# Application of a Distributed Hydrological Model to analyze bridge collapsing scenarios of the Gokase River basin during typhoon 0514


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## 1. Introduction

Several regions of Japan have experienced severe rainfalls induced by strong typhoons and intensified baiu-fronts during the last couple of years. The historical maximum 48-hour cumulative rainfall of the Gokase River basin was recorded during the typhoon 0514 (Nabi) from 2005/09/05 to 2005/09/07.

## 2. Typhoon 0514 and the Gokase River basin

The Gokase River basin in Miyazaki prefecture experienced recorded downpours and as a result severe flooding when typhoon 0514 passed through the region, causing severe damages to river structures and hampering livelihood of thousand of people. **Fig. 1** shows the rainfall related variables derived for the Gokase River basin using data from 37 ground measuring stations. The recorded maximum hourly, 6-hour, 12-hour, 24-hour, 48-hour and 72-hour rainfalls were 57 mm, 288 mm, 544 mm, 924 mm, 1184 mm and 1219 mm, respectively. The basin average hourly, 6-hour, 12-hour, 24-hour, 48-hour and 72-hour rainfalls were 33 mm, 165 mm, 314 mm, 553 mm 681 mm and 707 mm, respectively.

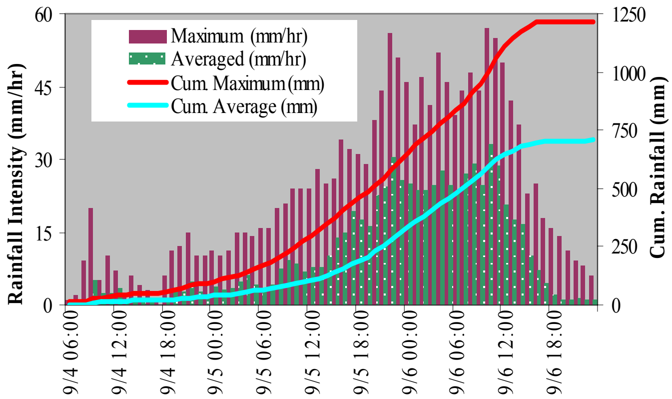


**Fig. 1** Temporal Characteristics of the Gokase River basin rainfall distribution during typhoon 0514

## 3. Distributed hydrological model and simulation results

Sub-Basin wise, TOPMODEL and Muskingum-Cunge flow routine method[1] was used to simulate hydrological processes of the basin (**Fig. 2**). The hydrological model was modified as follows to improve base flow contribution of the basin.

$$q_b(i,t) = T_0 e^{-SD(i,t)/m} \tan\beta = a_i * R = a_i * e^{-\left(\frac{\overline{SD}}{m}+\frac{\overline{m\gamma}}{m}\right)} \quad (1)$$

$$SD_i = \overline{SD}\left(\frac{m_i}{\overline{m}}\right) - m_i\left(\gamma_i - \frac{\overline{m\gamma}}{\overline{m}}\right) \quad (2)$$

$$Wheare \quad \gamma_i = \ln\frac{a_i}{T_{0,i}\tan\beta_i} \qquad \overline{m\gamma} = \frac{1}{A}\sum_i m_i \ln\frac{a_i}{T_{0,i}\tan\beta_i}$$

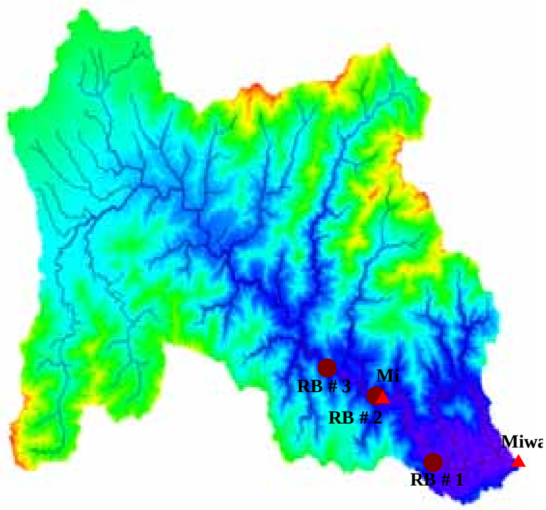


**Fig. 2** The Study area

The basin was divided into 90 sub-basins and parameters were assigned based on the land use of each 50 meter resolution grid. The model was calibrated with the help of observed stage heights at Miwa (1050 $km^2$) and Mi (880 $km^2$). The peak discharges of those two gauging stations were 8230 $m^3/s$

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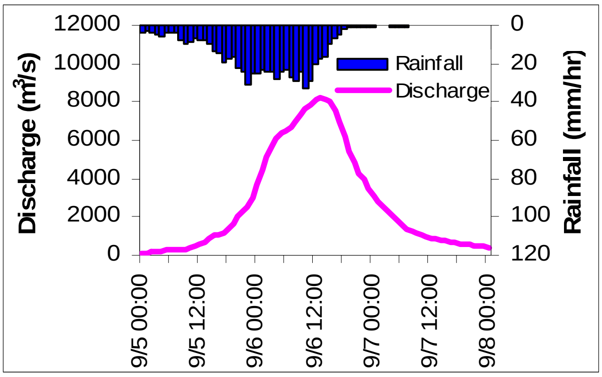


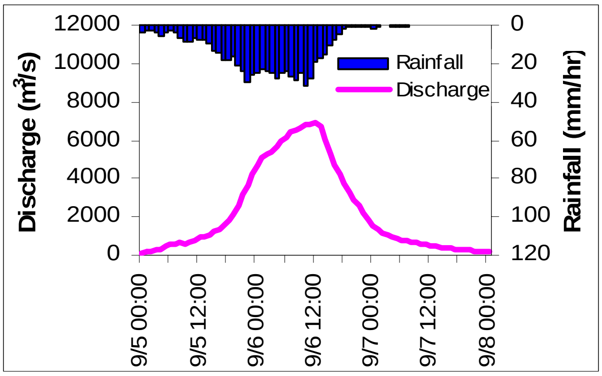


**Fig. 3** **Simulated river discharge at Miwa and Mi gauging stations**

and 6875 m$^3$/s **(Fig. 3**). The calibrated model was used to estimate river discharges at locations of two collapsed railway bridges (RB # 1 and RB # 2) and one non-collapsed railway bridge (RB # 3) (**Fig. 2**).

## 4. Bridge collapsing scenarios

Finally as explained in Nawarathna et al.(2006) bending stresses ( $\sigma$ ) of bridge piers were calculated and compared with the bearing capacities ( $\sigma_{ca}$ ) of the construction materials (0.18 – 2.6 N/ mm$^2$). The results are shown in the **table 1**. The estimated bending stresses of the collapsed sections were larger than 0.18 N/ mm$^2$ whereas the calculated maximum bending stress value at non-collapsed bridge section is less than 0.18 N/ mm$^2$.

**Table 1** Comparison bending stresses with bearing capacities of the bridge piers

| RB # | Drainage area (km$^2$) | Peak River Flow (m$^3$/s) | Maximum Flow Velocity (m/s) | $\sigma$ (N/mm$^2$) | $\sigma_{ca}$ (N/mm$^2$) |
|---|---|---|---|---|---|
| 1 | 980 | 7200 | 5.5 | 0.19 | 0.18～2.6 |
| 2 | 875 | 6860 | 5.3 | 0.20 | 0.18～2.6 |
| 3 | 780 | 5730 | 6.1 | 0.11 | 0.18～2.6 |

**Fig. 4** Collapsed bridge pier of RB # 2

## 5. Discussion

Nearly steady basin average rainfall (26 mm/hr) was observed from 09/05 21:00 to 09/06 11:00 hrs. As the typhoon started nearly 24 hours before, it is appropriate to presume that the watershed was nearly saturated at the beginning of steady rainfall. If we apply rational formula assuming a uniform spatial rainfall distribution and time of concentration of less than 14 hrs, the highest possible uniform discharges of Miwa and Mi are 7670 m$^3$/s and 6410 m$^3$/s. As simulated peak discharges are nearly equal to those values, we can conclude that even if the steady rainfall had continued longer, the peak discharges may not increase from the recorded. Because typhoon 0514 was considered as one of the severest typhoons, the river structures that withstood the typhoon 0514 may not be damaged by similar typhoons even in longer time span. However it is necessary to verify stability for torrential rains induced by baiu-fronts that could bring downpours of 100 mm of hourly rain with shorter time span and larger spatial variations[1].

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## REFERENCES

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