

## **RIVER MANAGEMENT AND ECOSYSTEM CONSERVATION IN CHINA**

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**Abstract:** China is endowed with about 50,000 rivers. River management constitutes the principle part of water resources management in the country. In the past five decades, China has made great efforts in river management and gained remarkable achievements. There are, however, many problems to be studied and solved, especially the negative impacts of large-sized projects on the ecosystem. Therefore, it is necessary to change from the project-based river management to resource-oriented river management, with an emphasis on preserving and improving the ecosystem. A new philosophy for river management in a sustainable manner and the relevant practice in China are discussed in this paper.

**Keywords:** River Management, Ecosystem, Rivers in China

### **1 RIVERS IN CHINA**

China is endowed with about 50,000 rivers, including 1,500 rivers with watershed area larger than 1,000 km<sup>2</sup> each. The main river systems consist of seven major rivers: The Yangtze, Yellow, Pearl, Haihe, Huaihe, Liaohe and Songhua rivers (Fig.1 and Table 1). The total annual average runoff in the national rivers is about  $2711.5 \times 10^9$  m<sup>3</sup>. The rivers have provided a large amount of water to the country and nourished the people in China for thousands of years. The water resources and river runoff in China, however, suffer an inherent shortage, and the per capita amount of water resources nationwide is only 2200 m<sup>3</sup> at present, about one fourth of the world average. Besides, the natural distribution of river runoff varies greatly in time and space. About 70% of annual rainfall is concentrated in the flood season lasting from June to September in most area, and the drastic variations in yearly precipitation tend to cause consecutive wet years or dry years. In the regions north of the Yangtze, where land area is 63.5% of the national total territory, the amount of water resources accounts only for 19% of the total. Moreover, soil erosion occurred seriously in many areas, especially west China, leading to heavy sediment load in many rivers. For example, the annual average sediment load at Sanmenxia Station on the middle Yellow River was 1.6 billion t from 1916-1960. The heavy sediment load supplied from the middle Yellow River led to severe deposition in the lower reach, forming a perched channel there. The extremely uneven temporal and spatial distribution of river runoff, in addition to heavy sediment load in river flow, constitutes the fundamental cause of frequent floods and waterlogging in summer and droughts in spring, and results in complicated fluvial processes in channels. This seriously threatens the social and economic development and the eco-environment of human being. The injury and death and property losses caused by floods and droughts rank the first among all the natural disasters in China. Therefore, management, development and taming of rivers have been conducted in China since ancient times, and reached an unprecedented scale in the past decades.

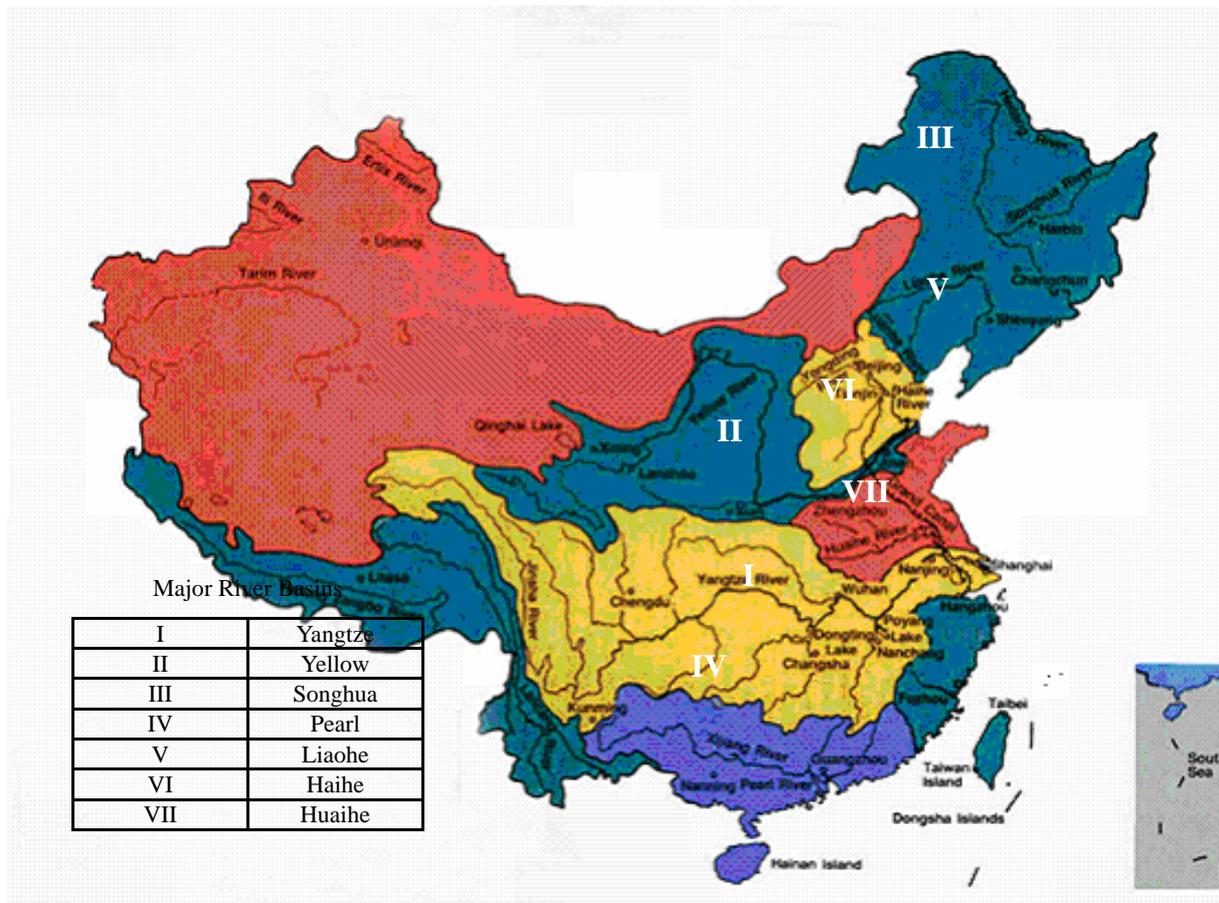


Fig. 1 Major Rivers in China

Table 1 Data of Seven Major Rivers in China

River	River Length(km)	Basin Area( $10^3 \text{ km}^2$ )	Average Annual Runoff( $\text{km}^3$ )
Yangtze	6,300	1808.5	975.5
Yellow	5,464	752.4	59.2
Songhua	2,308	557.2	74.2
Pearl	2,214	453.7	336.0
Liaohe	1,390	229.0	14.8
Haihe	1,090	263.6	22.8
Huaihe	1,000	269.3	61.1

## 2 ACHIEVEMENTS AND PROBLEMS

River management aims at promoting development of social economy and improving ecosystem through rationally utilizing water and energy resources and preventing natural disasters. It mainly involves watershed management with focus on soil and water conservation, river regulation through construction of dam, dike, revetment, training works etc., and management of water resources in rivers. Among them the river regulation, especially the dam construction, plays a key role in changes of river regime.

In the past five decades, China has made great efforts in river management and gained remarkable achievements:

- More than 85,000 dams and reservoirs have been constructed with total storage capacity of  $510 \times 10^9 \text{ m}^3$ . A total of 250,000 km of levees have been built and upgraded. A preliminary flood control system has been established in the seven large river basins. It may protect 400 million people, 470 cities, 33.3 million ha of farm land and some key railroads, highways and oil fields etc. from disasters caused by normal floods.
- Through river management along with other measures, the water supply capacity

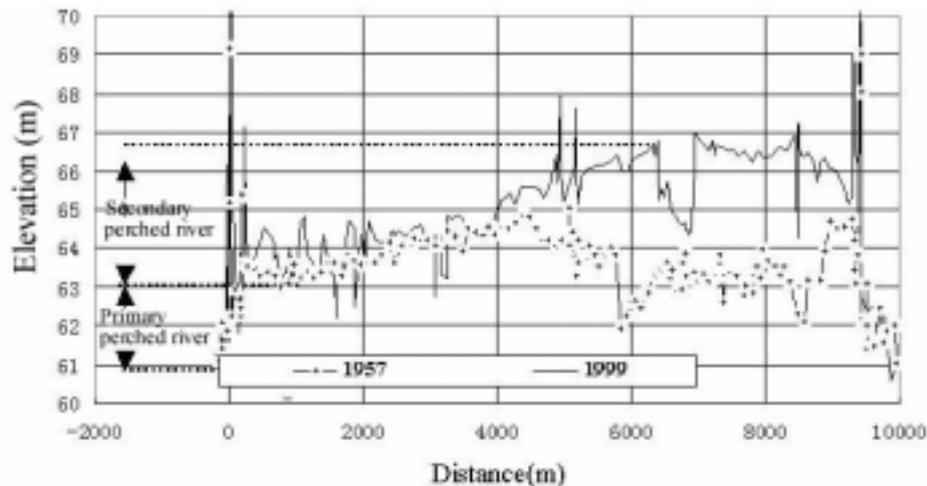
increased from  $100 \times 10^9 \text{ m}^3$  in 1949 to  $553 \times 10^9 \text{ m}^3$  in 2000, enabling the nation's irrigation area to increase from  $16 \times 10^6 \text{ ha}$  to  $53.3 \times 10^6 \text{ ha}$  for agriculture, forestry and stock raising.

- The hydropower resources of rivers have been exploited on a large scale. By the end of 2002, the total installed capacity of hydropower reached about 82.7 GW with a total electric generation of  $228 \times 10^9 \text{ kWh}$ , accounting for 17% the total power generation in China.
- A large-scale soil and water conservation program has been launched since the beginning of 1980's. Till now  $860 \times 10^3 \text{ km}^2$  of eroded area has been accumulatively controlled. Among them there were  $13 \times 10^6 \text{ ha}$  of basic farmland,  $48 \times 10^6 \text{ ha}$  of forestland and  $4.3 \times 10^6 \text{ ha}$  of grassland. In addition, a batch of projects for soil and water conservation has been constructed. The annual sediment load supplied into the middle Yellow River decreased by  $300 \times 10^6 \text{ t}$  due to the practice for soil and water conservation on the Loess Plateau. The local ecosystem has been improved and grain yield increased.
- Others - increase of navigation capacity through regulation of reservoirs and training of river channels and estuaries, development of fishery in reservoirs, as well as tourism and recreation, etc.

In general, however, the river management in China is essentially still of primitive stage. Not only many problems need to be solved by sustainable river management, but the activities for river management have brought some negative impacts on eco-environment also. The major issues are described as follows:

- *Low standard of flood control* The flood control works in 60% of cities and 50% of seawalls have not yet achieved the planned standards stipulated by the authority. There are not reliable countermeasures against the exceptional or extreme floods of large magnitudes. After operating for many years, about 50% of levees and 40% of reservoirs have aged to a certain extent and hidden some weaknesses and troubles. The construction and management of flood diversion and retention areas lag behind the requirements.
- *Losses of storage capacity in reservoirs and lakes* The total storage capacity of 601 large- and medium-sized reservoirs in the Yellow River basin is  $52.3 \times 10^9 \text{ m}^3$ , among which  $10.9 \times 10^9 \text{ m}^3$ , or 21% of the total, had been lost due to sedimentation till 1989. For 11931 reservoirs with total storage capacity of  $20.5 \times 10^9 \text{ m}^3$  in the upper Yangtze basin, the annual average deposition in the reservoirs was  $140 \times 10^6 \text{ m}^3$  before 1992, corresponding to annual loss rate of 0.68%. Sedimentation along with excessive reclamation made some lakes decrease in volume and area. The volume and surface area reduced from  $29.3 \times 10^9 \text{ m}^3$  and  $4350 \text{ km}^2$  in 1949 to  $17.4 \times 10^9 \text{ m}^3$  and  $2691 \text{ km}^2$  in 1978 for Lake Dongting, and from  $37.0 \times 10^9 \text{ m}^3$  and  $5190 \text{ km}^2$  in 1953 to  $29.8 \times 10^9 \text{ m}^3$  and  $3914 \text{ km}^2$  in 1976 for Lake Poyang, respectively. The losses of storage capacity decrease the capacity of water environment and aggravate the risk of floods and ecological deterioration.
- *Shrinking of river channels* Regulation of upstream reservoirs made peak floods decrease greatly in the Lower Yellow River during the past two decades, leading most sediment to deposit in the main channel of the river. This, in addition to irrational reclamation of floodplains along the river, caused shrinking of the channels. The lip of floodplain becomes even higher than the bed elevation at the levee toe, forming a "secondary perched river" (Fig. 2). The river capacity for flood conveyance and sediment transport was sharply reduced. The bankful discharge decreased from  $7,000 \text{ m}^3/\text{s}$  in 1970s to  $2,600 - 3,000 \text{ m}^3/\text{s}$  at present. Channel shrinking, as well as over abstraction of water upstream, which made the Lower Yellow River dry up during some non-flood seasons, deteriorated the water ecosystem. Similar phenomena occurred also in the Lower Weihe

River, the largest tributary of Yellow River, in Haihe River and the middle Huaihe River etc.



**Fig. 2** A Typical Cross Section in the Lower Yellow River

- *Severe soil erosion in the basins* Presently the national total area eroded is  $3.56 \times 10^6$  km<sup>2</sup> accounting for 37% of the total territory of the country, with  $5 \times 10^9$  t of annual amount of soil erosion. Serious soil erosion led to: annual loss of arable land of more than  $66 \times 10^3$  ha in the past 50 years, degradation of grassland of  $1 \times 10^6$  km<sup>2</sup> in total, land desertification of  $2.46 \times 10^3$  km<sup>2</sup> per year since 1990's, and sedimentation in reservoirs and river channels, reducing their flood regulation and conveyance capacity etc. The ecological degradation in eroded areas aggravates poverty. Over 90% of the poor in China live in such areas.
- *Serious water pollutions in rivers* Assessing of reaches totaling  $121 \times 10^3$  km of river in length indicated that in 14.2% of them the water belonged in Grade 4, and 24.4% in Grade 5 or worse.

Particularly, it already revealed that the dam construction and reservoir inundation showed the following negative impacts on the ecosystem in China.

- Large amount of resettlement ---- the total population relocated in the past half a century was about 15 million in China, which consumed a huge amount of money and caused new damage of ecosystem, such as deforestation, over cultivation and reclamation etc.
- Unfavorable changes of river regime ---- shrinking of river channels as mentioned above, degradation of downstream river channels due to the relatively clear flow released from reservoirs, which might affect channel stability, flood control and navigation.
- Deterioration of water quality ---- slowed velocity in a reservoir reduced the self-purifying ability of flow and the pollutants and toxicant adsorbed on sediment kept in the bottom of the reservoir.
- Losses of attractive natural landscapes and cultural heritages ---- for example, 44 archaeological sites and ancient monuments would be inundated by the Three Gorges Project Reservoir.
- Harmful effect on reserve of some species of plants and animals, especially rare species. For instance, the habit of Chinese sturgeon and Chinese dolphin changed to some extent by the Gezhouba Project.
- Induced seismic activity and other relevant environmental geological disasters, such as landslide and bank disintegration, etc.

### **3 PHILOSOPHY OF RIVER MANAGEMENT**

---- **HARMONIOUS COEXISTENCE BETWEEN HUMAN AND NATURE**

For a long period, people tend to overexploit rivers and water resources without considering its unfavorable results and to fight against floods and droughts instead of managing them, giving rise to a series of problems and negative impacts on ecosystem, society and economy. The history and practice of river management in China, as well as the achievement and problems in this field, enlighten us that it is necessary to change the traditional idea and found a new philosophy for river management in a sustainable manner, so as to achieve harmonious coexistence between human and nature. This means that river management should be changed from the project-based manner to the resource-oriented manner, with special emphasis on ecosystem conservation.

### **3.1 Flood Control**

The strategy for flood control must be changed from mainly constructing flood control works to establishing comprehensive flood-control and disaster-reducing system including structural and non-structural measures, technical and social-economic approaches, in order to achieve harmony between mankind and flood. Top priority should be given to the eco-beneficial schemes.

For example, a plan of digging up the reclaimed riparian land to recover the water volume in the Lake Dongting, Lake Poyang and the middle Yangtze and clearing away obstacles to flood on the floodway and floodplain has been launched after the severe flooding in 1998. After completion of the plan, about 2900 km<sup>2</sup> of water surface area will be resumed and 12.8×10<sup>9</sup> m<sup>3</sup> of storage capacity will be increased for store and detention of floods (1420 km<sup>2</sup> and 5.1×10<sup>9</sup> m<sup>3</sup> in the middle Yangtze, 600 km<sup>2</sup> and 2.65×10<sup>9</sup> m<sup>3</sup> in the Dongting and 880 km<sup>2</sup> and 5.05×10<sup>9</sup> m<sup>3</sup> in the Poyang, respectively). This will not only enhance the regulating capacity for floods in the middle Yangtze, but improve local eco-environment as well.

### **3.2 Allocation of Water in Rivers**

In the allocation of water resources the water demand of ecosystem should be ensured. It includes: water demand for forest, grass and other natural vegetation, water consumption for soil conservation, base flow in rivers to maintain the balance between water and sediment as well as to preserve diversity, and water needed to recharge depleted groundwater.

Comprehensive management of the Tarim River in Xinjiang Uygur Autonomous Region, the largest inland river in China, is a typical example in this field. Since 1972 the Lower Tarim had been dried up for a long time due to over exploitation of water resources upstream. As result, the watertable of groundwater in both banks lowered greatly, the forest of poplar diversifolia withered up, the scope of desertification expanded quickly and the ecosystem deteriorated seriously. Since April 2000 water was transferred from Lake Bosteng to the Lower Tarim for six times with total runoff over 1.4×10<sup>9</sup> m<sup>3</sup>. A series of measures for strictly controlling abstraction of water from the river and rationally allotting water resources were practiced. After that, the forest coverage was mostly recovered, withered diversiform-leaved poplars were replaced by lush and green forest (Figs 3 and 4), and oases reappeared too. The ecosystem in the basin rehabilitated gradually.



**Fig.3** Withered Diversiform-leaved Poplars



**Fig.4** Revived Forest of Diversiform-leaved Poplar

In order to alleviate water shortage and improve ecosystem in north China a South-to-North Water Transfer Scheme involving inter-basin regulation and management of rivers has been launched. The water is to be transferred through three routes:

- The East Route – from the Yangtze River near Yangzhou, Jiangsu Province to Shandong Province and Tianjin Municipality, transferring  $15 \times 10^9 \text{ m}^3$  of water per year.
- The Central Route – from the Danjiangkou Reservoir on the Hanjiang River to Beijing with  $13 \times 10^9 \text{ m}^3$  of diverted water annually.
- The West Route – from the Tongtian, the Yalong and the Dadu rivers in the Upper Yangtze Basin to the Upper Yellow River, with diverted water of  $(10-15) \times 10^9 \text{ m}^3$  annually.

### 3.3 Soil and Water Conservation

Soil and water conservation should be strengthened, especially for the soil-eroded areas. This may upgrade local ecosystem, enhance agricultural production, reduce the sediment entering rivers, and increase stream flow in dry seasons etc. The controlled area of soil-eroded regions will increase by  $550 \times 10^3 \text{ km}^2$  from 2000 to 2010 in the country, according to a national plan.

The Loess Plateau in Northwest China is the most serious eroded area in the country, with its total eroded area of  $454 \times 10^3 \text{ km}^2$ . Here the main approach for controlling erosion and conserving soil is comprehensive watershed management with check-dam systems as a key control measure. Up to date  $113 \times 10^3$  check-dams have been built and  $166 \times 10^3 \text{ km}^2$  of eroded area controlled. The check-dam has dual effects of both intercepting sediment and forming farmland (Figs. 5 and 6). In recent years the annual sediment load into the Yellow River has reduced by  $300 \times 10^6 \text{ t}$ , 80% of which might be attributed to trapping by the check-dams. The sediment trapped behind the check-dam formed fertile farmland, which along with other measures made the grain yield increase by  $4 \times 10^6 \text{ t}$  per year. The environment quality was improved, and income of local people grew remarkably.



**Fig. 5** A Check-dam



**Fig. 6** Farmland Formed behind a Check-dam

### 3.4 Regulation of Water and Sediment in the Lower Yellow River

The Lower Yellow River is a heavily aggradated river. The Xiaolangdi Reservoir located at

the Middle Yellow River commenced its operation in 2000. The reservoir with a total storage capacity of  $12.6 \times 10^9 \text{ m}^3$  aims at controlling floods and reducing aggradation rate in the Lower Yellow River. For the purpose of enlarging the discharging capacity and degrading the main channel of the river, an experimental program for regulating water and sediment in the Lower Yellow River by means of appropriate operation of the Xiaolangdi Reservoir has been carried out since 2002. Its purport is to operate the reservoir to create a released artificial flood with compatible discharge and sediment concentration for degrading the main channel of the Lower Yellow River (Fig. 7).



**Fig. 7** Flood Released from the Xiaolangdi Reservoir for Regulation of Water and Sediment Downstream

Such a flood with an average discharge of  $2600 \text{ m}^3/\text{s}$  and released sediment concentration of  $12.2 \text{ kg/m}^3$  at Huayuankou Station was created on 4-15 July 2002. As a result, the Lower Yellow River was degraded by  $36 \times 10^6 \text{ t}$  of sediment ( $106 \times 10^6 \text{ t}$  of degradation in main channel and  $70 \times 10^6 \text{ t}$  of aggradation on floodplain) with water consumption of  $2.6 \times 10^9 \text{ m}^3$ .

From 6 to 18 September 2003, through joint regulation of the Xiaolangdi and Sanmenxia reservoirs on the mainstream and the Guxian and Luhun reservoirs on the tributaries, an artificial flood was created with average discharge of  $2394 \text{ m}^3/\text{s}$  and sediment concentration of  $31.1 \text{ kg/m}^3$  at Huayuankou Station. About  $38.8 \times 10^6 \text{ t}$  of sediment were removed from the Lower Yellow River. The water stage at same discharge dropped by 0.22 m, 0.31 m and 0.40 m at Huayuankou, Gaocun and Lijin Stations, respectively, and the flood discharging capacity of the main channel increased by 200-400  $\text{m}^3/\text{s}$ .

### **3.5 Resettlement for Reservoirs**

Resettlement for reservoirs should be based on the principle of putting people first and according to rules governing economics and sociology. Selection of the sites for high dams and large reservoirs should take into account the pressure of farmland inundation and population relocation. A series of preferential policies and measures for resettlement have been worked out. Among them the most important one is the development-oriented resettlement policy, which signifies that the resettlement program should not merely be a compensation operation but should also be able to improve the living standard and labor productivity of those who are relocated and promote local economy development and environment improvement to benefit both the relocatees and the local population. New ideas such as “project owner’s responsibility system for resettlement” and “investment-based resettlement” should be explored to insure that relocatees are able to enjoy the benefit from the project.

### **3.6 Control of Water Pollution in Rivers**

The strategy for pollution control should be shifted from end of pipe treatment to source control, including the comprehensive control of point, non-point and internal sources of pollution, and developing recycling economy to decrease the total amount of pollutants. The planning, design, construction and operation of water works should be innovated according to eco-friendly principle to reduce their unfavorable impacts on ecosystem.