Vulnerability Analysis of the Parker and Mystic Watersheds in Massachusetts

Introduction

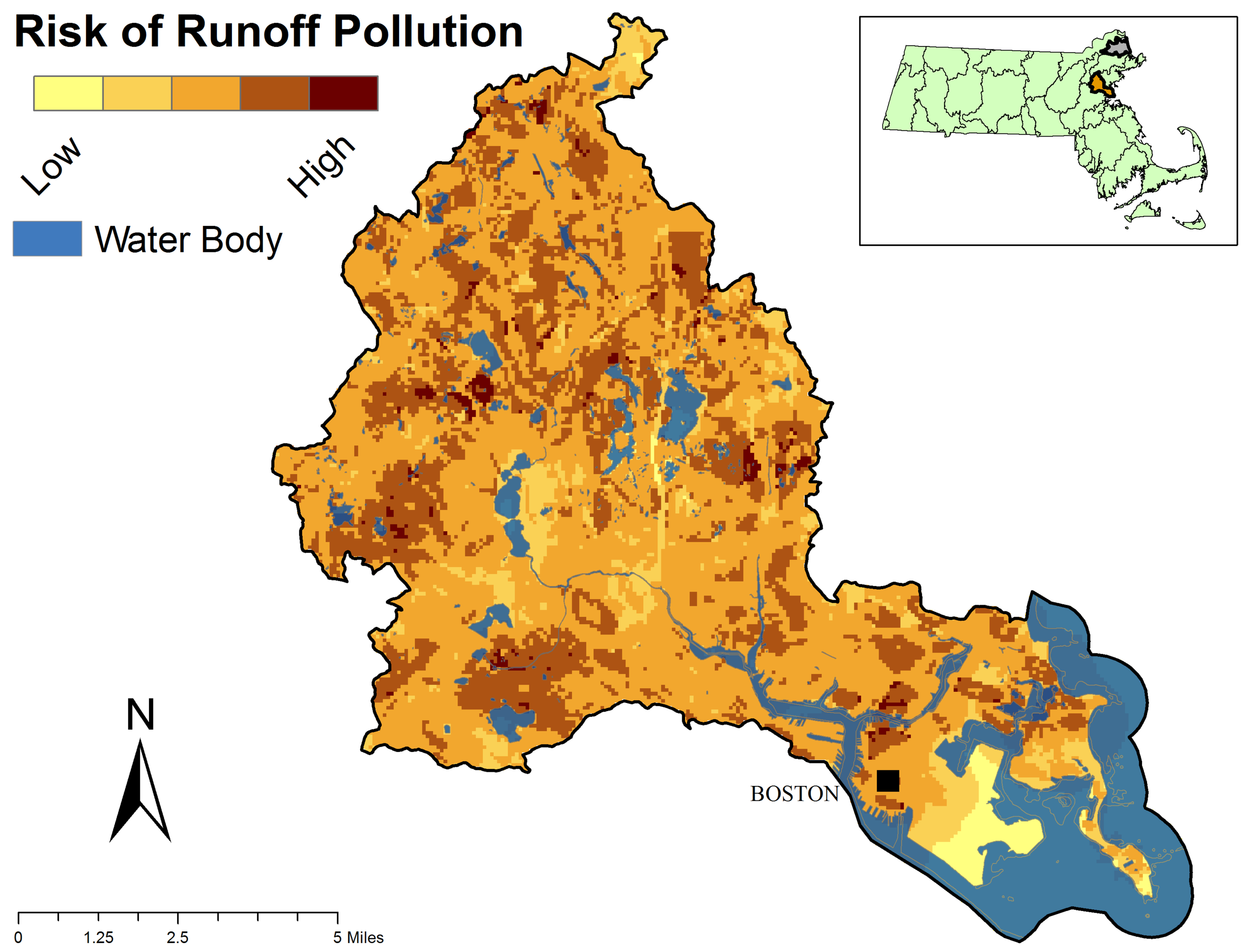
As the demand for clean water grows, so does the concern about the amount of pollution affecting our water bodies. Known sources of pollution are controlled with laws and permits but not all causes of pollution are accounted for. Runoff is defined as the amount of precipitation that does not evaporate or infiltrate into the soil; the precipitation travels over the surface of the land until it reaches a water body. Non-point source pollution occurs when runoff picks up pollutants from a variety of causes and deposits them in a water body. It is one of the main contributors to water quality degradation in the United States. Current research is endeavoring to attribute the pollution to their origins and quantify the damage caused and amount from each source.

Non-point source pollution frequently enters the ecosystem through storm runoff. The amount of runoff that will likely make it into a body of water depends on factors such as the slope and soil type of the surrounding area. A steep gradient has a much higher likelihood of runoff, whereas a flat surface is much more likely to filter the water into the ground. The hydrologic soil group also aids with the amount of absorption that takes place. Type A soils are the most permeable to water while Type D soils are the least permeable, and therefore contribute the most to runoff.

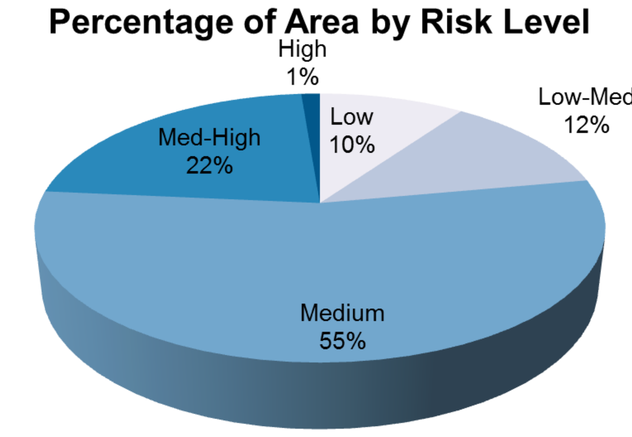
Common non-point sources of pollution are agriculture, industrial sites, waste sites, and roadways. Excess nutrients from farms can cause algal blooms in water ecosystems that prevent all other organisms from living in the area. Pesticides can wash off crops and make their way through food webs, like DDT. Metals, chemical compounds, and hazardous materials from industrial sites and landfills are commonly not disposed of properly, or unintentionally leak from waste sites into water bodies. For example, mercury is known to bioaccumulate and biomagnify through the food chain. Runoff from roadways is another concern. Gasoline and other chemicals used by vehicles spill onto the pavement and are washed into water bodies during periods of precipitation.

This analysis will integrate some of the components that cause runoff with potential pollution factors in an attempt to assess the vulnerability risk of nonpoint source pollution in two local watersheds. The watersheds examined will be from different communities, an urban area versus a more rural area. The investigation will strive to determine which area, urban or rural, is most at-risk and suggest which areas need to implement stricter water pollution regulations.

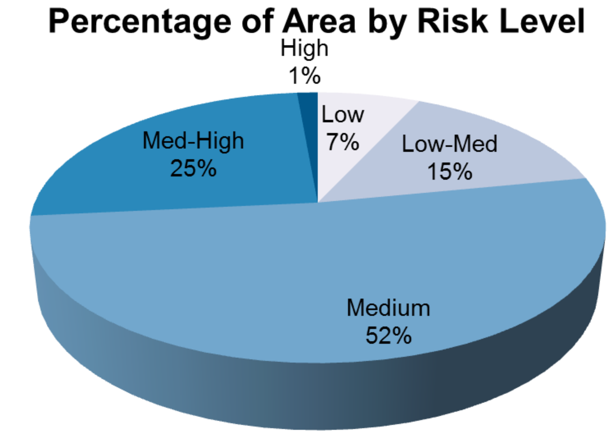
Mystic Watershed: Final Weighted Vulnerability



Results



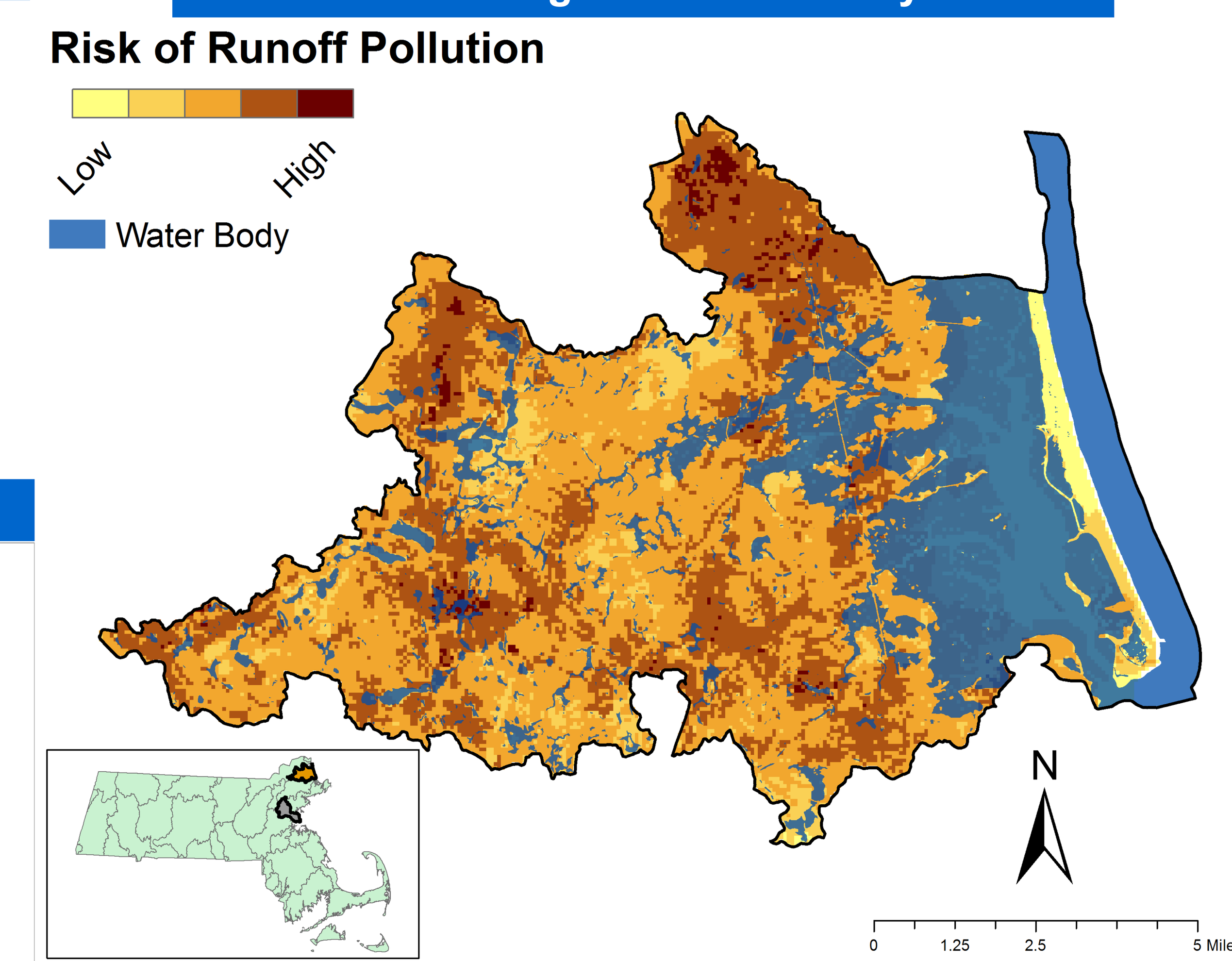
Mystic Watershed



Parker Watershed

As seen in the pie charts above, the combined categories of high risk, medium-high risk, and medium risk areas make up 78% of both watersheds. Each watershed has the same percentage of high risk areas. The Parker Watershed has slightly more medium-high risk areas, while the Mystic has more medium risk areas. The Mystic Watershed has the highest percent of low risk areas.

Parker Watershed: Final Weighted Vulnerability



Methods

Before beginning the analysis, the two study areas needed to be chosen. Two factors were used when making that decision: the area of water per area of watershed and the population density of that area. The two watersheds that had approximately equal water to land ratio and very different population densities (a low and high value) were the Parker and the Mystic Watersheds (see Table 1).

Watershed	Water to Land ratio	Population density (per km²)
Parker	82.3	341
Mystic	87.2	2861

Table 1. Comparison of the Parker and Mystic Watersheds.

Each layer was first clipped to the study area to limit the area of analysis. The main tools used in this investigation included Euclidean Distance, Reclassify, and the Raster Calculator. Each layer was reclassified on a risk of runoff scale or risk of pollution scale from 1 to 5, with 1 being the lowest at-risk area and 5 being the highest (see Table 2). The layers used in the analysis were slope, hydrologic soil groups, agricultural land use, industrial land use, major roads, oil and hazardous material sites, and solid waste land disposal sites.

The final risk of runoff pollution was calculated using the raster calculator after all of the factors were reclassified. All of the factors were added together and none were weighted any higher than the others. The raster scale was then re-grouped into 5 categories: 6-10 was given a value of low risk, 11-15 was given a value of low-medium, 16-20 was given a value of medium, 21-25 was given a value of medium-high, and 26-31 was given a value of high risk. The area of each category was calculated and presented as a percent of the total area to give a percentage of area at risk.

Factors	1= Low Risk	2= Low -Med	3= Medium	4= Med -High	5= High Risk
Slope (% Rise)	0-3	3-8	8-15	15-25	25-35
Hydrologic Soil Groups	A	B	C	C/D	D
Agricultural Land Use (m)	>2000	2000	1000	500	200
Industrial Land Use (m)	>2000	2000	1000	500	200
Major Roads (m)	>2000	2000	1000	500	200
Oil and Hazardous Material Sites (m)	>2000	2000	1000	500	200
Solid Waste Land Disposal (m)	>2000	2000	1000	500	200

Table 2. Reclassification categories for each factor.

Conclusion

The Mystic and Parker Watersheds appear to have equal percentages of vulnerable areas. The quantity of high, medium-high, and medium risk pollution areas are all approximately equal. This can be explained by the urban or rural nature of each watershed and the factors that contributed to the analysis.

The Parker Watershed is situated in a more rural area. As expected, it has a much larger agricultural area that is over 12 times that of the Mystic Watershed. It contains fewer major roads, a smaller industrial area, and less oil and hazardous material sites. The Parker Watershed also consists of more D and C/D type soil, the types that are least permeable and support the most runoff.

The Mystic Watershed is located in a very urban, densely populated area that includes the capital of Massachusetts. As anticipated, it contains approximately four times the amount of industrial land use, almost 38 times the amount of oil and hazardous waste sites, and many more major roads. There are far fewer agricultural areas and more locations with type A and B soil which the most permeable to water.

Both the Parker and Mystic Watersheds had similar numbers of solid waste land disposal sites (9 and 13, respectively). The variation in slope was also assessed to be about equal for both areas.

It is recommended that both watersheds focus on combatting the problem of nonpoint source pollution. Due to the nature of the communities in each watershed, different approaches should be taken. The Parker Watershed should aim to limit the amount of runoff that originates from agricultural land. They should concentrate on the farms located on the least permeable soils and conduct frequent water quality testing to test the levels of fertilizers and pesticides. On the other hand, the Mystic Watershed should direct their attention to the industrial sites, oil and hazardous waste sites, and roadways. They should ensure that all industries are disposing of their waste properly and can account for the life cycle of all chemicals. The areas around the oil and hazardous material sites should be examined for leaks routinely and water-quality testing should be performed regularly near major roads. These are just a few suggestions about what can be done to decrease the levels of nonpoint source pollution in the Parker and Mystic Watersheds.

Sources

Cartography by Stephanie Clarke
Intro to GIS, Fall 2014

Map Data Sources: MassGIS, 2014, U.S. Census 2010
Projection:
NAD_1983_StatePlane_Massachusetts_Mainland_FIPS_2001

Bhaduri, Budhendra, Harbor, Jon, Engel, Bernie, & Grove, Matt (2000). Assessing Watershed-Scale, Long-Term Hydrologic Impacts of Land-Use Change Using a GIS-NPS Model. *Environmental Management*, 26(6), 643-658. doi: 10.1007/s002670010122

Hamlett, J.M., Miller, D.A., Day, R.L., Peterson, G.W., Baumer, G.M., & Russo, J. (1992). Statewide GIS-based ranking of watersheds for agricultural pollution prevention. *Journal of Soil and Water Conservation*, 47(5), 399-404. (no doi available).

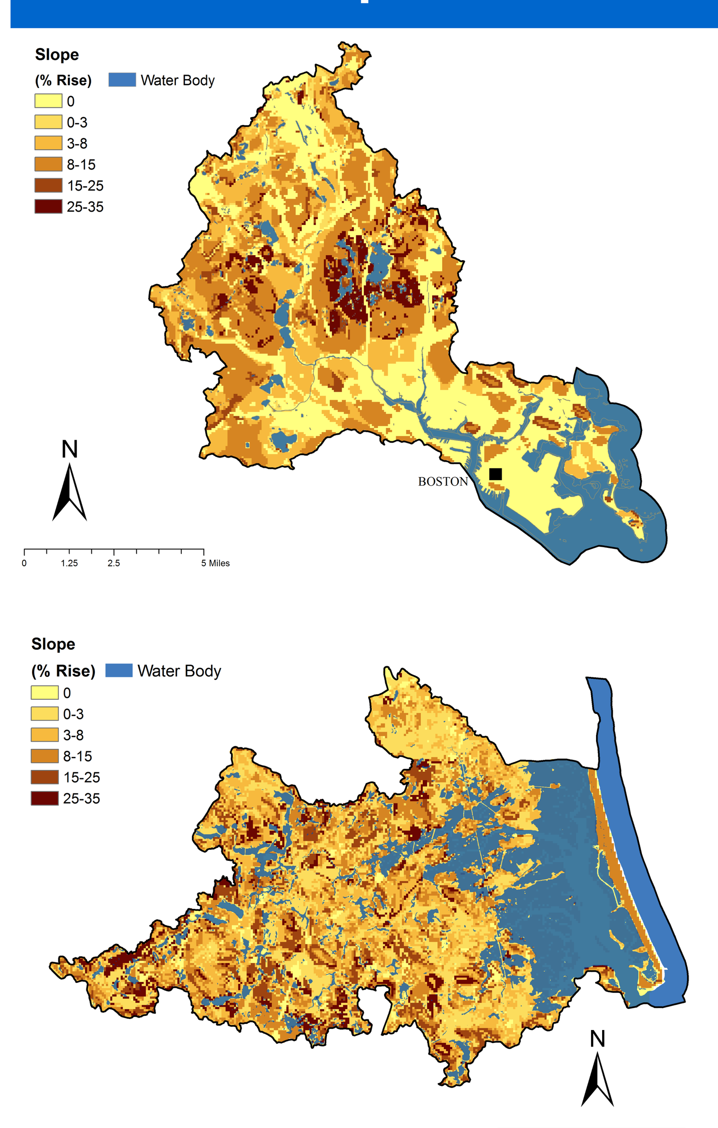
Heller, T. (2011). *Hydrologic Soil Groups*. Purdue University. Retrieved from https://engineering.purdue.edu/mapserve/LTHIA7/documentation/hsg.html.

Stuebe, Miki M. & Johnston, Douglas M. (1990). Runoff Volume Estimation Using GIS Technique. *Journal of the American Water Resources Association*, 26(4), 611-620. doi: 10.1111/j.1752-1688.1990.tb01398.x

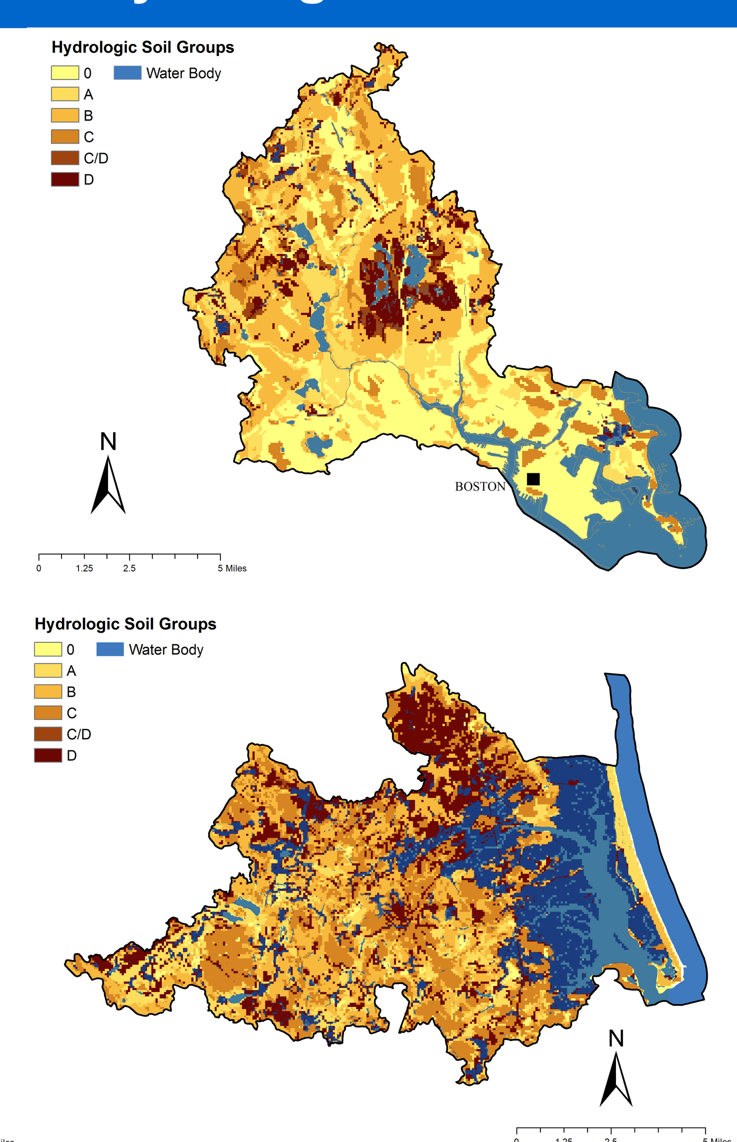
Weng, Qihao (2001). Modeling Urban Growth Effects on Surface Runoff with the Integration of Remote Sensing and GIS. *Environmental Management*, 28(6), 737-748. doi: 10.1007/s002670010258

U.S. Environmental Protection Agency. (2014). *Polluted Runoff: Nonpoint Source Pollution*. Retrieved from http://water.epa.gov/polwaste/nps/index.cfm.

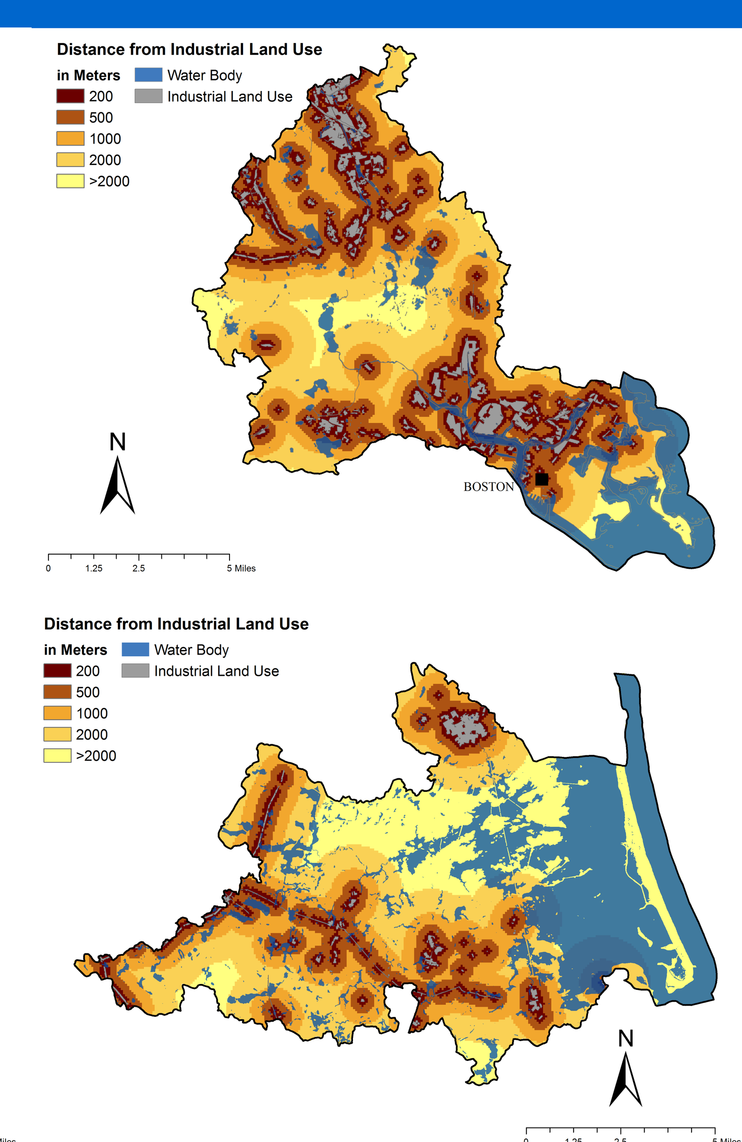
Slope



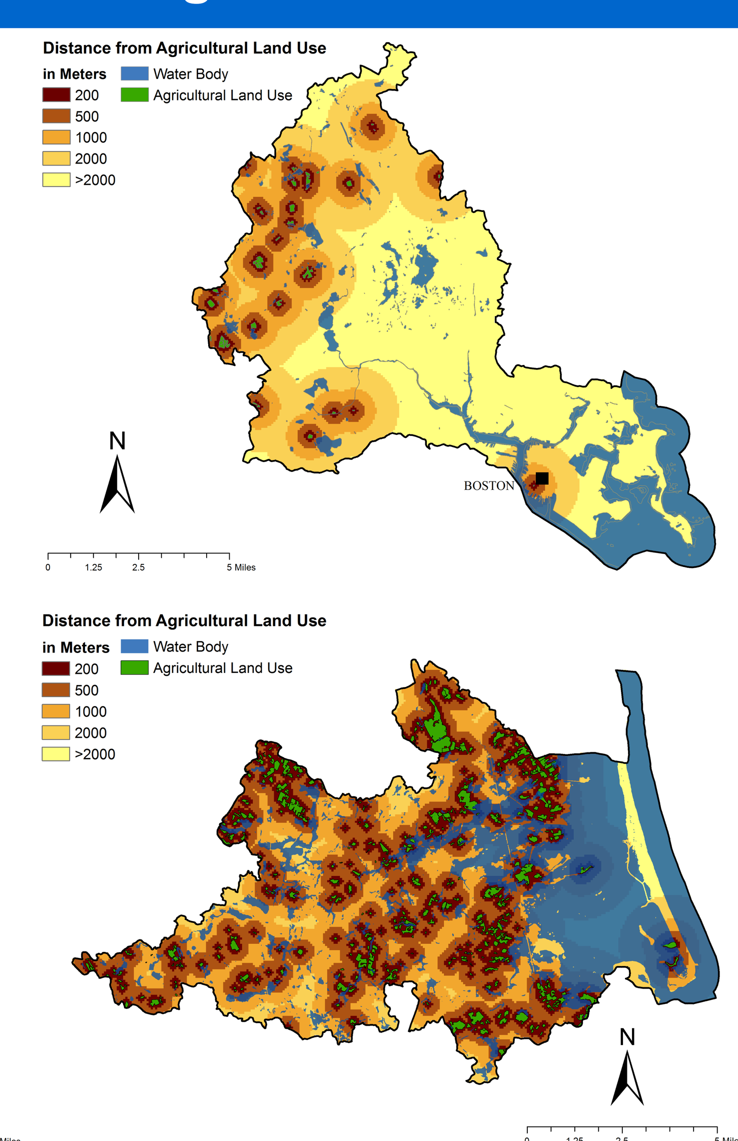
Hydrologic Soil Data



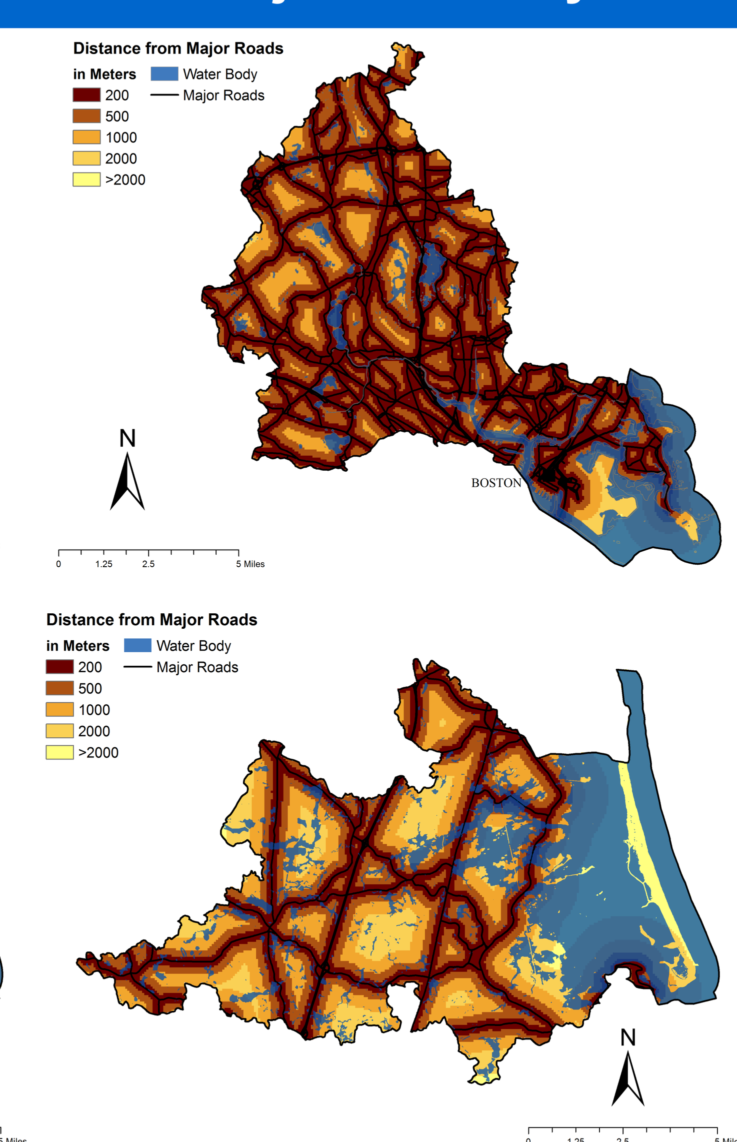
Industrial Land Use



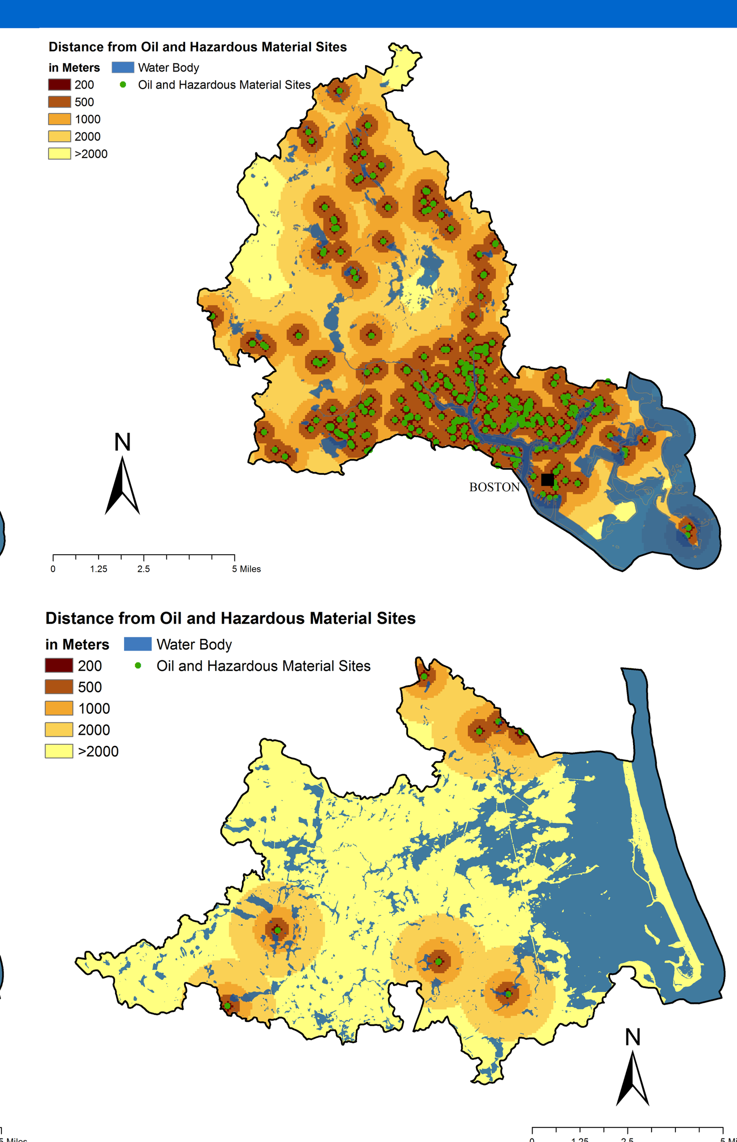
Agricultural Land Use



Major Roadways



Oil and Hazardous Waste



Solid Waste Disposal