Urbanization and Ground Water Recharge in the Raritan River Watershed

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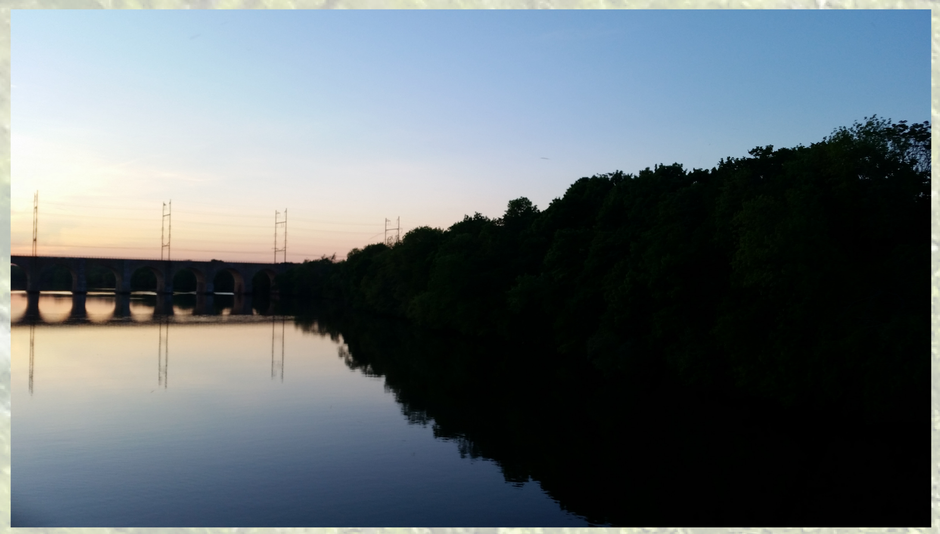
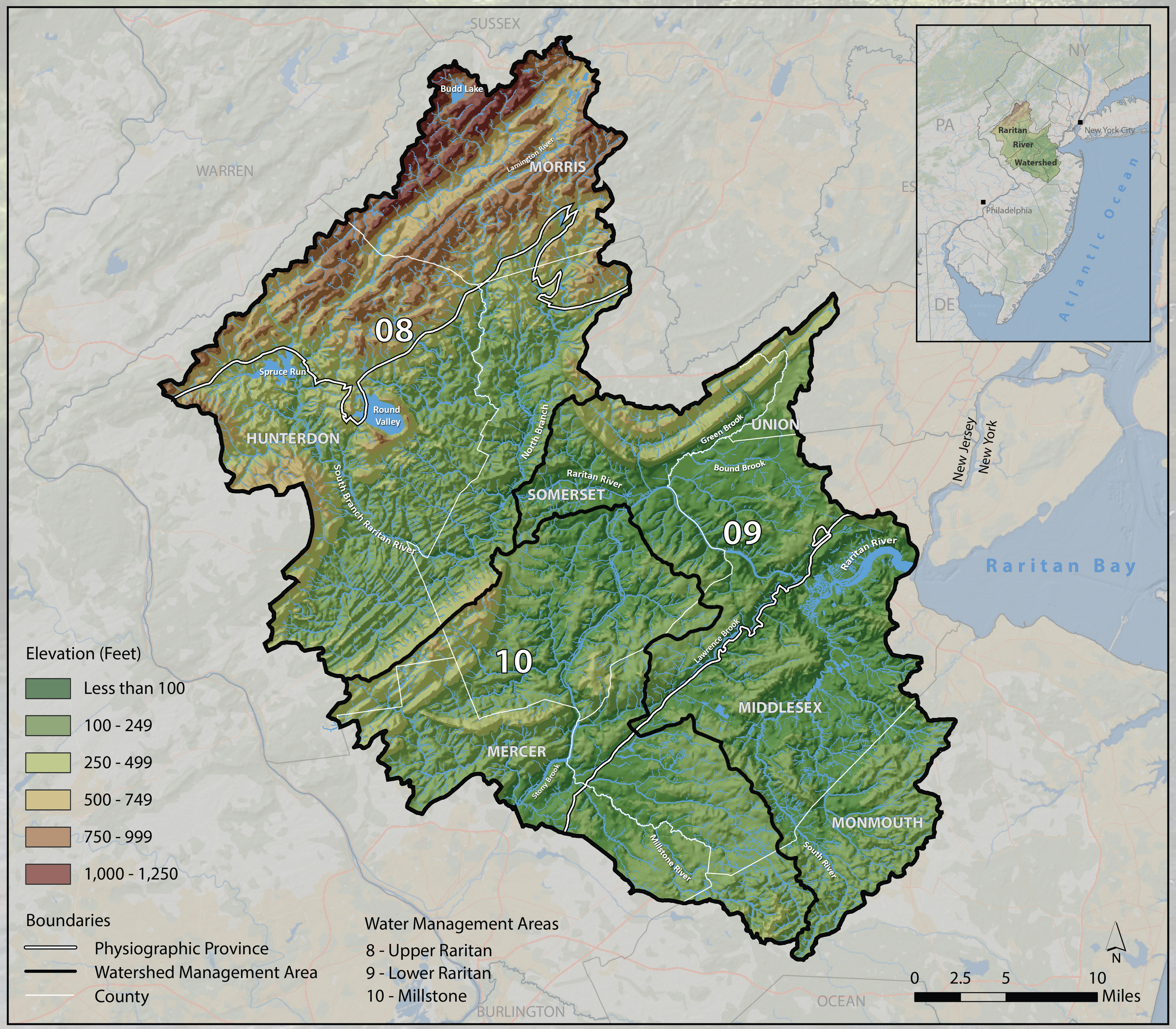


Abstract

Assessing watershed health through change in groundwater recharge is an alternative method of watershed health assessment. The objective of this study was to determine the spatiotemporal relationship between changes in groundwater recharge and changes in land use/land cover (LULC). Impervious surface, urban land, barren land, agricultural land, forest and wetlands were calculated in 1995 and again in 2012 for comparison. A geographical information system was used to determine the spatial variation and trend analysis of the change in land uses as well as change in groundwater recharge in the watershed. A more in depth analysis was developed using the statistical program, R. Multiple linear regression (MLR) and boosted tree regression (BRT) were used to determine more insight of predictors (change in land uses) to response variable (change in groundwater recharge).

Raritan River Watershed Geography

The Raritan River Watershed (RRW) is situated in central and northern New Jersey covering 1,105 square miles making it the largest watershed located entirely in New Jersey. The RRW is located entirely or partially in seven counties: Hunterdon, Mercer, Middlesex, Monmouth, Morris, Somerset and Union. The watershed is divided into three water management areas (WMA): the Upper Raritan (WMA 08), Lower Raritan (WMA 09), and Millstone (WMA 10). The RRW is further divided into 139 (HUC-14) smaller subbasins.[1]



GIS Data Sources:
New Jersey Department of Environmental Protection, US Census Bureau, New Jersey Office of Information Technology, SSURGO, Center for Remote Sensing and Spatial Analysis, ESRI

Acknowledgements:
Subhasis Giri, Richard Lathrop & John Bognar

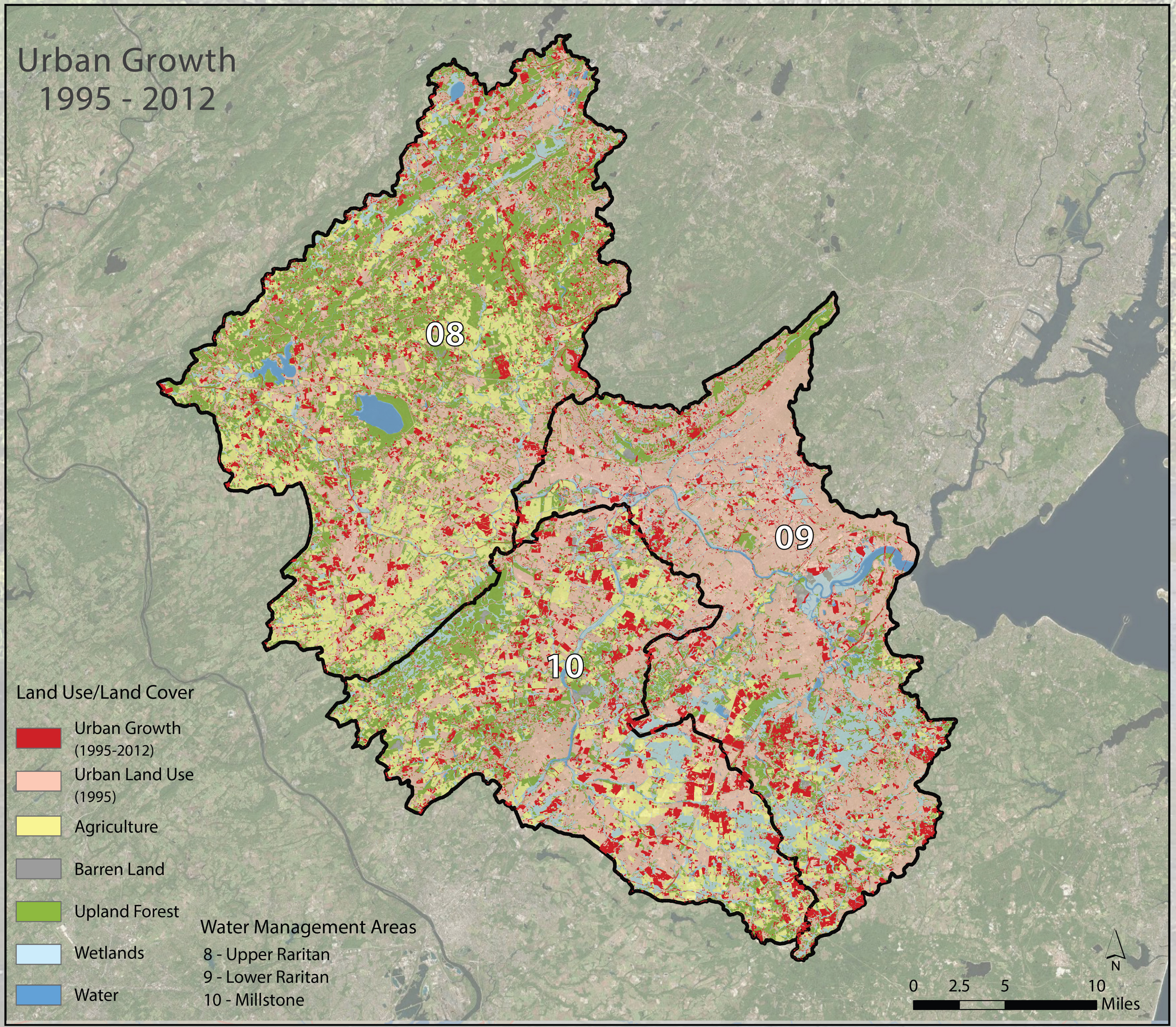
CRSSA RUTGERS

References:

1. Giri, Krasnuk, Lathrop, Malone, Herb. 2017. "State of the Raritan Report, Volume 1." Sustainable Raritan River Initiative Rutgers, The State University of New Jersey, New Brunswick, NJ 08901. http://raritan.rutgers.edu/
2. Giri, Krasnuk, Lathrop, Zhang. 2017. "Spatial Variation, Trend Analysis, and Relationship of Watershed Health Indicators in the Raritan River Watershed: A Case Study." Rutgers University, New Brunswick, NJ 08901.
3. Arnold & Gibbons (1996). "Impervious Surface Coverage: The Emergence of a Key Environmental Indicator." Journal of the American Planning Association, 62:2, 243-258

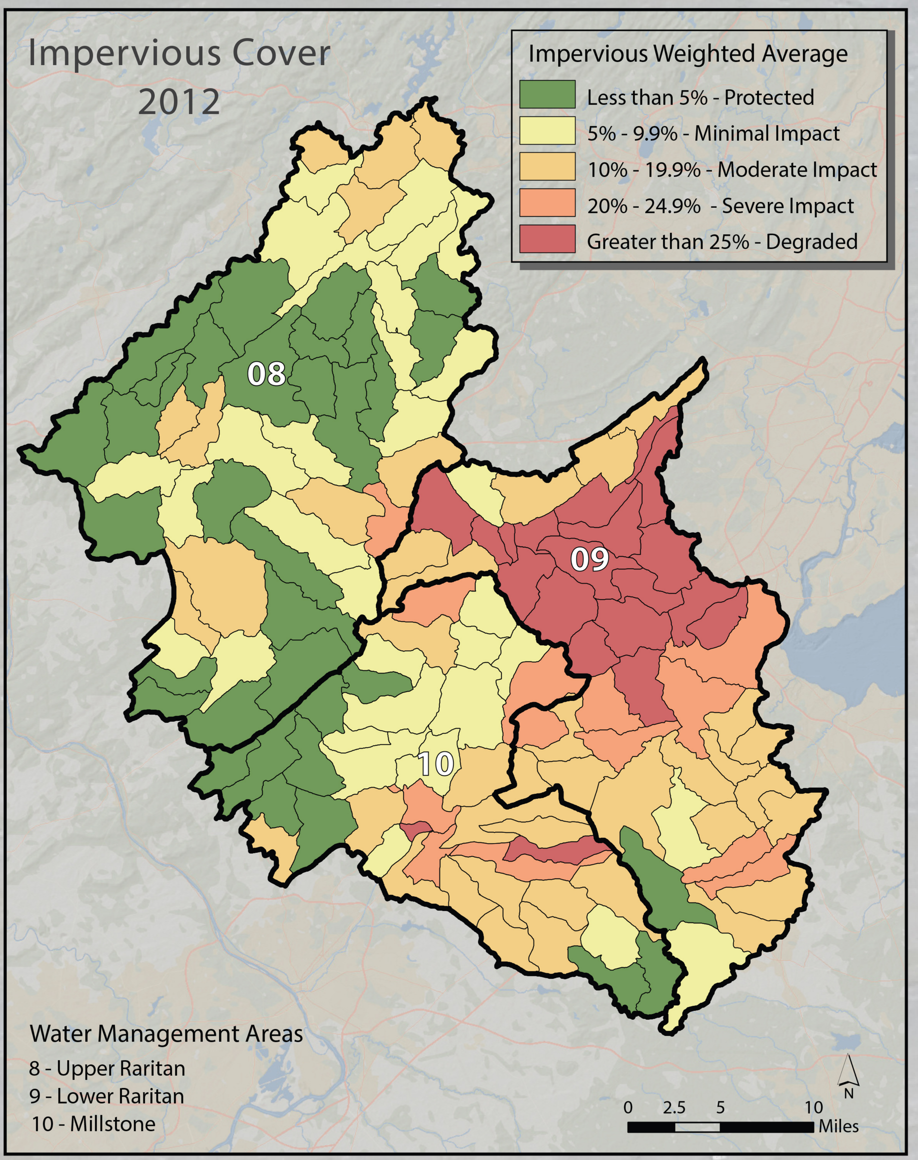
Urban Growth (1995 - 2012)

In 1995, the Raritan Watershed had 255,447 acres of urban land. In 2012, there were 307,515 acres of urban land. Over a span of 17 years, urban land use grew by about 20%. Consequently, wetlands and forest land cover have declined. Urban growth leads to the development of new roads, shopping centers, and commercial areas that are often associated with increases in impervious surfaces leading to less infiltration, more runoff increasing pollutant transfer rate and volume.[2]



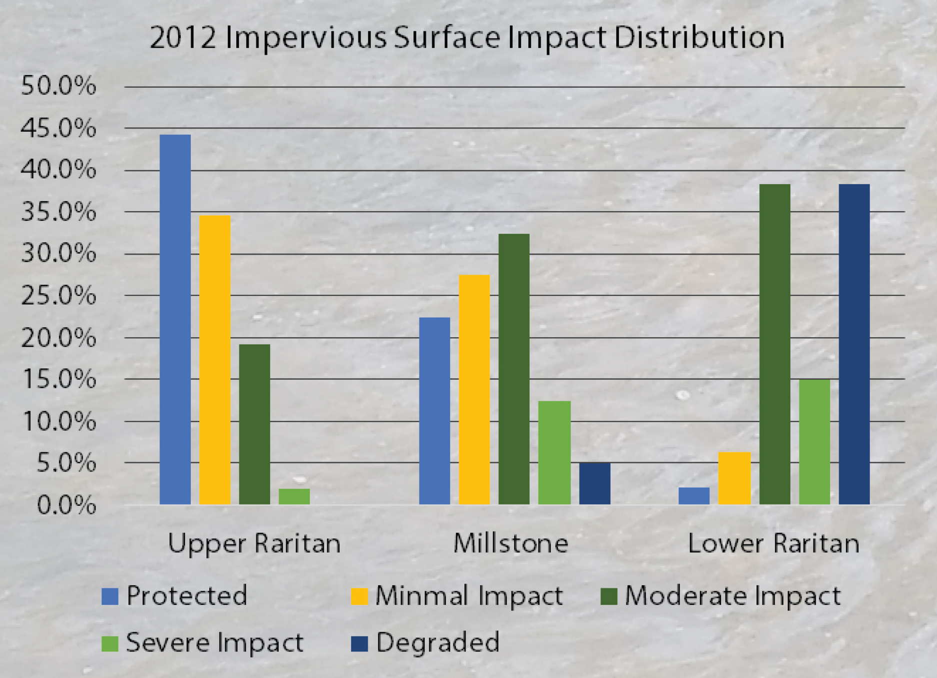
Population Growth and Impervious Surfaces

Population has increased by almost 26% from 1990 to 2010 in the Raritan River Watershed. Lower population densities usually result in disconnected impervious surfaces (lower %) and higher population densities usually result in connected impervious surface areas (higher %). Using 2012 data, the impact of impervious surfaces on watershed health for each HUC-14 was estimated by calculating the weighted average of impervious surface area.[3]



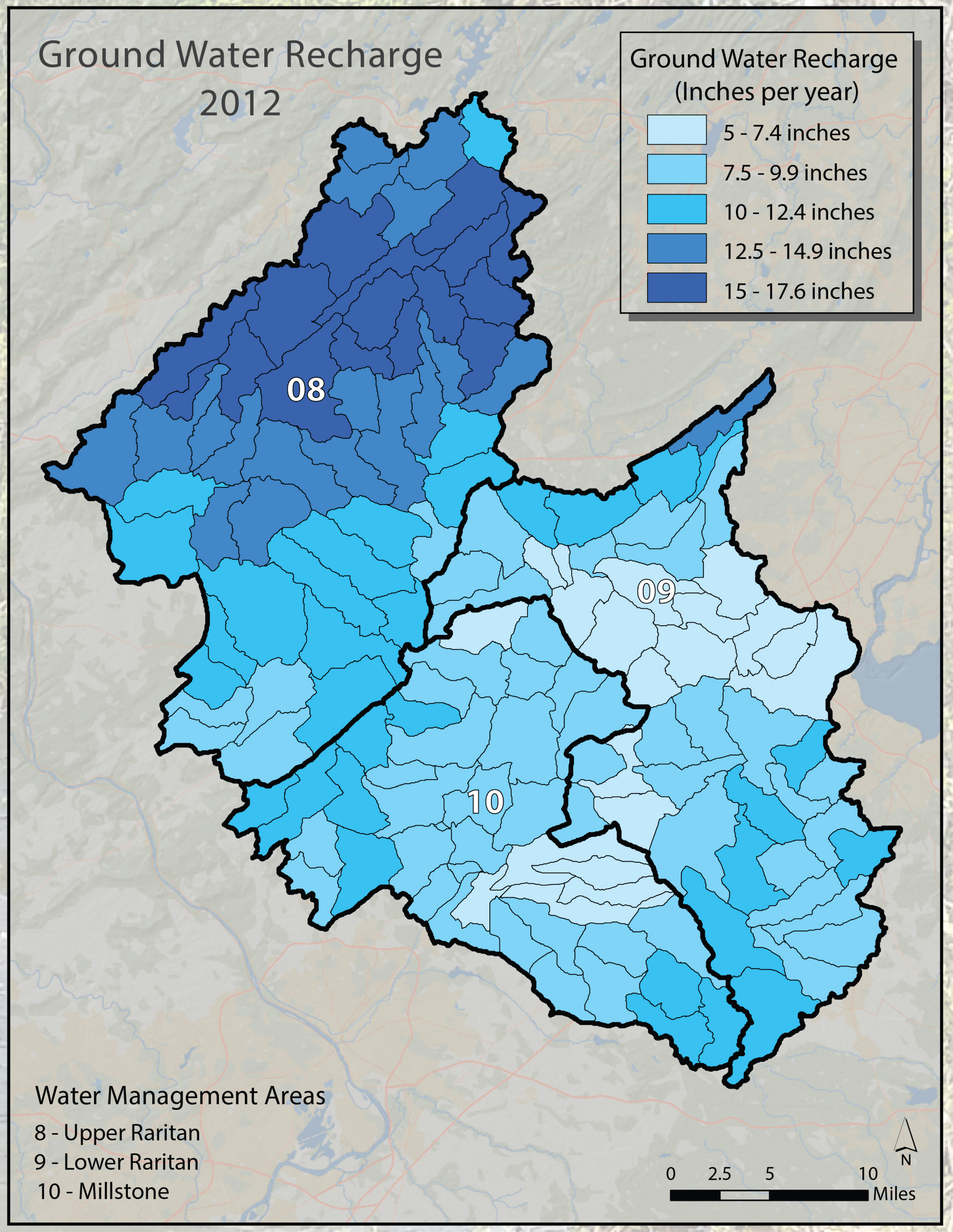
Population	1990 Population	2000 Population	2010 Population	Total Change
Raritan Watershed	1,040,996	1,213,862	1,307,003	266,007
Upper Raritan	174,516	212,375	223,002	48,485
Lower Raritan	684,472	764,792	819,136	134,663
Millstone	182,007	236,694	264,865	82,858

Impervious Surface	1995 Percent IS	2002 Percent IS	2012 Percent IS	Change in Percentage
Raritan Watershed	11.2%	12.1%	12.9%	1.7%
Upper Raritan	5.7%	6.3%	6.6%	0.9%
Lower Raritan	19.9%	21.2%	22.4%	2.5%
Millstone	9.4%	10.4%	11.5%	2.1%



Ground Water Recharge

Groundwater recharge (GWR) was estimated for each HUC-14 using the New Jersey Geological Survey's Groundwater Recharge Methodology Version 6.1. The map below was generated using 2012 LULC NJDEP data. LULC data for 1995 and 2012 were used for the change analysis.



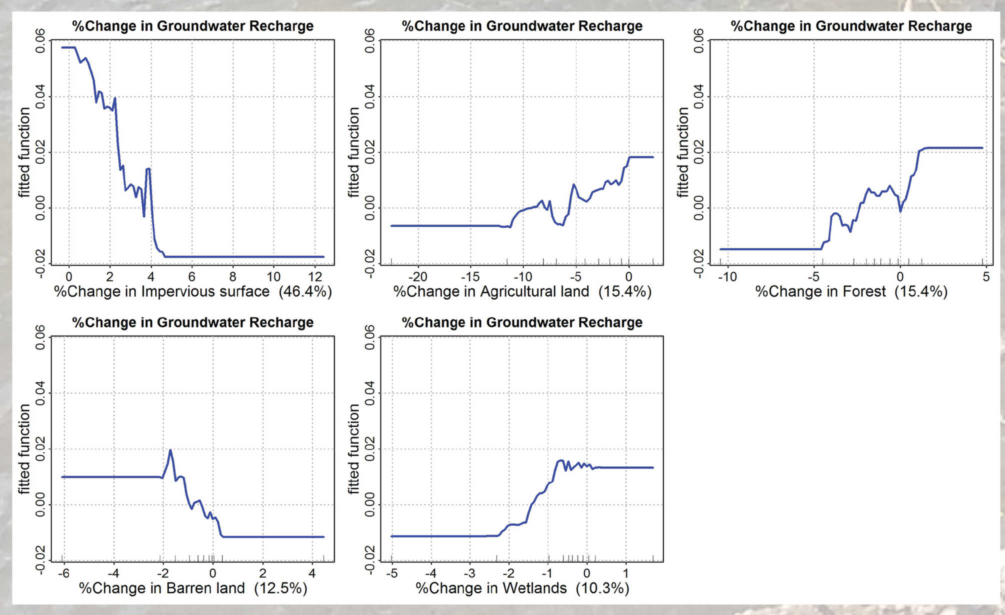
Results

An optimized MLR model revealed that all variables except change in urban land were significant predictors of change in GWR. The wide range in imperviousness among urban land use types ranging from rural urban to high density urban removed urban land as a reliable predictor. However, urban development has an indirect role in GWR through the loss of natural land cover types and an increase in impervious surfaces and barren land.

	Full Model		*Optimized Model*	
Predictors	**β-value**	**p-value**	**β-value**	**p-value**
Intercept	0.008	0.135	0.010	0.059
Change in Impervious surface	-0.014	0.000***	-0.014	0.000***
Change in Barren land	-1.342	0.049**	-0.626	0.003**
Change in Forest	-0.311	0.638	0.413	0.001***
Change in Agricultural land	-0.531	0.411	0.183	0.018**
Change in Wetlands	-0.130	0.840	0.528	0.041**
Change in Urban land	-0.714	0.266		

** indicates 5 % level of significance, *** depicts 1 % level of significance

The BRT model used in this study determined that the most important predictor in GWR change was change in impervious surface (-), followed by change in agricultural land (+), forest (+), barren land (-), and wetlands (+).



The partial dependence plots generated by the BRT model show the relative influence of the predictor variable on GWR response while keeping all other predictor variables average (in parentheses below the x-axis of each graph). The fitted function on the y-axis is the relative logit contribution of the variable.[2]