An Evaluation of Nitrogen Loading into Upper Narragansett Bay

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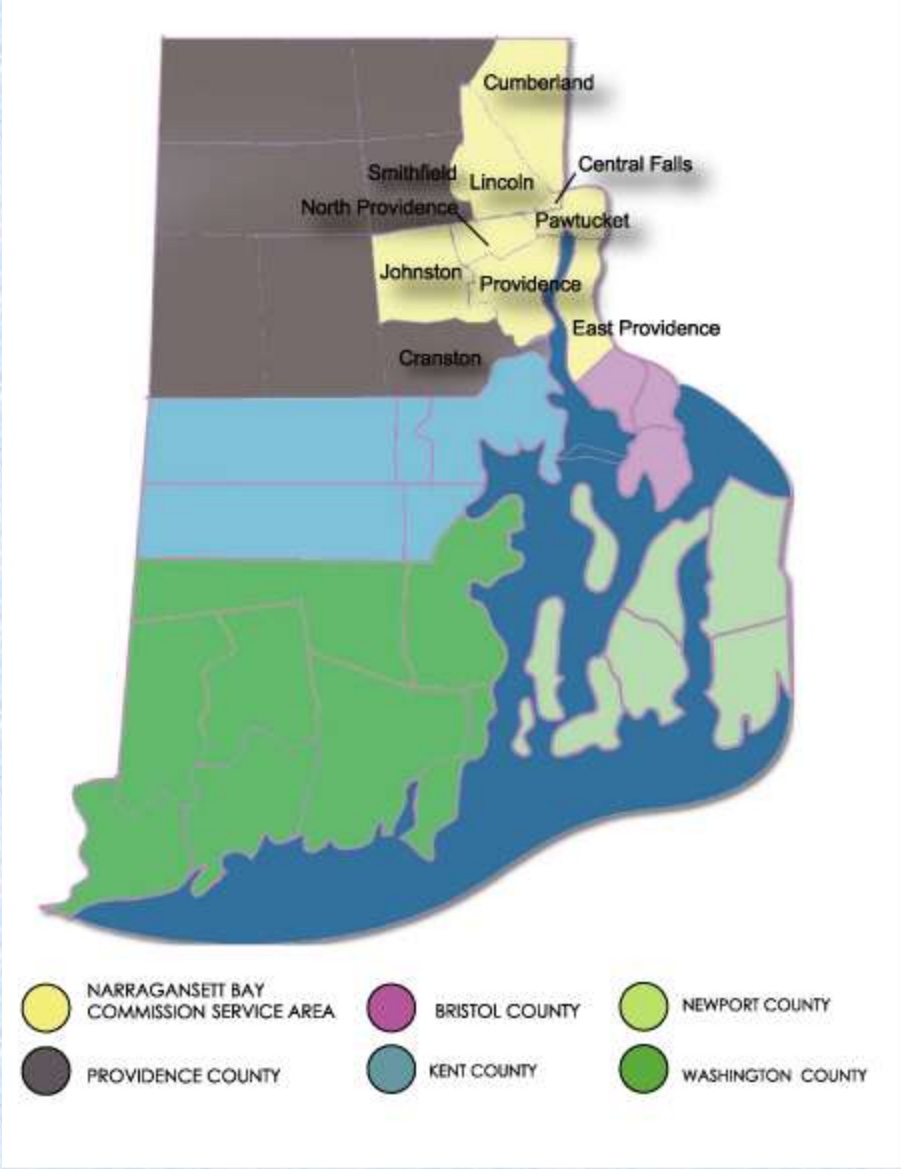
Narragansett Bay Commission

Providence, RI

Narragansett Bay Commission

- Narragansett Bay Commission (NBC) is a quasi-state agency which oversees the two largest WWTFs in Rhode Island:
  - Bucklin Point in East Providence
  - Field's Point in Providence
- 10 municipalities in service area
- 360,000 people served including 8,000 commercial and industrial customers



Field's Point WWTF
Providence, RI

- Constructed in 1901 and reconstructed in the 1980s
- Provides preliminary and primary treatment for up to 200 million gallons per day (MGD) of wastewater, secondary treatment for up to 91 MGD and has an average dry weather flow to the facility of 45.5 MGD
- 38 Combined Sewer Overflows and 80 miles of interceptors
- Biological nitrogen removal (BNR) upgrade under construction to meet seasonal 5 mg/l total nitrogen effluent permit limit
  - Expected to be completed in 2014

Bucklin Point WWTF
East Providence, RI

- Comprehensive upgrade completed in 2006 made it the most technologically advanced treatment plant in the state.
- Provides preliminary and primary treatment for up to 116 million gallons per day, secondary treatment for up to 46 million gallons per day, and has an average dry weather flow to the facility of 23.9 MGD.
- 26 Combined Sewer Overflows as well as the North Diversion Structure and 30 miles of interceptors

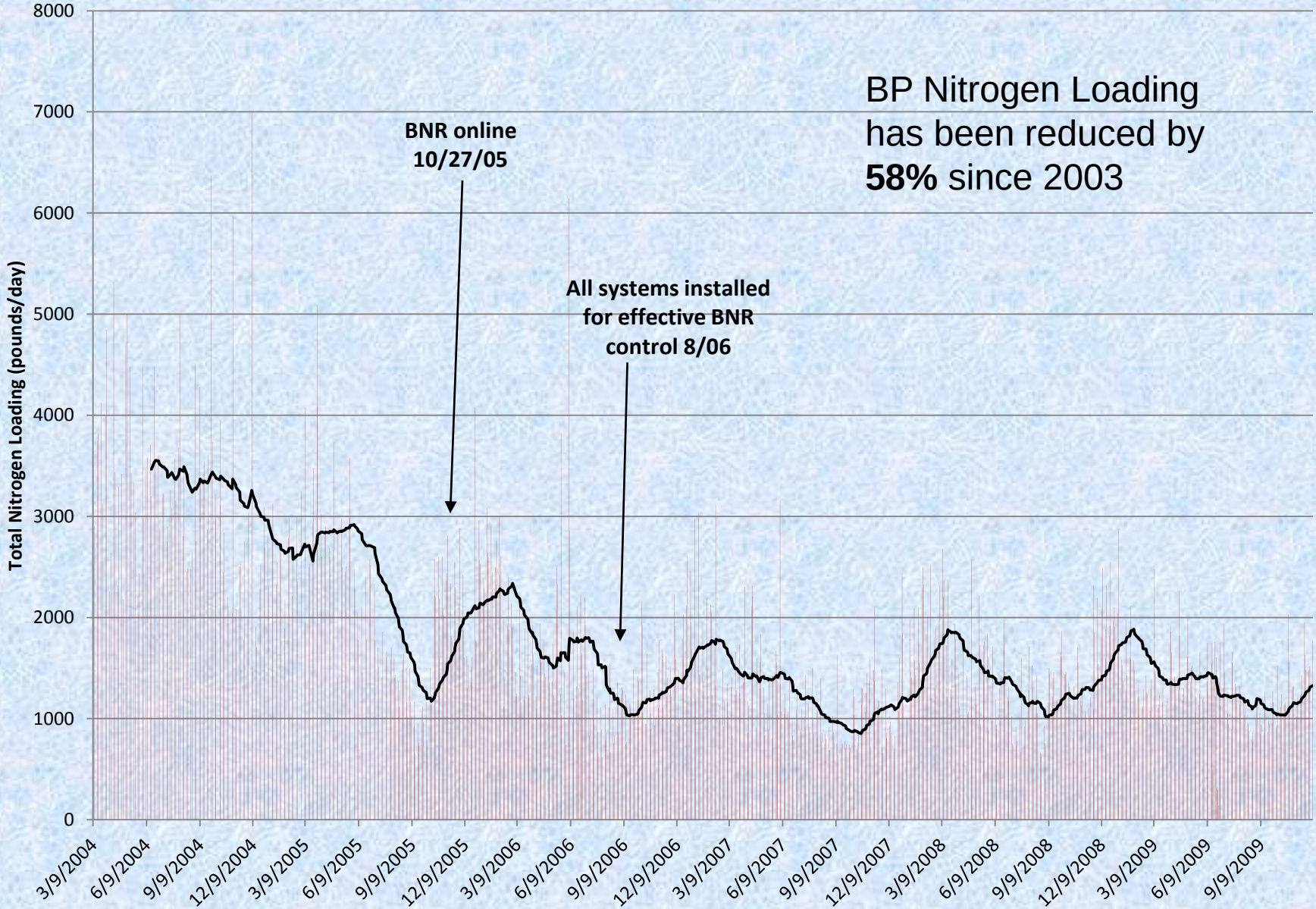
The Concerns about Nitrogen Loading

- Nitrogen: limiting nutrient for phytoplankton and macroalgae in the bay
  - Excess nitrogen can cause rapid growth (blooms) of microscopic phytoplankton and larger macroalgae.
- Blooms decompose, bacteria consumes O_2, reducing **D**issolved **O**xygen (D.O.) levels
  - Hypoxia (> 0 - 2.9 mg/l D.O.)
  - Anoxia (0 mg/l D.O.)
- In NB, hypoxia tends to occur during hot, calm summer periods, when the water is “stratified” or layered, preventing O_2 from reaching bottom waters.
- Effluent from WWTFs one source of nutrients, but N also from failing septic systems, fertilizers, atmospheric deposition, and animal waste
- Fish kill in Greenwich Bay 2003 accelerated plans by RIDEM to initiate N reductions at WWTF’s

Total Nitrogen Limits Imposed by the Rhode Island Department of Environmental Management (RIDEM)

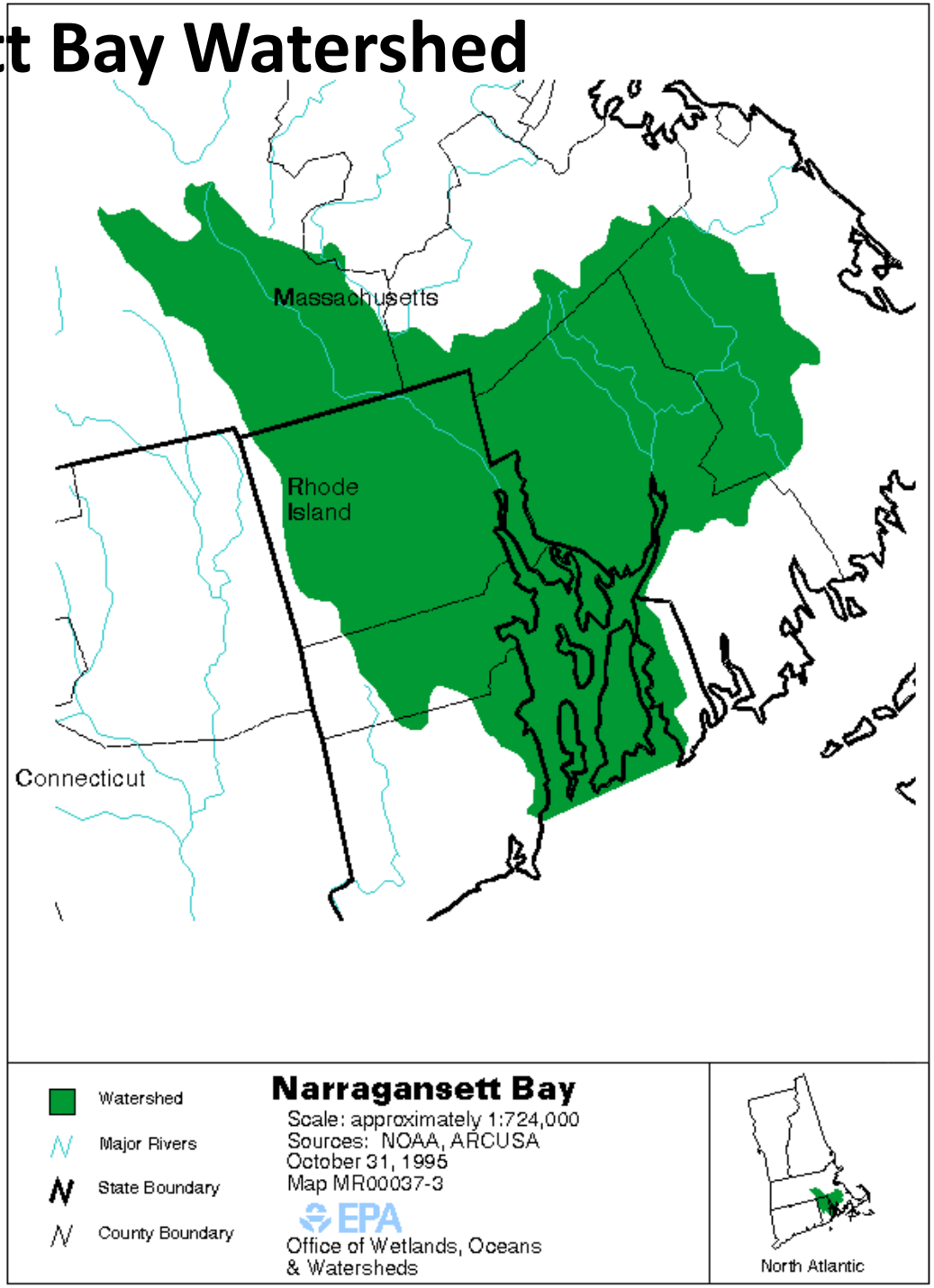
- Prior to imposed N limits, construction already planned at Bucklin Point to build BNR (biological nitrogen removal) facilities
  - Designed to reach 8 mg/L effluent TN
- TN limits imposed in 2005: BP - 5 mg/L and 1293 lbs/day
  FP - 5 mg/L and 2711 lbs/day
- C.A. signed: BP -what could be achieved with the current system?
  FP -plan and implement new construction
- C.A. limits imposed:
  - Field's Point 18.2 mg/L (May – October), measure and report lbs/day
  - Bucklin Point 10.0 mg/L (May – October), measure and report lbs/day
- BP - additional modifications necessary to meet 5 mg/L; RIDEM & NBC agreed to seasonal interim limit of 8.5 mg/L – effective May 2009

Bucklin Point Total Nitrogen Loading (March 2004 - present)

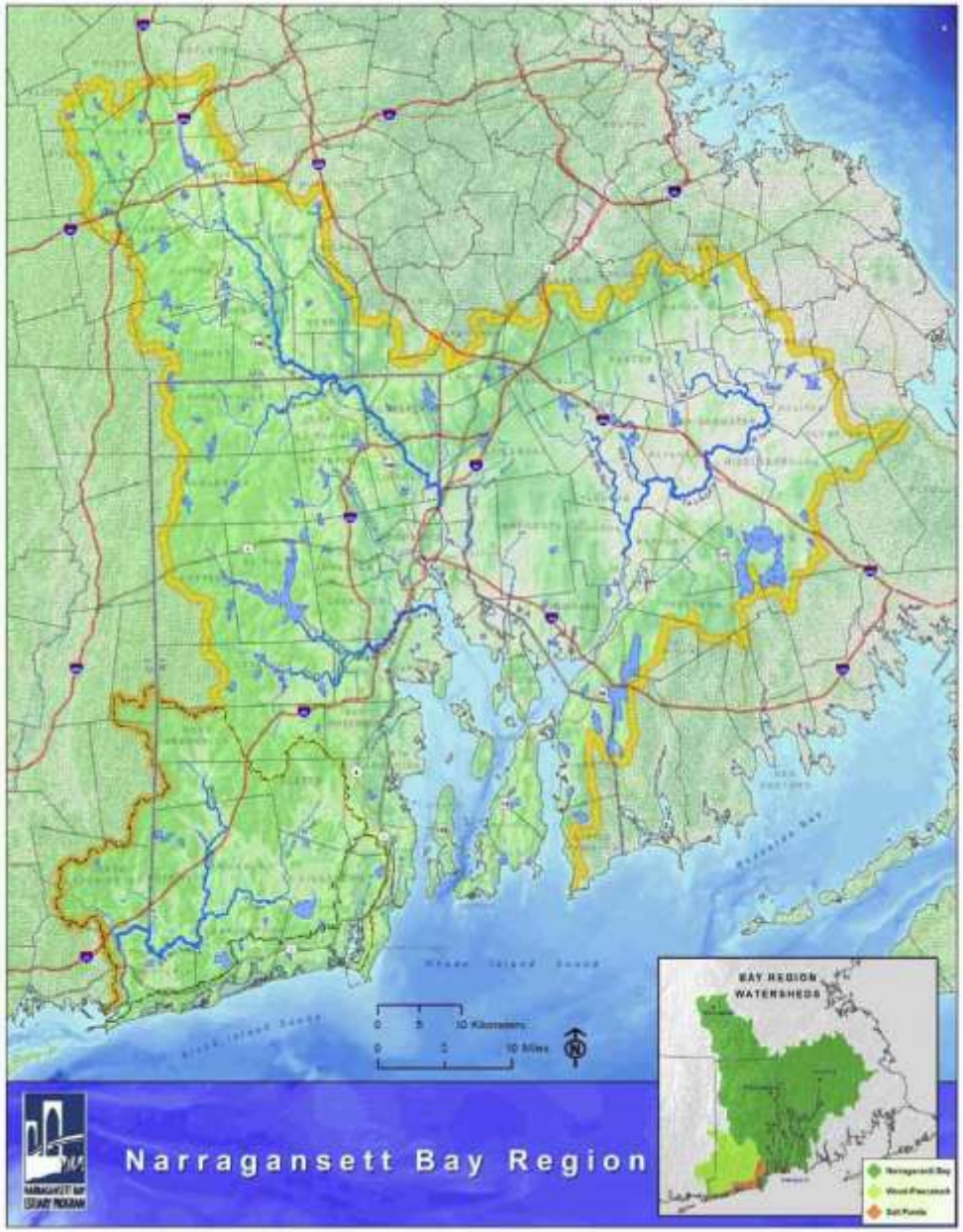


Narragansett Bay Watershed

- **Watershed Area:** 1,853 square miles
  60% in Massachusetts, 40% in Rhode Island
- **Daily Freshwater Input, Rivers:** 2.1 billion gallons
- **Daily Freshwater Input, All Sources:** 2.4 billion gallons
- **Largest Rivers Entering Narragansett Bay:** Blackstone, Pawtuxet, Taunton
- **Population:** Approximately 1.8 million people live in the watershed: 887,863 in Rhode Island; 949,465 in Massachusetts.
  (http://www.savebay.org)
- People living in the watershed contribute thousands of tons of nitrogen to the upper Bay annually by way of 35 WWTFs in Rhode Island and Massachusetts.
  (http://www.nbep.org)



River Sources of Nutrients into Narragansett Bay



- Three largest sources of freshwater = Blackstone River, Pawtuxet River, and Taunton River
  - Blackstone River flows into the Seekonk River in Pawtucket, Rhode Island
    - The Seekonk joins with the Providence River and flows into Narragansett Bay.
  - The Taunton River runs into Mt. Hope Bay which is part of Narragansett Bay
- Other smaller rivers: Woonasquatucket, Moshassuck, Ten Mile, Runnins, Palmer, Cole and Lee's Rivers
  - Providence River is formed by the confluence of the Woonasquatucket and Moshassuck Rivers.

Non-point sources of Nitrogen Pollution

- 1995 Study by Nixon et al. approximated a Nitrogen budget for the bay:
  - 1980's - 90's NB received an annual input of ~29 gN m^{-2}/year
    - Largest input of N - rivers (59%)
    - Second largest source – direct discharge of WWTFs (27%)
    - Runoff from urban areas adjacent to bay (6%)
    - Atmospheric deposition (4%)
    - Ocean Advection (4%)
- Runoff carries non-pt. sources into rivers
- Impervious surfaces increase runoff
- 14% of the land area in NB watershed is impervious
- More developed landscapes = higher river flows
- Higher river flows = increased nutrient loading, stratification
- Summers with large June river flows tend to have more severe hypoxia in July and August
- ROMS Model shows areas with little flushing – low DO zones

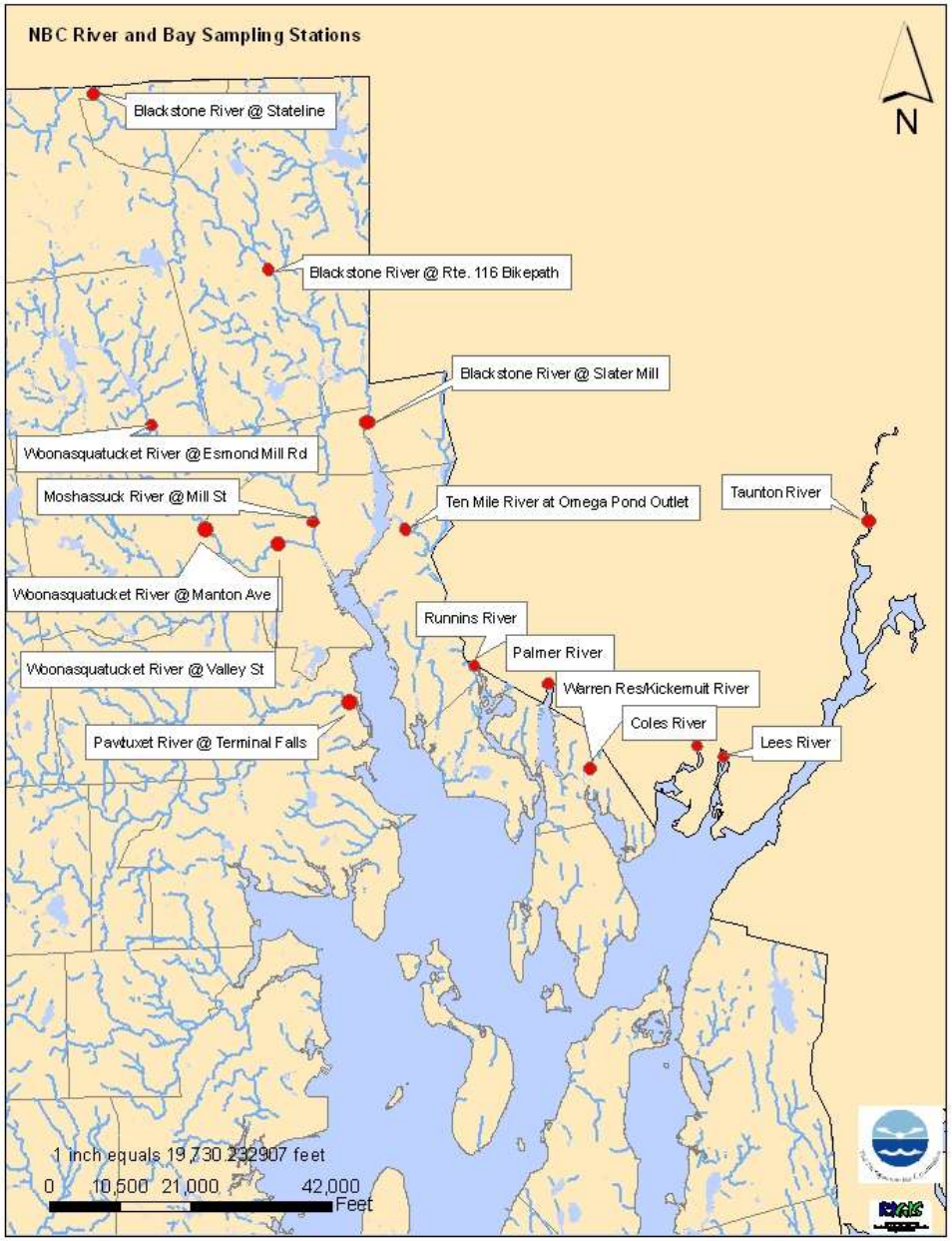
NBC's River Nutrient Monitoring Program

Blackstone River nutrient station

Nutrient Analyzer

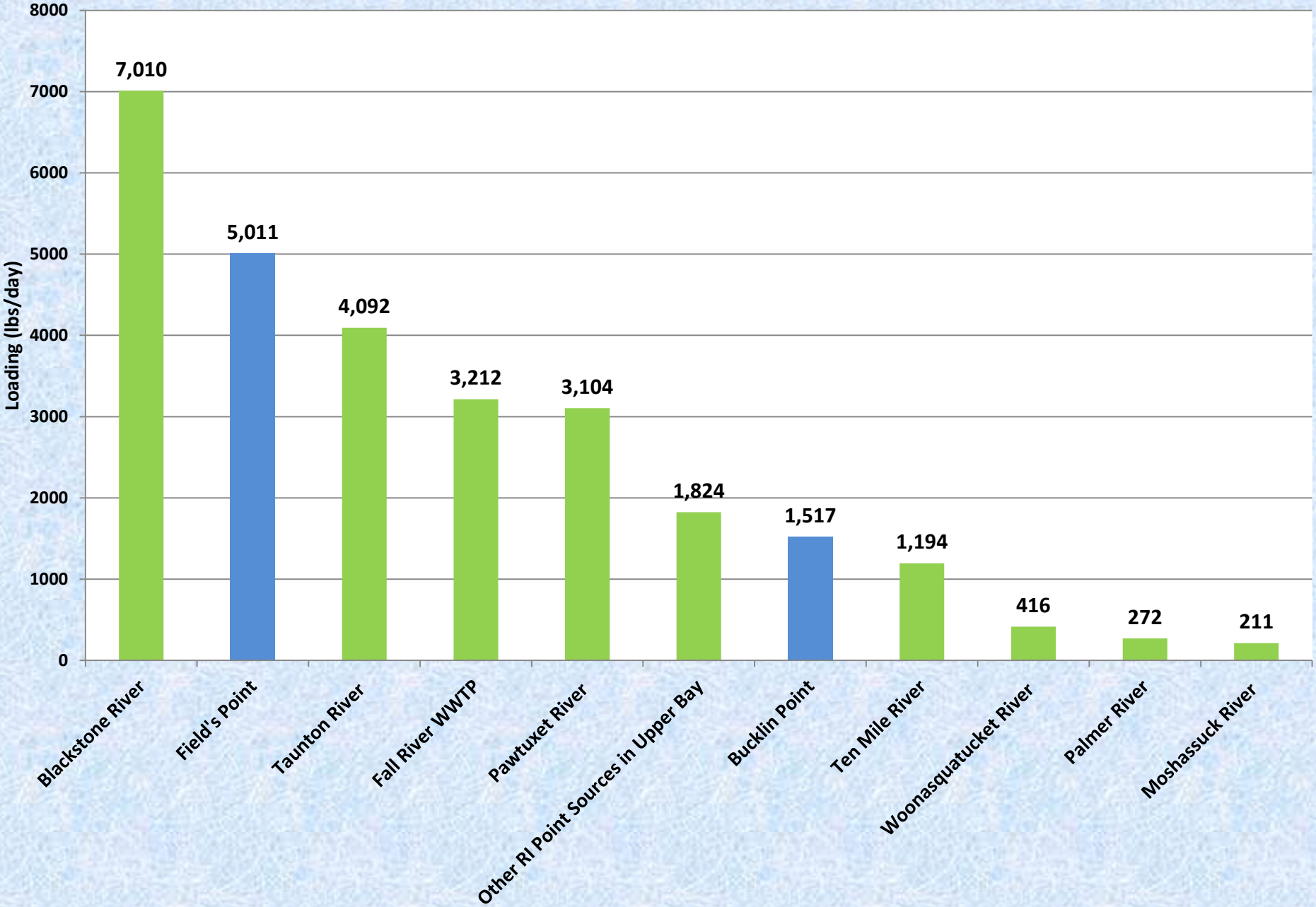
- Initiated in 2005
- Purpose: address and understand the magnitude of the impacts that facility operations have on receiving waters
- This sampling program was designed to encompass two components:
  - Evaluate nutrient loading in the urban rivers that empty into NB
  - Evaluate nutrients entering NB from Massachusetts
- NBC will be able to more accurately determine the impact of BNR systems at the WWTFs and inform stakeholders.

NBC River Sampling Locations

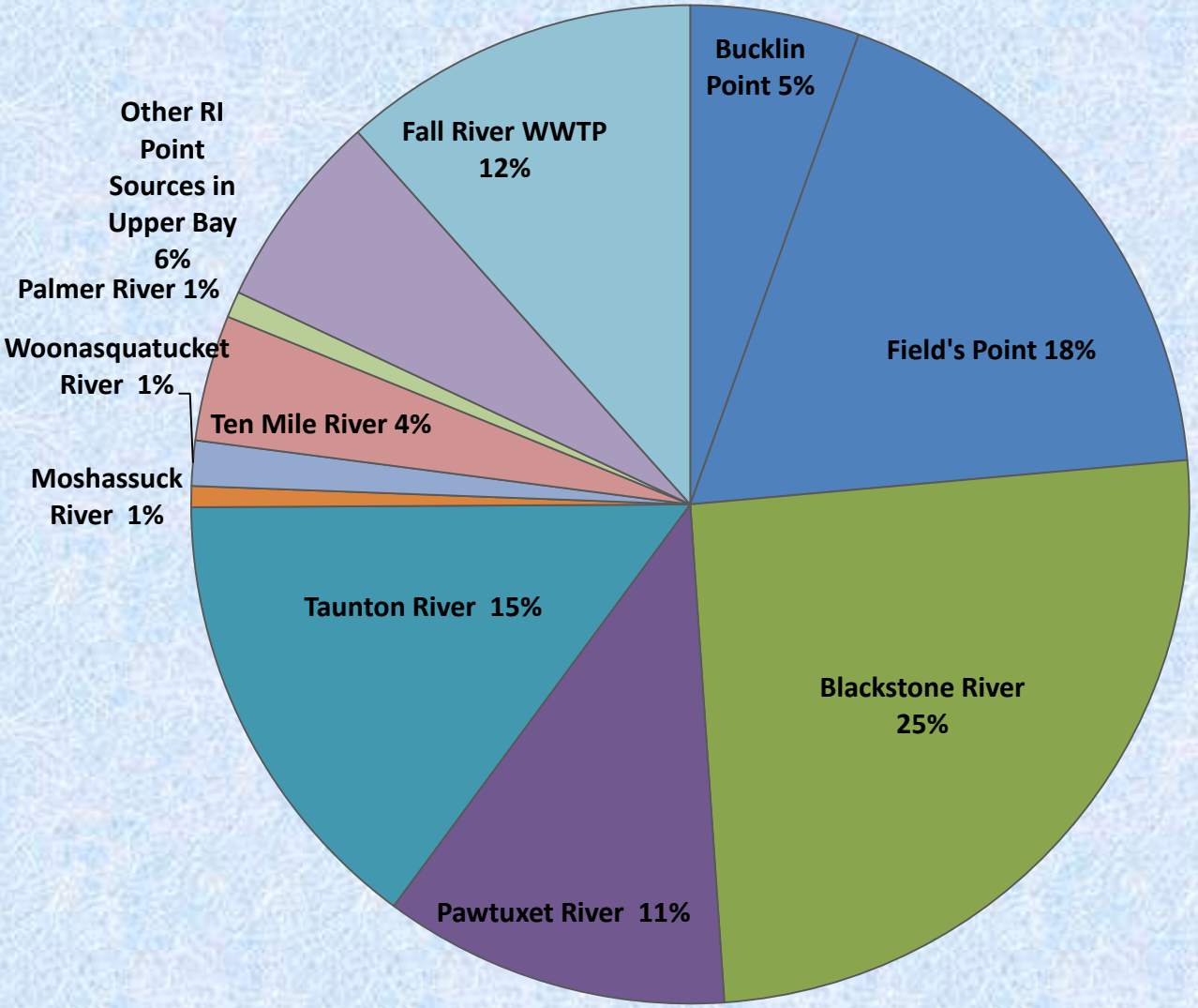


- Nutrients measured in RI and MA rivers that enter the upper bay (15 sampling sites)
- N loading (lbs/day) – determined by using NBC nutrient results and USGS river flow data
  - TDN (total dissolved nitrogen) and DIN (dissolved inorganic nitrogen) loading from the rivers are compared to the WWTFs
- Stations used in loading calculations based on where flow information is available:
  - Blackstone River @ Stateline
  - Moshassuck River @ Mill St
  - Woonasquatucket River @ Valley St
  - Pawtuxet River
  - Taunton River
  - Ten Mile River
  - Palmer River*
    - * flow data for this location ceased in July 2009

Average Total Nitrogen Loading Measured over Entire Sampling Period (May 2005 – November 2009)

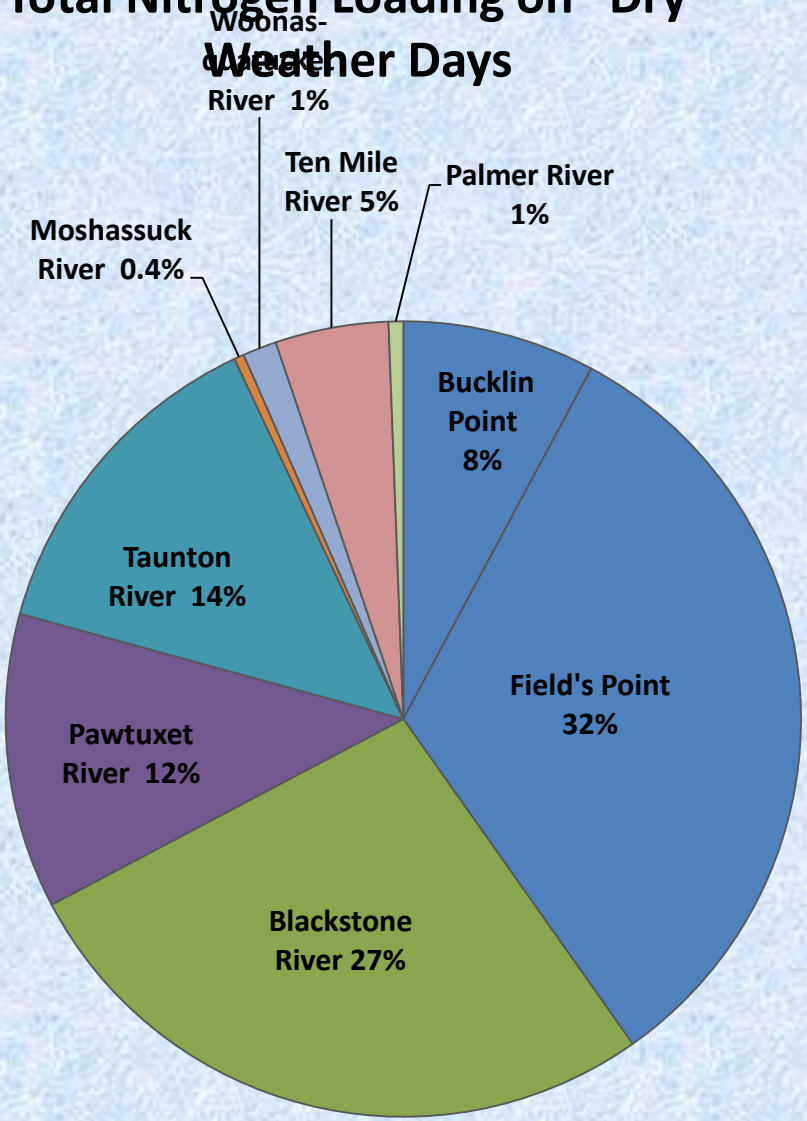


Estimated Percent contribution to Total Nitrogen Loading measured over entire sampling period

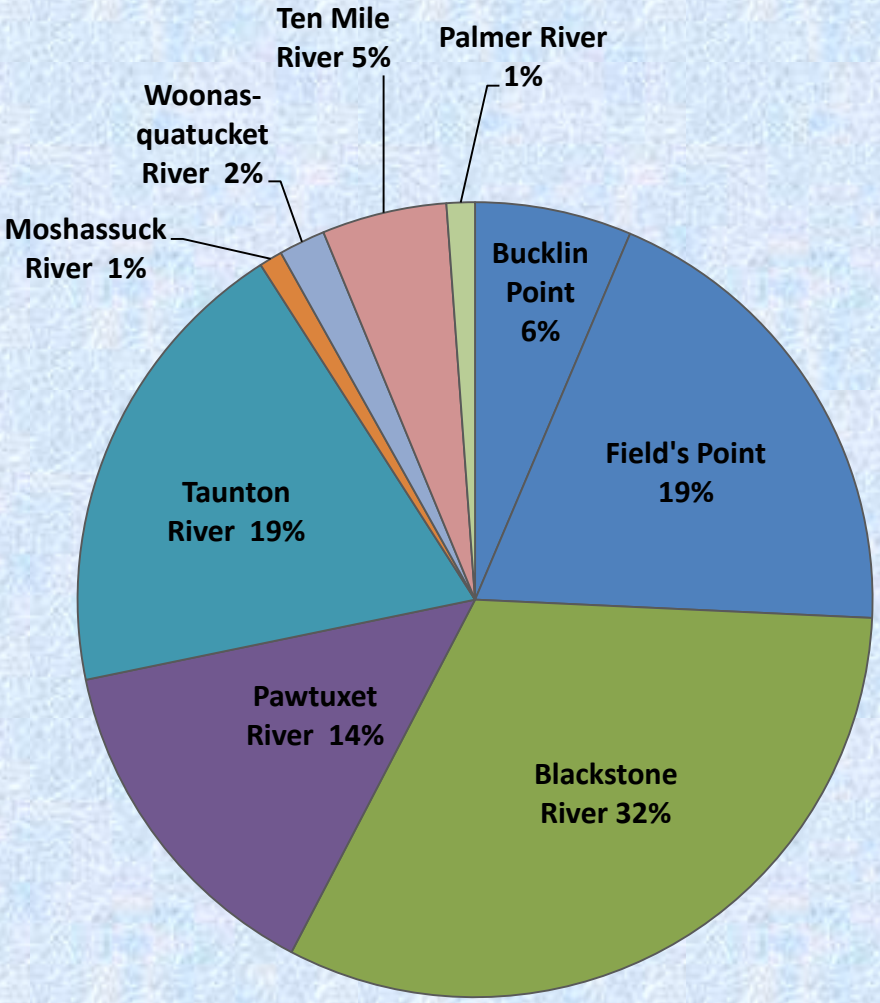


- NBC WWTFs account for 23%
  - BP & FP WWTF contribution is a conservative estimate - other sources of nitrogen not included.
- The three largest rivers make up 51% of the loading

Estimated Percent Contribution to Total Nitrogen Loading on "Dry" Weather Days

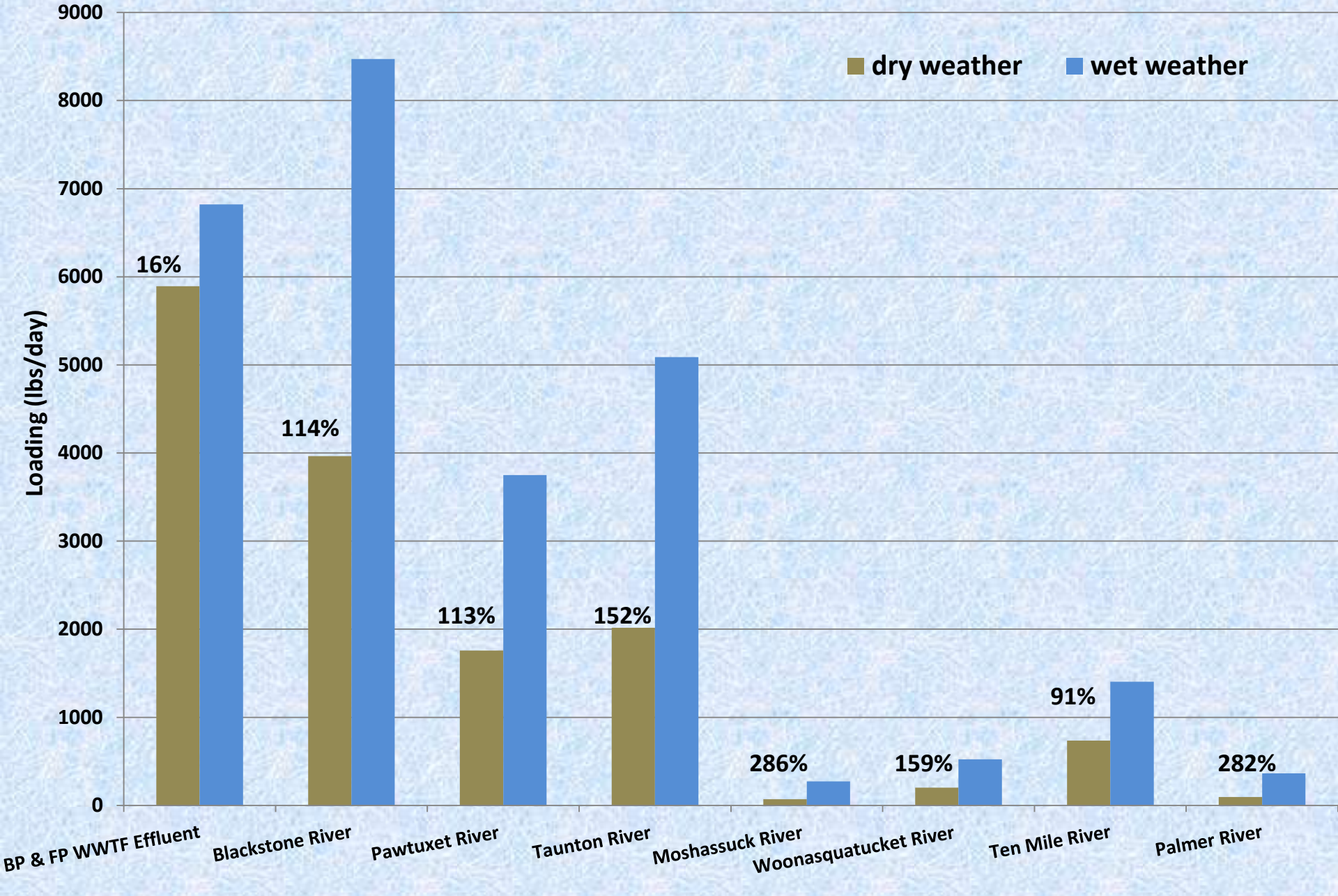


Estimated Percent Contribution to Total Nitrogen Loading on "Wet" Weather Days

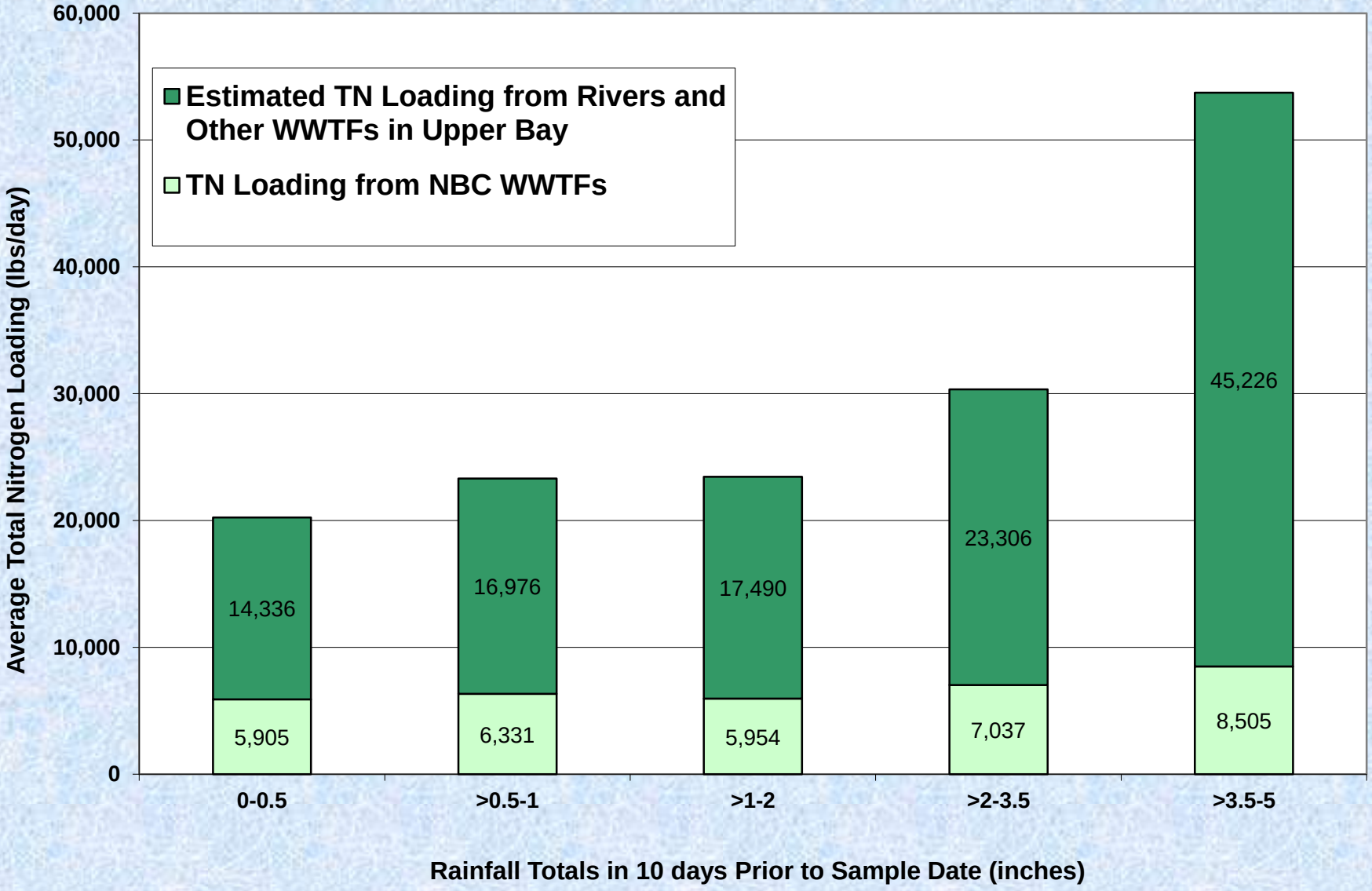


Dry weather – sample day in which there was less than 0.1 inches of rainfall in the previous 3 days.

Average Total Nitrogen Loading on Wet and Dry Days



Average Nitrogen Loading from Rivers and WWTFs in the Upper Bay During NBC Sample Dates from May 2006 - Sept 2009



Conclusions from NBC Nutrient Monitoring Program

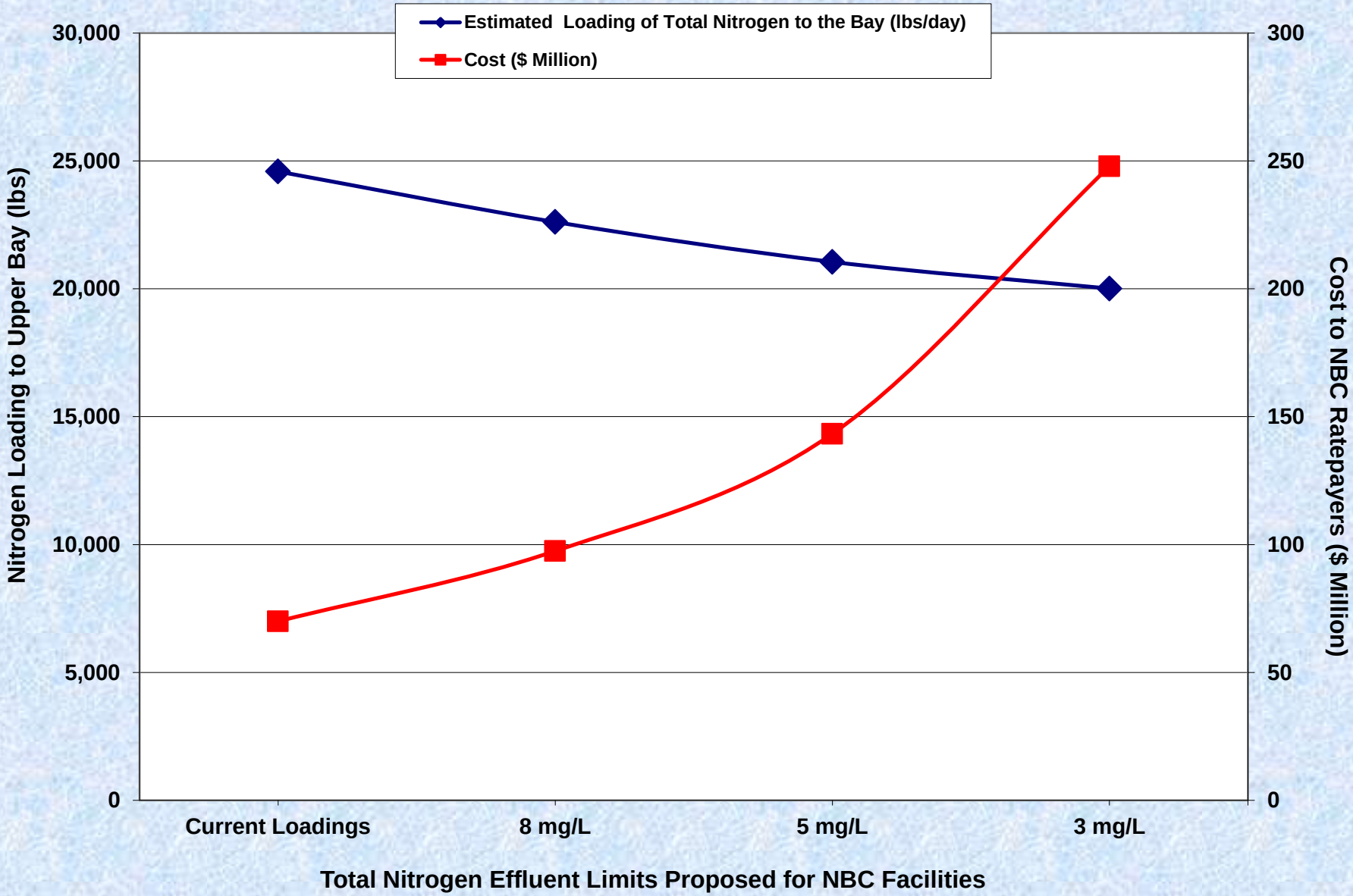
- Blackstone River contributed the most nitrogen throughout the sampling period; Field's Point was the second highest measured loading
- Data indicates that the Blackstone, Taunton, and Pawtuxet Rivers contributed 525,640 lbs. (51%) of the TN measured compared to 241,267 lbs. (23%) for the NBC WWTFs.
- Our results indicate that in wet weather, nitrogen loading from area rivers can increase between 91 – 286% whereas loading from the BP & FP WWTF increases by only 16%.
- During large rain events the loadings from rivers can increase by ~30,000 lbs, whereas loading from the NBC WWTFs increased by only ~2600 lbs.
- Nitrogen loading from the NBC WWTFs remains stable yet the extent and severity of hypoxia and the occurrence of fish kills varies year to year.

NBC WWTF Nitrogen Loading to Upper Bay

(May – Oct)

	Concentration (ppm)	Loading (lbs/day)	Percent Reduction (Loading)	
Field's Point TN Loading				
2003	15.7	5,872		
Presently	12.7	4,459	24%	46% reduction; 2671 lbs.
IFAS Upgrade	5.0	1,788	70%	12% reduction; 715 lbs.
If plant achieves 3 ppm	3.0	1,073	82%	
Bucklin Point TN Loading				
2003	14.8	2,920		
Before BNR	12.6	2,444	16%	
Presently	7.8	1,229	58%	14% reduction; 416 lbs.
When achieves 5 ppm	5.0	813	72%	11% reduction; 325 lbs.
If plant achieves 3 ppm	3.0	488	83%	
Combined NBC Facilities				
2003	BP=14.8, FP=15.7	8,792		
Before BNR	BP=12.6, FP=12.6	6,903	21%	
Presently	BP=7.8, FP=12.7	5,688	35%	35% reduction; 3087 lbs.
FP&BP Upgrade to 5 ppm	BP=5.0, FP=5.0	2,601	70%	12% reduction; 1040 lbs.
FP&BP Upgrade to 3 ppm	BP=3.0, FP=3.0	1,561	82%	

NBC Cost vs % Nitrogen Reduction to Upper Bay



More Questions than Answers ……

- Could the $104 million increase in cost associated with reducing overall N loading to the Bay by 1000 lbs be better spent on other projects?
- Would addressing nonpoint sources of nitrogen be more cost effective at this point?
  - EPA website suggests, “restoration may be more cost effective than point source controls“ and “restoration generally achieves a broader range of benefits with additional value compared to additional point source controls.” (http://www.epa.gov/nps/Ecology/chap5.html)
- What level of loading and N reductions will result in higher oxygen levels, less fish kills and less nuisance algae?
  - Regulations imposed to reduce sewage derived nitrogen loading to the bay by 50%, estimated that loading to the bay will only be reduced by 20% overall.
- What changes in ecosystem dynamics will be observed?
  - Impacts of N reduction on primary and secondary production in the bay?
  - Combined impacts of climate change and nitrogen reduction?
- Ecosystem Based Management is important
  - Multiple factors/stressors need to be considered (circulation patterns, climate change)
  - All sources of N need to be addressed (stormwater management, Low Impact Design and land-use planning)