

# Hydroclimatic Response of Watersheds to Urban Intensity: An Observational and Modeling-Based Analysis for the White River Basin, Indiana

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(Manuscript received 22 December 2008, in final form 30 June 2009)

## ABSTRACT

Impervious surface area (ISA) has different surface characteristics from the natural land cover and has great influence on watershed hydrology. To assess the urbanization effects on streamflow regimes, the authors analyzed the U.S. Geological Survey (USGS) streamflow data of 16 small watersheds in the White River [Indiana (IN)] basin. Correlation between hydrologic metrics (flow distribution, daily variation in streamflow, and frequency of high-flow events) and ISA was investigated by employing the nonparametric Mann–Kendall method. Results derived from the 16 watersheds show that urban intensity has a significant effect on all three hydrologic metrics. The Variable Infiltration Capacity (VIC) model was modified to represent ISA in urbanized basins using a bulk parameterization approach. The model was then applied to the White River basin to investigate the potential ability to simulate the water and energy cycle response to urbanization. Correlation analysis for individual VIC grid cells indicates that the VIC urban model was able to reproduce the slope magnitude and mean value of the USGS streamflow metrics. The urban model also reproduced the urban heat island (UHI) seen in the Moderate Resolution Imaging Spectroradiometer (MODIS) land surface temperature products, especially for the grids encompassing the city of Indianapolis, IN. The difference of the hydrologic metrics obtained from the VIC model with and without urban representation indicates that the streamflow regime in the White River has been modified because of urban development. The observed data, together with model analysis, suggested that 3%–5% ISA in a watershed is the detectable threshold, beyond which urbanization effects start to have a statistically significant influence on streamflow regime.

## 1. Introduction

Urbanization, one of the most pervasive land conversions by human activities (Alberti 1999), has a great effect on land cover and landscape characteristics, resulting in a sharp increase in impervious surface area

(ISA) on the global landscape. Under natural conditions, precipitation is intercepted by vegetation or stored in the soil body, from which it is taken up by vegetation to evapotranspire or drain slowly into streams (Dunne and Black 1970). In highly urban landscapes, more water flows over impervious surfaces or through drainage networks that can greatly increase the speed of flow to receiving water bodies (Arnold and Gibbons 1996). Increased ISA because of urbanization also leads to greater temperatures in urban areas than in nonurban areas, resulting in urban heat islands (UHIs; Oke 1982). Urban

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