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Assessing Long-term Hydrological Impacts of Climate Change Across Wisconsin

Executive Summary
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The object of this study was to generate statewide, high-resolution estimates of historical and projected-future changes in direct runoff and non-point source (NPS) water pollution under alternative climate and land-use scenarios. This type of information can help inform the development and refinement of climate adaptation strategies, as part of the Wisconsin Initiative on Climate Change Impacts (WICCI), as well as local and regional planning efforts. Decision-makers, planners, and the public have lacked geographically detailed information on the relative magnitude of changes in runoff and NPS pollution that have occurred in the recent past, as well as those that are projected to occur in the future under different climate and land-use scenarios.

Working with collaborators at Purdue University, we developed a customized version of the long-term hydrologic impact assessment (L-THIA) modeling system, capable of estimating runoff and NPS loadings using high-resolution precipitation projections from "downscaled" general circulation models (GCMs), generated for WICCI by researchers at the University of Wisconsin. The initial intent was to develop an L-THIA 3.0 extension to the Environmental System Research Institute's *ArcGIS* software package; however, data processing limitations within *ArcGIS* required us to develop a series of separate model routines using the Python programming language. Model parameters were calibrated using streamflow data from six gauged watersheds. Default event-mean concentration (EMC) coefficients were substituted with more regionally appropriate values.

Once completed, the customized L-THIA modeling system was run to predict average growing season runoff and NPS pollutant loadings for five successive decades: 1957-1966, 1967-1976, 1977-1986, 1987-1996, and 1997-2006. In addition, we modeled average runoff and NPS pollutant loadings for the future period of 2046-2055, under 18 combined land-use and climate scenarios. Climate scenarios included the Intergovernmental Panel on Climate Change's "B1," "A1B," and "A2" scenarios, representing best-, middle-, and worst-case scenarios, respectively. Land-use scenarios include no change, the reversion of Conservation Reserve Program (CRP) lands to cropland, the maintenance of CRP/adoption of additional conservation practices, urban expansion, urban expansion with 25% adoption of low impact development (LID) practices, and urban expansion with 50% adoption of LID practices.

The results of the L-THIA model runs for the historic period indicate a distinct pattern of hydrologic change that has occurred over the past fifty years, with growing-season direct runoff increasing substantially in the southeastern, central, and west-central portions of the state, while decreasing across the northern region and much of the east-central and southwestern portions of the state. The results of model runs based on downscaled future GCMs indicate that while growing-season rainfall totals are projected to decrease by 3-5% between now and 2050, runoff totals are projected to increase by 20%, 27%, and 28%, respectively, under climate scenarios B1, A1B, and A2.

Model results also indicate that the spatial pattern of change varies considerably depending on the scale of analysis, with significant small-scale variation in runoff and NPS pollution projected at the sub-watershed and stream catchment scale. In some areas of the state, adaptation strategies based on alternative land-use and land management scenarios were shown to be capable of offsetting significant proportions of additional runoff and NPS pollution projected to occur under future climate scenarios, particularly in agricultural or urbanizing watersheds.

This study adds to our current understanding of the impacts of electricity and natural gas use in Wisconsin by illustrating historic and possible future hydrologic impacts of a changing regional climate at a spatial resolution previously unattainable. L-THIA model outputs include historical and projected-future average direct runoff and NPS loadings under alternative climate and land-use scenarios. These are contained in statewide data tables that can be linked to publically available geographic information system (GIS) files. Model outputs and associated GIS-based maps can be used by decision-makers, planners, and the public to help inform energy policy as well as adaptation planning at regional and local scales, and can be used to target areas for more detailed hydrologic analysis, such as future changes in the frequency and intensity of major flood events.

Future directions could include expanding the temporal window of analysis from the historical growing season to projected future growing seasons and beyond in order to account for late winter/early spring runoff, including snowmelt. Additional analyses could include modeling runoff and NPS pollutant loading based on the full range of downscaled GCMs, as well as modeling monthly runoff to evaluate seasonal changes. In addition, we could substitute statewide rainfall-runoff parameters and EMC coefficients with separate sets of regionally-optimized values, in order to better account for variation in watershed conditions. A key future direction would be the creation and dissemination of a publically available L-THIA 3.0 GIS software extension to automate more of the modeling process and enable regional and local adaptation planners to conduct these types of analyses themselves.

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Abbreviations and Acronyms

avg. – average

CN – curve number
CRP – Conservation Reserve Program

EMC – event-mean concentration
ESRI – Environmental System Research Institute

ft^3/acre – cubic feet per acre

GCMs – general circulation models
GIS – geographic information system

HSG – hydrologic soil group
HUC – hydrologic unit code

lbs/acre – pounds per acre

LID – low impact development
L-THIA – Long-term Hydrological Impact Assessment modeling system
LTM – Land Transformation Model

m – meter
mg/L – milligrams per liter
ml – milliliter

NLCD – National Land Cover Data
NPS – non-point source
NRCS – Natural Resources Conservation Service

SCS – Soil Conservation Service
SSURGO – Soil Survey Geographic data
STATSGO – State Soil Geographic data
SWAT – Soil and Water Assessment Tool

TR-55 – *Technical Release 55* (USDA SCS 1986)

µg/L – micrograms per liter
USDA – United State Department of Agriculture
USGS – United States Geological Survey

VIC – Variable Infiltration Capacity model

WICCI – Wisconsin Initiative on Climate Change Impacts
WISCLAND - Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data

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