Study on the Flood Control Effect of Coal Mining Collapse Areas in the Huaihe River Basin

Abdiqani Hussein Jama

School of Earth and Environment, Anhui University of Science and Technology, Huainan, 232002, China

salmanah744791@gmail.com

Keywords: Flood Management, Flood Control, Huaihe River Basin, Coal Mining Collapse, Transitional River, China

Abstract: The Huaihe River Basin (HRB) in China, a critical transitional climate zone, frequently experiences significant floods, challenging the region's socio-economic stability. This research emphasizes the strategic importance of flood management, focusing on the impact of coal mining collapse areas on flood mitigation. The study reviews the basin's historical flooding patterns and major disasters, highlighting key developments in flood control strategies over the years. Specific case studies illustrate how coal mining activities have caused structural weaknesses, affecting flood behavior. The research evaluates the effectiveness of using collapsed areas for floodwater storage to buffer flood peaks and reduce downstream risks, integrating hydrological models and field data to assess water flow and storage capacity changes. The findings propose refined flood management strategies, incorporating lessons from local and international contexts to enhance the resilience and adaptability of the Huaihe River Basin. This research aims to provide insights for optimizing flood control in similar transitional river systems globally, emphasizing the intersection of industrial activities and natural disaster mitigation.

1. Introduction

Since the early 20th century, rising temperatures have led to an increase in emergencies. These disasters have caused financial losses exceeding USD 900 billion. Floods have caused the most significant economic damage among these calamities, around 32% [1]. Flood is the occurrence of water exceeding the usual boundaries of a canal or another water source or the gathering of water in regions that are not typically flooded. Due to the influence of climatic and physical variables, China is among the countries most severely affected by flood disasters worldwide. The floods in this country have the highest frequency, severity, economic damage, and geographical extent compared to other types of natural disasters [2].

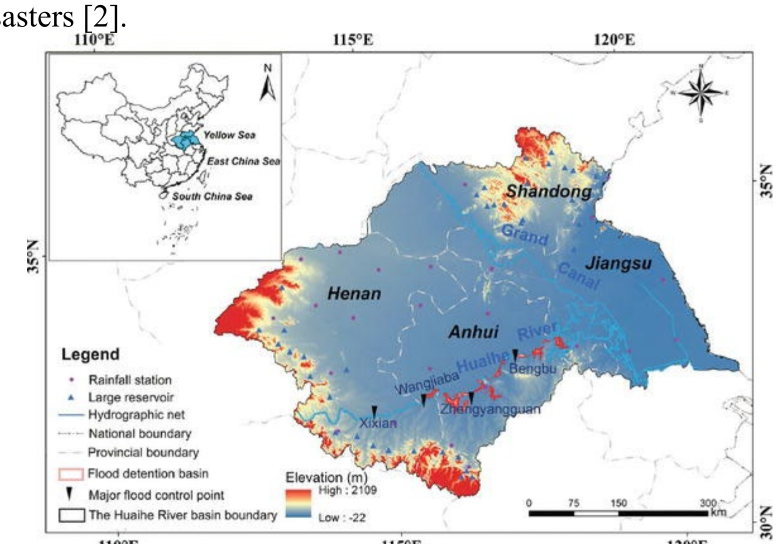

Figure 1 Study area

Coal is the main energy source in China. In 2021, raw coal production reached 4.13 billion tonnes, accounting for 56% of the country's total energy consumption [3]. Indirectly, floods can lead to anomalous water flow levels, water flexibility problems, groundwater pollution, and other related calamities [4]. Upon examining the information above and the study area shown in Figure 1, it is evident that preventing and managing coal mine flood disasters is paramount. China has made significant efforts to address flood-related challenges through various policies and regulations to control flooding and maintain safety. Additionally, numerous structural interventions, including the construction of dams, flood retention zones, lakes, dykes, water gatekeepers, and hydro-power junctions, have been implemented.

Our contribution:

- Assess the impact of coal mining collapse areas on flood dynamics within the Huaihe River Basin, including their contribution to flood risk and severity.
- Investigate the hydrological and geomorphological characteristics of coal mining collapse areas to understand their influence on surface runoff, sediment transport, and flood propagation.
- Evaluate the effectiveness of existing flood control measures in mitigating flood hazards associated with coal mining collapse areas, identifying potential gaps or areas for improvement.

The rest of the paper is organized as follows. Section 1 provides an introduction detailing the significance of flood management in China, particularly in the Huaihe River Basin (HRB. Section 2 reviews related works, summarizing existing research on flood risk. Section 3 outlines the research methodology and data analysis, including the study area, data collection methods. Section 4 presents detailed case studies focusing on developing the "Room for River" concept and the Jingshanhu flood bypass. The paper concludes in Section 5 with a discussion of the findings, highlighting our contributions to flood management strategies and offering future recommendations for improving flood risk management in China.

2. Related Works

The Chinese government has released public records aimed at preventing mine-related flooding catastrophes, such as "guiding conclusions on how to avoid coal catastrophes and incidents caused by thunderstorms and floods" and "note on how to avoid myself mishaps and catastrophes caused by emergencies like thunderstorms and floods" (National Mine Safety Administration, 2022)[5]. They emphasized that generalized disaster risk estimation involves evaluating a disaster system by considering the danger of disaster-causing factors, the reliability of the disaster-prone surroundings, and the susceptibilities of disaster-bearing physiques [6].

Assessing the risk of regional flood disasters in the Yellow River Basin using multiple indices [7]. According to Liu et al., disasters are contributed to by factors, ecosystems vulnerable to disasters, and the entities affected by disasters. To assess the risk of catastrophic floods, they compared different methods. They selected a suitable approach for evaluating the weightage using the Analytic Hierarchy Process (AHP) and AHP-entropy weight method. [8]. Ali et al. conducted a study to measure the perception and exchange of risk in flood-prone rural areas of District Dera Ghazi Khan, Pakistan. Their findings highlight the importance of risk dissemination in enhancing the success of storm mitigation efforts [9].

Bernhofen et al. studied the utility of worldwide data for predicting flood risk in Colombia, England, Ethiopia, India, and Malaysia. Six datasets of worldwide flood danger, seven datasets related to global population, and three different methodologies are used in assessing flood risk in each of the fifteen countries [10]. Sairam et al. and Shalikovskiy et al. used an area-specific flow model to assess flood disaster potential in Germany and Russia. [11], [12]. Specifically, Tanaka et al. investigated how upstream river overflows and dam operations affect severe floods below [13].

According to Wang, Cao, and Zhang, disaster risk in disaster-prone areas can be assessed. Thus, they developed a comprehensive index system for assessing flood risks in similar parks based on the effects of flooding on a chemical business park and its infrastructure [14], [15], [16]. Kong et al. (2019) studied the present condition of design requirements for flood management and secondary disasters in chemical parks [17]. During a dike breach, Hu et al. developed a model to predict river bursts and another to estimate the flood-prone areas near coal-fired power plants [18]. An underground system's flood vulnerability was evaluated using the AHP and I-AHP (Interval Analytic Hierarchy Process) methodologies by Lyu et al. [19].

3. Research Methodology and Data analysis

3.1. Study Area

The study area for this research is the Huaihe River Basin (HRB) in central China, spanning Henan, Anhui, Jiangsu, and Shandong provinces. This region has a transitional climate zone, making it vulnerable to floods and droughts. Covering around 270,000 square kilometers, the Huaihe River runs about 1,000 kilometers with key tributaries like Yinghe, Shiguanhe, and Guohe Rivers. The basin's topography varies from mountains in the west to plains in the east, affecting runoff and sediment transport. The HRB receives an average annual precipitation of 875 mm, with significant regional variation. Most rainfall occurs from June to September.

3.2. Research Design

The study used advanced hydrological models to simulate water flow and sediment transport in coal mining collapse areas, assessing their impact on flood dynamics. It will analyze flood frequency and magnitude before and after collapses, and evaluate current flood control measures. Qualitative data from local authorities and experts, field observations, and case studies of recent floods will be used to understand management responses and identify gaps in current strategies.

3.3. Data Collection

Primary Data will be gathered through field surveys, hydrological monitoring stations, and interviews. Historical flood records, satellite images, and previous research studies will be utilized to support the analysis. Statistical and Spatial Analysis Tools such as GIS for mapping flood extents and statistical software for analyzing data trends will be employed. Hydrological models will be validated using observed data from field measurements and historical records to ensure accuracy.

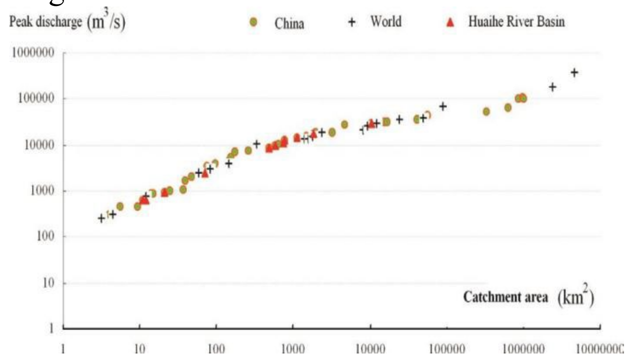

Figure 2 The relationship among peak discharge and catchment area in the Huaihe River Basin

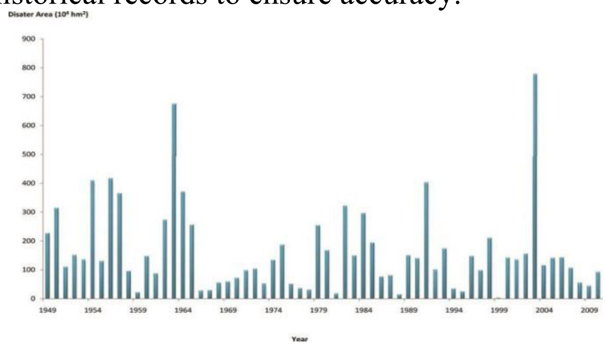

Figure 3 Disaster area in diverse years in the Huaihe River Basin

There is a mean annual rainfall of 875 mm in HRB, with the northern region receiving 600-700 mm and the southern region receiving 1400-1600 mm. As shown in Figure 2, the majority of precipitation occurs between June and September during the flood season, accounting for approximately 70% of the total year's rainfall. In HRB, the maximum point rainfall records often surpass those of the national and global regions. In Figure 3, we can see the flood area in the Huaihe River Basin in different years, highlighting the impact of significant flooding in the area. A statistical analysis of flood disasters, along with a comparison of maximum floods from different areas within the entire basin, as presented in Table 1.

Table 1 The maximum flood discharge for main rivers in the HRB (Hydrological River Basin) is being referred (Unit m3/s).

River	Gauged station	Catchment area (km2)	Observed	
			Discharge	Year
Huaihe River (main channel)	Wangjiaba	30,620	17,600	1968
Huaihe River (main channel)	Lutaizi	88,620	12,700	1954
Huaihe River (main channel)	Bengbu	121,320	11,600	1954
Pihe (southern primary tributary)	Hengpaitou	4365	6420	1969
Shayinghe River (northern significant tributary)	Fuyang	36,605	3310	1965
Guohe (northern significant tributary)	Mengcheng	15,472	2080	1963
Yihe (major tributary)	Linyi	10,310	15,400	1957
Shuhe (major tributary)	Daguanzhuang	4529	4250	1974

Important tributaries may have flood management requirements of once every 20 to once every 50 years. In particular, the channel discharge volume in the upper mainline has been increased from 2,000 - 7,000 m^3/s. The channel discharge size in the middle mainline has been increased from 5,000 - 7,000 to 7,000–13,000 m^3/s.

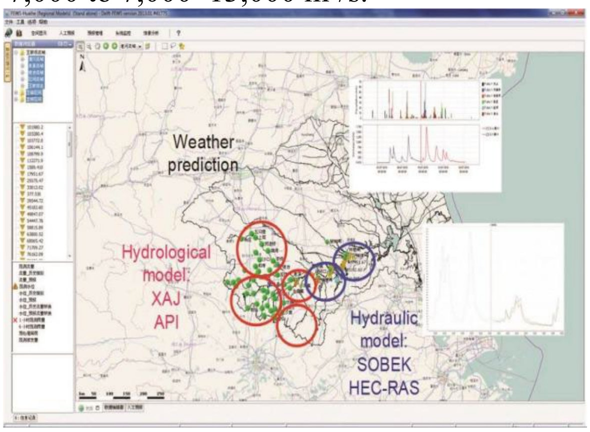

Figure 4 A probabilistic flood forecasting system designed for the Huaihe River Basin

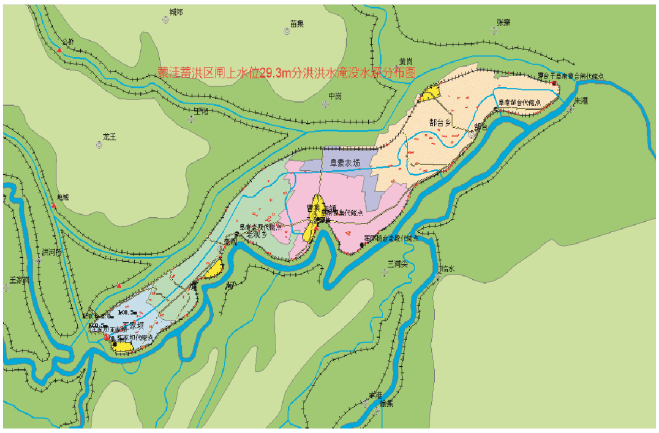

Figure 5 Flood risk mapping is being conducted for a crucial region inside the Huaihe River Basin.

The statistics of flood disasters in HRB for the years 1991, 2003, and 2007 show considerable variation. In 1991, the disaster area was 402.1 x 10^4 hectares, affecting 54.24 million people, destroying 1.95 million houses, displacing 2.257 million immigrants, and causing direct economic losses of 33.86 billion RMB. In 2003, the disaster area was reduced to 258.9 x 10^4 hectares, affecting 37.3 million people, destroying 770,000 houses, displacing 2.07 million immigrants, and resulting in economic losses of 28.6 billion RMB. By 2007, the disaster area further decreased to 159.1 x 10^4 hectares, affecting 24.7 million people, destroying 115,100 houses, displacing 812,000 immigrants, and causing economic losses of 15.62 billion RMB, as presented in Table 2.

Table 2 Statistics of flood disasters in 1991, 2003, and 2007 in HRB.

Year	Disaster area (10^4 hm^2)	Affected people (10^4)	Destroyed houses (10^4)	Immigrant (10^4)	Direct economic losses (10^8RMB)
1991	402.1	5424	195	225.7	338.6
2003	258.9	3730	77	207	286
2007	159.1	2470	11.51	81.2	156.2

For flood management in the Huaihe River Basin, advanced systems and tools are shown in Figures 4 to 5. A real-time flood prediction, alert, and monitoring, while a probabilistic flood forecasting system is illustrated in Figure 4. In Figure 5, the reservoir regulation interface, flood risk mapping for a critical area in the basin is depicted. The HRB employs sophisticated technological approaches to effectively manage and mitigate flood risks.

3.4. Legal and Institutional Structure

China has enacted various water management laws, including the Water Legislation, Flood Control Law, and regulations for flood control and river channels. The Flood Control Law of 1997 is pivotal for disaster management. Additional regulations, such as the 2005 Flood Control Regulation, outline responsibilities for flood control. Despite these policies' effectiveness, rapid societal changes have introduced new challenges. The Ministry of Water Resources (MWR) is responsible for overseeing water administration and developing policies, strategies, and regulations. Several major river basins, as well as local authorities, are responsible for the national flood control and drought relief system.

3.5. Flood Management

In the Huaihe River Basin, flood regulation is essential. In 2007, several government levels implemented flood control measures that included intercepting floodwater, discharging it, storing it, and diverting it. Despite operational challenges and safety concerns, upstream reservoirs like Suyahu and Meishan managed to store 2.1 billion cubic meters of floodwater, which relieved flood defenses from the load. Predicting short-term weather can help reduce water levels at crucial points like Bengbu Gate and Hongze Lake by pre-discharging rivers and lakes.

4. Case Studies

4.1. Development of “Room for river” idea in the Huaihe River Basin

There are 10 flood storage facilities in the area, covering 3,788 kilometers and storing 10.18 billion cubic meters of water, as well as 21 flood bypasses covering 1,301 kilometers and discharging 1,000-3,500 m3/s of water. HRB has five flood storage zones spanning 3,300 kilometers, storing 9.3 billion m3, along with 21 flood bypasses, all of which are important flood mitigation measures. There are still problems, however, such as excessive flood bypasses and the evacuation of 1.8 million people. From the mid-1980s, the focus has been on improving the river channel and reducing flood diversions and storage areas. Between 2000 and 2010, the number of bypasses fell from 21 to 17, and 120.7 km2 of land was restored to the river. The river capacity has been increased, the channel has been expanded, and 230 km2 of unused land has been returned to the river by 2020. By 2020, two bypasses will be abandoned, three converted into storage areas, and five modified for flood protection.

5. Conclusion

China suffers from flooding regularly, and flood disasters occur regularly. The Chinese government has achieved significant progress in flood prevention and drought relief through structural and non-structural approaches. However, flooding remains a major concern. To effectively manage floods, additional non-structural measures are needed, including the modification of legislation, the expansion of monitoring networks, the improvement of warning and forecasting systems, and the implementation of effective social management strategies. In extreme flood events, nonstructural measures such as hydrological management and flood forecasting become especially important for flood control. Our study uses advanced hydrological models to simulate water flow and sediment transport in coal mining collapse areas, assess their impact on flood dynamics, and analyze the efficacy of existing flood control measures. We also gathered qualitative data from local authorities and experts and conducted field observations and case studies to understand management responses and identify gaps in current strategies.

Advanced technology and well-designed plans are crucial for effective flood regulation, with lessons drawn from both domestic and international practices. Promoting advanced technology and continually improving flood control measures, China can better mitigate the impact of disasters and move from flood control to comprehensive flood risk management

References

[1] A. Benfield, "2016 annual global climate and catastrophe report," 2016, Accessed: Jul. 28, 2024. [Online]. Available: https://fundacionaon.es/wp-content/uploads/2020/07/20170117-ab-if-annual-climate-catastrophe-report.pdf

[2] Z. Fan, M. Zhang, and Y. Su, "Flood risk control of dams and dykes in middle reach of Huaihe River," Water Science and Engineering, vol. 7, no. 1, pp. 17–31, 2014.

[3] L. Zhang and T. Ponomarenko, "Directions for Sustainable Development of China's Coal Industry in the Post-Epidemic Era," Sustainability 2023, vol. 15, no. 8, p. 6518, Apr. 2023, doi: 10.3390/SU15086518.

[4] Z. Feng, Z. Hu, G. Li, Y. Zhang, X. Zhang, and H. Zhang, "Improving mine reclamation efficiency for farmland sustainable use: Insights from optimizing mining scheme," J Clean Prod, vol. 379, p. 134615, 2022.

[5] B. Wu, J. Wang, B. Qu, P. Qi, and Y. Meng, "Development, effectiveness, and deficiency of China's Coal Mine Safety Supervision System," Resources Policy, vol. 82, p. 103524, May 2023, doi: 10.1016/J.RESOURPOL.2023.103524.

[6] P. Shi, Disaster risk science. 2019. Accessed: Jul. 28, 2024. [Online]. Available: https://books.google.com/books?hl=en&lr=&id=HJebDwAAQBAJ&oi=fnd&pg=PR5&dq=Shi+et+al.,+2014+disaster+risk+&ots=oozB44Vm8V&sig=yEoAVRUL8vOe6CHiE2ydmJwdMdU

[7] L. Hu et al., "Flood disaster risk and socioeconomy in the Yellow River Basin, China," J Hydrol Reg Stud, vol. 44, p. 101272, Dec. 2022, doi: 10.1016/J.EJRH.2022.101272.

[8] T. Liu, P. Shi, J. F.-N. Hazards, and undefined 2022, "Spatiotemporal variation in global floods with different affected areas and the contribution of influencing factors to flood-induced mortality (1985–2019)," Springer, vol. 111, no. 3, pp. 2601–2625, Apr. 2022, doi: 10.1007/s11069-021-05150-5.

[9] M. Ali, Z. M. M. Mohammed, and F. M. O. Al-Shaghdari, "A Comprehensive Analysis of Recent Flood Disaster & Their Economic Impact on Pakistan Economy & Its Causes," Nov. 07, 2022. Accessed: Jul. 28, 2024. [Online]. Available: https://papers.ssrn.com/abstract=4271865

[10] M. V Bernhofen et al., "The Role of Global Datasets for Flood Risk Management at National Scales," Authorea Preprints, Nov. 2022, doi: 10.1002/ESSOAR.10508948.1.

[11] A. Shalikovskiy and K. Kurganovich, "Flood hazard and risk assessment in Russia," Natural Hazards, vol. 88, no. 1, pp. 133–147, Aug. 2017, doi: 10.1007/S11069-016-2681-6/FIGURES/5.

[12] N. Sairam et al., "Health-related Quality of Life and everyday functioning in the flood-affected population in Germany - a case study of the 2021 Floods in West Germany," Authorea Preprints, Jul. 2024, doi: 10.22541/ESSOAR.172124856.68287944/V1.

[13] T. Tanaka, Y. Tachikawa, Y. Ichikawa, and K. Yorozu, "Flood risk curve development with probabilistic rainfall modelling and large ensemble climate simulation data: a case study for the Yodo River basin," Hydrological Research Letters, vol. 12, no. 4, p. 28–33, 2018, doi: 10.3178/HRL.12.28.

[14] L. Zhang and J. Xia, "Flood Detection Using Multiple Chinese Satellite Datasets during 2020 China Summer Floods," Remote Sensing, vol. 14, no. 1, p. 51, 2021, doi: 10.3390/RS14010051.

[15] W. Cao, Y. Yang, J. Huang, D. Sun, and G. Liu, "Influential Factors Affecting Protective Coping Behaviors of Flood Disaster: A Case Study in Shenzhen, China," International Journal of Environmental Research and Public Health 2020, vol. 17, no. 16, p. 5945, 2020, doi: 10.3390/IJERPH17165945.

[16] X. Wang, J. Xia, B. Dong, M. Zhou, and S. Deng, "Spatiotemporal distribution of flood disasters in Asia and influencing factors in 1980–2019," Natural Hazards, vol. 108, no. 3, pp. 2721–2738, Sep.

2021, doi: 10.1007/S11069-021-04798-3/FIGURES/8.

[17] F. Kong, “Rising to the Climate Challenge: Better Understanding the Rural Rainstorm Flooding Disaster Risk Management Using Practical Insights from China,” Nat Hazards Rev, vol. 25, no. 2, p. 04024002, Jan. 2024, doi: 10.1061/NHREFO.NHENG-1877.

[18] P. Hu, Q. Zhang, P. Shi, B. Chen, and J. Fang, “Flood-induced mortality across the globe: Spatiotemporal pattern and influencing factors,” Science of The Total Environment, vol. 643, pp. 171–182, Dec. 2018, doi: 10.1016/J.SCITOTENV.2018.06.197.

[19] H.-M. Lyu, S.-L. Shen, J. Yang, and A.-N. Zhou, “Risk Assessment of Earthquake-Triggered Geohazards Surrounding Wenchuan, China,” Nat Hazards Rev, vol. 21, no. 3, Aug. 2020, doi: 10.1061/(ASCE)NH.1527-6996.0000375.