TECHNICAL SUMMARY

Estimation of Frequency Based Flood Peak for an Ungauged Watershed using Field Calibration

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INTRODUCTION

Accurate estimations of flood peak, frequency, and volume are needed for safe and economical design of highway drainage and flood control structures. For watersheds with systematic stream gauging records of sufficient length, flood frequency analysis can be conducted by following the U.S. Water Resources Council (WRC) procedure [1]. The WRC procedure uses log-Pearson Type III distribution as a base method for flood frequency studies.

Accurate flood frequency analysis is more difficult for ungauged watersheds or watersheds with significant changes in land use or in drainage systems. Hydraulics design engineers often need to resort to information transfer techniques or regionalization procedures to estimate flood peaks and hydrographs. The information transfer techniques may consist of: (1) regional regression equations correlating peak discharge to climatic and watershed parameters [2], [3], [4], [5],(2) rainfall-runoff models calibrated by watersheds that exhibit similar climatic and hydrogeologic conditions [7], [8], and (4) the transfer of a flood frequency curve from nearby gauging stations. Each flood prediction model has its own assumptions and calibration conditions upon which the model was developed. Hence, estimated discharges from a watershed by different models may vary substantially. In many cases, designs may be over-or underestimated by 50 percent or more.

The accuracy of model prediction is heavily dependent on the accuracy of model parameter estimation. For an ungauged watershed, model parameter estimation is a rather difficult but necessary task in flood frequency analysis. Although tables and nomographs for parameter estimation are often provided by each mode., determination of model parameters from these tables or nomographs is subject to large errors. Therefore, model calibration using short-term field data may be a better approach. If an accurate estimation of flood frequency is technically necessary and economically justified for a proposed project, one-year or longer rainfall-runoff data may be observed to calibratemodel parameters. This is especially true for the south central region of the United States where less variation of annual rainfall is experienced.

This report presents: (1) calculation of flood frequency for the Ward Creek watershed using eight flood prediction models, (2) establishment of the rating curve (stage-discharge relation) for the Ward Creek watershed, (3) evaluation of these flood prediction models, and (4) a procedure to apply a flood prediction model with parameters calibrated by using short-term field data. The eight selected models are (1) the Neely model [2], (2) the Lowe model [3], (3) the USGS seven-parameter model [4], (4) the USGS three-parameter model [4], (5) the Lee model [5], (6) the U.S. Soil Conservation Service (SCS) model [6], (7) the Louisiana Regional GEV-PWM model [7], and (8) the Louisiana GEV-OPT model [8].

A rural watershed on Beaver Bayou above Hooper Road in Baton Rouge was also selected at the beginning of the study. During the study, it was discovered that Beaver Bayou overbanks almost every year, so a proper rating curve cannot be established. The results for the Beaver Bayou watershed are not included in this report.

OBJECTIVES

The objectives of this study are:
(1) To compute flood magnitudes at the return periods of 2, 5, 10, 25, 50, and 100 years for an ungauged watershed using eight watershed models. The eight models are:
a) the Neely model [2]
b) the Lowe model [3]
c) the USGS seven-parameter model [4]
d) the USGS three-parameter model [4]
e) the Lee model [5]
f) the SCS model [6]

g) the Regional GEV-PWM model [7] and
h) the Regional GEV-OPT model [8];

2) To evaluate the eight models by comparing the model results with those derived from the WRC procedures [1] using long-term stream gauging data. The advantages and disadvantages of each model will be discussed; and

(3) To develop a field-calibration procedure for flood prediction when more accurate estimation of flood peaks are economically justified. This requires the designer(s) to set up a network of rain gauges and a flowmeter to collect rainfall-runoff data for one year or more. The model parameters are calibrated using short-term rainfall-runoff data to improve the accuracy of the model.

SCOPE

The scope of this project encompasses selection of eight frequently used flood prediction models, selection of a small watershed, installation of three rain gauges and a flowmeter on the watershed, computation of flood magnitudes and frequencies for the watershed using the eight models, evaluation of the eight models by comparing the model results with the flood peaks derived using the WRC procedure, and development of a procedure to improve flood prediction accuracy by calibrating model parameters using short-term field data.

CONCLUSIONS

In this study, eight flood prediction models for ungauged watersheds are applied to the Ward Creek watershed, and the results are compared with those derived using long-term stream gauging records by following the U.S. Water Resources Council procedure. It is found that the USGS 7-parameter model, the USGS 3-parameter model, the Lowe model, and the Neely model have better accuracy than the others. The Lee model was developed using watershed data from Louisiana, Mississippi and Arkansas, however, the model overestimates flood magnitudes for the Ward Creek watershed. The Louisiana Regiona GEV-PWM and the Louisiana regional GEV-OPT models are simple to apply because only drainage area and watershed location are needed. They may be used for quick and rough estimation of flood peaks. The SCS model is most widely used for flood prediction. However, the accuracy of flood prediction for the Ward Creek watershed using the SCS model is low. The RRMSE defined in Equation (7-6) is as high as 1.30 and the relative errors of the peak discharge predictin at all six frequencies are 50.2, 80.4, 94.5, 129.6, 163.7, and 197.4 percent, respectively. Errors in parameter estimation are substantial because the model was not calibrated using local data.

This study demonstrates that the accuracy of peak discharge prediction using the SCS model can be significantly improved if parameters are calibrated using short-term field data. With the runoff curve number and unit peak discharge calibrated using two-year rainfall-runoff data for the Ward Creek watershed,the RRMSE defined in Equation (7-6) is reduced to 0.07 and the relative errors of the peak discharge prediction at all six frequencies are 11.4, 5.9, 1.0, -3.3,-7.7, and -13.8 percent, respectively.

RECOMMENDATIONS

To estimate flood peaks from a watershed, it is of vital importance to choose an appropriate model of flood prediction. The selection of a flood prediction model depends on the watershed data availability and required accuracy.

1. For quick and approximate estimation of flood peaks with known drainage area and watershed location in Louisiana, the Louisiana regional GEV-PWM or the GEV-OPT model may be used.

2. If the watershed geometry, land coverage and local climatic data are known, one of the four models (the two USGS models, the Lowe model and the Neely model) may be used. One may also use all the four models and take the average of the model results.

3. If accurate flood prediction is technically necessary and economically justified, a temporary network of rain gauges and flowmeter may be set up to obtain rainfall-runoff data for one to two years. The SCS model is be applied with the parameters calibrated using the short-term field data. This study has shown that the accuracy of the SCS model can be significantly improved with the runoff curve number and unit peak discharge calibrated using short-term rainfall-runoff data. The procedure is (1) calibrate runoff curve number using 24-hour rainfall at the return periods of 2, 5 10, 25, 50, and 100 years using 24-hour rainfall frequency maps or I-D curves; (4) calculate net runoff at each frequency using Equation (5-7) in this report with calibrated runoff curve number; (5) determine unit peak discharge at each frequency using the calibrated unit peak discharge curve; and (6) compute peak discharge at each frequency using Equation (5-8) in this report.

4. If a watershed has long-term stream gauging data but has undergone significant hydrological changes, the flood peaks may be determined using the SCS model with parameter calibrated using the most recent stream gauging data and local rainfall data.