New Hampshire Department of Environmental Services
Great Bay Nitrogen Non-Point Source Study
Appendix A

Nitrogen Deposition to Great Bay – A Modeling Study

April 30, 2014

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Introduction

The intent of this study is to use a regional dispersion model to estimate source contributions to the 2009 atmospheric deposition of nitrogen to the Great Bay watershed. The two major questions to be assessed by this analysis include: (1) how much of the nitrogen deposition to the Great Bay watershed comes from sources inside New Hampshire versus how much comes from outside of the state, and (2) how much of the nitrogen comes from certain individual emissions source categories (on- and off-road mobile sources, power generation, and area sources). In addition, this analysis includes a review of data for establishing current estimates of total atmospheric nitrogen deposition for the Great Bay Estuary and a discussion of how the atmospheric deposition rate is expected to change over the next 10 years due to changes in emissions from Clean Air Act regulations on stationary and mobile emissions sources.

Background

Atmospheric deposition of nitrogen takes place in two primary forms, dry deposition (settling without assistance of precipitation), and wet deposition (including washout - or the adhesion of nitrogen compounds to the surface of precipitation, and rainout – where nitrogen compounds are included in the cloud-borne composition of the fluid or crystals that make up the precipitation). Both components of total deposition are largely dependant on atmospheric concentrations of the nitrogen containing gasses and suspended particles. Total nitrogen is the resulting sum of wet and dry nitrogen deposition.

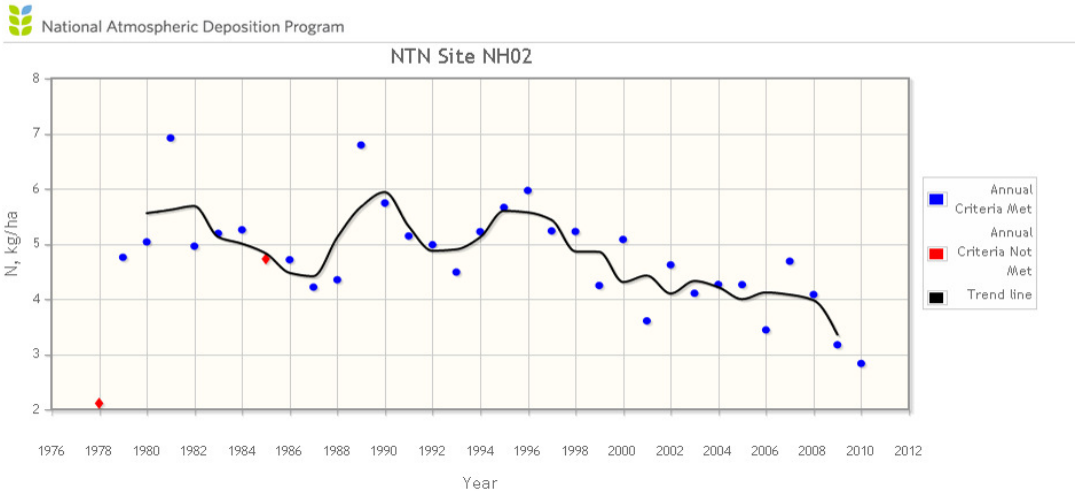
Below in Figure 1 are the wet deposition trends since 1980 for total nitrogen as measured at Hubbard Brook Experimental Forest (Woodstock, NH) located about 100 miles to the northwest of Great Bay. Due to transport patterns and topography, nitrogen deposition rates vary from year to year. For this reason, expressing deposition rates in terms of a range rather than a single number make sense when not focused on a single year of historical data. Because the Great Bay watershed is located closer to urban sources of nitrogen and because the area lies more directly in the path of regional transport, air pollution and deposition rates are expected to be higher at Great Bay than at Hubbard Brook. This is apparent in Table 1 when comparing the data for Hubbard Brook with data from Thompson Farm, located near Great Bay, which for most years had values higher than those for Hubbard Brook.

Table 1: Measured Wet Deposition Rates (kg N/Ha-Yr) (kilograms of nitrogen per hectare per year)

Year	Thompson Farm	Hubbard Brook	Cape Cod, MA	Quabbin Res., MA	Eastern MA	Bridgton, ME	Casco, ME
2002		4.62	4.45	4.38	4.62	3.36	3.30
2003		4.10	4.36	5.17	3.30	3.06	2.47
2004	4.23	4.26	2.77	4.15	3.92	2.41	3.72
2005	5.35	4.26	2.80	4.60	4.41	3.23	3.42
2006	4.79	3.44	3.02	4.48	4.56	2.87	3.47
2007	4.29	4.68	2.73	5.47	2.94	3.38	3.36
2008	6.58	4.08	2.63	6.08	4.65	3.80	3.10
2009	4.44						

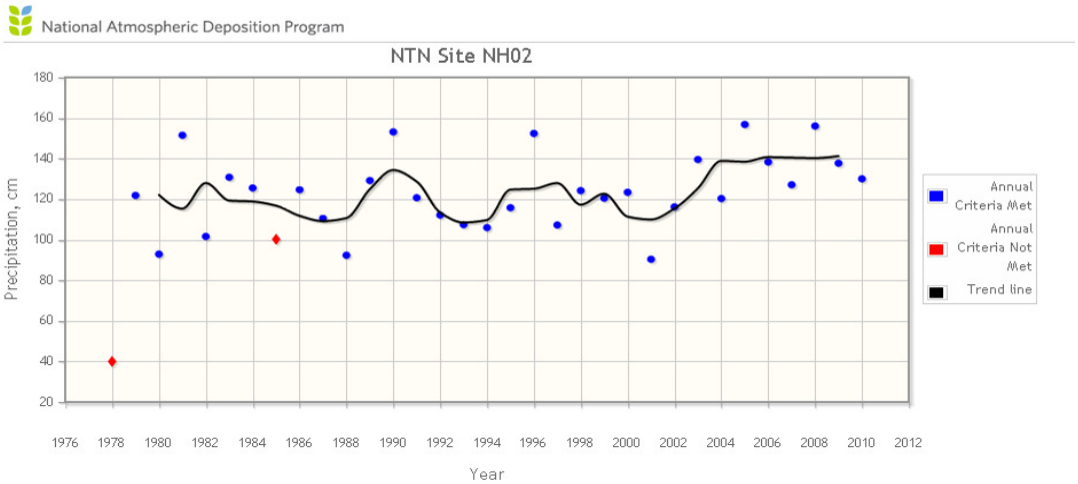
Data as presented in Table 2.2 of Daley et al. 2010. NITROGEN ASSESMENT FOR THE LAMPREY RIVER WATERSHED. New Hampshire Water Resources Research Center, University of New Hampshire. Available online: http://des.nh.gov/organization/divisions/water/wmb/coastal/documents/unh_nitrogenassessment.pdf.

Figure 1: Total Nitrogen Wet Deposition Trends – Hubbard Brook, NH 1980-2010



Note: Meeting annual criteria requires that a set number of samples per year are successfully collected and analyzed.
Source: National Atmospheric Deposition Program

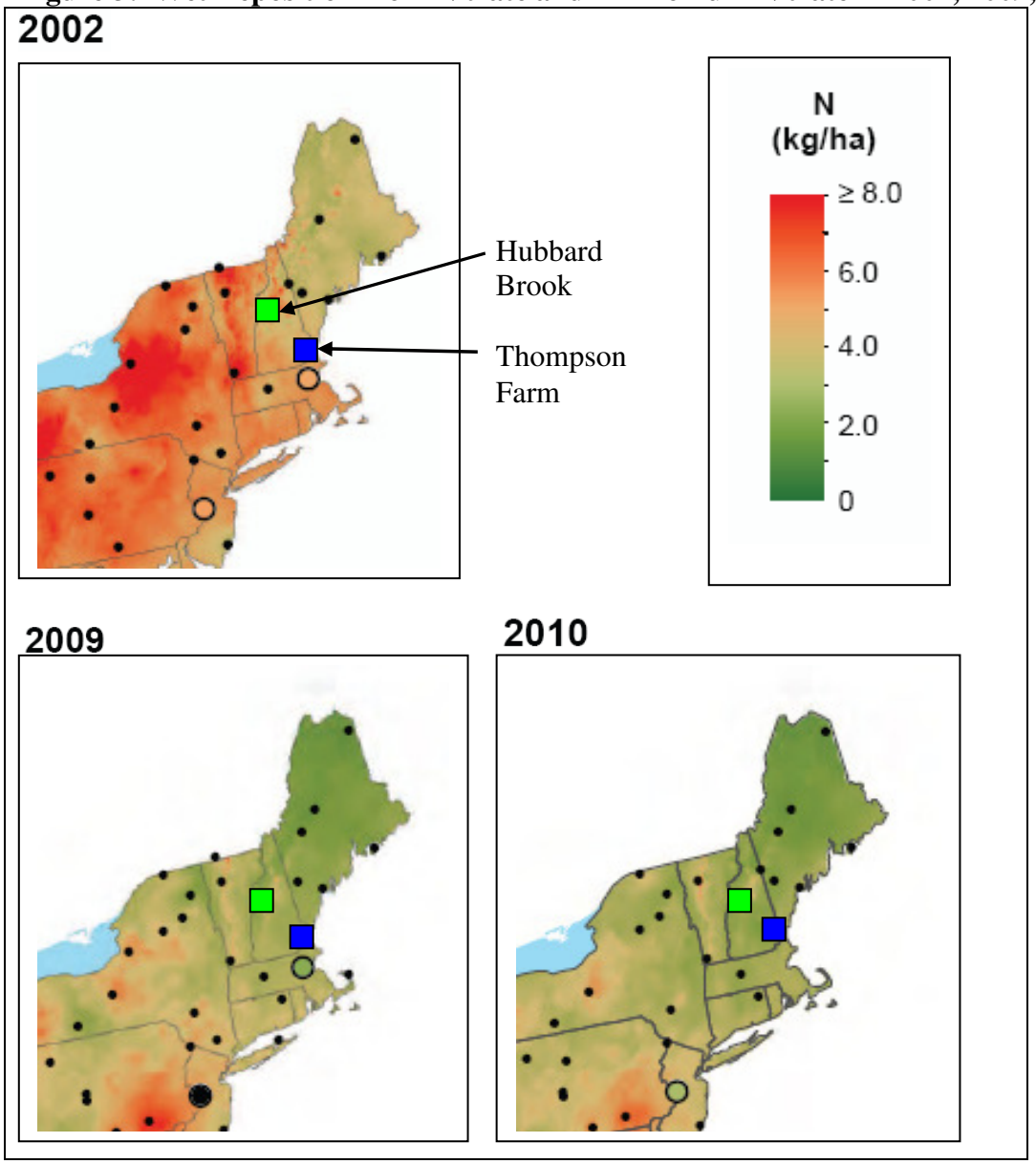
Figure 2: Precipitation Trends – Woodstock, New Hampshire 1980-2010



Note: Meeting annual criteria requires that a set number of samples per year are successfully collected and analyzed.
Source: National Atmospheric Deposition Program

It is a given that wet deposition variability depends on year to year precipitation. A plot of historical precipitation is provided in Figure 2 for comparative purposes. It is interesting to note that annual wet nitrogen deposition rates roughly trend the annual precipitation rates until approximately 1996, when the Federal NOx SIP Call rule was enacted, resulting in significantly reduced nitrogen oxide (NOx) emissions from power plants upwind of New Hampshire. From that point forward, nitrogen deposition has trended downward while precipitation has actually increased slightly. This trend is further evidenced by Figure 3, which shows wet deposition of nitrate and ammonium nitrate in the northeast for 2002, 2009, and 2010. The maps associated with Figure 3 show how higher terrain can be associated with higher deposition rates. This is due to orographic lifting of the air over the mountains which results in greater amounts of precipitation than occurs over flatter land. The increased precipitation and associated increased nitrogen deposition rates are localized effects.

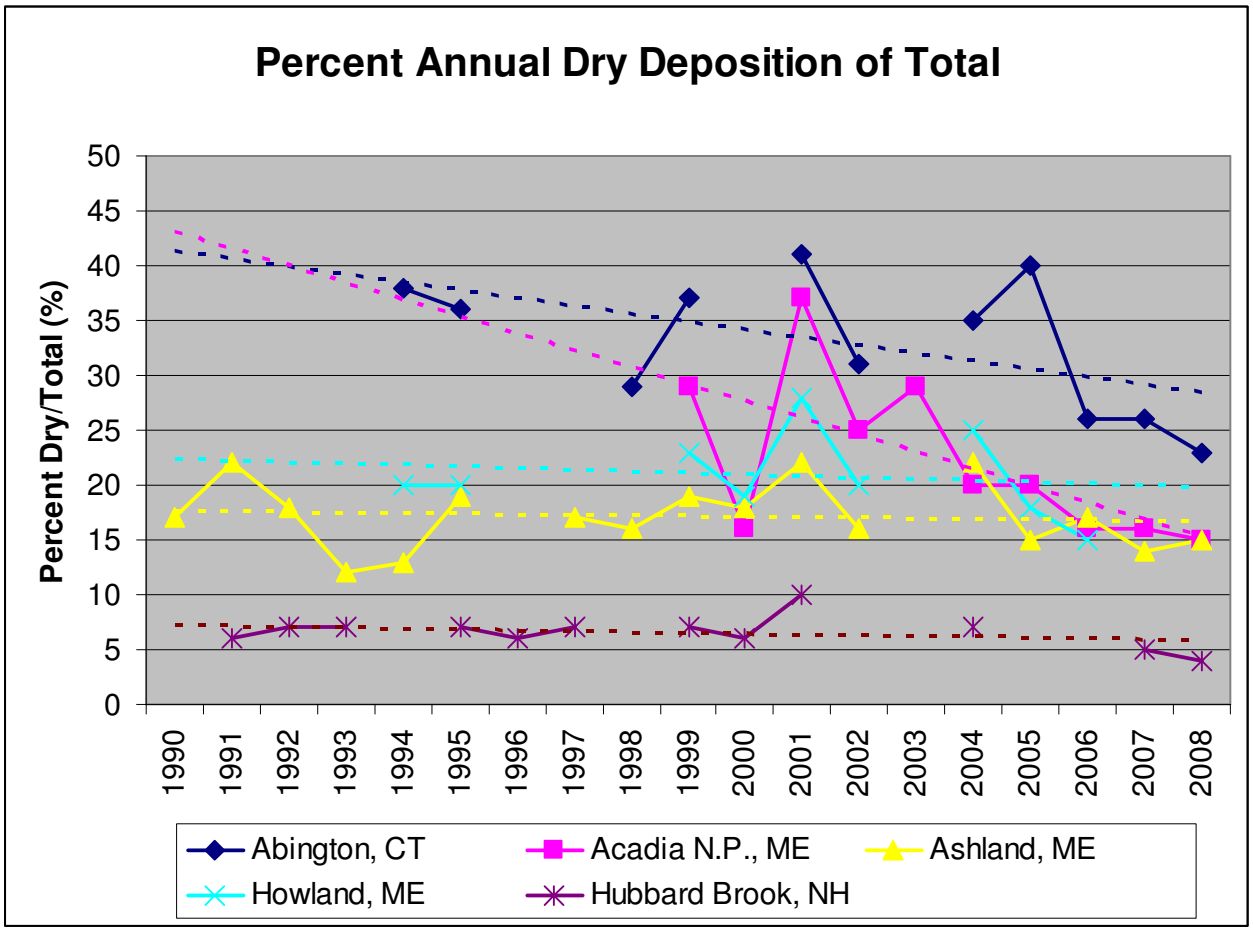
Figure 3: Wet Deposition from Nitrate and Ammonium Nitrate in 2002, 2009, and 2010



Source: National Atmospheric Deposition Program

Data presented in the University of New Hampshire (UNH) study for regional locations used a ratio of wet deposition to dry deposition of 1.73 at Thompson Farm based on data collected by a report by Ollinger, et. al (1993)[1]. Because of the inherent complexities associated with measuring dry deposition, it is typically estimated based on ambient air concentrations or as a ratio to measured wet deposition rather than actually measured. The UNH study used the latter technique and used a ratio consistent with regional studies (1.73 wet to dry). For this modeling analysis, the ratio has been updated to 3.17 based on data collected regionally to reflect the changes in nitrogen oxide emissions across the region since the timeframe of the Ollinger, et. al. (1993) report. Table 2 shows the dry deposition rates at Thompson Farm for 2004-2009 that were estimated from wet deposition using the updated ratio along with actual measurements of dry deposition collected nearby within the region. Figure 4 shows how the percentage of dry deposition to total deposition has dropped since the early 1990s. It is estimated that from 1993 to 2009 dry deposition in the Great Bay area has gone from 37% to the total nitrogen deposition rate to about 24%, thus changing the ratio of wet to dry deposition from 1.73 to 3.17.

Figure 4: Trends of Measured Percent Dry to Total Deposition of Nitrogen



[1] Ollinger, S., Aber, J., Lovett, G., Millham, S., Lathrop, R., and Ellis, J. 1993. A spatial model of atmospheric deposition for the northeastern U.S. *Ecological Applications* 3 (3): 459-472.

Note: Dry deposition collection techniques vary which can lead to widely varying dry deposition values (and percent dry to total deposition ratios). UNH researchers depended on data from the Ollinger, et. al (1993) report and applied a ratio of 37% (dry to total). Rather than introduce a different methodology, this study builds on the determinations made in the UNH report and upgrades the ratios based on more recent trends which show dry to total deposition ratios decreasing by about 35% during this period of data collection. As a result, this report applies a 24% rate of dry to total deposition for Great Bay.

Table 2: Dry Deposition Rates (kg N/Ha-Yr)

Year	Thompson Farm*	Hubbard Brook	Abington, CT
2002			2.08
2003			
2004	1.34	0.33	2.19
2005	1.69		2.20
2006	1.52		1.44
2007	1.36	0.26	1.50
2008	2.08	0.18	1.33
2009	1.41		

Data as presented in Table 2.5 of Daley et al. 2010. NITROGEN ASSESMENT FOR THE LAMPREY RIVER WATERSHED. New Hampshire Water Resources Research Center, University of New Hampshire. Published online:http://des.nh.gov/organization/divisions/water/wmb/coastal/documents/unh_nitrogenassessment.pdf.
** - Revised dry deposition rates for Thompson Farm use the updated wet to dry deposition ratio of 3.17.*

Analytical Approach

A regional dispersion model was run for the eastern United States to generate estimated deposition rates of key nitrogen species as well as atmospheric concentrations of the same species. Upon completion of the modeling, data was extracted for the portion of the modeling domain that corresponds to the Great Bay watershed.

A review of measured nitrogen deposition data from around the region shows significant variability. When selecting a measurement location to be representative of the study area, the location and year of the data are critical variables. Therefore, data from the closest measurement location that reasonably represents the targeted year should be used to approximate deposition to the study area of interest (in this case, the Great Bay watershed). It should be further noted that precipitation rates vary from year to year, and thus wet deposition of nitrogen, which depends on precipitation, will vary in proportion to the precipitation. Therefore, the year of the selected data should be as close as possible to the targeted year, and it should have similar precipitation totals as the targeted year.

Bearing the above in mind, it was determined that data collected and calculated for Thompson Farm (UNH) provides the best and most reasonable baseline for 2009 to use in this analysis. It is relatively recent and geographically nearby. Further, the year of the data (2009) is consistent with the emission inventory used for the modeling exercise. Based on a best-fit analysis of recent trends, annual total nitrogen deposition for the Great Bay for 2009 should be about 6.5 kg N/Ha-Yr with fluctuations of about ± 25%. Total deposition reported for Thompson Farm for 2009 is 5.85 kg N/Ha-Yr (using a 24% rate of dry to total), which is slightly below the mid-point but within the expected range of fluctuation.

Because the focus of this study is to estimate total nitrogen deposition onto the Great Bay watershed, the modeled estimates for wet deposition were combined with the results for dry deposition. Combined overall results are presented in the sections below.

Wet Deposition

For wet deposition, the New Hampshire Department of Environmental Services (DES) had some concerns regarding the regional dispersion model's ability to output reliable wet deposition rates; therefore, wet deposition was handled in a slightly more mechanical fashion. The model was used to estimate concentrations of key nitrogen species in the air above the Great Bay watershed. During periods when precipitation was reported in the area, these concentrations were accumulated and averaged over the vertical layers of the model (which represent various altitudes in the atmosphere) and multiplied by a precipitation scavenging factor as provided in research literature (Table 3).

Table 3: Relative Scavenging Rates Applied to Precipitation Column Ambient Concentrations

Chemical Species	Scavenging Rate
NH_3	1,148
HNO_3	308
NO	658
NO_2	420
HONO	1,302
PNO_3	300

Tabulated values are multiplied by cumulative average concentrations during periods of precipitation (over lowest 1000 meters of vertical layers)

Once wet deposition was estimated by the model for the 2009 base case, it was compared and normalized to levels measured at Thompson Farm for 2009. From this benchmark, additional modeling, which assessed contributions from different source areas and source categories, was considered on a relative basis.

The total 2009 wet nitrogen deposition estimate for the Great Bay area (based on Thompson Farm) applied to the modeling was: **4.44 kg N/Ha-yr**. This value is shown in Table 1 (above) alongside data at Thompson Farm for other years, as well as data from other sites in New England.

Dry Deposition

Because a number of uncertainties are associated with deposition modeling, the regional dispersion model was applied in a relative manner, similar to the process recommended by EPA for state implementation plan (SIP) attainment modeling. That is, model output is normalized with measured levels, as opposed to simply being used directly. For dry deposition, the modeling results for the 2009 base case were normalized in proportion to 2009 dry deposition measured in the region of Great Bay (Thompson Farm). From this benchmark, additional modeling, which assessed contributions from different source areas and source categories, was considered on a relative basis.

The total dry nitrogen deposition estimate for the Great Bay Area in 2009 comes from a revision to the data presented in the UNH report for Thompson Farm. The following value was used to normalize modeling results: **1.41 kg N/Ha-Yr**. This value is shown in Table 2 (above) alongside data at Thompson Farm for other years, as well as data from other sites in New England.

Modeling Approach

Air quality modeling for this analysis was conducted using a regional photochemical modeling platform capable of estimating the distribution and magnitude of air pollutant concentrations within a reasonable range of error. Estimated 2009 emissions inventories as used by EPA, the Ozone Transport Commission (OTC), and the Mid-Atlantic and Northeast States Visibility Union (MANE-VU) were used as input into the air quality model. Emission reduction strategies were applied to isolate the contribution of each emission source sector listed below:

- Point sources (including power generation) in NH
- Point sources (including power generation) outside of NH
- Area sources in NH
- Area sources outside of NH
- Non-road mobile sources in NH
- Non-road mobile sources outside of NH
- On-road mobile sources in NH
- On-road mobile sources outside of NH

The following is a description of each of these emissions source sectors:

- Point sources represent discrete facilities; examples include electrical generating units (EGUs), manufacturing facilities, and heating plants at large schools and hospitals
- Area sources represent facilities and activities that are too widespread or numerous to be counted individually, and are therefore estimated in aggregate
- Non-road mobile sources are vehicles and equipment that do not operate on roadways, including aircraft, locomotives, ships, construction equipment, and other types of commercial and recreational vehicles
- On-road mobile sources are vehicles that operate on roadways, including cars, trucks, buses and motorcycles

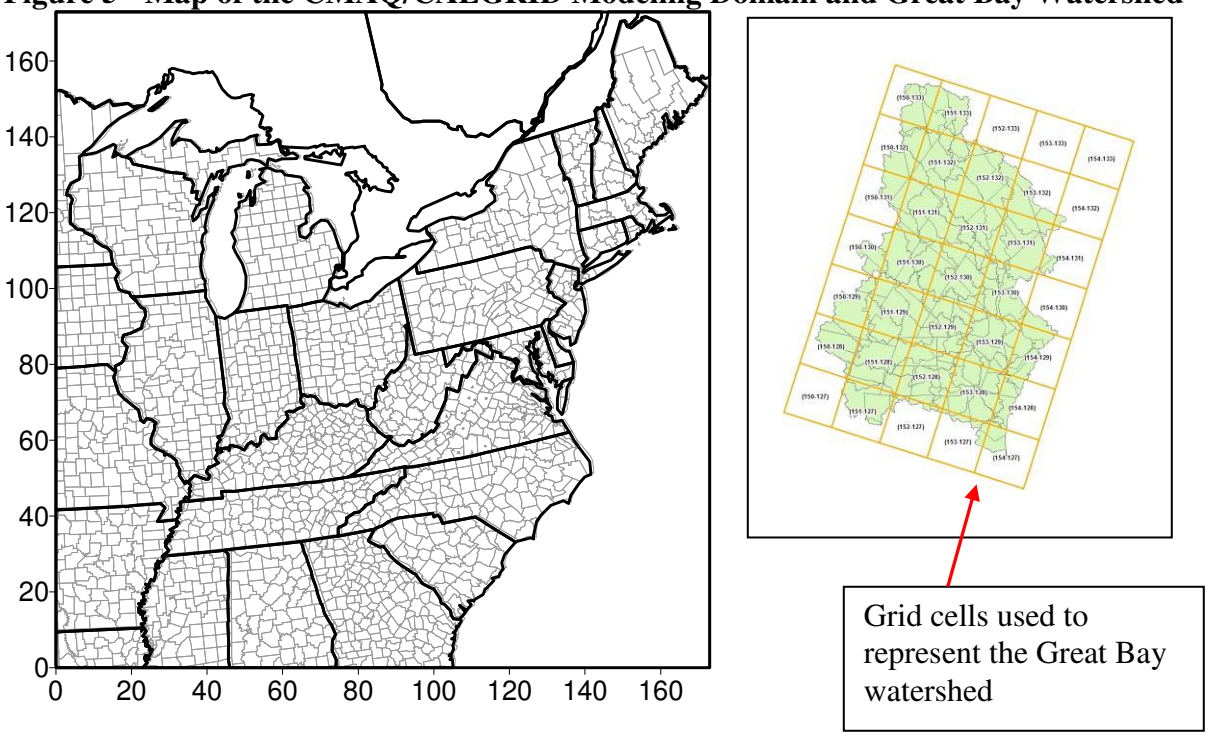
Modeling Methodology

For the nitrogen deposition analyses, DES used the California Photochemical Grid Model (CALGRID) screening-level modeling platform. CALGRID has been used by a number of Northeast states and California for photochemical modeling exercises. The general methodologies that were used in running this modeling platform are described below.

DES used the Ozone Transport Commission (OTC) ozone modeling domain which uses a Lambert Conic Conformal projection and covers the eastern United States and parts of Canada. The southwest corner of the domain was set at 264 km, -888 km and the northeast corner was set to 2328 km, 1176 km. A 12-km grid cell resolution was used with 172 grid cells in the east-west direction and 172 grid cells in the north-south direction. The vertical grid definition includes 9 layers. The OTC modeling domain is shown in Figure 5. The OTC 12-km ozone modeling domain is a subset of the 36-km national domain which was used by the Regional Planning Organizations (RPOs) for regional haze analysis.

Modeling for the Great Bay watershed focuses on grid cells 150 to 154 in the X dimension and from 127 to 133 in the Y dimension (see Figure 5).

Figure 5 - Map of the CMAQ/CALGRID Modeling Domain and Great Bay Watershed



Emissions Processing Methodology

The 2009 emissions inventories used for this study were the same ones used in regional photochemical air quality modeling for 8-hour ozone analyses and were prepared by the regional haze-based RPOs and their contractors. These inventories were processed for regional model input using the Sparse Matrix Operator Kernel Emissions (SMOKE) model. The SMOKE modeling was performed by New York Department of Environmental Conservation (NYSDEC) and other regional modeling centers, including Northeast States for Coordinated Air Use Management (NESCAUM) and the Virginia Department of Environmental Quality (VADEQ). Emissions processing was done for the 2002 Base Year and the 2009 On The Books/On The Way (OTB/OTW) modeling scenario. The OTB/OTW scenario accounted for those emissions control measures that were either on the books or reasonably anticipated to occur for the year 2009. The 2002 Base Year and 2009 OTB/OTW emissions are summarized by state in Table 4. Further details on the SMOKE processing that was done in support of the 8-hour ozone analyses are provided in NYSDEC's technical support document TSD-1c, *Emission Processing for the Revised 2002 OTC Regional and Urban 12 km Base Case Simulations*, September 19, 2006. Figure 6 shows the source sector breakout for 2009 NOx emissions for New Hampshire and non-New Hampshire sources within the modeling domain.

For the CALGRID modeling effort, the pre-merged SMOKE emissions files were obtained from the modeling centers and re-formatted for input into the CALGRID emissions processor (EMSPROC). EMSPROC allows the CALGRID user to adjust emissions temporally, geographically, and by emissions category for control strategy analysis. The pre-merged SMOKE files that were obtained from the modeling centers were broken down into the biogenic, point, area, non-road, and on-road emissions categories. These files by component were then converted for use with EMSPROC, thus giving CALGRID users the flexibility to analyze a wide variety of emissions control strategies. Quality assurance (QA/QC) plots were generated during the re-formatting of the emissions data to

ensure that an accurate modeling inventory was generated for the CALGRID platform. Example emissions QA/QC plots for NOx are shown in Figures 7 through 10.

Table 4 - Modeling Emissions Inventory: State-by-State Anthropogenic NOx

State	2002 Baseline (tons/day)	2009 OTW/OTB (tons/day)	Percent Reduction from 2002 Baseline
Connecticut	232.16	149.41	35.64%
Delaware	101.20	91.53	9.56%
D.C.	29.13	18.30	37.18%
Maine	170.64	109.75	35.68%
Maryland	548.58	312.77	42.99%
Massachusetts	483.18	312.68	35.29%
New Hampshire	131.02	84.22	35.72%
New Jersey	625.68	397.32	36.50%
New York	1199.32	831.85	30.64%
Pennsylvania	1614.24	1020.05	36.81%
Rhode Island	89.78	57.60	35.84%
Vermont	54.44	34.62	36.41%
Virginia	975.74	673.39	30.99%
Alabama	732.86	492.41	32.81%
Arkansas	519.30	268.22	48.35%
Georgia	1153.90	874.75	24.19%
Kentucky	1043.23	641.29	38.53%
Illinois	1797.25	1067.17	40.62%
Indiana	1329.23	926.42	30.30%
Michigan	902.07	812.06	9.98%
Mississippi	356.48	271.04	23.97%
Missouri	733.00	438.76	40.14%
North Carolina	1141.21	744.30	34.78%
Ohio	1379.28	848.93	38.45%
South Carolina	660.35	481.35	27.11%
Tennessee	1045.52	710.79	32.02%
West Virginia	902.95	432.65	52.08%
Wisconsin	667.49	447.50	32.96%

Figure 6: 2009 Emission Inventories by Major Sector for Inside and Outside New Hampshire

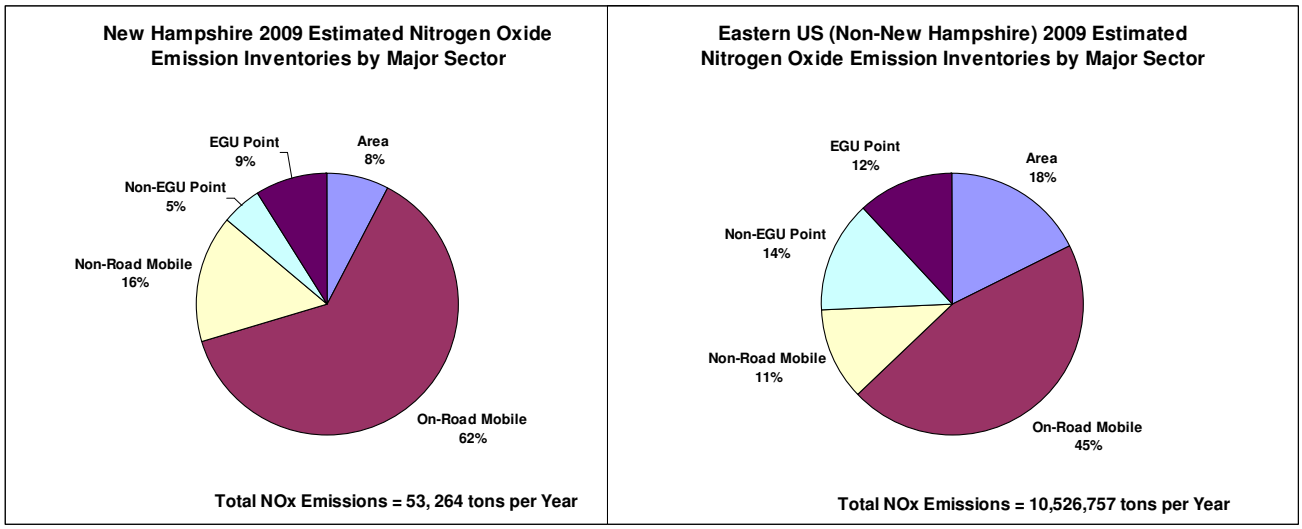


Figure 7: Sample QA/QC Plot of Point Source NOx Emissions (2002)

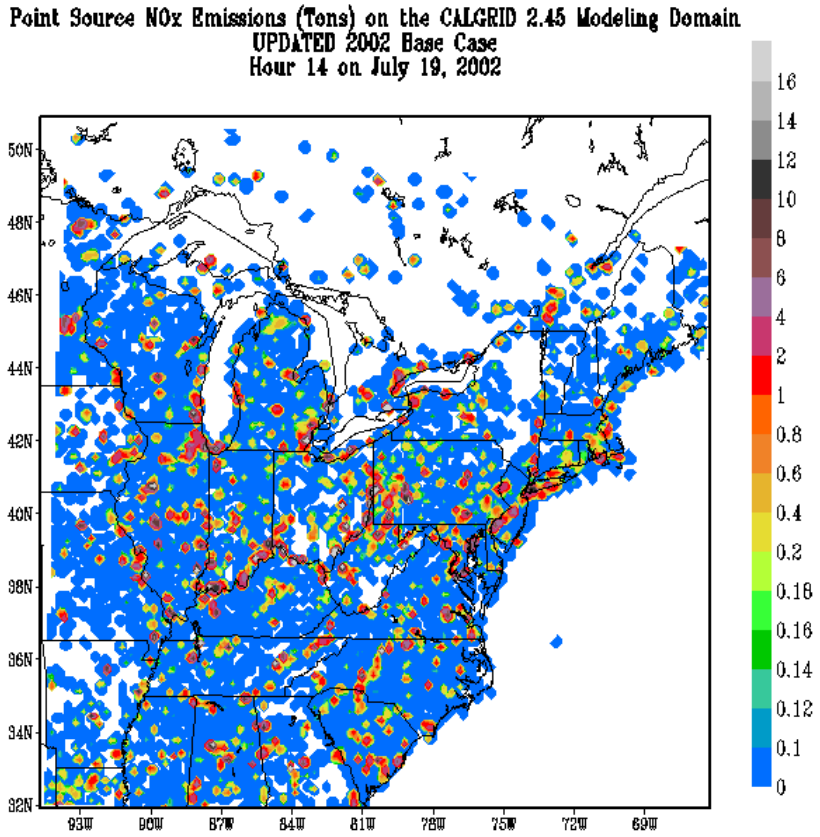


Figure 8: Sample QA/QC Plot of On-Road (Highway) NOx Emissions (2002)

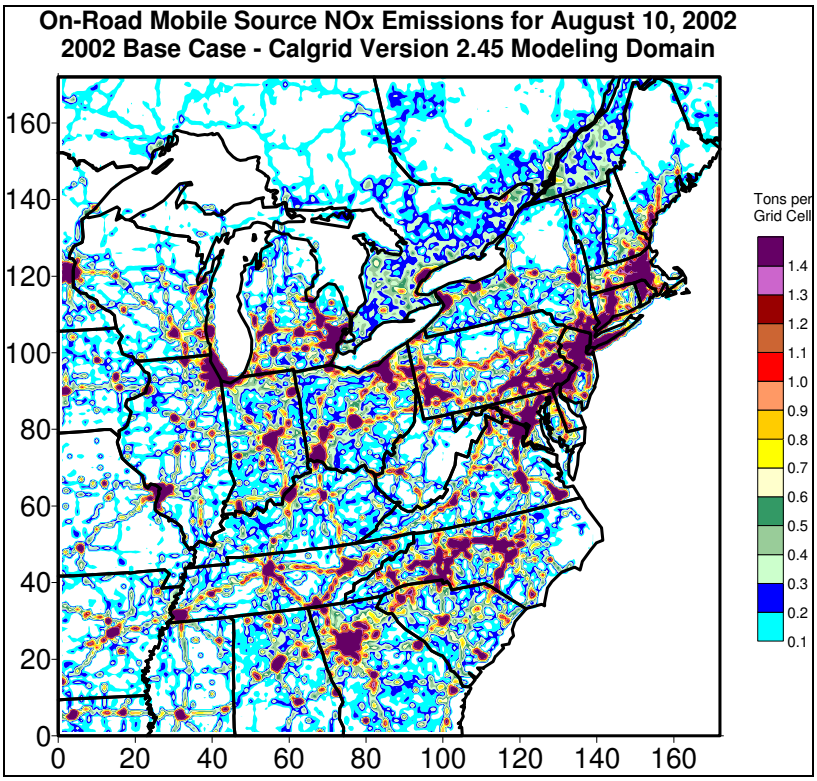


Figure 9: Sample QA/QC Plot of Non-Road NOx Emissions (2002)

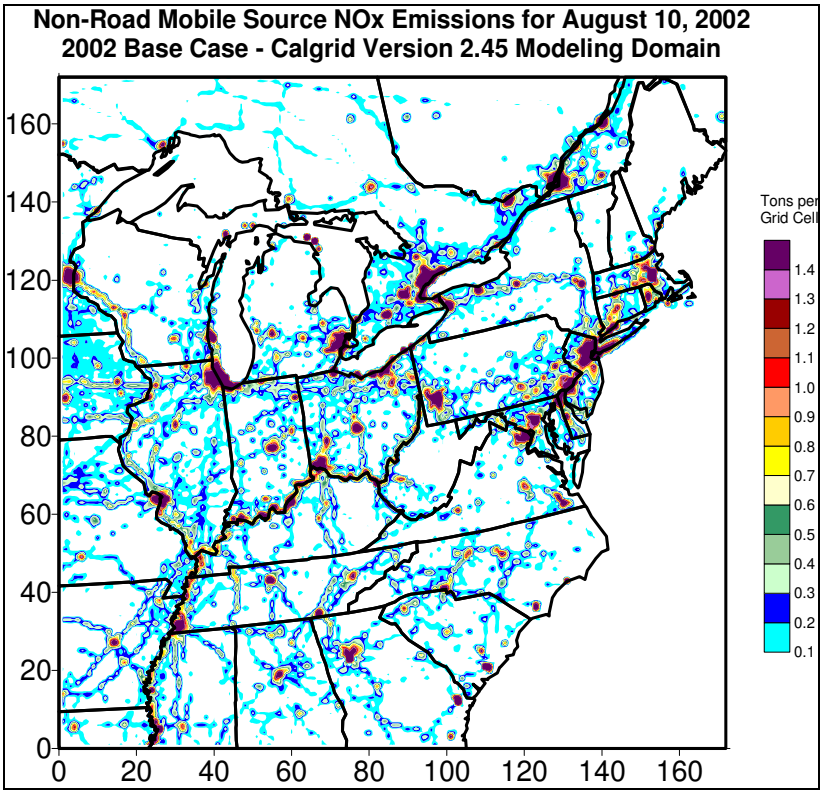
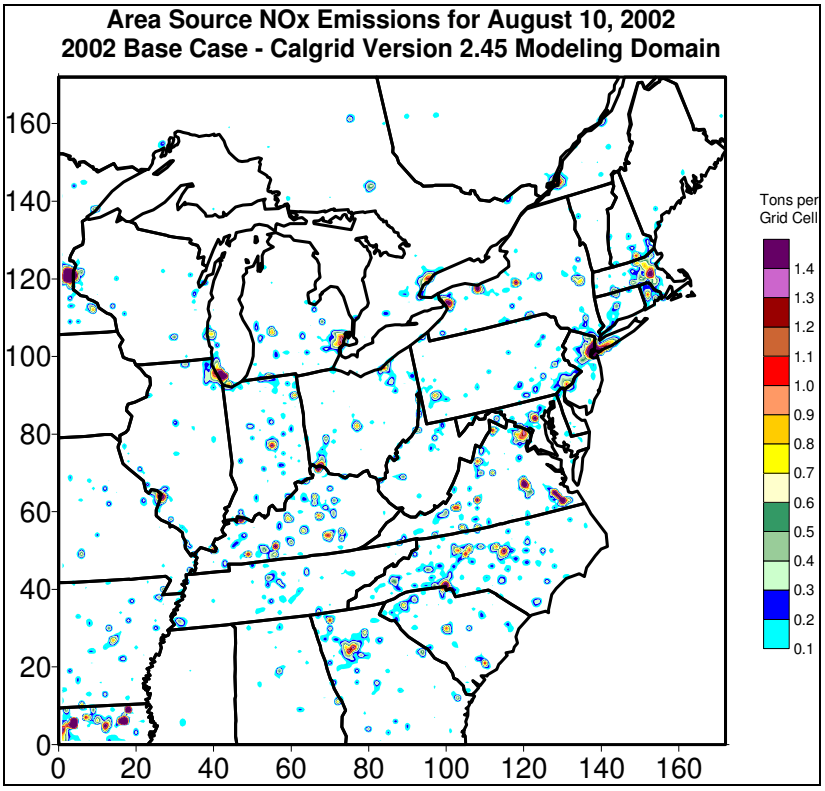


Figure 10: Sample QA/QC Plot of Area Source NOx Emissions (2002)



Meteorology Processing Methodology

The meteorological data used by CALGRID was developed by the University of Maryland (UMD) in conjunction with staff at NYSDEC. UMD used the Penn State/National Center for Atmospheric Research (NCAR) 5th Generation Mesoscale Model (MM5) Version 3.6 to generate year 2002 meteorological inputs. The MM5 modeling domain was set up on a two-way nested grid that followed the RPO national domain. The 36-km coarse mesh grid consisted of 149 grid cells in the east-west direction and 129 grid cells in the north-south direction. The 12-km fine mesh grid consisted of 175 grid cells in both the east-west and north-south directions. A total of 29 vertical layers were used in the MM5 simulations. An extensive analysis was undertaken to compare the MM5 predictions with observations for the period of May through September 2002. An assessment was made to compare MM5 outputs with surface observations from the National Weather Service and CASTNet, wind-profiler measurements from the Cooperative Agency Profilers (CAP) network, satellite cloud image data from the UMD Department of Atmospheric and Oceanic Science, and precipitation data from the Earth Observing Laboratory at NCAR. Technical details regarding the 2002 MM5 simulations and the assessment to compare them with observations are described in NYSDEC's Technical Support Document TSD-1a, *Meteorological Modeling Using Penn State/NCAR 5th Generation Mesoscale Model (MM5),* February 1, 2006.

For the CALGRID modeling platform, a processing program was used to interpolate the MM5 outputs to the CALGRID modeling grid and map them to CALGRID's vertical layer structure. QA/QC plots were generated during the processing to ensure the accuracy of the interpolated data. Figures 11 and 12 show example QA/QC plots from the re-formatting of the meteorological data for use with the CALGRID modeling platform.

Figure 11: Sample QA/QC Plot of Temperature Data

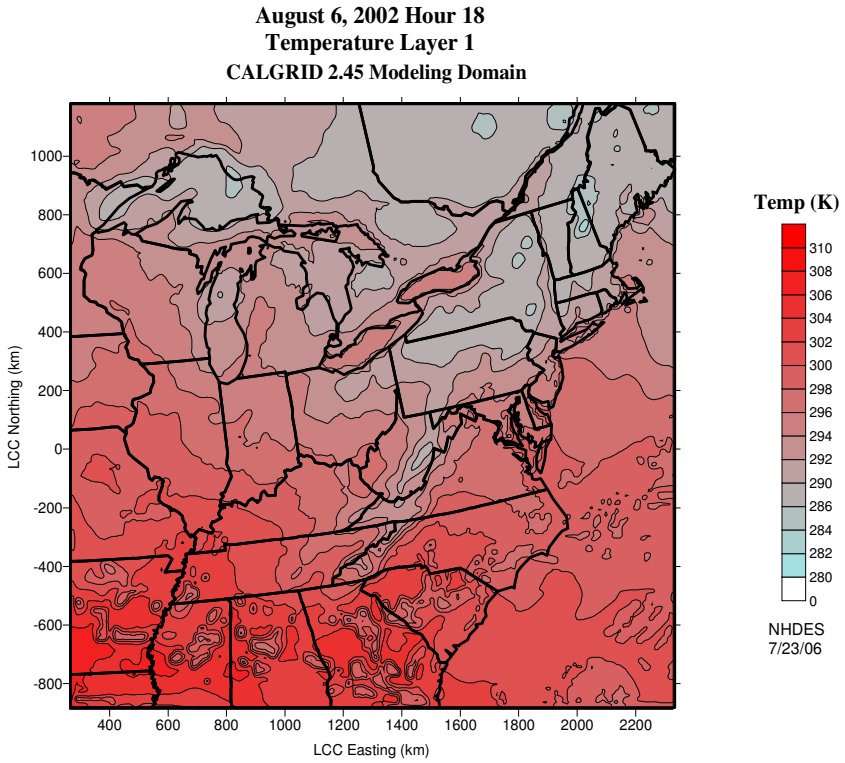
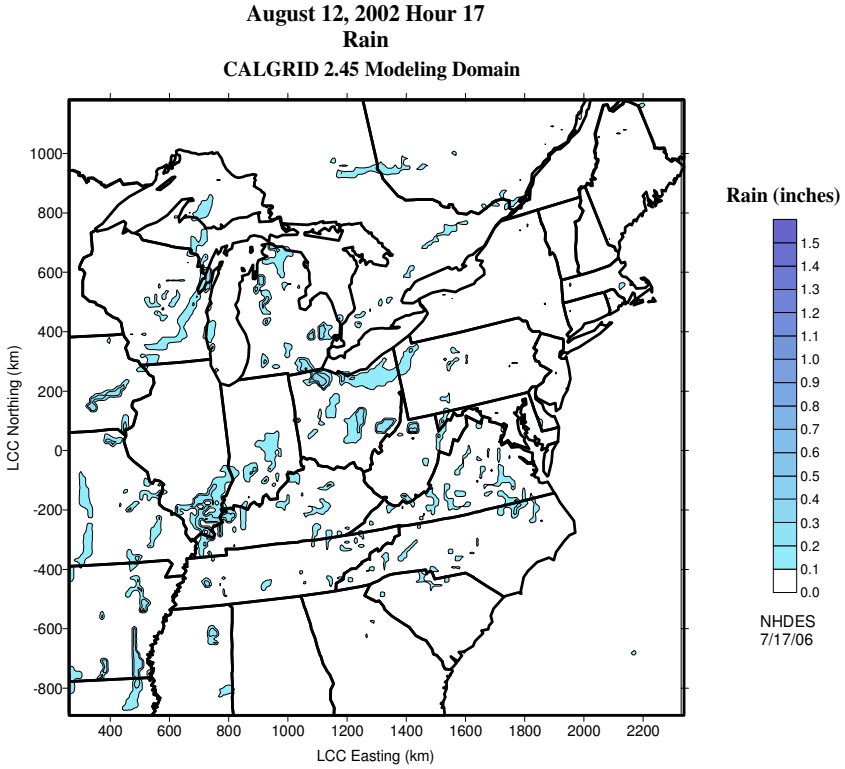


Figure 12: Sample QA/QC Plot of Rainfall Data



Modeling Results

As discussed in earlier sections, modeling was performed for representative periods using 2002 meteorology and 2009 emissions. This modeling accounts for emissions sources and weather patterns over most of the eastern United States in order to consider the role that all of these factors play in deposition patterns in New Hampshire.

The modeling was focused on the 35 12-km model grid cells best representing the Great Bay watershed (please refer to Figure 5). The values from these grid cells were averaged to provide an average deposition rate that could be applied to the entire Great Bay watershed. Dry deposition rates were fairly uniform over most of the 35 grid cells, but dropped off sharply over the eastern edge and the southeast corner of the watershed grid cell box (see Figure 13 below). Wet deposition rates were more uniform over all of the grid cells covering the watershed, with slightly higher rates seen along the eastern, southern, and southeastern grid cells. Figures 13 through 15 below show the percent deposition in each of the modeled grid cells representing the Great Bay watershed for dry, wet, and total deposition respectively.

The model produced estimates for dry deposition of key nitrogen-containing chemical species, and then this data was normalized to 2009 dry deposition estimates provided by UNH for Thompson Farm, which is located near Great Bay. For wet deposition, concentrations of key nitrogen species were predicted for the lowest 1000 meters for those hours when precipitation was occurring in southern New Hampshire. Wet deposition scavenging rates were applied to these concentrations to produce an estimate for rain-out and wash-out. These results were then normalized to Thompson Farm 2009 data for the grid cell containing the Thompson Farm site. An additional normalization factor was applied to estimate the deposition rate in the other grid cells. The modeled deposition rate in each of the grid cells was divided by the modeled deposition rate for the grid containing Thompson Farm. Grid cells that were predicted to have lower deposition rates than the grid cell containing Thompson Farm had a ratio that was less than 100%. Grid cells that were predicted to have higher deposition rates than the grid cell containing Thompson Farm had a ratio that was greater than 100%. This ratio was used to estimate the expected deposition rate for each grid cell based on the measured rate at Thompson Farm. The ratios for each grid cell are shown in Figure 16.

Figure 13: Percent Deposition Occurring in Each of the Modeled Grid Cells Representing the Great Bay Watershed - *Dry*

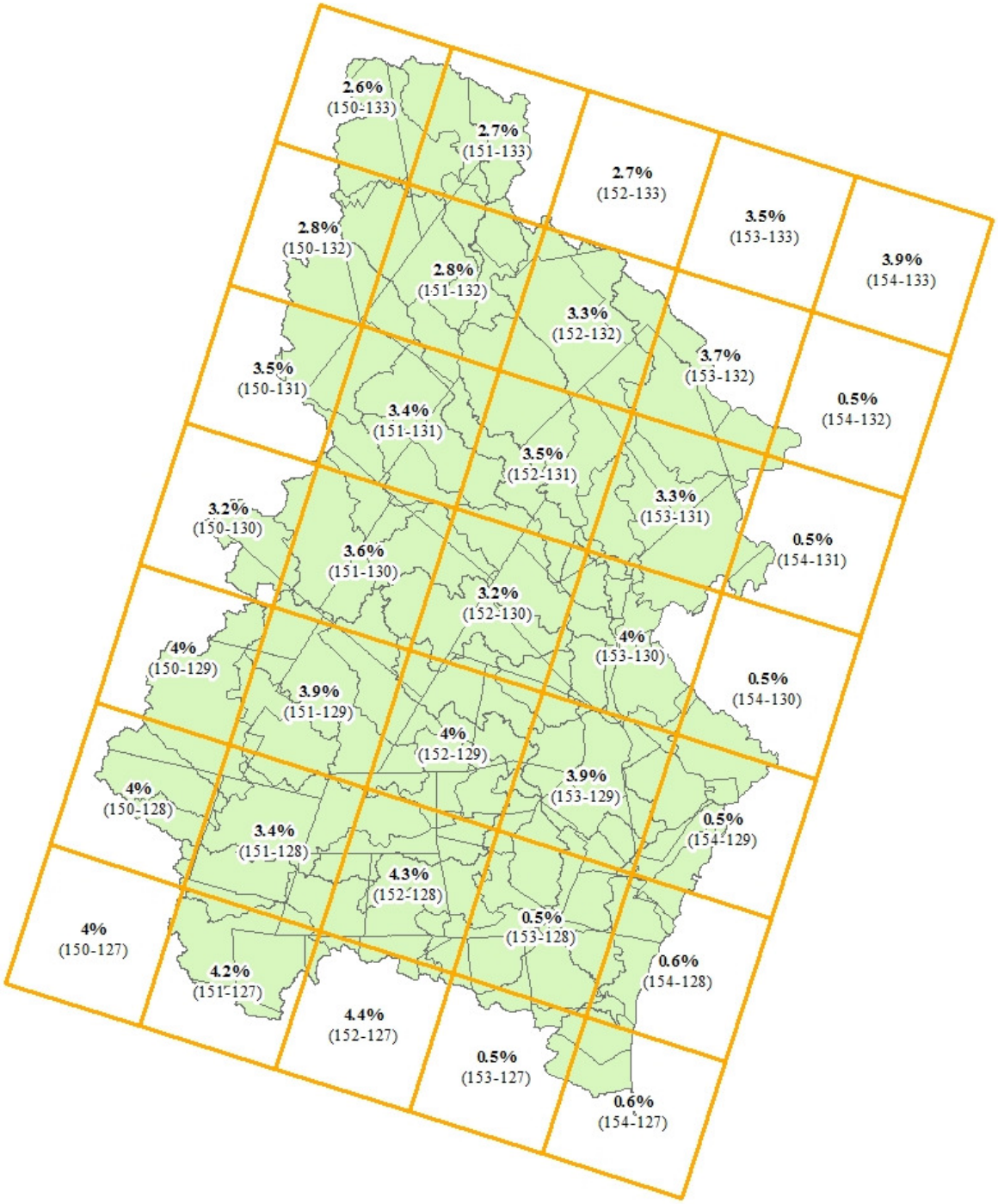


Figure 14: Percent Deposition Occurring in Each of the Modeled Grid Cells Representing the Great Bay Watershed - *Wet*

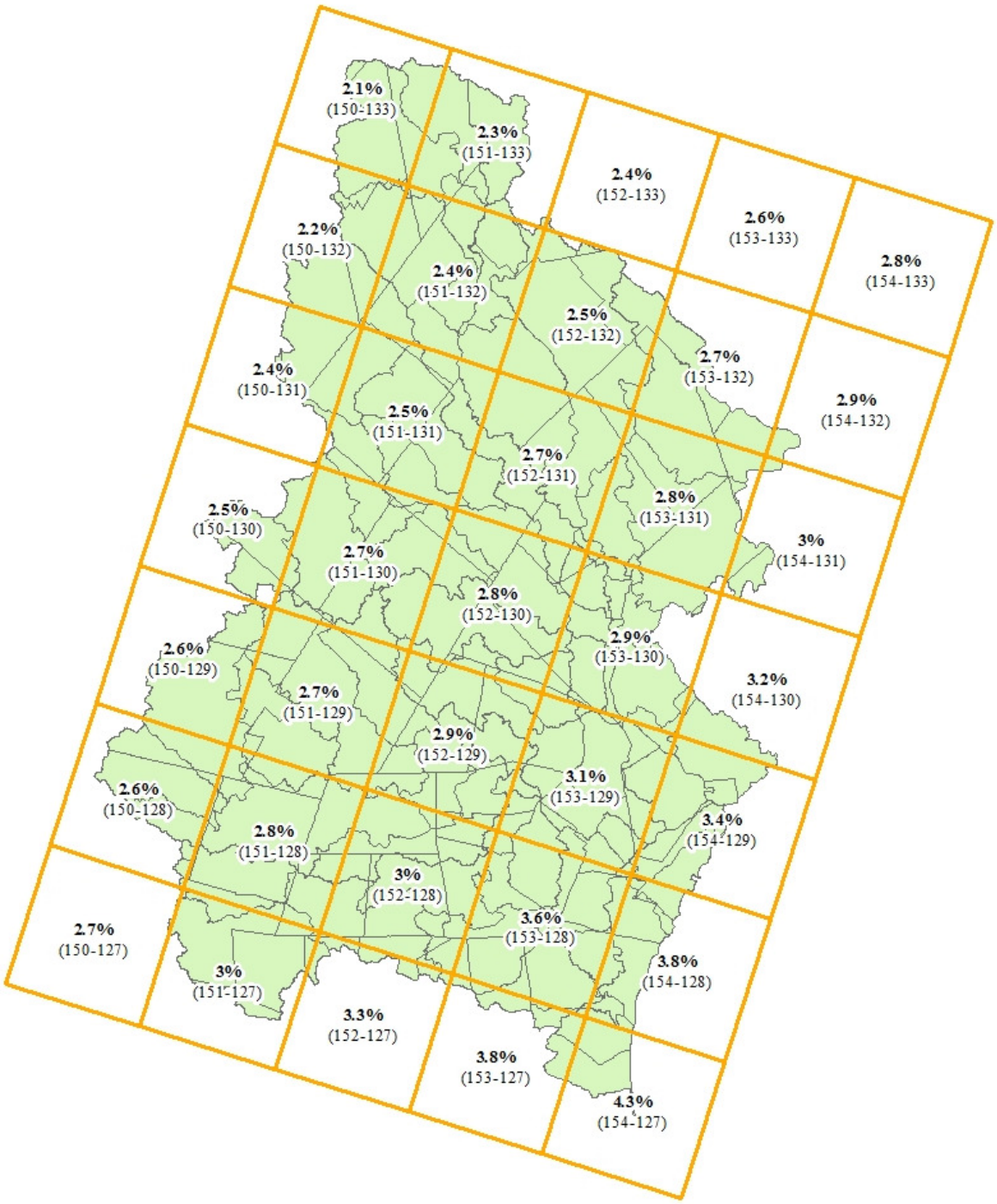


Figure 15: Percent Deposition Occurring in Each of the Modeled Grid Cells Representing the Great Bay Watershed - *Total*

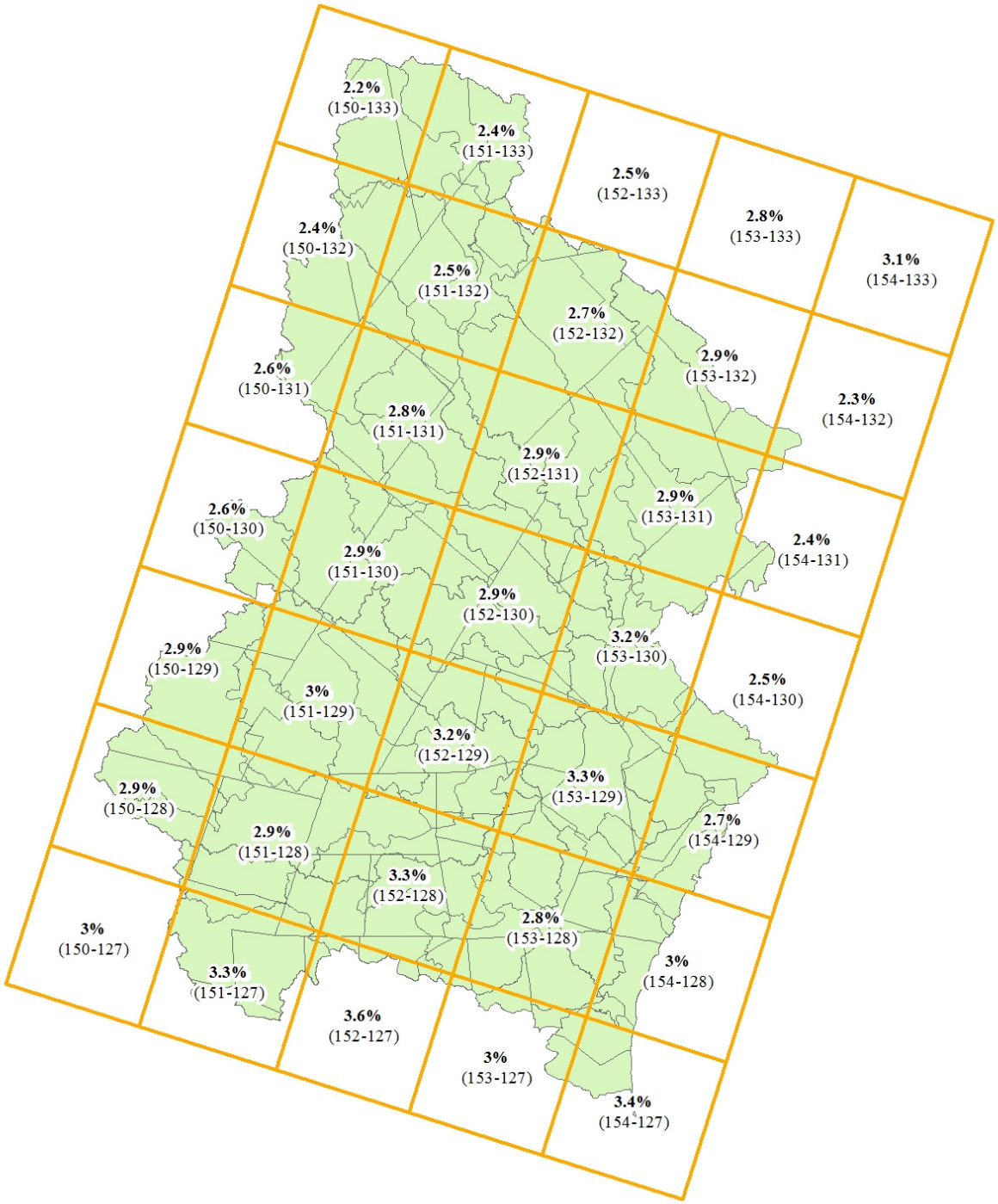
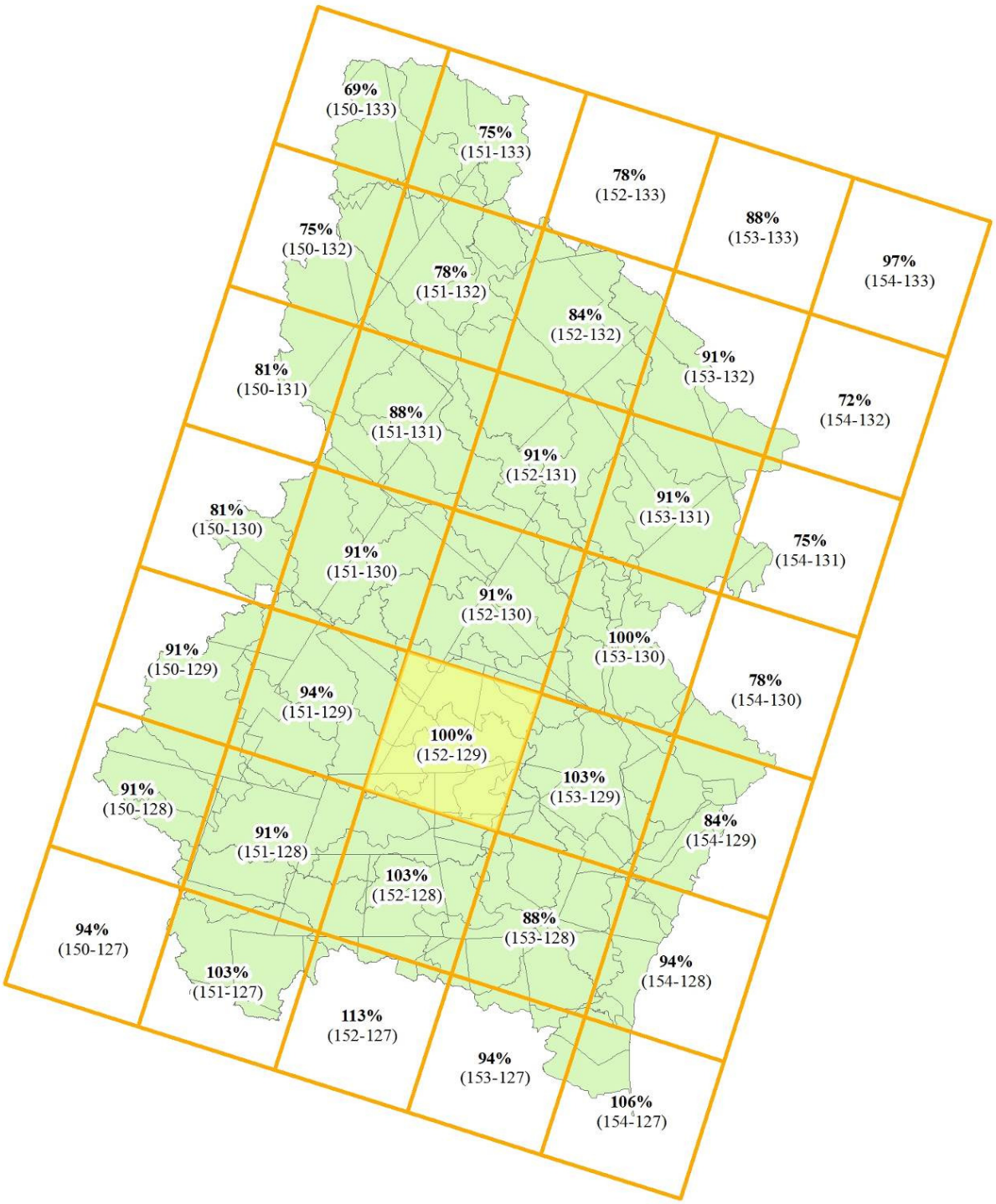


Figure 16: Ratio of Total Deposition Occurring in Each of the Modeled Grid Cells to the Modeled Deposition in the Grid Cell Containing Thompson Farm (in yellow)



Nine scenarios were modeled: a 2009 base case, and cases isolating the contributions of area, on-road non-road, and point (including power generation), for sources located inside and outside of New Hampshire. Normalized modeling results are provided below:

Table 5: Dry Deposition Modeled Estimates for 2009 (Kg/Ha-year)*

	Sources Located in:		
	All Locations	New Hampshire	All Other Areas
All Sources	**1.41**	**0.50**	**0.91**
On-Road – Mobile	0.49	0.13	0.36
Non-Road – Mobile	0.31	0.13	0.18
Area	0.27	0.12	0.15
Point - Power Generation	0.34	0.12	0.22

Table 6: Wet Deposition Modeled Estimates for 2009 (Kg/Ha-year)*

	Sources Located in:		
	All Locations	New Hampshire	All Other Areas
All Sources	**4.44**	**1.67**	**2.77**
On-Road – Mobile	1.28	0.43	0.85
Non-Road – Mobile	1.02	0.42	0.60
Area	0.92	0.41	0.51
Point – Power Generation	1.22	0.41	0.81

Table 7: Total Deposition Modeled Estimates for 2009 (Kg/Ha-year)*

	Sources Located in:		
	All Locations	New Hampshire	All Other Areas
All Sources	**5.85**	**2.17**	**3.68**
On-Road – Mobile	1.76	0.56	1.20
Non-Road – Mobile	1.33	0.54	0.79
Area	1.19	0.54	0.65
Point - Power Generation	1.57	0.53	1.04

Table 8: Total Deposition – Wet and Dry (Percent of Total - %)*

	Sources Located in:		
	All Locations	New Hampshire	All Other Areas
All Sources	**100**	**37**	**63**
On-Road – Mobile	32	10	22
Non-Road – Mobile	22	9	13
Area	20	9	11
Point - Power Generation	26	9	17

*** - Note that deposition rates were normalized to 2009 levels reported for Thompson Farm. Year to year weather and emission variations could increase or decrease by up to an estimated 25% of these rates for other years. Further, the percent contribution by source sectors and from inside and outside of New Hampshire are based on the weather patterns associated with the year modeled.**

Modeling indicates that approximately 63% of the total nitrogen deposition comes from sources located outside of New Hampshire. Of the four source sectors considered for in-state emissions, all had fairly equal contributions (9 to 10%). Out of state sources had sector contribution to total deposition in the range of 11 to 22%, with on-road mobile sources having the highest contribution.

According to the model, much of the out of state contribution originates along the urban corridor from Virginia to Massachusetts (i.e., the metro areas of Washington, DC, New York City, and Boston).

Wet and dry deposition patterns largely mirror the total deposition patterns in terms of the percent contribution from emissions sectors and geographic area.

Total atmospheric deposition to Great Bay for 2009 is estimated to be approximately 37% from New Hampshire sources and 63% from sources located outside of New Hampshire. One of the highest contributing sectors for both inside and outside of New Hampshire is on-road mobile sources (cars and trucks) (10% for inside New Hampshire and 21% for outside New Hampshire). The five highest contributing sectors, in order from greatest to least impact, are: 1. Non-NH on-road (22%), 2. non-NH point (17%), 3. non-NH non-road (13%), 4. non-NH area (11%), and 5. NH on-road (10%).

Future Projections

It is anticipated that atmospheric nitrogen deposition rates will decrease in future years, both on a local and regional scale. This is evidenced by the historical decrease in NOx emissions as well as projected future decreases in NOx emissions. Table 9 below shows NOx emissions estimates for a 20 year period for the continental United States. Theses figures were taken from the OTC and USEPA.

Table 9: NOx Emissions Estimates and Projections Over a 20 Year Period for the Continental U.S. (in Tons Per Year)

Category	2001	2007	2013	2020
Point Sources	7,880,016	3,749,506	2,762,007	2,635,895
Area Sources	1,701,207	2,124,670	2,088,960	1,972,546
Non-Road Mobile	4,050,655	1,517,771	1,353,752	971,222
On-Road Mobile	8,064,067	5,504,009	2,425,594	1,972,547
Total	21,695,945	12,895,957	8,630,314	7,552,211

Source: Ozone Transport Commission and EPA

The above table illustrates that projected 2020 NOx emissions decrease by about 65% with respect to 2001 emissions levels and 41% with respect to 2007 levels. NOx emissions in 2020 are projected to be about 12% lower than today's levels (i.e. 2013 levels). Most of these reductions come from the point and mobile sectors and are attributable to the Federal Clean Air Interstate Rule/Cross-State Air Pollution Rule, motor vehicle emissions control programs, and rules for non-road engines and fuels. Continued future emissions reductions are expected as older on- and off-road vehicles are phased out of the fleet and replaced by newer, cleaner vehicles. Note that the emission reductions benefits of the Federal programs and rules are enough to offset the increases in activity levels (e.g., vehicle-miles-traveled) for mobile sources.

The downward trend in NOx emissions is also expected to occur on a local and regional level. Table 10 shows 2009 and 2018 NOx emissions estimates for New Hampshire and the MANE-VU region. These figures were taken from emissions inventories prepared by MARAMA (Mid-Atlantic Regional Air Management Association) and its affiliated states for use in State Implementation Plan modeling for ozone and regional haze.

Table 10: 2009 and 2018 NOx Emissions Estimates for New Hampshire and the MANE-VU Region (in Tons Per Year)

	New Hampshire		MANE-VU States	
Category	**2009**	**2018**	**2009**	**2018**
Point Sources	4,312	4,258	434,682	374,951
Area Sources	11,879	12,180	278,038	263,061
Non-Road Mobile	8,485	6,344	353,219	271,181
On-Road Mobile	19,927	7,671	745,736	303,955
Total	44,603	30,453	1,811,675	1,213,148

Note: The MANE-VU region includes the six New England states plus DE, DC, MD, NJ, NY, and PA.
Source: NHDES and MANE-VU

Table 10 shows that NOx emissions reductions between 2009 and 2018 are anticipated to be 32% and 33% for New Hampshire and the MANE-VU region, respectively.

Because of the ongoing emission reductions associated with existing rules and control programs, it is anticipated that atmospheric nitrogen deposition into Great Bay will continue to decrease over the next 10 years and nitrogen deposition could decrease by as much as 12% from current (2012-13) levels and up to about 33% from the 2009 rates posted in this report. Projection of nitrogen deposition changes into the region beyond the year 2020 are too uncertain to project at this time due to the possible changes in fuels for mobile sources and for power generation.

New Hampshire Department of Environmental Services
Great Bay Nitrogen Non-Point Source Study

Appendix B

Methodology for Estimating
Disconnected Impervious Area,
Connected Impervious Area,
Water Area, and
Natural Vegetation Area
in the Piscataqua Region Watershed

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Purpose

This appendix contains detailed methodologies used to estimate the areas for four land use categories for the Nitrogen Loading Model: (1) Disconnected Impervious Area (DIA; e.g. roofs and driveways); (2) Connected Impervious Area (CIA; e.g. roads/lots/runways); (3) Water Area (e.g. lakes, rivers and estuaries); and (4) Natural Vegetation. The methods for estimating the area of agricultural lands, recreational turf, and lawns are provided in Appendices C, D, and E, respectively. The outputs of this analysis will be used to partially populate the Nitrogen Loading Model for the Great Bay Nitrogen Non-Point Source Study.

Disconnected Impervious Area (DIA) and Connected Impervious Area (CIA)

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).

The Nitrogen Loading Model contains default equations to estimate the area of DIA and CIA using the number of houses in the watershed, average roof and driveway areas, and certain high density land use classifications. However, the model can also be used with alternative methods to estimate DIA and CIA, if available.

For this study, more detailed information on impervious areas was substituted for the default calculations of DIA and CIA in the Nitrogen Loading Model. Impervious cover throughout the study area in 2010 was mapped by the Piscataqua Region Estuaries Partnership. This dataset provided the total impervious area in each modeled watershed. DES then used the approach from Sutherland (1995) to estimate CIA. DIA was calculated by difference. DES believes that this method for estimating DIA and CIA is more accurate than the default model calculations because it uses the best available data and does not rely on assumptions about roof and driveway sizes for all of the houses in the watershed.

Methodology

1. Information Inputs

Two types of information were needed for this study: (1) the 2006 C-CAP land cover dataset; and (2) Impervious area raster dataset (2010 30 meter pixel rasters produced by the University of New Hampshire, UNH).

UNH has created rasterized coverages of impervious area in the coastal watershed representing conditions in 1990, 2000, 2005, and 2010. The coverages were created using Landsat Thematic Mapper imagery with a pixel size of 30 meters. Each pixel is assigned an integer value between 0 and 10 representing the percent of the pixel covered by impervious area (IA). For this study, the most recent coverage from 2010 will be used. Metadata for this layer states that it represents constructed materials (e.g., pavement, buildings), not imperviousness of the ground from compaction or other processes.

The one land use/land cover dataset available for the whole Piscataqua Region watershed is the Coastal Change Analysis Program (C-CAP) 2006 land cover data. The C-CAP provides the "coastal expression" of the National Land Cover Database (NLCD) with a resolution of 30 meters. Landsat Enhanced Thematic Mapper imagery from 2006 was used to categorize each pixel into one of 25 land cover classes:

1 Unclassified (Cloud, Shadow, etc)	14 Palustrine Scrub/Shrub Wetland
2 High Intensity Developed	15 Palustrine Emergent Wetland
3 Medium Intensity Developed	16 Estuarine Forested Wetland
4 Low Intensity Developed	17 Estuarine Scrub/Shrub Wetland
5 Open Spaces Developed	18 Estuarine Emergent Wetland
6 Cultivated Land	19 Unconsolidated Shore
7 Pasture/Hay	20 Bare Land
8 Grassland	21 Water
9 Deciduous Forest	22 Palustrine Aquatic Bed
10 Evergreen Forest	23 Estuarine Aquatic Bed
11 Mixed Forest	24 Tundra
12 Scrub/Shrub	25 Snow/Ice
13 Palustrine Forested Wetland	

The C-CAP data is not ideal because the land cover classes do not directly match the requirements of the Nitrogen Loading Model and the 30-meter resolution is coarse. Unfortunately, there are no other alternatives. More detailed land cover data are available for only Rockingham County and parts of Strafford County, New Hampshire, which were mapped with 1-foot resolution by UNH in 2005. Likewise, the Maine portion of the watershed is covered by the Maine Land Cover Database which used older Landsat Thematic Mapper imagery from 1999-2001 with 5-meter resolution. The benefits of using the single C-CAP coverage for the whole watershed outweigh those that might be obtained by merging the two alternative datasets that were developed with different methods.

2. Study Area

The study area was the Piscataqua Region watershed. Only the portion of each town that is in the watershed was included.

3. Analytical Approach

Step 1: Total Area

The entire study area was divided up into 215 polygons ("study polygons") created by the intersection of major tributary watersheds, HUC12 subwatersheds, and town boundaries. Total area of these polygons were calculated from the geometry of the polygons in the ArcGIS shapefiles. This approach provides the most accurate area for the polygon but may differ from approximations of total area based on rasterized datasets.

- The most current HUC12 watershed (last modified: 02/14/2012) and town boundaries (last modified: 08/13/2012) were used

Step 2: Impervious Area/Land Use Zones

Within the study polygons, DES had to create unique land use "zones" in order to calculate directly connected impervious area. A zone is defined as all of the areas with the same land use class inside the study polygon.

- DES used the ArcGIS "Raster to Polygon" tool to convert the 2006 C-CAP raster dataset into a shapefile.
- Once converted, the ArcGIS "Dissolve" tool was used to combine all the individual pixels with the same land use type into multi-part polygons for each land use type.
- The ArcGIS "Identity" tool was then used to create unique polygons for each land use type that resided within each study polygon.
- A unique code (a combination of the study polygon ID & land use code) was assigned to each multi-part polygon of land use type in each study polygon.

Step 3: Impervious Area (IA)

To determine the IA in each study polygon, DES ran the ArcGIS "Tabulate Area" tool, which calculates cross-tabulated areas between two datasets and outputs a table.

- The multi-part polygons of land use zones in each study polygon created in Step 2 were used as the "Input raster or feature zone data", which is the dataset that defines the zones.

- The "Zone field", which is the field that holds the values that define each zone, was set to “study polygon ID_LU.”
- The combined NH and ME Impervious Surface coverage (last modified: 10/25/2011) provided by UNH was used as the "Input raster or feature class data", which is the dataset that defines the classes that will have their area summarized within each zone.
- The “Class” field, which is the field that holds the class values, was set to “Value”.
- Once generated, the output table was exported to an Excel spreadsheet. The output table reported the area (ft^2) of each of the ten values that could be assigned to the pixels in the rasterized impervious surface coverage within a given study area polygon/land use zone. The mid-point estimates of IA were then calculated for each zone by multiplying the reported area for each value by the percent IA for that value (Table 1) and summing across all values.
- The percent impervious area for each zone was then calculated by dividing the IA by the total area of the zone.

Table 1: Coefficients for Estimating Impervious Area (IA) from UNH Raster Dataset

IA raster value assigned by UNH	Representing a % IA range in pixel	%IA for Low IA Estimate	%IA for Mid IA Estimate	%IA for High IA Estimate
0	0%	0.0%	0.0%	0.0%
1	0-19%	0.0%	15.5%	19.0%
2	20-29%	20.0%	25.5%	29.0%
3	30-39%	30.0%	35.5%	39.0%
4	40-49%	40.0%	45.5%	49.0%
5	50-59%	50.0%	55.5%	59.0%
6	60-69%	60.0%	65.5%	69.0%
7	70-79%	70.0%	75.5%	79.0%
8	80-89%	80.0%	85.5%	89.0%
9	90-99%	90.0%	95.5%	99.0%
10	100%	100.0%	100.0%	100.0%

- The town of Salisbury, MA was only partially mapped for %IA by UNH so the process described above could not be performed. Instead, coefficients for different land use classes taken from the Rouge River Study conducted by EPA (RPO, 1994) were used to estimate %IA for all polygons representing portions of Salisbury. Table 2 indicates the %IA assigned to each land use category within Salisbury.

Table 2: Percent Impervious Area (IA) by Land Use Type

2006 C-CAP Land Use	% IA from Rouge River/EPA
Bare Land	0.0%
Cultivated Crops	2.0%
Deciduous Forest	1.9%
Developed, High Intensity	51.0%
Developed, Low Intensity	19.0%
Developed, Medium Intensity	38.0%
Developed, Open Space	11.0%

2006 C-CAP Land Use	% IA from Rouge River/EPA
Estuarine Emergent Wetland	1.9%
Estuarine Scrub/Shrub Wetland	1.9%
Evergreen Forest	1.9%
Grassland/Herbaceous	1.9%
Mixed Forest	1.9%
Open Water	0.0%
Palustrine Emergent Wetland	1.9%
Palustrine Forested Wetland	1.9%
Palustrine Scrub/Shrub Wetland	1.9%
Pasture/Hay	2.0%
Scrub/Shrub	1.9%
Unconsolidated Shore	1.9%

Step 4: Connected Impervious Area (CIA)

- To determine the CIA in each study area polygon, DES had to assign a connectivity class to each of the land use types, so that one of the "Sutherland Equations" (http://www.pacificwr.com/Publications/Estimating_EIA.pdf; Sutherland, 1995) could be utilized. The Sutherland Equations were used by EPA to calculate CIA from land use data in Massachusetts. Table 3 summarizes the connectivity class that was assumed for each land use type.
- The percent CIA in each study polygon/land use zone was calculated using the appropriate Sutherland equation (Table 3) and the percent IA calculated in Step 3.
- Where the percent IA calculated in Step 3 was <1, the percent CIA was set to zero. When the Sutherland equations were developed, IA was ground truthed to determine CIA. It was determined that when IA was less than 1%, CIA was equal to 0%.
- The total area of CIA in each zone was then calculated by multiplying the % CIA by the total acres within the zone.
- Pivot tables were used to sum the acres of CIA across all land use zones, and then to calculate the total CIA area in each study polygon.

Table 3: Sutherland Equations for C-CAP Land Use Types

2006 C-CAP Land Use	Connectivity	Sutherland Equation to predict %CIA (where IA(%) >1)
Developed, Medium Intensity	**Average**: Mostly storm sewered with curb & gutter, no dry wells or infiltration, residential rooftops not directly connected	$=0.1(IA)^{1.5}$
Developed, High Intensity	**Highly connected**: Same as Average, but residential rooftops are connected	$=0.4(IA)^{1.2}$
Barren Land (Rock/Sand/Clay)	**Mostly disconnected**: Small percentage of urban area is storm sewered, or 70% or more infiltrate/disconnected	$=0.01(IA)^{2}$
Bare Land		
Cultivated Crops		
Deciduous Forest		
Palustrine Forested Wetland		
Palustrine Scrub/Shrub Wetland		

2006 C-CAP Land Use	Connectivity	Sutherland Equation to predict %CIA (where IA(%) >1)
Palustrine Emergent Wetland		
Estuarine Scrub/Shrub Wetland		
Estuarine Emergent Wetland		
Unconsolidated Shore		
Palustrine Aquatic Bed		
Estuarine Aquatic Bed		
Evergreen Forest		
Grassland/Herbaceous		
Mixed Forest		
Open Water		
Pasture/Hay		
Scrub/Shrub		
Developed, Low Intensity	**Somewhat connected**: 50% not storm sewered, but open section roads, grassy swales, residential rooftops not connected, some infiltration	$=0.04(IA)^{1.7}$
Developed, Open Space		

Note: IA = %IA within group.

Step 5: Disconnected Impervious Area (DIA)
To determine the disconnected impervious area within each study polygon, DES subtracted the estimated acres of CIA calculated in Step 4 from the acres of IA calculated in Step 3.

4. Data Quality Objectives

To ensure the quality of the data, the following objectives were set at the beginning of the study.

a. CIA calculations should follow published methods whenever possible.
b. Uniform datasets covering the entire watershed should be used whenever possible.
c. Calculated CIA values should not exceed independent calculations of IA for watersheds and towns.

Natural Vegetation & Surface Waters

Methodology

1. Information Inputs

For estimating the area of natural vegetation and surface waters in the study area, six pieces of information were needed for this study: (1) the area covered by agricultural crops in the study area; (2) the area covered by residential lawns in the study area; (3) the area covered by managed turf in the study area; (4) the area covered by impervious surfaces in the study area; (5) the area of land (i.e. non surface waters) in the study area; and (6) the area of surface waters in the area.

2. Study Area

The study area was the Piscataqua Region watershed. Only the portion of each town that is in the watershed was included.

3. Analytical Approach

Step 1: Total Area

The entire study area was divided up into 215 polygons ("study polygons") created by the intersection of major tributary watersheds, HUC12 subwatersheds, and town boundaries. Total area of these polygons were calculated from the geometry of the polygons in the ArcGIS shapefile. This approach provides the most accurate area for the polygon but may differ from approximations of total area based on rasterized datasets.

- The most current HUC12 watershed (last modified: 02/14/2012) and town boundaries (last modified: 08/13/2012) were used.

Step 2: Water Area

To determine the area of surface waters within each of the unique study polygons, DES first combined the NHD Waterbody features (with FType = 390 - LakePond, 436 - Reservoir, and 493- Estuary) with the NHD Area features (with FType = 336 - CanalDitch, 364 - Foreshore, 403 - Inundation Area, 431 - Rapids, 445 - SeaOcean, 455 - Spillway, and 460 - StreamRiver).

This composite waterbody coverage was used to determine the amount of surface waters (lakes, estuaries and large rivers) within each study polygon using the ArcGIS Intersect tool, which computes a geometric intersection of the input features. The composite waterbody coverage was then used to remove duplicate information from the NHD Flowlines coverage (i.e. erase transport reaches through waterbodies). This step utilized the ArcGIS Erase tool and eliminated the possibility of double counting waterbodies when calculating the area of streams.

The ArcGIS Intersect tool was used to capture the length of each river reach within each study polygon. Once generated, the output table was exported to an Excel spreadsheet where the length of rivers in each study polygon was summed by Strahler Stream Order. According to stream order, river lengths were multiplied by median stream widths reported in J.A. Downing et al. (2012) (Table 4) to estimate stream area.

Table 4: Stream Width Relative to Strahler Stream Order

Strahler Stream Order	*n*	Mean Width (ft)	Median Width (ft)
1	46	6	5
2	48	9	6
3	50	25	18
4	59	90	36
5	41	239	156
6	68	637	325

The surface water areas calculated in the preceding steps were then summed within each study polygon.

Surface waters were further broken down into estuarine waters and fresh waters. To determine the area of estuarine waters within each study polygon, DES used the current DES Assessment Units (AUIDs). DES selected all AUID polygons that were coded as "EST", which is the designation for estuarine waterbodies. This composite waterbody coverage was used to determine the amount of estuarine waters within each study polygon using the ArcGIS Intersect tool.

Once generated, the output table was exported to an Excel spreadsheet where the areas of waterbodies in each study polygon were summed. The area of estuarine waters was subtracted from the total water area in order to determine fresh water area in each of the study polygons. In a few instances the area of estuarine waters was larger than that of the total water. This difference is due to the method used to create the AUID polygons. The AUIDs were created from DES's Shellfish Programs area classifications, which were built using a combination of NHD features, hydrography data, and aerial imagery. For this reason, the areas delineated do not match up perfectly with the NHD Waterbodies and NHD Areas. In these instances, the estuarine area was changed to match the total water area (1:1), and a note was placed in the spreadsheet with the original size calculated from the AUIDs. This correction was only needed in six study polygons, mostly in the Hampton-Seabrook area.

Step 3: Land Area
To determine the total land area within each of the study polygons, DES subtracted the total water area calculated in Step 2 from the total area calculated in Step 1.

Step 4: Area of agricultural crops, turf and impervious surfaces
The area of agricultural crops, turf and impervious surfaces were calculated by a variety of methods. See the following sections of this document for full explanations:

- Impervious Area (this document)
- Agricultural crops (Appendix C)
- Managed Turf (Appendix D)
- Residential Turf (Appendix E)

Step 5: Natural Vegetation Area
To determine the area of natural vegetation in each study polygon, DES summed the areas of impervious surfaces, agricultural crops, residential turf and managed turf. The sum of this area was then subtracted from the land area calculated in Step 3.

DES considered the potential for this approach to introduce error in the model from overlaps between the different land use datasets and found it to be low. There was concern that overlaps between different land use types could cause certain areas to be "double counted" for nitrogen loading. The impervious surface, agriculture, and residential lawn layers were all derived from the same Landsat Enhanced Thematic Mapper imagery with a 30-meter resolution. Different post processing techniques were used to analyze the data to develop the

different land use layers. As a result, there can be apparent overlaps between these layers (i.e., places where impervious surface and agricultural crops or some other land use appear to occur at the same location). These overlaps are a result of the scale at which the sampling occurred and the post processing of the data, not true overlaps of land use types. Although the same spatial datasets were used in multiple parts of the model, those multiple parts were applying and processing nitrogen from different sources and as such do not behave as redundant nitrogen overlaps in the model.

4. Data Quality Objectives

To ensure the quality of the data, the following objectives were set at the beginning of the study.

a. The area of natural vegetation calculated by difference for each watershed and town must be non-negative.

Results

Based on the above methodologies, the land area, water area, natural vegetation area, impervious area, disconnected impervious area, and directly connected impervious area in the study area were calculated. The results for the Piscataqua Region watershed are shown in Tables 5. The data quality objectives for the calculations were met.

Table 5: Area by Land Use Type in the Piscataqua Region Watershed

Land Use Type	Area (acres)	% of Study Area	% of Land Area
Full Study Area	695,227		
Land	662,507	95.3%	
Rivers	2,136	0.3%	
Lakes	16,791	2.4%	
Estuaries	13,794	2.0%	
Natural Vegetation	538,126		81%
Impervious Area (IA)	63,680		10%
Disconnected Impervious Area (DIA)	41,595		6%
Connected Impervious Area (CIA)	22,085		3%

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New Hampshire Department of Environmental Services
Great Bay Nitrogen Non-Point Source Study

Appendix C

Methodology for Calculating
the Area and Fertilizer Use for Agricultural Lands
in the Piscataqua Region Watershed

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Purpose

This appendix summarizes the detailed methods used to calculate the amount of chemical fertilizers applied to agricultural lands in the Piscataqua Region. The focus of this analysis is on chemical fertilizers, not manure, because the chemical fertilizers are imported to the watershed from elsewhere. Net nitrogen imports from livestock manure and pet waste are quantified in Appendix F. The outputs of this analysis will be used to partially populate the Nitrogen Loading Model for the Great Bay Nitrogen Non-Point Source Study.

Methodology

1. Information Inputs

For chemical fertilizer use, two types of information were needed for this study: (1) the area covered by different crops in the study area; and (2) typical chemical fertilizer application rates for the different crop types. The chemical fertilizer application rates should be overall averages for the watershed. Some percentage of crops are not fertilized and some crops receive all or some of the required nitrogen from manure. Therefore, the overall chemical fertilizer application rate for the watershed will be lower than typical recommendations for nitrogen additions for crop types.

2. Study Area

The study area was the Piscataqua Region watershed. Only the portion of each town that is in the watershed was included.

3. Analytical Approach

Area of Agricultural Lands

Agricultural lands in the Piscataqua Region were calculated using the 2011 New Hampshire, Maine and Massachusetts Cropland Data Layer published by the U.S. Department of Agriculture (USDA, National Agricultural Statistics Service, http://nassgeodata.gmu.edu/CropScape/). USDA reports that this layer has an overall accuracy of 81.5% for the major crop categories. The tabulate area tool in ArcGIS was used to calculate the area of each type of crop in each of the study polygons in the study area. The entire study area was divided up into 215 "study polygons" created by the intersection of major tributary watersheds, HUC12 subwatersheds, and town boundaries. For the study area, the following types of crops were identified in this layer:

ALFALFA	PEPPERS
APPLES	POTATOES
BLUEBERRIES	PUMPKINS
CHRISTMAS TREES	RYE
CORN	SOD GRASS SEED
CRANBERRIES	SOYBEANS
FALLOW, IDLE CROPLAND	SPRING WHEAT
MISC VEGS FRUITS	SQUASH
OATS	STRAWBERRIES
OTHER CROPS	SWEETCORN
OTHER HAY, NONALFALFA	WINTER WHEAT
PASTURE GRASS	

Fertilizer Use on Agricultural Lands

Typical fertilizer application rates for crops were obtained from the USDA National Agricultural Statistics Service (http://quickstats.nass.usda.gov/?sector_desc=ENVIRONMENTAL). Data reported from New York between 2005 and 2010 were selected for this study. New York was the closest state to the study area for which data were reported. USDA also reports national average fertilization application rates. These national averages include large-scale agriculture in the Midwestern United States and, therefore, were considered to be not representative of the small scale agriculture in New England. For example, for 2005-2010, the reported chemical fertilizer use on corn in New York was 59-67 lb/acre while the national average was 138-140 lb/acre.

USDA does not report fertilizer application rates for pasture, alfalfa, or hay. Nitrogen additions are not needed for pasture and alfalfa because of manure inputs and nitrogen fixation by legumes, respectively. Nitrogen fertilization rates for hay fields were estimated based on typical hay yields for New Hampshire and the recommended fertilization rates from UNH Cooperative Extension (discussed in more detail below).

4. Data Quality Objectives

To ensure the quality of the data, the following objectives were set at the beginning of the study.

a. The spatial units for agricultural inputs need to be equal to or smaller than the town and HUC12 polygons.
b. The fertilizer application rates should be confirmed by local agriculture experts as much as possible.
c. The predicted nitrogen imports of chemical fertilizer should be consistent with the values reported for counties in the study area from Ruddy et al. (2006).

Results

Area of Agricultural Lands

Based on the USDA 2011 Crop Datalayer, there are slightly less than 40,000 acres of crops in the Piscataqua Region watershed. The majority of these crops are hay fields, alfalfa, and pasture. The largest row crops are corn and apples.

Table 1: Acres of Crop Land by Type in the Piscataqua Region Watershed

Crop	Area (acres)	Percent of Total
HAY (NON-ALFALFA)	34,328	88%
ALFALFA	1,806	5%
CORN	1,529	4%
SWEET CORN	29	0.1%
PASTURE GRASS	635	2%
APPLES	598	2%
FALLOW, IDLE CROPLAND	195	0.5%
SOD, GRASS SEED	30	0.1%
OATS	26	0.1%
POTATOES	21	0.1%
OTHER CROPS	16	0.0%
RYE	9	0.0%
CHRISTMAS TREES	2	0.0%
SPRING WHEAT	1	0.0%
SOYBEANS	0.4	0.0%
WINTER WHEAT	0.2	0.0%
MISC VEGETABLES AND FRUITS	0.2	0.0%
TOTAL	39,226	100%

Fertilizer Use on Agricultural Lands

The fertilizer application rate has two components: (1) the amount of nitrogen typically applied per acre of cropland during the year; and (2) the percent of cropland that is fertilized each year. In the bullets below, the typical fertilizer application rates for major crops in the study area are summarized. The final weighted application rates are presented in Table 2.

- Hay: Hay fields require nitrogen depending on the nitrogen content of the soil and the amount of hay desired (the "hay yield"). Hay yields in New Hampshire and Maine in 2010 averaged 1.59 to 1.61 tons of hay harvested per acre (USDA, 2010). The low average yield indicates that the majority of hay fields are not being intensely managed to obtain more than two cuttings per year. UNH Cooperative Extension recommends that hay fields receive 50 to 125 pounds of nitrogen per acre per year. The low end of the range (50 lbs/acre) corresponds to the low average hay yields (1-2 cuttings per year) for the study area (UNH Cooperative Extension, Carl Majewski, personal communication, August 27, 2012). The average chemical fertilizer application rate spread across all hay fields will be lower than 50 pounds per acre because many fields are not actively fertilized for higher yields and manure is used to fertilize some fields (UNH Cooperative Extension, Carl Majewski, personal communication, August 27, 2012). In addition these estimates assume hay fields as straight grass, which is not typically the case, and does not account for the contribution of legumes in hay fields. The application of chemical fertilizers to grass only fields is simply not cost effective. There are a lot of fields that are cut year by year and are not actively managed for optimum production (little to no fertilizer application) because of cost recovery issues (NH Farm Bureau, Robert Johnson, official comments submitted on draft report, September 9, 2013). Moreover, the net contribution of nitrogen from manure to the soil depends on many factors including the rate at which the manure releases ammonia to the atmosphere. For the purposes of this study, DES has assumed a chemical fertilization rate of 5 pounds per acre for hay based on comments received from the NH Farm Bureau. This rate is equivalent to assuming that 10 percent of hay fields are fertilized per year at the recommended rate (50 lbs/acre) due to the factors discussed above.
- Alfalfa: Alfalfa is a legume that fixes nitrogen from the atmosphere and, therefore, does not require fertilization except at seeding. The University of Vermont does not recommend any nitrogen fertilizer for pastures or hay stands where legumes (e.g., alfalfa) are dominant (UVM, 2004). For the purposes of this study, DES has assumed no chemical nitrogen additions to alfalfa fields. UNH Cooperative Extension confirmed that this approach was appropriate (UNH Cooperative Extension, Carl Majewski, personal communication, October 9, 2012).
- Corn ("corn" and "sweet corn"): The average fertilization rates for corn in New York (the closest state to the study area with data) in 2005 and 2010 were 67 and 59 pounds N per acre, respectively (63 lb/ac, on average). Ninety percent of corn crops in New York were fertilized in 2005 and 2010 (USDA, 2012). For the purposes of this study, DES has assumed the measured rates and the percent of crops fertilized for New York are representative of New Hampshire as well. UNH Cooperative Extension confirmed that this approach was appropriate (UNH Cooperative Extension, Carl Majewski, personal communication, October 9, 2012).
- Pasture: Pasture lands are typically not fertilized because manure from grazing animals supplies enough nutrients. Net nitrogen imports from livestock manure and pet waste are quantified in Appendix F. For the purposes of this study, DES has assumed no chemical nitrogen additions to pasture lands. UNH Cooperative Extension confirmed that this approach was appropriate (UNH Cooperative Extension, Carl Majewski, personal communication, October 9, 2012).

- Apples: The average fertilization rates for apples in New York (the closest state to the study area with data) in 2007 and 2009 were 32 and 53 pounds N per acre, respectively (43 lb/ac, on average). Seventy-five percent of apples in New York were fertilized in 2007 and 2009 (USDA, 2012). For the purposes of this study, DES has assumed the measured rates for New York are representative of New Hampshire as well. UNH Cooperative Extension suspects that the chemical fertilizer rates for apple orchards in New Hampshire may be lower than New York but does not have NH-specific data (UNH Cooperative Extension, Becky Sideman, personal communication, October 9, 2012).
- Fallow: Fallow lands are not fertilized. For the purposes of this study, DES has assumed no chemical nitrogen additions to fallow lands.
- Other: All the rest of the crop categories account for 0.3% the total crop area. For these categories, the fertilization rate for corn will be assumed for the purposes of this study.

Table 2: Fertilizer Application Rates for NASS Land Types

NASS Land Cover Type	Crop Group	Initial Nitrogen Application Rate (lb N/acre)	Percent of Crop Fertilized Each Year	Final Nitrogen Application Rate (lb N/1000 ft^2)	Final Nitrogen Application Rate (lb N/acre/yr)
APPLES	Apples	42.5	75%	0.73	31.88
CORN	Corn	63	90%	1.30	56.70
SWEETCORN	Corn	63	90%	1.30	56.70
OTHERHAY_NONALFALFA	Hay	50	10%	0.11	5.00
ALFALFA	Alfalfa	0	0%	0.00	0.00
PASTURE_GRASS	Pasture	0	0%	0.00	0.00
FALLOW_IDLECROPLAND	Fallow	0	0%	0.00	0.00
BLUEBERRIES	Other	63	90%	1.30	56.70
CHRISTMASTREES	Other	63	90%	1.30	56.70
CRANBERRIES	Other	63	90%	1.30	56.70
MISCVEGS_FRUITS	Other	63	90%	1.30	56.70
OATS	Other	63	90%	1.30	56.70
OTHERCROPS	Other	63	90%	1.30	56.70
PEPPERS	Other	63	90%	1.30	56.70
POTATOES	Other	63	90%	1.30	56.70
PUMPKINS	Other	63	90%	1.30	56.70
RYE	Other	63	90%	1.30	56.70
SOD_GRASSSEED	Other	63	90%	1.30	56.70
SOYBEANS	Other	63	90%	1.30	56.70
SPRINGWHEAT	Other	63	90%	1.30	56.70
SQUASH	Other	63	90%	1.30	56.70
STRAWBERRIES	Other	63	90%	1.30	56.70
WINTERWHEAT	Other	63	90%	1.30	56.70

Validation

As a quality assurance check, the fertilizer application rates listed above were used to estimate the farm fertilizer use in Rockingham and Strafford counties (NH) based on the agricultural land totals in the counties in 2011 from the NASS Crop Datalayer. The amount of nitrogen used in farm fertilizer was predicted to be 211,114 and 91,503 pounds per year for Rockingham and Strafford counties, respectively. Ruddy et al. (2006) reported the average farm fertilizer use in 1987-2001 to be 348,047 and 364,133 pounds per year for Rockingham and Strafford counties, respectively. The estimates from this study for Rockingham and Stafford Counties were 39% and 75% lower than the measured value reported in Ruddy et al. (2006), 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 during this period. In 2005 local New Hampshire farmers were paying around $330 per ton for a common nitrogen fertilizer blend. In 2013, farmers were paying $565 per ton for the same blend, a 60% cost increase (NH Farm Bureau, Robert Johnson, official comments submitted on draft report, September 9, 2013). Increasing costs result in decreased fertilizer use, especially for hay which is the largest crop in the study area. Therefore, it is plausible that the 60% increase in cost is responsible for current estimates of fertilizer use being 39-75% lower than measured values in 2001.

The apparent reduction in fertilizer use in Rockingham County was approximately half the value for Strafford County. This discrepancy may be explained by different rates of change in the amount of agricultural lands between 1987-2001 and 2011 in the two counties. Agricultural lands in 1987-2001 can be approximated using the land use/land cover dataset for Rockingham and Strafford counties from 1998, which specifically delineated "hay fields, row crops, fruit orchards, etc." (land use class 20). The total area of agricultural lands in Strafford County was 11,012 acres in 1998 and 13,132 acres in 2011 (a 19% increase). For Rockingham County, the agricultural lands increased 43% from 16,287 acres in 1998 to 23,346 acres in 2011. Therefore, the large increase in the amount of agricultural lands in Rockingham County may have partially masked the reductions in fertilizer use in this county.

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New Hampshire Department of Environmental Services
Great Bay Nitrogen Non-Point Source Study

Appendix D

Methodology for Calculating
the Area and Fertilizer Use on Managed Turf
in the Piscataqua Region Watershed

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Purpose

This appendix summarizes the detailed methods used to calculate the area and the fertilizer application rate for all managed turf in the Piscataqua Region. The types of turf that were included in the study are golf courses, ball fields, and town parks. Residential lawns were studied separately (see Appendix E). The outputs of this analysis will be used to partially populate the Nitrogen Loading Model for the Great Bay Nitrogen Non-Point Source Study.

Methodology

1. Information Inputs

Two types of information were needed for this study: (1) the number and size of managed turf areas; and (2) the fertilizer application rate for these areas. Recreational fields and golf courses are typically large open areas that are easily identified from aerial photographs. The boundaries of the turf areas can be delineated using ArcGIS software. Fertilizer application rates are variable depending on the use and management of the turf and can be obtained from the person responsible for managing the turf.

2. Study Area

The study area was the Piscataqua Region watershed. Only the portion of each town that is in the watershed was included.

3. Analytical Approach

The boundary of each recreational field and golf course was delineated using 2009-2010 color aerial photographs. The party responsible for maintaining the turf (e.g., town officials, school officials, golf course superintendents) was surveyed to obtain fertilizer information for each turf area. Specific steps in the data acquisition process are listed below:

a. Created a list of golf courses in the study area towns from http://www.golflink.com/golf-courses/course-directory.aspx and http://www.worldgolf.com/courses/usa/ and from the list of registered water users who are golf courses (in NH only). Used ArcGIS to view aerial imagery for each golf course and to delineate the boundaries of each golf course.
b. Used the NH Office of Energy and Planning Recreation Inventory (GIS point and polygon files available through GRANIT; http://www.granit.unh.edu/) to identify other recreational fields in NH towns. Used ArcGIS to view aerial imagery for each turf area and to delineate the boundary of each area. Turf areas included ball fields, parks, golf courses, and driving ranges.
c. Used ArcGIS to view aerial imagery for the 10 Maine towns and one Massachusetts town in the watershed and to delineate the boundary of any managed turf areas that were visible.
d. Created a hard-copy and digital map of each recreational field and golf course to share with the party responsible for maintaining the turf (e.g., town officials, school officials, golf course superintendents) for quality assurance.
e. Developed a simple questionnaire about fertilizer use to accompany the map.
f. Distributed the maps and questionnaire to the persons responsible for managing the turf. Continued follow-up phone calls until data quality objectives were met.

4. Data Quality Objectives

To ensure the quality of the data, the following objectives were set at the beginning of the study.

a. The spatial units for managed turf need to be smaller than the town and HUC12 polygons.
b. The estimated area of managed turf in each town should be accurate to within 10% (absolute difference).
c. The fertilizer use questionnaire should be completed for at least 50 percent of the managed turf areas. Having data on more than half of the turf areas will improve the accuracy of the estimates for turf areas without data.

Results

Survey Response Rate

Following the process outlined in the methodology, DES generated draft maps of 220 turf areas. The draft maps were mailed to municipalities, golf courses, and educational institutions responsible for the turf areas on October 11, 2011. The organizations were asked to proof the draft maps and answer a series of questions regarding fertilization practices.

DES incorporated requested changes to the turf area boundaries and added new turf areas identified by the respondents. Ten of 108 (9%) of the survey respondents asked for the boundary of a turf area to be changed. The changes were typically small, less than 10% of the overall area. Two of the respondents

asked that turf areas be subdivided to account for varying fertilizer application rates, and one requested an additional turf area be added. These additional turf areas had been under construction when the aerial imagery was acquired and had since been completed. These changes brought the number of turf areas up to 227.

Overall, DES received responses for 108 of the 227 turf areas in the final database (overall response rate: 48%). The response rate for each of the different turf types was similar. Responses were received for 14 of 22 (64%) golf courses, 48 of 102 (47%) school fields, and 46 of 103 (45%) town recreational fields.

Managed Turf Areas

In the final database, there were 227 total managed turf areas, covering a total of 2,526 acres, within the study area. The managed turf areas were divided into 22 golf courses, 102 school athletic fields, and 103 town fields. A breakdown of the acreages is provided in Table 1.

Table 1: Summary of Managed Turf Areas in the Piscataqua Region Watershed

Type	Number	Min. Area (ac)	Ave. Area (ac)	Max. Area (ac)	Total Area in Watershed (ac)
Golf Course	22	31.00	84.01	168.45	1848.18
School Athletic Field	102	0.64	3.52	15.30	359.37
Town Park and Rec. Field	103	0.62	3.10	12.17	318.86
				Grand Total =	2526.41

Fertilizer Application Rates

The majority (82 of 108, 76%) of the survey respondents reported that they applied fertilizer to the turf areas. All of the golf course respondents reported using fertilizer (14 of 14, 100%), followed by most of the schools (40 of 48, 83%) and towns (28 of 46, 61%).

Information on the actual amount of fertilizer used in the past year was reported for 80 turf areas across all three turf types. Summary statistics for the nitrogen fertilizer application rate by turf type are shown in Table 2. 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). 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. These average yearly application rates are consistent with other published values and/or recommendations.

Table 2: Summary of Fertilizer Application Rates on Managed Turf Areas in the Piscataqua Region Watershed

Type	Number of Completed Surveys vs. Total Number of Turf Areas	Min Yearly Fertilizer Application Rate (lb N/1000 ft^2)	Ave Yearly Fertilizer Application Rate (lb N/1000 ft^2)	Max Yearly Fertilizer Application Rate (lb N/1000 ft^2)	Reference Yearly Fertilizer Application Rate (lb N/1000 ft^2)
Golf Course (fertilized area)	14 of 22	0.384	2.245	4.612	2.36 (average)[1] 2.50 (average)[2] 1-6.00[3]
Golf Course (total area)		0.185	0.860	1.977	See Note 4
School Athletic Field	39 of 102	0.274	1.886	6.112	2.36 (average)[1] 1-6.00[3]
Town Park and Rec. Field	27 of 103	0.061	1.242	4.000	2.36 (average)[1] 0-2.00[3]

[1] Latimer and Charpentier (2010), after Valiela et al. (1997)
[2] GCSAA (2009) study of actual application rates on golf courses in the Northeast in 2006
[3] Murphy and Murphy (2010), recommended application rates
[4] Published application rates were only available for the "fertilized area" of golf courses. The total area of the course includes rough, fringes, and utility areas that are not fertilized. On average, 42% of the total golf course area receives fertilizer. The survey responses from golf courses match the reference rates if the results are normalized to fertilized area, not total area.

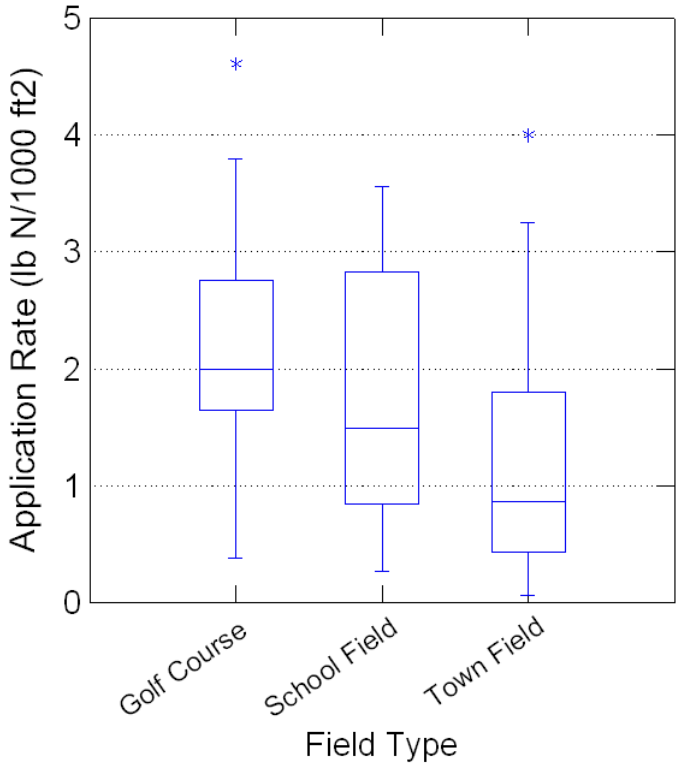
In the preceding table, the fertilizer application rate for golf courses is expressed in terms of both the fertilized area and the total area. Due to the nature of fertilization programs at golf courses, only part of the total area of the golf courses actually receives fertilizer (typically tees, greens, and fairways). The golf course boundaries digitized by DES included other areas, which are typically not fertilized. DES contacted each of the golf course respondents and obtained the fertilized area for their course. On average, the fertilized area of a golf course was 42% of the total area. When the reported fertilizer applications were normalized to the fertilized area, the reported rates closely matched reference values (see Table 2). For golf courses that did not respond to the survey, the average ratio of fertilized area to total area will be assumed to be valid.

Recommended Fertilizer Application Rates for Nitrogen Loading Model

One of the inputs to the Nitrogen Loading Model is the nitrogen load from fertilizer on managed turf throughout the watershed. The purpose of the survey was to gather local information on managed turf areas and actual fertilization rates. The response rate was high for a survey of this type (48%) and substantially met the data quality objectives of the study. There was also concurrence between the survey responses and published reference values for fertilizer application rates. Therefore, the objective of the survey to compile high-quality local information has been met and the survey results can be extrapolated to all the managed turf areas in the study area for the Nitrogen Loading Model.

The simplest extrapolation model would be to apply the average fertilization rate for each turf type to turf areas of the same type without survey results. This model appears to be appropriate because the different turf types seem to actually receive different treatments and there are statistically significant differences in the fertilization rates for different turf types. The reported fertilizer application rate was highest for golf courses, followed by school fields, and town fields (Figure 1). In addition to the higher application rate, golf courses are also distinct because they are much larger than school and town fields (84 acres vs. 3-4 acres, on average). School and town fields were similar in size but the average application rate for school fields was more than 50% higher than for town fields. More fertilizer is needed for fields that receive heavy use (Murphy and Murphy, 2010) and school fields may be more heavily used than town fields. An Analysis of Variance test showed that there were statistically significant differences between the three turf types ($p<0.05$). The only other extrapolation model that DES could use would be a single average application rate for all of the turf areas, but this model does not seem consistent with the survey results. Therefore, for the Nitrogen Loading Model, turf areas without survey results will be assigned the average fertilizer application rate for the relevant turf type.

Figure 1: Summary of Fertilizer Application Rates for Different Turf Types



Another factor that needs to be considered in the extrapolation is that some recreational fields are not fertilized every year. All of the golf courses reported using fertilizer, but 13% of the school fields and 39% of the town fields did not. Fields reported as unfertilized have probably been fertilized at some point, just not during the past year. Towns and schools may treat a few of their fields each year, covering them all over several years. The options for extrapolating these results to non-respondent fields are: (1) assume that all non-respondent fields are fertilized; (2) randomly assign "no fertilizer use" to some of the non-respondent fields; and (3) pro-rate the fertilizer application rate based on the fraction of unfertilized fields. The third option is the best because it will provide information relevant to multi-year average fertilizer application, which is the most relevant to the Nitrogen Loading Model. Therefore, non-respondent school and town fields will be assigned application rates that are pro-rated with the following percents: 87% for school fields and 61% for town fields.

The final recommended application rates for the Nitrogen Loading Model for the Piscataqua Region are listed in Table 3. These assumptions will only be made for turf areas without a completed survey and turf areas that were reported as being fertilized but no fertilizer application rate was provided. For turf areas with a completed survey, the reported fertilizer rate for the area will be used in the model.

Table 3: Fertilizer Application Rates Used in the Nitrogen Loading Model for the Piscataqua Region Watershed

Turf Type	Nitrogen Application Rate (lb N/1000 ft^2)	Comments
Golf Courses	0.95	Ave application rate of 2.245 pro-rated because 42% of total golf course area is fertilized
School Fields	1.64	Ave application rate of 1.886 pro-rated because 87% of school fields are fertilized
Town Recreational Fields	0.76	Ave application rate of 1.242 pro-rated because 61% of school fields are fertilized

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New Hampshire Department of Environmental Services
Great Bay Nitrogen Non-Point Source Study

Appendix E

Methodology for Estimating
Residential Lawn Area and Fertilizer Use
in the Piscataqua Region Watershed

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Purpose

Turf is the largest "crop" in the United States (Milesi et al., 2005). Therefore, fertilizer use on turf is potentially an important nitrogen input to the Piscataqua Region watershed. For recreational turf (e.g., ball fields, golf courses, and parks), DES created a custom land cover layer for the Piscataqua Region watershed. There were relatively few of these features in the watershed so they could all be digitized directly from aerial photography. The methodology for creating the custom layer is discussed in Appendix D. However, this inventory did not include residential lawns, which are expected to cover at least as much area as recreational fields. This appendix summarizes the detailed methods used to estimate the area of residential lawns in the Piscataqua Region from land use datasets. The outputs of this analysis will be used to partially populate the Nitrogen Loading Model for the Great Bay Nitrogen Non-Point Source Study.

Methodology

1. Information Inputs

Two types of information were needed for this study: (1) a recent land use/land cover dataset; and (2) recent, high resolution aerial imagery (2010 1-Ft Color Aerial Photos - Southern/Central NH) which has sufficient resolution to delineate residential turf areas for individual homes.

The one land use/land cover dataset available for the whole Piscataqua Region watershed is the Coastal Change Analysis Program (C-CAP) 2006 land cover data. The C-CAP provides the "coastal expression" of the National Land Cover Database (NLCD) with a resolution of 30 meters. Landsat

Enhanced Thematic Mapper imagery from 2006 was used to categorize each pixel into one of 25 land cover classes:

1 Unclassified (Cloud, Shadow, etc)
2 High Intensity Developed
3 Medium Intensity Developed
4 Low Intensity Developed
5 Open Spaces Developed
6 Cultivated Land
7 Pasture/Hay
8 Grassland
9 Deciduous Forest
10 Evergreen Forest
11 Mixed Forest
12 Scrub/Shrub
13 Palustrine Forested Wetland
14 Palustrine Scrub/Shrub Wetland
15 Palustrine Emergent Wetland
16 Estuarine Forested Wetland
17 Estuarine Scrub/Shrub Wetland
18 Estuarine Emergent Wetland
19 Unconsolidated Shore
20 Bare Land
21 Water
22 Palustrine Aquatic Bed
23 Estuarine Aquatic Bed
24 Tundra
25 Snow/Ice

The C-CAP data is not ideal because the land cover classes do not directly match the requirements of the Nitrogen Loading Model and the 30-meter resolution is coarse. Unfortunately, there are no other alternatives. More detailed land cover data are available for only Rockingham County and parts of Strafford County, which were mapped with 1-foot resolution by UNH in 2005. Likewise, the Maine portion of the watershed is covered by the Maine Land Cover Database which used older Landsat Thematic Mapper imagery from 1999-2001 with 5-meter resolution. The benefits of using the single C-CAP coverage for the whole watershed outweigh those that might be obtained by merging the two alternative datasets that were developed with different methods.

2. Study Area

The study area was the Piscataqua Region watershed. Only the portion of each town that is in the watershed was included.

3. Analytical Approach

For each of the "developed" land cover classes in the C-CAP dataset, a subsample of polygons was selected. Areas of residential turf in each of these polygons were digitized using high resolution aerial imagery and ArcGIS software. The number of residential homes in each polygon was also counted. This information was used to estimate the percentage of each of the developed land cover classes that is covered by residential turf and to calculate the average lawn size for residential homes. The specific steps for the process were:

a. Randomly select 20 polygons from the C-CAP dataset in the "Developed, high density", "Developed, medium density", "Developed, low density", and "Developed, open space" land use categories (80 polygons total) with areas between 10 and 50 acres. The size range of 10-50 acres was chosen to avoid very small and very large polygons.
b. Digitize all of the areas of residential turf and count the number of residential homes in each polygon.
c. For each polygon, sum the area of residential turf and total the number of residential homes.
d. Calculate the percent of each polygon that is covered by residential turf by dividing the sum of turf in the polygon by the total area of the polygon.
e. Compile the percent turf values for each polygon and calculate the mean and standard deviation for each land cover class.

f. Calculate the average area of a residential lawn in each land cover class by summing the area of residential turf in each class and dividing by the total number of residential houses in each class.
g. Use the mean percent turf values for each land cover class and the total area of each class in a watershed to estimate the total area of residential turf in the watershed.

4. Data Quality Objectives

To ensure the quality of the data, the following objectives were set at the beginning of the study.

a. Polygons selected for mapping should be randomly distributed across the watershed.
b. The average area for residential lawns from this approach should compare reasonably well with default input values for the Nitrogen Loading Model.
c. Uncertainty in the mean percent turf for each land use should be less than 10% (standard error).
d. Uncertainty in the overall nitrogen load estimate for residential turf should be less than 10%.

Results

Lawn Area Mapping in Developed Land Cover Polygons

Polygons of developed land use classes were selected at random using a random number generator. Twenty polygons in each land use class were initially chosen for this study. The selected polygons covered between 5 and 27% of all the polygons greater than or equal to 10 acres in size in the different land use classes. The majority of polygons in the watershed were smaller than 10 acres (Table 1). Digitizing land use in these small polygons would have introduced error because lawns and houses are often only partially inside of the polygon. The locations of the digitized polygons are shown in Figure 1.

Table 1: Summary of Developed Land Polygons for which Lawn Area Was Mapped

Land use	# Polygons Digitized in the 10-50 Acre Size Class	Total # of Polygons in the <=10 Acre Size Class	Total # of Polygons of all sizes	Mean Size (acres)	S.D. (acres)
Developed - High Density	20	75	2,906	1.70	9.54
Developed – Medium Density	20	252	16,494	1.14	5.35
Developed - Low Density	20	444	33,574	0.99	3.58
Developed - Open Space	20	97	15,199	0.85	3.78

The mean and standard error of the percent turf value for each land use category is shown in Table 2. Lawn area represented a large portion (23-45%) of the low and medium density development classes. Residential lawn was a much smaller percent (2-8%) of the high density and open space classes. The standard error of the means met the data quality objective of <10%.

Figure 1: Digitized Land Use

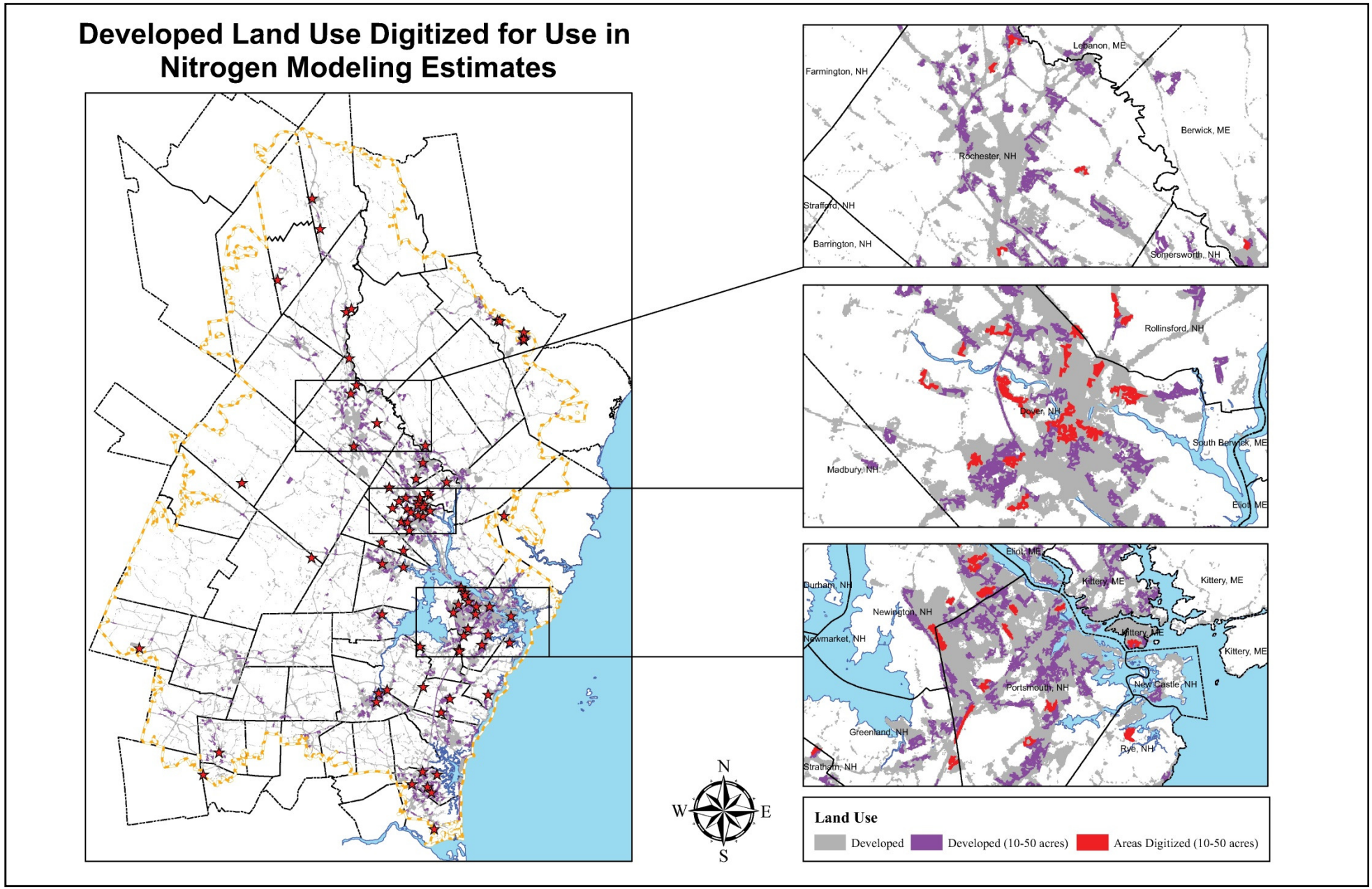

Table 2: Summary Statistics of Lawn Area in Developed Land Use Classes

Land use	Mean "Percent Turf" in Polygons	Standard Deviation	Standard Error of the Mean
Developed – high density	2.23%	2.41%	1.08%
Developed – medium density	23.69%	18.40%	8.23%
Developed – low density	44.93%	18.94%	8.47%
Developed - open space	7.62%	7.53%	3.37%

Estimates of Residential Lawn Area

Latimer and Charpentier (2010) published default assumptions for the Nitrogen Loading Model. The average lawn area for a home was reported as 0.12 acres. For this study, the average lawn area ranged from 0.05 ac for high density development to 0.30 ac for open space areas (Table 3). This range of values appears to be credible because it bracketed the assumed value published by Latimer and Charpentier (2010).

Table 3: Summary of Average Lawn Area Per House in Developed Land Use Classes

Land use	Number of Residential Homes in Polygons	Total Area of Residential Turf in Polygons (ac)	Average Lawn Area (ac/home)
Developed – high density	3	0.135	0.045
Developed – medium density	525	78.287	0.149
Developed – low density	537	137.670	0.256
Developed - open space	78	22.157	0.284

To estimate the total area of residential lawns in the Piscataqua Region watershed, the mean percent turf values for each land use class was multiplied by the total area for the class in the watershed. Low density residential areas contained the most turf (13,883 acres). The total area of residential turf in the watershed was 19,077 acres, which was 2.7% of the whole watershed area (Table 4). This value seems reasonable given that 8.9% of the watershed was categorized as "pasture/hay" and "grassland/herbaceous". Another way to check this number is to compare it to the state-wide turf estimates from Milesi et al. (2005). That study predicted between 225,600 and 330,900 acres of turf in New Hampshire, which would cover 3.8 to 5.5% of the state. In comparison, the total area of lawn in the Piscataqua Region from this study is low, but it also does not include golf courses and other recreational fields.

Table 4: Summary of Lawn Area in the Piscataqua Region Watershed

Land use	Mean "Percent Turf" for Land Use Class	LU class totals in P.R. watershed (ac)	Lawn area in P.R. watershed (ac)
Developed – high density	2.23%	4,559	102
Developed – medium density	23.69%	17,585	4,166
Developed – low density	44.93%	30,902	13,883
Developed - open space	7.62%	12,144	926
Total		694,578*	19,077 (2.7%)

* The total area for the Piscataqua Region watershed includes other land use classes besides the four listed on this table.

Lawn Fertilizer Application Rate Inputs for the Nitrogen Loading Model

The fertilizer application rate for residential lawns has two components: (1) how much nitrogen is typically applied to a lawn in a year and (2) what percent of lawns are fertilized. Each of these two components will be discussed separately.

First, based on a review of published reports, the typical fertilizer application rate for residential lawns is approximately 2 pounds of nitrogen per 1000 square feet of lawn area per year. Latimer and Charpentier (2010) used a rate of 2.1 lb N/1000 ft^2 for the Nitrogen Loading Model in southern New England. The University of Connecticut recommends a maximum application rate of 2 lb N/1000 ft^2 for mature lawns in New England (Guillard, 2008). The University of Minnesota Cooperative Extension recommends 1-2 lb N/1000 ft^2 for low maintenance lawns and 3-4 lb N/1000 ft^2 for high maintenance lawns (Rosen et al., 2006). In the Piscataqua Region watershed, turf managers surveyed by DES in 2012 reported applying 1.2 to 2.2 lb N/1000 ft^2, on average, on recreational fields and golf courses (see Appendix D). In a study of suburban watersheds in Maryland, Law et al. (2004) found that the average application rate was 2.2 lb N/1000 ft^2 for homeowners who maintain their own lawn and 2.1 to 3.3 lb N/1000 ft^2 for lawn care companies. Osmond and Hardy (2004) reported average application rates of 0.5 to 3.1 lb N/1000 ft^2 for watersheds in North Carolina. Therefore, while the exact fertilizer application rate for each lawn is not known, 2 lb N/1000 ft^2 is the recommended rate for most lawns and is a reasonable approximation of how much fertilizer homeowners actually apply.

The second issue is what percent of lawns are fertilized in a given year. A recent social science survey of residents in the Piscataqua Region found that 40% reported using fertilizer on lawns, either themselves or through a contractor (Rogers and Farrell, 2014). This value is consistent with the percentage used by Latimer and Charpentier (2010) for their application of the Nitrogen Loading Model for watersheds in southern New England (34%). However, multiple other studies from around the country have reported higher rates of fertilizer use. For example, a survey of homeowner behaviors in the Chesapeake Bay watershed found that 50% of lawns were regularly fertilized (CWP, 1999). This report also included a summary of eight other homeowner surveys across the country which showed that an average of 78% of lawns were fertilized yearly. More recent studies in Maryland, Florida, Georgia, and North Carolina reported average participation rates for fertilizing lawns of 62, 84, 76, and 70%, respectively (Law et al., 2004; Florida DEP, 2009; Varlamoff et al., 2001; Osmond and Hardy, 2004). Based on sales data, Scotts MiracleGro estimates that approximately 50% of homeowners in the United States fertilize their lawns (Augustin, 2007). A survey of residents in the Lamprey River watershed conducted in 2007 reported that 36.4% of residents never fertilized their lawns (i.e. 64% fertilized; Robertson, 2010). The results of these homeowner studies across the country consistently indicate greater than 50% fertilizer use by homeowners.

Given the range of possible values from various studies, DES used a calibration step to select the fertilizer use rate for residential lawns for the Nitrogen Loading Model. The calibration dataset was the total non-farm fertilizer use in Strafford County (361,765 lb N) and Rockingham County (973,653 lb N) in 2001 from Ruddy et al. (2006). This dataset is the most recent independent measurement of fertilizer use. DES assumed that the rate of fertilizer use did not change between 2001 and 2006.

The first step was to estimate the fertilizer use on managed turf (e.g., golf courses and ball fields) and subtract it from the total. Using the methodology in Appendix D, DES estimated that the fertilizer use on managed turf was 27,298 lb N in Strafford County and 51,875 lb N in Rockingham County. Therefore, the total fertilizer use on residential lawns should have been 334,467 lb N in

Strafford County and 921,778 lb N in Rockingham County. The total lawn area in each county was estimated to be 6,825 and 20,294 acres, respectively, using the 2006 C-CAP land use dataset and the methods described in this appendix. Dividing the total fertilizer use on lawns by the lawn area, the apparent lawn fertilizer application rate was 1.12 and 1.04 lb N/1000 ft^2, respectively. If the actual application rate was 2 N/1000 ft^2, then the percent of lawns fertilized would have been 56% and 52% in Strafford and Rockingham counties, respectively. The average of these two values (54%) is within the range of values reported for lawn fertilizer use in the literature both locally and nationally. Therefore, for the Nitrogen Loading Model, it will be assumed that 54% of residential lawns are fertilized yearly.

The Nitrogen Loading Model will integrate fertilizer use on lawns over whole towns and watersheds. It is not important to know which specific residential lawns are fertilized or not. Therefore the fertilizer application rate for lawns will be pro-rated by the percent of lawns that are fertilized as shown in Table 5.

Table 5: Summary of Lawn Fertilizer Application Rates for the Nitrogen Loading Model of the Piscataqua Region Watershed

Input Parameter	Value
Average fertilizer application rate for residential lawns	2.0 lb/1000 ft^2
Percent of lawns fertilized each year	54%
Pro-rated fertilizer application rate for residential lawns for the Nitrogen Loading Model	1.08 lb/1000 ft^2

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New Hampshire Department of Environmental Services
Great Bay Nitrogen Non-Point Source Study

Appendix F

Methodology for Calculating
the Nitrogen Imports in Animal Waste
to the Piscataqua Region Watershed

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Purpose

The objective for this appendix is to calculate the nitrogen inputs from livestock and domestic pet waste in the Piscataqua Region. The outputs of this analysis will be used to partially populate the Nitrogen Loading Model for the Great Bay Nitrogen Non-Point Source Study.

Methodology

1. Information Inputs

This study used information on the number of livestock and domestic animals in the Piscataqua Region and the excretion rates of these animals in the Piscataqua Region study area.

2. Study Area

The study area was the Piscataqua Region watershed. Only the portion of each town that is in the watershed was included.

3. Analytical Approach

The study followed a multi-step process:

   a. Total numbers for the different types of livestock and domestic animals in the region were compiled. Priority livestock and domestic animals, those animal types that contribute the majority of nitrogen, were selected for the study based on the number of animals in the study area and the excretion rates per animal.

b. For the priority livestock and domestic animals, the number of animals in each town in the study area was determined.
c. For the priority livestock and domestic animals, the excretion rates were determined.
d. For the priority livestock and domestic animals, the typical waste disposal practices were determined.
e. Town-level data on animals were converted to watershed totals using ArcGIS tools.
f. The potential for double counting nitrogen from fertilizer and atmospheric deposition as nitrogen in animal waste was evaluated.

4. Data Quality Objectives

To ensure the quality of the data, the following objectives were set at the beginning of the study.

a. The spatial units for agricultural inputs need to be equal to or smaller than the town and HUC12 polygons.

Results

A. Identification of Priority Livestock and Domestic Animals

To identify priority livestock and domestic animals, the populations of different types of animals were estimated in the four counties in the region. The four counties included in this screening analysis were Rockingham (NH), Strafford (NH), Carroll (NH), and York (ME). Livestock totals in these four counties were taken from the 2007 Census of Agriculture (USDA, 2009). Domestic animal totals were estimated using the average number of dogs and cats per household from the American Veterinary Medical Association (AVMA, 2007). The population totals were multiplied by the average excretion rate of nitrogen for each type of animal from Boyer et al. (2002), Valiela et al. (1997), ASAE (2005) and USDA (2009). The results of this screening analysis are shown in Table 1.

Table 1: County-level livestock and domestic animal totals and excretion rates of nitrogen for screening level analysis

Type	Total Number[1]	Excretion Rate[2,3,4] (lb-N/animal/yr)	Total Nitrogen in Animal Waste (lb-N/yr)	% of Total Nitrogen from Animal Waste
Cattle, Beef	1,743	145	252,735	8%
Cattle, Dairy	2,607	369	961,983	31%
Chickens, Broilers	1,937	1.1	2,088	0%
Chickens, Layers	23,180	1.2	28,048	1%

[1] Number of animals in Rockingham, Strafford, Carroll, and York counties. These counties cover the Piscataqua Region watershed. The combined area of these four counties is much larger than the Piscataqua Region watershed.
[2] Excretion rates for cattle and horses are an average from Van Horn (1998), Boyer et al. (2002), ASAE (2005) and USDA (2011).
[3] Excretion rates for other livestock from Van Horn (1998) as reported by Boyer et al. (2002). For broiler chickens, the per animal excretion rate was multiplied by 7 to account for multiple crops during the year (48 day grow-out period per ASAE, 2005).
[4] Excretion rates for dogs and cats from Valiela et al. (1997).

Type	Total Number[1]	Excretion Rate[2,3,4] (lb-N/animal/yr)	Total Nitrogen in Animal Waste (lb-N/yr)	% of Total Nitrogen from Animal Waste
Horses	5,806	78	452,868	14%
Goats	1,781	11	19,591	1%
Pigs and Hogs	645	12.8	8,287	0%
Sheep	2,919	11	32,109	1%
Turkeys	685	0.9	588	0%
Dogs	168,881	4.4	743,076	24%
Cats	190,351	3.3	628,158	20%
Total			3,129,531	100%

Based on this screening analysis, four types of animals account for 97% of the nitrogen in animal waste: cattle, horses, dogs, and cats. The amount of nitrogen from animal waste is a function of both the number of animals and excretion rate per animal. There are not very many cattle and horses but each one of these animals excretes between 78 and 369 pounds of nitrogen per animal per year. In contrast, the nitrogen excreted by dogs and cats is smaller (3.3-4.4 lb/animal/year) but dogs and cats are popular pets and there are many of these animals in the study area.

Therefore, for the purposes of this study, the priority livestock and domestic animals will be cattle, horses, dogs and cats. The populations, excretion rates, and waste disposal practices for these different types of animals will be defined and included in the Nitrogen Loading Model calculations.

In addition to livestock and domestic animals, people often mention wildlife as a significant source of pollution in the estuary. Two examples of wildlife that are often mentioned as being contributors to the nitrogen load are migratory waterfowl and deer which live in the forests. However, the contribution to the nitrogen load from both of these species is negligible. Moreover, wildlife almost always eat local food sources so their waste is not a new source of nitrogen in the watershed that needs to be quantified for this model.

- Great Bay has been identified as an Important Bird Area, which indicates it is an area where birds congregate during breeding, migration, or winter. The NH Audubon Society estimates that the annual population of waterfowl in Great Bay ranges from 5,400 to 10,450 (NHA, 2009). Geese and ducks excrete 1.28 lb-N/animal/year based on published studies from Manny et al. (1994) and ASAE (2005). Therefore, the maximum contribution of nitrogen from waterfowl would be 6 tons per year, which is less than 1% of the total non-point source load to Great Bay. The actual loading from waterfowl will be lower because most birds are transient and only reside in the estuary for part of the year.
- Deer are another potential wildlife source of animal waste. There are approximately 85,000 deer in New Hampshire (Bagley), which amounts to 9 deer per square mile on average. Assuming an equal distribution of deer in the Piscataqua Region, there would be approximately 9,000 deer in the watershed draining to the Great Bay Estuary. Using an average of the rates presented in Robbins et al. (1974) and Maloiy et al. (1970) (16 lb-N/animal/year), these deer would excrete 72 tons of nitrogen per year. Since deer live in the forests and naturally vegetated areas, approximately 90% of this load would be

attenuated before it reaches the estuary (see Appendix H). Therefore, the contribution of deer waste to the nitrogen load would be negligible.

B. Inventory of Priority Livestock and Domestic Animals

The total population numbers for priority animals from Table 1 were updated with population totals for each town in the study area. The methods used to estimate the populations of cattle, horses, dogs and cats in each town are summarized below. The methods to convert the animal populations for towns to animal populations in watersheds are discussed later in this document.

Cattle

The number of cattle in New Hampshire towns was provided by the New Hampshire Department of Agriculture, Markets & Food (DAMF), Division of Animal Industry. DAMF keeps records on all cattle that produce food product and tests them for tuberculosis and brucellosis. DAMF provided DES with the total number of cattle tested in each town in Strafford, Rockingham, and Carroll counties in 2010 and 2011. The names and locations of the individual farms were not provided to maintain the confidentiality of the farms.

To estimate the number of cattle in Maine, a list of the dairy and beef cattle farms was obtained from the state veterinarian at the Maine Department of Agriculture, Food and Rural Resources. DES contacted each of the farms within York County by phone and obtained the total number of cattle per farm. The results were then aggregated to the town level to maintain confidentiality.

No dairy or beef cattle farms were identified in the small part of the study area located in Essex County, Massachusetts.

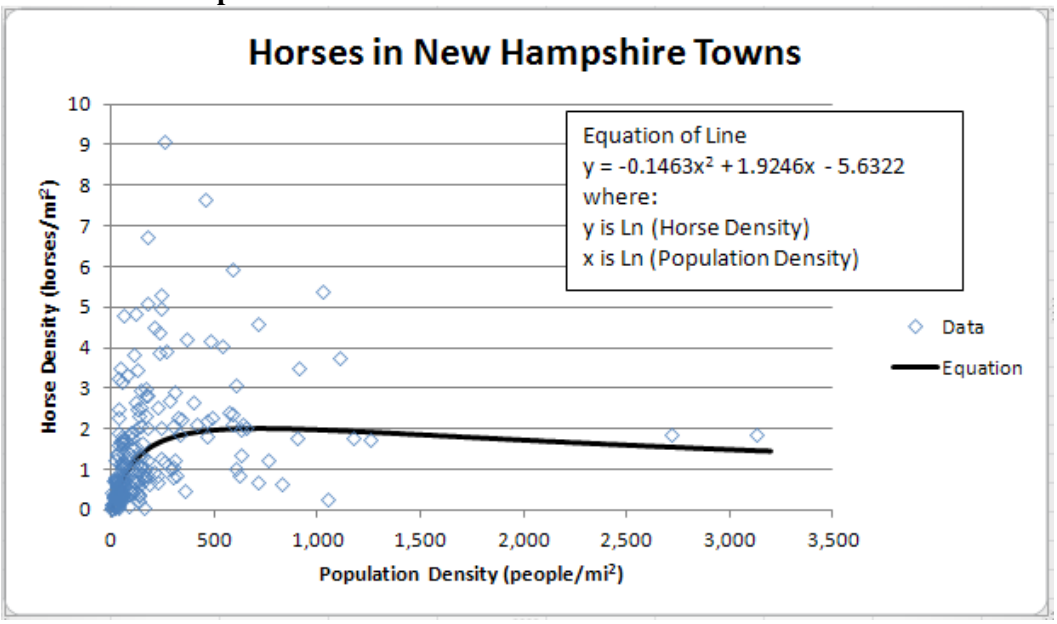
Horses

The number of horses in New Hampshire was estimated from data collected as part of the 2002-2003 New Hampshire Equine Economic Impact Study (Oden, 2004) and the 2007 Census of Agriculture (USDA, 2009). The NH Equine Economic Impact Study was a joint study conducted by the NH Horse Council Inc. and the NH Farm Bureau Federation. The study surveyed 5,698 household and business within New Hampshire, and had a 41% response rate. DES obtained the original survey and raw response data from Dr. Alberto Manalo at the University of New Hampshire. The 2002 survey results were used to calculate the percent of horses in each town relative to the total number of horses in the county. These percents were then used to pro-rate the county-level horse totals from the 2007 Agricultural Census to each town in the county.

While there were local data on horses in New Hampshire towns, similar data were not available for the Maine and Massachusetts towns in the study area. Therefore, a relationship was developed between the number of horses and people in a town using data from two New Hampshire counties. Figure 1 shows how the density of horses relates to population density in New Hampshire towns. The density of horses increases with population density for towns with less than approximately 800 people per square mile. In towns with higher population densities,

the horse density does not increase and appears to tail off. This pattern is consistent with the expectation that horse ownership will stop increasing with population in suburban municipalities and will eventually decline to zero in large cities. The best way to represent this pattern was through a quadratic polynomial fit to the natural logarithms of the horse density and population density in each town. The equation shown on Figure 1 was used to estimate the number of horses in Maine and Massachusetts municipalities in the study area using the 2010 Census data. The local data on horse totals from the NH Equine Economic Impact Study and the Census of Agriculture were used for the New Hampshire towns.

Figure 1: Number of horses per square mile compared to the number of people per square mile in New Hampshire Towns



Dogs

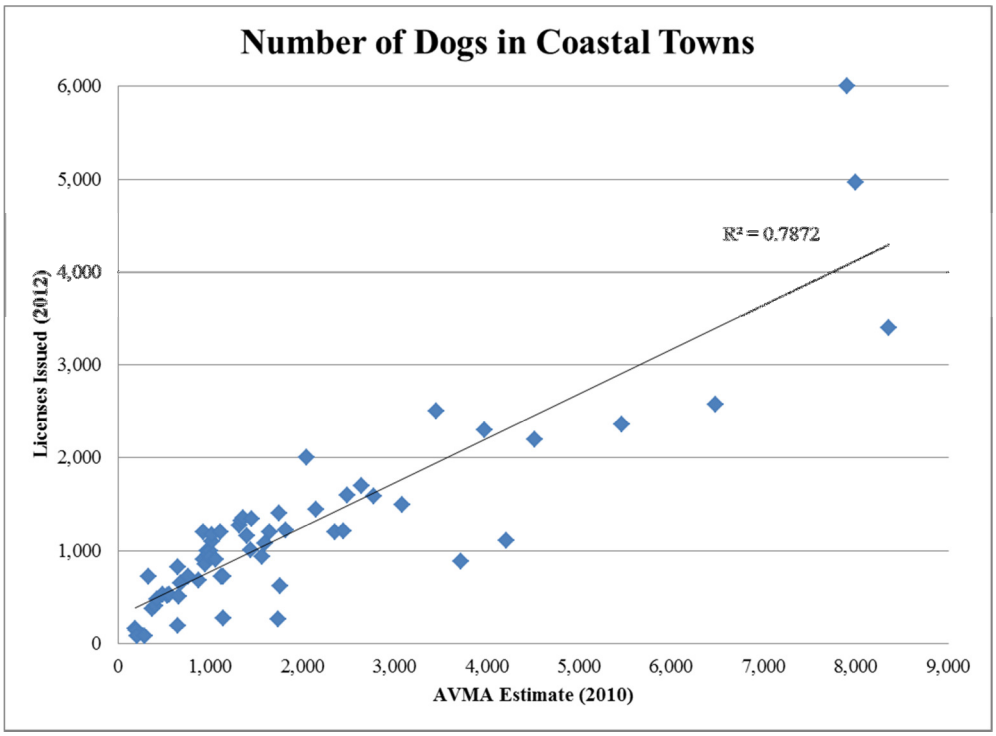
DES contacted the Town Clerk or Animal Control Officer for each town in the study area by phone to obtain the total number of dog licenses issued by the town in 2012.

The total number of licensed dogs in each town was confirmed using a formula established by the American Veterinary Medical Association (AVMA, 2007) to estimate number of dogs based on the number of people in a town. The AVMA estimation process began by estimating the number of households within each community. This was done by dividing the town population by the average household size. This data was obtained at the town level from the 2010 US Census. The second step estimated the number of dog owning households within each community. This was calculated by multiplying the number of households by 0.372 (fraction of dog owning households provided by AVMA). The last step calculated the number of dogs within each community by multiplying the number of dog owning households by 1.7 (average number of dogs owned provided by AVMA).

To check the accuracy of the AVMA estimates, a regression was run between the number of licensed dogs in each town and the estimated number of dogs from the AVMA formulas. The

regression had an R^2 of 0.79 (Figure 2), which shows that the two methods produce comparable results. The AVMA formulas predict a larger number of dogs in each town than the license records, which may reflect the fact that not all dogs are licensed. For this study, the number of dogs predicted by the AVMA formulas will be used, because the dog license data does not account for unlicensed pets and strays.

Figure 2: Number of licensed dogs in Piscataqua Region towns compared to estimated totals from AVMA formulas



Cats

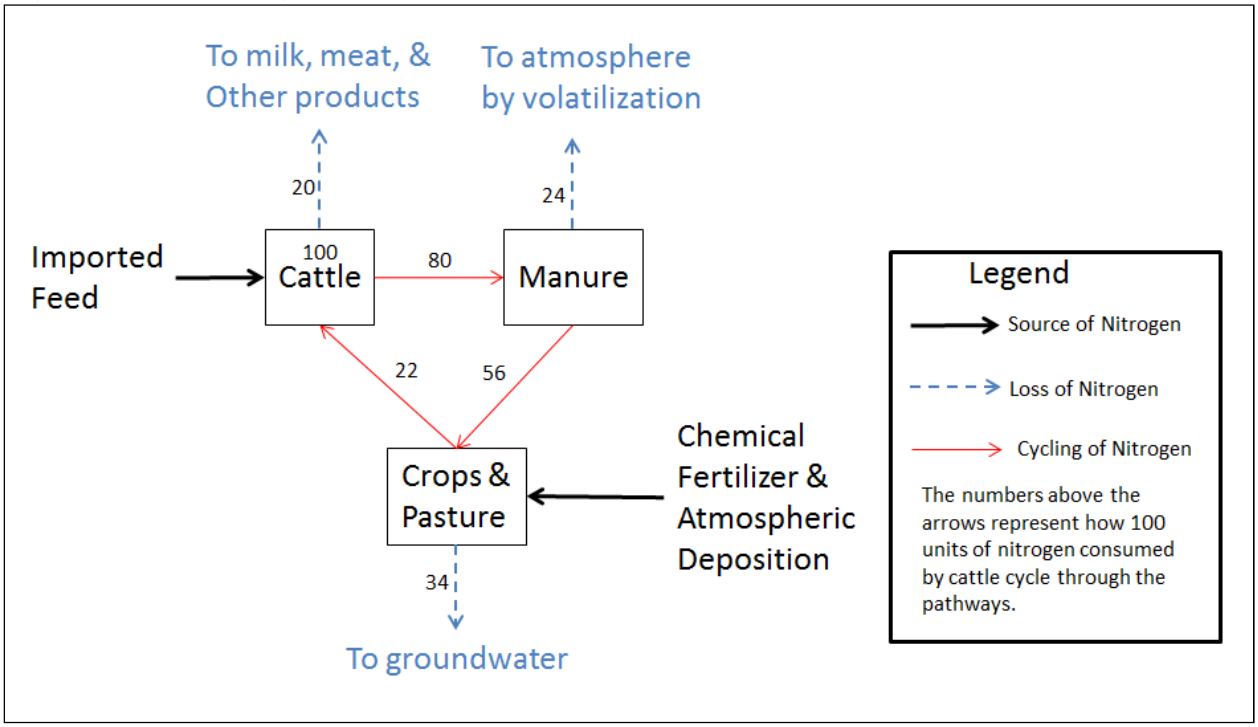
The numbers of cats in towns in the study area were estimated based on census population data and formulas established by the AVMA, because cat registrations are not available through the town offices. The good correspondence between the AVMA formula and the actual dog registrations provides confidence in the use of the AVMA formulas for estimating the number of cats within each town. The AVMA estimation process began by estimating the number of households within each community. This was done by dividing the town population by the average household size. This data was obtained at the town level form the 2010 US Census. The second step estimated the number of cat-owning households within each community. This was calculated by multiplying the number of households by 0.324 (fraction of cat owning households provided by AVMA). The last step calculated the number of cats within each community by multiplying the of cat owning households by 2.2 (average number of cats owned provided by AVMA).

C. Nitrogen Excretion Rates for Animals

Cattle

There is a complicated cycle of nitrogen in agricultural areas with livestock. Cattle consume nitrogen from a combination of feed, crops, and grass from pasture. Approximately 20% of the nitrogen is converted into milk, meat, and other products[5] (Jordan and Weller, 1996) which enters the local food supply and is accounted for by the human waste components of this model. The remainder of the nitrogen is excreted by the cattle and becomes manure. USDA predicts that 30% of the nitrogen in manure will be lost to the atmosphere through volatilization of ammonia (USDA, 2011, page 11-18). Finally, some of the remaining nitrogen in the manure will be recycled back to the cows through pasture grass or crops and the rest will enter the groundwater[6]. Figure 3 illustrates this cycle and how it is handled by the Nitrogen Loading Model.

Figure 3: Cattle Nitrogen Cycle



For the purposes of this study, nitrogen loads from animal waste will be calculated from effective excretion rate. The excretion rate represents the animal waste applied to the land surface *after* milk, meat, and other products have been removed. The excretion rate is further reduced by 30% to account for losses during storage. Table 2 summarizes the available information on the

[5] Jordan and Weller (1996) report that 31% and 7% of consumed nitrogen is converted into dairy products and meat products, respectively. For a herd with 60% dairy cattle, the weighted average of these two percentages would be 21%.

[6] Valiela et al. (1997) determined that 39% of the nitrogen applied to agricultural lands is incorporated into plants or lost at the land surface and 61% passes through to the groundwater (see Appendix H).

excretion rates for dairy and beef cattle. The excretion rate for dairy cows is much higher than for beef cattle. Table 1 indicates that approximately 60% of the cattle in the study area are dairy cows and the remainder are beef cattle. The weighted average of the two excretion rates is 280 lb-N/animal/year. After accounting for losses from manure during storage, the effective excretion rate is 196 lb-N/animal/year.

Table 2: Effective excretion rate for cattle

Source	Excretion Rate for Dairy Cows (lb-N/animal/yr)	Excretion Rate for Beef Cattle (lb-N/animal/yr)
ASAE (2005) Table 1b	361	153
Van Horn (1998)	367	129
USDA (2011) Table 4-5, 4-8	380	153
Average	369	145
Percent of Total Cattle	60%	40%
Weighted Average Excretion Rate	280	
Losses from manure during storage	30%	
Effective Average Excretion Rate	196	

Horses

The nitrogen cycling for horses follows a similar pattern as cattle, except for the food production component. Table 3 summarizes the available information on the excretion rates for horses. After accounting for losses to the atmosphere during storage, the effective excretion rate for horses will be 55 lb-N/animal/yr.

Table 3: Effective excretion rate for horses

Source	Excretion Rate for Horses (lb-N/animal/yr)
ASAE (2005) Table 1b	73
USDA (2011) Table 4-14	73
Boyer (2002) Table 3	88
Average	78
Losses from manure during storage	30%
Effective Average Excretion Rate	55

Dogs and Cats

The excretion rates for dogs and cats will be 4.4 and 3.3 lb-N/animal/year, respectively, as shown in Table 1.

D. Animal Waste Disposal Practices

Cattle and Horses

Cattle and horses reside on agricultural lands and pastures. Their wastes will either remain in place or be redistributed as manure fertilizer. Therefore, the nitrogen in waste from cattle and horses will be assumed to be spread out across agricultural and pasture land in the watershed. While manure may be moved by truck, for the purposes of this study, it will be assumed that manure is not trucked more than a few miles and stays within the same town/watershed.

Dogs

Using the results of surveys reported in a 1999 Chesapeake Bay study (CWP, 1999), it can be estimated that approximately 60% of dog owners usually pick up their pet's waste. This ratio can be extrapolated to the number of dogs. The survey also found that the dog waste that was picked up was disposed of in the trash approximately 60% of the time, in the toilet approximately 15% of the time, and somewhere else approximately 25% of the time. This last category will be assumed to be only moving the waste to some other location (e.g., in the woods), so it can be treated as if the waste were not picked up in the first place. Based on these percentages, nitrogen in dog waste will be assumed to end up in the following areas:

- Scooped and landfilled (36% of dogs). Waste assumed to be sequestered in a landfill, and therefore not transported into the watershed, or sent to a wastewater treatment plant in landfill leachate.
- Scooped and flushed (9% of dogs). The 9% is then divided between septic systems and sewers based on the ratio of people using septic systems versus sewers in the area.
- Not scooped or scooped and thrown somewhere else (55% of total dogs). The 55% is further divided between lawns, disconnected impervious areas, and directly connected impervious areas based on the ratio of each land use type to the sum of the three.

Cats

Cat waste is typically collected in a litter box and then disposed in the trash. Some people dispose of the waste in toilets, but this process is not recommended to prevent clogs and to protect marine mammals from disease. No studies were found that quantified the percent of people who dispose of cat waste using the trash vs. using the toilet. Similarly, no studies were found that quantified the percent of outdoor cats vs. indoor cats. Because of the lack of data, this study will assume that 100% cats reside indoors and 100% of waste from cats will be disposed of in landfills, which is the most common practice. In a lined landfill, the waste will be sequestered in the landfill, and therefore not transported into the watershed, or sent to a wastewater treatment plant in landfill leachate. Therefore, nitrogen in cat waste was not considered to reach the estuary.

E. Conversion of Town Animal Populations to Watershed Animal Populations

The total number of animals in each HUC12 subwatershed was needed for model calculations. Watershed boundaries do not follow town boundaries so the town-level data could not be used directly. To convert from the town totals to watershed totals, the density of animals was assumed to be uniform within the town. Therefore, if a watershed covered a portion of a town, the watershed area in the town was divided by the total town area to get the percent of the town

in that watershed. This percent was then multiplied by total number of animals in the town to estimate the number of animals from that town in the watershed.

The total populations of cattle, horses, dogs, and cats for the portion of each town in the Piscataqua Region watershed are listed on Table 4.

Table 4: Number of horses, cattle, dogs, and cats for the portion of each town in the Piscataqua Region Watershed

State	County	Town	Estimated Dogs in 2010*	Estimated Cattle 2010-2011*	Estimated Horses in 2007*	Estimated Cats in 2010*
NH	Belknap	Alton	9	0	0	10
NH	Carroll	Brookfield	145	19	7	164
NH	Carroll	Wakefield	841	4	19	947
NH	Carroll	Wolfeboro	21	1	0	24
NH	Merrimack	Pittsfield	0	0	0	0
NH	Rockingham	Brentwood	939	26	154	1,059
NH	Rockingham	Candia	580	11	66	654
NH	Rockingham	Chester	745	44	132	840
NH	Rockingham	Danville	262	0	13	295
NH	Rockingham	Deerfield	781	78	138	880
NH	Rockingham	Derry	170	1	3	192
NH	Rockingham	East Kingston	277	5	22	312
NH	Rockingham	Epping	1,559	35	138	1,758
NH	Rockingham	Exeter	3,968	12	91	4,473
NH	Rockingham	Fremont	964	68	35	1,086
NH	Rockingham	Greenland	873	108	52	984
NH	Rockingham	Hampstead	201	0	4	227
NH	Rockingham	Hampton	4,432	37	4	4,995
NH	Rockingham	Hampton Falls	528	0	64	595
NH	Rockingham	Kensington	438	235	31	493
NH	Rockingham	Kingston	399	15	16	450
NH	Rockingham	New Castle	259	0	0	292
NH	Rockingham	Newfields	364	10	6	410
NH	Rockingham	Newington	188	4	5	212
NH	Rockingham	Newmarket	2,436	0	28	2,746
NH	Rockingham	North Hampton	1,114	0	17	1,255
NH	Rockingham	Northwood	567	27	22	639
NH	Rockingham	Nottingham	1,100	252	92	1,240
NH	Rockingham	Portsmouth	6,473	0	29	7,296
NH	Rockingham	Raymond	2,485	13	66	2,801
NH	Rockingham	Rye	1,422	3	35	1,603
NH	Rockingham	Sandown	1,081	3	25	1,218

State	County	Town	Estimated Dogs in 2010*	Estimated Cattle 2010-2011*	Estimated Horses in 2007*	Estimated Cats in 2010*
NH	Rockingham	Seabrook	2,260	7	16	2,547
NH	Rockingham	South Hampton	0	0	0	0
NH	Rockingham	Stratham	1,738	24	28	1,959
NH	Strafford	Barrington	2,039	22	97	2,298
NH	Strafford	Dover	8,354	86	156	9,416
NH	Strafford	Durham	3,718	133	146	4,190
NH	Strafford	Farmington	1,558	279	23	1,756
NH	Strafford	Lee	1,049	311	91	1,183
NH	Strafford	Madbury	396	0	36	446
NH	Strafford	Middleton	413	0	8	466
NH	Strafford	Milton	1,140	83	12	1,285
NH	Strafford	New Durham	306	10	13	345
NH	Strafford	Rochester	7,906	53	91	8,911
NH	Strafford	Rollinsford	652	85	14	735
NH	Strafford	Somersworth	3,075	2	18	3,466
NH	Strafford	Strafford	665	14	38	750
ME	York	Acton	353	0	18	398
ME	York	Berwick	1,749	250	59	1,971
ME	York	Eliot	1,233	76	30	1,390
ME	York	Kittery	1,969	107	29	2,219
ME	York	Lebanon	1,392	0	66	1,569
ME	York	North Berwick	1,139	17	48	1,284
ME	York	Sanford	2,143	0	37	2,415
ME	York	Shapleigh	9	0	0	10
ME	York	South Berwick	1,495	0	46	1,685
ME	York	Wells	479	0	15	540
ME	York	York	179	0	5	202
MA	Essex	Amesbury	2	0	0	2
MA	Essex	Salisbury	398	0	17	448
		Grand Total =	**83,430**	**2,572**	**2,468**	**94,037**

* Animal counts are based off the portion of the town within the Piscataqua Region Watershed and assume an equal distribution of animals. The values presented are rounded to the nearest whole number.

F. Evaluation of the Potential for Double Counting Nitrogen from Fertilizer and Atmospheric Deposition as Nitrogen in Animal Waste

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 having 39% of the nitrogen applied to agricultural lands be "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.

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New Hampshire Department of Environmental Services
Great Bay Nitrogen Non-Point Source Study

Appendix G

Methodology for Calculating
the Number of People Using Onsite Septic Systems for Waste Disposal
in the Piscataqua Region Watershed

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Purpose

This appendix summarizes the detailed methods used to calculate the number of people using septic systems for waste disposal in the Piscataqua Region. Nitrogen loads from human waste are directly proportional to the number of people using septic systems for waste disposal. Therefore, to calculate the contribution of septic systems to the nitrogen load, the number of people using septic systems to dispose of waste must be determined. The outputs of this analysis will be used to partially populate the Nitrogen Loading Model for the Great Bay Non-Point Source Nitrogen Pollution Source Study.

Methodology

1. Information Inputs

The two basic sources of information for this study were the location of sewer lines and population totals from the 2010 U.S. Census. This information needed to be collected on a spatial scale that was smaller than town and subwatershed boundaries to provide credible results. The appropriate spatial scale for population data from the U.S. Census would be the 'census block'. Sewer service area data were obtained directly from municipalities and from the USGS Water Demand Model for New Hampshire towns (Hayes and Horn, 2009).

2. Study Boundaries

The study area was the Piscataqua Region watershed. Only the portion of each town that is in the watershed was included.

3. Analytical Approach

Each census block in the study area was classified according to what percent of the population living in that block was not served by a municipal sewer system and, therefore, can be assumed to use septic systems for waste disposal. The classifications were made based on the USGS Water Demand Model (Hayes and Horn, 2009) and sewer line maps for individual towns. The number of people in each census block using septic systems was calculated by multiplying the percent of the block using septic systems by the total population of the block from the 2010 U.S. Census. The results for all census blocks were rolled up to calculate totals for each town and subwatershed.

a. Census blocks were used as a base layer because blocks are the smallest unit of demographic data. Census blocks are typically smaller than towns or subwatersheds. The census blocks from the 2000 U.S. Census were used initially because the USGS Water Demand Model (USGS, 2009) was built on this platform.
b. The 2000 census blocks from New Hampshire, Maine, and Massachusetts were merged into one ArcGIS coverage. The intersect tool was used to select out all the census blocks that were within or touched the boundary of the Piscataqua Region watershed. This combined coverage ("Blocks_2000_NH_MAandME_IntersectCoastalWshed_withData.shp") was checked for any duplicate values in the block ID ("STFID") and none were found.
c. The USGS Water Demand Model (Hayes and Horn, 2009) used an algorithm based on sewer lines for wastewater treatment facilities (from approximately 2003) to estimate the population within each census block in New Hampshire that returned wastewater through a septic system. The values from this model were assigned to the 2000 census blocks in the New Hampshire portion of the Piscataqua Region watershed.
d. For Maine and Massachusetts blocks, available geospatial data on sewer lines were gathered from the towns and previous studies (e.g., Bolster et al., 2003). ArcGIS was used to overlay the sewer lines with the census blocks and aerial imagery. The selection tool was used to select all of the blocks within a town that did not intersect the sewer lines. These blocks were estimated to have 100% septic system usage. Blocks that intersected the sewer lines were individually examined using the aerial photos to estimate the percent of homes not connected to the sewer system based on the proximity of homes to sewer lines. The sources of sewer line information are listed below:
    i. Kittery, ME – sewer line coverage from Carl Bolster (UNH)
    ii. Berwick, ME – Hard copy of map obtained. Georeferenced and digitized by DES
    iii. North Berwick, ME – Hard copy of map obtained. Georeferenced and digitized by DES
    iv. South Berwick, ME – sewer line coverage from Carl Bolster (UNH)
    v. Eliot, ME – sewer line coverage from Town
    vi. Sanford, ME – sewer line coverage from Town
    vii. Salisbury, MA - Hard copy of map obtained. Georeferenced and digitized by DES

e. The most recent demographic data was collected during the 2010 U.S. Census. The 2010 census blocks from New Hampshire, Maine, and Massachusetts were merged into one ArcGIS coverage. The intersect tool was used to select out all the census blocks that were within or touched the boundary of the Piscataqua Region watershed. This combined coverage ("census_2010_coastal_watershed_with_data" in the Coastal_Watershed_Data_Layers.mdb geodatabase) was checked for any duplicate values in the block ID ("GEOID10") and none were found.

f. The percent septic system use assigned to the 2000 census blocks were transferred to the 2010 census blocks. However, the boundaries of the 2010 census blocks did not match the 2000 census blocks so the information could not be transferred directly. Instead, the "select-by-location tool" in ArcGIS was used to automate assignments for 2010 census blocks that had their centroid within 2000 census blocks classified as 100% or 0% septic usage. For the remaining 2010 census blocks, ArcGIS was used to overlay the sewer lines and sewer service areas with the census blocks and aerial imagery. Blocks that intersected the sewer lines or service areas were individually examined using the aerial photos to estimate the percent of homes not connected to the sewer system. The sources of sewer line and service area information are listed below:

    i. Farmington, NH – sewer and water service area coverage created by DES
    ii. Wakefield, NH – sewer and water service area coverage created by DES
    iii. Milton, NH – sewer and water service area coverage created by DES
    iv. Rochester, NH – sewer and water service area coverage created by DES
    v. Somersworth, NH – sewer and water service area coverage created by DES
    vi. Rollinsford, NH – sewer and water service area coverage created by DES
    vii. Epping, NH – sewer and water service area coverage created by DES
    viii. Brentwood, NH – sewer and water service area coverage created by DES
    ix. Dover, NH – sewer line coverage from Carl Bolster (UNH) and sewer and water service area coverage created by DES
    x. Durham, NH – sewer line coverage from Carl Bolster (UNH) and sewer and water service area coverage created by DES
    xi. Newfields, NH – sewer line coverage from Carl Bolster (UNH) and sewer and water service area coverage created by DES
    xii. Newmarket, NH – sewer line coverage from Carl Bolster (UNH) and sewer and water service area coverage created by DES
    xiii. Seabrook, NH – sewer line coverage from Carl Bolster (UNH) and sewer and water service area coverage created by DES
    xiv. Hampton, NH – sewer line coverage from Carl Bolster (UNH) and sewer and water service area coverage created by DES
    xv. Exeter, NH – sewer line coverage from Carl Bolster (UNH) and sewer and water service area coverage created by DES
    xvi. Stratham, NH – sewer line coverage from Carl Bolster (UNH) and sewer and water service area coverage created by DES
    xvii. Portsmouth, NH – sewer line coverage from Carl Bolster (UNH) and sewer and water service area coverage created by DES
    xviii. Kittery, ME – sewer line coverage from Carl Bolster (UNH)

xix. Berwick, ME – Hard copy of map obtained. Georeferenced and digitized by DES
xx. North Berwick, ME – Hard copy of map obtained. Georeferenced and digitized by DES
xxi. South Berwick, ME – sewer line coverage from Carl Bolster (UNH)
xxii. Eliot, ME – sewer line coverage from Town
xxiii. Sanford, ME – sewer line coverage from Town
xxiv. Salisbury, MA - Hard copy of map obtained. Georeferenced and digitized by DES

g. For each census block, the 2010 population in each block using septic systems was calculated by multiplying the 2010 population and the percent of block using septic systems.
h. The total population, population using septic systems, and population served by the municipal wastewater treatment plant (if any) were calculated for towns, watersheds, and areas within 200-meters of the estuaries and large rivers. The ArcGIS Identity tool was used to clip the census blocks associated with each town, watershed, and inside a 200 meter buffer around the estuaries and large rivers (5th order or higher). For census blocks that straddled watershed or buffer boundaries, the population was prorated based on the area of the block in the watershed or buffer assuming uniform population density. Note: This approach assumes that the sewer service area is uniform across the block.
i. For quality assurance, maps of sewered areas and the population totals for each town were shared with town officials for comment. The population totals were also compared to information on septic system totals from DES.

4. Data Quality Objectives

To ensure the quality of the data, the following objectives were set at the beginning of the study.

a. The spatial units for the study need to be smaller than the town and HUC12 polygons.
b. The sewer service areas should be approved by officials in the municipalities.
c. The estimated percent of people served by sewer and septic systems in each town should be accurate to within 10% (absolute difference).

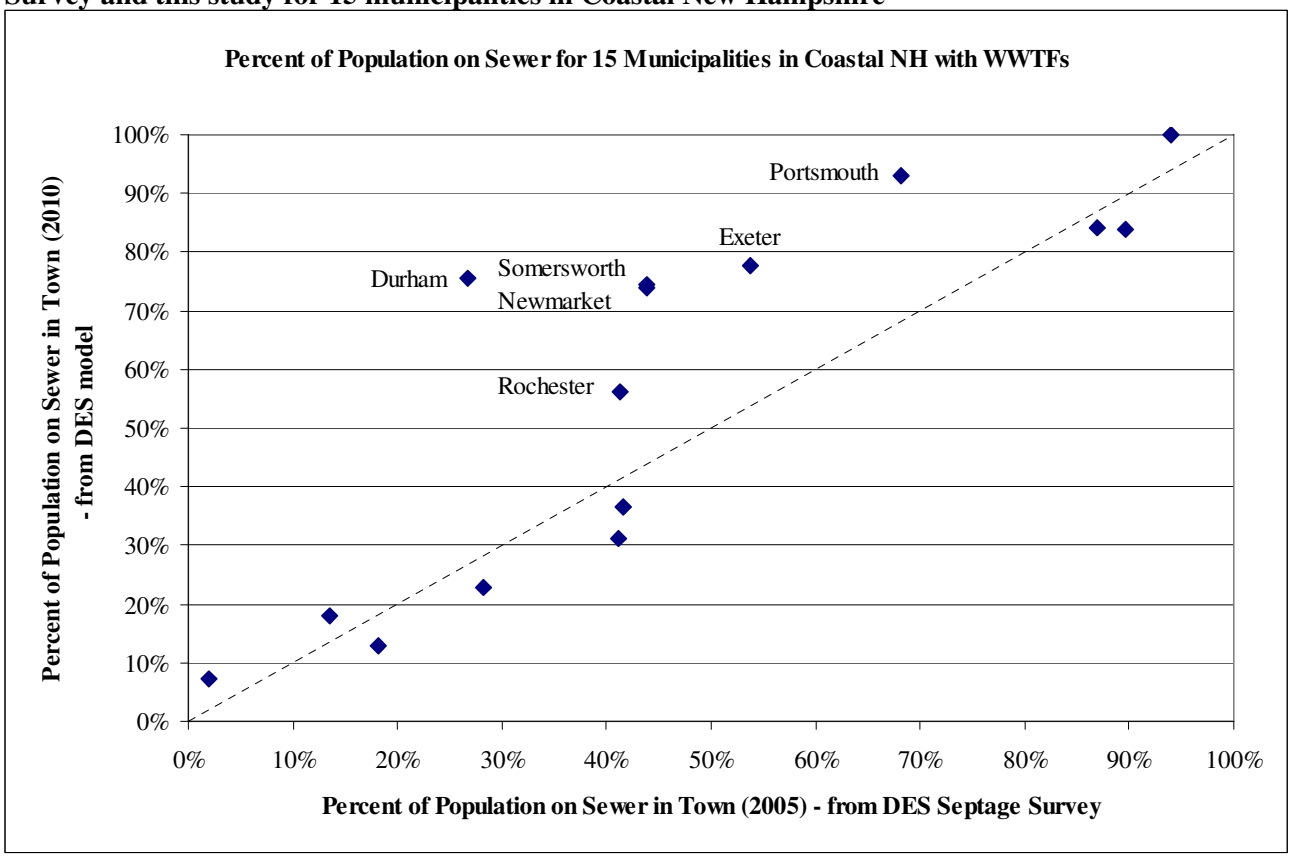
Results

<u>Number of Septic Systems</u>

Following the process outlined in the methodology, DES generated draft maps for each town showing the 2010 Census blocks coded according to the percent of the population that was served by sewer systems. The draft maps were mailed to all 61 municipalities in the study area on August 19, 2011. The municipalities were asked to proof the draft maps and to send DES any changes. Thirty-eight of the municipalities (73%) responded to the survey. DES incorporated the requested changes as much as possible. Many towns requested that Census blocks be split into smaller pieces. DES was not able to make these changes because the population totals from the 2010 Census could not be split into smaller areas than the blocks.

DES performed a check of the data to determine whether the data quality objectives had been met. The first two objectives (listed in Section 4, above) were met based on the small size of the Census blocks relative to the town boundaries and the 73% response rate for the municipal survey. To check the accuracy of the model, DES compared the percent of the population on sewer in towns from this study versus the percent that was determined by the DES Septage Program Survey of towns for 2005. The DES Septage Program Survey used 1990 census block group data on septic systems plus follow-up calls to some towns to estimate the percent of households in the town using septic systems for waste disposal. The DES Septage Program Survey is not necessarily a more accurate method than this study but it does represent an independent approach. Figure 1 shows the percent of population on sewer in each of the 15 towns in New Hampshire with a wastewater treatment facility for the 2005 DES Septage Program Survey and this study. Only towns with sewer service areas were included on this map, otherwise dozens of unsewered towns with null values would bias the chart. The two studies agree for most of the municipalities, but there was a greater than 10% difference for the six municipalities with large wastewater treatment facilities. Possible explanations for these differences are: (1) The sewer service area has expanded in these municipalities since 2005; (2) The 2005 survey of Durham looked at residential sewer hookups while the 2010 model includes sewer connections for the total population recorded in the U.S. Census (students, rental properties, etc.); and (3) There are a significant number of homes in sewered areas that are not connected to the sewer. These discrepancies should be investigated.

Figure 1: Comparison of the percent of population on sewer from the 2005 DES Septage Program Survey and this study for 15 municipalities in Coastal New Hampshire



* Points that fall far from the 1:1 line (dashed line) have been labeled with the name of the municipality

The study results are presented in Table 1 and on Figures 2 and 3. Key points:

- In the coastal watershed in 2010, there were 177,548 people who used septic systems for waste disposal at their place of residence (55% of 325,775 total).
- In 2010, there were 7,943 people served by septic systems within a 200-meter radius of the estuaries and large rivers (5th order or higher). Septic systems within 200-meters of the estuary or large rivers were identified because the Nitrogen Loading Model (Valiela et al., 1997) assumed a higher delivery rate of nitrogen from septic systems within 200-meters of the receiving water.

Table 1: Number of People Served by Wastewater Treatment Facilities (WWTFs) and by Septic Systems in Each Town in 2010

Town	Estimated Total Population within the Coastal Watershed[1]	Estimated Population within the Coastal Watershed[1] Served by WWTFs	Estimated Population within the Coastal Watershed[1] Served by Septic Systems	Estimated Population within 200-m of the Estuaries[2] Served by WWTFs	Estimated Population within 200-m of the Estuaries[2] Served by Septic Systems
Total NH	273,078	127,816	145,262	15,525	5,896
Total ME	47,822	17,902	29,920	4,334	2,045
Total MA	4,875	2,510	2,365	18	2
Grand Total	325,775	148,227	177,548	19,877	7,943

[1] Population within the 2010 census blocks adjusted using the % of area within the Piscataqua Region watershed. These numbers may not match total town populations if part of the town is outside the watershed.
[2] Population within the 2010 census blocks adjusted using the % of area within a 200-m buffer around the estuaries and large rivers (5th order or higher).

Figure 2: Percent of Population Using Septic Systems for Waste Disposal

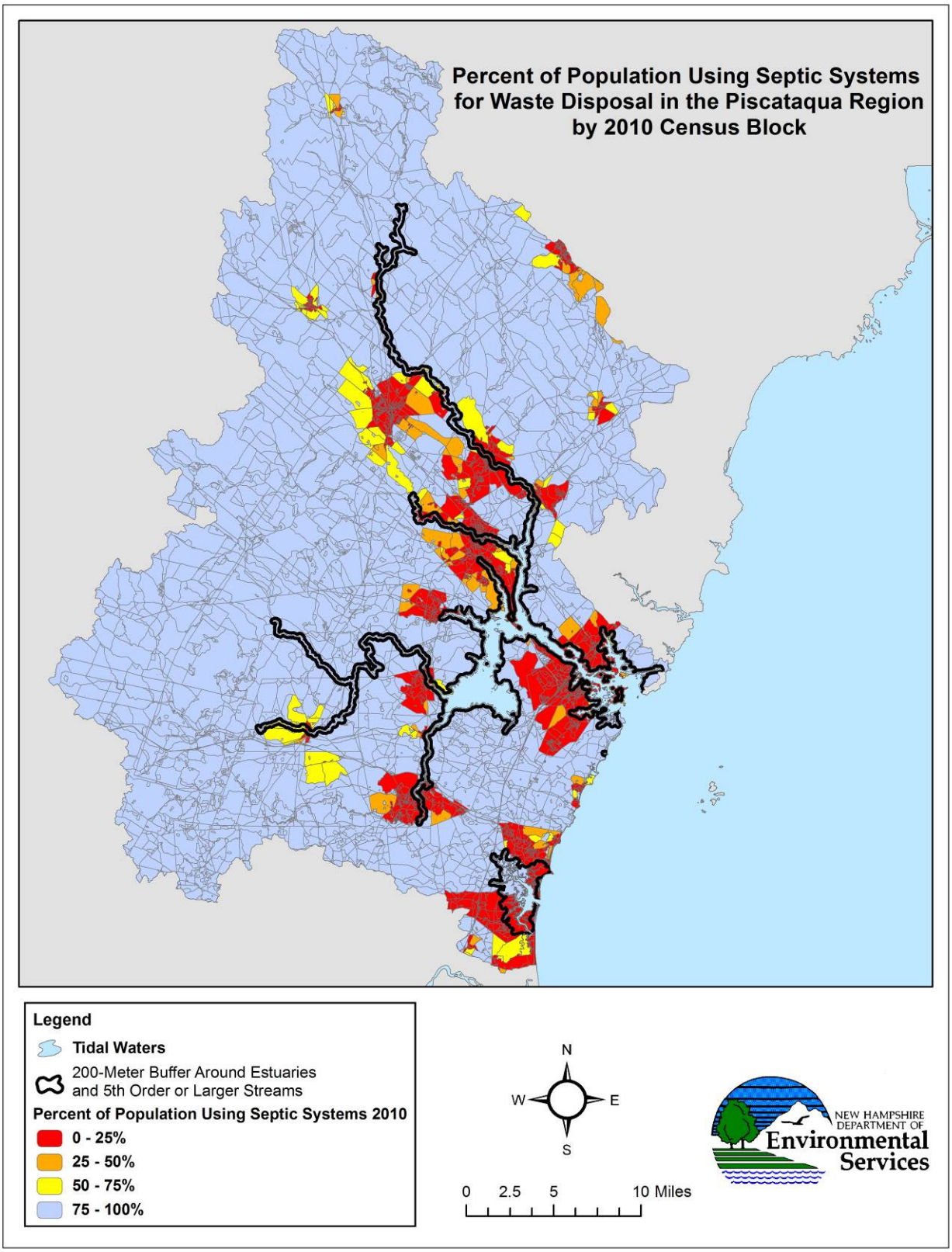
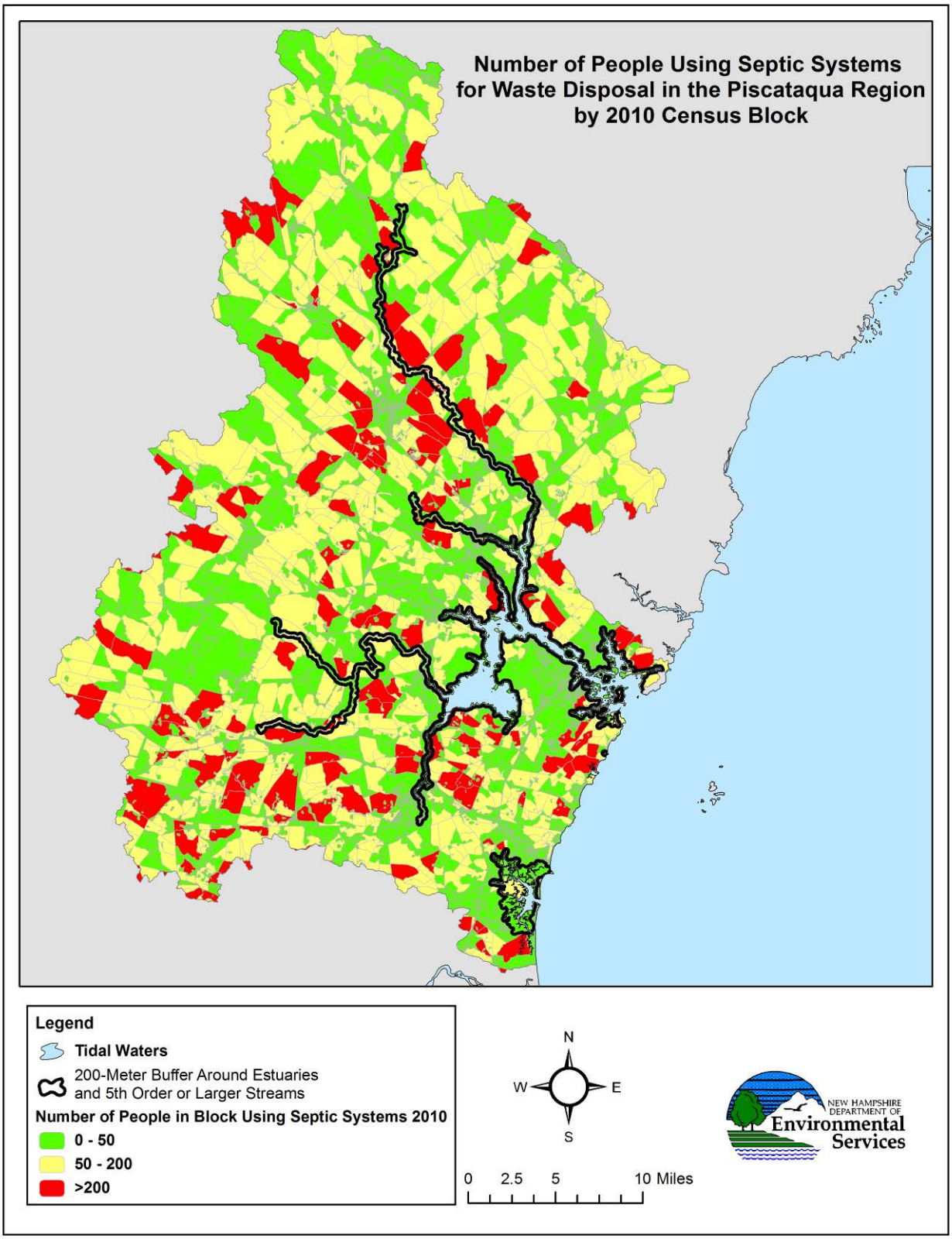


Figure 3: Number of People Using Septic Systems for Waste Disposal



Nitrogen in Human Waste

The Nitrogen Loading Model assumes a per person nitrogen excretion rate of 10.6 lb per year (4.8 kg per year) (Valiela et al., 1997). The value compares well with the 11 lb per year estimate used by Daley et al. (2010) for studies of the Lamprey River. Most of the nitrogen in human waste is in urine.

Septic Systems

The amount of nitrogen from human waste in septic systems can be estimated by multiplying the number of people using septic systems for waste disposal by the per person excretion rate of 10.6 lb per year. The delivered load of nitrogen from septic systems that actually reaches the estuary will depend on the distance of the septic system from the estuary and losses that occur during groundwater transport (see Appendix H).

Wastewater Treatment Facilities

There are 20 wastewater treatment facilities that collect, treat, and discharge human waste from the larger municipalities in the study area. It is already known that these facilities contributed 32% of all the nitrogen delivered to the Great Bay Estuary in 2009-2011(PREP, 2013). Table 2 from PREP (2012) lists the delivered load from each WWTF.

Table 2: Estimated Total Nitrogen Loads to the Great Bay Estuary from Wastewater Treatment Facilities in 2009-2011 (PREP, 2012)

WWTF	Discharge Location	Delivered TN Load in 2009-2011 (lb/yr)
Durham	Oyster River (tidal)	29,760
Exeter	Exeter River (tidal)	83,600
Newfields	Exeter River (tidal)	3,660
Newmarket	Lamprey River (tidal)	55,980
Dover	Upper Piscataqua River (tidal)	188,040
South Berwick	Salmon Falls River (tidal)	6,160
Kittery	Lower Piscataqua River	7,760
Newington	Lower Piscataqua River	1,920
Portsmouth	Lower Piscataqua River	58,980
Pease ITP	Lower Piscataqua River	4,960
Farmington	Cocheco River	7,500
Rochester	Cocheco River	280,020
Epping	Lamprey River	8,240
Berwick	Salmon Falls River	10,480
Milton	Salmon Falls River	2,940
Rollinsford	Salmon Falls River	4,600
Somersworth	Salmon Falls River	22,620
North Berwick	Great Works River	3,080
Hampton	Hampton-Seabrook Harbor	0[3]
Seabrook	Atlantic Ocean	0[3]
	Total =	780,320 (390 tons/yr)

[3] The Hampton and Seabrook WWTFs do not discharge to the Great Bay Estuary

The purpose of this study is to determine how much nitrogen is delivered to the estuary from septic systems. Information on the nitrogen load from wastewater treatment facilities has been provided for context only. PREP (2013) provides a summary of the total load of nitrogen to the estuary from both point and non-point sources.

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New Hampshire Department of Environmental Services
Great Bay Nitrogen Non-Point Source Study

Appendix H

Methodology for Estimating
Surface Water/Groundwater Partitioning (i.e. Stormwater)
in the Piscataqua Region Watershed

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Purpose

This appendix contains detailed methodologies used to estimate the amount of total nitrogen that will be directed through both the surface water and groundwater pathways, via an estimation of stormwater, for the Nitrogen Loading Model.

Introduction

The Nitrogen Loading Model (NLM) was initially developed and verified for the 20.5 square mile watershed draining to Waquoit Bay in Massachusetts (Valiela et al., 1997; Valiela et al., 2000). Because the soils around Waquoit Bay are sandy, the model assumes that all of the nitrogen will be transported by groundwater. The model has been validated by Latimer and Charpentier (2010) for 74 similarly sized estuaries in southern New England. Bowen et al. (2007) successfully applied the model using the default assumptions for the larger Barnegat Bay estuary in New Jersey (540 square miles).

Application of the NLM to the Great Bay Estuary presents some challenges because of the size of the watershed and the underlying geology. The watershed for the Great Bay Estuary (1,023 square miles) is nearly twice the size as Barnegat Bay and 50 times larger than Waquoit Bay. The soils in the Great Bay Watershed are not as sandy as those on Cape Cod so it cannot be assumed that all of the nitrogen travels through groundwater flow. Through consultations with

the author of the NLM and comparisons to measured loads, DES decided that the best way to customize the model to the Great Bay Estuary was to add a surface water transport pathway.

Transport Pathways and Delivery Factors for the NLM

The NLM estimates losses of nitrogen during transport through groundwater to the estuary (Valiela et al., 1997). The default model assumes two different pathways. However, due to the geology and development, some of the nitrogen applied to the land surface will not enter the groundwater, but will be carried directly into surface waters by stormwater runoff. Therefore, DES added a stormwater/surface water transport pathway to customize the NLM for the conditions in the Great Bay Estuary.

- **Land Surface to Groundwater Pathway**: The model assumes three stages of transport for nitrogen applied to the land surface. The first stage is loss of nitrogen into soil and plants at the land surface. The second stage is loss of nitrogen in the unsaturated vadose zone between the land surface and the groundwater. The third stage is loss of nitrogen during transport through the groundwater to the estuary. The default delivery factors for each stage are shown on Table 1.
- **Septic System to Groundwater Pathway**: The model assumes three stages of transport for nitrogen in septic systems. The three stages correspond to losses in the tank, losses in groundwater plumes, and losses during groundwater transport. For septic systems within 200-meters of the estuary, the NLM assumes that there is too little space for nitrogen losses in the groundwater to occur. Therefore, only losses in the tank are assumed. The default delivery factors for each stage are shown on Table 2.
- **Stormwater/Surface Water Pathway:** This pathway was added to the NLM to account for transport of nitrogen from certain land use types without passing through groundwater. Some of the nitrogen in the surface water pathway will be lost during transport but not nearly as much as during groundwater 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 a mean percent loss of nitrogen in upstream freshwater reaches of 13%. This delivery factor is not relevant to atmospheric deposition directly to the estuary. The delivery factors for the surface water pathway are shown on Table 3.

Table 1: Delivery Factors for Nitrogen through the Land Surface to Groundwater Pathway

Delivery Factors for N Sources to Estuary through Ground Waters					
Nitrogen Input Source	**Land Use Type**	**Delivery Factor: Surface to Vadose Zone**	**Delivery Factor: Vadose Zone to Aquifer**	**Delivery Factor: Aquifer to Embayment**	**Delivery Factor: Total**
Atmospheric Deposition	Natural Vegetation	35%	39%	65%	9%
	Agricultural Lands	38%	39%	65%	10%
	Lawns	38%	39%	65%	10%
	Managed Turf	38%	39%	65%	10%
	Disconnected Impervious Areas	38%	39%	65%	10%
Chemical Fertilizer	Agricultural Lands	61%	39%	65%	15%
	Lawns	61%	39%	65%	15%
	Managed Turf	61%	39%	65%	15%
Animal Waste	Agricultural Lands	61%	39%	65%	15%
(Manure and Pet Waste)	Lawns	61%	39%	65%	15%
	Disconnected Impervious Areas	38%	39%	65%	10%

Table 2: Delivery Factors for Nitrogen through the Septic System to Groundwater Pathway

Delivery Factors for N Sources to Estuary through Septic Systems					
Nitrogen Input Source	**Land Use Type**	**Delivery Factor: Septic Tank and Leach Field**	**Delivery Factor: Groundwater Plumes**	**Delivery Factor: Groundwater to Embayment**	**Delivery Factor: Total**
Animal Waste	Septic System - outside 200M buffer	60%	66%	65%	26%
(Manure and Pet Waste)	Septic System - inside 200M buffer[1]	60%	100%	100%	60%
Human Waste	Septic System - outside 200M buffer	60%	66%	65%	26%
	Septic System - inside 200M buffer[1]	60%	100%	100%	60%

[1] For septic systems that are less than or equal to 200 meters from the estuary and large rivers, losses in groundwater plumes in the aquifer were not assumed to occur following Valiela et al. (1997).

Table 3: Delivery Factors for Nitrogen through the Stormwater/Surface Water Pathway

Delivery Factors for N Sources to Estuary through Surface Waters			
Nitrogen Input Source	**Land Use Type**	**Delivery Factor: Surface Water to Embayment**	**Delivery Factor: Total**
Atmospheric Deposition	Natural Vegetation	87%	87%
	Lakes & Rivers	87%	87%
	Estuaries[2]	100%	100%
	Agricultural Lands	87%	87%
	Lawns	87%	87%
	Managed Turf	87%	87%
	Disconnected Impervious Areas	87%	87%
	Connected Impervious Areas	87%	87%
Chemical Fertilizer	Agricultural Lands	87%	87%
	Lawns	87%	87%
	Managed Turf	87%	87%
Animal Waste	Agricultural Lands	87%	87%
(Manure and Pet Waste)	Lawns	87%	87%
	Disconnected Impervious Areas	87%	87%
	Connected Impervious Areas	87%	87%

[2] Assuming 100% delivery for atmospheric deposition is directly to the estuary surface.

Relative Importance of Groundwater and Surface Water Pathways by Land Use

By adding the surface water pathway to the NLM, DES made the model more relevant to the local geology but also added a new variable: how much of the nitrogen applied to a certain land use runs off the land in the surface water pathway versus passes through the groundwater pathway. DES assumed that nitrogen would move with the water and that the percent of rainfall that runs off a land use on average would be a good surrogate. The average percent runoff variable for each land use as a function of soil type was determined by the following methods and is summarized in Table 4.

- **Natural Vegetation, Agriculture, Lawn and Managed Turf:** Most of the nitrogen applied to these pervious land uses will be transported by the default land-surface-to-groundwater pathway. However, some fraction of the nitrogen is expected to be transported to surface waters by 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 (NRCS, 2004). The appropriate Curve Number for each land use was selected based on the dominant soil type in the watershed and the land use characteristics. (See Technical Details of SWMM Modeling).
- **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. In the case of atmospheric deposition directly to the estuary, no transport pathway is required.

- **Connected Impervious Area (CIA):** CIA generates 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 CIA was assumed to travel through the surface water pathway.
- **Disconnected Impervious Area (DIA):** DIA generates runoff that "runs on" to neighboring pervious areas. If the impervious area is surrounded by much pervious area, the "run on" water will infiltrate and there will be no effective runoff from the DIA. However, as the ratio of impervious area to pervious area increases, the infiltration capacity of the pervious area will be reached and the "run on" from the impervious area will enter the stormwater/surface water pathway. To determine this effective runoff from the DIA, a long-term SWMM simulation was run with two linked watersheds. The first watershed was impervious. The runoff from this watershed was routed to the second, pervious watershed. The simulation predicted the cumulative runoff from the two linked watersheds. This result was compared to the predicted runoff from a long-term SWMM simulation for the pervious watershed alone. The difference between these two model simulations represented how much runoff was generated by the DIA. (see Technical Details of SWMM Modeling)

Table 4: Percent of Rainfall that Runs Off into the Surface Water Pathway by Land Use and Soil Type

Land Use Type	Percent Runoff by Hydrologic Soil Type[3]			
	A	B	C	D
Natural Vegetation	1%	5%	10%	14%
Agriculture	1%	6%	10%	15%
Lawn	2%	6%	12%	17%
Managed Turf	2%	6%	12%	17%
Lake	100%	100%	100%	100%
Estuary	100%	100%	100%	100%
Connected Impervious Area	100%	100%	100%	100%
Disconnected Impervious Area (for each developed land use type)[4]				
Developed-High	71%	72%	73%	73%
Developed-Medium	53%	59%	63%	65%
Developed-Low	28%	40%	50%	55%
Developed-Open Space	16%	29%	42%	49%

[3] The dominant hydrologic soil type in each study area polygon will be used to represent the soil type in each study area polygon. DES downloaded a soil type map for the Piscataqua-Salmon Falls Subbasin, Hydrologic Unit 01060003 from the Soil Survey Geographic Database (SSURGO). The SSURGO Downloader can be accessed directly at http://www.arcgis.com/apps/OnePane/basicviewer/index.html?appid=a23eb436f6ec4ad6982000dbaddea5ea. Soil type is spatially heterogeneous so there were often multiple soil types in the modeled polygons (see Figure 1a). To select the central tendency soil type for a polygon, DES calculated the area of the polygon that was covered by each soil type. The soil type that covered the largest percentage of the polygon was considered the dominant soil type and used in the model analyses (see Figure 1b). Areas coded as water, A/D and C/D were considered part of the D soil type for this analysis.

[4] The percent runoff from disconnected impervious area (DIA) is a function of both the dominant soil type and the dominant developed land use in the study polygon. The developed land use that covered the largest percentage of the polygon was considered the dominant developed land use type and used in the model analyses. All impervious areas were assumed to fall inside one of the developed land use types (see Figure 2).

Comparison of Delivery Factors to Reports in the Scientific Literature

The total delivery factor for each pathway is the product of the delivery factors and the percent of nitrogen transported through the pathway. The delivery factors for each combination of nitrogen source and land use are shown on Tables 1 through 3. The total delivery factors for the pathways range from 9 to 100% (see right-hand-column on Tables 1- 3). The land surface to groundwater pathway had the lowest total delivery, ranging from 9 to 15%. Slightly higher was the total delivery from the septic system to groundwater pathway, which ranged from 26 to 60%. In contrast to these low delivery rates, the stormwater/surface water pathway had a total delivery rate of 87 to 100%.

While some of these delivery factors may seem small, they are supported by watershed measurements locally and regionally. Daley et al. (2010) reported that only 19% of the total nitrogen imported to the Lamprey River Watershed was exported at the downstream station (L73) between 2000 and 2009. Boyer et al. (2002) showed that the delivered nitrogen loads from large watersheds in the northeastern United States were only 25% of nitrogen inputs on average. In a review paper on nitrogen cycling, Howarth (2008) reported that globally only 20% of the anthropogenic nitrogen inputs to watersheds are exported and, in the northeastern United States, the percent delivered is 30%. Galloway et al. (2003) estimated that 30% to 70% of nitrogen is delivered once it gets into the wetland-stream-river continuum. Therefore, the delivery factors for the NLM are consistent with multiple scientific studies.

Other models of nitrogen fate and transport have also assumed that the majority of nitrogen is lost during transport through the watershed. The Chesapeake Bay Watershed Model assumes that 17-29% of the nitrogen applied to agricultural lands from the atmosphere, fertilizer, and manure is delivered to surface waters (Linker et al. 2000). Vadeboncoeur et al. (2010) used delivery factors of 12.5 to 32% for a study of nitrogen loading to Narragansett Bay from 1850 to 2015. On Cape Cod, nitrogen loading studies by the Buzzards Bay Estuary Program assumed delivery factors of 20-25% for fertilizer (Costa et al., 1999).

Delivery of nitrogen through septic systems has been extensively studied. The most detailed studies have been done at the Massachusetts Alternative Septic System Test Center. Conventional septic systems tested at the Center had nitrogen concentrations in the leach field that were 19-22% lower than inputs (78-81% delivery factor) (BBEP, 2001). The Chesapeake Bay Watershed Model uses a similar delivery factor (80%) to estimate losses up to the edge of the leach field. The Chesapeake model assumes that an additional 60% of nitrogen is lost (40% delivered) during groundwater transport to surface waters (Linker et al, 2000). Based on this information, the expected total delivery factor for septic systems should be 32%. This estimate is within the range of delivery factors for a typical septic system used for this study, 26-60%.

Figure 1: Hydrologic Soil Type in the Piscataqua Region Watershed. (a) Original dataset from NRCS. (b) Dominant soil type in each study polygon.

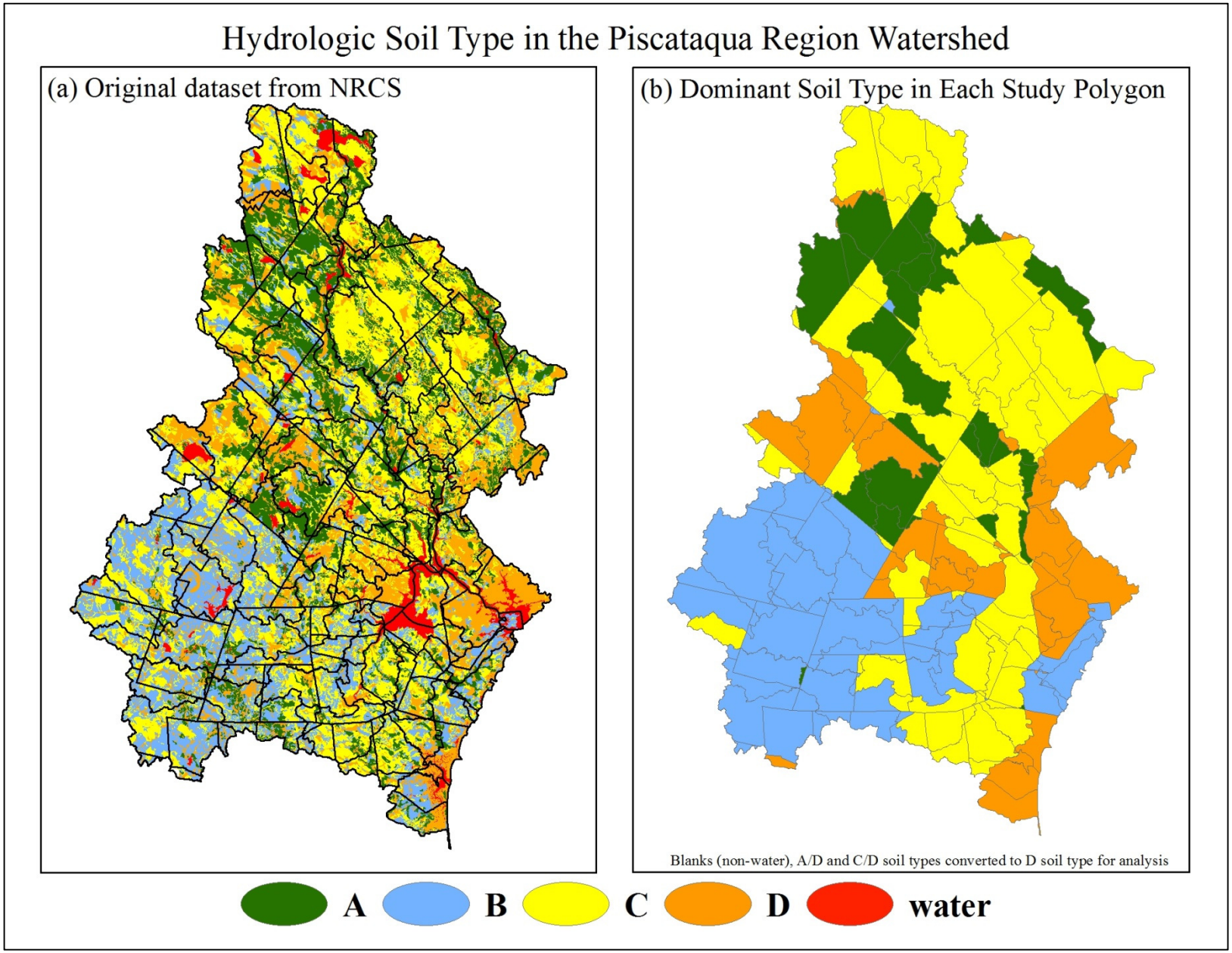
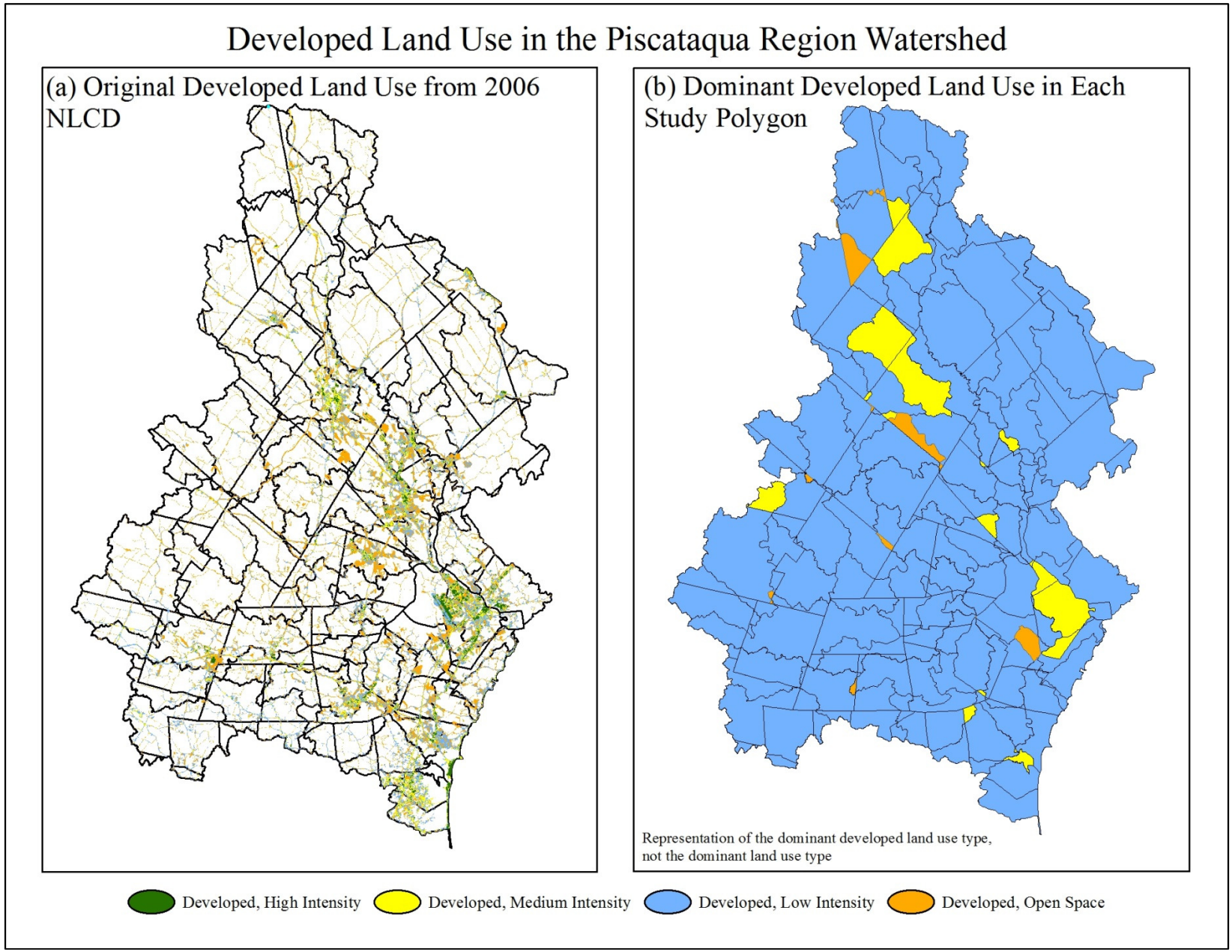


Figure 2: Developed Land Use in the Piscataqua Region Watershed. (a) Original developed land use from 2006 NLCD. (b) Dominant developed land use in each study polygon.



Technical Details of SWMM Modeling

The EPA Storm Water Management Model (SWMM, v 5.0) was used to predict the runoff from the pervious land use types (natural vegetation, agriculture, lawn, and managed turf). The model used the NRCS Curve Number (CN) approach in the long-term simulation. The appropriate CN for each land use and soil type was selected from Tables 9-1 and 9-5 in NRCS (2004), which are presented in Table 5. The long-term simulation dataset used the 10-year daily rainfall totals for Durham, NH (2000-2011) (NOAA). The total runoff during the 10-year simulation was divided by the total rainfall to estimate the average percent runoff from each combination of land use and soil type.

Table 5: Curve Numbers Selected for Use in Model

Land Use Type	CN for Hydrologic Soil Type				
	A	B	C	D	CN Description from Source*
Natural Vegetation	30	55	70	77	woods - good hydrologic condition
Agriculture	30	58	71	78	meadow - continuous grass, protected from grazing and generally mowed for hay
Lawn	39	61	74	80	open space - good hydrologic condition
Managed Turf	39	61	74	80	open space - good hydrologic condition

* CN chosen from Table 9-1 and 9-5, Chapter 9, Hydrologic Soil-Cover Complexes, Part 630 Hydrology National Engineering Handbook, USDA NRCS.
http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/?cid=stelprdb1043063

For Disconnected Impervious Area (DIA), a more complicated model was needed. DIA generates runoff that "runs on" to neighboring pervious areas. If the impervious area is surrounded by much pervious area, the "run on" water will infiltrate and there will be no effective runoff from the DIA. However, as the ratio of impervious area to pervious area increases, the infiltration capacity of the pervious area will be reached and the "run on" from the impervious area will enter the stormwater/surface water pathway. To determine this effective runoff from the DIA, a long-term SWMM simulation was run with two linked watersheds. The first watershed was impervious. The runoff from this watershed was routed to the second, pervious watershed. The simulation predicted the cumulative runoff from the two linked watersheds. This result was compared to the predicted runoff from a long-term SWMM simulation for the pervious watershed alone. The difference between these two model simulations represented how much runoff was generated by the DIA.

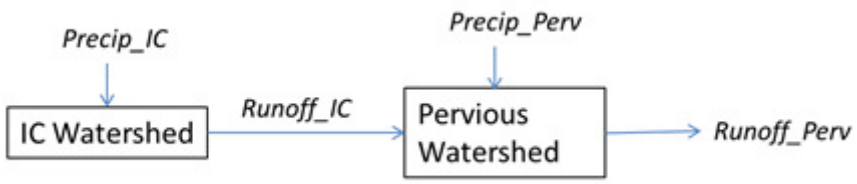
For this analysis, it was first necessary to determine the typical ratio between impervious area and pervious area in the four developed land use types. DES used a dataset created for the residential lawns assessment (Appendix E) to estimate these ratios. This dataset contains detailed land use characteristics for 20 polygons in each developed land use type (80 polygons total). The total acres of impervious and pervious area in these polygons were summed and then compared to determine average ratios (Table 6).

Table 6: Summary of Impervious and Pervious Areas in 80 Detailed Study Polygons in the Piscataqua Region, Totals for Each Developed Land Use Type

Developed Land Use	Impervious (acres)	Pervious (acres)	Ratio Impervious to Pervious	% Impervious
Developed-High	319.6	33.3	10:1	91%
Developed-Medium	199.0	200.3	1:1	50%
Developed-Low	70.7	265.7	1:4	21%
Developed-Open Space	15.0	312.3	1:21	5%

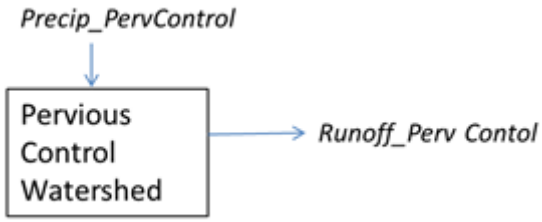
SWMM was used to model the runoff from a disconnected impervious area to neighboring pervious areas through a linked, two watershed model. One watershed was considered impervious (the "IC Watershed" in the Figure 3). Runoff from the IC Watershed was routed to the "Pervious Watershed", where some water would infiltrate and the rest would runoff along with any runoff generated from the Pervious Watershed. The IC Watershed was assumed to have 100% runoff. The Pervious Watershed was assumed to have the infiltration capacity and runoff characteristics of a lawn or managed turf (i.e., CN 39 to CN 80 depending on the soil type). SWMM was run in long-term simulation mode using the NRCS Curve Number method and the 10-year daily rainfall record for Durham, NH. The relative sizes of the IC Watershed and the Pervious Watershed were varied to match the ratios of impervious to pervious area in each of the developed land use types.

Figure 3: Structure of the Linked, Two Watershed Runoff Model



In order to isolate the runoff from just the IC Watershed, SWMM was used to predict the runoff from a pervious control watershed. This control watershed had all the same characteristics as the Pervious Watershed in the linked, two-watershed model except it did not receive runoff from a neighboring impervious area.

Figure 4: Structure of the Pervious Control Watershed Runoff Model



By subtracting the predicted runoff from the pervious control watershed from the linked, two watershed model, net runoff from the disconnected impervious area could be estimated. This runoff was divided by the total rainfall to calculate the percent runoff for DIA for each

combination of developed land use type and soil type. Specifically, using the diagrams shown above, the percent runoff from DIA was calculated as:

$$\%\ \text{Runoff Originating from DIA} = \frac{\text{Runoff_Perv} - \text{Runoff_Perv Control}}{\text{Precip_IC}}$$

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New Hampshire Department of Environmental Services
Great Bay Nitrogen Non-Point Source Study

Appendix I

Response to Comments on the
Draft Great Bay Nitrogen Non-Point Source Study
Dated May 16, 2013

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On May 16, 2013, the New Hampshire Department of Environmental Services (DES) released a draft of the report titled "Great Bay Nitrogen Non-Point Source Study" for public comment and review. Comments were requested by August 16, 2013.

Written comments were received from 13 organizations and individuals:

- Conservation Law Foundation
- Environmental Protection Agency (Mark Voorhees)
- Geosyntec Consultants
- Great Bay National Estuarine Research Reserve
- NH Farm Bureau Federation
- Lamprey River Watershed Association
- Strafford, NH Citizen (James Kerivan)
- Town of Brentwood
- Town of Newmarket
- Town of Stratham
- University of New Hampshire (Michelle Daley)
- Vanasse Hangen Brustlin, Inc. (VHB)
- Wright-Pierce

The major comments provided by these organizations and individuals have been summarized and responded to below. Original comments submitted are also included following the table. The Great Bay Nitrogen Non-Point Source Study was edited as appropriate to incorporate many of the comments expressed.

A. Summary of Comments Received and DES Responses

Organization Submitting Comment(s)	Summary of Comment(s)	Response by DES
Conservation Law Foundation	1. Reexamine the contribution of stormwater verses groundwater. Feels the report underestimates the contribution from stormwater and therefore overestimates the contribution from groundwater.	The approach for determining stormwater runoff was revised. The new approach uses the NRCS Curve Number Method, which significantly increases the contribution of stormwater.
Conservation Law Foundation	2. Reexamine the atmospheric deposition from localized sources. "The draft study does not appear to capture the significant, highly localized impacts of tailpipe emissions from vehicles in the watershed."	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.
Environmental Protection Agency (Mark Voorhees)	EPA suspects that the reported annual nitrogen loadings from urban stormwater runoff, particularly runoff from connected impervious surfaces, is being underestimated in the analysis. EPA suspects that a reason why the estimated loads for stormwater are on the low side is that the local near ground sources, mobile vehicle and organic detritus (i.e., vegetative matter) sources are not fully represented.	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.
Geosyntec Consultants	1. It is their understanding that the model does not factor in local atmospheric and/or transportation derived N. A 5th source needs to be added to the model which would distinguish between locally sourced N by traffic count, road type, or frequency of usage for parking, and distant atmospheric sources from the mid-	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

Organization Submitting Comment(s)	Summary of Comment(s)	Response by DES
	west power plants.	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.
Geosyntec Consultants	2. The GBNPSS study of septic systems is based on a method that was developed for a hydrogeologic environment on Cape Cod that is groundwater dominated, and has very few freshwater streams. Revisions should be made to better model the Great Bay region, whose hydrogeology is far more complex including a combination of stratified drift aquifers, glacial till, bedrock outcrops, and numerous large surface water contributions	The delivery factors used for this study were the defaults for the Nitrogen Loading Model. No local studies are available to confirm these default values. This study is meant for planning purposes. More detailed subwatershed studies may be able to develop local delivery rates through research.
Geosyntec Consultants	3. The model validation based on N monitoring at the bottom of the watershed will not accurately identify the various processes involved. Watershed outlets are appropriate for measuring hydrology, however, this location neglects the ecosystem processes and transformation of N that occurs as the N leaves the impervious surface, travels through a buffer zone, and travels through a surface water.	DES intends to work with UNH to compare the model results to the actual field data collected for the Nitrogen Sources and Pathways Study to further validate the model results.
Great Bay National Estuarine Research Reserve	1. “Nonpoint” needs to be better defined up front	A definition of "non-point source" has been added.
Great Bay National Estuarine Research Reserve	2. Total nitrogen (TN) should be better defined as to its components, rather than just being in the “Acronyms” listing	A definition of "total nitrogen" has been added.
Great Bay National Estuarine Research Reserve	3. “Reactive Nitrogen” is well explained, but not well defined.	A definition of "reactive nitrogen" has been added.
Great Bay National Estuarine Research Reserve	4. It would be helpful to have the “Important Terms” in alphabetical order	The "Important Terms" have been alphabetized.
Great Bay National Estuarine Research Reserve	5. Might consider more of a nitrogen “cascade” diagram. Figure ES-1 on Page ES-3 used in an EPA SAB report on Reactive Nitrogen (http://yosemite.epa.gov/sab/sabproduct.nsf/67057225CC780623852578F10059533D/$File/EPA-SAB-11-013-unsigned.pdf) may provide some ideas that will bring more understanding to the public	A full explanation of the "nitrogen cascade" is beyond the scope of this study. A reference to the SAB study was added to the report so readers can drill down to this information if they choose.

Organization Submitting Comment(s)	Summary of Comment(s)	Response by DES
Great Bay National Estuarine Research Reserve	6. "Natural" nitrogen is the best condition and might be better framed as natural, and not part of the manageable (anthropogenic) load. It can get confusing, but something to think about when targets are set, and what nitrogen is targeted for management.	The discussion of "natural" loads on pages 4 and 20 was modified to incorporate the concept of natural loads and enrichment factors.
Great Bay National Estuarine Research Reserve	7. It would be helpful to have a table or some graphics to better differentiate and quantify individual watershed areas	The tables in Section V contain the land use and input datasets used for the model calculations for all of the subwatersheds.
Great Bay National Estuarine Research Reserve	8. Flipping between the Great Bay watershed and the Piscataqua Region watershed was confusing. A clean break in the report between the two geographies would be helpful rather than flipping back and forth.	As explained on page 10 ("Results Summary"), DES ran the model for all subwatershed in the Piscataqua Region so that this information would be available to all local decision makers. The Piscataqua Region is not the same as the Piscataqua River. The Piscataqua Region covers the watersheds draining to the Great Bay Estuary, Piscataqua River, Hampton-Seabrook Harbor, and the Atlantic Coast. Results for all of the subwatersheds in this region were reported in Section V. The report also "rolled-up" the results for all the subwatersheds draining to the Great Bay Estuary/Piscataqua River to provide information that would be comparable to nitrogen load estimates from the 2013 State of Our Estuaries report (PREP, 2013).
Great Bay National Estuarine Research Reserve	9. On page 12, the "regional dispersion model" should be referenced to a study or publication.	The regional air dispersion model was completed for this study and is discussed in Appendix A. A reference to model platform (CALGRID) was added to the text.
Great Bay National Estuarine Research Reserve	10. Suggest not starting over the numbering with Figure 1 in Section V, which may be confused with earlier Figure 1 (main report).	The figure, table, and page numbers for Section V have been updated to continue on from the main report.
Great Bay National Estuarine Research Reserve	11. It's debatable whether nitrogen fixed from agricultural crops is "natural" nitrogen. Our opinion is that it's not. Cover crops such as alfalfa can provide very substantial loads of nitrogen enrichment from a field after senescing. Therefore, there is potential management of these sources.	The discussion of "natural" sources on page 4 of the report is consistent with this comment.
Great Bay National Estuarine Research Reserve	12. It would be helpful, probably in an appendix, to subdivide HUC 12 watersheds into finer scale watersheds within a town for both land cover and export statistics	The Nitrogen Loading Model is a watershed model. For this study, the model was run on 215 study units, which were often smaller than towns. The averaging assumptions inherent in the watershed model would be violated at smaller scales. More detailed models developed for towns of subwatersheds may be able to provide finer spatial resolution of nitrogen loads.
Great Bay National Estuarine Research Reserve	13. The role of weather on nitrogen delivery should be put into perspective of the presumably "average" loads that the report provides	The input datasets for the model represent average weather conditions. Stormwater runoff was modeled using a 10-year daily weather record (2000-2011). Atmospheric deposition of nitrogen was calibrated to measurements in 2009, a year that experience rainfall and hydrologic conditions that were typical for New England. Some text was added to the report to help the reader

Organization Submitting Comment(s)	Summary of Comment(s)	Response by DES
		to understand that the model results represent average weather conditions and that the actual nitrogen loads may differ depending on the actual weather.
Great Bay National Estuarine Research Reserve	14. Section III.c needs to be very clear on inputs, outputs, and attenuation.	Section III.c has been edited to clarify inputs, outputs, and attenuation.
Great Bay National Estuarine Research Reserve	15. A brief discussion of the biogeochemical differences between surface runoff and ground water and what they mean for nitrogen transport, denitrification and delivery to the estuary would be helpful and begin to school people on nitrogen removal opportunities in the natural landscape as well as adaptive management and constructed BMP placement, recovery potential, and capacity for treatment.	On page 19, the sentence discussing retention of nitrogen was modified to: "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."
Great Bay National Estuarine Research Reserve	16. Groundwater transport has some complications with lag times, denitrification rates, trapping, etc. that are not discussed much	Modeling groundwater lag times and saturation with nitrogen in urban areas is beyond the scope of this model. A linked watershed/groundwater model would be needed to answer this question. More detailed models for towns or subwatersheds may be able to answer this question.
Great Bay National Estuarine Research Reserve	17. Page 17. Note that Hubbard Brook is subject to atmospheric deposition, so 1.2 lbs/acre-yr is probably somewhat higher than a natural load, especially with possible acidification impacts on vegetation uptake and losses of buffering capacity	The discussion of "natural" sources on page 21 of the report is consistent with this comment.
NH Farm Bureau Federation	1. NHFB believe that the input data used in the draft report is lacking – particularly as it relates to agriculture – as it has not been confirmed by local farmers and is too often left to assumption.	Following the release of the draft report, DES met with representatives from the NH Department of Agriculture, Markets, and Food and the NH Farm Bureau. DES also presented the draft report at a NH Farm Bureau meeting on June 12, 2013 and then solicited comments from farmers in the audience. Through these interactions, DES has refined the input variables for agriculture.
NH Farm Bureau Federation	2. The assumed rate of 25 lbs. N per acre for hay is too high	Following advice from local farmers, DES has reduced the percent of hay fields that are fertilized from 50% to 10%, which results in an effective fertilization rate of 5 lb/ac on hay fields.
NH Farm Bureau Federation	3. The rate of 63 lbs. N per acre of corn may be low	No change in the fertilizer rate for corn because it is the best available information. If the rate is indeed low, it may counter balance any overestimates of fertilizer use on other crops.
NH Farm Bureau Federation	4. Growers do not typically apply nitrogen to bearing (crop producing) trees. The 75% application rate for apple trees is a gross overestimate of acres fertilized and NHFB agrees with Extension personnel that fertilizer rates in NH may be lower than the rates found in NY and used in the study	Given that orchards and other crops represent 2% and <1% of the agricultural lands, DES believes that the adjustments made to the hay fertilizer rate and the underestimate of the corn fertilizer rate address this comment. Hay represents (88%) of agricultural lands. Corn represents 4% of agricultural lands.
NH Farm Bureau Federation	5.NHFB believes the N application rate used for "other crops" is a gross overestimate of the nitrogen fertilizer commonly used on the crops in this category	Given that orchards and other crops represent 2% and <1% of the agricultural lands, DES believes that the adjustments made to the hay fertilizer rate and the underestimate of the corn fertilizer rate address this comment. Hay represents

Organization Submitting Comment(s)	Summary of Comment(s)	Response by DES
		(88%) of agricultural lands. Corn represents 4% of agricultural lands.
NH Farm Bureau Federation	6. Cost of nitrogen fertilizer must be considered when using data from years prior to 2008-2009 when there was a big jump in nitrogen fertilizer prices.	Appendix C has been updated with a discussion about increases in fertilizer price and subsequent use on crops.
NH Farm Bureau Federation	7. Wildlife and livestock loads should be treated equally – either both accounted for or each considered a recycling of nitrogen within the system. What are the wildlife numbers in the watershed? Was Fish and Game consulted with? Was any consideration given to looking at migratory waterfowl separately? How is loading caused by aquatic species taken into account?	Wildlife derive all of their food from local sources. They are recycling nitrogen already in the system. For cows and horses, however, the majority of the nitrogen needed to survive is imported to the watershed as feed (see analysis in Figure 3 of Appendix F). Therefore, it is appropriate to consider animal waste from cows and horses to be an imported source of nitrogen. A discussion of wildlife sources has been added to Appendix F to address this comment.
NH Farm Bureau Federation	8. The use of “cows” in the report is confusing.	The term "cattle" has been substituted for "cow" where appropriate.
NH Farm Bureau Federation	9. The potential for the animal waste component of the model to double count some of the nitrogen already tracked as fertilizer and atmospheric deposition is acknowledged in the study but is quickly dismissed. Explanations for ignoring any potential double counting include the assumption that it is “expected” to be small relative to larger sources and that livestock numbers are offset by low “estimates” of total livestock. Too much is left to assumption and rough estimates. Hard, more comprehensive livestock numbers are needed.	There is a complicated cycle of nitrogen in agricultural areas with livestock. Cattle consume nitrogen from a combination of feed, crops, and grass from pasture. Approximately 20% of the nitrogen is converted into milk, meat, and other products (Jordan and Weller, 1996) which enters the local food supply and is accounted for by the human waste components of this model. The remainder of the nitrogen is excreted by the cattle and becomes manure. USDA predicts that 30% of the nitrogen in manure will be lost to the atmosphere through volatilization of ammonia (USDA, 2011, page 11-18). Finally, some of the remaining nitrogen in the manure will be recycled back to the cows through pasture grass or crops and the rest will enter the groundwater. In Appendix F, DES estimates that this recycling amounts to 22% of the nitrogen consumed by cattle (Figure 3). This recycling of nutrients is already accounted for in the Nitrogen Loading Model, which assumes 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.
NH Farm Bureau Federation	10. The model also does not take into account nitrogen being removed from the non-point system in the form of milk, meat, eggs, fruits, vegetables etc.	Appendix F has been updated to explicitly account for milk and meat production by cattle.
NH Farm Bureau Federation	11. The study uses the number of dog licenses issued by towns to come up with the number of dogs in the watershed. We believe this is a significant underestimate.	The model was updated to use the dog estimates for each town from the AVMA estimates, which were higher than the town records of dog licenses.
NH Farm Bureau Federation	12. “For simplicity” the study assumes that 100% of waste from cats is disposed of in landfills. Where is the support for this	Unfortunately, information on cat waste disposal practices was extremely limited. The only objective information available was the recommendation on

Organization Submitting Comment(s)	Summary of Comment(s)	Response by DES
	assumption? Accuracy, not simplicity, should be the primary motivator behind numbers used in the study. NHFB finds this assumption highly suspect.	cat litter products to dispose of used litter in the trash. Moreover, cat waste specifically and pet waste in general is a small piece of the overall nitrogen loads. The expense of primary research to tighten up this component of the model could not be justified.
NH Farm Bureau Federation	13. NHFB are concerned the model inherently overstates the leaching of nitrogen into waterways. Cape Cod's sandy soils leach nutrients more aggressively than our region's clay-based soils.	The delivery factors used for this study were the defaults for the Nitrogen Loading Model. No local studies are available to confirm these default values. This study is meant for planning purposes. More detailed subwatershed studies may be able to develop local delivery rates through research.
NH Farm Bureau Federation	14. an "external review" of the model used was conducted by Dr. Ivan Valiela - the creator of the model. NHFB would like more information on what Dr. Valiela's review consisted of. Should a more independent review of the model be sought?	Dr. Valiela reviewed the model because he was the most qualified person to complete the review. The model is intended for planning purposes only. If any of the more detailed subwaterwshed models are used for regulatory purposes, it would make sense to seek additional outside review of the model.
Lamprey River Watershed Association	1. What this report needs to state is that all watershed residents are contributing to the nitrogen loading and that each of us can take measures to reduce our impact	This comment is related to regulatory and/or management issues. It is beyond the scope of the Great Bay Nitrogen Non-Point Source Study, which is a planning document. The study results are meant to 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.
Lamprey River Watershed Association	2. The summary of Non-Point Source Nitrogen Loads to the Great Bay Estuary gives a detailed breakdown of the non-point sources but never do we see the entire source pie with the subcategories	A pie chart showing all of the nitrogen sources (point and non-point) has been added to the report.
Lamprey River Watershed Association	3. The charts for animal waste and the summary statements appear to be at odds. In the Priority Animals table it is said that dogs are 26% and cats 22% of the Total Nitrogen from Animal Waste. Yet, in the Executive Summary it states that livestock account for 80% of all Animal Waste	In order to determine the priority animals to be included in the model, DES first estimated the total excretion rates for all animals in the four counties in the study area. This approach did not consider disposal practices or losses during delivery to the bay. Once the priority animals were determined, the model accounted for disposal practices and losses during delivery to the bay depending on the location of the animals within the watershed. The difference in the methodologies between the first and second steps explains the difference in these numbers.
Strafford, NH Citizen (James Kerivan)	1. The report neglects an overall discussion of nitrogen's place in our society. Requests the report include: a. Description of N as not evil but most common element in our lives b. Comparable baseline c. History of N in NH d. Fertilizer use through history e. Atmospheric Deposition as it relates to coal burning. Decreases in use should be reflected in discussion f. Terminology - N is not "waste" as described in report, but a	While the information presented in this comment is interesting, it is beyond the scope of this report to estimate loads on nitrogen throughout history. The goal of this report is to estimate the major sources of nitrogen currently. One factor that must be considered when thinking about historic nitrogen loads is the major change to the nitrogen cycle caused by the manufacture of synthetic fertilizer and combustion of fossil fuels. These processes greatly increased the amount of "reactive" nitrogen in the terrestrial and aquatic environment. See SAB (2011) for additional discussion of the cascade of reactive nitrogen through the environment.

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	valuable commodity.	
Strafford, NH Citizen (James Kerivan)	Conducted some calculation on historic N form cows as it relates to total load at present.	The calculation presented shows the total amount of nitrogen deposited to land surface from cattle manure given a set of assumptions. This amount needs to be reduced by up to 85% to estimate the nitrogen that would have been delivered to the estuary. There are losses of nitrogen to the atmosphere, soils, and plants during transport that were not considered in the calculation presented.
Town of Brentwood	Brentwood concludes that something is either wrong with the model or the inputs that went into the model because it does not account for all of the land protection efforts in Brentwood and request that further investigation be done prior to finalizing this study.	DES commends the Town of Brentwood for its land protection efforts. Conserved land and riparian buffers are expected to mitigate some of the nitrogen load from watersheds. Unfortunately, these efforts do not fully remove all of the nitrogen loads. More detailed subwatershed models may be able to better account for the mitigating effects of these conservation practices.
Town of Newmarket	1. To have an effective NPS-nitrogen control strategy, DES will need to define each community's responsibilities within this sub watershed and devise a system to promote intercommunity cooperation. What are DES' plans in this regard?	This comment is related to regulatory and/or management issues. It is beyond the scope of the Great Bay Nitrogen Non-Point Source Study, which is a planning document. The study results are meant to 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.
Town of Newmarket	2. More research is needed regarding the cost of the various NPS nitrogen mitigation strategies so prioritized strategies can be developed, costs understood and affordable implementation plans developed. Does DES plan on completing these additional studies?	After completing this study, DES intends to work with communities to understand the costs of non-point source nitrogen controls and to prioritize action.
Town of Newmarket	3. The NPS nitrogen control strategies are intended to achieve a DES defined nitrogen reduction goal. How will DES track progress toward this goal and how will success be defined?	This comment is related to regulatory and/or management issues. It is beyond the scope of the Great Bay Nitrogen Non-Point Source Study, which is a planning document. The study results are meant to 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.
Town of Stratham	Continued study and validation of the accuracy of the model is needed before it could be relied upon for the creation of any regulatory framework. Stratham supports future efforts to continue to refine the Study into a predictive tool based on sound science and actual field data.	DES intends to work with UNH to compare the model results to the actual field data collected for the Nitrogen Sources and Pathways Study to further validate the model results.
University of New Hampshire (Michelle Daley)	1. Report: Table 2 - Can either the area of each watershed be added as a new column or add a second table that is lb/ac/yr?	The area of each watershed was added to Table 2.
University of New Hampshire (Michelle Daley)	2. Appendix A - various editorial comments	ARD is reviewed and incorporated changes as appropriate on pp. 6-7
University of New	3. Appendix F - Would it be better to pro-rate cow numbers on	Animal waste from livestock is already associated with agricultural lands, not

Organization Submitting Comment(s)	Summary of Comment(s)	Response by DES
Hampshire (Michelle Daley)	Ag area rather than equal distribution in a town?	all areas within a town.
University of New Hampshire (Michelle Daley)	4. Appendix F - Is population density really the best predictor of the number of horses in a town? Did you consider using the area of agricultural land or pasture land instead? Can you list the total # of horses per town in a table?	DES explored many options for predicting the number of horses in a town. Population density was the best predictor variable. Even though the relationship is noisy, the pattern of the relationship is consistent with the expectation that horse ownership will stop increasing with population in suburban municipalities and will eventually decline to zero in large cities. A table with horse totals per town was added to Appendix F.
University of New Hampshire (Michelle Daley)	5. Appendix F - Shouldn't dogs be prorated based on housing density in the watershed?	The number of dogs per town was estimated from the population density of the town using equations from the American Veterinary Medical Association. When dividing up the total number of dogs in a town between different subwatersheds, DES elected to pro-rate the number of dogs based on area for the following reason. The population density data within a town is available at the census block level. In many towns, the size of the census blocks were as big or bigger than the watershed areas. Therefore, using the census block data was considered speculative and not necessary given the scale of the model.
University of New Hampshire (Michelle Daley)	6. Appendix H - Clarification to a citation from one of UNH's reports.	The percent of nitrogen delivered from a watershed attributed to Daley et al. (2010) was updated from 16% to 19% to reflect total nitrogen, not dissolved nitrogen.
VHB	1. Higher resolution land use data (1-meter vs. 30-meter) is essential to developing reasonably accurate estimates of the amount of land use areas, particularly in smaller watersheds.	DES used the best available land use dataset covering the entire study area. More detailed land use datasets can be used for subwatershed studies.
VHB	2. VHB found considerable inconsistencies and errors in the agricultural crop map data layers developed by the National Agricultural Statistical Service and that the use of high resolution aerial photo and ground-truthing was necessary to get more accurate estimates of the areas and locations of agricultural crops	DES used the best available agricultural dataset covering the entire study area. More detailed land use datasets can be used for subwatershed studies.
VHB	3. In relation to the stormwater pathway - available soil mapping could be used to identify various soil types and Hydrologic Group soil classifications and adjust the stormwater partitioning coefficient using a sliding scale to account for differing soil infiltration capacities within the various land uses of agricultural, lawn, managed turf and disconnected impervious area. Similarly a sliding scale using % impervious area could be use to IA land use types.	The approach for determining stormwater runoff was revised. The new approach uses the NRCS Curve Number Method, which significantly increases the contribution of stormwater.
VHB	4. VHB feels that the groundwater delivery rate used in the NLM deserves additional evaluation and possibly refinement, particularly since the model authors suggest that the default model used for Waquoit Bay is only appropriate for use in	The delivery factors used for this study were the defaults for the Nitrogen Loading Model. No local studies are available to confirm these default values. This study is meant for planning purposes. More detailed subwatershed studies may be able to develop local delivery rates through research.

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	watersheds with highly permeable soils.	
VHB	5. VHB feels that only buffering estuarine waters and 5th order streams may be underestimating the load from septic systems in close proximity to smaller streams and rivers as well as freshwater lakes and ponds.	DES followed the default approach from the NLM. The interpretation was that the 200 m buffer was relevant to "the coast". Therefore, rather than buffering all streams, DES used the larger rivers and the bay shoreline.
VHB	6. The model utilizes the same nitrogen load rate for the various types of impervious cover despite evidence expressed in the literature that suggests nitrogen accumulation and resulting loads vary for different types of impervious surfaces depending on the intensity of use/activity	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.
VHB	7. The model accounts for atmospheric deposition and loading from pet wastes as the only source contributions to impervious cover. The model does not include a chemical fertilizer component that may result from “run-on” or overspray during fertilizer applications, especially from residential lawns. Therefore, the model may be underestimating the loads attributed to impervious cover areas.	The model chosen for this study is not flexible enough to account for nitrogen that runs onto impervious surfaces from other land uses (e.g., fertilizer or organic matter). To account for this effect, the combined runoff from all land uses in urbanized areas should be combined to be reflective of urban runoff. More detailed subwatershed models may be able to resolve this issue.
VHB	8. It appears that Table 2 on page 14 presents the incorrect value for the estimated modeled load for the Oyster River at the head of tide. Figure 4 indicates the modeled load (at head of tide) to approximately 45,000 pounds which is closer to the 1:1 line instead of the 71,945 shown in the table.	Some of the numbers is Table 2 were incorrect. This table has been updated.
Wright-Pierce	1. There are a few potential sources of nitrogen that do not appear to be addressed that may be worth determining. a. Biosolids b. Septage c. Waste Food d. Imported wastes	DES looked into including these sources in the model. For the most part, these sources are either expected to be small or are already accounted for in the model. For example, there are only 3 biosolids sites in the watershed. Most of the nitrogen in human waste is in urine so septage is not expected to be a large source. Waste food is either part of septic system load or deposited in a lined landfill. Imported wastes (e.g., commuters) could not be addressed at the scale of this model.
Wright-Pierce	2. Could a cross check of delivered loads against water column nitrogen concentrations in the Bay be conducted?	Addressing this comment is beyond the scope of the study. The goal of the study is to model loads and make comparisons to measured loads, not water quality.
Wright-Pierce	3. Verify groundwater flux of nitrogen to the bay is insignificant	The NLM accounts for nitrogen loads that pass through groundwater for some

Organization Submitting Comment(s)	Summary of Comment(s)	Response by DES
		or all of the transport to the estuary.
Wright-Pierce	4. To arm the communities with the tools to develop cost-effective and efficient NPS education strategies, it would be desirable for this report or subsequent reports to : a. Target nitrogen reduction goals for each sub watershed b. Confirm how the nitrogen reduction goals will be established c. Discuss how normal annual nitrogen loading variability will impact the target goals d. Include a sensitivity analysis on water quality criteria that are driving the nitrogen reduction goals e. Project the impacts air pollution standards will have on the nitrogen removal requirements to focus the communities on the NPS reduction they have control over f. Include a discussion about the impacts of growth on the nitrogen control requirements g. Include a discussion of the macro level nitrogen attenuation factors used in this report and any limitations as it relates to applying these factors at a micro level to sub watersheds h. Estimate the expected range of nitrogen mitigation costs for the various sources of NPS nitrogen	This comment is related to regulatory and/or management issues. It is beyond the scope of the Great Bay Nitrogen Non-Point Source Study, which is a planning document. The study results are meant to 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.
Wright-Pierce	5. DES ultimately wants this report used by the various watershed communities to develop NPS reduction strategies. The following factors should also be considered to maximize the likelihood of timely progress: a. The allowable nitrogen loads and resulting NPS reduction requirements need to be allocated to each of the sub watershed communities b. Will there be any regulatory mandate to the watershed communities without NPDES permits to reduce NPS nitrogen? c. How will DES encourage inter-municipal cooperation? d. How does DES propose to monitor NPS reduction progress? e. How will success be defined? f. Will DES be considering a watershed-based permitting approach?	This comment is related to regulatory and/or management issues. It is beyond the scope of the Great Bay Nitrogen Non-Point Source Study, which is a planning document. The study results are meant to 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.
Wright-Pierce	6. Wright-Pierce estimates that ~25% reduction might be possible. This may make some of the goals in the 2010 repot unattainable. What will DES require? Will it be possible to	This comment is related to regulatory and/or management issues. It is beyond the scope of the Great Bay Nitrogen Non-Point Source Study, which is a planning document. The study results are meant to be useful for towns or

Organization Submitting Comment(s)	Summary of Comment(s)	Response by DES
	abandon the river eelgrass criterion? Will noncompliance with this criterion impact growth in the watershed? What are the consequences of not being able to achieve the goals? Ideally DES' report would touch on these important issues.	watershed groups for prioritizing nitrogen reduction efforts or as a starting point for more detailed studies of non-point sources.
Wright-Pierce	7. Will DES promote fertilizer control legislation (similar to that proposed by some Cape Cod communities)?	This comment is related to regulatory and/or management issues. It is beyond the scope of the Great Bay Nitrogen Non-Point Source Study, which is a planning document. The study results are meant to 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.

B. Original Comments Submitted to DES

Conservation Law Foundation

clf
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AUG 06 2013
DEPARTMENT OF ENVIRONMENTAL SERVICES

August 5, 2013

Mr. Philip Trowbridge
NHDES Watershed Management Bureau
29 Hazen Drive, P.O. Box 95
Concord, NH 03302-0095

Re: Draft Great Bay Nitrogen Non-Point Source Study

Dear Phil:

Conservation Law Foundation ("CLF") appreciates the opportunity to comment on the N.H. Department of Environmental Services' ("NHDES") draft Great Bay Nitrogen Non-Point Source Study ("draft study"). We also appreciate the significant time and effort you and NHDES have invested in addressing the problem of nitrogen pollution in the Great Bay estuary – a problem of significant concern warranting much needed action.

Because the draft study is not, nor does it purport to be, a TMDL, it is not clear what relationship it will have with respect to future regulatory actions. Nonetheless, we expect the draft study, once finalized, will influence management decisions pertaining to the estuary and the manner in which to reduce nitrogen loads. Accordingly, it is essential that the draft study accurately account for – at least in relative terms – the total nitrogen load contributions of the various sources. As discussed below, we are concerned that the draft study is significantly understating the nitrogen load contribution of stormwater and overstating contributions through groundwater.

The draft study's analysis of atmospheric deposition as a source of nitrogen appears focused on large-scale atmospheric conditions, to the exclusion of highly localized sources of nitrogen through vehicle nitrogen oxides (NOx) emissions. Specifically – and as confirmed by the draft study's reliance on Thompson Farm for purposes of "local" conditions – the draft study does not appear to capture the significant, highly localized impacts of tailpipe emissions from vehicles in the watershed. Automobiles and trucks traveling local highways and roads, idling at signalized intersections, and driving over and idling in local parking lots, are significant contributors of NOx, and in immediate proximity to both the very impervious surfaces which are generating stormwater, and the systems that collect and convey such stormwater to local surface waters. Absent close consideration of motorized vehicles *locally* (*i.e.*, traveling over impervious surfaces in the watershed), the draft study's conclusions about atmospheric deposition greatly understate stormwater as a source of nitrogen pollution.

The draft study relies heavily on a model focused exclusively on groundwater as the pathway for nitrogen pollution. While we understand the draft study amended that model by adding a stormwater/surface water pathway, it is not clear that this amendment fully accounts for conditions in the Great Bay estuary, including the very different geological conditions in the watershed as compared to those in Waquoit Bay and Cape Cod, where groundwater clearly is the major pathway of concern. At

least one study in the Great Bay estuary determined groundwater flow into the estuary to be minimal – on the order of 24.2 cubic feet per second of total groundwater discharge, and with a contribution of only 5 percent of the total non-point source load to the estuary. *See* CICEET Project Bulletin, "Assessing Groundwater Inflow and Loadings to Estuaries," provided herewith.

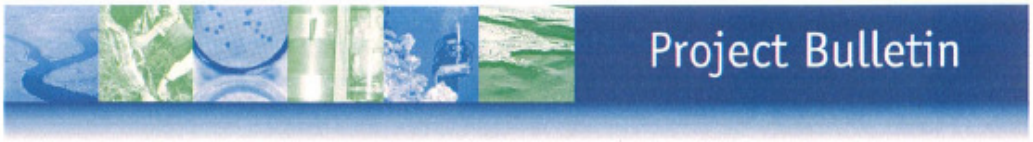
It is essential that NHDES's study, once finalized, neither understate the nitrogen contribution of stormwater, nor overstate the nitrogen contribution of groundwater, including septic systems. Again, it is not clear how this study will interact with regulatory programs, but it would be hugely problematic if, as a management tool, it diverted attention away from significant sources such as stormwater and toward other sources that may not, in light of the watershed's geology, have as great an impact. In light of the foregoing, we urge NHDES to closely assess localized motor vehicle exhaust emissions – particularly given their extremely close proximity to impervious surfaces and stormwater collection/conveyance systems – and ensure that its model is fully premised on local geologic/subsurface conditions.

Thank you again for the opportunity to comment on the draft study.

Very truly yours,

Tom Irwin

Tom Irwin
V.P. and CLF New Hampshire Director

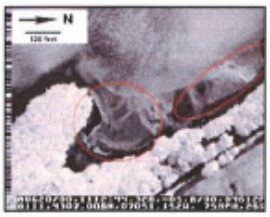


Project Bulletin

CICEET

Assessing Groundwater Inflow and Loadings to Estuaries

Challenge

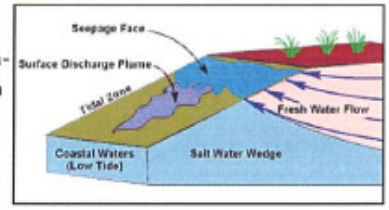


Several recent studies have indicated that groundwater flow into bays and estuaries can be equal in magnitude to river flow. Since groundwater is frequently contaminated by land based human activities, it can potentially represent a significant source of pollution to coastal waters. This project is using innovative thermal (heat sensitive) technologies and GIS-based analyses to identify the location, quantity and quality of groundwater flowing into the Great Bay Estuary in New Hampshire. The results of this project will provide important information on pollution sources in coastal waters.

Science

Project Approach

The conventional approach to detecting and quantifying submarine groundwater discharge (SGD) is based on extensive groundwater mapping. Here, researchers used aerial Thermal Infrared (TIR) surveys to quickly detect discharge zones (see circled areas, top right figure) within the intertidal zone of the Great Bay Estuary. Using GIS, researchers then ascertained the seepage face surface area (see adjacent figure). Together with field estimates of flow rates, this enabled scientists to quantify total discharge and assess the levels of nitrogen loadings from groundwater. This method was also verified by conventional assessments using groundwater mapping to estimate discharge to coastal waters.



Results

- The aerial TIR survey method for assessing SGD was verified by groundwater mapping methods.
- TIR proved to be a fast, effective, affordable alternative to conventional groundwater mapping. (In total, the TIR approach took one year and groundwater mapping took two.) Additionally, it has the capability to identify specific locations of discharge.
- Total groundwater discharge was calculated as 24.2 cubic feet per second; nutrient loading was calculated to be 19.3±21.2 tons of nitrogen per year for the total Great Bay Estuary, which accounts for approximately 5% of the total non-point source load to the estuary.

Application

Seasonal Variation

This project culminated in a snapshot of groundwater discharge quantity and quality. A subsequent CICEET project has been funded to analyze seasonal variation.

Automating the GIS Analysis

The process of using GIS to quantify seepage face surface area is very intricate. A related project will develop a software tool that will simplify this process and allow a wider range of users to effectively estimate contaminant loading from groundwater.

Nutrient Management

This project focuses on intertidal groundwater discharge zones; a separate CICEET project concentrates on detecting subtidal discharge sites. These projects are potential tools for resource managers striving to comply with Total Maximum Daily Load (TMDL) regulations, which set limits on the amount of pollutants a waterbody can receive and still meet water quality standards.

Project Essentials

Title: Inflow and Loadings from Groundwater to the Great Bay Estuary, New Hanpshire

Project Coordinator: Tom Ballestero — University of New Hampshire, (603) 862-1405, tom.ballestero@unh.edu

Start - End Date: 09/01/1998 - 09/01/2001

NERR Reserve(s): Great Bay, NH

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Environmental Protection Agency
(Mark Voorhees)

Text below was copied form the original e-mail from Mark Voorhees, US EPA.

Dear Philip:

Please accept the following as comments on the Draft Great Bay Nitrogen Non-Point Source Study. We would like to compliment you and the other co-authors at NHDES on the thoroughness and high quality of the report.

Our review was focused on the stormwater aspect of the nitrogen loading estimates in the draft study. Through our work in the NPDES stormwater permitting program and through developing performance estimates for various stormwater control technologies, we have been continually assessing stormwater nutrient quality. One of our goals is to estimate typical annual loading rates of nutrients in stormwater runoff for various land use categories based on measured quality and long-term continuous simulation hydrologic modeling.

The primary comment relates to the characterization of nitrogen loading for stormwater in the draft report. For reasons provided below we suspect that the reported annual nitrogen loadings from urban stormwater runoff, particularly runoff from connected impervious surfaces, is being underestimated in the analysis. Consequently, if this source category is being under represented then it is likely that other sources are being overrepresented in the analysis since the NLM was calibrated to measured data collected at the head of tides for several tributaries to Great Bay. As we understand, the stormwater nitrogen loading estimates in the draft report were derived by: 1) relying on atmospheric N deposition rate data at the Thompson Farm station located within the study area; 2)applying a regional air quality model; 3) estimating connected and disconnected impervious areas; 4) estimating transport pathways; and 5) then applying delivery factors depending on transport pathways. We suspect that a reason why the estimated loads for stormwater are on the low side is that the local near ground sources, mobile vehicle and organic detritus (i.e., vegetative matter) sources are not fully represented.

Following for your consideration are summaries of stormwater quality (event mean concentrations (EMCs) for total nitrogen (TN)) and the results of continuous simulation hydrologic modeling using regionally representative precipitation data. Based on our analysis of this information and other reported information concerning loading rates, we suspect that the actual nitrogen loading from urban stormwater is higher than reported in the Great Bay draft report. First, TN EMC data collected in the region and from a much larger database ,the National Stormwater Quality Database (NSQD), are provided in the following two tables. Only data from the NSQD collected in rainfall regions 1 and 2 are included since we have determined that the precipitation patterns are generally similar as is the TN quality of stormwater runoff from developed lands. Our reason for providing these data summaries is to show that median TN EMCs for developed land uses (excluding highways) are in the range of 1.4 to 2.6 mg/L (note that the median TN EMC for the Tedeschi parking lot in Durham is 1.9 mg/L). We will discuss the highway data below as it appears to illustrate the importance of local mobile sources of N. Recently, Robert Pitt has reported that averages are more appropriate for characterizing mass loadings from land uses comprised of impervious and pervious cover. Since most of our analysis has focused on loading from impervious cover from which the build-up wash-off processes

determine quality we have been putting more weight on the median values as a better representation of central tendency. Please keep in mind that for large storm events the EMCs for nutrients from impervious area only are typically lower than for small storms because of the limited supply of the constituent of concern. Either way and at this point in the process we are using this information to get a general sense of the magnitude of annual loading rates for TN from impervious surfaces.

Continuous simulation hydrologic modeling results provide estimates of annual runoff yields for impervious and pervious surfaces which can then be used to estimate annual nitrogen load export rates (NLERs) based on varying nitrogen quality. Two models have been employed, SWMM and P8. The primary difference in these models are related to how runoff is simulated from pervious areas. SWMM applies a dynamic infiltration model while P8 uses the Curve Number method, an empirical model. Below are the continuous simulation model results for SWMM and P8 showing annual runoff yields and annual NLERs for varying annual mean concentrations. For example, assuming the median TN EMC is representative of the annual mean TN concentration and it is between 1.5 and 2.0 mg/L, then the estimated annual NLER is between 14.7 and 19.6 kg/ha/yr (based on SWMM results).

These rates are notably higher than the resulting rates derived from results presented in the draft report. For example, if we applied this range, 14.7 to 19.6 kg/ha/yr, to the reported area of connected impervious area, 8940 ha (22,085 acres) results in estimated annual loads of 131,440 kg/yr to 175,250 kg/yr. Applying the delivery factor of 0.87 for surface waters results in a range of 114,350 to 152,500 kg/yr delivered to Great Bay. Compared to the reported value on pg 21 of 49,220 kg/yr (108,410 lbs/yr) for connected impervious area, this range is 2 to 3 times higher than the reported results. If the above NLERs are representative of impervious area in the Great Bay watershed then the N load from disconnected impervious area will also increase proportionally from the reported value of 12,255 kg/yr (27,000 lbs/yr) to a range of 28,500 kg/yr to 37,850 kg/yr. Assuming for the sake of understanding the overall magnitude of the numbers that the lower NLER of 14.7 kg/ha/yr is representative then the net increase for the total impervious area is on the order of 81,000 kg/yr.

A possible reason for the potential underestimation of N loading from urban stormwater sources in the draft report may be due the deposition data from the Thomson Farm station. It is possible that data from this station may not adequately reflect local near ground sources that are known to contribute significantly to stormwater nitrogen loading. Please consider the results presented below of TN EMC data collected from runoff from several Massachusetts highways by the USGS (report attached) with traffic counts varying from very low to high. These data illustrate a strong relationship between traffic volume and TN EMC. Please note that the median TN EMCs associated with the higher traffic counts of around 1.5 mg/L is of similar magnitude of median TN EMCs for developed land use categories presented in the TN EMC summary tables below.

Finally, as another point of reference the Chesapeake Bay program through its watershed model has estimated impervious areas have a NLER of 15.8 kg/ha/yr (14.1 lbs/ac/yr). This is generally from a Region that has about 15% less annual precipitation but also were the TN EMC appear to be slightly higher.

We offer this information for your consideration as DES finalizes the analysis. We understand that many are looking to this report for insights on future tracking and accounting of N sources in the watershed. Therefore, we believe it is very important that the magnitude of TN loading from stormwater sources reflects currently available information.

Thank you for your time and consideration of our comments. Please do not hesitate to contact me if you have questions or would like copies of our datasets. Best wishes on completing this important project.

Sincerely

Mark Voorhees

Summary of Stormwater Data for Total Nitrogen Event Mean Concentrations (EMCs) Collected in MA and Vermont			Total Nitrogen (nitrate + nitrite + TKN), mg/L							
Location (source)	land use	Station	Count (n)	Arithmetic mean	median	geomean	Standard deviation	25th%,	75th%	range
Lower Charles River Watershed, MA (USGS, Breault et. al., 2002)	Single-family residential	USGS -01104630	8	3.16	2.60	3.16	2.14	1.50	4.15	1.10 - 6.75
Lower Charles River Watershed, MA (USGS, Breault et. al., 2002)	Multifamily residential	USGS-01104673	8	2.19	2.15	2.19	1.05	1.60	2.60	0.70 - 4.40
Lower Charles River Watershed, MA (USGS, Breault et. al., 2002)	Commercial (01104677)	USGS-01104677	8	2.28	2.15	2.28	1.35	1.20	3.40	0.70 - 4.20
MA Highways - Low traffic volume (USGS, Smith & Granato, 2009)	Highway	Rte 119-P 424209071545201	17	0.81	0.59	0.59	0.69	0.40	0.86	0.09 - 2.52
MA Highways - Medium traffic volume (USGS, Smith & Granato, 2009)	Highway	Route 2 -P 423027071291301	18	1.42	1.09	1.17	1.01	0.73	1.57	0.32 - 4.42
MA Highways High traffic volume (USGS, Smith & Granato, 2009)	Highway	Interstate 95 -P 422620071153301	18	1.96	1.53	1.69	1.31	1.21	2.25	0.80 - 6.12
Englsby Watershed, Burlington, VT, (UVM, J. Nipper, 2012)	Residential	Inlet to Wet Pond	47	1.54	1.36	1.37	0.83	0.99	1.82	0.53 - 5.20
Tedeschi Parking Lot, Durham, NH (UNH 2011-12)	Commercial	Inlet to SW Control	8	2.49	1.85	1.94	2.18	1.08	2.68	0.06 - 0.49

National Stormwater Quality Database, R. Pitt, 2008 - Summary of Stormwater Event Mean Concentration (EMCs) Data for Rainfall Regions 1 &2 (Mid-Atlantic and Northeast)							
	Total Nitrogen EMC (nitrate + nitrite + TKN), mg/L						
Category	Count (n)	mean	median	geomean	standard deviation	25th%,	75th%
All land uses in database	1308	2.49	1.90	1.98	2.25	1.32	3.00
commercial	309	2.62	2.04	2.03	2.06	1.30	3.30
industrial	204	2.28	1.69	1.73	2.49	1.13	2.52
residential	686	2.41	1.94	1.96	2.07	1.36	2.93
open	32	2.05	1.61	1.73	1.28	1.24	2.35

Calculated annual nitrogen load export rates (NLE) based on various hydrologic conditions and stormwater total nitrogen (TN) concentrations

Watershed surface	Description	Annual Runoff Yield, MG/ha/yr	Flow weighted SW TN conc., mg/L --->	0.25	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	8.00	10.00
Impervious surface	impervious surface	2.59	Annual Nitrogen Load Export (NLE), kg/ha-yr	2.45	4.90	9.79	14.69	19.58	24.48	29.37	39.16	48.95	78.33	97.91
Pervious area HSG A	well drained soils	0.07		0.06	0.13	0.25	0.38	0.51	0.64	0.76	1.02	1.27	2.04	2.55
Pervious area HSG B	moderately drained soils	0.21		0.20	0.40	0.79	1.19	1.59	1.98	2.38	3.17	3.97	6.35	7.94
Pervious area HSG C	limited permeability	0.41		0.39	0.77	1.54	2.31	3.08	3.85	4.62	6.16	7.70	12.32	15.40
Pervious area HSG D	poorly drained soils	0.69		0.65	1.30	2.60	3.90	5.20	6.49	7.79	10.39	12.99	20.78	25.98

Annual Runoff yield by SWMM for hourly rainfall - Boston MA (1998-2002), Flow-weighted SW TN conc. = total annual N load divided by total annual runoff volume.

HSG= Hydrologic Soil Group, MG= million gallons, ha = hectare (1 ha= 2.47 acres)

P8 model simulations - Boston, MA hourly precipitation, 1998-2002		Runoff yield, MG/ha/yr	Annual Nitrogen Load Export Rate kg/ha/yr							
			Average Annual Flow Weighted Total Nitrogen Concentration, mg/l							
			0.5	1.0	1.5	2.0	3.0	5.0	8.0	10.0
curve number	30	0.00	0.01	0.02	0.03	0.04	0.06	0.09	0.15	0.19
	40	0.02	0.03	0.06	0.09	0.12	0.18	0.30	0.49	0.61
	50	0.05	0.09	0.17	0.26	0.34	0.52	0.86	1.37	1.72
	60	0.10	0.20	0.39	0.59	0.78	1.18	1.96	3.13	3.92
	70	0.21	0.39	0.78	1.16	1.55	2.33	3.88	6.21	7.76
	80	0.39	0.73	1.46	2.20	2.93	4.39	7.32	11.71	14.64
	90	0.79	1.49	2.97	4.46	5.95	8.92	14.86	23.78	29.73
	98	1.85	3.50	6.99	10.49	13.99	20.98	34.97	55.95	69.94
100% by P8		2.60	4.92	9.84	14.76	19.68	29.52	49.20	78.72	98.40

MG = million gallons, Average annual rainfall = 43.5 inches

Runoff Curve Numbers for Curve Number Method

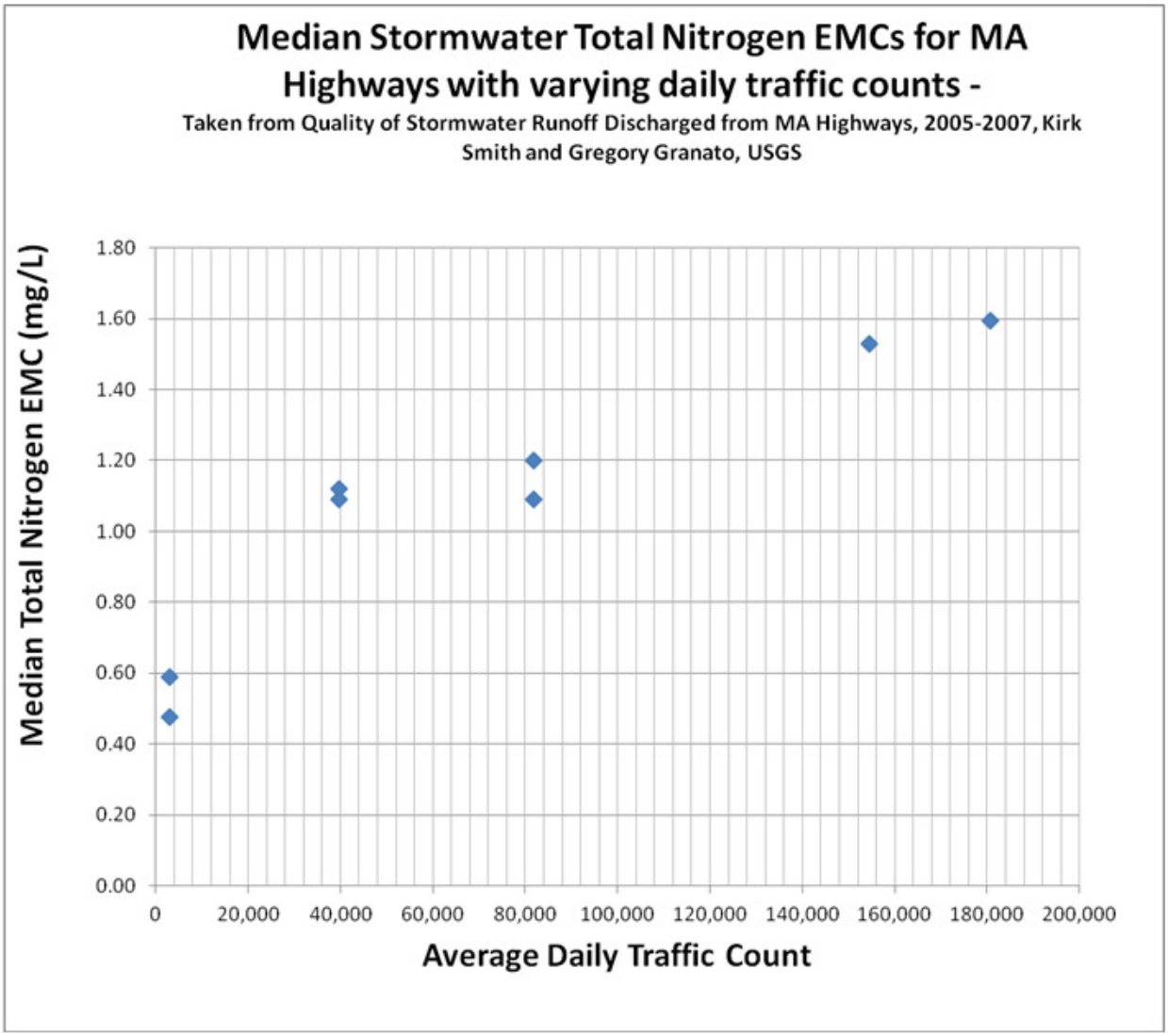
The specified SCS Curve Number (CN) reflects an area-weighted-average of the pervious areas, which generally reflect land cover and soil hydrologic group.

This is a change from previous P8 versions (<=3.2), which assumed that the specified CN value also reflected indirectly connected impervious areas (see below). When input files from previous versions are

The following table lists typical CN values as a function of land use, hydrologic condition, and soil group:

			Curve Number			
Land Use	Hydrologic Condition	Hydrologic Soil Group -->	A	B	C	D
Grassed Areas	Good (>75% Cover)		39	61	74	80
	Fair		49	69	79	84
	Poor (<50% Cover)		68	79	86	89
Meadow / Idle	Good		30	58	71	78
Woods	Good (thick forest)		25	55	70	77
	Fair		36	60	73	79
	Poor (thin, no mulch)		45	66	77	83
Construction Site	Newly Graded		81	89	93	95
Impervious	Not Connected (Draining to Pervious Areas)		98	98	98	98

Highway and designation	Annual ADT	median
Route 119 -P	3,000	0.59
Route 119 -S	3,000	0.48
Route 2 -S	39,693	1.12
Route 2 -P	39,700	1.09
Interstate 495 -P	81,900	1.20
Interstate 495 -S	81,900	1.09
Interstate 95 -P	154,500	1.53
Interstate 95 -S	180,600	1.60


Median Stormwater Total Nitrogen EMCs for MA Highways with varying daily traffic counts -
Taken from Quality of Stormwater Runoff Discharged from MA Highways, 2005-2007, Kirk Smith and Gregory Granato, USGS
Median Total Nitrogen EMC (mg/L)
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
180,000
200,000
Average Daily Traffic Count

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August 16, 2013

RE: Comments for the Great Bay Non-Point Source Study

Submitted by Robert Roseen, PE, PHD, D.WRE

NHDES is to be commended for the preparation of this important study. Understanding the relative value and sources of nitrogen (N) should be a central element of watershed management in the Great Bay.

The Great Bay Non-Point Source Study (GBNPSS) is a very thorough study and includes some very important advances, in particular for turf management. However, substantial concerns exist for the GBNPSS with respect to the following items:

- Simplified watershed N loading model and stormwater loads calculation based on atmospheric deposition
- Septic system loads over simplification
- Model validation and N monitoring

These concerns originate in part from the usage of the N-Load Model which was developed for evaluation of nitrogen in a hydrogeologic environment that is drastically different than the Great Bay Watershed, and one in which it is understood that groundwater nitrogen loads are the dominant contributors. The case for the Great Bay is at the least substantially different hydrogeologically, and it would follow that the dominant N load pathways would be different as well.

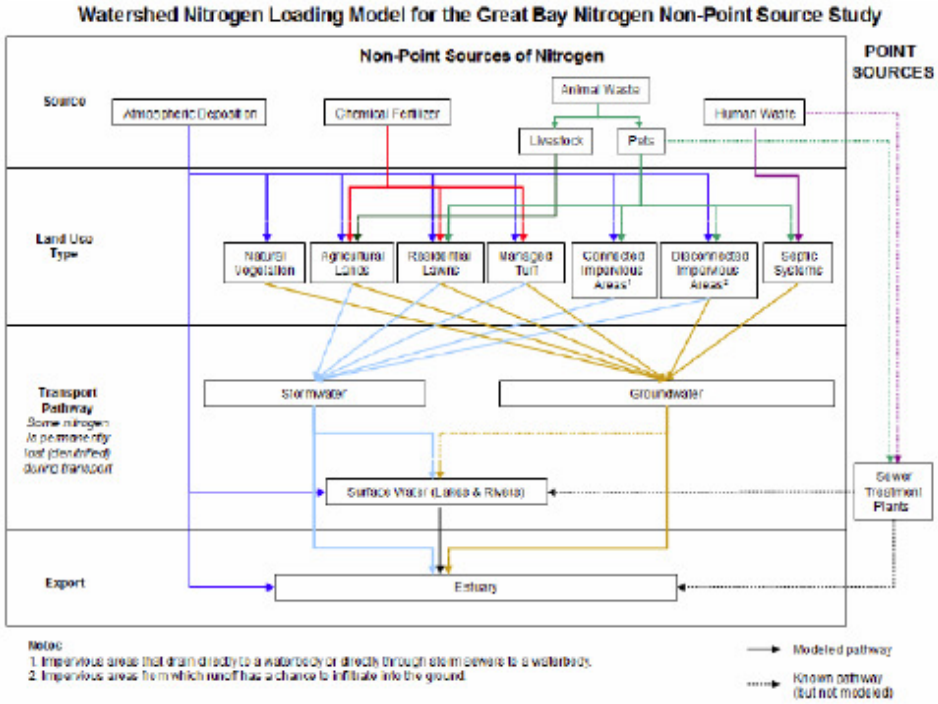
There is some important literature and precedent on the methods for estimating both stormwater derived loads and septic system loads that should be used.

The significance of these issues is substantial in that it shifts a focus away from advances in stormwater management and building momentum amongst communities to address these issues.

Simplified watershed N loading model and stormwater loads calculation based on atmospheric deposition

The simplified watershed N loading model presented by McDowell and Daley and used in the GBNPSS is missing a very central component which is locally derived nitrogen resulting from transportation. The 4 sources listed are feed, animal waste, atmospheric, and fertilizer and as depicted in Figure 3 below.

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



It is my understanding that the NLM sources model does not factor in local atmospheric and/or transportation derived N. Commonly atmospheric monitoring stations are in locations that are not heavily influenced by transportation derived sources. As an example, a vehicle run in a box, could eliminate all of the 4 sources (animal waste, human waste, chemical fertilizer, and distant atmospheric deposition), however, substantial nitrogen loads would be generated. This is exemplified by monitoring of 2 impervious surfaces that could be near one another however with drastically different N loads based on land use type and in particular based on traffic count[1]. This is well documented[2]. This variation would not be accounted for with the GBNPSS. A 5th source needs to be added to the model which would distinguish between locally sourced N by traffic count, road type, or frequency of usage for parking, and distant atmospheric sources from the mid-west power plants.

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[1] Kayhanian, M., Singh, A., Suverkropp, C., and Borroum, S. (2003). "Impact of Annual Average Daily Traffic on Highway Runoff Pollutant Concentrations." Environmental Engineering, 129(11), 975-990.
[2] NRC. (2008). Urban Stormwater Management in the United States, National Research Council, The National Academies Press, Committee on Reducing Stormwater Discharge Contributions to Water Pollution.
USEPA. (1983). "Results of the Nationwide Urban Runoff Program: Volume 1 - Final Report." Water Planning Division, U.S. Environmental Protection Agency, Washington, DC.

The standard of practice for the estimation of stormwater loads are commonly based on data from monitoring of stormwater runoff. Typically these data are either using locally derived monitoring data, or nationally available data based on extensive datasets[3]. There is a very deep literature on runoff quality. To my knowledge, there is not a similar precedent for calculation stormwater loads based on atmospheric deposition. The national urban runoff program[4], the national stormwater quality database, and locally in Region 1, the use of stormwater runoff monitoring data is all used to generate estimates of pollutant loading from stormwater runoff. The usage of atmospheric deposition to determine stormwater loads neglects the locally derived N sources. Typically atmospheric deposition monitoring is located in areas uninfluenced by local traffic.

Common modeling approaches to estimating watershed loads include the usage of HSPF, SWMM, WinSLAMM, SUSTAIN and others. There is a deep precedent for all of these models for development of stormwater loads, none of which are based on atmospheric depositon.

The standard of practice for the estimation of stormwater loads are commonly based on data from monitoring of stormwater runoff. Typically these data are either using locally derived monitoring data, or nationally available data based on extensive datasets. There is a very deep literature on runoff quality. To my knowledge, there is not a similar precedent for calculation stormwater loads based on atmospheric deposition. The national urban runoff program[5], the national stormwater quality database, and locally in Region 1, the use of stormwater runoff monitoring data is all used to generate estimates of pollutant loading from stormwater runoff. The usage of atmospheric deposition to determine stormwater loads neglects the locally derived N sources. Typically atmospheric deposition monitoring is located in areas uninfluenced by local traffic.

Septic system loads over simplification

The GBNPSS study of septic systems is based on a method that was developed for a hydrogeologic environment on Cape Cod that is groundwater dominated, and has very few freshwater streams. The degree to which the system is groundwater dominated is evident by the lack of large freshwater streams. For this reason, assumptions made with respect to the dominance of septic system derived groundwater N are less problematic. However in the Great Bay region, the hydrogeology is far more complex including a combination of stratified drift aquifers, glacial till, bedrock outcrops, and numerous large surface water contributions. There is a large body of literature examining groundwater derived N loading into coastal embayments. Much of this literature is based in Cape Cod, the Chesapeake Bay, and some exists locally in

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[3] Pitt, R. E., Maestre, A., and Morquecho, R. (2004). "The National Stormwater Quality Database (NSQD, version 1.1)."
[4] USEPA. (1983). "Results of the Nationwide Urban Runoff Program: Volume 1 - Final Report." Water Planning Division, U.S. Environmental Protection Agency, Washington, DC.
[5] USEPA. (1983). "Results of the Nationwide Urban Runoff Program: Volume 1 - Final Report." Water Planning Division, U.S. Environmental Protection Agency, Washington, DC.

the Great Bay. Local studies at UNH[6] identified two important elements that should be considered in this study. The 1) being the estimated nitrogen load by physical measurement and identification of groundwater discharge zones, and 2) the age-dating of groundwater discharge zones.

The estimation of groundwater derived nitrogen loads to the Great Bay was relatively small accounting for approximately 5%. The method was corroborated by several means, both the usage of thermal imagery to identify groundwater discharge locations, and the development of a piezometric groundwater map and model for the area. Total groundwater discharge to the estuary was calculated as 24.2 cubic feet per second (cfs) with an average of 0.81± 0.89 mg dissolved inorganic nitrogen (DIN)/L, with a maximum value of 2.7 mg DIN/L (n=20). Nutrient concentrations, averaging 0.83± 1.34 mg DIN/L, with a maximum value of 10.2 mg DIN/L, were observed in upgradient bedrock groundwater analyzed from 192 wells. Nutrient loading was calculated to be 19 tons of N per year for the total Great Bay Estuary, covering nearly 144 miles of shoreline. The groundwater derived nutrient loading accounts for approximately 5% of the total non-point source load to the estuary.

Estuarine water intrusion in groundwater discharge samples confounded the analyses for major ion chemistry and boron isotopes. CFC-derived and modeled groundwater ages in the study area averaged 23.2 years[7]. CFC analysis enabled correlation of nitrate concentrations at the SGD sites with the historic land use coverage for the years 1974 for most of the sites. Two types of correlation were made: 1) between the agricultural and residential land use for all observed nitrate concentrations in the recharge areas, and 2) correlation with the nitrate concentrations between developed and undeveloped land uses. Based on these models it was concluded that overburden groundwater comprises 75% to 95% of the groundwater discharging at the SGD sites.

The GBNPSS study makes an overly simplistic assumption that does not suit this complex hydrogeologic environment. The study makes the assumption that all septic system derived N travels towards the bay, and that sources within 200' are attenuated by 40%, and sources beyond 200' are attenuated by 80%. The geochemistry of submarine groundwater discharge is complex and there are studies which indicate that N transformation may occur at the discharge interface at the point which dissolved organic carbon is present.

The study does not consider travel time from the point of origin to the point of discharge. The age-dating of groundwater suggests that the current N-load is based on land use from over 20 years ago.

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[6] Ballestero, T. P., Roseen, R., and Mack, T. (2002). "Inflow Loadings from Groundwater to the Great Bay Estuary." Cooperative Institute for Coastal and Estuarine Environmental Technology, and the Department of Civil Engineering, Environmental Research Group, University of New Hampshire, Durham, NH 03824.

[7] Ballestero, T. P., Roseen, R., and Bacca-Cortez, G. (2004). "Land Use Influence on the Characteristics of Groundwater Inputs to the Great Bay Estuary, New Hampshire." Cooperative Institute for Coastal and Estuarine Environmental Technology, and the Department of Civil Engineering, Environmental Research Group, University of New Hampshire, Durham, NH 03824.

The impact of these assumptions may be a gross over-estimation of septic system derived N load.

Model validation and N monitoring

Lastly, the model validation based on N monitoring at the bottom of the watershed will not accurately identify the various processes involved. Watershed outlets are appropriate for measuring hydrology, however, this location neglects the ecosystem processes and transformation of N that occurs as the N leaves the impervious surface, travels through a buffer zone, and travels through a surface water. This is exemplified in the literature by looking at the hihg N loads at the end of pipe, and the lower N loads in a eutrophic waterbody where the N has been consumed.

I greatly respect the work and effort of the GBNPSS. I would be happy to discuss at greater length these important items. I hope you will consider these items of concern.

Respectfully submitted,

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Region 3 – Marine Fisheries Division
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14 August 2013

Mr. Philip Trowbridge
NH DES Watershed Management Bureau
29 Hazen Drive
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Concord, NH 03302-0095

Dear Mr. Trowbridge,

Thank you for the opportunity to comment on the draft report, "Great Bay Nitrogen Non-Point Source Study", Report R-WD-13-10 dated May 16, 2013. The Great Bay National Estuarine Research Reserve (GBNERR) has a vested interest in the subject of nitrogen enrichment and its impacts on the Great Bay ecosystem. We appreciate your efforts to improve our understanding and ability to manage watershed sources of nutrients to the estuary.

The analysis and report details many advances over prior efforts in the complex watershed dynamics and contributions of nitrogen. In particular:

- Use of the Nitrogen Loading Model (NLM) is an excellent analytical framework that parallels current understanding of nitrogen sources and transport efficiencies through the landscape; modifications to the NLM to reflect characteristics of the Great Bay watershed have provided realistic estimates of nitrogen inputs and delivery to Great Bay that will allow better targeting of source management. These estimates, and potential use of the NLM, should improve local ability to integrate point-nonpoint management efforts and facilitate efforts to implement adaptive management techniques that local communities seek.
- Model validation appears to demonstrate reliability of those estimates and the stated levels of error are reasonable and expected in the watershed and serve to minimize uncertainty of both estimated loads, and targeting of actions. Model outputs represent good consistency with field data and prior estimated loads, with rational explanations of changes that have occurred over time as well as new ways to categorize loads more effectively.
- Data and literature reviews were diligently performed and applied, adding confidence to the estimates with perspective to other nitrogen budget projects with more sophisticated (and

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costly) monitoring and modeling efforts.

- Appropriate categorization of source loads into atmospheric deposition, fertilizers, animal wastes, and human waste – both septic and sewage treatment plants – provide a comprehensive yet uncomplicated source assessment of use to research and management efforts. Use of connected and disconnected impervious cover helps explain some of the landscape processes and nitrogen load delivery variability associated with the "mosaic" of land cover and development.
- The appendices are well-formulated and provide topical analyses and technical support of loading estimate methodologies without cluttering the main body of the report.
- Figures and tables were used to good effect, especially for broad community and public understanding of where nitrogen is coming from, and how local landscapes and human presence contribute to those loads of nitrogen.

With that strong endorsement of the science behind the estimates, we have several comments and suggestions that we hope will improve clarity and presentation of the report, and make it more useful to local communities and also improve public understanding of nitrogen sources and management opportunities.

- "Nonpoint" needs to be better defined. To regulators, nonpoint does not include permitting stormwater sources, and nitrogen transported via the groundwater is generally considered NPS rather than SW, even when in an MS4 area. The public often treats NPS and SW as the same thing. It's probably best to dispense with this confusion up front, with the bottom line (or so it seems) is that ***all*** NPS and SW, whether delivered on the surface or via the ground water, fall under your definition of NPS.
- Total nitrogen (TN) should be better defined as to its components. Does it include all species of dissolved and particulate fractions, for example? TN, conventionally, is the sum of both dissolved and particulate fractions of ammonia, ammonium, nitrite, nitrate, and organic nitrogen. A diagram may help to this end, or at least a detailed definition in the "Important Terms" section rather than just the "Acronyms" listing.
- "Reactive Nitrogen" is well explained, but not well defined. Strictly, "Reactive Nitrogen" is equivalent to TN, but needs to be more clearly conveyed in the discussion as that is probably the most important point for readers to understand.
- It would be helpful to have the "Important Terms" in alphabetical order.
- It's always a challenge to diagram the nitrogen cycle, and flow of new nitrogen. While Figures 2 and 3 represent complete categorization of nitrogen sources and transport, you might consider more of a nitrogen "cascade" diagram. Figure ES-1 on Page ES-3 used in an EPA SAB report on Reactive Nitrogen (http://yosemite.epa.gov/sab/sabproduct.nsf/67057225CC780623852578F10059533D/$File/EPA-SAB-11-013-unsigned.pdf) may provide some ideas that will bring more understanding to the public, especially nitrogen loss pathways, though I'm not sure if it's less complicated. Your figure 3 is a good start and relevant to your analysis and geography.
- The concept of "natural sources" hasn't received much play in various studies of Great Bay, but is important and we're pleased to see it addressed in your report. In particular, the enrichment factors related to today's loadings is an effective way to provide perspective of the natural load and how much change has occurred with human habitation. It also sets a goal of the "ideal", i.e., the natural load, which is probably around 1 kg TN/ha-yr or 1 lb TN/acre-yr as your research shows. "Natural" nitrogen is the best condition and might be better framed as natural, and not part of the manageable (anthropogenic) load. It can get confusing, but something to think about when targets are set, and what nitrogen is targeted for management.

- It would be helpful to better differentiate and quantify individual watershed areas. A table with basic statistics that describe area for each watershed segment used in the calculations, as well as areas of land cover categories and impervious cover used in the calculations would be very useful to those who would like to dig a little deeper, understand more about the character of their town's or watershed's landscapes, or simply check the arithmetic of yields per acre used in the report. The table could be in an appendix, and would complement many of the figures that have gross nitrogen loads and export rates.
- Flipping between the Great Bay watershed and the Piscataqua Region watershed was confusing. A clean break in the report between the two geographies would be helpful rather than flipping back and forth. Especially, in Section III.a., the validation, the data seem only to be presented for the entire Piscataqua Region. Another reason for more local land cover statistics and export rates so readers can better understand how the non-Great Bay watershed areas of the Piscataqua Region influence the nitrogen budget statistics of the region.
- On page 12, the "regional dispersion model" should be referenced to a study or publication.
- Figure 4 is very nice and convincing!
- With Figures 1 and following beginning on Page 4 of Section V we suggest not starting over the numbering with Figure 1 here, which may be confused with earlier Figure 1 (or that may be a Word glitch that renumbered everything in the separate file, but needs to be fixed). This is where the land cover statistics discussed in an earlier bullet would help reveal the relationship of landscapes to loads. It might also be helpful to have a small map inset to show the watershed of interest.

As you developed this report, there were undoubtedly many "research agenda" issues that came to mind. While the report should not be overly cluttered with research issues that might obfuscate its utility, we offer some thoughts on how the load estimates might be improved and help shape future research and monitoring initiatives and their application. It should be clear, however, that the report's estimates of source and delivery quantification are, in our opinion, consistent with current understanding and reflect the best interpretation of local research and monitoring. While you may choose to revise the report to incorporate some of these suggestions that is at your discretion and should NOT be reason for any delay of finalizing the report or implementing appropriate management actions.

- It's debatable whether nitrogen fixed from agricultural crops is "natural" nitrogen, as your report seems to suggest on page 2. Our opinion is that it's not. Cover crops such as alfalfa can provide very substantial loads of nitrogen enrichment from a field after senescing, an order of magnitude above a natural load from a forested or meadow ecosystem. Similarly, clover in turf and lawns may be an important source of new nitrogen that would not have been fixed under natural conditions. Therefore, there is potential management of these sources.
- It would be helpful, probably in an appendix, to subdivide HUC 12 watersheds into finer scale watersheds within a town for both land cover and export statistics. Accuracy does become more questionable with increasingly fine-scale analysis, but when a whole town is in red, residents will be interested in the hot spots. Quantifying land cover as suggested in earlier bullets will help with those inquiries as well.
- The role of weather on nitrogen delivery should be put into perspective of the presumably "average" loads that the report provides. Weather is likely a large, if not the largest, contributor to the uncertainty of the annual loads, but underscores the importance of managing to average conditions to rein in wet years and not become complacent or assume goal attainment during dry periods.

- Section III.c needs to be very clear on inputs, outputs, and attenuation. These concepts are not intuitive for everyone, but are important to understand. High attenuation sources, for example, may not warrant as much management attention as those that are efficiently delivered to the estuary via a stormwater pipe. This could be important if management evolves into an integrated permit, or trading, where trading ratios would have to apply, or even in the construction of a TMDL.
- Page 16 provides a 78% nitrogen loss from NPS in the watershed, and statistics are effectively presented in the appendices to show where the attenuation occurs. Not addressed as well is the difference in attenuation rates in surface runoff compared to groundwater transport, though the calculations reflect those differences. A brief discussion of the biogeochemical differences between surface runoff and ground water and what they mean for nitrogen transport, denitrification and delivery to the estuary would be helpful and begin to school people on nitrogen removal opportunities in the natural landscape as well as adaptive management and constructed BMP placement, recovery potential, and capacity for treatment. The good news is that even highly-modified landscapes with large N inputs have an enormous capacity to remove nitrogen; the bad news is that the increment of enrichment is therefore very inefficient to treat in many cases.
- Groundwater transport has some complications with lag times, denitrification rates, trapping, etc. that are not discussed much. Also, for groundwater loads of nitrogen under urban areas, concentrations of groundwater N are often in the 2-3 mg/L range, coincidentally the limit of technology at sewage treatment plants. With the high nitrogen loss alluded to in the prior bullet, and the dilute, perhaps irreducible, concentrations in ground water, pollution prevention may be more important than infiltration that we currently promote in our management recommendations.
- Page 17. Note that Hubbard Brook is subject to atmospheric deposition, so 1.2 lbs/acre-yr is probably somewhat higher than a natural load, especially with possible acidification impacts on vegetation uptake and losses of buffering capacity.

We hope these comments are helpful and constructive. Again, a great job on the analysis and report, and we look forward to working with you to translate these data into effective management in the Great Bay watershed.

Sincerely,

Paul E. Stacey
Research Coordinator
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(603) 868-1095

NH Farm Bureau Federation

NEW HAMPSHIRE FARM BUREAU FEDERATION
295 Sheep Davis Road • Concord, New Hampshire 03301-5747 • (603) 224-1934 • Fax (603) 228-8432 • www.nhfarmbureau.org

September 9, 2013

Mr. Philip Trowbridge
NHDES Watershed Management Bureau
29 Hazen Drive, P.O. Box 95
Concord, NH 03302-0095

Re: Comments - Great Bay Nitrogen Non-Point Source Study

Dear Mr. Trowbridge:

Thank you for extending the comment deadline for New Hampshire Farm Bureau (NHFB). On behalf of NHFB, and including the farmers in attendance at the June 12 meeting in Lee, we offer the following comments on the draft study issued in May.

NHFB recognizes the Great Bay estuary as one of the state's natural treasurers and we want to keep it as one. We understand there is a complexity of contributing factors causing degradation of the Bay and that agriculture is a contributor. We also strongly believe, and the evidence shows, well-managed agricultural land is part of the solution.

We very much agree with the statement made during your June 12 presentation that "models are only good if they predict reality". Just as a successful farm bases decisions on good data, for example soil testing prior to applying fertilizer, the "accuracy of any model depends on having correct input data" (page 12 of the draft study). According to Appendix C (page 3) a stated data quality objective of the study was: "The fertilizer application rates should be confirmed by local agriculture experts as much as possible." We believe the input data used in the draft is lacking – particularly as it relates to agriculture – as it has not been confirmed by local farmers and is too often left to assumption.

This model will lay the foundation for future planning models for the other watersheds in the state, time and effort must be expended to assure it is an accurate and effective planning tool. NHFB offers our assistance in working with DES to develop and distribute a survey to obtain the data needed to do just that. We offer the following more specific comments on the data used:

Chemical Fertilizer Use

Hay – As was discussed at the June 12 meeting the consensus is that the assumed rate of 25 lbs. an acre is quite high. This category appears to assume hay fields as straight grass, which is not typically the case, and does not account for the contribution of legumes in hay fields. The application of chemical fertilizers to grass only fields is simply not cost

effective. There are a lot of fields that are cut year by year and are not actively managed for optimum production (little to no fertilizer application) because of cost recovery issues - no long-term agreements. Recent increases in nitrogen fertilizer prices are also not accounted for – see cost of nitrogen fertilizer below. Farmer data is needed in this area.

Corn – The rate of 63 lbs. an acre used in the draft study may be low. This being said, it may not be. Farmer data is needed. It should be noted the estimate derives from New York data where the soils are higher yielding than the soils in the Great Bay watershed and are managed accordingly, requiring greater fertilizer inputs. See also "Cost of nitrogen fertilizer" below.

Apples – The study uses the average fertilizing rates in New York in 2007 and 2009 with the result being 42.5 lbs. of nitrogen an acre on 75% of the 598 acres in apples in the watershed. Growers do not typically apply nitrogen to bearing (crop producing) trees. Nitrogen is applied to young, non-bearing trees in multiple applications. A good orchard will have 10% non-bearing trees at any one time. We believe 75% is a gross overestimate of acres fertilized and agree with Extension personnel that fertilizer rates in NH may be lower than the rates found in NY and used in the study.

Other Crops – The fertilization rate for corn is used for crops in this category. Corn is typically the crop receiving the highest nitrogen fertilizer rates in NH. Though this category is a relatively small number of acres, we believe it is a gross overestimate of the nitrogen fertilizer commonly used on the crops in this category. Better information is needed for these crops.

Cost of nitrogen fertilizer must be considered when using data from years prior to 2008-2009 when there was a big jump in nitrogen fertilizer prices. We point this out because the cost of nitrogen fertilizer has an affect on application rates – particularly when it comes to hay fields and to a lesser extent, field corn. For example the study uses 2005 data for corn application rates in New York. In 2005 local New Hampshire farmers were paying around $330 per ton for a common nitrogen fertilizer blend. Today farmers are paying $565 per ton for the same blend, a 60% cost increase.

Animal Waste

Wildlife – According to the study "wildlife in the watershed typically eat locally-grown food sources. Animal waste from wildlife is not a new source of nitrogen in the watershed but rather a recycling of nitrogen within the system." (page 2). The study goes on to say "The effects of natural sources of nitrogen on loads to the estuary are expected to be small and variable and accounted for within the uncertainty range (+/- 13%) of the model." (page 2). The same can be said for much of the livestock in the watershed – their food sources are typically locally grown and their loads to the estuary are within the uncertainty range. Wildlife and livestock loads should be treated equally – either both accounted for or each considered a recycling of nitrogen within the system. What are the wildlife numbers in the watershed? Was Fish and Game consulted with? Was any

consideration given to looking at migratory waterfowl separately? How is loading caused by aquatic species taken into account?

"Cows" – The use of "cows" in the report is confusing. In *Appendix F* on page 3 only "cows" are referred to where NH numbers are mentioned. Do the numbers used refer only to female cattle of a breeding age and not to other cattle: calves, heifers, bulls and steers? Part of our confusion results from the term "cattle" being used to estimate the numbers in Maine. In addition it is our understanding that the tuberculosis and brucellosis testing program conducted by the NH Department of Agriculture is voluntary and likely does not include all "cows" and cattle as is implied.

Livestock in general – The potential for the animal waste component of the model to double count some of the nitrogen already tracked as fertilizer and atmospheric deposition is acknowledged in the study (page 13 of the study and pages 7 and 8 of *Appendix F*) but is quickly dismissed. Explanations for ignoring any potential double counting include the assumption that it is "expected" to be small relative to larger sources and that livestock numbers are offset by low "estimates" of total livestock. Too much is left to assumption and rough estimates. Hard, more comprehensive livestock numbers are needed. See also "Wildlife" above. The model also does not take into account nitrogen being removed from the non-point system in the form of milk, meat, eggs, fruits, vegetables etc.

We are not clear wheather existing controls on livestock waste and its potential transport pathways were taken into account in comparison to existing controls and potential transport pathways for pet and wildlife waste.

Dogs – The study uses the number of dog licenses issued by towns to come up with the number of dogs in the watershed. We believe this is a significant underestimate. At a recent meeting of the Commission studying funding for the NH Veterinary Diagnostic Laboratory, the State Veterinarian, Stephen Crawford, DVM reported demographic studies consistently show somewhere around 50% of dogs are licensed. This lends support to the American Veterinary Medical Association estimates discussed in *Appendix F*. We also question the use of estimates from a 1999 Chesapeake Bay study estimating "approximately 60% of dog owners usually pick up their pet's waste" (*Appendix F*, page 6). We urge the Dog Owners of the Granite State and other local sources be sought out for local estimates.

Cats – "For simplicity" the study assumes that 100% of waste from cats is disposed of in landfills. Where is the support for this assumption? Accuracy, not simplicity, should be the primary motivator behind numbers used in the study. We find this assumption highly suspect.

<u>Study Model Used</u> – based on the model's original development and application for Cape Cod, we are concerned the model inherently overstates the leaching of nitrogen into waterways. Cape Cod's sandy soils leach nutrients more aggressively than our region's

clay-based soils. This would be a concern for all of the calculations, not solely for the agriculture related calculations.

Quality Assurance – on page 11 of the study states that an "external review" of the model used was conducted by Dr. Ivan Valiela - the creator of the model. We would like more information on what Dr. Valiela's review consisted of. Should a more independent review of the model be sought?

We did not see the USDA's Natural Resource Conservation Service mentioned in the study and urge they be consulted. We also urge greater consultation with the NH Department ofAgriculture, Markets and Food.

In closing, we thank you for your consideration of our comments and repeat our offer to assist you with developing and distributing a survey to farmers in the watershed.

Respectfully submitted,

Robert Johnson, II, Policy Director
Direct: 312-6877, robj@nhfarmbureau.org

New Hampshire Farm Bureau is a non-profit federation, formed in 1916, of the 10 NH county Farm Bureau organizations. NH Farm Bureau represents over 3,000 farm families and their supporters and is dedicated to advocating for and educating the public about agriculture. Farm Bureau is a general farm organization where the members establish policy and direction through a member driven (grassroots) policy development process.

Lamprey River Watershed Association

LAMPREY RIVER WATERSHED ASSOCIATION
Sharing Water Resources: Barrington, Brentwood, Candia, Deerfield, Durham, Epping, Exeter, Freemont, Lee, Newfields, Newmarket, Northwood, Nottingham, Raymond

May 23, 2014

Philip Trowbridge
NHDES Watershed Management Bureau
29 Hazen Drive, P O Box 95
Concord, NH 03302-0095

Dear Mr. Trowbridge:

Congratulations on the completion of a comprehensive study of the sources of nitrogen entering Great Bay. The study does an excellent job of defining the causes and distribution of nitrogen sources from throughout the Piscataqua watershed.

The Lamprey River Watershed Association has been an advocate for clean water and best management practices for over 30 years. Our volunteers contribute data to the Volunteer River Assessment Program annually and our programs are often centered around healthy, clean water. Our emphasis has turned to what individuals can do to be sure that their "footprint" in the watershed is as light as possible. What this report needs to state is that all watershed residents are contributing to the nitrogen loading and that each of us can take measures to reduce our impact.

It would be helpful if there was at least one pie chart that showed all of the potential sources of nitrogen loads in one pie. For example, the Summary of Non-Point Source Nitrogen Loads to the Great Bay Estuary gives a detailed breakdown of the non-point sources but never do we see the entire source pie with the subcategories. It would help the reader put some of the non-point sources in perspective by seeing relative comparisons at the same scale.

The charts for animal waste and the summary statements appear to be at odds. In the Priority Animals table it is said that dogs are 26% and cats 22% of the Total Nitrogen from Animal Waste. Yet, in the Executive Summary it states that livestock account for 80% of all Animal Waste.

Thank you for an excellent report. LRWA is ready to assist with the outreach to inform citizens of what actions they can take to reduce the non-point source impact.

Sincerely,

Dawn W. Genes
Executive Director

Working For A Clean and Healthy Watershed Since 1983
43 North River Road • Lee, NH 03861 • (603)659-9363 www.lrwa-nh.org

Strafford, NH Citizen (James Kerivan)

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kerivan@metrocast.net

August 14, 2013

Mr. Philip Trowbridge
NHDES Watershed Management Bureau
29 Hazen Drive
P. O. Box 95
Concord, NH 03302-0095

TRANSMITTED VIA EMAIL TO Philip.Trowbridge@des.nh.gov

Re: **Public Comments for Draft Great Bay Nitrogen Non-Point Source Study**

Dear Mr. Trowbridge:

The Conservation Law Foundation has somehow convinced the US EPA that the Piscataqua River is in peril of being polluted by nitrogen. The NHDES report focuses on a snap shot of recent nitrogen concentrations in Great Bay. The report neglects an overall discussion of nitrogen's place in our society. I respectfully request that your report be amended to include the following information.

1. Nitrogen – Describe that nitrogen is not an evil pollutant but the most common element in our lives. Eighty (80%) percent of our atmosphere is nitrogen. The word "fertile" is synonymous with the phrase "high in nitrogen content". Civilization was created by rivers carrying nitrogen down to valleys in Mesopotamia and Egypt.

2. Comparable Baseline – The draft report compares the Great Bay estuary watershed nitrogen levels to (a) pre-human estimates, and (b) an uninhabited, "pristine" watershed in North Woodstock, NH. More appropriate comparisons would be (c) other U.S. rivers with similar rainfall, watershed size, and population; (d) an historical estimate of Nitrogen levels in Great Bay; and (e) an historical estimate of Great Bay eel grass.

3. History of Nitrogen in New Hampshire – Nitrogen has played a dominant role in the history of New Hampshire that deserves description. The failure of New Hampshire agriculture is due, in large part, to a lack of nitrogen in our soil.

   10,000 years ago, the last American continental glacier stripped all the nitrogen from the States of New Hampshire, Vermont, and Maine leaving them devoid of top soil. Only boulders, rock, and hardpan soil remained. Early settlers had to eke out a life on a thin layer of relatively infertile soil that was quickly depleted of nitrogen. The only remedy was to apply manure to bring fertility back to a level where crops could grow. Even

today, the majority of our local fields will only support a low quality, low yield harvest of hay. The basic reason—low soil nitrogen levels. If one passes by a lush green field with a heavy stand of hay in an upland area, you can be sure that manure or fertilizer was used to create it.

150 years ago, New Hampshire agriculture was saved from collapse by a nitrogen production machine known as the cow. The fantastic amounts of manure and urine spread over the State's pastures created what must have been a visual utopia. Using DES's methodology, I estimate that the nitrogen produced by the 19th and early 20th Century cows was two to three times more than the current total of all "non-point source loads" in the Great Bay watershed. (See enclosed worksheet.) The loss of dairy farms in the Great Bay watershed has significantly lowered the area's nitrogen production. If the methodology presented in the DES report is correct, then the nitrogen levels in Great Bay were far higher in the past. The increase in human population has not come close to matching the nitrogen produced by cows.

4. Fertilizer – The early part of the 20th Century saw an early use of fertilizers allowing our farmers to produce enough corn to feed the dairy cows. Boston's milk supply was dependent on the nitrogen content of Vermont and New Hampshire soils. It is my opinion that fertilizer sales have dropped precipitously since the 1960s due to cost and farm loss. DES should verify this in discussions with Agway and Blue Seal.

5. Atmospheric Deposition – The burning of coal has been on a downward spiral for the last fifty years. Coal use in 1960 was four times the use in 2012 (US DOE). Surely this decrease in nitrogen should be factored into our outlook about Great Bay.

6. Terminology – the report categorizes nitrogen as a waste product. It is not. Your so called "animal waste" is not a waste at all but a valuable commodity that enhances our rural standard of living.

Please re-evaluate the nitrogen issue and stand with your fellow taxpayers in opposing these Federal requirements that Washington/Boston bureaucrats are implementing.

Respectfully,

James F. Kerivan

James F. Kerivan
Citizen, Strafford, NH

Enclosure

cc: Governor Maggie Hassan
Senator Kelly Ayotte
Senator Jeanne Shaheen

ALTUS ENGINEERING, INC.
133 Court Street
Portsmouth, NH 03801-4413
Tel. (603) 433-2335
Fax (603) 433-4194

JOB: N_2 FROM COW MANURE – 1900
SHEET NO. ____ OF ____
CALCULATED BY: V KERIVAN DATE: 8/13/13
CHECKED BY ____ DATE ____
SCALE ____

CALCULATION OF N_2 DELIVERY TO GREAT BAY WATERSHED FROM COW MANURE – CIRCA 1900

- MILK COW POPULATION IN NH WAS 8 TIMES THAT OF 2006 (FROM UNH EXT COOP LITERATURE)
- DAIRY CATTLE POPULATION IN GREAT BAY WATERSHED IN 2006 ESTIMATED AT 2,607 HEAD (DES N_2 STUDY)
- ASSUMING THE SAME DECLINE IN SE, NH AS WHOLE STATE THE 1900 DAIRY COW POP = 8 × 2607 = 20,856 HEAD
- N_2 LOAD FROM COWS IN GREAT BAY WATERSHED FROM DAIRY COWS IN 1900,

$$20{,}856 \text{ HEAD} \times 266.2 \text{ lb-}N_2/\text{YR} = 5{,}551{,}867 \text{ \#}N_2$$
$$= 2776 \text{ TONS/YEAR}$$

NHDES CURRENT ESTIMATE OF NITROGEN LOAD FROM WATERSHED FROM BOTH NON-POINT SOURCES AND SEWAGE TREATMENT PLANTS IN 2009 – 2011 WAS 1,225 TONS/YEAR (DES N_2 STUDY, PG 17)

Town of Brentwood

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Brentwood, New Hampshire 03833

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NH Department of Environmental Services
29 Hazen Drive
Concord NH 03301

RECEIVED
AUG 1 4 2012
DEPARTMENT OF
ENVIRONMENTAL SERVICES

August 13, 2013

Philip Trowbridge, PE &
Matthey A. Wood
Water Division

Jeffrey Underhill Ph.D. &
David S Healy
Air Resources Division

Gentlemen,

We are writing to you to raise concerns relative to your study that assumes that the water quality of Great Bay in a large part is due to communities upstream. Your assumptions seem to be aimed at proving watershed communities are responsible for poor water quality in the Bay. "Given all the proactive steps Brentwood has taken over the past decades to protect water quality, we are surprised and disappointed that the model output was that Brentwood is in the second highest category for nitrogen as shown in Section V. page 32. We can only conclude that something is either wrong with the model or the inputs that went into the model and request that further investigation be done prior to finalizing this study.

We can only speak to how The Town of Brentwood has been actively involved in planning and investing in land preservation. In 1993 the Town adopted its first land conservation and preservation chapter in its Master Plan. The intent has been to preserve open space, prime forest lands, and to reduce costs relative to development of the town. They realized the town needed a conservation plan that identified, for conservation and water quality purposes, high value properties, to retain rural character, preserve and protect our natural resources and to incorporate that plan into its Planning and Zoning regulations. As a result of that planning and prioritizing a significant amount of Exeter River frontage as well as brooks and streams feeding into it have been put into Conservation Easements since that time. Given the extensive easement buffer along the Exeter River and other surface waters in town, there are very few of the nitrogen inputs like septic systems, lawns, impervious pavement, and agriculture within close proximity to these surface waters. This adds to our disbelief that Brentwood is contributing the level of nitrogen that the model has predicted. These easements have eliminated or restricted development in those areas and as a natural benefit prevented water degradation which results from development.

The Town further committed itself to that goal in 2003 when it authorized a two million dollar bond issue for the acquisition of Open Land. Parcels along the waterways and in what is considered prime wetlands were given priority and considered high value for the protection of the Exeter River. Over the last 10 years we have leveraged that two million dollars into approximately four million three hundred and eighty nine thousand four hundred forty nine dollars for those high priority lands. This was done through active pursuit of grants, and gifts that were available during that time. There were additional expenditures of over one hundred thousand dollars from the annual Conservation budgets. The end result is that 27% or 2,900 acres of Brentwood's land mass has been put into conservation easements.

Our Conservation Commission has been in the forefront searching for new resources to meet protection and preservation goals. They have taken a proactive stand in improving water quality by investing in educational materials to make our residents more aware of water quality issues. They regularly enlist the help of residents for small projects aimed at involving and educating the general population. They sponsor roadside cleanups annually, and in 2012 in partnership with RCCD completed a two year project of work along the bank of the Exeter River. The project included storm water treatment, riverbank stabilization, and a conservation easement on 18 acres to protect over 5,600 feet of river frontage. The State permitted work included construction of vegetated swales, storm water treatment wetland, construction of infiltration stairs/ boating access, stabilization of the eroding river bank along Rowell Rd East, and buffer enhancement. All these improvements will improve the water quality of the Exeter River which terminates in Great Bay.

We urge you to take a fresh look at the assumption that communities up stream must be responsible for the poor water quality in Great Bay. We have been working as a responsible neighbor and community to preserve and protect water quality for a number of years. We have stepped up to the plate to put our economic resources in to this protection plan. This upstream, watershed community has been doing its part to improve water quality whenever it can.

Sincerely,
The Brentwood Board of Selectmen

_____ Andrew Artimovich

_____ Jeffrey Bryan

_____ Jane Byrne

_____ Kenneth Christensen

_____ David Menter

Cc. Harry Stewart, PE, Director Water Division Cc Thomas Burack, Commissioner Cc Vicki Quiram, Assistant Commissioner

Town of Newmarket

STEPHEN R. FOURNIER
TOWN ADMINISTRATOR

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FOUNDED DECEMBER 15, 1727
CHARTERED JANUARY 1, 1991

TOWN OF NEWMARKET, NEW HAMPSHIRE
OFFICE *of the* TOWN ADMINISTRATOR

RECEIVED
AUG 14 2013
DEPARTMENT OF
ENVIRONMENTAL SERVICES

August 12, 2013

Mr. Philip Trowbridge
NHDES Watershed Management Bureau
29 Hazen Drive, P.O. Box 95
Concord, NH 03302-0095

Comments on the Draft Great Bay Nitrogen Non-Point Source Study dated May 16, 2013

Dear Mr. Trowbridge

We have reviewed the above referenced report and applaud DES's efforts to better define the sources of non-point source (NPS) nitrogen. As DES knows, the Town of Newmarket's recently issued NPDES permit has provisions that allow EPA to issue more stringent nitrogen standards for our treatment plant if significant reductions in NPS nitrogen are not effected in the Lamprey River sub watershed. Accordingly, we have a significant incentive to promote NPS nitrogen reduction.

That said, the Town has control over only a small portion of this sub watershed. We believe to have an effective NPS-nitrogen control strategy, DES will need to define each community's responsibilities within this sub watershed and devise a system to promote intercommunity cooperation. The absence of allocation of nitrogen removal responsibility by community and by sub watershed will become a roadblock to inter-municipal collaboration and progress. What are DES' plans in this regard?

Ultimately, DES wants each community in the watershed to develop a plan to reduce NPS nitrogen. While the above referenced report advances this cause, it is not sufficient by itself to inform community NPS control strategies. More research is needed regarding the cost of the various NPS nitrogen mitigation strategies so prioritized strategies can be developed, costs understood and affordable implementation plans developed. It would seem that DES is in the best position to advance this necessary work, as opposed to having numerous towns undertake this work independently. Does DES plan on completing these additional studies?

The NPS nitrogen control strategies are intended to achieve a DES defined nitrogen reduction goal. How will DES track progress toward this goal and how will success be defined?

Thank you for the opportunity to comment on the draft report. We look forward to your continued assistance advancing the watershed NPS nitrogen control strategy.

Respectfully,

Stephen R. Fournier
Town Administrator

Town of Stratham

TOWN OF STRATHAM

Incorporated 1716

10 Bunker Hill Avenue • Stratham, NH 03885

Town Clerk/Tax Collector 603-772-4741
Selectman's Office/Administration/Assessing 603-772-7391
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August 12, 2013

Philip Trowbridge
NHDES—Watershed Management Bureau
29 Hazen Drive
P.O. Box 95
Concord, NH 03302-0095

RECEIVED
AUG 14 2013
DEPARTMENT OF
ENVIRONMENTAL SERVICES

RE: Great Bay Nitrogen Non-Point Source Study—Draft May 16, 2013

Dear Mr. Trowbridge,

Thank for the opportunity to comment on the above referenced draft study report. From all appearances, the Study is a great advancement in our collective understanding of non-point nitrogen sources entering Great Bay. This issue has been the subject of much speculation in recent years and the Study begins to provide a framework for future discussions. As a municipality located within the Great Bay Watershed, we have a keen interest in this subject and support its continued study.

With this in mind, we would also caution against the future use of the Study, as it is currently drafted, as a basis for future regulatory efforts. The Study, although comprehensive in content, is still just a model that needs further "ground truthing" to validate the many assumptions used to create its conclusions. Continued study and validation of the accuracy of the model is needed before it could be relied upon for the creation of any regulatory framework. We as a municipality do not have the resources to verify the outcomes shown in the Study as they pertain to Stratham, but would support future efforts to continue to refine the Study into a predictive tool based on sound science and actual field data. Once validated in the real world and subject to peer review, the Study could then become a source for policy determination and ultimately the drafting of future statutory and regulatory efforts.

Congratulations on a great first effort, and one of which we hope will be subject to continued refinement.

Sincerely,

Board of Selectmen

PRD

University of New Hampshire (Michelle Daley)

All of the comments from the University of New Hampshirre (Michelle Daley) are not able to be attached as they are embedded in a .pdf version of the draft Great Bay Nitrogen Non-Point Source Study. See the summary of comments above.

You replied to this message on 8/16/2013 11:05 AM.

From: Daley, Michelle <michelle.daley@unh.edu> Sent: Tue 8/13/2013 4:24 PM
To: Trowbridge, Philip
Cc:
Subject: Comments on GBNNPSS

Message | gbnnpss-report mld edits.pdf (4 MB)

Hi Phil,

I have looked over the Great Bay Nitrogen Non-Point Source Study and wanted to submit some minor comments for improving the clarity of the report. These are included as comments or sticky notes in the attached report and the appendix at the dropbox link below (too big to email both). Overall, I applaud the effort NH DES has put into compiling the most up to date information on inputs of non-point source nitrogen to the Great Bay watershed. This report certainly provides useful information at the entire watershed, HUC12 and town scale. Having new GIS layers for septic system density at the 2010 Census block level and managed turf will be useful in the "Great Bay N Sources and Transport" project that Bill, myself and others at UNH are working on. We look forward to working with you as we start comparing the N concentrations we have measured at ~250 freshwater sites in the watershed to N inputs and perhaps even yield predicted by using the approach NH DES has taken here.

https://www.dropbox.com/s/nzs8rxv37tu3ery/gbnnpss-appendix%20mld%20edits.pdf

Please let me know if you have any questions regarding these comments.

Michelle

****

Michelle L. Daley
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Vanasse Hangen Brustlin, Inc. (VHB)

VHB Planning | Transportation | Land Development | Environmental

To:	Philip Trowbridge NHDES Watershed Management Bureau 29 Hazen Drive, P.O. Box 95 Concord, NH 03302-0095	Date:	August 15, 2013
		Project No.:	Durham/UNH Oyster River Watershed Nonpoint Source Modeling and Integrated Planning and Permitting Study
From:	Bill Arcieri, VHB Project Manager	Re:	Comments on the Draft Great Bay Non-Point Nitrogen Source (GBNNPS) Study
Cc:	Dave Cedarholm, Durham Paul Chamberlin, UNH Jim Dombrosk, UNH Matt Kennedy, UNH Theresa McGovern, VHB		

Based on our recent use of the Nitrogen Loading Model (NLM) as part of the Oyster River Integrated Watershed Modeling and Planning effort for the Town of Durham and University of New Hampshire, VHB offers the following comments on the DRAFT GBNNPS Study released on May 16, 2013. These comments primarily offer suggestions on ways to improve the accuracy and use of model.

General

The NLM as modified by DES for the GBNNPS Study appears to perform reasonably well for predicting average annual nitrogen loads for larger watershed areas based on comparisons of the modeled watershed load estimate with that developed from limited measured water quality data. Our recent use of the model produced a fairly comparable average annual nitrogen load estimate for the Oyster River watershed that was within 8 percent of the estimated measured load for the same watershed.

The model's ability to track and account nitrogen loads by source types, land-uses or human activity, and pathways certainly is a major advantage over other models because it is critical to begin identifying and evaluating appropriate and effective management strategies for nitrogen reduction. However, there are certain data inputs, model assumptions and inherent pathway/ delivery factors that warrant further evaluation and possible refinement in order to gain greater confidence with respect to load estimates for particular sources and the modes of transport simulated within the model.

Data Inputs

Through our recent modeling analysis, the use of high resolution GIS data layers (1-meter resolution) appears to make a substantial difference in estimating the amount of impervious cover and lawn area as compared to the lower resolution GIS data (30-meter resolution) that is available for much of the Great Bay region and was used in the GBNNPSS model. This higher resolution data is essential to developing reasonably accurate estimates of the amount of land use areas, particularly in smaller watersheds.

In addition, we found considerable inconsistencies and errors in the agricultural crop map data layers developed by the National Agricultural Statistical Service and that the use of high resolution aerial photo and ground-truthing was necessary to get more accurate estimates of the areas and locations of agricultural crops.

Stormwater Pathway Partitioning Coefficient Factor

As discussed in Appendix H, the stormwater pathway was added to the Great Bay NLM model to estimate the amount of nitrogen delivered by stormwater runoff since the original model developed by Valiela et al. (1997) for the Cape Cod region assumed that all nitrogen inputs were delivered by groundwater flow. The GBNNPS model used a stormwater partitioning coefficient of 12 percent for agricultural land, lawn, managed turf and disconnected impervious surfaces, which was determined through an "optimization" process comparing overall modeled loads to measured load estimates. As reported in the Appendix, the scientific literature suggests that the amount of nitrogen applied to turf and other vegetated that ends up in stormwater runoff value ranges between 2 to 25 percent.

As a possible alternative approach perhaps available soil mapping could be used to identify various soil types and Hydrologic Group soil classifications and adjust the stormwater partitioning coefficient using a sliding scale to account for differing soil infiltration capacities within the various land uses of agricultural, lawn, managed turf and disconnected impervious area.

For disconnected impervious areas (IA), as well, GIS data could be used to distinguish various levels of imperviousness for disconnected IA and the stormwater partitioning coefficient could be based on a sliding scale according to the imperviousness. Using a uniform partitioning factor of 12 percent would seem to likely underestimate the amount of nitrogen delivered by stormwater especially from larger impervious surfaces or a dense grouping of impervious surfaces with limited surrounding vegetated areas. This is particularly important for evaluating the effect of future stormwater treatment measures as well as identifying other effective control measures for nitrogen conveyed by stormwater. The groundwater partitioning coefficient would also be adjusted accordingly.

Groundwater Delivery Factors

The default model assumes that 61 percent the land applied nitrogen is delivered through the vadose zone to the water table and that 39 percent is lost or attenuated at the ground surface or soil horizon for chemical fertilizer from agriculture lands, lawns and managed turf. In review of the research reported by Valiela et al., (1997), it appears that the assumed 39 % attenuation only accounts for gaseous losses via volatilization and denitrification. Thus, no attenuation through vegetation uptake and soil retention is accounted for. The same research findings presented in the 1997 Valiela Report (as compiled by Petrovic 1990) suggests that as much 46 percent of the applied nitrogen ends up in vegetative clippings and another 12 to 24 percent can be tied up in the roots, standing crop and organic thatch. Another 33 percent has been reported to be retained in the soil layer. Thus, the inherent assumption suggesting that only 39 percent of the applied nitrogen is attenuated or lost before it enters the groundwater seems to represent a very conservative long-term, steady-state, condition where the attenuation capacity of existing vegetation and soils is fully met and that 61 percent of all applied nitrogen will be delivered to the water table.

We feel that this delivery rate used in the NLM deserves additional evaluation and possibly refinement, particularly since the model authors suggest that the default model used for Waquoit Bay is only appropriate for use in watersheds with highly permeable soils. Travel time through the soil horizon may be important factor and may contribute to greater volatilization losses. We would be willing to discuss this further with DES personnel and other regional experts to assess whether this model assumption should be modified.

In addition, the GBNNPSS includes a higher delivery factor for shoreline septic systems but only for those located within 200 meters of 5th order or higher streams, which essentially consists of the tidal estuary portion of the Oyster River. It is unclear why the higher delivery factor would not be applied for other shoreline septic systems along 4th order or other smaller water bodies. We feel that this may be underestimating the load from septic systems in close proximity to smaller streams and rivers as well as freshwater lakes and ponds.

Impervious Cover

The model utilizes the same nitrogen load rate for the various types of impervious cover despite evidence expressed in the literature that suggests nitrogen accumulation and resulting loads vary for different types of impervious surfaces depending on the intensity of use/activity. For instance, nitrogen from vehicular emissions is likely to have a much greater influence on nitrogen loads from parking lots and roads as compared to roofs. The surrounding land use is also likely to be a factor in estimating nitrogen loads between different type of impervious cover and associated land uses (e.g., residential, commercial, industrial, agricultural, etc.)

The model accounts for atmospheric deposition and loading from pet wastes as the only source contributions to impervious cover. The model does not include a chemical fertilizer component that may result from "run-on" or overspray during fertilizer applications, especially from residential lawns. Therefore, the model may be underestimating the loads attributed to impervious cover areas.

Other

It appears that Table 2 on page 14 presents the incorrect value for the estimated modeled load for the Oyster River at the head of tide. Figure 4 indicates the modeled load (at head of tide) to approximately 45,000 pounds which is closer to the 1:1 line instead of the 71,945 shown in the table.

Please do not hesitate to contact us if you have questions or comments and we look forward to working with you on developing ways to improve and enhance the model's capabilities.

Wright-Pierce

WRIGHT-PIERCE
Engineering a Better Environment

Water

Wastewater

Infrastructure

August 13, 2013

Mr. Philip Trowbridge
NHDES Watershed Management Bureau
29 Hazen Drive, P.O. Box 95
Concord, NH 03302-0095

Subject: Comments on the Draft Great Bay Nitrogen Non-Point Source Study
Dated May 16, 2013

Dear Phil
Thank you for the opportunity to comment on the Draft Great Bay Nitrogen Non-Point Source (NF
Study. This is very good work that will help advance formulation of NPS reduction strategies. Here a
our comments on the report.

1. The major sources of nitrogen to the Bay appear accounted for. There are a few potential sourc
of nitrogen that do not appear to be addressed that may be worth determining if they a
meaningful and discussing within the report.

   a. Biosolids from the wastewater treatment plants—the nitrogen in the biosolids can be on t
   order of 20% of the nitrogen in the effluent of the typical secondary treatment plant. To t
   extent the biosolids are disposed of within the watershed, they can be a meaningful source
   nitrogen.

   b. Septage—Septage can be a meaningful source of nitrogen to the extent disposal occu
   within the watershed (other than at WWTFs which are already accounted for).

   c. Waste Food—Food is the source of the septic system and wastewater effluent nitrogen, b
   not all the food imported to the watershed is consumed by people and ends up as public
   private wastewater. A meaningful fraction of the food is thrown away as solid waste (sor
   estimates in the 40 to 50% range). To the extent this waste is disposed of within t
   watershed, this could be a meaningful source of nitrogen (unless it is disposed of at a landf
   with leachate collection and treatment at a municipal WWTF).

   d. Imported wastes—are there any wastes imported into the watershed (such as biosoli
   septage, food wastes, etc.) that need to be accounted for?

2. The nitrogen transport model was validated by comparing model output with data from the
tributaries. Was there any cross checking of delivered loads against water column nitrog
concentrations in the Bay? Is DES sure the groundwater flux of nitrogen directly to the Bay
insignificant?

3. To arm the communities with the tools to develop cost-effective and efficient NPS reduction strategies, it would be desirable for this report or subsequent reports to :

   a. Confirm/summarize the governing water quality criteria and target nitrogen reduction goals for each sub watershed.

   b. Confirm how the nitrogen reduction goals will be established (e.g., will there be a target TN concentration or mass loading at a certain location; will it be an annual average or a seasonal average; etc.)

   c. Discuss how normal annual nitrogen loading variability will impact the target goals. For example, how will the meaningful load differences between DES' 2010 and 2013 reports impact the target nitrogen reduction goals?

   d. Include a sensitivity analysis on water quality criteria that are driving the nitrogen reduction goals with resulting potential impacts on the NPS reduction goals (e.g., if the eelgrass criteria were 10% higher, what would the impacts be on the NPS reduction goals).

   e. Project the impacts air pollution standards will have on the nitrogen removal requirements to focus the communities on the NPS reduction they have control over (i.e., what are the nitrogen reduction goals for the rest of the NPS nitrogen sources, assuming the projected 33% decrease in air emissions).

   f. Include a discussion about the impacts of growth on the nitrogen control requirements. Ideally the report would include a build-out analysis to show how the nitrogen loads will be impacted by additional development in the watershed and to inform nitrogen management strategies for new growth. We now know that the watershed as currently developed exports more nitrogen than is desired and it would seem wise to understand if nitrogen based development standards are needed to prevent the problem from getting unnecessarily worse as a result of growth (likely to be more cost effective to impose nitrogen based development standards on new growth than impose post development remediation measures). Perhaps DES could check the per capita contribution of the various sources of nitrogen within each sub watershed to determine if there are some consistent factors that can be applied to estimate the growth impacts.

   g. Include a discussion of the macro level nitrogen attenuation factors used in this report and any limitations as it relates to applying these factors at a micro level to sub watersheds. How much variability do you expect in these attenuation factors as a function of distance to the Bay or geomorphology and how might this information impact decisions as to the most cost effective nitrogen reduction strategies. For example, does removing a septic system in Raymond provide the same benefit as removing one in Newmarket 300 meters from the Bay?

   h. Estimate the expected range of nitrogen mitigation costs for the various sources of NPS nitrogen so that nitrogen removal strategies can be prioritized on "a pound of nitrogen removed from the Bay per dollar invested in mitigation measures" basis (otherwise each community will have to do this independently and at greater total costs).

Does DES envision tackling these issues in this or subsequent reports? If not, what advice do you have for the watershed communities for accomplishing this work?

4. DES ultimately wants this report used by the various watershed communities to develop NPS reduction strategies. Based on our experience, the following factors should also be considered to maximize the likelihood of timely progress.

   a. The allowable nitrogen loads and resulting NPS reduction requirements need to be allocated to each of the sub watershed communities. The allocation of responsibility among the watershed communities will be an essential element for collaboration and progress. Municipalities need to understand their nitrogen removal responsibilities on a sub watershed basis for existing sources as well as from growth. Has DES established an allocation methodology?

   b. Communities with NPDES permits are receiving permit requirements to address NPS nitrogen. Will there be any regulatory mandate to the other watershed communities to reduce NPS nitrogen or will it be purely voluntary for the non-sewered communities?

   c. How will DES encourage inter-municipal cooperation?

   d. How does DES propose to monitor NPS reduction progress on a community, sub watershed and watershed basis?

   e. How will success be defined?

   f. Will DES be considering a watershed-based permitting approach?

5. It is helpful to begin the NPS reduction efforts with the end in mind. In addition to understanding the specific goals and how the goals might be impacted by the various variables (e.g., water quality criteria, normal variability in watershed output, growth, WWTF performance, etc.), it is important to understand the probability of success before too much energy is expended and to understand the consequences of failure to achieve the goals. We know that NPS reduction is difficult and even with the best efforts only a fraction of it will be removed. Based on the loading data in your report I made a guesstimate as to likely NPS reduction results through concerted NPS reduction efforts and concluded something on the order of 25% may be achievable (assumed: 5% reduction of human waste through sewering to remove some septic systems close to the Bay; 10% reduction in animal waste through improved management practices; 50% fertilizer reduction through aggressive legislation; and 33% reduction in atmospheric deposition as a result of Federal air emissions standards).Comparing this rough estimate of what can be practically removed with the removal goals summarized in DES's 2010 report shows that some sub watersheds might be able to achieve their reduction goal (i.e., those with a reduction goal of 25% or less) and some clearly won't be able to (i.e., those with more than a 25% reduction goal). For example, the Oyster River has a 63% reduction goal (assuming the WWTF achieves a 3mg/l TN limit) to allow eelgrass restoration in the river. This goal is clearly unattainable. The next most restrictive criterion is the Great Bay eelgrass criterion and this requires a 25% reduction, which may be achievable. So in situations such as this, what will DES require? Will it be possible to abandon the river eelgrass criterion? Will noncompliance with this criterion impact

growth in the watershed? What are the consequences of not being able to achieve the goals? Ideally DES' report would touch on these important issues.

6. While it is premature to determine which sources of nitrogen will be most cost effective to control, it is very likely that the use of chemical fertilizers in non-agricultural application will be the "low hanging fruit". Fertilizer control will be much easier at a state-wide or watershed-wide basis. Will DES promote fertilizer control legislation (similar to that proposed by some Cape Cod communities)? As part of such an initiative, it would be necessary to engage the turf management industry as their business sector would be impacted.

Thanks again for the opportunity to comment on this important work. Feel free to contact me if you have any questions about our comments.

Respectfully Submitted,

Wright-Pierce

William E. Brown, P.E.
President/CEO