Numerical Analysis of Flood Mitigation Effect by Traditional Water Management System “Motase”

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1.Introduction

In low-lying urban areas, distributed water management systems have historically evolved through dense networks of waterways and hydraulic structures. Yanagawa City, Fukuoka Prefecture, maintains a traditional system known as “Motase”, which regulates flow through channel constrictions and gate operations to balance flood control and water use. Although Motase represents a practical example of basin-scale decentralized management, its flood mitigation function has not been quantitatively evaluated due to the complex interaction of structural and operational factors.

This study aims to develop a numerical model capable of representing the hydrological characteristics of Motase and to evaluate its flood mitigation function at the watershed scale.

2.Materials and Methods

2.1 Study Area

The study area is a low-lying coastal watershed in Yanagawa City, facing the Ariake Sea. The watershed covers approximately 1,750 ha and contains a dense creek network regulated by 162 sluice gates and four agricultural pumping stations in Figure 1. Natural drainage is typically achieved using tidal fluctuations, while pumping stations provide forced discharge during unfavorable tidal conditions. These facilities are primarily operated based on managerial experience.

2.2 Data Acquisition

Data required for model construction were collected from multiple sources. Information on the operation of gates was obtained through interviews with local water management operators and message application records maintained by municipal authorities. In addition, field surveys were conducted to identify the connectivity and structural characteristics of the creek network.

2.3 Development of the Creek Model

The creek network is highly segmented by hydraulic structures, resulting in discontinuous water surface behavior that is difficult to simulate using conventional flood models. To address this, a creek sub-model was developed within an existing flood inundation framework. Each segmented creek section is treated as a storage unit, and water movement is calculated using a mass balance approach.

2.4 Simulation Scenario

Flood simulations were conducted using models with and without Motase to evaluate its flood mitigation effect. Rainfall conditions were defined using a 24-hour design rainfall event with a total precipitation of 325 mm and a peak intensity of 70 mm/h, corresponding to a 100-year return period. To examine the effect of rainfall timing, 24 hyetographs were generated by varying peak rainfall timing at hourly intervals.

3.Results and Discussion

The flood mitigation performance of Motase was evaluated by comparing results from the Motase-enabled model and model without Motase. Results showed that Motase reduced inundation volume by an average of 50%. For the rainfall event yielding the highest mitigation rate, the inundation volume in the Motase model was decreased by 60%, while the storage volume within the creek network at peak inundation was approximately 1.2 times greater than in the model without Motase. Furthermore, analysis of the discharge pathways revealed that, under Motase conditions, a greater the proportion of drainage through gravity-operated sluice gates in the upstream area increased, thereby reducing the dependence on

pumping stations.

4.Conclusion

These results demonstrate that Motase enhances internal storage capacity and suppresses rapid downstream runoff, thereby significantly contributing to flood mitigation in low-lying watersheds. The developed model provides a quantitative framework for evaluating traditional distributed water management systems and supports their application to sustainable flood management.

Keywords: Distributed water management, Flood mitigation, Creek network, Sluice gate operation