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Study of Sanmenxia Dam Effects on Backwater and Human Activities in Middle Yellow River, China

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Abstract

The study aimed to investigate Sanmenxia Dam effects on backwater and human activities in middle Yellow River through proposed models combined with statistical model, Backward Propagation Artificial Neural Network (BP-ANN) model, and hydrodynamic model. Simulation results showed that complex flood routing processes in the middle Yellow River were altered under changes of boundary conditions during the study period (1952-2003); backwater was resulted from divergent flows and bidirectional flood flow, and it occurred under specific conditions; fluvial transportation carried large amount of sediment depositions along Weihe River channel. It showed that the alternated river channel changed the boundary conditions of flood routing, especially for backwater; when discharge was bigger, bed slope had stronger effect on flood routing than roughness, and when discharge was smaller, roughness had stronger effect on flood routing than river bed slope. Model results revealed that sand transportation capacity of flood flow increased 15 kg /m^3 (52 kg /m^3 in 1962, and 67 kg /m^3 in 2003), more than 1.27×10^{10} m3 of sediment was deposited in lower Weihe River (from Huaxian to Tongguan) between 1962 and 2003. Analysis showed that backwater led to huge socioeconomic losses after the construction of Sanmenxia Dam. From 1964 to 2003, total economic losses increased

2.93×10^{10} USD (6.75×10^{6} USD in 1964 and 3.0×10^{10} USD in 2003) from 28 flood disasters related to backwater refluxing from the middle Yellow River to lower Weihe River. The inundated farmland increased 8.3×10^{5} ha (2.4×10^{5} ha in 1964 to 1.07×10^{6} ha in 2003), crops decreased 1.76×10^{10} tons (4.1×10^{6} tons in 1962, 1.8×10^{10} tons in 2003).

Key words

Sanmenxia Dam, backwater, flood disaster, human activities

Introduction

Flood disaster has been one of the most frequent and devastating forms in the middle Yellow River, China (Yu and Lin, 1996, Figure 1). Huge flood events transport sediments from upstream to downstream, and lead to changes of river channel morphology, such as river bed slope, channel roughness, and flood routing process (Speight 1965; Beven, et al. 1988; Carson and Griffiths 1989; Wharton, et al. 1989; Marston, et al. 1995; Wyzga 1997; Lee and Chang 2005; Webb and Leake 2006). One of distinctive behaviours of flood disasters in the middle Yellow River is that they were mostly resulted from backwater from downstream to upstream (Qian, 1992; Wang, 2004). Backwater from downstream dam and releases from tributaries created permanently flooded areas within the floodplain that were not present in the past. For decades, impacts of flood disasters of backwater have grown in spite of increasingly improved defence measures (Wang et al., 2005). From 1964 to 2003, there were 28 flood disasters of backwater from the middle Yellow River to lower Weihe River (State Flood Control and Drought Relief Headquarters. 1992). These floods resulted in huge econmoic losses, increased inundated farmlands, and decreased crop productivity (He, et al, 2006). Understanding the evolution of flood routing of backwater in middle Yellow River would improve risk analysis and regional emergency response.

Material and Methods

Data

In this study, input data of model simulation include datasets of topographic, hydraulic and hydrometric. Topographic data, such as river channel roughness, river bedslop, distance between each cross-section, are extracted from 30-meter Digital Elevation Model (DEM, from IRSA, CAS). Hydraulic and hydrometric data were obtained from gauge data compiled in the State Flood Control and Drought Relief Headquarters (State Flood Control and Drought Relief Headquarters, 1992).

Method 1: *Three Computational schemes for flood routing*

1. Simple boundary scheme for single main channel

2. Improved boundary scheme for convergent and divergent flow

3. Improved boundary scheme for bidirectional flow

Method 2: *Back Propagation Artificial Neural Networks (BP-ANN) Model for sediments movement*

Method 3: *Statistical model for economic losses of flood disasters*

Results

1. *Simulation of three computational boundary schemes in flood routing*

Simulation results showed that water volume had the greatest impacts on flood duration, peak discharge and water level, emergence time of peak discharge, and magnitude backwater (Figure 2). River bed slope had the second strong impacts on flood duration and magnitude backwater, and is followed by channel roughness. Channel roughness had the second strong impacts on peak discharge and water level, and is followed by river bed slope. Of all, it could be seen that discharge had strong influence on flood wave propagation and backwater effects. When discharge was bigger, bed slope had stronger effect on flood routing than roughness, and when discharge was smaller, roughness had stronger effect on flood routing than river bed slope.

2. *Simulation of sediments movement*

It showed that the construction of Sanmenxia Dam resulted in sediment silting, increasing river bed due to backwater effects (Table 1).

3. *Evaluation of economic losses from flood disasters*

It showed that impacts of flood disasters of backwater have grown in spite of increasingly improved defence measures (Table 2). From 1964 to 2003, there were 28 flood disasters of backwater from the middle Yellow River to lower Weihe River. These floods resulted in huge economic losses, increased inundated farmlands, and decreased crop productivity. We evaluated flood defence costs by evaluating economic losses through designed scenarios of pre-dam, post-dam, and dam-deconstruction. Simulation results showed that total economic losses reduced to 26% of 2003 within 20 years after dam-destruction from 2010.

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Figures

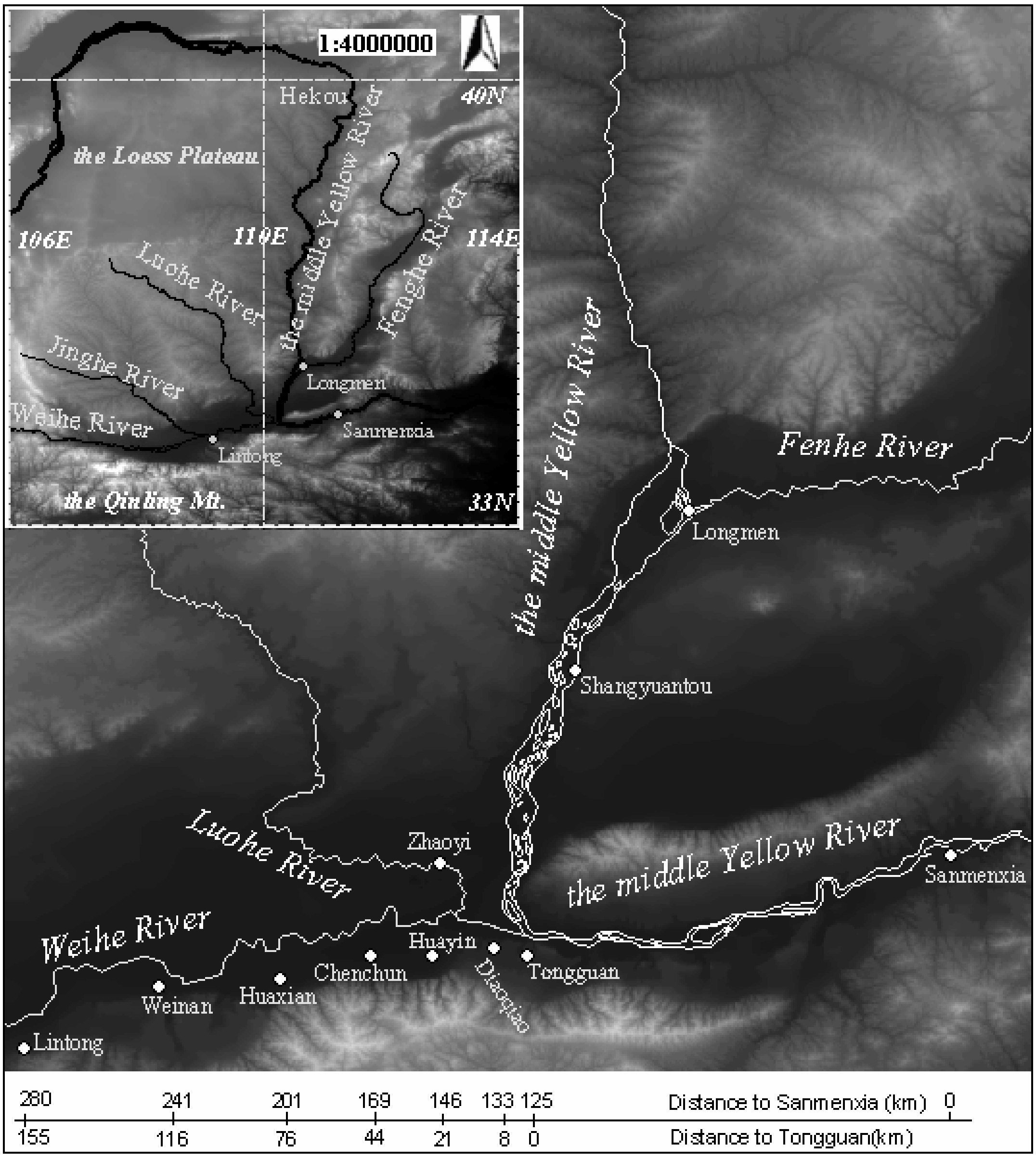

Figure 1. Location of study area in middle Yellow River

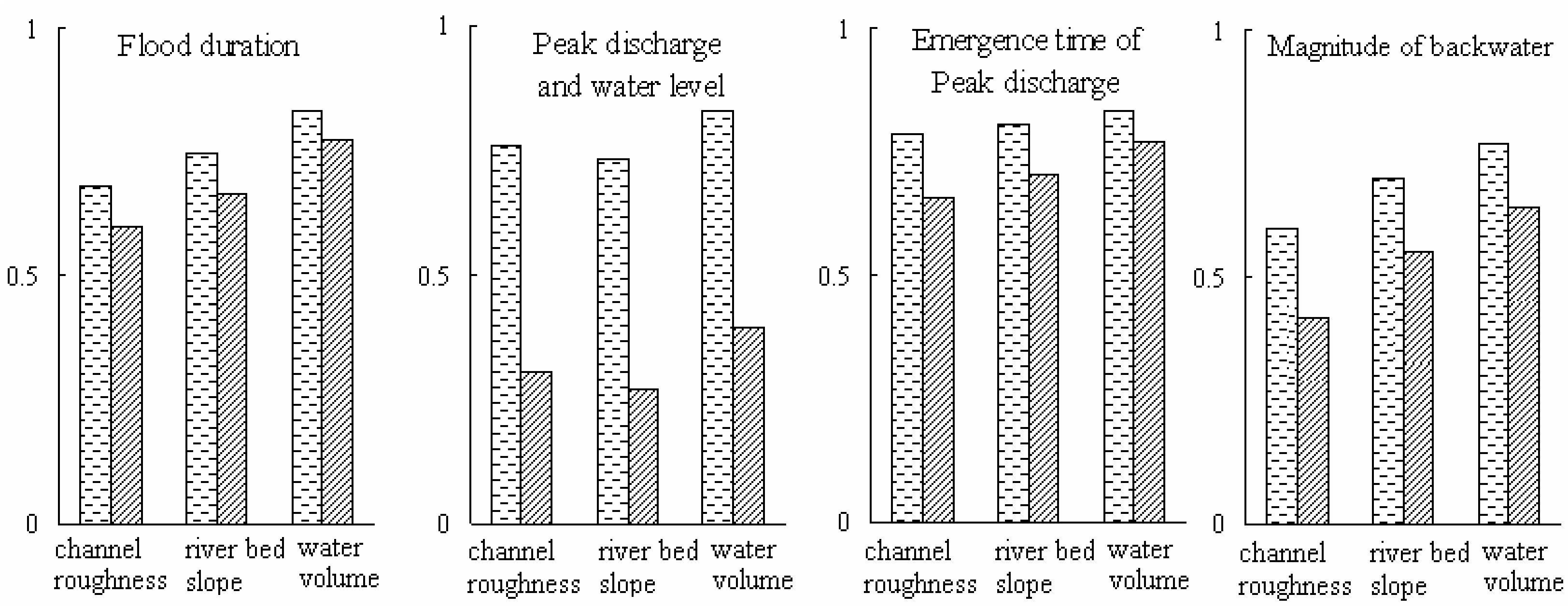

Figure 2. Integrated analysis of flood routing under combined scenarios in middle Yellow River

Tables

Table 1. Changes of sediments (Silting and scouring) in different seasons (non-flood/flood)

	Gauged($10^9m^3/s$)		**Simulated($10^9m^3/s$)**		**Relative error (%)**	
	silting	scouring	silting	scouring	silting	scouring
1990	1.716	0.974	1.725	0.977	-2.70	-0.35
1991	1.527	0.616	1.536	-	-0.60	-
1992	0.961	1.887	0.926	1.960	3.64	-3.87
1993	2.044	1.765	1.970	1.651	3.62	6.46
1994	1.297	1.489	1.285	1.458	0.93	0.75
1995	1.680	1.306	1.686	1.240	-0.36	5.05

Table 2. Economic losses from flood disasters

	1964(Pre-dam)	2003(Post-dam)	Dam-deconstruction
Economic loss (USD)	6.75×10^6	3.0×10^{10}	8.1×10^9
Inundated farmland (ha)	2.4×10^5	1.07×10^6	0.7×10^5
Crops decrease(Ton)	4.1×10^6	1.8×10^{10}	0.8×10^9