E02

A Method of Rainfall Designing for Flood Risk Assessment

〇Xinyu JIANG, Hirokazu TATANO

1. Introduction

Spatial flood risk assessment concerns on flood risk distribution at each place in an area. It requires integrated consideration of all possible flood sources and flood scenarios which may affect this place. Scholars usually use the following procedure to estimate probabilistic flood risk curve: 1. Design rainfall corresponding to return period. 2. Put the designed rainfall into rainfall-runoff-inundation model to simulate water depth at each place in the area. 3. Change dyke break or overtopping point to achieve many scenarios of flooding. 4. Calculate losses under each scenarios and calculate event curve and risk curve.

As the first step of the flood risk assessment procedure, rainfall connects the simulation to statistic risk analysis. Traditional methods of rainfall design such as “design from 1/n years rainfall intensity curve” or “extend from typical rainfall” are not proper for spatial flood risk assessment which considering multiple flood sources because two reasons: on one hand, for each return period, only one kind of rainfall could be designed from these methods. It hardly to says this kind of rainfall is most likely to occur under this return period. On the other hand, flood which affect the place may comes different sources, for example, larger rivers, smaller rivers or urban drainages. Different flood sources may have different responses to designed rainfall: larger rivers may require a longer duration of rainfall to produce a flood peak while urban drainage may be more sensitive to shorter duration of rainfall or peak rainfall. The rainfall design should reflect the relationship between response characteristics of different flood sources.

In this paper, a copula based rainfall design method is presented for spatial flood risk assessment. A case study in Otsu river basin, Osaka prefecture, Japan is conducted to demonstrate this methodology.

2. Methodology

Because different flood sources may have different responses to designed rainfall. The concentration time of flooding is used to reflect the responses characteristics of different flood sources. Concentration time of flooding is defined as the time required for disturbance of rainwater to propagate from the top of a slope at the most remote portion of the basin in the sense of dynamics to the outlet (Kadoya, 1976). Many empirical method such as Kraven formula, Uniform flow velocity formula, Public Works Research Institute formula and Kadoya formula (JSCE, 1986) could be used to calculate concentration time of flooding.

Use different concentration time of flooding as time scale to statistically analyze rainfall data. For example, concentration time of flooding of larger river is 3h, and concentration time of flooding of urban drainage is 1h. Then we should statistically analyze rainfall amount in 3h and rainfall amount in 1h: fit their distributions, make some extreme value analysis.

Use copula method to estimate the correlation of rainfall amount within different concentration time of flooding. Make a joint distribution of rainfall amount with different durations. Copulas are functions that join or “couple” multivariate distribution functions to their one-dimensional marginal distribution functions (Nelsen, 2006). In the bivariate case, according to Sklar’s theory (1959), the joint cumulative distribution function H(x,y) of any pair (x,y) of continuous random variables may be written in the form:

$$H(x,y) = C(F(x), G(y)) \quad x, y \in \mathrm{R}$$

Where F(x) and G(y)are continuous marginal distributions, so that the C:[0,1]2→[0,1] such that for all is copula. Readers may refer to the monographs by Joe (1997) and Nelsen (2006) for detail.

Simulate correlated rainfall amount of different durations from the estimated joint distribution. Integrate them to finish the core part of design rainfall.

The other part of rainfall could be completed through statistical method or empirical method.

3. Case study

The study area is located in the southern part of Osaka prefecture, Japan. Otsu River is a river of Osaka prefecture rising in the Katuragi Mountain and flowing about 68 km westward to the Osaka bay. For the flood risk assessment area downstream, there are four flood sources: water from Ushitaki river and water from Matsuo river, water from river Makio and urban drainage.

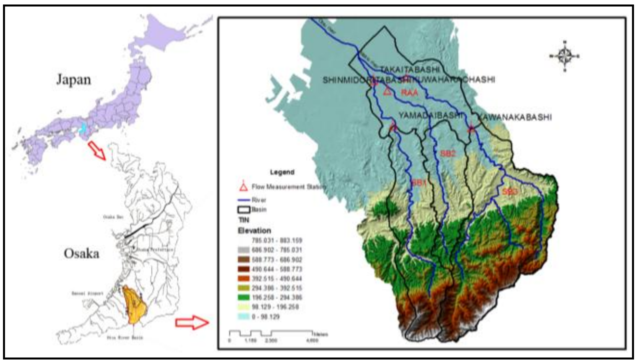

Figure1 Case study area

The concentration time of flood in Otsu river basin is estimated by Kraven formula. The flood concentration time of Ushitaki Basin is 2 h, that of Matsuo Basin is 1.6 h, and that of Makio Basin is 2.7h. It implied that 1h rainfall amount could represent basin rainfall in the risk assessment area; 2h rainfall could represent basin rainfall in Ushitaki and Matsuo basins, and 3h rainfall could represent that in Makio Basin.

The 1h, 2h and 3h extreme rainfall modeled with best fitted distributions and multivariate dependence structure between 1h, 2h and 3h rainfalls are modeled by copula. As is shown in table 1 and table 2.

Based on the copula model and marginal distributions, the joint distribution of 1h, 2h, and 3h rainfall could be obtained. Then, the correlated 1h, 2h, and 3h rainfall according to certain return period could be simulated.

Table 1 Distributions and parameters for marginal extreme distribution

Rainfall	Distribution	Parameters
1 h rainfall	Generalized Pareto distribution	k=0.12, s = 5.23, m = 17.41
2 h rainfall	Gamma distribution	a = 8.46, b = 3.89
3 h rainfall	Gamma distribution	a = 7.13, b = 5.44

Table 2 Copula models and parameters

Rainfall	Copula model	Parameters
1h vs. 2h	Gumbel copula	2.003
1h vs. 3h	Gumbel copula	1.913
2h vs. 3h	Gumbel copula	5.745

Each generated point include information of 1h, 2h and 3h rainfall amount. We allocate them as core part of design rainfall. Other part of rainfall are represented by statistical average, as is shown in figure 2. The points on the same counter have same return period, therefore, for one return period, many rainfall events could be designed that could be used for Monte Carlo simulation of spatial flood risk.

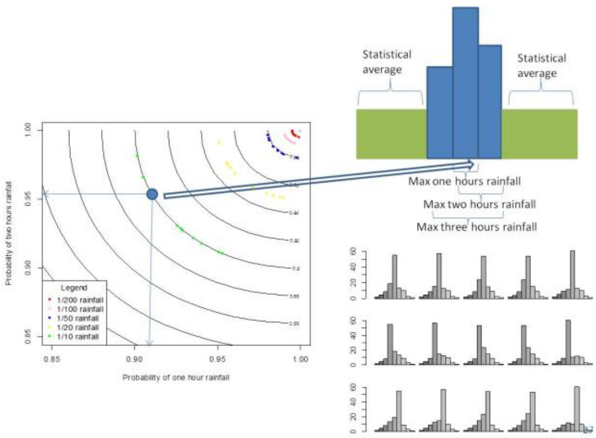

Figure2 Rainfall events generated from joint distribution

4. References

Kadoya, M, Fukushima, A. 1976. Concentration Time of Flood In Small or Medium River Basin. Disaster Prevention Research Institute Annuals, 19: 143-152.

Japan Society of Civil Engineers. 1986. The Collection of Hydraulic Formulae. (In Japanese)

Nelsen R. 2006. An Introduction to Copulas, Second edition, Springer, New York.

Sklar A. 1959. Fonctions de repartition an dimensions etleursmarges. Publ Inst Statist Univ Paris 8:229-231.

Joe H. 1997. Multivariate Models and Dependence Concepts. Chapman &Hall, London.