BCAS Vol.26 No.1 2012

New Challenges and Opportunities for Flood Control in the Huai River: Addressing a Changing River-Lake Relationship

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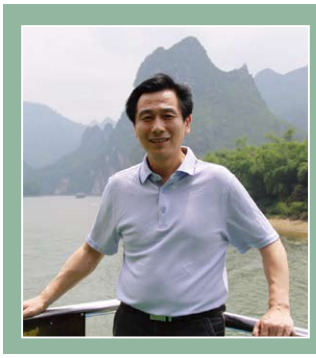
Abstract This paper addresses the change of the river-lake relationship in the Huai River and its causes due to environmental change and human activities. A preliminary analysis is made from three aspects: (1) the natural geographical change particularly captured by the Yellow River, (2) water conservancy project construction, and (3) socioeconomic development in the Huai River Basin. Key problems of changes in this river-lake relationship and the Huai River flood control are tackled, involving flood control and disaster alleviation ability of the Basin, engineering and non-engineering measurements applied to flood control and disaster mitigation, and water governance for adaptive management. Research shows that the Huai River is a rather complex one due to its complex geography with a hybrid wet and dry climate zoon, and higher population density. With the alternation of the river-lake relationship and socioeconomic development in the region, new problems keep arising, imposing new requirements on its sustainable water management. Thus, understanding the Huai River is a long and gradually improving process. Its future planning should keep absorbing new achievements of science and technology development, employing new technologies and methods, and gradually deepening our understanding of its fundamental principles. Water governance and adaptive water management will be new challenges and opportunities for the Basin in its river system change and flood control.

Keywords change of river-lake relationship, socioeconomic development, flood control in the Huai River



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The Huai River Basin (30°55'–36°36'N, and 111°55'–121°25'E), as one of the top eight river basins in China, is located between the Yangtze River Basin and the Yellow River Basin (Figure 1, Xia 2010). It flows through China's five provinces, namely Hubei, Henan, Anhui, Shandong and Jiangsu. Its total area is of 270,000 km^2 with a population of 170 million, and cultivated land of 190 million Mu (about 12 million hactares) (He, 2001). The terrain of the Huai River is vast plains, low-lying. Its climate is transitional between south and north. The weather system is complicated due to higher time–space variability of rainfall (Yi He, 2009). Thus, floods and droughts occur alternately, and numerous tributaries, which are intricate water systems, lose their trails and produce serious flooding due to the long-term influence of the tendency of being captured by the Yellow River. With abundant land and coal resources, the Basin is an important food and energy production base. Originated in Henan Province, the mainstream of the Huai River enters into the Yangtze River at Sanjiangying, with a total length of 1,000 km and a gross head of 200 m. The gradient is large in upper reaches, whereas it becomes flat in middle and lower reaches. The shape of its tributaries appears as an asymmetrical fan. The tributaries in Huainan have short radical streaming and large runoff coefficient. Because the watershed area of tributaries in Huaibei is large, their concentration time is long and the surface slope in this area is flat. As the main river channel is occupied by the flooding of tributaries in Huainan and upper reaches, floods often occur.

It is the most densely inhabited river basin and the main grain producing area of China. In 2005, its total population and grain yield accounted for 13.1% and 16.1% of the national total, respectively. Its average population density is approximately 5 times as much as the nation's average. Although annual mean precipitation and water resources of the basin are 888 mm and 83.5 billion m^3 respectively, its water resources per capita and unit area is less than one-fifth of the national average. Moreover, because 50–80% of the annual precipitation is concentrated in the flood season (June–September), the Basin faces both flood and drought problems. Before the establishment of the People's Republic of China in 1949, the average rates of flood and drought disasters were 94 and 59 per century, thus the Basin is also known as a disastrous river basin in China.

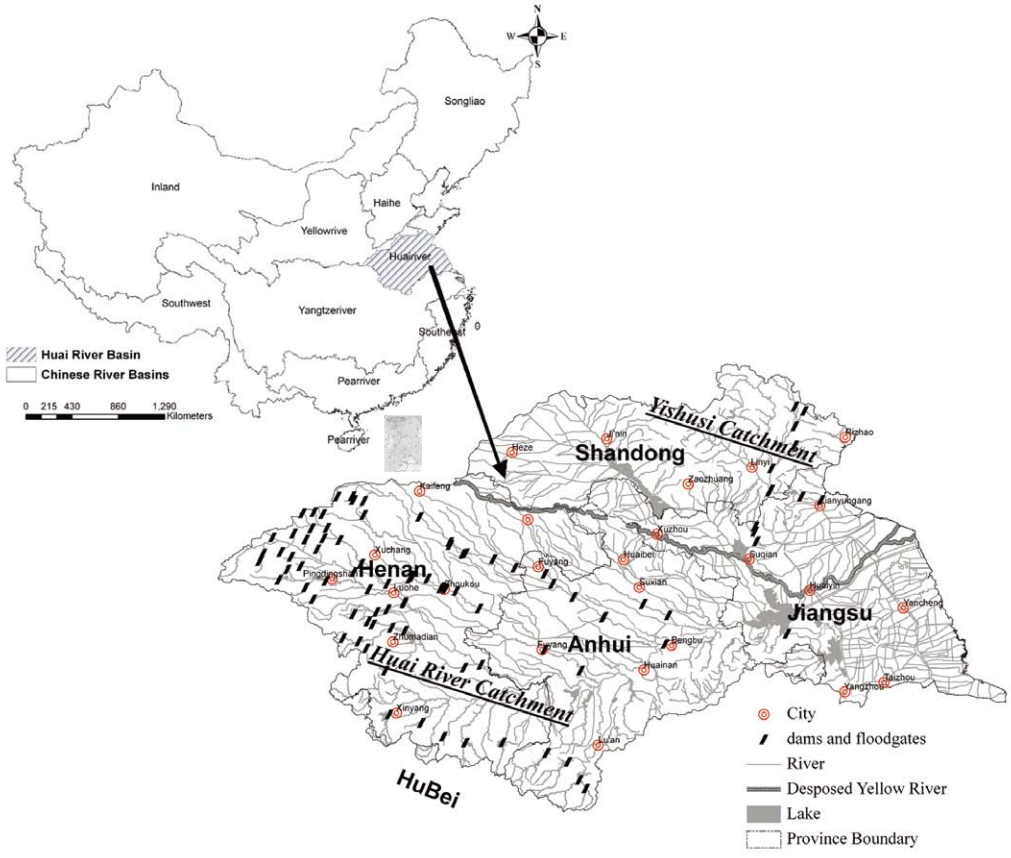

Figure 1. Location of the Huai River Basin.

Changes in river-lake relationship

(a) A relatively stable river-lake relationship before being captured by the Yellow River.

The Huai River had its own independent estuary before the 10th century AD, and the distance between the estuary and present coastline is 80 km. The middle and lower reaches of the Huai River are in deep water. Thus, its water flow channel is suitable straight. Most of the tributaries of the Huai River have their own headstreams with clear water. Discharge of the middle and lower reaches is stable with navigable waterways.

Before being captured by the Yellow River, famous lakes such as Putianze, Mengzhuze, Dayeze belonged to the middle reaches of the Yellow River and once were the main water sources of Yingshui, Wohe and Sishui, which were the main tributaries of the middle Huai River. Because of these lakes, the natural environment of the north bank of the Huai Plain was pleasant. The influence of sediments which were caused by the occasionally overbank of the Yellow River since the Han Dynasty (206 BC – 220 AD) was balanced by the desanding function of these lakes, a relatively stable Huai water system is not affected.

Numerous lakes were scattered in the Huaibei plain in the period between the Han Dynasty and the Tang Dynasty (618–907 AD), most of them were ponds with irrigation benifit and controlled by water projects. Although some lakes were transformed over the time, the number of lakes and their regional distribution rarely changed, so the natural environment of the Huaibei plain saw little change in that period.

(b) Significant changes in river-lake relationship after being captured by the Yellow River.

Ever since the diversion of the Yellow River mainstream in the year 1128, sediments coming with the Yellow River floods have been the dominant factors behind the evolution of the natural environment and the water system in Huai River Basin.

Sediments were conveyed to the Huai River with deluges through flood channels, changing its plain topography sequentially. For example, the Sishui water system, once was a tributary of the Huai River, then evolved into a tributary of the Yellow River, and at last become an independent water system.

The lake distribution in the Huai River Basin was transformed by the capture by the Yellow River. Some famous lakes near the south and north flood channels of the Yellow River gradually disappeared; so did natural lakes and artificial ponds in the original Huaibei plain. They were replaced by low-lying land formed by the construction of levees protecting cities and new lakes emerged due to seasonal water retention at the inflow period of anabranches of the Huai River. In the middle and lower reaches of the Huai River, a giant plain reservoir — the Hongzehu Lake, took form, making the Huai River lose its independent entrance to the sea. The jacking influence of the high water level of the Hongzehu Lake promoted the development of various lakes at the tail end of tributaries of the Huai River, such as the Mengwa Lake, the Chengxihu Lake, and the Chengdonghu Lake. These lakes were formed between the Qianlong Period (1736–1795) and the Daoguang Period (1821–1850), laying a foundation for the flood storage and retention areas of the Huai River.

(c) Shrinking of lakes and rising of water level in the mainstream and branches as a result of land reclamation from lakes in some areas.

There are many lakes and low-lying lands in the Huai River Basin, most of which are located in the plain with certain functions of flood diversion and storage. In the early 1950s, lakes were densely distributed in this area, with a sparse population and low and instable agricultural production. Its regional economy is relatively backward. Since the middle 1950s, under the pressure of population increase and economic development, people along the lakes began to construct water conservancy projects and reclaim farmland from lakes. Although the campaigns brought about short-term economic benefits, they destroyed the ecological balance, impairing the water storage capacity of the lakes and leading to frequent droughts and floods.

In the 1950s, in order to resettle the immigrants from land reclamation campaigns, dikes were constructed along the Hongzehu Lake. Now a total of 389 dikes have been completed, making some impact on the storage capacity of the lakes. According to preliminary statistics, the perennial water storage now is only 1,000 km^2, while the figure was about 3,000 km^2 in the 1950s.

(d) Changes in river-lake relationship as a result of water conservancy projects.

After 1949, when new China was founded, dikes,

sluices and reservoirs were constructed in the mainstream and branches of the Huai River in succession. To discharge floods, two artificial channels were opened in the middle reaches, and another three were cut to expand floodway in lower reaches. In addition, inter-basin water transfer projects have been implemented, such as the east route project of the south to north water transfer, Northern Jiangsu diversionriver engineering project *etc*.

Although these water conservancy projects have improved the ability of flood control and disaster alleviation to some extent, they altered the river-lake relationship. After the completion of the dikes and water conservancy projects, flood water would be stored in the basin, thus magnified flooding peaks could result in water level rises at same rank flood. This often causes long-term continuous high water level in the Huai River mainstream, preventing surface waterlog from discharging into the mainstream, creating outside flood and inner waterlog, and aggravating flood disaster situation.

Socioeconomic development in the Basin

(a) The relationship between population and economic growth in history from the socioeconomic perspective.

From the perspective of socioeconomic development, the large-scale agricultural development in the Huaibei plain began in the Wei and Jin dynasties about one thousand years ago. At that time, it was a grain production base with mass migratory settlement. By the end of the Dongjin Dynasty (316–420 AD), large number of people died in the turmoil of wars and natural disasters. Land reclamation through large-scale migration and large number of death occurred alternatively due to the ups and downs of regimes during the Sui and Tang dynasties. In this way, during the Song, Yuan, Ming and Qing dynasties, the development of the Huaibei plain expanded from the upstream to the middle reach gradually with the migration of people.

According to some studies, population grew sharply in the Qing Dynasty (1616–1911) in the four provinces of Jiangsu, Anhui, Shandong and Henan. Among them the population of Jiangsu and Anhui increased by 16.7 times from 3.45 million to 82 million, the population of Shandong increased by 18.9 times from 1.76 million to 33.2 million, and the figure in Henan even increased by 26 times between the years from 1851 and 1661. The constant change in population also led to a disorderly development in the Huaibei Plain. With the construction of water conservancy projects along the Huai River, many land areas, which once were used for flood discharge, became farmland, forming a pattern in which people and water fought against each other for land.

From the socioeconomic perspective in history, because wars and immigrant population growth, the Huai River Basin has changed significantly with rapid population growth after the Qing Dynasty, the population increase and economic growth produced the contradiction between human and water, bringing the chaos of the lakes development.

(b) Relatively slow socioeconomic development in the Huai River Basin.

The Huai River had a total population of 170 million in 2007, approximately 13% of the country's total. Among them, the number of urban population was 56.57 million, accounting for 9% of China's total urban population, with an urbanization rate of 33.3%. The average population density in the Basin was 631 people/km², 4.5 times more than the national average, as the number one in China seven big river basins. In Huai River Basin, the GDP reached 2.2 trillion yuan in 2007, with GDP per capita of 13.2 thousand yuan. The area of total cultivated land in the basin was 190 million mu, accounting for about 11.7% of the national total. Its rate of land per capita was 1.12 mu (about 0.075 ha), lower than the national average. Its total grain output was 94.9 million tons, accounting for about 17.4% of the national total.

(c) Economic development lags behind in the Huai River flood plain and beach area.

The present population in the Huai River flood plain and beach area is greater than that in the 1950s and the 1960s. With the regional economic development, its fixed assets have also increased a lot. Once a flood occurs, its property damage will be serious. Because frequent natural flooding damages, the regional economic development is restricted, the local economic strength is weak, and the ability to cope with disasters and to restore production ability is low. Thus, socioeconomic development requires water conservancy in the basin.

(a) Economic development and new requirements for water conservancy projects. With a fast socioeconomic development in the Basin, its economy will further expand, so will do its water demand from the industrial and agricultural production, and urban and rural life. Socioeconomic development in the Basin will require further accelerating the pace of water conservancy development, improving water infrastructure, enhancing the capacity of water conservancy projects, and strengthening the support ability of water resources for coordinated development. At the same time, it will demand to strengthen the integrated management of water. These include water resources allocation, water project optimal operation, improving water use efficiency, reducing water consumption, and protecting the environment.

(b) People's livelihood improvement sets new requirements for water conservancy projects. Water conservancy development and people's livelihood improvement are closely linked. Flood control is related to life and property safety, drinking water safety is related to physical and mental health, and water environmental improvement is related to social harmony in which people live and work in peace and prosperity. There is room for improvement in the current flood control and disaster alleviation system of the Huai River. Some areas are still under threat of flooding and face various problems in different degrees, including water pollution, water shortage, insufficient water supply facilities, and drinking water safety. In some areas, water and soil resources are overexploited, and the water ecological environment is damaged to various extents.

(c) Equally accessible basic public services set new requirements on water conservancy. Natural conditions and the socioeconomic development level vary a lot across the Huai River Basin with unbalanced water conservancy development and the low ability and level of public service in water conservancy. In order to promote a balanced development among different regions and narrow the development gap between them, great efforts are required to facilitate a comprehensive and coordinated development of the river basin water resources, improve public service ability in water conservancy, continuously promote the construction of backbone and key river harnessing projects, strengthen the development of the river basin water resources, and speed up projects to harness the low-lying areas and medium and small rivers. Special attention will be paid to the improvement of rural water management, the enhancement of the ability to combat flood disasters, and the improvement of water conditions for agriculture and rural economic development.

(d) Food safety sets new requirements on water conservancy. The Huai River Basin is China's major breadbasket, playing an important role in guaranteeing its food security. Keeping this in mind, , we need to further strengthen its rural water conservancy construction on the basis of cultivated land protection and flood control, give more support to existing irrigation areas, further develop its water-saving irrigation, gradually expand its effective irrigation areas, improve its irrigation coverage, strengthen management, and upgrade its farmland surface drainage standard and grain production conditions.

A sluice across the Huai River.

River-lake relationship change and the Huai River flood control

The capture of the Huai River by the Yellow River has a far-reaching influence on the river-Lake relationship, which was a main reason behind frequent flood disasters in the Huai River after 1949. In light of the principle "to give consideration to both storage and discharge functions," the Huai River and the Yishusi water system have been modified and administrated. A flood control and disaster alleviation system consisting of reservoirs, levees and flood plain, has been formed, greatly increasing its flood disaster prevention and mitigation capacity.

(a) Current capacity for flood control and disaster alleviation in the Huai River.

After 1949, a series of management measures for flood control and a disaster alleviation system were put in place in the Huai River, and remarkable achievements have been made in this aspect. The ability of water storage in the upper reaches has been strengthened, with a total area of 27 thousand km^2 under the controlled of a large-scale reservoir. Its flood discharge capacity has improved significantly, increasing from 2000 m^3/s to 7000 m^3/s in the upper reaches, and from 5000–7000 m^3/s to 7000–13000 m^3/s in the middle reaches between Wangjiaba and Hongzehu, and from 8000 m^3/s to nearly 18270 m^3/s in the lower reaches. The capability of of the Yishusi River system in flood discharge into the sea has been expanded to 14200m^3/s from less than 1000 m3/s. The flood control standard is 10 years' frequency for the upstream of the Huai River, and 100 years' frequency for important flood control and protection areas and important cities. The standard for flood control has been elevated to 50 years' frequency for important flood control and protection areas in the middle and lower reaches of the Yishusi River. The Standard for flood control has elevated to 20 years' frequency for important trans-provincial tributaries in Huaibei except along the Hongru River, which is 10 years' frequency. Furthermore, the flood-release conditions of low-lying land, which is vulnerable to waterlogging, have been improved, and the river drainage standard of important drainage riverways has reached 3-year return period.

(b) Improving the flood control and disaster alleviation engineering system to adapt to the change of river-lake relationship and socioeconomic development requirements.

The understanding of, and the requirements for, flood control are closely related to socioeconomic development, and all of them are making continuous changes. At present, although the Huai River harnessing has made a certain progress, compared with local socioeconomic development, its flood control system still needs improvement, and there is a long way to go to fulfill the requirements of socioeconomic development. This can be seen most clearly from the its insufficient capacity for floodwater storage and its lower flood-control standard in upper reaches, its often obstructed flood discharge in the middle reaches, its obvious deficient outlet of the flood discharge, and small discharge capacity in the Hongzehu Lake during medium and low water level.

In order to adapt to the changing requirements of flood control, further improvement is needed for the Huai River flood control and disaster alleviation project system. A comprehensive plan in this aspect includes the following arrangements:

(1) To construct 10 large-scale reservoirs such as the Chushandian Reservoir, build a new set of medium reservoirs, reinforce reservoirs and sluices in dangerous state, and upgrade flood-discharge capacity in the upper reaches;

(2) To bring the Huai River under control, adjust its flood-discharge areas in the mainstream, increase flood channels for medium-scale floods, and consolidate flood-discharge capacity in the middle reaches;

(3) To harness the river way to bring water into the Yangtze River, a set of important water projects should be planed and constructed, which include strengthening the levees of the Hongzehu Lake, building the 2nd phase water project to access water into the sea by building the Sanheyue big sluice, and further consolidate and extend its flood-discharge capacity in the lower reaches of the basin.

(4) To consolidate and improve the flood control in the basin's lakes and its backbone river flood control engineering system, it was suggested to enlarge the flood-discharge capacity by diverting water from the east to the south in the Yishusi river system on the basis of the existing project.

(5) To construct flood storage and retention areas, and build standardization levees;

(6) To harness important tributaries such as the Hongruhe River, the Shayinghe River, and medium and small rivers step by step;

(7) To take actions, such as storing, dewatering, interception, to harness low-lying waterlogged areas on the basis of reasonable subareas for low-lying land;

(8) To strengthen the construction of city flood control and seawalls, and improve the flood control and disaster alleviation system.

(c) Ensure people's security in the main flood-storage area of the Huai River.

The flood-storage area in the Huai River and its beach areas play an important part in discharging, storing floodwater and guaranteeing flood control safety. By the end of 2010, about 1.45 million people still lived in the storing floodwater and beach areas in the mainstream, including about 930 thousand people under direct threat. This not only makes it difficult o safeguard the people's lives and property, but also affects the normal flood and the flood control of entire basin. In the new plan for harnessing the Huai River, arrangements have been made for flood-storage adjustment and the replacement of residents in the districts of storing floodwater and beach areas in the mainstream.

To settle the contradiction among people, water and land and achieve harmony, according to the principle of "guidance by the government, expectation of the masses, unified planning and gradual implementation", endeavor will be made to propel the immigration in the floodwater storage districts and the beach areas in the mainstream, help the residents in dangerous area to move to a safe area gradually, and pave the way for minimizing the disaster losses. In line with wishes of the people involved, the mode of migration could either be the entire allocation of a village or partial allocation with part of a village.

(d) Strengthen the construction of a non-engineering system and make the transfer from flood control to flood management.

A non-engineering flood control system is part of the flood control system, and must be strengthened. At present, the non-engineering flood control system mainly includes the mainstream microwave communication system, the Yishusi flood control communication system and the hydrological telemetry system in the Zhengyangguan upstream. The information collection, transmission, processing, forecast and dispatch system, which is centered at the Yangtze River Commission and related four provincial water resources bureaus, has been connected to the National General Headquarters for Flood Control. The Office of State Flood Control and Drought Relief Headquarters, the Huai River Flood Control and Drought Relief Headquarters and relevant offices at various government levels constitute the nation-wide flood control and drought relief command organization system. In the future, we will continually strengthen the information system for water conservancy, improve the precision and accuracy of flood forecasting and scheduling, speed up water information collection and transmission through the engineering countermeasures and improve the flood risk forecast and the efficiency of the existing project.

Flood control and disaster alleviation have become a huge issue of China's sustainable development of China in the 21st century. To adjust the flood control and disaster alleviation strategy and realize the harmonious coexistence between people and nature are particularly important. In flood control and disaster alleviation, our work must follow the natural rules, bringing about a transform from flood control to flood management, making great efforts to build a comprehensive flood control and disaster alleviation system featured with harmony between human and nature, and to combine engineering measures with structural measures. In addition to flood prevention, people also need to adjust its behavior, stop the excessive use of natural resources and pollute the environment. Special emphasis should be laid on flood control and disaster alleviation, giving great importance to leaving out ways for flooding, and making changes from the flood control to flood management changes.

A bird's-eye-view of the Three Gorges Dam Project.

Conclusion remarks

The Huai River is extremely complex. The certainty of high frequencies of flood disasters is based on its unique climatic characteristics, geography conditions, social conditions and the long-term influence of being captured by Yellow River. The changing river-lake relationship and socioeconomic development continually produce new problems and put forward new requirements. The understanding of the River is a long and gradually improving process. The future planning of the River should keep absorbing new achievements of the science and technology development, employ new technologies and new methods, gradually upgrade the cognition of the fundamental principles. Special attention should be paid to the study and understanding of the river-lake and flood-waterlog relationships. It is inevitably to adapt harnessing measures with socioeconomic development, and comply with the basic law of the river itself.

Acknowledgements

The National Basic Research Program of China (2010CB428406), the National Natural Science Foundation of China (No. 41071025/40730632) & National Key Water Project (No.2009ZX07210-006)

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