Progress of River Restoration in China

Dong Zheren, Sun Dongya, Zhang Jing, Zhao Jinyong, Zhai Zhengli
China Institute of Water Resources and Hydropower Research, Beijing 100038

Abstract: The progress of river restoration in China is briefly introduced herein in the aspects of national policies and regulations, critical actions of different ministries, fundamental research, monitoring and assessment, special planning as well as demonstration project. Stress mechanism of hydraulic engineering on river ecosystem, holistic model of river ecosystem structure and function as well as the principle of design method following negative feedback are briefly introduced.
Key words: River restoration, policy, action, model, demonstration project

1 Introduction

There are numerous rivers in China and the total river length is more than 430,000 km. There are more than 50000 rivers whose individual watershed area is above 100 km^2, 79 rivers whose individual watershed area is above 10,000 km^2. There are 20 rivers whose individual length exceeds 1,000km. There are also many lakes in China. The total number of lake above 1 km^2 exceeds 2,800. Their total area is about 80,000 km^2. The total area of wetlands in China is 38,485,500 hm^2. They are classified into 5 categories and 28 types, i.e. coastal wetlands, river wetlands, lake wetlands, swamp wetlands and reservoir and ponds wetlands (constructed wetlands).

Along with the high-speed development of Chinese economy, many problems have occurred including the intensive exploitation of land, water shortage and deterioration of water environment, etc. In addition, there existed the problems of unordered and improper construction of hydraulic and hydroelectric projects. These problems have caused the persistent degradation of river habitat quality, the shrinkage of lake area, as well as the disappearance or degradation of natural wetlands. Up to the end of 2006, China had constructed 85,874 dams, 270,000km dikes and 40,603 sluices. The construction of these hydraulic and hydroelectric projects has brought great social and economic benefits. In the meantime, however, they also change the natural hydrological regime and fluvial geomorphology. As a result, varying degrees of stresses on river ecosystem are caused by these projects.

To solve these kinds of problems, Chinese government has carried out lots of work on river restoration step by step in a planned way. Major progresses have been achieved in the aspects of policy and regulation, fundamental research, monitoring and assessment, special planning and the construction of river restoration projects. The main contents with respect to these aspects are briefly described in the following paragraphs.

2 National policy and regulation of Ministry

2.1 National polices

Applying river restoration is one of the important measures to implement the scientific concept of development and new thoughts for water resources management, and to construct ecological civilization. It is also the basic condition and an important component of water resources conservation. Under the background of continuously high-speed development of national economy and the unceasing increase of environmental pressures, Chinese government has clearly put forward the strategy to accelerate the transformation of economic growth pattern, to take resource-conserving as basic national policy, to develop recycling economy and protect ecological environment, to build a resource-conserving and environment-friendly society, and to promote the harmony of economic development with the condition of population, resources and the environment. It is urged to exploit hydropower orderly on the basis of ecological conversation. All problems related with resettlement, environment protection, flood control and navigation should be comprehensively solved. It is also put forward to construct 222 wetlands conservation regions which include 49 national-level wetlands. It is proposed to restore important wetlands by reasonable water resources reallocation and management.

The demand of water resources and aquatic ecosystem conservation is put forward in the Water Law of PRC. With respect to the exploitation, utilization, saving and protection of water resources as well as the prevention and control of water disasters, planning should be carried out in a comprehensive and systematic manner with all aspects being taken into account and with emphases on multiple purpose utility and achieving maximum benefits so as to allow full play to the multiple functions of water resources. Rational allocation should be realized among domestic, industrial and ecological water users. In the process of making planning of the exploitation and utilization as well as the reallocation of water resource, attention should be paid to maintain a reasonable flow of rivers and a reasonable water level of lakes, reservoirs and groundwater, to maintain the natural purification capacity of water bodies.

The environment impact assessment law of PRC was put in force on September 1 of 2009. It is required to analyze, estimate and assess the environment impacts possibly caused by planned or constructed projects, and to propose countermeasure to prevent or alleviate adverse environment impacts. On August 2009, Chinese Premier Wen Jiabao subscribed the State Council Order (No. 559) of Provisions for Environmental Impact Assessment of New Projects, which demand that environment impact assessment should be conducted on relevant planning of land utilization and exploitation planning of regions, watersheds and sea areas.

2.2 Regulations of Ministries

On September 6 of 2004, Wang Shucheng, the then minister of the Ministry of Water Resources, brought forward for the first time that river basin commission should become the prolocutor of rivers to maintain the healthy life of rivers. In 2004, the Ministry of Water Resources issued a note on Some Opinions about Aquatic Ecosystem Conservation and Restoration. The guiding ideology, basic principles and objectives as well as main tasks are described in this note. Some pilot projects for aquatic ecosystem conservation and restoration were arranged in some urban and rural river

systems to explore and accumulate experiences.

In the late 1990s, water sectors of China began to explore the measures to restore rapidly degraded river ecosystems by means of emergency water diversion and achieved initiatory successes. Pilot projects of this kind include Tarim River, Heihe River and Zhalong wetland, etc. In recent years, the Ministry of Water Resources ratified ten pilot projects for aquatic ecosystem conservation and restoration such as Oujiang river in Lishui City of Zhejiang Province, and Tuojiang river in Fenghuang County of Hunan Province, etc. In December 2008, the Ministry of Water Resources ratified statement of planning tasks for Aquatic Ecosystem Conservation and Restoration of Main Rivers and Lakes in China to deploy relevant works in these aspects.

In allusion to increasingly serious water environment pollution situation, the Ministry of Environment Protection has taken many measures to control the total amounts of pollutants. It is required that 70 percent of urban sewage will be processed before being discharged and the chemical oxygen demand will drop by 10 percent from the 2005's level by 2010. Starting from 2010, tougher emission standards will be adopted for key drinking water resources and during the dry seasons. In October 2007, the Guidelines for the Plan on National Key Ecological Functional Protected Areas and the Guidelines for the Plan on the Protection and Utilization of National Resources of Biological Species were released. In 2008, National Ecological Regionalization was released. By the end of 2008, China had established 2358 nature conservation regions of various types and grades. The total area of conservation regions has amounted to 148,943,000 hm^2.

With regard to wetlands conservation, China acceded to the Convention on Wetlands of International Importance Especially as Waterfowl Habitat (the "Convention") in 1992. At the same time, six Chinese wetlands, such as Xianghai wetland in Jilin Province, became the first set of international important wetlands. The Chinese Wetlands Conservation Action was constituted in June 2000. The first national wetland resources survey was taken in 2006 and it was discovered that 40% of existing wetlands had the potential to be seriously degraded. In the same year, wetland conservation projects were launched formally.

To take into account both hydropower exploitation and the protection of specific fish resources, in combination with the environment protection plan of the Three Gorges Project, the State Council ratified the establishment of national nature reserve for precious, rare and endemic fish species in the upper Yangtze River formally in April of 2005. The nature reserves are divided into core, buffer and experimental zones. It is required that no hydropower station will be allowed to be constructed in the core zones. This kind of regulation has become a powerful measure in river ecosystem conservation.

3 Progress in river restoration theories and technologies

Compared with western countries, China is comparatively late in theoretical studies and practices in river restoration. However, great progresses have also been achieved. A few books related with river restoration have been published, such as Maintaining Yellow River Healthy Life (Li Guoying, 2005), Healthy Yangtze River (Cai Qihua, 2006), and Principles and Technologies of Ecological Hydraulic Engineering (Dong Zheren et al, 2007), etc. In the book written by Prof. Dong, some

important contents for river restoration are systematically elaborated, such as the ecological functions of rivers, variability of river restoration, strategies of river restoration, sediment and habitat, instream flow and environment flow, planning and design of river restoration, ecological engineering techniques, and adaptive management of river restoration, etc. In addition, much progress has also been achieved in professional model studies and technology developments.

3.1 Stress mechanism of hydraulic engineering on river ecosystem and river restoration models

The number of large and middle hydraulic projects increases significantly along with the increase in scope and intensity of water resources exploitation. As a result, the stresses of hydraulic projects on fluvial ecosystem become increasingly obvious. A lot of studies and analysis has been conducted by Chinese researchers to deal with this kind of problem.

Some Chinese institutions have launched long-term continuous monitoring and thorough studies on the response of Chinese Sturgeon and four major Chinese carps in the Yangtze River to hydraulic projects. For example, the project of long-term ecological effects of large dams on the important living resources, which is the major program financed by the National Natural Science Foundation of China, has deeply and utterly studied the impacts of the Three Gorges Project and Gezhouba Project on the eco-hydrological and eco-hydraulic conditions for the natural reproduction of important biological resources in Yangtze River such as Chinese Sturgeon and four major Chinese carps. The research has preliminarily revealed the changes of biogeochemical processes and its influence on ecosystem structure in the middle and lower reaches of the Yangtze River before and after impoundment of the Three Gorges Project. The ecological responses of major biome to environmental stresses are investigated.

Dong Zheren (2003) analyzed the stress mechanism of hydraulic engineering on river ecosystem. It is suggested that stresses on river ecosystem lie in 3 aspects: 1) channelization of natural river; 2) discontinuity of natural river; and 3) water diversion projects across river basins. He put forward a holistic model of river ecosystem structures and functions in order to depict the relationships between non-life variables and life variables. The relations are established between ecosystem structures and functions and the three kinds of habitat factors, i.e. flow pattern, hydrological regime and geomorphological landscape (see Fig. 1).

3.2 Ecological water demand

Chinese specialists have proposed to take account of ecological and environmental water demand in water resources reallocation since 1980s~1990s to treat the issues of river zero-flow and water pollution. Based on the relations of water resources exploitation and ecological water demands in a river basin, Liu Changming(1999) put forward the principles of balances in four aspects, i.e. water-heat balance, water-salt balance, water-sediment balance as well as water supply-demand balance. The sharing characteristics of domestic, industrial and ecological water demand are discussed. From the point view of water balance of ecological system and the water relations of biology, the important problems in calculating ecological water demand for different ecological system are analyzed. The framework to study ecological water demand under water use competition was worked out (Yan Denghua 2007). By adopting the principle and methodology of landscape ecology, Lian Yu (2008) established the models to assess environmental water demand

of the Yellow River Delta based on eco-hydrology. The ecological effects of different water supply schemes to estuary wetland are forecasted and assessed.

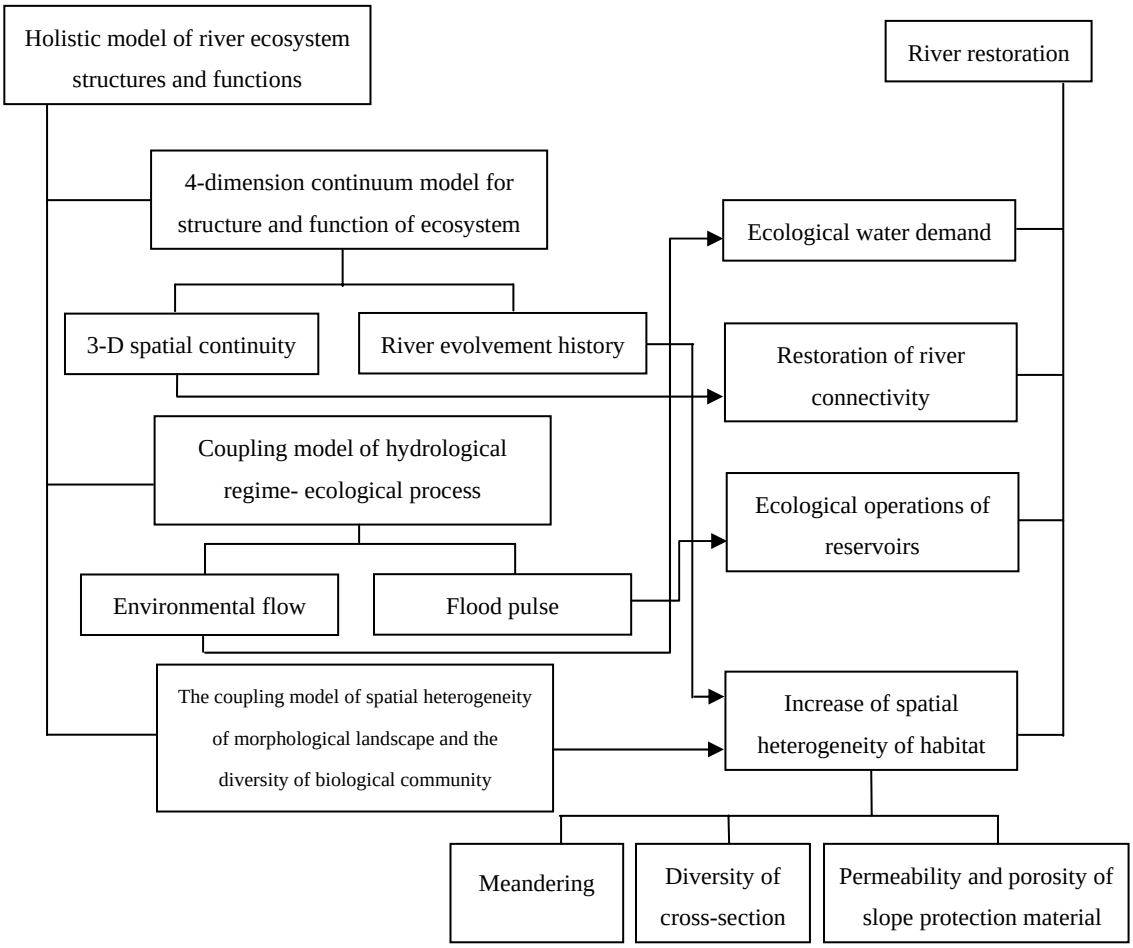

Fig. 1 Holistic model of river ecosystem structure and function and its application in river restoration

With regard to the assessment methodologies of river ecological water demand, many foreign methodologies are widely used in China, which include hydrological methodology, hydraulic rating methodology, habitat simulation methodology and holistic methodology, such as the Tennant Method, Wetted Perimeter Method and IFIM. There are also a few Chinese scholars who have investigated the methodology to determine ecological water demand from different perspectives. For example, Zheng Jianping (2006) brought forward a method of MFASP that focusing on the sensitive period of aquatic organisms.

Due to the excessive changes of river hydrological regime caused by reservoir operation, the ecological water demand downstream cannot be satisfied. To solve this kind of problem, many river commissions of China have initiated the studies and demonstrations on the ecological operation of reservoirs, such as the Yangtze River Commission, the Yellow River Commission, etc.

3.3 River health assessment

In recent years, the seven river commissions of China have conducted many investigations to

work out a river health criterion respectively that is suitable for their own river basin. In 2004, Li Guoying brought forward a new concept of maintaining the healthy life of the Yellow River. This concept has been accepted as the ultimate goal of the Yellow River harnessing. In 2004, the Yangtze River Commission initiated a special research program in order to maintain the health of the Yangtze River and achieve the coexistence between human and nature. The Report of this program was finished in May of 2005 (Cai Qihua 2005). Dong Zheren (2005) had expatiated on the connotation of river health and put forward that river health is an assessment tool for river management rather than a strictly scientific concept. It can be used to set up a reference point and an evaluation system.

3.4 Ecological effect of flood pulse

Flood pulse concept emphasized the important impacts of hydrological process to biologic process, and can be used to guide the conservation and restoration of river ecosystem. After the impoundment of the Three Gorges reservoir, the flood peaks in the spawning period of the four major Chinese carps may be regulated by electricity generation. As a result, flood peak magnitude will be reduced and thus affect their spawning and propagating. Some researchers have begun to study artificial flood peak to solve this kind of problem. For example, Chang Jianbo, who is a scholar of the Institute of Hydroecology of the MWR and CAS, has investigated the necessity and feasibility to actuate the natural spawning of the four major Chinese carps by means of artificial flood peak. Dong Zheren (2009) points out that flood pulse is the main driving force of fundamental ecological processes such as production, decomposition and consumption in river channel and floodplain system. The importance of flood pulse concept in guiding river restoration is discussed. It is then suggested that reservoir operation be improved based on the simulation of natural hydrological regime for multi-purposes including the improvements of downstream river ecosystem.

3.5 Adaptive management of river restoration

River restoration includes many complicated processes. There existed various uncertainties in river restoration due to the variability of these processes and people's cognitive limitations. To treat with this kind of problem, Dong Zheren proposed a planning and design method following negative feedback for river restoration (see Figure 2). It can be used to handle the problems related with decision methods in river restoration planning, design and implementation processes under complex circumstances. Design process following negative feedback is an iterative cycle process of planning- design- implementation (including management)- monitoring- assessment- adjustment. It aims at steadily reducing the differences between river ecosystem status and river restoration objectives.

4 Typical river restoration cases

4.1 Water diversion for river ecosystem improvement

To alleviate the situation of the drying up of river and the deterioration of fluvial ecosystem, China has put in practice a series of emergency water diversion projects in many river basins such as the Yellow River, the Heihe River, Zhalong wetland, Tarim River and Taihu lake. Meanwhile, the effects of these water diversion projects are monitored and analyzed. Two cases, including the water diversion to the Yellow River delta and the integrated management of Tarim River are

summarized below.

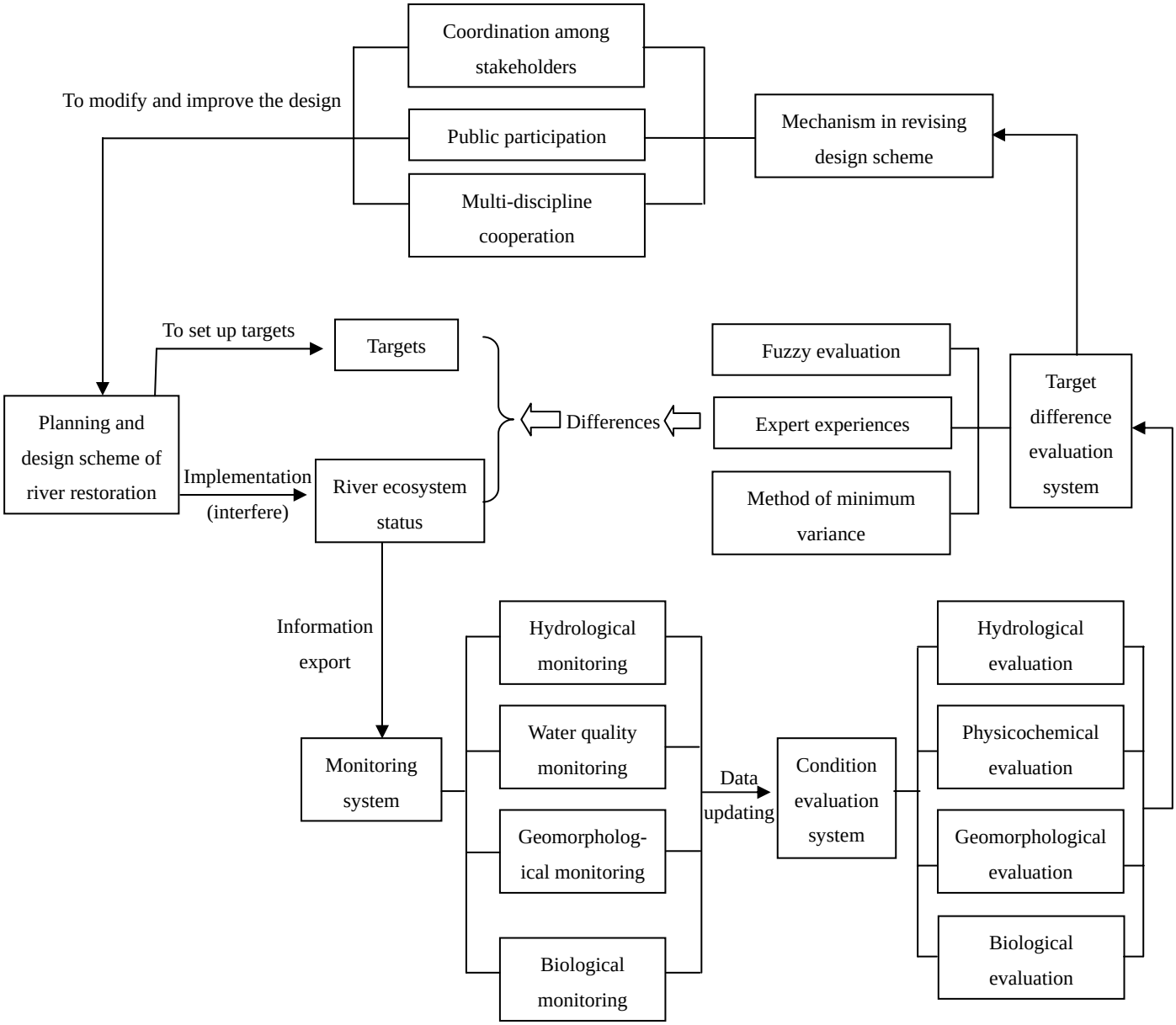

Fig. 2 Principle of design method following negative feedback for river restoration

4.1.1 Water diversion to the Yellow River delta

In June 2008, in combination with the 8th water and sediment regulation of the Yellow River, Yellow River Conservancy Commission conducted water diversion to Yellow River delta for ecological restoration purposes aiming to stabilize and expand the estuarine wetland, improve the wetland ecosystem and protect the biodiversity. By July 4th of 2008, totally 13.56 million m^3 water had been diverted to the Yellow River estuarine wetland, and the water depth in the core region was increased by 0.3m. The eco-efficiency is mainly reflected in the following aspects. The water area in the wetland is increased. This will be helpful to the consequent succession of vegetation and improvement of avian habitat; Groundwater in estuarine area is replenished and as a result groundwater level is increased. This will help prevent seawater intrusion and alleviate

salinization; Coastal freshwater supplement is increased and this will be conducive to maintaining a reasonable salinity of coastal seawater; appropriate runoff process can be produced. This will provide favorable conditions for fish migration and spawning in the estuarine area; Land reclamation process can be expedited. This will promote the consequent succession of wetland vegetation in the delta area (see Fig.3).

4.1.2 Integrated management of Tarim River basin

In June of 2001, Chinese government invested 10.7 billion for the integrated water resources management of the Tarim River basin. By the end of 2006, the Tarim River Basin administrative Bureau and the Bayingolin Mongolia Autonomous Prefecture had organized to carry out emergency water diversions for eight times from Bosten Lake (Baghrash Lake) to the lower reaches of Tarim River for the survival of Populus Enphratice Oliv and other aquatic organisms (see Fig.4). The distance from source water to water receiving area is over 730 km and the total water quantity had reached up to 2.275 billion m^3. A 360km-long segment of the Tarim River has been restored to have runoff and its history of 30-year drying-up is ended. In 2008 when the main stream of Tarim River was almost to dry up, emergency water diversion was carried out once more from Akesu River basin and the total water quantity was over 0.2 billion m^3.

Fig. 3 Remote sensing image of Yellow River delta

Fig. 4 Populus Enphratice Oliv on Tarim River

4.2 The training of urban lake and river system

Along with the development of social economy and people's constant pursuit for better living environment, people have put forward comprehensive requirements on the training of urban lake and river in many aspects including flood prevention, water quality improvement, ecology conservation and restoration as well as cultural landscape etc. Many cities of China have taken actions to make planning and practices on the environmental improvement of rivers and lakes such as Beijing, Shanghai, Guilin, Wuhan, etc. The river training of Beijing is briefly introduced herein as an example.

During the Tenth Five-year Plan period, Beijing focused on the training of water system in central urban and the investments were increased compared with the past years. In addition to traditional river training objectives, i.e. flood control and drainage, new objectives are added in the aspects of landscape and ecological rehabilitations in order to realize the harmonious coexistence of human and natural water.

The Zhuanhe River, which is 3.7 km long as a segment of the north-ring water system, connects

the Summer Palace and the Chaoyang Park. Its training follows the planning and design principles of maintaining its natural meandering and width. Stones and wood-like concrete piles, porous and pervious materials and live vegetation are applied for riverbank protection and erosion control (Fig.5). The multi-purpose training project of the 19km-long Liangshuihe river, started in October of 2004, has been completed up to now.

Fig. 5 Zhuanhe river restoration project

Beijing government approved the planning of the green Yonding River corridor in 2009. According to this planning, the Yongding River will become a healthy river. The connectivity of rivers, lakes and riparian wetlands will be rehabilitated by the year of 2014. From upstream to downstream, three river segments with different functional priorities are planned, i.e. ecological and natural segment, urban landscape segment and pastoral landscape segment.

4.3 Ecological restoration of rural rivers

At present, the ubiquitous problems existing in rural rivers are sedimentation, water and soil loss, shrinkage of water area, water quality deterioration and dirty environment. All these problems will seriously affect the basic functions of rivers such as flood discharge, drainage, water supply, irrigation and navigation. Many regions are gradually implementing river training projects to promote the construction of new countryside. It is advocated in the planning and design of rural river training project to follow the concept of design with nature to realize the multi-purposes of these projects.

In combination with the implementation of a research program financed by the Ministry of Water Resources, from 2004 to 2005, China Institute of Water Resources and Hydropower Research was involved in the construction of a pilot project for the ecological restoration of Xinjiangtang stream in Haining County of Zhejiang Province by supplying technical consultation to local water sector. The 32.4km-long Xinjiangtang stream is one of the main rivers in Haining County. In this project, present planform morphological patterns are kept and only a few local modifications are conducted to meet special requirements. The natural meandering and width of the river channel are maintained. Floodplain and riparian wetlands are rehabilitated. Natural cross-section profile is preserved as much as possible. Compound or trapezoid cross section is adopted only in particular conditions. By the implementation of these comprehensive measures, the results of Xinjiangtang river restoration project accord with primary design. The standard of flood control is improved; riverbank erosions are effectively controlled; water quality is improved; aquatic animals and riparian vegetation grow well and the project budget is greatly saved.

Fig. 6 Xinjinatang river restoration project

5 Conclusions

In recent years, China has been actively implementing the scientific concept of development. Much attention has been paid to river conservation and restoration. Studies and practices in different scopes and at different levels have been carried out and some progress and effects have been achieved. However, compared with the developed countries, there still existed big differences in several aspects such as basic investigation and data acquisition, river pollution control, and river restoration practice in river basin scale.

In future work, it is necessary to realize that the tasks of river conservation will vary in different periods or at different stages. Water pollution control should be put in top priority and then ecological restoration can be realized. Various deep-seated social problems should be solved by measures in institution, safeguard mechanism, legislation and administrative execution in order to achieve the objectives of water pollution control. The spatial and temporal scale issues need much concerns and long-term planning in river basin scale should be carried out. Meanwhile, monitoring and evaluation should be strengthened, esp. the coupling monitoring of fluvial ecosystem and river process.

With regard to the stresses of hydraulic projects on river ecosystem, studies still need to be conducted in project planning and operation technologies in order to achieve the objectives of ecological securities of river basins. Furthermore, it is suggested to carry out planning, design, construction and adaptive management of river training projects for the benefits of ecological conservation and restoration. Related technical standards and regulations for the planning and design of river restoration projects should be worked out.

In order to provide scientific guidance for river restoration, disciplinary crossing and integration of river ecology with other disciplines intercrossing of subjects should be further strengthened. Studies on the coupling relationships between life system and habitat factors such as hydrology, water quality, flow pattern and geomorphology should be carried out. It is suggested to promote the establishment of an integrated discipline on river science.

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