# Prediction of flood for extraordinary severe rainfall in the small river

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**Abstract** The extraordinary rainfall occurred in the small river basin (called Asano River) of Kanazawa city, Ishikawa prefecture, middle part of Japan, July 2008. The center of the city was affected by severe damages by the big flood due to the extraordinary rainfall. This study aims to make clear the probability of the extraordinary rainfall, the mechanism of the flood, the flood fighting activities etc. and to prepare to the future big flood.

**Keywords** severe rainfall; flood; flood disaster; runoff simulation; flood fighting

## INTRODUCTION AND OCCURRENCE OF EXTRAORDINARY SEVERE RAINFALL

Recently, the severe rainfall occurred frequently in Japan. The rainfall intensity ranges more than 100 mm/hour. The extraordinary severe rainfall occurred in the Kanazawa city in the central part of Japan. The Asanor River flow into the city flooded by the severe rainfall. Details are given in Kishii (2009) . The another river located in the neighbor of the Asano river called the Sai river. The Sai River flow along the major part of the city and there are many commercial shop and amusement building. So if the Sai river is flooded, then the severe damage will be occurred. So the prediction of the flood due to the extraordinary rainfall such as the same event as the Asano river becomes important.

The Asano River located in the middle part of Japan and flow into the Japan Sea. The main channel length is 20 km from the basin boundary to the gauging station and the area of the basin is 74.5 $km^2$ (Fig. 1). The closed numbers mean rain gage stations.

The surface geology is covered by the volcanic rocks. The major rocks consist of the sedimentary rock in Pleistocene of Quaternary, the volcanic rock in Pleistocene of Quaternary , and the volcanic rock in Miocene of Cenozoic. Forest area is major land use of 90 percent. Other land uses are the cultivated land of 10 percent, residential area is 5 percent. So rainwater is easy to infiltrate into surface in usual rainfall intensity.

Extraordinary severe rainfall occurred in 28 July, 2008. There are three rain gauging stations in the Asano River basin (Fig. 1) The amount of the rainfall intensity ware 138 mm per 60 minute and 251 mm in three hours in Shibahara-bashi rain gauging station shown as ② of the middle part of the three stations . The target station (called Tenjin-bashi) is shown as green circle in the Figure. The rainfall intensity of every ten minute is shown (Fig. 2).

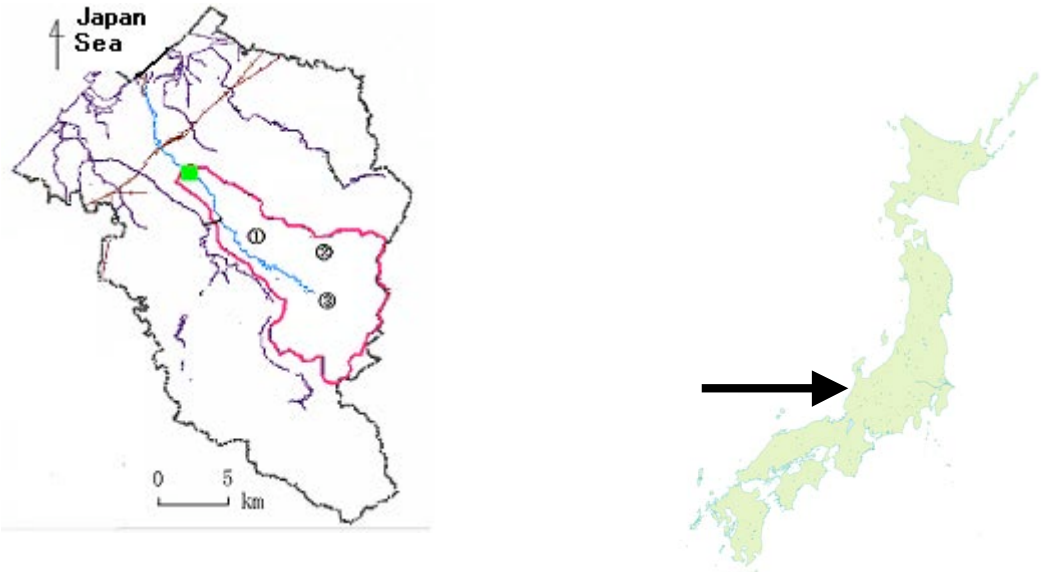


**Fig. 1 Location** of the Asano River basin

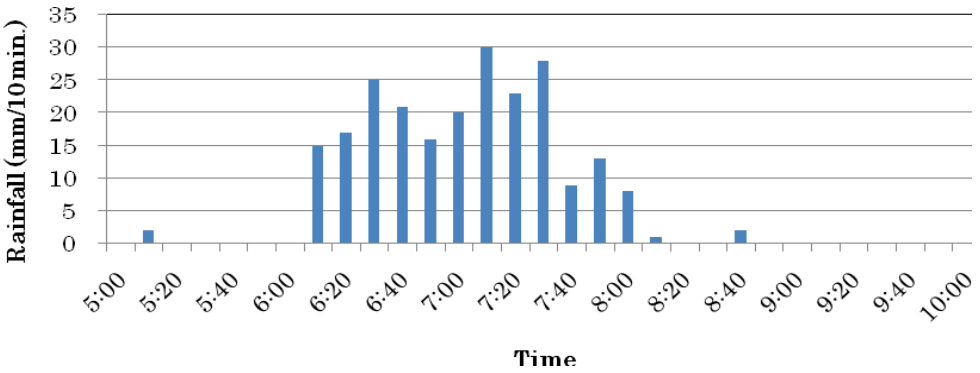


**Fig. 2** Hyetograph of ten minute rainfall

The return period of the rainfall event is analyzed. The three methods of the statics, that is, Gumbel method, Hazen plot, and Momentum method are used. The averaged curve of the statistics of the three methods is used.

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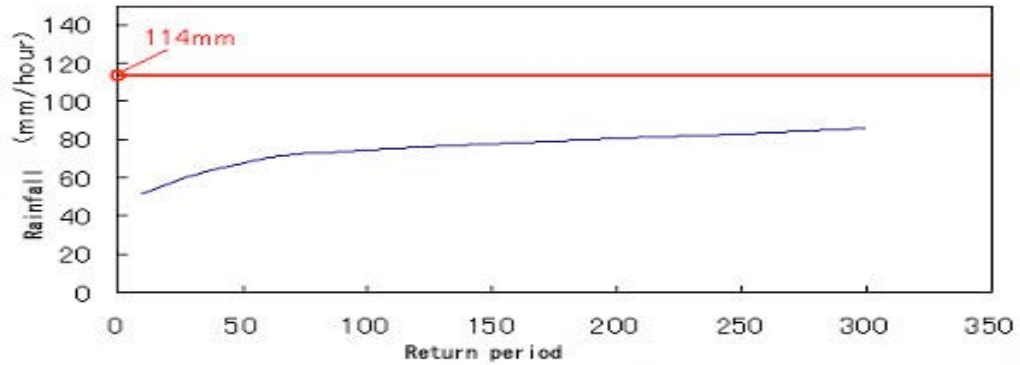


**Fig. 3**.Return period of one hour rainfall.

The result shows that this extraordinary rainfall (30 mm/10 min.) event of the ten minute return period shows 150 years. One hour rainfall intensity may be more than 300 year of the return period (Fig. 3). Furthermore daily rainfall (254 mm) shows 230 year return period (Fig. 4).

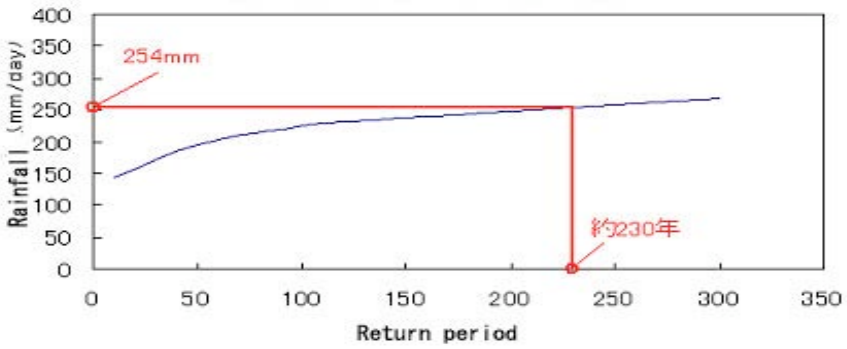


**Fig. 4** Return period of daily rainfall

## TARGET RIVER, RAINFALL TO MODEL AND FLOOD RUNOFF MODEL

The Sai River is located in the center of Kanazawa city (Fig. 5). The target station (red circle in the Fig. 5) is called Shimokiku-bashi. The main channel length is 29.5 km from the basin boundary to the gauging station and the area of the basin is 147.3 km$^2$ The surface geology is covered by the volcanic rocks. The major rocks consist of volcanic rocks of Tertiary. Forest area covers of 83 percent of the basin. Other land uses are the cultivated land of 5 percent of the basin. So rainwater is easy to infiltrate into surface in usual rainfall intensity.

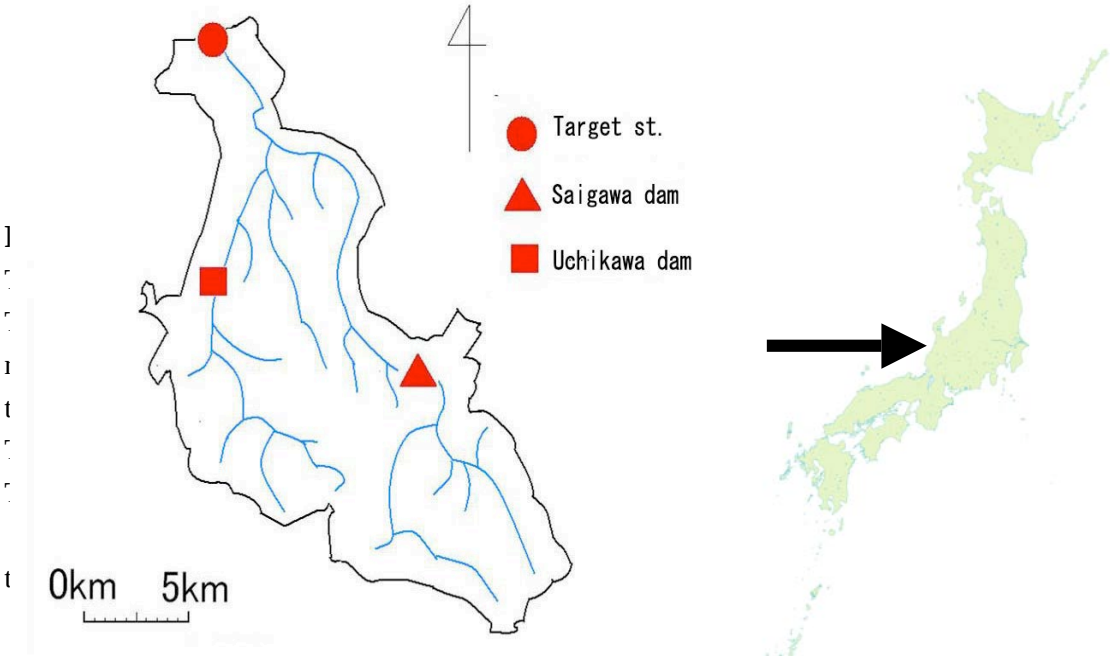


**Fig. 5** The location of the Sai River basin.

The runoff simulation was carried out using famous runoff model called “Sugawara’s tank model”. Details are given in Sugawara (1980). Rainfall amounts of input to the first tank are given as the area average by the isohyets map of the Asano River flood event shown (Fig. 6). Otherwise, the parameters of the tank model of the Sai River are calibrated using past three big flood of July 1991, June 1996 and September 1998 (Fig. 7). The runoff model consists of two tanks. The runoff from upper tank corresponds to rapid runoff or surface runoff and the runoff from lower tank to slow runoff or inter runoff.

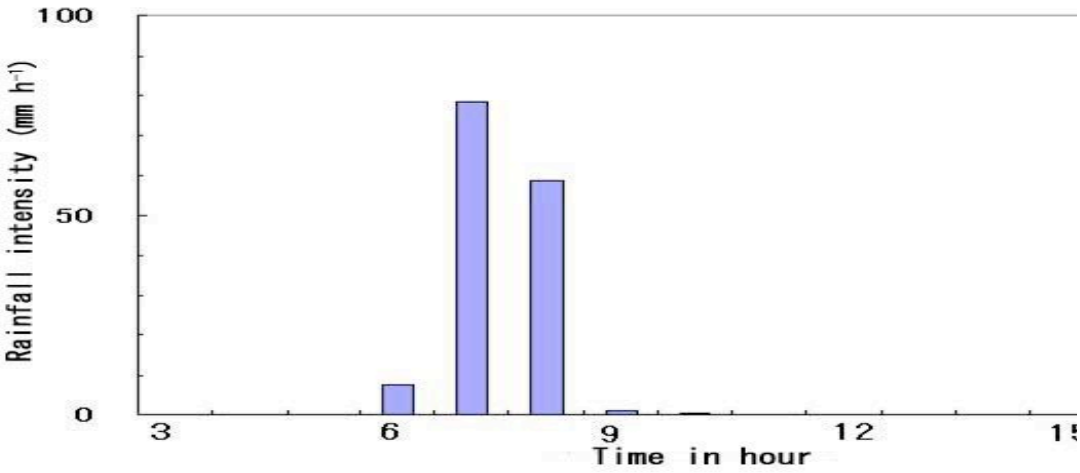


**Fig. 6** Hourly rainfall to input for runoff model.

This model is used for the prediction of the flood for the extraordinary severe rainfall same as the Asano River event to predict the flood of the Sai River. The input rainfall amounts ranges 145.2 mm per three hours. Hourly rainfall intensity ranges 7.8, 78.7 and 58.7 (mm per hour) in three hours.

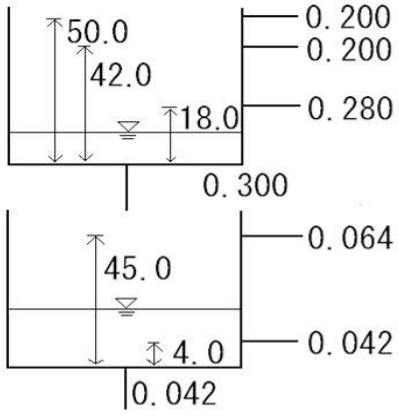


**Fig. 7** The runoff model (Tank model) for prediction of flood in the Sai River basin.

There are two reservoirs, namely Saigawa dam and Uchikawa dam in the upstream of the Sai River (Fig.5). The parameters are calibrated by the assumption without two reservoir using the modified discharge considering controlled releases of the discharge of two dams (reservoirs).

## RESULT OF PREDICTION

There are two results of the prediction of the flood to the Sai River. One is the case without two dams (reservoirs). Another is the case with two dam.

First time, the case without two dams is analyzed. The prediction result of the hydrograph is shown (Fig. 8). The peak discharge ranges 1,530 ($m^3$ $s^{-1}$) and less than the designed discharge (horizontal line) of 1,685 ($m^3$ $s^{-1}$). The almost part of the runoff is occupied by the surface flow (part of yellow coloured) from the top tank runoff.

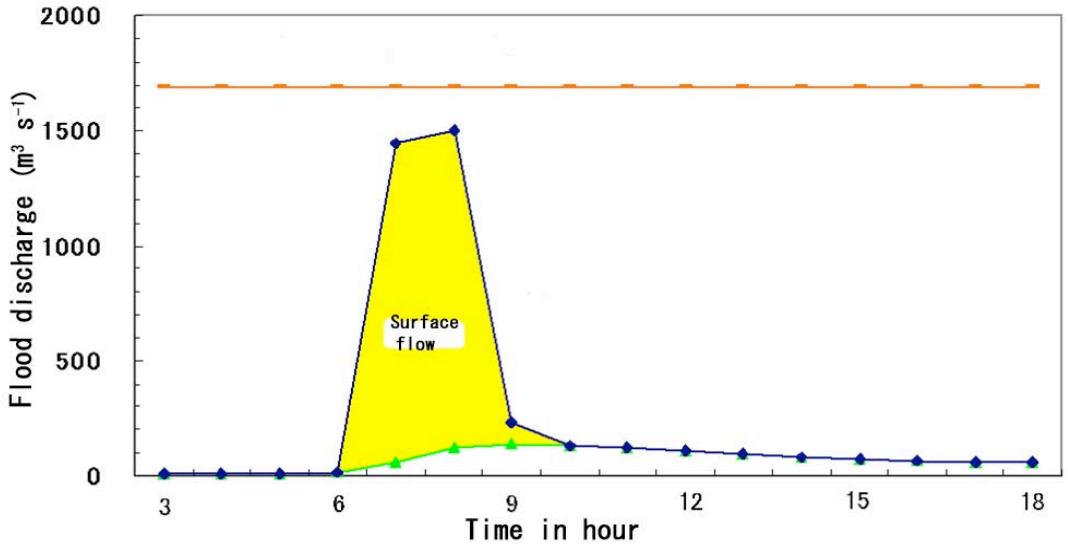


**Fig. 8** Prediction result in case without two dams.

Next stage, how much the peak discharge occurred if the input rainfall becomes bigger? The input rainfall to the tank model is used from 1.1 times to 1.5 times as much as the rainfall intensity of Fig. 6. The result is shown (Fig. 9). This shows that if the rainfall intensity is more than 1.1 times, then the peak discharge exceeds the designed discharge of 1,685 ($m^3$ $s^{-1}$).

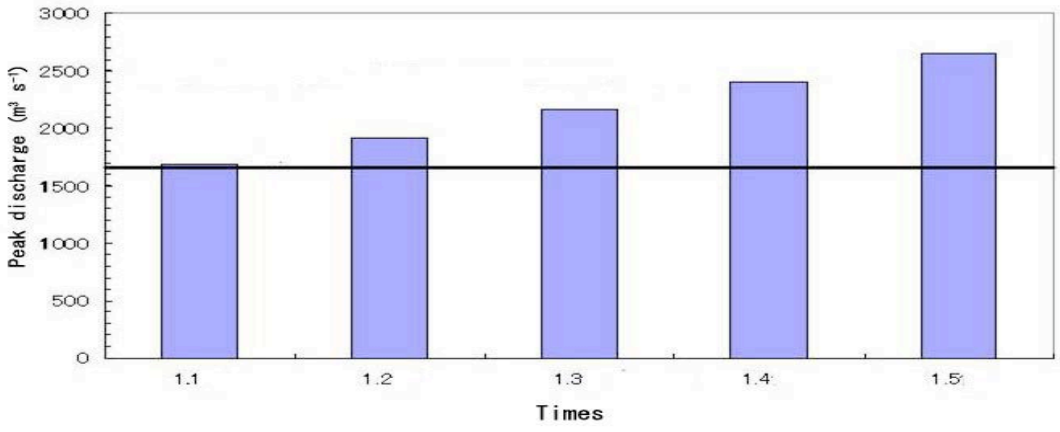


**Fig. 9** Prediction result on bigger rainfall in case without two dams.

Second time, the case with two dams is analyzed. The prediction result of the hydrograph is shown (Fig.10). The peak discharge ranges 910 ($m^3$ $s^{-1}$) and less than the designed discharge (horizontal line) of 1,190 ($m^3$ $s^{-1}$). The regulation pg the release from the Saigawa dam (56.1$km^2$) is the following. If Iiflow is less than 95 ($m^3$ $s^{-1}$), then no release. If inflow exceeds 95, the release is 150 ($m^3$ $s^{-1}$). In the case of the Uchikawa dam (34.7 $km^2$), if inflow is less than 130 ($m^3$ $s^{-1}$), then no release. If inflow exceeds 130 ($m^3$ $s^{-1}$), the release is 200 ($m^3$ $s^{-1}$). The inflow of each dam is estimated by multiplying the discharge of the target station (called Shimokiku-bashi) by the ratio of the upstream area of the dam to the Sai River area.

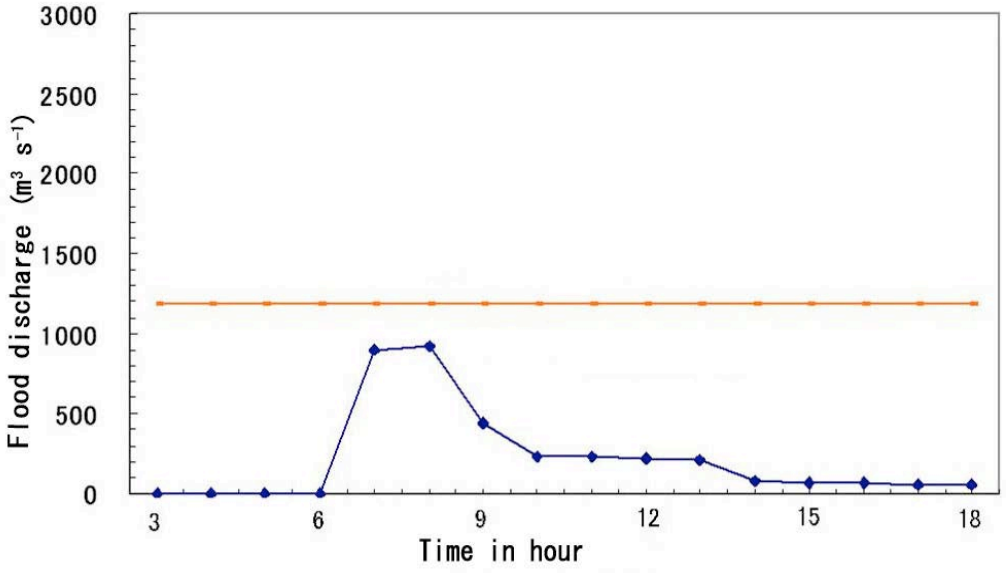


**Fig. 10** Prediction result on bigger rainfall in case with two dams.

Next stage, input rainfall to the tank model is used from 1.1 times to 1.5 times as much as the rainfall intensity of Fig. 6. The result is shown (Fig. 11). This shows that if the rainfall intensity is more than 1.3 times, then the peak discharge exceed the designed discharge of 1,190 ($m^3$ $s^{-1}$).

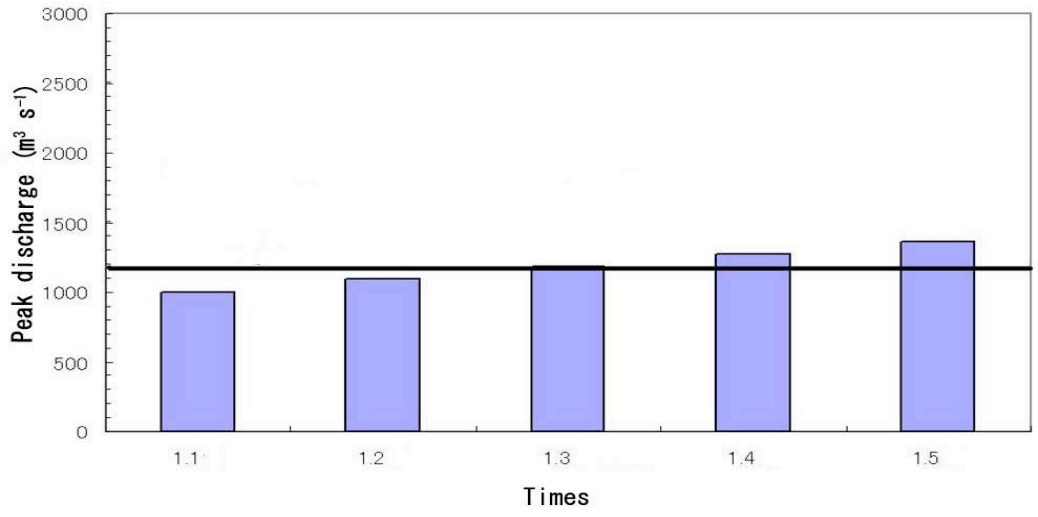


**Fig. 11** Prediction result on bigger rainfall in case with two dams.

## CONCLUSION

The extraordinary severe rainfall occurred on July 2008 in the central part, Kanazawa city, Japan. The severe flood damage is affected by the severe rainfall. The return period of this rainfall event shows 150 year in the ten minute and 230 years in a day. There is another important river named the Sai River which flow through the center of the city. If the same event occurred, then how big flood occurs? It is the urgent problem. So the prediction of flood runoff by the tank model using the severe rainfall is analyzed.

The result is the following. The peak discharge is less than the designed discharge. The almost part of the runoff is occupied by the surface flow. The input rainfall to the tank model is used from 1.1 times to 1.5 times as much as the rainfall intensity of Fig. 6. This shows that if the rainfall intensity is more than 1.1 times, then the peak discharge exceeds the designed discharge.

Second, the case with two dams is analyzed. The peak discharge is less than the designed discharge. Input rainfall to the tank model is used from 1.1 times to 1.5 times as much as the rainfall intensity of Fig. 6. This shows that if the rainfall intensity is more than 1.3 times, then the peak discharge exceed the designed discharge.

Above results, though the Sai River basin is covered by the volcanic rocks, it have much infiltration capacity analyzed by Kishii (2008), the flood by the severe rainfall have a capability to exceed the design flood of the Sai River.

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