Nitrogen and Phosphorus in the Barnegat Bay–Little Egg Harbor Watershed: Sources and Loads

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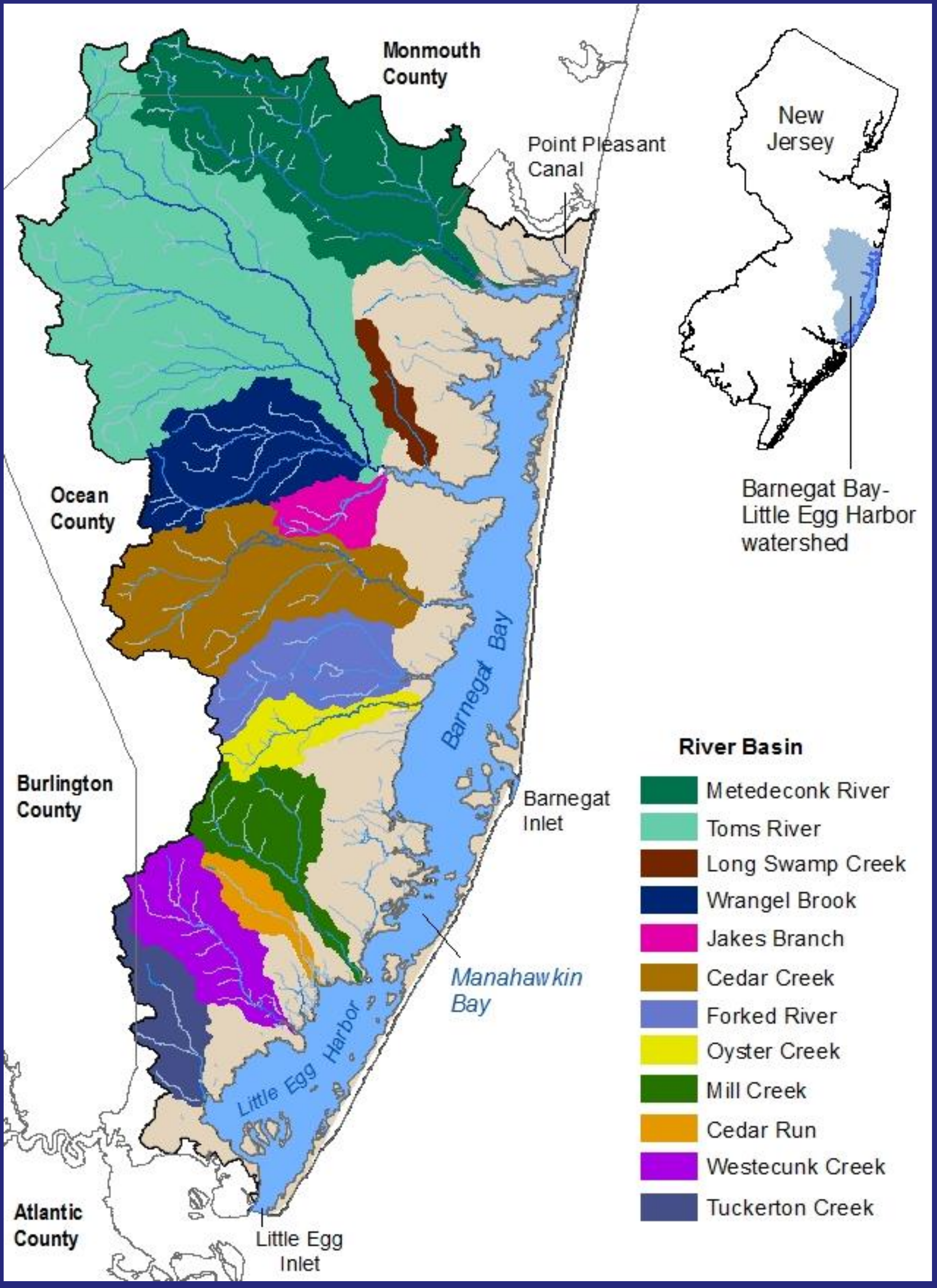
Study Area

- Barnegat Bay-Little Egg Harbor (BB-LEH) watershed and estuary
- Shallow, poorly flushed lagoonal system
  - Limited exchange with ocean
  - Long (70 km) and narrow (2-6 km)
  - Mean depth = 1.5 m
- Susceptible to impacts of nutrient enrichment



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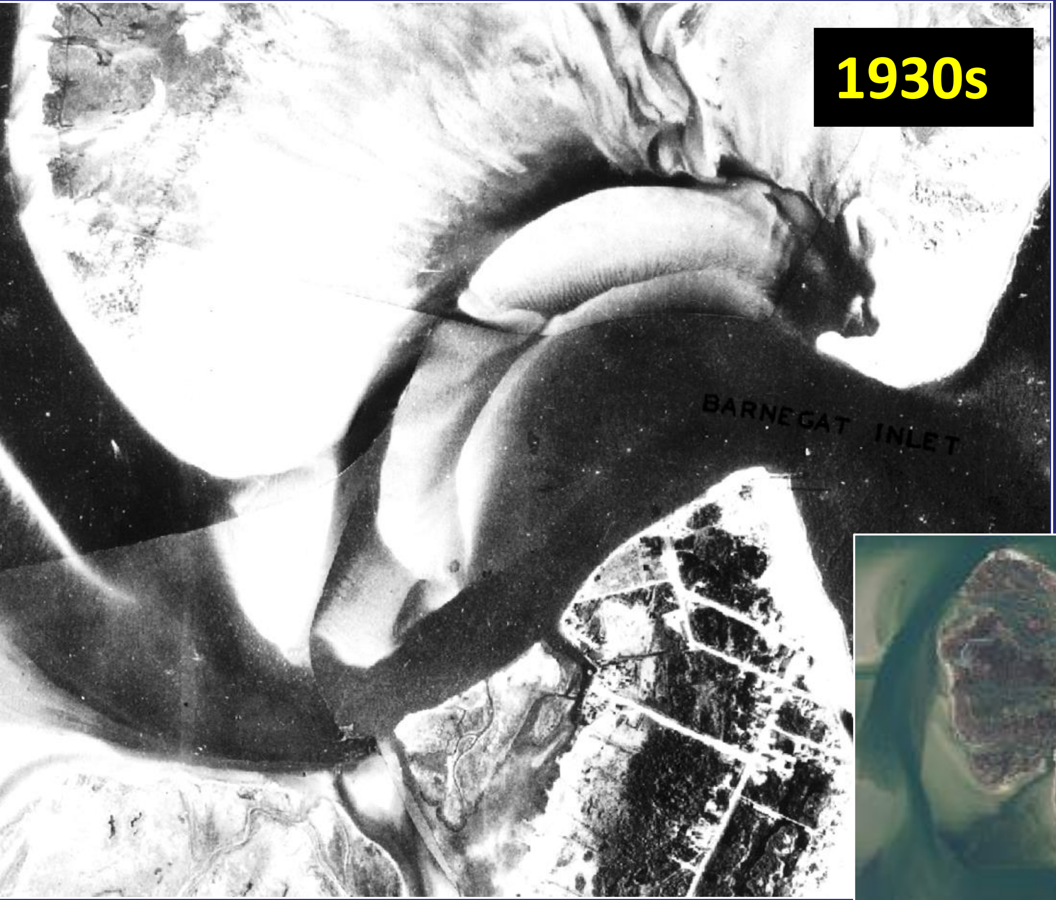
Barnegat Inlet



Data source: NJDEP Bureau of GIS (BGIS)

Data source: NJ Office of Information Technology (NJOIT), Office of Geographic Information Systems (OGIS)

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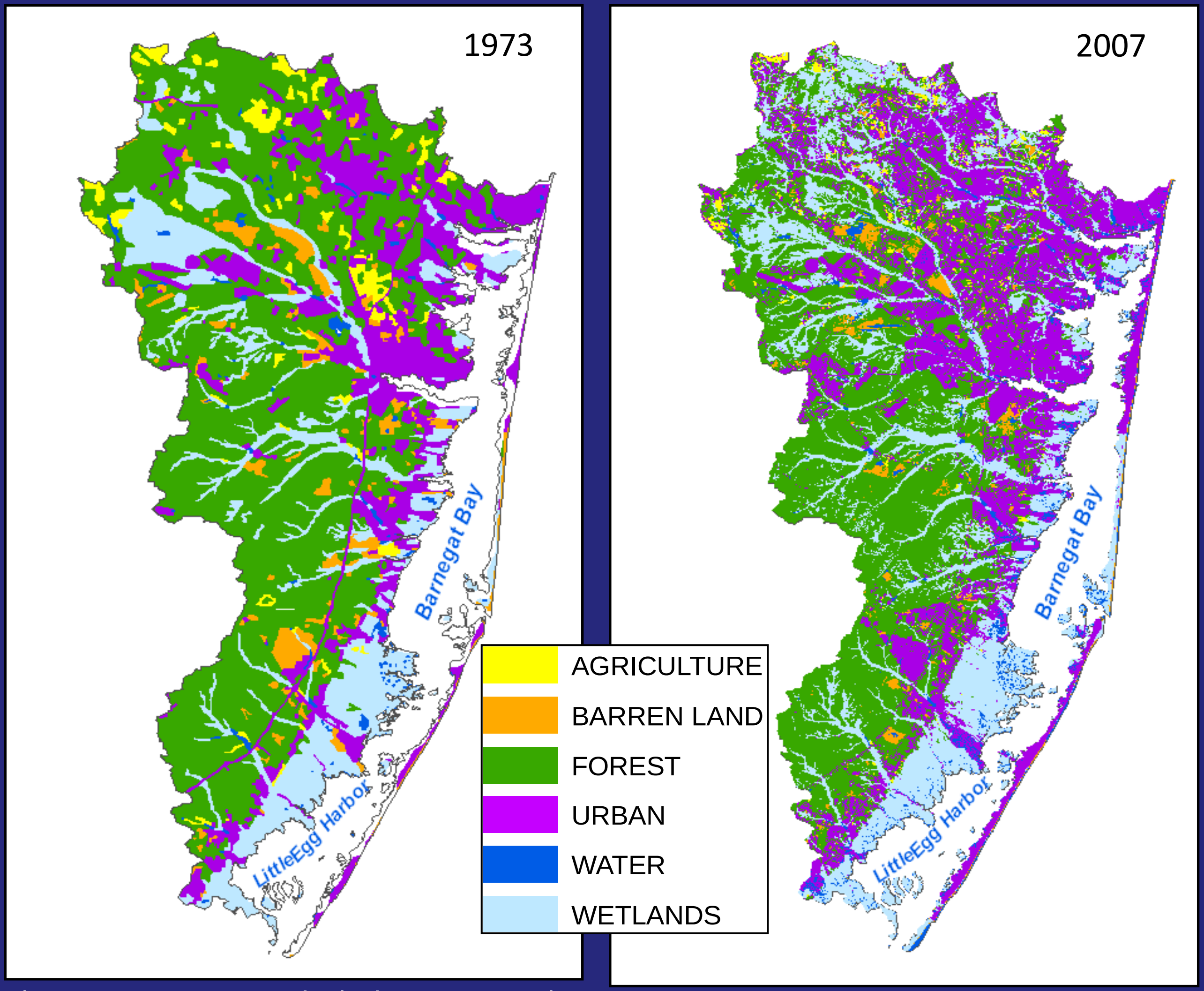
The Watershed



(Data source: U.S. Geological Survey, 1986)

(Data source: New Jersey Department of Environmental Protection, 2010)

- Land area: 1440 km^2
- Population: 560,000+
- <2% agriculture
- Few point sources

Bayville

Data source: NJDEP Bureau of GIS (BGIS)

Data source: NJ Office of Information Technology (NJOIT), Office of Geographic Information Systems (OGIS)

Ecological Concerns in the Estuary

- Decline in submerged aquatic vegetation (seagrass)
- Depletion of finfish and shellfish
- Algal blooms and brown tides
- Sea nettles
- Eutrophication

  = an increase in the rate of supply of organic matter in an ecosystem (Nixon, 1995)

Seagrass
Photo courtesy of Mike Kennish, Rutgers University

Atlantic sea nettle
Photo credit: Wally Gobetz

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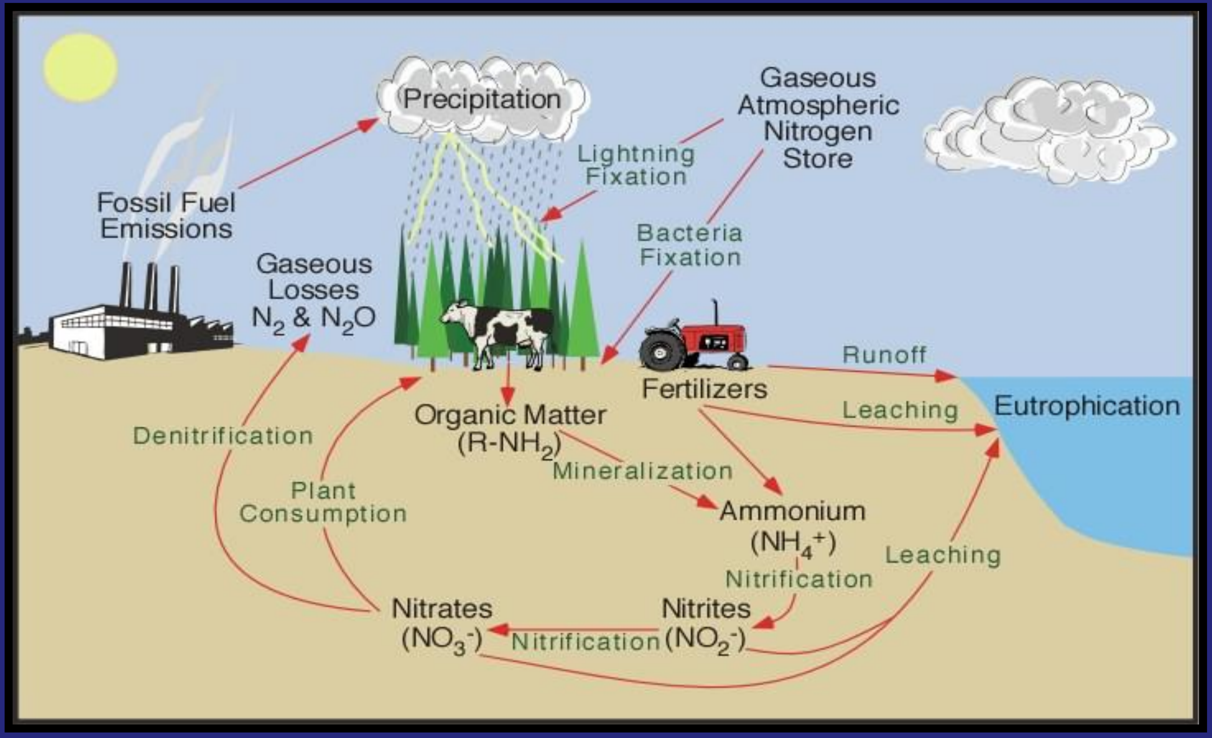
Objectives

- Quantify nutrient loads to the estuary
- Identify "hot spot" areas of elevated nutrient inputs
- Identify predominant sources of nitrogen throughout the watershed
- Help to identify effective nutrient-management strategies

Nitrogen

- Common forms
  - Organic nitrogen: proteins, decaying vegetation
  - Inorganic forms: nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_3)
  - Total nitrogen = the sum of organic and inorganic



(Graphic from Pidwirney, 2006)

Phosphorus

- Common forms
  - Organic phosphorus
  - Inorganic forms: orthophosphate (PO_4^{3-}), polyphosphates
  - Total phosphorus = the sum of organic and inorganic

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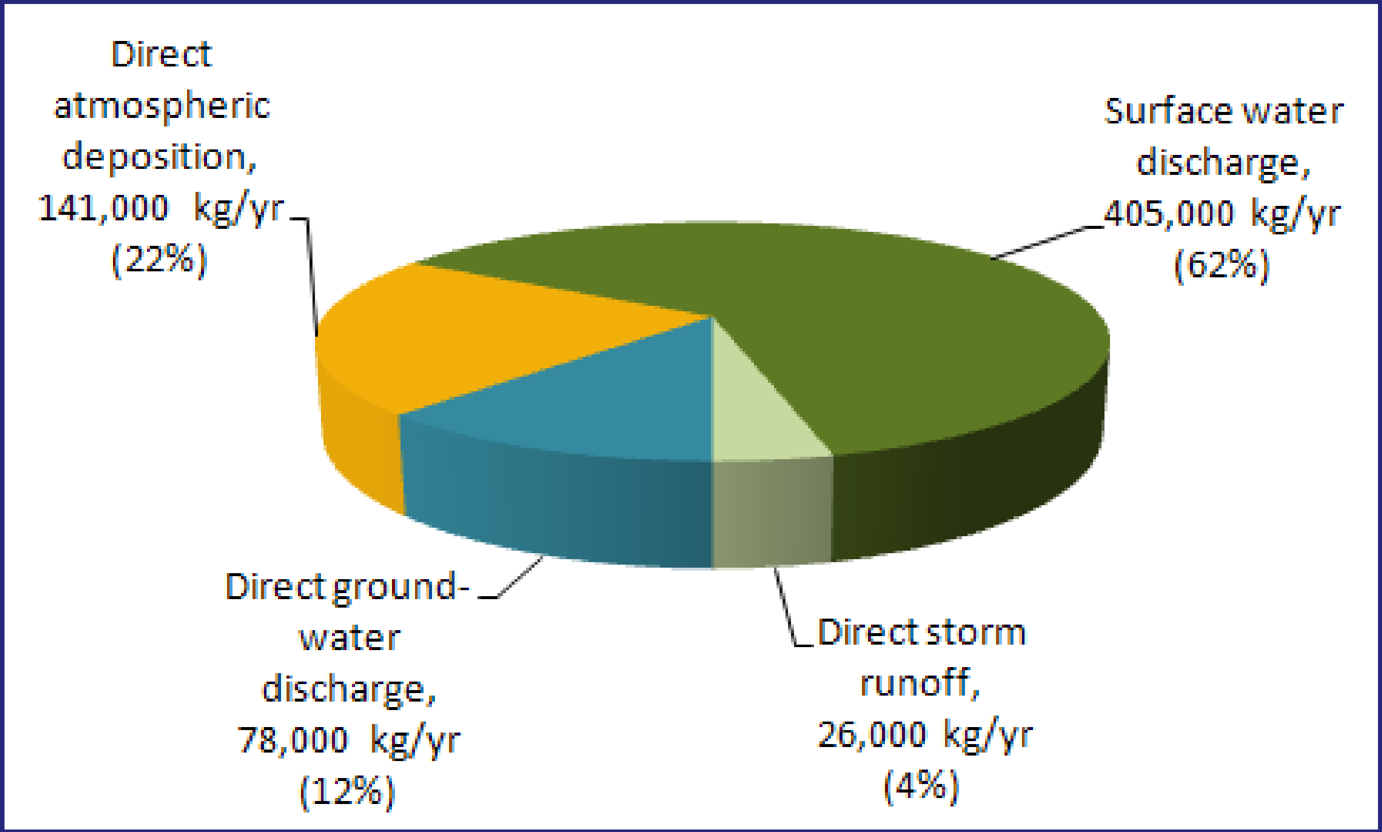
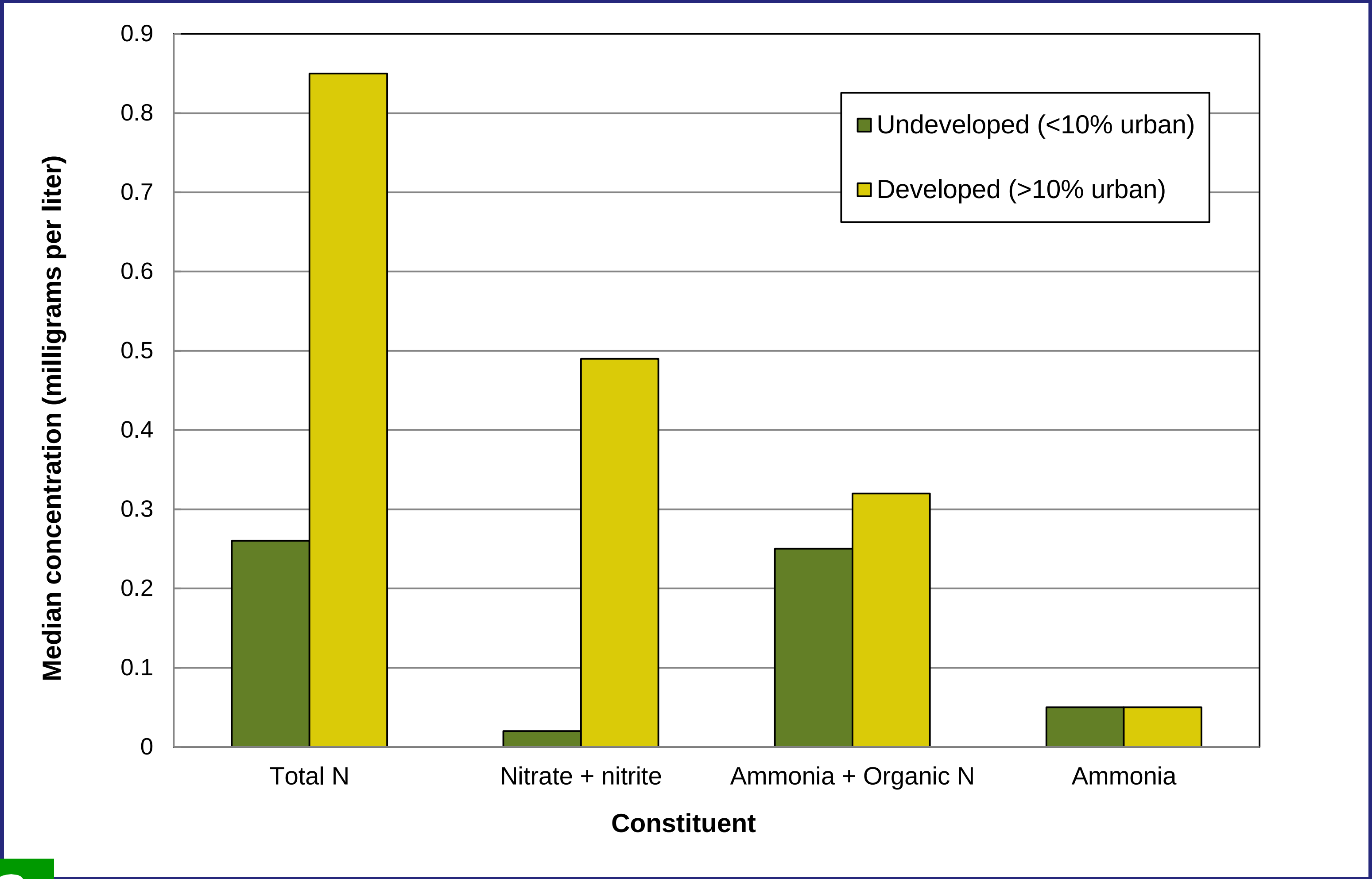
Transport Pathways of Nitrogen to BB-LEH estuary (previous study)



(Wieben and Baker, 2009)

Land-use effects on nitrogen concentrations in the BB-LEH watershed (previous study)



(Wieben and Baker, 2009)

Study 1: Sampling for nutrient concentrations and sources

Cedar Creek

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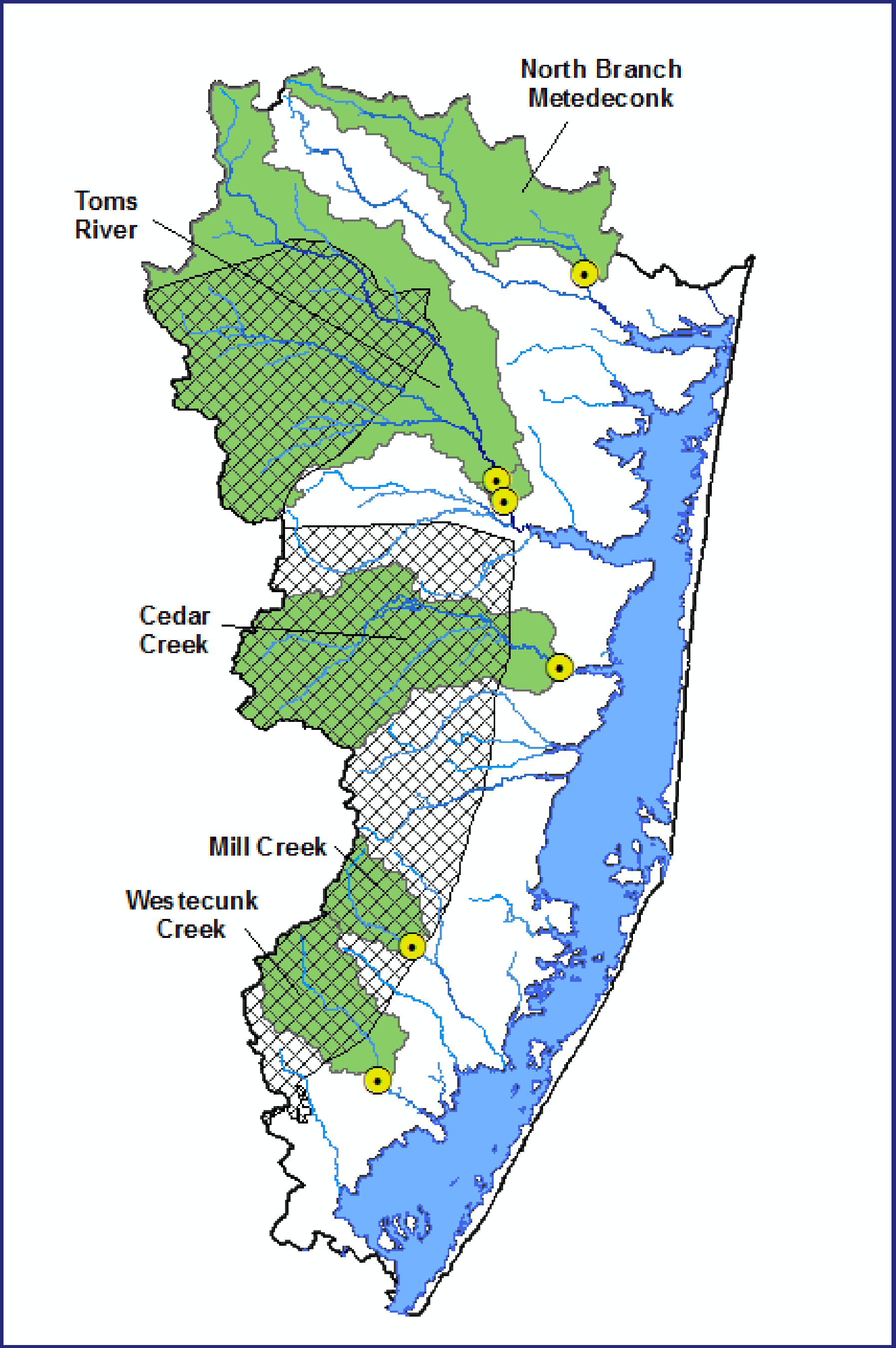
Storm sampling

- 5 sites, 2 storm events
  - March 2010, nongrowing season, 100-yr flooding
  - September 2010, growing season, drought

- 3 samples—base flow, first flush, near peak



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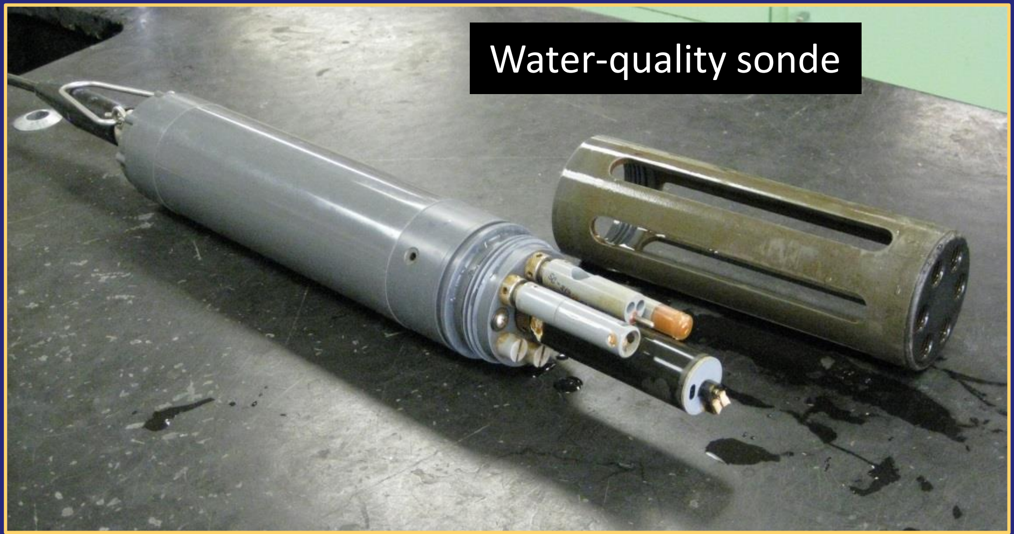
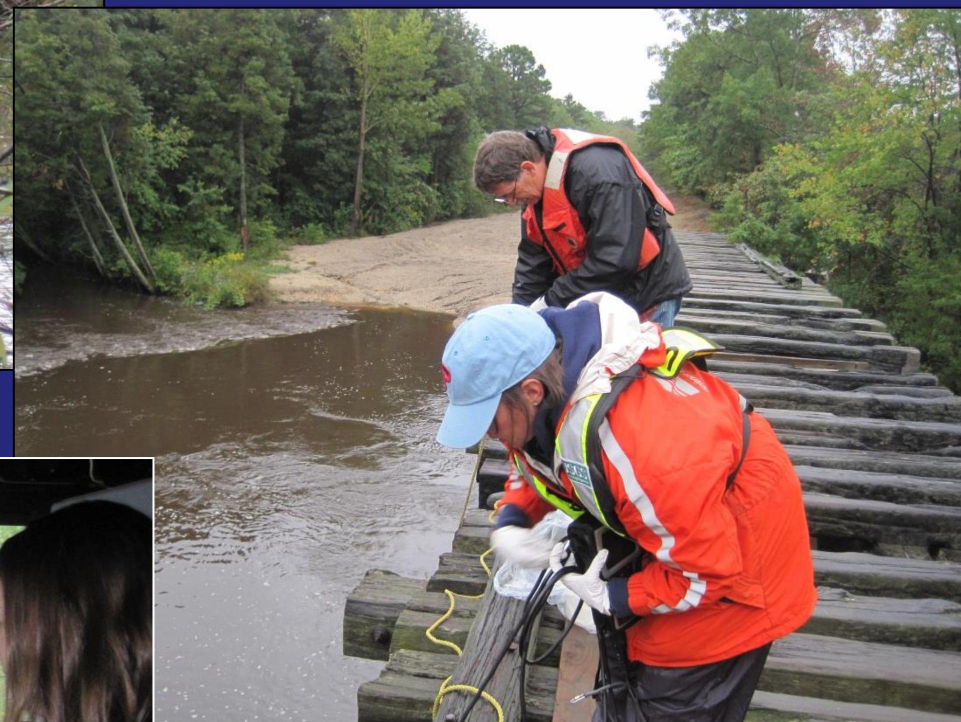
Continuous water-quality data



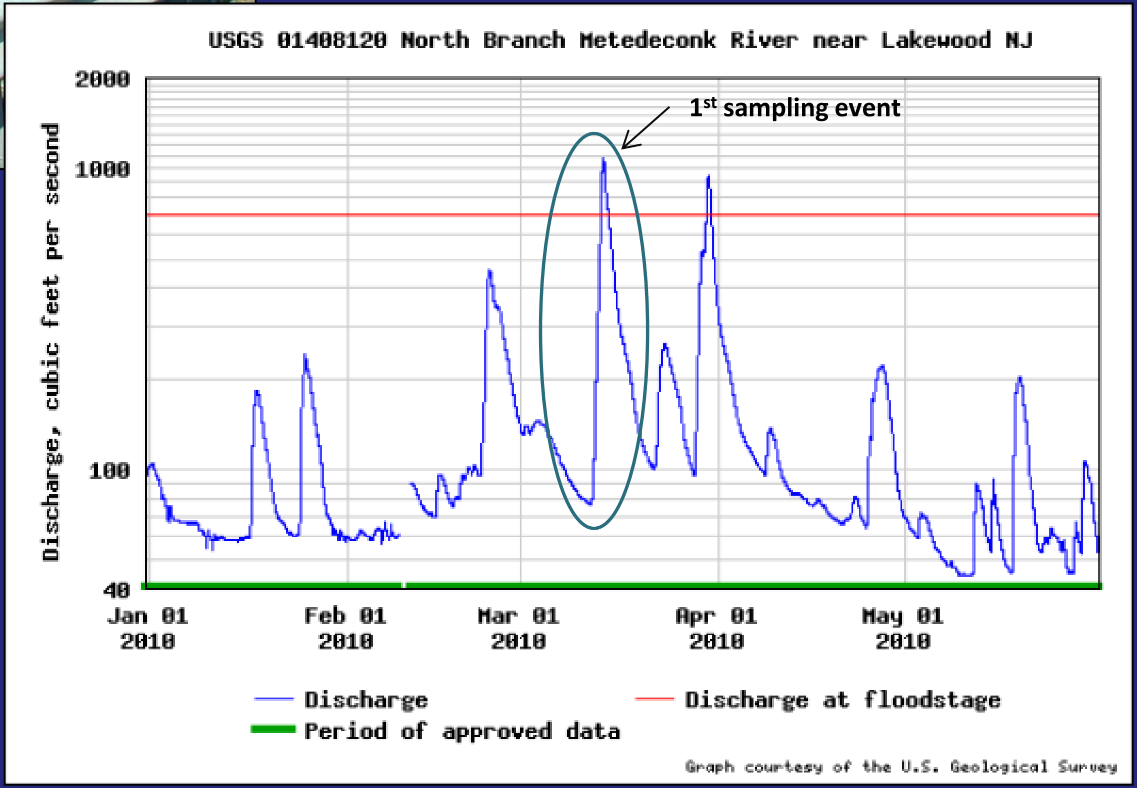
- Measured continuously for the duration of the storms:
  - -Water temperature
  - -Specific conductance
  - -pH
  - -Dissolved oxygen
  - -Turbidity

Water-quality samples



Streamflow (discharge) measurements

North Branch Metedeconk River streamflow gage



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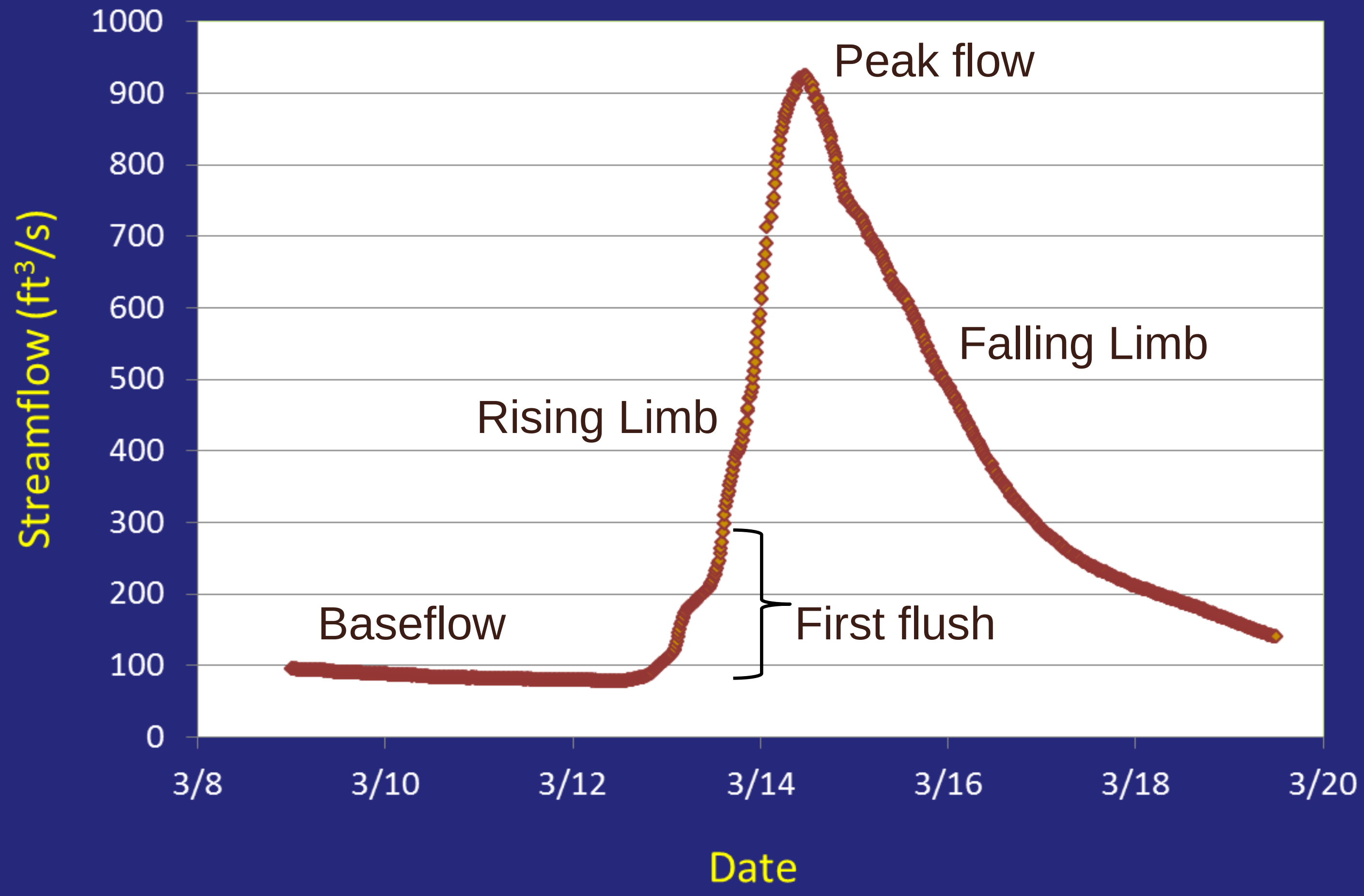
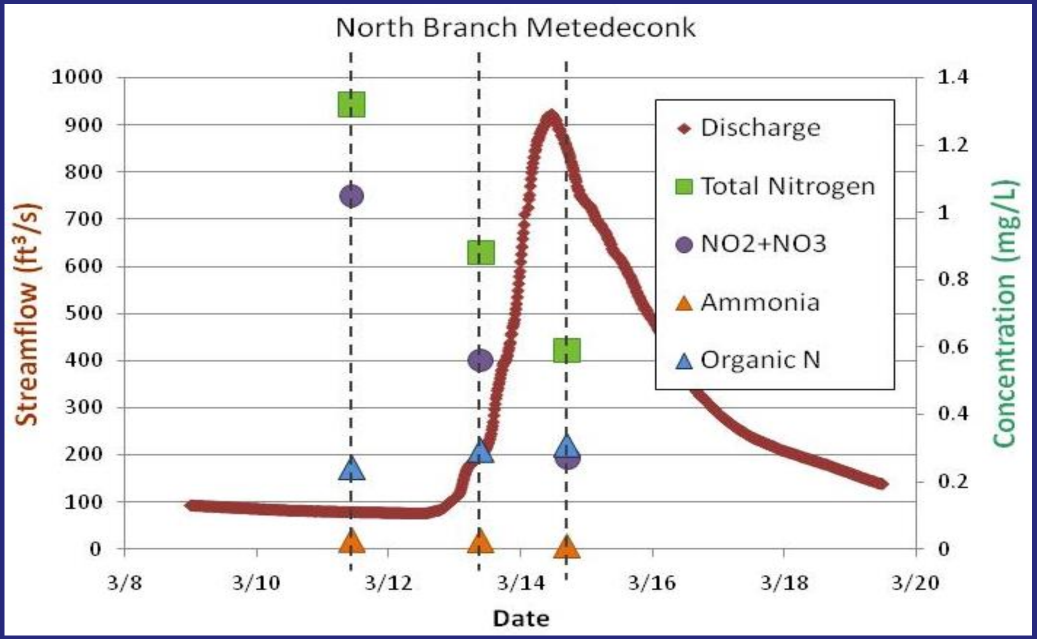
Hydrograph

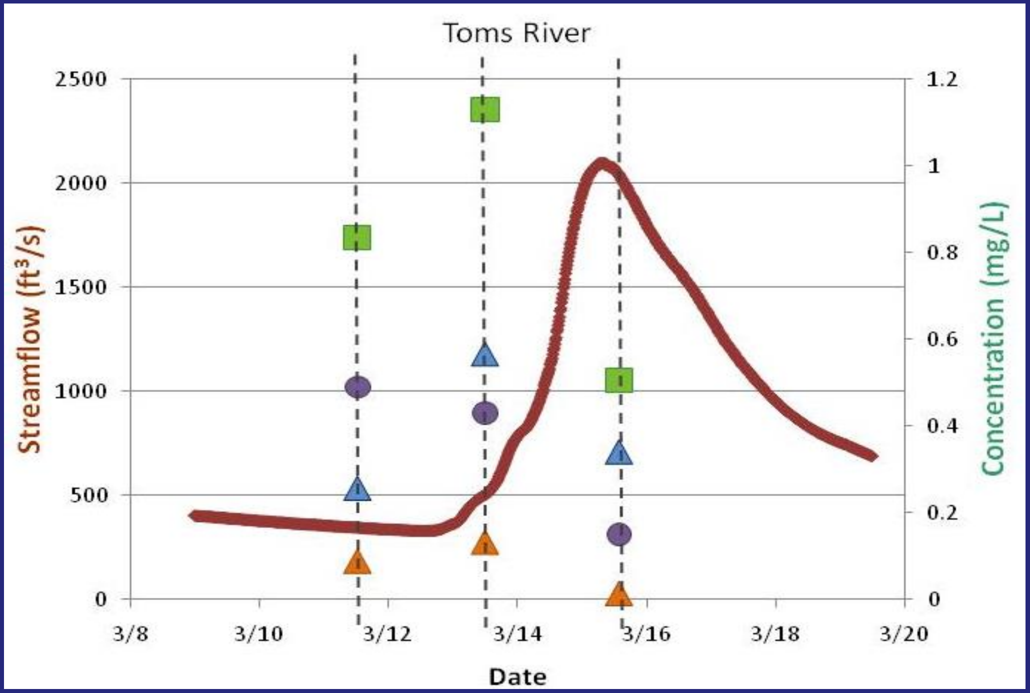


1000
900
800
700
600
500
400
300
200
100
0
Streamflow (ft³/s)
3/8
3/10
3/12
3/14
3/16
3/18
3/20
Date
Peak flow
Falling Limb
Rising Limb
Baseflow
First flush

Hydrographs and Concentrations

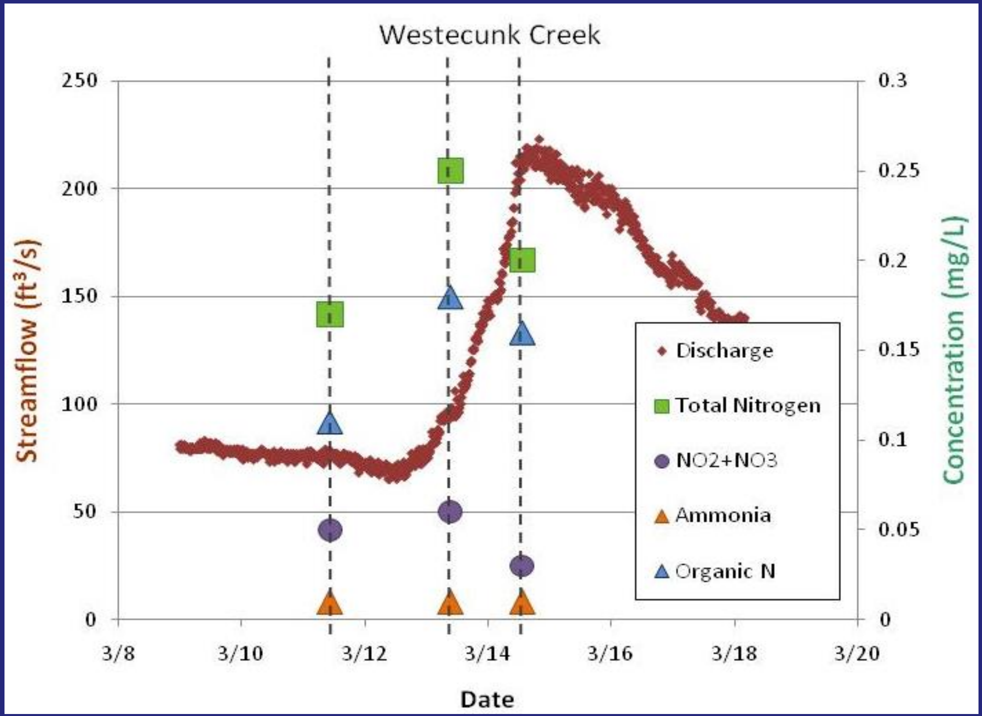
- Northern sites
  - Nitrate (NO_3^-) is major component of base flow total nitrogen
  - Dilution of NO_3^- during storm
  - Low concentrations of ammonia

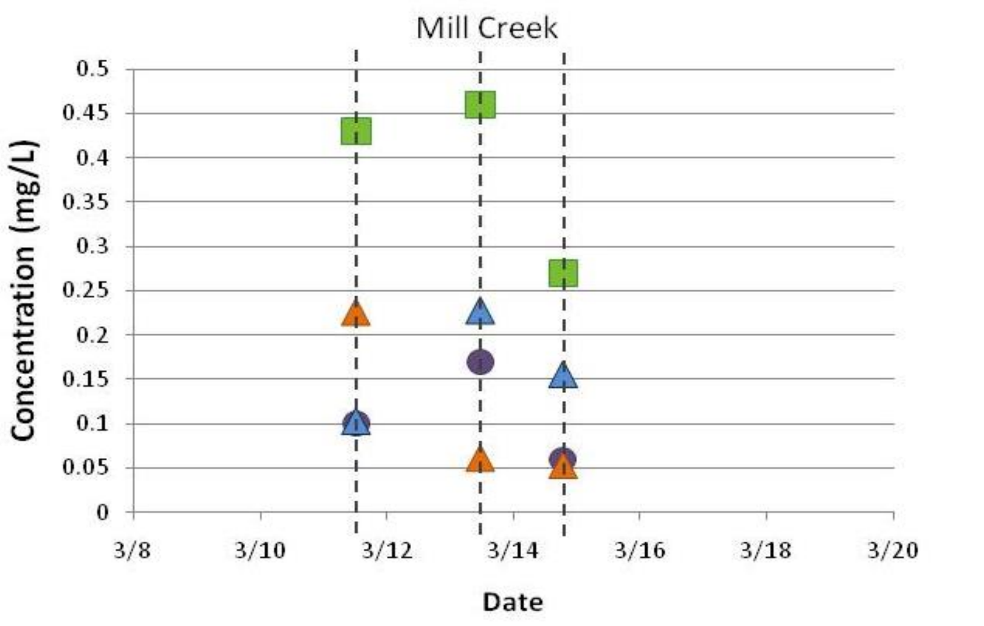




Hydrographs and Concentrations

- Southern sites
  - Lower ratio of NO_3^- to base flow total nitrogen
  - Organic nitrogen is a major constituent
  - Elevated levels of ammonia in Mill Creek

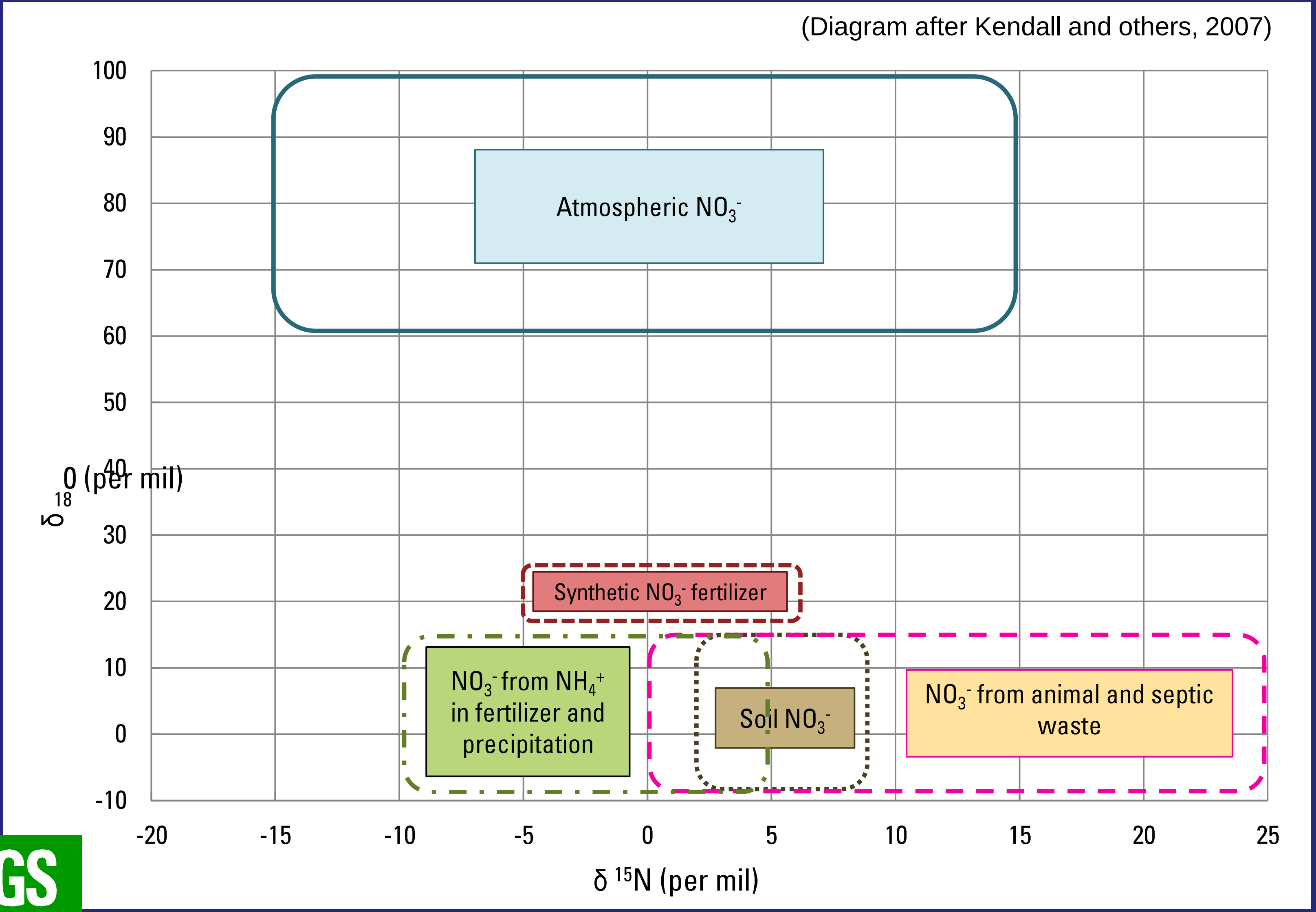




Stable Isotopes

- Nitrate = NO_3^-
- Stable isotopes for N include ^{14}N and ^{15}N
- Stable isotopes for O include ^{16}O and ^{18}O
- The δ value indicates the isotope ratio
  - Ratio of heavier:lighter isotope, compared to a standard
  - Lighter isotope is preferentially used
  - Indicates biogeochemical processes

Stable Isotopes



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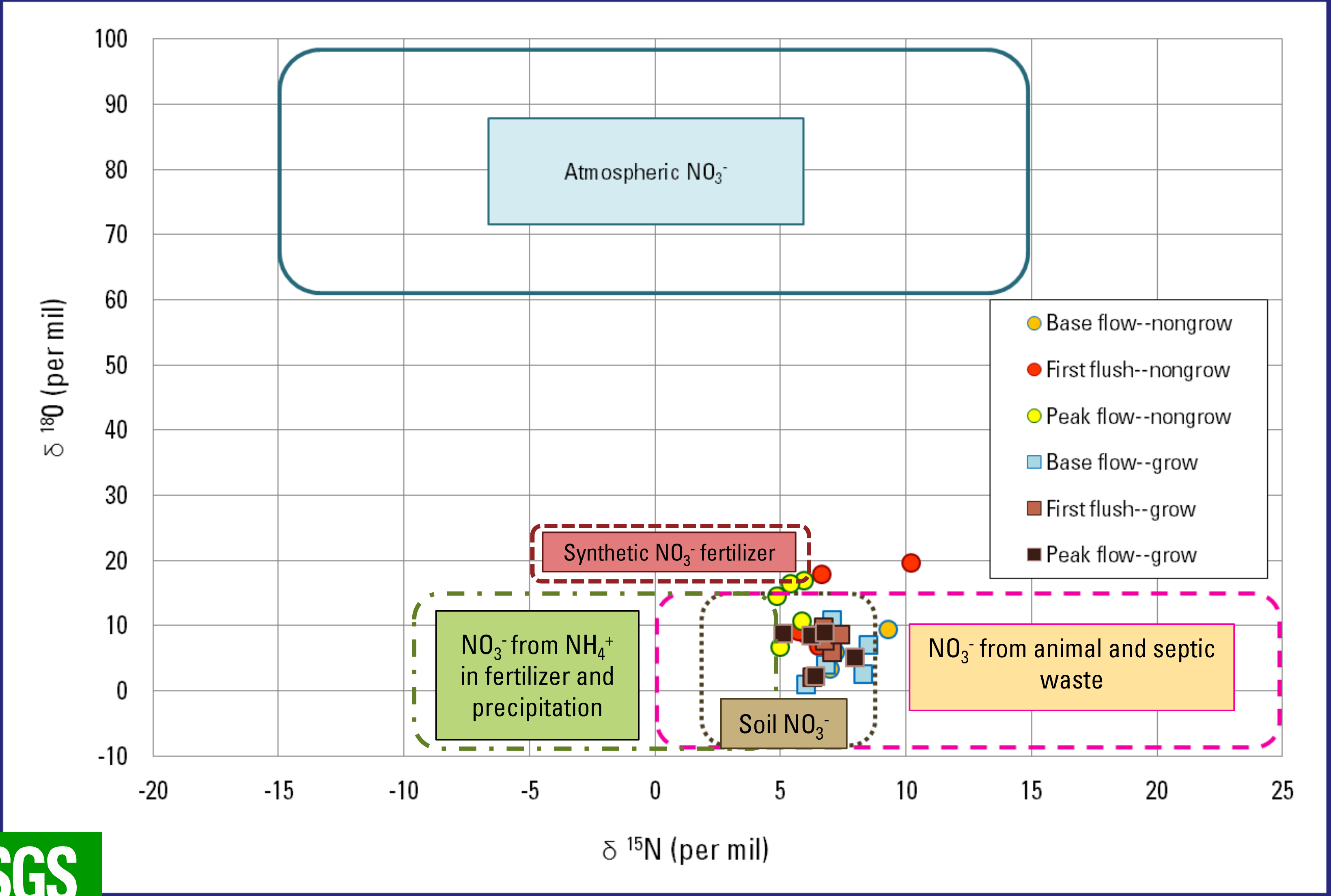
Stable Isotopes



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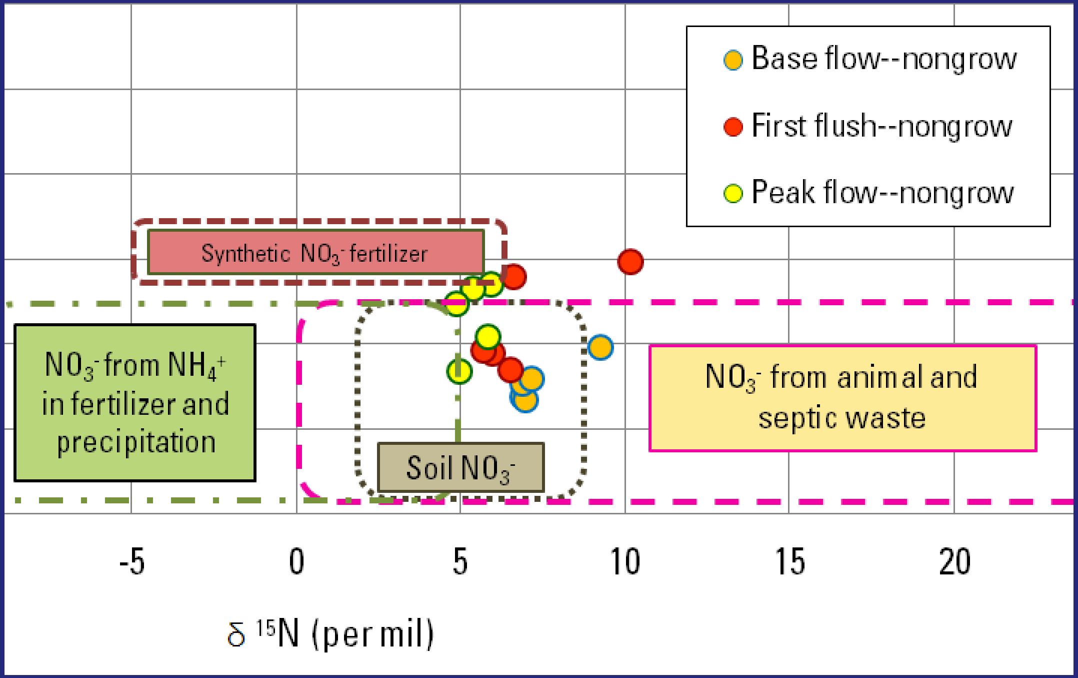
Comparison of base flow and storm flow

- Baseflow
  - Higher delta ^{15}N
  - Lower delta ^{18}O
- Stormflow
  - Lower delta ^{15}N
  - Higher delta ^{18}O

- Pattern is most evident in the March results



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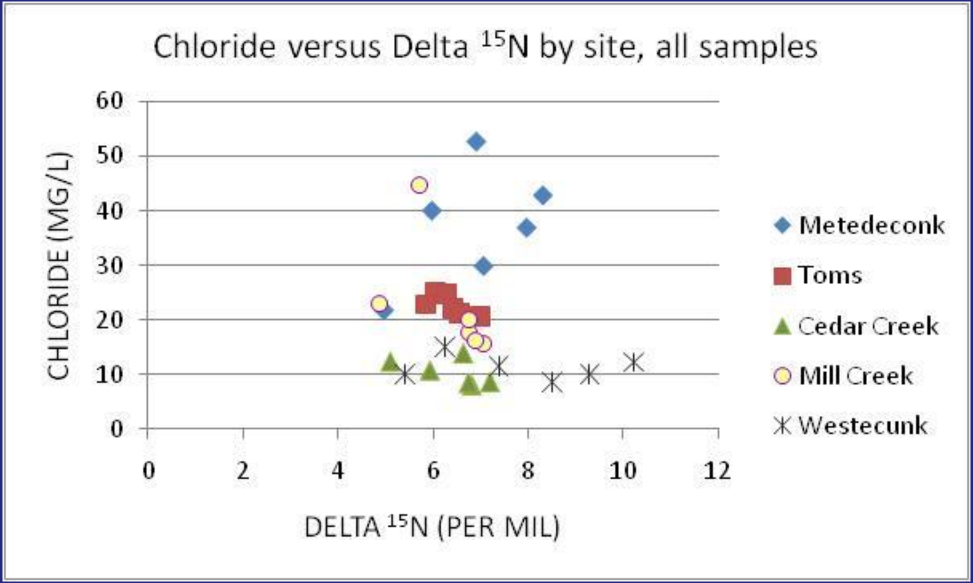
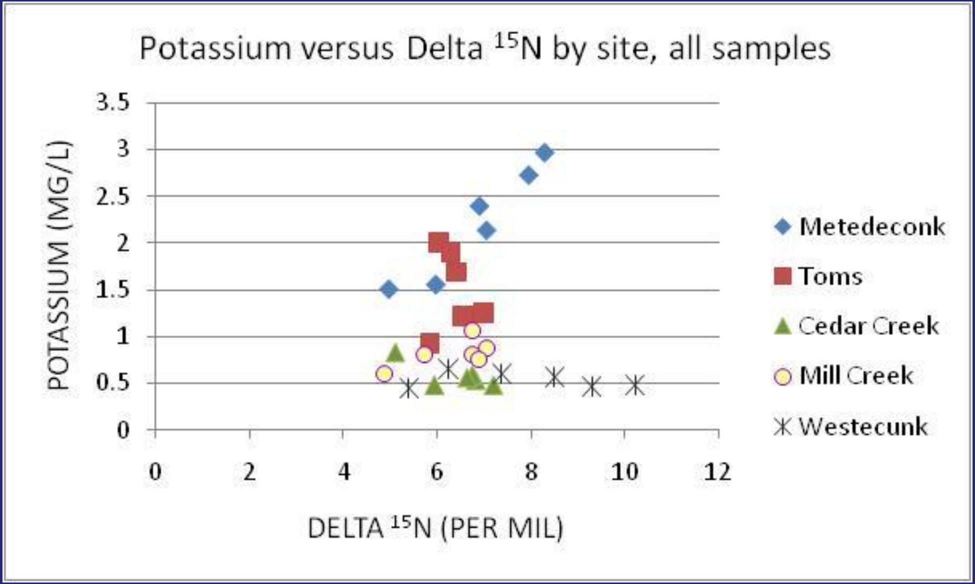
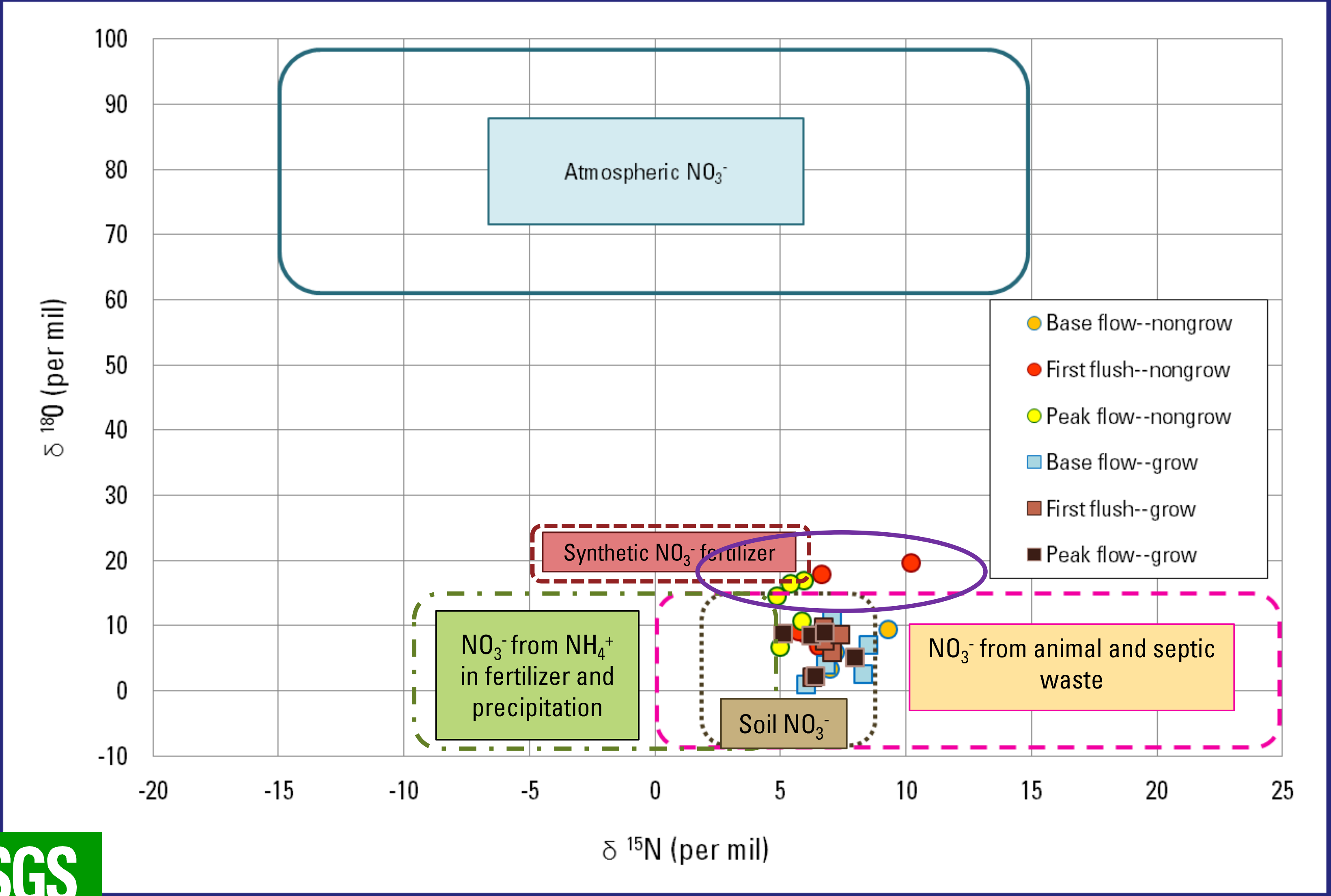
Dissolved solids





- Metedeconk
  - Higher delta ^{15}N, higher dissolved solids
  - Delta N-15 decreased
  - Consistent with possible septic, sewage, manure source
- Westecunk Creek
  - Dissolved solids constantly low

Stable Isotopes



Phosphorus

- Not detected, or measured at very low concentrations
- North Branch Metedeconk had the highest levels:
  - Total phosphorus: 0.02-0.09 mg/L
  - Orthophosphate: 0.008-0.011 mg/L

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Findings

- NO_3^- higher in more developed areas
- Mixing of nitrogen sources (soil, animal and septic, and fertilizer)
- Atmospheric not a predominant source in the watershed, but
  - More substantial in the south
  - More substantial as storm progresses

- Future sampling in headwaters, smaller tributaries, single land-use basins

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Study 2: Quantifying Nutrient Loads

Westecunk Creek
Photo courtesy of Robert Stern

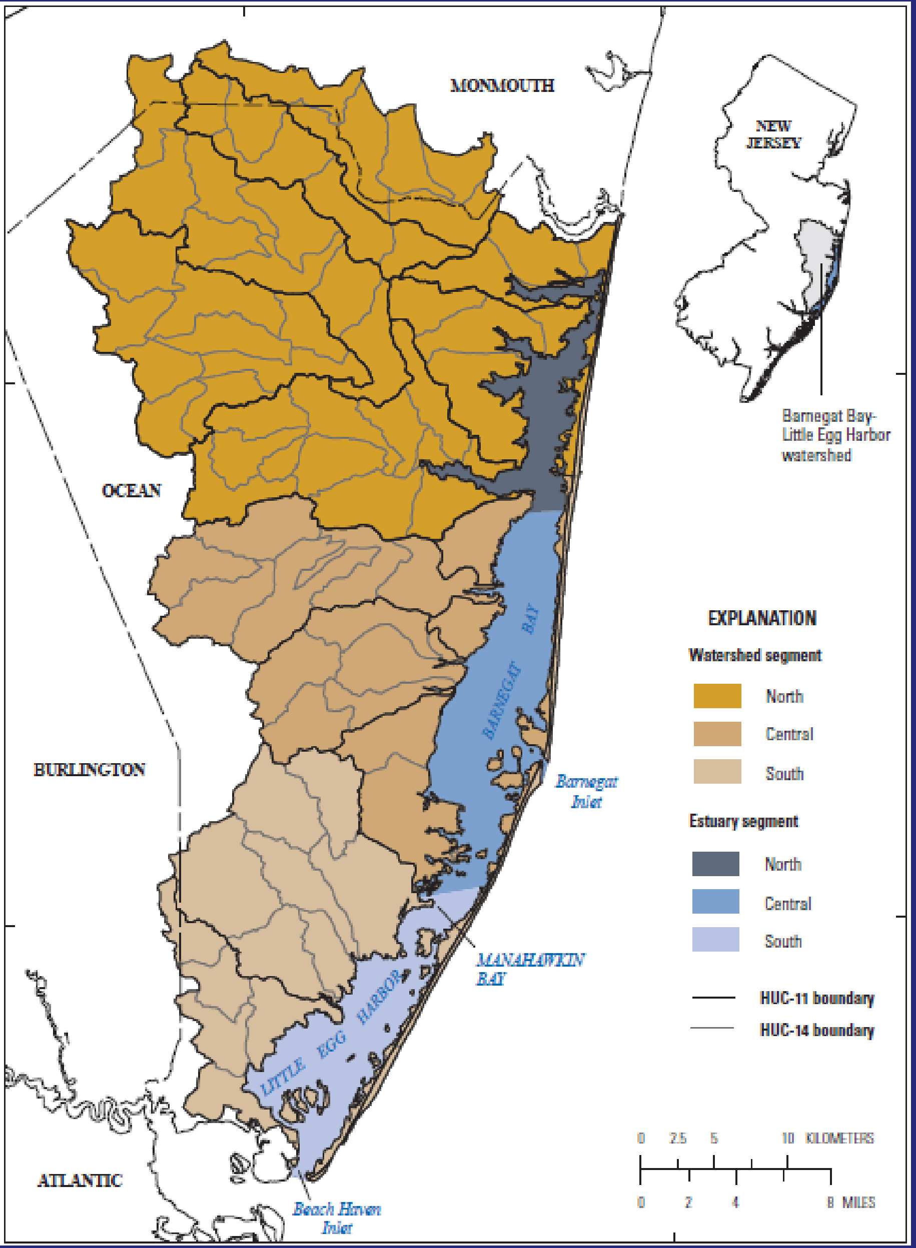
Constituent Loads and Yields

- Load: mass of a constituent delivered to a receiving water body over a specified period of time (e.g. kilograms of nitrogen per year)
  - Load = Concentration x Volume

- Yield: load per unit of watershed area (e.g. kilograms of nitrogen per year per hectare)
  - Yield = Load ÷ Area

Overview

- 1989-2011
- Base flow, runoff, total
- Multiple spatial scales
  - Hydrologic Unit Code- 14 (HUC-14)
  - Segment
  - Watershed



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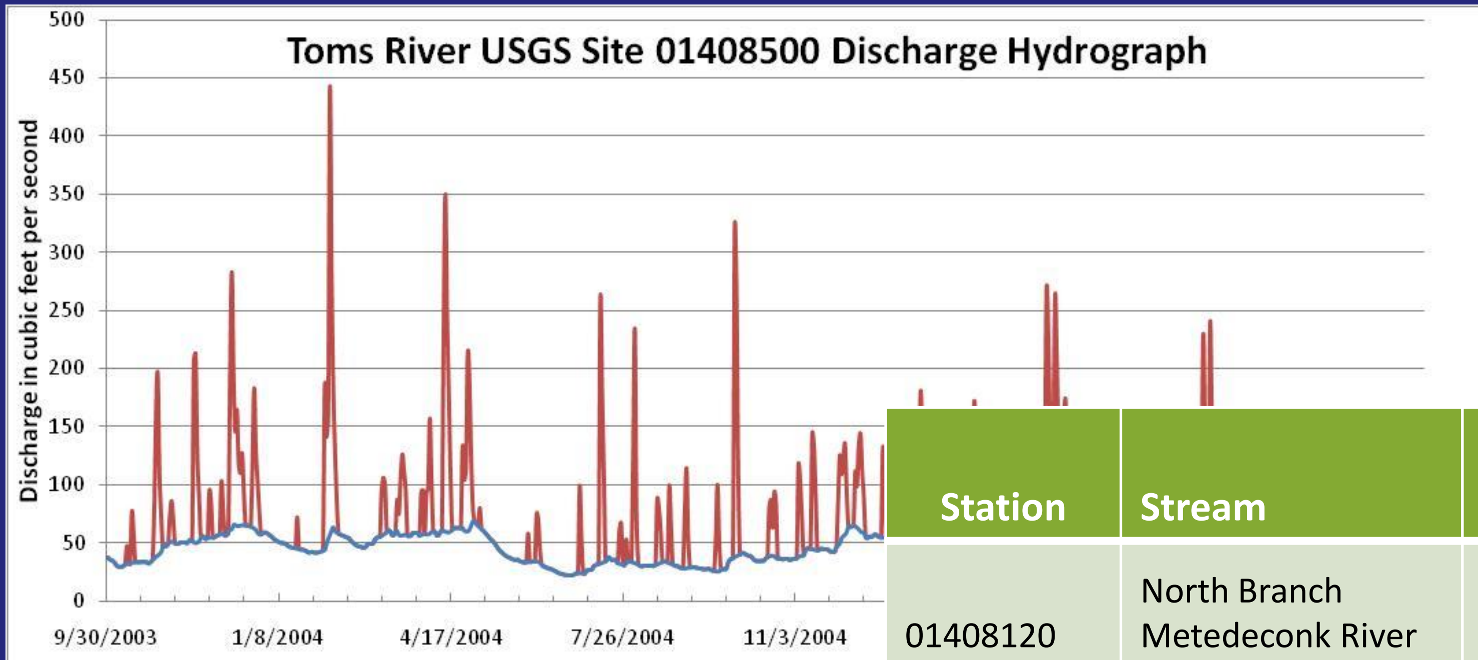
Base-flow separation



Station	Stream	Base-flow index
01408120	North Branch Metedeconk River	0.716
01408150	South Branch Metedeconk River	0.719
01408500	Toms River	0.853
01409000	Cedar Creek	0.906
01409095	Oyster Creek	0.913
01409280	Westecunk Creek	0.944

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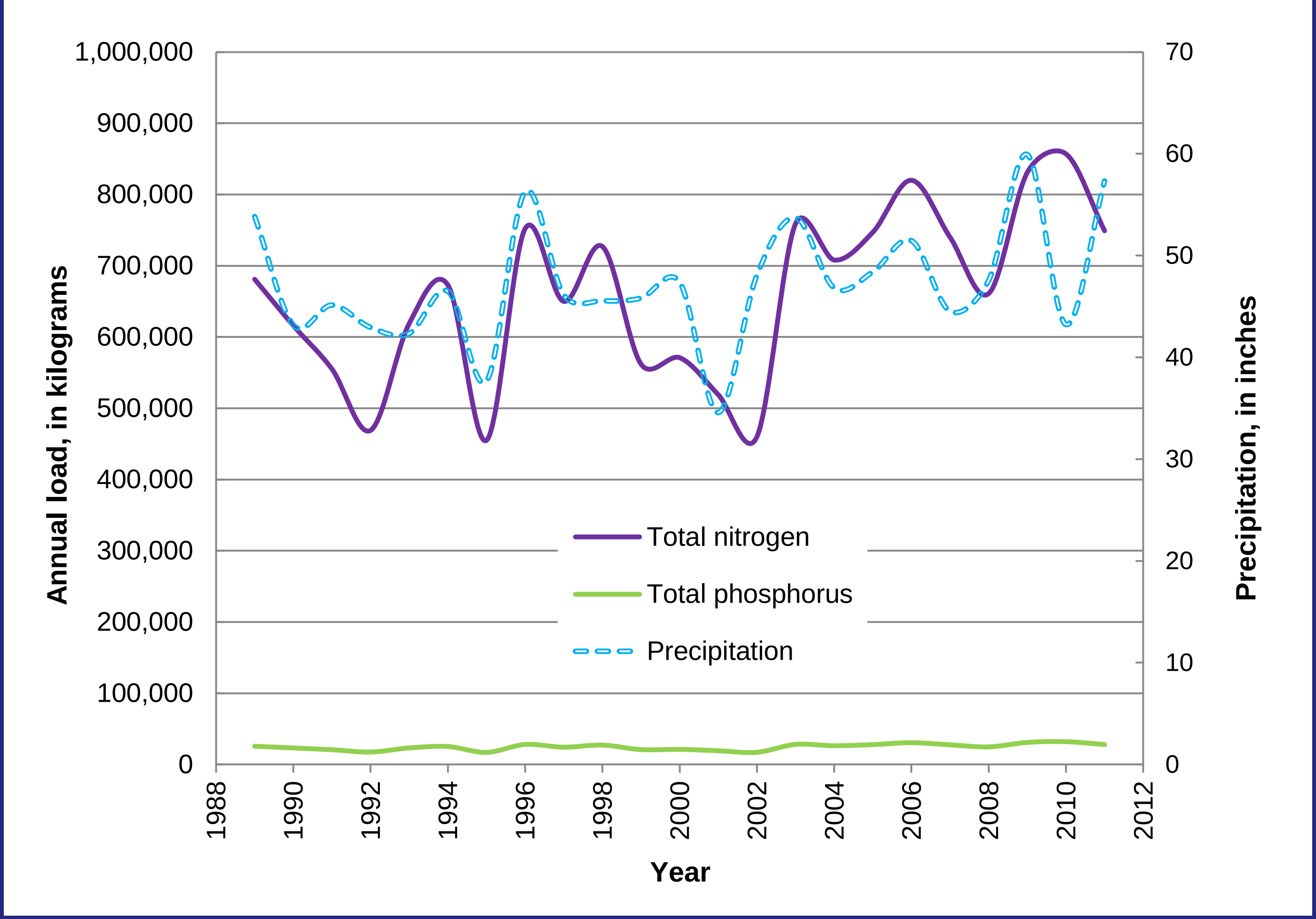
Annual Loads for the Watershed



Total nitrogen: 455,000 – 857,000 kg N/yr

Total phosphorus: 17,000 – 32,000 kg P/yr

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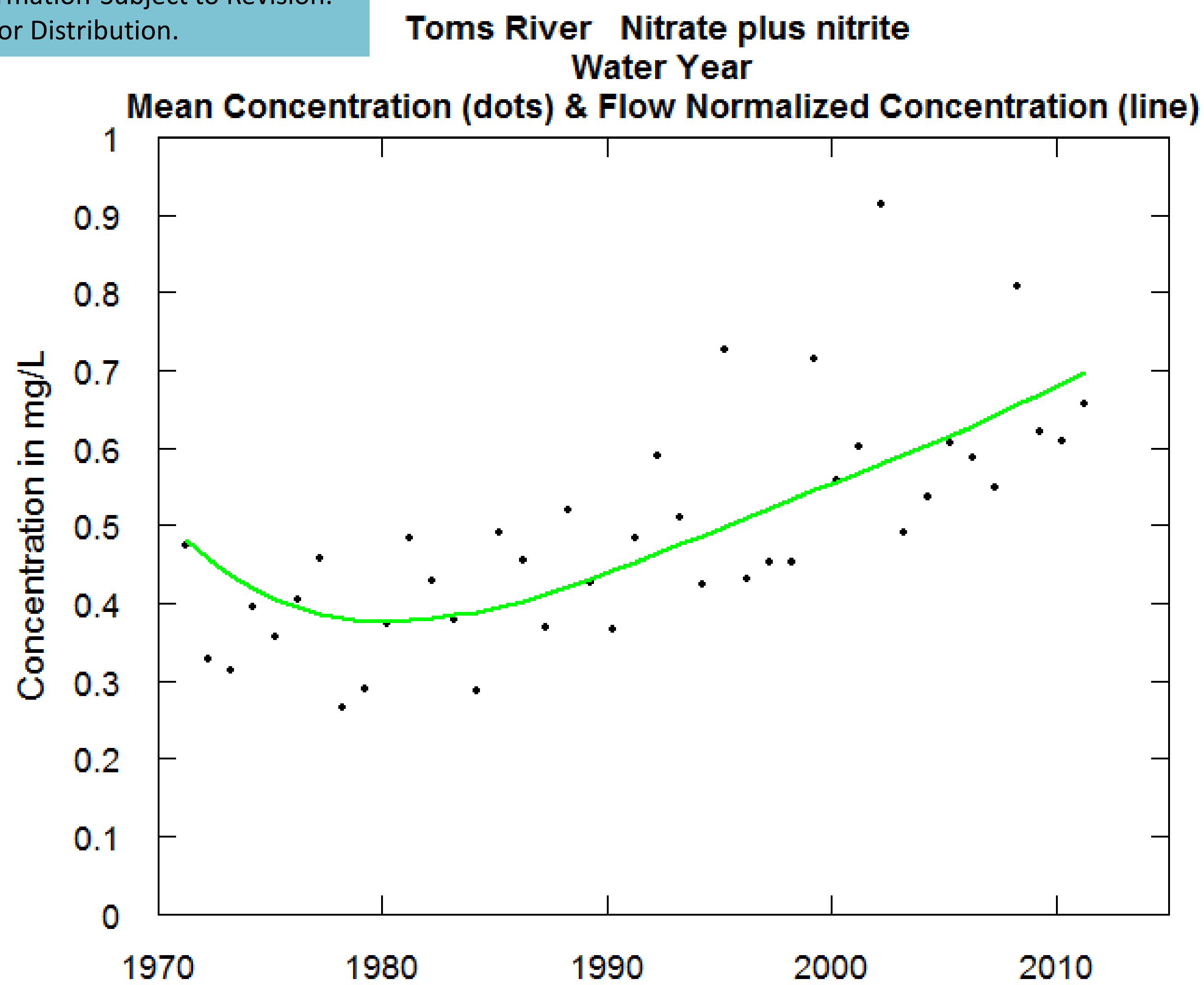
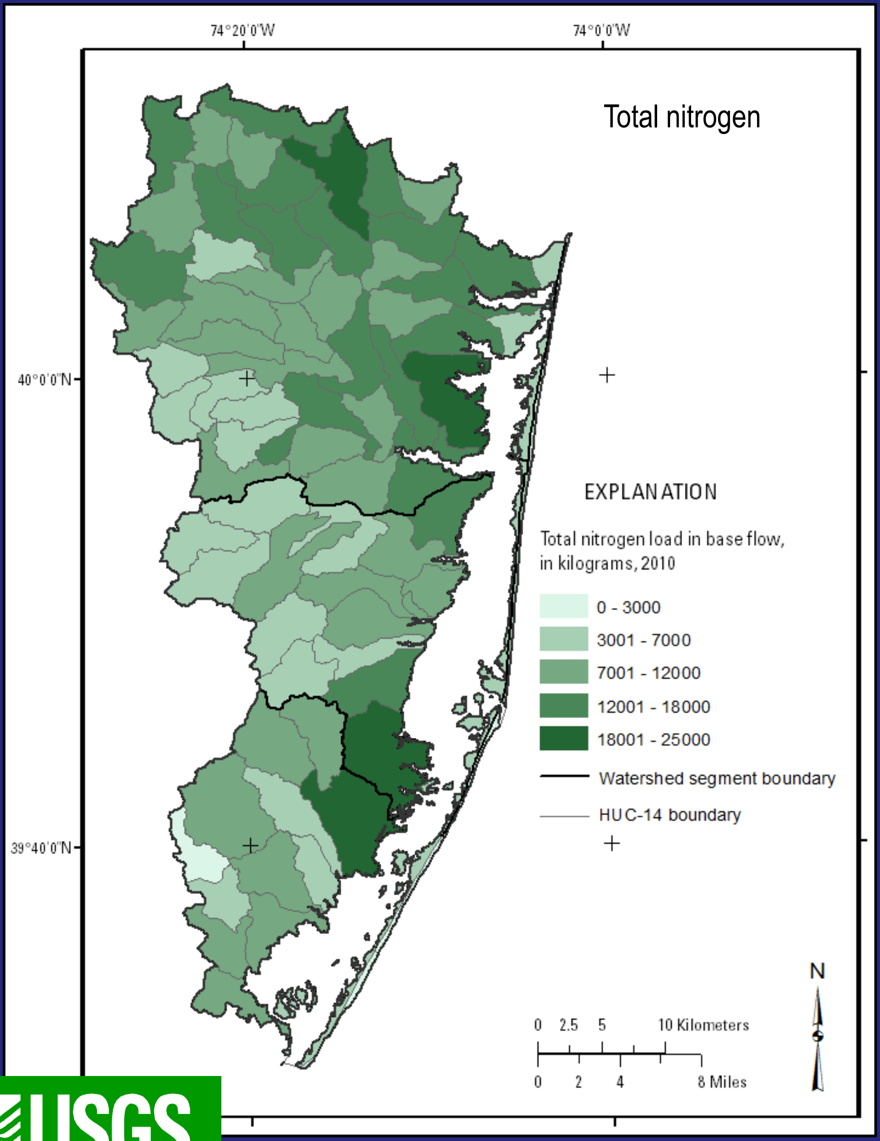
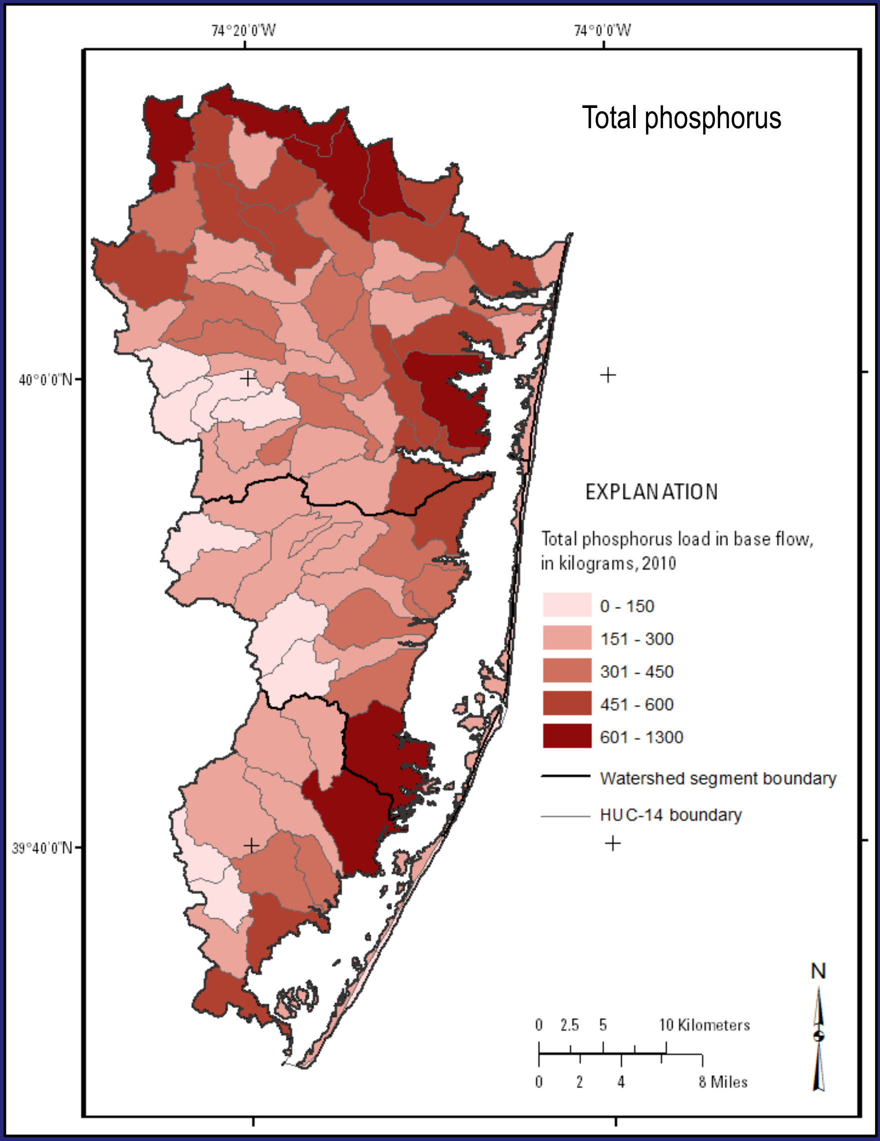
Preliminary Information-Subject to Revision.
Not for Citation or Distribution.



(Hickman, ongoing trend study, unpublished results)

Example output: Base-flow Loads, 2010





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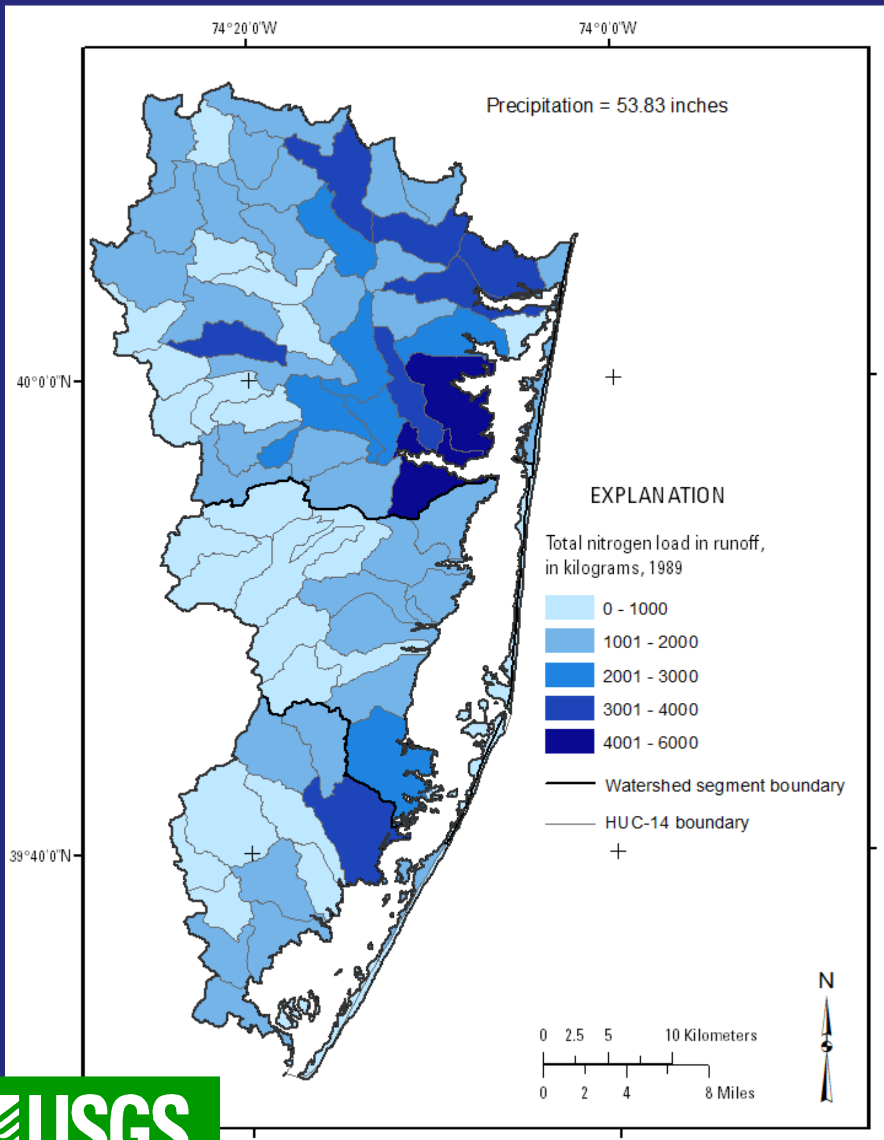
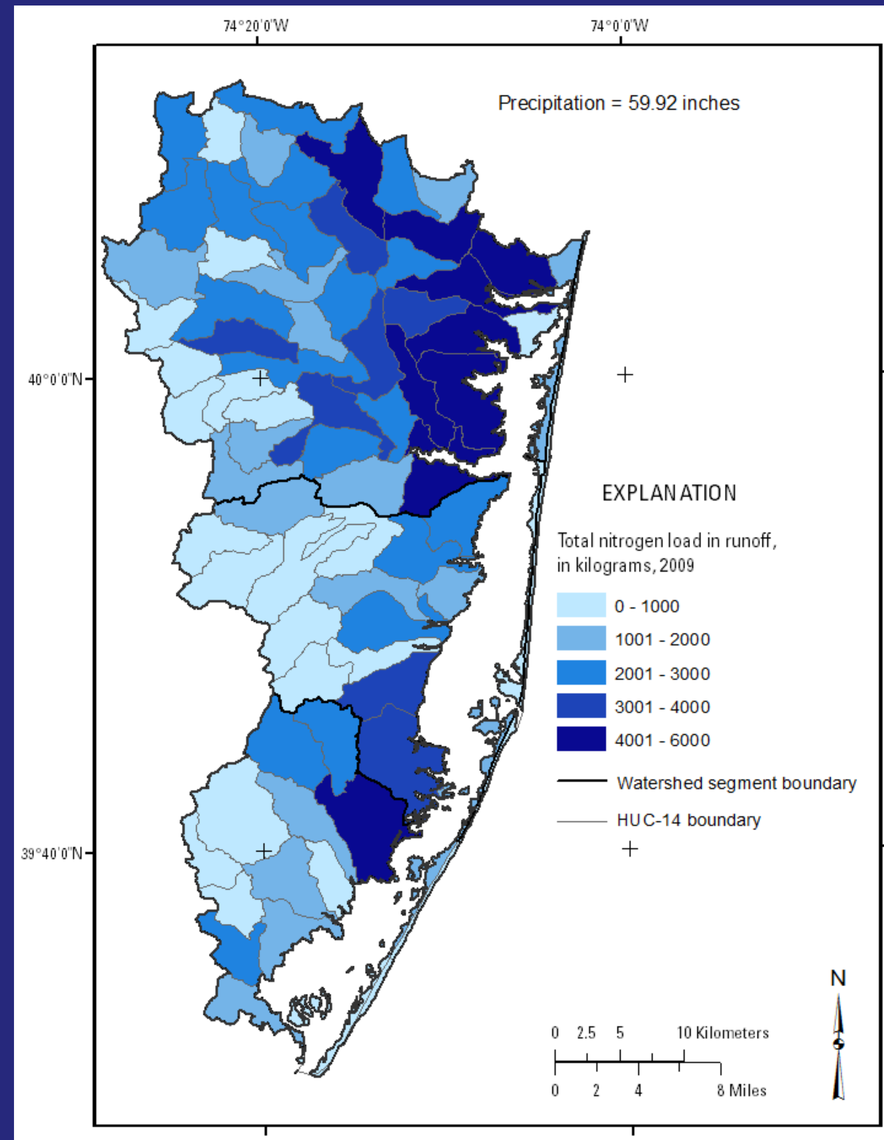
Land-Use Effects on Runoff Loads (similar precipitation amounts)





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Turf Analysis

- Turf delineation
  - Performed by Rutgers University, Center for Remote Sensing and Spatial Analysis
- Statistically related nutrient concentrations in subwatersheds to percent turf for year 2007
- Predicted concentrations for 3 scenarios:
  - 100% undeveloped
  - 100% developed, nonturf
  - 100% developed, turf

Turf Analysis

- Total nitrogen, total flow

Scenario	Concentration (mg/L)
100% undeveloped	0.44
100% developed, nonturf	1.21
100% developed, turf	1.83

- Total phosphorus, runoff

Scenario	Concentration (mg/L)
100% undeveloped	0.012
100% developed, nonturf	0.022
100% developed, turf	0.162

Summary of Nutrient Load Findings

- Annual loads fluctuated with hydrologic conditions, with precipitation having a:
  - Short-term and immediate effect on runoff loads
  - Longer-term and sometimes delayed effect on base-flow loads
- > 80% of the nutrient loads are contributed by base flow
- Higher yields of TN and TP in areas with more development (urban + agriculture)
- Lower yields of TN and TP in forested and protected land
- Expected nutrient concentrations are greater in turf areas

Ongoing and Future Activities

- *Fertilizer law
- *Circulation and bathymetry of the bay
- Ecology of the bay
  - Biology, water quality, sediments
- Water-quality modeling
- Stormwater management

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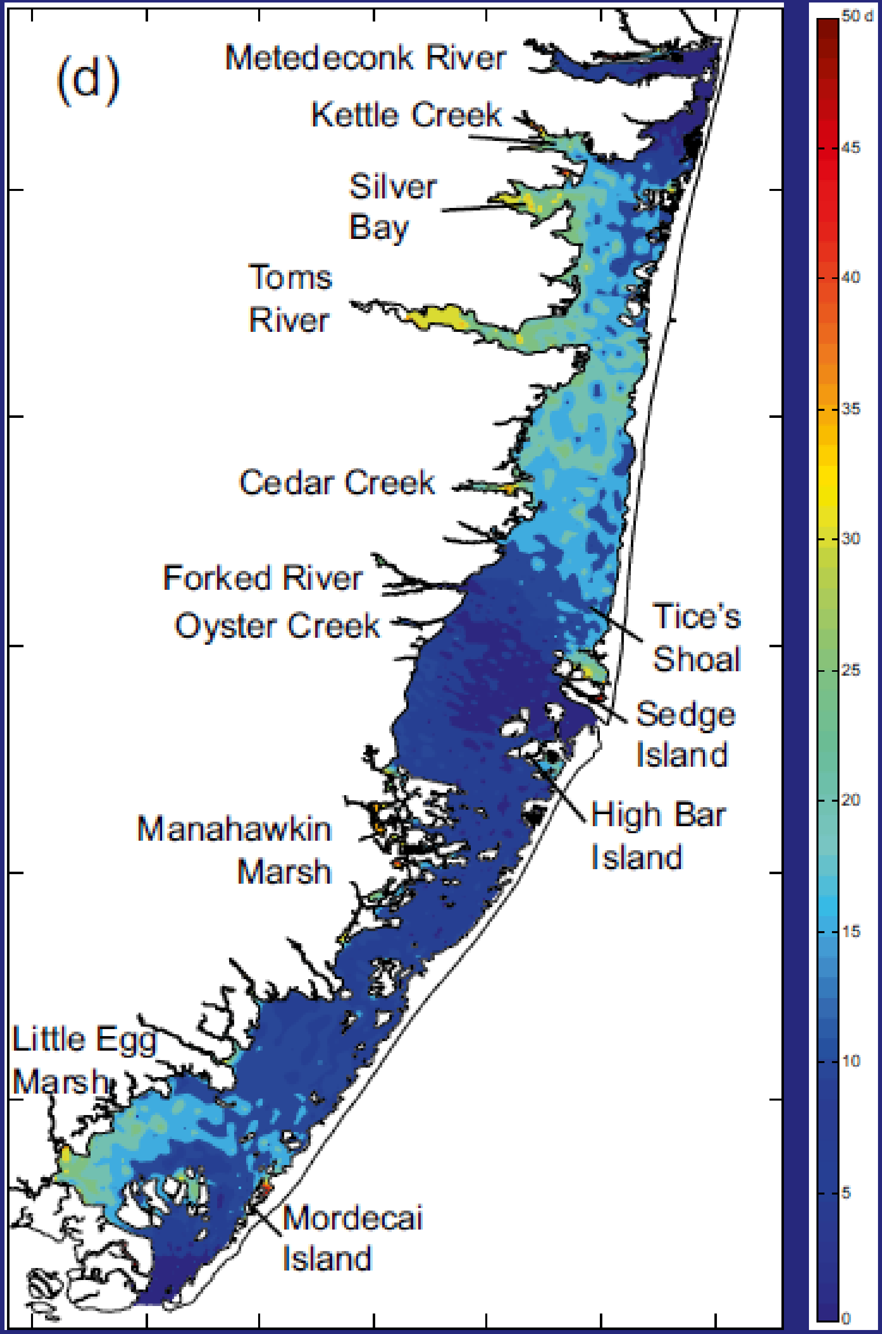
*Completed

Related studies

- Hydrodynamic model
  - USGS Woods Hole
  - Northward subtidal flow; better flushing in the south
  - Mean residence time of 13 days (varies spatially from 0 to 30 days)



(Defne and Ganju, 2014)

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Questions?

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Contact Info

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Photos:

- Atlantic Sea Nettle, taken by Wally Gobetz, https://www.flickr.com/photos/wallyg/5226388880/, link to license: https://creativecommons.org/licenses/by-nc-nd/2.0/legalcode