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Great Bay Nitrogen Non-Point Source Study

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Definitions of Acronyms, Important Terms, and Units

Acronyms

DES: New Hampshire Department of Environmental Services
ELM: Estuarine Loading Model
GBNNPSS: Great Bay Nitrogen Non-Point Source Study
HUC12: 12-Digit Hydrologic Unit Code watershed
NLM: Nitrogen Loading Model
NRCS: USDA, Natural Resources Conservation Services
PREP: Piscataqua Region Estuaries Partnership
TN: Total Nitrogen
USDA: U.S. Department of Agriculture
USEPA: U.S. Environmental Protection Agency
USGS: U.S. Geological Survey
WWTF: Municipal Wastewater Treatment Facility

Important Terms

Airshed: An airshed is a geographic area (domain) from which emissions would account for a significant majority of the deposition to the receptor watershed. Airsheds cross county, state, and national boundaries.

Atmospheric Deposition: The process by which a pollutant in the atmosphere falls to the land or surface waters through either wet or dry deposition. Wet deposition occurs when the pollutant is contained in rain or snow. Dry deposition occurs when the pollutant is attached to aerosols that fall to the earth.

Chemical Fertilizer: Any of a large number of organic and synthetic materials, spread on or worked into soil to increase its capacity to support plant growth.

Connected Impervious Area (CIA): Impervious surfaces from which runoff flows directly into municipal storm sewers and surface waters without any opportunity to infiltrate. Also known as Directly Connected Impervious Area or Effective Impervious Area.

Delivered Load: The amount of a pollutant (e.g. nitrogen) that is delivered from a watershed to the estuary. The delivered load is the initial load that enters a watershed minus the amount of the pollutant that is lost during transport to the estuary.

Disconnected Impervious Area (DIA): Impervious surfaces from which runoff flows onto lawn or natural vegetation areas where it can infiltrate.

Estuary: An estuary is a partially enclosed body of water along the coast where freshwater from rivers and streams meets and mixes with salt water from the ocean.

Great Bay Estuary: The body of water beginning at the confluence of the Piscataqua River with the Atlantic Ocean and extending to the head-of-tide dams on Winnicut, Squamscott, Lamprey, Oyster, Bellamy, Cocheco Salmon Falls, and Great Works Rivers. The Great Bay Estuary covers approximately 13,440 acres (21 square miles).

Great Bay Estuary Watershed: The area of land where all of the water that drains off of it goes into the Great Bay Estuary. The Great Bay Estuary watershed covers approximately 655,189 acres (1,023 square miles).

Hampton-Seabrook Estuary: The body of water beginning at confluence of the Hampton River with the Atlantic Ocean and extending to the head-of-tide on the Taylor, Blackwater, Browns, and Hampton Falls Rivers. The Hampton-Seabrook Harbor Estuary covers approximately 1,227 acres (1.9 square miles).

HUC12 Subwatershed: A small watershed covering typically 10,000 to 40,000 acres. The USGS has assigned Hydrologic Unit Codes (HUC) from 2 to 12 digits long to watersheds across the country. A HUC12 subwatershed is the smallest watershed in the USGS system and is denoted with a 12-digit code.

Managed Turf: Grass that is actively managed for use as golf courses, parks and sports fields.

Non-Point Source: Non-point source pollution generally results from land runoff, precipitation, atmospheric deposition, drainage, seepage or hydrologic modification. The model accounts for non-point source pollution as a function of its point of origin; it does not consider or track its point of entry into the estuary via point sources (i.e. stormwater outfalls, drainage swales, etc.).

Piscataqua Region Watershed: The area of land where all of the water that drains off of it goes into either the Great Bay Estuary, Hampton-Seabrook Estuary or directly in to the Atlantic Ocean along New Hampshire's coast. The Piscataqua Region watershed covers approximately 695,037 acres (1,086 square miles).

Reactive Nitrogen: The forms of nitrogen that are readily bioavailable, specifically nitrate, nitrite, ammonia, and ammonium. Other forms of nitrogen (e.g., organic nitrogen) are also "reactive" and bioavailable but at a slower rate.

Septic System: An on-site wastewater treatment system that typically consists of a settling tank and a leach field to treat and inject sewage into the ground. Septic systems are typically used for residences in rural areas or suburban areas where municipal sewer service is not available.

Total Nitrogen (TN): The sum of all forms of nitrogen: both dissolved and particulate fractions of ammonia, ammonium, nitrite, nitrate, and organic nitrogen.

Wastewater Treatment Facility: A facility that treats wastewater from municipal sewer systems in urban areas.

Watershed: A watershed is the area of land where all of the water that drains off of it goes into the same water body. Watersheds come in all shapes and sizes. They cross county, state, and national boundaries.

Units

lb/yr or lb N/yr: Pounds (of nitrogen) per year
lb/ac or lb N/ac: Pounds (of nitrogen) per acre
lb/ac/yr or lb N/ac/yr: Pounds (of nitrogen) per acre per year
lb/1000 ft^2or lb N/1000 ft^2: Pounds (of nitrogen) per one thousand square feet
tons/ac or tons N/ac: Tons (of nitrogen) per acre
tons/yr or tons N/yr: Tons (of nitrogen) per year
Acres/home: Acres per home

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[1] Currently with Geosyntec Consultants

Executive Summary

The Great Bay Estuary is 21 square miles of tidal waters located in southeastern New Hampshire. It is one of 28 "estuaries of national significance" established under the Environmental Protection Agency's National Estuary Program. The estuary is experiencing the signs of eutrophication, specifically, low dissolved oxygen, macroalgae blooms, and declining eelgrass habitat (DES, 2012).

Sixty-eight percent of the nitrogen that ends up in the Great Bay Estuary originates from sources spread across the watershed; the remainder derives from direct discharges of municipal wastewater treatment facilities (DES, 2010; PREP, 2013). In this report, these diffuse sources of nitrogen are called non-point sources and consist of atmospheric deposition, fertilizers, human waste disposed into septic systems, and animal waste. The purpose of this study is to determine how much nitrogen each non-point source type contributes to the estuary. The nitrogen loads from municipal wastewater treatment facilities have been reported elsewhere (DES, 2010; PREP, 2013) and, therefore, are not included in this study except to provide context.

The intended use of this study is for planning purposes, and is not meant for regulatory allocations or specific reduction requirements. The results of the model may be useful for towns or watershed groups for prioritizing nitrogen reduction efforts or as a starting point for more detailed studies of non-point sources. However, more detailed inventories of non-point sources will be needed to model nitrogen reduction efforts in smaller areas. In addition, the model makes no conclusions about the benefits of nitrogen reductions to receiving waters or overall estuarine health.

The model used in this study is the Nitrogen Loading Model, as originally published in Valiela et al. (1997). The Nitrogen Loading Model, as customized for this study, tracks nitrogen inputs from atmospheric deposition, chemical fertilizers, human waste through septic systems, and animal wastes. These sources are then routed through surface waters, stormwater and groundwater to the estuary as a delivered load of nitrogen. Local data were developed as inputs to the model. The model output was found to match field measurements of total non-point source nitrogen loads from eight watersheds within the model uncertainty of +/-13%.

For the watershed draining to the Great Bay Estuary, the model predicted a non-point source nitrogen load of 800 tons per year (+/-100 tons/yr)[2]. This estimate corresponds well with the most recent field measurement of non-point source load (835 tons/yr) (PREP, 2013). The breakdown of nitrogen non-point sources from the model of delivered loads to the estuary is:

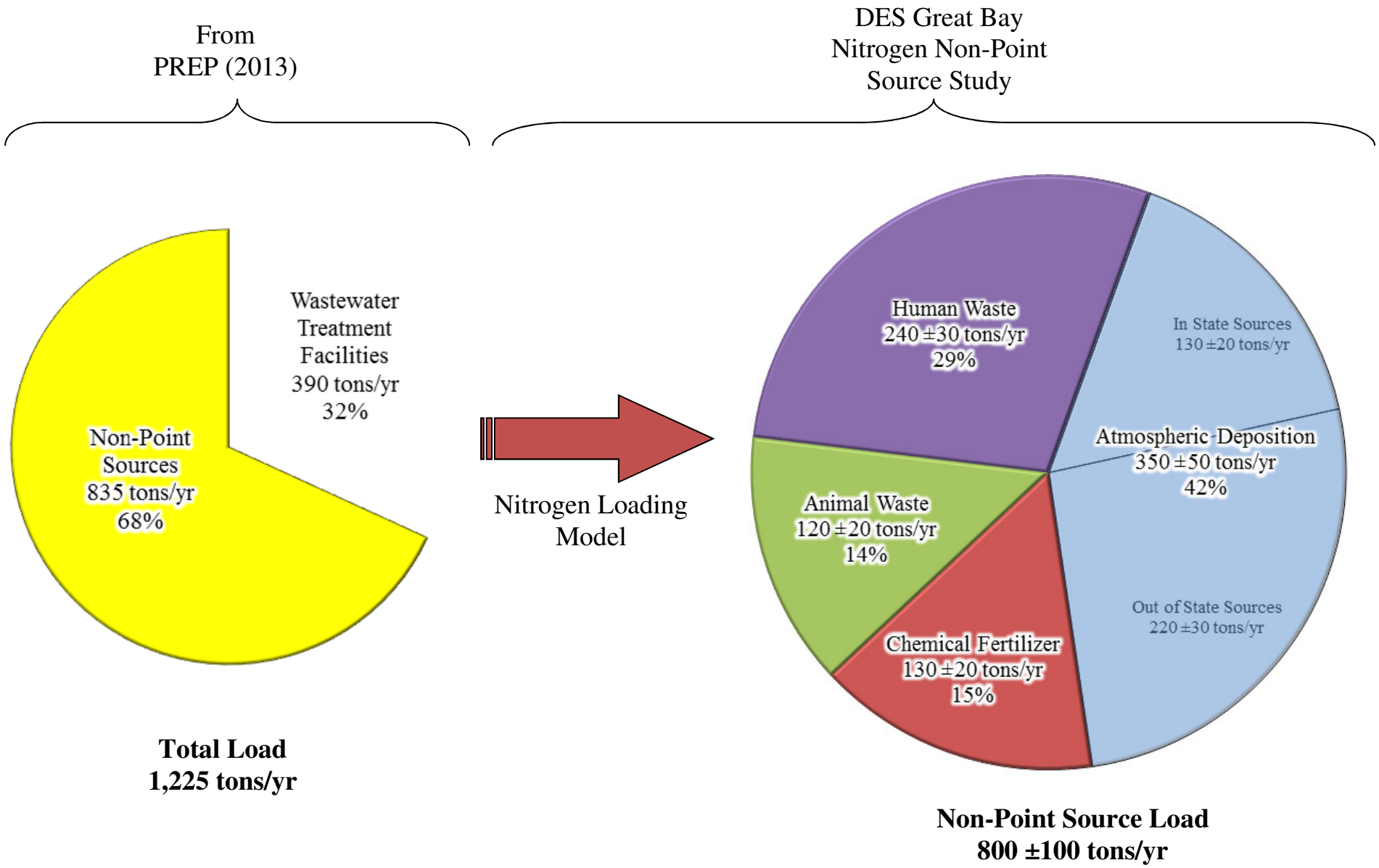
- Atmospheric Deposition – 42% (350 +/-50 tons/yr) – Out-of-state sources account for 62% of this source.
- Human Waste – 29% (240 +/-30 tons/yr) – This load is exclusively from septic systems because loads from wastewater treatment facilities (390 tons/yr (PREP, 2013)) were not considered in this study[3].

[2] The modeled results have been rounded to the number of significant digits consistent with the uncertainty of the model. This rounding causes slight discrepancies in some totals and percentages.
[3] The model did not address the condition of individual septic systems (i.e. functioning correctly vs. failing).

- Chemical Fertilizer – 15% (130 +/-20 tons/yr) – Lawns contributed 70%, agricultural areas contributed 23% and recreational fields were responsible for 8% of this load.
- Animal Waste - 14% (120 +/-20 tons/yr) – Livestock accounted for 58% of this load, while pet waste accounted for the remaining 42%.

Nitrogen loads were modeled for individual subwatersheds and towns in the study area to identify "hot spots" of non-point source pollution. The model also concluded that 34% of the nonpoint source loads were delivered through stormwater. The model tracks stormwater from its point of origin as overland flow, it does not differentiate between regulated and unregulated stormwater outfalls.

Figure ES: Summary of Non-Point Source Nitrogen Loads to the Great Bay Estuary



Non-Point Source Load Delivered by Stormwater = 34%

The modeled results have been rounded to the number of significant digits consistent with the uncertainty of the model. This rounding causes slight discrepancies in some totals and percentages.

I. Introduction

The Great Bay Estuary is 21 square miles of tidal waters located in southeastern New Hampshire. It is one of 28 "estuaries of national significance" established under the Environmental Protection Agency's National Estuary Program. The estuary is experiencing the signs of eutrophication, specifically, low dissolved oxygen, macroalgae blooms, and declining eelgrass habitat (DES, 2012).

Sixty-eight percent of the nitrogen that ends up in the Great Bay Estuary originates from sources spread across the watershed; the remainder derives from direct discharges of municipal wastewater treatment facilities (DES, 2010; PREP, 2013). In this report, these sources of nitrogen are called non-point sources and consist of atmospheric deposition, fertilizers, human waste disposed into septic systems, and animal waste. The purpose of this study is to determine how much nitrogen each non-point source type contributes to the estuary. The nitrogen loads from municipal wastewater treatment facilities have been reported elsewhere (DES, 2010; PREP, 2012; PREP, 2013) and, therefore, are not included in this study except to provide context.

The intended use of this study is for planning purposes, and is not meant for regulatory allocations or specific reduction requirements. The results of the model may be useful for towns or watershed groups for prioritizing nitrogen reduction efforts or as a starting point for more detailed studies of non-point sources. However, more detailed inventories of non-point sources will be needed to track the effects of nitrogen reduction efforts in smaller areas. In addition, the model makes no conclusions about the benefits of nitrogen reductions to receiving waters or overall estuarine health.

II. Methods

a. Study Area

The focus of this study is the watershed draining to the Great Bay Estuary. This watershed is in the Piscataqua Region which covers 1,086 square miles and parts of 61 municipalities in the states of New Hampshire, Maine, and Massachusetts in the northeastern U.S.A. The watershed for the Great Bay Estuary covers most of the Piscataqua Region (1,023 square miles). The remaining area drains to the Hampton-Seabrook Estuary or directly to the Atlantic Ocean.

In this study, the full Piscataqua Region watershed was split into smaller subwatersheds for three purposes. First, the watersheds of the eight major tributaries draining to the Great Bay Estuary were delineated so that measured nitrogen loads from these tributaries could be used to verify the model output. Second, the full watershed was divided into the 40 subwatersheds (the most current HUC12 boundaries, see definitions on page ii) to look for "hot spots" of non-point source nitrogen loading. Third, the study area was divided by the political boundaries of the 61 municipalities in New Hampshire, Maine, and Massachusetts so that town-wide nitrogen loads could be calculated. Overall, the intersections of these three boundaries split the Piscataqua Region into 215 small study areas for modeling purposes (Figure 1).

b. Types of Nitrogen Included in the Study

Nitrogen is the most abundant gas in the atmosphere. It is non-reactive in its gaseous form. The only natural processes that convert non-reactive nitrogen to reactive nitrogen are biological nitrogen fixation by specialized microbes associated with plants and, to a lesser extent, high temperature events, such as lightning. As a result, prior to human development, reactive nitrogen was scarce in natural ecosystems, with production of reactive nitrogen balanced by the natural processes that converted reactive nitrogen back to non-reactive nitrogen (Galloway et al., 2003).

For over one hundred years, human activities have vastly increased the production of reactive nitrogen (see definition under Important Terms), with the greatest increases occurring since 1960, mirroring the trend of increasing population. Reactive nitrogen production was accelerated by the manufacture of chemical fertilizer, the combustion of fossil fuels, and the cultivation of certain crops that biologically fix nitrogen from the atmosphere. Globally, these human activities have increased the reactive nitrogen production from 33 billion pounds per year in 1860 to 364 billion pounds per year in 2000. The amount of reactive nitrogen created for chemical fertilizers was greater than all the other sources combined (Galloway et al., 2003).

For the Piscataqua Region watershed, this study quantifies the imports and exports of reactive nitrogen created or enhanced by human activities. The specific sources of anthropogenic nitrogen considered are: deposition of nitrogen from the atmosphere (largely from pollution), application of chemical fertilizers, human waste disposed through septic systems, and animal waste. Reactive nitrogen from fossil fuel combustion for power generation or automobiles enters the watershed in the form of air pollution that settles onto the land surface. Reactive nitrogen from chemical fertilizers can be imported to the study area either through fertilizer imports directly (e.g. chemical fertilizers) or through imports of food and feed that were grown elsewhere (e.g. crops imported from outside the watershed). Animal waste contains nitrogen that was imported as animal feed. Nitrogen in imported food is converted to human waste which is either sent to a municipal wastewater treatment facility or an individual septic system. Nitrogen loads to the estuary from wastewater treatment facilities have been quantified in previous reports (DES, 2010; PREP, 2012; PREP, 2013). Therefore, this study will focus on nitrogen loads to the estuary from non-point sources. For a more detailed discussion of the nitrogen cycle, see SAB (2011).

There are also natural sources of nitrogen to the study area. Nitrogen can be fixed from the atmosphere by certain plant-microbe combinations in forests and in row crops such as alfalfa. However, Boyer et al. (2002) and Driscoll et al. (2003) have reported that nitrogen fixation by forests and crops in the Northeast amounts to less than 10% of the imported nitrogen. Fixation by row crops is an agricultural process, not a natural process, because these crops are specifically cultivated by humans and would not exist in large quantities otherwise. Similarly, animal waste from wildlife is a small source of nitrogen to the estuary (see Appendix F). Therefore, the effects of natural sources of nitrogen on loads to the estuary are expected to be small and variable and largely accounted for within the uncertainty range (+/- 13%) of the model. At the end of this report comparisons between current and ‘background’ or ‘natural’ nitrogen loads have been used to verify this assumption and illustrate the enrichment of nitrogen loads from the developed landscape compared to a natural landscape.

Figure 1: The Piscataqua Region Divided into the 215 Small Study Areas

c. Nitrogen Loading Model

The model used for this study is the Nitrogen Loading Model (NLM) as originally published in Valiela et al. (1997). The NLM has accurately predicted nitrogen loads in Waquoit Bay, Massachusetts (Valiela et al., 2000), Barnegat Bay, New Jersey (Bowen et al., 2007), and in 74 small embayments in southern New England (Latimer and Charpentier, 2010). The model output is an annual average nitrogen load. The model does not predict how non-point source nitrogen loads may change over the course of a year or during a particular weather event.

Inputs of Non-Point Source Nitrogen

The default NLM tracks nitrogen inputs from human activities from three major sources: (1) atmospheric deposition; (2) chemical fertilizers; and (3) human waste. For this study, animal waste has been added to the model as another source of nitrogen. Valiela et al. (1997) considered this factor originally but decided that it would be negligible in the small Waquoit Bay watershed. However, for the larger Piscataqua Region watershed animal waste was considered to be an important input to analyze. Figure 2 and
Figure 3 are simplified and detailed outlines of the model used for this study, respectively.

Atmospheric deposition rates for the model were taken from measurements in the study area in 2009. In addition, the DES Air Resources Division used a regional air dispersion model (California Photochemical Grid Model, CALGRID) to estimate how much of the nitrogen in atmospheric deposition originates from sources outside of New Hampshire and from different source categories (e.g., mobile sources, power generation, etc.). Appendix A contains a summary of the methods used for the regional air dispersion modeling and an analysis of how the deposition rate is expected to change over the next 10 years.

The model handles nitrogen from atmospheric deposition differently depending on the type of land use on which it falls. Land use data covering the entire study area was obtained from the NOAA Coastal Change Analysis Program 2006 data layer (Landsat TM, 30-meter resolution[4]). Impervious surface data for the study area in 2010 was obtained from the University of New Hampshire (Landsat TM, 30-meter resolution[5]). While more detailed land use and impervious cover datasets are available for some parts of the study area, only ones that covered the entire area were used. These datasets were used to estimate Connected Impervious Area and Disconnected Impervious Area in each study area following the approach from Sutherland (1995)[6]. The area of natural vegetation and surface waters in each study area were also estimated from these datasets. Appendix B provides detail on the methods used for land use calculations.

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[4] http://www.csc.noaa.gov/crs/lca/northeast.html
[5] http://www.granit.unh.edu/data/datacat/pages/coastalimperv10.pdf
[6] The Nitrogen Loading Model tracks nitrogen loads from two different types of impervious surfaces: (1) roofs and driveways and (2) roads, runways, and commercial areas. Runoff from roofs and driveways is presumed to flow "onto adjoining turf, where there are losses of nitrogen." Runoff from roads, runways, and commercial areas "largely flows into gutters and drains, and accumulates in catch basins". (Valiela et al., 1997) These two types of impervious surfaces fit the current definitions of "disconnected impervious area" (DIA) and "connected impervious area" (CIA).

Agricultural lands, managed turf areas, and lawn area were estimated separately and are discussed below.

The area of different agricultural crops in the study area was estimated from the USDA National Agricultural Statistics Service Cropland Data Layer for 2011 (Landsat TM, 30-meter resolution[7]). The expected fertilizer application rates for different crops were obtained from the USDA National Agricultural Statistics Service using data for New York as a surrogate for New Hampshire. New York was the closest state to the study area for which data were reported. Agricultural experts at UNH Cooperative Extension were also consulted regarding fertilizer applications rates, particularly for hay and pasture fields. Details of the methods used to estimate agricultural lands and fertilizer application rates are provided in Appendix C.

Golf courses, ball fields, and parks all have large areas of managed turf. The total area of managed turf in the study areas was determined by identifying all of these fields and delineating their boundaries using computer mapping software and aerial imagery from 2010-2011[8] at a 1-foot or 1-meter resolution. Golf courses and ball fields, relatively large features, were easily identified using the imagery. The fertilizer application rate for each field was obtained through a survey of the persons responsible for managing the fields. The survey had a 48% response rate. Average fertilization rates from the survey responses were used for the fields for which the survey was not completed. Details of the process used to delineate the boundaries of the managed turf areas and the survey are provided in Appendix D.

The area of lawns in the study area was estimated by quantifying lawn coverage in randomly selected areas and extrapolating the results to the rest of the watershed. In 80 randomly selected areas with homogeneous land use, the total coverage of lawn was digitized using aerial imagery (as described above). These data were used to estimate the average percent of each developed land use class that was covered by residential lawns. The total area of lawns was then estimated by multiplying these percentages by the area covered by each developed land use class. Fertilizer application rates for lawns and the percent of lawns that are fertilized in any given year were applied from the literature values. Appendix E contains details of the methods used to estimate lawn area and fertilization rates.

Animal waste was estimated by creating an inventory of priority livestock and pets and using the per animal nitrogen excretion rates from Van Horn (1998) , Boyer et al. (2002), ASAE (2005) and USDA (2009). Cattle, horses, dogs, and cats were identified as priority animals based on the animal totals for the four counties in the study area from the 2007 USDA Census of Agriculture and the American Veterinary Medical Association. These four species accounted for 97% of the nitrogen in animal waste. The number of these animals in each town in the study area was obtained from the State Department of Agriculture, State Veterinarian, individual farms, and formulas from the American Veterinary Medical Association. Watershed inputs from pet waste were estimated after taking into account expected rates of pet waste pick-up by owners reported

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[7] http://www.nass.usda.gov/research/Cropland/metadata/metadata_nh11.htm
[8] Imagery for New Hampshire and Massachusetts areas http://www.granit.unh.edu/resourcelibrary/specialtopics/2010aerialphotography/index.html. Imagery for Maine areas, http://geolibportal.usm.maine.edu/geonetwork/srv/en/metadata.show?id=926.

in the literature on the subject. Details of the methods for estimated animal waste inputs are provided in Appendix F.

Human waste inputs through septic systems were estimated by determining the percent of the population in each census block that was not served by municipal sewer networks. The remaining population was assumed to use septic systems for waste disposal[9]. The sewered population was determined based on previous work by the USGS Water Demand Model for New Hampshire (Hayes and Horn, 2009), maps of sewer lines, and consultation with public works officials. The number of people residing in each census block was obtained from the 2010 U.S. Census. Each person was assumed to excrete 10.6 pounds of nitrogen per year (Valiela et al., 1997). Appendix G contains the details of methods used to determine the number of people who use septic systems for waste disposal in the study area.

All of the input datasets were collected between 2005 and 2012, with most between 2010 and 2012. The atmospheric deposition rates are specific to 2009, a year which experienced rainfall[10] and hydrologic conditions that were typical for New England[11] and, therefore, consistent with the model assumptions. Consequently, the modeled time period for this study most closely represents conditions in 2009.

Transport Pathways

Within the Nitrogen Loading Model, the nitrogen imported from the sources described above is applied to different types of land use (or the subsurface through septic systems) and transported to the estuary through a groundwater pathway. A large fraction of the nitrogen that enters the watershed from these sources is permanently removed by denitrification to nitrogen gas. The remainder of the imported nitrogen is delivered from the watershed to the estuary. For septic systems within 200-meters of the estuary, the NLM assumes higher delivery rates, because there is too little space for significant nitrogen losses in the groundwater to occur. See Appendix H for details of the delivery factors for the groundwater transport pathways.

In the Great Bay Estuary watershed model, much of the nitrogen will follow the groundwater pathways per the default NLM. However, the soils in the Great Bay Watershed are not as sandy as those on Cape Cod. Some of the nitrogen applied to the land surface will be carried directly into surface waters by stormwater runoff. Therefore, a stormwater/surface water transport pathway was added to customize the NLM for conditions in the Great Bay Estuary. The components of this pathway are:

- Connected Impervious Area: Connected Impervious Area generates stormwater runoff that is carried directly into the stormwater drainage system and then discharged directly to surface waters. One hundred percent of the nitrogen applied to these areas was assumed to travel through the stormwater/surface water pathway.
- Lawn Area, Managed Turf, Agriculture, Natural Vegetation and Disconnected Impervious Area: Most of the nitrogen applied to these land uses will be transported by

[9] The model did not address the condition of individual septic systems (i.e. functioning correctly vs. failing).
[10] Total annual precipitation in Greenland, NH in 2009 was 53.9 inches
[11] Average annual precipitation in Greenland, NH between 2000-2012 was 53.9 inches

the default groundwater pathway. However, some fraction of the nitrogen is expected to be transported to surface waters by stormwater runoff when the infiltration capacity of the soils is exceeded. The average runoff from these land use types was estimated by an EPA Storm Water Management Model (SWMM) long-term simulation using the NRCS Curve Number method (see details in Appendix H). The runoff simulations were based on 10 years of daily weather data (2000-2011) and, therefore, are expected to be representative of average conditions.

- Lake, River, and Estuary Areas: Nitrogen falling from the atmosphere directly onto surface waters does not pass through the groundwater pathway. One hundred percent of the atmospheric deposition onto surface waters was assumed to travel through the surface water pathway.
- Delivery Factor: Some of the nitrogen in the surface water pathway will be lost during transport. The Estuarine Loading Model (ELM), a companion model to the NLM from Valiela et al. (2004), was used to estimate these losses. Essentially, the ELM assumes the mean percent loss of nitrogen in freshwater streams is 13%. This factor does not change with travel time to the estuary. The delivery factors for the surface water pathway are described in Appendix H.

In addition to the distinct groundwater and stormwater/surface water pathways, nitrogen is likely transported through a mixture of these two pathways. Some nitrogen may initially enter the groundwater and then discharge to a river or lake before reaching the estuary. This combination pathway was too complicated to model. However, the effects of this pathway are likely accounted for by the stormwater/surface water pathway.

Results Summary

Summary tables, figures, and discussion of the results for the watershed draining to the Great Bay Estuary as a whole are provided in Section III of this report. The Great Bay Estuary watershed is a subset of the Piscataqua Region for which there is a strong interest in understanding non-point source nutrient loads.

The model was also run for subwatersheds and towns in the Piscataqua Region to provide local information to decision-makers. These results are provided in the form of figures and tables in Section V of this report.

The authors of the model determined the variability of the model based on its input parameters to be 38% for individual applications and 13% on average[12]. For this study, the NLM was run on multiple different study areas with the results summed, so the average variability is the relevant target value. For summary graphics, the results were expressed with error bars and were rounded to the same decimal place as the error bars. No rounding was performed on tables and figures other than the summary graphics in order to accommodate review without introducing round-off errors. However, all model results should be recognized to have an inherent uncertainty of +/- 13%. Detailed methods for this study are provided in appendices as shown in Table 1.

[12] Average of the two estimates of variability from Table 11 of Valiela et al. (1997).

Table 1: List of Appendices Containing Detailed Methodologies for Nitrogen Import and Cycling

Source	Land Use or Process	Detailed Methods
Atmospheric Deposition	Deposition on different land use types	Appendix A (deposition rate) Appendix B through E (land use)
Chemical Fertilizer	Agricultural Lands	Appendix C
	Recreational Fields	Appendix D
	Lawns	Appendix E
Animal Waste	Manure on agricultural lands	Appendix F
	Pet waste on different land use types	Appendix F
Human Waste	Septic systems	Appendix G
Delivery Factors	Surface water/groundwater partitioning and transport pathways	Appendix H

d. Model Validation

Input parameters for the model were researched in depth to obtain the best-available, local information to represent conditions in the Piscataqua Region. The chosen values were validated by comparisons to other studies to ensure accuracy.

The model output was validated using measurements of nitrogen loads from the eight major tributaries to the Great Bay Estuary. PREP (2012) used the most recent monthly data (2009-2011) on nitrogen concentrations at the head-of-tide to calculate the total nitrogen load from non-point sources in each of the eight major watersheds. These three years had yearly rainfall between 53.1-64.8 inches per year. The NLM was run for these same watersheds. The model predictions were then compared to the measured loads to determine the accuracy of the model.

e. Quality Assurance

The model results were vetted by both internal and external review. An internal review was conducted by DES technical staff to verify the calculations and methods. An external review was completed by Dr. Ivan Valiela of the Marine Biological Laboratory at Woods Hole, MA.

f. Public Participation

DES developed two customized, geospatial datasets for this study. The first was a datalayer showing the percent of the population in each census block that uses a septic system for waste disposal. DES contacted each of the municipalities in the study area in August 2011 with a draft of this datalayer. DES accepted comments from the municipalities and revised the datalayer accordingly (Appendix G). The second datalayer showed the boundaries of every ball field, golf course, public parks, or other type of managed, recreation turf in the watershed. In October 2011, DES mailed maps of the managed turf boundaries to the organization responsible for maintaining them (e.g., municipalities, school districts, golf courses, etc.). DES accepted comments and revised the boundaries accordingly. DES also compiled results of a survey from the turf managers regarding turf fertilization practices (Appendix D).

The draft report was released for public comment from May 16, 2013 through August 16, 2013. Responses to comments received have been summarized in Appendix I.

Figure 2: Simplified Diagram of the Nitrogen Loading Model for the Great Bay Nitrogen Non-Point Source Study

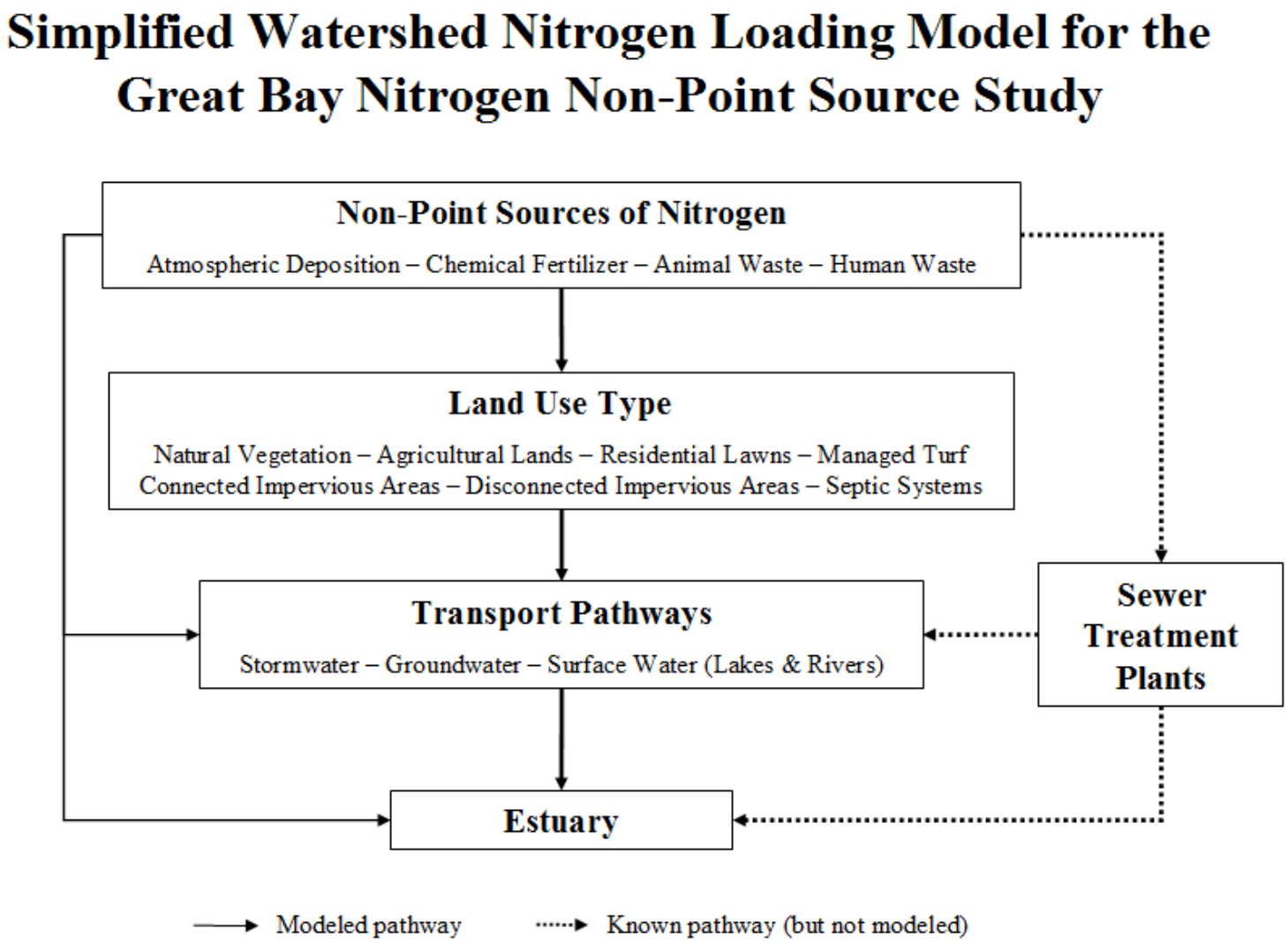
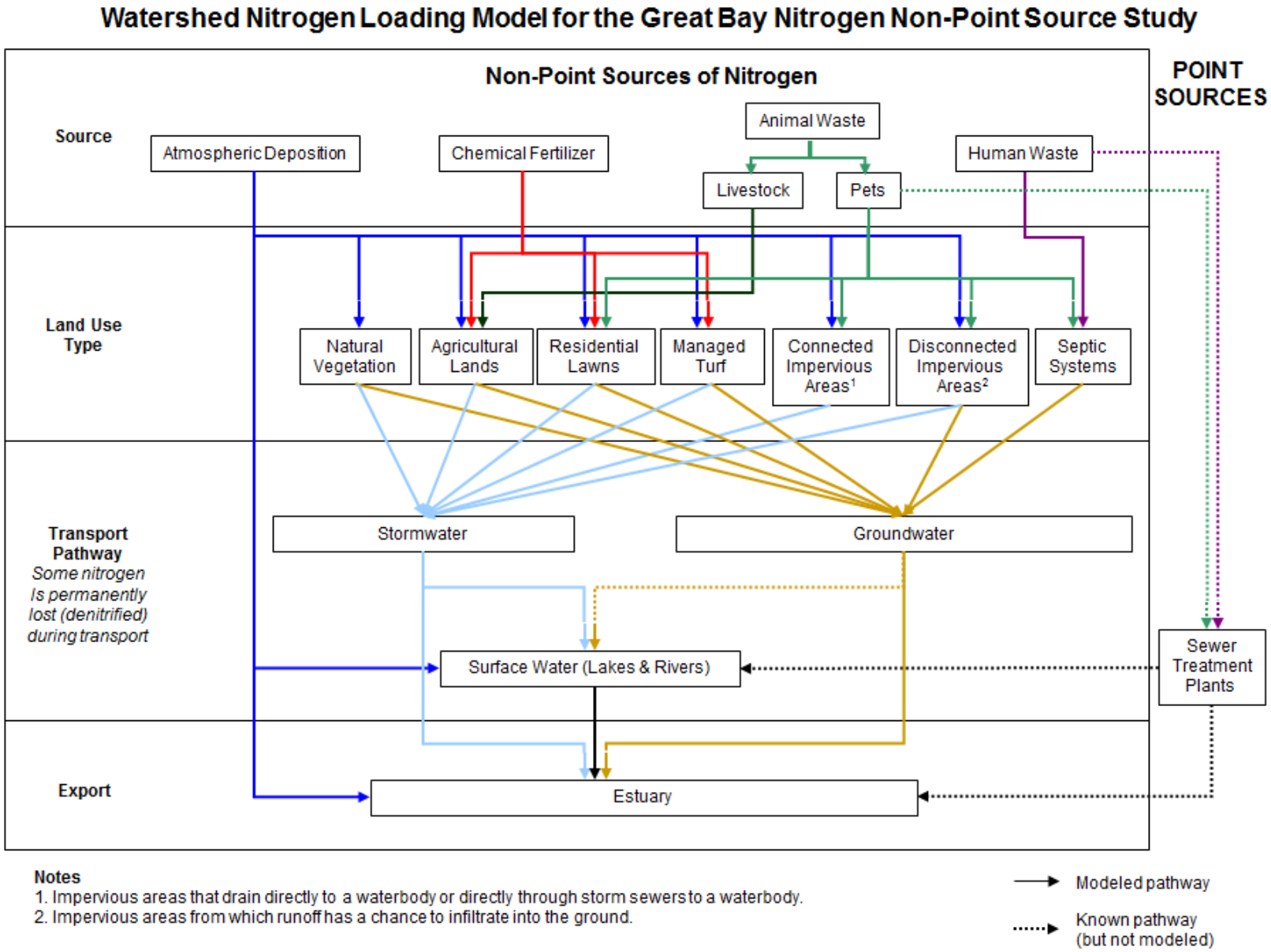


Figure 3: Detailed Diagram of the Nitrogen Loading Model for the Great Bay Nitrogen Non-Point Source Study



III. Results & Discussion

a. Validation of Model Input Parameters

The accuracy of any model depends on having correct input data. Each of the model input variables for the NLM was researched in depth to obtain the best available and local information to represent conditions in the Piscataqua Region. The chosen values were validated by comparisons to other studies to ensure accuracy.

The atmospheric deposition rate for 2009 was determined to be 5.21 lb/ac/yr based on measurements at a site near the center of the watershed in 2009 (Thompson Farm in Durham, NH). The chosen value was lower than the previous estimate of 6.24 lb/ac/yr in 2009 from Daley et al. (2010) because it takes into account the increasing trend in the wet-to-dry deposition ratio. The chosen value was confirmed by a regional deposition trending analysis that predicted a deposition rate of 5.79 lb/ac/yr based on emissions data for 2009. In addition, a regional air dispersion model was used to show that 63% of the nitrogen deposition in the Piscataqua Region was from sources outside of New Hampshire. The model also showed that 53% was from mobile sources, 27% was from power generation, and 20% was from area sources. The atmospheric deposition rate of nitrogen is expected to decline by one-third by 2020 as a result of USEPA rules and programs requiring emission reductions (see Appendix A).

Impervious surfaces were found to cover 10% of the land area of the Piscataqua Region. By using the approach from Sutherland (1995), it was estimated that approximately one third of the impervious surfaces were Connected Impervious Area which discharged stormwater runoff directly to surface waters. PREP (2013) reported that 9.6% of the Piscataqua Region watershed was covered by impervious surfaces, which matches the estimate in this report (see Appendix B).

Agricultural lands covered 39,226 acres or 6% of the land area in the Piscataqua Region. The largest crop was hay (88% of the agricultural area) followed by alfalfa (5%), and corn (4%). Fertilizer application rates ranged from 63 lb N/ac for corn to 0 lb N/ac for alfalfa, which is a nitrogen fixing crop. Ruddy et al. (2006) reported county-level estimates of farm fertilizer use for the United States. The average farm fertilizer use in 1987-2001 was reported to be 348,047 and 364,133 pounds per year for Rockingham and Strafford counties, respectively. The estimate for Rockingham and Stafford Counties were 39% and 75% lower than the measured value, respectively. The difference between the estimated farm fertilizer use in 2011 and the measured values from 1987-2001 may be due to cost increases for fertilizer and changes in agricultural practices during this period (see Appendix C).

Recreational fields with managed turf covered 2,526 acres in the Piscataqua Region. There were 22 golf courses, 102 school athletic fields, and 103 town parks or fields. Fertilizer application rates were obtained through a manager survey, which had a response rate of 48%. The results showed that the average yearly fertilizer application rate of nitrogen was 2.25 lb N/1000 ft^2 for golf courses, 1.89 lb N/1000 ft^2 for school fields, and 1.24 lb N/1000 ft^2 for town fields. The application rates are reported in the units typically used by landscaping companies (pounds of nitrogen per 1,000 square feet or lb N/1000 ft^2). These average yearly application rates are

consistent with other published values and/or recommendations. For example, Latimer and Charpentier (2010) used a value of 2.36 lb N/1000 ft^2 for recreational fields for a study of nitrogen loads to estuaries in southern New England. The survey also found that the fertilized area of golf courses (fairways, greens, tees) typically amounted to 42% of the total golf course size, and that 87% and 61% of school and town fields, respectively, were fertilized in a given year. These percentages were used to prorate the fertilizer application rates for the model (see Appendix D).

Residential lawns were estimated to cover 19,077 acres in the Piscataqua Region (2.7% of the watershed), which is an order of magnitude more than managed turf and more than any other 'crop' besides hay. This finding matches previous work by Milesi et al. (2005) at the national level. The average lawn area in the Piscataqua Region ranged from 0.05 acres/home for high density development areas to 0.30 acres/home for open space areas. This range of values appears to be credible because it brackets the value of 0.12 acres/home published by Latimer and Charpentier (2010). Based on a review of the literature, fertilizer use was estimated to occur on 54% of lawns in any given year at a rate of 2 lb N/1000 ft^2 (see Appendix E).

In the 2007-2012 time period, there were approximately 2,468 horses, 2,572 cattle (mostly dairy), 83,430 dogs, and 94,037 cats in the Piscataqua Region watershed. These values are likely low estimates because they are largely based on surveys of commercial farms[13] for horses and cattle, and estimations based on population for dogs and cats. Some of the feed and grass that is eaten by animals is grown in the watershed using either chemical fertilizer or atmospheric deposition as the source of nutrients. The Nitrogen Loading Model accounts for this cycling by assuming that 39% of the nitrogen applied to agricultural lands is "lost" to plants or the soil. When these plants are eaten by livestock, this nitrogen is remobilized and enters the model again in the animal waste component. Therefore, it is appropriate to treat animal waste as an independent source of nitrogen (see Appendix F).

Slightly more than half of the people in the Piscataqua Region watershed used septic systems for waste disposal. The study showed that 177,548 of the 325,775 people (55%) in the watershed lived outside municipal sewer service areas. Maps of sewered areas from this study were checked by municipal officials for quality assurance (see Appendix G).

b. Validation of Model Output

The output of the NLM was validated using measurements of nitrogen loads from the eight major tributaries to the Great Bay Estuary (Figure 4 and Table 2). For watersheds with upstream wastewater treatment facilities, the delivered load from the facilities (accounting for losses during transport) was subtracted from the measured load at the tidal dam in order to isolate the non-point source load to compare to the non-point source model results. The graph on the left of Figure 4 compares the measured and modeled loads in units of pound per year. The graph on the right shows the same data but normalized by watershed size and expressed as yields (lb/ac/yr). The uncertainty in each of the points is shown by error bars. Both graphs indicate good

[13] The USDA Agricultural Census covers "any place from which $1,000 or more of agricultural products were produced and sold, or normally would have been sold, during the census year." Residential animals are not included.

correspondence between the model results and actual measurements. The standard error of the regressions was 11-12% of the mid-point of the datasets.

Accuracy and simplicity are often competing objectives for modeling studies. Models can always be made more accurate through customization but then they are more difficult to explain and less transparent. Ultimately, models should be as simple as possible to achieve the objectives of the study. In order to improve the fit of the model, customized nitrogen attenuation factors for each watershed would be required. This change would add significant complexity without corresponding benefit relative to the overall objectives of the study. Therefore, it was decided not to customize the model any further. The model provides reasonably accurate predictions of the non-point source loads from Great Bay watersheds within the expected accuracy of 13%. However, the model may lose accuracy at smaller scales unless more detailed input datasets are used. The model results represent average weather conditions in the mid-2000s. Nitrogen loads may be higher or lower in any given year depending on the actual weather. The exact relationship between annual rainfall and non-point source loads is not clear at this time.

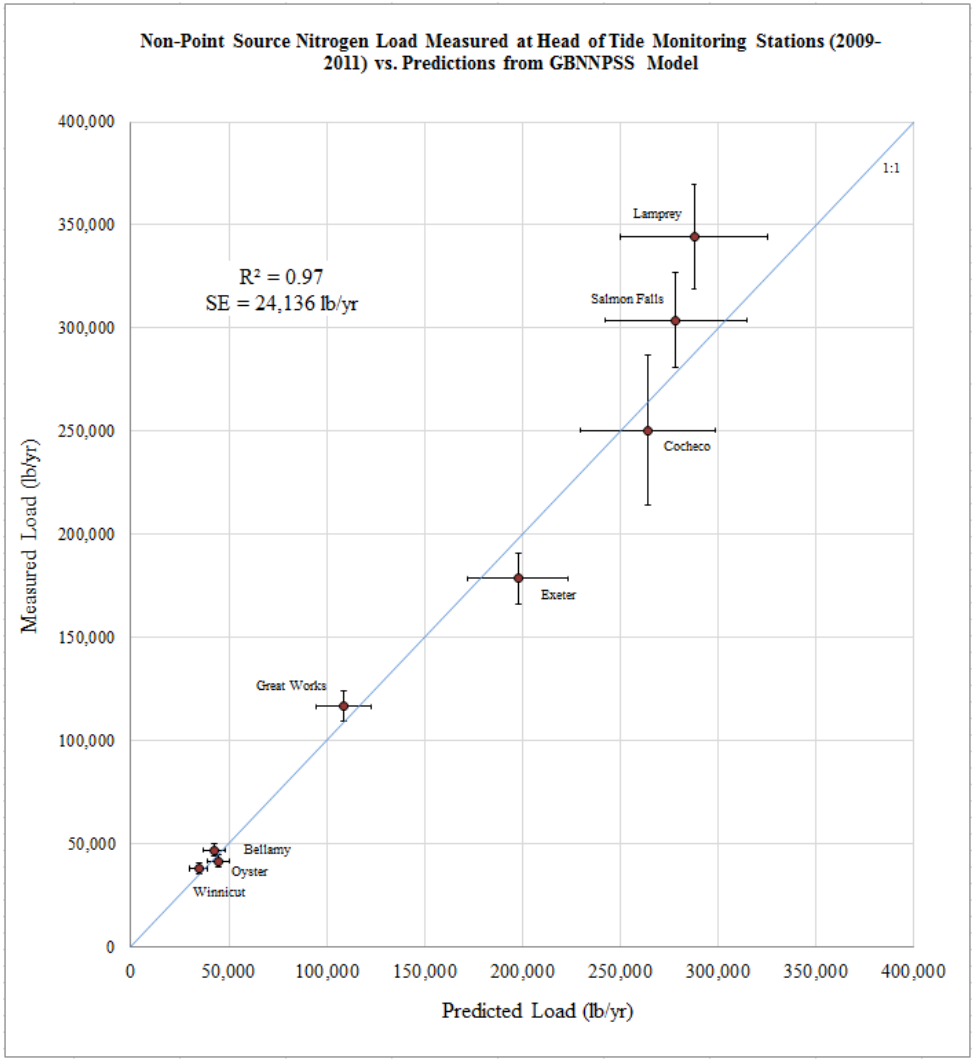
Table 2: WWTF and Non-Point Source Nitrogen from Great Bay Watersheds 2009-2011 (from PREP, 2012)

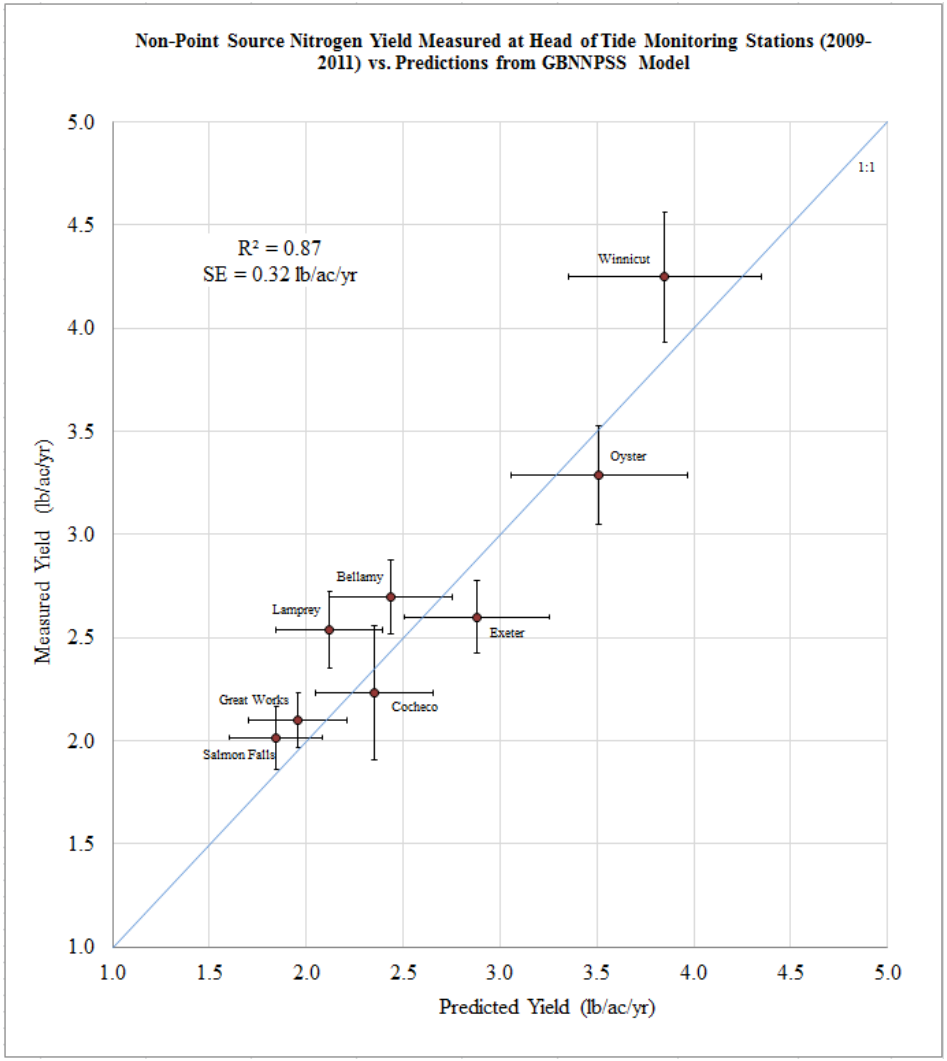
Watershed	Watershed Area (acres)	TN Load[14] (lb/yr)	Upstream WWTF TN Load[15] (lb/yr)	Non-Point Source TN Load (lb/yr)	Modeled Non-Point Source Load (lb/yr)
Winnicut River	9,000	38,280	0	38,280	34,700
Exeter River	68,677	178,620	0	178,620	197,785
Lamprey River	135,620	352,600	8,240	344,340	287,596
Oyster River	12,705	41,760	0	41,760	44,600
Bellamy River	17,449	47,080	0	47,080	42,474
Cocheco River	112,177	538,020	287,540	250,480	263,826
Salmon Falls River	150,662	344,560	40,620	303,940	278,096
Great Works River	55,483	119,720	3,080	116,620	108,656

[14] TN loads estimated using USGS software "LOADEST" with water quality data from the PREP Tidal Tributary Monitoring Program and streamflow data from USGS.

[15] The following wastewater treatment facilities (WWTFs) are located upstream of the tributary monitoring stations. The Epping WWTF is upstream of the Lamprey River station. The Rochester and Farmington WWTFs are upstream of the Cocheco River station. The Milton, Berwick, Somersworth and Rollinsford WWTFs are upstream of the Salmon Falls River station. The North Berwick WWTF is upstream of the Great Works River station. Upstream WWTF loads were reduced using an attenuation loss model to estimate the delivered load to the estuary.

Figure 4: Model Output Validation - Measured Watershed Loads and Yields vs. Model Predictions





c. Model Output for the Great Bay Estuary Watershed

For the watershed draining to the Great Bay Estuary, the NLM predicts a non-point source nitrogen load of 800 tons per year (+/-100 tons/yr)[16] (Figure 5). This estimate corresponds well with the most recent field measurement of the non-point source load (835 tons/yr) (PREP, 2013). The breakdown of nitrogen non-point sources from the model of delivered loads to the estuary is:

- Atmospheric Deposition – 42% (350 +/-50 tons/yr) – Out-of-state sources account for 62% of this source.
- Human Waste – 29% (240 +/-30 tons/yr) – This load is exclusively from septic systems because loads from wastewater treatment facilities were not considered in this study[17]. (The nitrogen load to the estuary from wastewater treatment facilities was 390 tons/yr in 2009-2011 (PREP, 2013). The combined contribution of nitrogen from human waste is 240 + 390, or 630 tons/yr).
- Chemical Fertilizer – 15% (130 +/-20 tons/yr) – Lawns contributed 70%, agricultural areas contributed 23% and recreational fields were responsible for 8% of this load.
- Animal Waste - 14% (120 +/-20 tons/yr) – Livestock accounted for 58% of this load , while pet waste accounted for the remaining 42%.

Overall, 76% of the nitrogen added to the watershed is lost before it reaches the Great Bay estuary (Figure 6). The model predicts that 800 +/-100 of the 3,386 tons of nitrogen applied to the land surface or discharged to a septic system were delivered to the estuary. Measurements of nitrogen inputs and outputs for watersheds in the study area have shown similar levels of nitrogen retention. Daley et al. (2010) reported that sub-basins of the Lamprey River watershed typically had nitrogen retention rates of 72 to 91%. The largest retention rates in the model are for natural vegetation and forests with a Hydrologic Soil Group of A (99.9%). The smallest retention rates are for runoff from connected impervious surfaces (13%). Therefore, nitrogen retention in a watershed generally decreases as development increases and more of the precipitation runs off the landscape as stormwater rather than infiltrating to the groundwater.

The model predicts that stormwater delivers 34% of the non-point source nitrogen to the Great Bay estuary (Figure 7). Stormwater is a transport pathway for nitrogen applied to lawns, agricultural lands, natural vegetation and urban lands. Approximately 42% of the nitrogen in stormwater comes primarily from impervious urban areas. The remaining 58% of nitrogen in stormwater originates from natural vegetation, agricultural lands and residential lawns, which contribute 29%, 15% and 14%, respectively. The model tracks stormwater from its point of origin as overland flow, it does not consider or track its point of entry into the estuary (i.e. stormwater outfalls). In other words, this report considers all stormwater as nonpoint source pollution even through some of that stormwater may enter the estuary through regulated point sources.

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[16] The modeled results have been rounded to the number of significant digits consistent with the uncertainty of the model. This rounding causes slight discrepancies in some totals and percentages.
[17] The model did not address the condition of individual septic systems (i.e. functioning correctly vs. failing).

The atmospheric deposition model used for the study includes local emission sources. However, local emissions are averaged out over the model grid cells (12 km x 12 km). The upshot is that the model accurately predicts the total mass of nitrogen from vehicle emissions but may underestimate the nitrogen deposition onto, and runoff from, impervious surfaces in urban areas. A number of studies have noted higher runoff rates for impervious surfaces than this model predicts (Davidson et al., 2009). However, there is no way to correct for this issue given the scale of this model. More detailed subwatershed models would be needed to more accurately predict the nitrogen load from impervious surface runoff, especially at the parcel or neighborhood scales.

As a way to identify potential "hot spot" areas, the yield of non-point source nitrogen from each small HUC12 watershed was calculated. The yield is the number of pounds of non-point source nitrogen delivered from the subwatershed to the estuary divided by the area of the subwatershed. A map of the watershed draining to the Great Bay Estuary is shown in Figure 8. The yield of non-point source nitrogen from each subwatershed is color coded on the map. For the entire Piscataqua Region study area, the top twenty percent of subwatersheds had delivered non-point source yields between 3.6 and 4.7 lb/ac/yr. In the Great Bay Estuary watershed, 7 of 38 HUC12 subwatersheds yielded amounts of nitrogen in this highest category.

- Lower Cocheco River (HUC# 010600030608)
- Squamscott River (HUC# 010600030806)
- Winnicut River (HUC# 010600030901)
- Oyster River (HUC# 010600030902)
- Great Bay (HUC# 010600030904)
- Portsmouth Harbor (HUC# 010600031001)
- Berrys Brook-Rye Harbor (HUC# 010600031002)[18]

The NLM was used to estimate delivered non-point source nitrogen loads from each of the eight major watersheds draining to the Great Bay Estuary, each of the 40 subwatersheds in the region, and each of the 61 towns in the region. In general, the patterns of nitrogen in non-point sources were similar across the different watersheds. Figure 9 and

Figure 10 show comparisons between the major watersheds and the whole Great Bay Estuary. Atmospheric deposition, chemical fertilizers, and human waste were the major sources in most of the watersheds. Animal waste was also one of the major sources in the Lamprey and Oyster River watersheds. The non-point source nitrogen yield for the major watersheds ranged from approximately 1.9 to 4.2 lb/ac/yr, which brackets the average non-point source yield of 2.6 lb/ac/yr. The percent of the non-point source load delivered by stormwater was within a range of 28 to 43% for the major watersheds. Detailed tables and figures showing the NLM output results for each of the subwatersheds and towns in the Piscataqua Region are provided in Section V of this report. These results may be useful to communities or watershed groups in two important

[18] Only a portion (46%) of HUC# 010600031002 drains to the Great Bay Estuary Watershed. The remaining 54% drains to the Atlantic Coast.

ways: 1) for prioritizing nitrogen reduction efforts; or 2) as a starting point for more detailed studies of non-point sources.

The nitrogen yield from temperate zone ecosystems in North America prior to human disturbance has been estimated to be 0.7-1 lb/ac/yr (NRC, 2000 at 122, Howarth, 2008). For the Great Bay Estuary watershed, this 'pre-development' nitrogen load would amount to 227 to 315 tons/yr. In contrast, the total nitrogen load from the watershed from both non-point sources and wastewater treatment facilities was 1,225 tons/yr in 2009-2011 (PREP, 2013). Therefore, nitrogen loads to the Great Bay Estuary are currently 4 to 5 times above pre-development levels. Another comparison can be made with the nitrogen loads from the Hubbard Brook Experimental Forest in North Woodstock, NH. Nitrogen yields of 1.2 lb/ac/yr from this forest (Bernal et al., 2012) reflect current atmospheric deposition rates but not human development on the ground because the watershed is pristine. For the Great Bay Estuary watershed, a yield of 1.2 lb/ac/yr would amount to nitrogen load of 408 tons/yr. Current loads are 3 times higher. These estimates of 'background' or 'natural' nitrogen loads are approximate. The exact amount of nitrogen currently delivered to the estuary from natural processes is unknown given that the nitrogen cycle in the Piscataqua Region is now dominated by human sources. However, these comparisons provide useful reference points for understanding current nitrogen loads compared to what they might have been in the past or what would naturally occur with no development in the watershed.

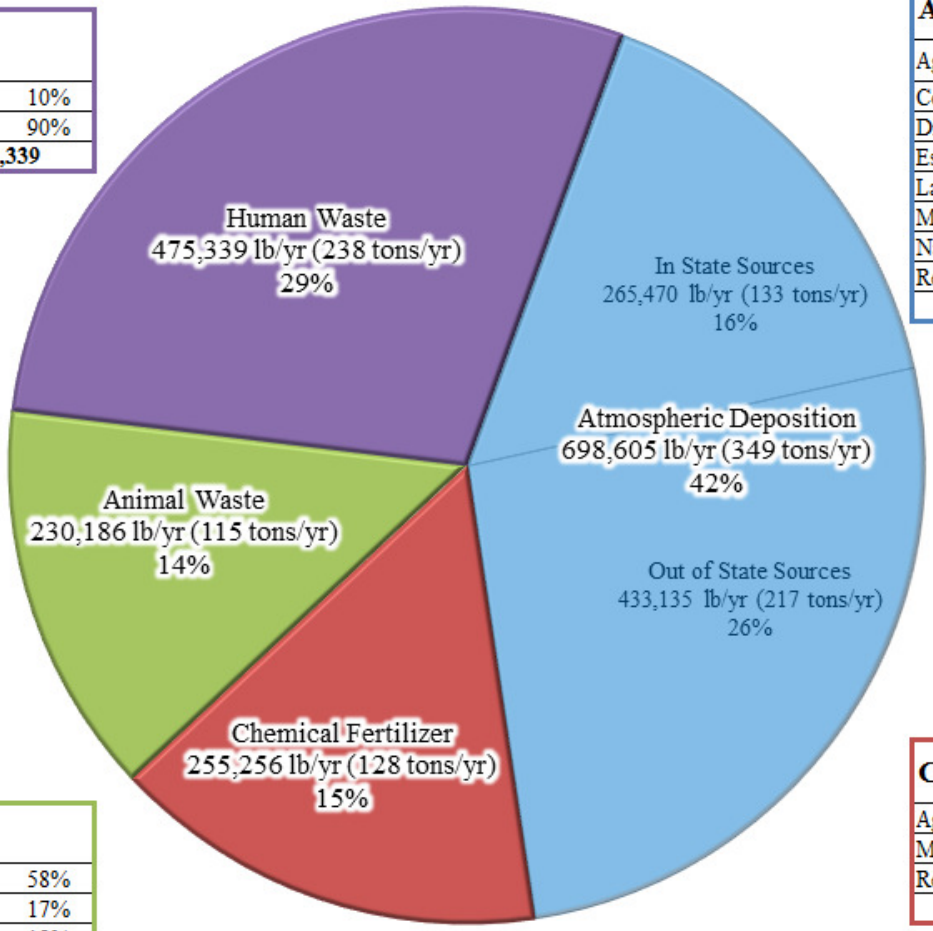
In summary, the NLM output for the watershed draining to the Great Bay Estuary, summarized in Figure 5 through Figure 8, provides useful information on the non-point sources of nitrogen to the estuary. It is now clear that human waste from both septic systems and wastewater treatment facilities accounts for 52% of the total nitrogen load to the estuary (Figure 11). The second biggest source, atmospheric deposition, is largely caused by out-of-state sources but is declining due to improved emissions controls. Chemical fertilizer is the third biggest source. Fertilizer use on recreational fields and golf courses is a small contributor compared to use on lawns and agricultural lands. Animal waste is the smallest source. Livestock contribute a little over half of the total nitrogen load from animal waste, with the remainder coming from domestic animals. Finally, the non-point source nitrogen yield was not consistent across the entire watershed. Lands closer to the estuary contributed more nitrogen per unit area than lands farther away.

Figure 5: Outputs of Non-Point Source Nitrogen by Source Type and Land Use Type for the Great Bay Estuary Watershed

Non-Point Source Nitrogen Delivered to Estuary
Total Load by Source Type and Land Use Type for the Great Bay Estuary Watershed

Human Waste - TN (lb/yr)		
Septic within 200m of Waterways*	48,362	10%
Septic >200m from Waterways*	426,977	90%
Total =	**475,339**	

Atmospheric Deposition - TN (lb/yr)		
Agriculture	30,643	4%
Connected Impervious Area	78,371	11%
Disconnected Impervious Area	82,293	12%
Estuaries	63,072	9%
Lakes & Rivers	71,582	10%
Managed Turf	1,086	0.2%
Natural Vegetation	357,610	51%
Residential Lawns	13,947	2%
Total =	**698,605**	



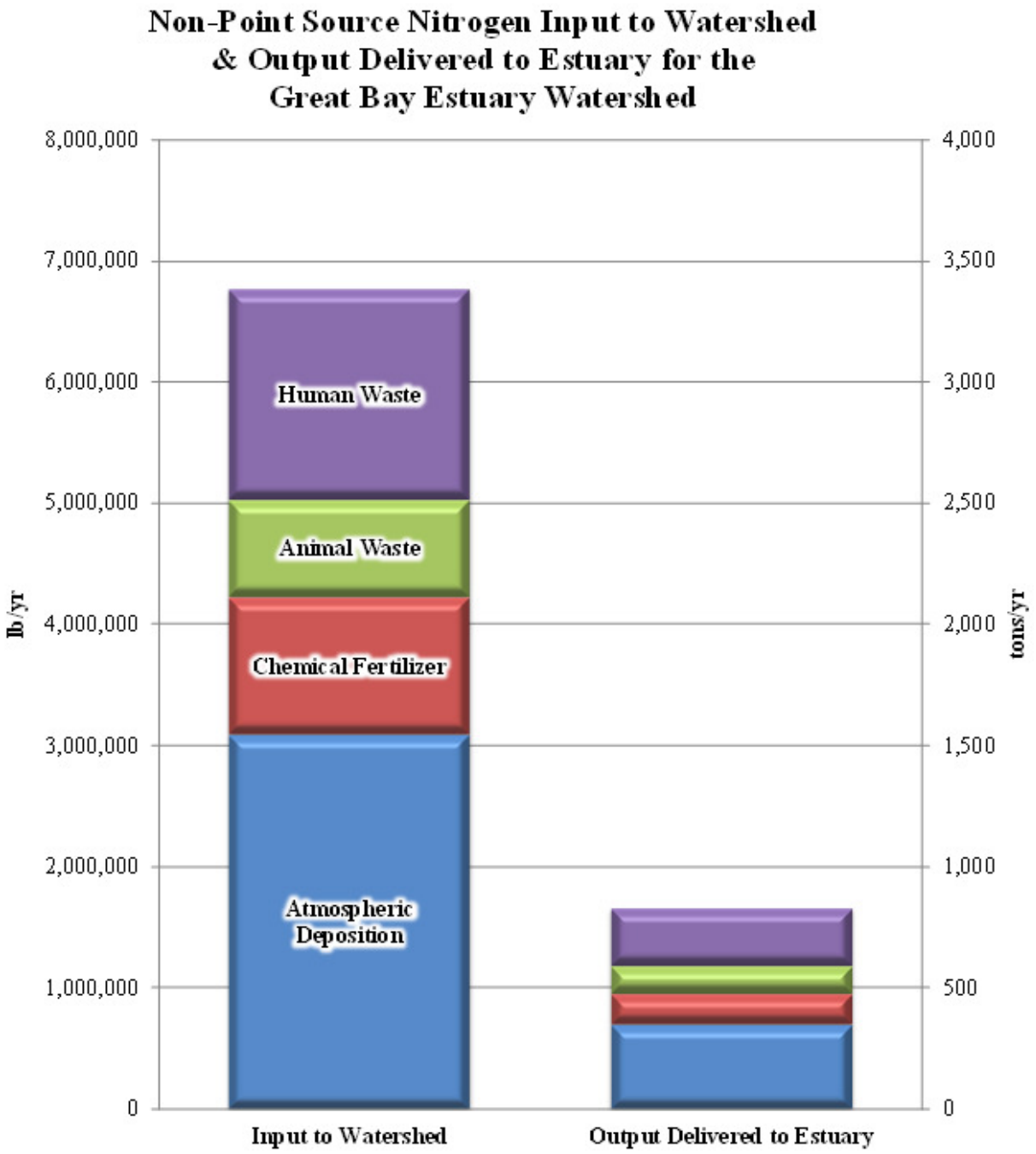
Chemical Fertilizer - TN (lb/yr)		
Agriculture	58,562	23%
Managed Turf	19,203	8%
Residential Lawns	177,491	70%
Total =	**255,256**	

Animal Waste - TN (lb/yr)		
Agriculture	133,396	58%
Connected Impervious Area	40,203	17%
Disconnected Impervious Area	42,246	18%
Residential Lawns	9,354	4%
Septic within 200m of Waterways*	590	0.3%
Septic >200m from Waterways*	4,397	2%
Total =	**230,186**	

Total Nitrogen Delivered = 1,659,387 lb/yr (830 tons/yr)

*Waterways include estuaries and 5th order or larger streams

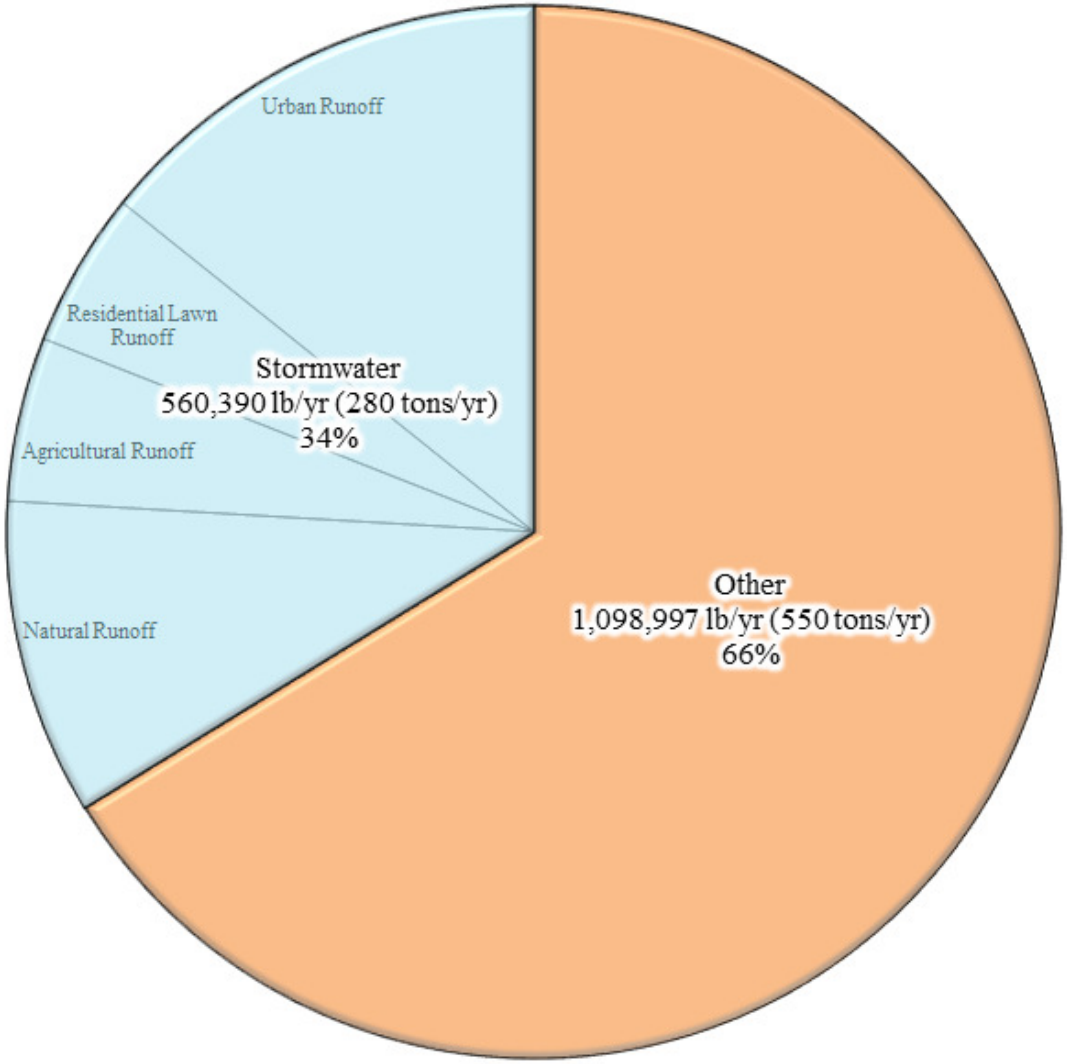
Figure 6: Inputs and Outputs of Non-Point Source Nitrogen by Source Type for the Great Bay Estuary Watershed



Source	Input to Watershed TN (lb/yr)		Output Delivered to Estuary TN (lb/yr)		TN Lost During Transport
Human Waste	1,739,412	26%	475,339	29%	*73%*
Animal Waste	805,250	12%	230,186	14%	*71%*
Chemical Fertilizer	1,134,455	17%	255,256	15%	*77%*
Atmospheric Deposition	3,092,718	46%	698,605	42%	*77%*
Total =	**6,771,836**		**1,659,387**		**75%**

Figure 7: Outputs of Non-Point Source Nitrogen Delivered Through Stormwater for the Great Bay Estuary Watershed

Non-Point Source Nitrogen Delivered to Estuary
Total Load through Stormwater for the Great Bay Estuary Watershed



Stormwater Delivered Load - TN (lb/yr)			
Agricultural Runoff - 15% of Stormwater - 5% of all Pathways			
Agriculture	Animal Waste	48,013	57%
	Atmospheric Deposition	14,644	17%
	Chemical Fertilizer	21,038	25%
		Sub-Total =	**83,695**
Residential Lawn Runoff - 14% of Stormwater - 5% of all Pathways			
Residential Lawns	Animal Waste	3,660	5%
	Atmospheric Deposition	7,009	9%
	Chemical Fertilizer	68,599	87%
		Sub-Total =	**79,269**
Urban Runoff - 42% of Stormwater - 14% of all Pathways			
Connected Impervious Area	Animal Waste	40,203	17%
	Atmospheric Deposition	78,371	33%
Disconnected Impervious Area	Animal Waste	37,475	16%
	Atmospheric Deposition	72,857	31%
Managed Turf	Atmospheric Deposition	178.2	0.1%
	Chemical Fertilizer	7,448	3%
		Sub-Total =	**236,533**
Natural Runoff - 29% of Stormwater - 10% of all Pathways			
Natural Vegetation	Atmospheric Deposition	160,893	100%
		Sub-Total =	**160,893**
		Stormwater Total =	**560,390**
		Total of all Pathways =	**1,659,387**

Total Nitrogen Delivered = 1,659,387 lb/yr (830 tons/yr)

Figure 8: Non-Point Source Nitrogen Yield (pounds delivered per acre per year) for HUC12 Subwatersheds Draining to the Great Bay Estuary

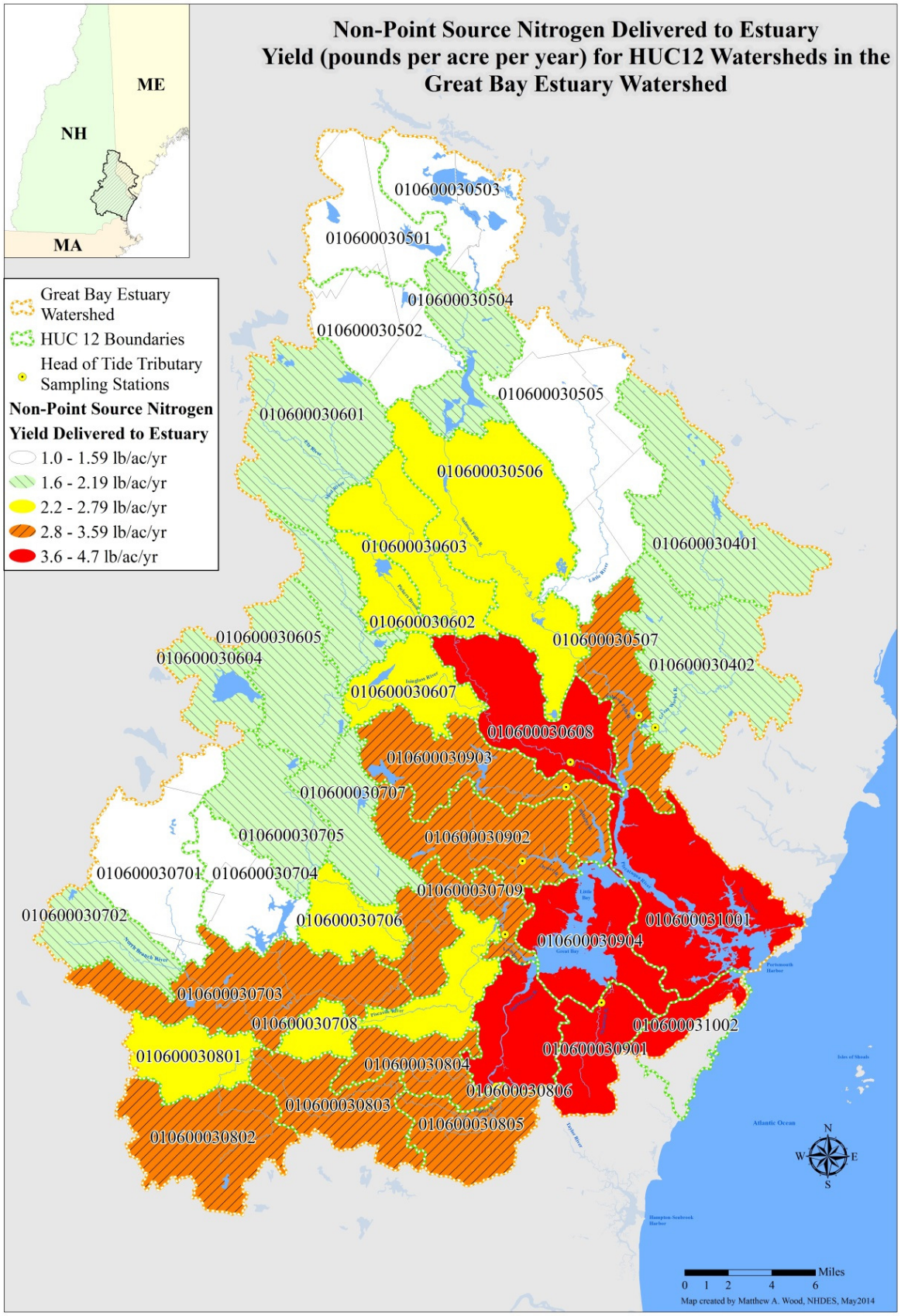


Figure 9: Percent of Non-Point Source Nitrogen Load from the Four Non-Point Sources in Each of the Major Watersheds Draining to the Great Bay Estuary

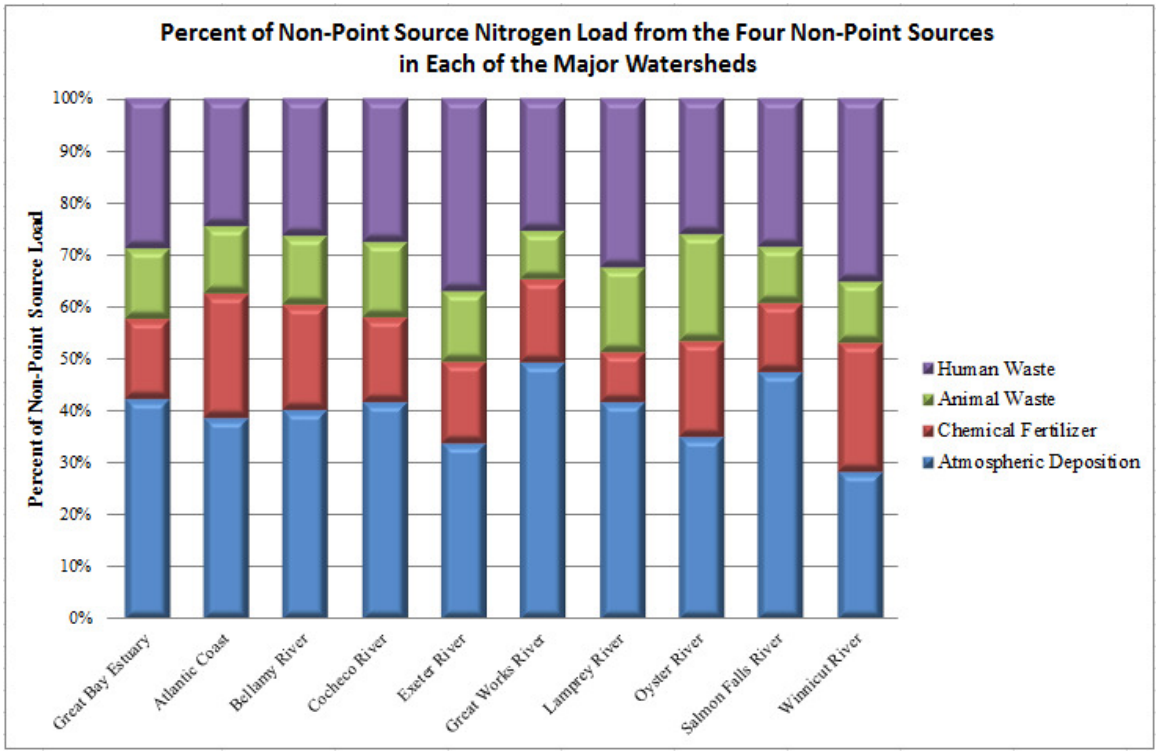


Figure 10: Non-Point Source Nitrogen Yield from the Four Non-Point Sources in Each of the Major Watersheds Draining to the Great Bay Estuary

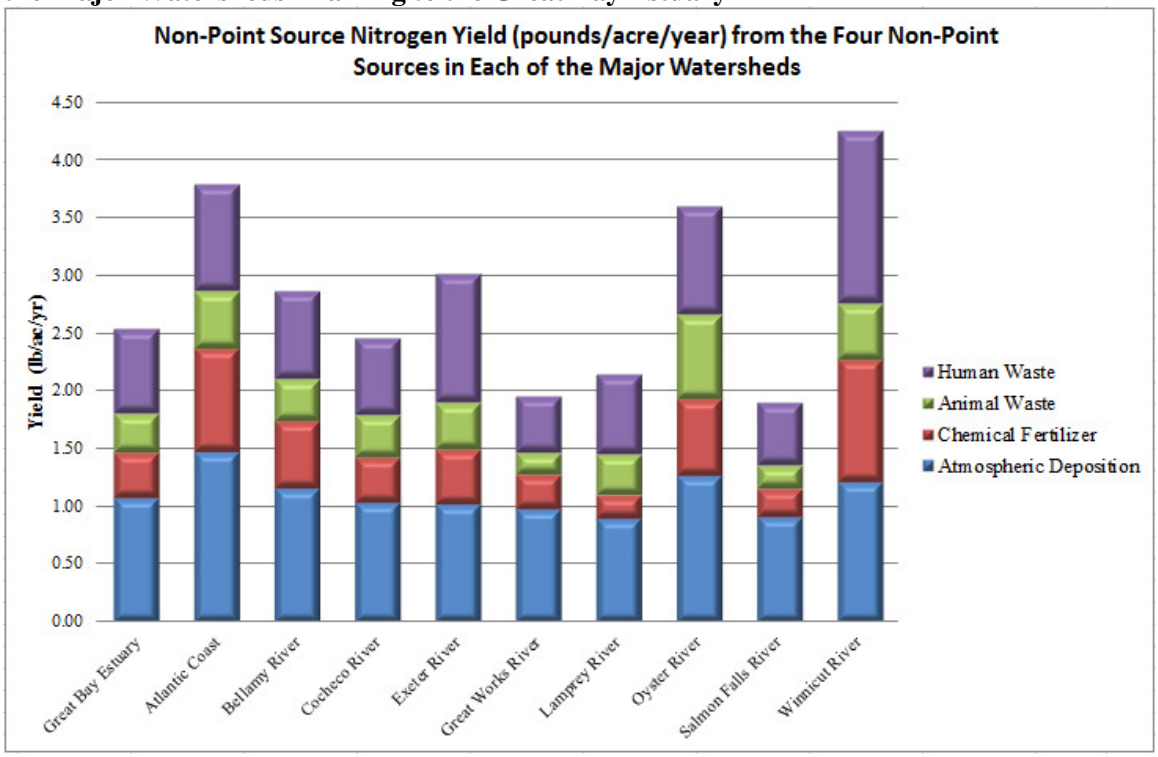
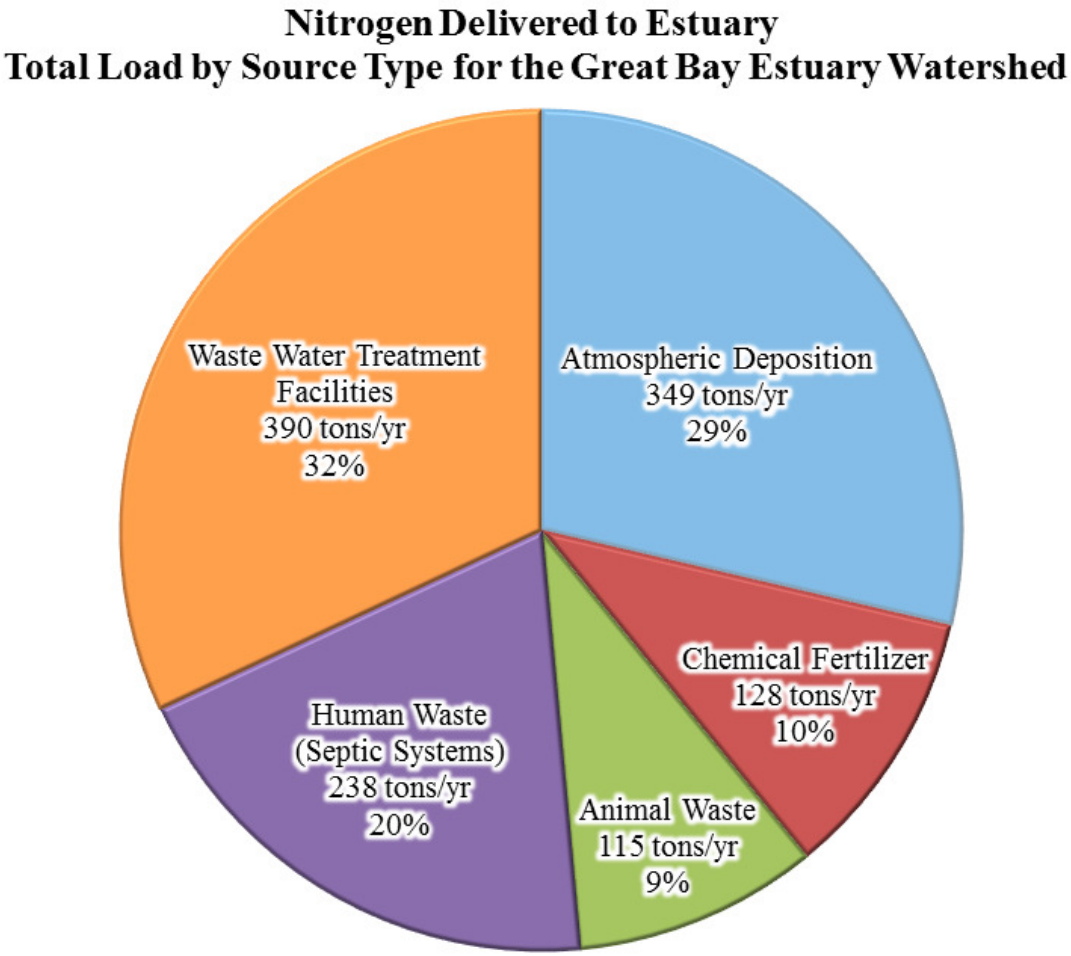


Figure 11: Outputs of Nitrogen by Source Type for the Great Bay Estuary Watershed



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V. Model Results for Subwatersheds and Municipalities in the Piscataqua Region

The NLM was used to estimate delivered non-point source nitrogen loads from each of the nine major watersheds draining to the Great Bay Estuary or the Hampton-Seabrook Estuary, each of the 40 subwatersheds in the region, and each of the 61 towns in the region. For towns that were partially in the Piscataqua Region watershed, the model output is for the portion of the town inside the watershed. The modeled results have been rounded to the number of significant digits consistent with the uncertainty of the model. This rounding causes slight discrepancies in some totals and percentages.

Figures 12-20 show the nitrogen inputs and outputs from the nine major watersheds.

Figures 21-29 show the delivered non-point source nitrogen load by source type and land use for the nine major watersheds.

Figures 30-38 show the non-point source nitrogen load delivered by stormwater for each of the nine major watersheds.

Figures 39-47 show the yield of non-point source nitrogen from each study area inside the nine major watersheds. The yield is the number of pounds of non-point source nitrogen delivered from the study area to the estuary divided by the area of the study area. For reference, the top twenty percent of study areas in the Piscataqua Region had yields between 4.2 and 9.2 pounds of delivered non-point source nitrogen per acre per year.

Figure 48 shows the delivered non-point source nitrogen yields from the 40 HUC12 subwatersheds in the Piscataqua Region. For reference, the top twenty percent of HUC12 subwatersheds in the Piscataqua Region had yields between 3.6 and 4.7 pounds of delivered non-point source nitrogen per acre per year.

Figure 49 shows the delivered non-point source nitrogen yields from the 61 municipalities in the Piscataqua Region. For towns that were partially in the Piscataqua Region watershed, the yield value is for the portion of the town inside the watershed. For reference, the top twenty percent of municipalities in the Piscataqua Region had yields between 4.0 and 5.3 pounds of delivered non-point source nitrogen per acre per year.

Tables 3, 4, and 5 contain details of the NLM output for the nine major watersheds, the 40 HUC12 subwatersheds, and the 61 municipalities, respectively.

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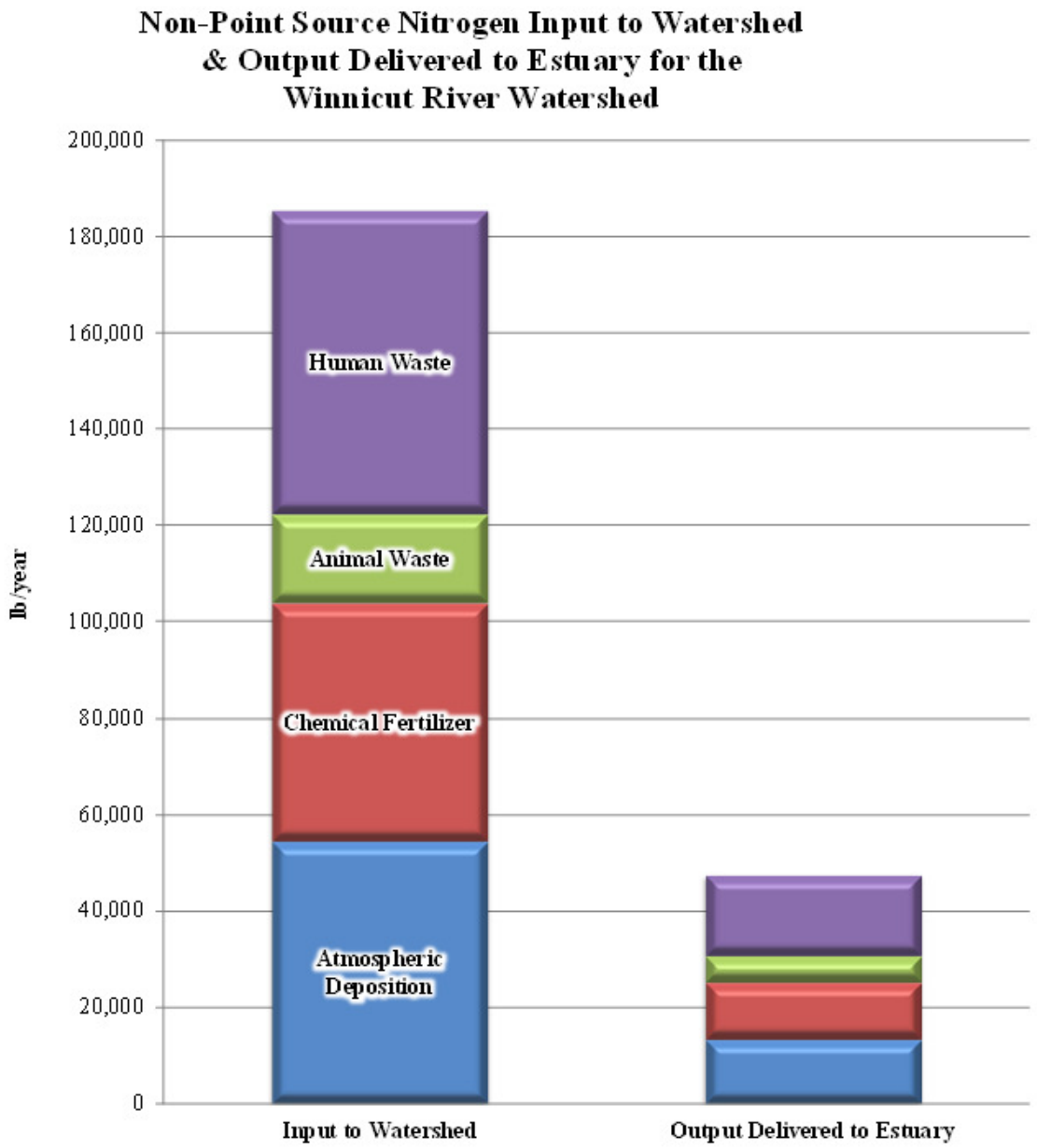
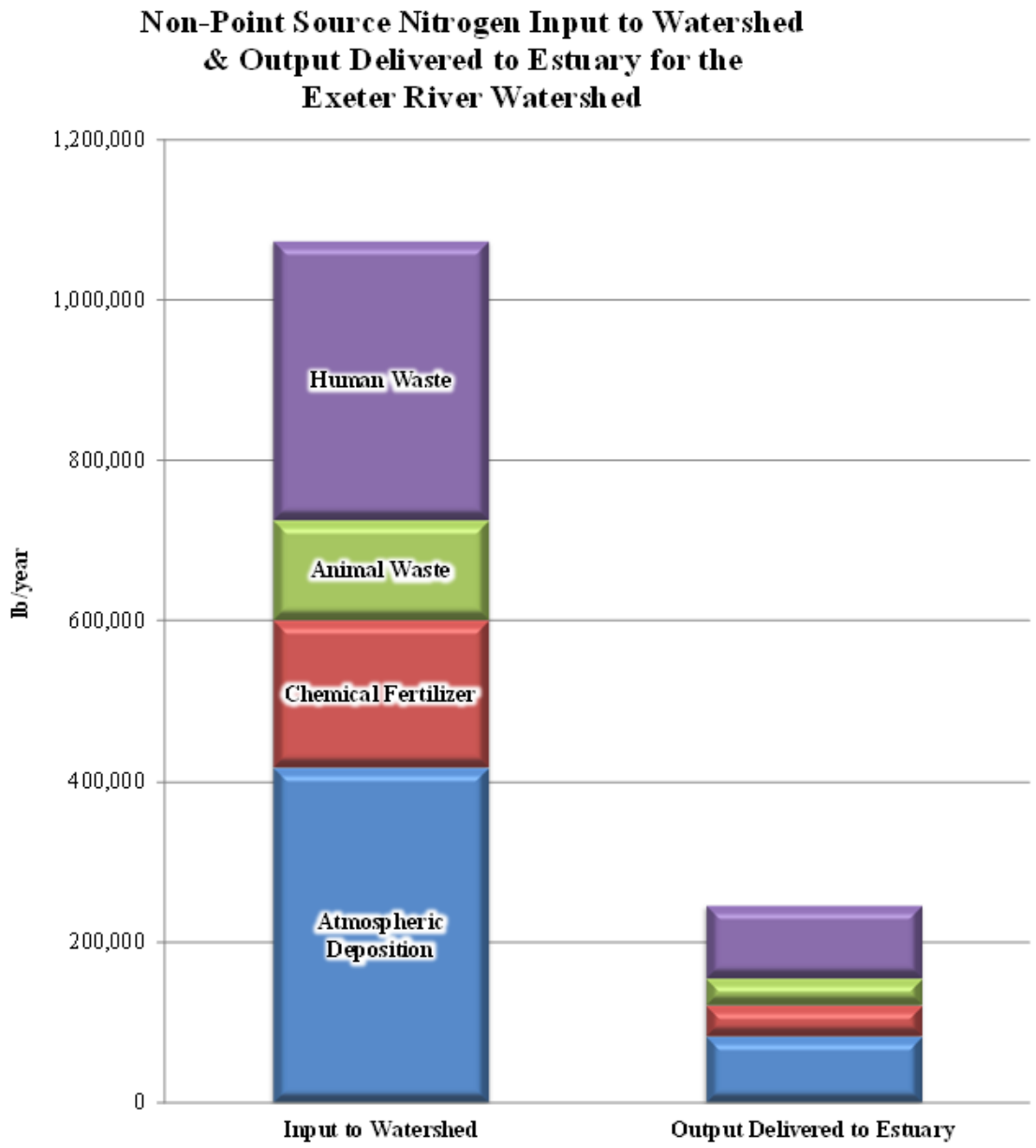
Figure 12: Inputs and Outputs of Non-Point Source Nitrogen by Source Type for the Winnicut River Watershed



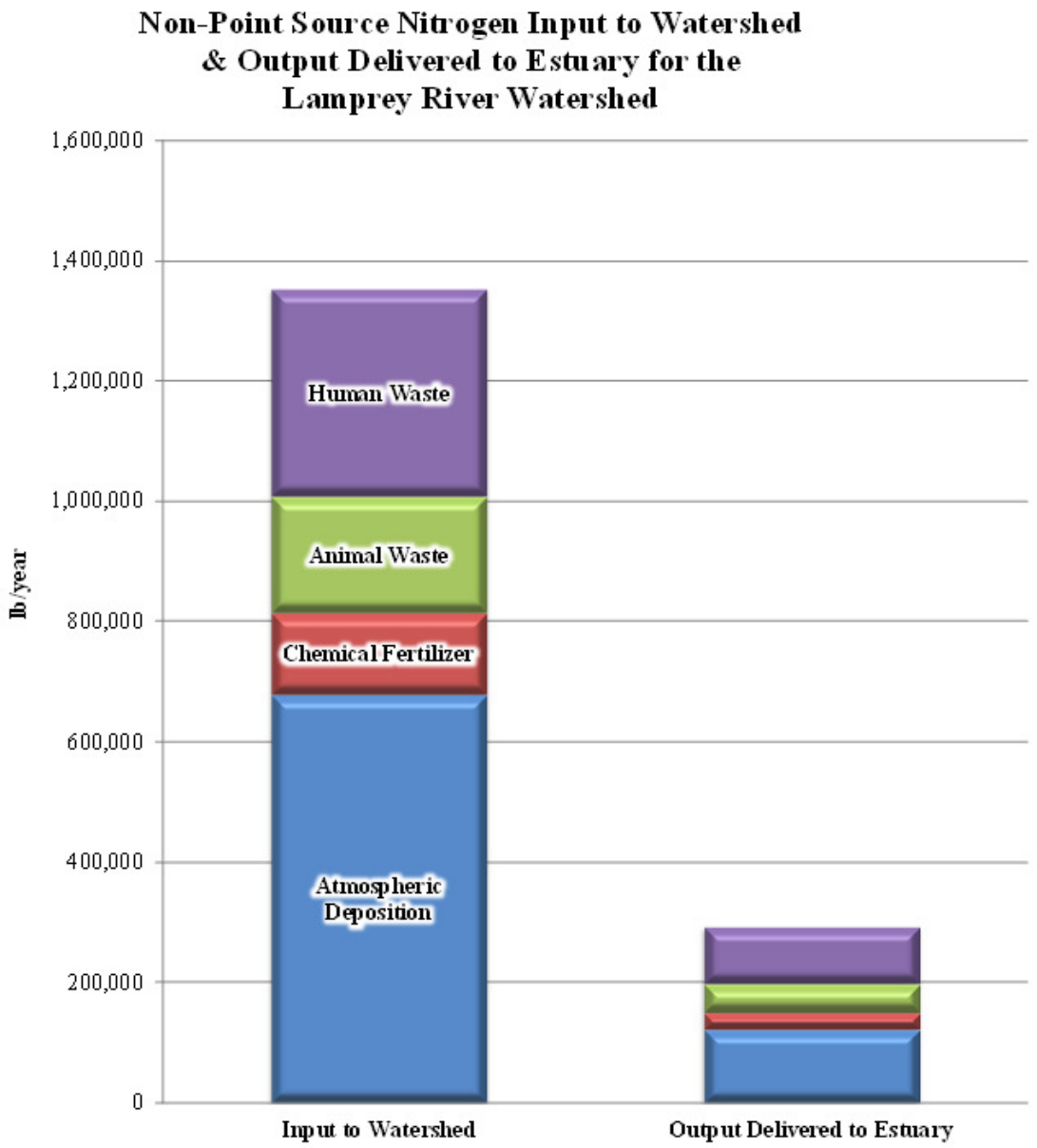
Source	Input to Watershed TN (lb/yr)		Output Delivered to Estuary TN (lb/yr)		TN Lost During Transport
Human Waste	63,080	34%	16,701	35%	*74%*
Animal Waste	18,479	10%	5,491	12%	*70%*
Chemical Fertilizer	49,481	27%	11,852	25%	*76%*
Atmospheric Deposition	54,457	29%	13,345	28%	*75%*
Total =	**185,496**		**47,389**		**74%**

Figure 13: Inputs and Outputs of Non-Point Source Nitrogen by Source Type for the Exeter River Watershed



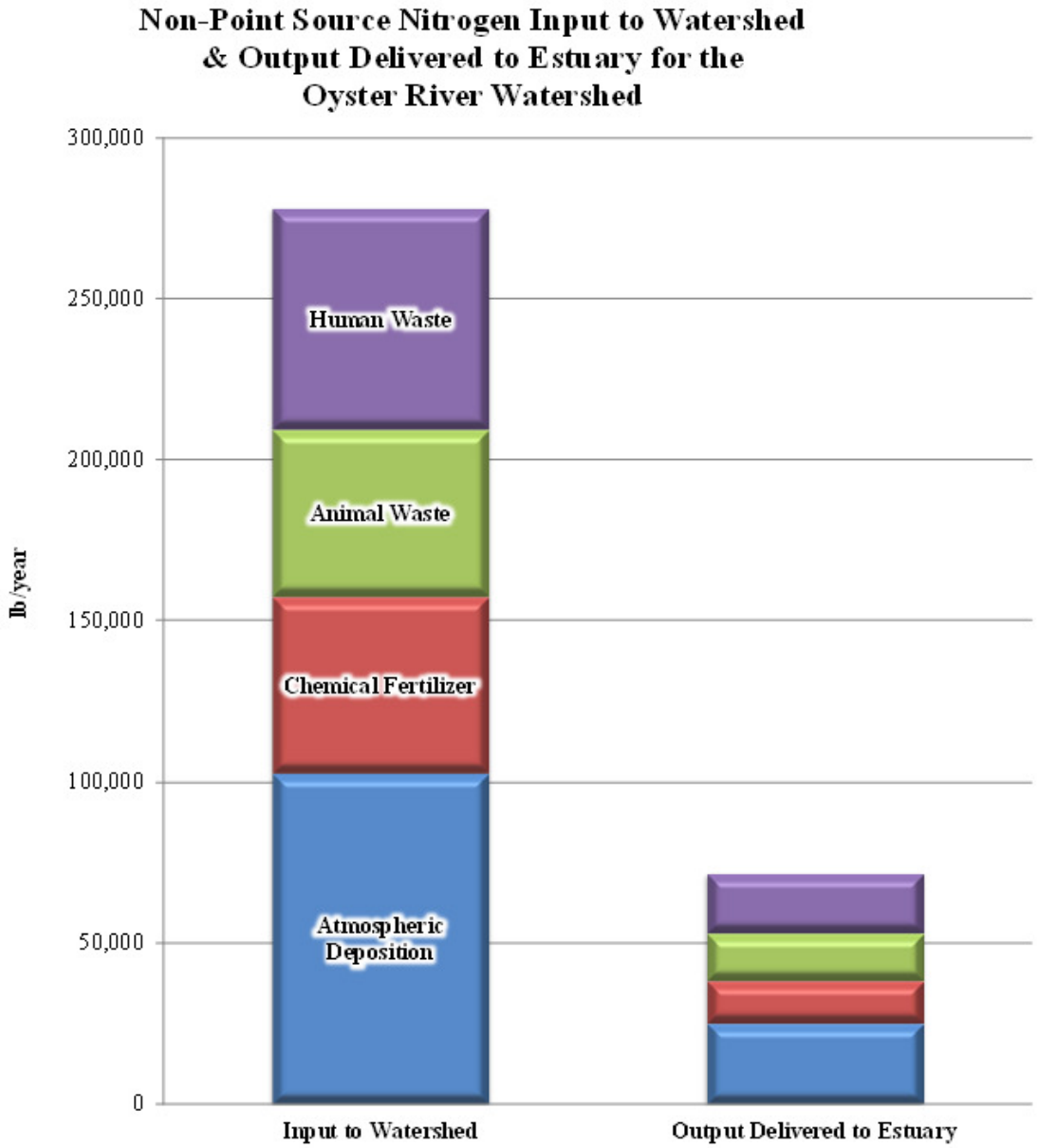
Source	Input to Watershed TN (lb/yr)		Output Delivered to Estuary TN (lb/yr)		TN Lost During Transport
Human Waste	347,770	32%	90,801	37%	*74%*
Animal Waste	124,644	12%	33,649	14%	*73%*
Chemical Fertilizer	183,790	17%	38,866	16%	*79%*
Atmospheric Deposition	417,899	39%	82,729	34%	*80%*
Total =	**1,074,102**		**246,046**		**77%**

Figure 14: Inputs and Outputs of Non-Point Source Nitrogen by Source Type for the Lamprey River Watershed



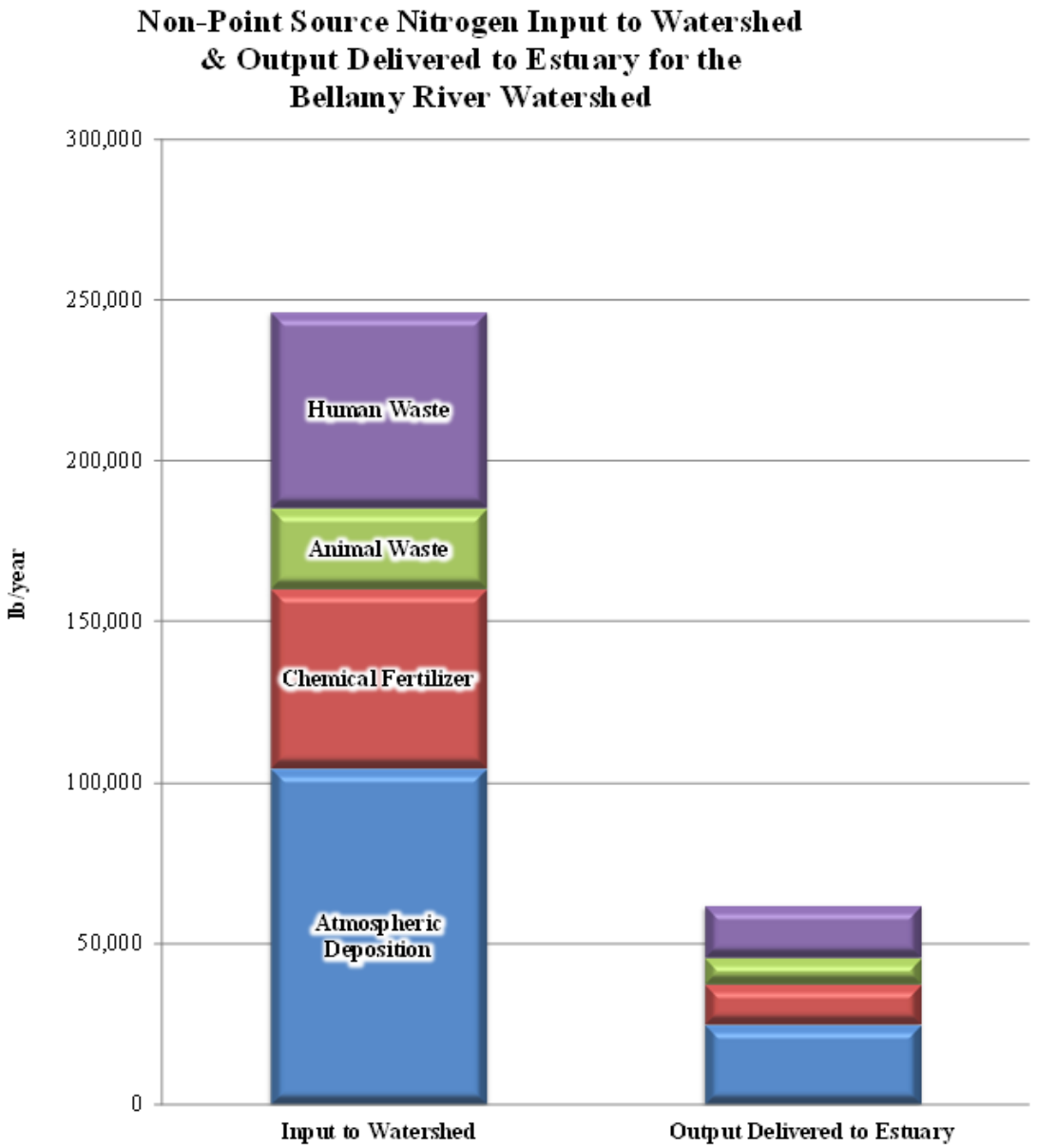
Source	Input to Watershed TN (lb/yr)		Output Delivered to Estuary TN (lb/yr)		TN Lost During Transport
Human Waste	345,102	26%	94,428	32%	*73%*
Animal Waste	193,661	14%	47,835	16%	*75%*
Chemical Fertilizer	135,984	10%	28,269	10%	*79%*
Atmospheric Deposition	678,509	50%	121,813	42%	*82%*
Total =	**1,353,256**		**292,345**		**78%**

Figure 15: Inputs and Outputs of Non-Point Source Nitrogen by Source Type for the Oyster River Watershed



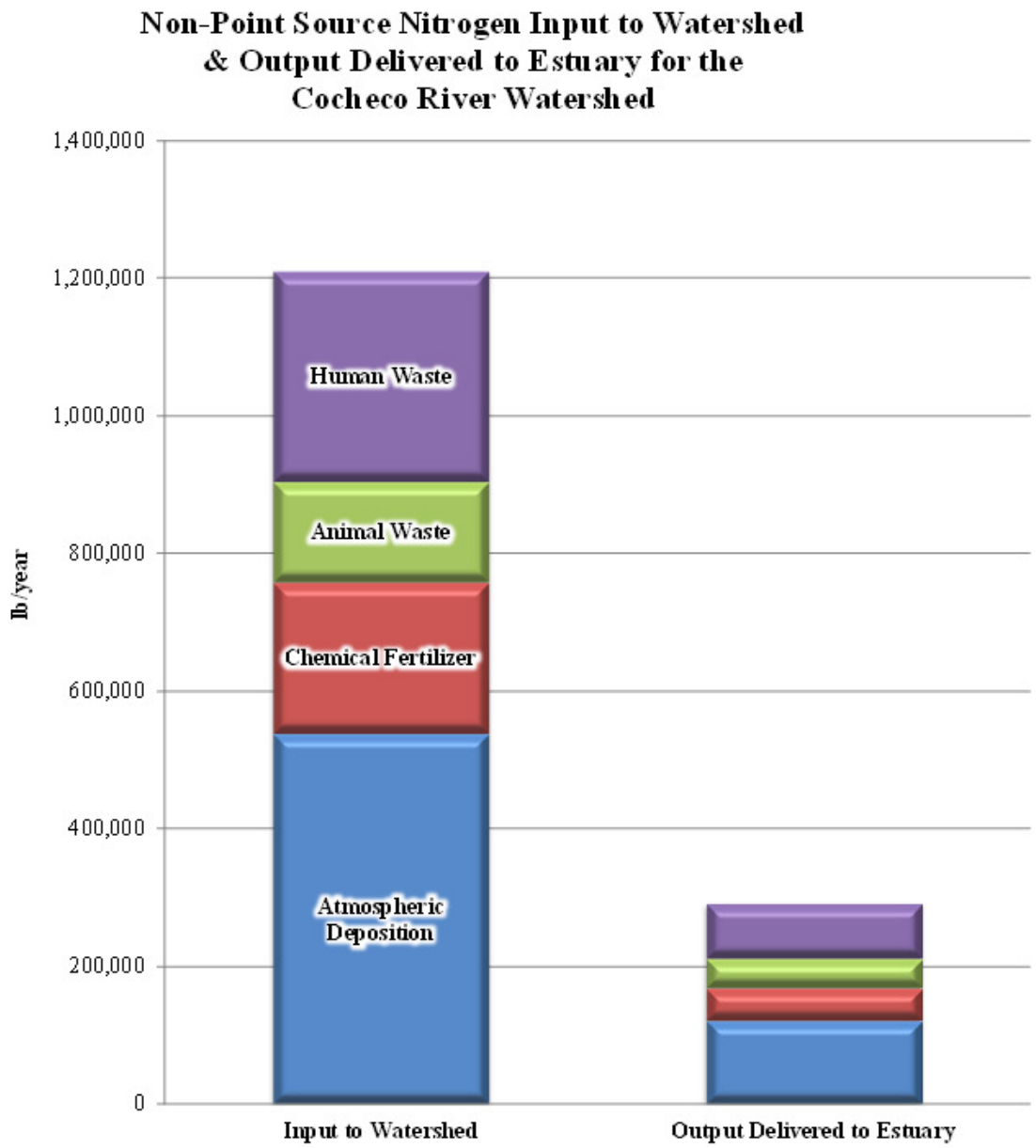
Source	Input to Watershed TN (lb/yr)		Output Delivered to Estuary TN (lb/yr)		TN Lost During Transport
Human Waste	68,744	25%	18,550	26%	*73%*
Animal Waste	51,891	19%	14,821	21%	*71%*
Chemical Fertilizer	54,872	20%	13,184	18%	*76%*
Atmospheric Deposition	102,677	37%	25,021	35%	*76%*
Total =	**278,185**		**71,576**		**74%**

Figure 16: Inputs and Outputs of Non-Point Source Nitrogen by Source Type for the Bellamy River Watershed



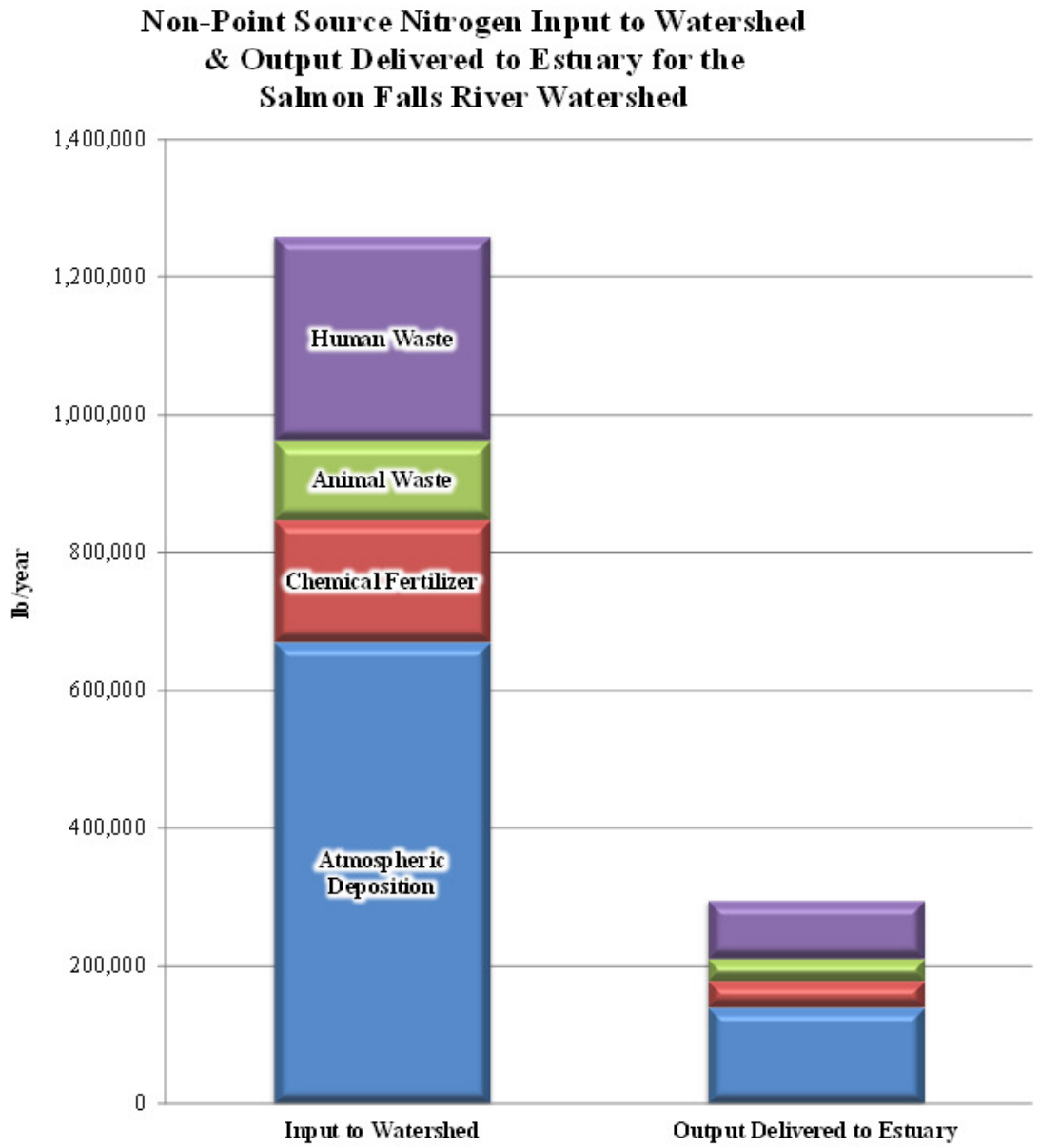
Source	Input to Watershed TN (lb/yr)		Output Delivered to Estuary TN (lb/yr)		TN Lost During Transport
Human Waste	60,979	25%	16,260	26%	*73%*
Animal Waste	25,125	10%	8,184	13%	*67%*
Chemical Fertilizer	55,747	23%	12,583	20%	*77%*
Atmospheric Deposition	104,541	42%	24,833	40%	*76%*
Total =	**246,391**		**61,860**		**75%**

Figure 17: Inputs and Outputs of Non-Point Source Nitrogen by Source Type for the Cocheco River Watershed



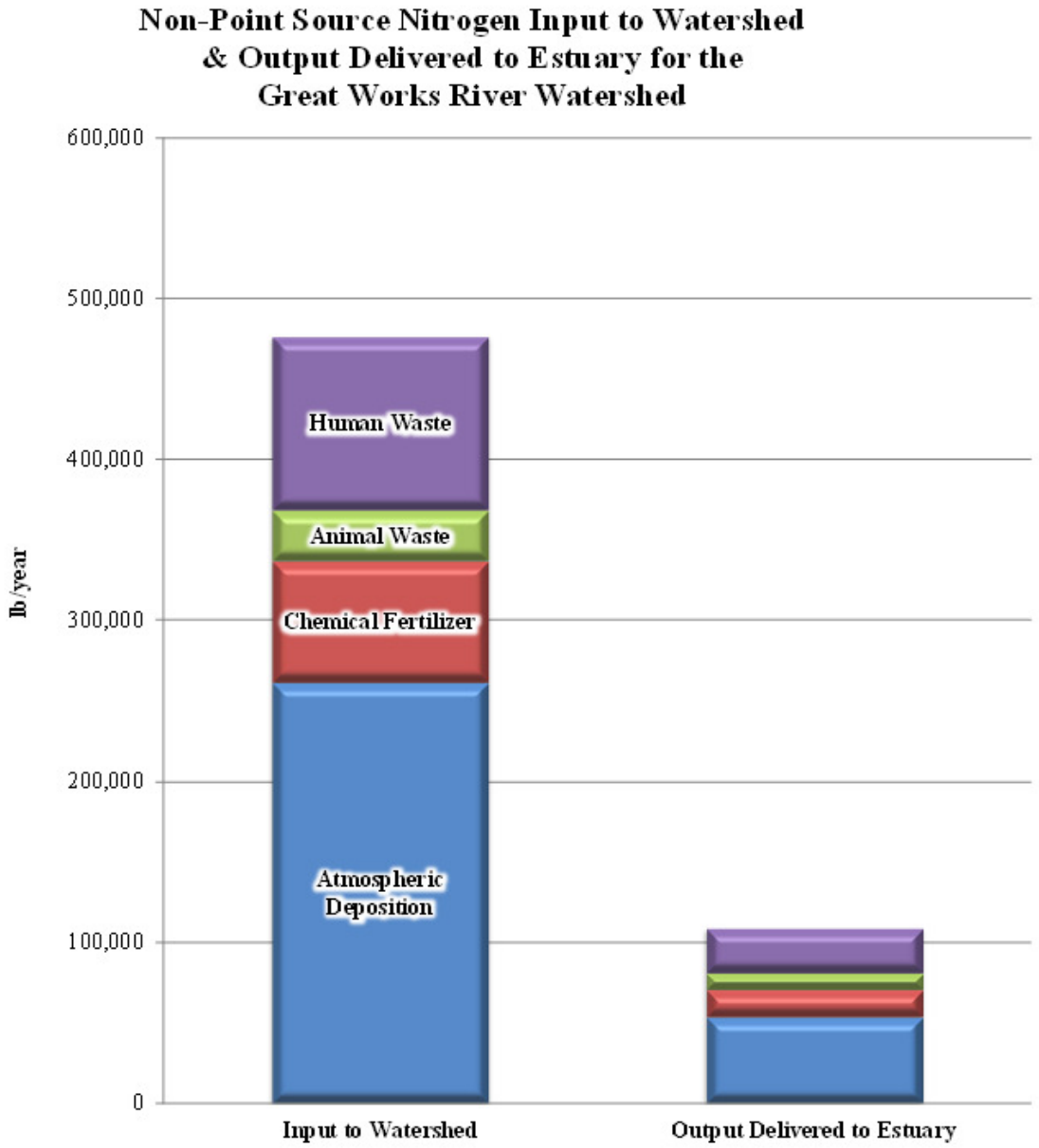
Source	Input to Watershed TN (lb/yr)		Output Delivered to Estuary TN (lb/yr)		TN Lost During Transport
Human Waste	306,144	25%	79,768	27%	*74%*
Animal Waste	146,410	12%	43,005	15%	*71%*
Chemical Fertilizer	220,021	18%	47,442	16%	*78%*
Atmospheric Deposition	538,186	44%	120,857	42%	*78%*
Total =	**1,210,761**		**291,073**		**76%**

Figure 18: Inputs and Outputs of Non-Point Source Nitrogen by Source Type for the Salmon Falls River Watershed



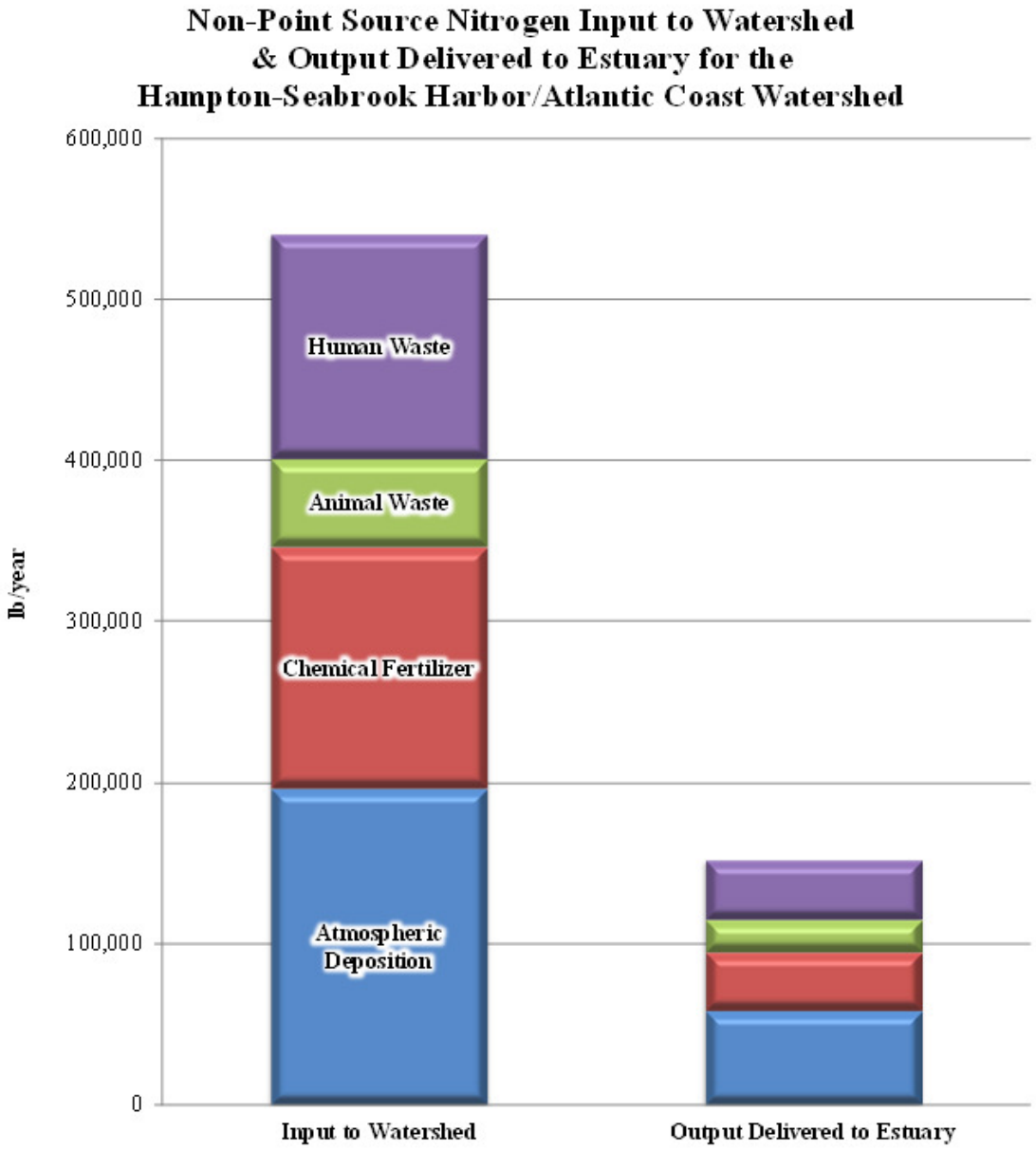
Source	Input to Watershed TN (lb/yr)		Output Delivered to Estuary TN (lb/yr)		TN Lost During Transport
Human Waste	296,965	24%	84,370	29%	*72%*
Animal Waste	114,721	9%	31,925	11%	*72%*
Chemical Fertilizer	177,188	14%	39,038	13%	*78%*
Atmospheric Deposition	670,497	53%	139,642	47%	*79%*
Total =	**1,259,371**		**294,974**		**77%**

Figure 19: Inputs and Outputs of Non-Point Source Nitrogen by Source Type for the Great Works River Watershed



Source	Input to Watershed TN (lb/yr)		Output Delivered to Estuary TN (lb/yr)		TN Lost During Transport
Human Waste	107,780	23%	27,776	26%	*74%*
Animal Waste	31,778	7%	10,208	9%	*68%*
Chemical Fertilizer	75,443	16%	17,137	16%	*77%*
Atmospheric Deposition	261,492	55%	53,535	49%	*80%*
Total =	**476,493**		**108,656**		**77%**

Figure 20: Inputs and Outputs of Non-Point Source Nitrogen by Source Type for the Hampton-Seabrook Harbor/Atlantic Coast Watershed



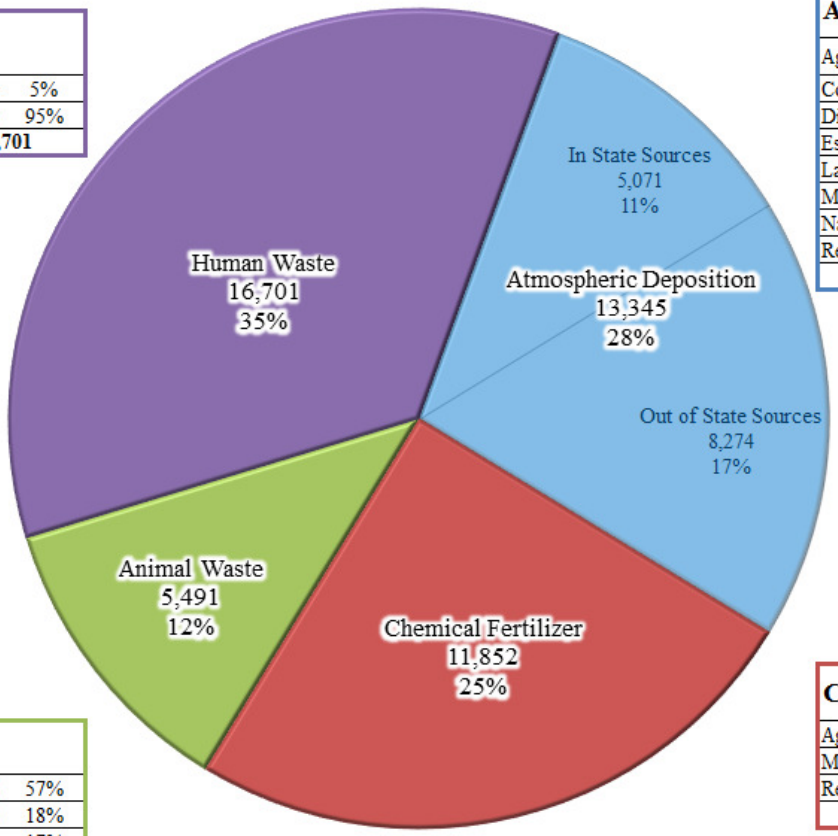
Source	Input to Watershed TN (lb/yr)		Output Delivered to Estuary TN (lb/yr)		TN Lost During Transport
Human Waste	139,433	26%	37,074	24%	*73%*
Animal Waste	54,791	10%	20,108	13%	*63%*
Chemical Fertilizer	150,041	28%	36,385	24%	*76%*
Atmospheric Deposition	196,351	36%	58,381	38%	*70%*
Total =	**540,617**		**151,948**		**72%**

Figure 21: Outputs of Non-Point Source Nitrogen by Source Type and Land Use Type for the Winnicut River Watershed

Non-Point Source Nitrogen Delivered to Estuary
Total Load by Source Type and Land Use Type for the Winnicut River Watershed

Human Waste - TN (lb/yr)		
Septic within 200m of Waterways*	814	5%
Septic >200m from Waterways*	15,888	95%
Total =	**16,701**	

Atmospheric Deposition - TN (lb/yr)		
Agriculture	823	6%
Connected Impervious Area	2,710	20%
Disconnected Impervious Area	2,503	19%
Estuaries	108	1%
Lakes & Rivers	510	4%
Managed Turf	234	1.8%
Natural Vegetation	5,881	44%
Residential Lawns	577	4%
Total =	**13,345**	



Chemical Fertilizer - TN (lb/yr)		
Agriculture	1,225	10%
Managed Turf	3,642	31%
Residential Lawns	6,986	59%
Total =	**11,852**	

Animal Waste - TN (lb/yr)		
Agriculture	3,108	57%
Connected Impervious Area	1,000	18%
Disconnected Impervious Area	941	17%
Residential Lawns	273	5%
Septic within 200m of Waterways*	6	0.1%
Septic >200m from Waterways*	163	3%
Total =	**5,491**	

Total Nitrogen Delivered = 47,389 lb/yr

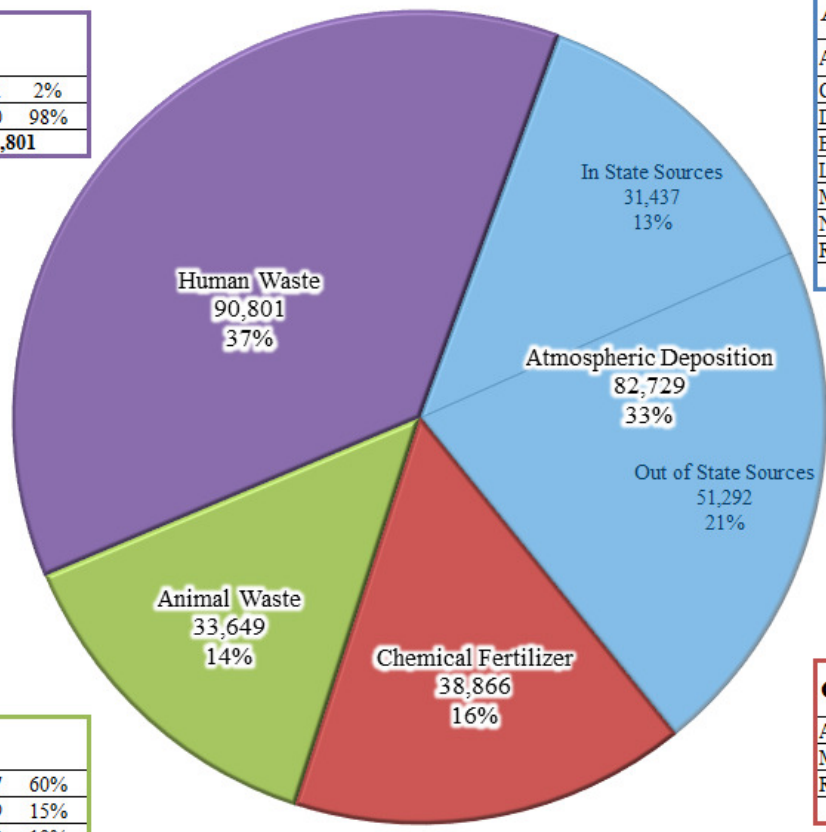
*Waterways include estuaries and 5th order or larger streams

Figure 22: Outputs of Non-Point Source Nitrogen by Source Type and Land Use Type for the Exeter River Watershed

Non-Point Source Nitrogen Delivered to Estuary
Total Load by Source Type and Land Use Type for the Exeter River Watershed

Human Waste - TN (lb/yr)		
Septic within 200m of Waterways*	2,251	2%
Septic >200m from Waterways*	88,550	98%
Total =	**90,801**	

Atmospheric Deposition - TN (lb/yr)		
Agriculture	5,734	7%
Connected Impervious Area	10,373	13%
Disconnected Impervious Area	13,894	17%
Estuaries	2,422	3%
Lakes & Rivers	5,007	6%
Managed Turf	163	0.2%
Natural Vegetation	43,185	52%
Residential Lawns	1,951	2%
Total =	**82,729**	



Chemical Fertilizer - TN (lb/yr)		
Agriculture	12,044	31%
Managed Turf	2,394	6%
Residential Lawns	24,428	63%
Total =	**38,866**	

Animal Waste - TN (lb/yr)		
Agriculture	20,147	60%
Connected Impervious Area	5,059	15%
Disconnected Impervious Area	6,369	19%
Residential Lawns	1,258	4%
Septic within 200m of Waterways*	30	0.1%
Septic >200m from Waterways*	787	2%
Total =	**33,649**	

Total Nitrogen Delivered = 246,046 lb/yr

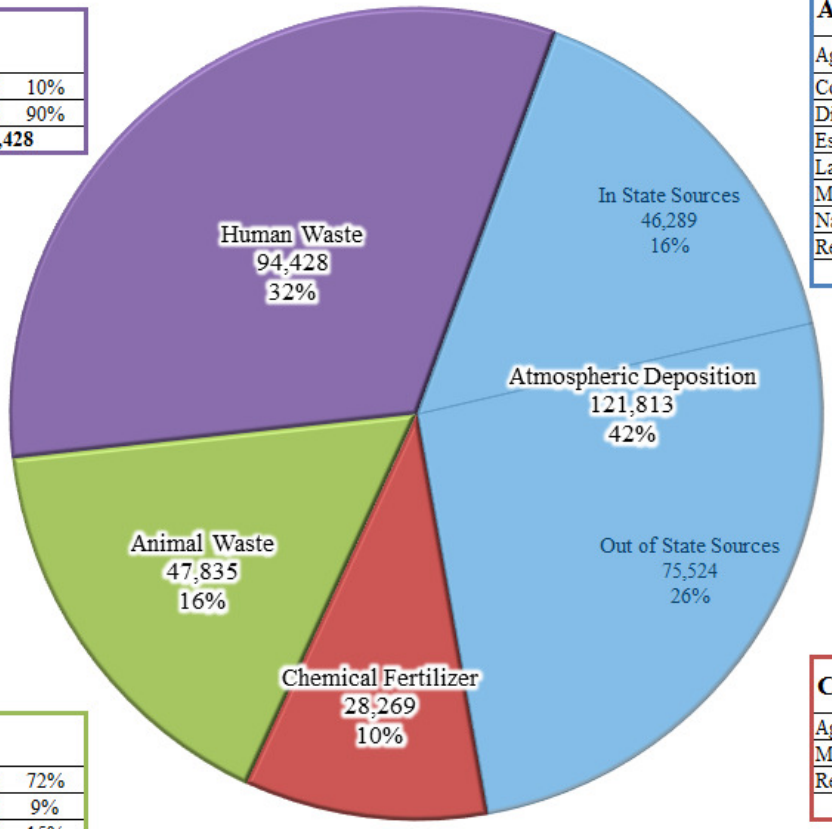
*Waterways include estuaries and 5th order or larger streams

Figure 23: Outputs of Non-Point Source Nitrogen by Source Type and Land Use Type for the Lamprey River Watershed

Non-Point Source Nitrogen Delivered to Estuary
Total Load by Source Type and Land Use Type for the Lamprey River Watershed

Human Waste - TN (lb/yr)		
Septic within 200m of Waterways*	9,806	10%
Septic >200m from Waterways*	84,623	90%
Total =	**94,428**	

Atmospheric Deposition - TN (lb/yr)		
Agriculture	5,226	4%
Connected Impervious Area	9,167	8%
Disconnected Impervious Area	14,545	12%
Estuaries	770	1%
Lakes & Rivers	14,929	12%
Managed Turf	41	0.0%
Natural Vegetation	75,764	62%
Residential Lawns	1,373	1%
Total =	**121,813**	



Chemical Fertilizer - TN (lb/yr)		
Agriculture	10,394	37%
Managed Turf	601	2%
Residential Lawns	17,274	61%
Total =	**28,269**	

Animal Waste - TN (lb/yr)		
Agriculture	34,536	72%
Connected Impervious Area	4,119	9%
Disconnected Impervious Area	7,320	15%
Residential Lawns	858	2%
Septic within 200m of Waterways*	119	0.2%
Septic >200m from Waterways*	883	2%
Total =	**47,835**	

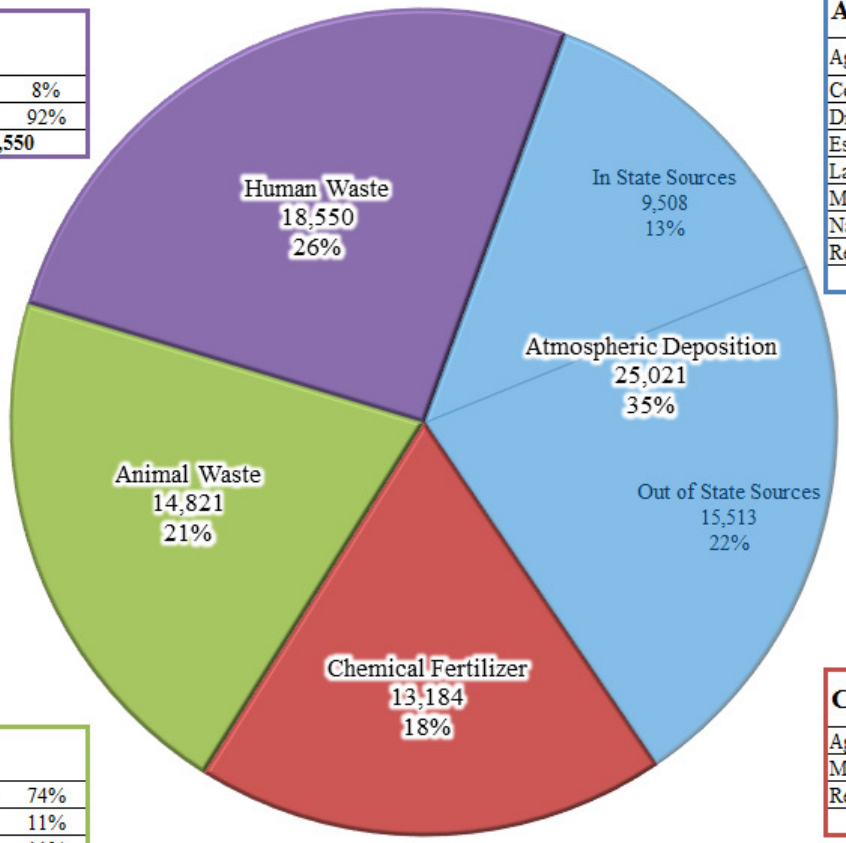
Total Nitrogen Delivered = 292,345 lb/yr

*Waterways include estuaries and 5th order or larger streams

Figure 24: Outputs of Non-Point Source Nitrogen by Source Type and Land Use Type for the Oyster River Watershed

Non-Point Source Nitrogen Delivered to Estuary
Total Load by Source Type and Land Use Type for the Oyster River Watershed

Human Waste - TN (lb/yr)		
Septic within 200m of Waterways*	1,498	8%
Septic >200m from Waterways*	17,052	92%
Total =	**18,550**	



Atmospheric Deposition - TN (lb/yr)		
Agriculture	1,675	7%
Connected Impervious Area	3,438	14%
Disconnected Impervious Area	3,521	14%
Estuaries	1,843	7%
Lakes & Rivers	1,270	5%
Managed Turf	19	0.1%
Natural Vegetation	12,408	50%
Residential Lawns	847	3%
Total =	**25,021**	

Chemical Fertilizer - TN (lb/yr)		
Agriculture	3,120	24%
Managed Turf	367	3%
Residential Lawns	9,697	74%
Total =	**13,184**	

Animal Waste - TN (lb/yr)		
Agriculture	10,966	74%
Connected Impervious Area	1,661	11%
Disconnected Impervious Area	1,562	11%
Residential Lawns	516	3%
Septic within 200m of Waterways*	2	0.0%
Septic >200m from Waterways*	113	1%
Total =	**14,821**	

Total Nitrogen Delivered = 71,576 lb/yr

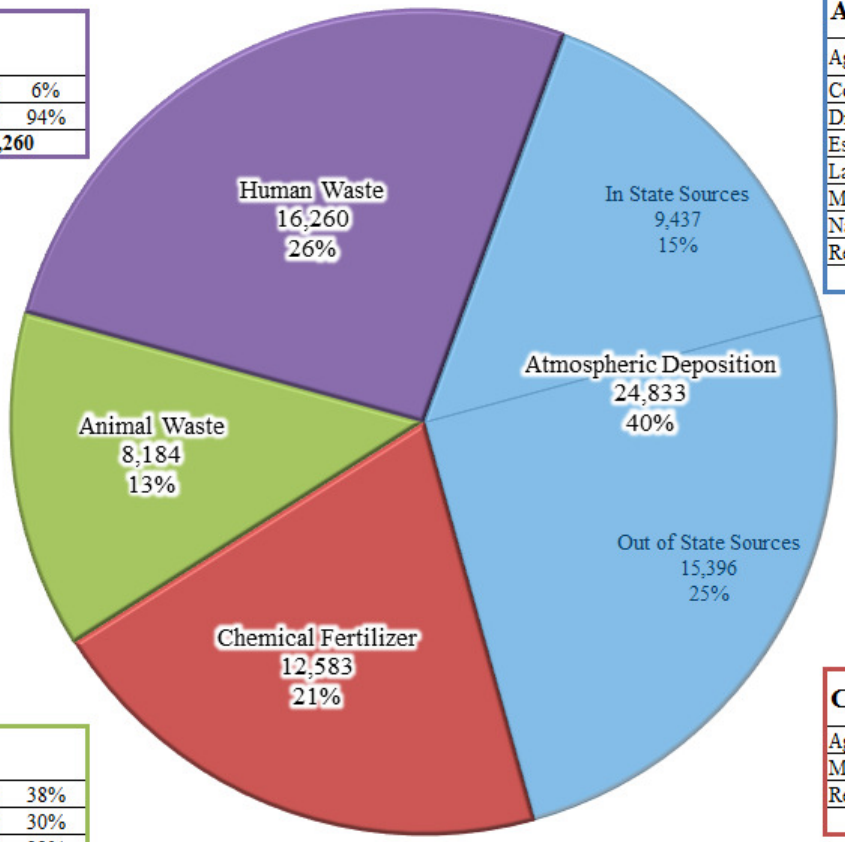
*Waterways include estuaries and 5th order or larger streams

Figure 25: Outputs of Non-Point Source Nitrogen by Source Type and Land Use Type for the Bellamy River Watershed

Non-Point Source Nitrogen Delivered to Estuary
Total Load by Source Type and Land Use Type for the Bellamy River Watershed

Human Waste - TN (lb/yr)		
Septic within 200m of Waterways*	988	6%
Septic >200m from Waterways*	15,272	94%
Total =	**16,260**	

Atmospheric Deposition - TN (lb/yr)		
Agriculture	1,407	6%
Connected Impervious Area	4,025	16%
Disconnected Impervious Area	3,336	13%
Estuaries	2,362	10%
Lakes & Rivers	3,672	15%
Managed Turf	22	0.1%
Natural Vegetation	9,247	37%
Residential Lawns	761	3%
Total =	**24,833**	



Chemical Fertilizer - TN (lb/yr)		
Agriculture	2,577	20%
Managed Turf	607	5%
Residential Lawns	9,400	75%
Total =	**12,583**	

Animal Waste - TN (lb/yr)		
Agriculture	3,135	38%
Connected Impervious Area	2,466	30%
Disconnected Impervious Area	1,808	22%
Residential Lawns	620	8%
Septic within 200m of Waterways*	19	0.2%
Septic >200m from Waterways*	135	2%
Total =	**8,184**	

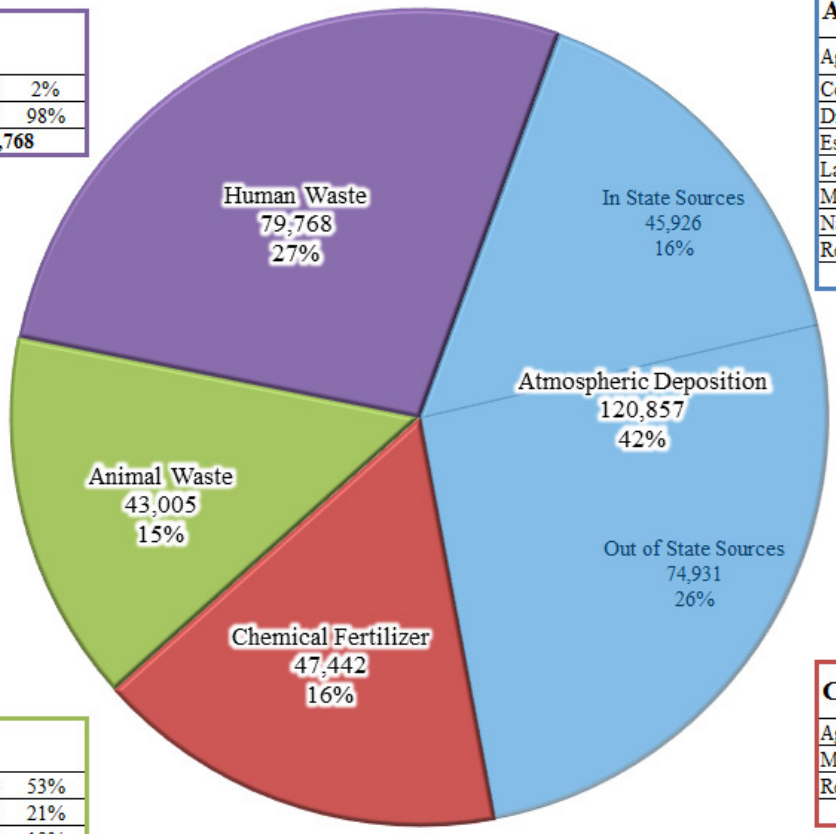
Total Nitrogen Delivered = 61,860 lb/yr

*Waterways include estuaries and 5th order or larger streams

Figure 26: Outputs of Non-Point Source Nitrogen by Source Type and Land Use Type for the Cocheco River Watershed

Non-Point Source Nitrogen Delivered to Estuary
Total Load by Source Type and Land Use Type for the Cocheco River Watershed

Human Waste - TN (lb/yr)		
Septic within 200m of Waterways*	1,692	2%
Septic >200m from Waterways*	78,075	98%
Total =	**79,768**	



Atmospheric Deposition - TN (lb/yr)		
Agriculture	4,778	4%
Connected Impervious Area	15,426	13%
Disconnected Impervious Area	14,341	12%
Estuaries	973	1%
Lakes & Rivers	16,063	13%
Managed Turf	226	0.2%
Natural Vegetation	66,543	55%
Residential Lawns	2,508	2%
Total =	**120,857**	

Chemical Fertilizer - TN (lb/yr)		
Agriculture	10,007	21%
Managed Turf	4,008	8%
Residential Lawns	33,427	70%
Total =	**47,442**	

Animal Waste - TN (lb/yr)		
Agriculture	22,916	53%
Connected Impervious Area	8,951	21%
Disconnected Impervious Area	8,318	19%
Residential Lawns	1,919	4%
Septic within 200m of Waterways*	25	0.1%
Septic >200m from Waterways*	875	2%
Total =	**43,005**	

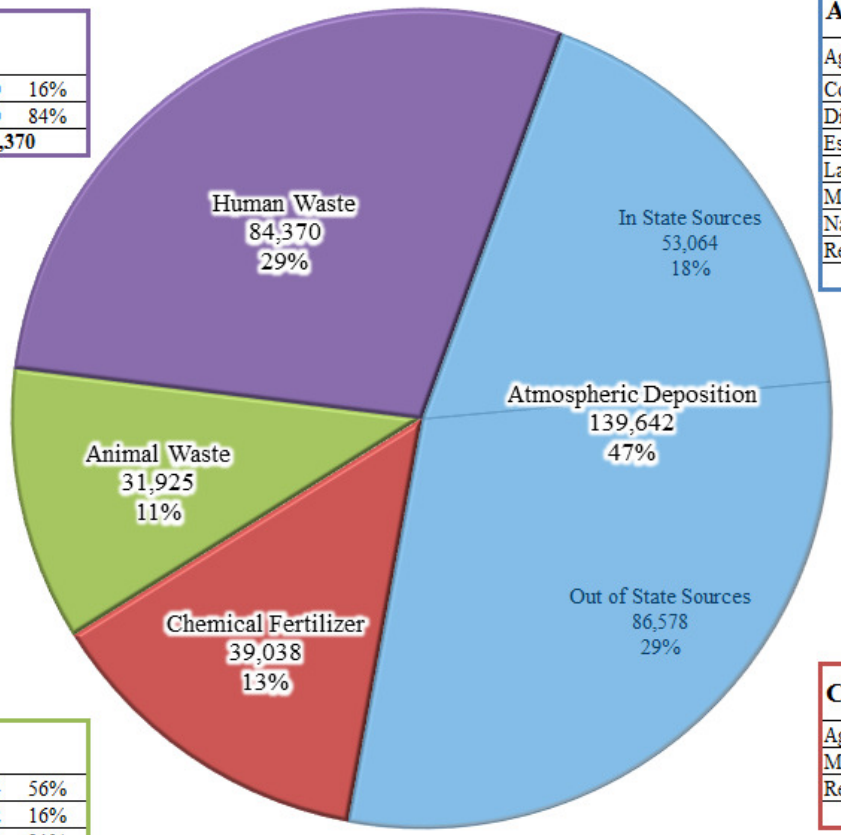
Total Nitrogen Delivered = 291,073 lb/yr

*Waterways include estuaries and 5th order or larger streams

Figure 27: Outputs of Non-Point Source Nitrogen by Source Type and Land Use Type for the Salmon Falls River Watershed

Non-Point Source Nitrogen Delivered to Estuary
Total Load by Source Type and Land Use Type for the Salmon Falls River Watershed

Human Waste - TN (lb/yr)		
Septic within 200m of Waterways*	13,890	16%
Septic >200m from Waterways*	70,480	84%
Total =	**84,370**	



Atmospheric Deposition - TN (lb/yr)		
Agriculture	4,953	4%
Connected Impervious Area	10,291	7%
Disconnected Impervious Area	13,527	10%
Estuaries	1,929	1%
Lakes & Rivers	22,649	16%
Managed Turf	104	0.1%
Natural Vegetation	84,097	60%
Residential Lawns	2,092	1%
Total =	**139,642**	

Chemical Fertilizer - TN (lb/yr)		
Agriculture	8,450	22%
Managed Turf	2,273	6%
Residential Lawns	28,315	73%
Total =	**39,038**	

Animal Waste - TN (lb/yr)		
Agriculture	17,834	56%
Connected Impervious Area	5,052	16%
Disconnected Impervious Area	6,781	21%
Residential Lawns	1,346	4%
Septic within 200m of Waterways*	150	0.5%
Septic >200m from Waterways*	762	2%
Total =	**31,925**	

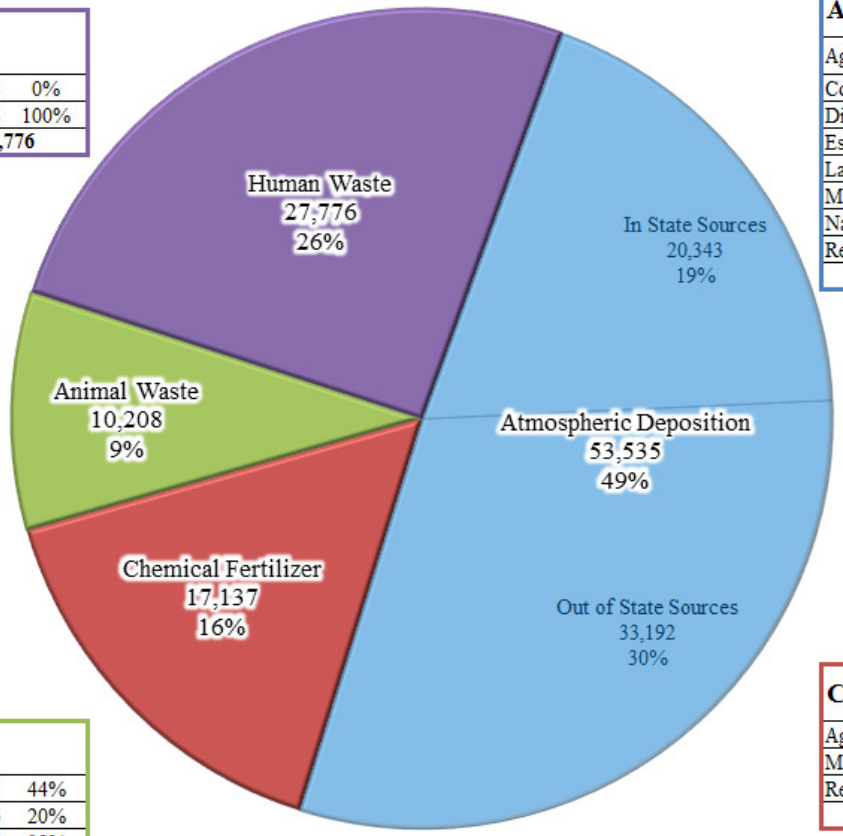
Total Nitrogen Delivered = 294,974 lb/yr

*Waterways include estuaries and 5th order or larger streams

Figure 28: Outputs of Non-Point Source Nitrogen by Source Type and Land Use Type for the Great Works River Watershed

Non-Point Source Nitrogen Delivered to Estuary
Total Load by Source Type and Land Use Type for the Great Works River Watershed

Human Waste - TN (lb/yr)		
Septic within 200m of Waterways*	58	0%
Septic >200m from Waterways*	27,718	100%
Total =	**27,776**	



Atmospheric Deposition - TN (lb/yr)		
Agriculture	3,057	6%
Connected Impervious Area	4,064	8%
Disconnected Impervious Area	5,582	10%
Estuaries	0	0%
Lakes & Rivers	3,553	7%
Managed Turf	108	0.2%
Natural Vegetation	36,426	68%
Residential Lawns	745	1%
Total =	**53,535**	

Chemical Fertilizer - TN (lb/yr)		
Agriculture	5,304	31%
Managed Turf	2,181	13%
Residential Lawns	9,651	56%
Total =	**17,137**	

Animal Waste - TN (lb/yr)		
Agriculture	4,483	44%
Connected Impervious Area	2,036	20%
Disconnected Impervious Area	2,867	28%
Residential Lawns	522	5%
Septic within 200m of Waterways*	1	0.0%
Septic >200m from Waterways*	300	3%
Total =	**10,208**	

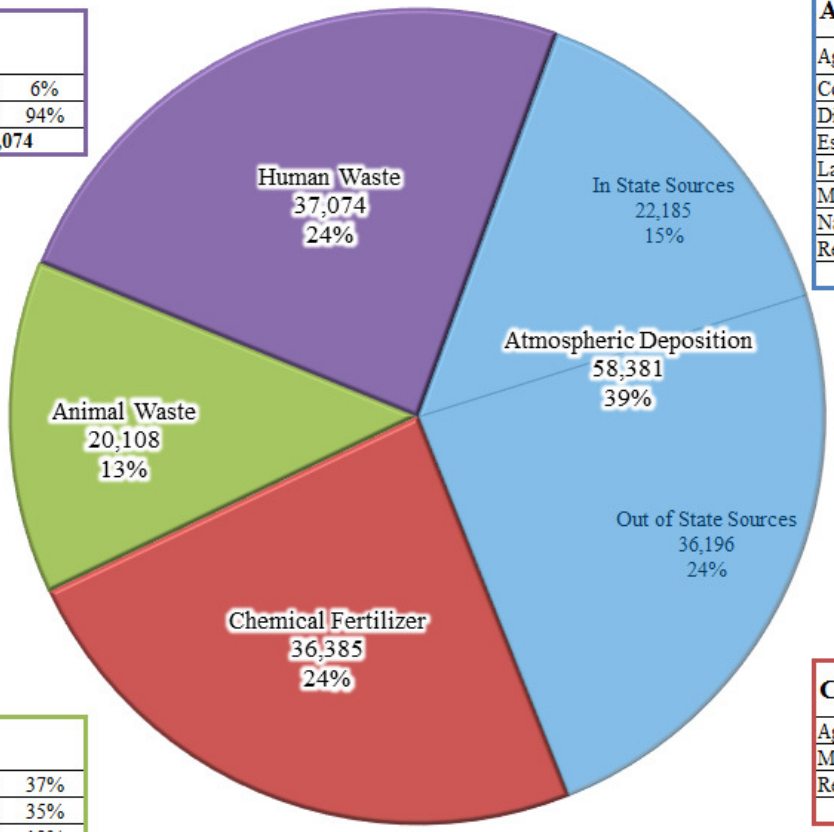
Total Nitrogen Delivered = 108,656 lb/yr

*Waterways include estuaries and 5th order or larger streams

Figure 29: Outputs of Non-Point Source Nitrogen by Source Type and Land Use Type for the Hampton-Seabrook Harbor/Atlantic Coast Watershed

Non-Point Source Nitrogen Delivered to Estuary
Total Load by Source Type and Land Use Type for the Hampton-Seabrook Harbor/Atlantic Coast Watershed

Human Waste - TN (lb/yr)		
Septic within 200m of Waterways*	2,074	6%
Septic >200m from Waterways*	35,000	94%
Total =	**37,074**	



Atmospheric Deposition - TN (lb/yr)		
Agriculture	1,429	2%
Connected Impervious Area	14,267	24%
Disconnected Impervious Area	8,696	15%
Estuaries	6,647	11%
Lakes & Rivers	2,879	5%
Managed Turf	66	0.1%
Natural Vegetation	21,905	38%
Residential Lawns	2,493	4%
Total =	**58,381**	

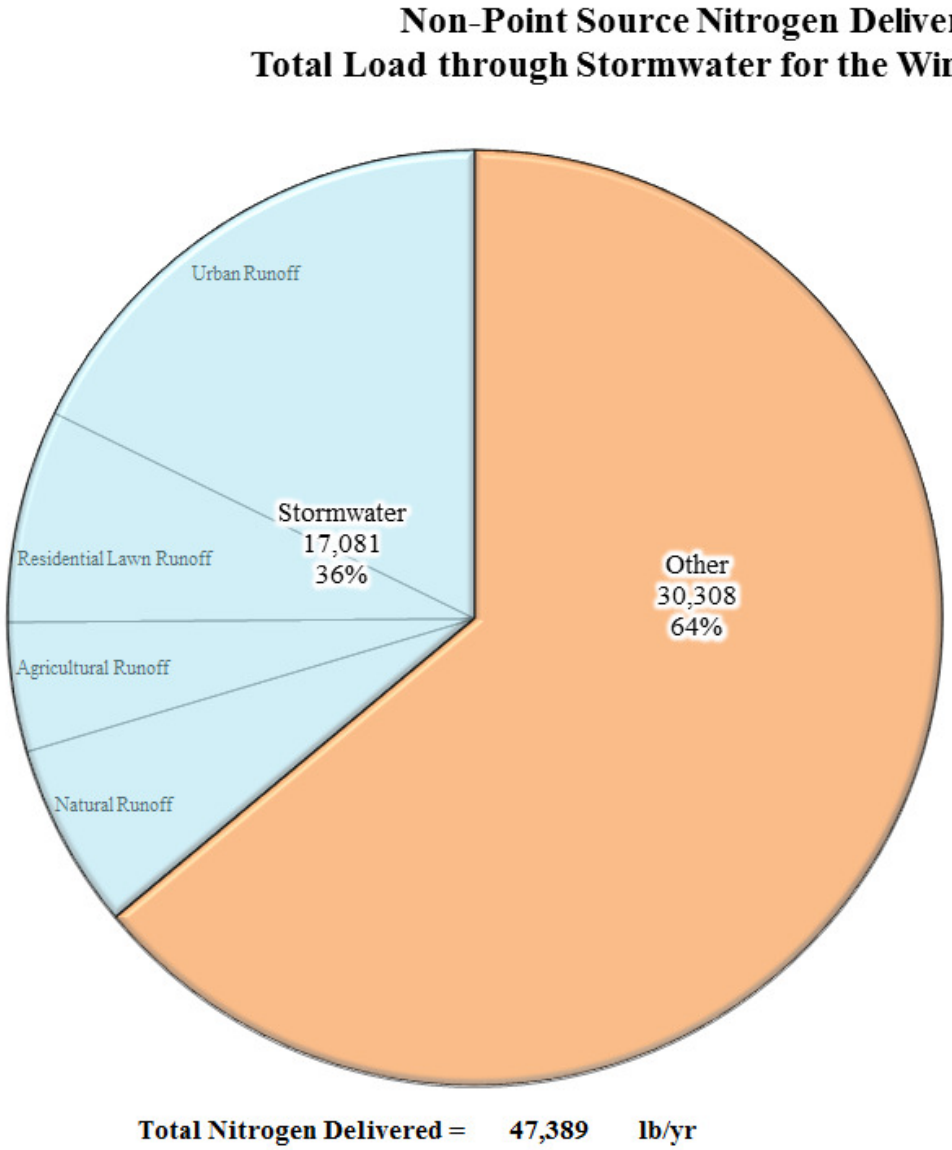
Chemical Fertilizer - TN (lb/yr)		
Agriculture	4,669	13%
Managed Turf	2,424	7%
Residential Lawns	29,291	81%
Total =	**36,385**	

Animal Waste - TN (lb/yr)		
Agriculture	7,375	37%
Connected Impervious Area	7,050	35%
Disconnected Impervious Area	3,920	19%
Residential Lawns	1,450	7%
Septic within 200m of Waterways*	29	0.1%
Septic >200m from Waterways*	284	1%
Total =	**20,108**	

Total Nitrogen Delivered = 151,948 lb/yr

*Waterways include estuaries and 5th order or larger streams

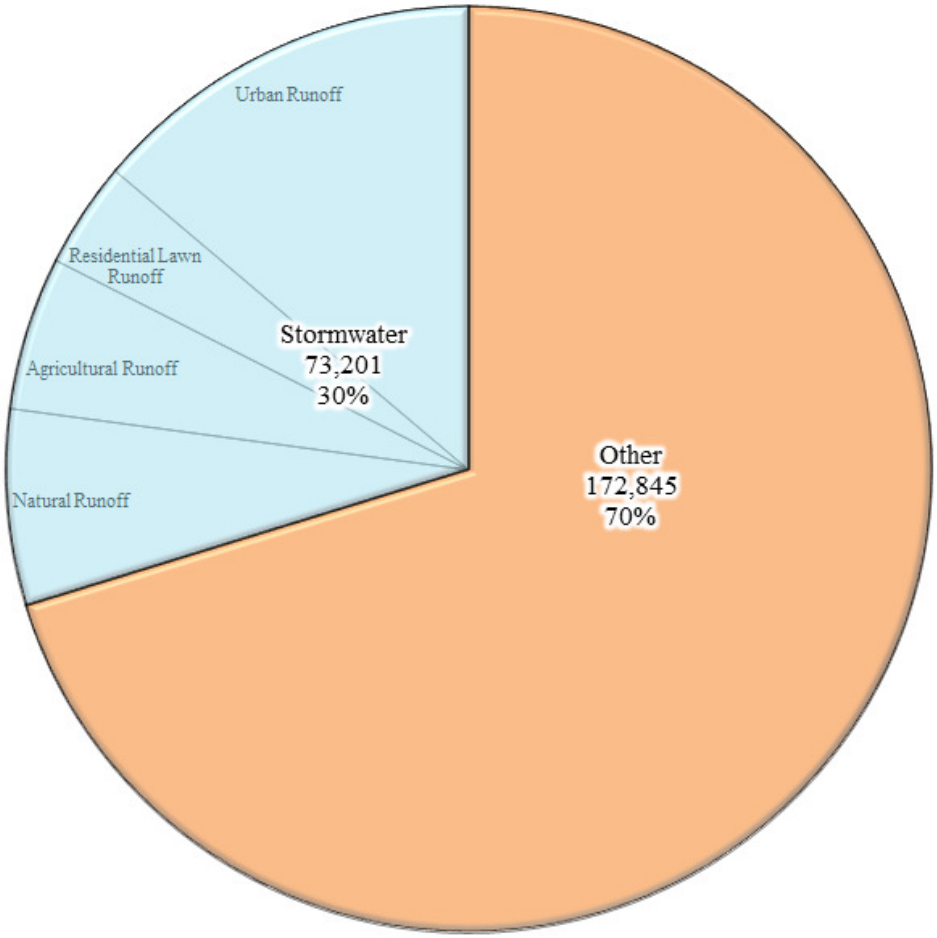
Figure 30: Outputs of Non-Point Source Nitrogen Delivered Through Stormwater for the Winnicut River Watershed



Stormwater Delivered Load - TN (lb/yr)			
Agricultural Runoff – 12% of Stormwater – 4% of all Pathways			
Agriculture	Animal Waste	1,221	58%
	Atmospheric Deposition	419	20%
	Chemical Fertilizer	481	23%
	Sub-Total =	**2,120**	
Residential Lawn Runoff – 20% of Stormwater – 7% of all Pathways			
Residential Lawns	Animal Waste	121	3%
	Atmospheric Deposition	320	9%
	Chemical Fertilizer	3,047	87%
	Sub-Total =	**3,488**	
Urban Runoff – 49% of Stormwater – 18% of all Pathways			
Connected Impervious Area	Animal Waste	1,000	12%
	Atmospheric Deposition	2,710	32%
Disconnected Impervious Area	Animal Waste	846	10%
	Atmospheric Deposition	2,239	27%
Managed Turf	Atmospheric Deposition	41.5	0.5%
	Chemical Fertilizer	1,581	19%
	Sub-Total =	**8,417**	
Natural Runoff – 18% of Stormwater – 6% of all Pathways			
Natural Vegetation	Atmospheric Deposition	3,055	100%
	Sub-Total =	**3,055**	
	Stormwater Total =	**17,081**	
	Total of all Pathways =	**47,389**	

Figure 31: Outputs of Non-Point Source Nitrogen Delivered Through Stormwater for the Exeter River Watershed

Non-Point Source Nitrogen Delivered to Estuary
Total Load through Stormwater for the Exeter River Watershed

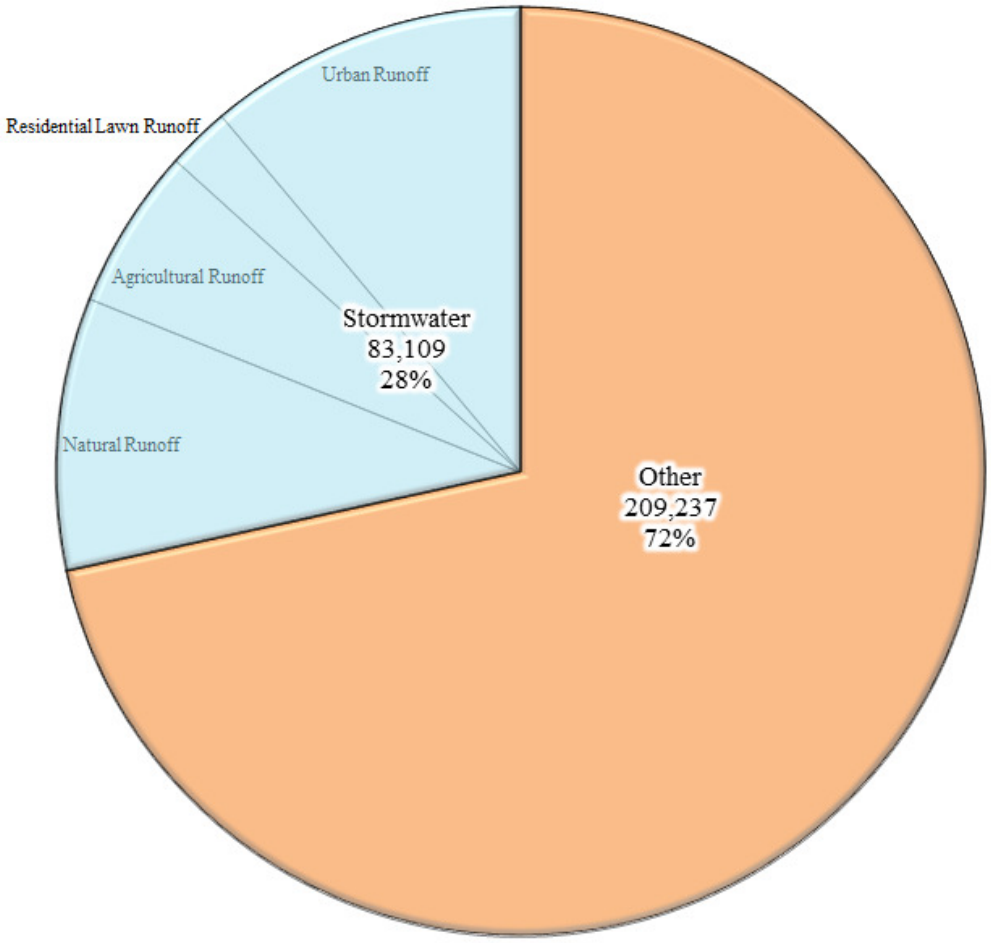


Stormwater Delivered Load - TN (lb/yr)			
Agricultural Runoff – 18% of Stormwater – 5% of all Pathways			
Agriculture	Animal Waste	6,614	50%
	Atmospheric Deposition	2,554	19%
	Chemical Fertilizer	4,007	30%
	Sub-Total =	**13,175**	
Residential Lawn Runoff – 12% of Stormwater – 4% of all Pathways			
Residential Lawns	Animal Waste	412	5%
	Atmospheric Deposition	839	9%
	Chemical Fertilizer	7,867	86%
	Sub-Total =	**9,117**	
Urban Runoff – 46% of Stormwater – 14% of all Pathways			
Connected Impervious Area	Animal Waste	5,059	15%
	Atmospheric Deposition	10,373	30%
Disconnected Impervious Area	Animal Waste	5,574	16%
	Atmospheric Deposition	12,147	36%
Managed Turf	Atmospheric Deposition	28.2	0.1%
	Chemical Fertilizer	830	2%
	Sub-Total =	**34,011**	
Natural Runoff – 23% of Stormwater – 7% of all Pathways			
Natural Vegetation	Atmospheric Deposition	16,897	100%
	Sub-Total =	**16,897**	
	Stormwater Total =	**73,201**	
	Total of all Pathways =	**246,046**	

Total Nitrogen Delivered = 246,046 lb/yr

Figure 32: Outputs of Non-Point Source Nitrogen Delivered Through Stormwater for the Lamprey River Watershed

Non-Point Source Nitrogen Delivered to Estuary
Total Load through Stormwater for the Lamprey River Watershed

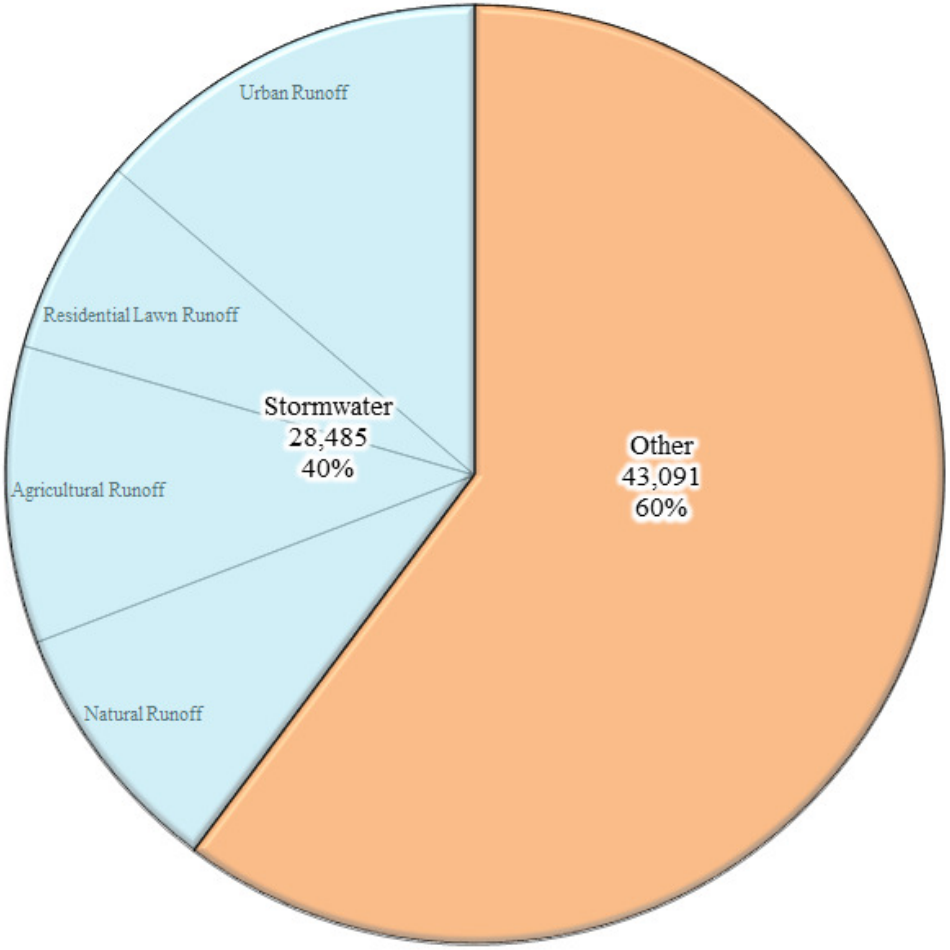


Total Nitrogen Delivered = 292,345 lb/yr

Stormwater Delivered Load - TN (lb/yr)			
Agricultural Runoff – 20% of Stormwater – 6% of all Pathways			
Agriculture	Animal Waste	11,110	68%
	Atmospheric Deposition	2,204	13%
	Chemical Fertilizer	3,100	19%
	Sub-Total =	**16,415**	
Residential Lawn Runoff – 8% of Stormwater – 2% of all Pathways			
Residential Lawns	Animal Waste	288	5%
	Atmospheric Deposition	591	9%
	Chemical Fertilizer	5,522	86%
	Sub-Total =	**6,402**	
Urban Runoff – 39% of Stormwater – 11% of all Pathways			
Connected Impervious Area	Animal Waste	4,119	13%
	Atmospheric Deposition	9,167	28%
Disconnected Impervious Area	Animal Waste	6,387	20%
	Atmospheric Deposition	12,635	39%
Managed Turf	Atmospheric Deposition	6.0	0.0%
	Chemical Fertilizer	184	1%
	Sub-Total =	**32,498**	
Natural Runoff – 33% of Stormwater – 10% of all Pathways			
Natural Vegetation	Atmospheric Deposition	27,793	100%
	Sub-Total =	**27,793**	
	Stormwater Total =	**83,109**	
	Total of all Pathways =	**292,345**	

Figure 33: Outputs of Non-Point Source Nitrogen Delivered Through Stormwater for the Oyster River Watershed

Non-Point Source Nitrogen Delivered to Estuary
Total Load through Stormwater for the Oyster River Watershed

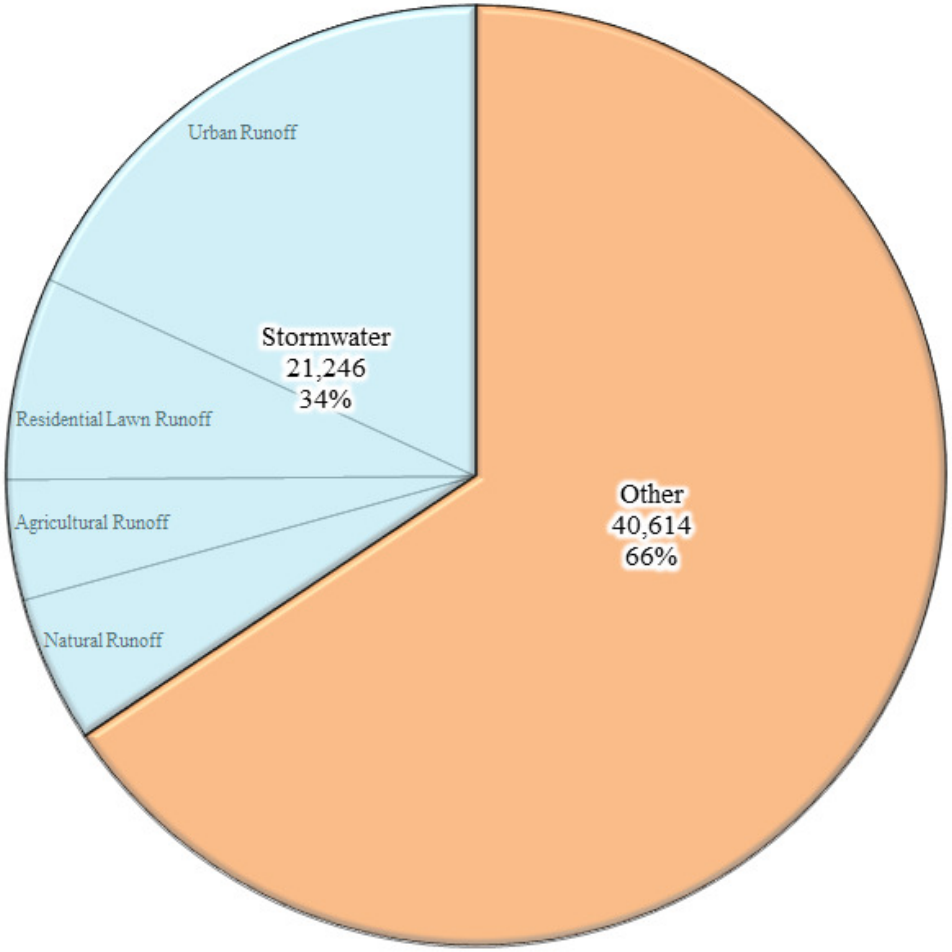


Total Nitrogen Delivered = 71,576 lb/yr

Stormwater Delivered Load - TN (lb/yr)			
Agricultural Runoff – 26% of Stormwater – 10% of all Pathways			
Agriculture	Animal Waste	5,029	69%
	Atmospheric Deposition	933	13%
	Chemical Fertilizer	1,374	19%
	Sub-Total =	**7,336**	
Residential Lawn Runoff – 17% of Stormwater – 7% of all Pathways			
Residential Lawns	Animal Waste	220	5%
	Atmospheric Deposition	465	10%
	Chemical Fertilizer	4,187	86%
	Sub-Total =	**4,872**	
Urban Runoff – 35% of Stormwater – 14% of all Pathways			
Connected Impervious Area	Animal Waste	1,661	17%
	Atmospheric Deposition	3,438	35%
Disconnected Impervious Area	Animal Waste	1,410	14%
	Atmospheric Deposition	3,176	32%
Managed Turf	Atmospheric Deposition	3.5	0.0%
	Chemical Fertilizer	154	2%
	Sub-Total =	**9,843**	
Natural Runoff – 23% of Stormwater – 9% of all Pathways			
Natural Vegetation	Atmospheric Deposition	6,434	100%
	Sub-Total =	**6,434**	
	Stormwater Total =	**28,485**	
	Total of all Pathways =	**71,576**	

Figure 34: Outputs of Non-Point Source Nitrogen Delivered Through Stormwater for the Bellamy River Watershed

Non-Point Source Nitrogen Delivered to Estuary
Total Load through Stormwater for the Bellamy River Watershed

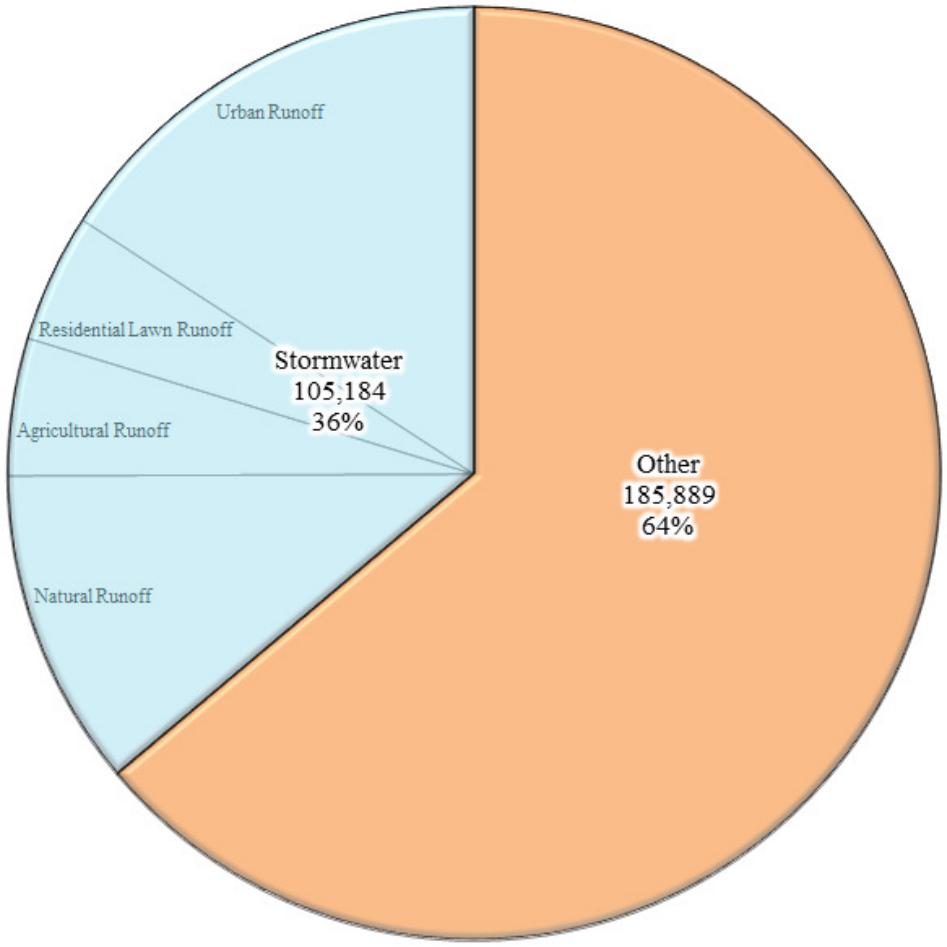


Stormwater Delivered Load - TN (lb/yr)			
Agricultural Runoff - 12% of Stormwater - 4% of all Pathways			
Agriculture	Animal Waste	1,000	39%
	Atmospheric Deposition	668	26%
	Chemical Fertilizer	898	35%
	Sub-Total =	**2,565**	
Residential Lawn Runoff - 20% of Stormwater - 7% of all Pathways			
Residential Lawns	Animal Waste	255	6%
	Atmospheric Deposition	388	9%
	Chemical Fertilizer	3,683	85%
	Sub-Total =	**4,326**	
Urban Runoff - 53% of Stormwater - 18% of all Pathways			
Connected Impervious Area	Animal Waste	2,466	22%
	Atmospheric Deposition	4,025	36%
Disconnected Impervious Area	Animal Waste	1,587	14%
	Atmospheric Deposition	2,888	26%
Managed Turf	Atmospheric Deposition	3.9	0.0%
	Chemical Fertilizer	239	2%
	Sub-Total =	**11,208**	
Natural Runoff - 15% of Stormwater - 5% of all Pathways			
Natural Vegetation	Atmospheric Deposition	3,146	100%
	Sub-Total =	**3,146**	
	Stormwater Total =	**21,246**	
	Total of all Pathways =	**61,860**	

Total Nitrogen Delivered = 61,860 lb/yr

Figure 35: Outputs of Non-Point Source Nitrogen Delivered Through Stormwater for the Cocheco River Watershed

Non-Point Source Nitrogen Delivered to Estuary
Total Load through Stormwater for the Cocheco River Watershed

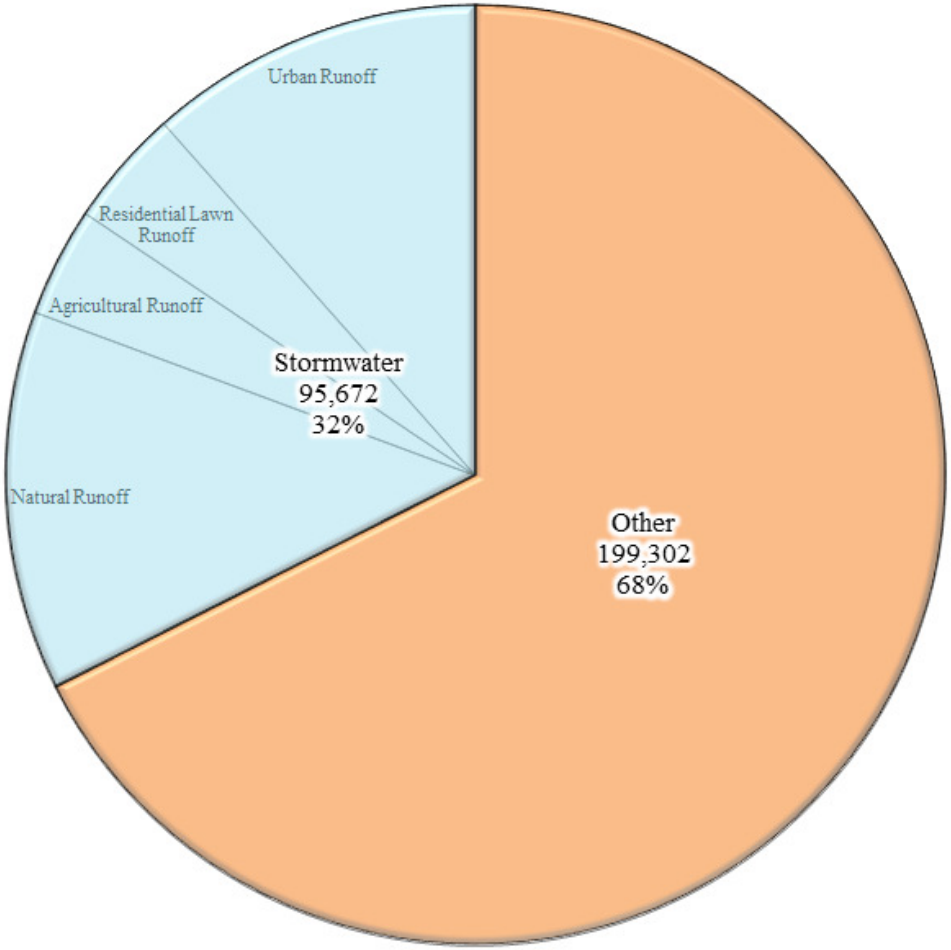


Total Nitrogen Delivered = 291,073 lb/yr

Stormwater Delivered Load - TN (lb/yr)			
Agricultural Runoff - 13% of Stormwater - 5% of all Pathways			
Agriculture	Animal Waste	7,945	57%
	Atmospheric Deposition	2,298	17%
	Chemical Fertilizer	3,629	26%
	Sub-Total =	**13,871**	
Residential Lawn Runoff - 12% of Stormwater - 4% of all Pathways			
Residential Lawns	Animal Waste	674	5%
	Atmospheric Deposition	1,129	9%
	Chemical Fertilizer	11,166	86%
	Sub-Total =	**12,968**	
Urban Runoff - 44% of Stormwater - 16% of all Pathways			
Connected Impervious Area	Animal Waste	8,951	19%
	Atmospheric Deposition	15,426	33%
Disconnected Impervious Area	Animal Waste	7,415	16%
	Atmospheric Deposition	12,756	28%
Managed Turf	Atmospheric Deposition	39.1	0.1%
	Chemical Fertilizer	1,526	3%
	Sub-Total =	**46,114**	
Natural Runoff - 31% of Stormwater - 11% of all Pathways			
Natural Vegetation	Atmospheric Deposition	32,231	100%
	Sub-Total =	**32,231**	
	Stormwater Total =	**105,184**	
	Total of all Pathways =	**291,073**	

Figure 36: Outputs of Non-Point Source Nitrogen Delivered Through Stormwater for the Salmon Falls River Watershed

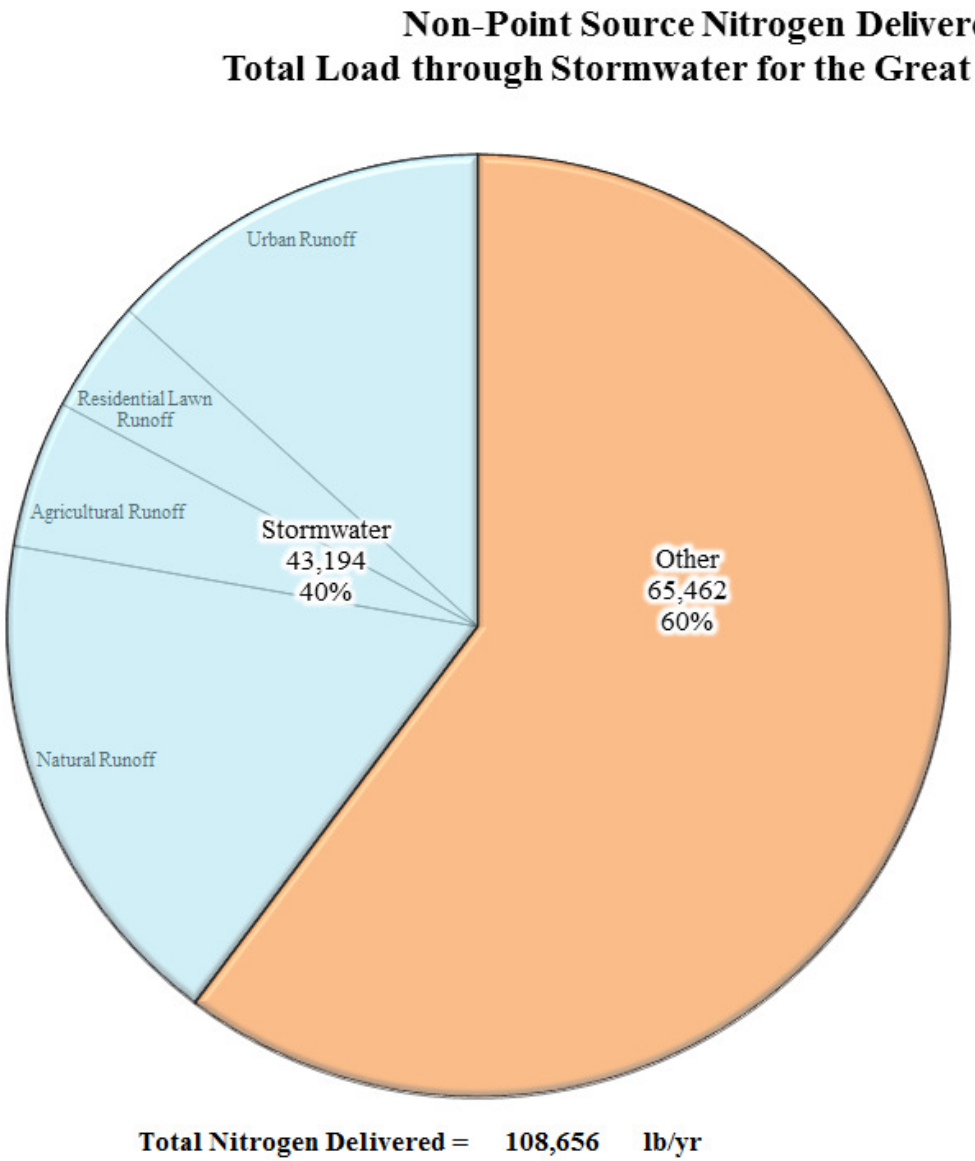
Non-Point Source Nitrogen Delivered to Estuary
Total Load through Stormwater for the Salmon Falls River Watershed



Stormwater Delivered Load - TN (lb/yr)			
Agricultural Runoff - 12% of Stormwater - 4% of all Pathways			
Agriculture	Animal Waste	5,827	52%
	Atmospheric Deposition	2,310	21%
	Chemical Fertilizer	2,978	27%
	Sub-Total =	**11,116**	
Residential Lawn Runoff - 12% of Stormwater - 4% of all Pathways			
Residential Lawns	Animal Waste	483	4%
	Atmospheric Deposition	1,017	9%
	Chemical Fertilizer	10,442	87%
	Sub-Total =	**11,941**	
Urban Runoff - 36% of Stormwater - 12% of all Pathways			
Connected Impervious Area	Animal Waste	5,052	15%
	Atmospheric Deposition	10,291	30%
Disconnected Impervious Area	Animal Waste	5,976	18%
	Atmospheric Deposition	11,956	35%
Managed Turf	Atmospheric Deposition	15.8	0.0%
	Chemical Fertilizer	734	2%
	Sub-Total =	**34,024**	
Natural Runoff - 40% of Stormwater - 13% of all Pathways			
Natural Vegetation	Atmospheric Deposition	38,590	100%
	Sub-Total =	**38,590**	
	Stormwater Total =	**95,672**	
	Total of all Pathways =	**294,974**	

Total Nitrogen Delivered = 294,974 lb/yr

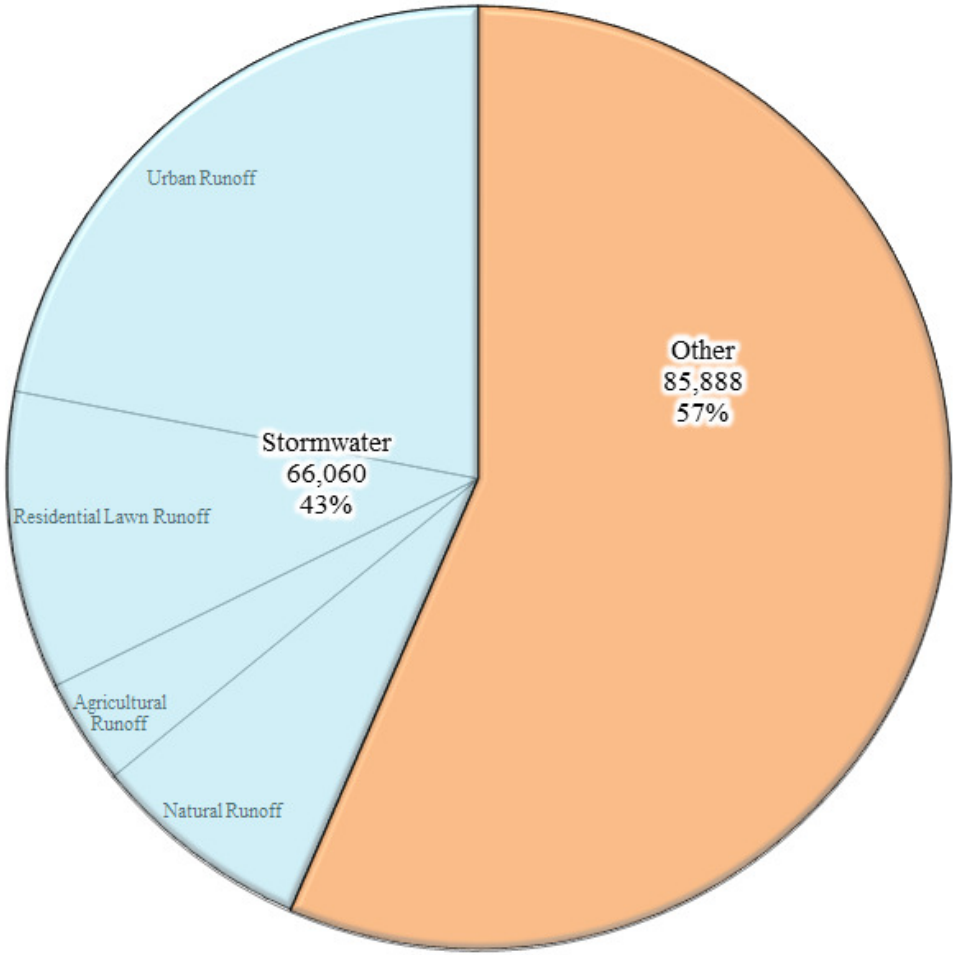
Figure 37: Outputs of Non-Point Source Nitrogen Delivered Through Stormwater for the Great Works River Watershed



Stormwater Delivered Load - TN (lb/yr)			
Agricultural Runoff – 13% of Stormwater – 5% of all Pathways			
Agriculture	Animal Waste	1,754	32%
	Atmospheric Deposition	1,594	29%
	Chemical Fertilizer	2,171	39%
	Sub-Total =	**5,519**	
Residential Lawn Runoff – 10% of Stormwater – 4% of all Pathways			
Residential Lawns	Animal Waste	199	5%
	Atmospheric Deposition	368	9%
	Chemical Fertilizer	3,651	87%
	Sub-Total =	**4,219**	
Urban Runoff – 33% of Stormwater – 13% of all Pathways			
Connected Impervious Area	Animal Waste	2,036	14%
	Atmospheric Deposition	4,064	28%
Disconnected Impervious Area	Animal Waste	2,542	18%
	Atmospheric Deposition	4,951	34%
Managed Turf	Atmospheric Deposition	20.1	0.1%
	Chemical Fertilizer	831	6%
	Sub-Total =	**14,444**	
Natural Runoff – 44% of Stormwater – 17% of all Pathways			
Natural Vegetation	Atmospheric Deposition	19,012	100%
	Sub-Total =	**19,012**	
	Stormwater Total =	**43,194**	
	Total of all Pathways =	**108,656**	

Figure 38: Outputs of Non-Point Source Nitrogen Delivered Through Stormwater for the Hampton-Seabrook Harbor/Atlantic Coast Watershed

Non-Point Source Nitrogen Delivered to Estuary
Total Load through Stormwater for the Hampton-Seabrook Harbor/Atlantic Coast Watershed



Stormwater Delivered Load - TN (lb/yr)			
Agricultural Runoff - 8% of Stormwater - 4% of all Pathways			
Agriculture	Animal Waste	3,014	54%
	Atmospheric Deposition	707	13%
	Chemical Fertilizer	1,812	33%
	Sub-Total =	**5,532**	
Residential Lawn Runoff - 24% of Stormwater - 10% of all Pathways			
Residential Lawns	Animal Waste	677	4%
	Atmospheric Deposition	1,448	9%
	Chemical Fertilizer	13,410	86%
	Sub-Total =	**15,535**	
Urban Runoff - 51% of Stormwater - 22% of all Pathways			
Connected Impervious Area	Animal Waste	7,050	21%
	Atmospheric Deposition	14,267	43%
Disconnected Impervious Area	Animal Waste	3,532	11%
	Atmospheric Deposition	7,808	23%
Managed Turf	Atmospheric Deposition	3.3	0.0%
	Chemical Fertilizer	811	2%
	Sub-Total =	**33,471**	
Natural Runoff - 17% of Stormwater - 8% of all Pathways			
Natural Vegetation	Atmospheric Deposition	11,521	100%
	Sub-Total =	**11,521**	
	Stormwater Total =	**66,060**	
	Total of all Pathways =	**151,948**	

Total Nitrogen Delivered = 151,948 lb/yr

Figure 39: Non-Point Source Nitrogen Yield (pounds delivered per acre per year) for Study Areas in the Winnicut River Watershed

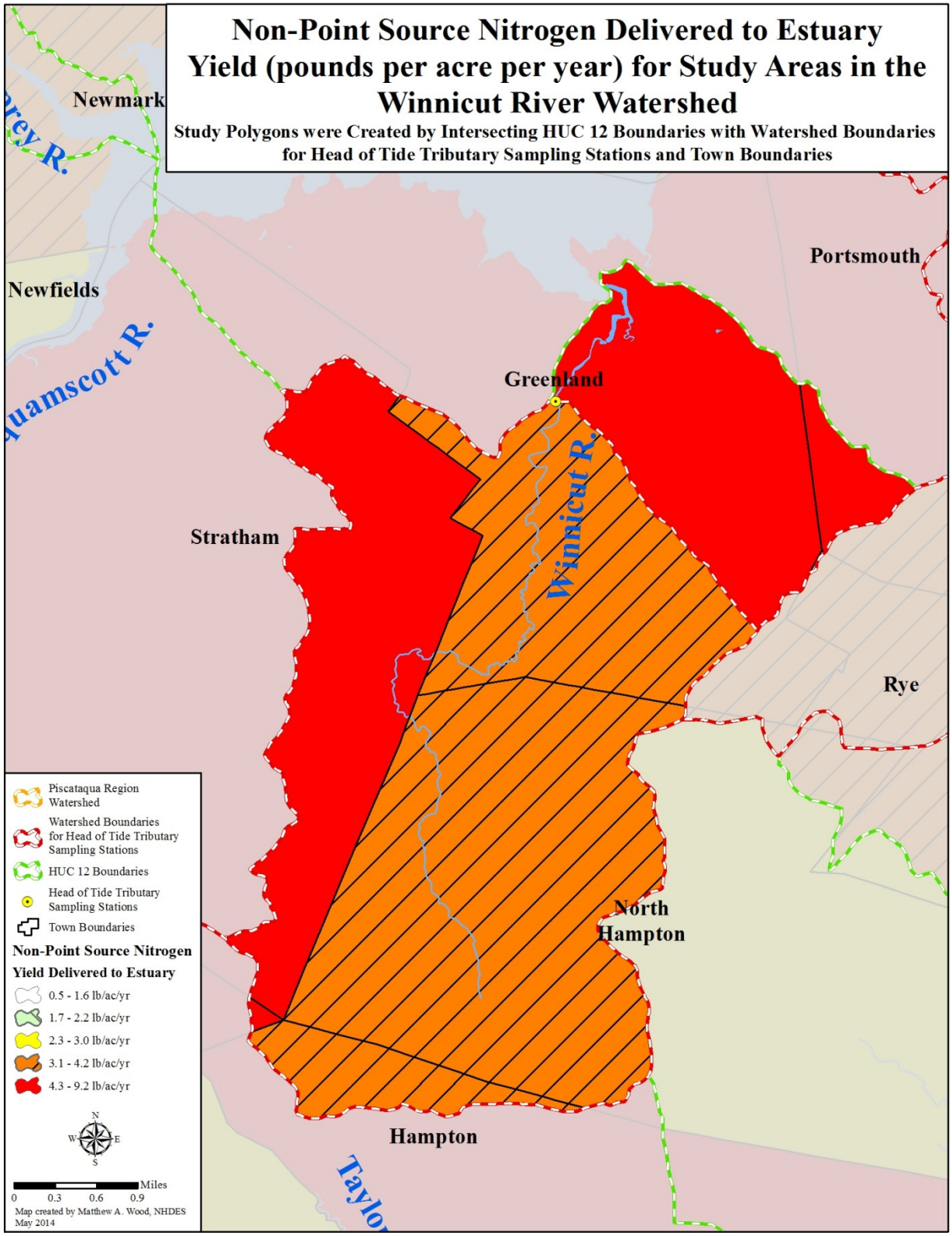


Figure 40: Non-Point Source Nitrogen Yield (pounds delivered per acre per year) for Study Areas in the Exeter River Watershed

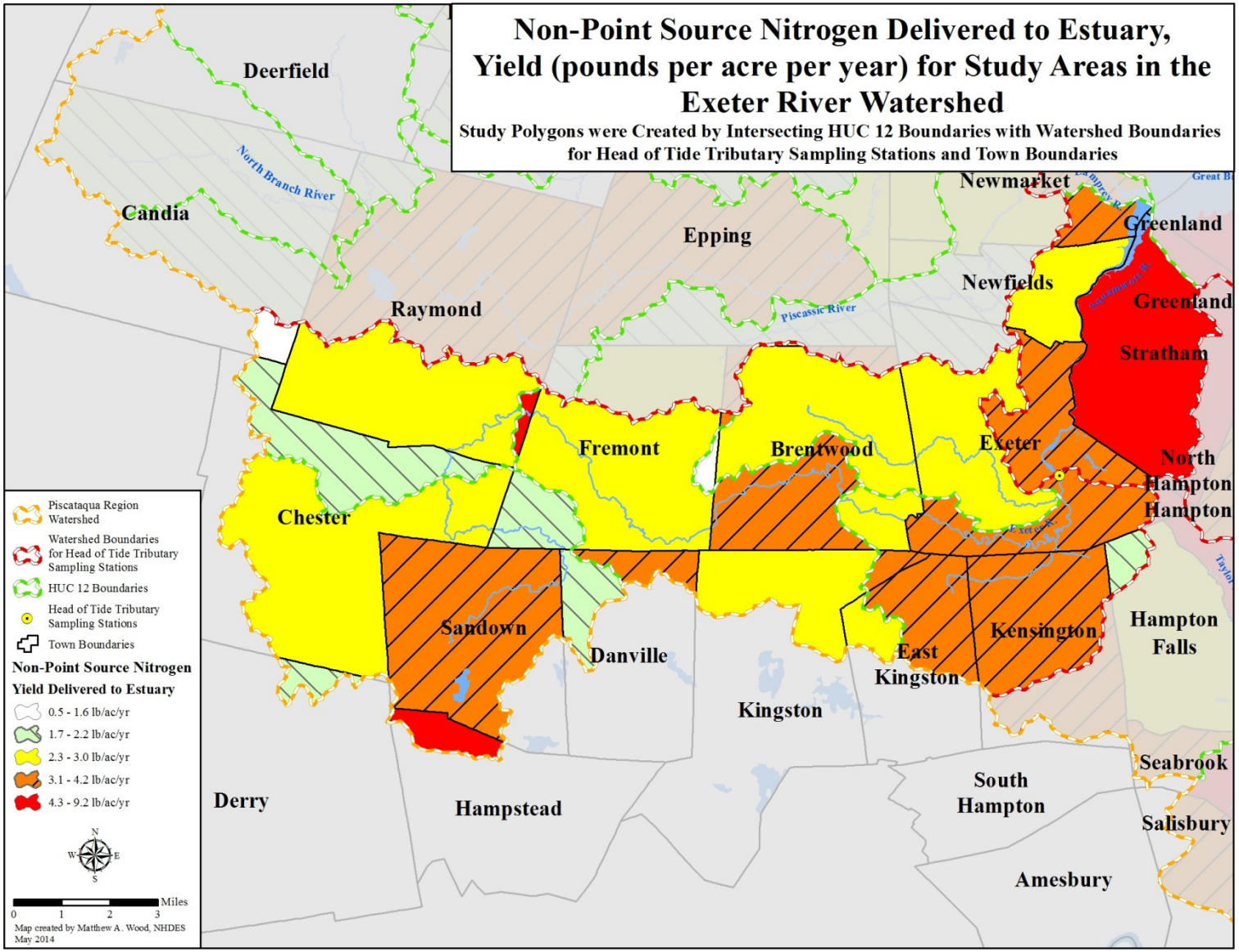


Figure 41: Non-Point Source Nitrogen Yield (pounds delivered per acre per year) for Study Areas in the Lamprey River Watershed

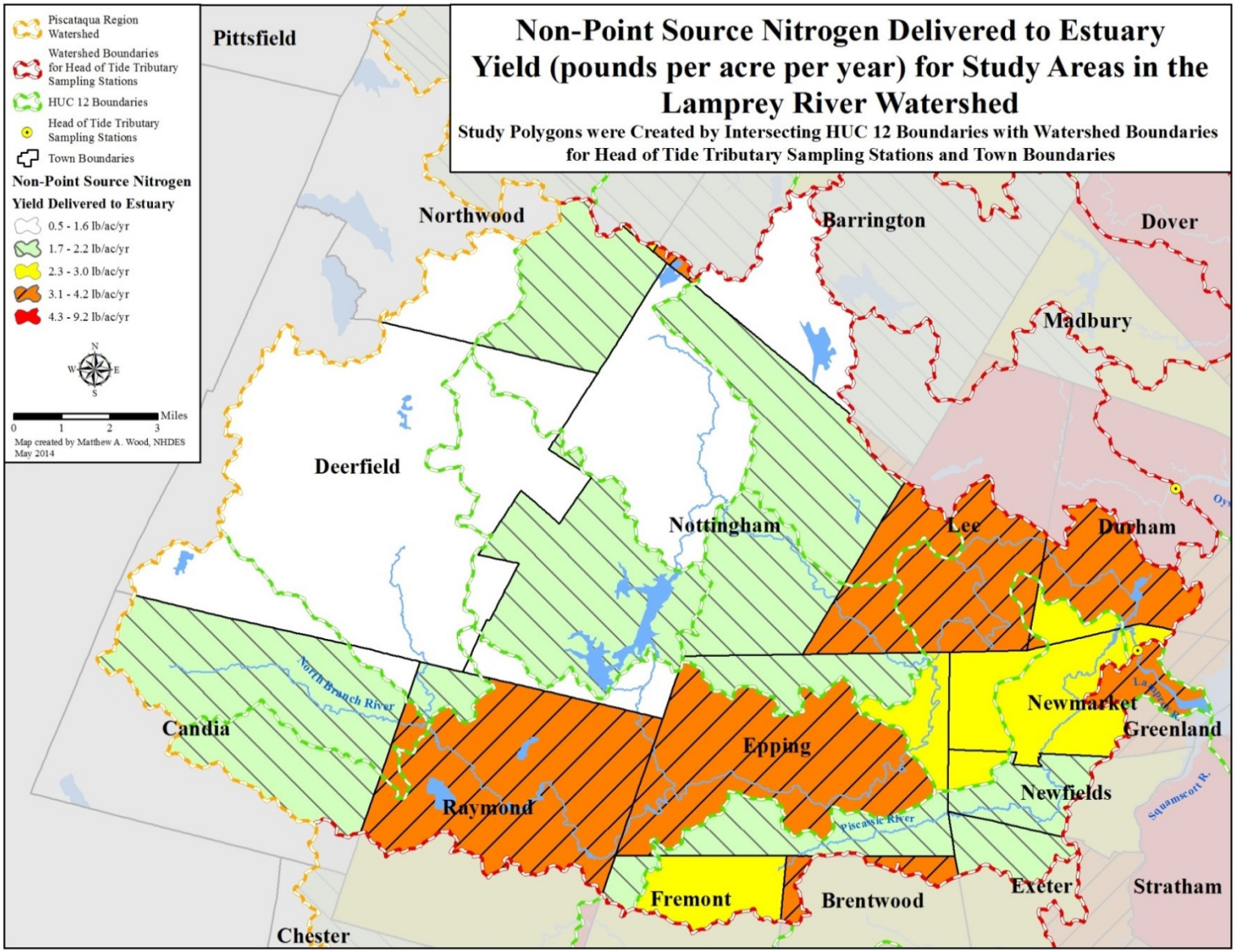


Figure 42: Non-Point Source Nitrogen Yield (pounds delivered per acre per year) for Study Areas in the Oyster River Watershed

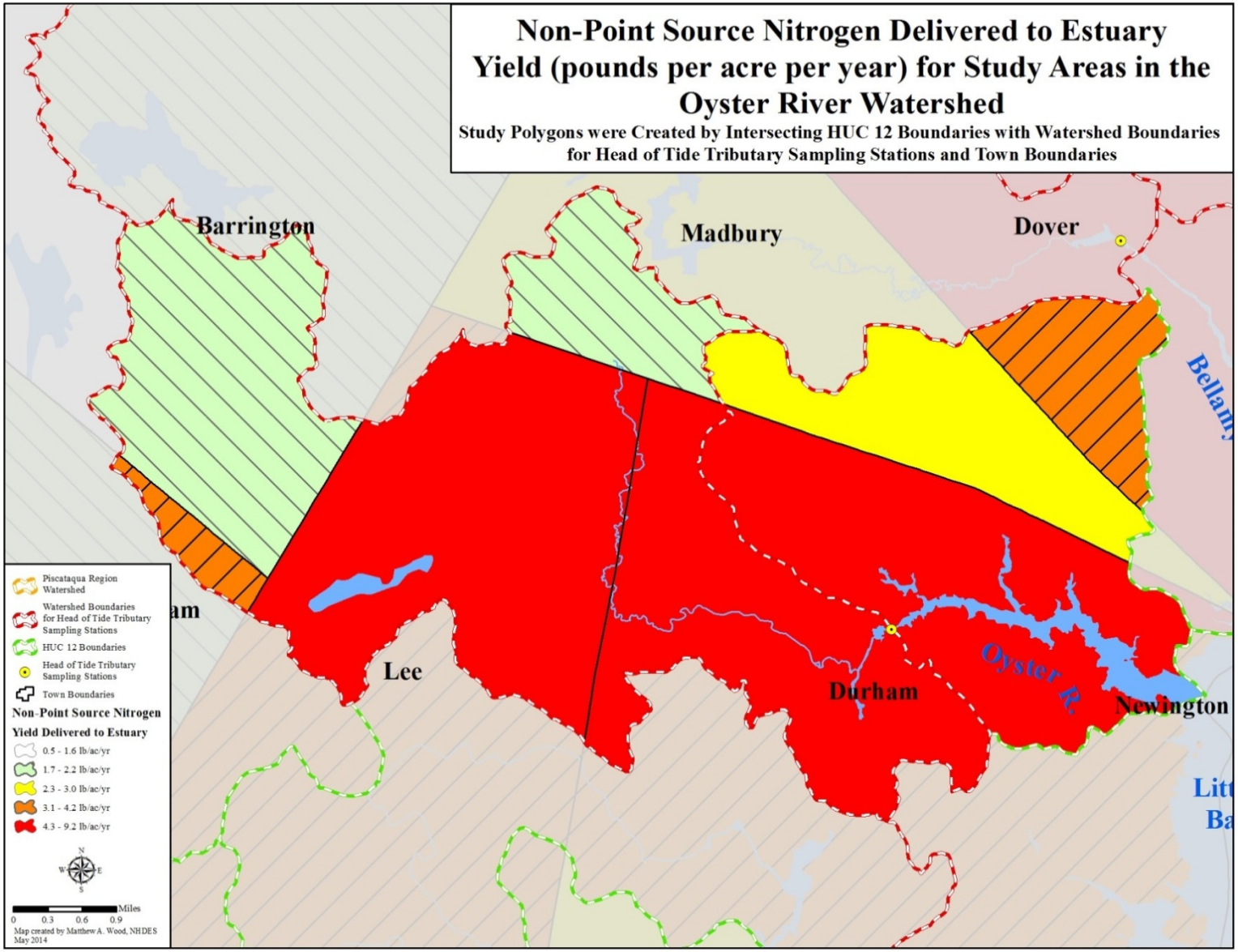


Figure 43: Non-Point Source Nitrogen Yield (pounds delivered per acre per year) for Study Areas in the Bellamy River Watershed

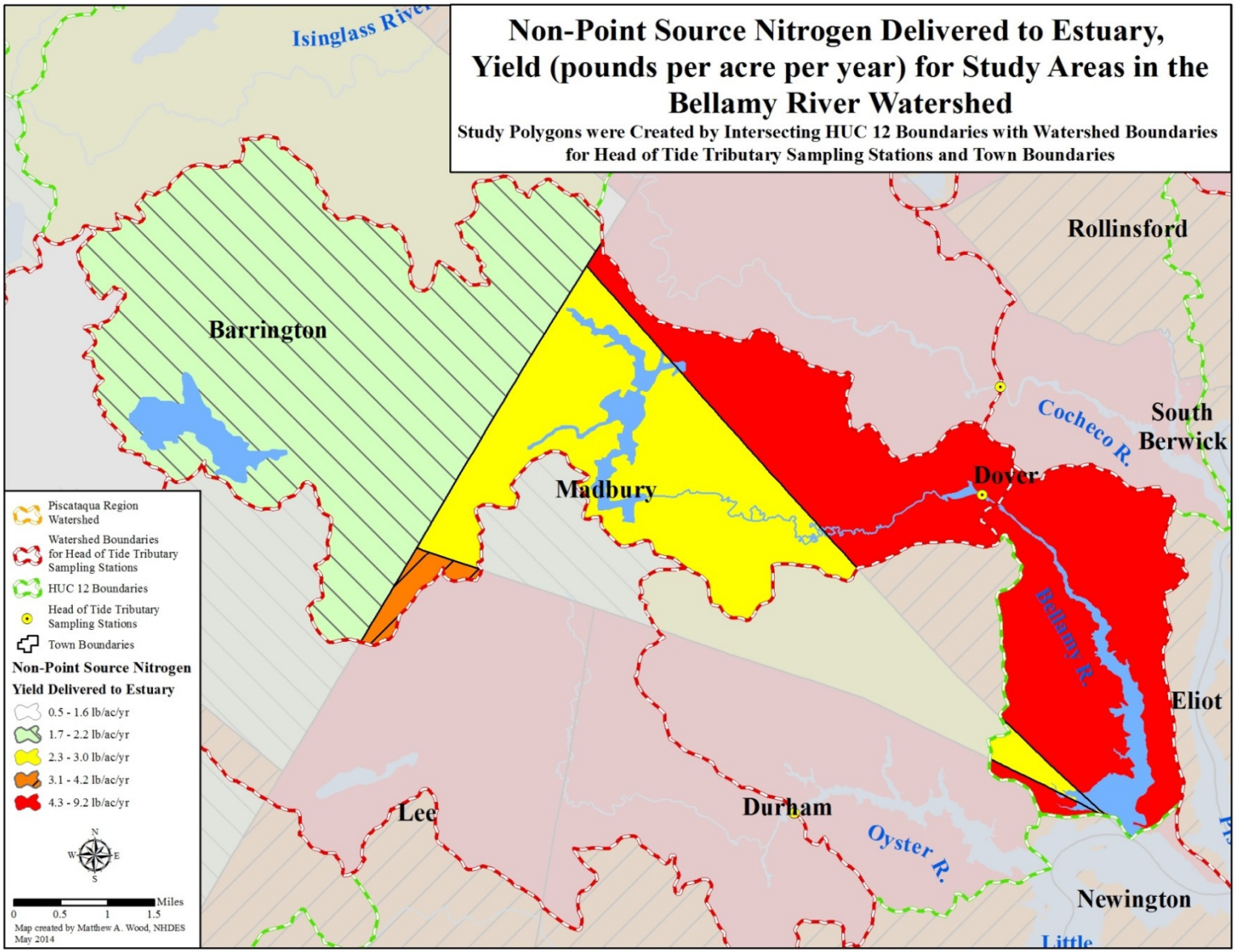


Figure 44: Non-Point Source Nitrogen Yield (pounds delivered per acre per year) for Study Areas in the Cocheco River Watershed

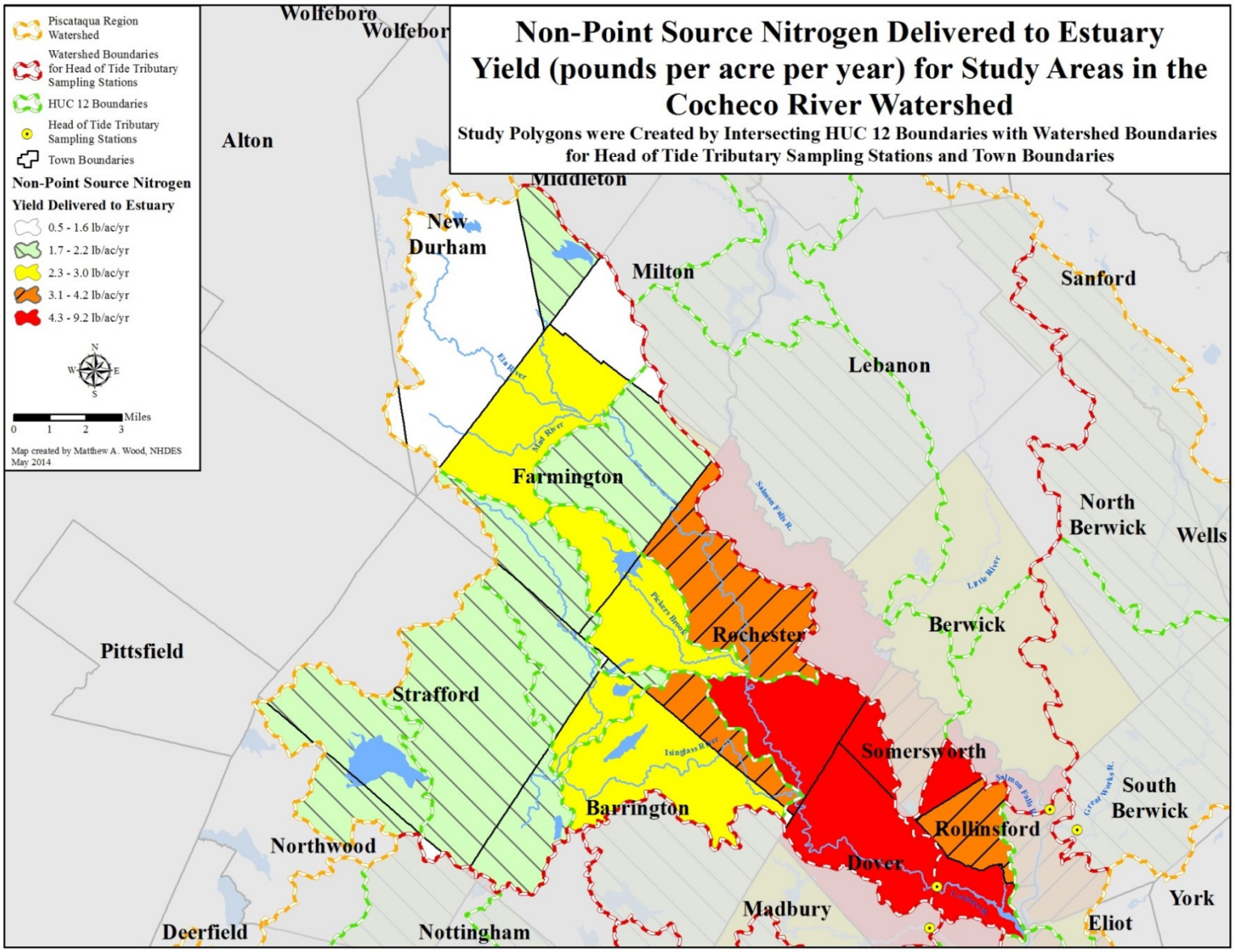


Figure 45: Non-Point Source Nitrogen Yield (pounds delivered per acre per year) for Study Areas in the Salmon Falls River Watershed

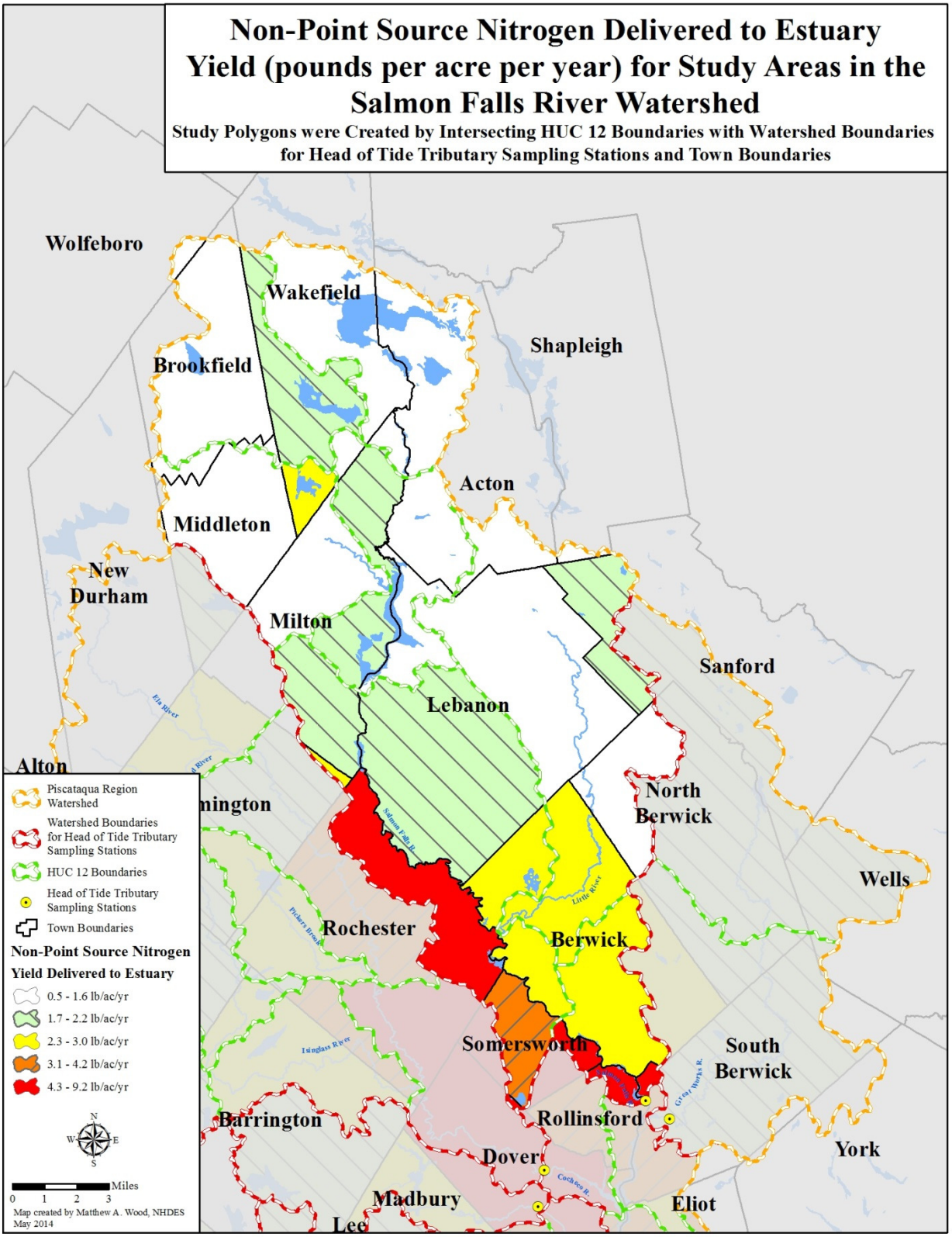


Figure 46: Non-Point Source Nitrogen Yield (pounds delivered per acre per year) for Study Areas in the Great Works River Watershed

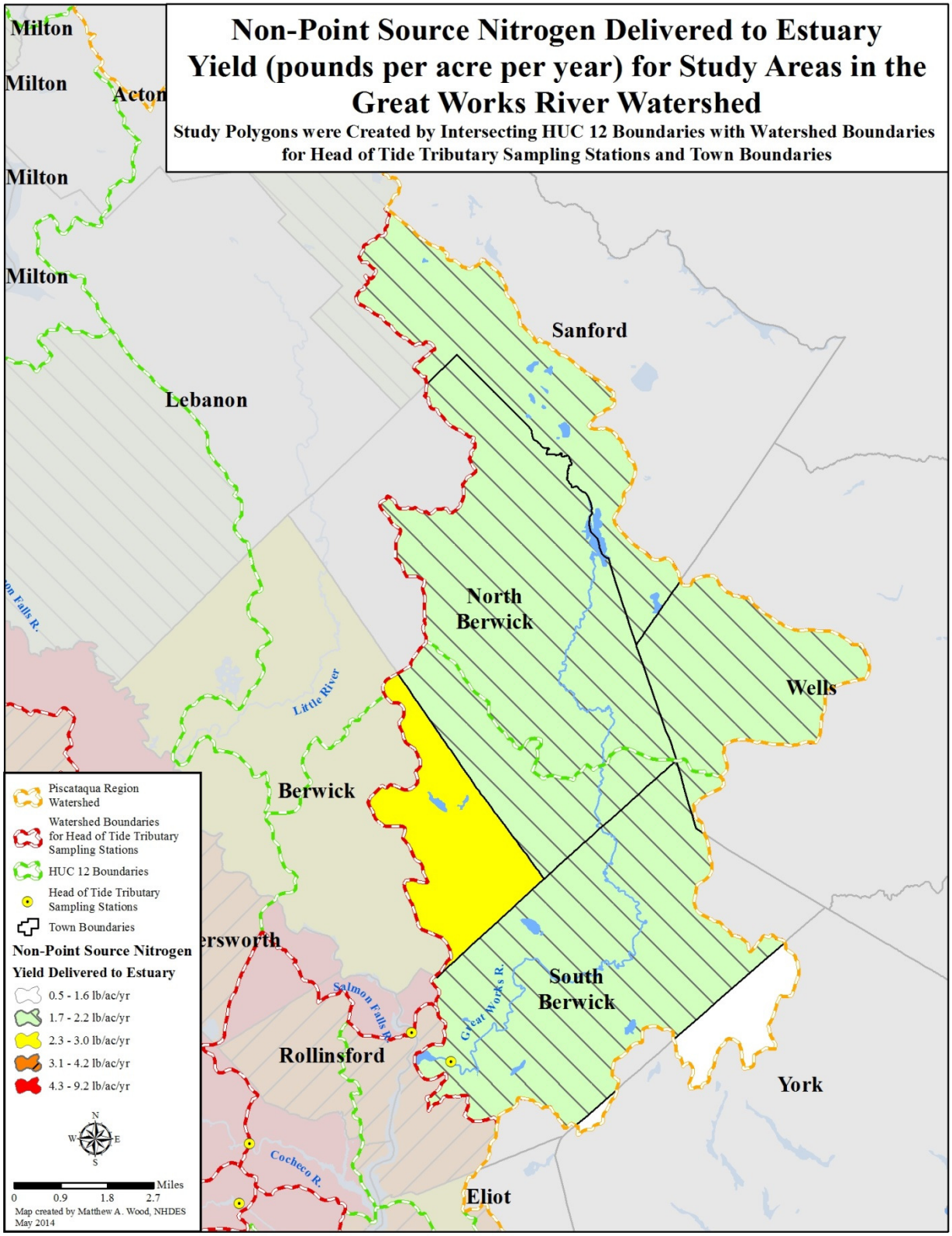


Figure 47: Non-Point Source Nitrogen Yield (pounds delivered per acre per year) for Study Areas in the Hampton-Seabrook Harbor/Atlantic Coast Watershed

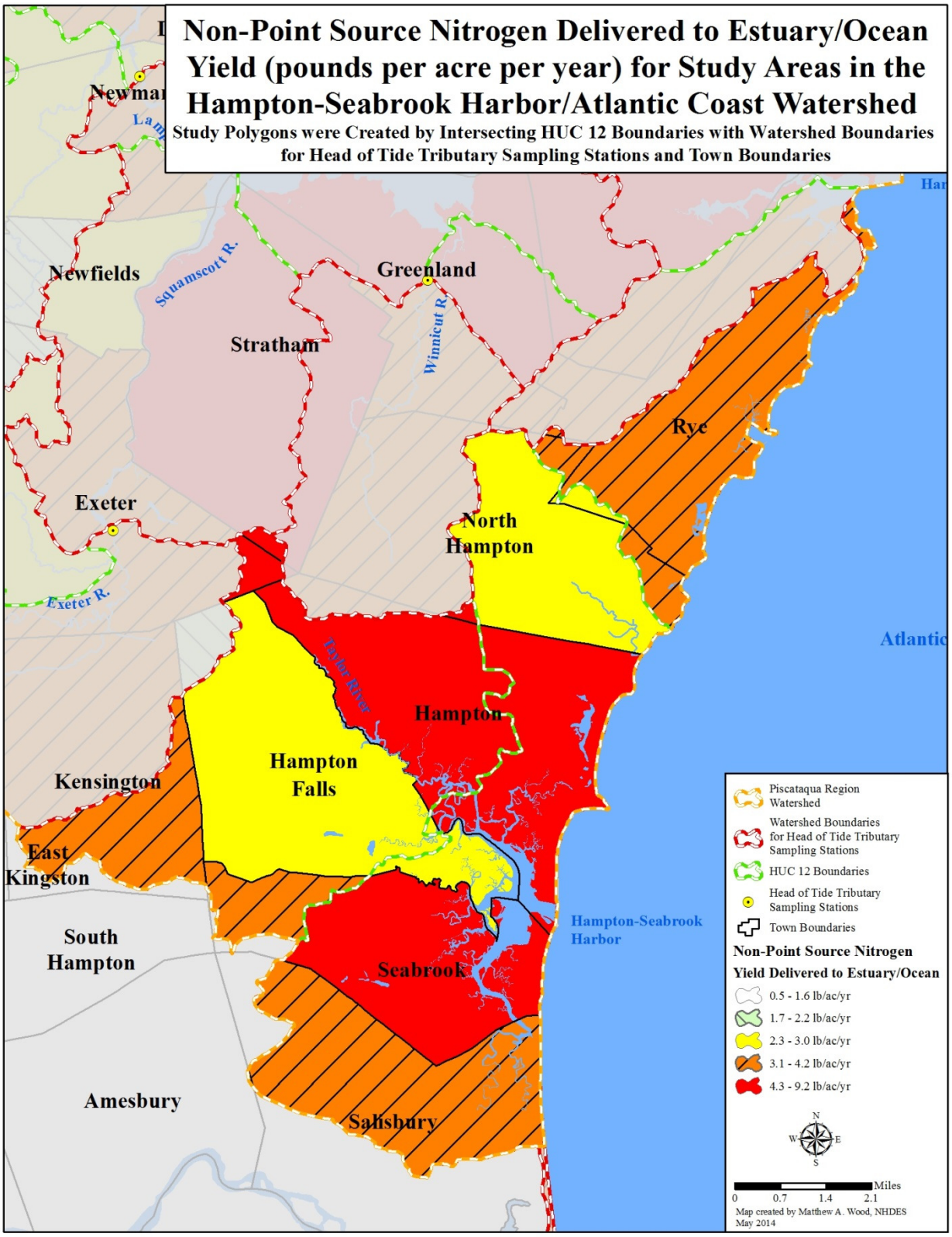


Figure 48: Non-Point Source Nitrogen Yield (pounds delivered per acre per year) for HUC12 Subwatersheds

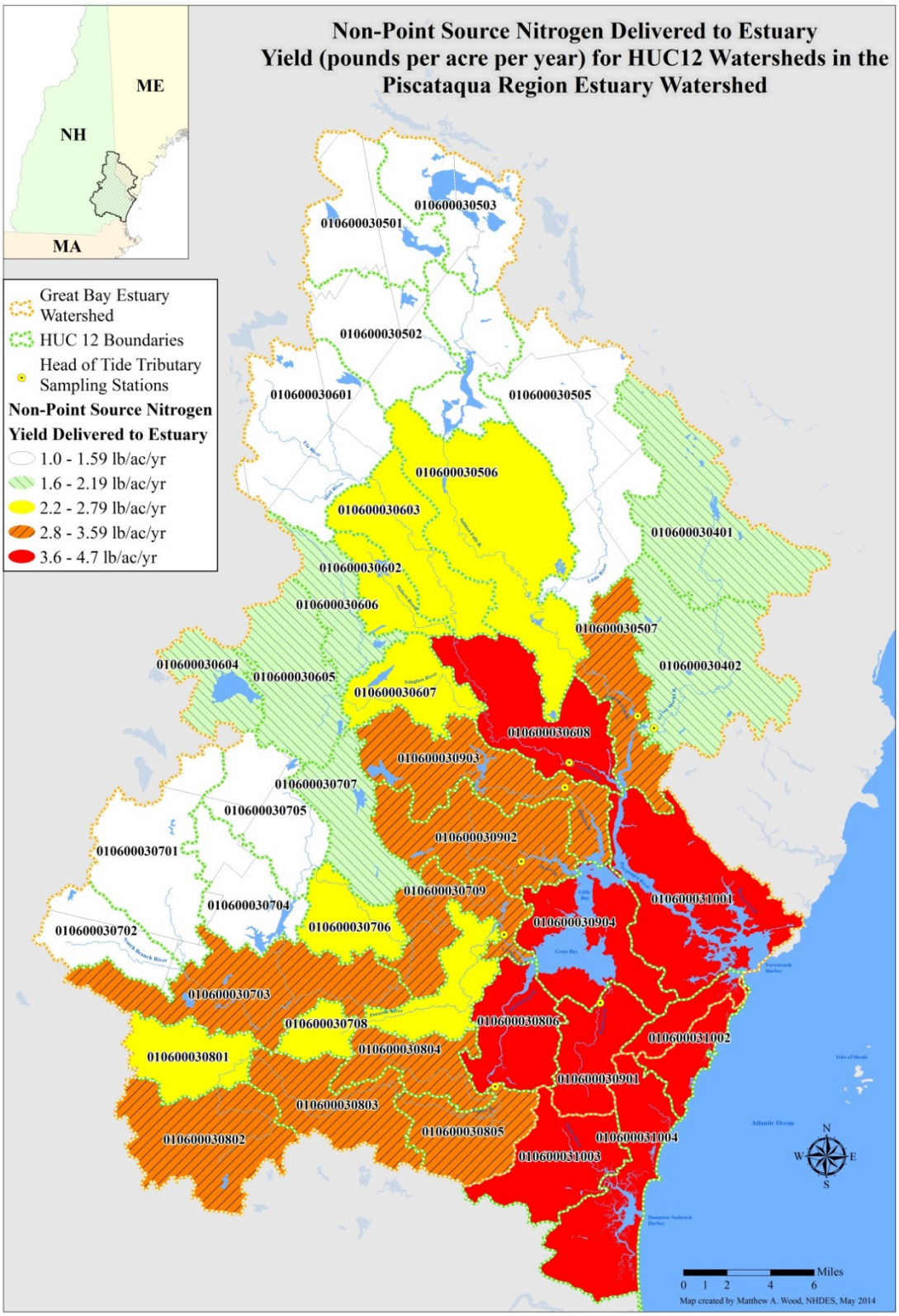


Figure 49: Non-Point Source Nitrogen Yield (pounds delivered per acre per year) for Towns

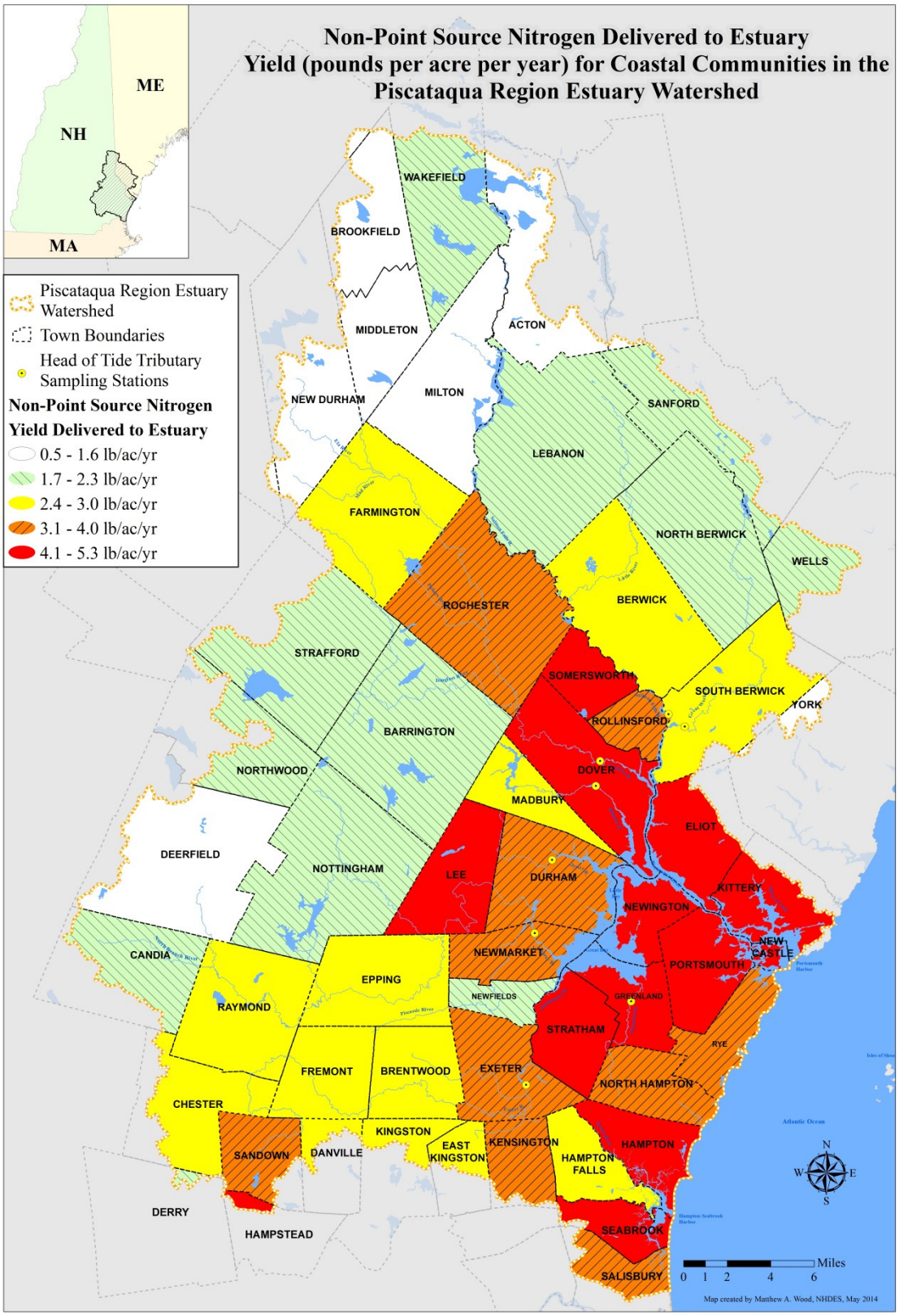


Table 3: Non-Point Source Nitrogen Output from Major Watersheds Delivered to the Estuary

Major Watershed	Source: Atmospheric Deposition								Source: Chemical Fertilizer		
	via Lakes & Rivers (lb/yr)	via Estuarine Waters (lb/yr)	via Natural Vegetation (lb/yr)	via Agriculture (lb/yr)	via Residential Lawns (lb/yr)	via Golf Courses, Parks and Sports Fields (Managed Turf) (lb/yr)	via Connected Impervious Area (lb/yr)	via Disconnected Impervious Area (lb/yr)	via Residential Lawns (lb/yr)	via Golf Courses, Parks and Sports Fields (Managed Turf) (lb/yr)	via Agriculture (lb/yr)
Bellamy River	3,671.8	2,362.0	9,247.2	1,407.5	761.1	22.1	4,025.1	3,336.1	9,399.5	606.9	2,576.5
Cocheco River	16,062.9	973.1	66,542.8	4,777.6	2,508.3	225.6	15,425.9	14,340.8	33,426.8	4,008.2	10,007.4
Exeter River	5,007.0	2,421.9	43,185.1	5,733.9	1,951.4	163.0	10,372.8	13,893.8	24,427.6	2,394.4	12,044.1
Great Works River	3,552.6	0.1	36,426.0	3,057.5	744.6	108.4	4,064.4	5,581.7	9,651.4	2,181.3	5,304.2
Lamprey River	14,928.5	769.6	75,763.6	5,225.9	1,372.7	40.5	9,167.3	14,544.8	17,274.1	601.4	10,393.7
Oyster River	1,270.0	1,843.4	12,408.0	1,674.6	846.6	19.4	3,437.9	3,521.3	9,697.1	367.5	3,119.9
Salmon Falls River	22,648.9	1,929.3	84,097.0	4,952.6	2,091.9	104.5	10,291.1	13,526.6	28,314.8	2,273.3	8,449.7
Winnicut River	510.2	108.1	5,880.8	822.8	577.3	233.9	2,709.6	2,502.5	6,985.8	3,641.7	1,224.5
Great Bay Estuary	71,582.3	63,072.4	357,610.0	30,643.5	13,947.2	1,085.5	78,371.4	82,293.2	177,491.3	19,202.6	58,562.1
Hampton-Seabrook Harbor/Atlantic Coast	2,878.7	6,647.2	21,905.2	1,428.8	2,493.0	65.8	14,266.8	8,695.7	29,291.3	2,424.4	4,669.2
Piscataqua Region Total =	**74,461.0**	**69,719.6**	**379,515.3**	**32,072.2**	**16,440.1**	**1,151.3**	**92,638.3**	**90,988.9**	**206,782.6**	**21,627.0**	**63,231.3**

Table 3 (cont.)

Major Watershed	Source: Animal Waste						Source: Human Waste		Total from the Four Sources (lb/yr)	Total from the Four Sources (lb/ac/yr)	% Stormwater from the Four Sources
	via Agriculture (lb/yr)	via Residential Lawns (lb/yr)	via Connected Impervious Area (lb/yr)	via Disconnected Impervious Area (lb/yr)	via Septic within 200m of Waterways* (lb/yr)	via Septic >200m from Waterways* (lb/yr)	via Septic within 200m of Waterways* (lb/yr)	via Septic >200m from Waterways* (lb/yr)			
Bellamy River	3,135.3	619.7	2,466.2	1,808.4	19.3	135.1	988.1	15,272.0	**61,859.9**	**2.9**	**34%**
Cocheco River	22,916.3	1,919.4	8,951.4	8,318.3	25.2	874.6	1,692.4	78,075.3	**291,072.5**	**2.5**	**36%**
Exeter River	20,147.0	1,257.5	5,058.8	6,369.1	29.6	787.3	2,251.2	88,550.1	**246,045.6**	**3.0**	**30%**
Great Works River	4,483.4	521.5	2,035.9	2,866.9	0.5	299.6	57.8	27,717.8	**108,655.7**	**2.0**	**40%**
Lamprey River	34,536.3	857.5	4,119.2	7,319.5	118.8	883.5	9,805.8	84,622.6	**292,345.5**	**2.1**	**28%**
Oyster River	10,966.3	515.7	1,661.1	1,562.3	1.9	113.4	1,497.9	17,052.0	**71,576.2**	**3.6**	**40%**
Salmon Falls River	17,834.2	1,345.8	5,051.7	6,781.1	149.7	762.2	13,889.7	70,480.2	**294,974.3**	**1.9**	**32%**
Winnicut River	3,107.9	272.9	999.8	941.3	5.9	162.9	813.6	15,887.8	**47,389.2**	**4.2**	**36%**
Great Bay Estuary	133,396.1	9,354.1	40,202.8	42,246.0	589.8	4,397.3	48,361.9	426,977.4	**1,659,386.9**	**2.5**	**34%**
Hampton-Seabrook Harbor/Atlantic Coast	7,375.5	1,450.2	7,049.7	3,920.2	28.6	283.8	2,073.7	35,000.5	**151,948.1**	**3.8**	**43%**
Piscataqua Region Total =	**140,771.6**	**10,804.4**	**47,252.5**	**46,166.1**	**618.4**	**4,681.1**	**50,435.6**	**461,977.9**	**1,811,335.1**	**2.6**	**35%**

Table 4: Non-Point Source Nitrogen Output from HUC12 Subwatersheds Delivered to the Estuary

HUC 12	Source: Atmospheric Deposition								Source: Chemical Fertilizer		
	via Lakes & Rivers (lb/yr)	via Estuarine Waters (lb/yr)	via Natural Vegetation (lb/yr)	via Agriculture (lb/yr)	via Residential Lawns (lb/yr)	via Golf Courses, Parks and Sports Fields (Managed Turf) (lb/yr)	via Connected Impervious Area (lb/yr)	via Disconnected Impervious Area (lb/yr)	via Residential Lawns (lb/yr)	via Golf Courses, Parks and Sports Fields (Managed Turf) (lb/yr)	via Agriculture (lb/yr)
010600030401	2,062.4	0.0	16,691.1	1,221.5	404.3	52.8	2,663.0	2,938.3	5,464.6	690.2	2,012.8
010600030402	1,490.2	0.1	19,734.9	1,835.9	340.3	55.6	1,401.5	2,643.4	4,186.8	1,491.0	3,291.3
010600030501	2,911.2	0.0	9,949.0	204.6	132.8	4.7	607.7	1,155.8	2,055.8	134.8	436.8
010600030502	970.3	0.0	6,984.9	105.3	99.4	0.0	581.2	846.6	1,642.8	0.0	260.4
010600030503	8,792.1	0.0	9,072.4	204.7	72.8	0.7	249.2	1,079.6	1,113.5	13.5	391.7
010600030504	4,272.8	0.0	6,107.8	277.1	72.0	1.8	485.4	773.8	1,196.1	18.7	497.8
010600030505	1,183.8	0.0	22,310.8	1,475.4	205.6	1.7	709.9	2,310.1	2,769.4	30.0	2,326.4
010600030506	3,540.2	0.0	21,892.5	1,367.9	977.9	69.3	5,279.8	5,215.9	12,999.2	1,010.6	2,298.2
010600030507	978.6	1,929.3	7,779.6	1,317.6	531.5	26.3	2,377.9	2,144.8	6,538.1	1,065.7	2,238.3
010600030601	2,125.8	0.0	12,837.3	399.0	277.8	4.6	1,369.9	1,987.6	4,011.3	83.7	970.3
010600030602	1,559.8	0.0	4,398.9	478.3	76.0	0.0	385.0	873.4	991.8	0.0	1,314.0
010600030603	1,208.7	0.0	5,288.1	318.4	457.9	52.2	4,416.6	2,873.2	7,079.3	511.9	735.8
010600030604	4,596.7	0.0	5,709.1	178.5	41.4	4.2	136.9	596.1	569.4	165.1	363.5
010600030605	1,340.7	0.0	14,094.3	710.6	108.1	7.4	355.9	1,293.1	1,320.2	171.3	1,032.2
010600030606	1,543.8	0.0	8,245.5	433.9	47.1	0.0	148.8	725.4	572.1	0.0	794.7
010600030607	1,855.1	0.0	7,229.8	257.8	193.4	27.8	1,151.5	1,397.7	2,528.1	603.1	495.1
010600030608	1,832.3	973.1	8,739.8	2,001.0	1,306.4	129.4	7,461.3	4,594.4	16,354.6	2,473.0	4,301.9
010600030701	1,179.4	0.0	11,754.7	618.2	72.9	1.8	554.6	1,608.7	994.3	34.8	1,389.6
010600030702	714.4	0.0	5,848.7	245.2	79.1	1.1	459.4	976.4	1,078.9	27.5	548.8
010600030703	2,978.9	0.0	13,585.6	868.6	518.4	14.6	3,714.3	4,122.9	6,687.9	242.9	2,008.6
010600030704	4,041.7	0.0	7,167.8	150.6	13.3	0.0	119.4	487.3	174.9	0.0	380.8
010600030705	1,466.9	0.0	8,341.4	339.3	84.9	2.4	525.8	992.0	1,120.9	64.0	589.6
010600030706	527.8	0.0	5,225.3	586.5	54.6	0.0	305.2	865.0	663.1	0.0	1,632.2
010600030707	1,673.1	0.0	7,014.3	196.0	91.4	0.0	530.0	1,196.0	1,159.7	0.0	364.0
010600030708	882.0	0.0	8,237.3	764.1	211.5	13.1	1,715.8	2,360.8	2,539.3	190.4	1,258.7
010600030709	1,464.4	769.6	8,588.5	1,457.4	246.5	7.5	1,242.9	1,935.8	2,855.2	41.8	2,221.4
010600030801	624.5	0.0	5,349.0	254.9	172.0	2.9	738.4	1,295.0	2,345.5	37.3	691.7
010600030802	1,420.0	0.0	11,398.7	955.4	461.2	8.4	1,577.0	3,143.6	5,532.5	129.3	2,390.2
010600030803	1,040.8	0.0	8,150.6	698.9	361.9	19.4	1,787.6	2,636.8	4,380.7	322.1	1,453.7
010600030804	458.6	0.0	5,851.7	931.0	237.9	12.4	1,854.2	2,119.0	2,802.6	282.5	1,546.5
010600030805	956.5	0.0	6,734.3	1,714.2	291.2	63.8	1,205.0	2,068.3	3,678.3	413.7	2,632.3
010600030806	506.7	2,421.9	5,700.9	1,179.5	427.2	56.0	3,210.5	2,631.1	5,688.0	1,209.4	3,329.7
010600030901	510.2	108.1	5,880.8	822.8	577.3	233.9	2,709.6	2,502.5	6,985.8	3,641.7	1,224.5
010600030902	1,270.0	1,843.4	12,408.0	1,674.6	846.6	19.4	3,437.9	3,521.3	9,697.1	367.5	3,119.9
010600030903	3,671.8	2,362.0	9,247.2	1,407.5	761.1	22.1	4,025.1	3,336.1	9,399.5	606.9	2,576.5
010600030904	647.1	31,560.1	8,536.8	1,325.1	683.2	108.2	3,654.6	2,837.4	7,481.9	1,499.7	2,467.7
010600031001	3,187.0	20,159.3	13,235.1	1,597.2	2,207.1	24.5	13,826.8	7,410.0	28,055.7	901.6	2,873.0
010600031002	572.0	949.1	4,530.2	200.4	406.0	69.3	2,838.1	1,874.2	5,737.0	2,204.7	337.6
010600031003	963.8	466.9	7,378.1	997.7	719.7	14.5	4,543.1	3,487.8	9,247.1	614.8	3,788.9
010600031004	1,439.4	6,176.6	12,284.4	299.3	1,570.2	17.5	8,281.6	4,131.8	17,083.7	331.6	644.1
Total =	**74,461.0**	**69,719.6**	**379,515.3**	**32,072.2**	**16,440.1**	**1,151.3**	**92,638.3**	**90,988.9**	**206,782.6**	**21,627.0**	**63,231.3**

Table 4 (cont.)

HUC 12	Source: Animal Waste						Source: Human Waste		Total from the Four Sources (lb/yr)	Total from the Four Sources (lb/ac/yr)	% Stormwater from the Four Sources
	via Agriculture (lb/yr)	via Residential Lawns (lb/yr)	via Connected Impervious Area (lb/yr)	via Disconnected Impervious Area (lb/yr)	via Septic within 200m of Waterways* (lb/yr)	via Septic >200m from Waterways* (lb/yr)	via Septic within 200m of Waterways* (lb/yr)	via Septic >200m from Waterways* (lb/yr)			
010600030401	1,194.0	258.9	1,311.0	1,297.5	0.0	147.5	0.0	15,537.3	53,947.3	1.9	35%
010600030402	3,289.4	262.6	724.9	1,569.5	0.5	152.1	57.8	12,180.5	54,708.3	2.0	45%
010600030501	1,054.0	47.1	168.1	373.7	0.0	42.0	0.0	5,619.2	24,897.3	1.4	36%
010600030502	982.4	71.2	277.5	430.7	0.2	73.4	7.0	4,538.5	17,871.9	1.0	22%
010600030503	467.8	51.3	141.0	585.1	0.0	66.8	0.0	4,815.9	27,118.2	1.5	28%
010600030504	975.8	43.4	204.6	351.0	18.1	52.3	1,937.5	6,656.4	23,942.1	1.6	17%
010600030505	4,140.9	214.6	536.4	1,798.0	0.4	217.6	26.4	13,555.7	53,813.2	1.5	38%
010600030506	5,012.3	677.7	2,869.5	2,386.1	95.7	237.1	10,368.8	26,917.0	103,215.6	2.7	33%
010600030507	5,200.9	240.5	854.6	856.5	35.2	72.9	1,550.0	8,377.4	44,116.0	3.2	38%
010600030601	5,607.7	121.9	447.4	679.2	0.0	88.5	0.0	14,562.0	45,574.1	1.6	27%
010600030602	1,977.1	132.3	533.6	1,158.3	0.0	123.5	0.0	4,519.1	18,521.0	2.5	38%
010600030603	3,855.8	305.5	1,956.4	1,261.9	0.0	90.9	0.0	10,825.3	41,237.9	2.6	29%
010600030604	757.3	25.9	71.8	312.4	0.0	33.9	0.0	4,395.2	17,957.5	2.0	30%
010600030605	1,015.4	58.0	158.9	557.8	0.0	64.3	0.0	7,246.5	29,534.5	1.7	43%
010600030606	2,942.5	32.7	114.2	666.3	0.0	63.2	0.0	3,884.8	20,215.0	2.0	45%
010600030607	879.1	124.4	618.7	632.3	0.2	122.1	7.9	9,511.0	27,635.2	2.6	34%
010600030608	5,881.4	1,118.8	5,050.4	3,050.2	25.1	288.3	1,684.5	23,131.4	90,397.4	4.5	41%
010600030701	3,403.0	36.4	207.1	658.9	0.0	81.4	0.0	8,615.7	31,211.6	1.4	27%
010600030702	1,209.4	37.6	161.8	353.0	0.0	52.1	0.0	6,004.8	17,798.1	1.6	26%
010600030703	3,372.5	242.6	1,338.0	1,453.7	30.1	231.0	3,977.8	28,465.5	73,853.8	2.8	26%
010600030704	3,685.3	12.4	86.2	365.3	0.0	44.4	0.0	2,773.4	19,502.7	1.5	23%
010600030705	3,732.2	44.6	199.7	422.4	1.1	62.1	96.0	6,778.9	24,864.1	1.6	25%
010600030706	4,156.9	35.4	149.4	417.4	12.7	48.9	1,501.7	4,901.4	21,083.4	2.4	30%
010600030707	4,653.8	43.5	182.3	442.7	0.3	66.4	32.5	7,740.7	25,386.8	2.0	26%
010600030708	2,656.3	158.7	935.7	1,584.7	0.8	169.0	5.1	10,967.5	34,650.8	2.4	34%
010600030709	7,666.9	246.4	858.8	1,621.4	73.8	128.2	4,192.7	8,374.7	43,994.1	3.3	36%
010600030801	1,357.2	120.2	378.6	649.9	0.0	110.5	0.0	11,043.7	25,171.2	2.4	24%
010600030802	3,168.1	251.6	643.4	1,457.4	0.0	229.5	0.0	25,936.5	58,702.9	2.9	24%
010600030803	3,429.5	155.7	548.1	838.4	0.0	146.0	0.0	19,086.6	45,056.8	3.0	24%
010600030804	2,116.0	196.4	1,037.5	1,010.4	0.2	75.5	0.0	8,331.7	28,864.2	2.8	39%
010600030805	8,511.0	226.7	757.0	1,082.1	4.8	85.4	34.4	9,530.8	39,989.8	3.2	39%
010600030806	1,565.2	307.0	1,694.3	1,330.8	24.7	140.3	2,216.7	14,620.8	48,260.8	3.7	33%
010600030901	3,107.9	272.9	999.8	941.3	5.9	162.9	813.6	15,887.8	47,389.2	4.2	36%
010600030902	10,966.3	515.7	1,661.1	1,562.3	1.9	113.4	1,497.9	17,052.0	71,576.2	3.6	40%
010600030903	3,135.3	619.7	2,466.2	1,808.4	19.3	135.1	988.1	15,272.0	61,859.9	2.9	34%
010600030904	5,465.5	480.3	1,931.5	2,039.4	96.3	185.3	3,653.2	8,770.5	83,423.9	4.4	28%
010600031001	10,371.5	1,357.7	6,732.0	3,623.2	127.2	131.7	12,248.3	15,184.4	143,253.3	4.7	44%
010600031002	737.4	318.6	1,768.8	1,047.1	17.2	135.2	1,710.0	13,324.3	38,777.2	3.6	31%
010600031003	5,243.2	481.6	2,363.6	1,461.2	7.5	118.5	1,343.2	12,729.1	55,970.3	3.8	43%
010600031004	1,827.3	856.0	4,112.4	2,028.4	19.3	91.9	484.4	14,311.6	75,991.5	3.9	48%
Total =	140,771.6	10,804.4	47,252.5	46,166.1	618.4	4,681.1	50,435.6	461,977.9	1,811,335.1	2.6	35%

Table 5: Non-Point Source Nitrogen Output from Towns within the Piscataqua Region Watershed Delivered to the Estuary

Town	Source: Atmospheric Deposition								Source: Chemical Fertilizer		
	via Lakes & Rivers (lb/yr)	via Estuarine Waters (lb/yr)	via Natural Vegetation (lb/yr)	via Agriculture (lb/yr)	via Residential Lawns (lb/yr)	via Golf Courses, Parks and Sports Fields (Managed Turf) (lb/yr)	via Connected Impervious Area (lb/yr)	via Disconnected Impervious Area (lb/yr)	via Residential Lawns (lb/yr)	via Golf Courses, Parks and Sports Fields (Managed Turf) (lb/yr)	via Agriculture (lb/yr)
Alton, NH	2.8	0.0	221.1	23.1	1.6	0.0	0.5	9.2	23.2	0.0	177.0
Barrington, NH	6,097.2	0.0	17,576.2	473.3	274.2	36.8	1,523.3	2,876.7	3,615.2	783.6	914.3
Brentwood, NH	806.5	0.0	6,403.3	1,180.2	200.2	1.0	1,548.3	2,410.9	2,309.6	29.8	1,887.1
Brookfield, NH	938.2	0.0	6,709.7	74.6	17.8	0.0	55.6	361.8	295.2	0.0	202.6
Candia, NH	410.4	0.0	7,070.5	332.9	162.5	6.0	632.0	1,272.5	2,119.4	98.7	673.8
Chester, NH	571.8	0.0	6,671.0	683.3	230.1	2.4	813.6	1,713.9	2,841.1	27.3	1,867.6
Danville, NH	41.4	0.0	1,335.6	31.3	20.3	0.0	98.3	261.2	222.6	0.0	57.2
Deerfield, NH	1,554.2	0.0	14,501.6	743.5	79.4	1.8	591.0	1,860.9	1,078.2	34.8	1,640.2
Derry, NH	22.0	0.0	287.9	44.7	0.3	0.0	0.5	11.5	3.5	0.0	54.3
Dover, NH	1,089.1	6,915.6	7,242.7	1,717.3	1,419.8	72.1	8,112.9	4,701.4	17,345.0	1,679.0	2,994.2
Durham, NH	1,271.6	7,265.5	10,977.1	1,379.1	641.9	13.4	2,221.6	2,466.4	7,096.9	183.2	2,299.2
East Kingston, NH	141.8	0.0	1,758.8	665.2	56.0	35.1	253.3	635.9	623.1	122.8	961.0
Epping, NH	1,706.2	0.0	8,827.6	916.8	266.1	8.1	2,168.0	2,690.5	3,212.6	82.2	2,332.0
Exeter, NH	956.0	432.1	6,281.1	313.2	542.2	61.0	3,486.5	2,375.7	7,091.8	1,037.5	611.0
Farmington, NH	1,955.1	0.0	13,128.3	629.8	271.5	31.0	1,529.9	2,352.4	3,696.7	291.1	1,812.4
Fremont, NH	696.6	0.0	6,200.6	421.8	141.6	5.1	742.9	1,533.4	1,726.0	79.5	755.9
Greenland, NH	346.0	9,363.6	3,571.0	724.9	406.6	209.8	1,830.0	1,653.0	4,546.4	3,464.5	1,391.0
Hampstead, NH	17.0	0.0	677.0	58.1	27.2	6.0	150.9	240.0	290.5	102.0	112.8
Hampton, NH	890.6	2,161.3	4,521.0	109.7	733.1	12.6	4,414.6	2,290.2	9,094.3	566.4	222.2
Hampton Falls, NH	491.2	1,343.4	4,535.3	661.6	137.2	2.1	971.1	1,462.7	1,787.9	140.4	2,940.8
Kensington, NH	305.3	0.0	3,814.9	1,032.8	118.6	9.6	383.4	1,072.6	1,502.3	79.9	1,873.1
Kingston, NH	200.3	0.0	1,833.9	269.5	122.0	15.0	519.1	666.0	1,469.1	240.8	615.6
Lee, NH	1,346.7	0.0	9,365.4	1,571.9	244.3	3.1	1,111.2	2,269.6	2,742.5	0.0	2,255.6
Madbury, NH	1,694.5	96.2	4,694.4	814.0	133.5	4.0	448.0	983.5	1,677.8	139.4	1,746.8
Middleton, NH	1,069.1	0.0	4,225.1	45.5	47.1	0.0	284.1	418.3	854.4	0.0	147.3
Milton, NH	3,189.5	0.0	8,503.6	255.8	170.0	1.8	1,165.4	1,510.0	2,905.4	18.7	504.6
New Castle, NH	2,768.3	0.0	116.3	7.9	41.0	4.3	335.1	213.1	605.6	81.0	8.5
New Durham, NH	792.9	0.0	4,696.7	142.5	42.9	0.0	291.9	548.9	777.5	0.0	377.5
Newfields, NH	222.0	452.3	2,628.0	235.4	58.5	1.5	437.4	660.6	698.2	35.4	296.4
Newington, NH	324.2	14,145.9	2,650.1	606.9	415.9	16.4	3,437.4	1,411.6	4,521.2	214.1	1,152.7
Newmarket, NH	488.0	5,213.6	4,113.4	703.8	242.2	29.4	1,555.9	1,499.2	2,922.0	365.8	1,114.5
North Hampton, NH	378.0	0.0	4,402.4	338.1	314.3	66.2	2,186.8	1,744.4	4,131.6	796.3	564.3
Northwood, NH	996.4	0.0	6,076.0	305.5	67.9	5.9	408.8	708.8	907.7	209.1	542.6
Nottingham, NH	5,337.9	0.0	17,152.8	516.7	114.2	0.8	688.9	1,968.7	1,493.7	20.0	1,289.5
Pittsfield, NH	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Portsmouth, NH	156.9	3,235.1	4,453.2	126.2	1,429.8	57.8	8,864.3	3,325.9	17,968.7	907.8	234.7
Raymond, NH	2,316.9	0.0	9,001.9	352.1	399.8	8.4	2,815.8	2,882.9	5,472.0	126.8	1,014.5
Rochester, NH	3,304.2	0.0	12,898.2	1,489.1	1,312.2	75.5	8,531.5	6,094.7	17,848.9	1,294.7	3,432.7
Rollinsford, NH	447.5	406.7	2,010.6	814.2	208.0	8.2	853.1	769.8	2,546.6	121.5	1,264.8
Rye, NH	510.6	1,094.2	3,271.9	152.9	267.1	58.9	1,763.2	1,396.9	3,942.4	1,936.5	252.8
Sandown, NH	899.1	0.0	4,111.9	217.2	233.5	0.0	711.3	1,348.2	2,812.3	0.0	560.8
Seabrook, NH	173.7	2,696.7	3,058.8	66.3	735.7	6.8	4,982.5	1,903.3	7,863.5	74.1	195.2
Somersworth, NH	778.7	0.0	1,755.8	213.8	415.7	90.6	3,244.6	1,204.5	5,818.2	1,277.6	473.3

Table 5 (cont.)

Town	Source: Animal Waste						Source: Human Waste		Total from the Four Sources (lb/yr)	Total from the Four Sources (lb/ac/yr)	% Stormwater from the Four Sources
	via Agriculture (lb/yr)	via Residential Lawns (lb/yr)	via Connected Impervious Area (lb/yr)	via Disconnected Impervious Area (lb/yr)	via Septic within 200m of Waterways* (lb/yr)	via Septic >200m from Waterways* (lb/yr)	via Septic within 200m of Waterways* (lb/yr)	via Septic >200m from Waterways* (lb/yr)			
Alton, NH	2.4	1.6	0.4	7.1	0.0	0.9	0.0	73.0	**544.1**	**1.5**	**41%**
Barrington, NH	1,948.6	165.2	651.4	1,366.7	0.0	207.8	0.0	23,400.4	**61,910.9**	**2.0**	**25%**
Brentwood, NH	2,947.1	70.7	408.5	683.7	0.0	84.4	0.0	10,784.9	**31,756.2**	**2.9**	**34%**
Brookfield, NH	943.6	14.9	20.0	130.2	0.0	14.8	0.0	1,666.4	**11,445.6**	**1.0**	**41%**
Candia, NH	1,204.2	60.2	182.9	392.0	0.0	59.1	0.0	6,952.1	**21,629.1**	**1.7**	**31%**
Chester, NH	3,103.0	84.1	217.3	463.7	0.0	76.0	0.0	11,066.6	**30,432.7**	**2.4**	**25%**
Danville, NH	139.3	16.1	60.8	197.9	0.0	26.7	0.0	2,485.9	**4,994.5**	**2.5**	**23%**
Deerfield, NH	4,444.2	35.0	183.8	611.8	0.0	79.6	0.0	9,405.4	**36,845.5**	**1.4**	**27%**
Derry, NH	62.1	5.3	7.3	154.2	0.0	17.4	0.0	297.1	**968.0**	**2.0**	**30%**
Dover, NH	5,569.4	1,343.6	5,908.8	3,552.3	66.5	123.2	2,774.8	11,684.8	**84,312.4**	**4.5**	**45%**
Durham, NH	8,585.3	538.7	1,538.1	2,657.2	88.2	189.8	3,102.1	8,385.6	**60,900.9**	**3.8**	**41%**
East Kingston, NH	487.0	24.5	86.8	217.3	0.0	28.2	0.0	3,590.0	**9,686.8**	**3.0**	**33%**
Epping, NH	2,816.6	124.4	693.1	963.8	41.9	117.7	4,774.9	12,282.2	**44,024.6**	**2.6**	**26%**
Exeter, NH	1,504.6	493.6	2,410.1	1,933.7	9.6	116.5	284.6	8,613.1	**38,554.0**	**3.0**	**41%**
Farmington, NH	11,804.0	145.8	604.3	1,203.6	0.0	130.3	0.0	12,599.9	**52,186.0**	**2.3**	**34%**
Fremont, NH	2,964.7	75.3	293.8	642.0	0.0	98.3	0.0	11,746.5	**28,124.1**	**2.5**	**24%**
Greenland, NH	5,442.2	134.1	470.2	474.1	21.1	79.9	2,384.9	8,656.9	**45,170.1**	**5.3**	**28%**
Hampstead, NH	58.1	21.4	97.2	154.6	0.0	20.5	0.0	2,028.3	**4,061.6**	**4.8**	**34%**
Hampton, NH	1,824.2	742.7	3,555.8	1,867.8	11.0	94.8	976.3	6,393.6	**40,482.1**	**4.5**	**51%**
Hampton Falls, NH	814.1	42.6	264.9	401.6	15.5	46.7	813.9	5,721.6	**22,594.6**	**2.8**	**36%**
Kensington, NH	10,902.1	48.0	122.3	347.2	0.0	44.6	0.0	5,445.6	**27,102.4**	**3.9**	**37%**
Kingston, NH	744.3	53.1	164.0	209.5	0.0	40.7	0.0	3,849.7	**11,012.6**	**3.0**	**27%**
Lee, NH	16,283.3	110.5	391.0	838.3	22.2	97.4	2,298.7	10,816.1	**51,767.8**	**4.0**	**40%**
Madbury, NH	457.5	47.9	128.9	301.5	0.5	40.0	61.9	4,793.3	**18,263.7**	**2.3**	**36%**
Middleton, NH	71.2	27.6	124.2	206.5	0.0	42.1	0.0	4,838.2	**12,400.7**	**1.1**	**13%**
Milton, NH	2,959.1	102.2	452.0	672.9	15.8	100.5	1,570.9	10,312.5	**34,410.7**	**1.6**	**19%**
New Castle, NH	0.0	29.8	177.1	112.6	12.3	1.4	1,092.0	191.1	**5,797.2**	**4.7**	**18%**
New Durham, NH	455.0	19.2	86.6	162.8	0.0	31.2	0.0	4,521.4	**12,947.0**	**1.0**	**13%**
Newfields, NH	453.9	27.2	131.0	249.5	2.3	29.5	186.5	3,461.1	**10,266.4**	**2.2**	**28%**
Newington, NH	245.5	25.4	146.2	91.0	9.1	12.3	1,123.1	1,377.7	**31,926.7**	**4.0**	**31%**
Newmarket, NH	307.6	274.0	1,199.1	1,363.7	36.4	76.4	996.5	5,946.0	**28,447.6**	**3.1**	**31%**
North Hampton, NH	194.2	135.0	689.5	570.3	0.0	113.3	0.0	11,701.6	**28,326.3**	**3.2**	**32%**
Northwood, NH	1,342.3	38.0	174.1	460.9	0.0	57.8	0.0	5,977.2	**18,279.1**	**1.7**	**28%**
Nottingham, NH	10,606.4	54.2	263.7	853.7	7.2	109.1	1,202.5	12,515.2	**54,195.1**	**1.7**	**24%**
Pittsfield, NH	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.9	**3.7**	**1.0**	**38%**
Portsmouth, NH	413.9	1,214.8	6,226.9	2,353.4	11.0	58.7	1,604.7	3,254.8	**55,898.7**	**5.2**	**63%**
Raymond, NH	1,202.0	252.1	1,246.9	1,354.7	0.0	253.3	0.0	27,566.2	**56,266.3**	**3.0**	**23%**
Rochester, NH	3,145.3	1,039.4	4,827.2	4,040.3	56.8	441.5	6,439.0	32,732.2	**109,003.3**	**3.7**	**34%**
Rollinsford, NH	3,492.2	105.2	305.5	298.3	6.1	52.1	799.0	3,960.1	**18,469.5**	**3.8**	**30%**
Rye, NH	484.8	174.7	826.5	661.9	21.1	112.3	2,353.9	11,027.0	**30,309.5**	**3.6**	**25%**
Sandown, NH	391.6	146.8	325.5	616.9	0.0	110.2	0.0	13,013.8	**25,499.1**	**3.3**	**21%**
Seabrook, NH	562.2	385.0	2,125.2	811.9	0.1	0.4	22.4	39.3	**25,703.1**	**4.3**	**64%**
Somersworth, NH	238.5	402.1	2,309.6	866.0	11.4	113.1	644.4	7,867.9	**27,725.9**	**4.3**	**34%**

Table 5 (cont.)

Town	Source: Atmospheric Deposition								Source: Chemical Fertilizer		
	via Lakes & Rivers (lb/yr)	via Estuarine Waters (lb/yr)	via Natural Vegetation (lb/yr)	via Agriculture (lb/yr)	via Residential Lawns (lb/yr)	via Golf Courses, Parks and Sports Fields (Managed Turf) (lb/yr)	via Connected Impervious Area (lb/yr)	via Disconnected Impervious Area (lb/yr)	via Residential Lawns (lb/yr)	via Golf Courses, Parks and Sports Fields (Managed Turf) (lb/yr)	via Agriculture (lb/yr)
South Hampton, NH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Strafford, NH	5,452.9	0.0	18,525.2	905.0	146.1	1.4	430.4	1,719.5	1,809.6	57.3	1,352.3
Stratham, NH	273.3	929.2	4,677.5	1,244.2	327.3	29.9	2,048.5	2,378.4	4,188.3	868.7	3,535.5
Wakefield, NH	6,791.7	0.0	9,352.9	275.5	203.3	4.7	906.1	1,574.9	3,088.1	134.8	511.2
Wolfeboro, NH	1.3	0.0	255.9	1.5	0.1	0.0	0.8	13.2	1.1	0.0	2.5
Acton, ME	4,458.5	0.0	7,467.5	279.7	48.4	0.7	165.3	722.3	734.3	13.5	506.4
Berwick, ME	2,191.5	0.0	15,155.4	1,871.9	429.0	8.6	1,814.6	2,709.2	5,410.8	287.0	3,396.4
Eliot, ME	244.1	4,945.0	7,058.7	1,205.2	398.8	8.1	1,823.3	2,444.1	4,383.1	442.8	2,097.8
Kittery, ME	104.5	7,645.8	4,119.8	326.4	476.4	2.2	2,643.5	1,807.8	6,713.0	149.4	642.5
Lebanon, ME	2,910.9	0.0	22,857.3	1,129.8	286.2	3.0	1,137.5	2,943.9	3,730.8	51.0	1,797.7
North Berwick, ME	1,015.6	0.0	16,175.9	1,306.2	239.7	13.5	1,251.5	2,183.8	3,036.3	414.6	1,982.3
Sanford, ME	1,350.8	0.0	5,510.3	420.8	193.3	49.4	1,566.6	1,117.8	2,842.8	626.3	657.7
Shapleigh, ME	6.1	0.0	218.1	66.9	1.1	0.0	9.4	21.1	14.1	0.0	96.0
South Berwick, ME	1,306.2	935.3	14,071.3	1,176.4	349.8	59.6	1,288.8	2,062.1	4,157.4	1,863.2	1,980.8
Wells, ME	114.9	0.0	4,636.9	272.4	82.7	0.0	394.6	813.6	1,041.8	0.0	536.2
York, ME	14.0	0.0	1,456.8	7.5	0.7	1.9	0.7	4.2	10.5	55.9	11.9
Amesbury, MA	0.0	0.0	1.8	0.1	0.1	0.0	0.0	0.0	2.0	0.0	0.2
Salisbury, MA	518.1	442.2	4,638.8	119.9	493.6	0.0	992.2	691.6	5,117.8	0.0	299.6
Total =	**74,461.0**	**69,719.6**	**379,515.3**	**32,072.2**	**16,440.1**	**1,151.3**	**92,638.3**	**90,988.9**	**206,782.6**	**21,627.0**	**63,231.3**

Table 5 (cont.)

Town	Source: Animal Waste						Source: Human Waste		Total from the Four Sources (lb/yr)	Total from the Four Sources (lb/ac/yr)	% Stormwater from the Four Sources
	via Agriculture (lb/yr)	via Residential Lawns (lb/yr)	via Connected Impervious Area (lb/yr)	via Disconnected Impervious Area (lb/yr)	via Septic within 200m of Waterways* (lb/yr)	via Septic >200m from Waterways* (lb/yr)	via Septic within 200m of Waterways* (lb/yr)	via Septic >200m from Waterways* (lb/yr)			
South Hampton, NH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	51%
Strafford, NH	1,281.4	63.7	155.0	624.2	0.0	67.8	0.0	9,566.6	42,158.4	1.8	40%
Stratham, NH	1,420.0	191.8	956.4	1,117.5	18.7	169.0	1,926.6	18,977.1	45,278.0	4.6	30%
Wakefield, NH	403.6	90.1	304.7	639.3	0.0	78.7	0.0	7,956.2	32,315.6	1.8	31%
Wolfeboro, NH	34.6	0.2	1.4	24.0	0.0	2.2	0.0	70.9	409.7	0.9	45%
Acton, ME	218.3	28.1	67.8	295.7	0.1	36.0	9.9	3,501.8	18,554.2	1.3	28%
Berwick, ME	11,909.5	220.9	715.3	1,203.9	12.2	126.3	1,102.7	12,210.6	60,776.0	2.5	39%
Eliot, ME	4,301.9	160.0	627.8	874.6	35.2	91.9	3,483.0	9,988.1	44,613.5	4.2	37%
Kittery, ME	5,862.4	320.2	1,459.6	998.1	57.0	29.5	5,114.2	3,836.6	42,308.9	4.4	39%
Lebanon, ME	810.9	129.8	410.2	1,090.7	24.5	131.3	2,752.2	15,254.4	57,452.3	1.6	35%
North Berwick, ME	1,361.6	110.0	424.7	875.3	0.0	94.0	0.0	9,630.9	40,115.8	1.6	41%
Sanford, ME	378.9	229.3	1,068.7	1,072.6	0.0	123.7	0.0	7,241.6	24,450.7	2.0	29%
Shapleigh, ME	6.5	0.5	3.5	7.9	0.0	0.9	0.0	56.9	509.0	1.5	54%
South Berwick, ME	661.0	204.0	555.8	1,161.6	4.4	92.3	525.0	9,535.2	41,990.2	2.3	45%
Wells, ME	195.2	47.7	172.6	368.7	0.0	48.8	0.0	4,402.3	13,128.6	1.9	38%
York, ME	69.6	31.5	26.3	150.4	0.0	18.3	0.0	269.1	2,129.3	1.1	55%
Amesbury, MA	0.1	0.8	0.0	0.0	0.0	0.2	0.0	8.9	14.1	3.4	4%
Salisbury, MA	238.0	123.8	204.5	142.5	0.2	19.6	15.0	6,427.2	20,484.4	3.8	40%
Total =	140,771.6	10,804.4	47,252.5	46,166.1	618.4	4,681.1	50,435.6	461,977.9	1,811,335.1	2.6	35%