New Flood Control Frame considering Future Climate Changes

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1. Introduction

With regard to the July 2018 Heavy Rain, which caused a great flood disaster centering on the western part of Japan, the Meteorological Agency, based on the results of discussion in the August 2018 extraordinary meeting of the Abnormal Weather Study Workshop, operated by the same Agency, referred to "the long-term trend of increase in water vapor content in the air in accordance with the long-term upward trend of air temperature due to global warming" and to the well-known fact that "water vapor content will increase about 7% when air temperature rises by 1 °C." The Agency also announced for the first time the manifestation of climate change effect on heavy rain generated, stating, "Increase in water vapor content due to global warming is also considered to have contributed to this heavy rain."

In recent years, large-scale flood disasters have frequently occurred and there is a concern that flood disasters are expected to become more intensified and frequent if global warming proceeds without improvement. In addition, for the future of Japanese society, depopulation and declining birthrate and aging are forecasted and the capacity of investment in disaster prevention / mitigation and resistance to disasters may become weak. While scale of disasters is expected to increase, stability and sustainable development of society may be impaired if there is no improvement in disaster prevention / mitigation capacity. Hence, management of flood disasters by promoting disaster prevention / mitigation measures is increasingly important.

In response to the circumstances stated above, this paper details forecasted changes in heavy rain due to climate changes, consequential changes in river flow, and the new flood control frame proposed by the NILIM.

2. Future climate forecast

Future climate forecast is conducted basically with General Circulation Model (GCM), which conducts three-dimensional calculation for the whole earth and Regional Climate Model (RCM), which conducts high resolution calculation for some regions with the calculation result of GCM as the boundary condition. In the climate forecast for regions with complex topography as in Japan, RCM is useful since it is based on high resolution, and calculation has been conducted with the horizontal resolutions of 20 km and 5 km, and calculation based on 2 km resolution is being conducted. Future climate forecast is conducted based on some scenarios. The 5th IPCC Assessment Report selected four scenarios, including Low Emission Scenario (RCP2.6), which controls air temperature rise to 2 ℃ after the Industrial Revolution, and High Emission Scenario (RCP8.5), which does not conduct mitigation measures considering air temperature rise to be 4 ℃.

With the resolution of 20 km prepared in the Climate Change Risk Information Creation Program by the Ministry of Education, Culture, Sports, Science and Technology, the NILIM collected data for each basin of the 109 first class river systems across the country using d4PDF, which is a database in which ensemble calculation is conducted on the data for the past 3,000 years and future 5,400 years. As a result of analyzing the data, rainfall from heavy rain is expected increase by approx. 1.3 times on a national average at the end of the 21st century under the RCP8.5 scenario. Based on this result, future rainfall is estimated to increase approx. 1.1 times under the RCP2.6 scenario. Further, as a result of conducting run-off calculation using the results above as rainfall conditions, the flow rate in the scale of flood control plan under the RCP8.5 and RCP2.6 scenarios showed approx. 1.4 times and approx. 1.2 times and the frequency of flood in the same scale increases about 4 times and 2 times, respectively.

Table 1: Forecast of future changes in heavy rain size, flood size, flood probability (national average)

Climate scenario	Heavy rain variation magnification	Plan size flow rate variation magnification	Flood probability variation magnification
RCP8.5 (4°C rise)	approx. 1.3 times	approx. 1.4 times	approx. 4 times
RCP2.6 (2°C rise)	approx. 1.1 times	approx. 1.2 times	approx. 2 times

From the forecast of the effect of climate changes, it was found that heavy rain size in the scale of the present flood control plan (occurrence probability) is forecasted to increase about 1.1 times on a national average under the low emission scenario with temperature rise of 2℃, while flood probability was forecasted to increase about 2 times. Thus, even if change in heavy rain seems not so great, it is likely to be a great change in terms of occurrence of flood / inundation (flood disaster). The meaning of increase in flood discharge will be easier to understand when examined with a chart with horizontal axis of flood discharge and vertical axis of non-exceedance probability (probability of not exceeding a certain flow rate: When it is 99%, the probability of exceeding the flow rate (exceedance probability) is 1%). For example, when a flow rate of the flood control plan is set based on the current climate conditions (blue line) with non-exceedance probability of 99%, i.e., exceedance probability of 1%, the flood discharge at the position of blue circle will be the plan size flow rate. If the occurrence probability of flood discharge in future when flood discharge is forecasted to increase changes to the distribution as shown in brown lines, the flood discharge variation magnification (comparison with horizontal axis) corresponding to the exceedance probability in the present flood control plan will be different from the flood probability variation magnification (exceedance probability variation magnification of the present plan size flow rate (comparison with vertical axis). When a probability distribution changes as shown in Fig. 1, there is a risk of great increase in flood disaster occurrence probability (frequency) only with a little increase in heavy rain size.

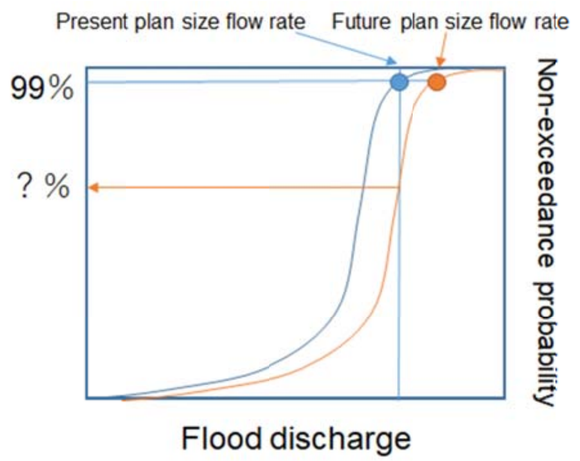

Fig. 1 Flood discharge probability distribution variation and flood disaster frequency variation

3. New flood control frame

Now that flood disaster probability has been forecasted to increase substantially due to climate changes, in order to prevent fall in safety level of flood control in river basin, it is also necessary to fully prepare a flood exceeding the plan size in addition to further promotion of river development. Fig. 1 suggests that residual risk may remain to be increased under the future flood discharge probability even if river development is conducted by raising exceedance probability to the current level.

Considering the effect of climate changes on the water policy as stated above, the NILIM proposes a new flood control frame as a flood disaster control policy that principally implements disaster prevention and mitigation in combination of flood frequency reduction (disaster prevention by river development, etc.) and damage control after flood occurrence (disaster reduction or risk management). The estimation curve ("risk curve". Fig. 2) showing how flood disaster damage changes according to heavy rain sizes is drawn at lower right of the Figure and results of technical studies are organized about basic matters for implementation using all possible measures that should be implemented for control, scenario setting methods, concept of evaluation in damage control, method of studying measures, evaluation of climate change adaptability, etc. [1)]

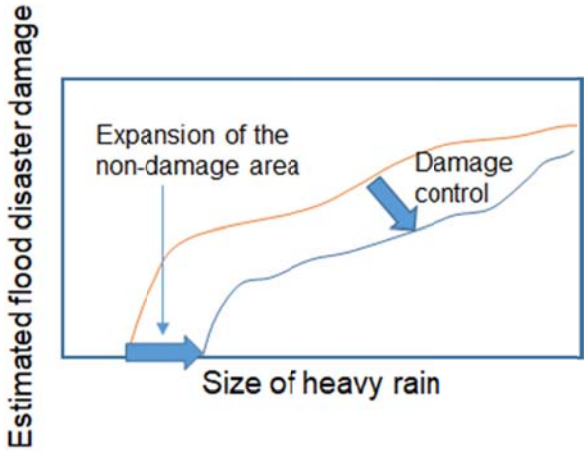

Fig. 2 Concept of flood disaster risk curve

In studying control measures, they were classified into (i) measures in the river, (ii) measures in basins (run-off area from rainfall to flood), and (iii) measures in flooded area, and an overall frame is formulated by incorporating measures available for damage reduction systematically and properly at each stage of mechanism in the range from occurrence of the source event (heavy rain) that causes a disaster to final flood disaster damage, such as control to prevent flood damage from expansion or control to facilitate recovery from damage in addition to the control of flood size in the process from heavy rain to flooding. For the new flood control frame, it is necessary to further advance technical study in actual application, including the effect of measures and quantitative evaluation method of uncertainty, which are an important future issue for the River Department.

☞**See the following for details.**

1) NILIM Project Research Report No.56, Research on Climate Change Adaptation Measures in River and Coast Fields
http://www.nilim.go.jp/lab/bcg/siryou/kpr/prn0056.htm