Analysis of Nitrogen Loading Reductions for Wastewater Treatment Facilities and Non-Point Sources in the Great Bay Estuary Watershed

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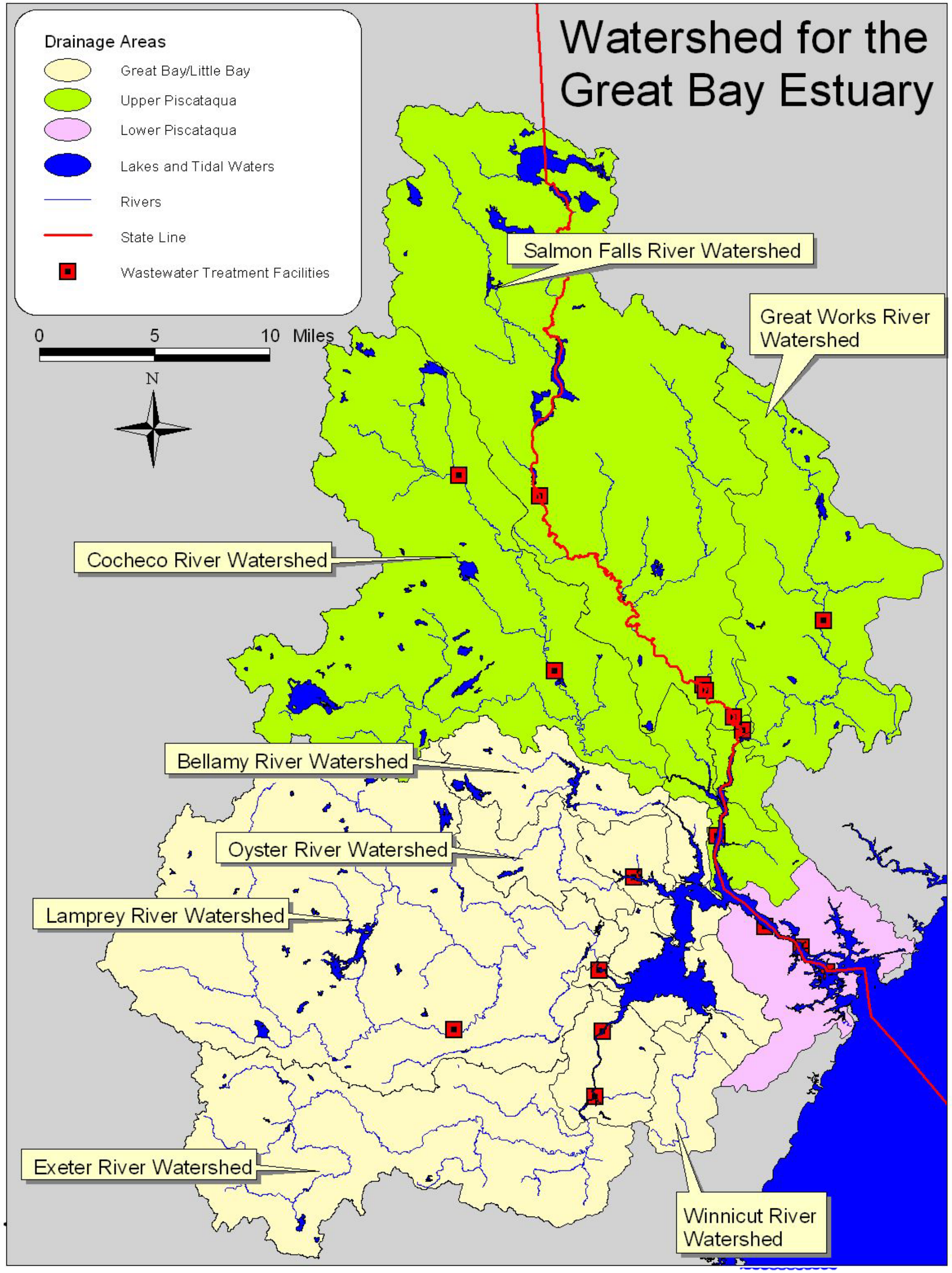
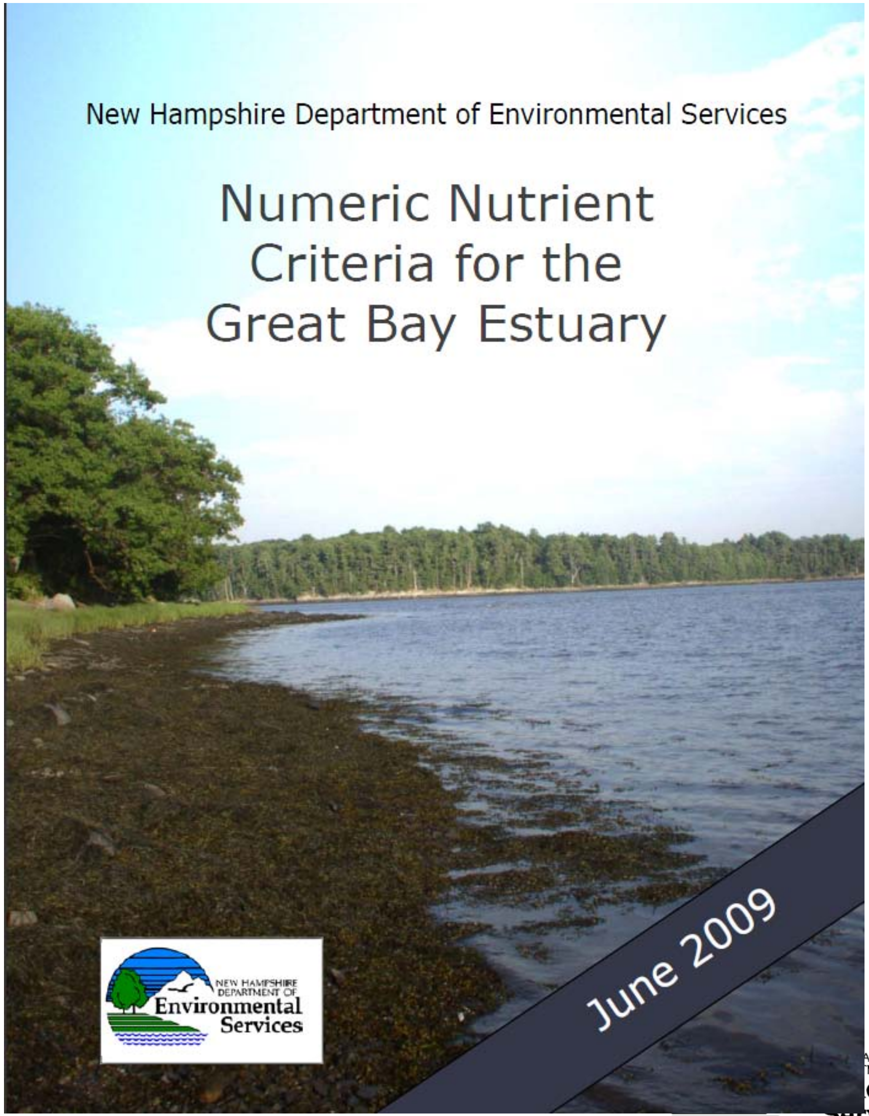
Great Bay Estuary

- Watershed covers 1023 mi^2 (80% in NH, 20% in ME)
- Home to 14% of the population of NH and ME
- Contains 18 WWTFs
- Fed by 7 tidal rivers
- Part of the EPA National Estuary Program



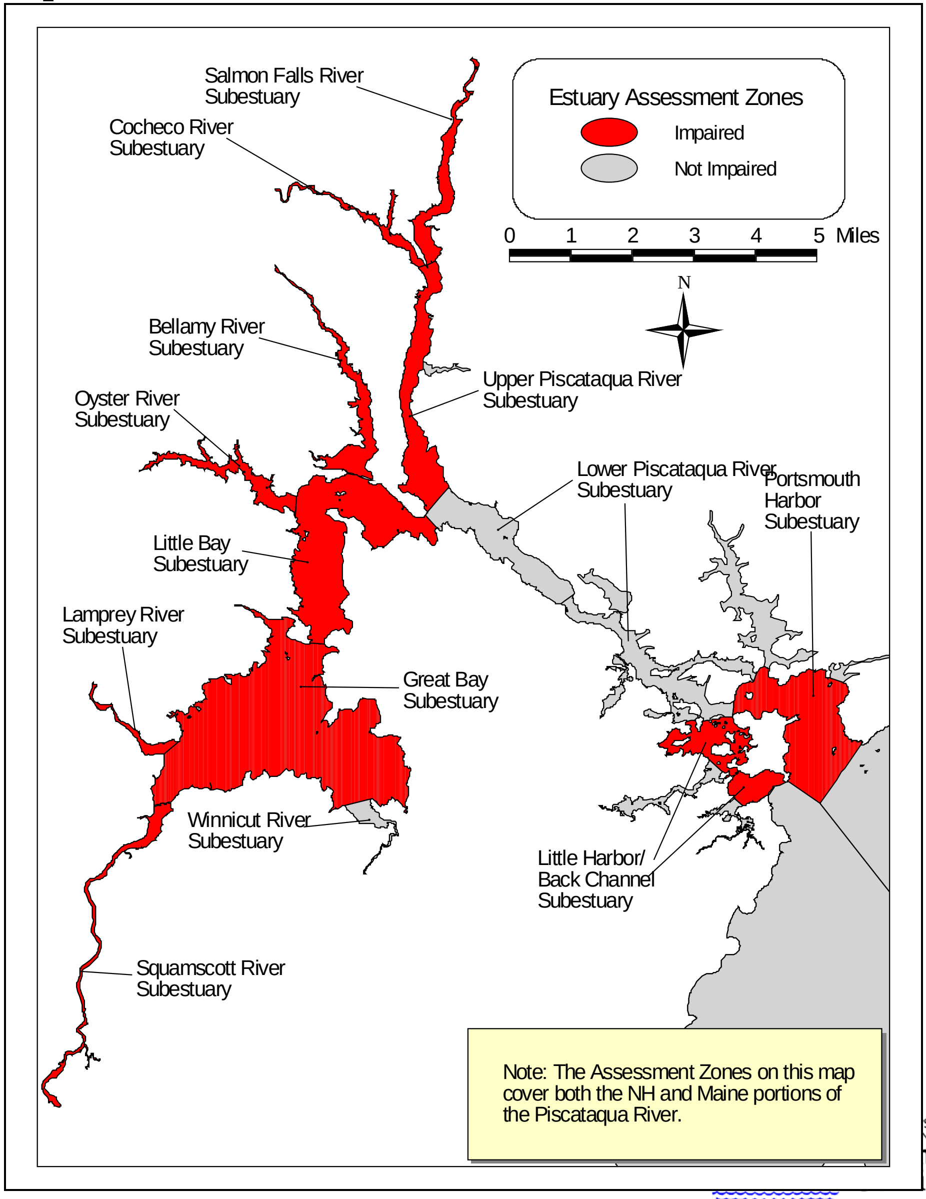
Numeric Nutrient Criteria

- The 2006 State of the Estuary report by PREP showed signs of nutrient enrichment
- In 2009, DES developed numeric nutrient criteria to protect eelgrass habitat and prevent low dissolved oxygen in the estuary.
- Reviewed and validated by national experts
- Confirmed by recent studies



Nitrogen Impairments

- Nutrient criteria were used by DES to add most of the estuary to the 303d list for nitrogen impairments in 2009.
- The impairments triggered a TMDL process.



Nitrogen TMDL Process for the Great Bay Estuary

Completed – Great Bay Nitrogen Loading Analysis

- Set preliminary nitrogen loading thresholds for the seven watersheds
- Determine options for bulk wasteload and load allocations by watershed

Future Work

- Determine non-point sources of nitrogen in each watershed
- Develop Watershed Implementation Plans and TMDLs for each watershed based on detailed planning and local input

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Questions to be answered by the Great Bay Nitrogen Loading Analysis

- What are the loading thresholds to meet the nutrient criteria and how much of reduction from existing loads would be needed?

- What would be the effects of different NPDES permitting scenarios for WWTFs on nitrogen loads and requirements for NPS reductions?

- How much will WWTF upgrades cost?

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Methods for the Great Bay Nitrogen Loading Analysis

- Current Watershed Nitrogen Loads
- Watershed Nitrogen Loading Thresholds
- Evaluation of Permitting Scenarios
- Quality Assurance
- WWTF Capital and O&M costs

The study was limited to watershed upstream of Great Bay, Little Bay, and Upper Piscataqua. The model could not be applied to the Lower Piscataqua or Portsmouth Harbor.

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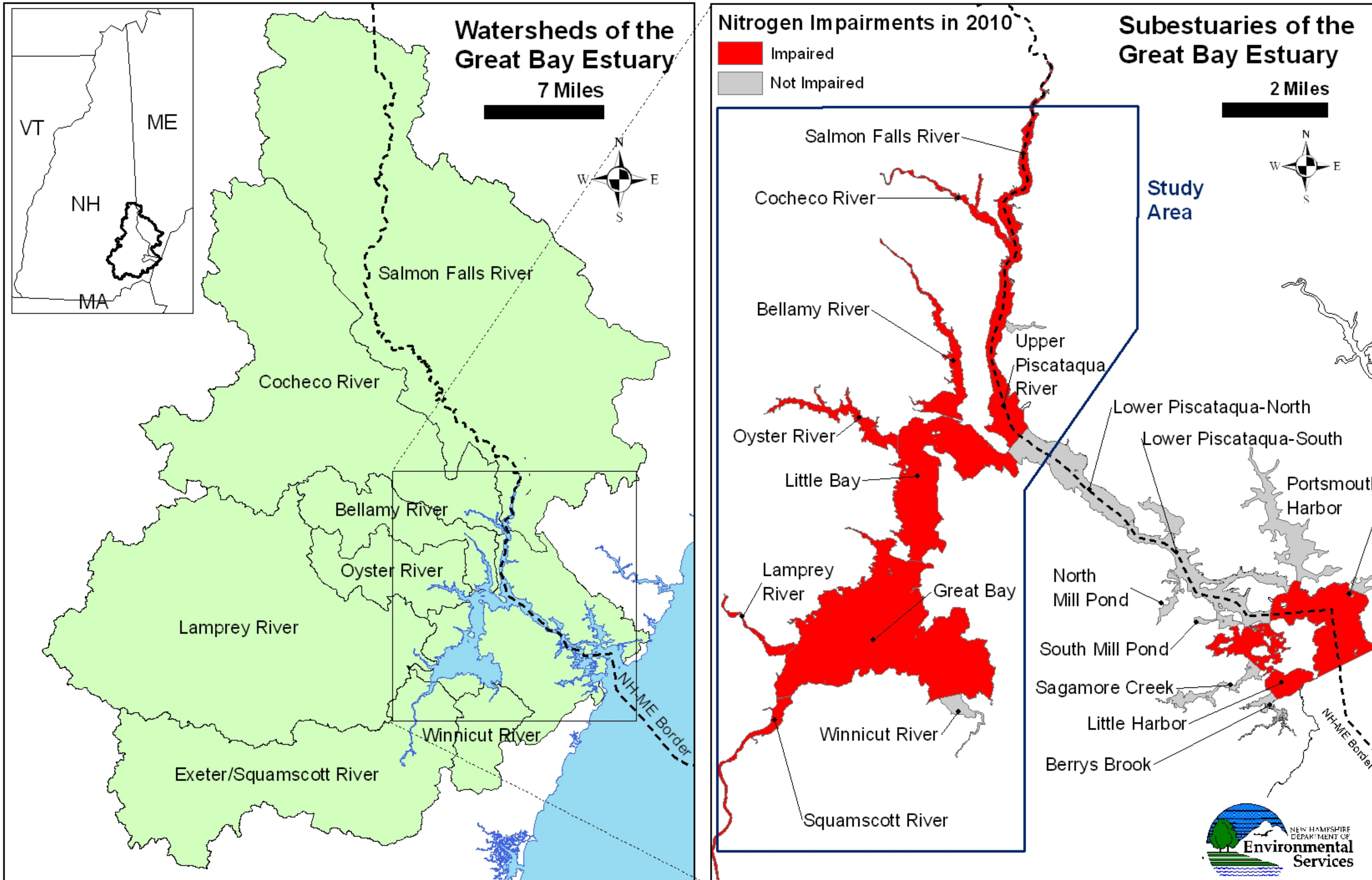
Study Area



Watersheds of the Great Bay Estuary
7 Miles
N
W
E
S
VT
ME
NH
MA
Salmon Falls River
Cocheco River
Bellamy River
Oyster River
Lamprey River
Winnicut River
Exeter/Squamscott River
NH-ME Border
Nitrogen Impairments in 2010
Impaired
Not Impaired
Subestuaries of the Great Bay Estuary
2 Miles
Study Area
Salmon Falls River
Cocheco River
Bellamy River
Upper Piscataqua River
Oyster River
Lower Piscataqua-North
Lower Piscataqua-South
Little Bay
Portsmouth Harbor
Lamprey River
Great Bay
North Mill Pond
South Mill Pond
Sagamore Creek
Winnicut River
Little Harbor
Berrys Brook
Squamscott River
NH-ME Border
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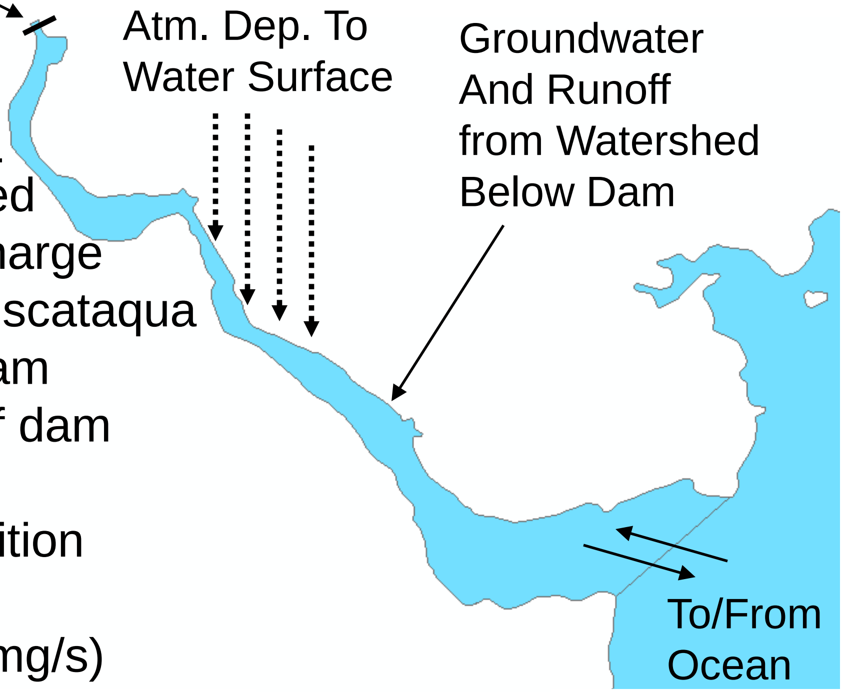
Mass Balance Model for Watershed Nitrogen Loading Thresholds

Example: Lamprey River Subestuary



<u>Sources of Nitrogen</u>
WWTFs in watershed
WWTFs direct discharge
WWTFs in Lower Piscataqua
NPS upstream of dam
NPS downstream of dam
Groundwater
Atmospheric Deposition

Total N Load "L_{tot}" (mg/s)

<u>Sources of Water</u>
WWTFs direct discharge
Streamflow above dam
Runoff below dam
Groundwater
Precipitation to surface
Net loss from withdrawals
Ocean (tidal flushing)

Total Flow "Q_{tot}" (L/s)

$$\frac{L_{tot}}{Q_{tot}} = N_{est|w}$$

$$N_{est} = N_{est|w} + N_{est|o}$$

N_{est}: Ave N conc. In subestuary

$N_{est|w}$: Ave N conc. in subestuary from wshed sources

$N_{est|o}$: Ave N conc. in subestuary from ocean water

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Different Types of Watershed Nitrogen Loading Thresholds

- Threshold for <u>watershed loads</u> to prevent DO violations locally

$$T = MOS \times \left[\left(N_{crit} - N_{est|o} \right) \times Q_{tot} \right]$$

Margin of Safety (0.9)

Nutrient Criteria (0.45 mg/L)

Total Water Flow

$$N_{est|o} \cong N_o \times \frac{S_{est}}{S_o}$$

N conc. in estuary due to ocean water

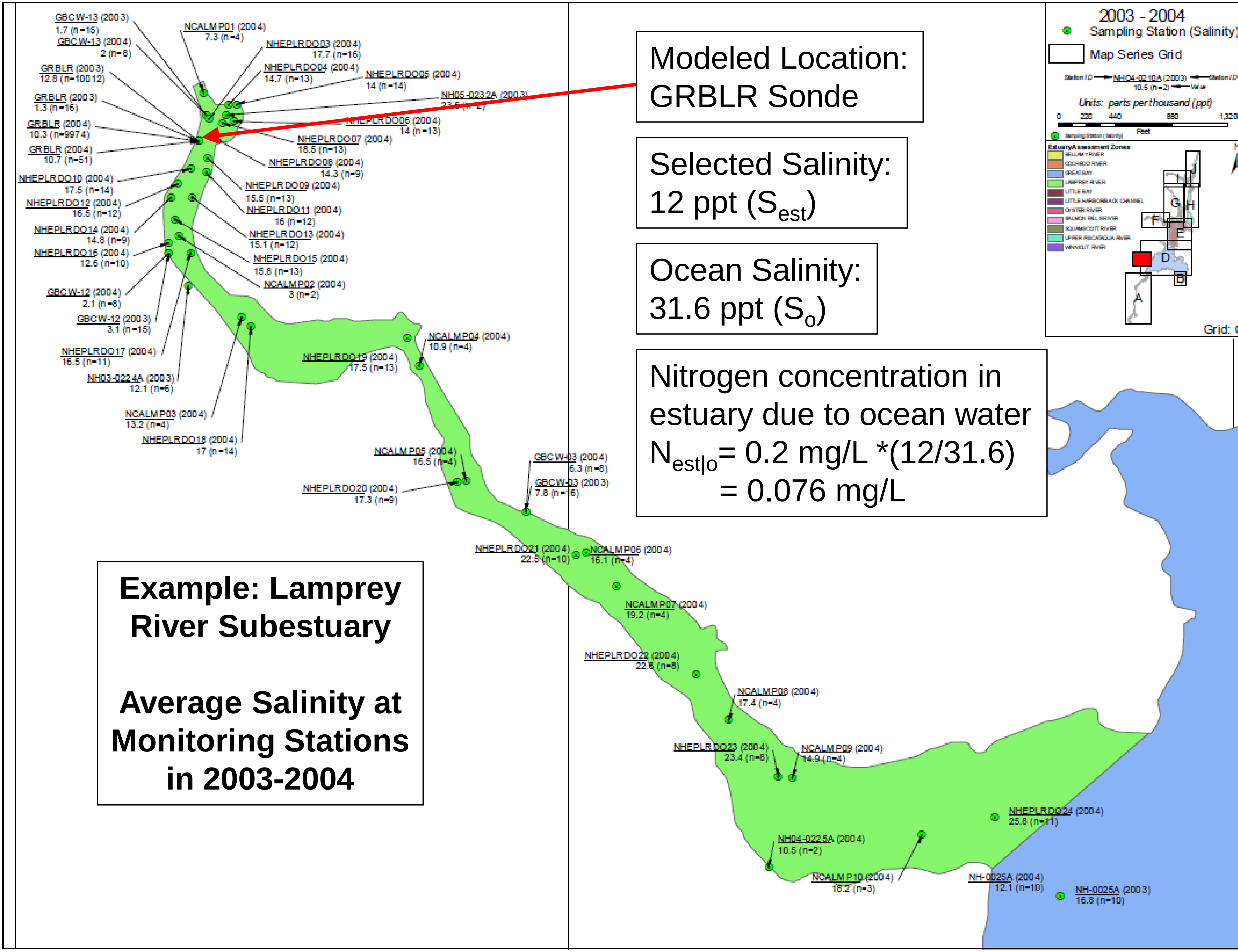
N conc. in ocean (0.2 mg/L)

Salinity in Estuary

Salinity in Ocean

- Threshold to protect eelgrass locally
  - Use equations above substituting 0.3 mg/L for N_{crit}
- Threshold to protect eelgrass in downstream subestuaries

  Threshold to protect eelgrass locally in downstream subestuary minus expected N load from downstream WWTFs, divided between watersheds according to percent of existing upstream N load.



Modeled Location:
GRBLR Sonde

Selected Salinity:
12 ppt (S_{est})

Ocean Salinity:
31.6 ppt (S_o)

Nitrogen concentration in estuary due to ocean water

$$N_{est|o} = 0.2 \text{ mg/L} * (12/31.6) = 0.076 \text{ mg/L}$$

Example: Lamprey River Subestuary

Average Salinity at Monitoring Stations in 2003-2004

Water Budget	Value (cfs)
WWTFs direct discharge	1.04
Streamflow above dam	344.76
Runoff below dam	2.77
Groundwater	0.64
Precipitation to surface	0.52
Net loss from withdrawals	-1.92
Ocean (tidal flushing)	212.94
Total Flow "Q_{tot}"	**560.74 (cfs)** **15,880 (L/s)**

Example: Lamprey River Subestuary 2003-2004

$$Q_o = Q_{fw} * \frac{S}{S_o - S}$$

Salinity in estuary (S)

Total Freshwater Flow (Q_{fw})

Salinity in ocean (S_o)

Watershed Nitrogen Loading Thresholds for Local Effects

$$T = MOS \times \left[(N_{crit} - N_{est|o}) \times Q_{tot} \right]$$

To Prevent DO Violations = 0.9 x (0.45 – 0.076) x 15,880 = 5346 mg/s = 185 tons/yr

To Prevent Eelgrass Loss = 0.9 x (0.30 – 0.076) x 15,880 = 3202 mg/s = 111 tons/yr

Watershed Nitrogen Loading Thresholds for Downstream Effects

Upstream watershed threshold to protect eelgrass in Great Bay = 330 tons/yr
Percent of existing upstream load from the Lamprey watershed = 49.6%
Downstream protective threshold = 330 x 0.496 = 163 tons/yr

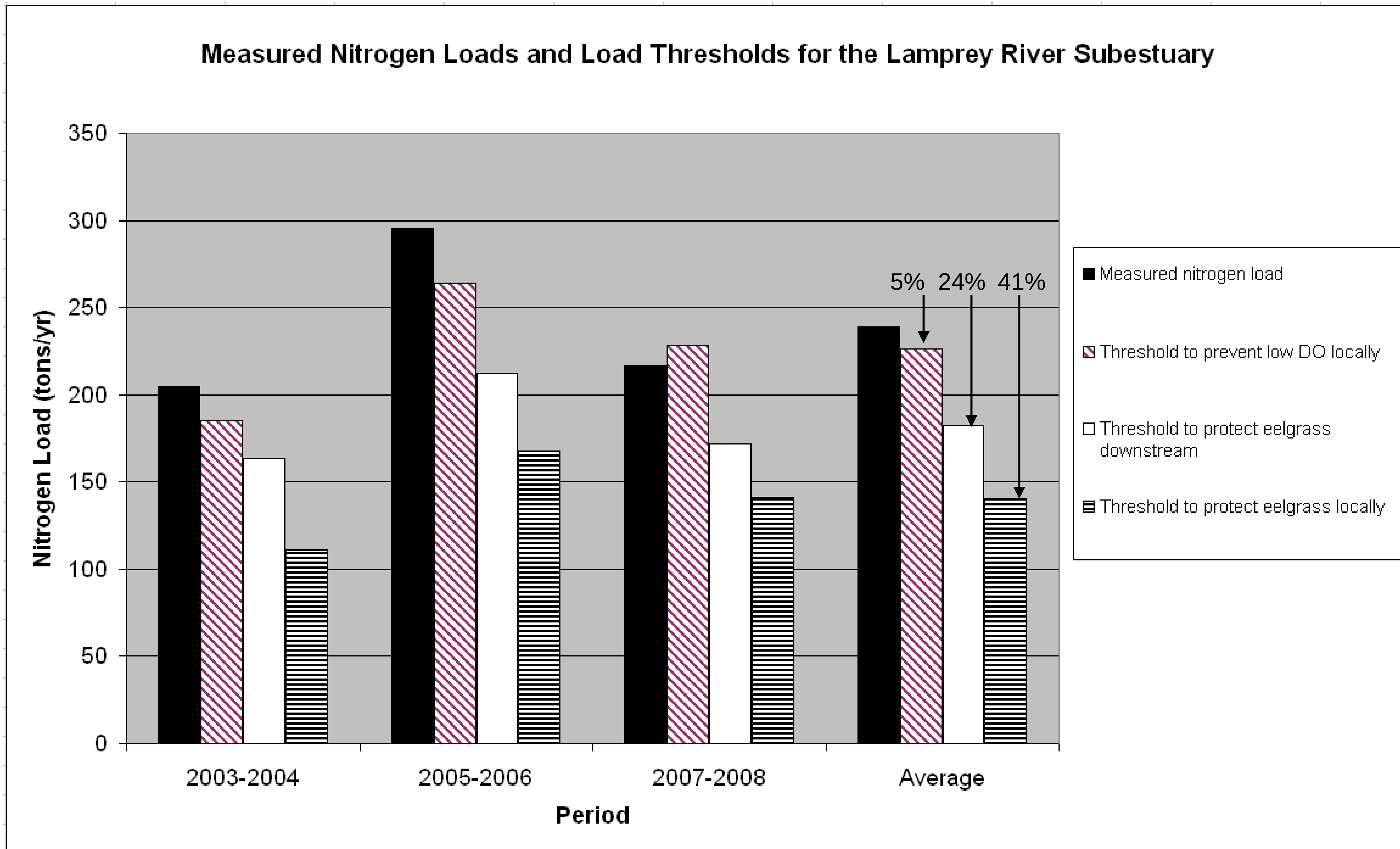
Evaluation of WWTF Permitting Scenarios on Nitrogen Loads

- 33 scenarios
- Calculate delivered N load for scenarios
- Compare delivered N load to thresholds
  - Yellow: Prevents low dissolved oxygen
  - Green: Protects local eelgrass
  - Red: Protects downstream eelgrass
- Determine NPS reductions for each WWTF permit scenario

Delivered Nitrogen Loads for the Lamprey River Subestuary for Permitting Scenarios, 2003-2004

		WWTFs @ design flow and		
		8 mg/L	5 mg/L	3 mg/L
NPS Percent Reduction	0%	184.0	178.8	175.3
	10%	166.9	161.7	158.3
	20%	149.9	144.7	141.3
	30%	132.9	127.7	124.3
	40%	115.9	110.7	107.3
	50%	98.9	93.7	90.2
	60%	81.9	76.7	73.2
	70%	64.9	59.7	56.2
	80%	47.9	42.7	39.2
	90%	30.9	25.7	22.2
	100%	13.9	8.7	5.2

Reductions in Nitrogen Loads for the Lamprey River Watershed



Non-Point Source Reductions for the Lamprey River Watershed

- WWTFs contribute 15% of the nitrogen to Lamprey River Subestuary.

- If WWTFs are permitted at…
  - 8 mg/L: NPS reduction of 17% or 38% needed
  - 5 mg/L: NPS reduction of 15% or 36% needed
  - 3 mg/L: NPS reduction of 13% or 34% needed

To protect eelgrass in downstream areas and prevent low DO in the tidal rivers

To protect eelgrass in all areas

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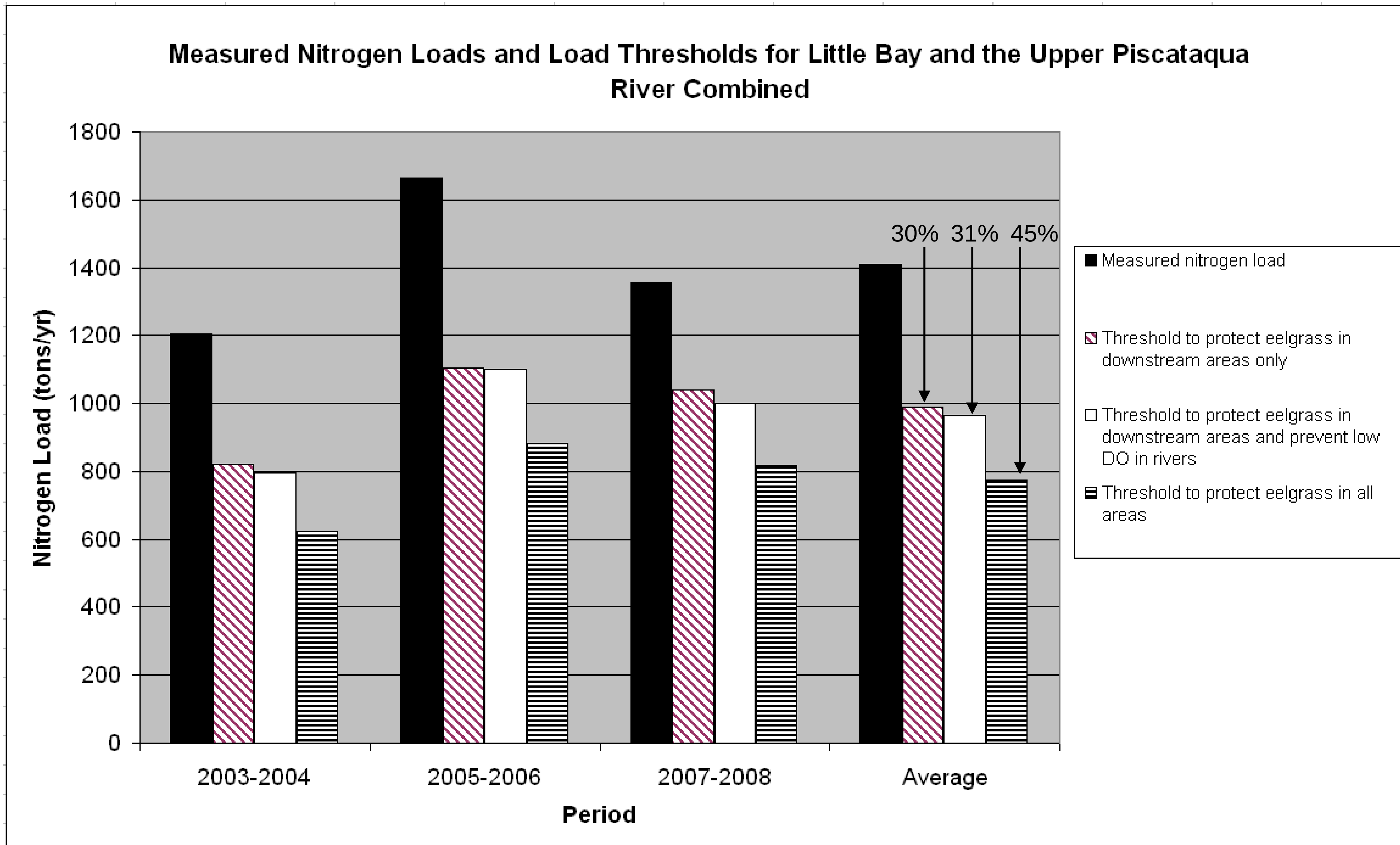
Reductions in Nitrogen Loads for the Whole Watershed



Non-Point Source Reductions for the Whole Watershed

- WWTFs contribute 27% of the nitrogen to Great Bay, Little Bay, and Upper Piscataqua.

- If WWTFs are permitted at…
  - 8 mg/L: NPS reduction of 32% or 50% needed
  - 5 mg/L: NPS reduction of 22% or 41% needed
  - 3 mg/L: NPS reduction of 16% or 34% needed

To protect eelgrass in downstream areas and prevent low DO in the tidal rivers

To protect eelgrass in all areas

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Quality Assurance Tests

- Accuracy
  - Measured vs Modeled N concentration
  - +/-11% (average)
- Precision
  - Monte Carlo Uncertainty Analysis
  - +/-12% for tidal rivers, +/-29% downstream areas
- Sensitivity
  - Monte Carlo Sensitivity Analysis
  - Important variables are ocean N conc., stream flow, salinity, criteria

Lamprey River Subestuary

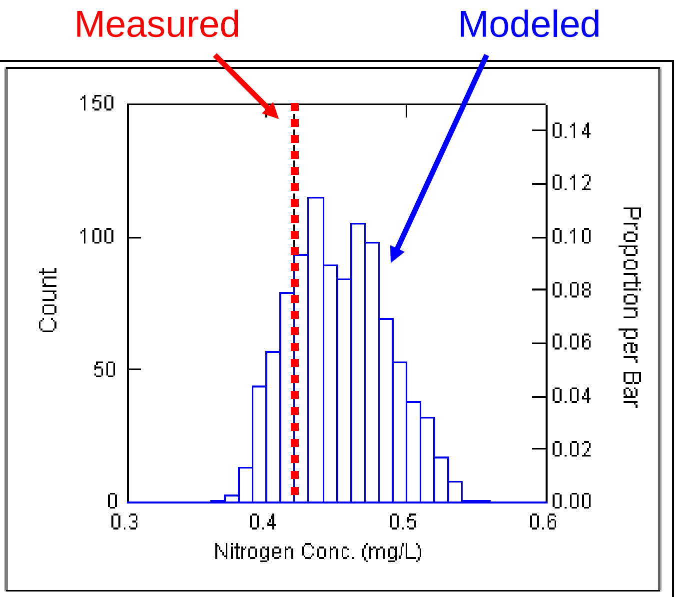
Median TN Concentrations (mg/L)

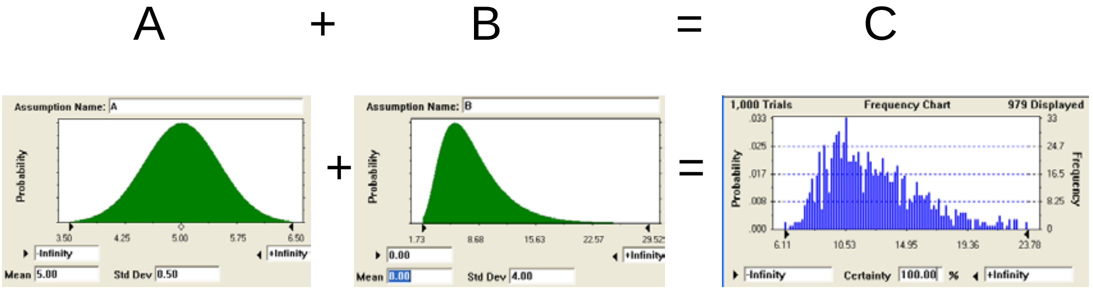
	Predicted (bars)	Measured (dashed line)
5th %ile	0.39	NA
Median	0.45	0.42
95th %ile	0.50	NA

Key for graph:

Bars = Histogram of predicted values

Dashed line = Measured median





Summary

- Most of the Great Bay estuary is impaired for nitrogen as shown by persistent low dissolved oxygen in the tributaries and eelgrass loss.
- Mass balance models predict that watershed nitrogen loads need to be reduced by 30-45%.
- Non-point source reductions range from 16-50% depending on the WWTF permitting scenario.
- Reducing nitrogen loads enough to prevent low dissolved oxygen in the tributaries will typically also protect eelgrass in downstream areas.

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Next Steps

- Identify non-point sources of nitrogen in the watershed and reductions in the non-point source loads if best management practices are implemented.
- Develop models and nitrogen loading thresholds for the Lower Piscataqua River, Portsmouth Harbor, and Little Harbor.
- Continue research on nutrient criteria and existing models.
- Develop a comprehensive monitoring program to track the effectiveness of phased implementation activities.
- Develop Watershed Implementation Plans and TMDLs for each watershed.

For More Information

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Reports available at:

http://des.nh.gov/organization/divisions/water/wmb/coastal/great-bay-estuary.htm