

JOINT TRANSPORTATION RESEARCH PROGRAM

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Development of a Multiple Water Course Joint Probability Analysis Procedure for Indiana Watersheds

Introduction

The practice of hydrology in Indiana makes very frequent use of the Unit Hydrograph Method to determine flood flow rates at ungauged sites. In theory, a unit hydrograph is a runoff hydrograph resulting from one unit of direct runoff within a specified time duration. The Unit Hydrograph Method assumes that for any given amount of excess rainfall, the shape of the runoff hydrograph will be proportional to the shape of the unit hydrograph.

A number of years ago, the Soil Conservation Service (now the NRCS) conducted research in which they determined unit hydrographs for a wide variety of streams across the nation. These individual unit hydrographs were then averaged into a composite unit hydrograph known today as the “NRCS Unit Hydrograph.” This average unit hydrograph has been incorporated into most computer software packages that are used to compute flood hydrographs, including TR-20 and HEC-HMS. Application of NRCS Unit Hydrograph in Indiana shows



Example of confluence in Fort Wayne, Indiana.

Boomsa, J. (2019, April 3). *Fort Wayne is a small city in Northern Indiana* [Photograph]. iStock. <https://www.istockphoto.com/photo/fort-wayne-is-a-small-city-in-northern-indiana-gm1139979584-304897433>

that it tends to yield poor results for Indiana watersheds by mostly overpredicting the flow in the northern part and underpredicting the flow in the southern part, although the over prediction is much worse compared to the under prediction. To overcome the limitation of over-prediction or underprediction, a customized “Indiana Unit Hydrograph” is needed that could be used in lieu of the NRCS Unit Hydrograph. In the past, attempts have been made to address this limitation by developing regional regression-based equations to compute parameters for the Clark Unit Hydrograph method, but its implementation has proven tedious for practical applications. The goal of this project is to develop a custom unit hydrograph that is as easy to use and apply as the current NRCS method.

This broader goal is accomplished through the following objectives: (1) revisit the basic theory of NRCS UH, including its development, limitations and recent improvements; (2) derive UHs for watersheds in Indiana using historical rainfall-runoff event data and estimate the parameters of the NRCS UH; (3) relate UH parameters developed in Objective 2 to watershed characteristics by performing both statewide and regional regression analyses; and (4) develop customized Indiana UH using the regression expressions developed in Objective 3; and (5) compare the performance of the customized INUH with the original NRCS UH.

Findings

- Derivation of unit hydrographs for the 30 study watersheds using data from the last 20 years show that the mean value of the peak rate factor (*PRF*) is 371, which is lower than the default *PRF* of 484. Additionally, the lag time obtained from the derived UHs is higher than the lag time estimated by the NRCS lag time equation.
- The statewide regression analysis shows that the *PRF* is related to the main channel slope, and the

lag time is related to the percentage of sinks and urban land cover. Regional regression analysis, where regions are created based on the channel slope, shows that the *PRF* of flat watersheds depends on the flow length and the stream network, whereas the *PRF* for steep watersheds depends on the ruggedness and basin shape. The lag time is primarily related to the channel slope, the basin relief, and the curve number.

- Validation results indicate that the performance of custom UH is better compared with the original NRCS UH method for the watersheds in Indiana in terms of the predictions of peak discharge and time to peak.

Implementation

The findings from this study are translated into a computer program with a graphical user interface. This program is submitted to INDOT as a part of the final project report. A user manual for the program is also included in the final project report. This program will be used by INDOT’s hydraulics division for design projects and Federal Aid local projects

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