NewHampshire EstuariesProject

2006

New Hampshire Estuaries Project

Environmental Indicator Report: Land Use and Development

Prepared by:

Phil Trowbridge
NHEP Coastal Scientist
New Hampshire Department of Environmental Services

May 2006

ENVIRONMENTAL INDICATOR REPORT

LAND USE AND DEVELOPMENT

Prepared By

Phil Trowbridge
NHEP Coastal Scientist
New Hampshire Department of Environmental Services
Watershed Management Bureau
Concord, NH

Prepared For

New Hampshire Estuaries Project
University of New Hampshire
Durham, New Hampshire

Jennifer Hunter, Director

May 2006

This report was funded in part by the U.S. Environmental Protection Agency
through an agreement with the University of New Hampshire.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

This report was peer-reviewed by the NHEP Technical Advisory Committee. The members of this committee have expertise in water quality, biology, hydrology, geographic information systems, shellfish populations, finfish populations and environmental regulation.

NHEP Technical Advisory Committee

NAME	TITLE	ORGANIZATION
Steve Jones, Ph.D.	Research Associate Professor	University of New Hampshire, Marine Program
Tom Ballestero, Ph.D.	Associate Professor	University of New Hampshire, Civil Engineering Department
Jean Brochi	Project Manager for the NH Estuaries Project	U.S. Environmental Protection Agency, Region I
Gregg Comstock, P.E.	Supervisor	NH DES, Watershed Management Bureau, Water Quality Planning Section
Paul Currier, P.E.	Administrator	NH DES, Watershed Management Bureau
Ted Diers	Manager	NH DES, Coastal Program
Jennifer Hunter	Director	New Hampshire Estuaries Project
Natalie Landry	Coastal Restoration Supervisor	NH DES, Watershed Management Bureau
Richard Langan, Ph.D.	Director	UNH/NOAA Cooperative Institute for Coastal and Estuarine Environmental Technology, Cooperative Institute of New England Mariculture and Fisheries
Chris Nash	Supervisor	NH DES Shellfish Program
Jon Pennock, Ph.D.	Director	University of New Hampshire, Marine Program and Sea Grant
Fay Rubin	Project Director	University of New Hampshire, Complex Systems Research Center
Fred Short, Ph.D.	Research Professor	University of New Hampshire, Marine Program
Sally Soule	Coastal Nonpoint Pollution Control Program Coordinator	NH DES, Coastal Program
Phil Trowbridge, P.E.	Coastal Scientist	NH DES and New Hampshire Estuaries Project

INTRODUCTION

The New Hampshire Estuaries Project (NHEP) is part of the U.S. Environmental Protection Agency's National Estuary Program, which is a joint local/state/federal program established under the Clean Water Act with the goal of protecting and enhancing nationally significant estuarine resources. The NHEP is funded by the EPA and is administered by the University of New Hampshire.

The NHEP's Comprehensive Conservation and Management Plan for New Hampshire's estuaries was completed in 2000 and implementation is ongoing. The Management Plan outlines key issues related to management of New Hampshire's estuaries and proposes strategies (Action Plans) that are expected to preserve, protect, and enhance the State's estuarine resources. The NHEP's priorities were established by local stakeholders and include water quality improvements, shellfish resources, land protection, and habitat restoration. Projects addressing these priorities are undertaken throughout NH's coastal watershed, which includes 42 communities.

Every three years, the NHEP prepares a State of the Estuaries report with information on the status and trends of a select group of environmental indicators from the coastal watershed and estuaries. The report provides the NHEP, state natural resource managers, local officials, conservation organizations, and the public with information on the effects of management actions and decisions.

Prior to developing each State of the Estuaries report, the NHEP publishes four technical data reports ("indicator reports") that illustrate the status and trends of the complete collection of indicators tracked by the NHEP. Each report focuses on a different suite of indicators: Shellfish, Water Quality, Land Use and Development, and Critical Habitats and Species. All of the indicators are presented to the NHEP Technical Advisory Committee, which selects a subset of indicators to be presented to the NHEP Management Committee and to be included in the State of the Estuaries report. The Management Committee reviews the indicators and finalizes the list to be included in the report. Between 10 and 20 indicators are included in each State of the Estuaries report. The 2006 Land Use and Development Indicator Report is the second NHEP indicator report on this subject. Data from this report will be used in the 2006 State of the Estuaries report.

The following sections contain the most recent data for the 7 land use and development indicators tracked by the NHEP. In some cases the NHEP funds data collection and monitoring activities; however data for the majority of indicators are provided by other organizations with monitoring programs. The details of the monitoring programs and performance criteria for the indicators are listed in the NHEP Monitoring Plan (NHEP, 2004).

The results and interpretations for the indicators presented in this report have been peer reviewed by the NHEP Technical Advisory Committee and other experts in relevant fields. The Technical Advisory Committee consists of university professors, researchers and state and federal environmental managers from a variety of disciplines and perspectives. The conclusions of this study represent the current scientific consensus regarding conditions in New Hampshire's estuaries.

LUD1 - IMPERVIOUS SURFACES IN COASTAL WATERSHEDS

Monitoring Objective

The objective of this indicator is to estimate the percentage of land area that is covered by impervious surfaces in each subwatershed of the coastal watershed. This indicator answers the following monitoring questions:

How much of New Hampshire's coastal watershed is covered by impervious surfaces?

How many watersheds have more than 10% of the land area covered by impervious surfaces?

Has the rate of creation of new impervious surfaces in coastal watersheds changed over time?

Measurable Goal

The goal is to have none of the subwatersheds in the coastal watershed with impervious surfaces covering more than 10% of the watershed area. In other states, impervious surfaces covering greater than 10% of the watershed area has resulted in water quality deterioration (CWP, 2003; Shueller, 1995). A recent New Hampshire study confirms this finding (Deacon et al., 2005). However, the proximity of the impervious surfaces to water bodies and stormwater management practices in effect may be more important than the total area in the watershed.

Data Analysis and Statistical Methods

Impervious surfaces were mapped throughout the coastal watershed using satellite imagery (Landsat TM, 30-meter resolution) from 1990, 2000 and 2005 (Justice and Rubin, 2002; Justice and Rubin, 2006). Using ArcInfo/ArcView software, the total area of impervious surfaces in each HUC12 subwatershed and town in the coastal watershed was calculated and then divided by the total land area of that watershed or town to estimate the percent impervious cover. Land area was calculated by subtracting the area in hydrography polygons from the total area of the watershed or town. The uncertainty in each percent impervious calculation was assumed to be +/- 0.7%. This uncertainty was calculated in NHEP (2003) for the average size watershed and town. Therefore, in order to account for uncertainty, a calculated value of percent imperviousness was considered to be significantly higher than the goal of 10% if the calculated value was greater than 10.7%.

Results

The percent impervious results for the 37 HUC12 watersheds and 42 municipalities in the coastal watershed are reported on Table 1 and Table 2. Overall, the area of impervious surfaces has grown from 24,349 acres in 1990 to 35,503 acres in 2000 to 41,784 acres in 2005 (Table 3). The number of watersheds with greater than 10% impervious surface cover was 2 in 1990, 6 in 2000, and 10 in 2005. The number of

towns with greater than 10% impervious surface cover has grown similarly (Figure 1). On a percentage basis, the 4.7%, 6.8%, and 8.0% of the land area in the watershed was covered by impervious surfaces in 1990, 2000, and 2005, respectively (Figure 2). Between 1990 and 2000, 11,154 acres of impervious surfaces were added to the watershed (1,115 acres per year). Impervious surfaces were added at a slightly higher rate between 2000 and 2005 (1,256 acres per year) (Figure 3). All of these summary statistics show that impervious surfaces continue to be added to the watershed at about the same rate. On average, 1,185 acres of impervious surfaces were added to the watershed each year for the 15-year period, which amounts to 0.2% of the land area in the watershed each year.

Maps of the percent of impervious surfaces in each coastal watershed in 1990, 2000, and 2005 are shown in Figure 4, Figure 5, and Figure 6, respectively. The coastal watersheds which did not meet the NHEP goal of <10% impervious surface cover in 2005 are shown on Figure 7. Similar maps for the coastal municipalities are provided in Figure 8, Figure 9, Figure 10, and Figure 11. The watersheds and municipalities which did not meet the NHEP goal are along the Atlantic Coast and up the Route 16 corridor along the Salmon Falls River and the Cocheco River (Figure 7, Figure 11).

The original goal from the NHEP Management Plan, which was set before the level of impervious surface cover was known, was to keep the percent impervious surfaces in all coastal watersheds less than 10%. Based on the results presented above, this goal is not being met, nor will the goal be met in the near future since impervious surfaces are unlikely to decline over time. As an interim goal, the NHEP should work to slow the growth of impervious surfaces in those watersheds that are still less than 10% impervious so that the number of watersheds exceeding 10% impervious does not increase from the current number of 10. In those watersheds and towns where there is already greater than 10% impervious, the priority should be to develop stormwater management plans to mitigate the effects of stormwater runoff, as well as promoting mechanisms to slow additional impervious surface growth.

Table 1: Impervious surface coverage in coastal watersheds

Watershed		Mapped Area (acres)			Impervious Surfaces (acres)			Percent Imperviousness (%)				Meeting	Comments
HUC10	HUC12	Water	Land	Total	1990	2000	2005	1990	2000	2005	Goal	Goal	
Salmon Falls River	Upper Branch River-Lovell Lake	840	17,543	18,383	402.8	555.4	616.7	2.3%	3.2%	3.5%	10%	Yes	
Salmon Falls River	Junes Brook-Branch River	166	17,074	17,240	318.7	442.6	497.0	1.9%	2.6%	2.9%	10%	Yes	
Salmon Falls River	Headwaters-Great East Lake	1,307	8,761	10,068	168.3	246.5	287.6	1.9%	2.8%	3.3%	10%	Yes	(1)
Salmon Falls River	Milton Pond	323	7,002	7,325	194.6	275.0	327.1	2.8%	3.9%	4.7%	10%	Yes	(1)
Salmon Falls River	Middle Salmon Falls River	193	15,563	15,755	1,093.7	1,535.8	1,929.0	7.0%	9.9%	12.4%	10%	No	(1)
Salmon Falls River	Lower Salmon Falls River	5	3,054	3,059	295.9	379.1	436.0	9.7%	12.4%	14.3%	10%	No	(1)
Cocheco River	Upper Cocheco River	516	27,141	27,657	699.9	970.3	1,174.8	2.6%	3.6%	4.3%	10%	Yes	
Cocheco River	Axe Handle Brook	310	7,087	7,397	212.3	290.2	363.9	3.0%	4.1%	5.1%	10%	Yes	
Cocheco River	Middle Cocheco River	98	15,853	15,952	1,267.3	1,684.5	1,911.7	8.0%	10.6%	12.1%	10%	No	
Cocheco River	Bow Lake	1,240	7,885	9,125	121.0	184.7	216.7	1.5%	2.3%	2.7%	10%	Yes	
Cocheco River	Nippo Brook-Isinglass River	250	17,139	17,389	266.0	373.5	452.8	1.6%	2.2%	2.6%	10%	Yes	
Cocheco River	Long Pond	324	9,829	10,153	148.0	220.7	248.9	1.5%	2.2%	2.5%	10%	Yes	
Cocheco River	Lower Isinglass River	337	14,271	14,609	802.7	1,183.8	1,339.2	5.6%	8.3%	9.4%	10%	Yes	
Cocheco River	Lower Cocheco River	100	16,084	16,184	1,502.4	2,080.2	2,535.1	9.3%	12.9%	15.8%	10%	No	
Lamprey River	Headwaters-Lamprey River	200	21,727	21,927	371.6	593.2	726.9	1.7%	2.7%	3.3%	10%	Yes	
Lamprey River	North Branch River	114	10,933	11,047	255.0	392.7	459.4	2.3%	3.6%	4.2%	10%	Yes	
Lamprey River	Middle Lamprey River	426	25,796	26,222	1,232.4	1,879.7	2,217.0	4.8%	7.3%	8.6%	10%	Yes	
Lamprey River	Pawtuckaway Pond	913	12,140	13,052	111.6	171.0	193.9	0.9%	1.4%	1.6%	10%	Yes	
Lamprey River	Bean River	252	14,820	15,072	256.3	374.4	461.9	1.7%	2.5%	3.1%	10%	Yes	
Lamprey River	North River	66	8,555	8,622	155.8	255.7	320.6	1.8%	3.0%	3.7%	10%	Yes	
Lamprey River	Little River (Lamprey)	369	12,804	13,173	289.0	446.0	531.2	2.3%	3.5%	4.1%	10%	Yes	
Lamprey River	Piscassic River	96	14,414	14,510	513.6	885.0	1,091.0	3.6%	6.1%	7.6%	10%	Yes	
Lamprey River	Lower Lamprey River	86	13,141	13,226	521.4	767.8	831.1	4.0%	5.8%	6.3%	10%	Yes	
Exeter River	Watson Brook	91	10,484	10,575	330.5	531.5	642.3	3.2%	5.1%	6.1%	10%	Yes	
Exeter River	Towle Brook-Lily Pond	222	20,985	21,208	649.6	1,090.9	1,360.5	3.1%	5.2%	6.5%	10%	Yes	
Exeter River	Spruce Swamp-Little River	46	14,338	14,384	649.2	1,022.8	1,179.2	4.5%	7.1%	8.2%	10%	Yes	
Exeter River	Little River (Exeter)	34	9,855	9,889	563.0	823.0	1,001.0	5.7%	8.4%	10.2%	10%	Yes	
Exeter River	Great Brook-Exeter River	53	12,309	12,363	497.1	782.7	928.9	4.0%	6.4%	7.5%	10%	Yes	
Exeter River	Squamscott River	25	13,269	13,294	915.1	1,379.6	1,645.0	6.9%	10.4%	12.4%	10%	No	
Great Bay Drainage	Winnicut River	67	11,147	11,214	777.9	1,189.7	1,381.4	7.0%	10.7%	12.4%	10%	No	
Great Bay Drainage	Oyster River	161	19,714	19,875	969.3	1,480.3	1,664.1	4.9%	7.5%	8.4%	10%	Yes	
Great Bay Drainage	Bellamy River	467	21,167	21,634	1,147.9	1,707.9	2,028.4	5.4%	8.1%	9.6%	10%	Yes	
Great Bay Drainage	Great Bay	135	18,192	18,327	810.3	1,185.9	1,342.0	4.5%	6.5%	7.4%	10%	Yes	
Coastal Drainage	Portsmouth Harbor	205	11,650	11,855	2,310.3	2,974.9	3,363.5	19.8%	25.5%	28.9%	10%	No	(1)
Coastal Drainage	Berrys Brook-Rye Harbor	123	10,503	10,626	842.6	1,236.8	1,414.8	8.0%	11.8%	13.5%	10%	No	
Coastal Drainage	Taylor River-Hampton River	195	14,412	14,607	1,156.6	1,745.4	2,145.1	8.0%	12.1%	14.9%	10%	No	
Coastal Drainage	Hampton Harbor	172	14,114	14,286	1,529.2	2,163.3	2,518.5	10.8%	15.3%	17.8%	10%	No	(1)
TOTAL		**10,525**	**520,756**	**531,281**	**24,349**	**35,503**	**41,784**	**4.7%**	**6.8%**	**8.0%**	10%		

(1) Only NH portion of watershed was mapped.

(2) Data Source: UNH Complex Systems Research Center

(3) The uncertainty for all the percent impervious values was assumed to be +/-0.7%. This value is the size of the error bar for an average watershed.

Table 2: Impervious surface coverage in coastal municipalities

Town		Mapped Area (acres)			Impervious Surface (acres)			Percent Imperviousness (%)				Meeting
Name	FIPS	Total	Water	Land	1990	2000	2005	1990	2000	2005	Goal	Goal
BARRINGTON	17005	31,117	1,398	29,719	763.5	1,186.7	1,387.0	2.6%	4.0%	4.7%	10%	Yes
BRENTWOOD	15015	10,862	121	10,742	532.1	828.8	1,023.2	5.0%	7.7%	9.5%	10%	Yes
BROOKFIELD	3015	14,880	287	14,593	139.2	190.8	198.2	1.0%	1.3%	1.4%	10%	Yes
CANDIA	15020	19,557	215	19,342	531.4	794.0	930.9	2.7%	4.1%	4.8%	10%	Yes
CHESTER	15025	16,718	98	16,620	423.4	720.4	855.5	2.5%	4.3%	5.1%	10%	Yes
DANVILLE	15030	7,569	131	7,439	260.4	445.3	533.7	3.5%	6.0%	7.2%	10%	Yes
DEERFIELD	15035	33,349	762	32,587	492.0	768.0	969.0	1.5%	2.4%	3.0%	10%	Yes
DOVER	17010	18,592	1,498	17,094	1,872.6	2,626.4	3,171.6	11.0%	15.4%	18.6%	10%	No
DURHAM	17015	15,852	1,543	14,308	675.0	1,025.6	1,098.0	4.7%	7.2%	7.7%	10%	Yes
EAST KINGSTON	15045	6,381	62	6,319	221.5	335.2	439.3	3.5%	5.3%	7.0%	10%	Yes
EPPING	15050	16,776	308	16,468	657.8	1,070.8	1,291.8	4.0%	6.5%	7.8%	10%	Yes
EXETER	15055	12,814	261	12,553	937.4	1,375.8	1,559.3	7.5%	11.0%	12.4%	10%	No
FARMINGTON	17020	23,640	419	23,221	687.1	965.6	1,089.5	3.0%	4.2%	4.7%	10%	Yes
FREMONT	15060	11,143	107	11,036	329.3	537.9	654.3	3.0%	4.9%	5.9%	10%	Yes
GREENLAND	15065	8,524	1,744	6,780	455.0	712.6	844.9	6.7%	10.5%	12.5%	10%	No
HAMPTON	15075	9,071	754	8,317	1,179.3	1,605.5	1,717.1	14.2%	19.3%	20.6%	10%	No
HAMPTON FALLS	15073	8,077	358	7,719	341.8	536.1	698.7	4.4%	6.9%	9.1%	10%	Yes
KENSINGTON	15085	7,668	31	7,637	243.3	378.4	469.8	3.2%	5.0%	6.2%	10%	Yes
KINGSTON	15090	13,450	955	12,495	651.0	1,018.7	1,211.7	5.2%	8.2%	9.7%	10%	Yes
LEE	17025	12,928	248	12,680	467.6	740.5	840.6	3.7%	5.8%	6.6%	10%	Yes
MADBURY	17030	7,799	396	7,403	251.5	393.7	391.7	3.4%	5.3%	5.3%	10%	Yes
MIDDLETON	17035	11,843	283	11,560	204.5	284.2	350.4	1.8%	2.5%	3.0%	10%	Yes
MILTON	17040	21,935	836	21,099	597.4	838.8	985.3	2.8%	4.0%	4.7%	10%	Yes
NEW CASTLE	15100	1,348	843	504	108.1	155.0	170.9	21.4%	30.7%	33.9%	10%	No
NEW DURHAM	17045	28,054	1,707	26,347	458.3	627.9	727.2	1.7%	2.4%	2.8%	10%	Yes
NEWFIELDS	15105	4,647	105	4,542	141.6	250.6	307.5	3.1%	5.5%	6.8%	10%	Yes
NEWINGTON	15110	7,916	2,701	5,215	686.9	941.0	1,055.8	13.2%	18.0%	20.2%	10%	No
NEWMARKET	15115	9,080	1,007	8,073	479.7	706.6	818.8	5.9%	8.8%	10.1%	10%	Yes
NORTH HAMPTON	15125	8,922	57	8,865	647.5	957.6	1,100.2	7.3%	10.8%	12.4%	10%	No
NORTHWOOD	15130	19,356	1,380	17,976	424.1	610.1	716.7	2.4%	3.4%	4.0%	10%	Yes
NOTTINGHAM	15135	30,997	1,116	29,880	447.9	692.7	842.2	1.5%	2.3%	2.8%	10%	Yes
PORTSMOUTH	15145	10,763	762	10,001	2,128.3	2,726.0	3,054.3	21.3%	27.3%	30.5%	10%	No
RAYMOND	15150	18,944	495	18,448	977.3	1,483.6	1,713.6	5.3%	8.0%	9.3%	10%	Yes
ROCHESTER	17050	29,081	750	28,331	2,395.2	3,304.5	3,942.3	8.5%	11.7%	13.9%	10%	No
ROLLINSFORD	17055	4,843	161	4,682	265.5	381.3	437.4	5.7%	8.1%	9.3%	10%	Yes
RYE	15155	8,424	426	7,997	586.5	877.9	1,026.3	7.3%	11.0%	12.8%	10%	No
SANDOWN	15165	9,232	343	8,889	337.2	544.2	701.3	3.8%	6.1%	7.9%	10%	Yes
SEABROOK	15170	6,160	491	5,669	801.6	1,206.1	1,538.7	14.1%	21.3%	27.1%	10%	No
SOMERSWORTH	17060	6,399	179	6,220	767.7	1,021.2	1,256.7	12.3%	16.4%	20.2%	10%	No
STRAFFORD	17065	32,779	1,626	31,153	434.0	637.9	726.6	1.4%	2.0%	2.3%	10%	Yes
STRATHAM	15180	9,901	228	9,672	628.3	979.2	1,245.7	6.5%	10.1%	12.9%	10%	No
WAKEFIELD	3090	28,716	3,452	25,264	877.9	1,224.8	1,407.1	3.5%	4.8%	5.6%	10%	Yes
TOTAL		**616,105**	**30,643**	**585,462**	**26,507**	**38,708**	**45,501**	**4.5%**	**6.6%**	**7.8%**		

(1) Data Source: UNH Complex Systems Research Center

(2) The uncertainty for all the %impervious values was assumed to be +/-0.7%. This value is the size of the error bar for an average watershed.

Table 3: Summary statistics for impervious surfaces in coastal watersheds and towns, 1990-2005

Statistic	1990	2000	2005
Acres of impervious surfaces in coastal watershed	24,349	35,503	41,784
Percent of land area covered by impervious surfaces	4.7%	6.8%	8.0%
Number of subwatersheds with more than 10% impervious surface cover (out of 37)	2	6	10
Number of towns with more than 10% impervious surface cover (out of 42)	7	11	13

Figure 1: Number of watersheds and towns with greater than 10% impervious surface cover in 1990, 2000 and 2005

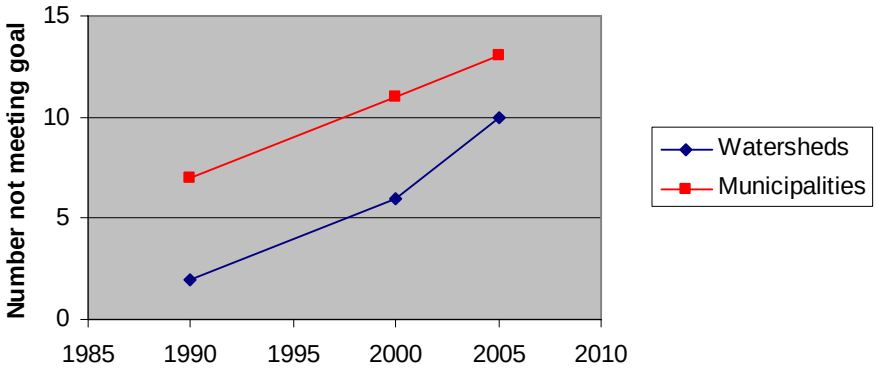


Figure 2: Impervious surface cover in the entire coastal watershed in 1990, 2000, and 2005

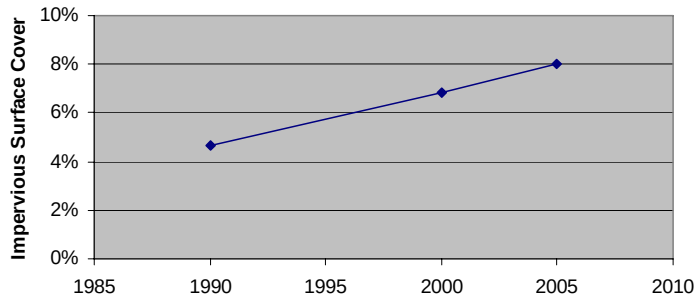


Table 4: Summary statistics for impervious surfaces added to the coastal watershed in 1990 to 2000 and 2000 to 2005

Statistics	1990-2000	2000-2005
Acres of impervious surface added in period	11,154	6,282
Acres of impervious surfaces added per year in period	1,115	1,256

Figure 3: Acres of impervious surfaces added to the coastal watershed per year

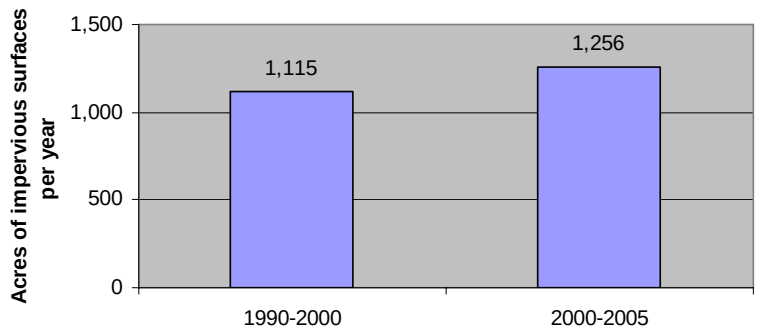


Figure 4: Percent impervious surfaces in coastal watersheds in 1990

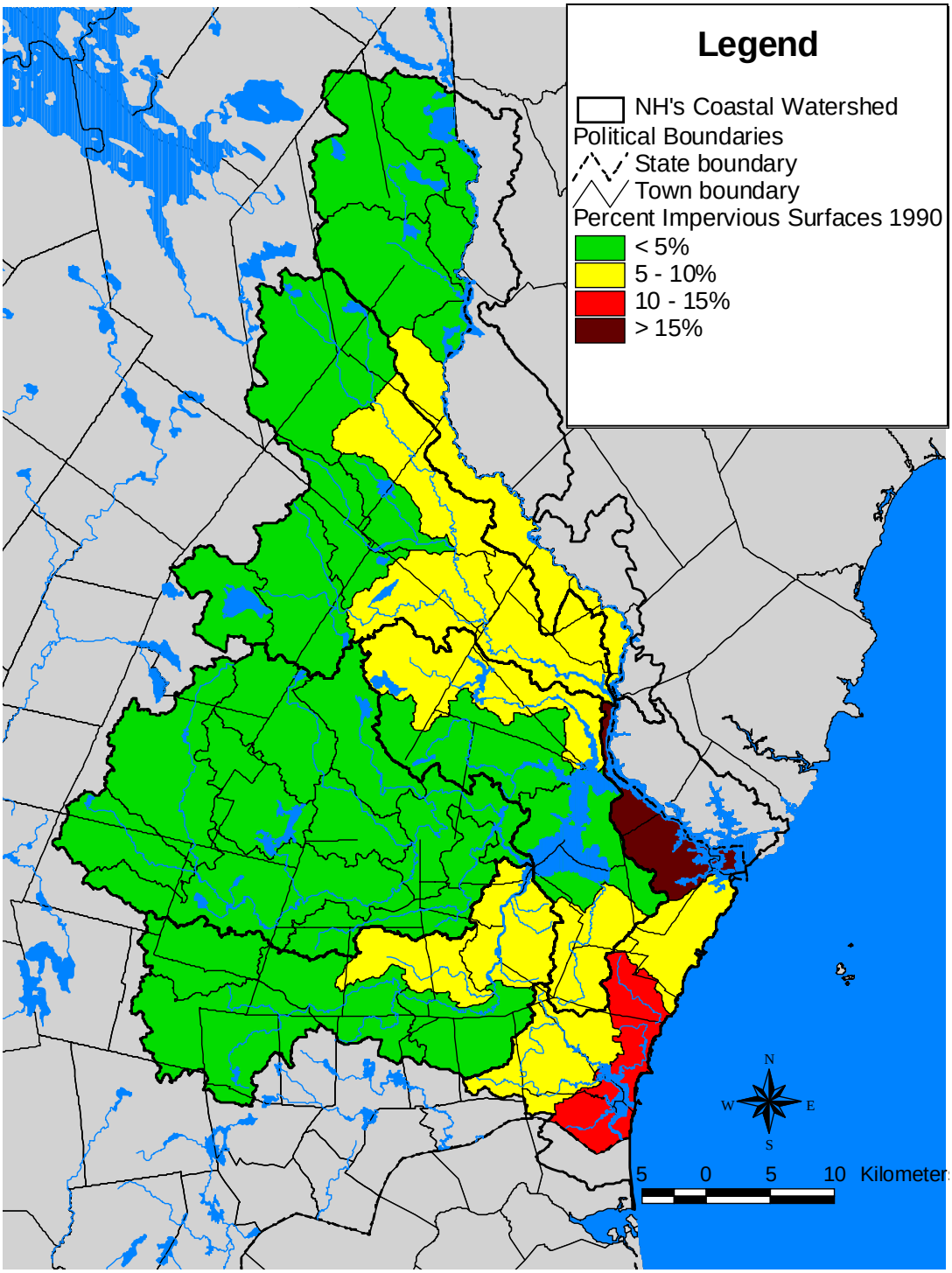


Figure 5: Percent impervious surfaces in coastal watersheds in 2000

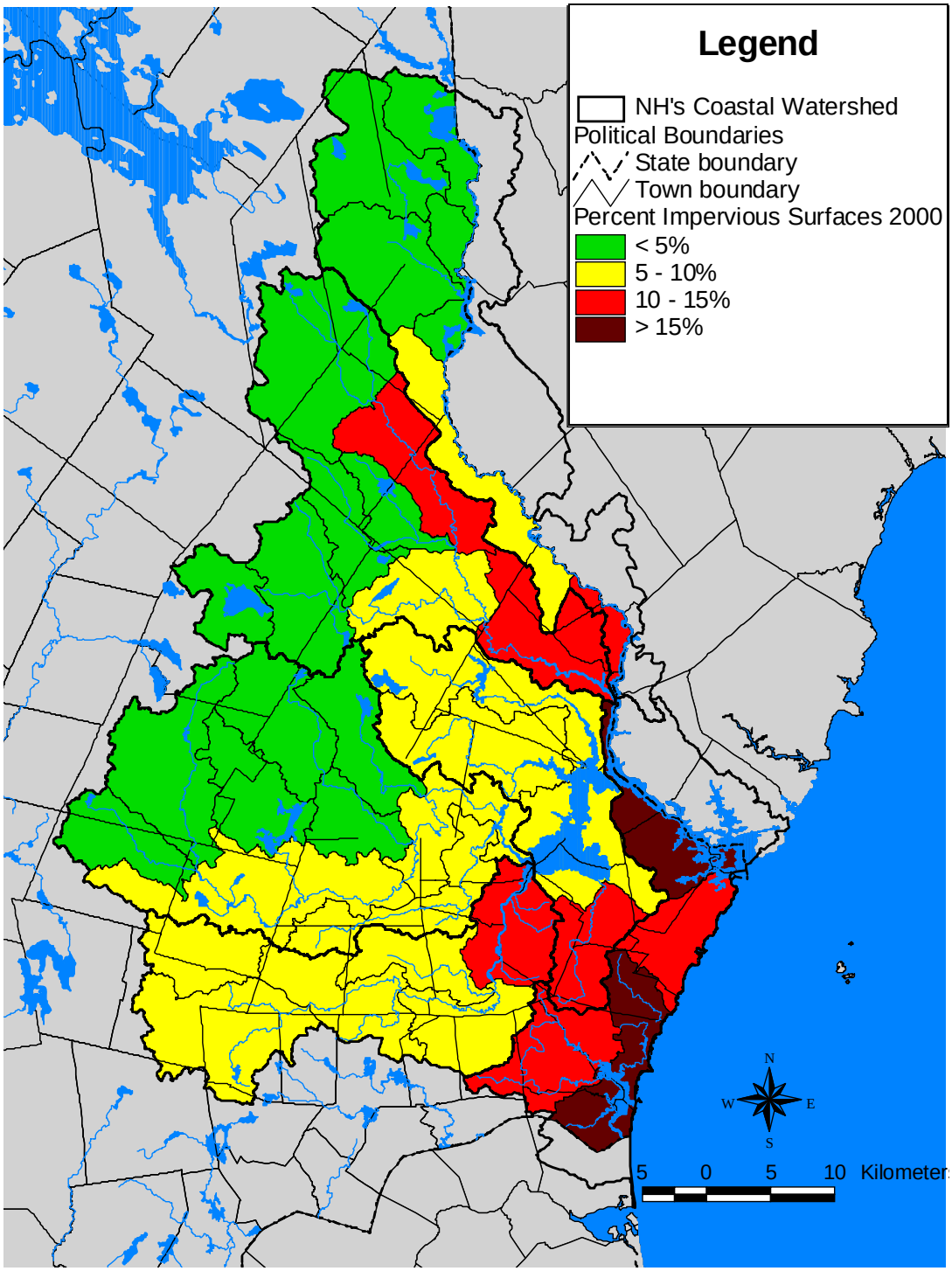


Figure 6: Percent impervious surfaces in coastal watersheds in 2005

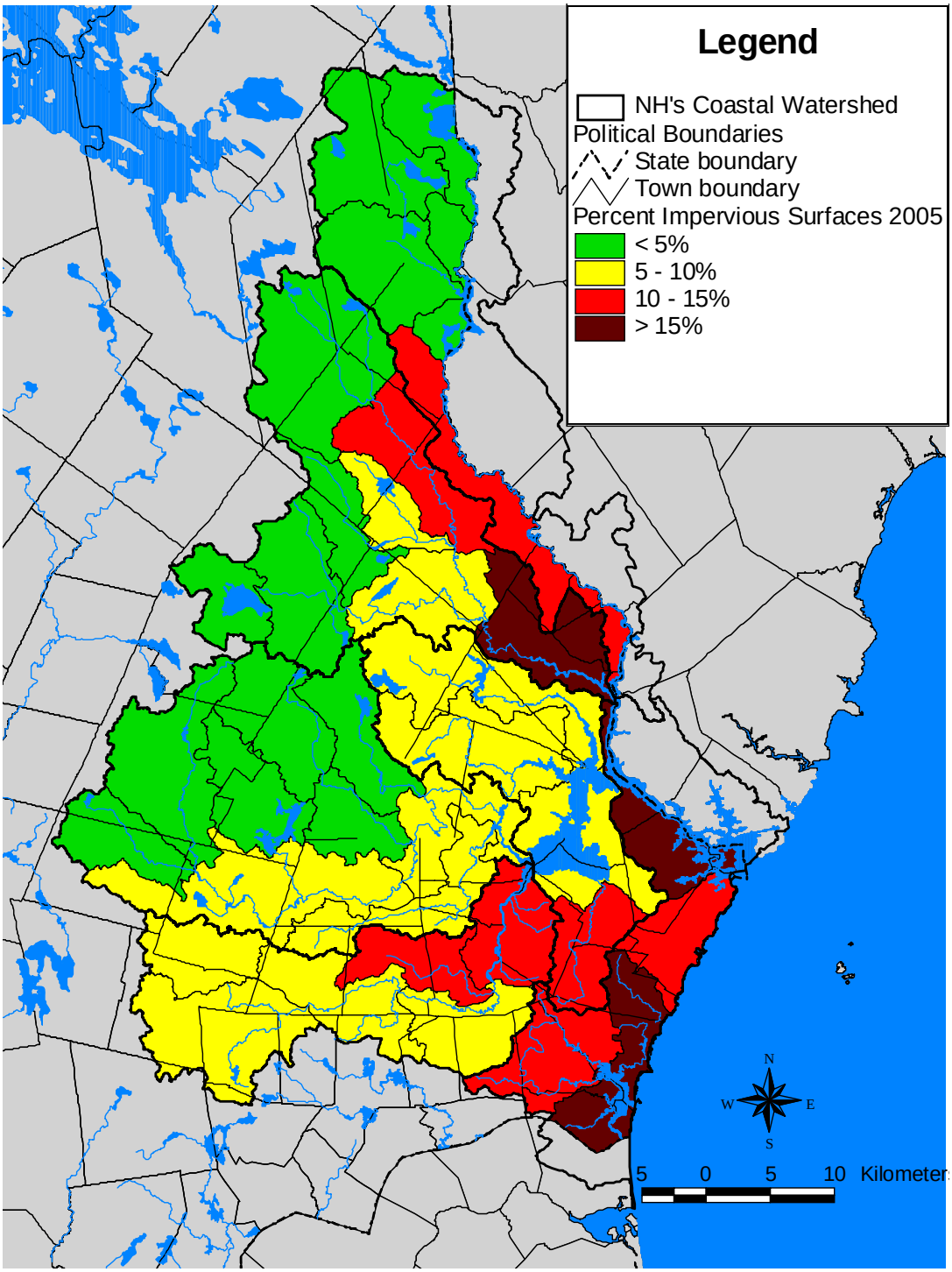


Figure 7: Coastal watersheds that did not meet the NHEP goal for percent imperviousness in 2005

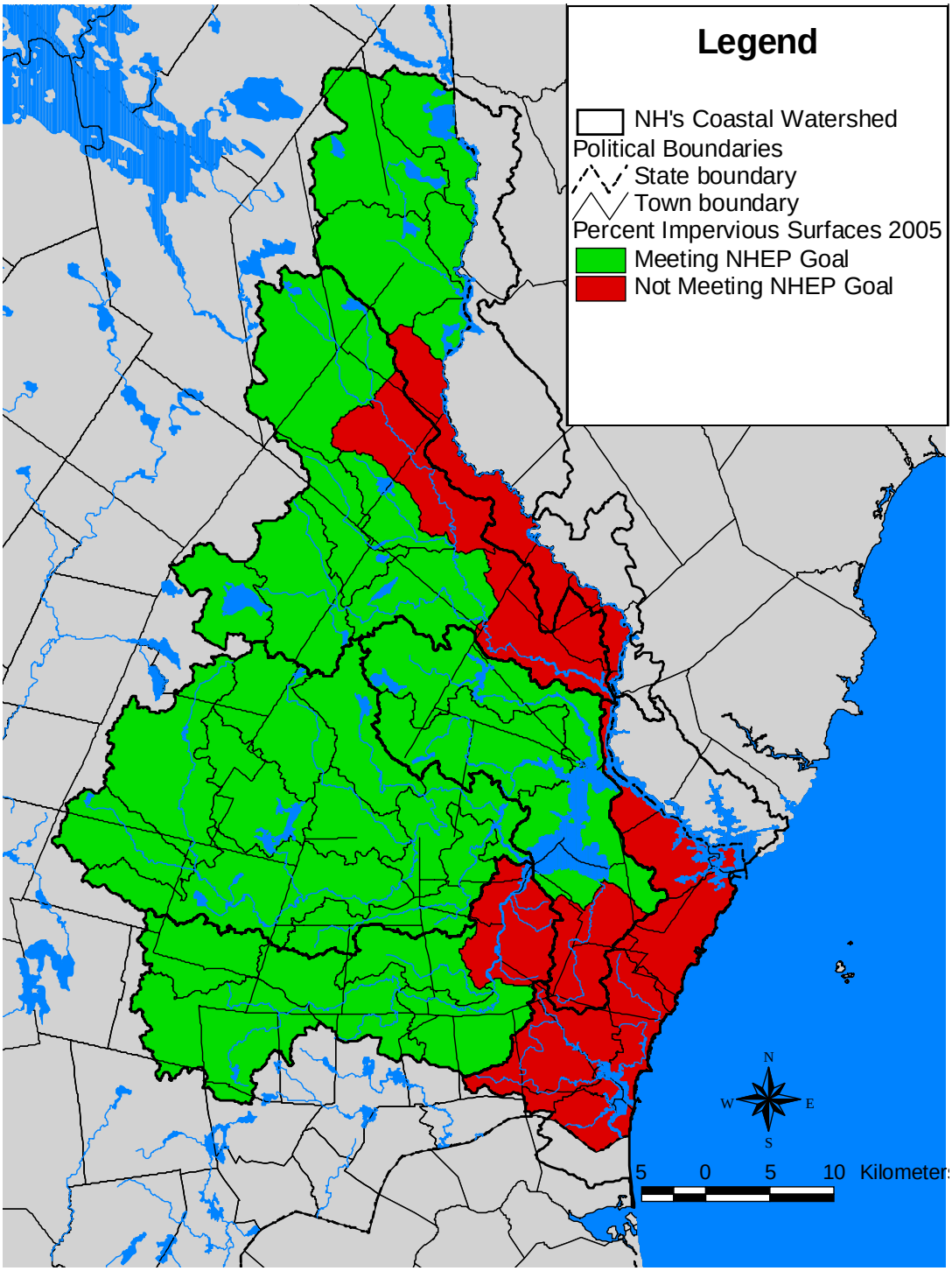


Figure 8: Percent impervious surfaces in coastal municipalities in 1990

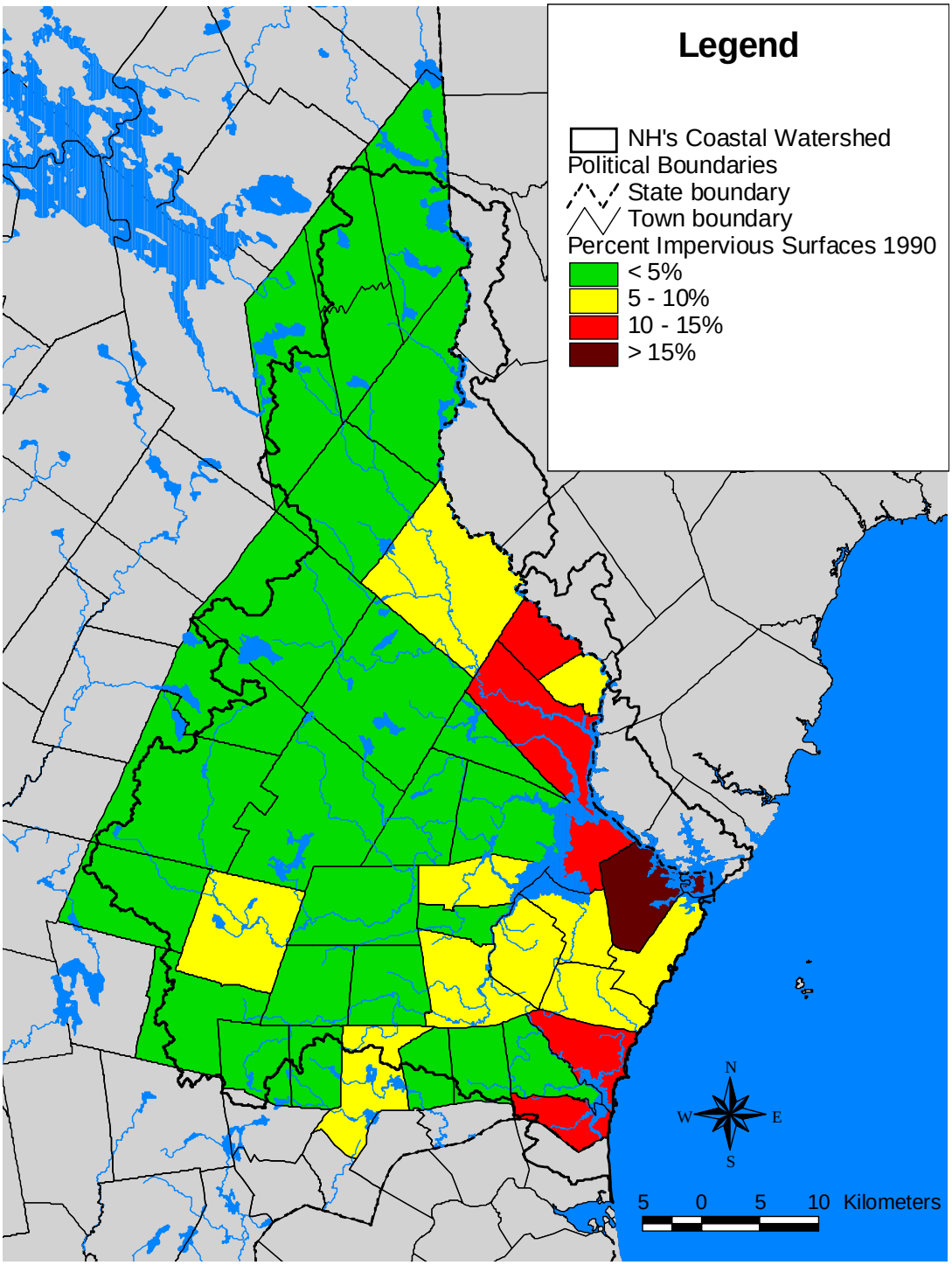


Figure 9: Percent impervious surfaces in coastal municipalities in 2000

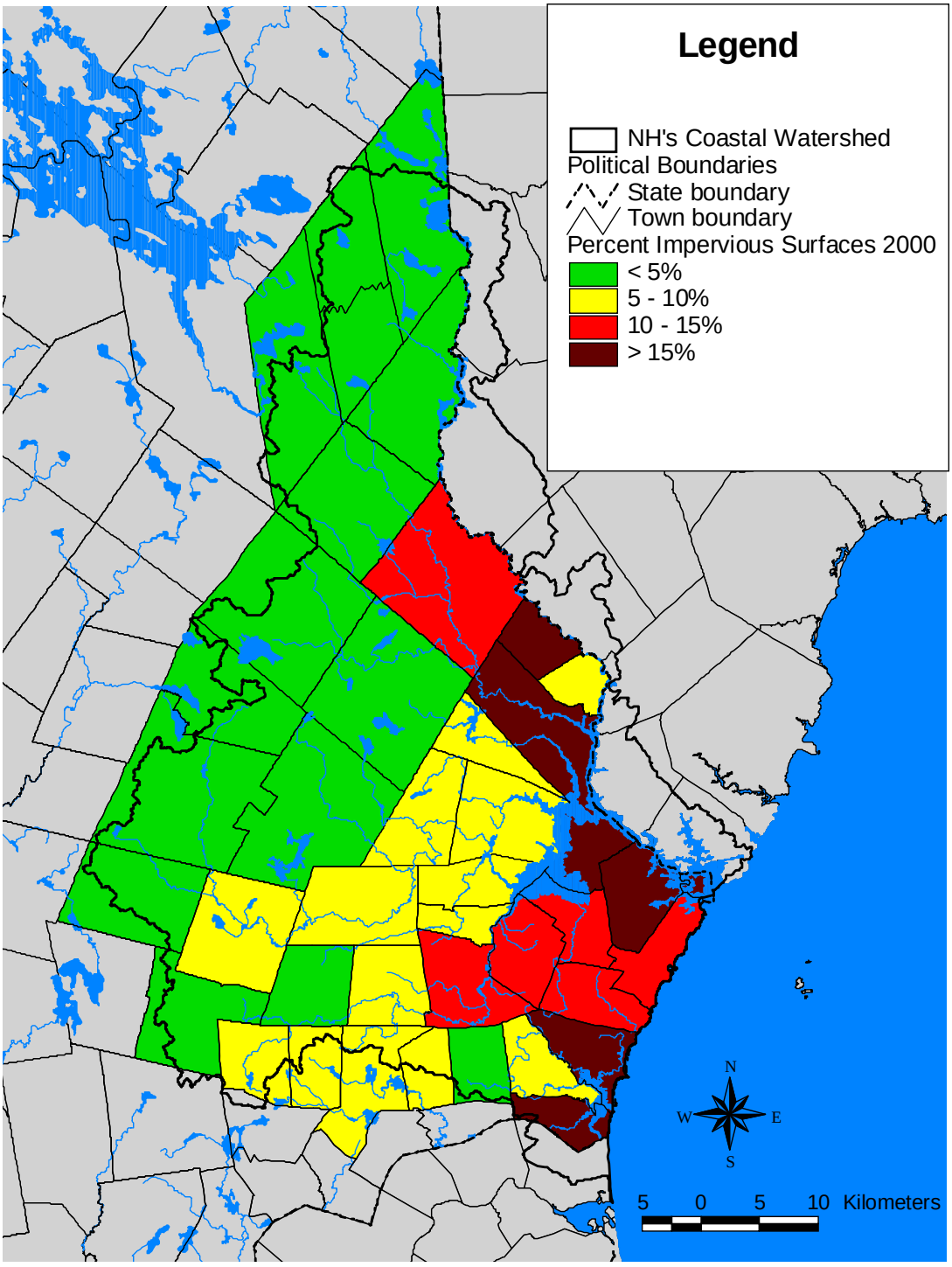


Figure 10: Percent impervious surfaces in coastal municipalities in 2005

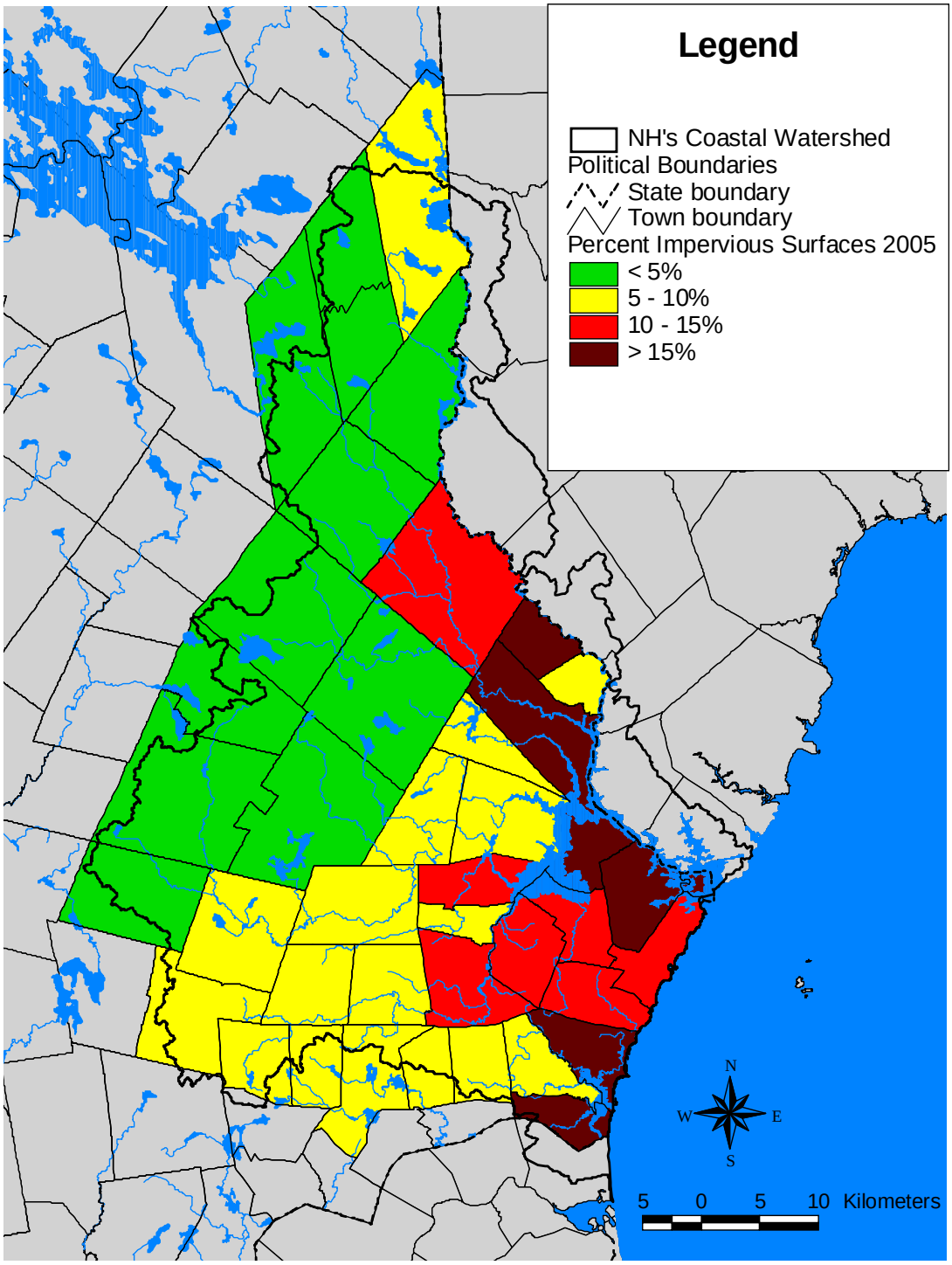
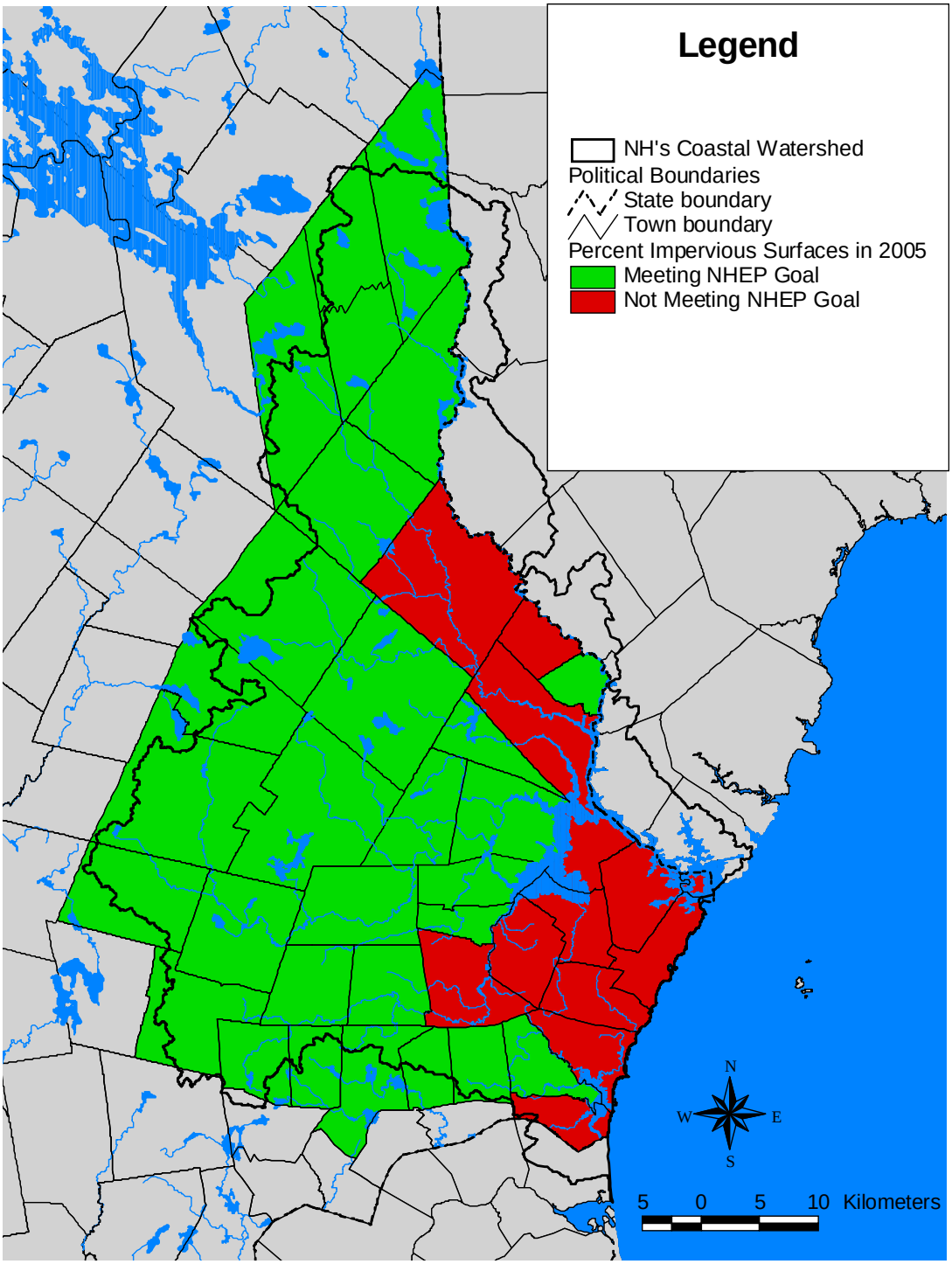


Figure 11: Coastal municipalities that did not meet the NHEP goal for



LUD2 - RATE OF SPRAWL – HIGH IMPACT DEVELOPMENT

Monitoring Objective

There is no accepted metric for calculating the rate of sprawl. However, common attributes of land use associated with sprawl include increasing land consumption per person. For this first indicator of sprawl, the ratio of the acres of imperviousness to the total population ("imperviousness per capita") are calculated for each town. An increase of impervious surfaces in a town is a particularly good indicator of the level of high impact development (e.g., large shopping malls, highways). Ratios of imperviousness to population for different years are compared to determine whether the development per capita is growing, declining, or remaining the same for a town. The imperviousness per capita ratios are used to answer the following monitoring question:

Is the coastal watershed experiencing "sprawl-type" development?

Measurable Goal

New development in coastal watershed towns between 2000 and 2010 should add no more than 0.1 acres of impervious surfaces per new resident. In 2000, the average imperviousness per capita in the coastal watershed was 0.2 acres/person. The NHEP goal is to cut in half the average rate of production of imperviousness per person for new construction. Specifically, the goal for each municipality will be calculated according the following formula:

$$Goal = \frac{impacres_{2000} + 0.1 \times (pop - pop_{2000})}{pop}$$

where $impacres_{2000}$ is the acres of impervious surfaces in the town in 2000, pop_{2000} is the population of the town in 2000, and pop is the population of the town at the time of the assessment.

Data Analysis and Statistical Methods

Impervious surfaces were mapped throughout the coastal watershed using satellite imagery (Landsat TM, 30 meter resolution) from 1990, 2000 and 2005 (Justice and Rubin, 2002; Justice and Rubin, 2006). Using ArcInfo/ArcView software, the total area of impervious surfaces in each town in the coastal watershed was calculated. US Census population totals for each town were obtained for 1990 and 2000 from the NH State Data Center. Town level population totals were not available for 2005. The 2005 population totals were estimated using the 2004 town population estimates from the NH Office of Energy and Planning and the 2005 state population estimate from the US Census Bureau. Each of the 2004 town populations was divided by the state population in 2004. The resulting fraction for each town was subsequently multiplied by the 2005 state population to estimate the town population in 2005. The "imperviousness per capita" for 1990, 2000 and 2005 was calculated by dividing the total acres of impervious surfaces in the town by the town population. The uncertainty in each impervious surface per capita calculation was assumed to be +/-

0.015 acres/person. This uncertainty was calculated in NHEP (2003) for the average size watershed and town. Therefore, in order to account for uncertainty, a calculated value of impervious surfaces per capita was considered to be significantly higher than the goal if the calculated value was greater than the goal by more than 0.015 acres/ person.

Results

Population totals, impervious surface acres, and the imperviousness per capita for each municipality in the coastal watershed in 1990, 2000, and 2005 are shown in Table 5. Overall, the average imperviousness per capita for the 42 municipalities grew from 0.152 acres per person in 1990 to 0.201 acres per person in 2000 to 0.217 acres per person in 2005 (Figure 12). The average value for 2005 was higher than the average of the NHEP goals for the individual towns (0.193 acres per person). Only 15 of the 42 municipalities met their NHEP goals for imperviousness per capita. These statistics are clear evidence that land consumption per person in the coastal watershed is still increasing. The NHEP goals to reduce the imperviousness per capita for new construction have not been met.

While the average values indicate an overall problem with sprawling growth, the imperviousness per capita varied between municipalities. The imperviousness per capita in each municipality in 1990, 2000, and 2005 are shown on Figure 14, Figure 15, and Figure 16, respectively. The municipalities which did not meet their NHEP goal in 2005 are shown in Figure 17. Overall, there was a marked difference in imperviousness per capita between municipalities with <10,000 people (0.207 acres/ person) and municipalities with >10,000 people (0.120 acres/person) (Table 6). Of the 27 municipalities that did not meet their NHEP goal in 2005, only one was a municipality with >10,000 people (Somersworth). It makes sense that as municipalities approach build out, population growth results in development of smaller lots and in multi-storied buildings which do not have a much bigger impervious surface foot print than single family homes. The linear relationship between population and imperviousness may only be applicable to smaller towns with abundant undeveloped land.

The one municipality which is radically different from the rest is Newington. The imperviousness per capita for Newington was 1.33 acres per person in 2005, which is six times the average value. Newington is an exception due to the presence of runways for the former Pease Air Force Base, extensive commercial development, and low population.

Table 5: Impervious surfaces, population, and imperviousness per capita in coastal municipalities in 1990, 2000, and 2005

Town		Impervious Surface (acres)			Population			Imperviousness per Capita (ac/person)				Meeting
Name	FIPS	1990	2000	2005	1990	2000	2005	1990	2000	2005	Goal	goal?
BARRINGTON	17005	763.5	1,186.7	1,387.0	6,164	7,475	8,071	0.124	0.159	0.172	0.154	No
BRENTWOOD	15015	532.1	828.8	1,023.2	2,590	3,197	4,069	0.205	0.259	0.251	0.225	No
BROOKFIELD	3015	139.2	190.8	198.2	518	604	666	0.269	0.316	0.298	0.296	Yes
CANDIA	15020	531.4	794.0	930.9	3,557	3,911	4,141	0.149	0.203	0.225	0.197	No
CHESTER	15025	423.4	720.4	855.5	2,691	3,792	4,570	0.157	0.190	0.187	0.175	Yes
DANVILLE	15030	260.4	445.3	533.7	2,534	4,023	4,426	0.103	0.111	0.121	0.110	Yes
DEERFIELD	15035	492.0	768.0	969.0	3,124	3,678	4,190	0.157	0.209	0.231	0.196	No
DOVER	17010	1,872.6	2,626.4	3,171.6	25,042	26,884	28,776	0.075	0.098	0.110	0.098	Yes
DURHAM	17015	675.0	1,025.6	1,098.0	11,818	12,664	13,321	0.057	0.081	0.082	0.082	Yes
EAST KINGSTON	15045	221.5	335.2	439.3	1,352	1,784	1,983	0.164	0.188	0.222	0.179	No
EPPING	15050	657.8	1,070.8	1,291.8	5,162	5,476	5,935	0.127	0.196	0.218	0.188	No
EXETER	15055	937.4	1,375.8	1,559.3	12,481	14,058	14,584	0.075	0.098	0.107	0.098	Yes
FARMINGTON	17020	687.1	965.6	1,089.5	5,739	5,774	6,540	0.120	0.167	0.167	0.159	Yes
FREMONT	15060	329.3	537.9	654.3	2,576	3,510	3,989	0.128	0.153	0.164	0.147	No
GREENLAND	15065	455.0	712.6	844.9	2,768	3,208	3,408	0.164	0.222	0.248	0.215	No
HAMPTON	15075	1,179.3	1,605.5	1,717.1	12,278	14,937	15,423	0.096	0.107	0.111	0.107	Yes
HAMPTON FALLS	15073	341.8	536.1	698.7	1,503	1,880	2,014	0.227	0.285	0.347	0.273	No
KENSINGTON	15085	243.3	378.4	469.8	1,631	1,893	2,068	0.149	0.200	0.227	0.191	No
KINGSTON	15090	651.0	1,018.7	1,211.7	5,591	5,862	6,205	0.116	0.174	0.195	0.170	No
LEE	17025	467.6	740.5	840.6	3,729	4,145	4,364	0.125	0.179	0.193	0.175	No
MADBURY	17030	251.5	393.7	391.7	1,404	1,509	1,741	0.179	0.261	0.225	0.239	Yes
MIDDLETON	17035	204.5	284.2	350.4	1,183	1,440	1,662	0.173	0.197	0.211	0.184	No
MILTON	17040	597.4	838.8	985.3	3,691	3,910	4,329	0.162	0.215	0.228	0.203	No
NEW CASTLE	15100	108.1	155.0	170.9	840	1,010	1,045	0.129	0.153	0.164	0.152	Yes
NEW DURHAM	17045	458.3	627.9	727.2	1,974	2,220	2,429	0.232	0.283	0.299	0.267	No
NEWFIELDS	15105	141.6	250.6	307.5	888	1,551	1,646	0.160	0.162	0.187	0.158	No
NEWINGTON	15110	686.9	941.0	1,055.8	990	775	794	0.694	1.214	1.330	1.187	No
NEWMARKET	15115	479.7	706.6	818.8	7,157	8,027	9,184	0.067	0.088	0.089	0.090	Yes
NORTH HAMPTON	15125	647.5	957.6	1,100.2	3,637	4,259	4,522	0.178	0.225	0.243	0.218	No
NORTHWOOD	15130	424.1	610.1	716.7	3,124	3,640	3,897	0.136	0.168	0.184	0.163	No
NOTTINGHAM	15135	447.9	692.7	842.2	2,939	3,701	4,182	0.152	0.187	0.201	0.177	No
PORTSMOUTH	15145	2,128.3	2,726.0	3,054.3	25,925	20,784	21,117	0.082	0.131	0.145	0.131	Yes
RAYMOND	15150	977.3	1,483.6	1,713.6	8,713	9,674	10,416	0.112	0.153	0.165	0.150	Yes
ROCHESTER	17050	2,395.2	3,304.5	3,942.3	26,630	28,461	30,337	0.090	0.116	0.130	0.115	Yes
ROLLINSFORD	17055	265.5	381.3	437.4	2,645	2,648	2,690	0.100	0.144	0.163	0.143	No
RYE	15155	586.5	877.9	1,026.3	4,612	5,182	5,298	0.127	0.169	0.194	0.168	No
SANDOWN	15165	337.2	544.2	701.3	4,060	5,143	5,711	0.083	0.106	0.123	0.105	No
SEABROOK	15170	801.6	1,206.1	1,538.7	6,503	7,934	8,432	0.123	0.152	0.182	0.149	No
SOMERSWORTH	17060	767.7	1,021.2	1,256.7	11,249	11,477	11,851	0.068	0.089	0.106	0.089	No
STRAFFORD	17065	434.0	637.9	726.6	2,965	3,626	3,962	0.146	0.176	0.183	0.169	Yes
STRATHAM	15180	628.3	979.2	1,245.7	4,955	6,355	6,965	0.127	0.154	0.179	0.149	No
WAKEFIELD	3090	877.9	1,224.8	1,407.1	3,057	4,252	4,705	0.287	0.288	0.299	0.270	No
AVERAGE								**0.152**	**0.201**	**0.217**	**0.193**	

(1) Data source for population: NH Office of Energy and Planning, 2004 estimates extrapolated to 2005 by NHEP

(2) Data source for impervious surfaces: UNH Complex Systems Research Center

(3) The uncertainty for imperviousness per capita values was assumed to be +/-0.015 ac/person. This value is the size of the error bar for an average town.

Figure 12: Average impervious surface per capita in coastal municipalities in 1990, 2000, and 2005

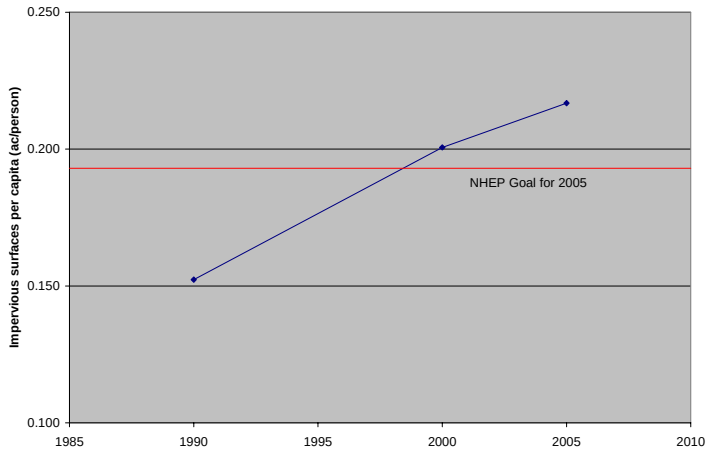
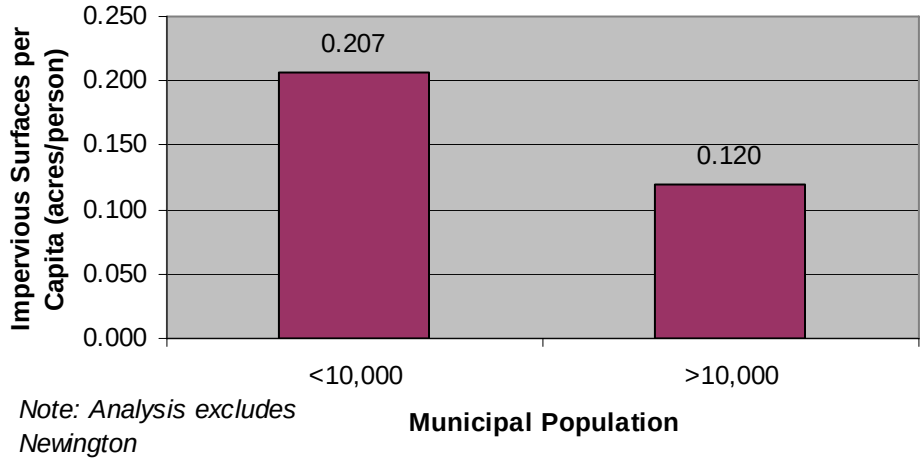


Table 6: Summary statistics for impervious surfaces per capita in 2005 in large and small municipalities

Population	Number of Towns	Average Impervious Surfaces per Capita (acres/person)	Percent of Towns Meeting NHEP Goal
<10,000	33	0.207	24%
>10,000	8	0.120	88%

(1) Analysis excludes Newington

Figure 13: Average impervious surfaces per capita in 2005 in large and small municipalities



Note: Analysis excludes Newington

Figure 14: Impervious surfaces per capita in coastal municipalities in 1990

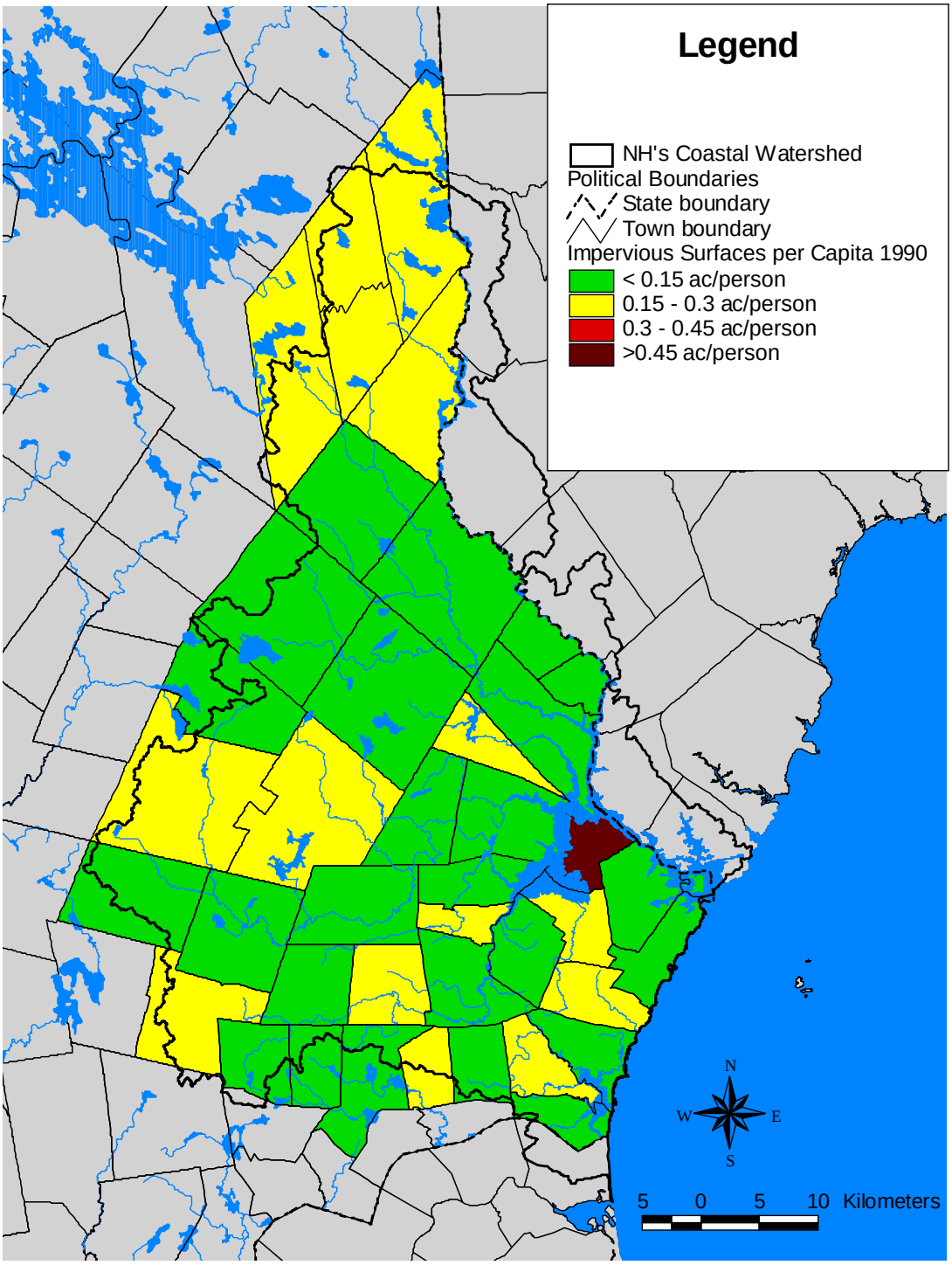


Figure 15: Impervious surfaces per capita in coastal municipalities in 2000

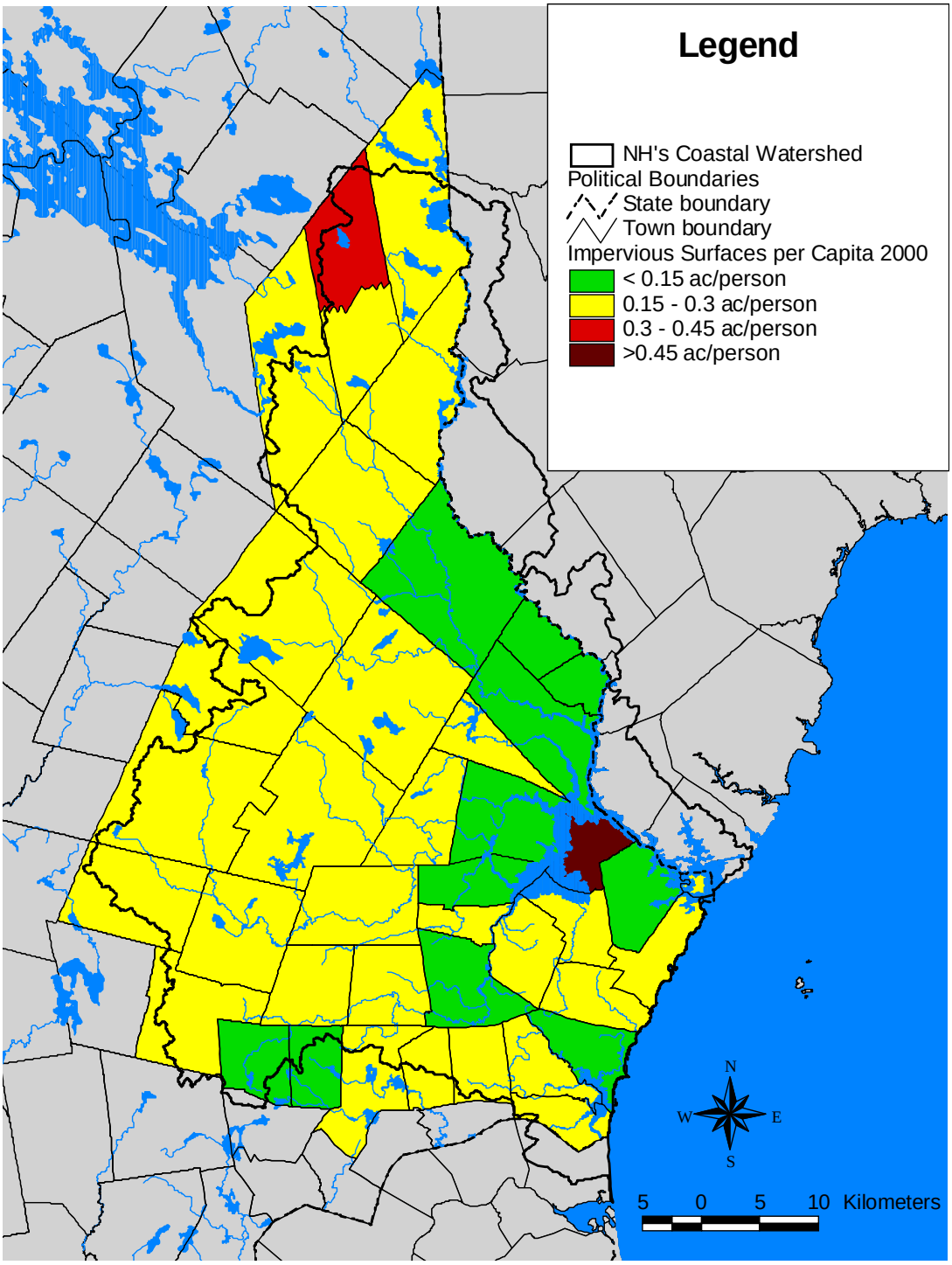


Figure 16: Impervious surfaces per capita in coastal municipalities in 2005

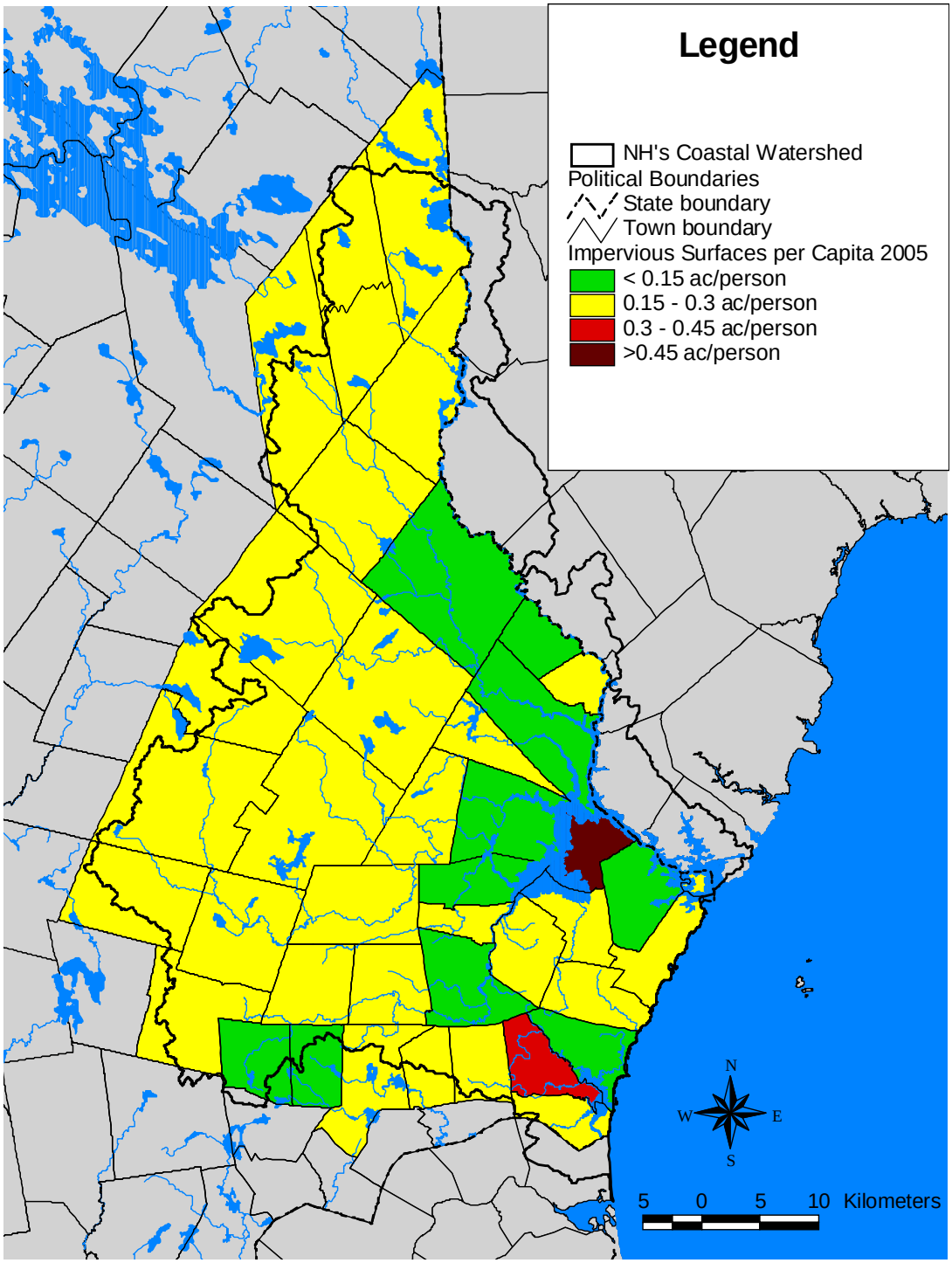
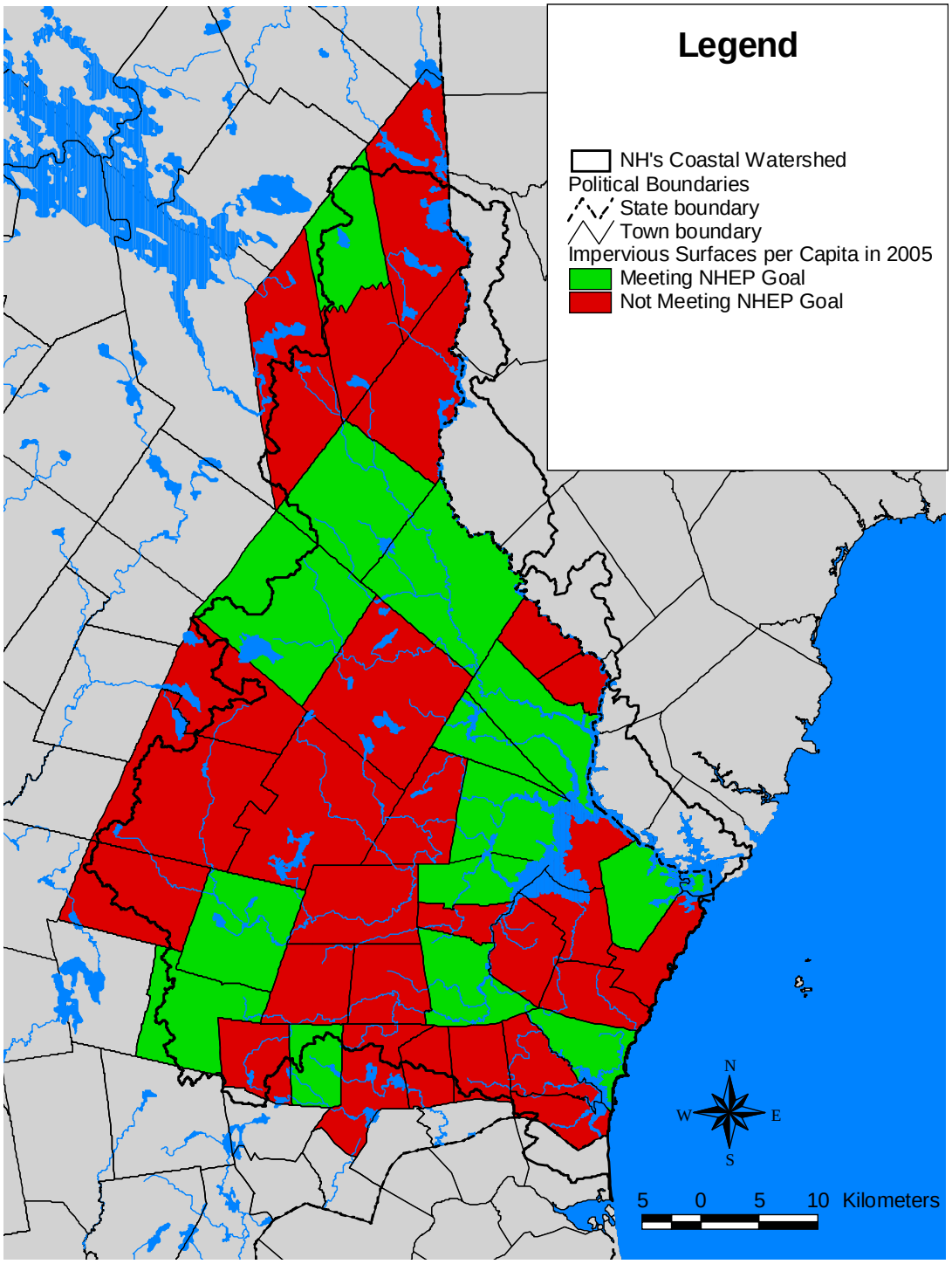


Figure 17: Coastal municipalities that did not meet the NHEP goal for impervious surfaces per capita in 2005



LUD3 - RATE OF SPRAWL – LOW-DENSITY, RESIDENTIAL DEVELOPMENT

Monitoring Objective

The objective of this indicator is to estimate the rate of low-density residential development in the towns of the coastal watershed. The second of three indicators of "sprawl" development, this indicator uses increases in road miles in each town as a proxy for new low-density, residential development. Changes in low density residential development are not expected to be accurately accounted for in the assessment of changes in impervious surface conducted under the previous indicator. Most rural, low-density residential development affects too small an area on the landscape to be identified using satellite imagery. Similar to the previous indicator, the ratio of the total road miles to the population ("road miles per capita") is calculated for each town. Ratios for 1990, 2000, and 2005 are compared to determine whether the road miles per capita is growing, declining, or remaining the same for a town to answer the following monitoring question:

Is the coastal watershed experiencing "sprawl-type" development?

Measurable Goal

New development in coastal watershed towns between 2000 and 2010 should add no more than 0.007 road miles per new resident. In 2000, the average road miles per capita in the coastal watershed was 0.014 miles/person. The NHEP goal is to cut in half the average rate of production of roads per person for new construction. Specifically, the goal for each municipality will be calculated according the following formula:

$$Goal = \frac{roadmiles_{2000} + 0.007 \times (pop - pop_{2000})}{pop}$$

where $roadmiles_{2000}$ is the miles of road surface in the town in 2000, pop_{2000} is the population of the town in 2000, and pop is the population of the town at the time of the assessment.

Data Analysis and Statistical Methods

Road miles per town were defined as the sum of Class I, II, III, IV, and V road miles as reported by the NH Department of Transportation (NHDOT) in the classified road tables. Private roads have only recently begun to be not included in the road inventory maintained by NHDOT. Therefore, the comparisons of the newer data (2005) to the older data (1990, 2000) will not capture the effects of low density private subdivisions. Population estimates were obtained in the manner described for the previous indicator. The "road miles per capita" for 1990 and 2000 was calculated by dividing the total road miles in the town by the town population. The uncertainty in each road miles per capita calculation was assumed to be +/-0.00014 miles/person. This uncertainty was calculated in NHEP (2003) for the average size watershed and town. Therefore, in order to account for uncertainty, a calculated value of road miles per capita was considered to be significantly higher than the goal if the calculated value was greater than the goal by more than 0.00014 miles/person.

Results

Population totals, road miles, and the road miles per capita for each municipality in the coastal watershed in 1990, 2000, and 2005 are shown in Table 7. Overall, the average road miles per capita has decreased from 0.014 miles per person in 1990 to 0.013 miles per person in 2000 to 0.012 miles per person in 2005 (Figure 18). Only six of the 42 towns did not meet their NHEP goal for road miles per capita in 2005. Taken at face value, these statistics would indicate that fewer roads are being built to accommodate the growing population of the watershed. Maps of the road miles per capita in coastal municipalities in 1990, 2000, and 2005 are shown in Figure 19, Figure 20, and Figure 21. The coastal municipalities that did not meet their NHEP goal for road miles per capita in 2005 are shown on Figure 22.

While the road miles per capita statistics are encouraging, they probably do not reflect real changes in the watershed. The classified road mile totals do not include private roads. Increasingly developments are built on private roads so this omission makes the value of this indicator questionable. Moreover, the road miles indicator is redundant with the impervious surface indicator. The impervious surface maps created by UNH for the NHEP "burn in" roads available on DOT coverages.

Table 7: Road miles and population in coastal municipalities in 1990, 2000, and 2005

Town		Road Miles (miles)			Population			Road Miles per Capita				Meeting
Name	FIPS	1990	2000	2005	1990	2000	2005	1990	2000	2005	Goal	goal?
BARRINGTON	17005	82.86	84.50	84.50	6,164	7,475	8,071	0.013	0.011	0.010	0.011	Yes
BRENTWOOD	15015	38.54	45.03	49.91	2,590	3,197	4,069	0.015	0.014	0.012	0.013	Yes
BROOKFIELD	3015	20.85	20.86	20.86	518	604	666	0.040	0.035	0.031	0.032	Yes
CANDIA	15020	63.74	63.61	65.41	3,557	3,911	4,141	0.018	0.016	0.016	0.016	Yes
CHESTER	15025	46.98	46.98	58.66	2,691	3,792	4,570	0.017	0.012	0.013	0.011	No
DANVILLE	15030	24.05	27.22	27.22	2,534	4,023	4,426	0.009	0.007	0.006	0.007	Yes
DEERFIELD	15035	74.49	73.52	74.65	3,124	3,678	4,190	0.024	0.020	0.018	0.018	Yes
DOVER	17010	146.07	148.25	148.99	25,042	26,884	28,776	0.006	0.006	0.005	0.006	Yes
DURHAM	17015	70.52	76.97	76.97	11,818	12,664	13,321	0.006	0.006	0.006	0.006	Yes
EAST KINGSTON	15045	19.52	20.57	20.57	1,352	1,784	1,983	0.014	0.012	0.010	0.011	Yes
EPPING	15050	72.21	73.86	73.91	5,162	5,476	5,935	0.014	0.013	0.012	0.013	Yes
EXETER	15055	73.25	83.64	84.11	12,481	14,058	14,584	0.006	0.006	0.006	0.006	Yes
FARMINGTON	17020	62.93	62.93	62.92	5,739	5,774	6,540	0.011	0.011	0.010	0.010	Yes
FREMONT	15060	29.13	32.17	36.61	2,576	3,510	3,989	0.011	0.009	0.009	0.009	No
GREENLAND	15065	27.89	34.81	38.44	2,768	3,208	3,408	0.010	0.011	0.011	0.011	No
HAMPTON	15075	87.73	88.12	97.11	12,278	14,937	15,423	0.007	0.006	0.006	0.006	No
HAMPTON FALLS	15073	29.10	29.12	29.12	1,503	1,880	2,014	0.019	0.015	0.014	0.015	Yes
KENSINGTON	15085	26.76	27.20	27.24	1,631	1,893	2,068	0.016	0.014	0.013	0.014	Yes
KINGSTON	15090	60.29	70.30	70.30	5,591	5,862	6,205	0.011	0.012	0.011	0.012	Yes
LEE	17025	59.59	60.94	60.94	3,729	4,145	4,364	0.016	0.015	0.014	0.014	Yes
MADBURY	17030	26.37	26.66	26.66	1,404	1,509	1,741	0.019	0.018	0.015	0.016	Yes
MIDDLETON	17035	25.27	29.22	29.22	1,183	1,440	1,662	0.021	0.020	0.018	0.019	Yes
MILTON	17040	70.39	76.63	76.56	3,691	3,910	4,329	0.019	0.020	0.018	0.018	Yes
NEW CASTLE	15100	6.01	6.11	6.11	840	1,010	1,045	0.007	0.006	0.006	0.006	Yes
NEW DURHAM	17045	58.89	61.83	61.83	1,974	2,220	2,429	0.030	0.028	0.025	0.026	Yes
NEWFIELDS	15105	13.41	15.49	15.49	888	1,551	1,646	0.015	0.010	0.009	0.010	Yes
NEWINGTON	15110	17.52	18.90	18.90	990	775	794	0.018	0.024	0.024	0.024	Yes
NEWMARKET	15115	37.71	45.31	45.31	7,157	8,027	9,184	0.005	0.006	0.005	0.006	Yes
NORTH HAMPTON	15125	44.05	44.06	49.20	3,637	4,259	4,522	0.012	0.010	0.011	0.010	No
NORTHWOOD	15130	45.99	45.96	46.28	3,124	3,640	3,897	0.015	0.013	0.012	0.012	Yes
NOTTINGHAM	15135	67.47	71.30	71.89	2,939	3,701	4,182	0.023	0.019	0.017	0.018	Yes
PORTSMOUTH	15145	105.90	110.04	110.30	25,925	20,784	21,117	0.004	0.005	0.005	0.005	Yes
RAYMOND	15150	83.16	88.74	95.52	8,713	9,674	10,416	0.010	0.009	0.009	0.009	No
ROCHESTER	17050	170.11	179.53	176.05	26,630	28,461	30,337	0.006	0.006	0.006	0.006	Yes
ROLLINSFORD	17055	25.35	26.75	26.75	2,645	2,648	2,690	0.010	0.010	0.010	0.010	Yes
RYE	15155	52.58	54.16	54.16	4,612	5,182	5,298	0.011	0.010	0.010	0.010	Yes
SANDOWN	15165	41.20	43.81	43.81	4,060	5,143	5,711	0.010	0.009	0.008	0.008	Yes
SEABROOK	15170	39.74	40.12	40.12	6,503	7,934	8,432	0.006	0.005	0.005	0.005	Yes
SOMERSWORTH	17060	52.46	54.32	54.32	11,249	11,477	11,851	0.005	0.005	0.005	0.005	Yes
STRAFFORD	17065	68.89	71.53	71.53	2,965	3,626	3,962	0.023	0.020	0.018	0.019	Yes
STRATHAM	15180	47.30	49.06	49.07	4,955	6,355	6,965	0.010	0.008	0.007	0.008	Yes
WAKEFIELD	3090	80.90	80.96	81.62	3,057	4,252	4,705	0.026	0.019	0.017	0.018	Yes
AVERAGE								**0.014**	**0.013**	**0.012**	**0.012**	

(1) Data source for population: NH Office of Energy and Planning, 2004 estimates extrapolated to 2005 by NHEP

(2) Data source for road miles: NH DOT Classified Road Miles for Class I, II, III, IV, and V Roads

(3) The uncertainty for road miles per capita values was assumed to be +/-0.00014 miles/person. This value is the size of the error bar for an average town.

Figure 18: Average road miles per capita in coastal municipalities in 1990, 2000, and 2005

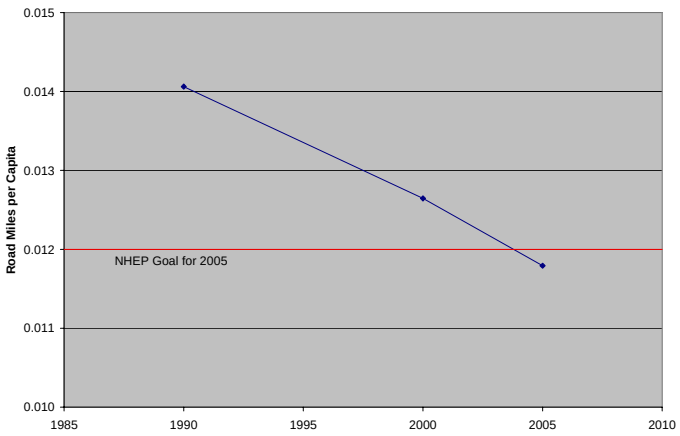


Figure 19: Road miles per capita in coastal municipalities in 1990

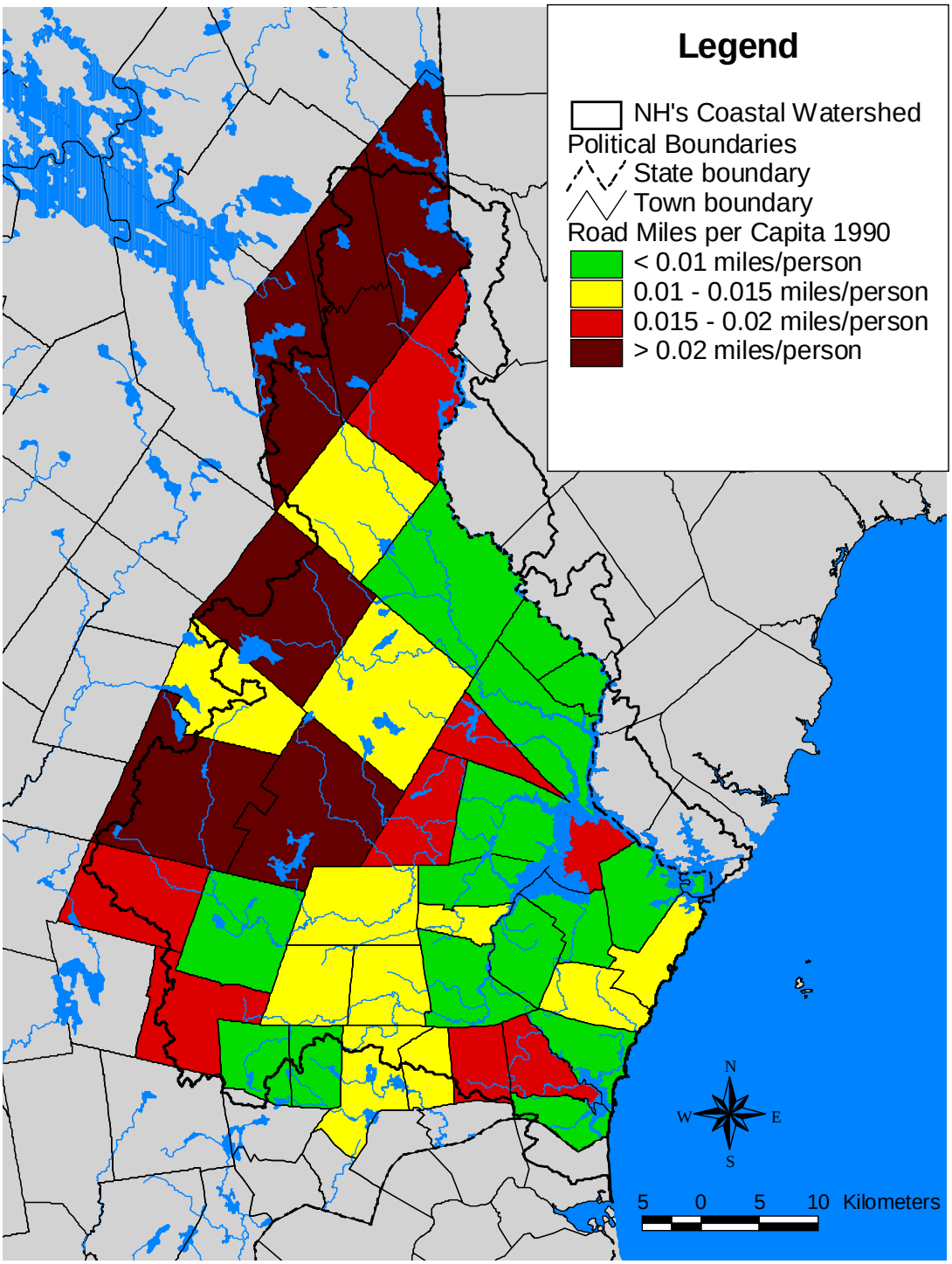


Figure 20: Road miles per capita in coastal municipalities in 2000

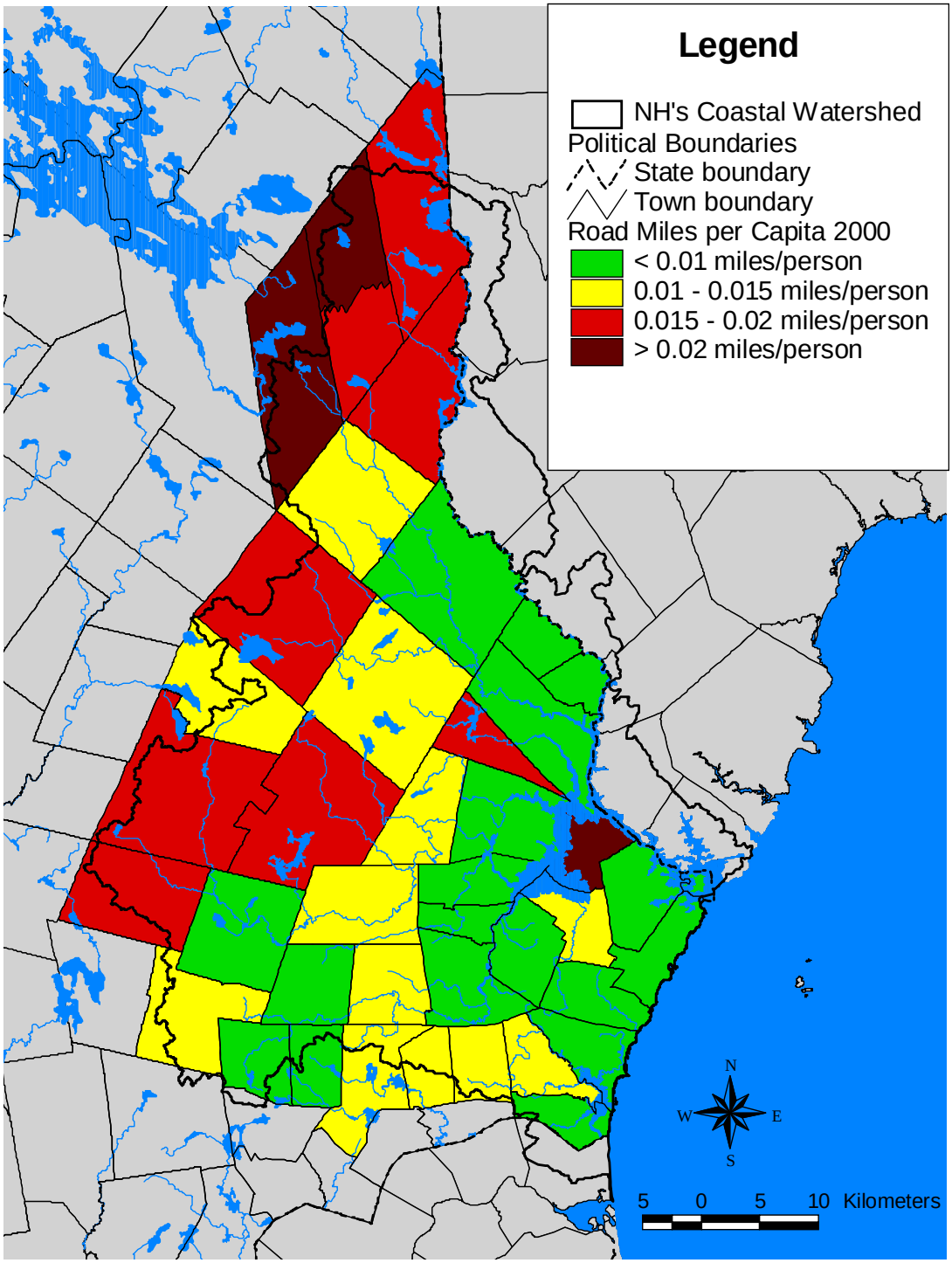


Figure 21: Road miles per capita in coastal municipalities in 2005

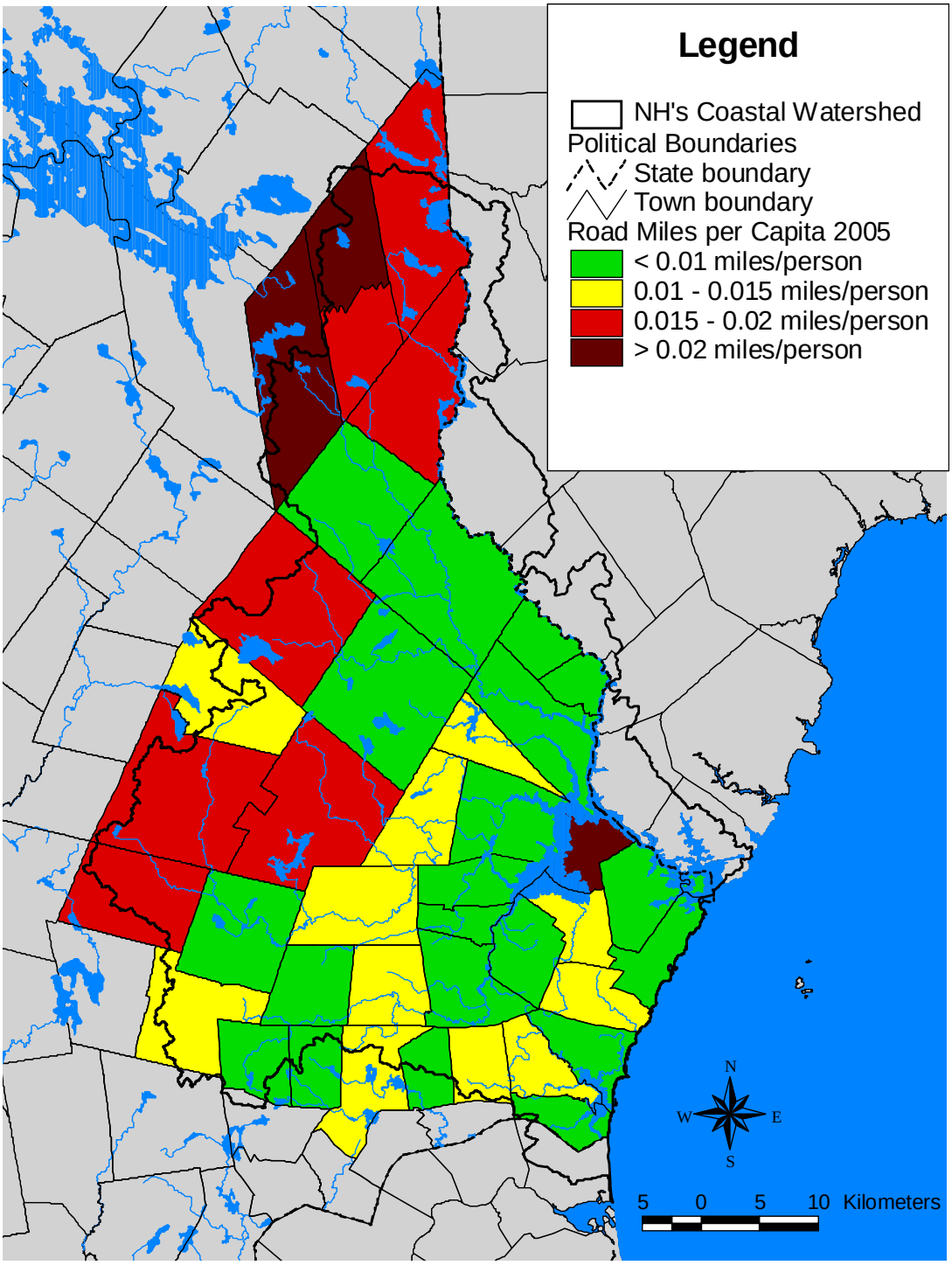
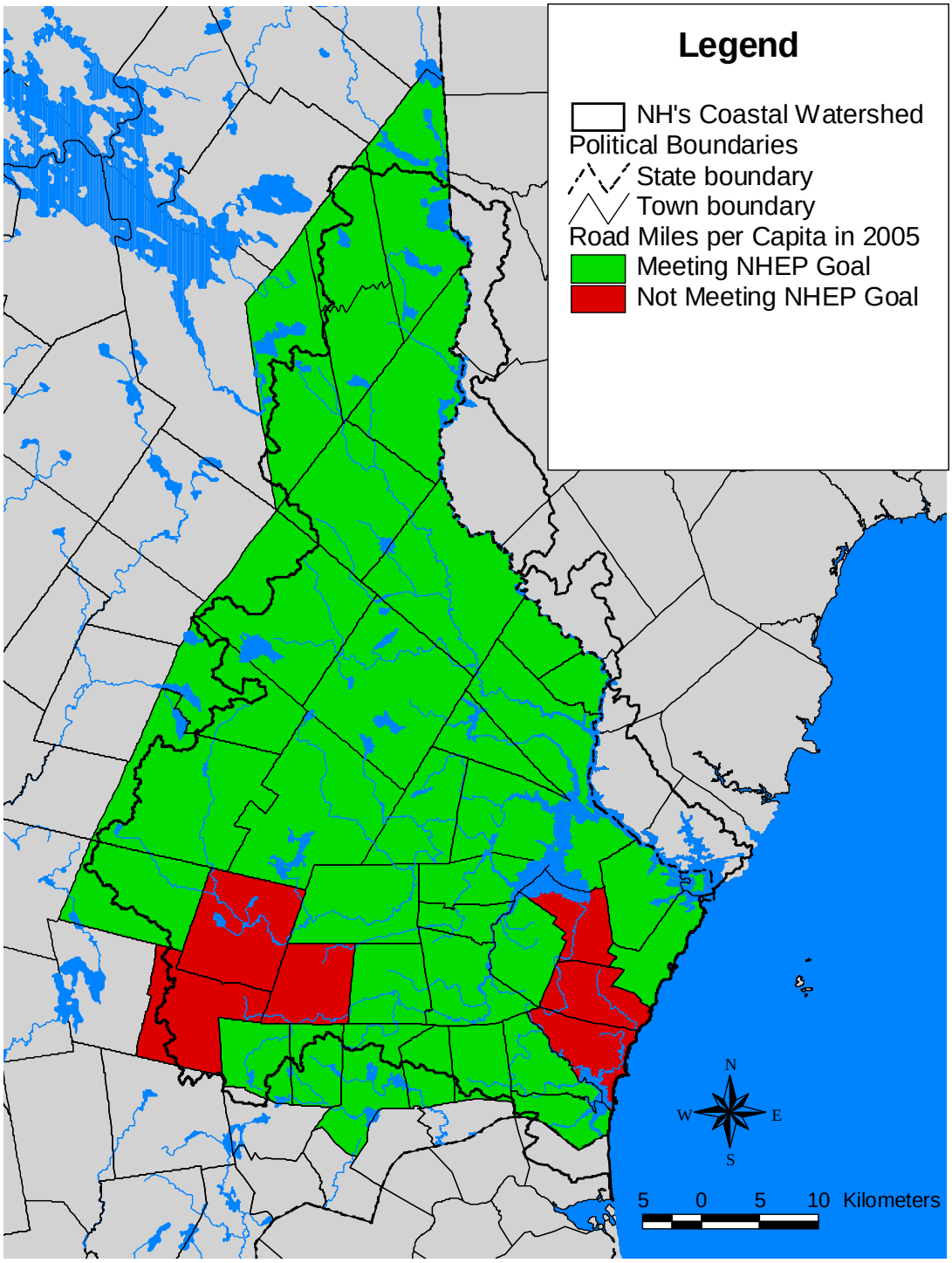


Figure 22: Coastal towns that did not meet the NHEP goal for road miles



LUD4 - RATE OF SPRAWL – FRAGMENTATION

Monitoring Objective

The objective of this indicator is to estimate the rate at which towns are losing unfragmented blocks of open space due to development patterns. The fragmentation of open lands due to new roads and sprawling patterns of development can have significant consequences on habitat and hydrologic functions within the coastal watershed. The changes in impervious surface and road miles examined by the first two sprawl indicators do not account for the impact of the location of these development activities. This third indicator of "sprawl" development uses the loss of unfragmented blocks of undeveloped land to assess the impacts of the location of new road construction and development. This indicator is used to partially answer the following monitoring question:

Is the coastal watershed experiencing "sprawl-type" development?

Measurable Goal

For this report, the only data on unfragmented lands that was available was for 2001. Therefore, it was only possible to report on the status of unfragmented lands as of 2001. Change in unfragmented lands over time relative to population changes (as was done for impervious surfaces and road miles) could not be assessed. Therefore, none of the measurable goals from the Monitoring Plan (NHEP, 2004) apply.

Data Analysis and Statistical Methods

Unfragmented lands data was obtained from the Society for the Protection of New Hampshire Forests (SPNHF). SPNHF had processed 2001 land cover data from GRANIT using USGS digital line graphs of roads and NHDOT's G_roads datalayer to identify blocks of unfragmented lands in southeastern New Hampshire. The methodology and assumptions used by SPNHF to process the data are included below.

> Natural land cover types were extracted from the GRANIT land cover data for the study area as a precursor to generating an unfragmented blocks datalayer. These land cover types included: all forest cover types except Alpine (440), forested and non-forested wetlands, and tidal wetlands; and bedrock/vegetated, sand dunes, and cleared or disturbed land covers. Active agriculture was excluded.
>
> A special roads datalayer was generated for use as a fragmenting feature; only traveled roadways were included. The USGS-based datalayer and the NHDOT datalayer were merged after selecting out all jeep trails, CI 6 roads, and other non-traveled roadways; private roads in the NHDOT datalayer were included in the merged dataset even though some function only as occasional use access roads.

Note that the influence of urban land uses and transportation land cover types as fragmenting features was automatically accounted for in the selection of natural land cover types above, but the transportation land cover type was found to be insufficient within the GRANIT land cover mapping due to tree cover occluding many road segments. Furthermore, frontage development could not be accounted for in the GRANIT land cover mapping, so a 300' buffer was created from the merged road datalayers.

NHDES clipped the unfragmented data layer from SPNHF to the coastal watershed boundary (HUC8 01060003) and then selected only those blocks that covered greater than 250 acres inside the watershed. The selected blocks were further stratified by town boundaries to determine the area of large, unfragmented forest blocks in each coastal watershed town. Forest blocks were allowed to straddle town boundaries. For instance, a 300 acre block that was half in one town and half in another was still counted an a "large, unfragmented block". Since the data were not being compared to a management goal, no tests for statistical significance (e.g., with confidence intervals) were applied.

Results

Changes in the fragmentation of forest lands could not be evaluated. The only coverage of unfragmented forest blocks was created for 2001. A change analysis will be completed after the unfragmented forest blocks are mapped again. The following information was included in the 2003 NHEP Land Use and Development Indicator Report (NHEP, 2003).

Table 8 shows the percentage of land area in each coastal watershed town that is covered by unfragmented blocks greater than 250 acres in 2001. The towns with the greatest percentages of land area covered by unfragmented blocks are Middleton (70%), Nottingham (69%) and Milton (64%). The towns with the smallest percentages are New Castle (0%), Newington (5%) and Kingston (10%). Figure 23 and Figure 24 shown the unfragmented blocks >250 acres in the coastal watershed and the percent of each municipality that is covered by unfragmented blocks, respectively.

Table 8: Coverage of large, unfragmented forest blocks in coastal watershed municipalities

Town	Town Area (acres)				Acres of Unfragmented	Percent of Land Area in Unfragmented
Name	FIPS	Land	Water	Total	Blocks >250 acres	Blocks >250 acres
MIDDLETON	17035	11,560	283	11,843	8,102	70.09%
NOTTINGHAM	15135	29,880	1,116	30,997	20,478	68.53%
MILTON	17040	21,099	836	21,935	13,585	64.39%
FARMINGTON	17020	23,221	419	23,640	14,525	62.55%
BARRINGTON	17005	29,719	1,398	31,117	18,434	62.03%
NEWFIELDS	15105	4,542	105	4,647	2,812	61.90%
BROOKFIELD	3015	14,593	287	14,880	8,729	59.81%
FREMONT	15060	11,036	107	11,143	6,543	59.29%
DEERFIELD	15035	32,587	762	33,349	18,699	57.38%
EPPING	15050	16,468	308	16,776	9,186	55.78%
BRENTWOOD	15015	10,742	121	10,862	5,725	53.30%
MADBURY	17030	7,403	396	7,799	3,809	51.45%
STRAFFORD	17065	31,153	1,626	32,779	15,874	50.95%
NORTH HAMPTON	15125	8,865	57	8,922	4,168	47.01%
RAYMOND	15150	18,448	495	18,944	8,328	45.14%
NORTHWOOD	15130	17,976	1,380	19,356	7,564	42.08%
HAMPTON FALLS	15073	7,719	358	8,077	3,240	41.98%
EXETER	15055	12,553	261	12,814	5,175	41.23%
KENSINGTON	15085	7,637	31	7,668	3,091	40.47%
CANDIA	15020	19,342	215	19,557	7,774	40.19%
CHESTER	15025	16,620	98	16,718	6,652	40.02%
ROCHESTER	17050	28,331	750	29,081	11,274	39.79%
STRATHAM	15180	9,672	228	9,901	3,734	38.60%
NEWMARKET	15115	8,073	1,007	9,080	3,102	38.42%
DURHAM	17015	14,308	1,543	15,852	5,367	37.51%
WAKEFIELD	3090	25,264	3,452	28,716	9,357	37.04%
RYE	15155	7,997	426	8,424	2,872	35.91%
NEW DURHAM	17045	26,347	1,707	28,054	9,127	34.64%
SANDOWN	15165	8,889	343	9,232	2,921	32.86%
ROLLINSFORD	17055	4,682	161	4,843	1,506	32.17%
GREENLAND	15065	6,780	1,744	8,524	2,053	30.28%
EAST KINGSTON	15045	6,319	62	6,381	1,843	29.17%
LEE	17025	12,680	248	12,928	3,338	26.33%
HAMPTON	15075	8,317	754	9,071	2,034	24.45%
SOMERSWORTH	17060	6,220	179	6,399	1,249	20.08%
DOVER	17010	17,094	1,498	18,592	3,336	19.51%
SEABROOK	15170	5,669	491	6,160	1,079	19.03%
DANVILLE	15030	7,439	131	7,569	1,341	18.02%
PORTSMOUTH	15145	10,001	762	10,763	1,687	16.87%
KINGSTON	15090	12,495	955	13,450	1,263	10.11%
NEWINGTON	15110	5,215	2,701	7,916	242	4.65%
NEW CASTLE	15100	504	843	1,348	0	0%

Data Source: 2001 Land cover with fragmentation analysis by SPNHF

Figure 23: Large (>250 acres), unfragmented forest blocks in the coastal watershed

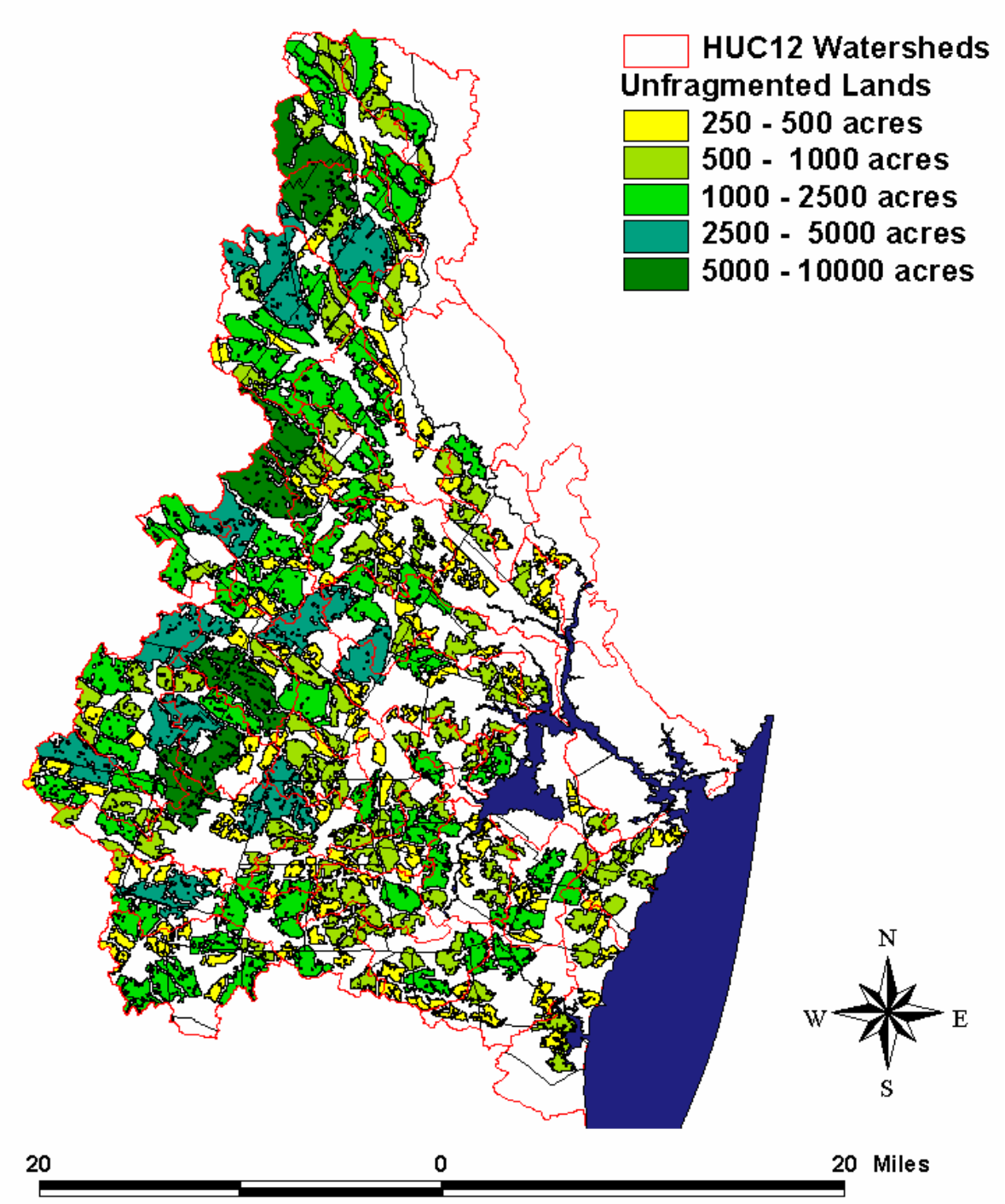
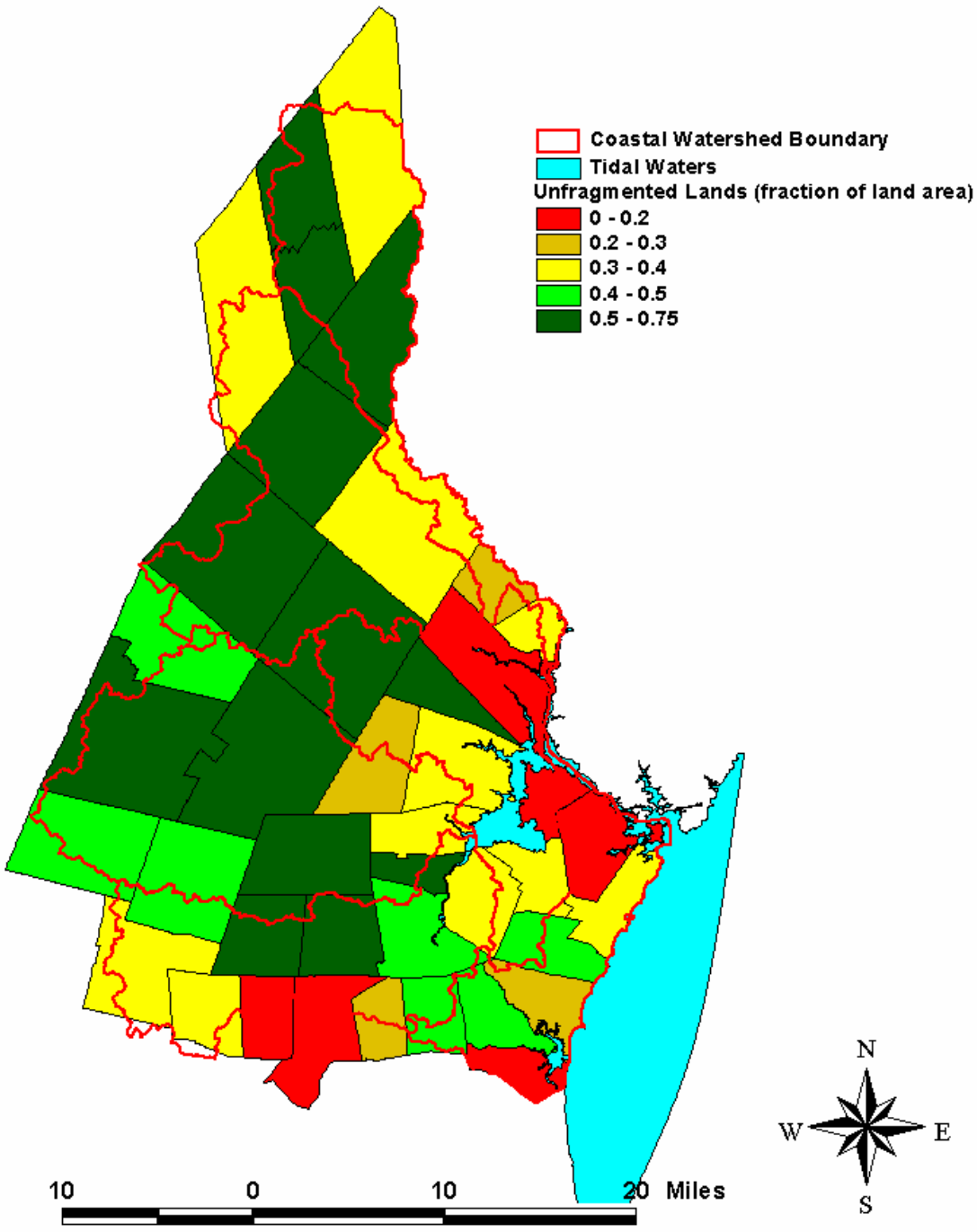


Figure 24: Fraction of land area in coastal municipalities covered by large, unfragmented forest blocks in 2001



HAB6 - CONSERVATION LANDS

Monitoring Objective

The objective of this indicator is to report on the total acres of lands protected from development in the coastal watershed. The indicator answers the following monitoring question:

How much of the coastal watershed is protected from development?

Measurable Goal

Increase the acres of protected private and public lands from baseline levels to 15% of the coastal watershed and 15% of the coastal communities by 2010. This goal is consistent with the NH Everlasting campaign of the Society for the Protection of NH Forests which calls for 25% of each town to be protected by 2025 (SPNHF, 2001). The goal is also compatible with the Gulf of Maine Council on the Marine Environment's goal to protect an additional 5,000 acres in "coastal communities" (i.e., towns that border salt water) by 2006 (GOMC, 2002). There are 17 communities with tidal shoreline in NH's coastal watershed.

Data Analysis and Statistical Methods

The most recent (January 2006) coverage of conservation lands in the state was the primary data source for this indicator (Rubin and Phaneuf, 2006). The coverage includes data reported to and maintained by UNH Complex Systems Research Center. The database was queried to identify the conservation lands within the coastal watershed (HUC8 01060003). The total area of public and private conservation lands in the coastal watershed and the 17 coastal communities was calculated by summing the areas of individual conservation polygons in these two zones. Error bars on acreage totals were not calculated because it was assumed that parcels under easement had been surveyed and therefore had accurate acreage values.

Results

Table 9 summarizes the acres of conservation lands in each municipality in the coastal watershed. The total conservation lands in the coastal watershed and coastal communities relative to the NHEP goals are shown on Figure 25.

By the end of 2005, there were 54,622 acres of protected land in the coastal watershed. This area is equivalent to 10.7% of the watershed land area of the NH portion of the watershed. During the three years between 2002 and 2005, 12,037 acres of land were permanently protected. The average rate of land protection was 4,012 acres per year. By means of comparison, the rate of impervious surface creation is 1,185 acres per year (see indicator LUD1). In order to reach the NHEP goal of having 15% of the watershed protected by 2010, an additional 21,790 acres need to be protected in the next four years (5,500 acres per year). Therefore, the rate of land protection must increase to meet the goal.

The total amount of conservation lands in the 17 coastal communities was 21,570

acres, which is 15.2% of the total area of these communities. Therefore, the NHEP goal for 2010 has already been achieved in these communities. Future land conservation efforts in these communities will work toward the New Hampshire Everlasting goal of protecting 25% of the land area in each town by 2025 (SPNHF, 2001). Between 2002 and 2005, 3,972 acres of land in the coastal communities was protected from development, which is 79% of the GOMC goal for 2006.

The percentage of land area that is protected in each town is shown on Figure 26. This map reinforces the understanding that progress toward the NHEP goals has been good in the towns around Great Bay, near the coast, and in the vicinity of the Bear Brook and Pawtuckaway State Parks. In contrast, there is a lower percentage of protected land in the Salmon Falls River and Cocheco River watersheds.

Figure 25: Conservation lands in the coastal watershed

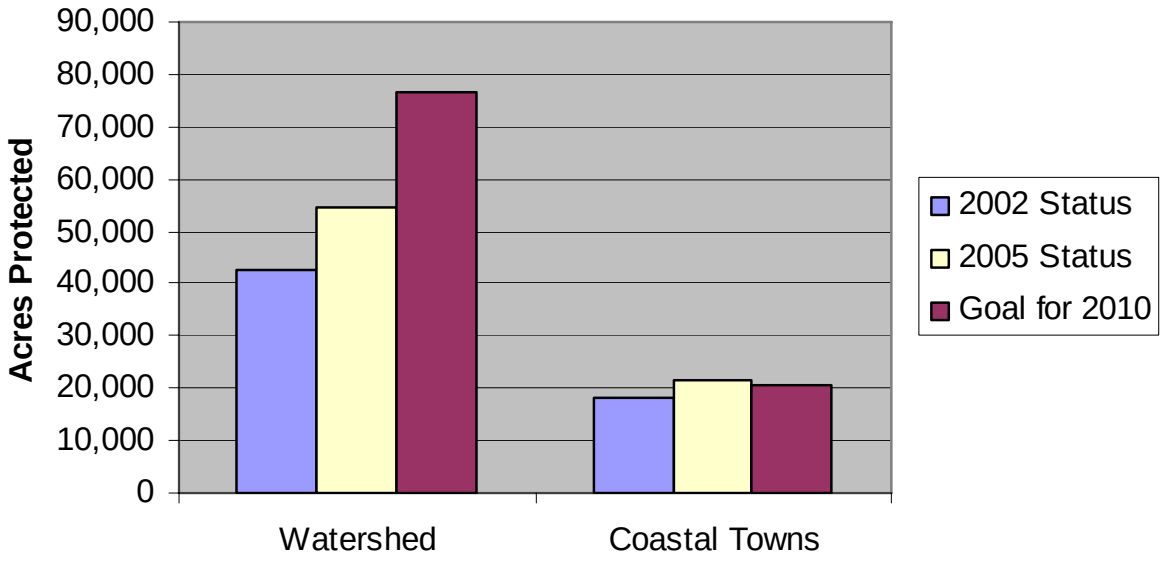
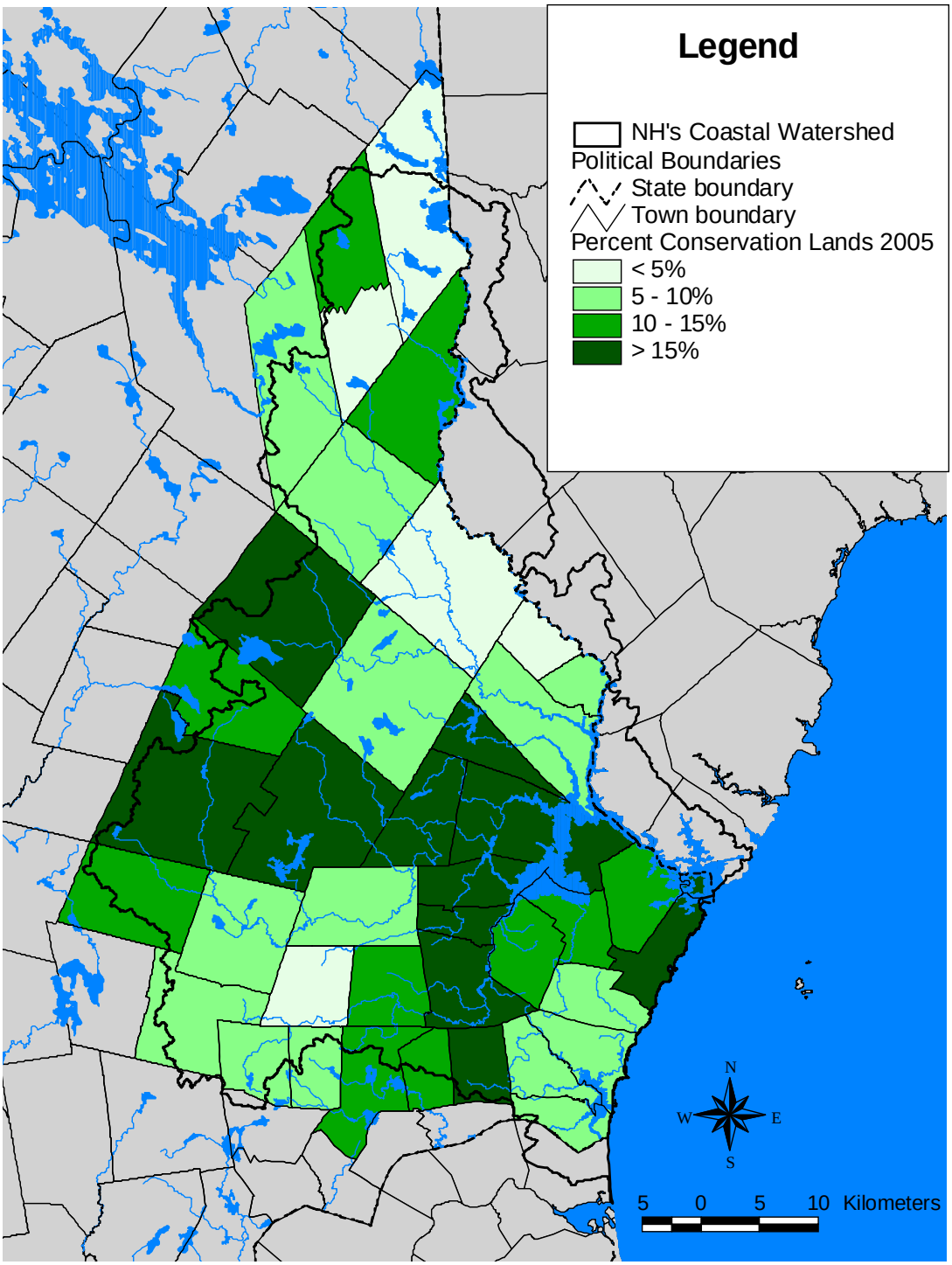


Table 9: Conservation lands in coastal municipalities in 2002 and 2005

Town Name (*=coastal community)	FIPS	Land Area (ac)	Water Area (ac)	Total Area (ac)	Conservation Lands - 2002 (ac)	Conservation Lands - 2005 (ac)	Percent Conservation - 2005
BARRINGTON	17005	29,719	1,398	31,117	2,551	2,734	9.2%
BRENTWOOD	15015	10,742	121	10,862	460	1,474	13.7%
BROOKFIELD	3015	14,593	287	14,880	1,813	1,845	12.6%
CANDIA	15020	19,342	215	19,557	1,891	2,046	10.6%
CHESTER	15025	16,620	98	16,718	1,320	1,312	7.9%
DANVILLE	15030	7,439	131	7,569	458	557	7.5%
DEERFIELD	15035	32,587	762	33,349	5,332	5,582	17.1%
DOVER*	17010	17,094	1,498	18,592	1,589	1,529	8.9%
DURHAM*	17015	14,308	1,543	15,852	3,401	4,326	30.2%
EAST KINGSTON	15045	6,319	62	6,381	156	670	10.6%
EPPING	15050	16,468	308	16,776	498	1,367	8.3%
EXETER*	15055	12,553	261	12,814	2,447	3,496	27.9%
FARMINGTON	17020	23,221	419	23,640	1,146	1,242	5.3%
FREMONT	15060	11,036	107	11,143	209	231	2.1%
GREENLAND*	15065	6,780	1,744	8,524	727	899	13.3%
HAMPTON*	15075	8,317	754	9,071	631	630	7.6%
HAMPTON FALLS*	15073	7,719	358	8,077	483	633	8.2%
KENSINGTON	15085	7,637	31	7,668	626	1,548	20.3%
KINGSTON	15090	12,495	955	13,450	1,067	1,376	11.0%
LEE	17025	12,680	248	12,928	1,239	2,340	18.5%
MADBURY*	17030	7,403	396	7,799	1,641	1,328	17.9%
MIDDLETON	17035	11,560	283	11,843	398	488	4.2%
MILTON	17040	21,099	836	21,935	2,568	2,553	12.1%
NEW CASTLE*	15100	504	843	1,348	106	106	21.0%
NEW DURHAM	17045	26,347	1,707	28,054	1,754	1,753	6.7%
NEWFIELDS*	15105	4,542	105	4,647	394	784	17.3%
NEWINGTON*	15110	5,215	2,701	7,916	1,216	1,307	25.1%
NEWMARKET*	15115	8,073	1,007	9,080	761	1,330	16.5%
NORTH HAMPTON*	15125	8,865	57	8,922	481	718	8.1%
NORTHWOOD	15130	17,976	1,380	19,356	2,150	2,381	13.2%
NOTTINGHAM	15135	29,880	1,116	30,997	5,676	5,860	19.6%
PORTSMOUTH*	15145	10,001	762	10,763	1,107	1,103	11.0%
RAYMOND	15150	18,448	495	18,944	1,075	1,017	5.5%
ROCHESTER	17050	28,331	750	29,081	436	436	1.5%
ROLLINSFORD*	17055	4,682	161	4,843	411	409	8.7%
RYE*	15155	7,997	426	8,424	1,246	1,495	18.7%
SANDOWN	15165	8,889	343	9,232	336	591	6.6%
SEABROOK*	15170	5,669	491	6,160	285	451	7.9%
SOMERSWORTH	17060	6,220	179	6,399	221	221	3.6%
STRAFFORD	17065	31,153	1,626	32,779	3,646	5,261	16.9%
STRATHAM*	15180	9,672	228	9,901	671	1,025	10.6%
WAKEFIELD	3090	25,264	3,452	28,716	284	397	1.6%
TOTAL:		**585,462**	**30,643**	**616,105**	**54,909**	**66,852**	**11.4%**
TOTAL Coastal Communities:		**139,396**	**13,337**	**152,733**	**17,598**	**21,570**	**15.2%**
TOTAL for Coastal Watershed:		**509,412**	**21,857**	**531,269**	**42,585**	**54,622**	**10.7%**

(1) Data source for conservation land: 2005 update of the consland database by UNH Complex Systems Research Ctr
(2) Results are for the whole town.The NHEP also reports on conservation lands in the coastal watershed.Some towns are only partially in the watershed.Therefore, they are some small discrepancies between the totals on this table and the totals for the whole watershed.

Figure 26: Percent of land area that is permanently protected in each municipality in the coastal watershed



HAB3 - SHORELAND DEVELOPMENT AND PROTECTION

Monitoring Objective

The objective of this indicator is to track the amount of development in the tidal and freshwater shorelands of the coastal watershed. Development is measured by the presence of significant amounts of impervious surface. The undeveloped shorelands are further stratified into "protected" and "unprotected" categories depending on whether they are permanently protected from development. This indicator answers the following monitoring question:

How much of the shorelands in the coastal watershed are protected from development?

Measurable Goal

The goal is to increase the acres of permanently protected, undeveloped shorelands from baseline (2000) levels by 2010. Tidal and freshwater shorelands are assessed separately.

Data Analysis and Statistical Methods

Impervious surfaces were mapped throughout the coastal watershed using satellite imagery (Landsat TM, 30-meter resolution) from 1990, 2000 and 2005 which was post-processed using subpixelization analysis (Justice and Rubin, 2002; Justice and Rubin, 2006). A pixel was considered "developed" if it was assigned a value representative of 30 to 100% impervious cover. The threshold of 30% was chosen after consulting with the Complex Systems Research Center at UNH and reviewing impervious surface coefficients for different land use types (NOAA, 2002). For example, developed land has a median imperviousness coefficient between 30 and 40%. The coefficients for other land use types were between 10% and zero.

Shorelands were defined as land within 250 feet of tidal waters, salt marshes ("E2EM" wetlands from the National Wetlands Inventory), great ponds/lakes, and third order or higher rivers. This definition matches the jurisdiction of the Comprehensive Shoreland Protection Act (RSA 483-B) with the exception that the Act only covers 4th order or higher rivers. If a pixel straddled the shoreland buffer boundary, the pixel was clipped to the boundary and only the portion of the pixel inside the buffer was counted.

For the 2005 estimates, lands protected from development by conservation easements or through other conservation mechanisms were taken from the most recent version of the conservations lands database (Rubin and Phaneuf, 2006). For the 2000 estimates, the conservation lands database as of October 2002 was used. The conservation lands database corresponding to 1990 was not available. Therefore, protected undeveloped shorelands in 1990 could not be calculated. This indicator does not attempt to account for regulatory protections aimed at protecting shorelands from development that might be in place at a town level; only conservation lands (easement or fee ownership) are considered "protected."

ArcView/ArcInfo software was used to combine the impervious surface, shorelands buffer, and conservation lands datalayers. Spatial queries were used to calculate the total area of (1) developed shorelands; (2) undeveloped shorelands not permanently protected; and (3) undeveloped shorelands permanently protected from development. Based on error analysis calculations in NHEP (2003), the uncertainty in each sum was assumed to be +/-10%. Using these area totals, the percent of shorelands in each category was calculated. The error in each percentage was determined to be +/-1% for freshwater shorelands and +/-2% for tidal shorelands.

Results

Table 10 summarizes the acres of tidal and freshwater shorelands in the different classes (protected, developed, undeveloped/unprotected) in 2005. Approximately, 20% all tidal shorelands are already developed (Table 10, Figure 27). Another 60% of tidal shorelands are undeveloped but are not protected from future development. Some of these lands are not developable in reality due to zoning or physical constraints. The remaining 20% of tidal shorelands are already protected from development by easements or public ownership. For freshwater shorelands, a much lower percentage of the total has already been developed (Figure 28). Only 7% of the freshwater shorelands are classified as developed in 2005. Approximately 78% of the freshwater shorelands are undeveloped but could be developed in the future. As stated above, zoning or physical constraints will prevent some of these properties from being developed. Finally, 15% of the freshwater shorelands are already protected from further development in 2005.

Trends in shoreland development and protection are illustrated by Table 11, Table 12, Figure 29, and Figure 30. Between 1990 and 2005, the rate of development has remained constant at approximately 55 acres per year for freshwater shorelands and 33 acres per year for tidal shorelands. Changes between 2000 and 2005 indicate that 147 acres per year of freshwater shorelands and 44 acres of per year of tidal shorelands were protected during this time. Therefore, for the 2000-2005 period, the rate of shoreland protection has at least kept pace with the rate of development.

The NHEP goal to increase the acreage of protected, undeveloped shorelands has been met, although the change on a percentage basis from 2000 to 2005 levels is only significant for freshwater shorelands.

This indicator probably underestimates developed shorelands because most shoreland development is too dispersed to be documented by the impervious surface mapping techniques. Moreover, the impervious surface data were meant to be aggregated on a town or watershed scale, not a 250 foot wide shoreland buffer.

Table 10: Protected and developed shorelands in the coastal watershed in 2005

2005 Shorelands Summary

Category	Freshwater	Tidal
Developed	1,914	1,444
Undeveloped and Protected	4,141	1,476
Undeveloped and Unprotected	21,822	4,361

Figure 27: Protected and developed tidal shorelands in 2005

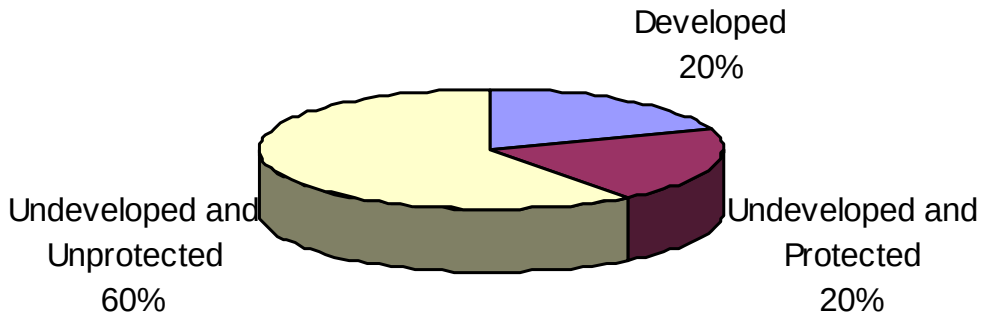


Figure 28: Protected and developed freshwater shorelands in 2005

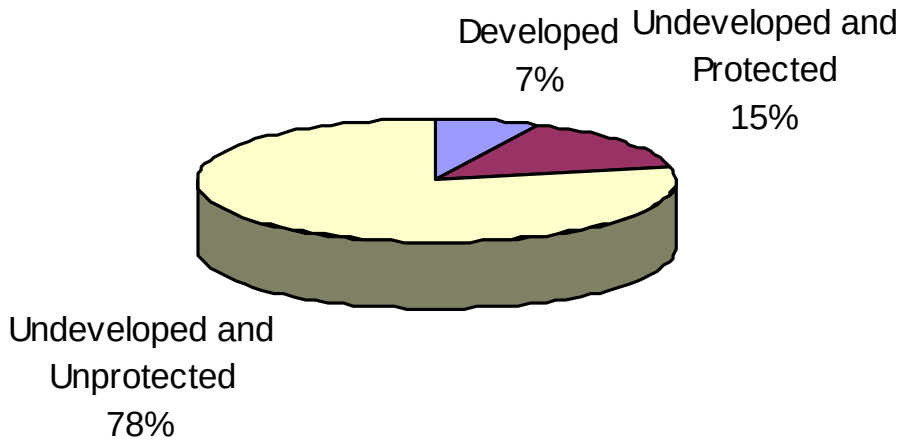


Table 11: Trends in freshwater shoreland development and protection (1990-2005)

Year	Developed		Undeveloped and Protected	
	acres	% of total	acres	% of total
1990	1,073	3.8%	NA	NA
2000	1,646	5.9%	3,408	12.2%
2005	1,914	6.9%	4,141	14.9%

**Note: Undeveloped/protected sum for 1990 is not available.*

Figure 29: Trends in freshwater shoreland development and protection (1990-2005)

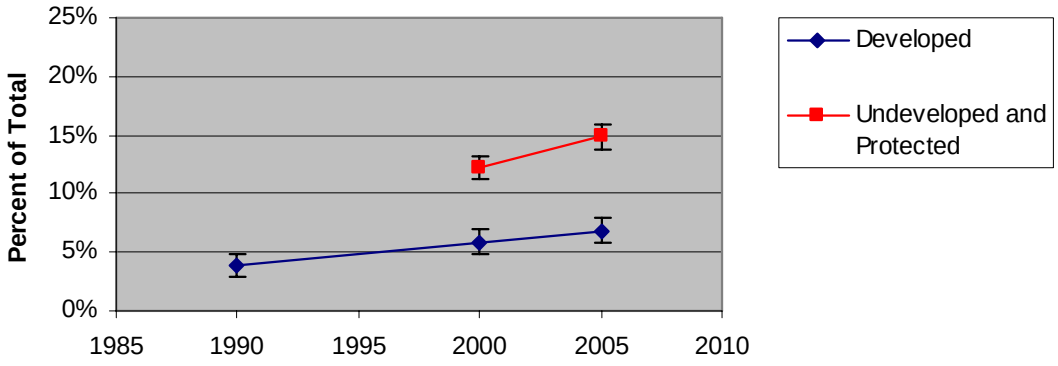
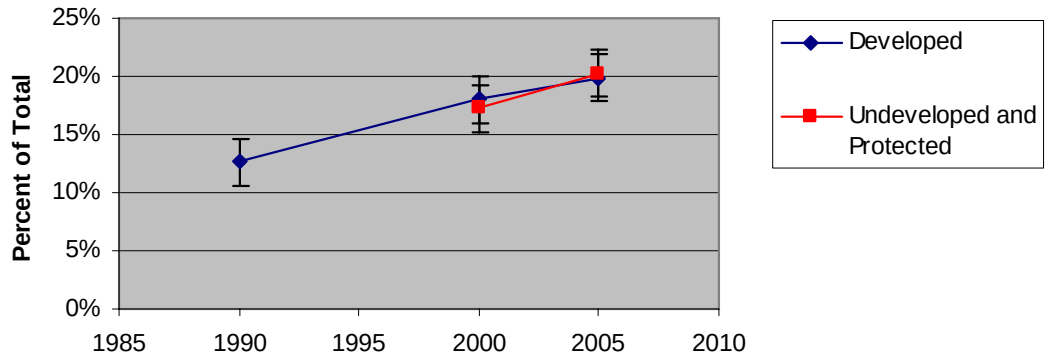


Table 12: Trends in tidal shoreland development and protection (1990-2005)

Year	Developed		Undeveloped and Protected	
	acres	% of total	acres	% of total
1990	915	12.6%	NA	NA
2000	1,307	18.0%	1,255	17.3%
2005	1,444	19.8%	1,476	20.3%

**Note: Undeveloped/protected sum for 1990 is not available.*

Figure 30: Trends in tidal shoreland development and protection (1990-2005)



HAB5 - RARE AND EXEMPLARY NATURAL COMMUNITIES

Monitoring Objective

The objective for this supporting variable is to track the percentage of known rare and exemplary natural communities in the coastal watershed that exist on land protected from development. The NH Natural Heritage Bureau (NHB) is the primary data source for this indicator. This indicator answers the following monitoring question:

How many of the rare and exemplary natural communities in the coastal watershed are protected from development?

Measurable Goal

Information on rare and exemplary natural communities is not used to answer a management question therefore no goal has been set.

Data Analysis and Statistical Methods

In April 2006, the NH Natural Heritage Bureau queried the NHB database (using unshifted, georeferenced points and polygons and data current through March 15, 2006) for the total number and area of the NHB records that were within the coastal watershed. The following quadrangles from the NH Natural Heritage Bureau were used: 114-115, 126-128, 138-142, 152-156, 166-171, 182-186, 202. The records from these quadrangles were clipped using the watershed boundary of HUC8 01060003. Only records whose location was known to within 300 feet (PRECISION="S") and that had been field verified since 1980 were used. The NH Natural Heritage Bureau then determined the number and area of the records that occur on land protected from development using all the properties in the conservation lands database at the end of 2005 but prior to the updates documented in Rubin and Phaneuf (2006). A record was considered to be "on protected land" if >50% of the polygon representing the record overlapped with protected lands.

Results

The results of the NHB analysis from 2003 and 2006 are shown on Table 13 and Table 14, respectively. There was an apparent increase in the percent of communities that are protected: from 28% in 2003 to 48% in 2006. However, this trend probably reflects changes in the NHB database, not changes in watershed protection. First, the official state list of Threatened and Endangered plants was reviewed and revised. A total of 22 taxa previously listed were de-listed, and 35 taxa were added. Inventory work for the new taxa on the list is still ongoing. Second, as part of the NH Fish & Game Department's work on the Comprehensive Wildlife Plan, extensive data entry was done for existing wildlife information that had not previously been added to the NHB database. These two changes to the NHB database confound direct comparisons between the 2003 and 2006 analysis.

Regardless of relative changes, in both years the NHB indicates a higher percentage of

protected communities than the percent of conservation lands in the watershed. Only 10.7% of the coastal watershed is covered by protected lands (see indicator HAB6). In contrast, between 28 and 48% of the NHB communities are on protected lands. The high rate at which NHB records collocate with conservation lands is probably due to targeted natural resource assessments on conservation lands and the tendency to protect lands with high habitat values.

This analysis indicates that the rare and exemplary species indicator is subject to changes in data recording and is generally biased toward conservation lands. The indicator does not provide consistent information between years.

Table 13: Summary of NH Natural Heritage Bureau data for the coastal watershed in 2003

Record Type	Number of Records in Watershed	Number of Records on Protected Lands	Area in Watershed (acres)	Area Protected (acres)
Plant community - Estuarine	61	18	34,900	5,400
Plant community - Palustrine	56	21	3,200	900
Plant community - Terrestrial	44	21	1,800	850
Plant species	330	84	NA	NA
Insects	4	2	NA	NA
Mussels	2	0	NA	NA
Fish	0	0	NA	NA
Birds	31	4	NA	NA
Reptiles	35	7	NA	NA
Amphibians	0	0	NA	NA
TOTAL	563	157 (28%)	39,900	7,150 (18%)

Data Source: NH Natural Heritage Bureau

Table 14: Summary of NH Natural Heritage Bureau data for the coastal watershed in 2006

Record Type	Number of Records in Watershed	Number of Records on Protected Lands	Area in Watershed (acres)	Area Protected (acres)
Plant community - Estuarine	64	25	34,893	5,826
Plant community - Palustrine	75	33	4,144	1,578
Plant community - Terrestrial	53	39	2,368	1,789
Plant species	303	145	NA	NA
Insects	4	3	NA	NA
Mussels	2	1	NA	NA
Fish	22	2	NA	NA
Birds	94	53	NA	NA
Reptiles	94	41	NA	NA
Amphibians	NA	NA	NA	NA
Mammals	4	1	20	< 1
TOTAL	715	343 (48%)	41,425	9,194 (22%)

Data Source: NH Natural Heritage Bureau

CONCLUSIONS

While it is difficult to summarize overall conditions in the NHEP project area, the land use and development indicators presented in this report show that:

- Impervious surfaces continue to be added to the watershed at an average rate of 1,185 acres/year. By 2005, 8.0% of the land area of the watershed was covered by impervious surfaces.
- In 10 of the 37 coastal watersheds and 13 of the 42 coastal municipalities, the percent of land area covered by impervious surfaces in 2005 was greater than the NHEP goal of 10%.
- Land consumption per person, which is an indicator of sprawl-type growth, continues to increase. The average imperviousness per capita in coastal municipalities increased from 0.152 in 1990 to 0.0201 in 2000 to 0.217 in 2005. Higher imperviousness per capita values were found in the smaller towns than in the larger cities.
- The percent of each town that is covered by large, unfragmented forest blocks ranged from 0% for some coastal towns to 70% for towns in the western part of the watershed. Only 2001 data were available for unfragmented lands so the rate of loss of these lands could not be calculated for this report.
- Over the past three years, 12,037 acres in the coastal watershed have been permanently protected from development (4,012 acres per year on average). Currently, 54,622 acres are protected, which amounts to 10.7% of the land area of the watershed. The rate of land protection will need to increase in order to meet the NHEP goal to protect 15% of the watershed land area by 2010.
- Land protection of shorelands has kept pace with development in recent years. As of 2005, tidal shorelands were 20% developed and 20% protected and undeveloped. Freshwater shorelands were 7% developed and 15% protected and undeveloped.
- Many (48%) of the records of rare and exemplary natural communities in the NH Natural Heritage Bureau database were located on lands already protected from development.

RECOMMENDED CHANGES TO THE NHEP MONITORING PLAN

- Indicator LUD3, road miles per capita, does not reflect the true extent of road building because it does not include private roads. Furthermore, the available information on roads is already included in the impervious surface maps created for indicator LUD1. Therefore, LUD3 is redundant and inaccurate, and should be removed from the NHEP Monitoring Plan.
- Indicator HAB4, protected unfragmented forest blocks, was not included in this report because an updated base layer for unfragmented lands was not available. Regardless, this indicator does not provide reliable information. The indicator reports on the percent of large unfragmented forest blocks that are protected from development. The percentage will change if more lands are conserved or if fewer forest blocks remain. The other conservation indicators (HAB6 and HAB3) are more stable and provide adequate information for management decisions. Indicator HAB4 should be removed from the NHEP Monitoring Plan.
- Indicator HAB3, shoreland development and protection, probably underestimates developed shorelands because most shoreland development is too dispersed to be documented by the impervious surface mapping techniques. Moreover, the impervious surface data were meant to be aggregated on a town or watershed scale, not a 250 foot wide shoreland buffer. The results from this indicator do not provide much useful information beyond what indicators LND1 and HAB6 report. Therefore, this indicator should be removed from the NHEP Monitoring Plan.
- Indicator HAB5, rare and exemplary natural communities, is subject to changes in data recording and is generally biased toward conservation lands. The indicator does not provide consistent information between years. Therefore, this indicator should be removed from the NHEP Monitoring Plan.

REFERENCES

CWP (2003) Impacts of Impervious Cover on Aquatic Systems. Watershed Protection Research Monograph Number 1. Center for Watershed Protection, Ellicott City, MD. March 2003. Available from: www.stormwatercenter.net.

Deacon, J.R., Soule, S.A., and Smith, T.E. (2005) Effects of urbanization on stream quality at selected sites in the Seacoast region in New Hampshire, 2001-03: U.S. Geological Survey Scientific Investigations Report 2005-5103, 18 p.

GOMC (2002) Gulf of Maine Council on the Marine Environment Action Plan 2001-2006. Gulf of Maine Council on the Marine Environment. 2002.

Justice D and Rubin F (2002) Developing Impervious Surface Estimates for Coastal New Hampshire, A Final Report to the New Hampshire Estuaries Project. Submitted by David Justice and Fay Rubin, Complex Systems Research Center, Institute for the Study of Earth, Oceans and Space University of New Hampshire, Durham, NH. December 2002.

Justice D and Rubin F (2006) Impervious Surface Mapping for Coastal New Hampshire – 2005. A Final Report to the New Hampshire Estuaries Project. Prepared by the Complex Systems Research Center, University of New Hampshire, Durham, NH. April 28, 2006.

Schueller (1995). The importance of imperviousness. *Watershed Protection Techniques*, **1** (3): 100-111.

NHEP (2004) NHEP Monitoring Plan. New Hampshire Estuaries Project, Durham NH June 30, 2004. Available from: www.nhep.unh.edu/resources/pdf/nhepmonitoringplan-nhep-04.pdf

NHEP (2003) Environmental Indicator Report: Land Use and Development. New Hampshire Estuaries Project, Portsmouth, NH. April 30, 2003. Available from: www.nhep.unh.edu/resources/pdf/environmentalindicatorreport-landuseand-nhep-03.pdf

NOAA (2002) Impervious Surface Mapping Tool. NOAA Coastal Remote Sensing Center, www.cdc.noaa.gov/crs/is/.

Rubin F and Phaneuf C (2006) Coastal Conservation Lands Update – 2005. A final report to the New Hampshire Estuaries Project. Prepared by the Complex Systems Research Center, University of New Hampshire, Durham, NH. April 28, 2006.

SPNHF (2001) New Hampshire Everlasting, Working Proposal. Society for the Protection of New Hampshire Forests, Concord, NH. September 22, 2001 Available from: http://www.spnhf.org/aboutus/nh-everlasting.asp.

www.nhep.unh.edu