Problem and Research Objectives:

One of the major impacts of impervious surfaces associated with urbanization is the alteration of hydrologic cycles resulting in excessive runoff, lack of infiltration, and insufficient aquifer recharge (Booth and Jackson 1997; Brabec, Schulte, and Richards 2002). Consequently, human-induced flooding at various scales is a problem in urbanized areas, particularly under the increased intensity and duration of storm events promised by climate change in the New England Region (IPCC 2007; Rock et al. 2001). Past research has focused on the relationship between stormwater runoff and land cover associated with land use and density either at the overall watershed scale or at the neighborhood scale. Current research has focused on the connection between the effectiveness of stormwater best management practices (BMPs) such as porous paving, infiltration trenches, bioswales, and greenroofs, from the neighborhood scale to the watershed scale. However, this research has not been incorporated into models that test the interactions of three variables: (1) projected climate change precipitation levels, (2) varying development patterns (land use and land cover), and (3) flooding impacts. Therefore, further research is needed to understand the relationship between effective impervious area (EIA), stormwater infiltration BMPs, and land use and land cover (Brabec 2009) under various storm events. In addition, understanding whether such relationships at the neighborhood scale can be effectively aggregated at a watershed scale is crucial for policy-making in implementing BMPs across scales.

Nature, Scope, and Objectives of the Research:

This study is part of a larger scope of research that aims to answer the following questions: (1) to what degree does installing stormwater BMPs at the neighborhood scale effectively reduce stormwater runoff and minimize flooding? (2) to what degree does the effectiveness of stormwater BMPs at the neighborhood scale translate to effects at the watershed scale? (3) what is the implication of additional non-structural stormwater BMPs such as land use planning and open space preservation on stormwater management at the watershed scale when limited structural stormwater BMPs exceed their capacity for infiltration and retention of stormwater onsite at the neighborhood scale?

Methodology:

This study employed SWAT (Soil and Water Assessment Tool) for hydrological modeling. The long-term flooding hazard index (HI) was constructed based on the SWAT output of streamflow and was defined as the probability of the number of days in 45 years when stream flows overbank. Detention was identified as a key tool for mitigating flooding and was selected for testing in the model. Growth scenarios were developed under the Boston ULTRA-ex project. Four land use scenarios varying by distribution of projected population growth in the watershed were created and tested in the model. Climate change assessment was incorporated into SWAT modeling along with detention and land use scenarios input in separate procedures. First, climate sensitivity tests were conducted using 150 combinations (+0, 1, 2, 3, 4, 5°C in mean temperature; 0, ±10%, ±20% in mean precipitation; 0, ±10%, ±20% in precipitation variation) under current land use. The results from climate sensitivity tests were compared with GCM models projected for climate change trends in the Northeast region—increased precipitation and temperature. Therefore, only positive increase in precipitation and temperature up to 3°C were selected for testing the effect of detention with a total of 36 combinations (+0, 1, 2, 3°C in mean temperature; o, +10%, +20% in mean precipitation; 0, +10%, +20% in precipitation variation). Finally, three climate change scenarios were selected to test urban growth scenarios. Low Impact climate change scenario was the combination of +3°C, +10% in mean precipitation and 0% in precipitation variation; Medium Impact climate change scenario was the combination of +2°C, +10% in mean precipitation and +10% in precipitation variation; High Impact climate change scenario was the combination of +1°C, +20% in mean precipitation and +20% in precipitation variation. Linear regression analysis was used to investigate the relationship between the percentage of land areas used for detention and the HI value under each climate sensitivity tests in current land use.

Principal Findings and Significance:

1. Under the definition of long-term flooding hazards defined in this study, the Charles River watershed was the most flood-prone at the lower basin with increasing flooding hazards toward upstream when the climate change impact becomes greater. Therefore, the long-term climate change-induced flooding hazards are more severe in the suburban communities of Boston.
2. Detention alone as a long-term climate change-induced flooding hazard mitigation strategy was effective (1% increase in detention may reduce HI by 0.06% to 0.28%) yet weak (R square ranges from 0.07 to 0.15). Therefore, it is critical to integrate multiple BMPs and incorporate land use planning into hazard mitigation.
3. Current Trend growth scenario encountered the most land change converting agricultural and forest lands to urban development and resulted in higher HI than other growth scenarios that were focusing on densifying or redeveloping currently built areas. In addition, the climate change impacts showed a greater variance in HI than the impacts from growth scenarios.
4. The findings suggested that suburban communities along the main stem of the Charles River watershed would be exposed to a greater probability of long term climate change-induced flooding hazards. Climate change adaptation is critical since the impacts from climate change are greater than land use impacts on streamflow. Finally, green infrastructure incorporating multiple structural and non-structural BMPs plays an important role in serving as flooding mitigation and climate change adaptation strategy.