2D-FEM による低平域の氾濫過程のモデリング
2D-FEM Modeling of Floodplain Inundation Processes in Low-lying Areas

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1. Introduction

A simulation model, which covers floodplains of the Mekong River from Kratie in Cambodia to Tan Chau in Vietnam, the Bassac River down to Chau Doc in Vietnam, the Tonle Sap River and Tonle Sap Lake, was developed by using the Finite Element Method with depth averaged 2D shallow water equations. The model was applied to typical flows of the years 2000 and 2003 (as representatives of recent largest flood and drought years) in the river and flood plain systems. Main roads, dikes and waterway-opening works in the study area were considered by assigning their elevations on mesh nodes in the simulation. Observed water-levels and discharges data at Kompong Cham, Kompong Luong, Prek Dam, Koh Khel and Neak Luong gauges are used for verification of results of the model simulation. The ability of the model such as prediction of flooded area, inundation-depth, inundation-time and flow-field, can be used as a tool to produce un-gauged hydrologic data of the basin as well as to evaluate the effects of the basin management on floods and agricultural water uses.

2. Model description

The model has been described in detail by P. T. Hai *et al.* (2004), so only a brief description is given here. The model is based on 100m grid-sized DEM topographic data of the study area. And refined unstructured-triangular FEM meshes of 62,965 nodes and 124,997 elements were generated. Bed elevations of grids in the DEM data are used to interpolate elevations of FEM nodes in the flood plain domain, while more precise and new updated sound-bathymetry data of the main rivers as bed elevations are utilized to interpolate FEM nodes' elevations in the main rivers' domain. The weighted-residual of the standard Galerkin FEM is applied to the 2D shallow water equations for spatial discretization, and the selective lumping two-step explicit FEM is employed for numerical integration in time. Observed (or calculated) discharges of 12 tributaries around Tonle Sap Lake are set up at ever-wet nodes which located in water-edge of the Lake in dry season, as inflow-boundaries. Measured water levels as a function of time at Kratie water level gauge are specified for the inflow of upstream conditions, while those at Tan Chau and Chau Doc water level gauges are specified as for the outflow of downstream conditions. Moving boundary problem was treated by applying a threshold technique, where a thin water depth is reset in dry nodes of all moving boundary elements every time.

3. Assigning elevations of main roads, dikes and road-opening works to FEM nodes

Based on "Road Opening Survey" report of MRC (2003) and others available data, we selected National-roads NR1 from Phnom Penh to Vietnam border, NR5, NR6, NR7, local road on left side bank of Mekong River from Khsach Kandal to the junction with NR11 at Takeo; dikes on both sides of Mekong River from KomPong Cham to near Tan Chau, dikes of Tonle Sap river from Phnom Penh to Prek Dam, dikes on both

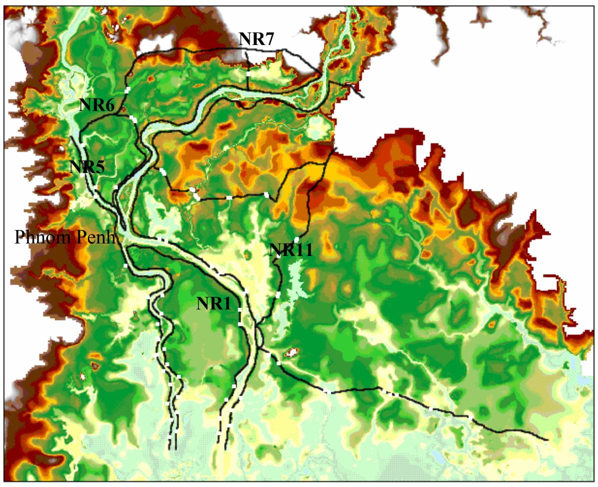

Fig.1 Selected roads, dikes and road-opening works in the model simulation.

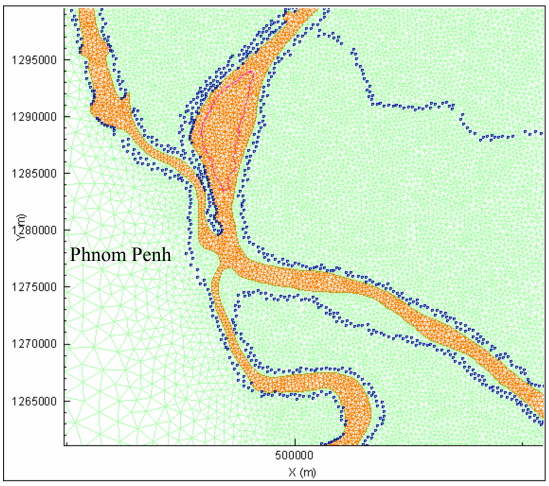

Fig.2 FEM nodes which are assigned elevations of the selected roads, dikes and road-opening works.

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Keywords: FEM, Inundation, Tonle Sap Lake and its Environs, Moving boundary, Low-lying Floodplain

sides of Bassac river from Phnom Penh to near Chau Doc; and main road opening-works which located on the selected roads and dikes, in order to assign their elevations to FEM nodes in the model simulation (Fig. 1). These construction works were considered that have significant influence on flow regimes in the study area. Tools of ArcGIS are used to convert poly-line-shape data of the selected roads, dikes and road-opening works to points data. Coordinates of these points are used to find FEM nodes which are closest to the points, then found FEM nodes are assigned elevations of the selected roads, dikes and road-opening works (Fig. 2).

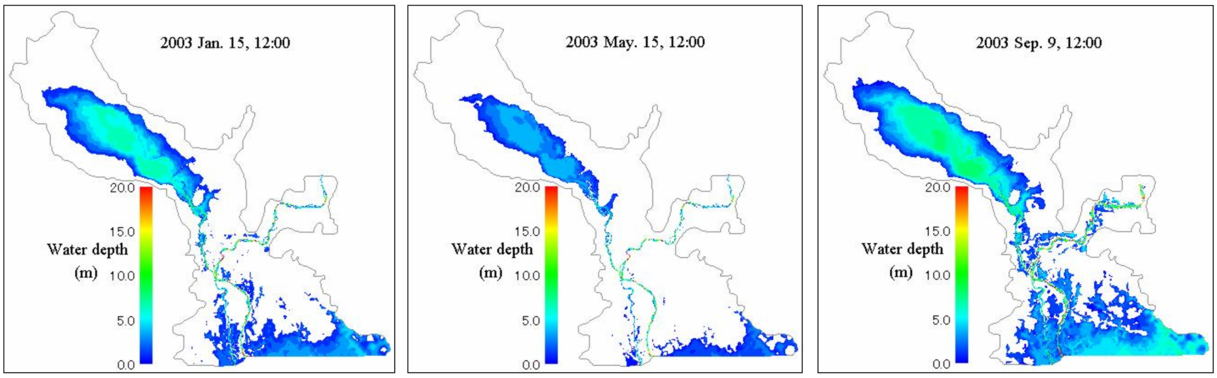

Fig.3 Simulated results of flood inundation extent on Jan. 15th, May 15th and Sep. 9th, Year 2003.

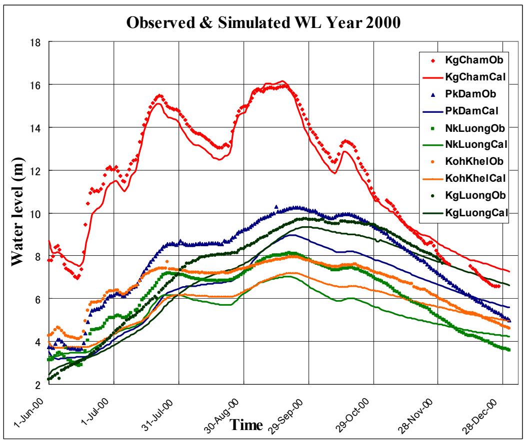

Fig.4 Observed and simulated water levels.

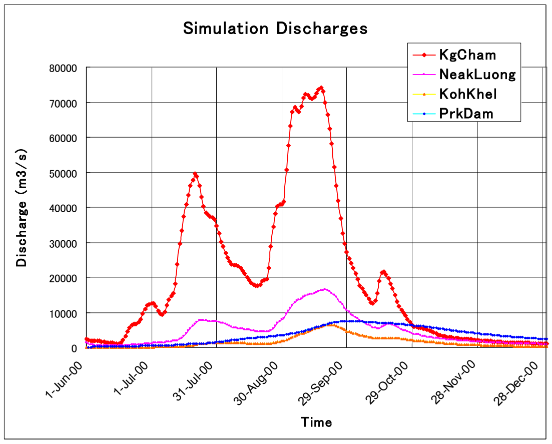

Fig.5 Simulated discharges.

4. Model Simulation Results and Discussion

By applying the methods as described above, we obtained the following simulation results. Figure 3 shows some simulated results of inundated area and water depth in the year 2003. The simulated results reproduced well inundation processes of the year, namely, in drying season (as May 15th) water flows only in the main rivers, while during flooding season (as on Jan. 15th and Sep. 9th) flood water spills out gradually to adjacent areas, and consequently, flood water expands out both sides floodplains of rivers. Based on location of stations and available data in Hymos, we setup 5 positions to calculate water-levels (Fig. 4) are Kompong Cham, Kompong Luong, Prek Dam, Koh Khel and Neak Luong, and 4 cross-sections to calculate discharges (Fig. 5) are Kompong Cham, Prek Dam, Koh Khel and Neak Luong. Comparison of simulation and observed water levels showed that the simulation water level at Kampong Cham met well with observed data, while at the others positions are different; about 0.5m to 1m at Kg Luong, Koh Khel and Neak Luong stations, and from 1.5m to 2m at Prek Dam station. Peak discharge of the model simulation at Kompong Cham (73,000m^3/s) is higher than result simulated by MRC (64,000m^3/s). Result verifications of simulation flow-fields and water-levels showed that, Manning roughness coefficients used in the simulation are small ($n = 0.020$ for main rivers and $n = 0.025$ for flood-plains). This makes the simulation flood flows faster than in real state, and consequently, simulated water levels are lower than observed data. Therefore, in next simulations we have to try larger Manning roughness coefficients which will retard the flood flows and raise simulation flood water levels. Finally, the model has been developed to simulate flood inundation processes in floodplains and used topographic data of Digital Elevation Models which are commonly used and available for many lowland floodplain areas, so that it will be conveniently applied in other river basins.

Reference:

1) P. T. Hai *et al.*, (2004). *Development of a 2D-FEM simulation model for flood flows in Tonle Sap Lake and its environs*. Proc. of Advances in Integrated Mekong R. Manag.:339-346.

2) Mekong River Commission, (2003). *Consolidation of hydro-meteological data and multi-functional hydrologic roles of Tonle Sap Lake and its vicinities*, Main Report and Appendices.