Viewing Great Bay from a Nitrogen (and Watershed) Perspective

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UNH Dept. Natural Resources & the Environment

NH Water Resources Research Center

Bay Views - Hugh Gregg Coastal Conservation Center – July 13, 2011

University *of* New Hampshire

LAMPREY RIVER ADVISORY COMMITTEE

AIRMAP

MAPPING NEW ENGLAND'S CHANGING CLIMATE AND AIR QUALITY

NEW HAMPSHIRE WATER RESOURCES RESEARCH CENTER

Outline

- Introduction to Great Bay and nitrogen impairment status
- Existing nitrogen data from the Lamprey and Oyster watersheds
- Overview of nitrogen in other Great Bay tributaries
- Introduction of new project "*Nitrogen Sources and Transport Pathways: Science and Management Collaboration to Reduce Nitrogen Loads in the Great Bay Estuarine Ecosystem*"
- What does the future hold for Great Bay?

Communities question science in determining nitrogren in Great Bay

Wastewater mandate gets turbulent

By **JOSHUA CLARK**
jclark@seacoastonline.com
June 20, 2010 2:00 AM

Growing concerns of several communities targeted by the N.H. Dep

EPA must prove need to spend millions

April 01, 2011 2:00 AM

Great Bay is a treasure shared by all Seacoast citizens. We derive valu
and our lives are made richer by its contributions to the region's ecolog
who would disagree that Great Bay and the entire Piscataqua Region V
pollution and preserved for future generations.

Shaheen, Lynch join call for EPA to delay new nitrogen limits

EPA ruling could cost Exeter tens of millions

By **AARON SANBORN**
asanborn@seacoastonline.com
April 29, 2011 2:00 AM

EXETER — U.S. Sens. Jeanne Shaheen, D-N.H., and Kelly Ayotte, R-N.H., are throwing their support to the communities surrounding the Great Bay estuary and asking the Environmental Protection Agency to delay issuing final discharge permits for nitrogen.

Scientists: We can't wait to cut discharge levels

By **Aaron Sanborn**
asanborn@seacoastonline.com
May 12, 2011 2:00 AM

PORTSMOUTH — While proponents of a delay in tougher Environmental Prot
discharged into the Great Bay estuary cite the need for additional scientific s
action to mitigate pollution needs to start now.

nhpr

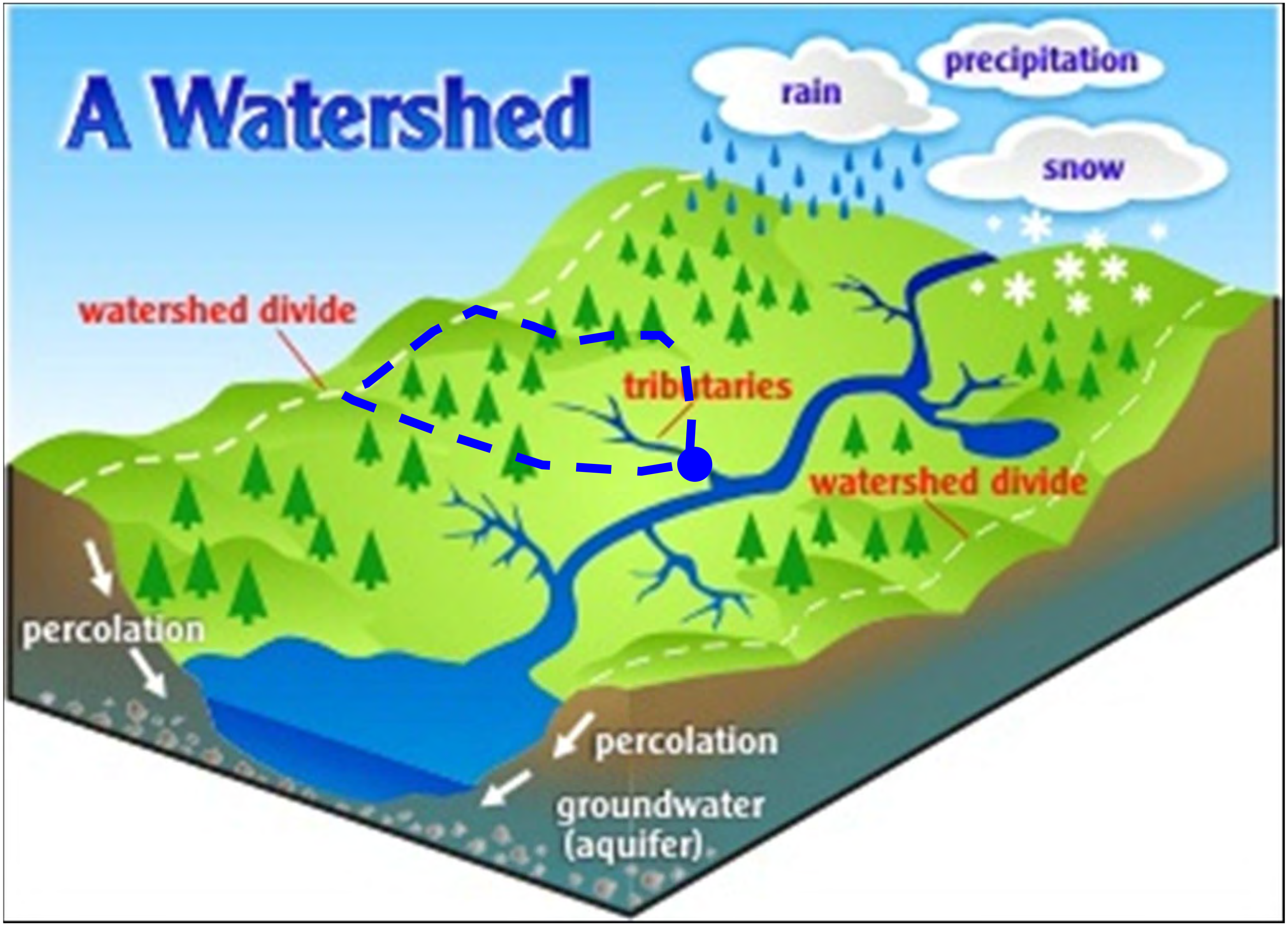
May 29, 2011

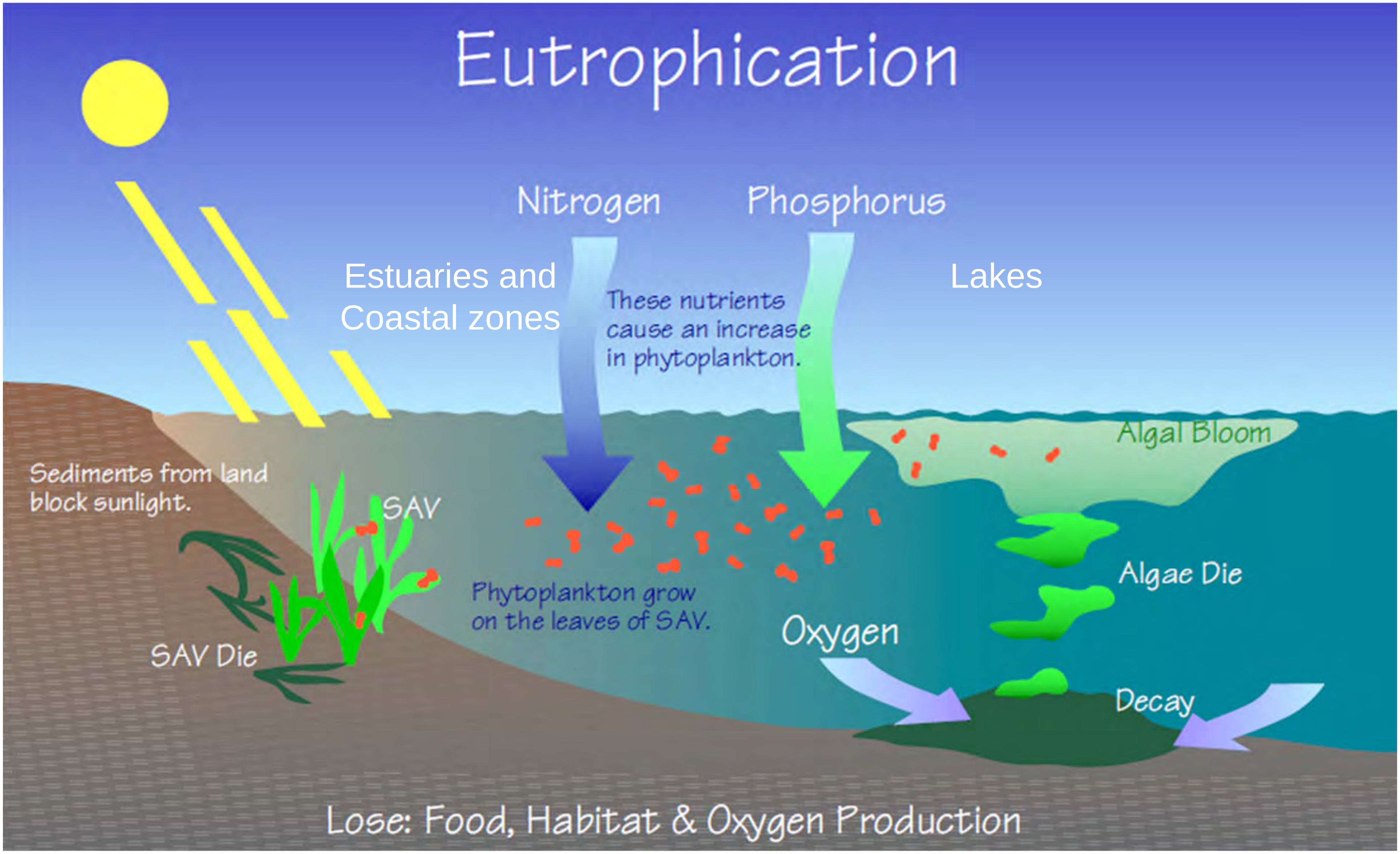
news prog

Home › NHPR News › Sewer Plants in Great Bay Face Tougher Clean Water Standards

Sewer Plants in Great Bay Face Tougher Clean Water Standards

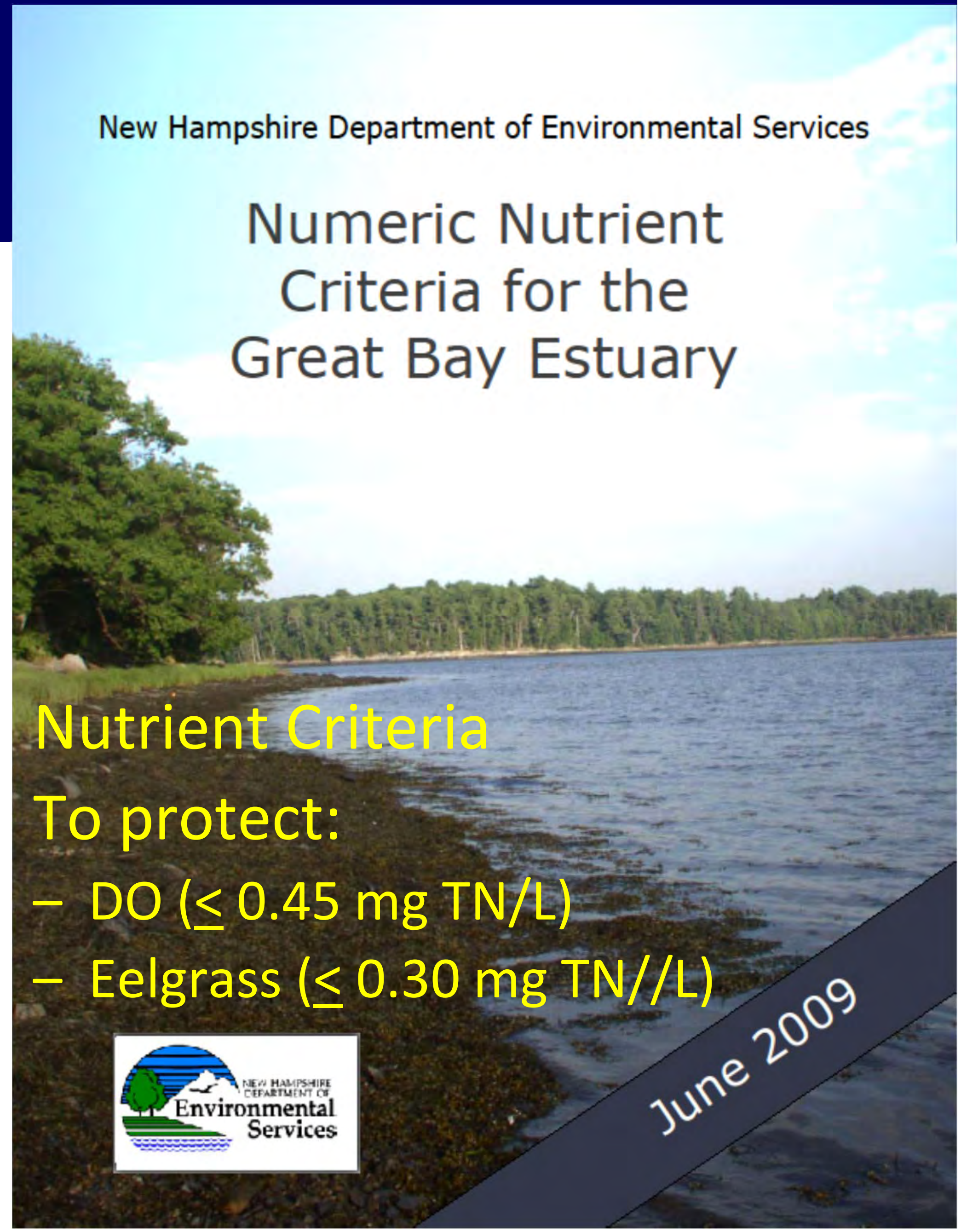
By **Amy Quinton** on Friday, May 20, 2011


A Watershed
rain
precipitation
snow
watershed divide
tributaries
watershed divide
percolation
percolation
groundwater
(aquifer)



SAV – Submerged Aquatic Vegetation e.g. Eelgrass
http://www.fiu.edu/~envstud/labs/imageJ1B.JPG

- NH's most significant estuary
- Home to 22% of NH's population
- Deterioration of water quality and aquatic life
  - Increased suspended sediment, chlorophyll-a and nitrogen
  - Low dissolved oxygen (DO)
  - Loss of oysters
  - Loss of eelgrass
- Numeric nutrient criteria developed by NH DES approved by EPA to protect DO and eelgrass



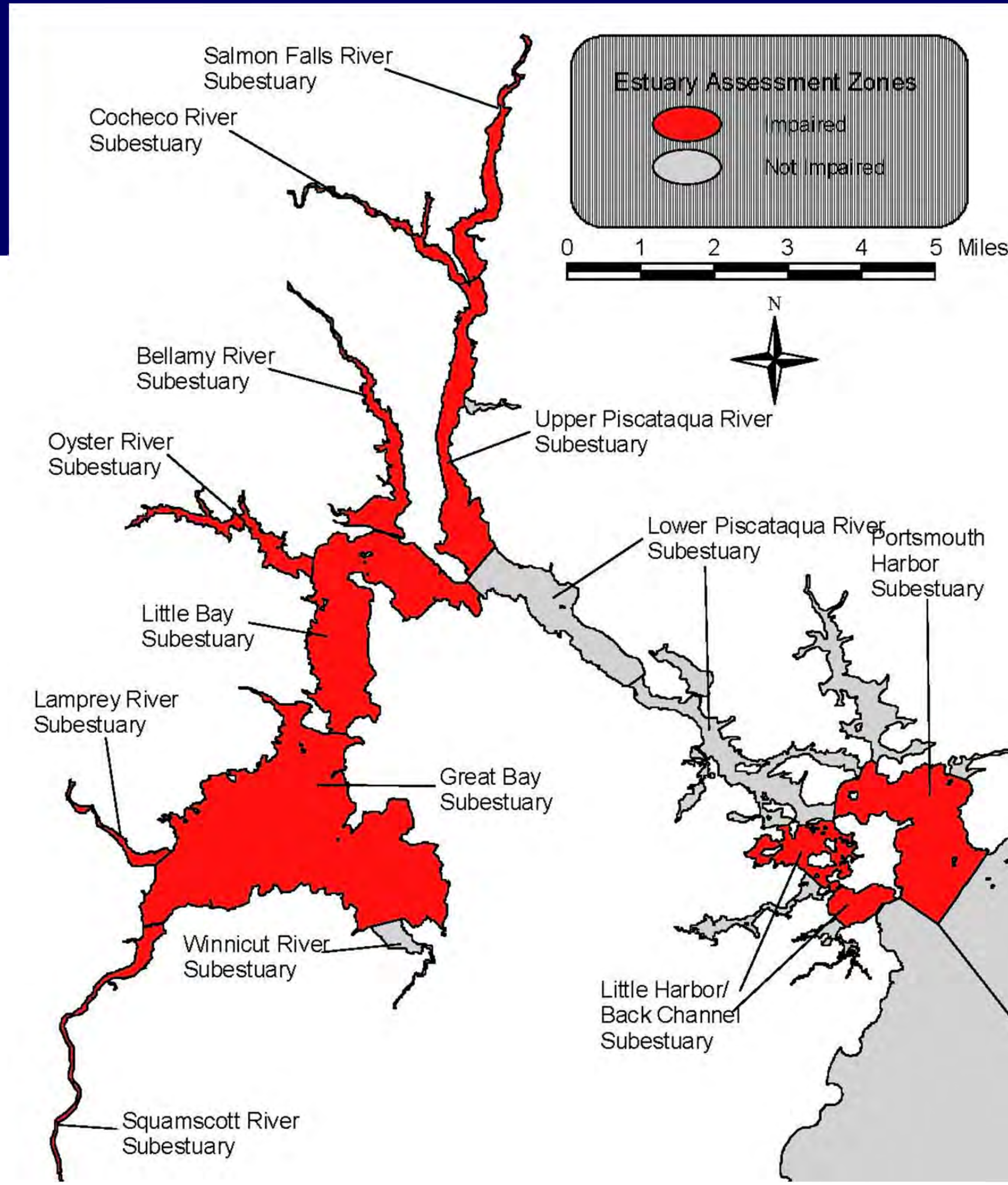
Nutrient Criteria

To protect:

- DO ($\leq$ 0.45 mg TN/L)
- Eelgrass ($\leq$ 0.30 mg TN//L)

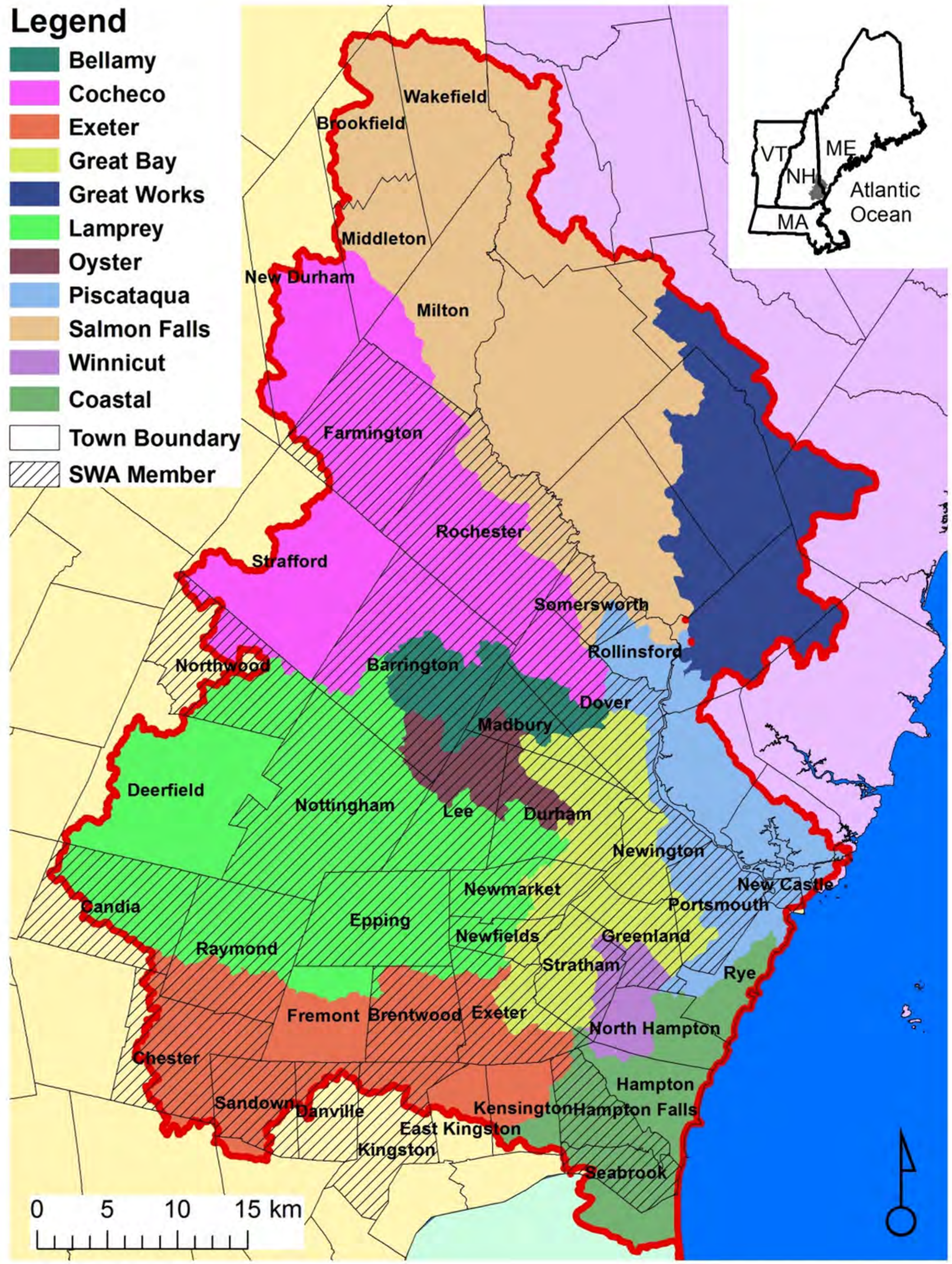
Nitrogen Impairments for Great Bay Estuary

Violation of Clean Water Act



Southeast Watershed Alliance (SWA)

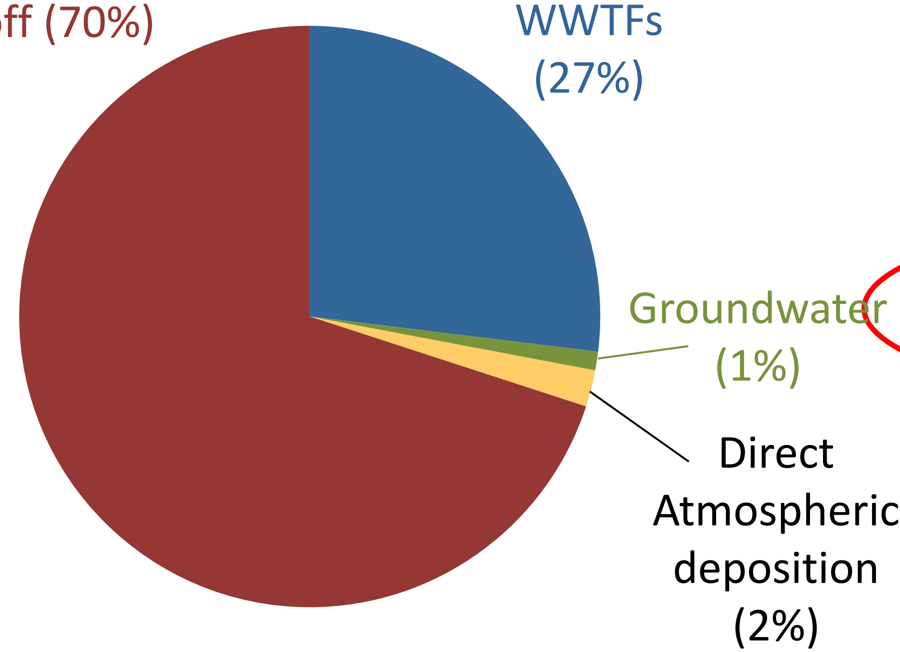
- Enabled by RSA 485-E in the 2009 legislative session
- Collaborative of NH communities to improve and protect water quality
- More effectively address the challenges of meeting clean water standards
- 28 of 42 eligible communities have joined



N Loading Reductions for WWTFs and Non-Point Sources in the Great Bay Estuary Watershed

Draft Report December 2010

N Load to the Great Bay, Little Bay and Upper Piscataqua River 1404.8 tons/yr from 2003-2008



Overall Reduction Needed:

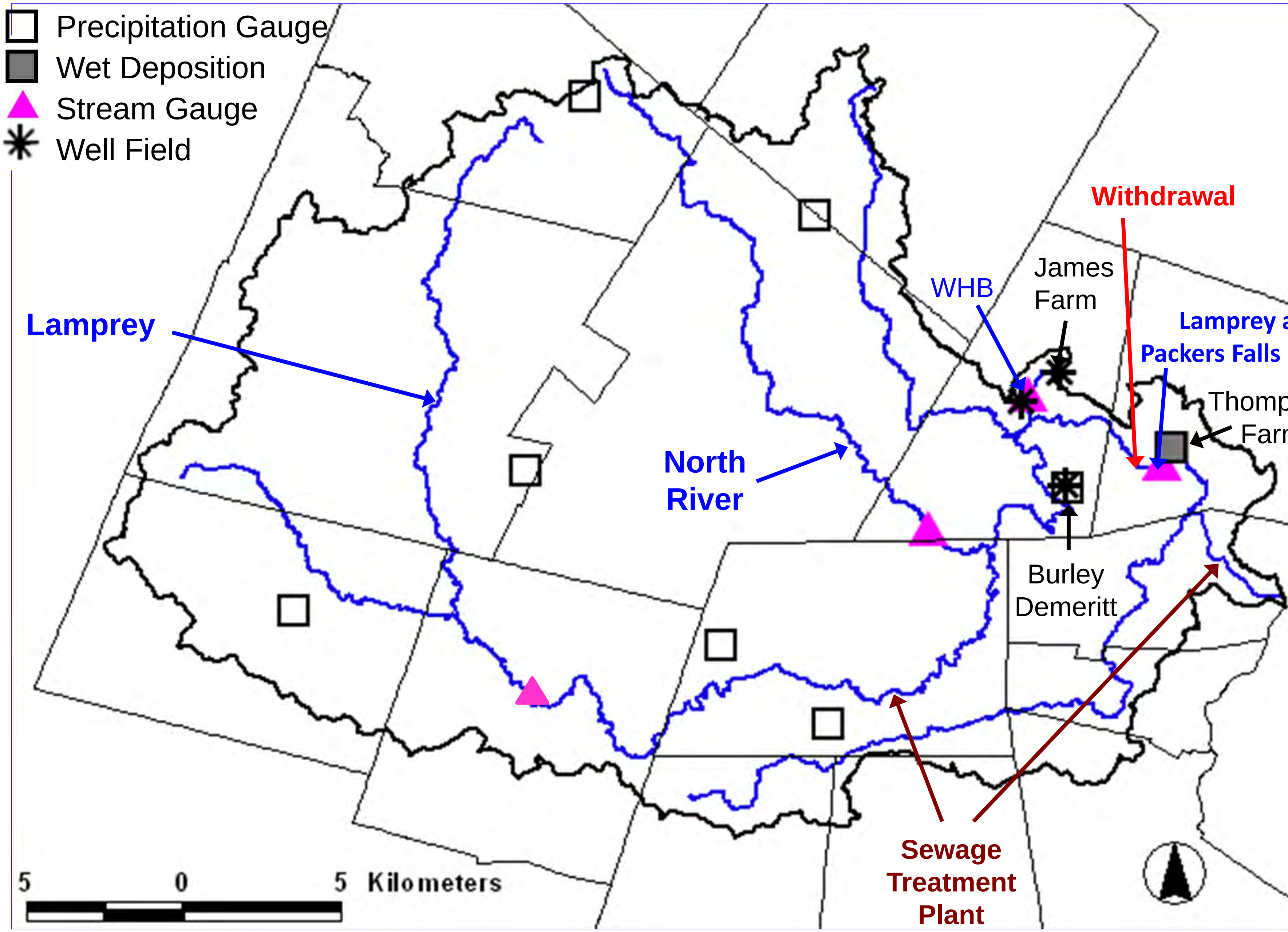
- ~~45% to protect DO and eelgrass in all areas~~
- 31 % to protect DO levels in tidal rivers and eelgrass downstream
- WWTFs Permits will be reduced to 8, 5 or 3 mg N/L
- 31-74% reduction in point sources
- 16-32% reduction in non-point N needed to protect DO levels in tidal rivers and eelgrass downstream
- Costs to upgrade WWTFs are known but high
- Uncertainty as to which non-point sources to target, and the costs

27% Point Sources; 73% Non-Point – But not all non-point N is manageable!

The Lamprey River is the Largest Tributary to Great Bay

LR Watershed = 550 km^2

Lamprey River Hydrologic Observatory - Est. 1999



Nitrogen Research Questions

1. Are there *long-term trends* in LRHO stream chemistry?
   – Weekly, storm event stream water N since 1999 at L73
2. What is the *N budget* for the LRHO?
   – Quantify N inputs, outputs and retention from 2000-2009
3. How do N outputs (and retention) vary for Lamprey and Oyster *sub-basins with different landscape attributes and levels of inputs?*
   – Quantify N budgets, population density, land use and impervious surfaces for various sub-basins

Forms of Nitrogen (N)

Particulate N

(Measured Since Oct 2002)

Attached to Sediment

Dissolved N

(Measured since Sept. 1999)

"Reactive" Nitrogen Associated with Human Activity

Dissolved Inorganic Nitrogen (DIN)

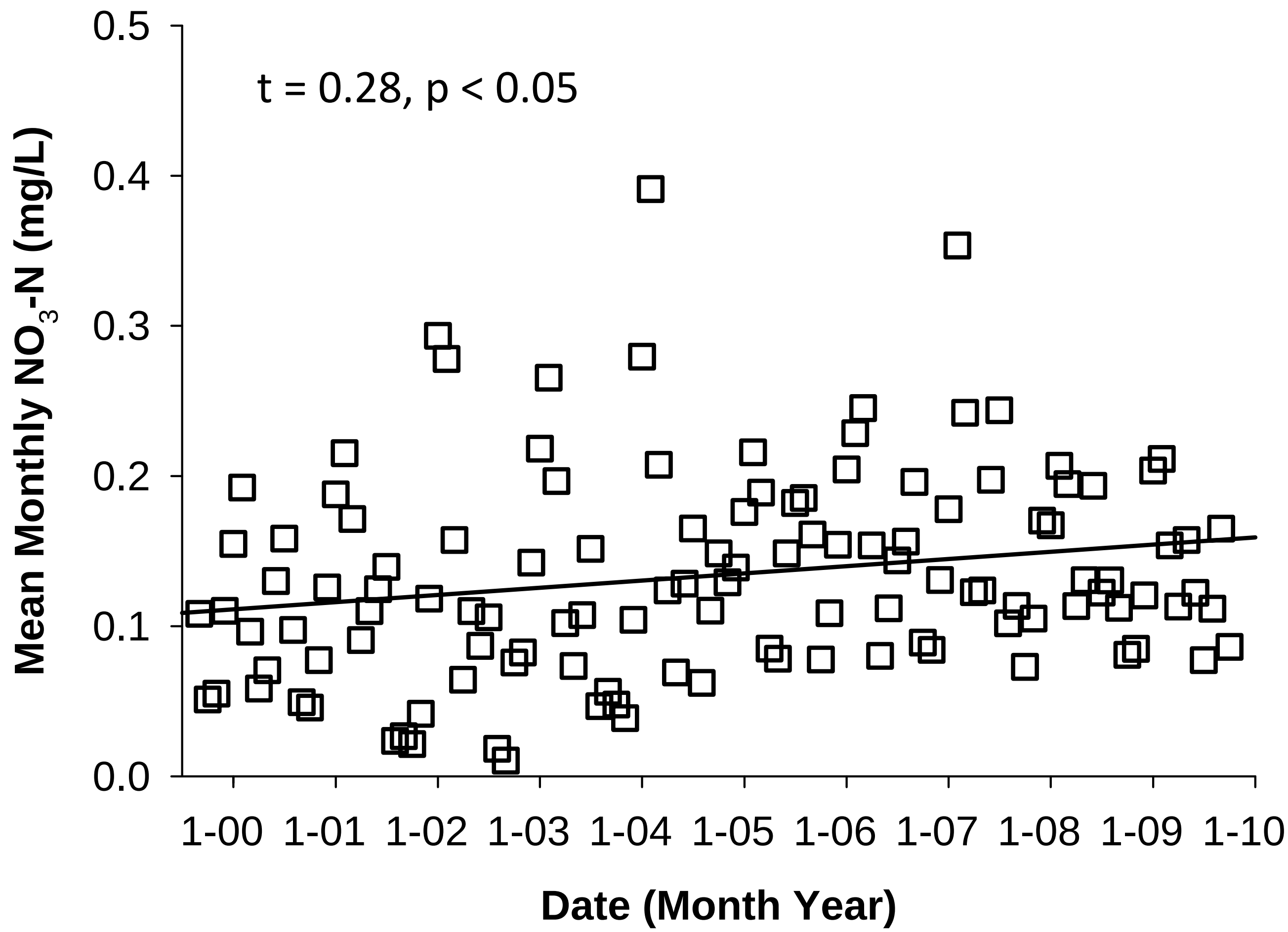
Nitrate (NO_3^-)

Ammonium (NH_4^+)

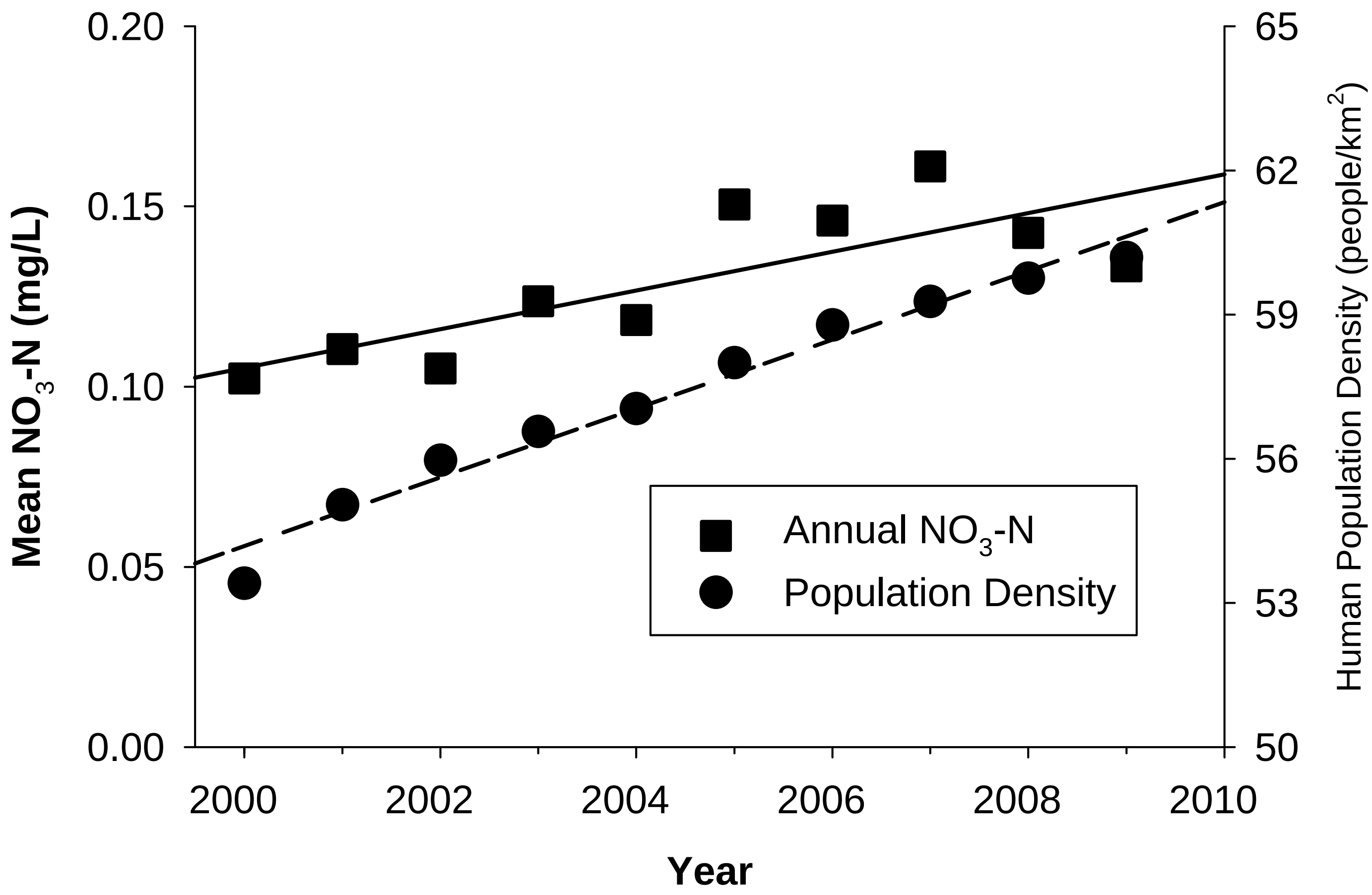
Dissolved Organic Nitrogen (DON)

Use 10 years of data to examine trends in dissolved N at L73

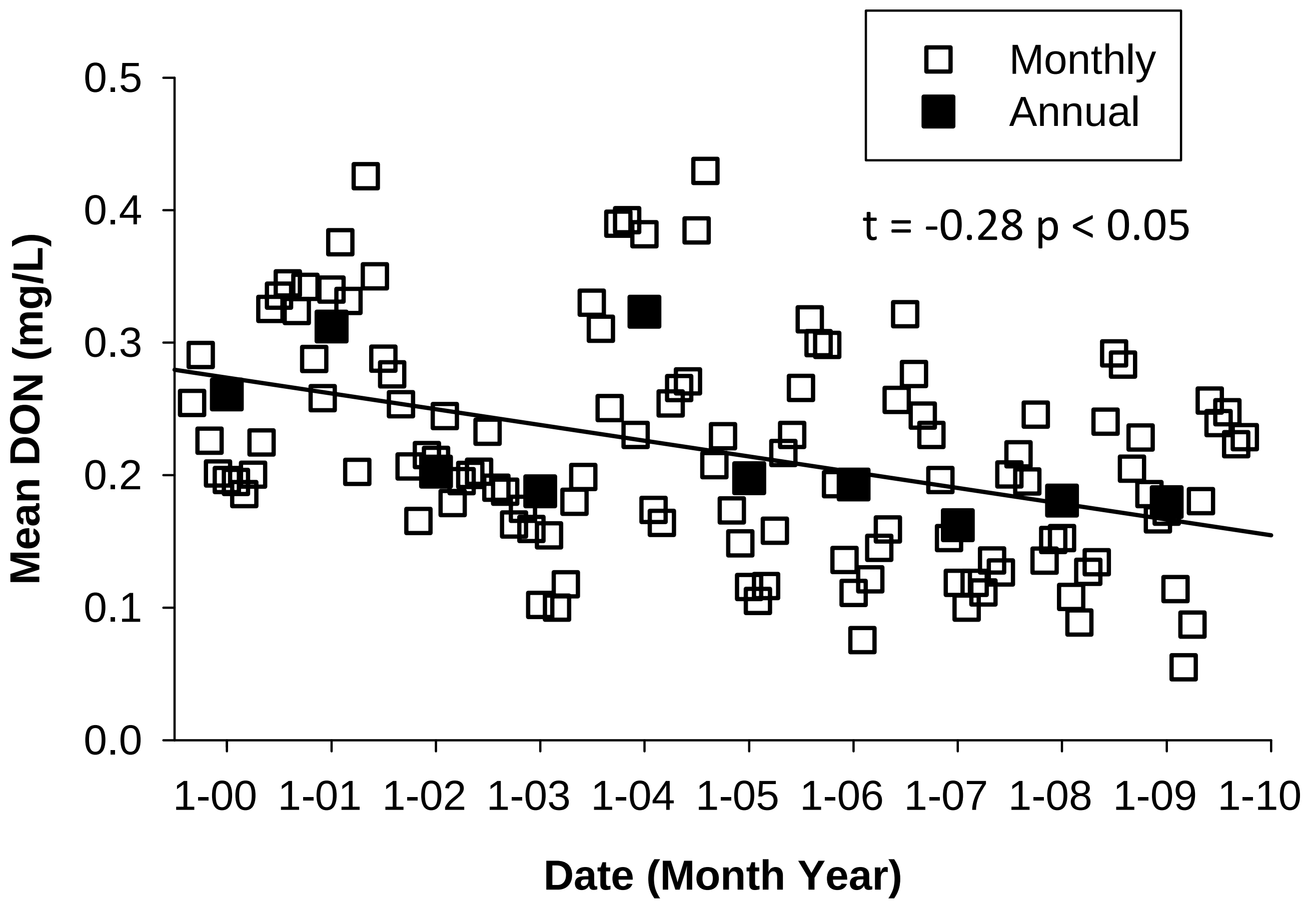
Nitrate (NO_3^-) is increasing at L73



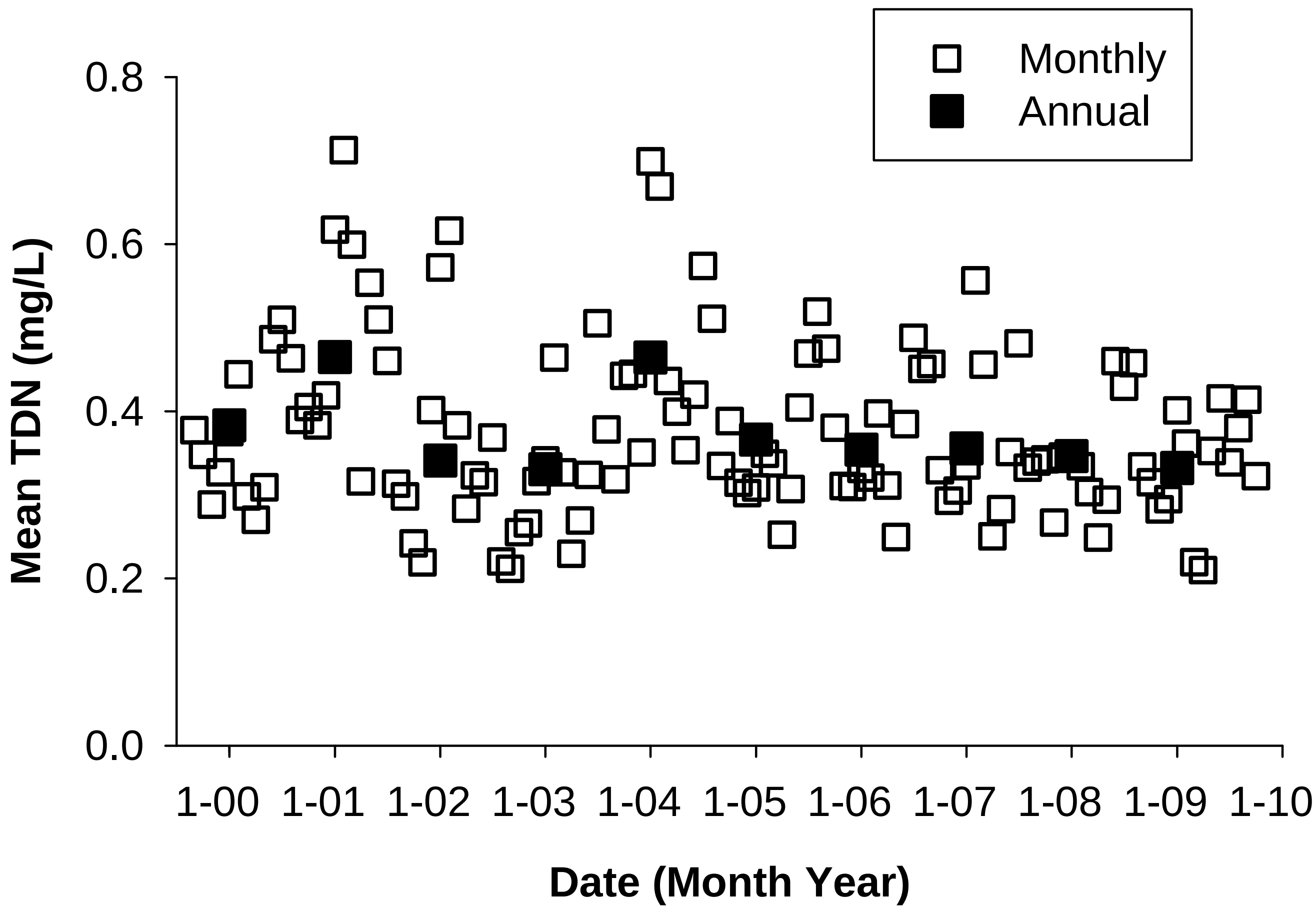
Increase is associated with increasing human population density



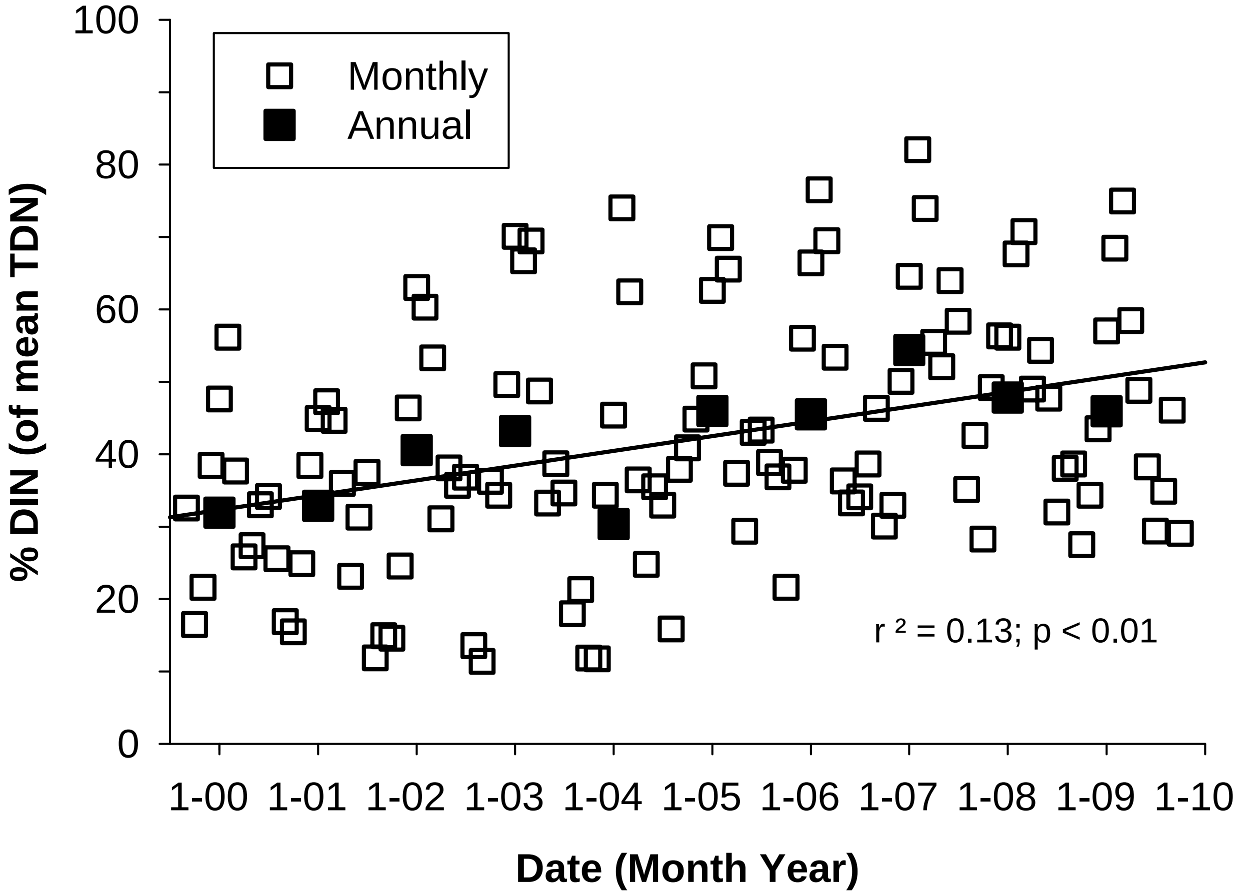
Dissolved Organic Nitrogen (DON) is decreasing at L73



Total Dissolved Nitrogen (TDN) is unchanged at L73



% Dissolved Inorganic Nitrogen (DIN) is increasing at L73



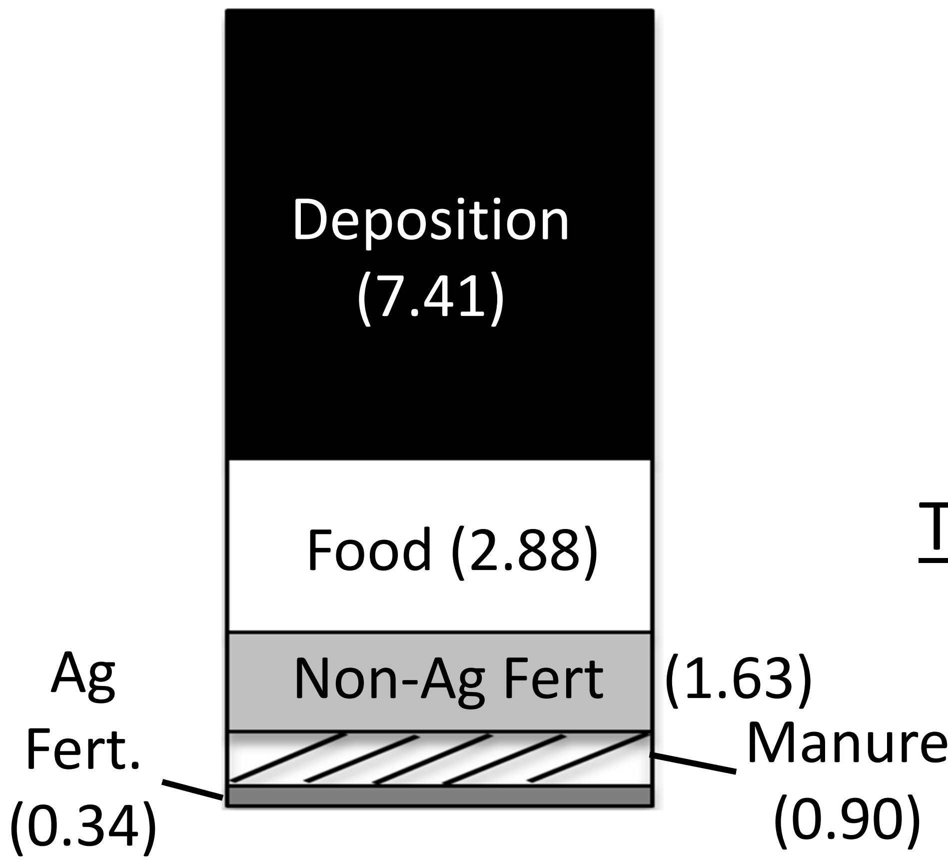
Nitrogen in the Lamprey River is shifting to the most "reactive" or biologically available form - DIN ($NH_4 + NO_3$)

Nitrogen budget for the Lamprey watershed (L73)

(Median 2000-2009)

Total N Input

13.2 kg/ha/yr

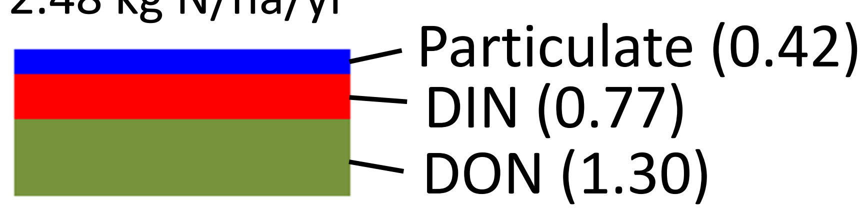


81% N Retained

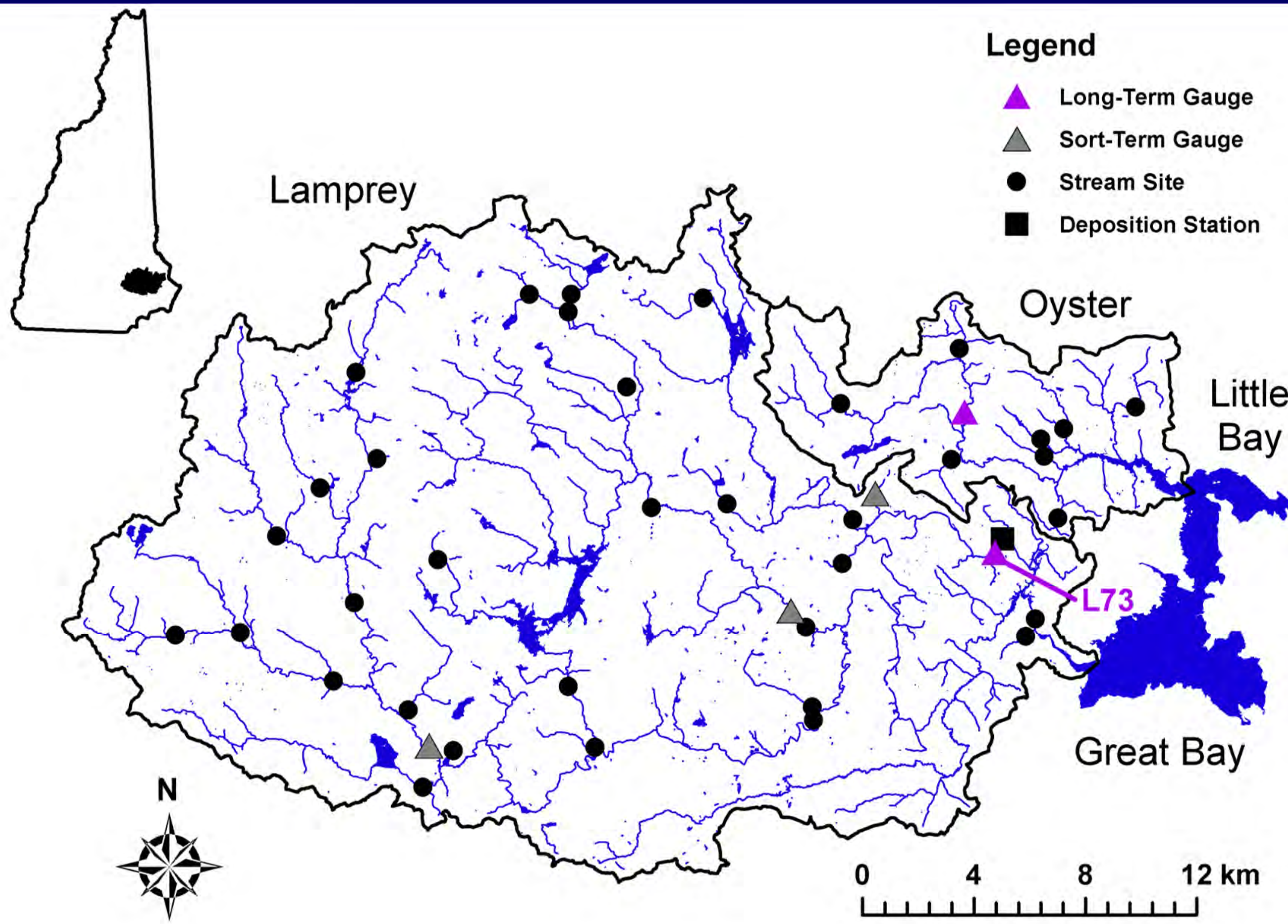
(10.72 kg N/ha/yr)

Total N Output

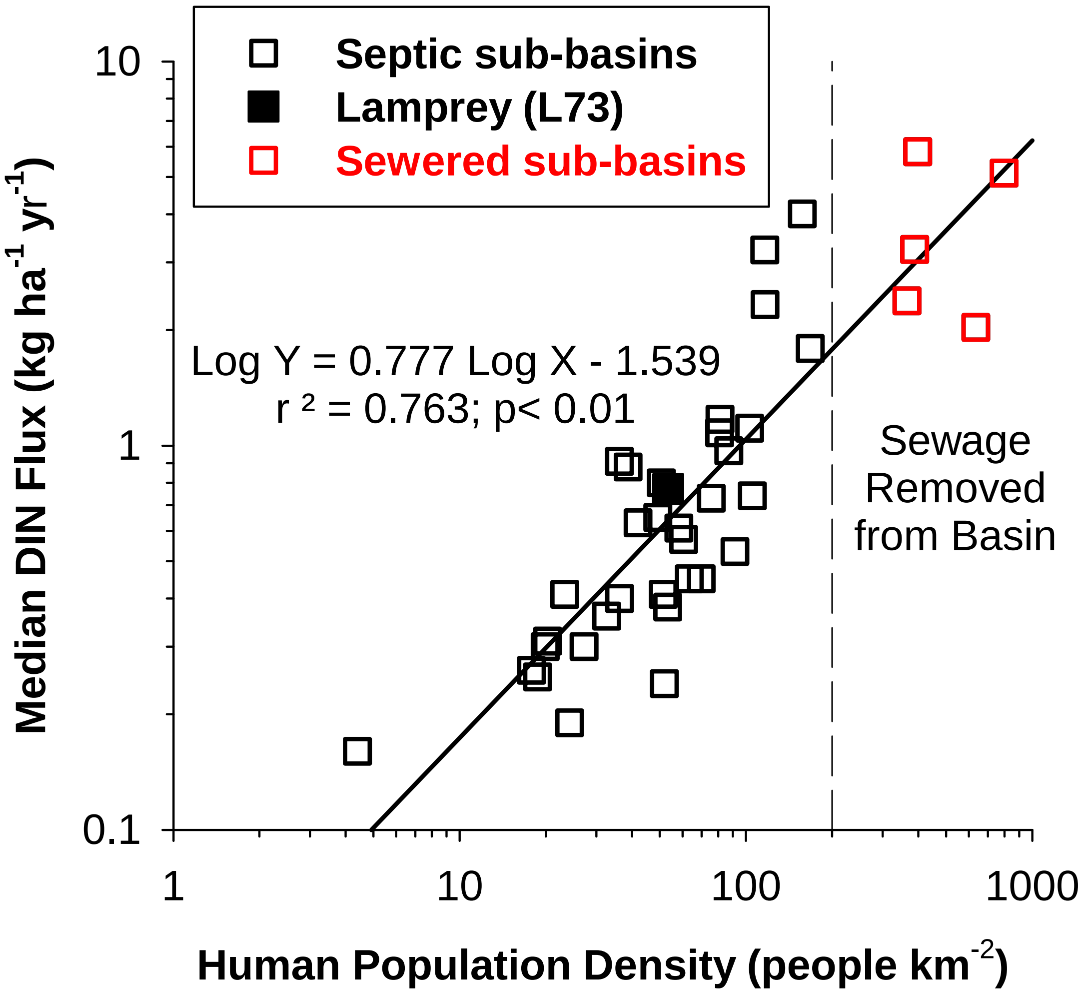
2.48 kg N/ha/yr



Sites in the Lamprey and Oyster watershed



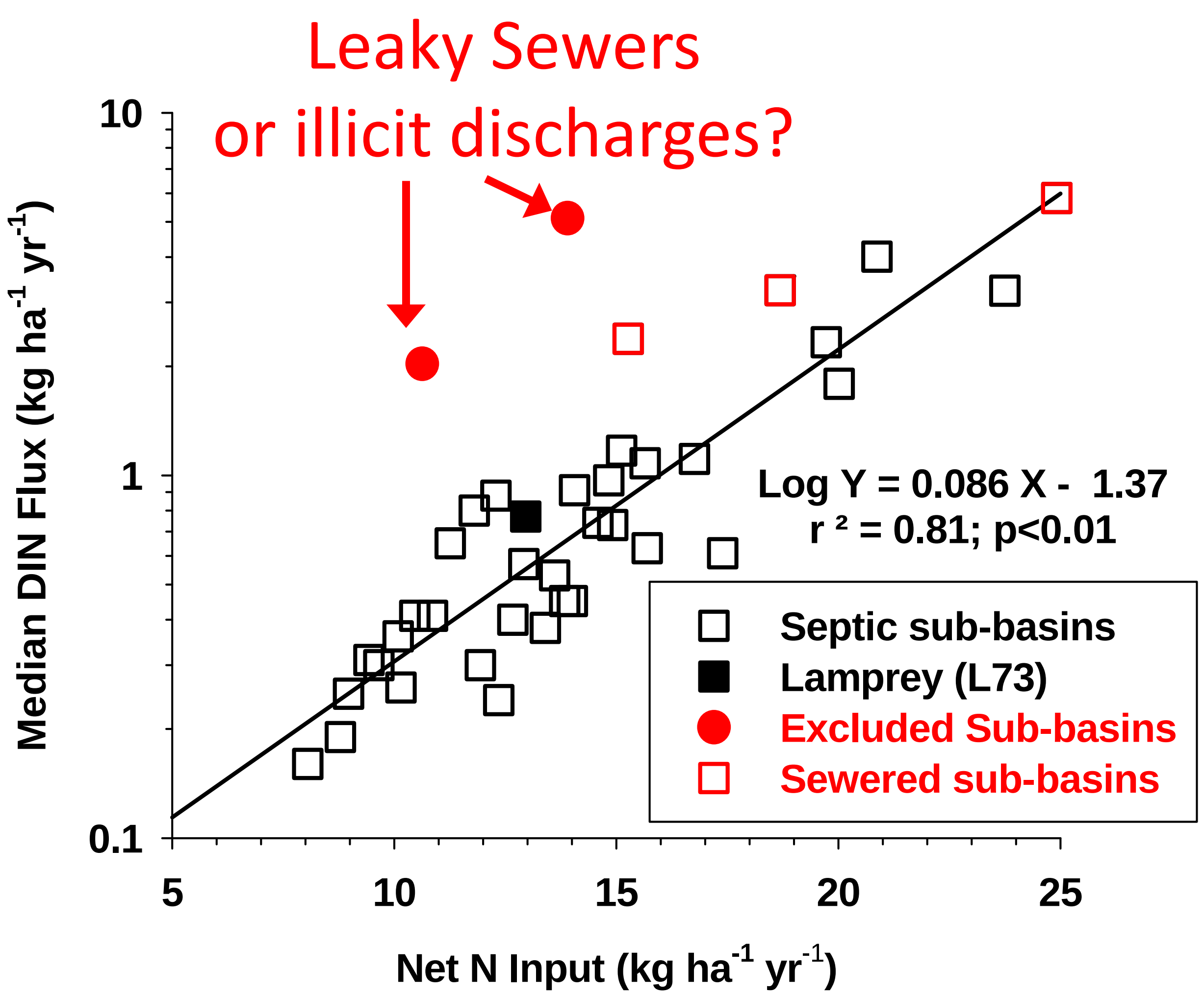
DIN related to sub-basin population density

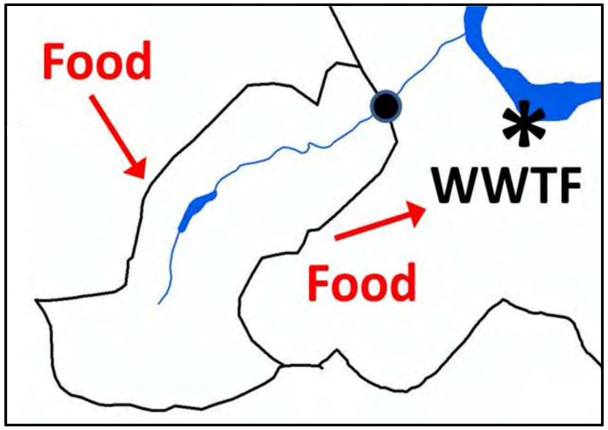


Potential Sources:

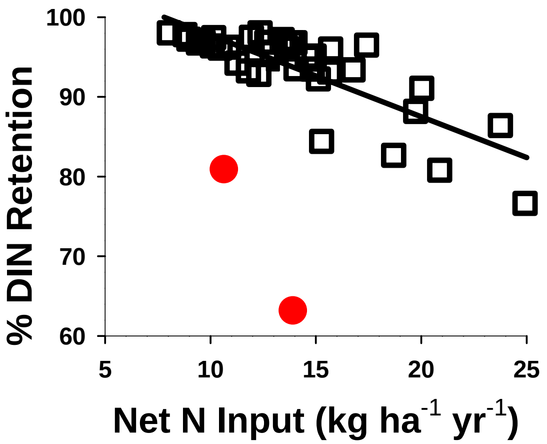
- Septic Systems
- Leaky sewers
- Pet waste
- Fertilizers
  - Residential
  - Commercial
  - Recreational
- Deposition delivered from impervious surfaces
- Interspersed agriculture
  - Fertilizers
  - manure

DIN also related to N inputs
(*Note Log Scale*)

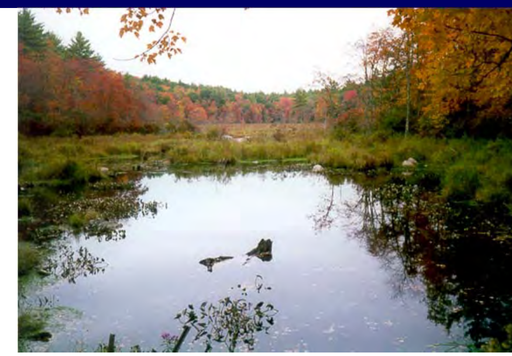


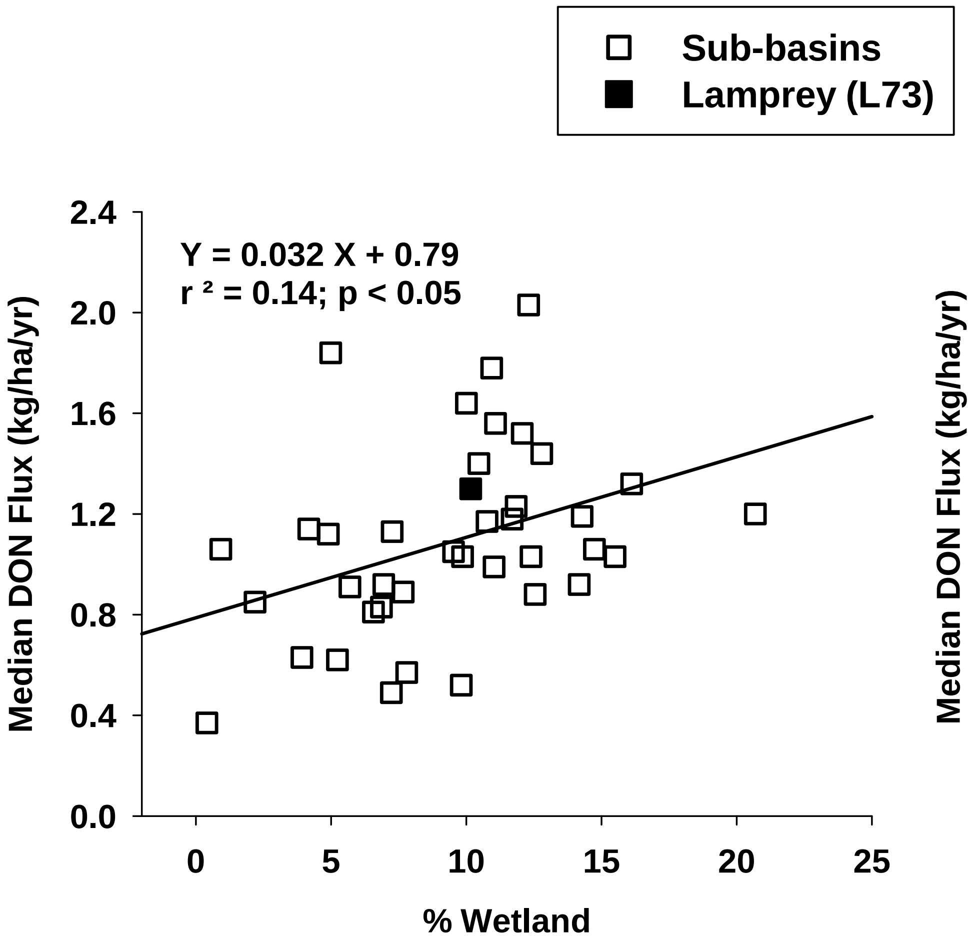


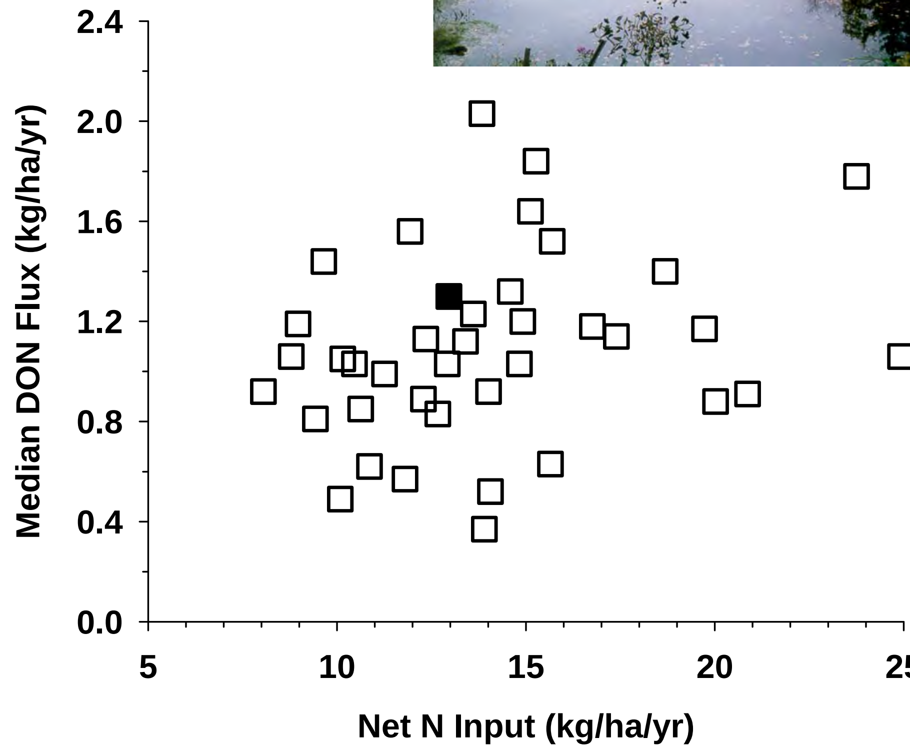
Net Food Input = 0



DON is related to natural features not human activity



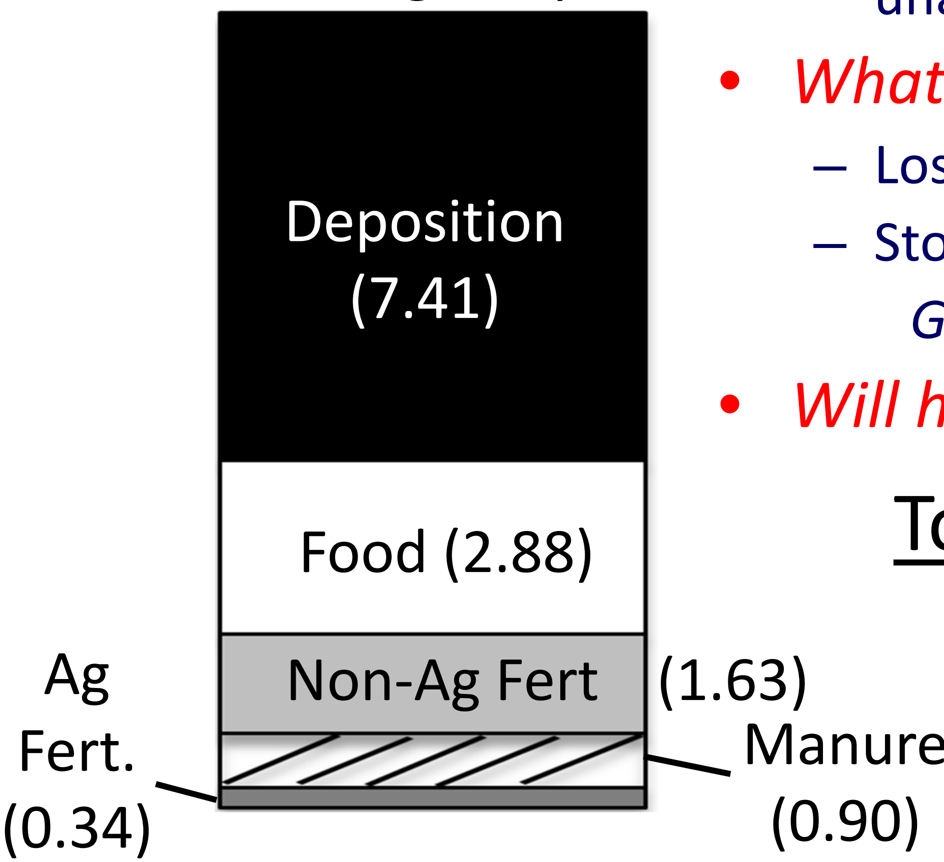




Increased Inputs increase DIN output and decrease retention, but…

Total N Input

13.2 kg/ha/yr

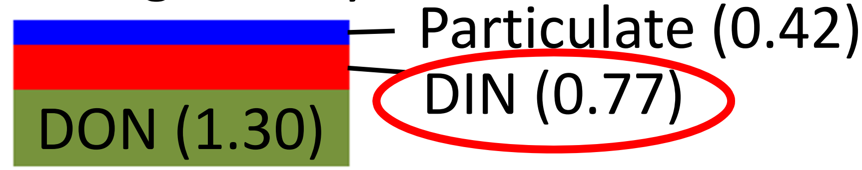


- *Which inputs become DIN outputs?*
  - NO_3 isotopes ($\delta^{15}N$ and $\delta^{18}O$) suggest not unaltered deposition
- *What happens to 81% of the inputs?*
  - Lost to atmosphere (via denitrification)?
  - Stored in vegetation or groundwater?

    Groundwater N >> Stream water N
- *Will high N retention rates continue?*

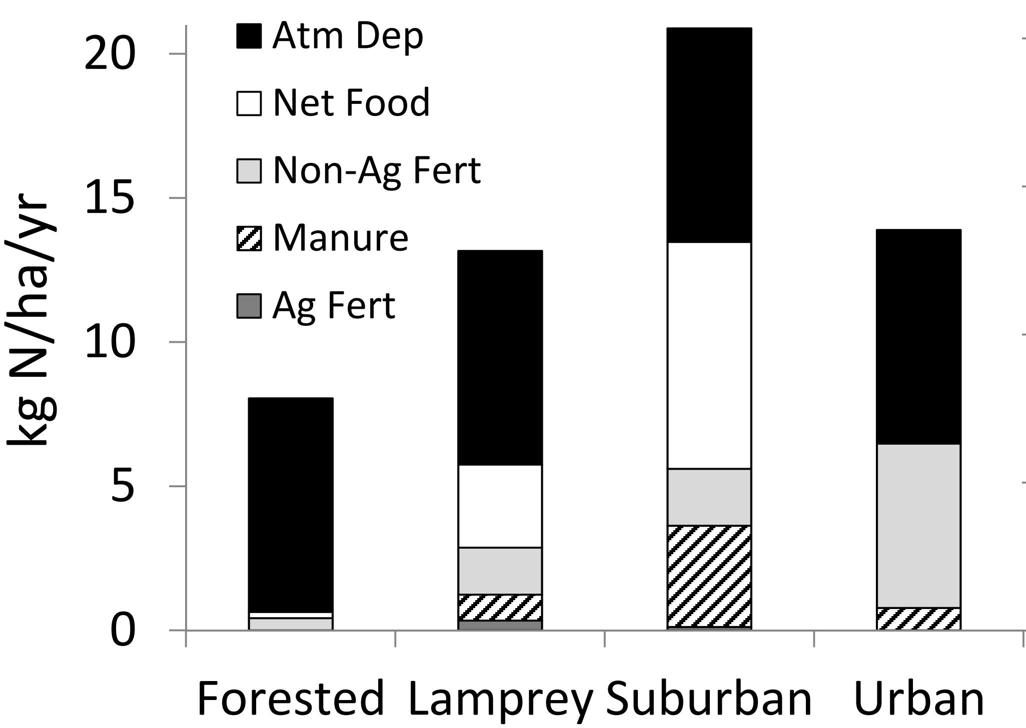
Total N Output

2.48 kg N/ha/yr

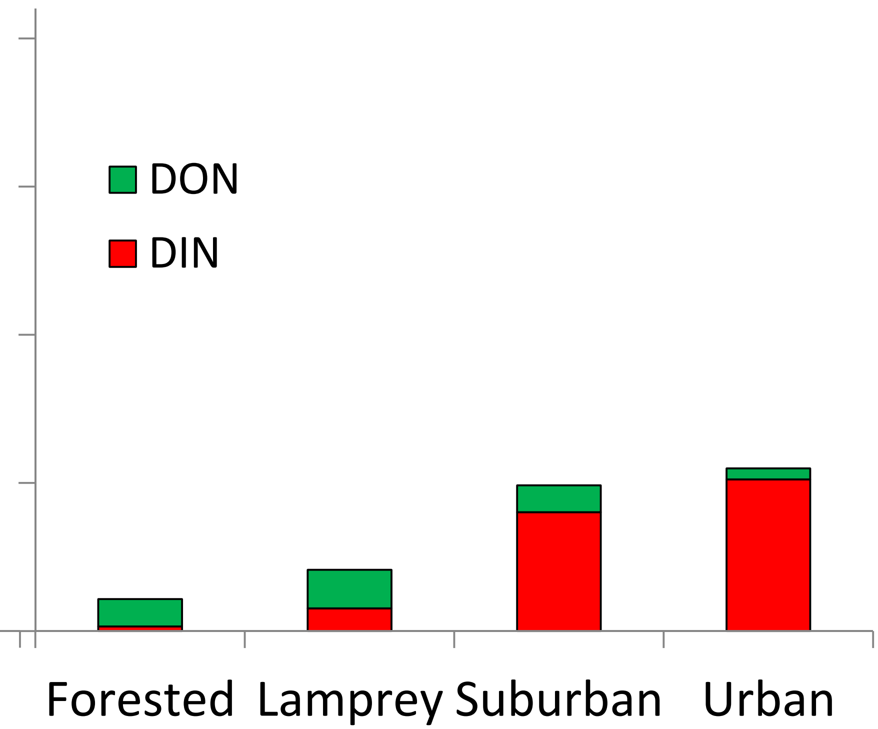


As Watersheds Urbanize…

N Inputs Change



N Outputs Increase



% N Retention Decreases **87%** **81%** **76%** **61%**

Simple lessons from input-output analysis

- ***Good news*** is that the LRHO is efficient (better than many NE watersheds) in retaining and/or removing N
- *BUT* there is no guarantee it will continue to do so, given evidence of possible N saturation, elevated groundwater N and unknown groundwater residence times in the basin
- ***Bad news*** is that all inputs are big enough to matter

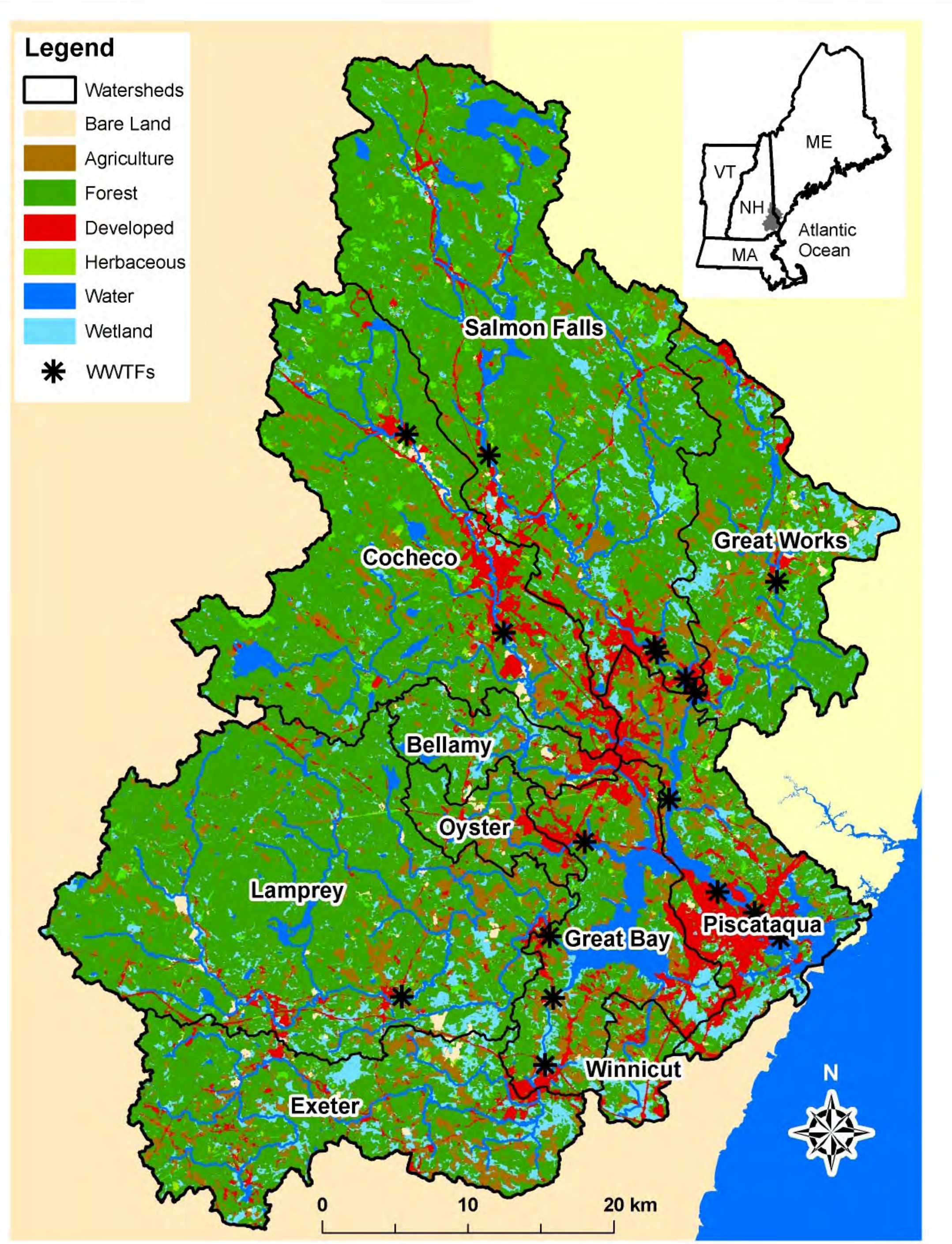
➢ Must understand drivers of stream chemistry to be confident in the best approaches to reduce N loads from watersheds to Great Bay

All forms of N are not equal!

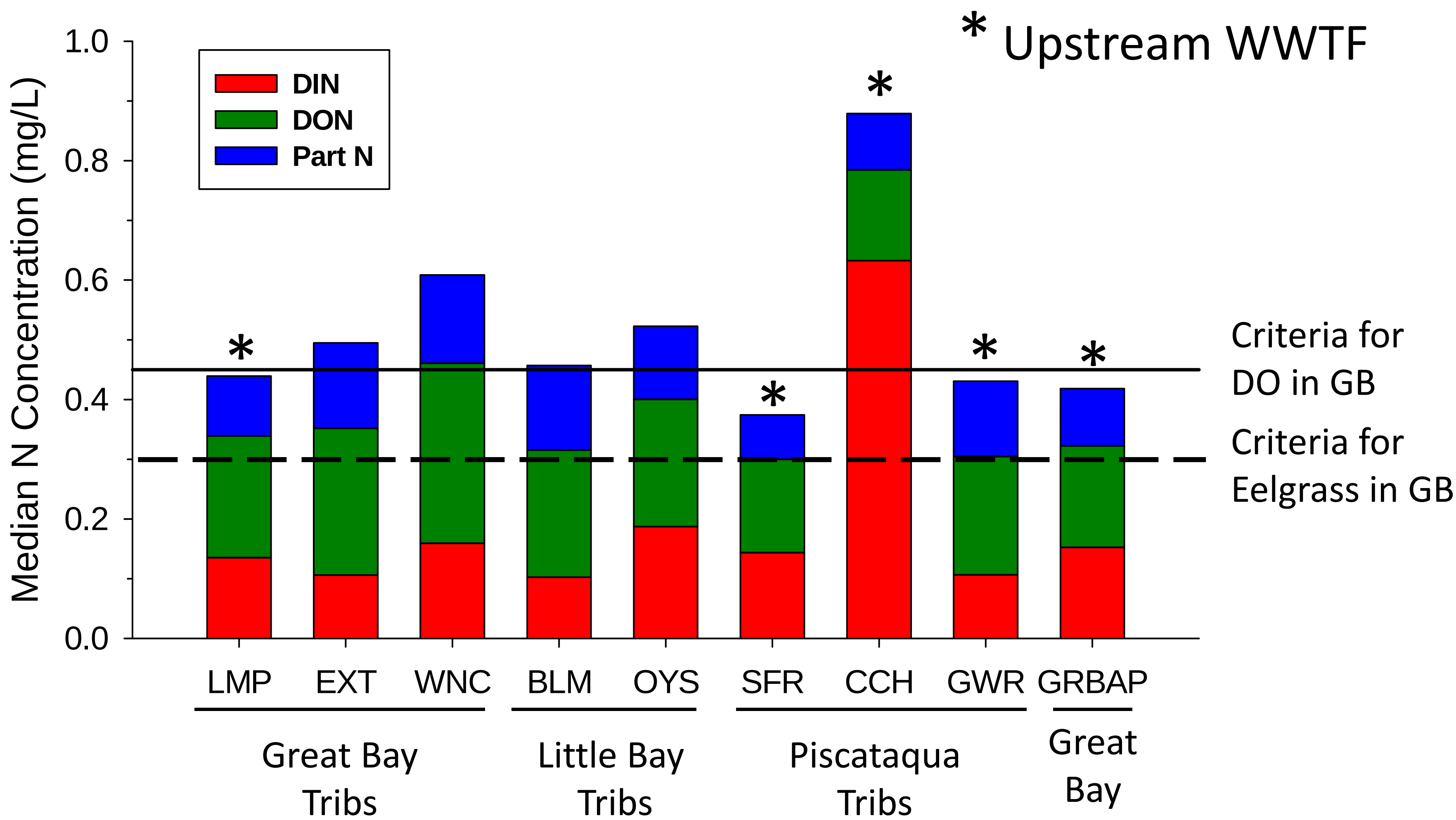
- Not equal in their ***impacts***, and not equal in their ***susceptibility to management***
- DIN (NH_4 + NO_3) most biologically available to algae and microbes, and most susceptible to increases driven by humans = **HIGH PRIORITY**
- PN (Particulate N) somewhat biologically available, smallest fraction of total N load, no data on land use effects but high during storms = MEDIUM PRIORITY
- DON (Dissolved organic nitrogen) somewhat biologically available, correlated only with amount of wetlands in a sub-basin = LOW PRIORITY

Overview of nitrogen in other Great Bay tributaries

Watersheds in the Great Bay Estuary System



All tributary watersheds are not equal!



New NERRS Science Collaborative Project

Nitrogen Sources and Transport Pathways: Science and Management Collaboration to Reduce Nitrogen Loads in the Great Bay Estuarine Ecosystem

Investigators: Dr. William H. McDowell, Dr. John Bucci, Dr. Erik Hobbie, Dr. Charlie French, Michelle Daley, Jody Potter and Steve Miller

funded by NOAA

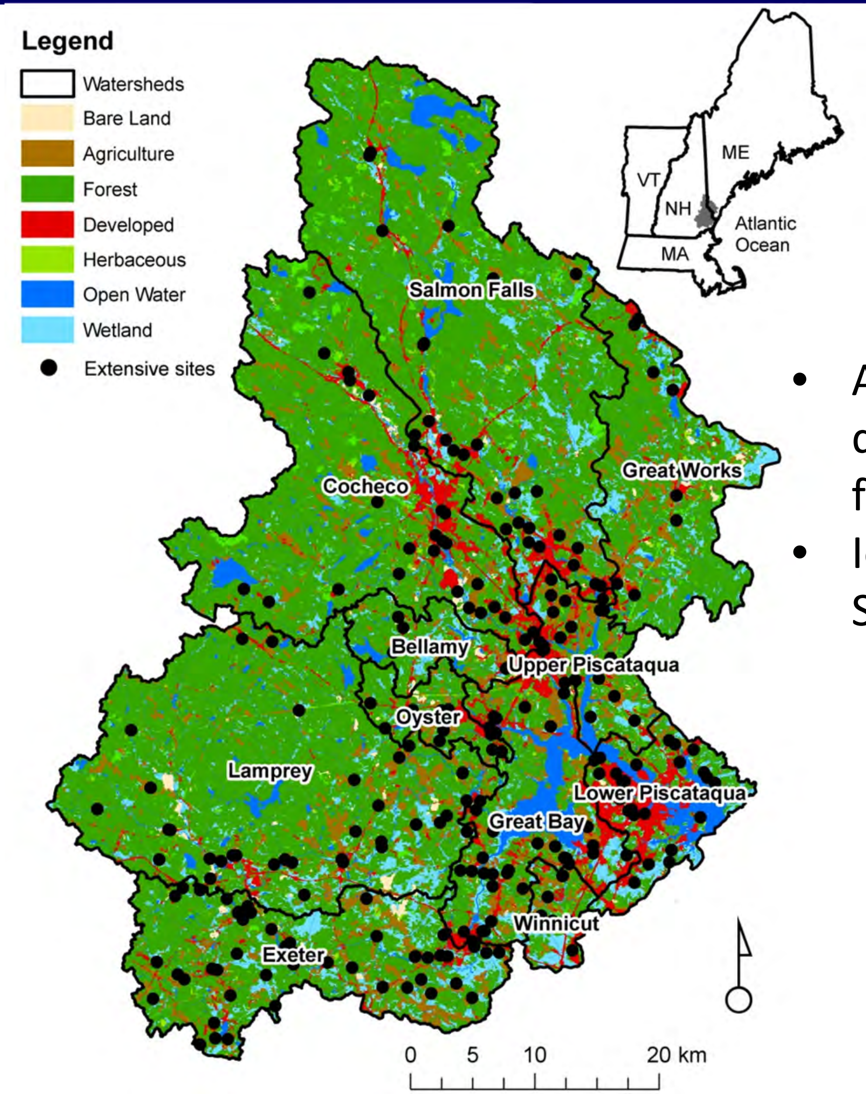
Nitrogen Sources and Transport Pathways Objectives

Objectives:

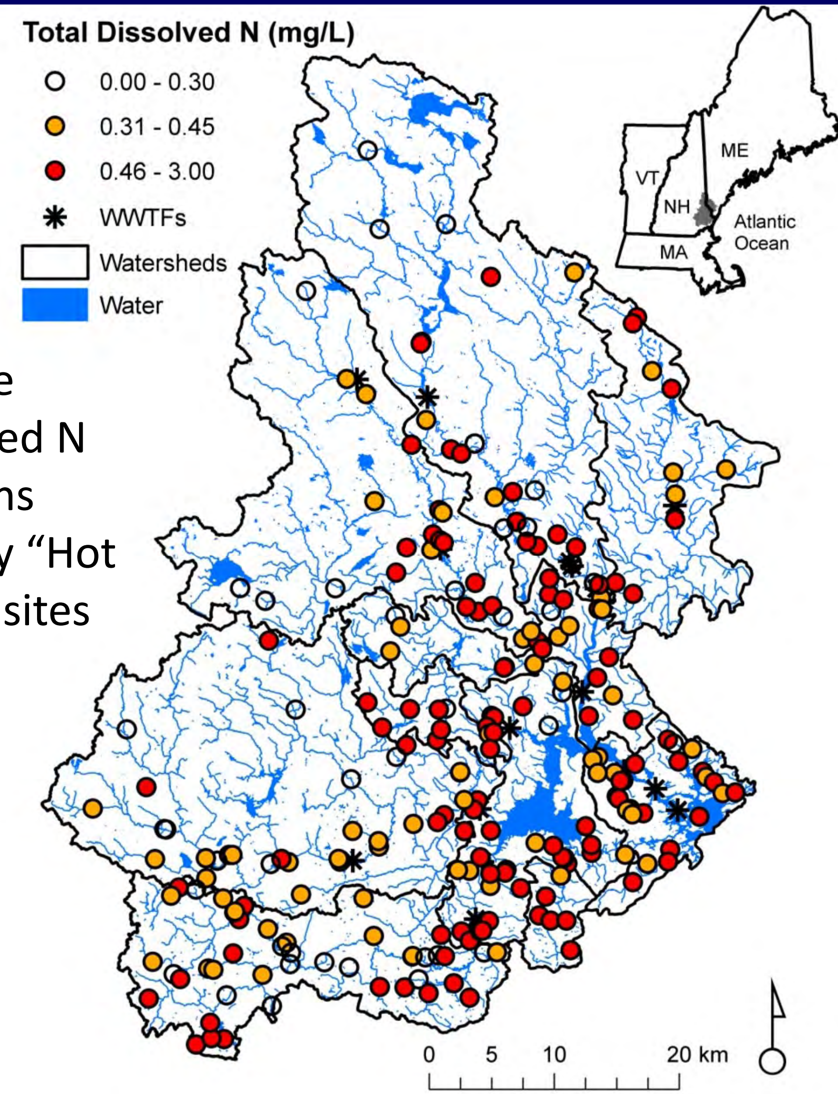
- Integrate scientific investigations with stakeholders to ensure results are useful and accessible to environmental managers and other stakeholders

1. Identify, model and map N concentrations in surface waters throughout the Great Bay Watershed to identify "hot spots"
2. Identify non-point sources of N that reach surface waters and the delivery pathway (e.g. groundwater vs. stormwater)
3. Quantify N attenuation in large river reaches by modeling N inputs and outputs and inferring N attenuation

Identify N Concentrations at ~250 "Extensive" sites

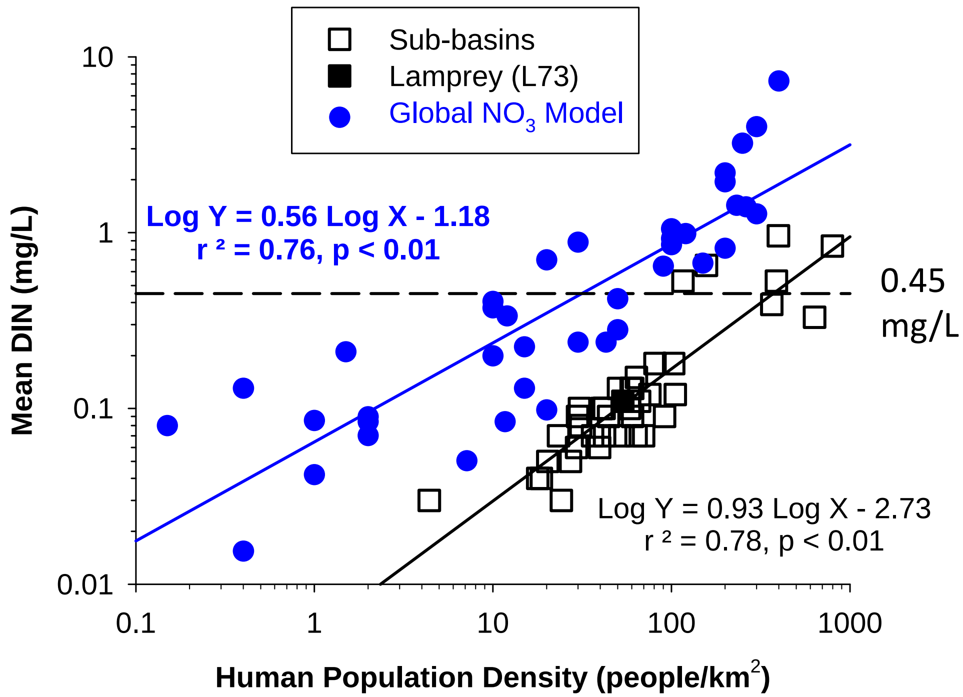


- Analyze dissolved N fractions
- Identify "Hot Spots" sites



Build Landscape Models that Predict N Concentration

- Relate stream N concentration (~250 extensive sites) to landscape characteristics (e.g. population density, impervious surfaces and land use)
- Identify N "hot spots"
  - Sites with high N (> DES 0.45 mg/L threshold)
  - "Outlier" sites with higher than expected N
- Do relationships that we have seen in the Lamprey/Oyster watersheds hold at the Great Bay scale?
- Use landscape models to predict N at unsampled streams

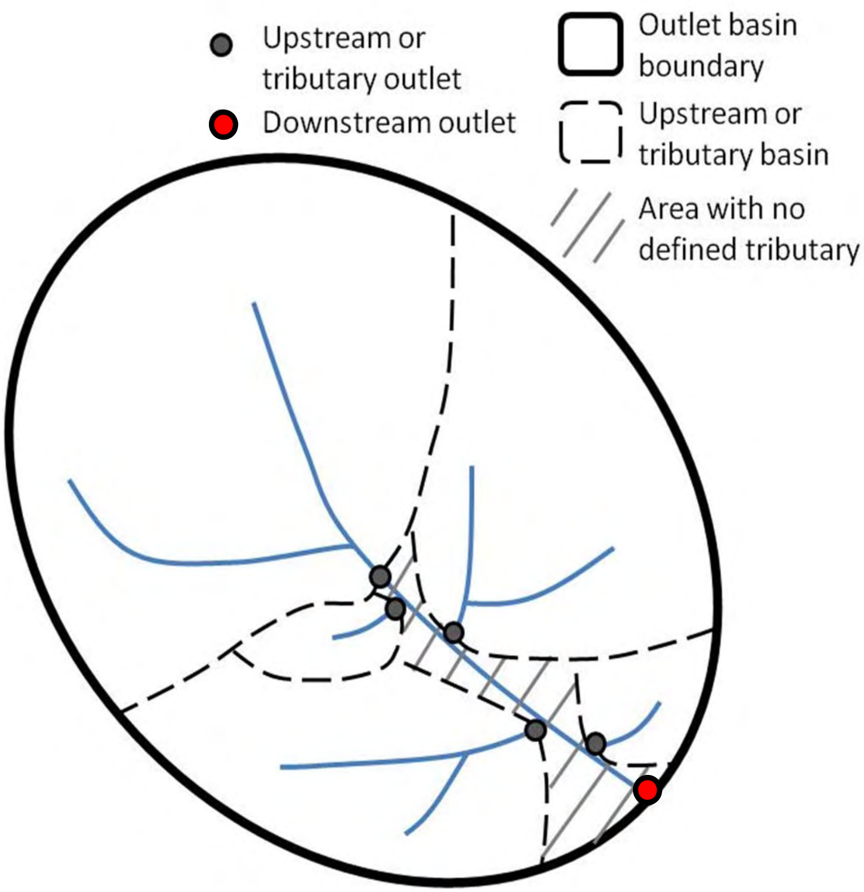


Multi tracer approach to identify the dominant non-point sources at 20-30 Intensive study sites

- Chemical
  - Caffeine - human waste signal
  - Optical brighteners– laundry detergents, human waste signal
- Stable Isotopes
  - Nitrate (NO_3^-) isotopes - $\delta^{15}N$ and $\delta^{18}O$ to distinguish between atmospheric, fertilizer and animal waste
  - Sediment isotopes - $\delta^{15}N$ of surficial sediment (2 cm) to distinguish between fertilizer and animal waste
- Microbiological source tracing to identify animal waste sources – e.g. Human, Bovine, Pig

➢ Sample streams, shallow groundwater, storm events to characterize transport pathway

N attenuation in large river reaches



- Quantify N attenuation in large river reaches by modeling N inputs and outputs and inferring N attenuation
- N attenuation = N load at outlet
  - upstream N load
  - tributary N loads
  - N load for riparian area not drained by defined tributary

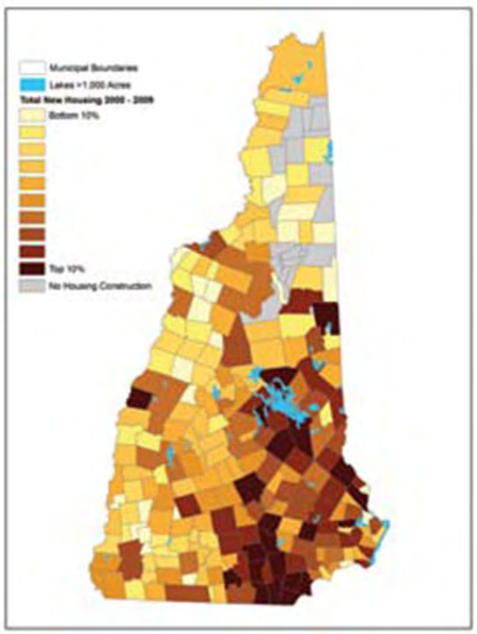
What does the future hold for Great Bay?

Reduce N Loading in the face of continued population growth?

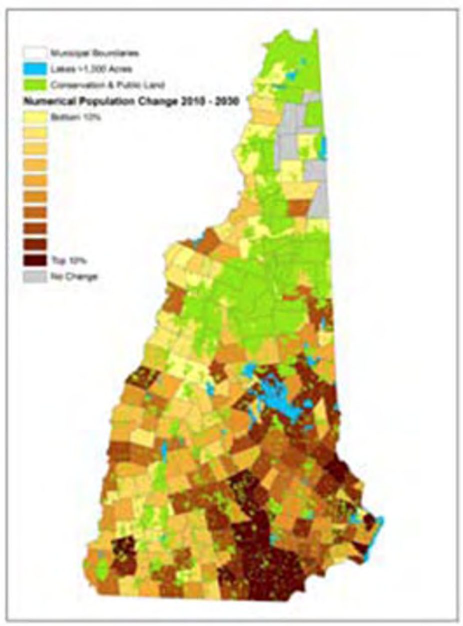
NH's population is projected to increase by 180,000 persons from 2010 to 2030.

Roughly 70% of that growth will occur in the four southeastern counties.

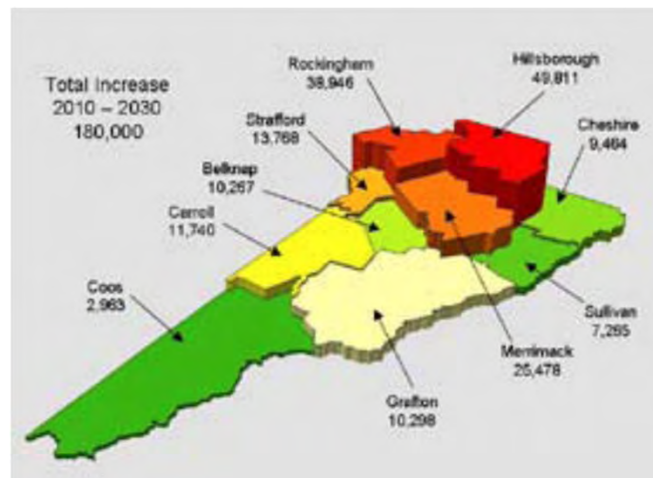
Total New Housing 2000-2009



% Population Change 2010-2030

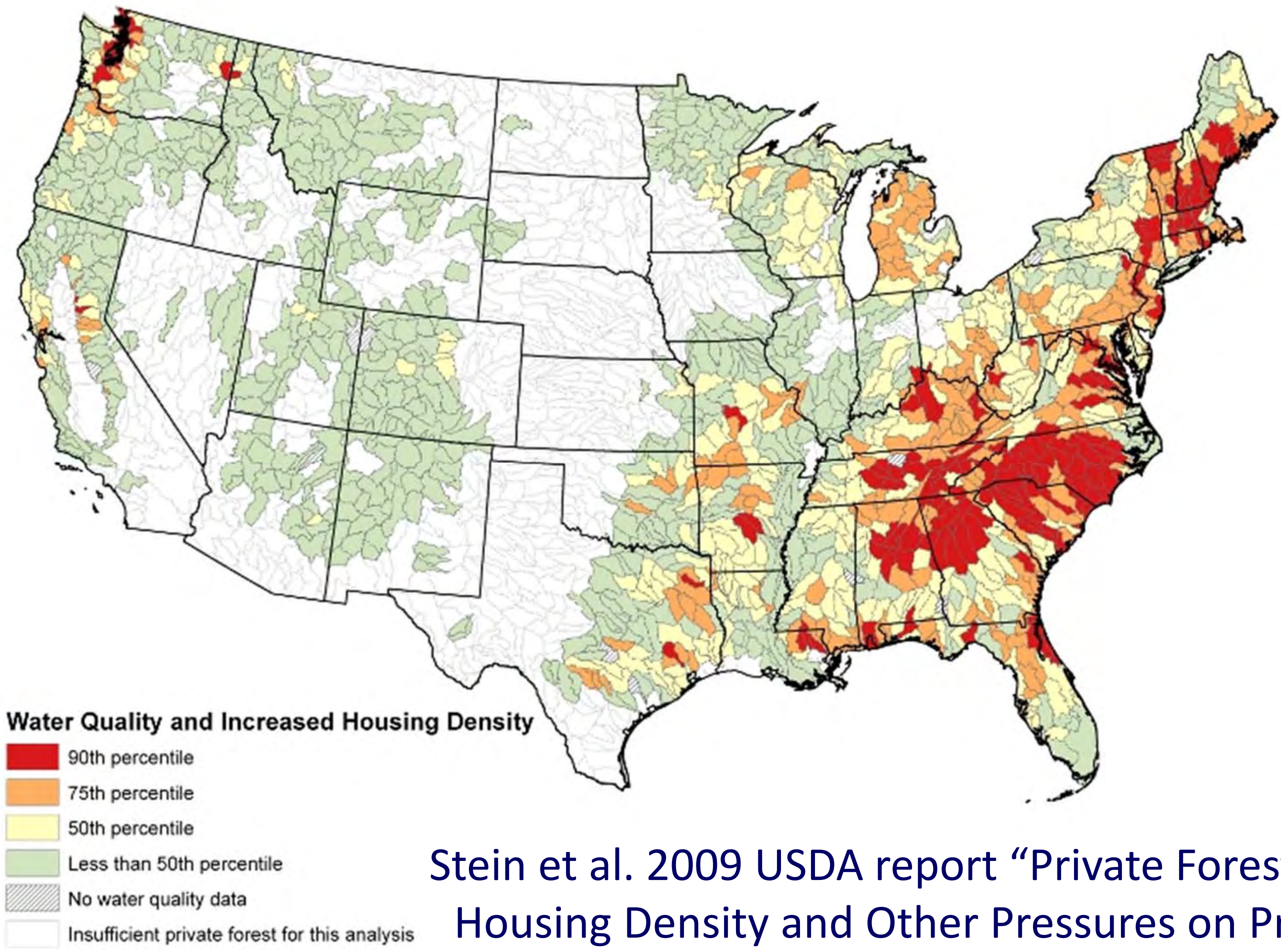


Total Population Increase 2010-2030, 180,000 persons



2010 Population Growth and Land Use Change Report by SPNHF

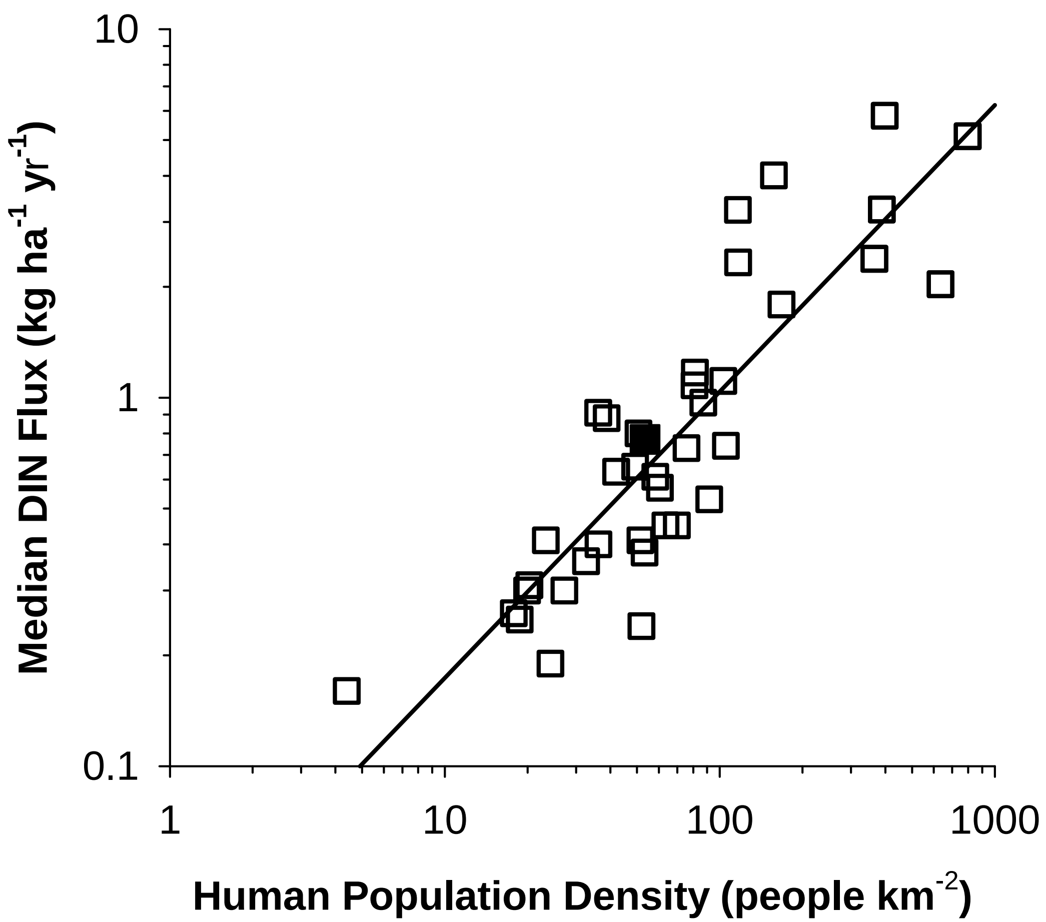
Watersheds projected to experience largest declines in water quality due to increased housing density on private forest lands



- Piscataqua-Salmon Falls watershed ranked highest in the nation
- 3 of the 4 highest ranked watersheds occur at least partially in New Hampshire

Stein et al. 2009 USDA report “Private Forests, Public Benefits: Increased Housing Density and Other Pressures on Private Forest Contributions”

How do we break down the relationship between population density and DIN?



Reduce inputs

- Reduce meat consumption
- Ban/tax fertilizer
- Reduce air pollution

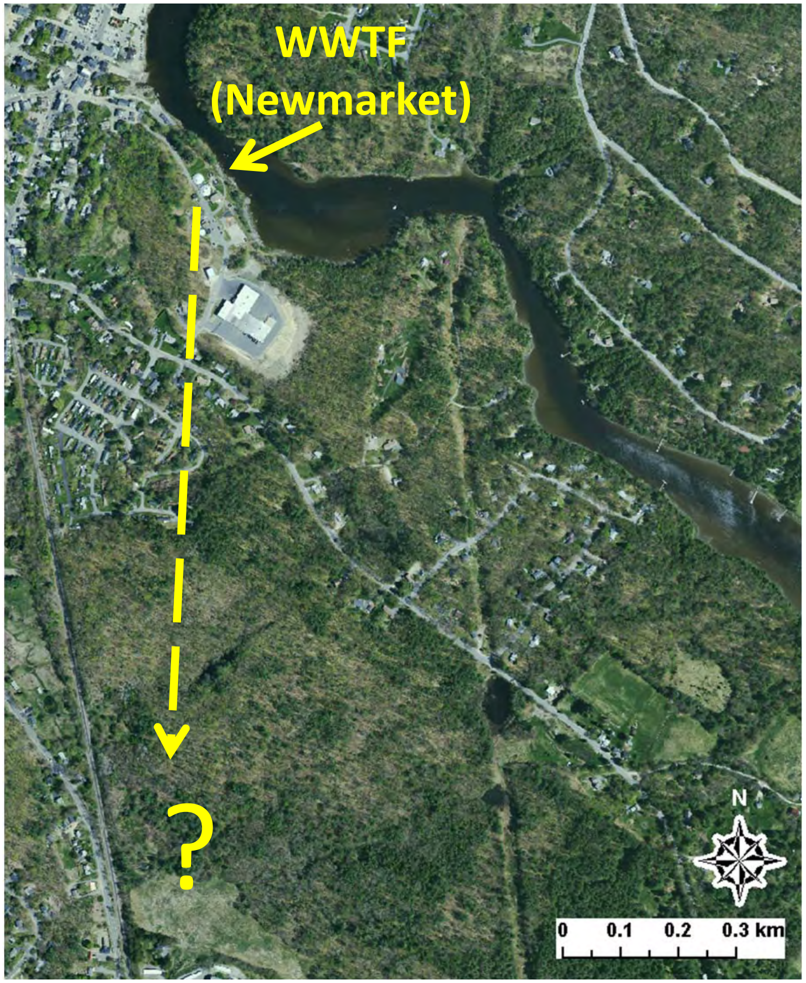
Increase retention or removal

- Upgrade WWTFs and fix leaky sewer lines
- Improve new septic systems and retrofit old ones
- Improve stormwater management
- Protect and restore vegetated riparian zones

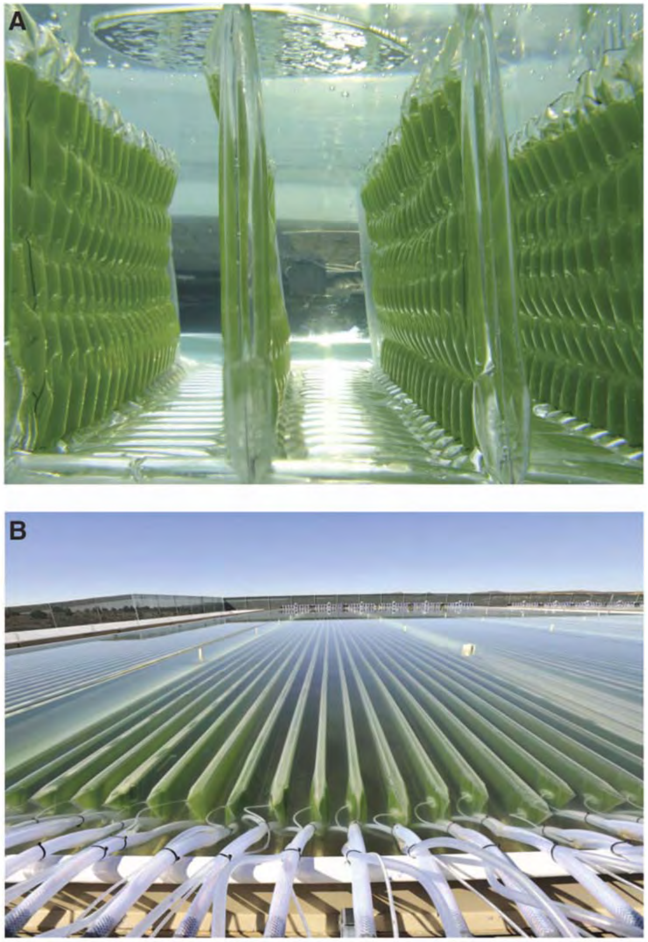
➢ Need stakeholder and private landowner involvement

Potential ways to reduce costs of WWTF upgrades

Land apply effluent to use watershed retention capacity?



Produce biofuel from WWTFs effluent?



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- Liz Holden, Heather Gilbert and Rachel Skokan for field and lab assistance
- Graduate students including Paul Proto, Tracey O'Donnell, and Lauren Buoyofsky
- EPA, NH WRRC, UNH Agricultural Experiment Station, AIRMAP, Lamprey River Advisory Committee and NOAA for funding


A River, Estuary or Lake is a Reflection of its Watershed
Questions?
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