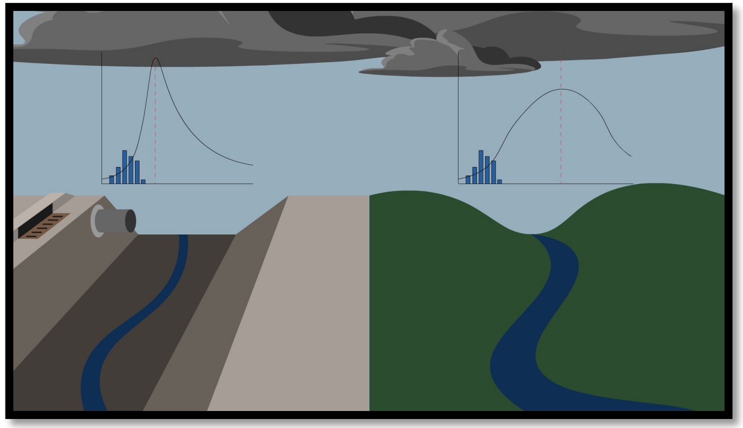
<u>Tree canopy and turfgrass cover:</u>
Commercial – 32%
High-density Residential – 36%
Single-family Residential – 54%

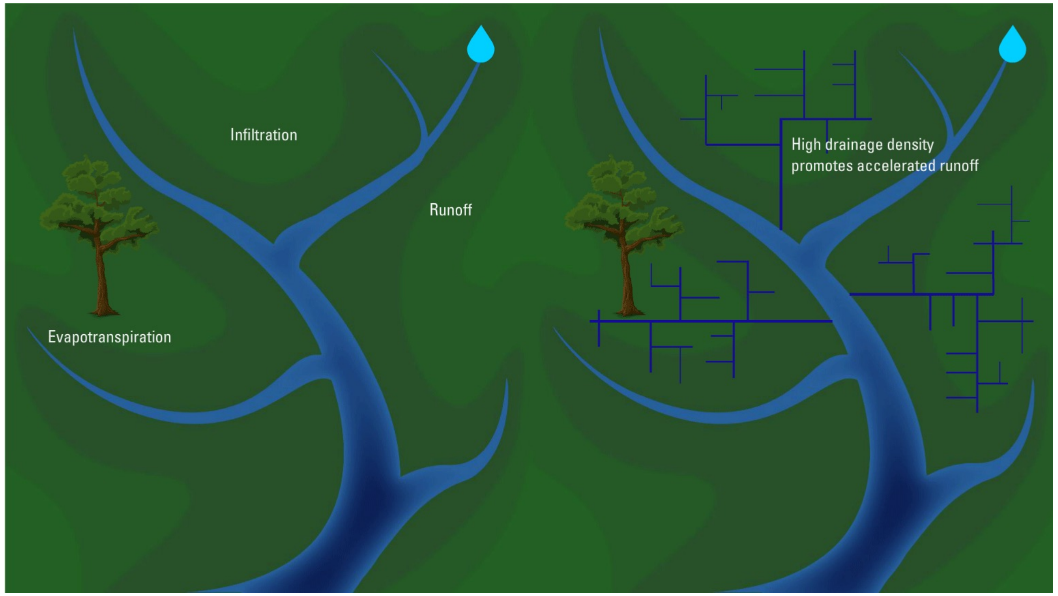
<u>Watershed area, in acres</u>
Commercial – 52
High-density Residential – 57
Single-family Residential – 142

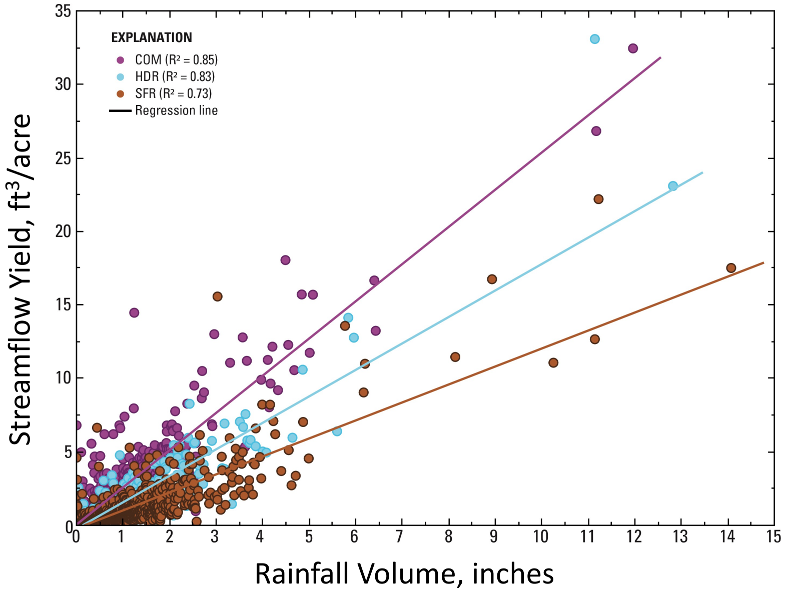
Why may land use/cover matter?

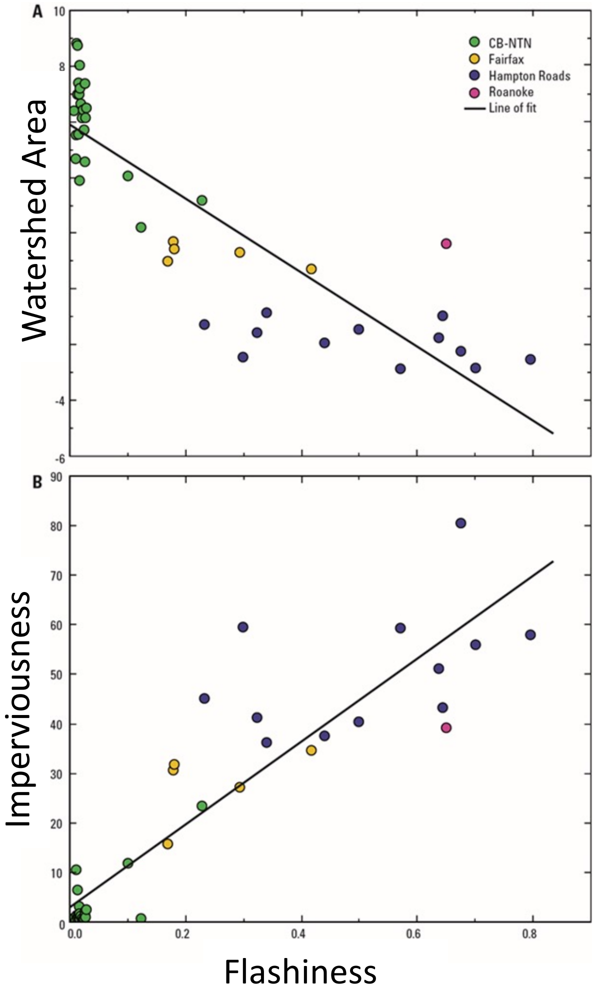
1. Impervious surfaces: alters the rate and volume of runoff which affects the retention of nutrients and sediments
2. Sources: more lawns = more fertilizer and grass clippings, more trees = more leaf litter, homes = pets, more impervious cover = increase transport of atmospheric deposition
3. Watershed area: smaller watersheds typically have higher yields of nutrients and sediment than larger watersheds

Small highly developed urban watersheds produce a very flashy runoff response



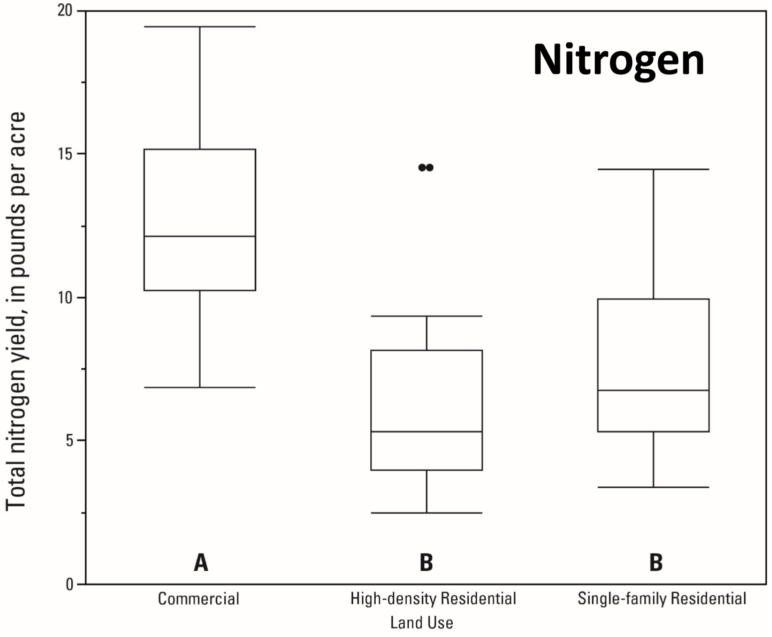






- The Hampton Roads study watersheds were much flashier than CB-NTN and other monitored urban areas – related to watershed area and impervious cover
- Engineered storm sewers significantly increase the drainage density of a watershed – producing greater runoff and constituent transport
- Commercial lands produced more runoff per unit rainfall than both residential types

N, P, and S concentrations and yields varied across 3 urban land-use types



Key Findings

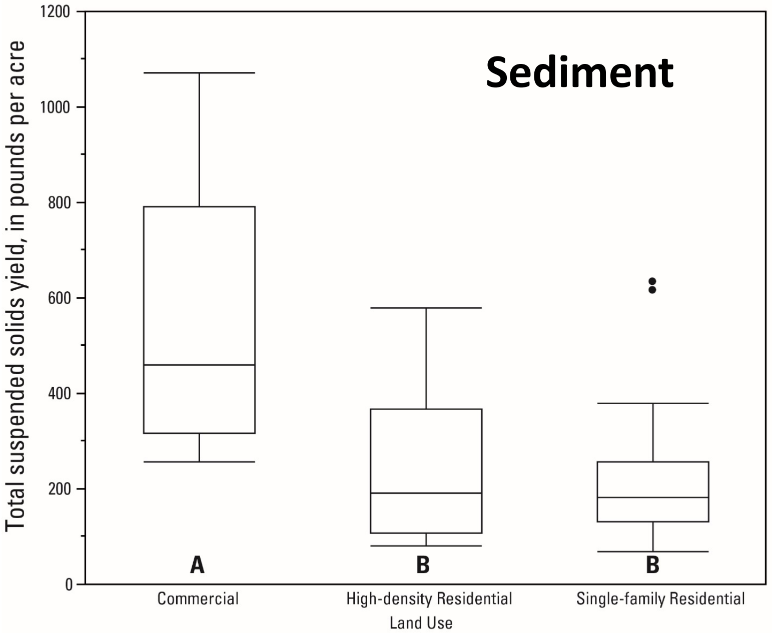
- Commercial lands generated the most **streamflow**
- **Concentrations** were highest in residential watersheds
- Yields were highest in Commercial watersheds

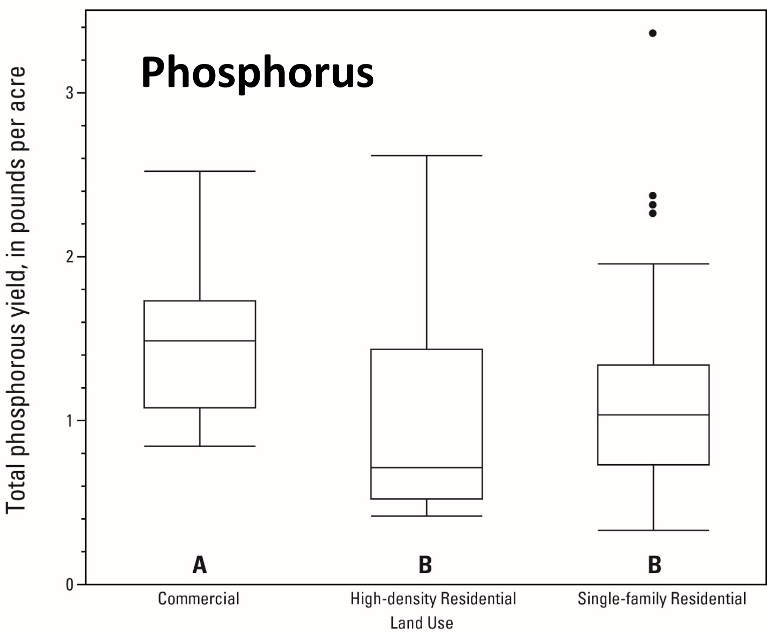
Additional observations

- Residential density did not have a clear influence on loading

- Particulate and dissolved nitrogen yields were higher in commercial watersheds

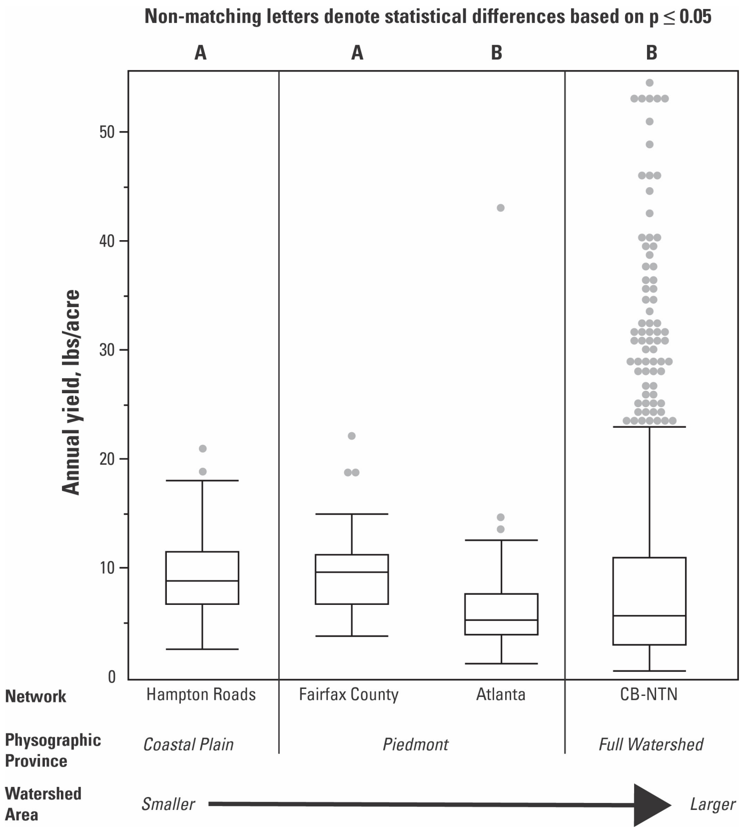
- Particulate phosphorus yields were higher in commercial watersheds BUT dissolved P did not differ



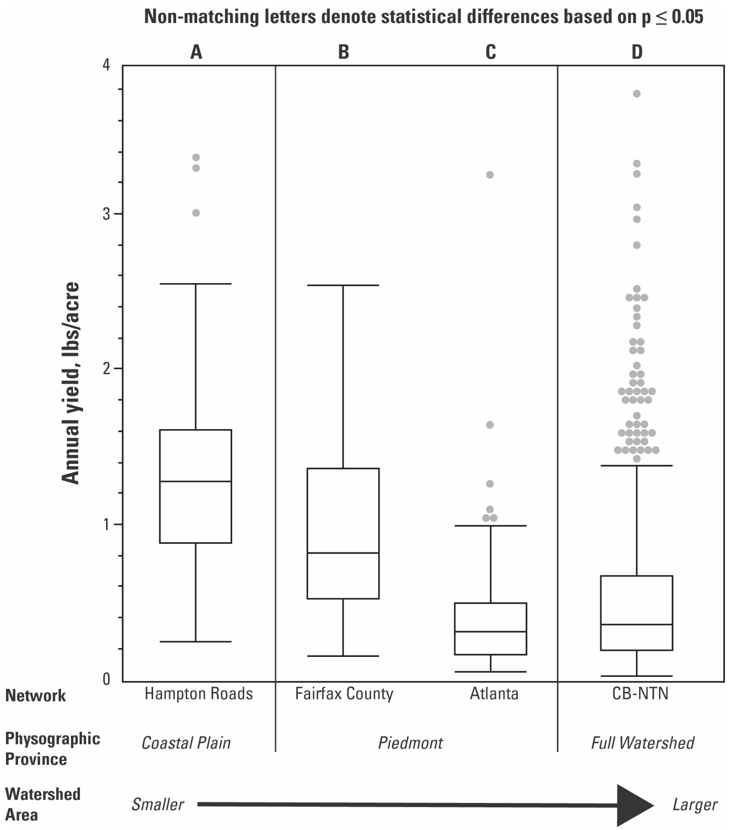


• Nitrogen and phosphorus yields in Hampton Roads are high relative to most other networks

Total Nitrogen



Total Phosphorus



Possible Drivers

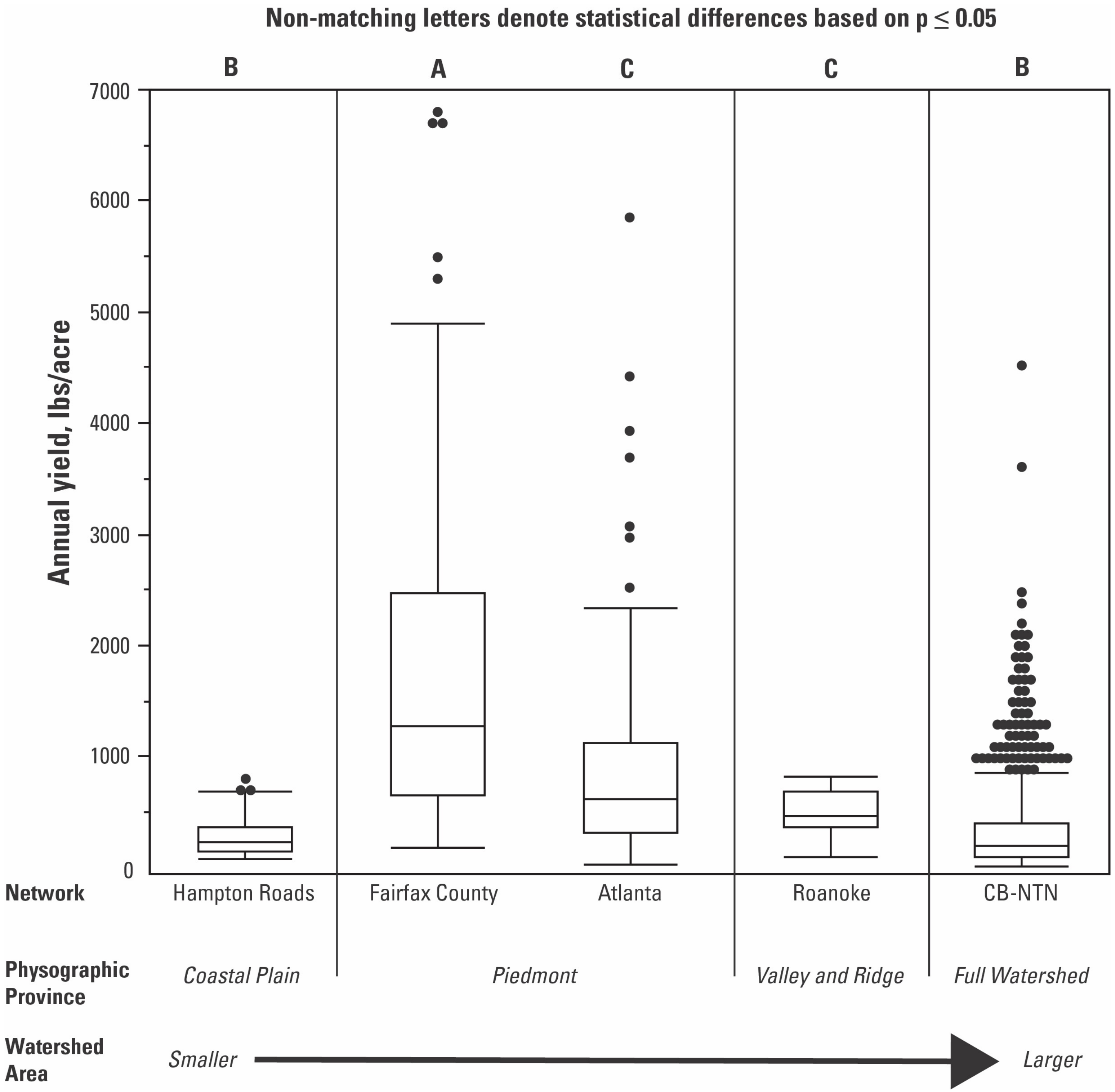
- Watershed area: Higher yields in smaller watersheds
- Channel type: (concrete vs earthen streams) affects sources, chemical processes, and transit time
- Urbanization: high imperviousness and drainage density: factors that increase transport, limit retention, and can bypass natural ecosystem services
- Physiographic Province: different sources, retention rates, and transport times (e.g., phosphorus may be more mobile in CP soils)

- Load Years: Each network includes all available annual loads from 2008 through 2022 (date ranges are not identical for each network),
- Watershed areas: Hampton Roads 30-275 acres, Fairfax 2-5 mi^2, Atlanta 1 – 161 mi^2, CB-NTN 0.7-27,100 mi^2

Annual sediment yields were lower in Hampton Roads than comparison networks.

<u>Possible Drivers</u>

- Watershed imperviousness: source-limited
- Channel type: concrete-lined channels vs earthen streambanks (no bank erosion)
- Soil properties: Coastal Plain sands vs Piedmont legacy clays/silts
- Low topographic relief: limits erosional processes



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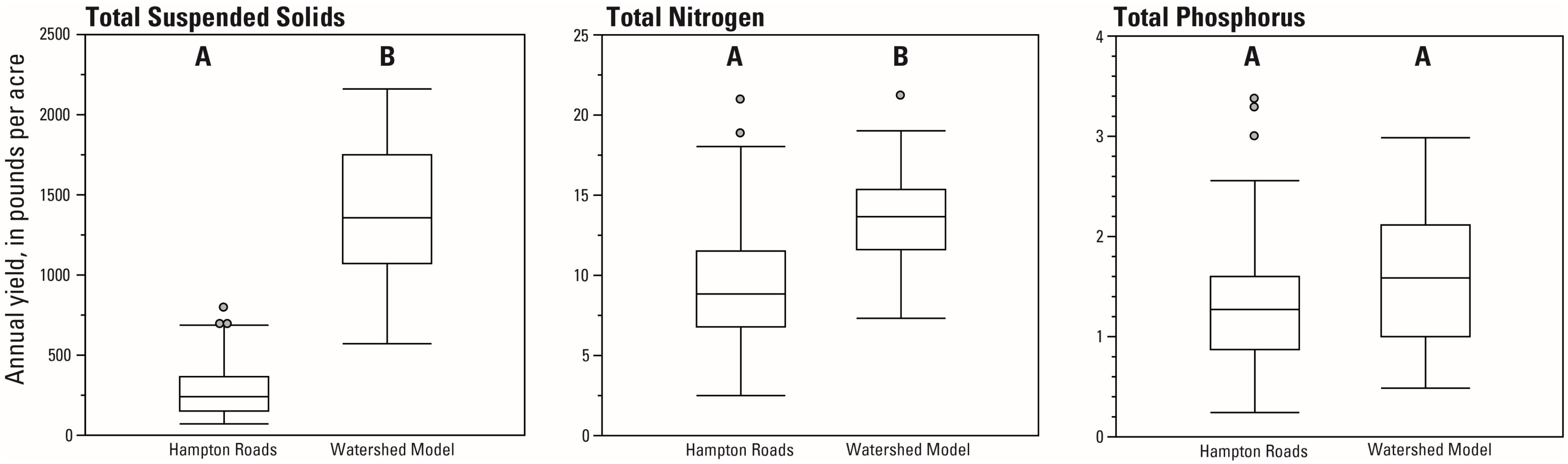
- Watershed areas: Hampton Roads 30-275 acres, Fairfax 2-5 mi^2, Atlanta 1 – 161 mi^2, CB-NTN 0.7-27,100 mi^2
- Constituent: Hampton Roads and Atlanta sediment yields are TSS, whereas other networks are SSC

How do modeled yields compare to measured yields?

These are not apples-to-apples datasets and therefore difficult to compare

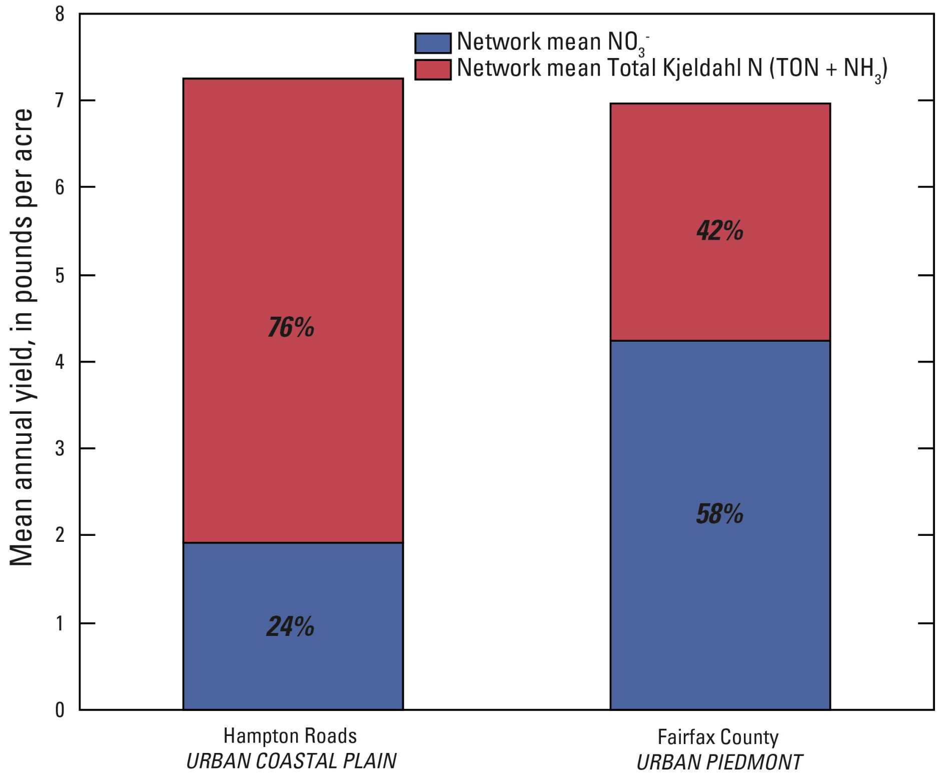
Chesapeake Bay Watershed Model estimates presented here represent the average annual yield (1984-2014) for all MS4 land use types in the 6 land segments (the cities of Chesapeake, Hampton, Newport News, Norfolk, Portsmouth, and Virginia Beach) that make up the Hampton Roads study region



The composition of nitrogen and phosphorus loads differed by region (urban Coastal Plain vs Urban Piedmont)

In Hampton Roads nitrogen yields were primarily composed of organics whereas in the Fairfax nitrate was dominant

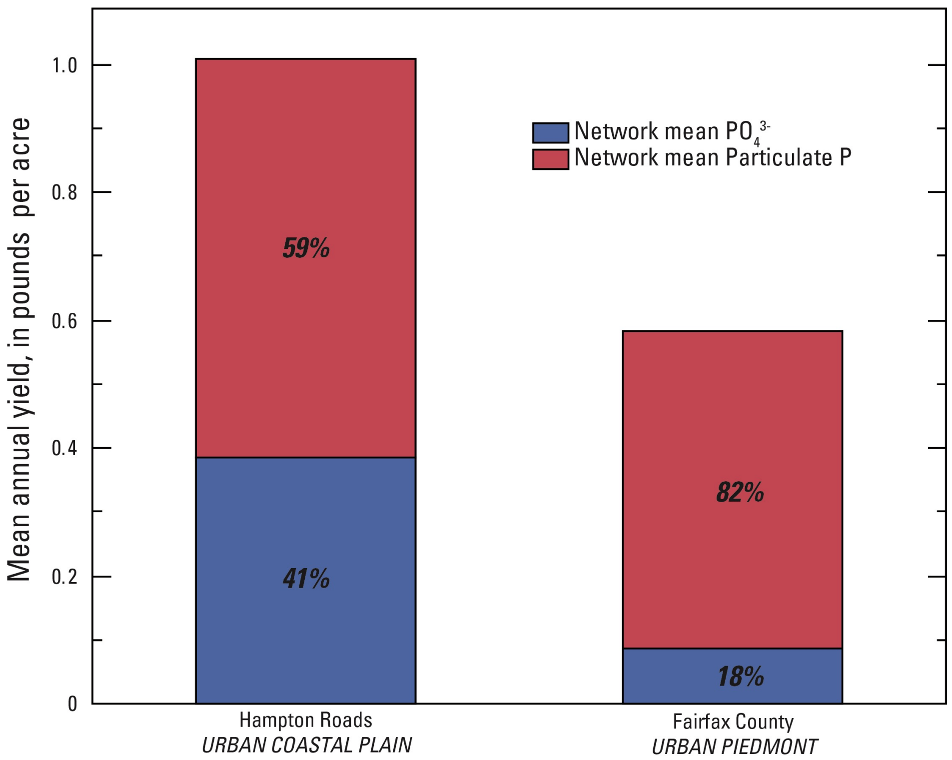
Nitrogen



Drivers: differences in denitrification, septic infrastructure, limited decomposition of organic material in storm drains

Phosphorus yields were primarily particulate in both networks but to a far lesser extent in Hampton Roads

Phosphorus



Drivers: Soil properties effect retention, saturation from historical applications, geological sources, organic matter buildup

Potential Future Work

Continued monitoring to support computation of annual loads

Compute trends in flow-adjusted loads once the dataset matures

Quantify the bioavailability of organic nitrogen in stormwater in the Hampton Roads region

Identify and quantify relative proportions of sources of loads (e.g., atmospheric deposition, wastewater, pet waste, fertilizer applications)

Evaluate efficiency of watershed management implementations (BMPs) and explore other drivers of spatio-temporal variability.

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