Integration
Of National Coastal Assessment Data, Freshwater Nutrient (Sparrow) Modeling And Estuary Nutrient Mass Balance Calculations:

An Example

From Narragansett Bay

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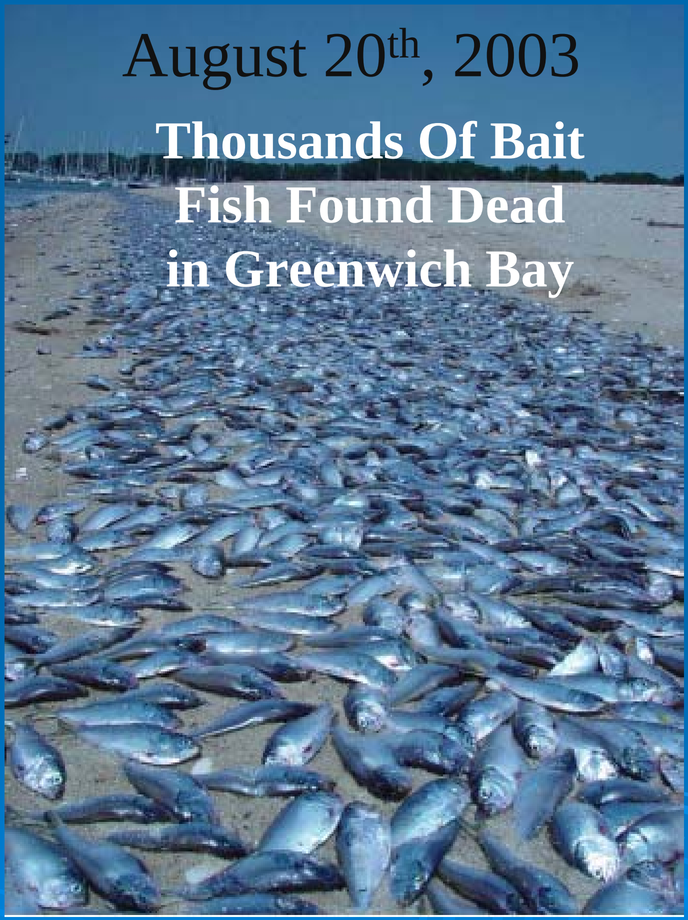
The following is being proposed as part of a National Water Quality Monitoring Network for U.S. Coastal Waters and their Tributaries:

- probability survey data from estuaries,
- measurements in estuaries from moored instrumentation,
- water and nutrient flux measurements from fixed stations in streams, and
- Estuarine and SPARROW models

- We illustrate the utility of this approach in support of recent management decisions to reduce nutrient loadings to Narragansett Bay

Identification of the problem

- Episodic Fish Kills



In Upper Narragansett Bay, RI
Episodic Fish Kills

Fish Kill 6 / 28 / 01 – Greenwich Bay

Surface D.O. : 3.8 mg/l inshore; 6.0 mg/L offshore

Bottom D.O. : < .05 mg/L near shore @ 1.8 m ;

0.6 mg/L offshore @ 3 m

Water Quality Monitoring Network components:

1) probability survey data, and

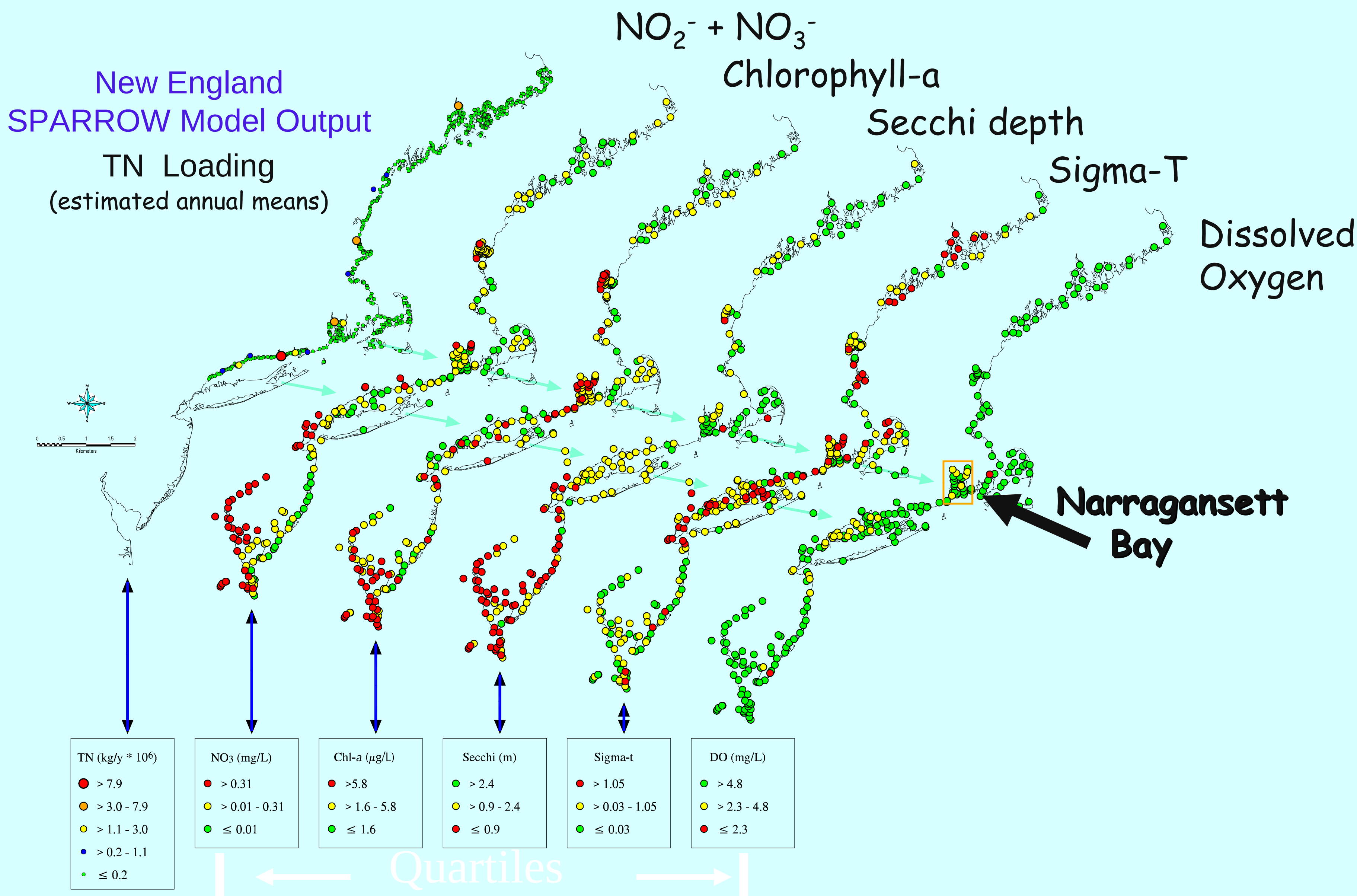
2) moored instrumentation

Used to:

- **Characterize the Problem**
- **Diagnose Causes**
- **Diagnose Interactions and**
- **Forecast**

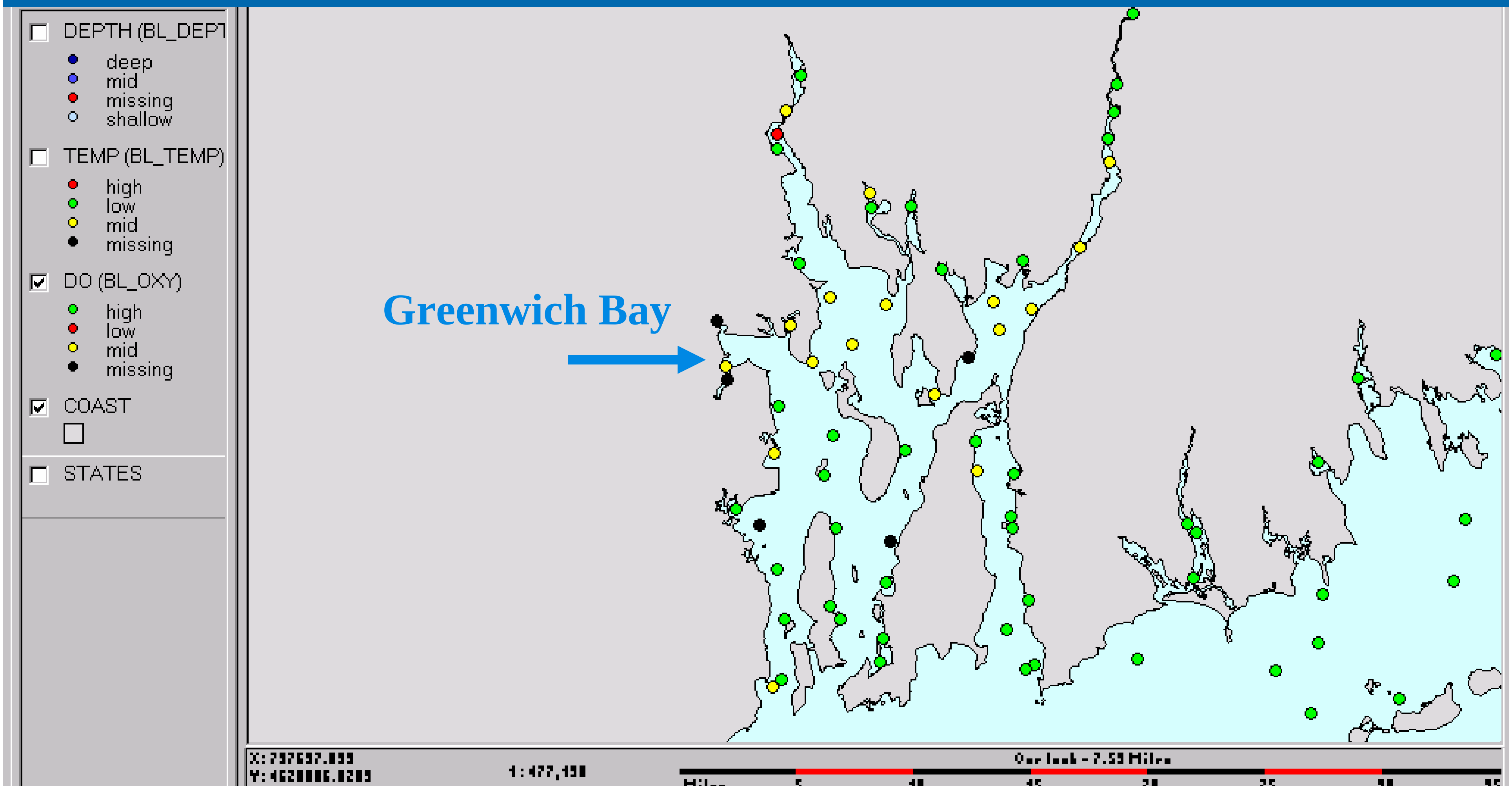
National Coastal Assessment: Regional Characterization

Probabilistic sampling design / Summer 2000.



NCA Bottom Water Dissolved Oxygen

NCA samples from summer of 2000, & 2001 illustrate
[DO] < 5.0 mg / l in upper Bay, but rarely capture "acute" events
[DO] < 2.3 mg / l



Narragansett Bay

Temporal variability in surface and bottom DO studies using automated time-series measurement systems.

Dana Kester et al,
Detailed diagnostic studies at fixed station network

Narragansett & Mt Hope Bay: Automated Instrumentation at 12 sites sensors 0.5 m below the surface and 1.0 m above the bottom :
T, S, O_2 , Chl Fluorescence, & Water level

University of Rhode Island, Graduate School of Oceanography (stations 1 thru 6)

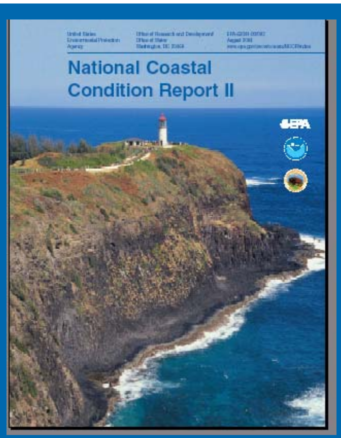
RI DEM

Roger Williams Univ.,

University of Mass
(Boston and Dartmouth)

Mass. Coastal Zone Management Office.

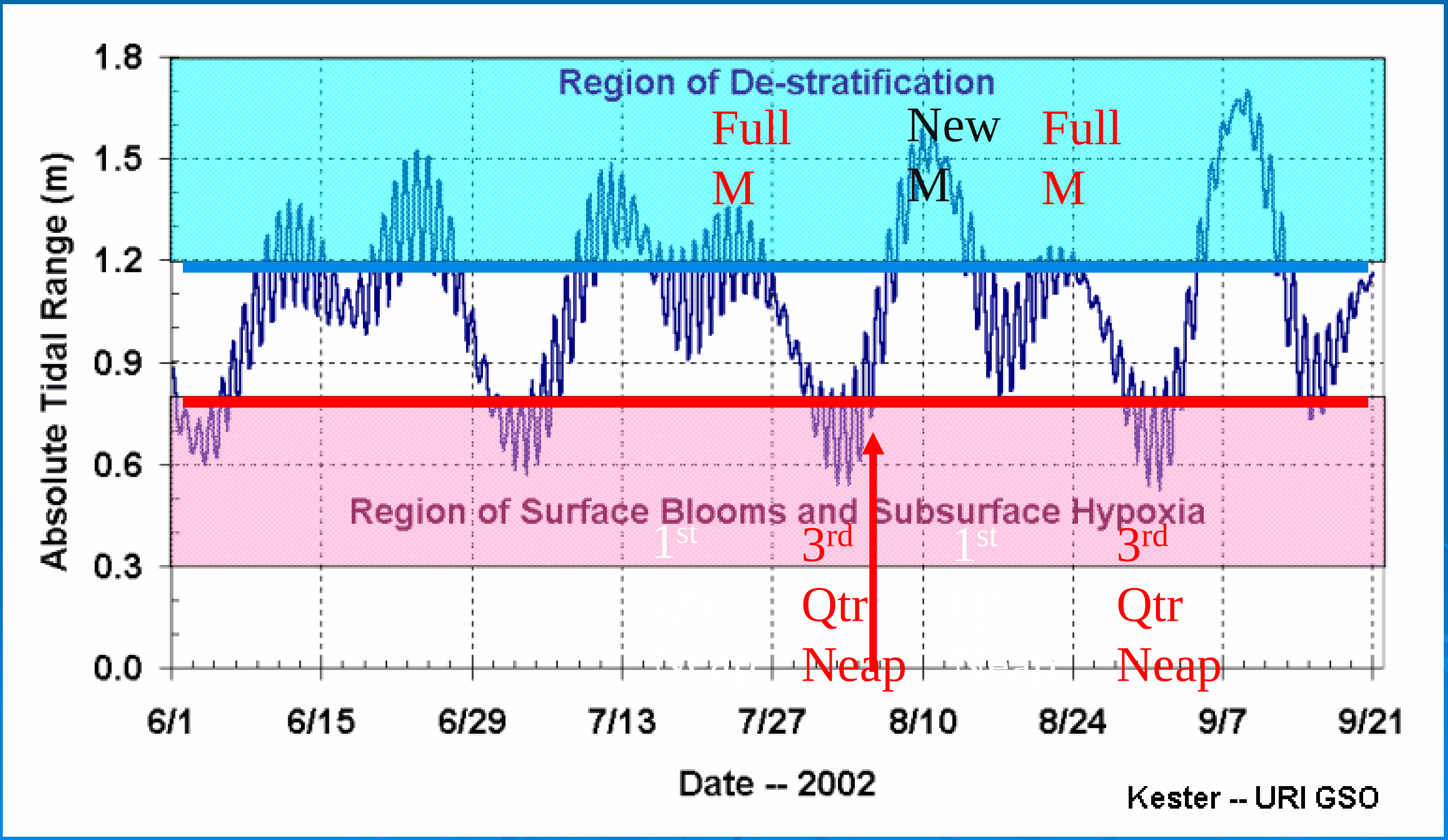
http://www.gso.uri.edu/~dkester/nbay/obsnet.htm



2004

Chap. 3 Report Highlight:
Highlight on Narragansett Bay

Influence of tidal range variations on stratification in the upper Bay



http://www.gso.uri.edu/~dkester/nbay/index.htm

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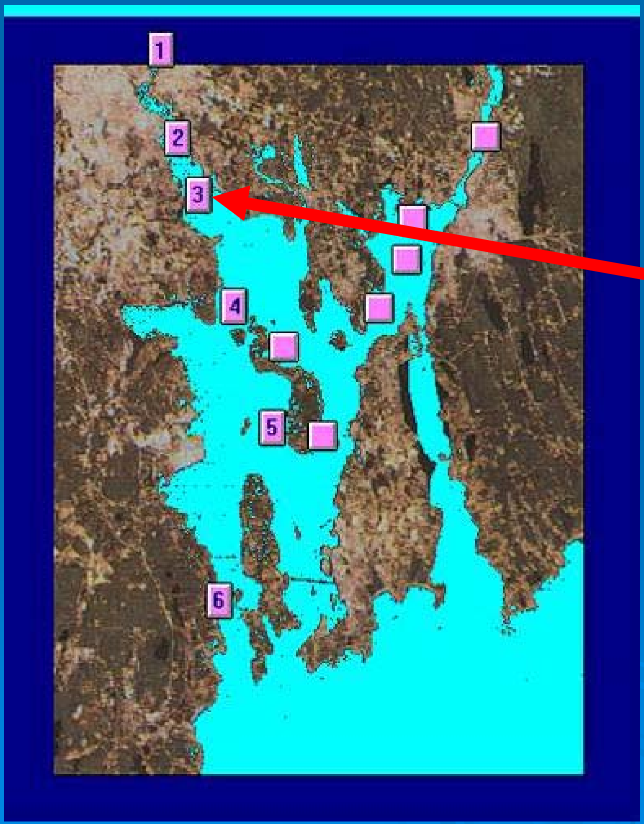
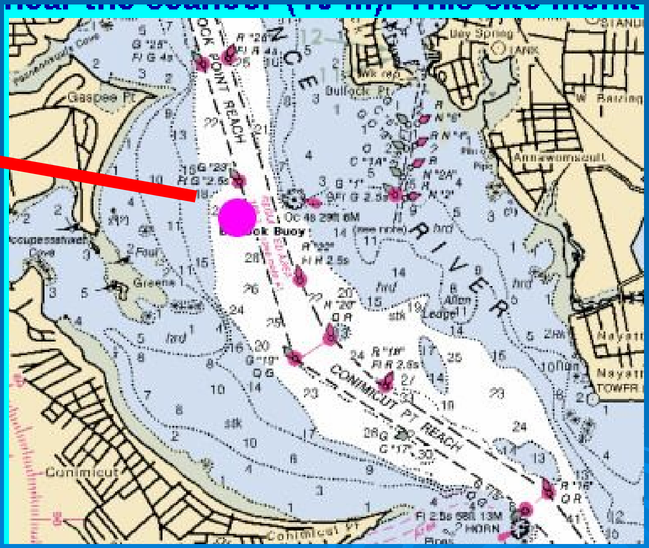


Bullock Reach Buoy



http://www.gso.uri.edu/~dkester/nbay/bullock.htm

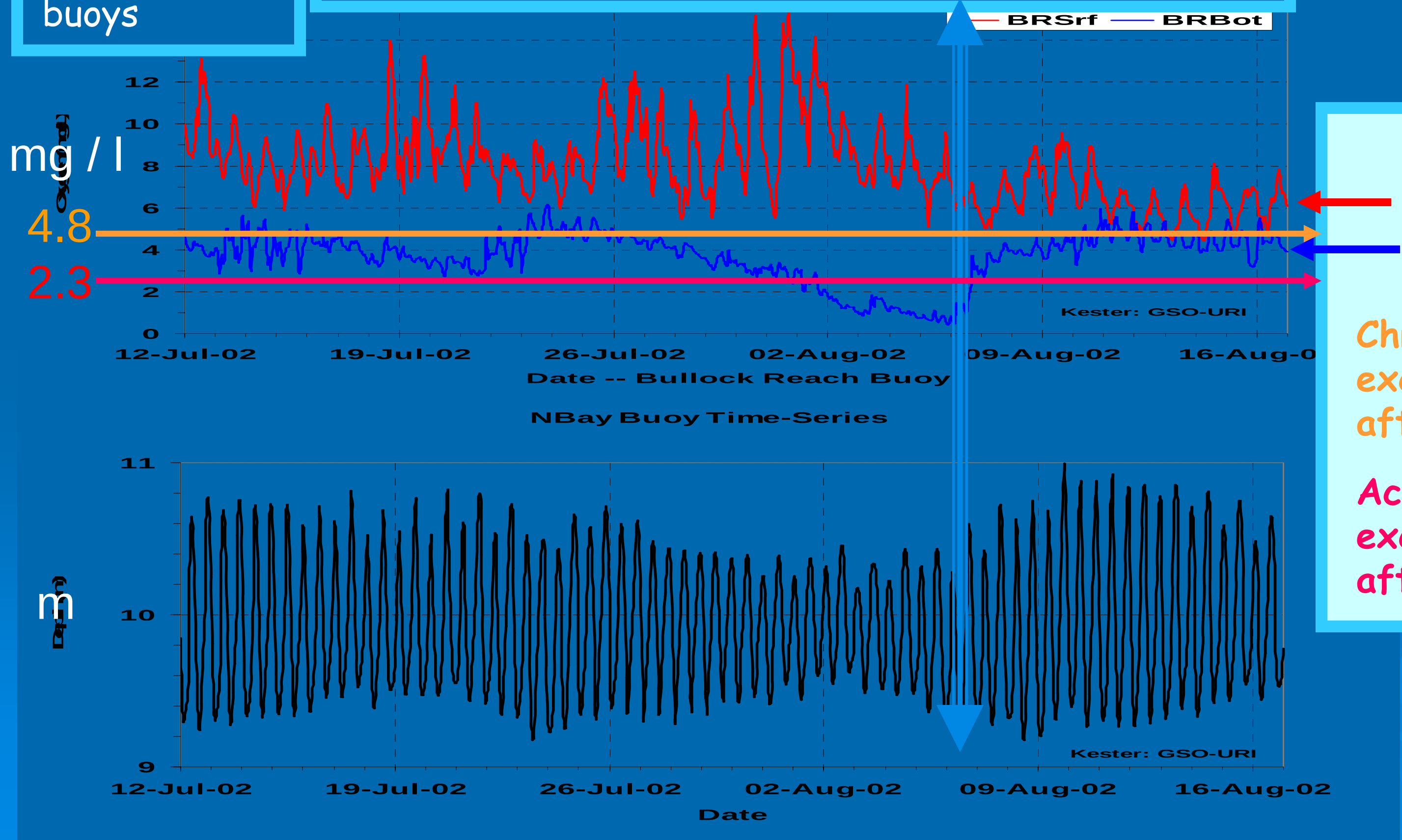
Time Series measurements

DISOLVED OXYGEN (and tidal fluctuations)

Targeted DO Sampling Criteria are based on combination of dissolved oxygen concentration and duration

Data from moored buoys

Targeted Sampling for low DO on August 6,2002
5 days after the minimum neap tide on August 1st



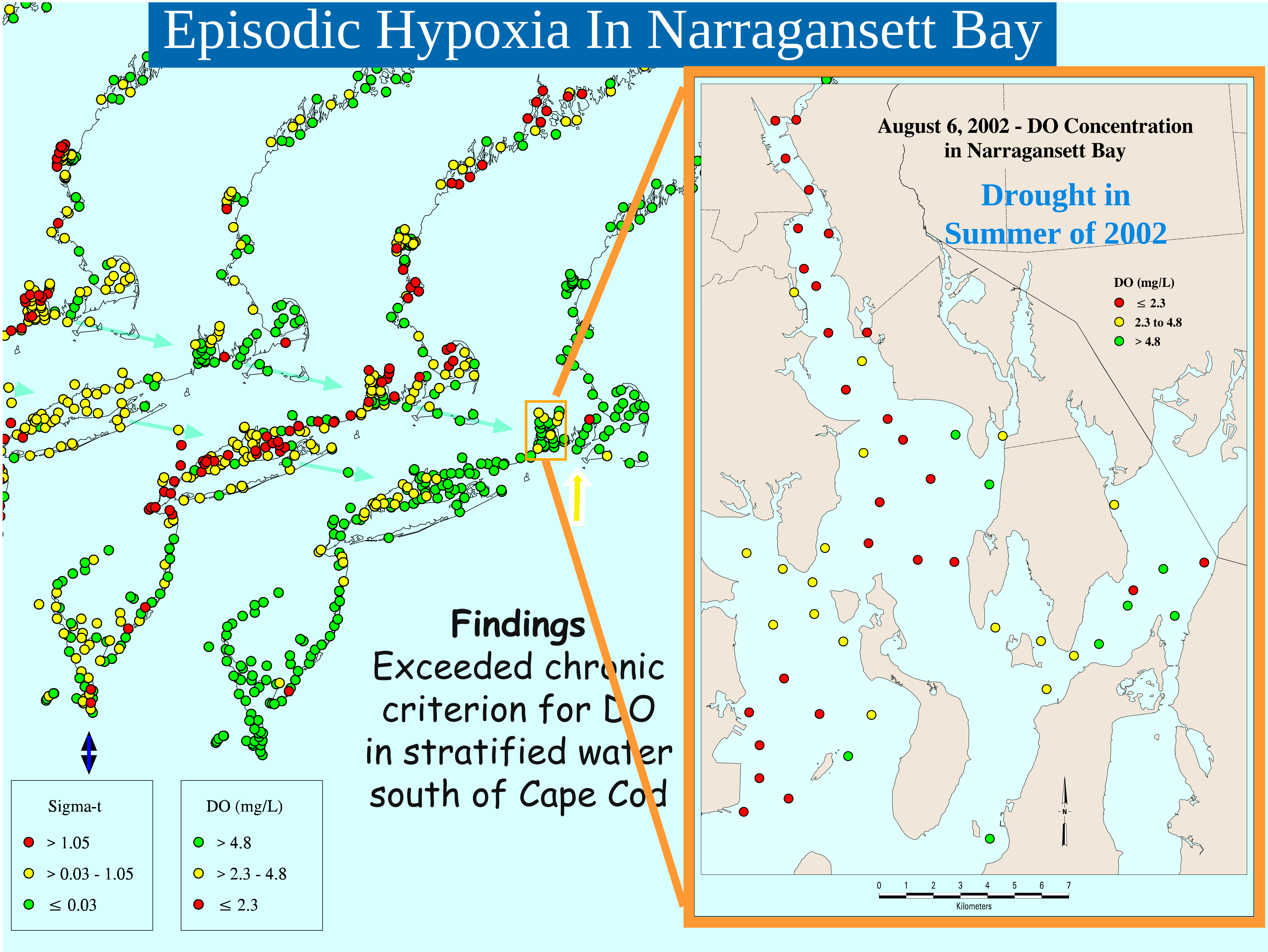
Findings

In bottom water:

Chronic DO Criterion exceeded for 10 days after July 26th

Acute DO Criterion exceeded for 5 days after Aug 1st neap tide.

Episodic Hypoxia In Narragansett Bay

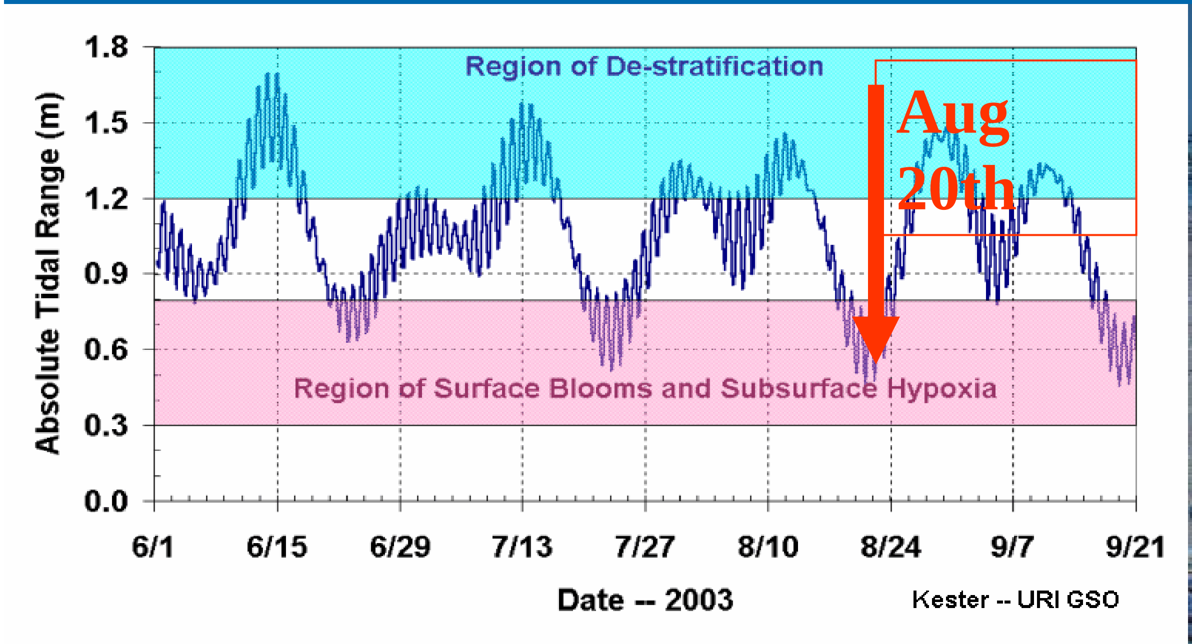


Findings

Exceeded chronic criterion for DO in stratified water south of Cape Cod

Dissolved Oxygen in Narragansett Bay

Summer of 2003



Water Quality Monitoring Network components:

3) Estuarine, and
4) Riverine (SPARROW)
Nutrient Models

The Estuary Nitrogen Model.

Dettmann (2001)

N Loading

$$\frac{dN}{dt} = L_{land} + L_{sea} - E - \alpha N$$

Export Internal Losses

Assumptions:

Model deals with long-term (e.g. annual or multi-year averages.

Approximate steady state at scale of yearly cycle, i.e.

$$\frac{dN}{dt} = 0$$

Summary of Data Requirements of the Estuary Nitrogen Model

Annual Loads of Total Nitrogen to Estuary from:

- Watershed
- Atmosphere
- Point sources

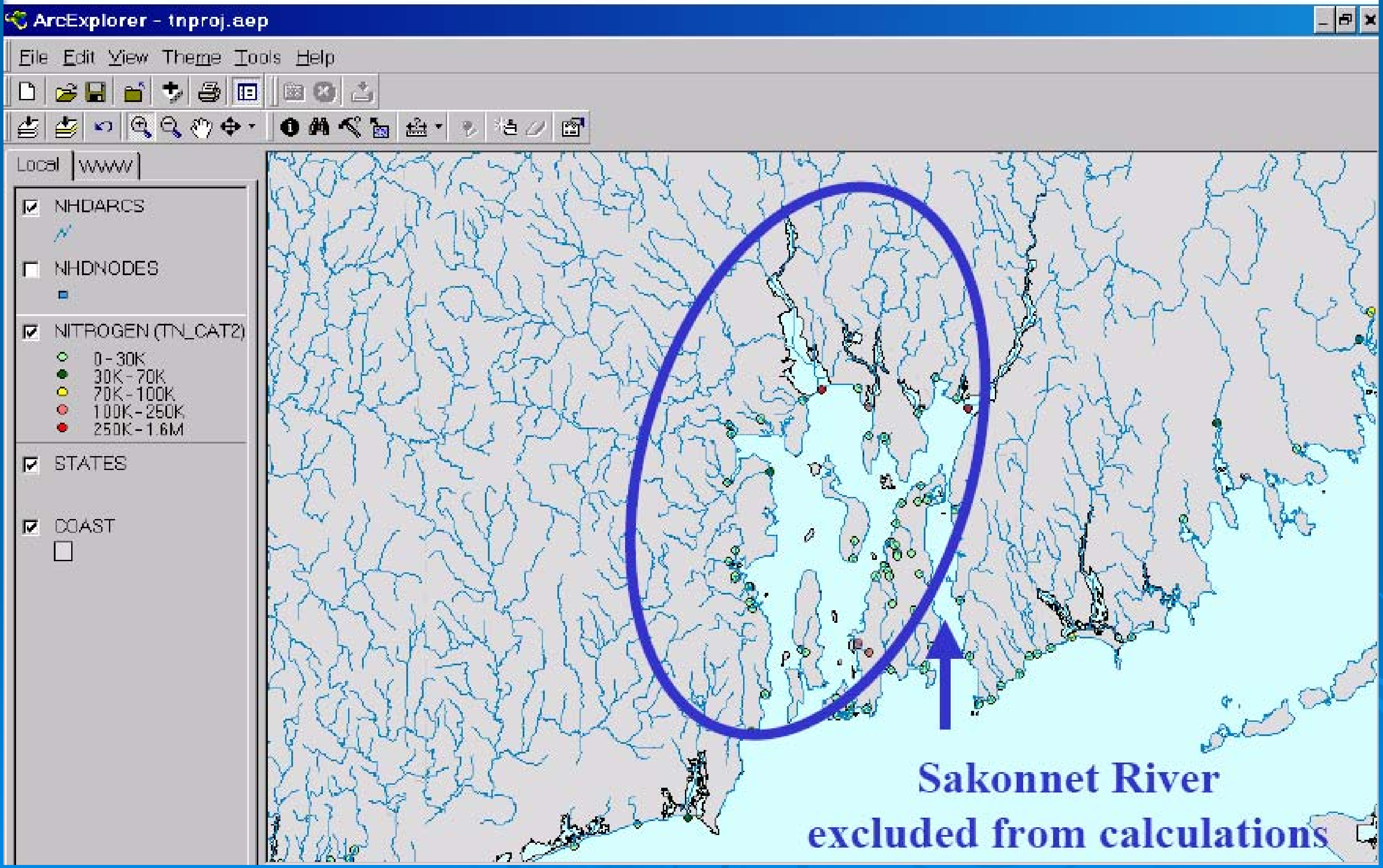
Average Annual Freshwater Residence Time (τ)

Estuary Volume

Background Nitrogen Concentration from Transport Across Seaward Boundary ([N_{sea}])

Estimated TN Input to Narragansett Bay from Rivers & Streams

(NE SPARROW Model)



TN Loading to Narragansett Bay

	kg N y^{-1}
Sparrow (30 tributaries)	6,227,261
Nixon et al. (1995)	6,120,928

TN loading from SPARROW	6,227,261
Direct Atmospheric Deposition*	420,201
Sewage Treatment Plants*	2,563,226
Total TN Loading	9,210,688

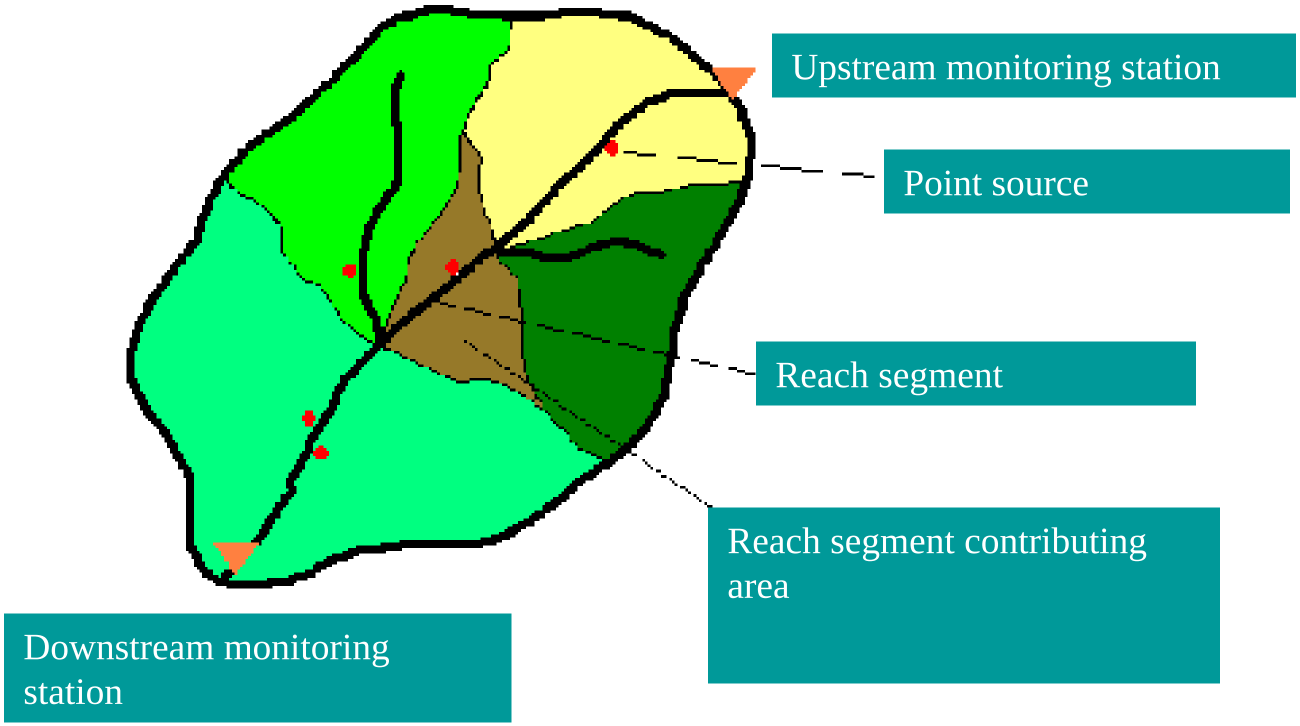
*(Nixon et al., 1995)

Riverine TN loading to Narragansett Bay from New England SPARROW Model is 68% of total.

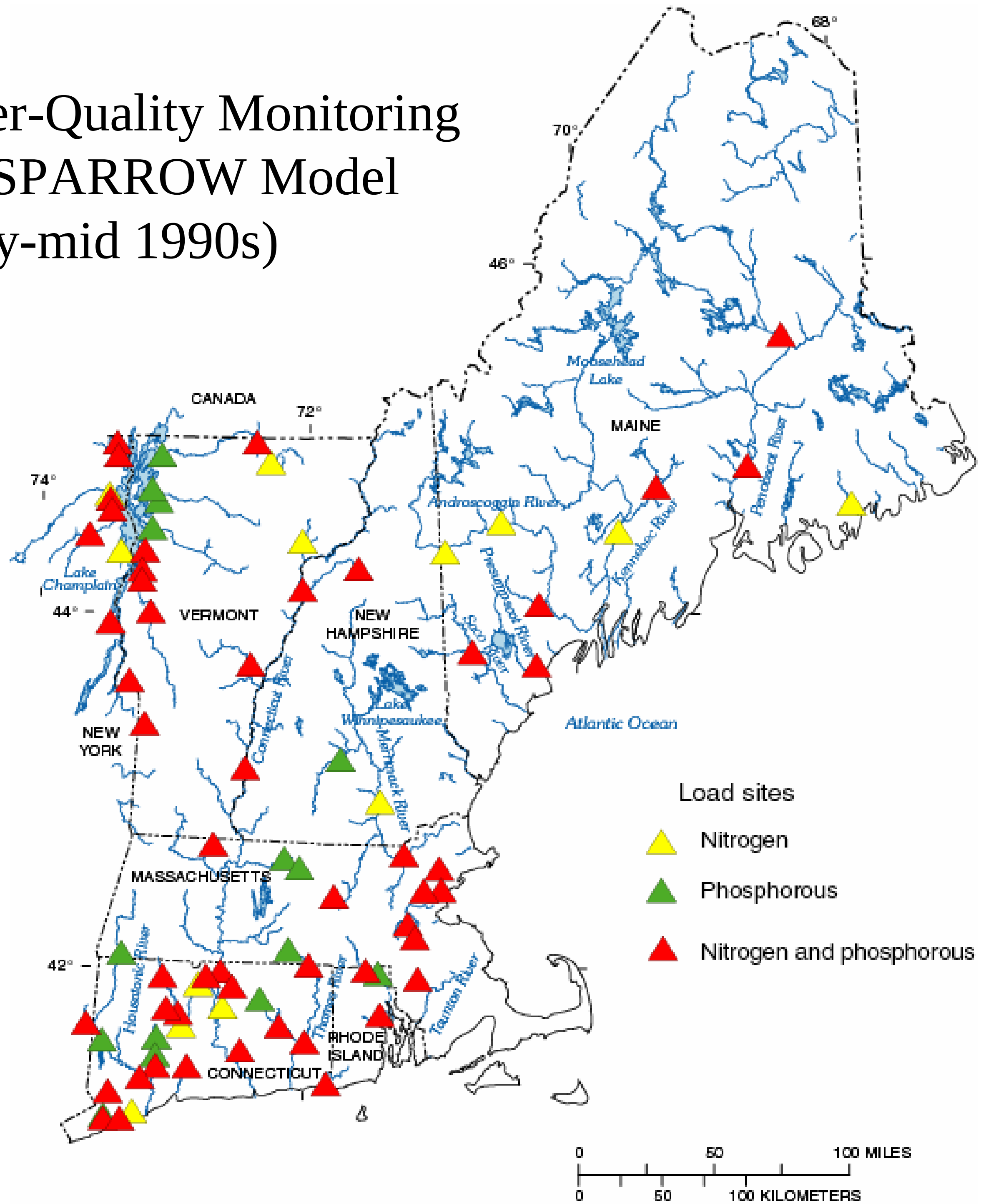
SPARROW

- An empirical approach relating observed water-quality data (TN and TP) to upstream watershed characteristics
- Incorporates variables to simulate in-stream processes
- Incorporates only statistically significant parameters.

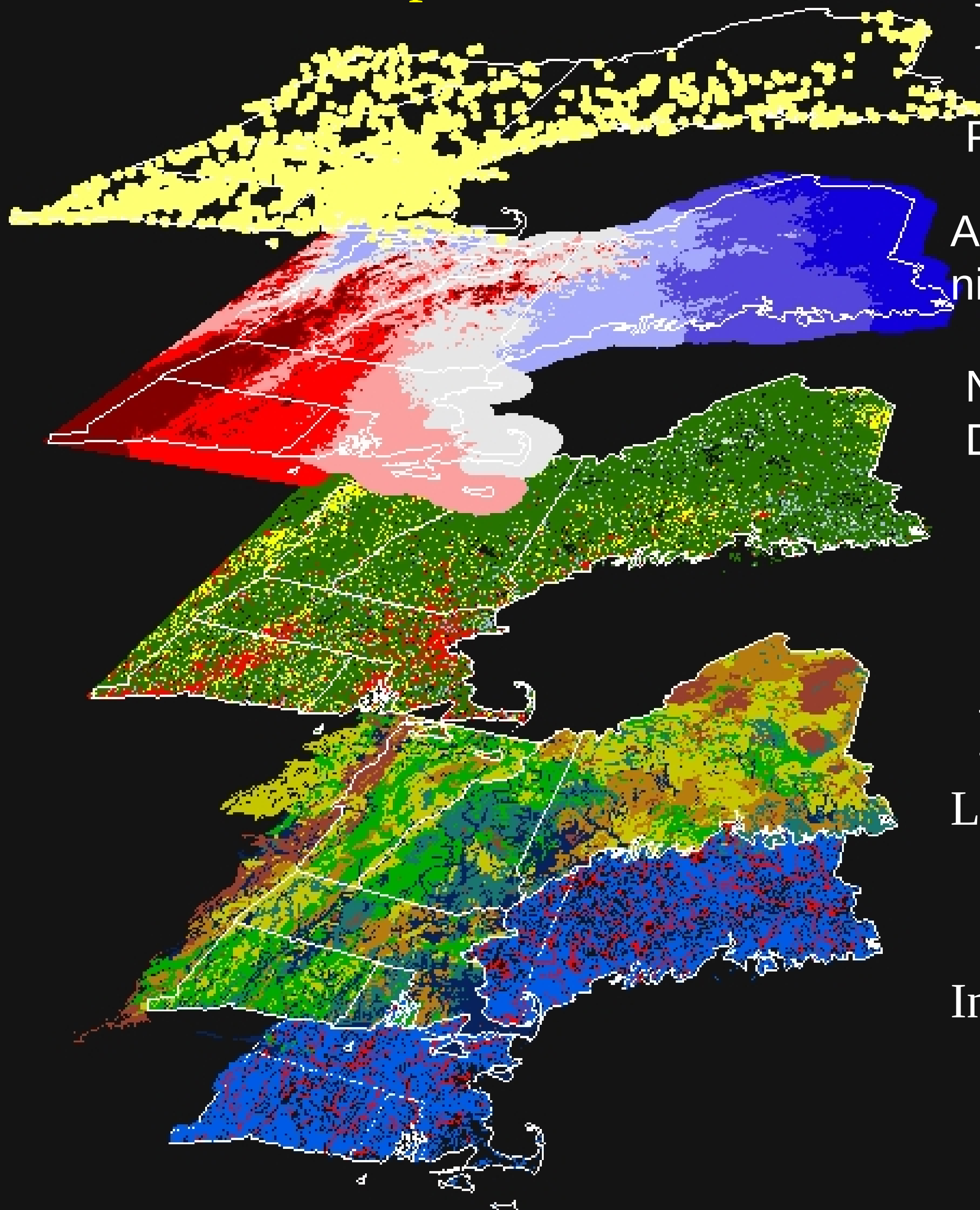
Schematic of a Nested Basin



Nutrient Water-Quality Monitoring Sites used in SPARROW Model (Data for early-mid 1990s)



NE SPARROW Model Input



Nutrient Sources

Point Source

Atmospheric deposition of nitrogen (Ollinger 1992)

National Land Cover Dataset 1992

- Agriculture
- Developed
- Forest

Processes

Land to water delivery

Soil permeability – STATSGO

In-stream loss

Stream travel time
Reservoir detention

Model Calibration Results for the New England SPARROW Nitrogen Model

R-squared = .95, MSE = 0.16

Variable SOURCES	Bootstrap model coefficient	Standard error of coefficient	p-value
Municipal wastewater-treatment facilities	1.13	0.36	<.005
Atmospheric deposition	.36	.07	<.005
Agricultural land ($kg/km^2/y$)	910	362	.005
Developed land ($kg/km^2/y$)	988	385	.010

Model Calibration Results for the New England SPARROW Nitrogen Model (cont.)

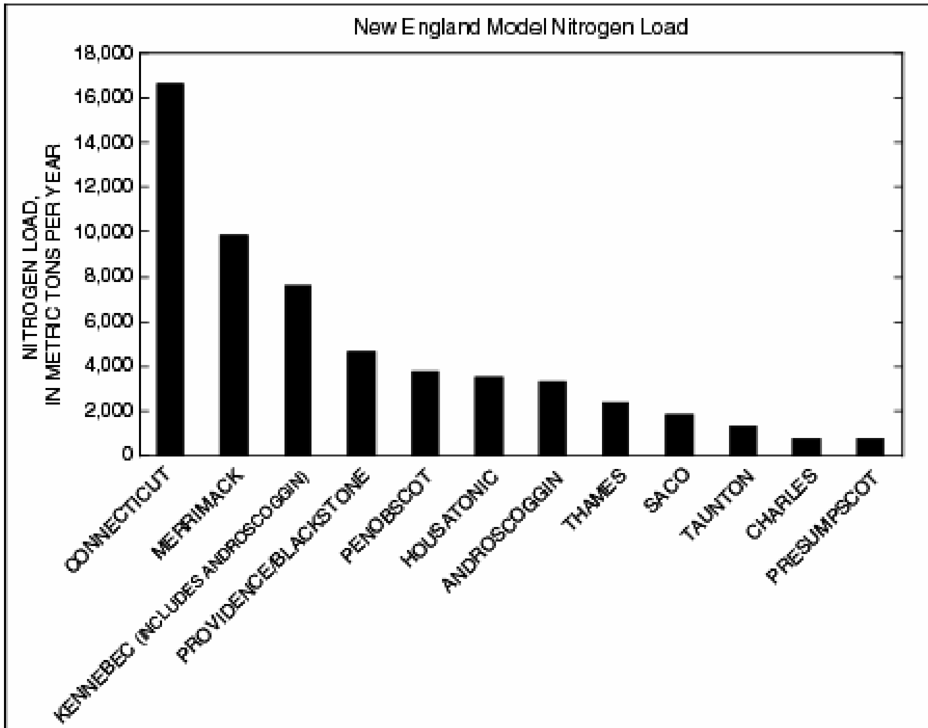
R-squared = .95, MSE = 0.16

Variable	Bootstrap model coefficient	Standard error of coefficient	p-value
Delivery variable:			
Natural Log of Soil Permeability	0.36	0.14	<.005
Decay Variable:			
Stream decay for streams <= 100 cfs (per day)	.71	.52	.065

Application of SPARROW Results

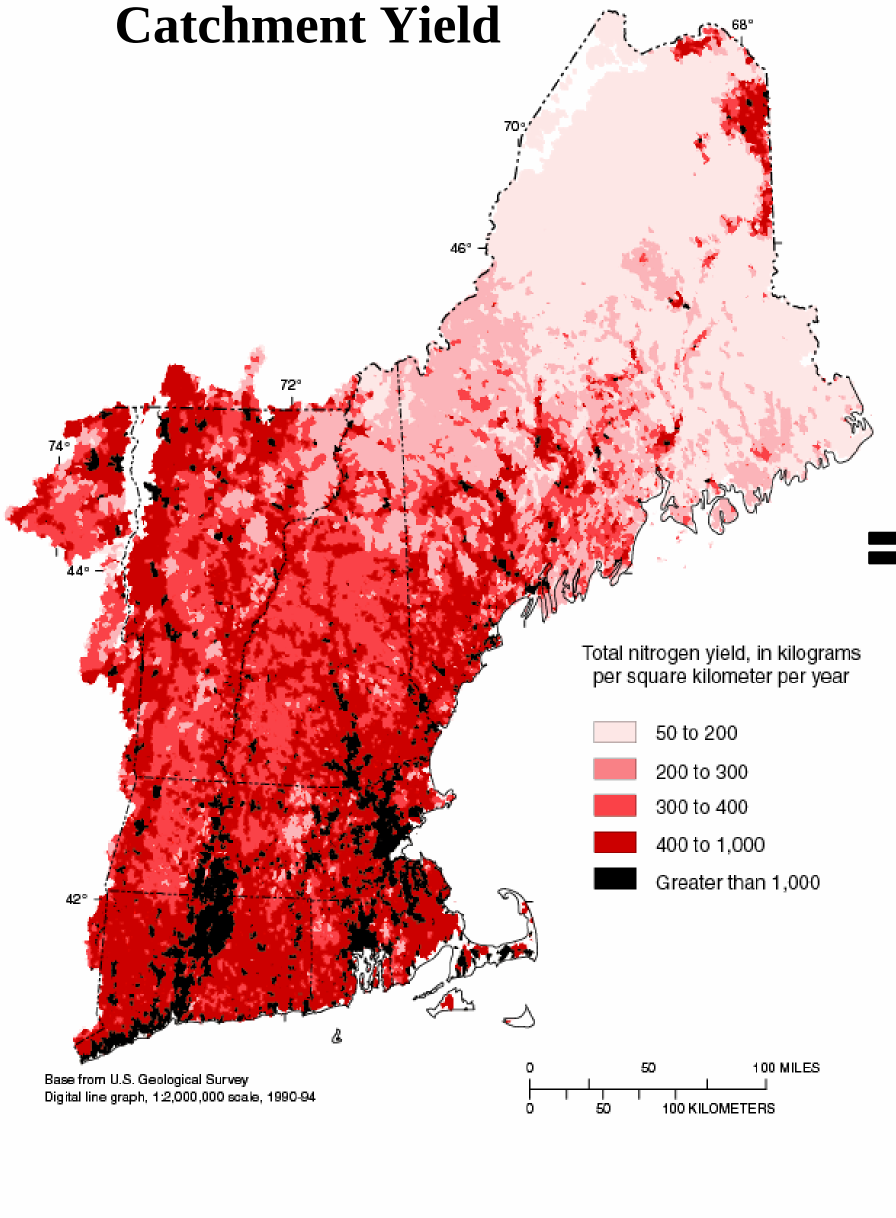
- SPARROW nutrient load predictions are made for 42,000 stream reaches throughout New England

New England SPARROW Model



SPARROW Model Results:

Predicted Total Nitrogen Catchment Yield



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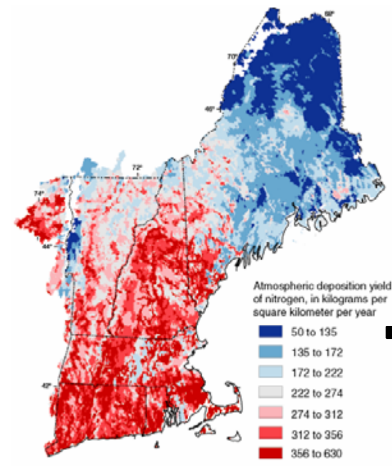
Contributions to Total Nitrogen from each source



Atmospheric

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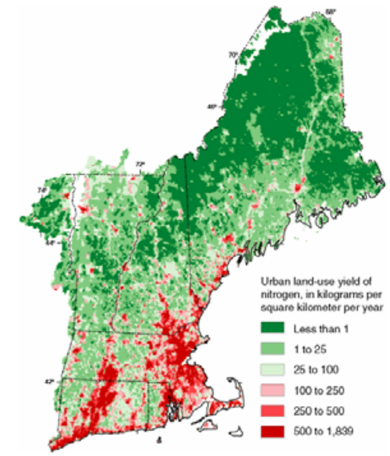

Developed

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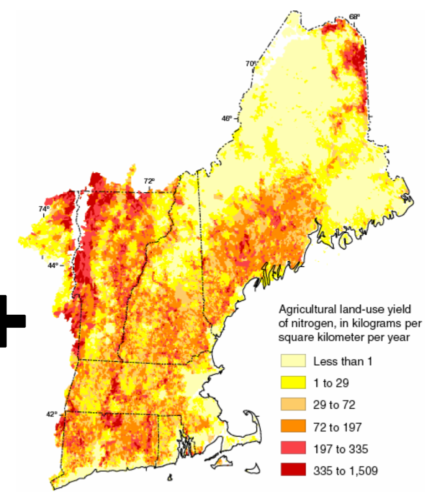

Agriculture

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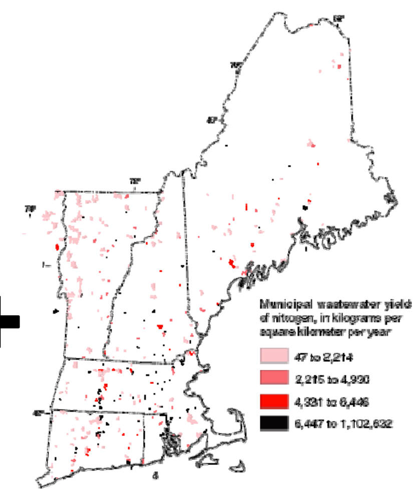
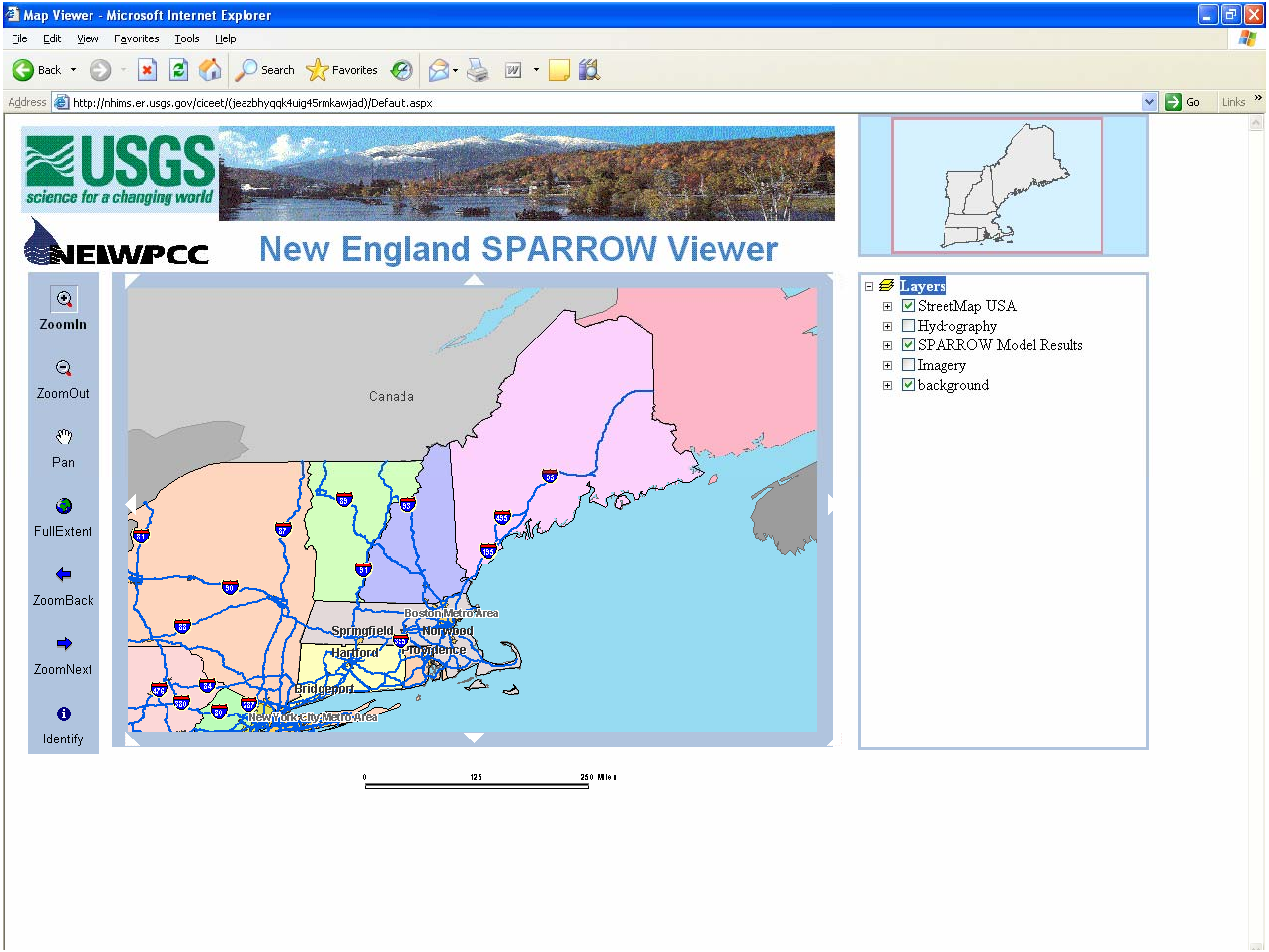


Point Source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SPARROW Model Results
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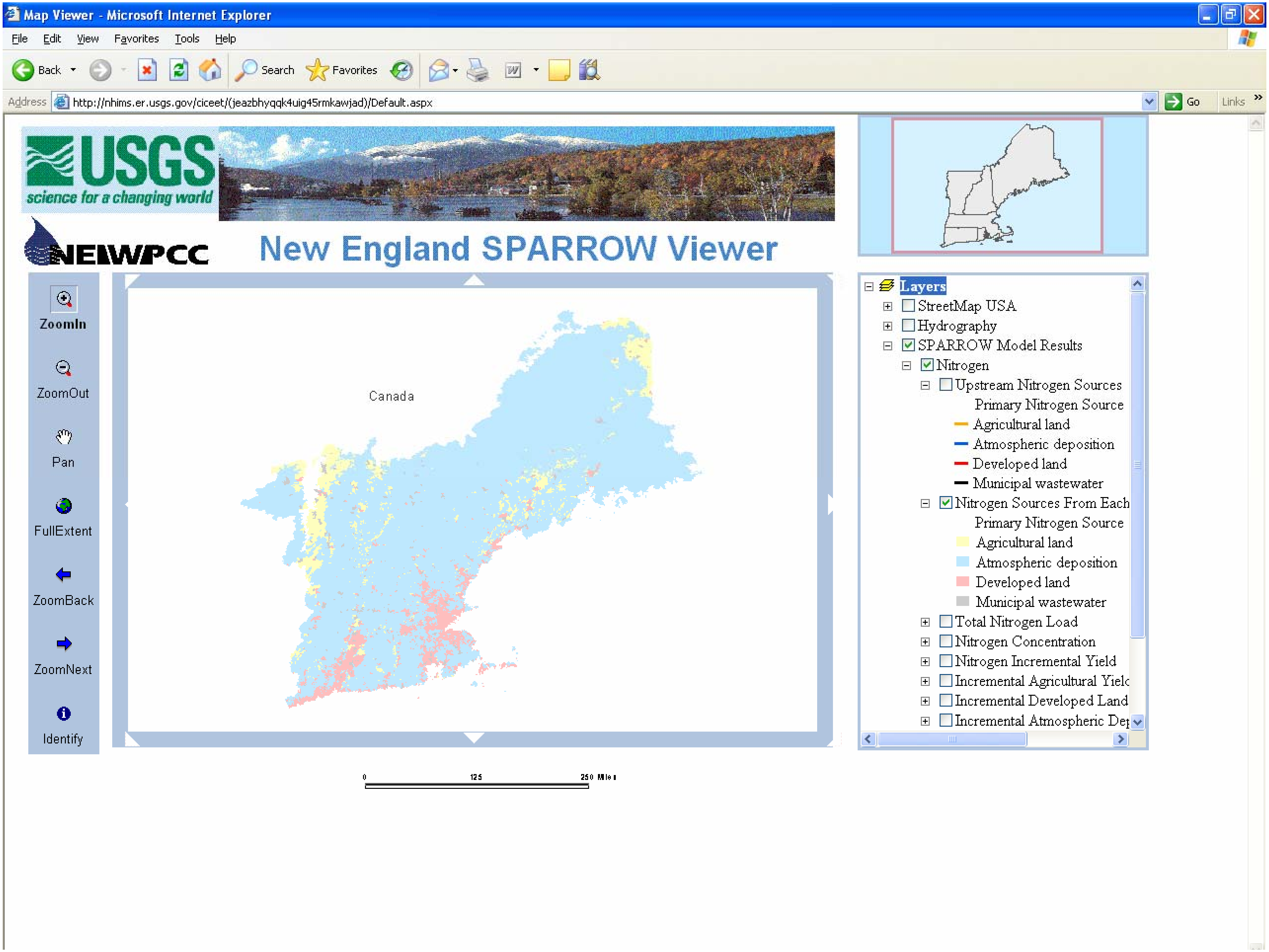
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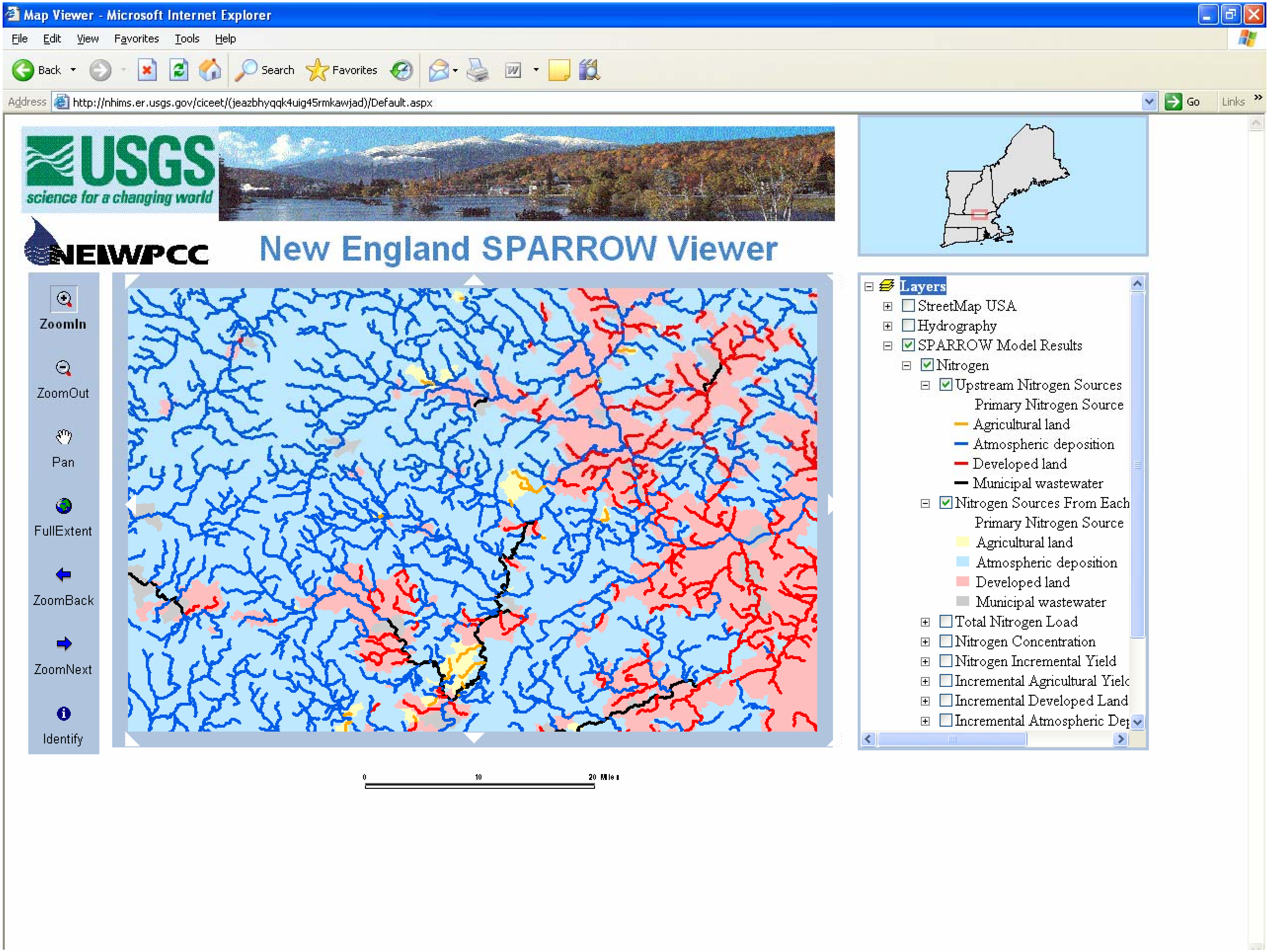
Nitrogen
Upstream Nitrogen Sources
Primary Nitrogen Source
Agricultural land
Atmospheric deposition
Developed land
Municipal wastewater
Nitrogen Sources From Each
Primary Nitrogen Source
Agricultural land
Atmospheric deposition
Developed land
Municipal wastewater
Total Nitrogen Load
Nitrogen Concentration
Nitrogen Incremental Yield
Incremental Agricultural Yielc
Incremental Developed Land
Incremental Atmospheric Dep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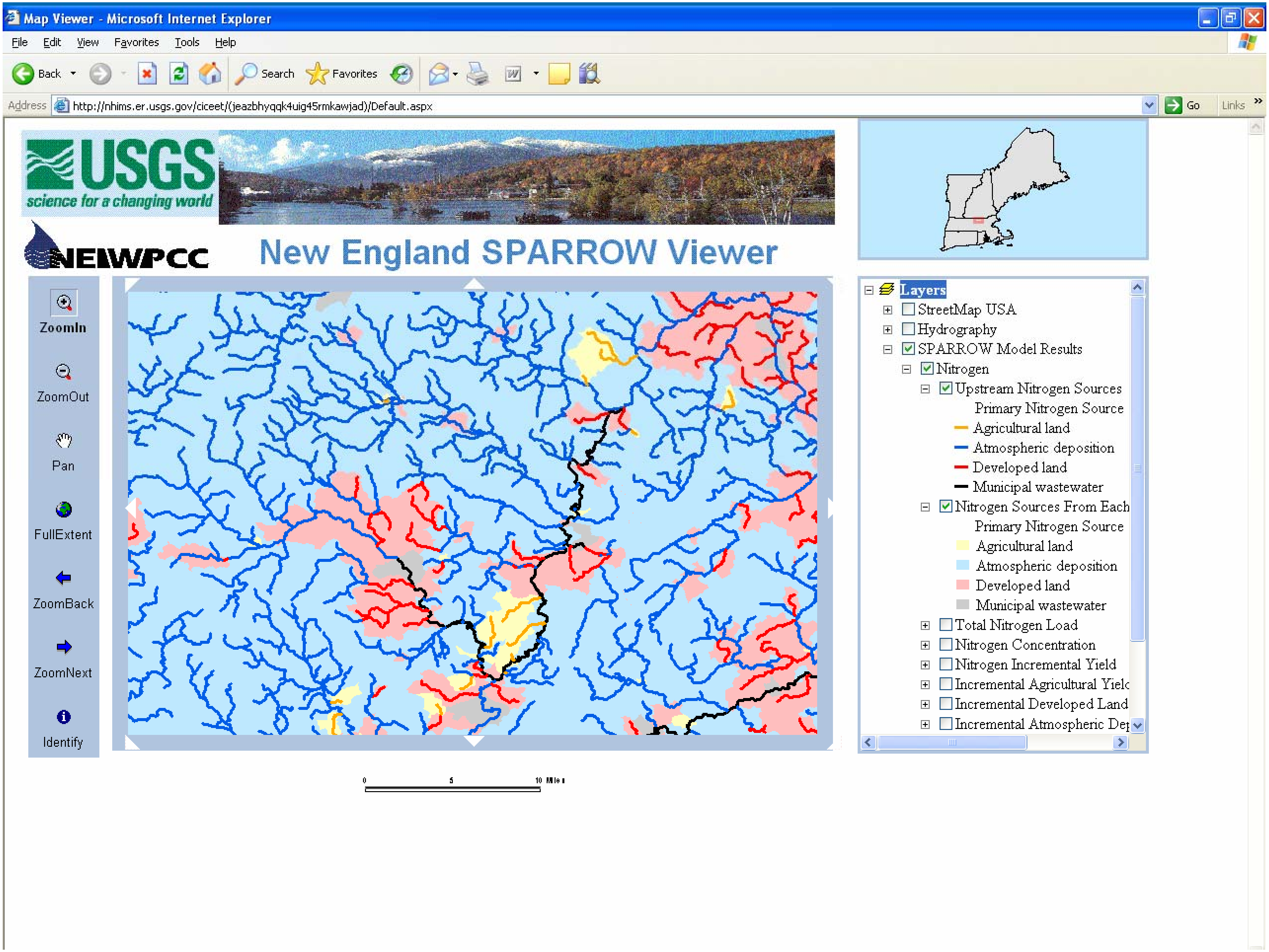
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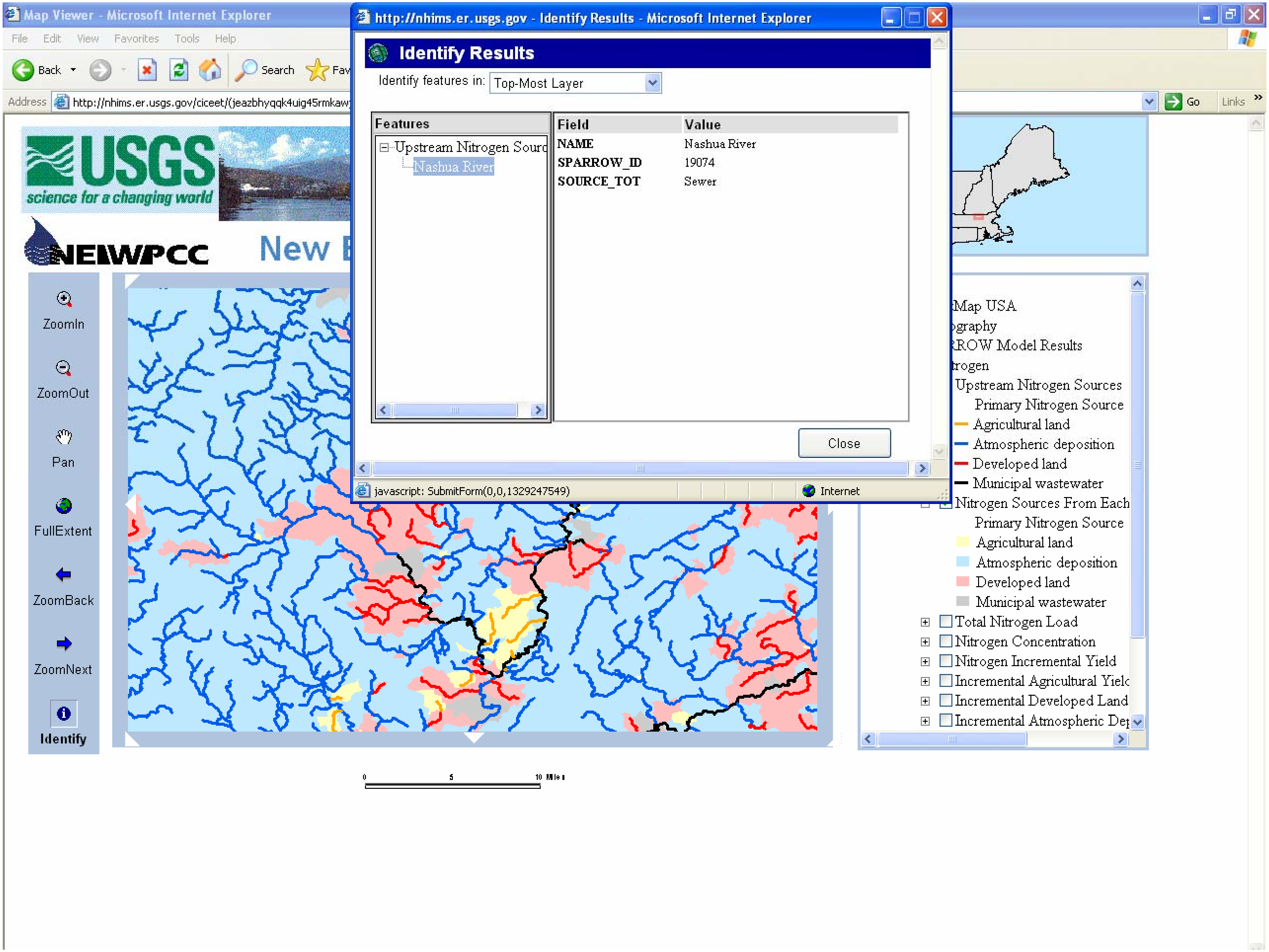

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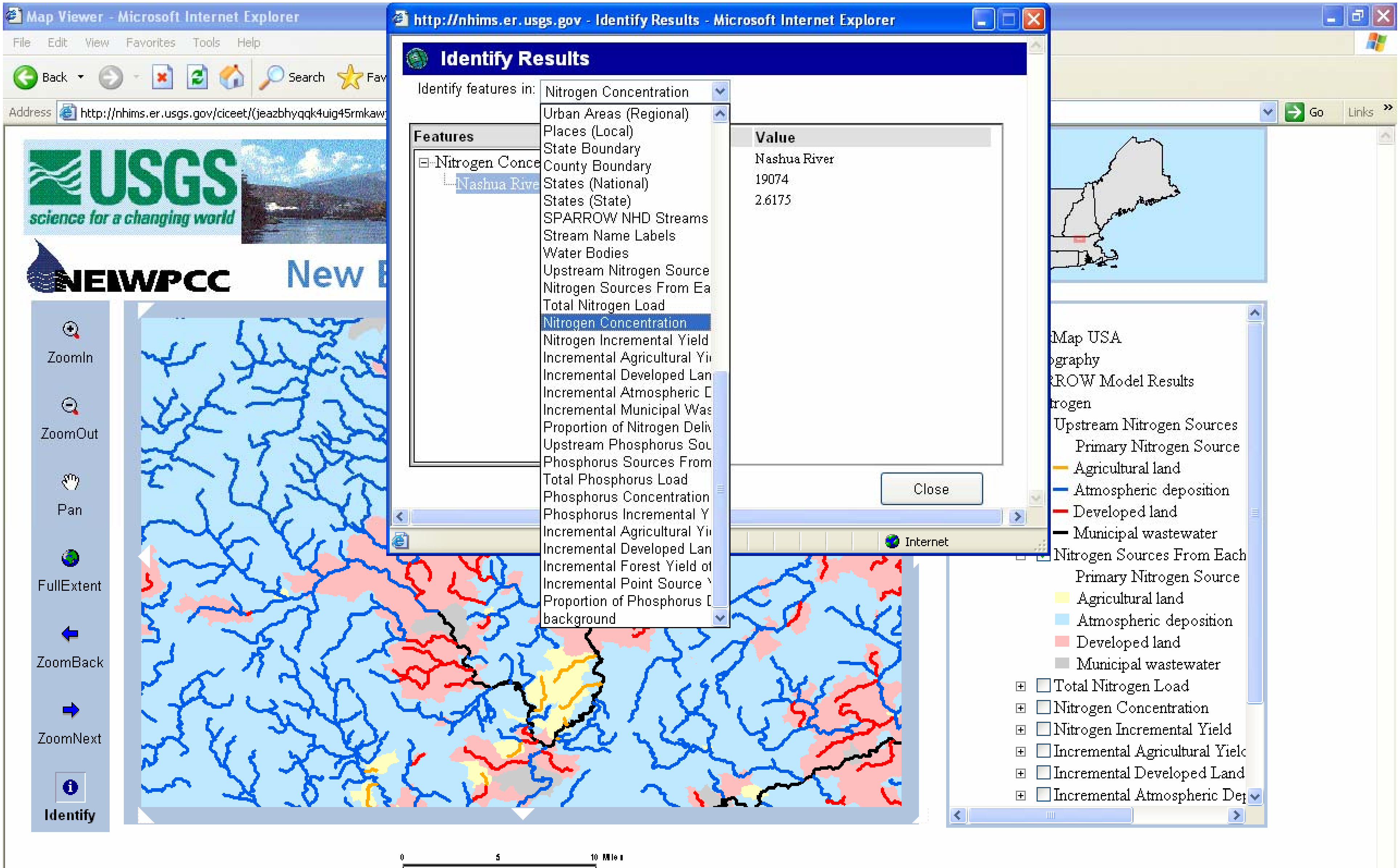


http://**nh.water.usgs.gov**

Riverine (SPARROW) 68% of TN loading to Narragansett Bay

of which:

➢ Atmospheric:	17.4%
➢ Urban:	18.4%
➢ Agriculture:	2.6%
➢ Point Sources:	61.2%

(point sources discharging directly into estuary not included)

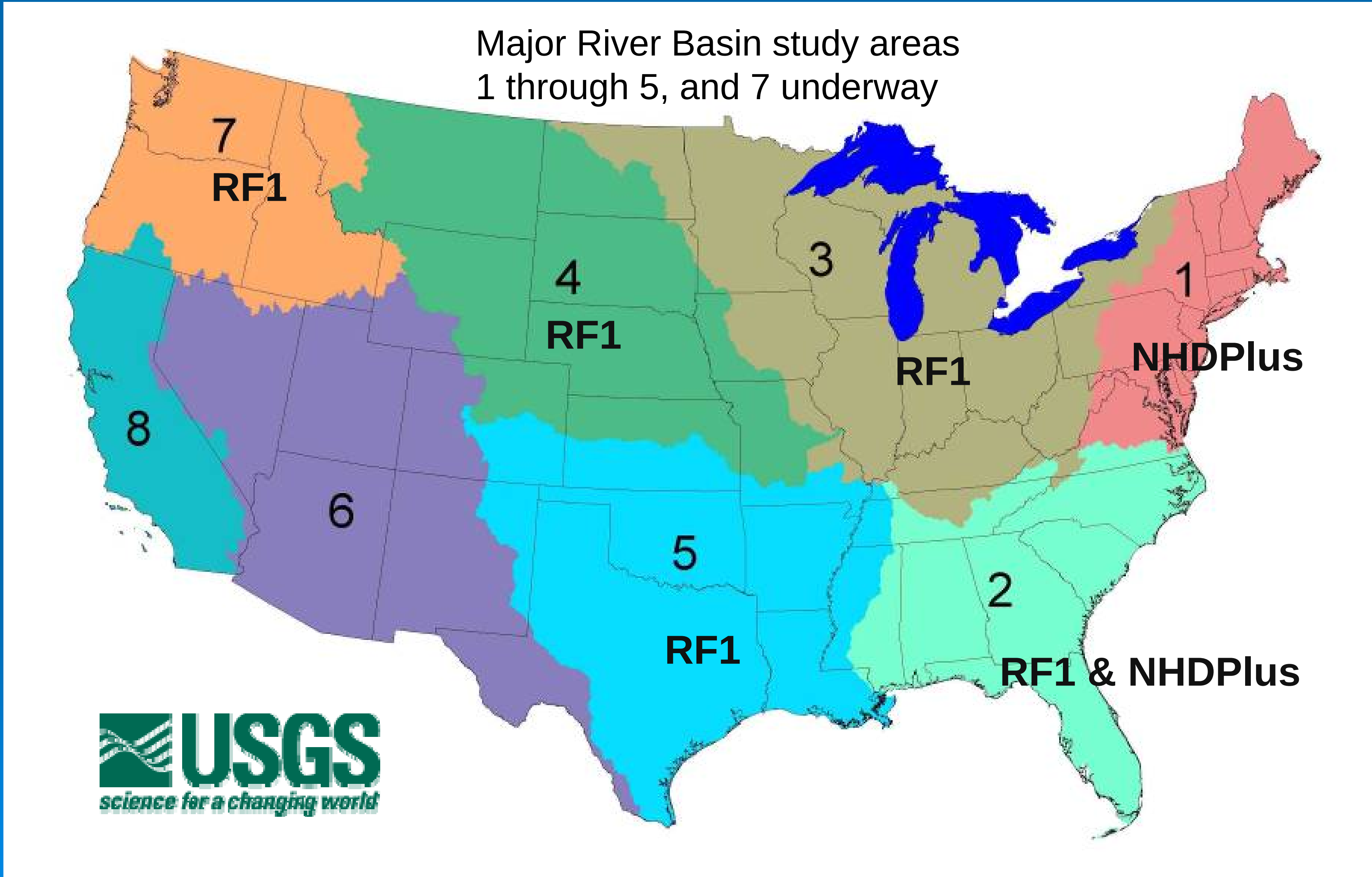
Point Sources

About 70 % of the TN loadings to the bay were estimated to be from point sources

- 28 % directly into the bay
- 42 % from upstream point sources (SPARROW model data)

Supports recent management decisions by the State of Rhode Island to use tertiary treatment to reduce nitrogen loading to Narragansett Bay.

Regional Nutrient SPARROW models now being developed for 2002 conditions



Research and Monitoring within an Integrated Assessment Framework

"Only through a coordinated and integrated effort can coastal coastal monitoring be successful at all levels at which is is necessary to preserve, protect, manage and enhance the coastal resources of the United States"

NCCR-2001

Average TN Concentration in Narragansett Bay

L_{land} = 766,766 kg N mo^{-1}

τ = 26 d = 0.855 mo

α = 0.3 mo^{-1}

V = 2.821 x 10^{9} m^{3}

V_{sw} = 2.584 x 10^{9} m^{3}

[N_b] = 0.201 mg L^{-1}

[N_{sea}] = 0.184 mg L^{-1}

α = 0.3 mo^{-1} (*permanent removal due to denitrification & burial*)

$$[N] = \left(\frac{L_{land}\ \tau}{V} + [N_{sea}] \right) \frac{1}{1 + \alpha\tau}$$

Calculated [TN] (model) = (0.232 + 0.184)/1.2565 = 0.331 mg L^{-1}

Measured [TN] (1985—1986 SINBADD Cruises)* = 0.358 mg L^{-1}

*(rough calculation, based on weighted average of TN. Hunt et al., (1987)