Projected Changes in Flood Peak Discharge across Iowa: A Flood Frequency Perspective

Tech Transfer Summary

Project # 20-SPR2-002

March 2023

Sponsored by Iowa Department of Transportation and Federal Highway Administration

This project provides an assessment of the projected changes in flood frequency at the community level in Iowa, and a web portal to make this information easily accessible by users and decision makers.

Project Overview

The study provides an evaluation of the current approach to flood frequency analysis and the potential modifications accounting for the physical processes at play and changes in the climate system. It assesses the projected changes in flood frequency across Iowa under different emission scenarios, with the information that is provided at the community level through a web portal.

Problem Statement

Numerous modeling studies point to an intensification of the hydrological cycle under projected climate warming, with increasing frequency of extreme events, including heavy rainfall and flooding. This brings the question, what would projected changes in flooding mean for the Iowa Department of Transportation (IDOT) and the bridges and structures that constitute Iowa's highway system? How resilient are these highway structures to different climate warming scenarios?

Addressing these questions requires flood frequency analysis. The currently used methodology relies on the guidelines by Bulletin 17C. However, issues related to regionalization of at-site estimates as well as accounting for the projected changes in the climate system have received little attention despite the potentially large impacts, including to the IDOT's infrastructure.

Project Background

Flooding is one of the most devastating natural hazards, responsible for numerous fatalities and economic damage in the tens of billions of dollars. Over the 1985-2014 period, the average yearly flood losses were $7.96 billion (adjusted to 2014 inflation) and 82 fatalities (http://www.nws.noaa.gov/hic/). The occurrence of extreme flooding has become the norm rather than the exception in Iowa, with the 2008 Eastern Iowa flood representing the "poster child" for this catastrophic situation: during this event, for

instance, the eastern half of the state experienced the closure of a number of roads, including Interstate 80.

Therefore, addressing questions about changes in flood frequency and their projections over the course of this century has important societal and economic consequences in terms of our adaptation and mitigation strategies to water-related hazards. From an engineering perspective, the development of flood frequency estimation rooted in physical processes rather than statistical methods would also lead to the development of innovative methodologies allowing for the engineering design and management under nonstationary conditions.

Project Objectives

The study aimed at:

1) revisiting the current approach to flood frequency analysis and examining the potential modifications or updates accounting for the physical processes at play and changes in the climate system;
2) the examination of the projected changes in peak discharge; and
3) the development of a web interface highlighting the projected changes in flood frequency at the community level across Iowa.

Research Description

Revisiting the current approach to flood frequency analysis

Flood frequency estimation in the United States has been primarily driven by statistical analysis for the past 100 years. For ungauged locations, the regionalized equations are developed to provide annual exceedance probability discharge estimates. These equations establish a relationship between discharge quantiles and catchment physical properties through statistical regression. For Iowa, only one-third of developed regional equations use a climatic parameter (i.e., precipitation) which is a critical driver of hydrologic processes. The authors explore an alternative approach to regional flood quantile estimation analysis by analyzing the performance of the Iowa Flood Center's physically-based, calibration-free, and spatially-distributed Hillslope-Link Model (HLM). The model is used operationally in real-time forecasting of streamflow over Iowa by the Iowa Flood Center.

Projected changes in flood frequency

Understanding the projected changes in annual maximum peak discharge is important to improve resiliency in water resource planning and design at the community level. Currently, much of the literature on climate change impacts focuses on analyses at the regional scale. Here the authors use the HLM to evaluate the projected changes in annual maximum peak discharge at the community-level across Iowa under different emission scenarios. They utilize climate forcings from global climate models, part of the Coupled Model Intercomparison Projected Phase 5 (CMIP5) and Phase 6 (CMIP6).

Development of a web interface highlighting the projected changes in flood frequency at the community level across Iowa

Current guidelines for water related infrastructure (e.g., culverts, bridges) do not provide guidance on the incorporation of climate change into their design. Furthermore, there is a lack of tools available that provide projections of flooding at a community level that would enable site specific planning. Therefore, the authors introduce the Iowa Flood Frequency and Projections tool (IFFP) that provides projections of flooding up to the end of the 21st century at any river links in the State of Iowa for different scenarios. The tool utilizes annual maximum flood peaks simulated based on climate model forcings from CMIP5 and CMIP6.

Key Findings

The final report for this project includes detailed findings from these analyses. Here is a brief summary:

- Compared to regional regression equations, flood frequency analyses based on the HLM show similar discharge values for all annual exceedance probability where regional equations contain rainfall as a predictor. However, in areas where regional equations are only based on catchment properties, regional regression equations overestimated discharge for all quantiles. These results highlight inconsistencies in current regional regression equations for flood quantile estimates in Iowa and provide support for reevaluation of flood quantile estimates with physically-based hydrologic models.
- The simulations performed as part of this study show a detectable increase in annual maximum discharge for many of Iowa's communities, especially for the high-emission scenarios and towards the end of the 21st century.
- The development of the IFFP web-based tool provides flood frequency projections for Iowa and allows the exploration of future changes in flood peaks. It fills a current software gap for stakeholders as current tools do not provide flood projections for end-users. IFFP offers the user the capability to examine climate change information related to flooding across Iowa and is an effort to provide easy-to-use tools for water resource planning and management.

Implementation Readiness and Benefits

The work performed as part of this study included a literature review about the state-of-the-science of the historical and future flooding in Iowa, an evaluation of the current methodology for flood frequency analysis, an assessment of the projected changes in flooding across the state, and the development of a web interface to access the results of this project. The authors recommend the use of the HLM model to obtain consistent estimates of flood frequency across the state. Moreover, because of the projected changes in flooding during the 21st century, they also recommend the incorporation of climate change in the design of future IDOT infrastructure, taking advantage of the IFFP web portal.